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Résumé de l'article

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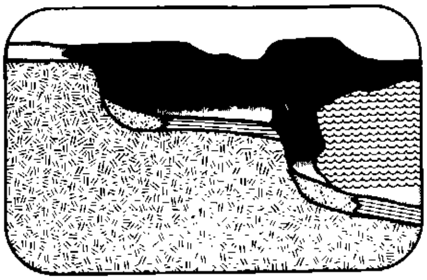

Postglacial Emergence in Atlantic Canada

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Summary
Elevated marine features occur in Atlantic Canada and those that appear to represent the upper marine limit and have been dated cluster around 13,000 + 500 years B.P., with a range from 14,000 to 11,500 years B.P. Although the scatter of dates precludes the drawing of truly synchronous isobases, simple isopleths can be drawn and show regional variations in uplift that are probably related to ice loads. Two main centres of maximum uplift are shown, namely New Brunswick, and northern Newfoundland - southeastern Labrador. The uplift in southwestern and northern New Brunswick is probably related to strong ice outflow in those areas, while thick Labrador ice caused rebound to increase towards the north in Newfoundland. A northward deflection of the isopleths in the Gulf of St. Lawrence suggests that it was free of grounded ice during the late Wisconsinan.

Introduction
Features marking postglacial shorelines now situated above sea level have been recorded from many localities in the Atlantic region of Canada. The celebrated Swedish geologist, Baron Gerard de Geer, presented in 1892 a remarkable map showing "the last changes of level in Eastern North America" in which the isobases (lines of equal uplift) for the Atlantic region are strikingly similar to those presented here. Fairchild (1918) also gave a broad interpretation of postglacial uplift for the same large region. In 1921, Daly used data from Newfoundland to estimate the amount of crustal warping there, and in 1924 Goldthwait produced a map showing inferred isobases for the highest beaches in a region encompassing New England, Nova Scotia and the area of Quebec south of the St. Lawrence. Flint (1940) made a tentative attempt to link Nova Scotian levels to those of Newfoundland, recognizing in the latter the possible existence of more than one former sea-level surface. New data led Jenness (1960) to modify Flint's interpretation for Newfoundland. Farrand and Gajda (1962) published a map showing generalized isobases for the late Wisconsinan marine limit in Canada, including the Atlantic region. Borns (1966) drew isobases for the Minas Basin in the Northumberland Strait area, subsequently slightly modified (Swift and Borns, 1967). The marine limit, and some elevations of raised shoreline features are plotted on the Glacial Map of Canada (Prest *et al.*, 1968), but no isobase lines are presented.

One barrier to any precise regional synthesis is the fact that most of the raised marine features are not dated and there are sometimes more than one level. For the upper marine limit, the age determinations that have been published range from about 14,000 to 11,500 years B.P., but with a strong concentration around 13,000± 500 years B.P. (Table I). This precludes the drawing of truly synchronous isobases but, nevertheless, simple isopleths do show regional variations in emergence, which probably result mainly from differences in ice loads that have been removed, although there may also be some modifications due to bedrock structure. This means that coastlines that retained "late" ice may not record some of the emergence shown by coastlines that were deglaciated at an earlier date. However, although the dates suggest that deglaciation occurred a little later in northern Newfoundland than in most other parts of the Maritimes, recorded uplift is greatest there. Neither isopleths nor isobases define the total amount of uplift at any one place as uplift begins soon after the ice starts to thin and shrink, well before the area is completely uncovered.

The position of the present sea level relative to Late Pleistocene sea levels is dependent upon the "absolute" amounts of sea level rise and on glacial rebound since the time of deglaciation, as well as on possible recent tectonic movements. The amount of postglacial rebound varies from area to area, as it is primarily dependent upon ice thickness. Hitherto, postglacial sea level rise was thought to be uniform on a world-wide scale and this view has led to the construction of eustatic sea level curves, such as those of Shepard (1963) and Mörner (1969). Recent geophysical theory (Farrell and Clark, 1976) shows that the postglacial rise in sea level varies in a complex way from place to place, and thus simple global eustatic curves can no longer be drawn. Essentially, large ocean basins receive a disproportionately larger amount of meltwater than small ocean basins because their elastic deformation is greater and isostatic adjustment faster. This necessitates the construction of local sea level curves and Beaumont (1977) has solved the sea level equation, based on this theory, for the Halifax area. He proposes a sea level rise of only 20 m since 14,000 years B.P. This reduces the amount of recorded uplift, as uplift equals emergence plus sea level rise, and implies that the thickness of the overlying ice may have been less than was formerly postulated.

"Late" ice has been used by several authors to account for the absence of postglacial emergent features in some areas, or to explain away progressive changes in elevation of the marine limit. The raised fluviomarine terrace on the northern shore of the Minas Basin, Bay of Fundy, is a good example. The marine limit decreases in elevation from 35 m at the west end of the Basin, to zero at Saints' Rest in the east. It has been suggested that "late" ice receded slowly eastwards and caused progressively lower deglacial transgression towards the Truro lowlands at the eastern end of the terrace. Can the decrease in elevation from west to east along the terrace be attributed to a slow eastward deglaciation of the Minas Basin? If Shepard's (1963) sea level curve were valid, total uplift on the west end of the terrace would be 105 m (70 m sea level rise + 35 m of emergence). It has been assumed that 56 per cent of the recorded uplift is completed 2000 years after initiation

(Andrews, 1968), which would indicate that the initial rate of uplift was 59 m/2000 years or 5.9 m/200 years. Shepard's curve indicates that sea level rise from 14,000 to 12,000 years B.P. was approximately 20 m or 2 m/200 years. Accordingly, the rate of emergence from 14,000 to 12,000 years B.P. was 5.9 - 2.0 = 3.9 m/200 years. At that rate, 1800 years would be required to produce a differential uplift of 35 m, implying an extremely slow eastward retreat of the ice.

Beaumont's (1977) sea level curve is almost flat from 14,000 to 8,000 years B.P., the time when the rate of uplift would be greatest (Andrews, 1968). This would seemingly increase the rate of emergence, but as the rate of uplift is also dependent of the amount of uplift, this is not necessarily so. Using Beaumont's sea level curve, an analogous calculation shows that 2300 years would be required to produce a differential uplift of 35 m. These figures are only rough estimates, but they show that the required rate of eastward deglaciation is unreasonably slow using either of the assumed sea level curves and that relative rates of emergence can not be deduced from sea level curves per se.

The features that have been used to estimate the marine limit in the Atlantic region vary from erosional features, such as cliff notches, to depositional features such as beaches and deltas. Deltas are the most common and delineate the former sea level at the angular unconformity between the topset and foreset beds (Gilbert, 1890). However, many authors have established marine limits at the levels of the upper surfaces of deltas. If the sea level is reasonably stable, this limit is too high, as there is an unknown thickness of fluvial topset beds below the upper surface of the delta. The thickness of topset beds, and thus the potential error, generally increases towards the source of the sediment. Beaches, wave-cut benches and subtidal marine deposits are potentially less accurate indicators of former sea level. The highest elevation along a raised beach is usually taken as the marine limit. This may be too high as beach ridges, piled up by storm waves, frequently develop in the backshore zone of a beach (Shepard, 1973). Wave-cut benches and subtidal marine deposits are formed some distance below mean sea level and provide a minimum elevation for marine overlap. However, the errors do not mask the larger regional variations in uplift and it is hoped that more careful work in the future will reduce these errors.

The Maps

The marine limits used in Figure 1 have been compiled from the literature and incorporate new data in the Minas Basin. Where several marine limits are given for an area, the most recently published data have been employed. Data from wave-cut terraces have been used discriminately as the terraces may be of Sangamon age or older, as on the Burin Peninsula of Newfoundland (Grant, 1975). In Figure 1 the isopleths have been drawn to conform to all the data

Table 1
Radiocarbon Dates of Marine Limits in Atlantic Canada

Date yrs. B.P.	GSC Lab Number	Marine Limit (m)	Location	Material
14,100 ± 200	1259	—*	Gilbert Cove, Nova Scotia	Algal Detritus
13,325 ± 500	7	69	Saint John, New Brunswick	Shells
13,200 ± 200	965	69	Saint John, New Brunswick	Shells (*Macoma calcarea*)
13,000 ± 170	1340	69	Saint John, New Brunswick	Shells (*Mya* sp.)
13,000 ± 240	882	69	Pennfield, New Brunswick	Shells (*Portlandia* sp.)
12,600 ± 400	1383	60*	Shippegan, New Brunswick	Shells (*Mytilus edulis*)
12,200 ± 180	1018	37*	New Richmond, Quebec	Shells (*Mya truncata, Hiatella arctica*)
12,670 ± 340	160	23	Tignish Shore, P.E.I.	Shells (*Macoma, Astarte, Balanus*)
12,410 ± 170	101	23	Miminegash, P.E.I.	Shells (*Mya pseudoarenaria*)
13,800 ± 260	2113	5	Wreckhouse Brook, Nfld	Shells (*Macoma calcarea*)
13,700 ± 230	1074	43	Abrahams Cove, Nfld.	Shells (*Hiatella arctica*)
13,600 ± 180	968	43	Abrahams Cove, Nfld	Shells (*Hiatella arctica*)
13,600 ± 110	2015	43	Abrahams Cove, Nfld.	Shells (*Hiatella arctica*)
13,500 ± 210	1200	44	Robinsons Head, Nfld	Shells (*Hiatella arctica*)
13,420 ± 190	598	28	Highlands, Nfld	Shells (*Macoma calcarea*)
13,400 ± 290	1187	39	Port Au Port, Nfld	Shells (*Balanus* sp.)
13,200 ± 220	937	—	Rocky Point, Port Au Port Bay, Nfld	Shells (*Mya arenaria*)
12,600 ± 170	868	49	Cox's Cove, Nfld.	Shells (*Hiatella arctica*)
12,000 ± 320	1462	47	Little Port, Nfld.	Shells (*Mytilus edulis*)
12,000 ± 220	1733	75	South Brook, Halls Bay, Nfld	Shells (*Balanus*)
11,950 ± 170	75	—	Middle Arm, Green Bay, Nfld.	Shells (*Hiatella arctica*)
11,880 ± 190	87	60?	Southwest Arm, Green Bay, Nfld	Shells (*Balanus*)

**Marine deposit, not necessarily demarcating marine limit* points, in so far as this is possible. The lone data point (37 m) for the Magdalen Islands requires an improbable distortion of the isopleths and the discrepancy needs explanation. Helmut Geldsetzer (pers. commun.) suggests that the salt dome beneath the Magdalen Islands may have been reactivated during the last glaciation, causing the anomalous emergence. In northern Newfoundland, several data points require complex contours that may or may not be real. In Figure 2, the isopleths have been drawn so that a simpler pattern results and the omitted data (northern Newfoundland and Magdalen Islands) are shown in white figures.

Although few of the raised features in the Maritimes are dated, there are enough scattered dates to outline the general pattern of deglaciation (Table I). The oldest date, 14,100 years B.P. (GSC-1259), is from Gilbert Cove in the southwestern part of the Bay of Fundy, Nova Scotia (Grant, 1971, 1976a). Several dates on the northern shore of the Bay of Fundy in New Brunswick are 13,000 years B.P. or older, the oldest being 13,325 years B.P. (GSC-7). Together they suggest that at least the entrance to the Bay of Fundy was deglaciated at approximately 14,000 years B.P. (Grant, 1972). Marine shells from raised deposits on the western end of Prince Edward Island are dated at 12,410 and 12,670 years B.P. (GSC-101,160) approximately the same as deposits dated as 12,600 and 12,200 years B.P. (GSC-1383, 1018) at Chaleur Bay. Thus western Prince Edward Island and Chaleur Bay were apparently deglaciated some 1000 years later than the Bay of Fundy.

In Newfoundland, the raised marine deposits become slightly younger towards the north. At Wreckhouse Brook on the southwestern tip of Newfoundland, marine shells have been dated at 13,800 years B.P. (GSC-2113). Farther north in St. George's Bay, marine sediments have been dated at 13,700 years B.P. (GSC-1074) at Abrahams Cove and 13,500 years B.P. (GSC-1200) at Robinsons Head. Thus, the southwestern part of Newfoundland was deglaciated at approximately the same time as the Bay of Fundy, 14,000 years B.P. In the Bay of Islands, north of St. George's Bay, marine shells from a delta at Cox's Cove have been dated at

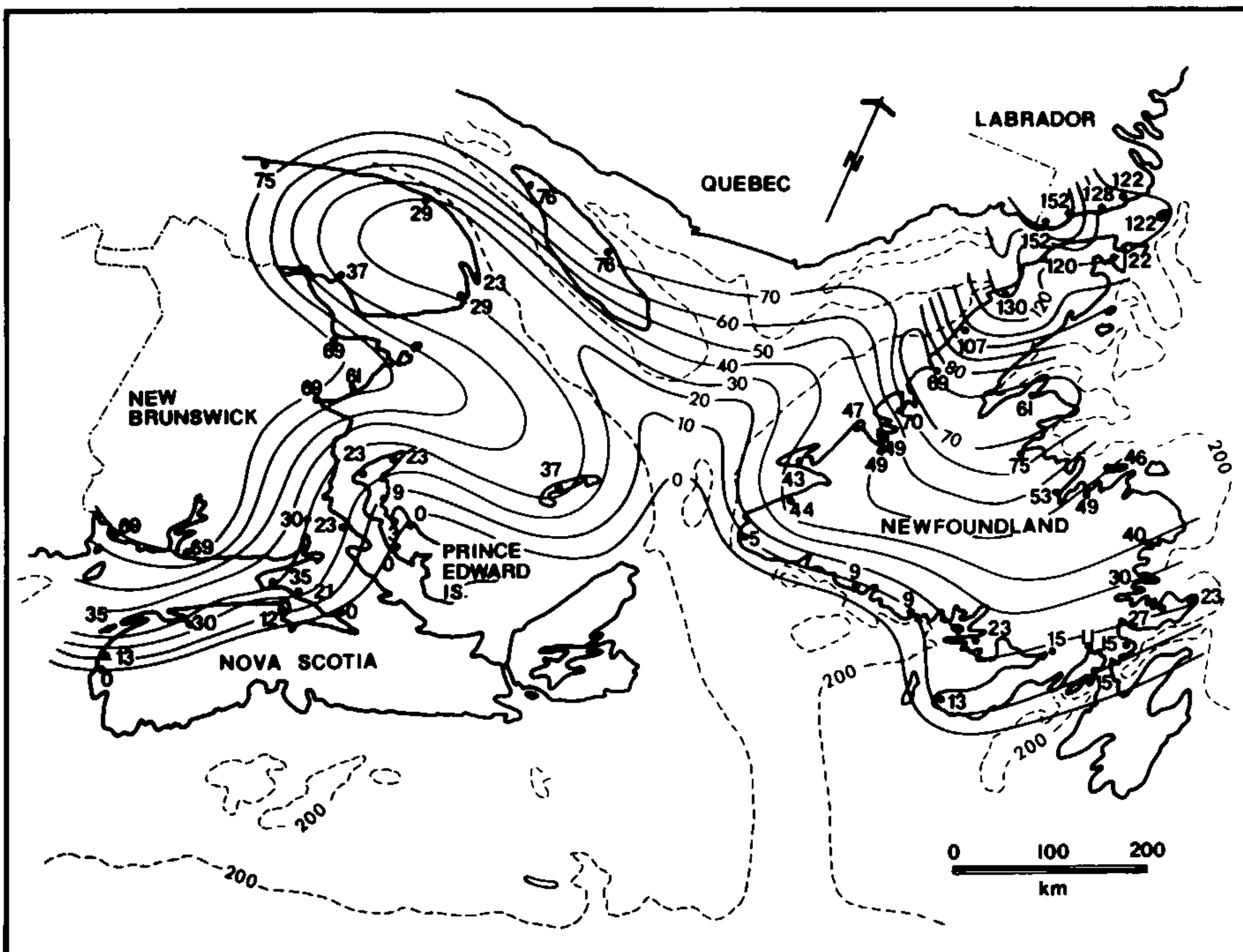

Figure 1
Isopleths of postglacial emergence in Atlantic Canada. Elevations in metres, contour interval, 10 m, dashed lines show 200 m bathymetric contour.

12,600 years B.P. (GSC-868). On the northern coast at Hall's Bay and Southwest Arm, Green Bay, shells from deltaic sediments give dates of 12,000 and 11,800 years B.P. (GSC-1733, 87). Farther north, sediments from the marine limit have not been dated.

As the amount of postglacial rebound is primarily a function of ice thickness during the Pleistocene, some inferences on the patterns of ice flow may be made from Figures 1 and 2. The isopleths show two main centres of maximum uplift, namely New Brunswick, and northern Newfoundland - southeastern Labrador Prest (1970) suggested that Laurentide ice flowed strongly down the St. John River valley into the Bay of Fundy and down the Matapedia River valley into Chaleur Bay. The strong outflow of Laurentide ice must have created considerable ice thicknesses in these two areas, but it is also possible that New Brunswick was itself a more or less independent major ice centre (Prest and Grant, 1969). Newfoundland appears to have had its own ice cap but thick Labrador ice apparently extended to northern Newfoundland (Grant 1969; Prest 1970) causing rebound to increase towards the north. The larger bays on the north and west coasts of Newfoundland apparently were major outflow areas for ice from central Newfoundland.

The deflection of isopleths away from the eastern end of Prince Edward Island suggests that only thin ice existed in the eastern Northumberland Strait-Cape Breton area (Grant, 1976b, 1977b). Much of the St. Lawrence, including the main channels, would have been submerged even with a lowered sea level. Calving of the ice would have prevented, or at least inhibited, extension of ice into the Gulf. At the eastern end of the Gaspé Peninsula, the St. Lawrence River valley must have been wide enough and/or the Shickshock Mountains high enough to divert Laurentide ice down the present St. Lawrence estuary and prevent it from accumulating with any appreciable thickness on the peninsula (Prest and Grant, 1969). Farther to the southwest where the St. Lawrence River valley narrows and the mountains are lower, Laurentide ice extended southwards and some of the ice may have been funnelled into Chaleur Bay and southwestern New Brunswick.

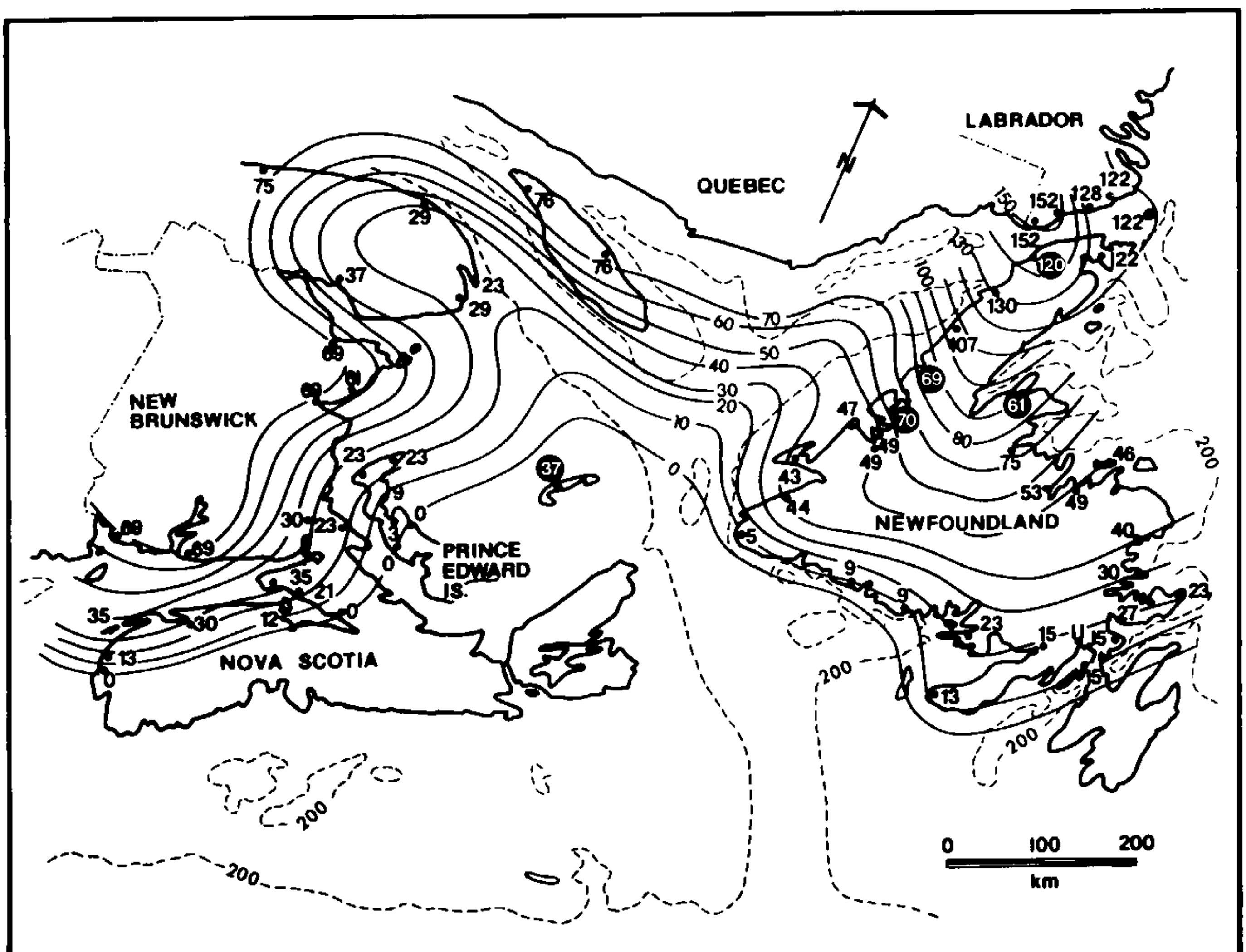

Figure 2
Isopleths of postglacial emergence in Atlantic Canada. Elevations in metres, contour interval 10 m, omitted data in white numerals on black, dashed lines show 200 m bathymetric contour

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