Late Pleistocene and Holocene history of La Malbaie, Gaspésie, Québec

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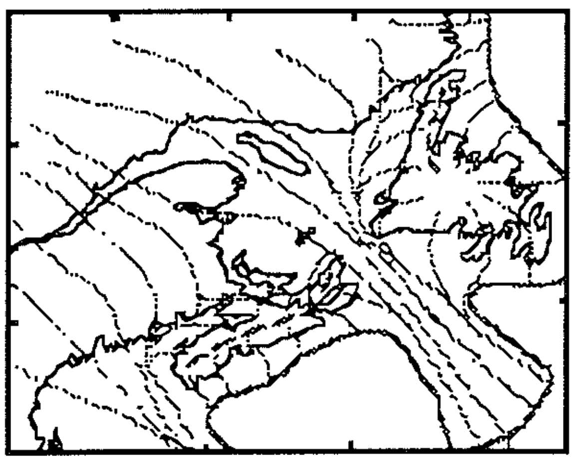
1. Regional Context. The Atlantic Provinces of Canada, which surround the Gulf of St. Lawrence and include Nova Scotia, New Brunswick, Newfoundland, and parts of Quebec, show surface deposits and landforms that are controlled primarily by two processes: the most recent continental glaciation, and late Pleistocene and Holocene fluctuations in relative sea level that accompanied and followed the retreat of this ice.

Atlantic Canada was unquestionably glaciated during the Wisconsinan glaciation in the late Pleistocene, but the extent of ice and its flow regime is uncertain and controversial. Since the late nineteenth century, investigators working in Atlantic Canada have developed two basic models for the Wisconsinan glacial flow regime. The first of these models places the limit of the Laurentide ice sheet, which covered most of Canada and the northern United States some 18,000 years ago, at the north shore of the Gulf of St. Lawrence. This leaves the Atlantic Provinces covered only by local ice caps drained by valley glaciers, with the limit of glacial ice near the present coastline. This minimum hypothesis is illustrated in Figure 1 below. The second model places the terminus of the Laurentide ice sheet tens of miles out in the Atlantic Ocean, far beyond the shorelines of Newfoundland and Nova Scotia. This maximum hypothesis implies that most of the Atlantic Provinces were covered by more than one thousand feet of continental ice flowing inexorably to the southeast in outright defiance of the local topography, a situation diagrammed in Figure 2.

Ice limit

Figure 1. The minimum Wisconsinan ice-sheet model (adapted from Grant, 1977)



Ice limit   Ice divide

Figure 2. The maximum Wisconsinan ice-sheet model (adapted from Hughes and Borns, 1985)

The record of post-Wisconsinan relative sea level (RSL) change is less disputed than the evidence for the two contradictory ice-sheet models. Past RSL in the Atlantic Provinces is controlled by two factors: an isostatic component created by the downward and upward motion of the earth's crust due to ice loading at glacial maximum conditions and unloading during deglaciation; and a eustatic component created by global fluctuations in sea level as the melting of the great ice sheets caused the oceans to rise. Most of Atlantic Canada experienced significant isostatic depression during glacial maximum and rebounded quickly enough to outpace eustatic sea-level rise during deglaciation; this history is recorded in myriad fossil beaches and wave-cut terraces that are now raised well above present sea level. The past marine limit signified by these features at any location is roughly proportional to the proximity of thick ice, and from zero at the edges of Nova Scotia and Newfoundland it rises as high as 100 meters above present sea level to the north and west. (Wightman and Cooke, 1978)

2. Project outline. The study area consists of La Malbaie, an 8-km wide embayment on the east end of the Gaspé peninsula, and the valley immediately inland to the west. The purpose of this project is, first, to study the surficial geology of the field area, La Malbaie, and determine the history of glaciation and RSL change that is preserved therein; and, second, to fit this history into the regional context described above to help evaluate the various regional models for glaciation and RSL change in an area that has not been extensively studied. The project has three components: mapping of surficial deposits and glacial direction indicators, a microgravity survey to determine the shape and extent of the buried bedrock valley, and a detailed sedimentological analysis of some of the surficial deposits in the field area, primarily various glacial tills.

3. Surficial mapping. Figure 3 shows that till is present as a thin, patchy deposit in the center of the valley, and as a more consistent mantle up to 10 m thick on the north shore of the bay. A deposit interpreted as a paleodelta is found in remnants clinging to the sides of the valley carved by the Malbaie River, topped by a flat surface approximately 20 meters above present river level nearby. The presence of these elevated deltaic deposits less than one kilometer from the ocean indicates that RSL must have stood approximately 20 m higher at some time in the past 13,000 years for this delta to exist. This delta was the highest evidence of marine transgression found in the area, and hence must be considered to define the marine limit, which is also shown in Figure 3. Other surficial units present include currently active shoreline, salt marsh, and alluvial deposits.

Some indicators of the direction of past ice flow do exist in the study area (Figure 4). Striated surfaces occur in the north part of the valley and on the north shore of the bay. Several U-shaped valleys, which presumably contained ice streams at one time, enter the field area from the west and northwest. One streamlined feature--or, in the French, *forme fuseleé*--crops out near the Malbaie River in the northern part of the valley.

4. Sedimentological analysis. Granulometric and lithologic analysis of till has been used by previous investigators for two primary purposes: to determine the conditions under which the till in question was deposited; and to constrain the direction of ice flow by tracing various rock types found as clasts in the till to their bedrock source areas. Granulometric analysis of several samples of till from the study area showed that they are sandy, with a relatively low clay content. They are similar to tills from the Gaspé area, north of La Malbaie, that were analyzed by previous investigators (Veillette, 1988), and consistent with other tills found in Atlantic Canada (Scott, 1976). Although the grain-size distributions of the various samples are not uniform, they are consistent with previously identified ablation tills (Dreimanis, 1976), deposited as material melted out of a retreating glacier, rather than basal tills which originate as material that is crushed and compacted under the bed of an active ice stream (Figure 5). No tills with granulometry characteristic of basal tills were found in the study area.

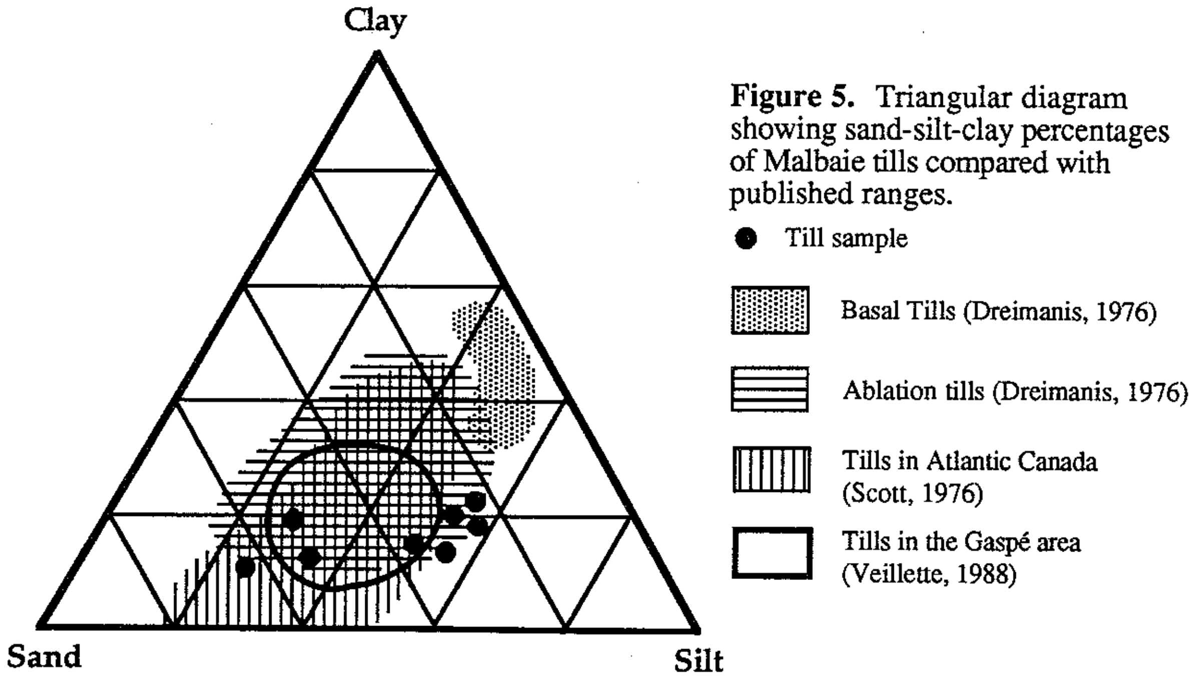


Figure 5. Triangular diagram showing sand-silt-clay percentages of Malbaie tills compared with published ranges.

A lithologic analysis of the clasts greater than 4 mm in the sampled tills yielded information about past ice-flow directions. Clasts originating from the Malbaie formation, which crops out to the north and west of the study area, occurred in tills sampled at sites B and C (shown in Figure 4). This indicates transport of material from either

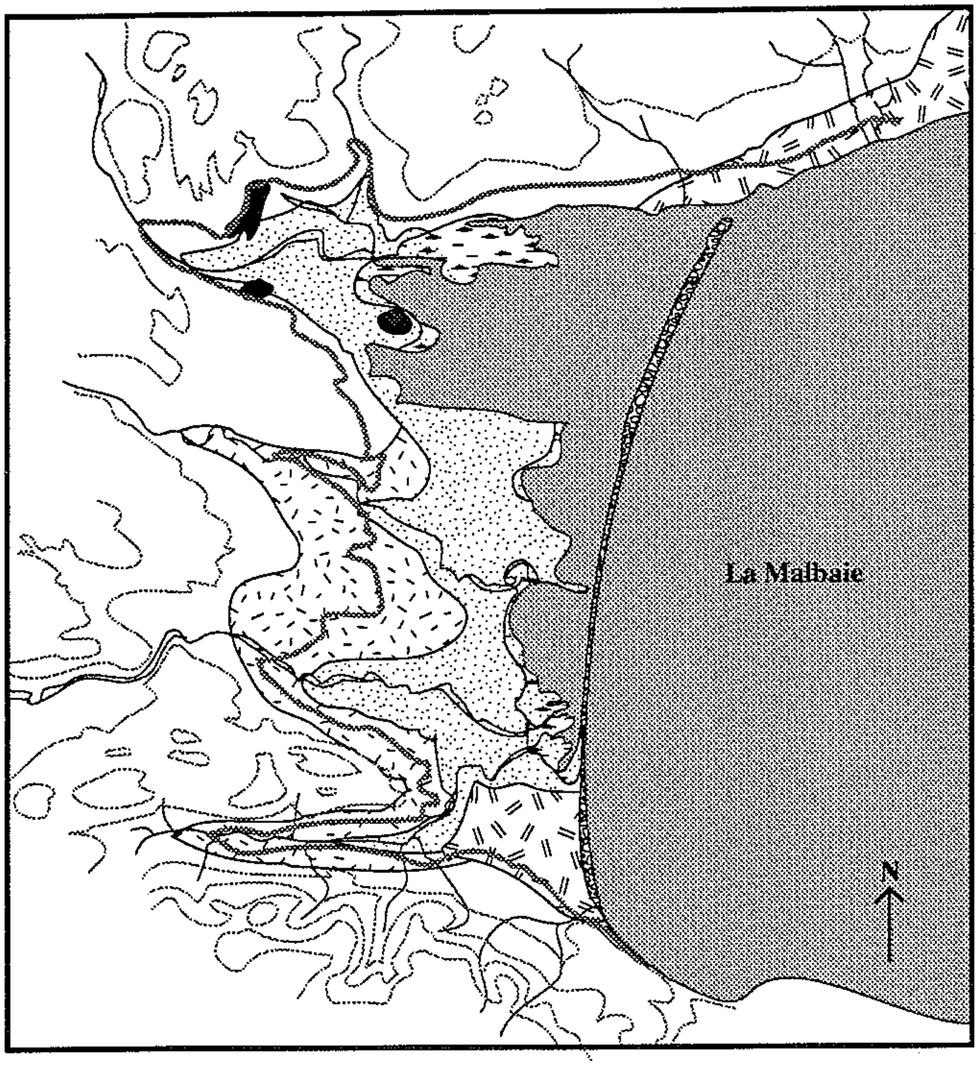


Figure 3.
Surficial geology of study area

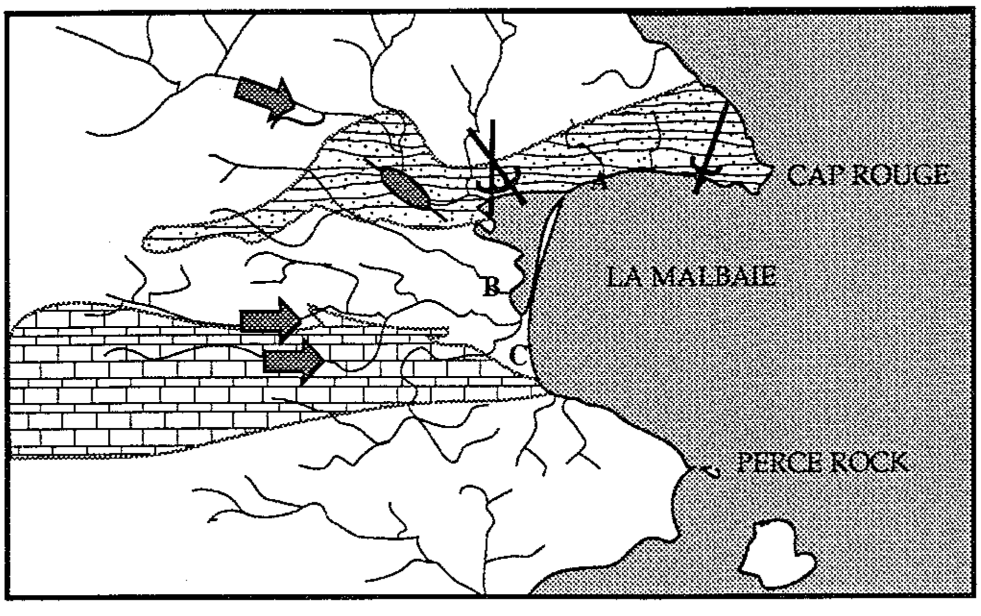


Figure 4.
Ice-flow direction indicators and till source areas

the north or west. The Malbaie formation did not occur at site A, which lies to the north of B and C. This indicates that the ice that deposited tills B and C flowed from the west into the valley. At site C, a large percentage of the clasts in the till were limestone, which was present only in trace amounts at the other two sites. The only outcrops of limestone in the area are found directly to the west of site C. Ice, therefore, seems to have flowed eastward from the highlands into the valley.

5. Microgravity survey. Differences in the density of subsurface materials in an area cause variations in the gravitational field that can be measured at the surface. These variations can be analyzed to yield information about the subsurface geology. A Worden microgravity meter was used to survey a traverse across the study area in an attempt to model the shape of the buried bedrock valley. Various corrections were applied to the data, and when the computer program GravModel (Burger, 1991) was used to model various subsurface configurations that were constrained by observations at the surface and measured densities of various substances, the interpretation that produced the best fit with the observed gravity anomaly was a broad, flat-bottomed bedrock valley, about 120m below the surface at its deepest point, filled primarily with till. The presence of a valley that is U-shaped rather than V-shaped suggests that it was carved by glaciers moving to the east rather than a river that existed before the arrival of glacial ice.

6. Conclusions. Most of the evidence outlined above suggests glaciation of the study area by valley glaciers flowing from the west, out of the interior of the Gaspé peninsula, rather than by thick continental ice moving from the north. The presence of patchy ablation till in the valley bottoms and absence of thick basal till that might be expected underneath massive continental ice, the presence of ice-flow direction indicators parallel to the valleys feeding the study area, the evidence for west-east ice flow provided by the till lithology, and the wide, flat paleo-valley disclosed by the microgravity survey, all support the minimum model proposed for Atlantic Canada in which the primary glacial activity on the Gaspé peninsula was a local ice cap drained by shoreline valley glaciers. There is little evidence for transgression of continental ice over the study area, with the exception of the striated surfaces to the north of La Malbaie that indicate ice flow to the SSW and can not be explained by valley glaciation.

The RSL record in the study area is almost nonexistent, consisting only of one high sea-level stand at 20 meters above present sea level, indicating that sufficient isostatic rebound did occur to outpace a rising sea level during deglaciation. This is consistent with other work in Atlantic Canada. Since the deposits at 20 m could not be dated, little information was gained regarding the RSL record.

7. References cited.

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