An analysis of the material underlying the Penouille and Sandy Beach Spits and the Haldimand and Douglastown coastal littoral features on the Gaspé Peninsula, Québec, Canada and its implications for coastal littoral feature formation

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In the Bay of Gaspé, along the northernmost Gaspé Peninsula, Québec, Canada, four coastal littoral features covering an approximate linear distance of 9 km across two separate but adjacent bays show a remarkable lineation of trend. The study area (fig. 1) is located on the extreme eastern edge of the Gaspé Peninsula. The littoral features known as the Penouille Spit in the Forillon Provincial Park and the Sandy Beach Spit which lies to the south are located at the mouths of the Dartmouth and York Rivers respectively. The Douglastown and Haldimand coastal littoral features are situated approximately 3 km to the south in the Bay of Gaspé at the mouth of the Saint Jean River. The morphology of the former two littoral features suggests that they may indeed be spits. The latter have the appearance of a bay mouth bar, but in the absence of geographic names, and until their nature is determined, they shall be referred to by the more general term of coastal littoral features. The alignment of all four of these coastal littoral features may be more than coincidence. It is the purpose of this study to test feasible explanations for the alignment. I have chosen to address as accurately as possible the character of the materials which underlie the coastal littoral features in question. Both regional sheets and local ice caps covered much of the Gaspé Peninsula during the last Wisconsinan glaciation (David, 1982; Veillette, 1988; David and Lebuis, 1985; et al). It is possible that, following the westward retreat of this ice a terminal morraine formed the basis for the coastal littoral features in question. If so, it would be expected that till would underlie the littoral features. In contrast if these features formed as the result of a complex interaction of waves, longshore currents and other coastal processes, then the material underlying them should be saturated sands.

A gravity survey was conducted along the eastern edge of the Douglastown and Haldimand coastal littoral features and along the eastern edge of the Sandy Beach Spit. A total of 113 readings were made at 26 data stations using a Worden gravimeter. The gravimeter measures the difference in observed gravity between points to a precision of 0.01 milliGal (mGal). Most stations were situated 1000 feet apart. Multiple readings were made at each site to ensure precision measurements, and certain sites were returned to at two hour intervals to provide a means by which to compensate for instrument drift (Dobrin, 1960). The effects of the earth's rotation and the resultant outward-directed centrifugal force, the distance of the data station from the equator, and the fact that the earth is not a perfect sphere but rather an ellipsoid of rotation, combine in such a way that there is a net increase in gravity from the equator to either one of the poles (Burger, 1992). Thus it is important that the position of each of the data stations be known as accurately as possible. Each of the stations in my survey was pinpointed using the Magellan Global Positioning System which, by triangulation using the three most convenient of the many available military satellites overhead at any given time, is able to determine latitude and longitude within approximately 5m. Changes in elevation of the land surface result in variations in observed gravity due to a variation in the amount of material between the data station and the center of the earth and also due to variations in distance from the earth's center of mass. Accurate relative altitudes of the stations in the survey were determined using a laser theodolite. Data reduction was performed in the form of a free-air correction, which compensates for both the effects of latitude and elevation. The free-air correction would suffice if there were no additional material beneath the gravimeter and sea level, but since this is not so, a Bouguer correction, which assumes a slab of uniform material of infinite extent to directly underlie the gravimeter, is used to account for the additional attraction of this added material underneath the gravimeter. Since it is not entirely correct to assume an infinite slab of uniform material, a terrain correction was used to compensate for the variations in attraction due to local topography. Based on techniques proposed by Hammer (Dobrin, 1960), templates were constructed which, when superimposed upon a topographic map, allow estimations of average elevations to be determined for each of the 68 sectors on the template. The elevation differences between the data station and each sector were used to calculate a correction value. This terrain correction was based on 1:12,000 (le Service Hydrographique du Canada, 1991) and 1:75,000 (le Service Hydrographique du Canada, 1989) scale topographic maps.

Handsample sized specimens of Paleozoic sandstone bedrock were collected from outcrops at the points at which the coastal littoral features in question connect to the mainland, and numerous sand samples were collected all along each feature. These were subjected to density determinations both by means of mass / water displacement and mass / volume measurements (using calipers to ascertain accurate volumes for the cylindrical, regular sandstone cores.) In both cases masses were determined to 0.01g by means of a balance. This density data was used to enhance the interpretation of the above-mentioned gravity survey.

A shallow refraction survey consisting of a total of eight seismic refraction lines laid out parallel to the length of each of the coastal littoral features was also conducted. Refraction surveys, by combining the times taken for seismic waves to travel from the energy source to the geophone and the distances of each of the geophones from this source, yield data on seismic velocities of the various subsurface materials as well as on the layered geometry of these materials. Two different seismic wave sources were used in the studies. For some of the lines the impact onto a steel plate of a special sledge hammer equipped with a device to automatically trigger a timer was used. For other lines the explosion of a 10-gauge shotgun shell just beneath the surface was triggered by the impact of a steel rod. The impact of the rod automatically triggered the timing device. 230m-long double refraction lines, in which 12 geophones are arrayed on either side of the source, were run on Penouille Spit, Douglastown feature and on Sandy Beach Spit. Two single lines 135m long with 12 geophones each were also run on Sandy Beach Spit. An additional 135m long single line was run on Douglastown feature.

An analysis of the seismic refraction data, in the form of time v. distance plots (fig. 2), graphically depicts layering in the subsurface down to a maximum depth of approximately 100 m. Best-fit lines to the travel time plots are hand picked. From the slope of those lines a computer program (Burger and Burger, 1992) constructs depth cross sections showing layers of different velocities. Computer-chosen lines, calculated according to the least squares method or some similar method, were avoided since the computer would not disregard points which fall well outside of the average velocity for a layer probably as a result of small scale subsurface irregularities. Standards in Clark (1966) were used for determining materials that correspond to the velocities observed. Many of these plots typically show a thin layer (less than 1 m) of material with velocity ranging from 270 to 300 m / sec and the layer probably corresponds to sand exposed at the surface. Typically, beneath this a thicker 1400 to 1600 m / sec layer is found. It is interpreted as wet, saturated sands for which Clark gives estimates of 1000 to 1800 m / sec. Beneath this layer is typically found yet a higher velocity material which spans depths from approximately 8 m to 25 m depending upon the location of the seismic line. Velocities ranging from 2600 to 3200 m / sec characterize this layer. The next and lowest layer sampled is interpreted as the sandstone bedrock with velocities ranging from approximately 3700 to 4400 m / sec. It is the layer directly above the bedrock which eludes straightforward classification. Its velocities suggest that it may very well be some sort of unconsolidated sediment or weathered bedrock, yet thicknesses of this layer seem to rule out the latter possibility. However, seismic velocities as recorded on a known till deposit in the vicinity using a 10 geophone line with a 10m interval between geophones and a 5m offset from the source yield a value of approximately 2400 m / sec which is somewhat lower than the velocities of the unknown layer lying just above the bedrock. The reduced gravity data yields a profile which should aid in this interpretation.

References Cited

Burger, H. R., (1992) Exploration Geophysics of the Shallow Subsurface. Prentice-Hall, Inc., New York, 489 pp.

---------, and Burger, D. C. (1992) *Refract Solve* (computer program), Prentice Hall, Inc., New York.

David, P. M., (1982) Geomorphology and Quaternary geology of the Gaspé Peninsula, *International Assoc. of Sedimentologists Excursion 7B*, p.61-68.

---------, and LeBuis, J. (1985), Glacial maximum and deglaciation of western Gaspé, Québec, Canada: *GSA Special Paper 197*, p. 85-109.

Dobrin, M. B., (1960) Introduction to Geophysical Prospecting, second edition. McGraw-Hill Book Co., Inc., New York, 446 pp.

Le Service Hydrographique du Canada, (1991) carte 4416.

----------, (1989) carte L/C 4485.

Veillette, J. J. (1988) Observations sur la géologique glaciaire du nord-est de la Gaspésie, Québec: *GSC Current Research Paper 88-1B*, p. 209-219.

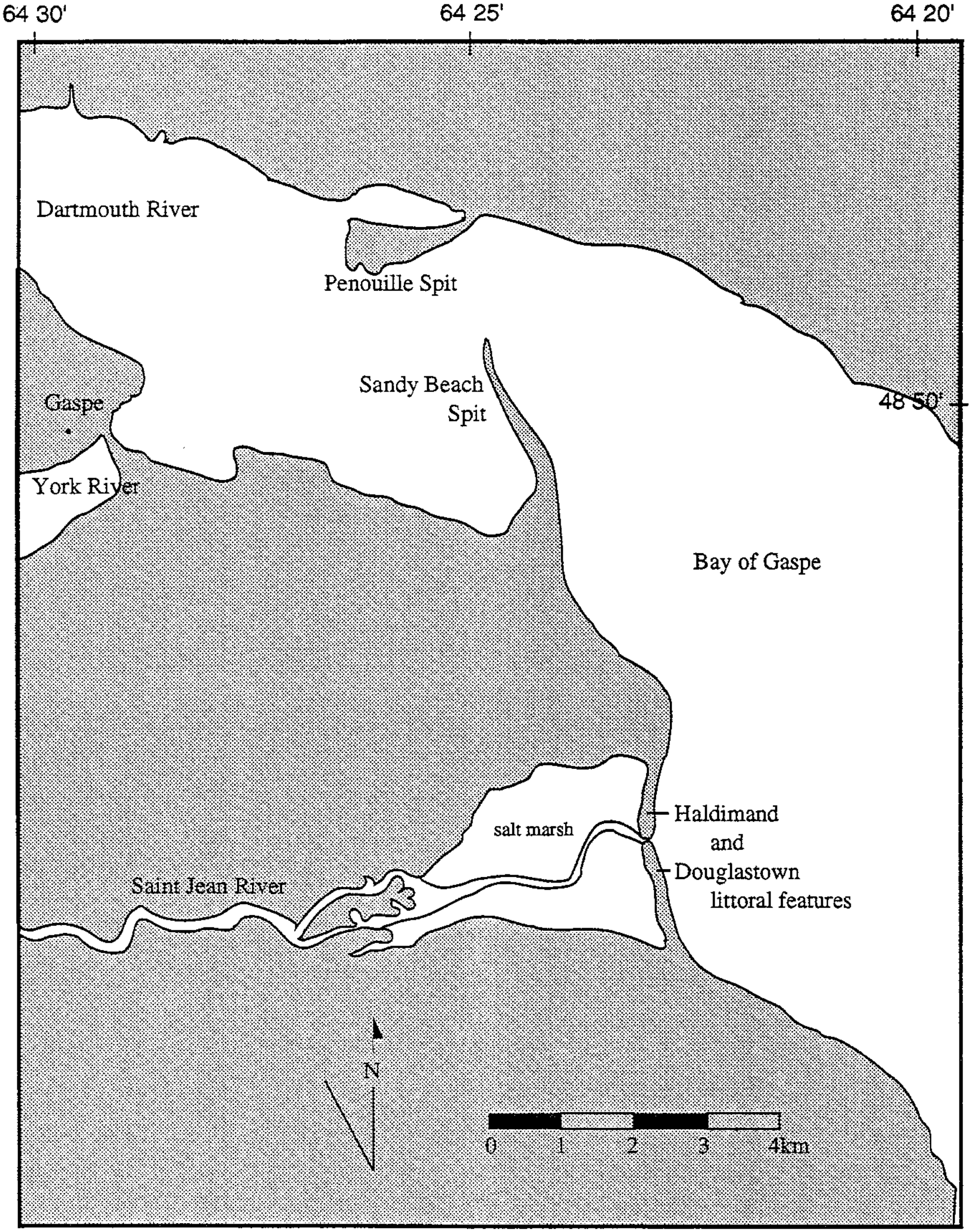
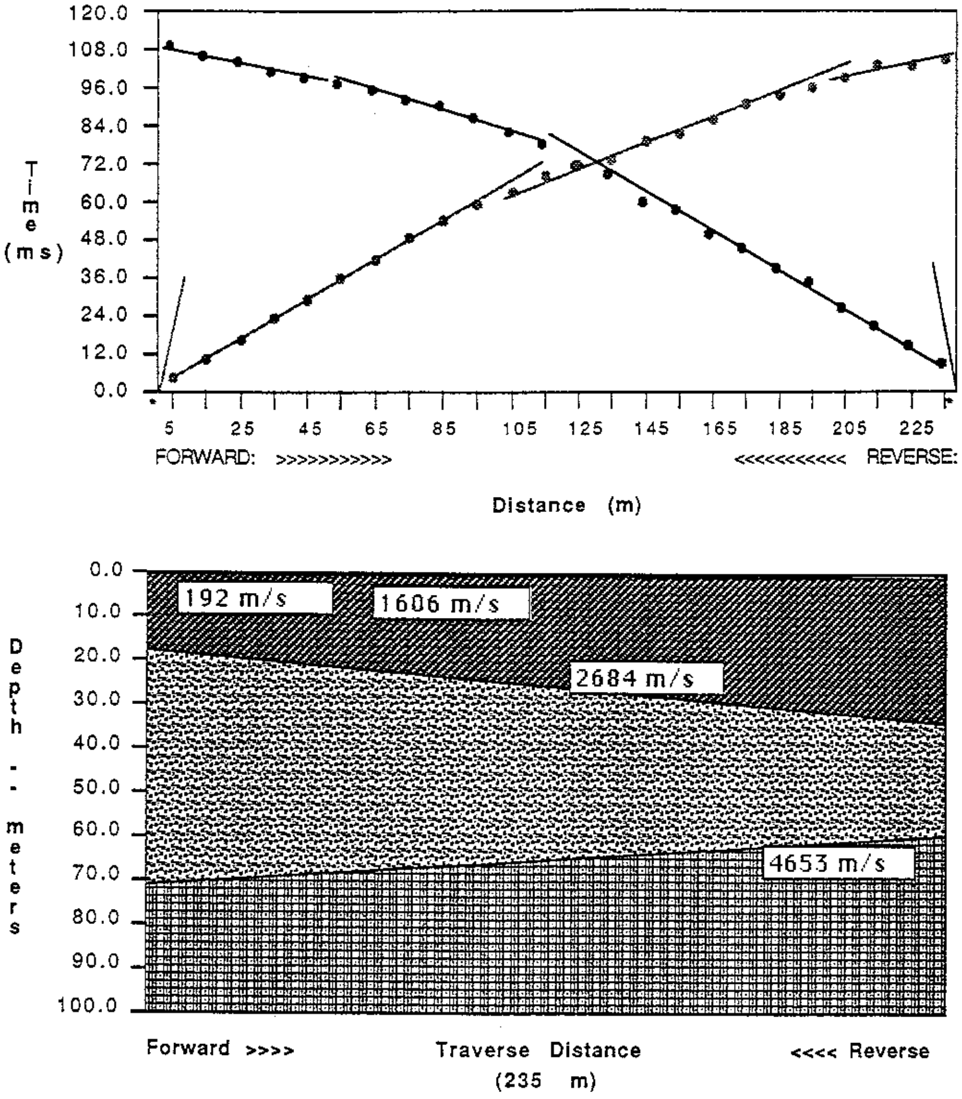


Fig. 1: Map showing the area of study on easternmost Gaspe Peninsula, Quebec, Canada



Input Data **Spread Length = 235 m**

Layer	Apparent Forward Velocities (m/s)	Apparent Reverse Velocities (m/s)	Forward Intercept Times (msec)	Reverse Intercept Times (msec)
1	210.3	172.9	0.0	0.0
2	1604.9	1607.5	1.9	5.1
3	2426.9	3025.2	19.1	38.4
4	4538.8	4840.2	54.7	59.9

Computed Structure

Layer	Velocity	For. Thickness	Rev. Thickness	Dip	For. Depth	Rev. Depth
1	191.6	0.2	0.5		0.2	0.5
2	1606.2	17.3	33.5	-0.00	17.5	34.0
3	2684.4	53.5	25.7	-4.63	71.0	59.6
4	4653.4			3.08		

Fig 2: Example of the seismic refraction data obtained. Shown here is the double line from Douglastown.