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Postglacial Sea-Level History and Coastline Change at Port au Choix, Great Northern Peninsula, Newfoundland

TREVOR BELL, I. ROD SMITH, and M.A.P. RENOUF

INTRODUCTION

CLOSENESS TO THE COAST and access to marine resources has always been an important determinant in the location of habitation centres at Port au Choix (Figure 1), from the earliest occupation by Maritime Archaic Indians over 6000 years ago to the present town. Since the end of the last glaciation the coastline of Port au Choix has changed dramatically. Melting ice sheets caused volumetric changes in sea water and vertical adjustments in the Earth's crust, which resulted in significant sea-level changes. The former seabed emerged out of the water and the coastline moved in a seaward direction. As sea level dropped, old sites were abandoned and new sites established as the coastline was reconfigured. The purpose of this paper is to examine how postglacial changes in sea level affected the position and configuration of the Port au Choix coastline, and to show how the changing coast influenced the location of prehistoric occupation. Following a brief introduction to the spatial and temporal patterns of sea-level history in Newfoundland, we describe the study approach and the data set used to reconstruct sea-level change in the Port au Choix region. A series of palaeogeographic maps illustrates how the present coastline has evolved over the last 11,250 cal BP.[1] Finally, we examine the location of archaeological sites in the context of the contemporary coastline.

Figure 1. Location map for place names and sample sites referred to in the text. See Table 1 for details of radiocarbon-dated samples.

Prehistoric Human Occupations of Newfoundland

Newfoundland was home to prehistoric Amerindians and Palaeoeskimos. Each cultural tradition had a distinctive pattern of subsistence economy and material culture, rooted in its distinct ancestry. Amerindians were generalists who exploited marine, freshwater, and terrestrial resources, with a stone tool industry based on slates and relatively coarse-grained cherts and quartzites. Palaeoeskimos were marine specialists, and their stone tools, made from fine-grained cherts, were smaller and more delicate. The different economic emphases of the two cultural traditions are reflected in site locations: while coastal locations were important to both, Palaeoeskimo sites tend to be found in exposed outer coast locations suitable for hunting harp seals, whereas prehistoric Amerindian sites are usually found in sheltered inner bay areas, or inland (Pastore 1986; Schwarz 1994; Renouf 2003; Renouf and Bell in press).

The first people to occupy Newfoundland were the prehistoric Amerindians called Maritime Archaic Indians (MAI). In Labrador, MAI sites have been dated as early as 9500 cal BP (McGhee and Tuck 1975), but the oldest site in Newfoundland, at Port au Choix, dates from 6290 cal BP (Renouf and Bell 2000). Maritime Archaic groups flourished on the island until about 3340 cal BP. No later sites have been found, and the complex of reasons behind this disappearance from the archaeological record is not understood.

Maritime Archaic Indians were followed by the first of two Palaeoeskimo cultures, the Groswater Palaeoeskimos. Groswater sites date from between 2990 and 1820 cal BP, with some dates as recent as 1720-1570 cal BP, from Bird Cove on the Northern Peninsula (Hartery and Rast 2001). Two well-preserved Groswater sites have been found at Port au Choix, and faunal material indicates the primacy of harp seal hunting, although a wide range of bird and small mammals were also utilized (Renouf 1994; Wells this volume).

Groswater Palaeoeskimos were followed by another Palaeoeskimo culture known as Dorset. The relationship between the two populations is unclear. Dorset Palaeoeskimo sites occur in many of the same locations as the Groswater sites, but the Dorset sites are larger and were more permanent. Where faunal material is available, it shows an almost exclusive focus on harp seal hunting (Renouf and Murray 1999; Hodgetts et al. 2003). Dorset sites in Newfoundland date to between 1990 and 1020 cal BP. Why the Dorset abandoned Newfoundland is unclear, but at Port au Choix this was a time of warmer-than-normal temperatures (Renouf and Bell 2004).

A second Amerindian culture shared Newfoundland with the Dorset. Recent Indians populated Newfoundland between 2110 cal BP to the historic period, when Europeans identified them as Beothuks. Archaeological research on Recent Indians is in its infancy, but three Recent Indian sub-groups or cultural complexes are recognized: Cow Head (2110-930 cal BP), Beaches (2030-800 cal BP), and Little Passage (970 cal BP to the historic period). While a Beaches-Little Passage-Beothuk continuum is generally accepted (Pastore 1992), the relationship of Cow Head people to the earlier Maritime Archaic groups and the later Beaches groups is undetermined.

These are the peoples who occupied Newfoundland during the prehistoric period. Their cultural patterns differed, but the coast was important to all of them.

They exploited its resources and situated their camps on its shorelines. The shoreline changed over time, and thus the history of relative sea level in Newfoundland has important implications for understanding the details of this long and varied prehistoric record, in particular each culture's site locations.

Sea-Level History in Newfoundland

The relationship between changes in sea level and glaciation is well established (e.g., Andrews 1987). The combination of eustatic sea-level change through capture and release of water in continental ice sheets, and isostatic depression and rebound of the Earth's crust due to the growth (crustal loading) and decay (crustal unloading) of ice sheets can result in a complex history of relative sea-level (RSL) change. Glacioeustatic sea-level changes are relatively rapid, and may be experienced simultaneously over large regions, whereas glacioisostatic processes, including the lateral movement of low viscosity mantle material, are relatively slow, taking 10,000 years or more to complete. Together, these processes result in spatially variable sea-level records (e.g., Shaw et al. 2002).

Postglacial changes in sea level in Newfoundland are complex, because the island experienced the combined loading effects of the continental Laurentide Ice Sheet to the north and west, and the Newfoundland Ice Complex over other areas (Quinlan and Beaumont 1981; Liverman 1994). Immediately following the retreat of the ice, most of the island experienced a rapid fall in sea level, followed by a slow rise to its present level. This is a type-B sea-level history, following the terminology of Quinlan and Beaumont (1981). On the northeast Avalon Peninsula, the magnitude of the later sea-level rise exceeded the earlier sea-level fall, and today the sea is at its highest level since the last 120,000 years or so (a type-C sea-level history, Figure 2). In contrast, for much of the Great Northern Peninsula and adjacent Labrador, sea level has continued to fall during the entire postglacial period due to continued isostatic rebound (a type-A sea-level history, Figure 2).

Sea-Level Studies at Port au Choix

The first scientist to collect and radiocarbon date samples for palaeo sea-level studies at Port au Choix was Douglas Grant of the Geological Survey of Canada. His sea-level chronology (Grant 1994) was partly developed with James Tuck, in the 1970s, in connection with archaeological investigations at the MAI cemetery in the town centre (Grant 1972). On the basis of dated samples from Port au Choix, and others from the surrounding region, Grant proposed two models of postglacial RSL history for the central region of the Great Northern Peninsula. The first postulated a more or less continuously decelerating fall in sea level of 140 metres over the last

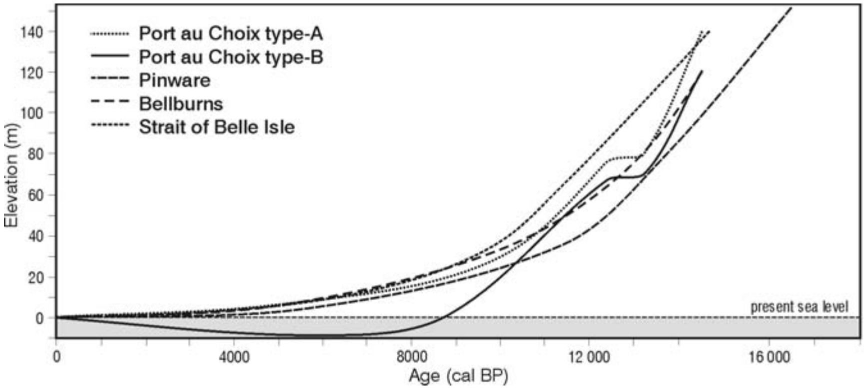


Figure 2. Comparison of RSL *curves reconstructed for the west coast of the Great Northern Peninsula and southern Labrador. Sources: Pinware, southern Labrador — Clark and Fitzhugh (1992); Strait of Belle Isle — Grant (1992); Port au Choix types A and B — Grant (1994); Bellburns — Bell (unpublished).*

14,700 cal BP (Port au Choix type-A, Figure 2). The second suggested that the sea fell 10 metres below its present level, and then slowly rose over the last 6000 cal BP (Port au Choix type-B, Figure 2). Grant was fairly confident that the type-A sea-level history was representative of the area from Bartlett's Harbour (20 km north of Eddies Cove West, Figure 1) to River of Ponds (15 km south of Port Saunders, Figure 1), but less confident that a type-B sea-level history characterized the coast farther south. His interpretation hinged on the correct interpretation of the palaeo sea-level elevations associated with three dated shell samples in that area (Bell unpublished).

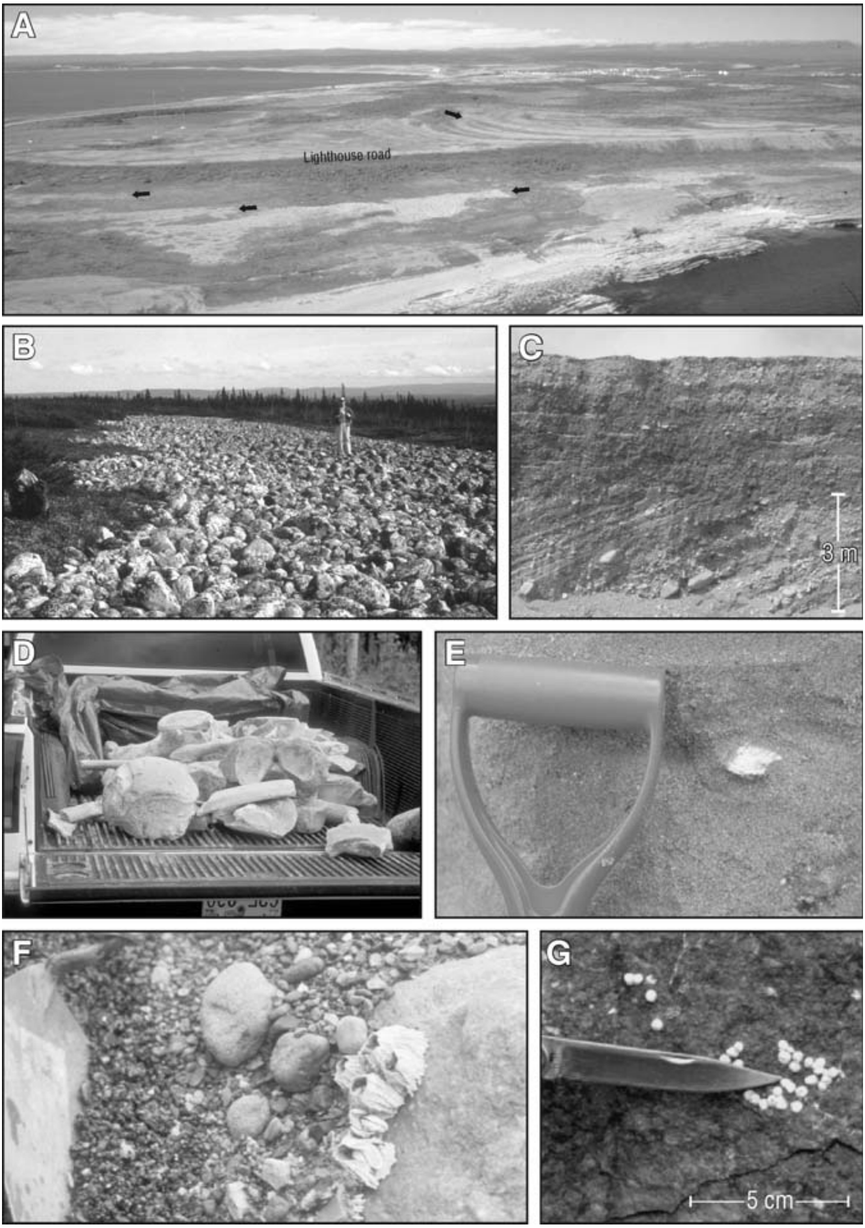
Grant (1992) postulated that the sea level did not change between 13,300 and 12,600 cal BP across the Great Northern Peninsula. This "stillstand" was associated with a readvance of Long Range Mountain ice to the Ten Mile Lake moraine. He argued that the increased mass of ice, and its related gravitational attraction, would be sufficient to largely offset the emergence of 3 metres per century. Grant (1994) also argued that a minor oscillation (~10 m) of sea level occurred between 3700 and 2000 cal BP to accommodate the formation of a low, horizontal cliff just above present high tide. Dated beaches between 4500 and 900 cal BP old apparently bracket the age of the cliff. Smith et al. (this volume) directly test the validity of this sea-level fluctuation, using the "isolation basin" method at several sites between Hawke's Bay and Brig Bay. In this paper, however, we examine the larger picture of sea-level history and apply a broad range of palaeo sea-level data to develop a RSL curve for the Port au Choix region.

Approach

The magnitude and timing of RSL changes may vary greatly over short distances along the west coast of the Great Northern Peninsula, because the postglacial isobase pattern runs more or less at right angles to it (Grant 1989; Shaw et al. 2002). For this reason we utilize palaeo sea-level data from within 20 kilometres of Port au Choix to reconstruct a representative RSL curve.

Shoreline features and deposits are evidence of former sea levels (Figure 3a-c) and, when dated by means of their associated fossils (Figure 3d-g), serve to outline the course of postglacial sea-level change. The upper limit of marine submergence, known as marine limit, is typically marked by deltas recording where glacier-fed

*Figure 3. (Right) The following are some examples of landforms and associated fossils, which are used to reconstruct RSL history on the Great Northern Peninsula. A) Oblique photograph looking across Point Riche towards Phillip's Garden and Old Port au Choix in the background. Remnants of raised beaches (arrowed) can be traced from the modern shoreline (in the right foreground) up to the height of land. At least 17 Dorset Palaeoeskimo dwellings have been mapped on lower beaches in the left foreground and farther west (EeBi-20, site 28, Table 1; Eastaugh and Taylor this volume). B) Raised gravel beaches occur up to 20 km inland of Port au Choix on the lower slopes of the Highlands of St. John (photo courtesy of I.A. McKnight). C) A photograph of a quarry face through a raised marine delta on Bateau Barrens, 15 km south of the map boundary in Figure 1. Deltas are masses of sediment built out into the sea by rivers. Coarse sediment avalanches down the delta front forming sloping foreset beds, whereas fluvial (river) sediments accumulate above water level as horizontal topset beds. The contact between the topset and foreset beds represents the elevation of sea level when the delta was being formed; in the case of this delta, when sea level was 70 m higher than present. D) The vertebrate and rib bones from a whale were uncovered by Terry Patey, River of Ponds, during quarrying of deltaic sediments on Bateau Barrens. Upon death, whales commonly float ashore and become incorporated in the beach, or in this case delta deposits. Because of the contamination potential of whalebone, shells (shown here in photograph E), were radiocarbon dated. They provided an age of 12,850 cal BP (Bell unpublished) which dates the sea-level position identified in (D) above. F) Buried barnacle remains (*Balanus crenatus*) were found attached to large boulders in a quarry at Port Saunders (site 12). They have an age of 9720 cal BP, which roughly dates a former sea-level position recorded by a nearby marine terrace at 40 m elevation. G) Photograph of worm tubes (*Spirorbis borealis*) found attached to wave-rounded bedrock at 21 m asl in Hawke's Bay (site 8). A sample of tubes provided an age of 10,710 cal BP, which suggests that the worms were living in water depths of 60 m or so at that time.*


A
Lighthouse road
B
C
3 m
D
E
F
G
5 cm

rivers entered the sea. Lower sea-level positions are recorded by various coastal landforms, including beaches, sea cliffs and wave-cut terraces (Figure 3a-b).

Organic material, most commonly marine shells or bone from marine mammals, is radiocarbon dated to provide temporal data concerning former sea levels. For example, shells preserved in the dipping gravel beds on a delta front can usually date when sea level occupied the position of the flat delta top (Figure 3c-e). The RSL curve therefore would pass through the projected sea-level position at the elevation of the delta top, not the shell collection site. On the other hand, most marine shells in and on raised beaches are reworked from the seafloor, and incorporated into beaches during emergence. Radiocarbon dates on shells from beaches therefore provide only maximum ages on beach formation, and tend to plot below the RSL curve because they relate to a higher sea level. Shells that have no apparent relationship to raised coastal landforms — for example, shells preserved in life position in deepwater mud on the former seafloor — may be radiocarbon dated because they provide minimum estimates of sea-level elevation at the time of shell growth. They too will plot below the actual RSL curve.

Dates on freshwater peat and organic material from archaeological sites (e.g., charcoal from hearths) provide maximum ages on emergence of the sites at which they are found. In other words, sea level at the time when the freshwater peat was accumulating, or the archaeological site was occupied, must have been below the elevation of the sample site. Dates on these materials therefore must plot above the RSL curve.

During periods of higher sea level freshwater lakes or ponds below marine limit were inundated by seawater. The isolation basin method, described by Smith et al. in this volume, attempts to date boundaries between marine and freshwater sediments in the lake basin in order to determine when sea level fell below the elevation of the basin lip/outlet, and the basin evolved into a freshwater lake.

Palaeo Sea-Level Data

A total of 29 new and published radiocarbon-dated samples from a 400-square-kilometre area of the coastal lowlands surrounding Port au Choix are used here to reconstruct postglacial sea-level history (Table 1, Figure 1). The samples consist of marine shell (12), charcoal (7), plant remains (6), organic mud (2), human bone (1), and charred material (1). About half of these samples are from terrestrial or freshwater environments and therefore define an upper limit to the RSL position. The other half comes from deep- to shallow-water marine environments.

Table 1. Radiocarbon dates and details of samples used to reconstruct relative sea-level history in the Port au Choix region

Site #[a]	Radiocarbon date (yr BP)[b]	Laboratory number	Calibrated age (yr BP)[c]	Sample elev. and error (m)[d]	Related sea level elev. (m)	Material dated[e]	Ref.[f]
7	10,790 ± 180	GSC-2919#	12570 (12760) 13010	75 ± 20†	75 ± 20	*M.t.*	3
8	10,710 ± 90	TO-9168	12310 (12630) 12960	21 ± 2‡	≥21 ± 2	*S.b.*	6
17	9380 ± 150	GSC-5661	10380 (10720) 10870	9*	9	marine organic mud	5
9	8790 ± 80	GSC-3998	9560 (9860) 10150	34 ± 2‡	>34≤40	*M.e.*	4
10	8780 ± 80	TO-9164	9500 (9840) 10160	28 ± 2‡	>28≤40	*M.e.*	6
11	8760 ± 80	TO-9165	9480 (9800) 10150	28 ± 2‡	>28≤40	*M.e.*	6
12	8710 ± 80	TO-10947	9430 (9720) 10040	38 ± 2‡	>38≤40	*B.c.*	6
15	7920 ± 130	Beta-32598	8420 (8780) 9030	55*	55	organic mud	6
3	7570 ± 90	Beta-107796	8200 (8430) 8630	9 ± 1	≥9 ± 1	*N.l.*	5
21	5440 ± 50	Beta-148518	6170 (6230) 6310	10.5 ± 0.01	<10.5 ± 0.1	charcoal	5
16	5100 ± 50	Beta-115782	5730 (5820) 5930	9*	9	conifer bark	5
18	4670 ± 120	TO-8518	5030 (5390) 5610	7.89 ± 0.01	<7.89 ± 0.01	*Ericaceae* stem	5
1	4480 ± 130	GSC-1403#	4970 (5190) 5340	6.1 ± 0.3	≥6.1 ± 0.3	*M.p.*	1
22	4220 ± 50	GrA-6478	4249 (4391) 4591	6.1§	<6.1	human bone	5
23	4060 ± 50	Beta-146081	4420 (4550) 4650	8.32 ± 0.01	<8.32 ± 0.01	charcoal	5
19	4010 ± 160	TO-8520	4070 (4480) 4860	8.23 ± 0.01	<8.23 ± 0.01	*Ericaceae* leaf, bark	5

Site #[a]	Radiocarbon date (yr BP)[b]	Laboratory number	Calibrated age (yr BP)[c]	Sample elev. and error (m)[d]	Related sea level elev. (m)	Material dated[e]	Ref.[f]
4	3770 ± 80	Beta-149994#	4000 (4240) 4430	5.62 ± 0.2	≥5.62 ± 0.2	*N.l.*	5
14	3460 ± 40	Beta-151259	3630 (3730) 3830	7.9*	7.9	plant material	5
2	2900 ± 130	GSC-1318	2970 (3150) 3320	4.5 ± 0.3	≥4.5 ± 0.3	*M.a.*	1
24	2760 ± 90	Beta-23979#	2740 (2880) 3080	10.5§	<10.5	charcoal	5
25	2540 ± 160	Beta-49759#	2300 (2590) 2970	13§	<13	charcoal	5
26	2140 ± 100	Beta-23976#	1920 (2130) 2340	8.5§	<8.5	charcoal	5
27	1850 ± 110	Beta-15379#	1530 (1780) 2010	10.5§	<10.5	charcoal	5
28	1810 ± 40	Beta-160978	1690 (1740) 1830	10.41§	<10.41	charred material	5
29	1420 ± 70	Beta-49754	1230 (1330) 1420	2.4§	<2.4	charcoal	5
5	1350 ± 80	Beta-107797#	1150 (1300) 1480	3 ± 1	≥3 ± 1	*N.l.*	5
20	970 ± 120	TO-8522	740 (870) 970	5.59 ± 0.01	<5.59 ± 0.01	*Ericaceae* stems	5
6	380 ± 130	GSC-1602#	640 (740) 880	1.5 ± 0.5	≥1.5 ± 0.5	*M.e.*	2
13	130 ± 40	Beta-151259	10 (130) 150	1.5 ±*	0.5	*Picea* needles	6

[a] See Figure 1 for location of sample sites.

[b] All dates, except those on marine shell samples with GSC laboratory designations or marked with a # symbol, have been corrected (normalized) for fractionation to a base of $\delta^{13}C$ = -25‰, and where applicable have been adjusted for a marine reservoir effect of 610 years. GSC shell dates have been normalized to a base of $\delta^{13}C$ = 0‰, which is roughly equivalent to a fractionation correction to a base of $\delta^{13}C$ = -25‰ and a marine reservoir correction of 400 years. An additional 210-year correction has been applied to these dates to make them

equivalent to other dates on marine carbonates. Dates with a # symbol have estimated $\delta^{13}C$ values, based on values typical of the material type. Unconventionally, GSC date errors represent two standard deviations. Samples GSC-5661 and GrA-6478 have an undetermined amount of marine carbon and therefore no marine reservoir correction has been applied to them.

[c] Radiocarbon calibration for this study was carried out using the computer program *Calib* version 4.4html (Stuiver and Reimer 1993). Normalized radiocarbon ages with 1-sigma standard deviation were input to the program. For non-marine samples, the atmospheric data set INTCAL98 was used (Stuiver et al. 1998a). Organisms from marine environments have been exposed to different levels of ^{14}C than their counterparts in the subaerial and aquatic environments and therefore a different calibration data set MARINR98 is used (Stuiver et al. 1998b). This marine calibration incorporates a time dependent global ocean reservoir correction of about 400 years, which must be adjusted to accommodate local effects (ΔR). Dyke et al. (2003) have determined that the marine reservoir correction for the Gulf of St. Lawrence is roughly 610 years and so a ΔR value of +210 years was used. For samples derived from a mixture of marine and terrestrial carbon, such as bones of humans who relied heavily on marine food resources or marine mud with a freshwater input, the percent of marine carbon is first determined or estimated and a "mixed" atmospheric and marine calibration data set is used. In the case of samples GSC-5661 and GrA-6478, where $\delta^{13}C$ values suggest a marine carbon influence but the amount is unknown, a value of 50% is assumed for the age calibration method. The full 2-sigma probability age range is listed here with the median probability age in parenthesis.

[d] Sample elevation for sediment core dates (*) is given as pond elevation. Elevation for archaeological samples (§) is given as elevation of associated terrace, except for samples from the Gould site, where surveyed elevations are available. Elevations measured with an altimeter (‡) have an error of at least ±2 m; larger errors cited in Grant (1992). Elevations interpolated from local topographic maps (†), which have a NATO accuracy rating of A-3, have vertical errors of ±20 m (A. Wood, pers. comm. 2002). Elevation errors revised from those in Grant (1992) are based on information obtained from original field scientists. All elevations are measured relative to high tide.

[e] *B.c. Balanus crenatus; M.a. Mya arenaria; M.e. Mytilus edulis; M.p. Mya pseudoarenaria; M.t. Mya truncata; N.l. Nucella lapillus; S.b. Spirorbis borealis.*

[f] 1. Geological Survey of Canada Radiocarbon Dates XIII (Lowden and Blake 1973); 2. Geological Survey of Canada Radiocarbon Dates XVII (Lowden et al. 1977); 3. Geological Survey of Canada Radiocarbon Dates XXIII (Blake 1983); 4. Geological Survey of Canada Radiocarbon Dates XXV (Blake 1986); 5. Bell et al. (this volume); 6. this study.

Radiocarbon Dating and Calibration

The radiocarbon method relies on the accurate measurement of the amount of ^{14}C lost through radioactive decay in a carbon-bearing sample since the death of the organism (Taylor 1987). Since the decay rate for ^{14}C is known, the time elapsed since the death of the organism, when carbon exchanged with the atmosphere ceased, can be calculated in radiocarbon years. Radiocarbon years do not correspond directly to calendar years because the proportion of ^{14}C in the atmosphere has varied over time. Consequently, to compare the RSL history with other events that are measured in calendar years, we need to calibrate radiocarbon dates to the calendar timescale. This has been achieved primarily by radiocarbon dating tree rings in both live and dead trees, which provide a measure of atmospheric ^{14}C concentration from year to year for more than the last 11,000 years.

This study used a calibration programme that produces a range of calendar years, which is 95 percent accurate. The age range is a result of the limited precision of radiocarbon measurements, both in the study sample and in the calibration data set, and given the variation in atmospheric radiocarbon concentration, there might be several possible ranges for a given radiocarbon date. The full probability age range is listed for each sample in Table 1, whereas the median probability age is plotted on the RSL graph in Figure 4 and used in the text.

Radiocarbon-Dated Samples

Shells were recovered from the upper (6.1 m above sea level [asl]) and lower (4.5 m asl) raised beaches at the MAI cemetery, and from beach sediments underlying the MAI Gould site. Both locations are in the Port au Choix town site (sites 1-4, Table 1, Figure 1). Another shell sample was collected from the lowest terrace (3 m asl) at the Dorset Palaeoeskimo Phillip's Garden site on the Point Riche Peninsula (site 5, Table 1, Figure 1). Grant (1992) dated shell samples from the first raised beach above high tide level at Eddies Cove West (site 6, Table 1, Figure 1).

Shell samples from sublittoral sediments that have little or no stratigraphic context provide ages for a sea level position at some unknown height above the collection site (sites 7-12, Table 1, Figure 1). For example, a gravel pit in the town of Port Saunders exposes horizontally interbedded sand and gravelly-sand, capped by boulder-gravel in a 10-metre-high section below a marine terrace. This sedimentary sequence probably represents sublittoral deposition on a barrier beach or spit, overlain by debris flow deposits, primarily large boulders (Blake 1986). Radiocarbon dating of mussel beds of *Mytilus edulis* in the sand and barnacles (*Balanus crenatus*) on the boulders provided overlapping dates of about 9850 cal BP (sites 9-12, Table 1, Figure 3f) on a former sea-level position marked by the marine terrace at 40 metres above sea level.

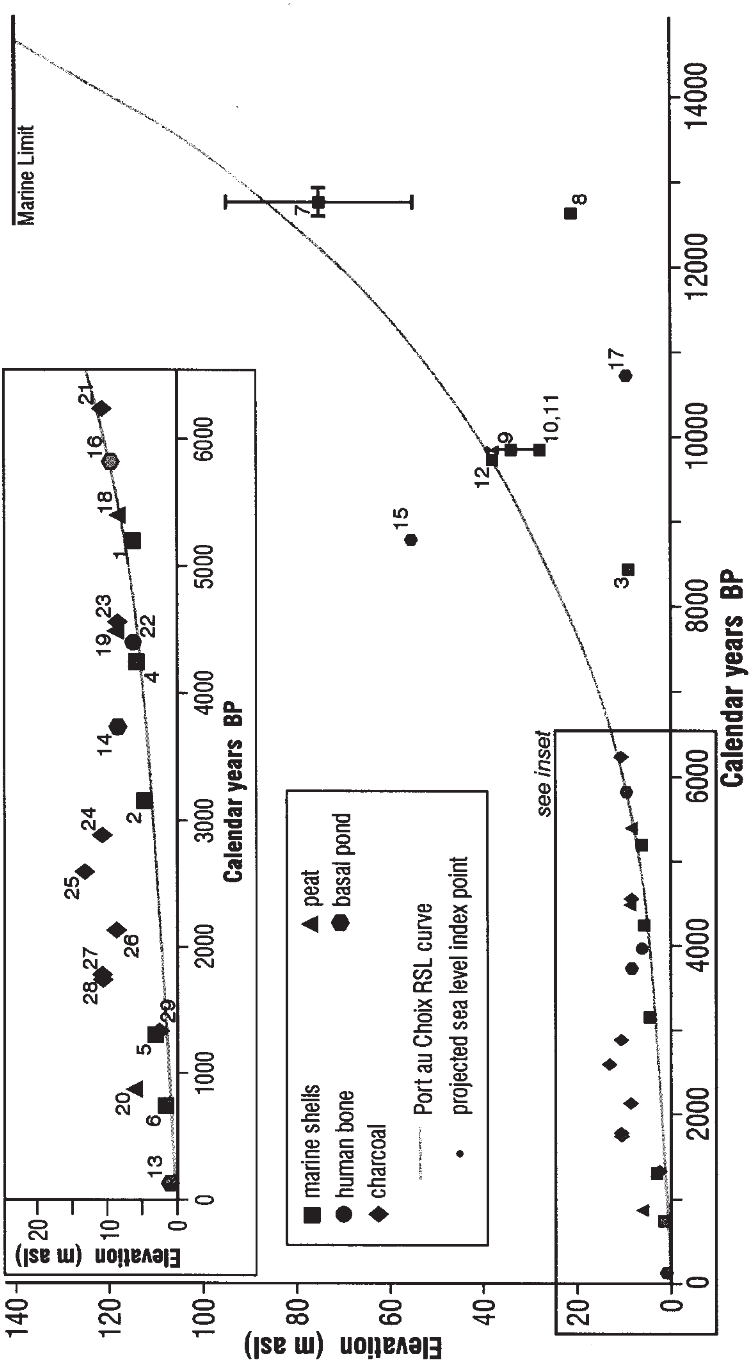


Figure 4. Relative sea-level curve for the Port au Choix region. See text and Table 1 for sample details.

Ecological information on the species being dated may also help to refine palaeo water depth. The spirally arranged, calcareous white tubes of *Spirorbis borealis* (polychaete worm) were found on wave-rounded bedrock at 21 metres above sea level near Hawke's Bay (Figure 3g). These worms are commonly observed today on the fronds of seaweed, and on rocks and mollusc shells in as much as 30 metres water depth (J. Maunder, Newfoundland Museum, pers. comm. 2004). A sample of tubes provided a calibrated age of 12,630 cal BP (site 8, Table 1).

Smith et al. (this volume) use diatoms (aquatic algae) to identify and date the points in time when Gilmores Pond (35 km north of Figure 1 map boundary) and Otter Pond (site 13, Table 1, Figure 1) were isolated from the sea. The Otter Pond record indicates that RSL was within 0.5 metres of its present elevation in the last 150 years or so. In other ponds where sediment was found to be devoid of diatoms (e.g., Field Pond; Figure 1, site 14) or diatom analysis was not carried out (Stove and Bass ponds; Figure 1, sites 15 and 16, respectively), the lowermost dated level in the freshwater component of the sediment core is used as a minimum estimate on the date of isolation of the freshwater basin. For Field Pond (~8 metres asl), which is adjacent to the MAI Gould site, a plant macrofossil at 54.5 centimetres depth in a 78.5-centimetre-long sediment core provided a calibrated age of 3730 cal BP (site 14, Table 1, Figure 1). Microfossil and sediment records suggest that the entire core consists of freshwater sediment (Bell et al. this volume). For Stove Pond, located at approximately 55 metres above sea level and 11 kilometres inland of Port au Choix, a bulk sediment sample from between 180 and 187 centimetres in the 253-centimetre-long core was dated at 8780 cal BP (Beta 32598; site 15, Table 1). Although this basal date is close to the transition between organic mud and sandy clay containing marine foraminifera (protozoa) at approximately 190 centimetres, the radiocarbon date is considered unreliable (Bell et al. this volume). Bass Pond is a shallow coastal marl pond at 9 metres above sea level, near the Palaeoeskimo sites at Phillip's Garden. The upper limit of marine sediment at approximately 145 centimetres depth in the 210-centimetre-long sediment core is marked by abundant foraminifera below this level and the rapid increase in Pediastrum above this level (Bell et al. this volume). A calibrated date of 5820 cal BP (site 16, Table 1) on conifer bark from 82 centimetres depth is considered more reliable than one of 10,720 cal BP (site 17, Table 1) on bulk marine organic sediment from the 200-210-centimetre interval (Bell et al. this volume).

Additional upper constraints on the RSL curve are provided by dates on basal freshwater peat samples from the Gould site (sites 18-20, Table 1), and the oldest date from each major archaeological site in the region (sites 21-29, Table 1).

SEA-LEVEL HISTORY

A type-A sea-level curve showing continued emergence since deglaciation is considered to be the best fit for the palaeo sea-level data from Port au Choix. The curve is anchored at one end by modern sea level, and at the other by the height and age of marine limit, estimated by Grant (1994) to be approximately 140 metres from the elevation of local washing limits, and at 14,700 cal BP based on the oldest marine shell sample in the area, respectively. The form of the curve is dictated by: (i) the age of four overlapping radiocarbon-dated shell samples (9850 cal BP; sites 9-12, Figure 4, Table 1) projected to the elevation of their corresponding sea level at 40 metres above sea level; and (ii) interpolation between narrowly bracketed data points represented on the one hand by a maximum sea-level position recorded by the elevation of freshwater peat (site 18), and, on the other hand, by a minimum sea-level position related to the elevation of marine shells in a raised beach (site 1, Figure 4). The rate of sea-level fall decreases from 2.1 metres per century before 10,000 cal BP to 0.1 metres per century in the last 5000 years. The type-A curve shows a typical RSL history for many parts of glaciated North America and Europe, where isostatic recovery of the crust from removal of the last ice load predominates (e.g., Lambeck 1991; Dyke 2000).

The Port au Choix RSL curve is similar in form to the one reconstructed by Grant (1994) for the northern part of his study area with the following exceptions:

(1) There are no data to support a sea-level stillstand between 13,300 and 12,600 cal BP. The single data point that Grant (1994; GSC-2919, his site 18) used to support his interpretation has a vertical error range of ±20 metres (site 7, Figure 4), which is too large to resolve his proposed sea-level adjustment.

(2) Based on the arguments presented in Smith et al. (this volume), there is no evidence to support the minor sea-level fluctuation between 3700 and 2000 cal BP postulated by Grant for his entire study region (Bartletts Harbour to Parson's Pond).

REGIONAL PATTERNS

RSL curves reconstructed along the western coast of the Great Northern Peninsula illustrate a southward transition from exclusively emergence (type-A) to emergence followed by submergence (type-B). RSL curves from Pinware (Clark and Fitzhugh 1992), Strait of Belle Isle (Grant 1992), Bellburns (Bell unpublished) and Port au Choix are type-A (see Figure 2), whereas data from Cow Head (Brookes and Stevens 1985) and St. Paul's (Bell et al. 2001) exhibit type-B characteristics (Figure 2). This pattern is consistent with the effects of a migrating forebulge, a slow lithospheric response to removal of the last regional ice sheet (Walcott 1970).

Modelling the passage of a forebulge from southeast to northwest across Newfoundland towards the former ice sheet centre predicts variable sea-level curves along the west coast, characterized by submergence to the south and emergence to the north (Quinlan and Beaumont 1981). The transition zone or hinge between rising and falling sea level appears to be located south of Port au Choix, and, therefore, assuming the forebulge continues to migrate northwestward and has not completely collapsed, we would expect the sea-level trend in the Strait of Belle Isle to reverse and become submergent over time.

Coastal Palaeogeography

According to archaeological data, Maritime Archaic Indians, the province's first inhabitants, occupied Labrador more than 3000 years before Newfoundland. The oldest MAI site in southern Labrador is dated to 10,150-9770 cal BP; the earliest dated site for Newfoundland is 6290-6200 cal BP. Should MAI have crossed the Strait of Belle Isle from southern Labrador as early as 10,000 years ago — and this is possible — they would have seen numerous offshore islands, and a shallow embayed coastline backed, in the Port au Choix region, by the Highlands of St. John (Figure 5). The rapid rate of RSL fall at this time would have produced a dynamic landscape as new land emerged from the sea, closing off marine channels as the shoreline shifted seaward. These changes would have occurred on time scales of decades to centuries, suggesting that original coastal locations occupied by early MAI would have become, within a few generations, too far from the sea for convenient access. The people would therefore have shifted their campsites to more suitable lower elevations.

These abandoned coastal sites would today be located on raised beaches tens of kilometres inland and tens of metres above present sea level (Figure 5; Bell and Renouf 2003). These potential sites are remote from modern coastal communities and are probably covered by peat or forest. Thus any early MAI sites are unlikely to be accidentally discovered by construction and gardening activities, which have in the past uncovered younger archaeological sites near the coast. Any survey designed to find these oldest sites will require a targeted search strategy based on what is known about site location preferences of more recent MAI sites, as well as detailed reconstruction of the shoreline palaeogeography (Bell and Renouf 2003).

Sites younger than 6300 cal BP have been documented on the emerging landscape, and show a steady progression in age with distance from the modern shoreline. For example, in the community of Port au Choix, MAI sites are in strategic locations above their contemporary shoreline at 6-10 metres above sea level. During the MAI occupation of Port au Choix (6290-3270 cal BP) the modern-day Point Riche and Port au Choix peninsulas formed an island separated from the mainland by a shallow marine channel (Figure 6a). The MAI cemetery site was located on the

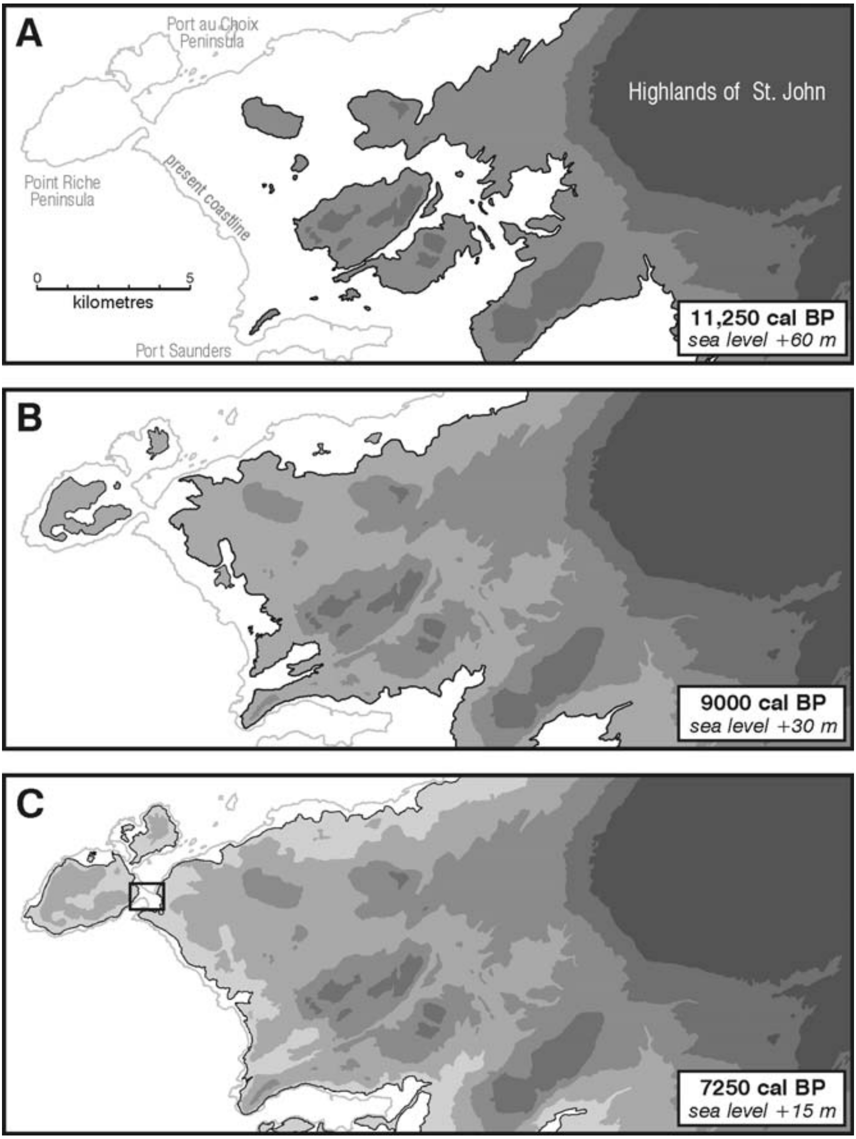


Figure 5. Palaeogeographic reconstructions for (A) 11,250 cal BP, (B) 9000 cal BP, and (C) 7250 cal BP in the Port au Choix region. Box on map C refers to area shown in Figure 6.

sandy eastern point of the island, at 4-6 metres above present sea level, whereas the Gould and Old Boatyard non-mortuary sites were on gravelly substrates on the mainland coast facing the cemetery site, at 6-10 metres above present sea level (Renouf and Bell 1999).

Groswater (2950-1820 cal BP) and Dorset (1990-1010 cal BP) Palaeoeskimo sites in Newfoundland are commonly found on exposed outer coasts of peninsulas and headlands, and the Point Riche (site 28, Figure 1) and Phillip's Garden (site 27, Figure 1) sites near Port au Choix are classic examples. However, Palaeoeskimo sites can also occur in more sheltered areas, and examples of these are found in what is today the main harbour at Port au Choix (Figure 6b). Placing these sites on their contemporaneous shoreline, the Spence site is situated on a sandy spit of the former island at 2-4 metres above present sea level (Figure 6b). The Hamlyn, Lloyd, and Party sites are at 4-8 metres above present sea level (Figure 6b). These sites are at the base of an almost vertical limestone escarpment which would have been set back about 50-100 metres from the contemporaneous shore and was an ideal location that provided a wide ocean view, shelter, and a rock face that radiated heat from the day's sun (Renouf and Bell 1999; Wheatley 2004). These sites have both Groswater and Dorset components, indicating that this location was favoured over a long period of time. The Old Boatyard site is situated along this same terrace and the younger of its two cultural levels dates to 1680-1420 cal BP, although there is no identifying cultural material (Figure 6b).

By the time Recent Indians occupied Port au Choix, the Point Riche and Port au Choix peninsulas were connected to the mainland by a narrow isthmus, which today is the main commercial centre of Port au Choix (Figure 6c). The Spence site was re-occupied by late Recent Indians (1400-1170 cal BP) but at this time it was no longer on a point of land but was on the shore of a small embayment (Figure 6c). The Gould site was re-occupied by early Recent Indians (2110-1300 cal BP) at which time the 6-8-metre terrace was approximately 250 metres back from the shore. Excavation showed that this was a wooded area at the time, suggesting that forested shelter was a desired site characteristic (Renouf and Bell 1999; Teal 2001). If the younger component of the Old Boatyard site was early Recent Indian, it speaks of how Recent Indians, like Palaeoeskimos, considered the escarpment base a desirable campsite location.

These examples show that the geography of the emerging coastline, in combination with the rate of coastal emergence, affects the spatial separation of coastal archaeological sites; older sites are today higher than younger sites, even when total emergence during the occupation period is minimal. In Port au Choix, the total emergence (10 m) experienced over the last 5000 years was barely sufficient to vertically stratify cultural occupations by elevation (Figure 7). For example, MAI habitation sites at 6-10 metres above sea level are higher than, although they overlap with, Recent Indian sites at 2-8 metres above sea level. However, where the coastline is steep, shoreline position did not change much and certain locations tended to

Figure 6. Locations of archaeological sites superimposed on palaeogeographic reconstructions for (A) 5500-4500 cal BP, (B) 2500-1500 cal BP, and (C) 1500-750 cal BP in Port au Choix town site. The base image is an aerial photograph of Port au Choix taken in 1995.

MAI = Maritime Archaic Indian
GPE = Groswater Palaeoeskimo
DPE = Dorset Palaeoeskimo
RI = Recent Indian

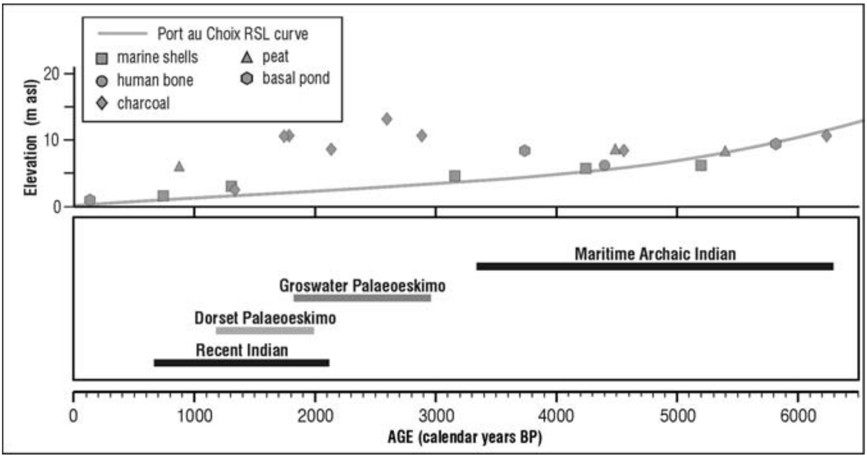


Figure 7. Date ranges for Port au Choix precontact occupations (bottom) in relation to changing sea level (top). The small difference in sea-level elevation between major periods of occupation was only just sufficient to vertically stratify cultural occupations by elevation at Port au Choix. See text for discussion.

be re-occupied by succeeding cultures; this occurred at the Hamlyn, Lloyd, Old Boatyard, and Party sites. At the same time, site preferences were probably based on considerations other than proximity to shore. The situation of the Hamlyn, Lloyd, Old Boatyard, and Party sites at the base of a coastal limestone escarpment shows that shelter and warmth were also important factors in site choice. Early Recent Indians at the Gould site, set back in the forest, chose to forego view and closeness to shore in favour of shelter. Examining the Port au Choix sites in the context of their contemporaneous landscapes illustrates that reconstructing RSL and palaeogeography are essential to identifying and understanding archaeological site location patterns.

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Note

[1]Dates are expressed in the text in calibrated calendar years before present (cal BP) as either a one-sigma probability age range or a median probability single age.

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