Natural Resources Canada | Ressources naturelles Canada

Lost Landscapes:

A Palaeogeographic Reconstruction of Canada's northern Pacific margin 14 250 to 8750 ^{14}C YBP

Our environment as we know it today is only a temporary condition; land and ocean surfaces, when glimpsed through a broader time perspective, have changed significantly, and at times very rapidly.

Renée Hetherington [1, 2], J. Vaughn Barrie[2, 1], Robert G. B. Reid [1], Roger MacLeod [2], and Robert Kung [2]*

[1]University of Victoria

[2]Geological Survey of Canada

*Corresponding author. Tel.: 250-472-4013 *E-mail address:* reneehet@ocean.seos.uvic.ca (R. Hetherington)

Recommended Citation:
Hetherington, R., Barrie, J.V., Reid, R.G.B., and MacLeod, R.F. 2004: The environment of the late Pleistocene - early Holocene, Queen Charlotte Islands archipelago, Western Canada and implications for early peoples; Geological Survey of Canada, Open File 4675

Figure 1. Queen Charlotte Island Region - Present Day

Photo: J. Vaughn Barrie; Rose Spit, northwest Graham Island, QCI looking south.

Photo: J. Vaughn Barrie; northwest Graham Island, QCI .

Photo: Robert I. Thompson; Louise Narrows/ Carmichael Channel, QCI.

Map projection:
NAD83, Transverse Mercator, central meridian 130°W.

Figure 2. Diagrammatic representation of crustal displacement caused by ice loading and eustatic adjustments

The development of extensive ice sheets prior to and during the Last Glacial Maximum (~15 000 ^{14}C YBP) and their melting during subsequent global warming precipitated eustatic and isostatic sea-level adjustments. This diagrammatic representation of the QCI region shows ice atop a relatively flexible lithosphere resulted in a complex and rapidly changing pattern of uplift and crustal depression. The weight of ice pushed the mainland down, while adjacent areas were uplifted, forming a peripheral bulge. Sea level rose at least 120 m higher than present along the BC mainland, and dropped more than 150 m in the adjacent QCI archipelago, located only 150 km offshore.

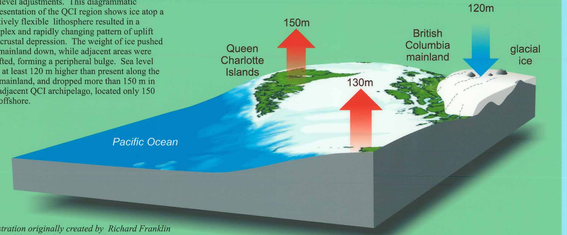


Illustration originally created by Richard Franklin
Adapted from: Hetherington et al. 2003

If humans migrated from Asia into North America, how does one explain human presence in southern Chile ~12 500 ^{14}C years before present (YBP), approximately 1300 years before what has traditionally been considered the first North American culture – *Clovis*? This research seeks to determine if early peoples could have lived and migrated along the northwest coast of Canada (Fig. 1), between 14 250 and 8750 ^{14}C YBP, a time when the environment was significantly different than it is today (Fig. 2).

A series of palaeogeographic and isostatic crustal displacement maps (Figs. 3-9) chart evolving landscapes and temporal changes in the magnitudes and extent of crustal flexure resulting from changing eustatic sea level and the impacts of isostacy during the late Pleistocene and early Holocene. Charting coastal movements and deciphering nearshore ecology were made possible by careful examination of lithological, sedimentological, and geological survey data, and mollusc shells preserved within intertidal and benthic sediments that are now found above sea level along the fringe of the Queen Charlotte Islands (QCI) and the British Columbia (BC) mainland, and submerged beneath coastal waters. The presence of intertidal molluscs elucidates not only the ancient environment, but also that grounded glacial ice was gone and that an accessible food source was present. Radiocarbon dates were obtained from mollusc shells that possessed a clear indication of elevation relative to sea level at the time of their deposition. Using these site-specific relative sea-level observations, a spatial and temporal interpolation model was developed illustrating palaeogeography. Crustal displacement maps were created by subtracting eustatic sea-level change (Fig. 10a; Fairbanks 1989) from the relative sea-level data.

Glacial ice approximately 690 m thick began retreating from Dixon Entrance after 14 000 and prior to 12 640 ^{14}C YBP, resulting in 100 m of uplift in northern Hecate Strait (Fig. 10). The forebulge persisted in Hecate Strait and Queen Charlotte (QC) Sound from 13 250 ^{14}C YBP until after 9750 ^{14}C YBP , implying a fixed ice-front, and continued ice presence on the BC mainland until at least 10 000 ^{14}C YBP.

Palaeogeographic reconstructions show two emergent ice-free terrains, one extending eastward from the QCI the other located in QC Sound. Expansion of the coastal plains resulted in the connection of the QCI archipelago to the North American continent (Fig. 6a), closing Hecate Strait, forming "Hecate Sea", and causing significant changes to littoral dynamics, sea-surface temperatures, and coastal habitats. The disappearance of most bivalve molluscs species and the presence of some cold-hardy species, whose sea-surface temperature tolerance is below 9 °C, between 11 000 and 10 000 ^{14}C YBP supports palaeooceanographic and palynological studies of a late-glacial Younger Dryas cooling event around the southern limits of Hecate Sea and Cook Bank.

Despite rapid changes in sea level, highly productive intertidal zones were available to support an early coastal culture in the outer coast environment and in protected bays and estuaries. Ice-free terrain, present by at least 13 790 ^{14}C YBP, a landbridge, and edible molluscs dating to 13 200 ^{14}C YBP demonstrate that open-water conditions and subaerially exposed land were available to provide habitat for plants and animals, and also for coastally migrating early North American peoples.

Acknowledgments
The authors would like to acknowledge the following individuals for their contribution to this poster. *Cartography:* Richard Franklin, Parm Dhesi, and Patrick Bartier. *Fieldwork support:* Jim Haggart and Daryl Fedje. *Invertebrate identification:* Phil Lambert. *Fish identification:* Becky Wigen, Pacific Identification Company and Cindy Wright. *Library research:* Pam Olson. *Oceanography:* Richard E. Thomson, Jean-Pierre Guilbault, Joe Linguanti, and Roy Hourston. *Geology and palaeoenvironment:* John Clague, Kim Conway, and Rolf Mathewes. *Geophysics:* Roy Hyndman, Tom James, Kristin Rohr. *Photography:* R.I. Thompson, James P.M. Syvitski, and R.W. Mathewes. GPS *measurements:* Carmel Lowe. Lionel E. Jackson Jr. kindly reviewed this poster and contributed to its improvement. Research funding for this project has been generously provided by the Geological Survey of Canada, Parks Canada, and research scholarships from the Natural Science and Engineering Research Council, the University of Victoria, and the Ord and Linda Anderson Interdisciplinary Scholarship fund to Hetherington. This poster is a contribution to UNESCO and the International Geological Correlation Program, Project No. 464.

References:

Archer, D.J.W. 1998. Early Holocene Landscapes on the north coast of B.C. Paper presented at the 31st Annual Meeting of the Canadian Archaeological Association, Victoria, BC.

Barrie, J.V. 1991. Contemporary and relict tiraniferous sand facies on the western Canadian continental shelf. Continental Shelf Research **11**: 67-79.

Barrie, J. V., and Conway, K.W. 1999. Late Quaternary glaciation and postglacial stratigraphy of the northern Pacific margin of Canada. Quaternary Research **51**: 113-123.

Barrie, J.V., and Conway, K.W. 2002. Rapid sea level change and coastal evolution on the Pacific margin of Canada. Sedimentary Geology **150**: 171-183.

Barrie, J.V., Bornhold, B.D., Conway ,K.W., and Luternauer, J.L. 1991. Surficial geology of the northwestern Canadian continental shelf. Continental Shelf Research **11**: 701-715.

Barrie, J.V., Conway, K.W., Mathews, R.W., Josenhans, H.W., and Johns, M.J. 1993. Submerged Late Quaternary terrestrial deposits and paleoenvironment of northern Hecate Strait, British Columbia continental shelf, Canada. Quaternary International **20**: 123-129.

Clague, J.J., Harper, J.R., Hebda, R.J., and Howes, D.E. 1982. Late Quaternary sea levels and crustal movements, coastal British Columbia. Canadian Journal of Earth Sciences **19**: 597-618.

Fairbanks, R.G. 1989. A 17,000-year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation. Nature **342**: 637-642.

Fedje, D.W., and Josenhans, J.W. 2000. Drowned forests and archaeology on the continental shelf of British Columbia, Canada. Geology **28**: 99-102.

Hetherington, R., Barrie, J.V., Reid, R.G.B., MacLeod, R., Smith, D.J., James, T.S., and Kung, R. 2003. Late Pleistocene coastal palaeogeography of the Queen Charlotte Islands, British Columbia, Canada, and its implications for terrestrial biogeography and early postglacial human occupation. Canadian Journal of Earth Sciences **40**: 1755-1766.

Hetherington, R., Barrie, J.V., Reid, R.G.B., MacLeod, R., and Smith, D.J. 2004. Paleogeography, glacially-induced crustal displacement, and Late Quaternary coastlines on the continental shelf of British Columbia, Canada. Quaternary Science Reviews **23**: 295-318.

Josenhans, H.W., Fedje, D.W., Conway, K.W., and Barrie, J.V. 1995. Post glacial sea levels on the western Canadian continental shelf: evidence for rapid change, extensive subaerial exposure, and early human habitation. Marine Geology **125**: 73-94.

Josenhans, H.W., Fedje, D., Pienitz, R., and Southon, J. 1997. Early humans and rapidly changing Holocene sea levels in the Queen Charlotte Islands-Hecate Strait, British Columbia, Canada. Science **277**: 71-74.

Lowden, J. A., and Blake, W. Jr. 1979. Geological Survey of Canada radiocarbon dates XIX. Geological Survey Canada Paper 79-7.

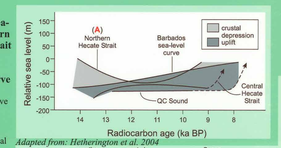
Luternauer, J.L., Clague, J.J., Conway, K.W., Barrie, J.V., Blaise, B., and Mathewes, R.W. 1989a. Late Pleistocene terrestrial deposits on the continental shelf of western Canada: evidence for rapid sea-level change at the end of the last glaciation. Geology **17**: 357-360.

Luternauer, J.L., Conway, K.W., Clague, J.J., and Blaise, B. 1989b. Late Quaternary geology and geochronology of the central continental shelf of western Canada. Marine Geology **89**: 57-68.

Patterson, R.T., Guilbault, J-P., Thomson, R.E., and Luternauer, J.L. 1995. Foraminiferal evidence of Younger Dryas age cooling on the British Columbia shelf. Géographie physique et Quaternaire **49**: 409-428.

Southon, J.R., Nelson, D.E., and Vogel, J.S. 1990. A record of past ocean-atmosphere radiocarbon differences from the northeast Pacific. Paleoceanography **5**: 197-206.

Figure 10a. Relative sea-level curves for northern and central Hecate Strait and Queen Charlotte Sound, and the Barbados sea-level curve (Fairbanks, 1989). The Barbados sea-level curve is assumed to represent eustatic sea level. Dashed lines are inferred from malacological and geological interpretations of samples.



Adapted from: Hetherington et al. 2004

Figure 10b. A time-series of cross-sections of isostatic crustal displacement curves.

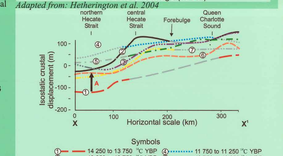
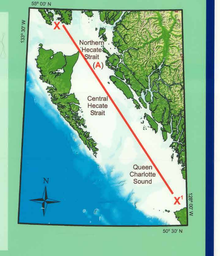


Figure 10b illustrates the cross-section (X to X'; Fig. 10c) from northwest Dixon Entrance to southeast QC Sound taken from isostatic crustal displacement maps for each mapped interval (Figs. 3b to 9b) indicating forebulge position. Greyed lines denote interpolated and extrapolated data. Glacial ice retreated from Dixon Entrance subsequent to 13 750 °C YBP, illustrated by more than 100 m of uplift (line A) at northern Hecate Strait. Persistence of the forebulge in central Hecate Strait and QC Sound after 13 750 °C YBP implies continued ice presence on the BC mainland until at least 10 000 °C YBP.

Figure 10c. Cross-section position. Red line shows the position of the cross-section used in Figure 10b.

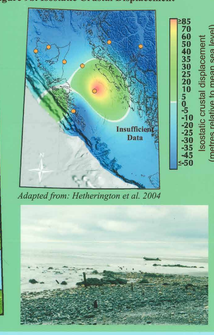


9750 to 8750 ^{14}C YBP

Figure 9a. Palaeographic Reconstruction

Adapted from: Hetherington et al. 2004

Figure 9b. Isostatic Crustal Displacement



Adapted from: Hetherington et al. 2004

The crustal displacement map (Fig. 9b) and crustal displacement cross-section (Figs. 10a and 10b) show continued uplift in central Hecate Strait. Although data is lacking from the QC Sound region, the authors surmise that the forebulge extended far enough south to maintain uplift at Cook Bank as well as in central Hecate Strait (Fig. 9a). A transition from intertidal to deep-water benthic molluscs found in submarine cores in central Hecate Strait, implies rapid sea level rise in this area subsequent to 9130 °C YBP (see photo). On the B.C. mainland at Kitimat (548a), sea levels were 35 m higher than today at 9300 °C YBP (GSC-2425; Lowdon and Blake 1979), reflecting continued ice-induced depression.

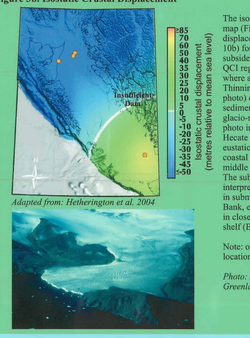
Photo: J. Vaughn Barrie; Drowned forest, east Graham Island, near Cape Fife.

14 250 to 13 750 ^{14}C YBP

Figure 3a. Palaeographic Reconstruction

Adapted from: Hetherington et al. 2004

Figure 3b. Isostatic Crustal Displacement



Adapted from: Hetherington et al. 2004

Photo: James P. M. Syvitski; East Greenland coastal ice sheet,

The isostatic crustal displacement map (Fig. 3b) and crustal displacement cross-section (Fig. 10b) for this period portray subsidence throughout the entire QCI region except QC Sound where a forebulge had developed. Thinning mainland ice sheets (see photo) deposited fine-grained sediments into a cold-water, glacio-marine outwash plain (see photo in Fig. 4) along western Hecate Strait where lowered eustatic sea level resulted in a coastal plain that extended to the middle of Hecate Strait (Fig. 3a). The sub-aerially exposed tundra, interpreted from organic deposits in submarine cores from Dogfish Bank, east of Graham Island, was in close proximity to a floating ice shelf (Barrie *et al.* 1993).

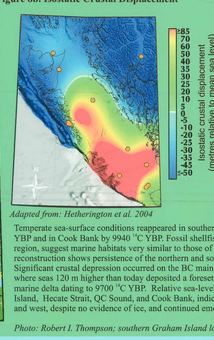
Note: orange dots identify sample locations.

10 250 to 9750 ^{14}C YBP

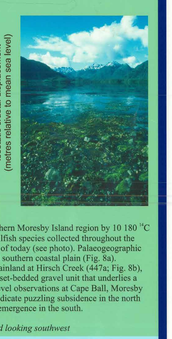
Figure 8a. Palaeographic Reconstruction

Adapted from: Hetherington et al. 2004

Figure 8b. Isostatic Crustal Displacement



Adapted from: Hetherington et al. 2004



Temperate sea-surface conditions reappeared in southern Moresby Island region by 10 180 °C YBP and in Cook Bank by 9940 °C YBP. Fossil shellfish species collected throughout the region, suggest marine habitats very similar to those of today (see photo). Palaeogeographic reconstruction shows persistence of the northern and southern coastal plain (Fig. 8a). Significant crustal depression occurred on the BC mainland at Hirsch Creek (447a; Fig. 8b), where seas 120 m higher than today deposited a foreset-bedded gravel unit that underlies a marine delta dating to 9700 °C YBP. Relative sea-level observations at Cape Ball, Moresby Island, Hecate Strait, QC Sound, and Cook Bank, indicate puzzling subsidence in the north and west, despite no evidence of ice, and continued emergence in the south.

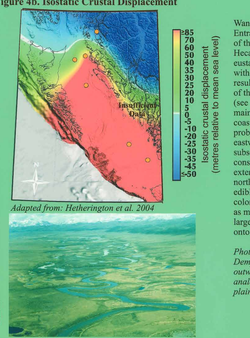
Photo: Robert I. Thompson; southern Graham Island looking southwest

13 250 to 12 750 ^{14}C YBP

Figure 4a. Palaeographic Reconstruction

Adapted from: Hetherington et al. 2004

Figure 4b. Isostatic Crustal Displacement



Adapted from: Hetherington et al. 2004

Photo: Rolf W. Mathewes; north Dempster Highway in Yukon, outwash channel tundra, analogue for emerging coastal plains

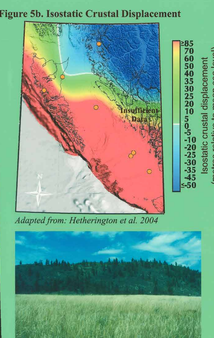
Waning ice sheets in Dixon Entrance resulted in migration of the forebulge northward into Hecate Strait (Fig. 4b). Lowered eustatic sea level, combined with uplift in Hecate Strait, resulted in eastward expansion of the northern coastal plain (see photo) almost to the BC mainland (Fig. 4a). The coastline near Dogfish Bank probably extended more north-eastward than shown; subsequent erosion has likely consumed a coastal plain that extended north to Rose Spit on northeast Graham Island. The edible bivalve *Macoma nasuta*, colonized central Hecate Strait as melting ice sheets deposited large quantities of sediment onto an outwash plain.

12 750 to 12 250 ^{14}C YBP

Figure 5a. Palaeographic Reconstruction

Adapted from: Hetherington et al. 2004

Figure 5b. Isostatic Crustal Displacement



Adapted from: Hetherington et al. 2004

Photo: Robert I. Thompson; Kalamalka Lake Park, BC, analogue for QCI coastal plain and pine forests

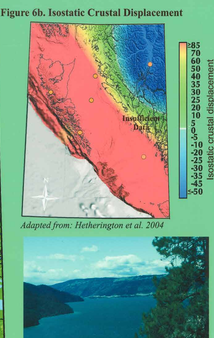
Continued northwestward migration of the forebulge (Fig. 5b) is a result of ice retreat from Dixon Entrance prior to this interval. At Port Simpson (Archer-1, -2) on the BC mainland, thick ice sheets remained causing 146 m of crustal depression; a productive estuary (50 m above present msl) was colonized by numerous edible molluscan species. Climate warming resulted in the development of a grassy, and pine forested coastal plain (see photo) on the uplifted QC Sound (Fig. 5a). In central Hecate Strait, the edible intertidal mollusc *Saxidomus giganteus*, along with charcoal and wood, suggest the presence of a mud-floored estuary there at 12 520 °C YBP.

11 750 to 11 250 ^{14}C YBP

Figure 6a. Palaeographic Reconstruction

Adapted from: Hetherington et al. 2004

Figure 6b. Isostatic Crustal Displacement



Adapted from: Hetherington et al. 2004

Photo: Robert I. Thompson; Kalamalka Lake Park, BC, analogue for QCI pine forests and lakes during climate warming.

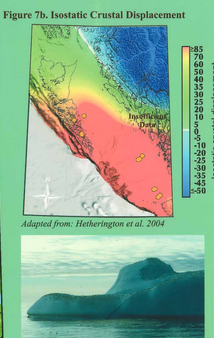
A warming climate supported pine forests; lakes were numerous (see photo). Despite rising eustatic sea levels, continued uplift in QCI, Hecate Strait, and QC Sound (Fig.6b) combined to permit the continued presence of the two coastal plains (Fig. 6a). Hecate Strait closed, creating a landbridge between the QCI and mainland BC, facilitating faunal, floral, and potentially human migration. Hecate Strait became "Hecate Sea" (Patterson *et al.* 1995), a narrow, elongate, shallow water embayment that opened southward into QC Sound. Wood and organic matter were deposited in a post-glacial meltwater delta that was constructed during sea level low-stand and early transgression, at the head of Hecate Sea.

10 750 to 10 250 ^{14}C YBP

Figure 7a. Palaeographic Reconstruction

Adapted from: Hetherington et al. 2004

Figure 7b. Isostatic Crustal Displacement



Adapted from: Hetherington et al. 2004

Photo: J.Vaughn Barrie; Iceberg, Labrador shelf.

Climate warming was followed by a brief, cold interval consistent in timing with the Younger Dryas cooling event. The appearance of cold-water molluscs (*Serripes groenlandicus* and *Clinocardium ciliatum*) signify the onset of a short interval of much cooler (< 9 °C) sea-surface temperatures. The crustal displacement map (Fig. 7b) illustrates the continued presence of the forebulge in central Hecate Strait and QC Sound, and although the landbridge no longer remains, the two coastal plains persist (Fig. 7a).

OPEN FILE
DOSSIER PUBLIC
4675
GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA
2004

Open files are products that have not gone through the GSC formal publication process.

Les dossiers publics sont des produits qui n'ont pas été soumis au processus de publication de la CGC.

Canada