Quaternary Science Reviews 97 (2014) 148–169

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

A post-glacial sea level hinge on the central Pacific coast of Canada

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ARTICLE INFO

Article history:
Received 24 January 2014
Received in revised form
2 May 2014
Accepted 20 May 2014
Available online 20 June 2014

Keywords:
Isostatic
Eustatic
Sea level change
Northeast Pacific Rim
Central Pacific coast of Canada
Archaeology
Northwest coast
Sea level hinge
Coastal migration route

ABSTRACT

Post-glacial sea level dynamics during the last 15,000 calendar years are highly variable along the Pacific coast of Canada. During the Last Glacial Maximum, the Earth's crust was depressed by ice loading along the mainland inner coast and relative sea levels were as much as 200 m higher than today. In contrast, some outer coastal areas experienced a glacial forebulge (uplift) effect that caused relative sea levels to drop to as much as 150 m below present levels. Between these inner and outer coasts, we hypothesize that there would have been an area where sea level remained relatively stable, despite regional and global trends in sea level change. To address this hypothesis, we use pond basin coring, diatom analysis, archaeological site testing, sedimentary exposure sampling, and radiocarbon dating to construct sea level histories for the Hakai Passage region. Our data include 106 newly reported radiocarbon ages from key coastal sites that together support the thesis that this area has experienced a relatively stable sea level over the last 15,000 calendar years. These findings are significant in that they indicate a relatively stable coastal environment amenable to long-term human occupation and settlement of the area. Our results will help inform future archaeological investigations in the region.

1. Introduction

During the peak of the Last Glacial Maximum of the Pleistocene, global eustatic sea level was as low as 120 m below present (Fairbanks, 1989; Peltier and Fairbanks, 2006) and many coastal regions that were located away from ice sheets saw an appreciable drop in relative sea level. With post glacial eustatic sea level rise, past shorelines are now deeply submerged along most of the earth's coasts. In contrast, parts of the Pacific coast of Canada that were covered by several hundreds of metres of ice during the last glaciation have relict shorelines that are submerged, while others are stranded above current sea level as a result of the complex interplay between regional glacial isostatic depression, global eustatic responses, and tectonic plate displacements (e.g., Clague et al., 1982; Clague and James, 2002). Over the late Quaternary, relative sea level dynamics in the region have been highly variable and dependent, in large part, on proximity to ice loading during the Last Glacial Maximum (Clague et al., 1982; Clague, 1983). Shugar et al. (2014) provide a regional synthesis of relative sea level changes on the Pacific coast of North America and identify the central Pacific coast of Canada as a region requiring further research. During the late Pleistocene, ice proximal parts of the coast were subject to appreciable isostatic depression, resulting in relative sea level positions up to 200 m higher than today (Clague et al., 1982; James et al., 2009). Much of the outer coast was located further away from ice loading and was uplifted by a forebulge that formed through differential vertical displacement of the crust from inland to the edge of the continental shelf (Clague, 1983). As a result, relative sea level in outer coastal areas was up to 150 m lower than today (Luternauer et al., 1989; Josenhans et al., 1997; Barrie and Conway, 2002a). Sea level curves from various locations on the Canadian Pacific coast show regional variations to this trend and illustrate that tectonics can also be a significant factor in

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http://dx.doi.org/10.1016/j.quascirev.2014.05.023

sea level change in particular after 10,000 Cal BP (Fig. 1 and also Shugar et al., 2014).

Our research developed in the context of these rapid and regional sea level histories. This research was guided by the following question: is there a region between the inner and outer coasts where sea levels have remained relatively stable since late Pleistocene times? This hypothesized phenomenon is referred to as a "sea level hinge" (cf. McLaren, 2008). The concept of the sea level hinge is different from an "isostatic hinge" or "zone of flexure" in the earth's crust. The sea level hinge is dependent on both isostatic and eustatic factors and can be thought of as a place where the shoreline is stable. The sea level hinge lies between two areas with very different relative sea level histories, to the east with higher than today relict shorelines, and to the west with lower than today relict shorelines. In this paper, we identify the Hakai Passage area of the central coast of British Columbia as a sea level hinge.

1.1. Study area

The Hakai Passage region, located on the central Pacific coast of Canada, provides an opportunity to search for evidence to test our hypothesis (Fig. 2). Located 30 km to the west of Hakai Passage is Goose Bank – a now-drowned coastal platform approximately 45 km wide and extending 20–90 km offshore of the outer islands of the central coast. During the late Pleistocene when relative sea level was about 135 m lower than today, Goose Bank was a low, flat island (Luternauer, 1989; Barrie and Conway, 2002a). Contrasting with this, 110 km to the east of Hakai Passage, in the Bella Coola valley, relative sea level was between 150 and 200 m higher than today following deglaciation (Andrews and Retherford, 1978).

Previous sea level histories developed for the Hakai Passage region (e.g., Retherford, 1972; Andrews and Retherford, 1978; Cannon, 2000) are contradictory and do not corroborate well with recently obtained archaeological data. These inconsistencies are likely a consequence of data limitations and collation of data from a large geographic area. For instance, data points used in Andrews and Retherford (1978) extend along the outer coast islands as well as the mainland shore in areas both distal and proximal to major Wisconsin glacial ice loading.

Stable, relict shorelines are of interest for both geomorphic research that reconstructs relative sea level histories as well as for archaeological research as they favour and often preserve long-term accumulation of sedimentary and archaeological materials in a relatively constrained region (as opposed to being spread across the landscape during gradual sea level regression or transgression). The use of relative sea level histories and geomorphic interpretation of relict shorelines has been key to locating archaeological sites of different ages along the Northwest Coast of North America (e.g., Fedje and Christensen, 1999; Mackie et al., 2011; McLaren et al., 2011). The hypothesized central coast sea level hinge is a location where late Pleistocene and early Holocene shorelines would be close to modern sea level. This presents a significant opportunity for locating long-term archaeological sites and evidence of early post-glacial human occupation. Fedje et al. (2004) proposed that the east side of Hecate Strait to the north, between Haida Gwaii and the mainland, would be a suitable place for this type of investigation. McLaren (2008) investigated the sea level history of the Dundas Island Archipelago, northeast of Haida Gwaii, and found that relative sea level dropped only 14 m over the last 15,000 years[1] and characterized this phenomenon as being the result of the presence of a sea level hinge.

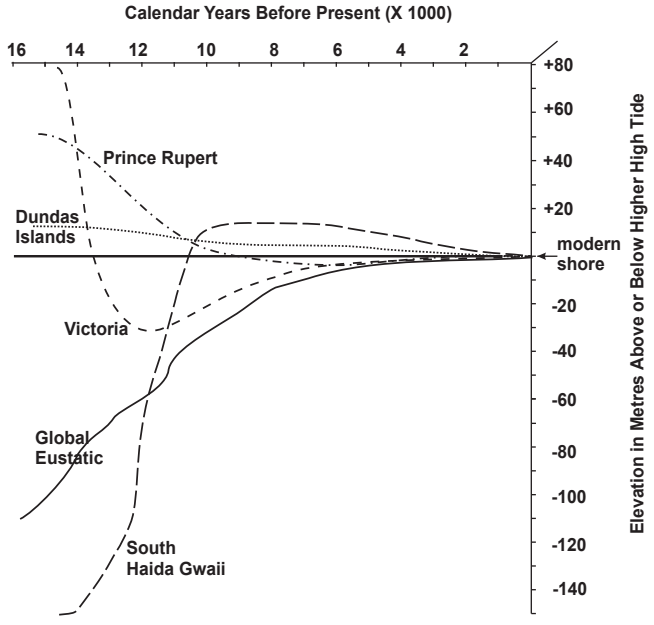

Fig. 1. Regional sea level curves constructed for the Pacific Coast of Canada. Victoria: Fedje et al. (2009) and James et al. (2009); Dundas: McLaren et al. (2011); Prince Rupert (including data from Port Simpson) and south Haida Gwaii: Fedje et al. (2005); global eustatic: Peltier and Fairbanks (2006). This figure illustrates the diversity of relative sea level curves on the Northwest Coast.

1.2. Regional setting

The central Pacific coast of Canada remains a remote region only accessible by boat or aircraft. The research presented here was undertaken in the territories of the Heiltsuk, Wuikinuxv, and Nuxalk First Nations. Field research was based out of the Hakai Beach Institute on Calvert Island, just south of Hakai Passage. The physiography of the Hakai Passage area is characterized by the Coast Mountains to the east (which reach elevations of up to 4000 m above sea level), and isolated rocky islands and skerries to the west. Marine channels intersect the landscape increasingly with distance from the mainland. Inner shores consist of steep-sided fjords, whereas the outer shores are exposed, consisting generally of flat islands with irregular, steep bedrock intertidal zones or smaller embayed sedimentary beaches. A few sandy, dune- or bluff-backed beaches exist on the northern and western shores of the larger Calvert Island, which also hosts mountain plateaus, saddles, and peaks reaching 1000 m above sea level. Glaciers are found today only on the mainland, in the far eastern part of the region (Fig. 2). Average yearly rainfall is high, between 240 and 330 cm per year. The area is located in the Coastal Western Hemlock biogeoclimatic zone (Meidinger and Pojar, 1991) and with the exception of higher alpine areas, most of the region is heavily forested by conifers which can grow to be massive and over 1000 years old (Fig. 3). Areas of low relief found on the outer coast often host sphagnum vegetation and have developed into bogs and bog forests (Fig. 4).

The timing of the Last Glacial Maximum is not well known in the study area. Paleontological and vegetation evidence from southeast Alaska and Haida Gwaii, to the northwest of the study area, indicate that the Last Glacial Maximum occurred between 20,500 and 19,000 calendar years ago (Warner et al., 1982; Heaton and Grady, 2003). Parts of the west coast of Vancouver Island to the south were ice free at this time and the Last Glacial Maximum occurred later, between 19,000 and 17,700 calendar years ago (Ward et al., 2003).

[1] All dates are in calendar years before present (1 sigma with a datum of AD 1950) unless otherwise noted.