Late Glacial and Holocene Sedimentation and Investigation of Fjord Tsunami Potential in Lower Howe Sound, British Columbia

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Abstract

Preliminary investigation of the history of sedimentation in lower Howe Sound fjord near Vancouver, B.C. indicates that no rock slide capable of generating a destructive displacement wave has occurred during the latter half of the Holocene. Possible rock slide run-out deposits were detected along the western margin of Bowen Island. These could date from any time during the Holocene. Investigation of the adjacent slope suggests it is creeping and is not an imminent large rock slide failure.

Keywords

Fjord tsunami • Fjord geomorphology • Paraglacial sedimentation

12.1 Introduction

Howe Sound (HS) is the southernmost fjord on the mainland coast of British Columbia (Fig. 12.1). Study of swath multibeam bathymetry (SMB) imagery generated in 2007 revealed apparent submarine rock slide run-out deposits on the sea bottom west of Bowen Island in Collingwood Channel (Fig. 12.2D) (Jackson et al. 2008). This caused immediate concern with regard to the likelihood of future landslide activity in this area that could cause displacement waves (landslide-triggered tsunamis) that could potentially affect nearby communities and marine traffic.

This report summarizes the results of the evaluation of slope stability along Bowen Island with preliminary exploration of these sediments beneath the ocean bottom of HS. A compete account is presented in Jackson et al. (in press).

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12.2 Setting

HS is the southernmost fjord on the mainland of western Canada (Fig. 2.1). It is located immediately north of the City of Vancouver. It measures 38 km along its long (north-south) axis and has an average width of 6 km. Average water depths within Howe Sound are in the 200–250 m range. HS and surrounding parts of the rugged and glacially sculpted Coast Mountains are underlain by the Jurassic to Eocene crystalline rocks of the Coast Plutonic complex (Woodsworth et al. 1991, p. 515). Mountain peaks rise 2,000 m above sea level within 3 km of the shore. Relief contrasts of 1,000–1,500 m are common. Subaerial landslide and debris flow activity is common around HS (Blais-Stevens and Septer 2008).

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Fig. 12.1 Howe Sound region

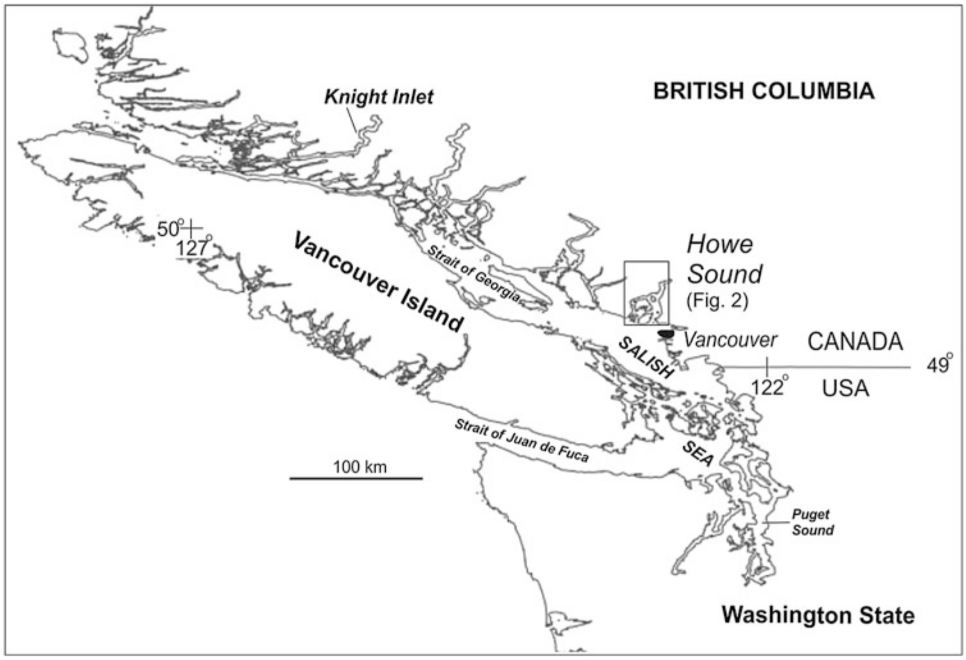
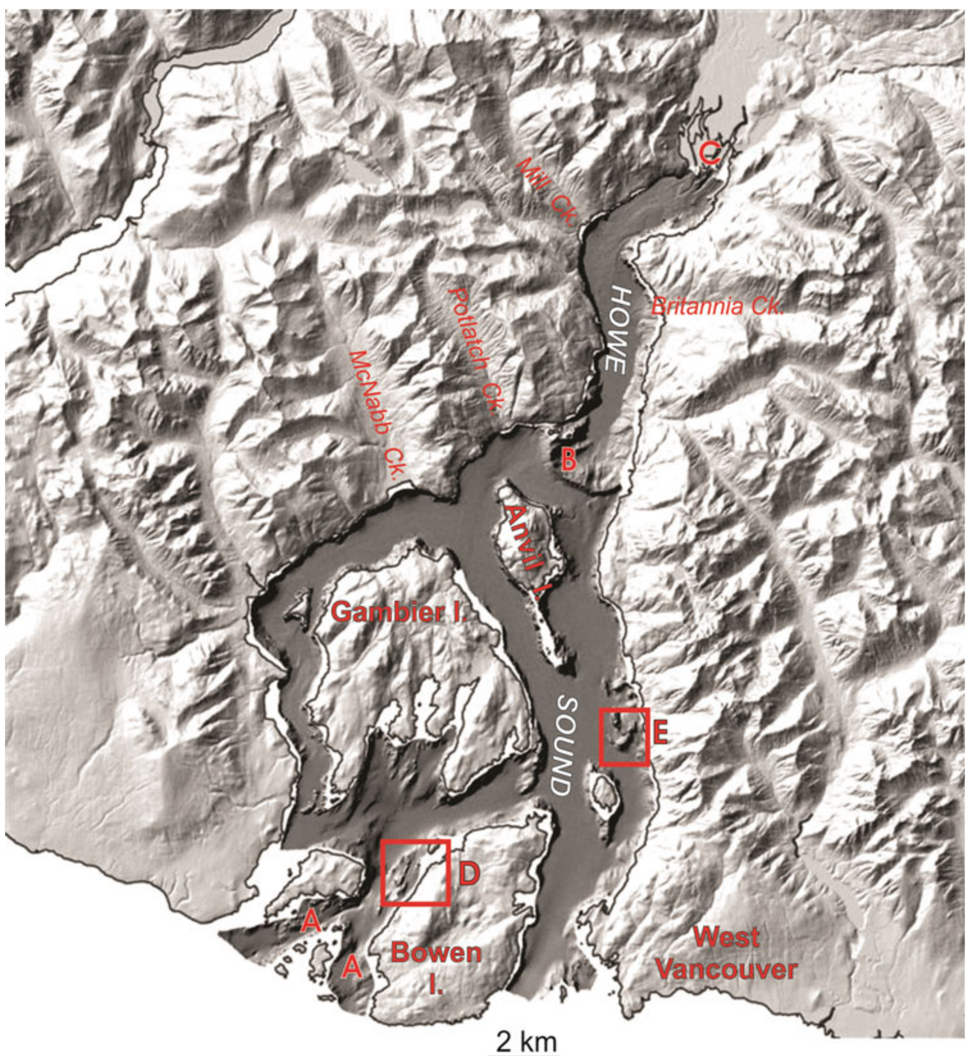


Fig. 12.2 Digital elevation model of Howe Sound: *A* outer sill of ice stagnation glacial sediments; *B* moraine which creates the inner sill that divides Howe Sound into an upper and lower basin; *D* west slope of Mt. Gardner on Bowen Island which has failed as a small rock slide or debris flow. Sediment cores 42–44 were collected from the adjacent sea bottom; *E* Lions Bay area: location sediment cores 40 and 40



The HS area was inundated by the Cordilleran Ice Sheet during the last glaciation. Three radiocarbon ages document deglaciation of Bowen Island by as early as ca. 13,000 radiocarbon years before present.

The bottom of HS is divisible into a lower basin bounded by a sill of ice stagnation sediments and a moraine (Fig. 12.2A and B, respectively) and an upper basin between the moraine and the delta of the Squamish River (Fig. 12.2C).

12.3 Methods

This study consisted of terrestrial and marine components. The western slopes of Bowen Island, where open fissure fissures were noted locally, were traversed to determine the nature of extant slope deformation. Structural geology mapping was carried out along with a stability analysis as a part a M.Sc. thesis (van Zeyl 2009). The coastline of the island immediately across Collingwood Channel was traversed to look for evidence of prehistoric run-up of displacement waves. The marine geology component consisted of sub-bottom seismic reflection profiling, piston coring, and radiocarbon dating of organic materials from the cores to determine the sea bottom stratigraphy and sedimentation rates.

12.4 Findings

van Zeyl (2009) found that the northwest slope of Mount Gardner appears to have deformed gravitationally due to adverse structure and stratigraphy and erosion at the toe of the slope. This large-scale deformation apparently has ceased or is taking place at a rate that does not generally manifest itself in active surface deformation features. He concluded that the slope does not appear to be actively deforming toward a failure. However, he recommended precautionary long term monitoring.

Three sediment cores (42–44) ranging from 10.5 to 1.5 m in length were collected from piston coring of the sea bottom within about 200 m west of the west coast of Bowen Island and two other sediment cores (40 and 41, ~7 m in length) were taken from the Lions Bay area (D and E respectively, Fig. 12.2). Textural, stratigraphic, biostratigraphic investigations and radiocarbon dating of the shells of marine invertebrates within the cores have yielded insights into the sedimentological history of HS (Jackson et al. in press).

Rainout of gravel-size clasts from icebergs ceased by ca. 9,400 ^{14}C years before present (core 42). This apparently indicates the cessation of glacier margin calving and iceberg production presumably at the head of HS. Holocene sedimentation has been highly non-uniform: it has been almost zero in Collingwood Channel along the west coast of Bowen Island (cores 42–44). There has been significant Holocene sedimentation in the Lions Bay area (E, Fig. 12.2). However, almost all took place during the early half of the Holocene. Radiocarbon ages determined on invertebrates within core 41 are commonly inverted with respect to one another. The disturbance that caused disruption of stratigraphy is the either the result of bioturbation or the geyser-like eruption of methane from bottom sediments. The floor of HS is marked by craters formed by the latter process. These gas-escape craters (or pockmarks) are common features on the floors of other fjords and the continental shelf of British Columbia (Barrie et al. 2005) and Chile (Dowdeswell and Vásquez 2013).

12.5 Discussion

The site of sediment core 41 (in widest reach of lower HS) is separated from the complex of submarine fans along the eastern coast of HS by submarine topography. Holocene sedimentation has been entirely from suspended sediment. The Squamish and Fraser rivers are the sources of suspended sediment within HS. Although accurate estimation of sedimentation rates within sediment core 41 is not possible due to inversion of some ^{14}C ages, the aggregate range of ^{14}C ages suggests that sedimentation has been in the order of more than a metre per thousand years until the mid Holocene (ca. 5,000–4,000 ^{14}C years BP). Less than 1 m of sediment was deposited since that time. The site of sediment core 40 is located within the submarine fan below the mouth of Lone Tree Creek, one of many mountain torrents that have built an apron of coalescent submarine fans along the eastern margin of HS (Jackson et al. 2008). Radiocarbon ages are not sequential which would be expected in a submarine fan environment where scour and reworking of the fan can take place. However, there is less than 100 cm of sediment in the core that appears to be related to the last 4,000 ^{14}C years. This suggests that the rate of sedimentation on the submarine fan below the mouth of Lone Tree Creek has decreased dramatically in the area of core 40 since the mid-Holocene.

The decrease in the rates of sedimentation apparent in cores 40 and 41 during the latter half of the Holocene is in agreement with the findings of Brooks (1994) who investigated the fluvial geomorphology of the Squamish River basin with respect to the of transport of residual glacial sediment from tributaries to the main stem of the Squamish River during the Holocene. He found that this fluvial system incised through glacial fill to bedrock thousands of years before the present so that present sediment transport of the Squamish River to HS is small compared to sediment transport earlier in the Holocene. This pattern, whereby erosion and transport of sediment relict from a recent glaciation was most intense early in the post glacial period and progressively approaches new rates adjusted to non-glacial conditions, is referred to as the 'paraglacial effect' (Church and Ryder 1972). This has been documented on alluvial fans and river systems throughout North American Cordillera (Jackson et al. 1982; Ritter and Ten Brink 1986), and recently deglaciated mountains elsewhere (Iturrizaga 2008). Likewise, sediment core 40 indicates that most of the submarine fan below Lone Tree Creek was deposited during the first half of the Holocene.

12.6 Conclusion

One of the prime objectives of this study was to determine if subsequent sedimentation would conceal past rock slides from SMB imagery in HS. Holocene sedimentation ranged from almost negligible along the west margin of Bowen Island to more than 11 m in the Lion's Bay. The run-out deposits along west side of Bowen Island originated from small rock slides or debris flows that may or may not have been coeval during the Holocene. In the Lion's Bay area, the lack of similar deposits, as recorded by SMB imagery (Jackson et al. 2008), indicate that no rock slide events that produced relief in run-out areas of more than 1 m has occurred since at least mid Holocene time. The lack of such run-out features in SMB imagery of lower HS suggests that large rapidly moving rock slides capable of generating displacement waves have not occurred during the latter half of the Holocene.

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