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Large-scale sedimentary bedforms and sediment dynamics on a glaciated tectonic continental shelf: Examples from the Pacific margin of Canada

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ABSTRACT

The Pacific margin of Canada has been subjected to tectonism, dramatic sea level change and vigorous storm and tidal energy since glacial times resulting in a complex seafloor. Extensive multibeam mapping of this shelf has provided an opportunity to understand how these processes have impacted sedimentology and morphology. Bathymetric restriction of the tidally dominated flow between the inland seas and the open Pacific has resulted in the development of very large subaqueous dune fields and terrace moats. For example, in the southern Strait of Georgia nearly symmetrical dunes with wavelengths between 100 and 300 m, dune heights up to 28 m, cover the seafloor in 170–210 m water depth. In northern Hecate Strait a 72 km^2 area of large 2D dunes occurs at the transition with Dixon Entrance which opens to the Pacific Ocean and steep ($>10^\circ$) wave-cut terraces and drowned spits, a result of sea level changes during the Holocene, are now being undercut to generate moats 7 m deep, in a narrowing shelf trough. Currents, with velocities ranging between 0.2 and 2.2 m s^{-1}, are dominated by semi-diurnal tidal streams that are continually modified by wind and estuarine circulation. There appears to be a clear association of grain size, water depth and flow velocity controlling the size of the subaqueous dunes.

1. Introduction

The seafloor of the northwest Canadian Pacific continental shelf (Fig. 1) has developed under a complex interplay of tectonism, glaciation, sea level change and ocean energy. Each process has a significant impact on the development of the seafloor morphology, but it is the active tidal, storm and estuarine flow energy acting on the seafloor, that in many areas were once sub-aerial, that defines the dynamic morphology of the present continental shelf. Rapid crustal displacement brought on by the advance and retreat of continental and alpine glaciers during the Late Quaternary drove the rapid sea level change (Clague, 1983; Hetherington et al., 2004). Consequently, the position of the coastline changed with respect to the thickness and position of the ice, the elastic thickness of the lithosphere, and local mantle viscosity (Hetherington and Barrie, 2004). Mapping using multibeam bathymetry and high-resolution sub-bottom profiling allows for the continuous 3D imagery of sea level lowstand features such as wave-cut terraces, drowned lakes, river channels, spits and deltas. For example, wave-cut terraces are a dominant legacy feature of the rapid sea level changes and are now found in water depths from 40 m to greater than 200 m (Barrie and Conway, 2002a). The same imagery highlights areas of significant sedimentary bedforms and sediment transport. Consequently it is now possible to visualize and model the primary sedimentary processes modifying the seafloor.

Very large subaqueous dunes (>5 m in height and 100 m in wavelength (Ashley, 1990)) have been found on continental shelves of southeast Africa (Flemming, 1978), South China Sea (Keller and Richards, 1967; Kubicki, 2008), NE Mediterranean Sea, (Lykousis, 2001), Argentina (Aliotta and Perillo, 1987), US Atlantic (Jordan, 1962; Fenster et al., 1990, 2006) and Pacific coasts (Bouma et al., 1980; Barnard et al., 2006), and the western Canadian continental shelf. A dynamic seafloor with the presence of large and mobile sedimentary bedforms can directly impact the design and feasibility of locating engineering structures on the seabed. For example, in 2003 a plan to bring natural gas from mainland of British Columbia to Vancouver Island for power generation involved the placement of a pipeline across the Strait of Georgia. To access the onshore facilities the proposed pipeline was to transit Boundary Pass, a narrow pass separating Canada from the USA (Fig. 2). During surveys to determine a pipeline route, a field of very large dunes was encountered (Barrie et al., 2005) requiring a significant change in the overall routing. In Queen Charlotte Basin, the proposed generation of wind power on Dogfish Bank (Fig. 1b) will require the laying of electrical transmission lines

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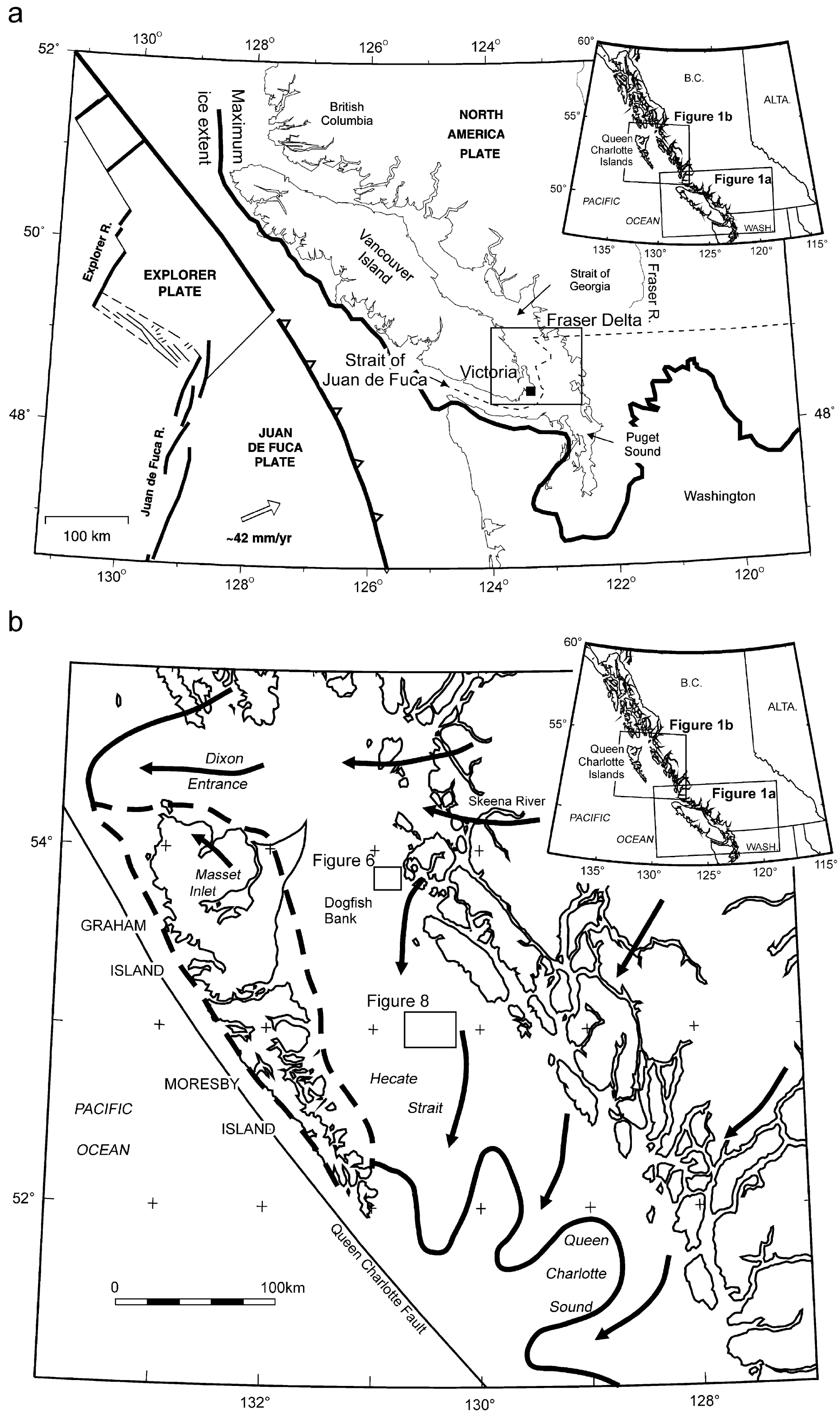

Fig. 1. (a) The regional and tectonic setting of Georgia Basin. The heavy line shows the maximum extent of the late Wisconsin ice (after James et al., 2000). Location of Fig. 2 is shown. (b) Queen Charlotte Basin showing the extent and flow direction of the late Wisconsin ice (Cordilleran ice is the solid line and Queen Charlotte Island ice is the dashed line) during the late Wisconsin maximum (modified from Barrie and Conway, 2002b). Locations of Figs. 6 and 8 are shown.

across Hecate Strait and such cables are very sensitive to burial by sediments because of transmission efficiency issues and thermal insulation of the cables. Consequently, the cables cannot be buried by sediment dunes. Subaqueous dunes can migrate over significant distances when the ebb and flood velocities are unequal, due to a superimposed residual current or an M4-related asymmetry (Knaapen et al., 2005). In the case of a residual current, the flow velocities in the direction of the residual current