Glacial-Marine Sedimentation: an important dimension of the Alaska/Aleutian Margin

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Proposed themes addressed: interconnections between surface processes, subduction zone dynamics, and margin evolution

a) Overview

The GeoPRISMS Draft Implementation Plan (DIP) highlights diverse impacts of sediments on the Alaska/Aleutian Margin, as well as on the more general theme of long-term margin evolution and material transfer. *Surprisingly, the source of sediment is hardly mentioned and yet it is severely understudied; it merits considerable more attention.* Statements regarding sediments include 1) "Sediment influx appears to influence megathrust slip behavior. The largest megathrust events are associated primarily with the sediment rich eastern-half of the subduction zone, where Neogene glacial erosion led to an elevated flux of sediment to forearc basins and the trench." 2) "The age of the subducting oceanic lithosphere changes little along the arc, but... sediment flux to the trench… change systematically along the arc." 3) "recycling of sediment/continental materials occurs in the eastern part of the arc [close to the sediment sources, where sediments fill the trench], but not in the west." 4) "explicit inclusion of sediment transport and deposition along subducting margins will increase our understanding of… geologic hazards such as landslides and tectonic or climate-driven shoreline change." Moreover, in the discussion of w*hat controls the segmentation of a subduction zone,* the DIP mentions that the eastern sector of the *"*Alaskan-Aleutian trench… receives a large sediment supply that is probably sourced mostly from the glaciated Gulf of Alaska; this flux likely has varied as glacial coverage has evolved in the Neogene. Increased sediment supply from the glaciated northern end of the subduction zone may contribute to the along trench variability in seismogenesis, although long-distance axial transport needs to be quantified…Segmentation may be controlled by …in roughness of the plate interface, which is influenced by,,, sediment thickness beneath and seaward of the trench wedge; and uneven distribution of sediment composition… Fully characterizing the composition of the incoming plate sediments could significantly improve understanding of the role of sediments in controlling seismogenic segmentation."

In view of the importance of sediments on the Alaska/Aleutian Margin, a substantial gap in GeoPRISMS Implementation Plan is the lack of focus on studies that illuminate the diverse sources of sediments, the underlying processes, and their variation in time and space. Glaciers are obvious sources, which are sensitive to climate, but we understand all too little how glaciological processes and the rates at which they operate control the production of sediment, its volume and character, and its transport to proximal and distal portions of the margin. Such studies are also critical for guiding and assessing numerical models of the influence of climate on the internal dynamics of actively deforming collisional margins, especially as Alaska has "experienced profound changes with the onset of Neogene glaciation". Ample motivation also exists for studying glacial-marine sedimentation in its own right, as outlined below.

b) Glacial-Marine Sedimentation

Glacial-marine sedimentation responds to and provides sedimentary archives for a diversity of important processes associated with continental-margin dynamics. Glaciers are extremely effective in eroding mountains, transferring much ice and sediment to the sea, and aiding continued uplift. In areas with high coastal mountains, the ice commonly extends to sea level as tidewater glaciers (e.g.: southern Alaska;

Patagonia; south island New Zealand; Antarctic Peninsula). Today, in these settings, the glacial sediments are typically released into a fjord (Fig. 1) with nearly complete entrapment of erosion products, forming a well-preserved sedimentary record of uplift, ice build-up, associated climatic variations, erosion, and transfer events. Through much of the Quaternary, however, ice cover was much more extensive and the sediments were shed off the continent, constructing exceptionally wide continental shelves off the southern coast of Alaska and other glaciated margins. Our understanding of the linkages between glaciers, glacial and periglacial processes, and tidewater sedimentation is, however, very sparse.

c) Tectonics, Subduction and Uplift

Spectacular coastal mountain ranges, including the St. Elias Mountains, can form where continental terranes coupled to oceanic crust converge with continental plates. Based on much work in this area, Berger et al. (2008) hypothesize that "alpine glaciation in late Cenozoic time modified denudation and deformation within numerous mountain belts worldwide. This is consistent with climate as the driver of observed changes in exhumation rates, sedimentation rates and relief within many orogenic systems over the past few million years. Where present, glaciation may thus have a significant role in the internal processes of mountain building, empirically supporting the paradigm that orogenic architecture, kinematics and evolution may be heavily influenced by external climatic processes." This influence remains poorly understood, however.

d) Glacial Erosion

Glacial erosion is receiving much attention due to the high erosion rates documented for many active glaciers (e.g., Hallet et al., 1996; Delmas et al., 2009), and its role in curtailing the height of mountain ranges, the "glacier buzzsaw" (see Fig. 2; Egholm et al., 2009). Because many active orogens were extensively glaciated during the Plio-Pleistocene and now contain only small alpine glaciers, studies of the coupling between glacial erosion and tectonic processes are largely based on geomorphic studies of formerly glaciated landscapes, and on models (Tomkin and Roe, 2007). With rare exceptions (e.g., Enkelmann et al., 2009), little is known about erosion rates in extensively ice-covered active orogens.

e) Tidewater Glacial-Marine Sedimentation

Sedimentation proximal to the calving ice front impacts glacial advance and retreat, and the distal sedimentation records their history. Many tidewater glaciers advance slowly into deep water over a period of centuries with little sensitivity to climate variability, by keeping before them a moraine shoal that drastically reduces ice loss by calving (Meier and Post, 1987). This shoal, which can buttress not only a tidewater glacier but the massive ice sheet behind it, is slowly moved forward by erosion on the glacier side and deposition on the far side. The sediment accumulation on the seabed, which decreases with distance from the ice front (Syvitski, 1989; Cowan and Powell, 1991; Domack and Ishman, 1993; Jaeger and Nittrouer, 1999), and the detailed sedimentary signatures record the rich histories of the climate, ice masses and the supply and release of sediment. More detailed studies of glacier-sediment systems that extend well beyond the water line are needed to improve the interpretation of this record.

f) Sea-Level Rise

Glacial retreat around the world has been used as dramatic and visible evidence of climate change, and has considerable practical importance because it directly contributes to global sea-level rise, which is one of the largest potential threats of future climate change. However, the controls on the fluctuations of some of the most important outlet glaciers are only partly related to climate variability (Fig. 1), and these non-climatic controls remain poorly understood. On a global scale, the complex behavior of outlet glaciers and rapid ice-marginal changes are prime factors limiting confidence in predictions of impending sea-level rise. So, along glaciated continental margins, the record of recent history and the prediction of future events (e.g., next century) have great scientific, environmental and human value.

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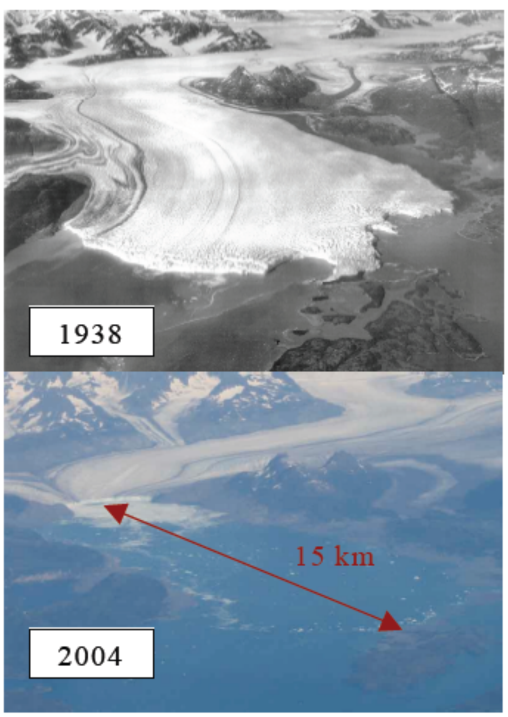

Fig. 1 – One example of a tidewater glacier from a coastal mountain source is Columbia Glacier, a massive (1000 km^2; 60 km long) calving glacier in south-central Alaska that flows into Prince William Sound. During the 1980s, it began a rapid retreat controlled largely by factors affecting ice loss at its marine terminus (modified from Pfeffer et al., 2007).

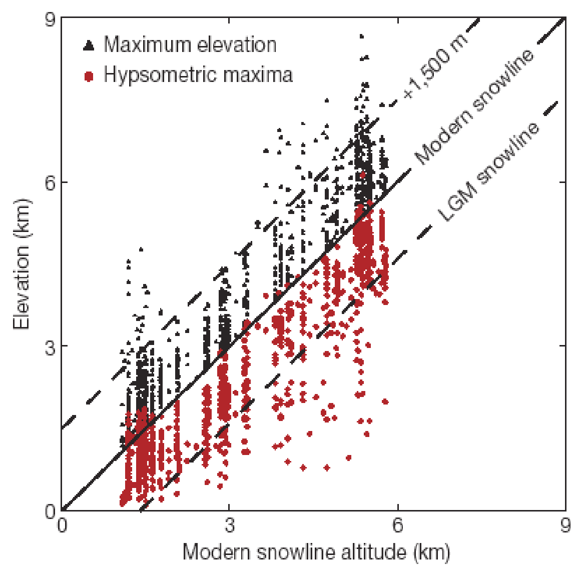

Fig. 2 – A global compilation of maximum elevations (peaks) and hypsometric maxima elevations. They correlate well with local snowline altitudes despite large spatial variation in factors that are generally recognized to control rates of uplift and erosion, including rock type, amounts of precipitation, and rates of exhumation/uplift. Hence mountain-range height seems directly influenced by glaciations through an efficient denudation mechanism known as the glacial buzzsaw (from Egholm et al., 2009).