Effects of spatial and temporal variation in sediment flux on the Aleutian subduction zone

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SCD Themes Addressed: *4.1 (Size, location and frequency of subduction zone EQs)*
4.2 (Evolution of plate boundary deformation in space and time)
4.7 (Climate/surface/tectonic feedbacks)

The understanding of sedimentary input to a subduction zone is key to the interpretation of long-term behavior of the subduction cycle. The complex tectonic relationships created by the Yakutat terrane collision with North America and strong glacial-climate signal in the Gulf of Alaska margin create multiple point and distributed sediment sources that create a significant feedback between surface and tectonic processes in the region. Field studies strongly suggest that subduction zone and orogenic dynamics are influenced by surficial processes and the sediment delivery rates to subduction zones (Brocklehurst and Whipple, 2002; Lamb and Davis, 2003; Whipple and Meade, 2004). Climate, in turn, directly affects precipitation rates and types, thus controlling the rate and timing of sediment production. Glacial advance-retreat cycles provide the primary climate forcing that may affect structural evolution of the Gulf of Alaska margin. Recent thermochronologic studies in the area provide evidence for intensified exhumation and uplift onshore in response to focused erosion by glaciers (Berger et al., 2008; Enkelmann et al., 2010); offshore drilling shows that terrigenous flux throughout the Gulf more than doubles at ~1 Ma (Lagoe et al., 1993; Rea and Snoeckx, 1995). These data make a strong case for an increased effect of sediment flux on Aleutian subduction since ~5 Ma. A five-fold increase in sediment delivery to the Aleutian Trench during the Pleistocene (Piper et al., 1973) may have altered subduction zone dynamics through significant along strike and temporal variations in the incoming sedimentary section as well as sediment loading within forearc basins (e.g., Simpson, 2010).

Three major sediment bodies atop the Pacific Plate are currently subducting at the Aleutian Trench. The first is the Surveyor Fan, the terrigenous outwash body that comprises the majority of the Alaska Abyssal Plain and thickens into the Yakutat shelf. The Kodiak-Bowie Seamount Chain is the southern boundary of the Surveyor Fan, beyond which lies the second sediment body, the inactive Zodiac Fan (Fig. 1) (Reece et al., 2011; Stevenson and Embley, 1987). The third deposit is an axially-deposited wedge of sediments that lies within the Aleutian Trench and atop the subducting Surveyor and Zodiac Fans. Herein we refer to this wedge of sediments as the Aleutian Trench fill.

The St. Elias Range glacial systems feed the modern Surveyor Fan as multiple point sources from the Yakutat shelf edge. While both the Surveyor Fan and Aleutian Trench fill deposits decrease in thickness overall away from the Yakutat margin, the Aleutian Trench fill receives sediment from a few prominent point sources along its extent, likely creating local increases in trench fill sediment thickness. Perhaps the two greatest sources of trench fill are the Bering glacial system at the trench head, and the end of the Surveyor Channel, which terminates at the trench between the Kodiak Bowie and Patton Murray Seamount Chain. Additionally, Chugach Range glaciers are a source for trench fill, perhaps most notably those that feed the Copper River and Cook Inlet systems. The majority of sediment in the Fan and Trench is supplied during glacial maxima due to an abundance of accommodation space on the Aleutian foreland and the ~100 km wide Yakutat shelf and no major mechanism for cross-shelf transport during highstand (Reece et al., 2011; Worthington et al., 2010). A thin, distal Surveyor Fan abuts the Patton-Murray Seamount Chain, south of which is a much thicker section of the older Zodiac Fan (Fig. 1). This boundary between fans creates the single increase in fan-type sediment along the axis of the trench. The narrow focusing of the point sources within the trench fill allows this sediment body to exert an influence on subduction beyond the boundaries of the Surveyor Fan to at least as far southwest as the Zodiac Fan.

These sediment bodies drive growth of the Alaskan-Aleutian accretionary prism to a first order. The along strike variation of sediment thickness arriving at the Trench has clearly affected the size and shape of the accretionary prism and forearc; the width and thickness of the prism decreases substantially towards the distal Aleutians. Any increase in sedimentation to these systems could potentially extend the transition from an accretionary to a non-accretionary/erosional subduction system.

The configuration and nature of the subducting and accreting sediment in the Gulf of Alaska lead us to ask some key questions about the effect of sediment on the Aleutian subduction zone:

1- How do spatial and temporal variations in sediment thickness affect taper of the prism, fault vergence, width of the prism, location of forearc basins, development of out of sequence thrusts, and the potential for backthrusts and/or splay faults?

2- What are controls on the formation of the décollement and how do they vary along strike, especially with regards to point source sediment input and the boundary between the Zodiac and Surveyor Fans? How does this relationship affect the amount of sediment underplating versus accretion to the front of the prism?

3- What is the extent of the Aleutian Trench fill sediment body and how far along strike does it exert an influence on subduction? Where does the subduction process fundamentally change along strike from an accretionary to non-accretionary margin?

4- How do significant amounts of sedimentation affect the length of seismogenic zone segments, namely, what is the potential for sediments to overtop basement topography, effectively smoothing out the subducting plate and removing potential asperities?

5- Do existing locked and creeping zones correspond to differences in 1) sedimentary inputs 2) sediment loading on the shelf in forearc basins and/or 3) sediment interaction with subducting basement topography?

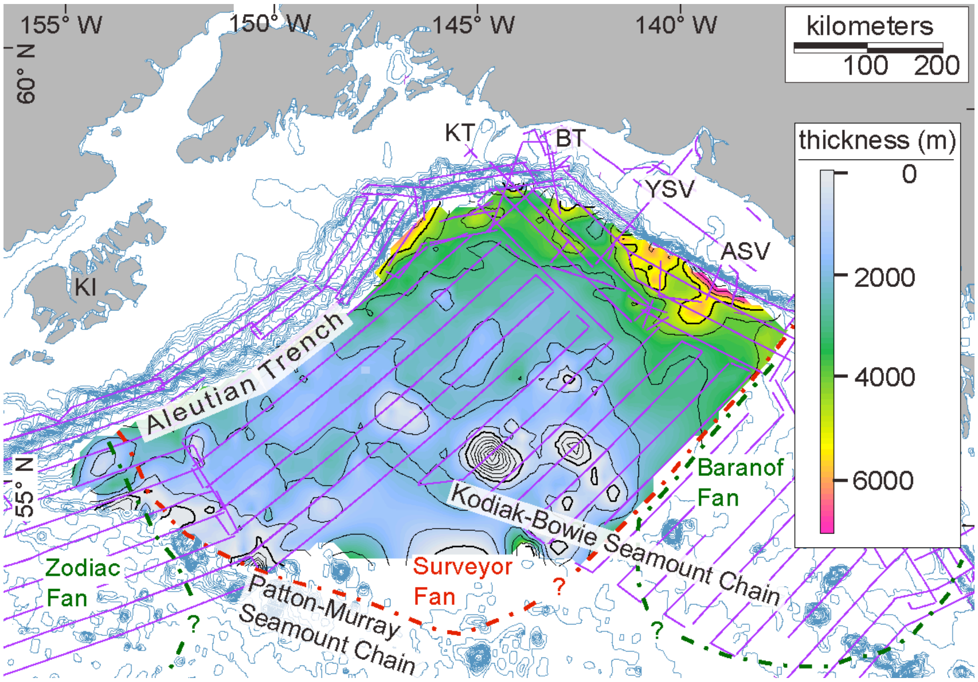

Figure 1. Two-way travel time thickness map of the Surveyor Fan. Seismic reflection data tracklines used in calculation shown in purple. Estimated boundaries of the Surveyor, Zodiac, and Baranof Fans shown in red and green dashed lines, respectively. ASV- Alsek Sea Valley; BT- Bering Trough; KI- Kodiak Island; KT- Kayak Trough; YSV- Yakutat Sea Valley. (Reece et al., 2011).

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