Controls on faulting, earthquakes and water cycling in the Alaska subduction zone

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Subduction zones worldwide exhibit remarkable variations in seismic activity and slip behavior along strike and down dip, and many factors have been invoked to explain this variability. Here we will review constraints on plate boundary properties and the incoming oceanic plate off the Alaska Peninsula from marine seismic reflection/refraction data and their relationship to pronounced variations in earthquake behavior in this subduction zone. We observe remarkable along-strike changes in incoming sediment thickness and plate structure and along-strike and downdip variations in megathrust reflection character that correlate with changes in seismicity, locking and earthquake rupture history.

MCS reflection and wide-angle seismic data were collected off the Alaska Peninsula in July-August 2011 on the R/V *Langseth* during the Alaska Langseth Experiment to Understand the megaThrust (ALEUT) program. This region encompasses the full spectrum of coupling: 1) the weakly coupled Shumagin Gap; 2) the Semidi segment, which last ruptured in the 1938 M8.2 event, appears to be locked at present, and 3) the Kodiak asperity, the western part of the 1964 M9.2 rupture. It also exhibits substantial variations in seismicity.

Remarkable variations in bend faulting and hydration of the subducting oceanic plate are observed along strike, which may be controlled by the relationship between the orientations of pre-existing structures in the incoming oceanic plate and the subduction zone. Significantly more bending faulting is observed in MCS profiles and bathymetry data from the Shumagin Gap, where pre-existing structures are favorably aligned, than the Semidi segment where they are oblique to the trench. Abundant bending fault enables hydration of the crust and upper mantle based on a reduction in P-wave velocity from seismic refraction data. The thickness of sediment on the incoming plate also changes along strike. Up to 1.5 km of sediment are observed on the incoming oceanic plate in the Semidi segment. In the Shumagin Gap, the incoming sediment section is >0.5 km thick and more pervasively faulted at the outer rise.

These changes in bending faulting, hydration and sediment thickness on the incoming plate correlate with variations in changes in plate boundary properties and interplate and intermediate depth intraslab seismicity. In the Semidi segment, we observe a continuous 600- to 900-m-thick low velocity zone along the plate boundary to distances >30 km from the trench that we interpret as a subducted sediment layer. The subducted sediment layer in the neighboring Shumagin Gap is thinner and irregular and can only be traced to <10 km from the trench. We estimate that differences in velocity of subducted sediments relate to differences in pore fluid pressure. Although the Semidi segment is locked and capable of producing great earthquakes, very little interplate seismicity occurs here compared with the adjacent Shumagin Gap, which appears to be creeping and exhibits abundant seismicity. We suggest that the faulted oceanic crust with limited sediment entering the Shumagin Gap contributes to a more heterogeneous plate boundary at depth, which may partially account for the relative abundance of small earthquakes here compared with the Semidi segment. The Shumagin Gap is also characterized by more intermediate depth earthquakes than the Semidi segment. We suggest that more water enters the subduction zone at the Shumagin Gap than the Semidi segment largely due to favorably oriented remnant structures, and thus more water is available to drive dehydration embrittlement and possibly intermediate-depth seismicity here.

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