Local structural controls on outer-rise faulting, hydration, and seismicity in the Alaska subduction zone

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Abstract

We present evidence from marine geophysical data that pre-existing structures in the incoming oceanic plate off the Alaska Peninsula control bending faulting and hydration at the outer rise, which in turn correlate to changes in the abundance of interplate and intermediate-depth earthquakes within the subduction zone. Thus, pre-existing heterogeneities in the downgoing plate can result in significant variations in plate hydration over relatively small distances and may in part explain the observed global diversity of seismicity in subduction zones. ALEUT MCS and bathymetry data reveal large changes in the style and amount of bending in the incoming plate. To the west, outboard of the Shumagin Gap, there is significant bending faulting, with fault offsets up to ~250 m at the seafloor and larger offsets at depth. Faults create rugged topography at the seafloor, and sediment cover is thin (~0.5 km). Most faults have strikes within ~25 degrees of the trench. In contrast, the downgoing plate outboard of the Semidi segment to the east exhibits less dramatic bending faulting, with maximum offsets at the seafloor of 30 m, and the sediment cover is thicker (>1 km). These along-strike changes in faulting correlate with changes in the expected orientation of pre-existing structures in the incoming oceanic crust, which is nearly parallel to the trench near the Shumagin Gap, but highly oblique to the trench near the Semidi segment. This implies that more favorably-oriented pre-existing structures may facilitate bending faulting. P-wave velocity models from wide-angle seismic data reveal that along-strike changes in faulting are accompanied by variations in the velocity structure of the incoming plate. Mantle velocities are reduced by ~0.5 km/s at the outer rise off the Shumagin Gap, where significant bending faulting is observed. We interpret decreased velocities to represent serpentinization of the upper mantle. In contrast, the velocity structure is more variable off the Semidi segment, where the profile obliquely crosses seafloor fabric, but no comparable reduction is observed, implying less hydration at the outer rise. Variations in outer rise faulting and hydration correlate to changes in seismicity at depth. The Shumagin area is characterized by abundant interplate and intermediate depth microseismicity, while the Semidi segment exhibits relatively fewer events in both depth ranges. We suggest that local controls on bending faulting and hydration control the occurrence of both types of microseismicity. The greater deformation and hydration of the plate in the Shumagin Gap may enable intermediate depth earthquakes through dehydration embrittlement and/or the reactivation of bending faults. The paucity of both in the Semidi segment may limit the amount of intermediate depth seismicity. Likewise, the rougher plate surface in the Shumagin may form many small asperities when subducted and thus generate abundant small interplate earthquakes, while the smooth, sedimented surface of the Semidi segment would be associated with more distributed, even coupling and less seismicity when subducted, with fewer small events but capable of rupturing more easily in great (M>8) earthquakes.

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