Constraints from seismic reflection signature on the seismogenic region in the Alaska/Aleutian subduction zone from the 1938 Alaska rupture zone to the Shumagin gap

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Abstract

Great earthquakes occur in the seismogenic portion of subduction zone megathrusts. Downdip, the megathrust changes from stick-slip behavior to stable sliding. Competing models suggest that the transition is controlled by temperature or the intersection of the megathrust with the serpentinized forearc mantle wedge. In some subduction zones, changes in behavior appear to be accompanied by changes in seismic reflection signature. In 2011, ALEUT program acquired 3700 km of deep penetration multichannel seismic (MCS) reflection and 800 km of ocean bottom seismometer (OBS) data along a part of the Aleutian-Alaska subduction zone that exhibits lateral and downdip variability in present-day locking and earthquake history. One goal of this program is to use reflection signature of the megathrust to map out downdip and along-strike changes in plate boundary properties and correlate them with constraints on coupling and earthquake rupture history. Our study area encompassed the freely sliding Shumagin Gap, the locked Semidi segment and the locked western Kodiak asperity. The Semidi and the Western Kodiak segments have last ruptured in 1938 M8.2 Earthquake and 1964 M9.2 Earthquake, respectively, while no large earthquake ruptured the entire Shumagin Gap. Here we present seismic reflection profiles from two MCS lines that image the plate boundary at the transition between the Semidi segment and Shumagin Gap. ALEUT Line 4 is a ~300-km-long dip profile across the western edge of the 1938 M8.2 rupture zone. Reflections from the plate interface can be traced on this profile from the trench, at ~8 s twtt (~5.5-6.0 km depth), to 140 km landward of the trench, at 10-12 s twtt (~30-40 km depth). However, large variations in the reflection response are observed with depth. The plate interface is marked by a single, simple reflection within the 1938 Mw 8.2 earthquake rupture zone. This area is characterized by relatively sparse small-to-moderate megathrust seismicity. Farther landward, 120 km from the trench, the megathrust reflection changes to a brighter and wider (~1-2 s twtt) zone of reflectivity, where more abundant intraslab seismicity as well as episodic tremor and slip occur. The change in the megathrust reflection response appears to occur where it intersects a shallower band of reflectivity, which we tentatively interpret as the continental Moho. Thermal model predicts that the temperature on the thrust reaches 350 degrees Celsius, the temperature at which a change in rheology can occur, significantly deeper and farther landward. We will also show results from the along-strike ALEUT Line 7 that crosses the Semidi segment and Shumagin gap. The thickening of reflection band in the transition zone could be related to rheological change from brittle deformation to plastic shearing or a fluid-rich layer formed by dehydration process. We test this hypothesis by producing synthetic seismograms based on simple end member scenarios for the origin of the imaged megathrust reflection band (e.g., mylonites, a low velocity layer(s) with overpressured fluid) and comparing them with the data.

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