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Seismic imaging the slow-slip inter-plate boundary in the northern Cascadia subduction zone

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In the Cascadia subduction zone, landward dipping regions of low S wave velocity and elevated Poisson's ratio that extend to approximately 50 km depth have been identified using passive teleseismic surveys. These dipping regions are interpreted to be all or part of the subducting igneous oceanic crust, which is considered to be overpressured owing to fluid trapped beneath an impermeable seal along the overlying inter-plate boundary. Seismic reflection profiles shot during the SHIPS (Seismic Hazards Investigations in Puget Sound) program reveal a 6-12 km thick package of landward dipping reflections that extend to >50 km depth. These so-called E reflectors, which can be traced intermittently seaward to reflections at the top of the subducting oceanic crust near the deformation front, are interpreted to be a shear zone because they truncate overlying crustal structures such as the Leech River fault. Magnetotelluric data also reveal a landward dipping 30-100 ohm-m conductor, which is approximately coincident with the shear zone and terminates landward close to the onset of eclogitization and inslab seismicity. Is it possible to combine these seismic observations into an integrated interpretation when the wavelengths of data acquired in these surveys differ by almost two orders of magnitude?

All seismic recordings are functions of time, and comparison of results available from different seismic methods requires that they be presented in a common reference frame, i.e. depth, for which consistent P wave and S wave velocity models are required. P and S wave velocity models for southern Vancouver Island have been developed using 3-D double-difference tomographic inversion of travel times from local earthquakes, low frequency earthquakes (LFEs), the 1998 SHIPS wide-angle survey, and all post-2002 seismograph stations. These models extend across the region of slow slip from the landward end of the locked zone at 25-30 km depth to the forearc mantle. LFEs, which exhibit particle motions consistent with low-angle thrusting, define a landward dipping surface, and occur immediately below the E reflectors and a 3-5 km thick, landward dipping zone of 0.3-0.4 Poisson's ratio inferred from teleseismic data to be at near-lithostatic pore pressure. The inter-plate boundary could be thin, <1 km thick, and correspond closely to the LFEs; however, since recorded LFEs account for <1% of the total slow slip, slip could alternatively be distributed vertically through a thicker inter-plate boundary zone within the lowermost E reflectors and include the zone of high Poisson's ratio. The tomographic velocity models also indicate that Poisson's ratio is elevated here, but with lower values that are largely due to higher P wave velocities, rather than the ultra-low S wave velocities suggested by the teleseismic data. In the tomographic velocity model, there is a lower magnitude S wave low velocity zone, but it is shallower, dips less steeply, and can be traced into the lower crust of the overriding plate at 35 km depth. LFEs, and thus the approximate location of the plate boundary, project downdip into the top of a ~10 km thick band of seismicity that occurs in the subducting slab below 40 km depth. The overlying mantle wedge has anomalous elastic properties with a Poisson's ratio of 0.26-0.28 and P wave velocity of 7.1-7.7 km/s consistent with peridotite serpentinized by 20-60% owing to water rising from the subducting oceanic slab.