Seismic characterization of the Juan de Fuca Plate from Ridge to Trench

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Plate-scale seismic reflection images and seismic velocity characterization of the sediments, crust, and shallowest mantle along two transects crossing the Juan de Fuca (JdF) plate and along a margin parallel transect seaward of the Cascadia deformation front are used to characterize the evolution and hydration of this young plate prior to subduction. Reflection images for the two-plate crossing transects (Han et al., 2016) reveals faults in the sediment section beginning 55-70 km from the ridge axis with sparse reflections from presumed hydrated abyssal hill faults in the upper crust below. The lower crust is mostly acoustically transparent except for low-angle (20-40°) ridgeward dipping reflectors found in same age (6-8 Ma) crust along both transects, possible ductile shear zones in the lower crust due to temporal variations in mantle upwelling. Near the deformation front (DF), plate bending due to sediment loading and subduction begins ~150 and 80 km from the DF offshore Oregon and Washington respectively with greater bending observed along the Oregon transect. Bright fault plane reflections are imaged on the Oregon transect that extend through the crust and 6-7 km into the mantle beginning ~40 km from the DF (Fig. 2A) and attributed to hydrated fault zones due to subduction bend faulting. On the Washington transect, bend faults are confined to the sediment section and upper crust and more limited plate hydration in this outer trench slope region is inferred. From tomographic analysis of seismic velocity structure along the plate transects, we infer that the JdF plate acquires a mature structure within one million year after accretion (Fig.2B, Horning et al., 2016; Boulahanis et al., 2020). This mature structure is characterized by a hydrated, porous upper crust, and a lower crust and uppermost mantle with seismic velocities consistent with dry gabbro and peridotite, respectively. Propagator wakes are associated with velocity and hydration anomalies at lower crustal and upper mantle levels. Along both transects, three age intervals (1-3.4/4Ma, 3.5/4-6 Ma, > 6-8 Ma) of distinct crust and upper mantle Vp structure, basement roughness, and spreading rate history are identified. These distinct periods are attributed to differences in the mode of accretion at the paleo-JdF Ridge due to plate motion change at 6 Ma and a period of possible enhanced flux to the ridge from the Cobb hotspot at ~ 4Ma.

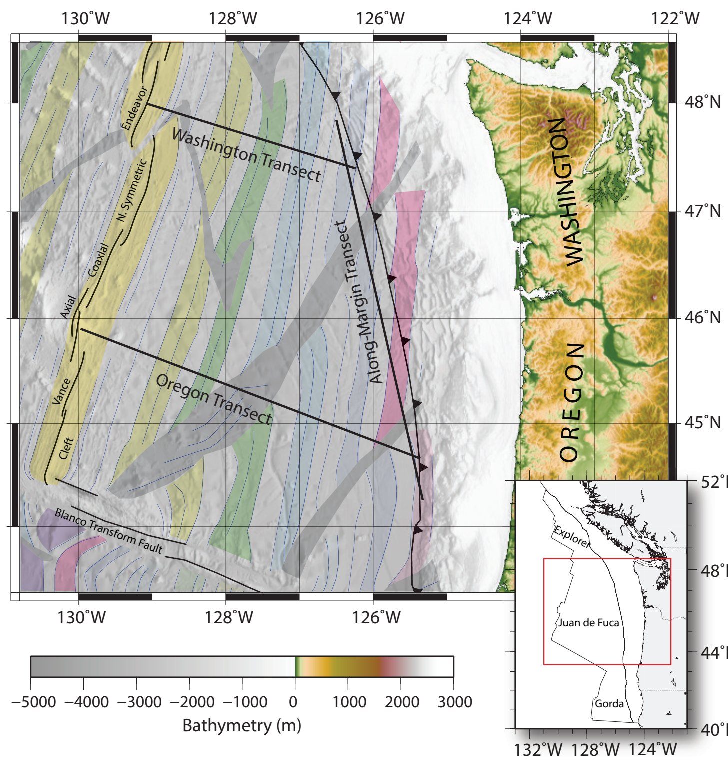

Figure 1. Map of the seismic experiment.

Along the margin transect, we find that the JdF lower crust and mantle are drier than at any other subducting plate, with most of the water stored in the sediments and upper crust (Canales et al., 2017). Variable but limited bend faulting along the margin (Han et al., 2016; 2018) limits slab access to water, and a warm thermal structure resulting from a thick sediment cover and young plate age prevents significant serpentinization of the mantle. The implications from these findings for subduction processes are that fluids that facilitate episodic tremor and slip downdip from the seismogenic zone must be sourced from the subducted upper crust,and that decompression rather than hydrous melting must dominate arc magmatism in central Cascadia. ■

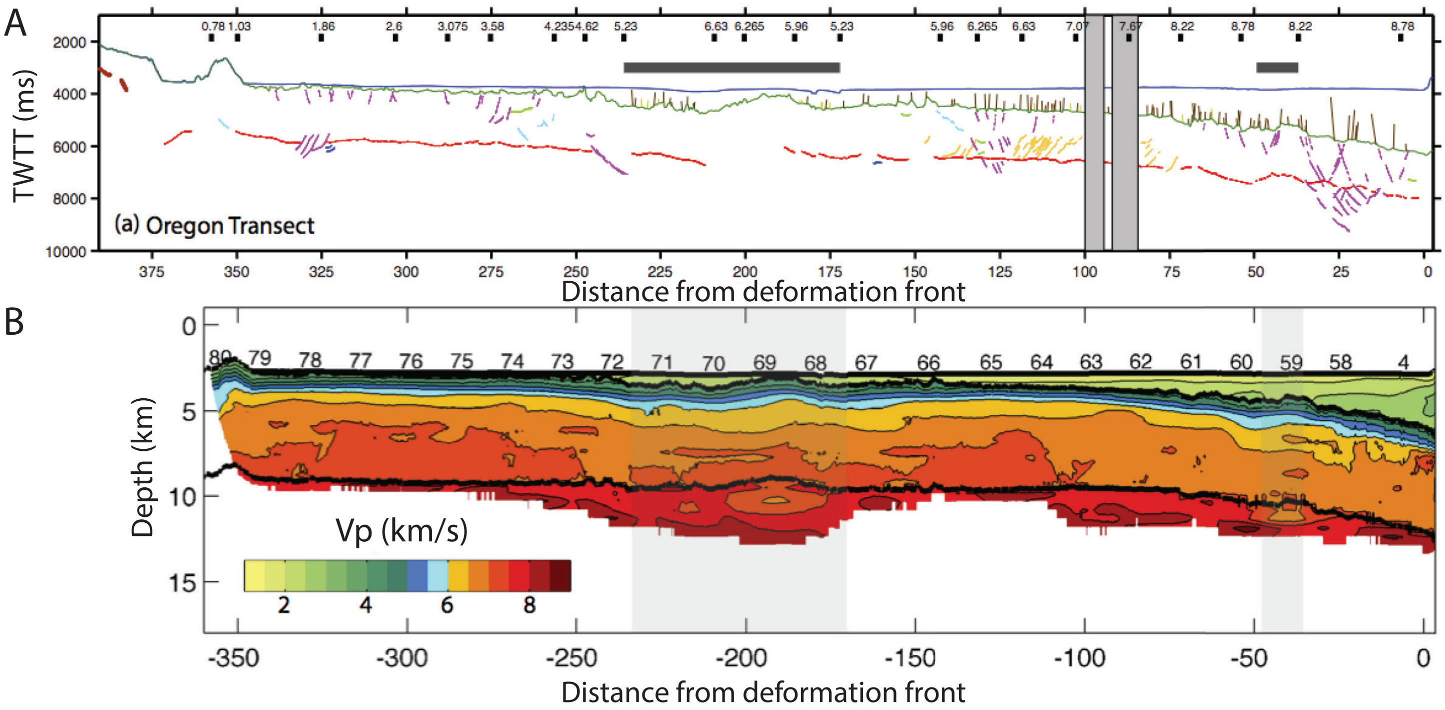

Figure 2. A. Interpretation of Oregon plate transect showing faults within the sediment section (brown), crust and uppermost mantle (purple), ridgeward dipping lower crustal reflections (orange), and other sparse events in crust and near Moho (blue) (from Han et al. submitted); B. Seismic Tomography Model for Oregon transect (Horning et al., in prep). Propagator wakes are indicated with black horizontal bars in (A) and gray shading in (B).

References

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The Cascadia Subduction Zone primary site offered outstanding opportunities, in particular leveraging onshore and offshore infrastructure associated with EarthScope's Plate Boundary Observatory (PBO), and deployment of the EarthScope Amphibious Array, all part of the ARRA-funded Cascadia Initiative. Work in this region built upon a broad spectrum of geological and geophyscial data collected over the past decades and engaged a range of US, Canadian, and international scientists.