Physical properties of Cascadia incoming sediments

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Seismic data from the Ridge2Trench (R2T) experiment combined with ocean drilling data indicate that offshore Washington where the megathrust is inferred to be strongly locked, over-consolidated sediments near the deformation front are incorporated into a strong outer wedge, with little sediment subducted (Han et al., 2017). These conditions are favorable for strain accumulation on the megathrust and potential earthquake rupture close to the trench. In contrast, offshore central Oregon, a thick under-consolidated sediment sequence is subducting, and is probably associated with elevated pore fluid pressures on the megathrust in a region where reduced locking is inferred. These results suggest that the consolidation state of the sediments near the deformation front is a key factor contributing to megathrust slip behavior and its along-strike variation, and it may also have a significant role in the deformation style of the accretionary wedge. Using advanced methodologies - full waveform inversion or FWI and analyses of seismic reflection attributes and P-to-S converted waves - applied to the R2T multichannel seismic (MCS) and ocean bottom seismometer (OBS) datasets, we map out and infer the physical properties of the incoming sediment section and the megathrust, and their along-strike variations.

The FWI-derived fine-scale structure of the incoming sediments offshore central Oregon shows that a ~400-m-thick low-velocity interval initiates ~7 km seaward of the deformation front likely associated with anomalously high porosity that developed due to poor drainage beneath a thin layer of low permeability (Fig. 1). Further landward, décollement develops within this interval with along-strike variations in depth of a few hundred meters. In contrast, offshore Washington, we do not observe low velocity intervals in the incoming sediment section near the deformation front and the décollement is only ~200 m above the basement.

The average Vp/Vs structure of Cascadia basin sediments derived from analyses of P-to-S converted waves (Fig. 2A) can be well described by a compaction trend decaying exponentially with depth. On a finer scale, Vp/Vs structure of incoming sediments near the deformation front offshore northern Oregon and Washington shows little variability along strike, while the structure of incoming sediments offshore central Oregon is more heterogeneous and includes intermediate-to-deep sediment layers of anomalously high Vp/Vs likely due to elevated pore pressures (Fig. 2).

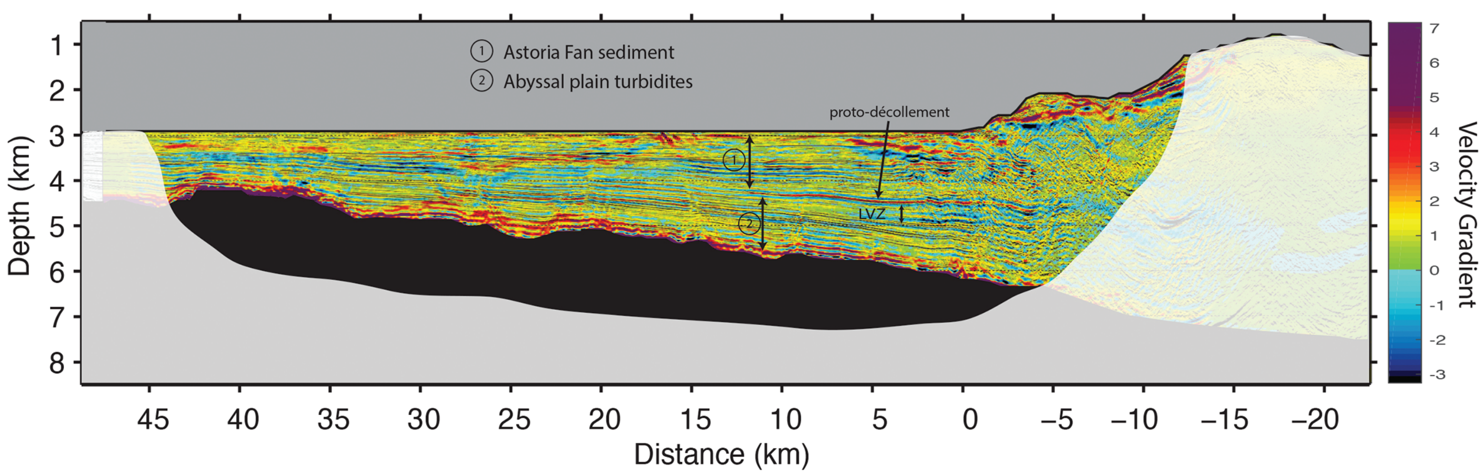

Figure 1. FWI velocity gradient model superimposed on pre-stack depth migrated image of the Oregon transect. LVZ: low velocity zone. (Han et al., 2019).

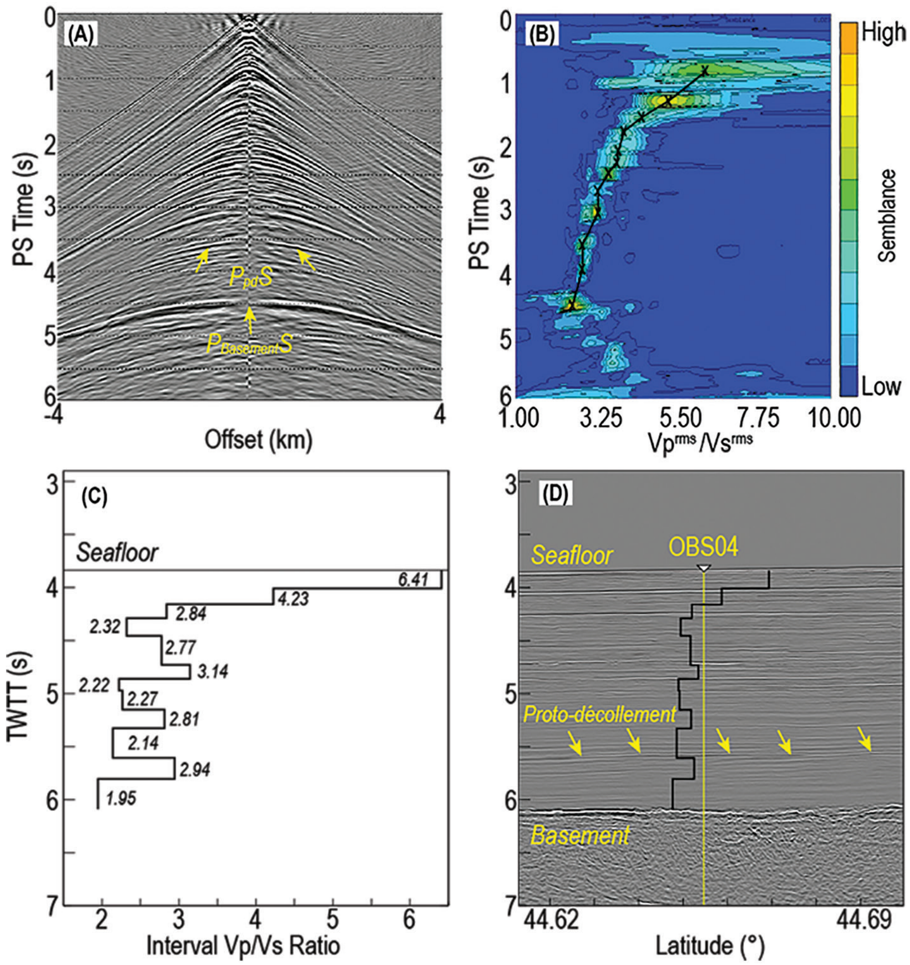

Figure 2. Modified from Zhu et al. (2020). A. OBS receiver gather (radial) after downward continuation of sources to the seafloor. Yellow arrows PS reflection from the basement (PBasementS), and from the proto-décollement (PPdS); B. Contoured semblance Vp/Vs spectrum of OBS gather. Black crosses connected with solid line indicate picked PS arrivals with high semblance; C. Calculated interval Vp/Vs ratio as a function of P-wave two-way travel time; D. MCS section in the vicinity of the OBS showing sediment layering and oceanic basement, with calculated Vp/Vs function overlaid.

We infer a step down in the proto-décollement from shallow depths of ~1500 m to ~300 m above basement at 44°46'N from analyses of seismic attributes. Further north along the margin a horizon interpreted as a mid-level detachment in the accretionary wedge can be identified above a layer of distinct sediment properties that may reflect diagenetic alteration.

Collectively, our results indicate that the incoming sediment section offshore Washington where landward vergence dominates is well drained and characterized by normal fluid pore pressures. In contrast, incoming sediments with the highest estimated fluid overpressures occur offshore central Oregon where deformation of the accretionary prism is seaward vergent. Our results also suggest that the presence of a low permeability layer at the base of Astoria Fan sediments with fluid overpressures below it, may play an important role in forming a shallow décollement offshore central Oregon. ■

References

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