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Frictional Shear Stress, Pore Fluid Pressure and Wedge Mechanics on the Cascadia Megathrust Timothy Kane, Chris Goldfinger and Chris Romsos

Details

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Abstract

Although Cascadia is one of the most studied subduction zones in the world, the mechanics of the seismogenic zone remain shrouded by a lack of offshore data quantifying both inter-seismic and co-seismic behavior. We use an analysis of accretionary wedge morphology and overburden-defined frictional shear stress to constrain the range of pore fluid pressures suggested by seismic and geological observations. We also compare this result to the location of the down-dip maximum of inter-plate coupling as inferred from current geodetic and paleoseismic models of the locked zone. Using a new 100m bathymetric mosaic, McCrory et al.'s 2004 model of slab depth, a matrix of typical values for basal pore fluid pressure (70-95% of lithostatic) and rock density (2300-2500 kg/m3), and assuming Byerlee's Law, where µb (coefficient of basal friction) = 0.85, to be valid on the decollement, shear traction on the Cascadia megathust was calculated from the deformation front east to the 450 degree basal isotherm as defined by Spinelli, 2012. On the basis of heat flow and thermal modeling, megathrusts worldwide are predicted to have an average maximum shear stress of 15MPa. Employing pore fluid pressures above hydrostatic but well below lithostatic ($\lambda b = 0.7 - 0.86$), our analysis resulted in frictional shear stress on the Cascadia megathrust meeting or exceeding 15MPa within 5-10 km of the deformation front, failing to satisfy the upper-slope to outer-shelf location of the down-dip limit of the locked zone and maximum inter-plate coupling as determined by current geodetic models. Basal pore fluid pressures of at least 90% of lithostatic are required over the entire seismogenic zone to satisfy the proposed down-dip limit of the locked zone. This supports high pore fluid pressures in the accretionary wedge, particularly in Washington, as suggested by the presence of landward-vergent thrusts, listric normal faults and near surface methane horizons in recent multi-channel seismic data. Moreover, our analysis of frictional shear stress also suggests that it is unlikely that a sudden change in pore fluid pressure occurs across the basal decollement. With the coefficient of basal friction corrected for dissimilar pore fluid pressures on the decollement and in the overlying wedge, even a 5% variance resulted in a pronounced eastward shift in basal shear stress magnitudes such that values of 15MPa and greater occurred landward of the coast - a result inconsistent with both seismic and geological observations and current models of the locked zone. In addition, our analysis of frictional shear stress employing near lithostatic pore fluid pressures, typical density values, and a 15MPa threshold appears to be consistent with the upper-slope to outer-shelf position of the down dip limit of the locked zone inferred from the CAS3D-2 geodetic model, with the coupling parameter falling within 1 standard deviation of our determined mean for a 15MPa threshold. The down-dip trend of increasing frictional stress also suggests that the plate interface up-dip of maximum coupling (i.e. the lower slope and deformation front) contributes only marginally to strain accumulation and is passive inter-seismically, particularly in Washington where basal traction and traction gradient are low from the deformation front to 50km landward.

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