Warm thermal structures in subduction zones lead to ample dehydration at the depths of deep slow slip and tremor and resultant transformations in viscous rheology

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Feedbacks amongst petrologic and mechanical processes along the subduction plate boundary play a central role influencing slip behaviors and deformation styles. Metamorphic reactions, resultant fluid production, deformation mechanisms, and strength are strongly temperature dependent, making the thermal structure of these zones a key control on slip behaviors.

Firstly, we investigate the role of metamorphic devolatilization reactions in the production of Episodic Tremor and Slip (ETS) in warm subduction zones. Geophysical and geologic observations of ETS hosting subduction zones suggest the plate interface is fluid-rich and critically stressed, which together, suggests that this area is a zone of near lithostatic pore fluid pressure. Fluids and high pore fluid pressures have been invoked in many models for ETS. However, whether these fluids are sourced from local dehydration reactions in particular lithologies, or via up-dip transport from greater depths remains an open question. We present thermodynamic models of the petrologic evolution of four lithologies typical of the plate interface along predicted pressure–temperature (P-T) paths for the plate boundary along Cascadia, Nankai, and Mexico which all exhibit ETS at depths between 25-65 km. Our models suggest that 1-2 wt% H₂O is released at the depths of ETS along these subduction segments due to punctuated dehydration reactions within MORB, primarily through chlorite and/or lawsonite breakdown. These reactions produce sufficient in-situ fluid across this narrow P-T range to cause high pore fluid pressures. Punctuated dehydration of oceanic crust provides the dominant source of fluids at the base of the seismogenic zone in these warm subduction margins, and up-dip migration of fluids from deeper in the subduction zone is not required to produce ETS-facilitating high pore fluid pressures. These dehydration reactions not only produce metamorphic fluids at these depths, but also result in an increased strength of viscous deformation through the breakdown of weak hydrous phases (e.g., chlorite, glaucophane) and the growth of stronger minerals (e.g., garnet, omphacite, Ca-amphibole). Lastly, we present preliminary data on viscosity along warm subduction paths
showing the locations of these dehydration pulses correlate with viscosity increases in mafic lithologies along the shallow forearc.