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Controls of faulting and reaction kinetics on serpentinization and double Benioff zones

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The subduction of partially serpentinized oceanic mantle may potentially be the key geologic process leading to the regassing of Earth's mantle and also has important consequences for subduction zone processes such as element cycling, slab deformation, and intermediate-depth seismicity. However, little is known about the quantity of water that is retained in the slab during mantle serpentinization and the pattern of serpentinization that may occur during bending-related faulting; an initial state that is essential for quantifying subsequent dehydration processes. We present a 2-D reactive-flow model simulating hydration processes in the presence of faulting at the trench outer-rise. The model is calibrated to geophysical observations of hydration from the Nicaraguan and south central Chilean subduction zones. We find that the temperature dependence of the serpentinization rate in conjunction with outer-rise faulting results in hydration patterns dependent on both the age of the subducting plate and the subduction velocity, i.e. the amount of serpentinization increases with increasing lithospheric age and decreases as the subduction velocity increases. Mantle serpentinization also results in an advective downflow of seawater due to the uptake of fluids in the reactive region. This, in turn, results in a reduction in surface heat flux towards the trench. However, observed heat flow reductions at subduction zones are larger than the reduction due to the minimum-water downflow needed for partial serpentinization, predicting that active hydrothermal vents and chemosynthetic communities should also be associated with bend-fault serpentinization. Lastly, our model results agree with previous studies that the lower plane of double Benioff zones can be generated due to dehydration of serpentinized mantle at depth. More importantly, the depth-dependent pattern of serpentinization including reaction kinetics obtained from our model predicts a separation between the two Benioff planes consistent with seismic observations.