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Implications of deep transport of slab-adjacent hydrated material at subduction zones

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The interaction between fluids derived from dehydrating subducting lithosphere and material in the slab-adjacent mantle impacts melting relationships and the rheology of the mantle wedge (Hirth and Kohlstedt, 1996; Billen and Gurnis, 2001; Manea and Gurnis, 2007; Cagnioncle et al., 2007; Iwamori, 2007; Hebert et al., 2009a; Hebert et al., 2009b). Focus has primarily been on the shallow (< 200 km) dynamical and geochemical processes and their implications for arc-related magmatism, but retention of fluids in the mantle opens the possibility of deeper fluid release with implications for slab dynamics, geochemical enrichments, generation of low-velocity regions, and the global water budget.

Here, we investigate the dynamical implications of serpentinite dehydration and potential fluid pathways using 2-D finite element models of kinematic slab subduction to the core-mantle boundary. Fluid release follows a mapping of experimentally-derived dehydration reactions. Fluids are assumed to migrate upward at a predetermined Darcy velocity. We incorporate a temperature-dependent viscosity that includes viscosity reduction due to a hydrogen-defect population in Nominally-Anhydrous Minerals (NAMs). We investigate the impact of excess buoyancy due to the presence of free fluid, and variations in water storage capacity in lower mantle minerals.

We find that the locations of slab dehydration vary with subduction parameters such as slab age and convergence velocity, and that dehydration may occur in the upper part of the lower mantle. Slow fluid velocities ($<0.001 \times$ solid flow velocity) do not allow fluids to escape the slab-dominated solid flow field but allow a fluid phase to reach the deep lower mantle. Fast fluid velocities ($>1000 \times$ solid flow velocity) do allow the fluid to escape the slab flow field. However, fluids can still be delivered to the lower mantle if the water storage capacity of the lower mantle is high (e.g. Murakami et al., 2002). In that case, fluids hydrate a thick slab-adjacent envelope of NAMs, which will be transported with the solid flow field into the deep lower mantle. If the lower mantle water storage capacity is low (e.g. Bolfan-Casanova et al., 2002), fluid will hydrate NAMs within the transition zone and upper mantle, and, due to secondary dehydration at the base of the transition zone, result in a locally hydrated transition zone and possibly a partially molten layer at 400 km depth. Both situations would result in significantly different regions of lowered viscosity, with implications for slab dynamics.