Numerical simulations of slab stagnation with trench retreat

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We have investigated interaction mechanisms between trench retreat and slab behaviors in the mantle transition zone. We use 2-D dynamical subduction models. No imposed forces are applied to the plate and surface boundaries so that the plate motion is created by the plate buoyancy. The model dimension is 8000 km (length) by 2000 km (depth). The viscosity depends on the temperature, depth, and stress. In some cases, the intrinsic viscosity contrast between the bottom of the upper mantle and the top of the lower mantle is a factor of 10 or 30. We consider two conditions for the overriding plate; (1) it is fixed to the boundary or (2) it is freely movable. The freely-movable condition is modeled by introducing a low viscosity region into the overriding plate portion at the right-hand side boundary. The model includes two phase changes of olivine; (1) olivine to wadsleyite at 410 km, and (2) ringwoodite to perovskite and magnesiowustite at 660 km. The positive Clapeyron slope at 410 km is assumed to a fixed value of +3 MPa/K. Three values are tested for the negative Clapeyron slope at 660 km: -3, -2, or -1 MPa/K.

When the overriding plate is fixed to the right-hand side boundary, the subducted slab penetrates into the lower mantle with a steep angle. Positive buoyancy at the 660 km phase boundary does not impede the subducting slab. The viscosity jump at 660 km makes the mantle flow slower and acts as a barrier to the subducting slab. However, the slab which collides vertically with the high-viscosity lower mantle sinks into the lower mantle and shows a blob-like structure.

When the overriding plate is under the freely movable condition, it is passively pushed by the mantle flow due to the subducting plate. The trench starts migrating at an early stage of the subduction (i.e., trench retreat takes place). This induces the slab with a shallow dip angle. When the negative Clapeyron slope is -3 MPa/K, the slab is bent upward above the 660 km phase boundary. This promotes retreat of the slab. Consequently, a horizontally lying slab is formed with a dimension of about 2000 km, that is accompanied by trench retreat. On the other hand, when the negative Clapeyron slope is -2 and -1 MPa/K, the slab deforms because of the positive buoyancy at the 660 km phase boundary, but penetrates into the lower mantle. In these cases, the slab does not stagnate while the trench retreat occurs.