Numerical Simulation of Trench Retreat and Slab Stagnation Related to Tensional Lithospheric Strength

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We carry out numerical modeling of spontaneous subduction to study dynamical influences of tensional lithospheric strength on the slab configuration and trench retreat. Recent seismic tomography models reveal subducted slab images [e.g., Fukao et al., 2001]; some stagnate horizontally in the mantle transition zone and others penetrate into the lower mantle through the 660 km seismic discontinuity. It is also suggested that slab deformation above the 660 km discontinuity is often accompanied by trench retreat, i.e., backward migration of the subducting slab. In previous numerical studies, velocities of the plates and the trench retreat are imposed as a boundary condition [e.g., Christensen, 1996; Cizkova et al., 2002]. In this study, we develop fully dynamical models in which the plate subduction is generated without forced velocity conditions to understand interaction machanisms between the slab migration and the stagnation. We use a layer with hysterisis-dependent rheology [Honda et al., 2000] which is a thin wet oceanic crust (6 km thickness) to initiate subduction spontaneously. We employ internally heated fluid in a 2-D Cartesian box and an extended Boussinesq approximation. At all the boundaries, free slip mechanical boundary conditions are applied so that all the motions are determined self-consistently by the internal forces. We incorporate the tensional yield strength of the lithosphere which is lower than compressional strength. Effects of phase transformations and subsequent superplasticity associated with grain-size reduction are introduced.

Results show that the trench retreat is produced spontaneously when the weaker tensional strength is included. The subducted slab shows a shallow dip angle because the trench retreat affects to prevent the slab from bending at the trench. On the other hand, the slab without tensional strength penetrates into the lower mantle and no trench retreat is generated. When both weaker tensional strength and superplasticity are introduced, the subducted slab deforms with sufficient reduction of viscosity and lies horizontally in the mantle transition zone.