Effects of Rheology on Slab Dynamics

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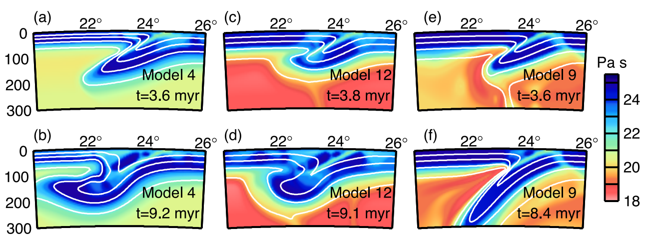
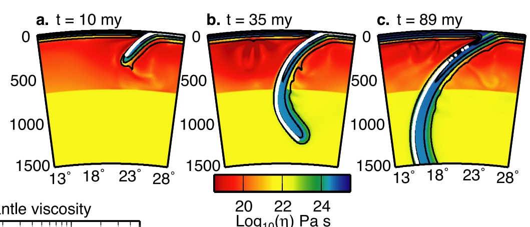
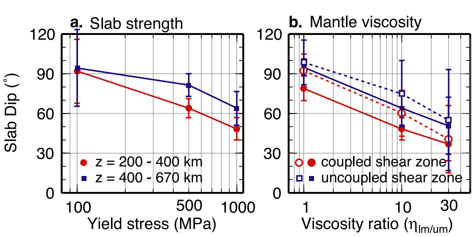
By making the numerical advances necessary to incorporate realistic mantle and lithosphere rheology, including non-Newtonian upper mantle rheology and stiff slabs, we find that: 1) Non-Newtonian rheology aids subduction initiation by maintaining a weak mantle wedge corner and decoupling the overriding and subducting plate until the slab weight is sufficient to drive subduction (Fig. Pt 1). 2) Coupling of the slab to the overriding plate can help to unbend a stiff slab at early stages of subduction (Fig. Pt 2): a shear zone viscosity of $1e^{21}$ Pa s maintains the slab dip of 30° to slab lengths up to 300 km. However, the slab tip curls backwards under the subducting plate for weaker shear zones ($1e^{20}$ Pa s). 3) A yield stress of 500–1000 MPa leads to sufficiently stiff slabs with dips ranging from 30°–90° . A lower yield stress of 100 MPa (equivalent to a viscosity of $1e^{23}$ Pa s at a strain-rate of $1e^{-15}$ Pa s) leads to break-off of mini-slabs with lengths of 200–300 km (Fig. Pt 3). 4) Including the drying effect of melting at the ridge on slab viscosity leads to larger integrated slab strength and smaller slab dips. 5) An increase in viscosity and change to Newtonian-only rheology in the lower mantle causes the slab dip to decrease from near-vertical at the early stages of lower-mantle penetration to smaller dips as subduction progresses. This is caused by the transfer of stress from the shallow to the deeper portion of the stiff slab, which responds by migrating longitudinally instead of thickening as occurs in weaker slabs (Fig. Pt 2). This project has shown the important role mantle and lithosphere rheology plays in slab dynamics. As with any set of numerical models, some simplifications were made that if incorporated in future models could modify these results. The most important of these simplifications is the use of a fixed trench instead of a trench that is free to migrate in a self-consistently in response to the dynamics.



Part 1: Non-Newtonian rheology during subduction duration Model 4 and 12 are Newtonian, Model 9 is non-Newtonian.



Part 2: Time-dependent evolution of slabs with realistic mantle and slab rheology.



Part 3: Slab dip dependence on yield stress and upper-lower mantle viscosity ratio.

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