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Subduction-transition zone interaction: a perspective from dynamic models

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As subducting plates reach the base of the upper mantle, some appear to flatten and stagnate, while others seemingly go through unimpeded. This variable resistance to slab sinking has been proposed to affect long-term thermal and chemical mantle circulation. A review of observational constraints and dynamic models highlights that neither the increase in viscosity between upper and lower mantle (likely by a factor 20-50) nor the coincident endothermic phase transition in the main mantle silicates (with a likely Clapeyron slope of -1 to -2 MPa/K) suffice to stagnate slabs. However, together the two provide enough resistance to temporarily stagnate subducting plates if they subduct accompanied by significant trench retreat. Older, stronger plates are more capable of inducing trench retreat, explaining why back-arc spreading and flat slabs tend to be associated with old-plate subduction. Slab viscosities that are about 2 orders of magnitude higher than background mantle (effective yield stresses of 100-300 MPa) lead to similar styles of deformation as those revealed by seismic tomography and slab earthquakes. None of the current transition-zone slabs seem to have stagnated there more than 60 Myr. Since modelled slab destabilisation takes over 100 Myr, lower mantle entry is apparently usually triggered (e.g. by changes in plate buoyancy). Many of the complex morphologies of lower-mantle slabs can be the result of sinking and subsequent deformation of originally stagnated slabs, which can retain flat morphologies in the top of the lower mantle, fold as they sink deeper and eventually form bulky shapes in the deep mantle. From these insights, we expect that in the past, when the mantle was hotter, decreased plate density and strength would have limited trench retreat thus facilitating plate sinking into the lower mantle, and making whole mantle mixing more efficient than it is today.