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Deep subduction modes and mid-mantle slab mobility

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Seismic tomography models show a plethora of mid-mantle slab morphologies. Some slabs (e.g. North Kurile) penetrate directly into the lower mantle beyond a 1000 km depth, while others, like the Honshu or Western Java slabs, are significantly deflected either at 660 or 1000 km. Other slabs like the Tonga or the Farallon slabs seem to have broken directly at mid-mantle depths, where the parent slab is deflected at 660 km, abandoning the orphan slab at deeper depths. However, it is yet unclear as to how exactly the mantle transition zone can give rise to so many different slab behaviours.

We suggest here that slab behaviour and mobility at mid-mantle depths, can be described by either penetrative or sinking subduction. The first is the classical understanding of subduction where the slab continuously and constantly sinks vertically towards the core-mantle boundary (CMB) without significant deflection or changes in the angle at the slab tip. In the latter case, subduction is more passive and less driven by the slab that is attached to the surface. In this type of subduction, the slab can be better understood as sinking Stokes blob undergoing deformation and flattening. Thus, the slab is highly deflected and its journey to the CMB has a strong lateral component. Sinking subduction is also characterised by prominent intra-slab deformation, resulting in a bent and flattened slab. In this case, slab tip-angles decrease dramatically at around 1000 km depth.

Lateral slab mobility at mid-mantle depths, coupled with trench mobility at the surface, can provide insight and understanding into the myriad of slab morphologies observed at mid-mantle depths. Numerical models of self-sustained, single-sided subduction using the mantle convection code StagYY (Tackley 2008, PEPI) show that negligible slab roll-back at mid-mantle depths coupled with moderate trench retreat at the surface give rise to slabs that penetrate directly into the lower mantle beyond 1000 km depth. On the other hand, when mid-mantle slab rollback dominates over trench retreat at the surface, slabs are deflected horizontally. This is particularly prominent at 1000 km depth where slabs sink towards the core-mantle boundary with a strong horizontal component. When slab rollback is interrupted by a temporary pinching and trapping of the slab at mid-mantle depths, this leads to slab-orphaning.