

Effect of a weak layer at the base of an oceanic plate on subduction dynamics

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The plate tectonics model relies on the concept of a relatively rigid lithospheric lid moving over a weaker asthenosphere. In this frame, the lithosphere asthenosphere boundary (LAB) is a first-order discontinuity that accommodates differential motions between tectonic plates and the underlying mantle.

Recent seismic studies have revealed the existence of a low velocity and high electrical conductivity layer at the base of subducting tectonic plates. This thin layer has been interpreted as being weak and slightly buoyant and was suggested to affect the dynamics of subducting plates.

However, geodynamically, the role of a weak layer at the base of the lithosphere remains poorly studied, especially at subduction zones. Therefore, we here use numerical models to investigate the first-order effects of a weak buoyant layer at the LAB on subduction dynamics.

We employ both 2-D and 3-D models in which the slab and mantle are either linear viscous or have a more realistic temperature-dependent visco-elastic-plastic rheology. Results show that a weak layer affects the dynamics of the plates, foremost by increasing the subduction speed. The impact of this effect depends on the thickness of the layer and the viscosity contrast between the mantle and the weak layer. For moderate viscosity contrasts (<100) and a layer thickness of ~ 30 km, it increases the plate velocity but not the overall shape of the slab. However, for larger viscosity contrasts (>1000), it can also change the morphology of the subduction itself, perhaps because this changes the overall effective viscosity contrast between the slab and the mantle. For thinner layers, the overall effect is reduced. Yet, if seismological observations are correct that suggests that this layer is ~ 10 km thick and partially molten, such that the viscosity is ~ 1000 times lower than that of the mantle, our models suggest that this effect should be measurable. Some of our models also show a pile-up of weak material in the bending zone of the subducting plate, consistent with recent seismological observations.