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Horizontal and vertical slab tearing as different stages of a self-sustaining process developing in a non-collisional setting with oblique subduction

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Slab break-off is usually referred to as an early collisional process driven primarily by the slowing of the subduction rate as negatively buoyant oceanic lithosphere detaches from positively buoyant continental lithosphere that is attempting to subduct. In this context, slab tearing (or slab break-off propagation) is traditionally attributed to continental corner dynamics, when the subducting plate first detaches in the area of continental collision and then the slab window opens toward the adjacent segment of the convergence boundary, where ocean-continent subduction continues. Another important process, previously thought to be independent of slab break-off and horizontal slab tearing, is a fragmentation of the subducting slab along vertical planes perpendicular to the convergence direction. Previous numerical studies have linked this vertical slab tearing to pre-existing weakness within the subducting plate and/or abruptly changing convergence rates along the trench.

In our study, we use a 3D thermo-mechanical numerical approach to study slab tearing in a non-collisional geodynamic context. The effects of subduction obliquity angle, age of oceanic slab, and partitioning of boundary velocities have been investigated. We show, for the first time, that horizontal and vertical slab tearing are different stages of the same process, which can develop in a self-sustained manner in a non-collisional environment of oblique ocean-continent subduction. Even with an initially absolutely homogeneous oceanic plate and laterally unchanging and temporally constant boundary velocities, the obliquity of the active margin appears to be a sufficient factor to trigger complex system evolution, which includes the transition from horizontal to vertical slab tearing along with additional processes such as retreat and rotation of the trench, decoupling of the overriding and downgoing plates by upwelling asthenosphere in the mantle wedge (also termed “delamination”), initiation of new subduction, and formation of a transform fault.

Our results show striking similarities with several features – such as trench curvature, subduction zone segmentation, magmatic production, lithospheric stress/deformation fields, and associated topographic changes – observed in many subduction zones (e.g., Marianas, New Hebrides, Mexico,

Calabrian).