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The role of the plate stiffness in trench migration: Insights from numerical models

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Subduction zones are not static features, but trenches retreat (roll-back) or advance.

Subduction operates by bending of the lithosphere plate at trench. The geometries of a bending slab indicate significant deformation, suggesting that lithospheric plates might be weakened somehow during subduction. The faults close to the trenches accommodate bending, promoting hydration of the crust and weakening the lithospheric strength by possible serpentinization. The variation of the slab strength at trench has important consequences on the kinematics and dynamics of subduction, and the partitioning of the subduction velocity between trench ad plate motions. On Earth such a partition of the subduction zones between retreating and advancing styles can be recognized in different geographical reference frames.

Here we explore the idea that trenches motion represents the surface manifestation of the dynamics of subduction. We performed two and three-dimensional numerical models of self-consistent subduction zones in an attempt to understand the complex trench dynamics. Numerical models allow a quantitative investigation of a wide range of geometrical and rheological parameters and the assessment of derived quantities such as the amount of energy dissipated during the whole subduction process.

Simulating a multilayered lithosphere-upper mantle system, we found that slabs with different properties interact differently with the 660-km discontinuity, which is mod-

eled in this case as an impermeable barrier. Hence, we found that thicker/high viscous/less dense plates move in advancing style, and dissipate $\sim$45% to $\sim$50% of the energy in the system. On the other hand, thinner/less viscous/denser plates promote the retreating style, dissipating $\sim$35% to $\sim$40% of the total dissipated energy. Most of the energy dissipation occurs in the mantle to accommodate the slab motion, whereas the lithosphere dissipates the remaining part to bend and "unbend".

By means of a simple scaling law, we are able to reduce significantly the complexity of the system, and to identify lithospheric stiffness Sas the key parameter in the subduction process. Stiffer slabs cause the trench to advance, whereas more flexible slabs lead to trench retreat. Given the fact that also on Earth the oldest (and therefore, probably stiffest) plates have the fastest advancing trenches, we hypothesize that the ability of slabs to unbend after subduction forms the dominant control on trench migration.