Asymmetric convergent margins: What controls the hinge motion in subduction zones?

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Looking at subduction zones worldwide, a striking asymmetry can be identified: W- to SW-directed subduction zones (e.g., Marianas, Tonga, Sandwiches) present the lowest topography in the world, while on the E- to NE-directed subduction (e.g., Andes) and collision zones (e.g., Alps, Himalaya) are characterized by the highest mountains worldwide. This asymmetry appears primarily controlled by the slab polarity with respect to the westward drift of the lithosphere due to a global-scale eastward mantle flow (Doglioni *et al.*, 2007). However, the potential influence of a polarized mantle flow on the hinge motion in subduction zones has never been tested quantitatively, thus leaving significant gap in understanding of this key plate tectonic phenomenon. Here, we explore the effects of a priori defined mantle flow on the slab dynamics and response at the surface by means of self-consistent two-dimensional thermomechanical numerical experiments in which an oceanic plate sinks beneath a continental plate under the control of realistic visco-plastic rock rheologies.

Results show that the motion of the subduction hinge toward or away relative to the upper plate is the simple kinematic control for the occurrence of two different subduction styles: (1) When the subduction hinge converges toward the upper plate, the upper plate is shortened and a double vergent belt, such as the Alps, forms. On the contrary, (2) when the slab and the related hinge retreat relative to the upper plate, the upper plate is stretched (a backarc basin opens) and a single vergent belt develops, such as along the western Pacific margin. The two settings also show different type of rocks involved in the mountain building process. In the first setting, in fact, the orogen is principally composed by sedimentary cover, i.e., young and shallow rocks coming from superficial erosion of the plates involved in the subduction process. This occurs because the basal decollement of the subducting plate is never connected to the surface but is rather folded and swallowed down inside the subduction zone, being thus unable to feed the accretionary prism with rocks coming from high depths. On the other hand, the second subduction setting show orogens involving older and deeper rocks because of the deeper décollement planes, being thus able to involve the basement of the subducted plate. These findings are supported by a quantitative agreement with observations derived from the global-scale models, which indicate that mantle flow would be the leading feature influencing slab-dip, subduction rate and motion of the slab hinge: E- or NE-directed subductions have shallower slabs, with low dip angles (24° on average), while W- or SE-directed slabs are deeper and steeper (61° on average, Ficini *et al.*, 2017). These results, thus, mimic the asymmetry that can be recognized along the subduction zones worldwide. These models, combined with the observations, support the hypothesis of an asymmetric pattern of the mantle convection strongly driven by the easterly-polarized mantle flow.

References

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