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Comparing the effects of rheology on the dynamics and topography of 3D subduction-collision models

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Most of the major mountain belts and orogenic plateaus are found within the overlying plate of active or fossil subduction and/or collision zones. It is well known that they evolve differently from one another as the result of specific combinations of surface and mantle processes. The differences among the structures and evolutions of mountain belts arise for several reasons, such as different strengths of materials, different amounts of regional isostatic compensation, and different mechanisms by which forces are applied to the convergence plates. All these possible controlling factors can change with space and time.

Of all the mountain belts and orogenic plateaus, the most striking example is the India-Asia collision zone, which gave rise to the Himalayas and the Tibetan Plateau, the largest region of elevated topography and anomalously thick crust on Earth. Understanding the formation and evolution of such a highly elevated region has been the focus of many tectonic and numerical models. While some of these models (i.e. thin sheet model) have successfully illustrated some of the basic physics of continental collision, none can simultaneously represent active processes such as subduction, underthrusting, channel flow or extrusion, for which fully 3D models are required.

Here, we employed the 3D code LaMEM to investigate the role that subduction, continental collision and indentation play on lithosphere dynamics at convergent margins, and the implications they have for the Asian tectonics. Our model setup resembles a simplified tectonic map of the India-Asia collision zone and we performed long-term 3D simulations to analyse the dynamics and the conditions under which large topographic plateaus, such as the Tibetan Plateau can form in an integrated lithospheric and upper-mantle scale model.

Results of models with linear viscous rheologies show different modes between the oceanic subduction side (continuous subduction, trench retreat and slab roll-back) and the continental collision side (trench advance, slab detachment, topographic uplift and lateral extrusion of material). Moreover, different topographic regimes can be identified in the upper plate during continental subduction/collision, which can be determined using the Argand number and an initial buoyancy ratio of the upper plate. Next, we investigate the effect of using more complex (powerlaw viscous and plastic) rheologies and compare the results with linear viscous models.

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