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Cross-scale modeling of Slab Rollback Orogeny Model: The Central Alps case

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The process of continent–continent collision in shaping mountain ranges and adjacent foreland basins has been discussed for many decades. The orogeny driving forces — whether vertical or horizontal — are central for our understanding and it seemed settled in favor of horizontal forces. For the central European Alps, however, this traditional concept fails to explain first-order observations of the mountain belt. Recent stratigraphic, palaeo-altimetry and lithosphere structural evidence suggest that a Slab Rollback Orogeny model is capable of explaining the construction of thick nappe successions and the large-scale evolution of the Swiss Alps (Kissling and Schlunegger, 2018). This new concept questions the traditionally assumed bulldozing effect of Adria indenter as a necessary component of the dynamic system and proposes the buoyancy forces of the postulated post-collisional rollback is sufficient to drive the evolution and to shape the Central Alps as we know them today. Here we explore these challenging questions using a high-resolution, rheologically consistent, two-dimensional visco-elasto-plastic thermo-mechanical numerical model (Dal Zilio et al., 2018), which simulates both tectonic and seismic processes in a subduction and subsequent continental collisional setting. Our numerical experiments reproduce the self-driven stages of oceanic subduction, continent-continent collision, and spontaneous oceanic lithosphere slab breakoff. The post-collisional evolution of the orogen shows how slow — but persistent — flexural bending of the post-breakoff residual slab in combination with the crustal delamination control the most recent stage of the orogen. Bending-related slab suction and coeval development of crust-mantle and intracrustal delamination and nappe stacking through the slab bending zone, leads to the appearance of crustal shortening on the foreland basin, and widening of the orogen. We find good correlations of our numerical results with the previously conflicting tectonic observations in the Central Alps and the foreland (Molasse) basin. In particular, we discuss how the current crustal seismicity pattern implies the occurrence of extensional forces at work beneath the Molasse Basin and within the Alps. Our results thus support the emerging hypothesis that the remaining slab exerts a first-order control on the motions and deformations of the orogen. In light of these results, we propose that the tectonic history of the Central Alps does require an alternative view.

Dal Zilio, L., van Dinther, Y., Gerya, T. V., & Pranger, C. C. (2018). Seismic behaviour of mountain belts controlled by plate convergence rate. Earth and Planetary Science Letters, 482, 81-92.

Kissling, E., & Schlunegger, F. (2018). Rollback orogeny model for the evolution of the Swiss Alps. Tectonics, 37(4), 1097-1115.