Analogue Modelling of Continental Subduction: Implications on the Alpine Crustal Deformation

Stefan Luth, Ernst Willingshofer & Dimitrios Sokoutis

VU University Amsterdam, De Boelelaan 1085, 1081 HV Amsterdam (The Netherlands)
(stefan.luth@falw.vu.nl)

Tomographic images from the Alps reveal southeasterly-directed subduction of the European mantle lithosphere in the central Alps and a north-easterly dipping subduction of the Adriatic mantle lithosphere underneath the Eastern Alps. We studied the deformation and surface expression of this lateral change in subduction polarity by using lithospheric-scale physical models. The main parameters investigated for uni-polar and bi-polar subduction systems of the continental lithosphere are: (a) the weakness of the plate interface, (b) the presence of weak lower crust (c) the width of the transition zone between the oppositely dipping slabs.

The results of the analogue experiments show that upper crustal deformation initiated at the plate interface by the formation of a pop-up structure. Along the inclined plate boundary lithosphere-scale underthrusting and a significant amount of Moho displacement occurred. The downgoing plate suffered upper crustal thrusting and a foredeep basin developed. The thickness of the weak-zone interface plays a key role in the amount of continental subduction, and consequently on the onset of intraplate deformation, which occurs only after the weak interface is consumed or sufficiently thinned. However, continental collision and coinciding mantle lithosphere subduction beneath an orogenic wedge takes place only if the lower crust is weak enough to allow crust-mantle decoupling. During collision weak lower crust partly subducts, while the detached part thickens below the orogen effecting the upper crustal deformation pattern and topography.

From the second series of bi-polar subduction it can be observed that the first pop-up structure is laterally continuous pointing out its independence on the vergence and obliquity of subduction. Ongoing deformation causes the formation of a second pop-up structure on the downgoing plates resulting in lateral asymmetry and the development of a narrow transition zone. Cross sections through the interior of the model illustrate an asymmetry in the upper crustal wedge with a clear pro- and retro- side. On the contrary, a wide and symmetrical orogen overlying a vertical slab of mantle lithosphere is characterizing the zone of subduction polarity change. The width of this symmetrical domain matches the width of the predefined transition zone between the oppositely dipping slabs.

Our modelling results can be compared with the crustal and lithosphere-scale structure of the Alps, where the orogenic wedge in the Western Alps is asymmetric and a relatively large pro-wedge overlays the downgoing European plate. Eastwards, the upper crustal deformation is more symmetrically distributed above the colliding plates, and the orogen widens reaching maximum values along the TRANSALP profile. Hence, lateral variations of the crustal architecture (symmetry of mountain belts) may be indicative for changes in the subduction polarity of the lower lithosphere.