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How AlpArray is guiding us to a new model of Alpine orogenesis

Mark R. Handy[1] and the members of 4D-MB and the AlpArray Working Group[*]
[1]Freie Universität Berlin, Geologische Wissenschaften, Earth Sciences, Berlin, Germany (mark.handy@fu-berlin.de)
[*]A full list of authors appears at the end of the abstract

AlpArray has challenged notions of lithospheric subduction along the Alps and its effects on the asthenosphere and orogenic lithosphere. Teleseismic V_p tomography reveals a slab of European lithosphere that is largely detached at and below 150 km in the Western and Eastern Alps. Only in the Central Alps is the slab still attached, possibly reaching down to the MTZ, where it may be connected to subducted remains of Alpine Tethys. Downgoing European lithosphere appears thicker and more heterogeneous than the Adriatic upper plate. Arcuate SKS directions beneath the Alps suggest that asthenosphere not only flowed passively around the sinking slab, but may have induced the anomalous northward dip of the detached slab segment beneath the Eastern Alps.

The structure of the orogenic lithosphere differs profoundly along strike of the Alps, as revealed by local earthquake tomography, ambient-noise studies, as well as S-to-P receiver-functions and gravity studies: In the Central Alps west of the Giudicarie Fault where the slab is still attached, the exhumed retro-wedge of the orogen overrides a wedge of Adriatic lower crust. East of this fault where the slab has detached, exhumation is focused in the orogenic core (Tauern Window) north of and above a bulge of thickened lower crust of presumed Adriatic origin. The Moho is not offset by the Giudicarie Fault and shallows eastward, from 50-60 km beneath the western Tauern Window to 20-30 km beneath the Pannonian Basin. This necessitates massive decoupling at and above the Moho to accommodate coeval Miocene N-S shortening, orogen-parallel thinning and eastward extrusion of Eastern Alpine orogenic lithosphere.

We propose a new model for Alpine orogenesis that invokes changing wedge stability and migrating subduction singularities above the delaminating and detaching Alpine slab in the east to explain east-west differences in Oligo-Miocene structure, magmatism, erosion and sedimentation in peripheral Alpine basins. A decrease in Adria-Europe convergence rate to <1 cm/yr after collision at ~35 Ma led to slab steepening and northward motion of the singularity, combined with increased shortening and taper of the Central Alpine wedge. There, rapid exhumation and denudation during this stage were initially focused in the retro-wedge just north of the Periadriatic Fault. In the Eastern Alps, slab pull during northward delamination drove subsidence and marine sedimentation in the eastern Molasse basin from 29-19 Ma, while the western Molasse basin filled with terrigeneous sediments. The dramatic switch at 23-21 Ma from northward advance and stagnation of the northern front in the Eastern Alps to southward advance of the southern front in the eastern Southern Alps, as well as rapid exhumation of Penninic units in the Tauern Window are attributed to slab detachment beneath the Eastern Alps combined with a northward and upward shift of the subduction singularity to the tip of the lower crust bulge. This is inferred to have reduced the wedge taper in the Eastern Alps. Rapid west-to-east filling of the eastern Molasse basin between 19-16 Ma is interpreted to reflect eastward propagation of the slab tear and the onset of Carpathian rollback subduction.

members of 4D-MB and the AlpArray Working Group: The complete member list of the

AlpArray Working Group can be found at http://www.alparray.ethz.ch. A list of active members of the 4D-MB is available at http://www.spp-mountainbuilding.de/research/projects/index.html.