Geophysical Research Abstracts
Vol. 20, EGU2018-15423-1, 2018
EGU General Assembly 2018

Modelling orogenic wedge formation from hyper-extended passive margins and exhumed sub-continental mantle with application to the Western Alps

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The concept of orogenic wedges has been applied to explain the geodynamic evolution of many orogens worldwide. Recent numerical modelling studies have investigated orogenic wedge formation in a shortening lithosphere which was initially homogeneous, that is, having initially a constant crustal thickness. However, many orogens, such as the Western Alps, are characterised by the collision of hyper-extended passive margins which exhibited a significant variation of crustal thickness from the onset of orogenic wedge formation. Also, the pre-Alpine Liguria-Piemonte basin likely lacked newly formed oceanic crust and consisted mainly of inherited and impregnated subcontinental mantle exhumed to the seafloor until embryonic ocean formation.
To study the impact of hyper-extended passive margins and exhumed lithospheric mantle on subsequent orogenic wedge formation we perform high resolution 2D thermo-mechanical numerical simulations. An initial configuration where the crust and the lithospheric mantle are represented by an alternating sequence of mechanically strong and weak horizontal layers is compared to a configuration where the upper and lower crust and the lithospheric mantle are initially not mechanically layered. We model first the formation of hyper-extended passive margins and exhumed lithospheric mantle during extension and then subsequently shorten the evolved basin to model orogenic wedge formation. Hence, the starting configuration for orogenic wedge formation has been modelled in a self-consistent way by a prior lithospheric extension phase. We quantify the impact of the thermal state and the associated strength distribution of the exhumed lithospheric mantle by starting the compression of the extended lithosphere after different durations of cooling. During cooling, the lithosphere is neither extended nor compressed. Once subduction is active and collision of the two margins has occurred during compression, we decelerate the far-field compression. The role of cooling of the exhumed lithospheric mantle for subduction initiation and the evolution of the underthrusting plate after deceleration during lithospheric shortening is discussed. Furthermore, potential applications of the model results to the Western Alpine orogeny are discussed.