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Orogenic Wedges and Subduction in Analogue Models: Expressions of Rheology Induced Plate Decoupling

S.W Luth (1), E. Willingshofer (2), and D. Sokoutis (2)

(1) VU University Amsterdam, Tectonics, Amsterdam, Netherlands (stefan.luth@falw.vu.nl), (2) University of Utrecht, Department of Tectonics, Utrecht, Netherlands

The influence of plate decoupling on orogenic wedge formation and mantle lithosphere subduction has been investigated by varying the rheological stratification of converging lithospheres in analogue experiments.
Different decoupling conditions were induced by implementation of: 1) weak lower crust surrounding only the plate interface, 2) weak lower crust throughout the entire lower plate, and 3) weak mantle lithosphere within the lower- and/or upper plate. In the second scenario, the effect of an entire weak lower crust was tested as well as a lower crust containing only a weak horizon.
The experimental results allow for a classification of orogenic wedges according to their different mechanical responses on various lithosphere rheologies. As such, the distribution of weak lower crust largely determined the width of the overlying crustal wedge. A restriction of weak lower crust to the plate boundary region resulted in a narrow wedge, whereas wide wedges formed when a weak lower crust was present throughout the entire lower plate. In this scenario the lower crust acted as a decollement layer underlying thrust propagation within the brittle upper crust. A similar result was obtained when a weak layer was represented by only a thin horizon separating upper- from lower crust. Such rheological stratification of the lithosphere promoted ongoing subduction of the mantle lithosphere by lubrication of the plate boundary and allowed for crust/mantle decoupling. Weakening the lower plate's mantle lithosphere additionally resulted in subduction of the lower crust, while a crustal wedge with low topography was formed on the lower plate. Weakening the mantle lithosphere of both plates induced plate coupling and hence lowering of the total amount of mantle subduction.
These outcomes emphasize a strong interrelation between plate (de)coupling conditions and the rheological stratification of the lithosphere on one hand, and the architecture of the orogenic wedge and subduction of the mantle lithosphere on the other hand. In particular, the rheological properties of the lower crust seem to have a major imprint on the interaction between crustal deformation and mantle lithosphere subduction during continental collision.