Crust-mantle and inter-plate decoupling during continental collision

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Fundamental aspects of mountain building such as the dominant deformation mechanism, strain localization, and topography development in response to the presence of decoupling zones within different levels of the lithosphere and/or along boundaries of weak and strong domains of continental lithosphere are studied by analogue modelling at the scale of the lithosphere. Scenarios are investigated where (1) a weak part of the lithosphere is bordered on either side by stronger lithospheres (Fig. 1a) and (2) where the rheology of the colliding plates is varied (Fig. 1b). In both set-ups strong decoupling along plate boundaries or at the crust-mantle boundary is implemented by the presence of low viscosity layers.

In the first series of models geometries of the weak zone vary from box- to wedge- to graben shaped representing lateral strength variations as a consequence of earlier deformation phases. The rheologic and geometric configuration at the onset of shortening is therefore considered as representative for continental collision and intra-plate settings. Our modelling results show that the geometric and topographic evolution of mountain belts through time is sensitive to decoupling along their major tectonic boundaries. The decoupled boundaries localize strain, control the dominant deformation mechanism and hence the locus of uplift and subsidence. As such, decoupled boundaries favor deformation by thrusting and in the case of an initially wedge-shaped weak zone the development of mountain belts with overall triangular shape (Fig. 2a). In contrast, lithospheres with coupled boundaries dominantly deform by buckling irrespective of the initial geometry of the weak zone. As a result of buckling, domains of uplift and subsidence affected the entire model including the plate interiors. Strong decoupling at mid-crustal levels within the weak zone favors vertical strain partitioning and the formation of plateau shaped mountains (Fig. 2b). The modeling results suggest that natural systems should respond to an increase in plate coupling through time by widespread uplift of the mountain belt including its foreland basins which were created under decoupled conditions.

In the second series of models strong decoupling along the plate interface and the lower crust of the downgoing plate results in asymmetric orogenic wedges This foreland-directed thrusting depends on decoupling between the brittle upper crust and viscous lower crust, and less on the rheology of the mantle lithosphere (Fig. 2c). However, reducing the strength contrast between the lower crust and the mantle lithosphere enhances lower crustal subduction and hence decreases the volume of material accumulated within the orogenic wedge (Fig. 2d). In cases where also the mantle lithosphere of the upper plate is weak shortening results in less deep subduction but thickening of the lower and upper plates mantle lithospheres.

Our modelling results are in agreement with the analogue modeling studies of Willingshofer & Sokoutis (2009) and Luth et al. (2010) and numerical modeling studies of Faccenda et al. (2008) or de Franco et al. (2008) and emphasize the importance of decoupling during collision and intra-plate deformation.

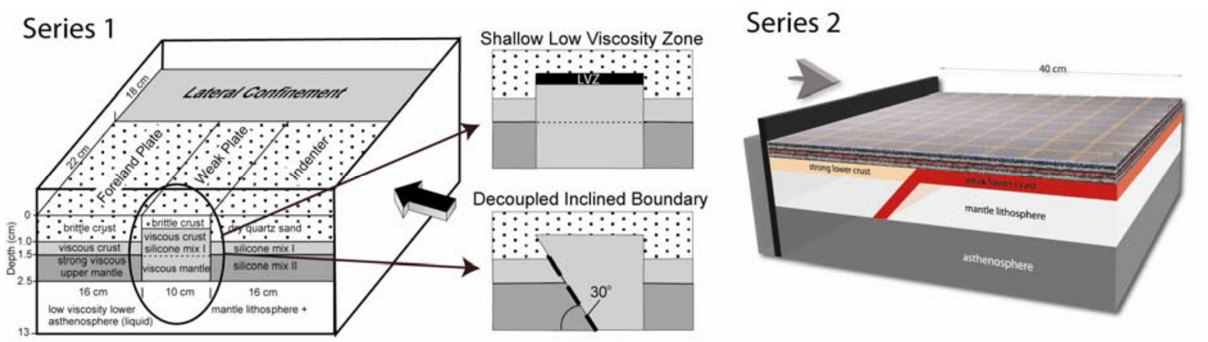

Fig. 1 Modelling setup.

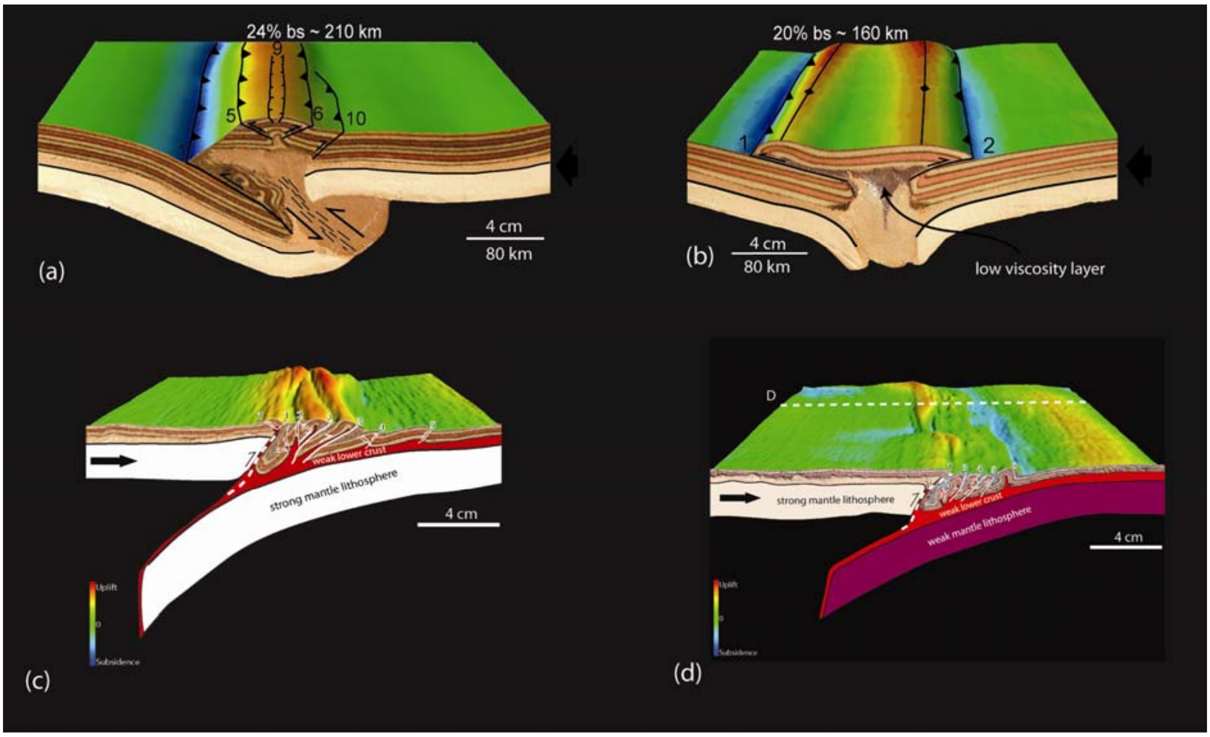

Fig. 2: Modelling results of series 1 (a & b) and series 2 (c & d).

References

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