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The evolution of collisional mountain belts as a function of the geometry of pre-existing weak zones within the lithosphere

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Retro-deformation of crustal-scale sections across the for example the European Alps or the Pyrenees resulted in distinctly different geometries of the pre-collisional geometry of the crust and the entire lithosphere. For this stage in the evolution of the Alps its cross-sectional shape can be envisioned as a wedge structure confined on both sides by the Adriatic and European plates, whereas the Pyrenees resemble more closely the geometry of a graben structure, flanked by Iberian and European crust, prior to convergence. It has been argued for that both the wedge as well as the graben-type structures exhibit weak rheological behavior, thereby representing significant lateral strength variations within continental lithosphere.

The influence of such pre-existing weak zone and its initial geometry on the structural/tectonic evolution of continental collision zones is investigated through lithospheric-scale analogue modelling. Strength heterogeneities were incorporated by varying the strength of the layers analogue to the crust and the upper mantle and by implementing a weak plate or part-of-a-plate between two strong lithospheres. Plate boundaries are orthogonal to the convergence direction. Three (brittle crust/viscous crust/strong viscous upper mantle) layer models were bordered by a weak silicone layer on one convergence-parallel side in order to contain but not oppose to lateral extrusion. Cases are discussed where the weak zone exhibits the shape of a wedge or

graben.

In the experiments with graben geometry of the weak zone thrusting remained localized along the boundaries and resulted in underthrusting of the strong plates beneath the weak one. Uni-polar underthrusting was obtained for initially wedge-shape geometries of the weak zone. In this case the strong plate with inclined boundary underthrusted the weak zone and the strong plate with vertical boundary remained nearly undeformed. In contrast, a symmetric initial setup with both sides inclined (graben shape) resulted in a bi-vergent thrusting system involving both strong plates that also experienced lithospheric-scale buckling.

The experimental results suggest that the initial geometry of zones of weakness within continental lithosphere play an important role on controlling the deformation history and the large-scale structure of collisional mountain belts. Furthermore they have implications for interpretation of deep seismic and tomographic data, in both Alps and Pyrenees.