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What controls the geometry of mountain ranges: insights from numerical modelling

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When continents collide mountain ranges with high topographies and complex geometries are formed. Compressional stresses during ongoing convergence result in crustal thickening, localized deformation, and material transport at which crustal material is transported and redistributed within the orogen.
We use numerical high-resolution thermo-mechanical models to investigate the physical processes of continent collision zones and its implications on crustal scale deformation and geometry. We demonstrate that compression of two continental blocks, separated by a rheologically weak suture zone can result in (i) double-vergent or (ii) single-vergent orogens, with distinct geometries, deformation and exhumation patterns.
Double-vergent orogens are formed in response to the gradual accretion of crustal material to the upper plate along retro-shears (back thrusts) and are characterized by deformation of both upper and lower plate material. Typical examples include the collision recorded by the Swiss Alps and the Pyrenees. In contrast, single-vergent orogens are characterized by large-scale lower plate deformation and are accompanied by the subduction of lower crustal material. In this situation, no significant retro-shear formation is observed, which is in agreement with recent physical modelling studies on deformation of the continental lithosphere. Natural examples of such single vergent orogens are common in the Mediterranean (Carpathians, Dinarides, Apennines, Betics) or the SE Asia subduction zones.
The transition between these different modes of collision is strongly controlled by the rheology of the continental lithosphere. Coupled crustal layers form double vergent orogens, while decoupled crustal layers result in single-vergent orogens.
We conclude that deformation and exhumation in continent-continent collision zones may occur in foreland or hinterland settings, depending on the rheological structure of the continental lithosphere, forming single-vergent or double vergent orogens.