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Evaluating the effect of rheology on the evolution of continental collision: Application to the Zagros orogen.

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We explore the impact of thermo-rheological structure of the lithosphere on the transition from oceanic to continental subduction and evolution of the continental collision at moderate convergence rates. We have designed large-scale (3082×590 km), high-resolution fully coupled thermo-mechanical numerical models to (1) study the evolution of continent-continent collision and (2) draw some parallels with the tectonic evolution of the Zagros, where collision between the Arabian craton and the Eurasian lithosphere resulted in the rise of the Iranian plateau. This collision zone is of particular interest due to its disputed resemblance to the faster Himalayan collision between the Indian craton and Eurasia, which gave birth to the vast Tibetan plateau.
Our models implement free upper surface boundary, surface erosion, rheological stratification (upper crust, lower crust, lithospheric mantle and asthenosphere), brittle-elastic-ductile rheology, metamorphic phase changes (density and physical properties), and account for the specific crustal and thermal structure of the Arabian and Iranian continental lithospheres. The initial model geometry corresponds to the pre-continental collision phase, with an oceanic, Neotethyan subducting lithosphere still separating the two continents. In the experiments we investigate different thermo-rheological structures for both the lower and upper plate, going from wet to dry olivine (plus Peierls) rheology for the mantle parts and from two-layer to three-layer crustal structures with all possible granite, diorite, granulate and diabase rheologies.
As in some previous Himalayan studies, the experiments suggest that, whatever the crustal rheology, the continental subduction occurs only in the case of relatively strong mantle lithospheres with dry olivine rheologies (for the lower plate, temperature at Moho depth, Tm < 550° C) and high initial convergence rates (>1.5-5 cm/yr). Depending on the lower-crustal rheology (strong or weak), either the whole (upper and lower) crust or only the lower crust is involved in subduction. In case of weak metamorphic rheologies, phase changes and progressive densification along the subduction zone improve chances for stable subduction. In general, exhumation of UHP-HP rocks to the surface is favored if the crustal rheological profile is characterized by two internal ductile decollement levels (between the upper and lower or intermediate crust and the lower crust and mantle lithosphere). On the other hand, the formation of the Iranian plateau is compatible with the assumption of rather weak mantle and crustal rheology. Hence, the models show that only a relatively narrow range of rheological parameters is compatible with the evolution of Zagros collision, which in turn allows us to further constrain the long-term rheology of the continental lithosphere.