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Rheological controls on the development of the convergent margins

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We use thermo-mechanical numerical models to explore the impact of rheological structure, brittle-elastic-ductile rheology and metamorphic reactions on localization and style of deformation in convergent contexts, during ocean-continent or continent-continent interactions. Even though continental subduction may occur in most cases of strong lithospheres with competent mantle at sufficiently high initial convergence rates (>1-1.5 cm/y), the subduction/collision styles and topography evolution are quite different depending on the initial configuration and preceding tectonic history but also on the particular structure of the continental crust, eventually affected by tectonic heritage, and localising properties of the subduction channel. Depending on lower and intermediate crustal rheology, the entire (upper, intermediate, lower) crust, intermediate or only the lower crust can deform independently of the mantle lithosphere. This results in different characteristic tectonic styles (leading, for example, to development of thin-sheet to thick-sheet tectonics structures), wavelengths, altitudes of surface topography and slab geometries. Certain rheological structures of the continental crust, while looking plausible from the geological and experimental rock mechanics point of view, are not compatible with the development of continental subduction, resulting in either blockage of the subduction channel and transition to folding and collision, or in gravitationally instable behaviours. Phase changes leading to material softening significantly improve chances for stable subduction, which is marked by exhumation of UHP-HP rocks to the surface that is particularly favoured if the crustal rheological profile has internal ductile decolement levels between the upper and lower or intermediate crust and the lower crust and mantle lithosphere. Pure shear or unstable RT-type collision is dominant when the mantle is rheologically weak or at convergence rates lower than 1-1.5 cm/yr. In continent-continent convergence settings, formation of high plateaux instead of rather narrow mountain ranges is conditioned by the degree of locking of the subduction channel, slow-down of the convergence causing slab retreat and by the rheological structure of both the upper and lower plates. Similarly, obduction and the associated exhumation processes appear to be largely dependent on the rheological properties of both the continental and oceanic crust, so that obduction is only possible for very specific combinations of rheological properties, requiring, in particular, relatively weak lower crust of the continental counterpart and presence of a weak serpentinized layer between the oceanic crust and mantle. These conditions drastically narrow the range of the rheological parameters compatible with tectonically realistic scenario of evolution of convergent zones allowing us to put a number of quantified constraints on the ductile rheology laws for crustal and mantle materials, and hence providing new possibilities for extrapolation of laboratory based rheology laws to geodynamic spatial and temporal scales.