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Thinning of heterogeneous lithosphere: insights from field observations and numerical modelling

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The nature and mechanisms of formation of extremely thinned continental crust (< 10 km thick) and lithosphere during rifting remain debated. Observations from present-day and fossil continental passive margins highlight the spatial heterogeneity of the continental lithosphere. This contribution aims at investigating the mechanisms of extreme lithospheric thinning by exploring, in particular, the role of initial heterogeneities on the architecture and evolution of rifted margins. To address such a topic, we use a multidisciplinary approach by coupling field observations from fossil passive margins and numerical models of lithospheric extension.

Two field examples from the Alpine Tethys margins outcropping in the Eastern Alps (E Switzerland and N Italy) and in the Southern Alps (N Italy) were selected for their exceptional level of preservation of rift-related structures. This situation enables us to characterize (1) the pre-rift architecture of the continental lithosphere, (2) the localization of rift-related deformation in distinct portion of the lithosphere and (3) the interaction between initial heterogeneities of the lithosphere and rift-related structures. In a second stage, these observations are integrated in high-resolution, two-dimensional thermo-mechanical models taking into account various patterns of initial mechanical heterogeneities.

Our results show the importance of initial pre-rift architecture of the continental lithosphere during rifting. Key roles are given to high-angle and low-angle normal faults, anastomosing shear-zones and decoupling horizons during hyperextension. Such structures accommodate the lateral extrusion of mechanically stronger levels mainly in the middle to lower crust. As a result, the hyper-thinned continental crust represents the juxtaposition and amalgamation of distinct strong levels of the crust separated by major extensional structures.

Altogether, these results highlight the critical role of the lateral extraction of mechanically strong layers during the extreme thinning of the continental lithosphere and enable us to propose a new model for the formation of continental passive margins and, eventually, make predictions about the nature of the basement in extremely thinned margins.