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Mechanical heterogeneities and lithospheric extension

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Detailed geological and geophysical studies of passive margins have highlighted the multi-stage and depth-dependent aspect of lithospheric thinning. Lithospheric thinning involves a variety of structures (normal faults, low angle detachments, extensional shear zones, extraction faults) and leads to a complex architecture of passive margins (with e.g. necking zone, mantle exhumation, continental allochthons). The processes controlling the generation and evolution of these structures as well as the impact of pre-rift inheritance are so far incompletely understood.

In this study, we investigate the impact of pre-rift inheritance on the development of rifted margins using two-dimensional thermo-mechanical models of lithospheric thinning. To first order, we represent the pre-rift mechanical heterogeneities with lithological layering. The rheologies are kept simple (visco-plastic) and do not involve any strain softening mechanism.

Our models show that mechanical layering causes multi-stage and depth-dependent extension. In the initial rifting phase, lithospheric extension is decoupled: as the crust undergoes thinning by brittle (frictional-plastic) faults, the lithospheric mantle accommodates extension by symmetric ductile necking. In a second rifting phase, deformation in the crust and lithospheric mantle is coupled and marks the beginning of an asymmetric extension stage. Low angle extensional shear zones develop across the lithosphere and exhume subcontinental mantle. Furthemore, crustal allochthons and adjacent basins develop coevally. We describe as well the thermal evolution predicted by the numerical models and discuss the first-order implications of our results in the context of the Alpine geological history.