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The Thermomechanical Evolution of Hyper-Extended Lithosphere: Inheritance, Depth-Dependent Thinning and Detachment Faults.

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High quality, long offset seismic data from many distal rifted margins show evidence for hyper-extended crust. Direct observation of such domains is very difficult as they lie, at great water depth, buried beneath thick sedimentary sequences. In addition to seismic data, outcrops of preserved hyper-extended crust have been discovered and studied in collisional orogens suggesting that the formation of these domains is likely controlled by the complex interaction of detachment faults. These faults extend in the mantle lithosphere when crust and mantle deformation is coupled and are sometimes rooted in sub-horizontal ductile shear zone in the middle to lower crust when the crustal and mantle deformation is decoupled.

These detachments initially delimitate a major keystone structure (H-block) that controls most of the evolution of the deformation during rifting. Non-uniform, depth-dependent thinning (DDT) and hyper extension have been proposed to result from the formation of H-block. The formation of H-block also predicts that the mantle lithosphere undergoes a phase of fast uplift and increased heat flow during thinning. Using dynamic models of the rifting process, we show that in the presence of a weak inherited structure extending in the mantle lithosphere controls H-block formation. We also show that continuous extension in H-block generates a thermomechanical instability in the lithosphere during coupling of deformation in the crust and lithospheric mantle and that the growth of this instability drives DDT.

Finally, we demonstrate how brittle normal faults and localized ductile shear zones form and interact from rift initiation to final lithospheric breakup. In order to do so we developed a rheological parameterization to simulate the formation of and slip on large offset normal faults rooted in ductile shear zones. The evolution of these structures leads to the formation of a hyper-extended domain eventually exhuming serpentinized mantle. We also propose a simplified formulation to simulate volcanic underplating and seafloor spreading. The resulting numerical models provide a self-consistent picture for the evolution of magma-poor rifted margins from initiation to seafloor spreading that compare favorably with observations of magma-poor margins.