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Numerical modelling of edge-driven convection during rift-to-drift transition: application to the Red Sea

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We use numerical modeling to investigate the coupling of mantle instabilities and surface tectonics along lithospheric steps developing during rifting. We address whether edge driven convection (EDC) beneath rifted continental margins and shear flow during rift-drift transition can play a role in the observed post-rift compressive tectonic evolution of the divergent continental margins along the Red Sea.

We run a series of 2D simulations to examine the relationship between the maximum compression and key geometrical parameters of the step beneath continental margins, such as the step height due to lithosphere thickness variation and the width of the margins, and test the effect of rheology varying temperature- and stress-dependent viscosity in the lithosphere and asthenosphere. The development of instabilities is initially illustrated as a function of these parameters, to show the controls on the lithosphere strain distribution and magnitude. We then address the transient evolution of the instabilities to characterize their duration. In an additional suite of models, we address the development of EDC during plate motions, thus accounting for the mantle shearing due to spreading.

Our results show an increase of strain with the step height as well as with the margin width up to 200 km. After this value the influence of ridge margin can be neglected. Strain rates are, then, quantified for a range of laboratory-constrained constitutive laws for mantle and lithosphere forming minerals.

These models propose a viable mechanism to explain the post-rift tectonic inversion observed along the Arabian continental margin and the episodic ultra-fast sea floor spreading in the central Red Sea, where the role of EDC has been invoked.