Geophysical Research Abstracts
Vol. 21, EGU2019-6037, 2019
EGU General Assembly 2019

Regional analysis of necking domains in young, incipient and failed rifted margins from deformable plate tectonic models and geophysical data

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Studies examining the margin evolution of the magma-poor Iberian-Newfoundland margins, defined the necking domain as the transition zone between hyperextended crust (i.e. <10 km) and the crust of normal thickness ∼30 km (e.g. Sutra et al. 2013). The necking domain corresponds to a tapered region where the interpreted seismic basement and Moho appear to converge oceanwards. It also marks a major change in structural style corresponding to the mechanical transition between decoupled, where faults sole out along intra-crustal decollements, and coupled crustal thinning, where faults couple both the crust and the mantle, (e.g. Sutra et al. 2013). The process of necking during continental rifting marks the transition from diffuse extension to localized extension. The controlling faults should be observable with high-quality seismic reflection data. Unfortunately, the identification of coupled (crust-mantle) faults is not easily defined in all seismic reflection datasets. Moreover, in margins with increased magma budgets, where magmatic intrusions and underplating have thickened the crust, the delineation of the necking domain becomes increasingly problematic. Consequently, the competing processes of necking/thinning and thickening due to syn-tectonic and post-tectonic magmatic overprints can be hard to separate. Leading to increased uncertainty when mapping the necking, coupling or oceanic domains at magma-rich margins. Thus, the question remains, to what extent these concepts can be applied while mapping necking, coupling or oceanic domains at magma-rich margins?

Necking can occur at both crustal and lithospheric mantle levels, the former however, is more readily constrainable, due to the availability of regional refraction and/or gravity datasets. In frontier basins where long-offset and long-record seismic reflection or refraction datasets are limited, a crustal approach is needed to understand the first-order margin evolution. The study of crustal necking from the Gulf of Suez, Aden, and the Red Sea provides an insight into a region that combines magma-poor and magma-rich margins end-members and lateral transitions from the one to the other.

In this study different necking domains in the Red Sea-Aden system are investigated using crustal thickness estimates from gravity inversion and earthquake tomography. A base-case workflow is first investigated where the necking domain is interpreted based on crustal thickness assumptions relating to an extensional beta factor of >3. Therefore, if a region has a pre-rift crustal thickness of ∼35 km, we assume that at <12 km, coupling processes will have succeeded. Then through examining different resultant crustal models and assumptions we map alternative necking domains and coupling lines, examining the impacts of the possible necking zones through palinspatic deformable plate (GPlates) reconstructions for the region. Using the deformable plate models, we investigate the relationship between necking, coupling and seafloor spreading processes within a plate kinematic framework. In addition, we elucidate the impact of magmatic thickening and how modified interpretations of the necking may be attempted in the Red Sea-Aden system, providing the first regional-necking domain model for the region. Our study highlights the importance of constraining the location of necking domains and the usefulness of deformable plate tectonic models in assessing kinematic constraints along frontier rifted margin.