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Plume-induced continental break-up from Red Sea to Lake Malawi: 3D numerical models of the East African Rift System

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We use numerical thermo-mechanical experiments in order to analyze the role of active mantle plume, far-field tectonic stresses and pre-existing lithospheric heterogeneities in structural development of the East African Rift system (EARS).
It is commonly assumed that the Cenozoic rifts have avoided the cratons and follow the mobile belts which serve as the weakest pathways within the non-uniform material structured during pre-rift stages. Structural control of the pre-existing heterogeneities within the Proterozoic belts at the scale of individual faults or rifts has been demonstrated as well.
However, the results of our numerical experiments show that the formation of two rift zones on opposite sides of a thick lithosphere segment can be explained without appealing to pre-imposed heterogeneities at the crustal level. These models have provided a unified physical framework to understand the development of the Eastern branch, the Western branch and its southern prolongation by the Malawi rift around thicker lithosphere of the Tanzanian and Bangweulu cratons as a result of the interaction between pre-stressed continental lithosphere and single mantle plume anomaly corresponding to the Kenyan plume.
The second series of experiments has been designed in order to investigate northern segment of the EARS where Afro-Arabian plate separation is supposed to be related with the impact of Afar mantle plume. We demonstrate that whereas relatively simple linear rift structures are preferred in case of uni-directional extension, more complex rifting patterns combining one or several ridge-ridge-ridge triple junctions can form in response to bi-directional extensional far-field stresses. In particular, our models suggest that Afar triple junction represents an end-member mode of plume-induced bi-directional rifting combining asymmetrical northward traction and symmetrical EW extension of similar magnitudes. The presence of pre-existing linear weak zones appears to be not mandatory for deformation localization ultimately leading to present configuration of the Afar triple junction.
Finally, for laterally extended experiments we have used parameters of the best-fit models for the southern and northern segments of the EARS in order to define the position of Kenyan plume and the velocity boundary conditions. These models cover all rifting and spreading structures associated with both Afar and Kenyan plumes: Red Sea Rift and the Aden Ridge to the north of the Afar Triple Junction; Main Ethiopian Rift running to the south that continues as the Kenyan Rift; Western Rift and its southern prolongation corresponding to Malawi rift.
We argue that all these basic features associated with Cenozoic rifting in the EARS can be reproduced in a relatively simple context of the interaction between two mantle anomalies corresponding to Afar and Kenyan plumes and pre-stressed rheologically stratified continental lithosphere containing only first-order structural heterogeneities (such as Tanzanian and Bangweulu cratons).