Geophysical Research Abstracts
Vol. 19, EGU2017-6507-1, 2017
EGU General Assembly 2017

Influence of the inherited lithospheric structure on the interaction between the Kenyan and Ethiopian rifts across the Turkana depression: analog and numerical models

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Rifting processes result from the application of extensional stresses to a pre-deformed, and thus already structured, anisotropic lithosphere; consequently, the pre-rift lithospheric rheological structure and its along-axis variations play a major role in controlling the evolution and architecture of continental rifts. The East African Rift is a classic example of this process. The rift system developed within a region that has experienced several deformation events, which have given rise to significant variations in the rheological structure of the lithosphere. These variations -in turn- have played a major role on rift evolution, as clearly testified by the localisation and propagation of major rift segments within weak Proterozoic mobile belts surrounding cratonic areas. Linkage and mechanical interaction between adjacent rift segments typically occurred in correspondence to transverse pre-existing fabrics, where structurally complex areas (transfer zones) allowed significant along-axis variations in subsidence of grabens and elevation of uplifted flanks.

One of these complex areas is the Turkana depression where the Ethiopian and Kenyan rifts interact. The region is characterised by anomalous morphology and distribution of deformation with respect to the rift valleys in Kenya and Ethiopia. In this work we investigate whether these anomalies result from the presence of a pre-existing Mesozoic graben, transverse to the trend of the rift valleys and characterized by thin crust and lithosphere. To this aim, we integrate crustal-scale, isothermal analog experiments with lithospheric-scale, thermo-mechanical numerical models. The two different methodologies generate very similar results, reproducing the along-axis transition from narrow rift valleys in Ethiopia/Kenya to a distributed deformation within the Turkana depression. Modeling results indicate that this variation results from the inherited distribution of lithospheric strength and -in particular- from the presence of a NW-SE trending region of thinned crust generated during the Mesozoic rifting event. Similarly to what observed in nature, our models show that the rift valleys propagated away from each other within the Turkana depression, thus avoiding a direct link to form a throughgoing N-S structure. Our models indicate that local-scale characteristics of the fault pattern (such as the occurrence of horse-tail splays at fault terminations or the presence of faults with zig-zag plan-view geometry giving rise to basins with a 'staircase' pattern as in the case of Lake Turkana) may result from a minor component of strike-slip motion controlled by relative orientation between the NW-SE oriented domain of thinned crust and roughly E-W direction of extension.