The Afro-Arabian Rift System

The Afro-Arabian Rift System from mantle to surface

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In Short

- Elucidate fundamental geodynamic processes shaping the continental rifts and their interaction within the Afro-Arabian Rift System.
- Bridge spatial and temporal scales of mantle flow, rift fault network formation and erosion and sedimentation.
- Integrate geophysical, geodetic and geological observations into high-performance 2D and 3D thermo-mechanical forward modelling.

1 | Motivation. Tectonic plate boundaries provide a unique window into the geodynamic system of our planet and the processes that shape the geological evolution of its surface. The Afro-Arabian Rift System is a well-studied, currently-active example of a continental plate being torn apart through tectonic and magmatic processes. In this divergent plate boundary, extension did not initiate uniformly. Distinct rift segments, junctions and microplates form a complex plate boundary system in which rift segments interact with each other and pre-existing structures.

The forces driving extension in the Afro-Arabian plate boundary over the last tens of millions of years are debated. Possible drivers include far-field plate forces from for example subduction elsewhere, gravitational potential energy of elevated regions, mantle upwellings such as the Kenyan plume impinging on the bottom of the lithosphere and tractions exerted by mantle flow on the plates involved. Numerical modeling can help distinguish between the individual contributions of these drivers to deformation and elucidate how rift segments develop and interact within this force field.

The geodynamic processes acting in the Afro-Arabian system and the potential hazards they pose (e.g. earthquakes) cross a vast range of scales, ranging from several meters to the size of tectonic plates and from seconds to millions of years. Moreover, the relevant processes often take place at inaccessible depths and times, avoiding direct observation. Within this project we have managed to bridge the scales between mantle flow and surface processes (Fig. 1), allowing us to model through time rift evolution from initiation to break-up and passive margin formation.

Our numerical predictions of the evolution of the Afro-Arabian system are constrained and informed by direct and indirect observations of its current state (e.g. plate motions, crustal thickness). With this multi-scale, data-driven forward modeling, the proposed research aims at a thorough understanding of the system's particular dynamics. It will yield profound geodynamic insight in the effect of surface processes on individual segments such as the Ethiopian Rift and the Dead Sea Transform, the interaction of multiple rift segments such as in the Turkana region or at the Afar triple junction, and the importance of individual potential drivers of extension such as the Kenyan plume.

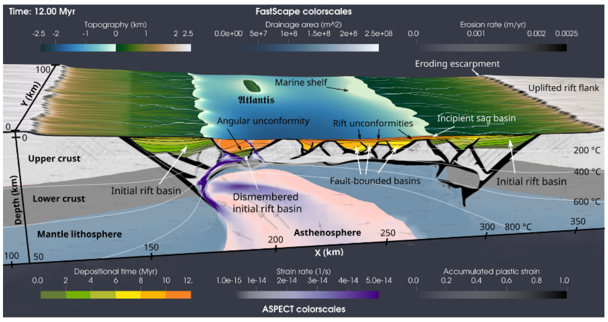

***Figure 1:** High-resolution numerical results of rifted continental margin architecture. This model depicts the close interaction between sedimentation and rift tectonics. Figure based on coupled ASPECT-FastScape models described in Neuharth et al.[1] run within the context of this project.*

2 | Methods. We use the open-source, massively-parallel, finite-element code ASPECT [2], which is designed to solve the equations for thermally and chemically driven convection and long-term tectonic deformation. ASPECT employs fully-adaptive meshes, which enable us to resolve small local objects such as crustal faults over time without refining the mesh in the whole model domain. Other key characteristics of the code are adaptive time stepping, efficient non-linear solvers to deal with visco-plastic rheologies [3] as well as its excellent scalability. We recently two-way coupled ASPECT to a surface processes code [1] to incorporate the effect of erosion and sedimentation on tectonics and vice versa (Fig. 1).

3 | Goals. The key objective of our Geodynamic Modeling section is to transcend the scales of geodynamics through innovative modelling techniques. In this project we will 1) bridge the scales between

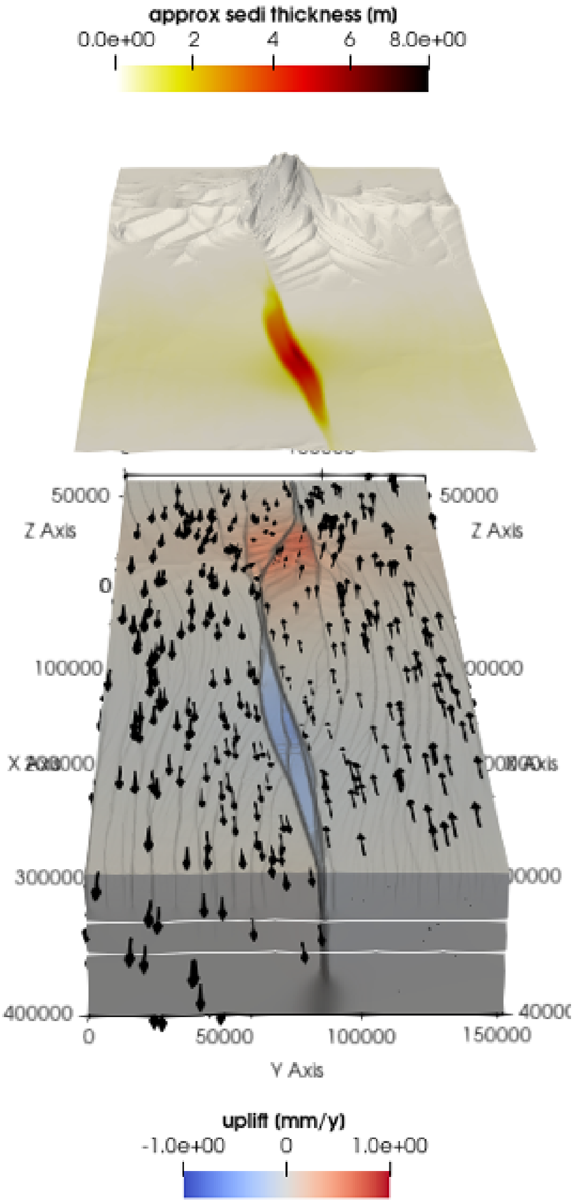

Figure 2: *3D simulation of the Dead Sea Transform showing the coeval formation of the Dead Sea pull-apart basin and the pop-up Lebanese Mountains at transform fault stepovers. Top: FastScape topography, bottom: ASPECT fault structures. Figure by E. Heckenbach created in the context of this project.*

faults, rift segments and the dynamics of individual plates (e.g. Fig. 2); 2) investigate the interaction, deflection and linkage of specific rift segments of the Afro-Arabian system; and 3) quantify the contributions to extension of geodynamic drivers such as mantle plumes. We build on our recent numerical studies of continental rift dynamics [4–6] and strike-slip fault basin formation [7] to understand the interaction and feedback between mantle flow, lithosphere deformation and surface processes in the Afro-Arabian Rift System.

WWW

https://www.gfz-potsdam.de/en/section/geodynamic-modeling/overview/

More Information

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Project Partners

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DFG Subject Area

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