Breaking Continents

Structures and Dynamics of Continental Rift Systems

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In Short

- Numerical modelling of geodynamics
- Integrating geophysical and geological observations
- Accounting for interaction of brittle faults, ductile shear zones, and melting in continental rift systems

1 | Motivation. Continental rifts provide a unique window into the geodynamic system of our planet and the processes that shape the geological evolution of the Earth's surface. Rifts develop where a continent is torn apart by tectonic and magmatic processes. Well-studied currently active examples are the East African Rift System, the German Rhine Graben, and the Baikal Rift. At present, continental rifts comprise only a small portion of tectonic plate boundaries, but their current extent is only a fraction of the total length of rifts generated during the break-up of Pangea when more than 100,000 km of rifted continental margins were formed defining the majority of Earth's coastlines.

Our understanding of rift processes is generally hindered by two fundamental problems of geodynamics. First, large-scale tectonic deformation involves a vast range of scales ranging from several hundred meters to the size of tectonic plates. Second, most of the relevant processes take place at inaccessible depths and they can only be studied indirectly through geophysical, geological, and geochemical techniques where the collected data captures only limited aspects of the entire system.

The proposed research aims at a thorough understanding of continental rift dynamics and rifted margin formation. This will be achieved through a comprehensive multi-scale numerical modelling design using adaptive mesh refinement methods in order to investigate and connect geodynamic processes ranging from several 100 meters to more than 3000 kilometers. Focussing on the East African Rift System, our modelling approach allows the integration of regional geoscientific data sets and will yield profound geodynamic insights on the present-day thermo-mechanical state of the East African Rift System as well as its geological evolution.

2 | Methods. We use the highly parallelised finite-element code ASPECT [1], which is designed to solve the equations for thermally driven convection and long-term tectonic deformation. ASPECT employs fully adaptive meshes, which enable us to resolve small local objects in the flow field such as faults and shear zones (Fig. 1) without refining the mesh for the whole model. ASPECT's numerical methods are at the forefront of research in adaptive mesh refinement, linear and nonlinear solvers and the stabilisation of transport-dominated processes.

3 | Goals. The main objective of the Young Investigators Group CRYSTALS is to develop modelling techniques that transcend the scales of rift tectonics. ASPECTs adaptive mesh refinement and its excellent scalability will be used in this project to bridge the scales between faults, magmatic processes and the dynamics of individual plates within the East African Rift System. In order to accomplish this goal we plan to combine implementations of melting, visco-plasticity [2] and strain-dependent rheology. We will thereby build on recent numerical modelling studies of continental rift dynamics [3,4], melt production and melt migration [5,6], and plume-lithosphere interaction [7,8]. We will apply these models to understand the geodynamics of the East African Rift System, a type example of continental rifts, featuring magmatic and magma-poor rift segments. Using 3D models, we will focus on the impact of rift obliquity (Fig. 1) on tectonic surface expressions, the interaction of oblique rifting with melting through time, and the geodynamics of transfer zones between individual rift segments. Finally we will run regional simulations of the entire East African Rift in order to elucidate the dynamics of the rift's central block, the Victoria microplate, whose movements are entirely controlled by the dynamics of the Eastern and Western branch, as well as the mantle flow below.

WWW

http://www.gfz-potsdam.de/wg/crystals/

More Information

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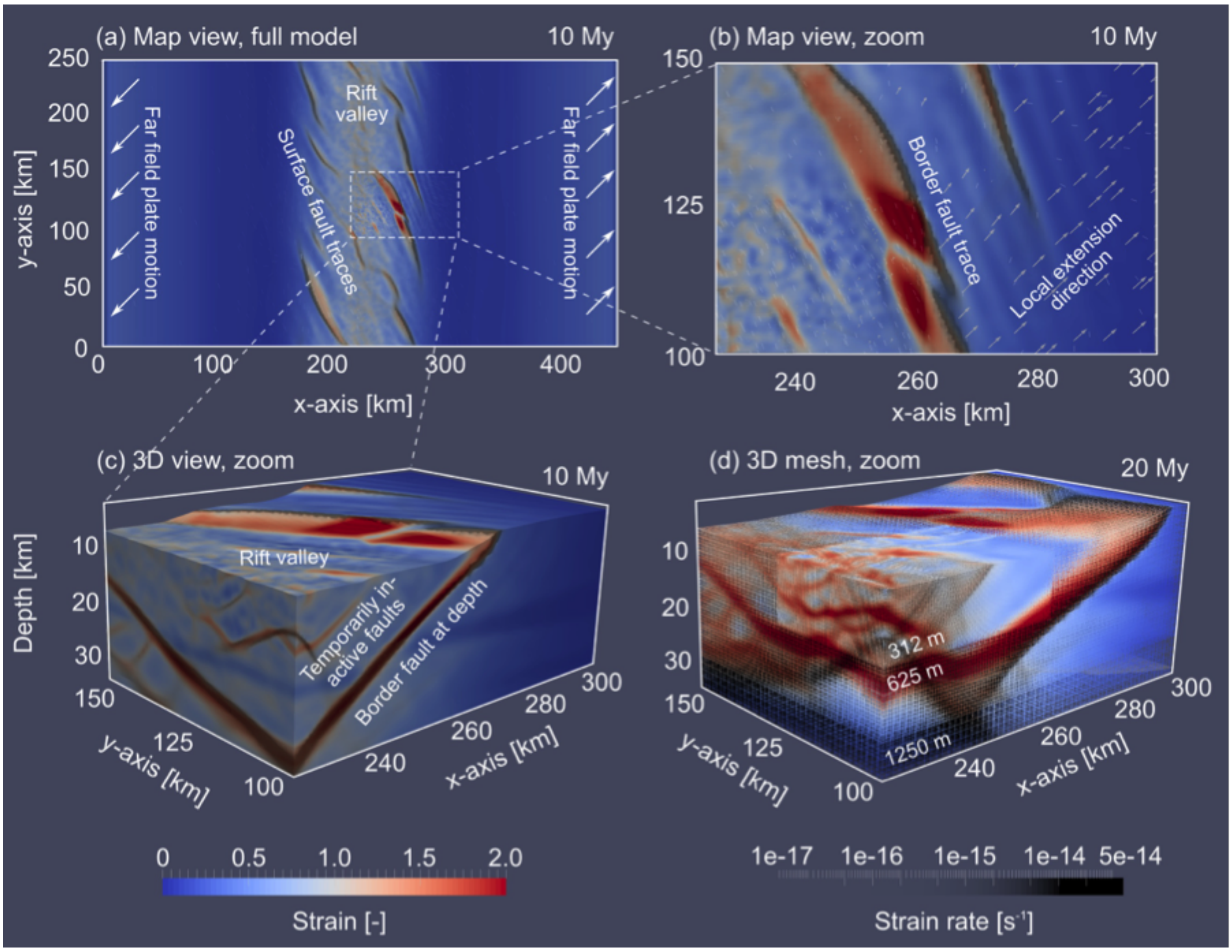

Figure 1: *3D model of oblique rifting. Normal faults cut through Earth's crust (a) creating a deep rift valley reminiscent of the Central Kenya Rift. Mesh refinement provides a very high resolution of 312 m within the region of interest, while the coarsest elements is 5000 m (d). The unprecedentedly high resolution reveals a complex deformation pattern with local velocity deviations from the far field extension direction (b) and temporarily inactive faults beneath the rift valley (c) that get reactivated during basin-ward localisation (d).*

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Project Partners

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