Continental Rifting - From Inception to Break-up

Structures and Dynamics of Continental Rift Systems

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In Short

- Geodynamics modelling of continental rifts and rifted margin formation
- Integrating geophysical and geological observations
- Accounting for interaction of brittle faults, ductile shear zones, and melting in continental rift evolution

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 and ultimately opening the Atlantic, Indian, and Southern Ocean Basins.

Our understanding of rift processes is generally hindered by the vast range of geodynamic scales ranging from several meters to the size of tectonic plates. Moreover, the relevant processes often take place at inaccessible depths and they can only be studied indirectly.

The proposed research aims at a thorough understanding of continental rift dynamics and rifted margin formation by means of a comprehensive multi-scale numerical modelling design where we investigate and connect geodynamic processes ranging from several 100 meters to more than 3000 kilometers. Our modelling approach allows the integration of regional geoscientific data sets and will yield profound geodynamic insights on the geological evolution of the East African Rift, the North and South Atlantic margins as well as the ocean basin between Australia and Antarctica.

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 melt regions (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 key objective of the Young Investigators Group CRYSTALS is to transcend the scales of rift tectonics by means of innovative modelling techniques. 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 [3–5], melt production and melt migration [6], and plume-lithosphere interaction [7,8]. We will apply these models to understand the geodynamics of the North East Atlantic Rift, the southern segments of the South Atlantic Ocean, the Australia-Antarctica

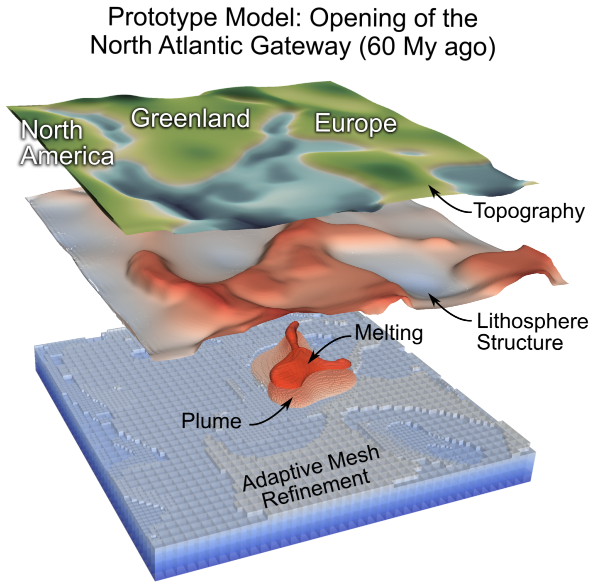

***Figure 1:** Regional prototype model of the North Atlantic opening (60 million years ago). The model box is 3000x3000x660 km with element size varying between 4 and 60 km. The model yields the time evolution of topography accounting for faulting, plume buoyancy, and isostasy. The Iceland plume is integrated into the model setup as a thermal and velocity boundary condition at the model base (Steinberger et al., 2018). Its structures can be optionally resolved in more detail using adaptive mesh refinement.*

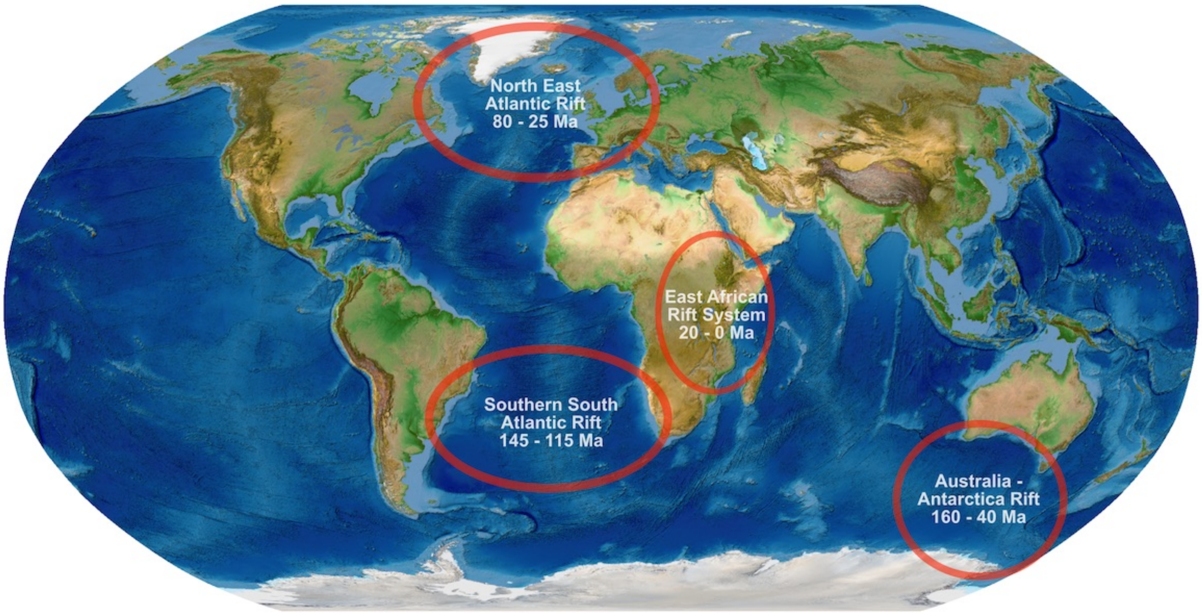

Figure 2: *Location of study regions: the largest currently active rift system on Earth - the East African Rift and three major Cretaceous rifts that eventually opened large ocean basins - the North East and South Atlantic Rifts as well as the Australia-Antarctica Rift.*

Rift, and the currently active East African Rift System (Fig. 2). We thereby focus on the interaction between rift dynamics and plate motions, plume impingement and strain localization as well as the resulting dynamic and isostatic topography evolution.

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

More Information

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Project Partners

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