From crust to core

Geodynamic modelling of the crust, lithosphere and mantle

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In Short

- Geodynamic modelling of continental rifts, subduction zones and mantle convection
- Integrating geophysical and geological observations
- Great earthquakes, microplate formation and mantle-lithosphere interaction

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 the its surface. Rifts develop where a continent is torn apart by tectonic and magmatic processes. The East African Rift System is a well-studied currently active example. At present, continental rifts comprise only a small portion of the plate boundaries. However, during the break-up of Pangea 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.

Subduction zones form where plates converge; this convergence can lead to mountain building, earthquakes, volcanism and extensive deformation of the plates involved. Large stretches of plate boundary are at present convergent boundaries, like the west coast of South America, where subduction of the Nazca plate has formed the Andes, the longest continental mountain range. The largest recorded earthquakes also occurred along this plate interface.

Unfortunately, our understanding of geodynamic processes and the hazards they can pose is generally hindered by the vast range of scales on which these processes take place, 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 can only be studied indirectly.

The proposed research aims at a thorough understanding of continental rift and subduction dynamics 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 and from minutes to years. 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 Andean mountains.

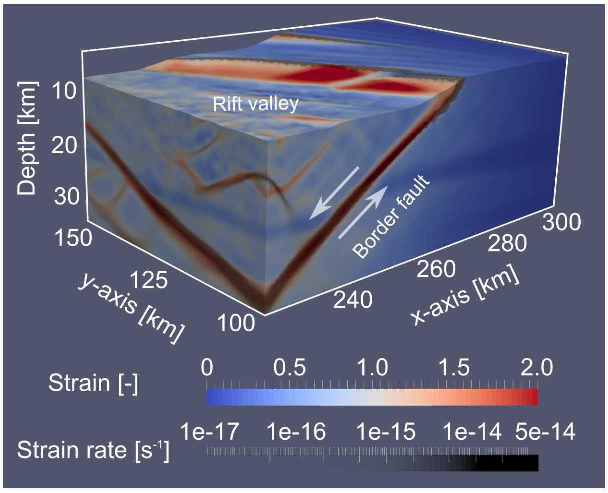

***Figure 1:** 3D prototype model of oblique rifting. The shown box is a cutout of a larger model of 450x250x150 km. Within this region of interest, we employ a very high mesh resolution of 312 m, while the coarsest resolution is 5000 m. The unprecedentedly high resolution reveals a complex deformation pattern with local velocity deviations from the far-field oblique extension direction and temporarily inactive faults beneath the rift valley (low strain rates, but high strains) that get reactivated during basin-ward localisation.*

2 | Methods. We use the highly parallelised finite-element code ASPECT [1], 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 in the flow field such as faults and melt regions without refining the mesh for the whole model (Fig. 1). 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 our Geodynamic Modeling section is to transcend the scales of geodynamics by means of innovative modelling techniques. ASPECTs adaptive mesh refinement and time stepping as well as its excellent scalability will be used in this project to bridge the scales between 1) faults, rift segments and the dynamics of individual plates (e.g. Fig. 2); 2) between earthquakes and the long-term tectonic history of converging plates; and 3) surface deformation and the long-wavelength mantle

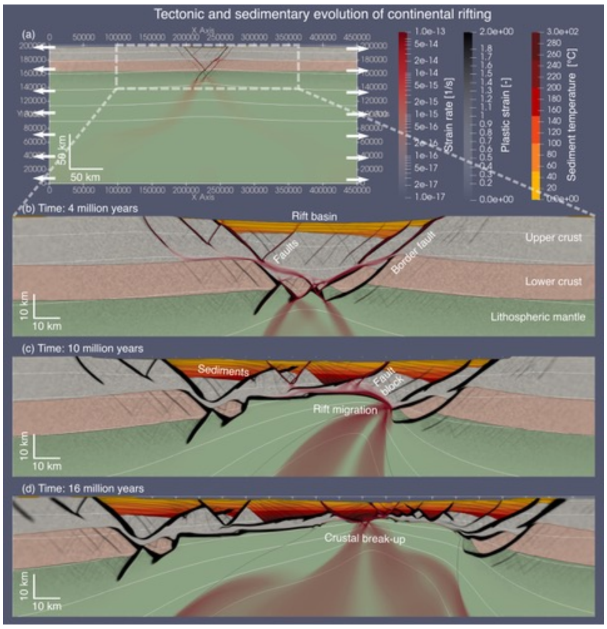

Figure 2: *High-resolution 2D rift model of joint tectonic and sedimentary evolution. Active faults and shear zones are depicted in red, inactive ones in black. Sediments are colored in terms of their temperature (orange/red) and contoured in 1-million-year deposition intervals. These contours illustrate the tight connection between upper-crustal faults, rotation of normal fault blocks and the sedimentary structure. We exploit the mesh refinement capabilities of ASPECT by employing coarse (10 km) elements in the lower part of the model. Towards the surface and the model center, elements are successively refined 5 times to a minimum element size of 312.5 m. Given the second order elements, this results in an effective resolution of ∼150 m.*

convective processes. To accomplish this goal we will combine recent implementations of elasto-visco-plasticity [2] and strain-dependent rheology, mesh deformation [3] and surface processes code coupling. We will thereby build on recent numerical modelling studies of continental rift dynamics [4–6], melt production and melt migration [7], self-consistent lithosphere subduction [2] and plume-lithosphere interaction [8,9]. We will apply these models to understand the geodynamics of the North East Atlantic Rift, the southern segments of the South Atlantic Ocean, and the currently active East African Rift System, as well as central Andes subduction dynamics, the seismic cycle of great earthquakes at subduction zones and transform faults and the feedback between mantle convection and lithosphere deformation.

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www.gfz-potsdam.de/sektion/geodynamische-modellierung

More Information

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