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# How preexisting lithospheric heterogeneities and mantle upwellings affect Victoria's rotation in the East African Rift System


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## 1. Introduction

The Victoria microplate is encompassed by the partly overlapping eastern and western branches of the East African Rift System (EARS; **Fig. 1a**). These branches follow the inherited lithospheric weaknesses of the Proterozoic mobile belts (**Fig. 1b**). Victoria also rotates counter-clockwise with respect to Nubia, in striking contrast to its neighboring plates. Numerical modeling[1] (**Fig. 2**) has shown that this rotation is induced through the 'edge-driven' mechanism[2], where stronger lithosphere transmits the drag of the major plates along the edges of the microplate, while weaker regions facilitate the rotation. Rotation is controlled by the distribution of strength heterogeneity. Model predictions of stress and velocity match EARS observations when the first-order strength distributions of the EARS are included (**Fig. 2**). Rotation and rift-obliquity reorient local extension directions to WNW-ESE.

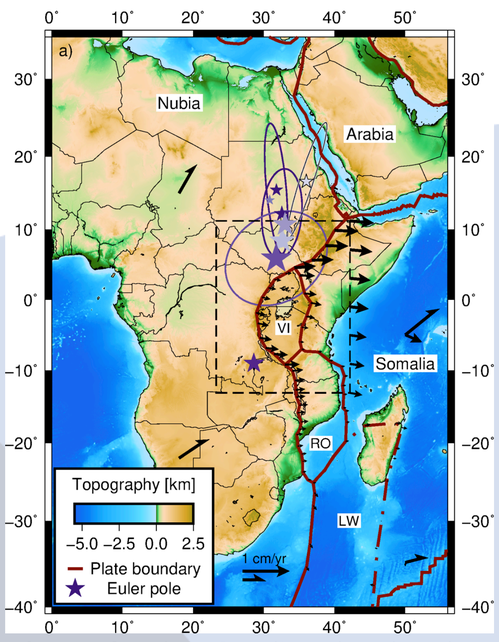
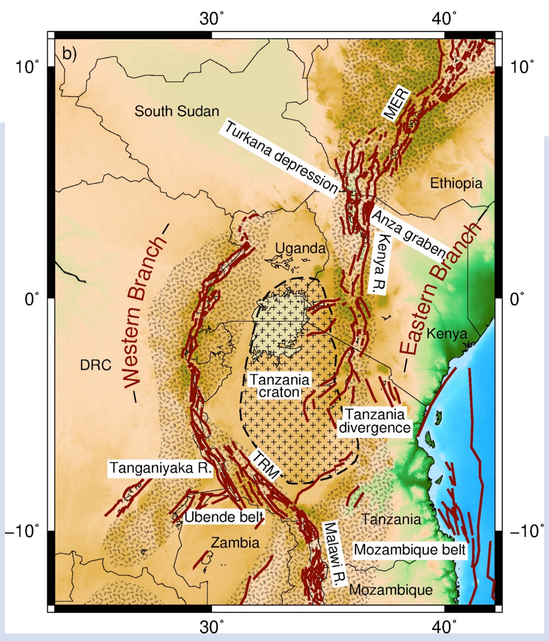



**Fig. 1 a)** Nubian-Somalian plate boundary configuration from geodetic block models[3]. Euler poles of Victoria microplate rotation computed from same models (purple stars). Absolute (~NE) and relative (~E-W) plate motions represented by black vectors with halved and full heads, resp.




**b)** Region of interest and numerical model domain (dashed rectangle in a) showing the topography, mobile belts and active faults (GEM database). The curved Western and Eastern branch encompass the Victoria microplate, which includes the Archean Tanzania craton. The branches terminate in/against strong lithospheric regions.

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Lithospheric strength distribution controls Victoria microplate rotation.

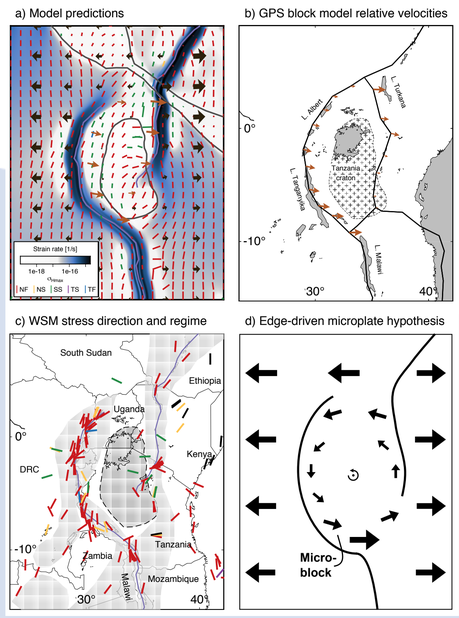


**Fig. 2 a)** Model predictions after 10 My showing Victoria rotation (black vectors) under E-W extension of curved overlapping branches following weak mobile belts and terminating in strong regions, like in d). Predominantly normal faulting, like observed (panel c). **b)** Kinematic block model prediction of Victoria microplate rotation[4] that predictions in a) agree with. **c)** Observed, predominantly normal faulting, $\sigma_{Hmax}$ directions (World Stress Map[10], uniform length) that rotate along the branches. **d)** Our schematic representation of the edge-driven microplate rotation due to transmittance of motion of the major plates.

## 2. East African Rift System after 2 My

*Rotation from data-driven lithospheric structure?*

Cartesian models of abstracted EARS strength configuration (mobile belts, craton, Turkana depression), but an otherwise homogeneous lithosphere, reproduce Victoria's rotation and the stress distribution in the EARS. Building on these models, we change to spherical geometries and a lithospheric structure derived from observational data. Subsequent models will test the additional effect of mantle structure and plumes on dynamic topography, strain localization and stress distribution in the EARS.

*Model setup*

- FE code ASPECT[4,5]
- Domain: 3D chunk of 19°x24°x660 km
- **Fig. 3**: Present-day Moho[6] and LAB depth[6]
- **Fig. 4**: prescribed GPS in- and outflow on lithosphere, compensating flow through bottom boundary
- **Fig. 5**: strain-weakened plastic yielding[7] + diffusion & dislocation creep
- True free surface[8]
- Mesh resolution: 41 km to 10 km in the crust

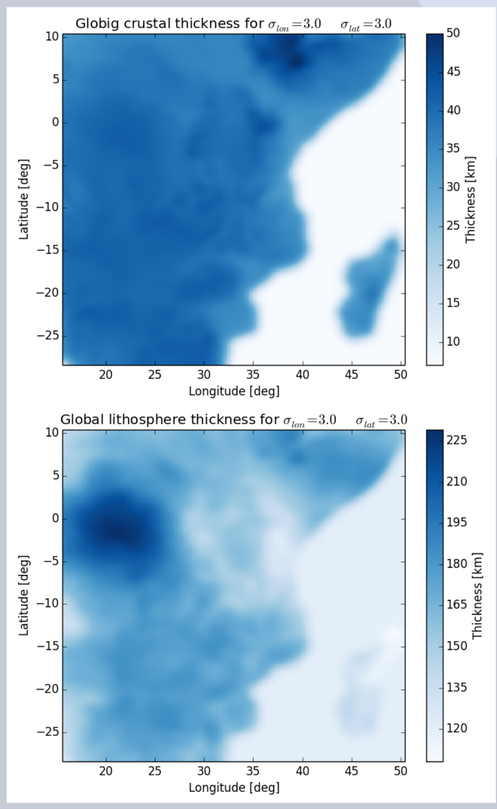


**Fig. 3** Input Moho and LAB depth[6] smoothed with a Gaussian filter. Moho and LAB depth in the old oceanic plate are set to 7 and 120 km respectively.

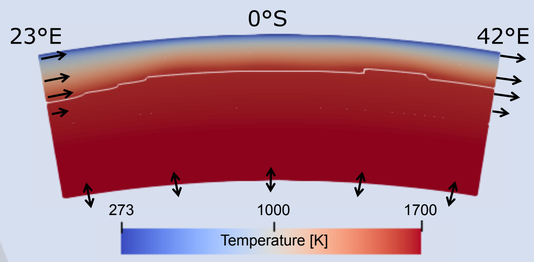


**Fig. 4** W-E slice at equator showing initial temperature distribution (steady-state continental geotherm[9] and adiabatic mantle), LAB isotherm (1623 K) and prescribed velocity boundary conditions based on geodetic block model Euler poles[3] and compensating bottom flow.

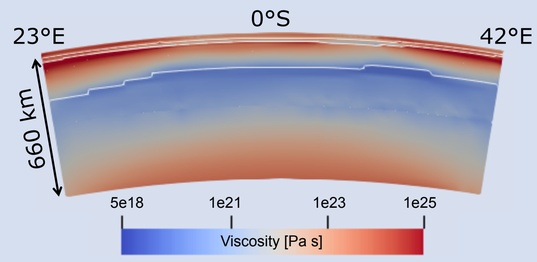


**Fig. 5** W-E slice at equator showing initial viscoplastic viscosity distribution as well as upper wet quartzite and lower wet anorthite crust and mantle lithosphere contours. The upper crust thickness is taken as 55% of the Moho depth.

*Preliminary results & Discussion*

**Fig. 6**:

- Nubia and Somalia plate boundary develops self-consistently along present-day EARS. Velocity pattern is largely controlled by lithospheric thickness variations, initial strain has little effect.
- More active deformation along eastern EARS branch than along the western branch.
- Partitioning of deformation correlates with minimum LAB depth.

**Fig. 7**:

- After 2 My, Victoria microplate rotates counter-clockwise, but much slower than present-day.
- ➢ Run for 10 My model time
- ➢ Incorporate other lithospheric structure datasets
- ➢ Incorporate mantle temperature heterogeneity from tomography

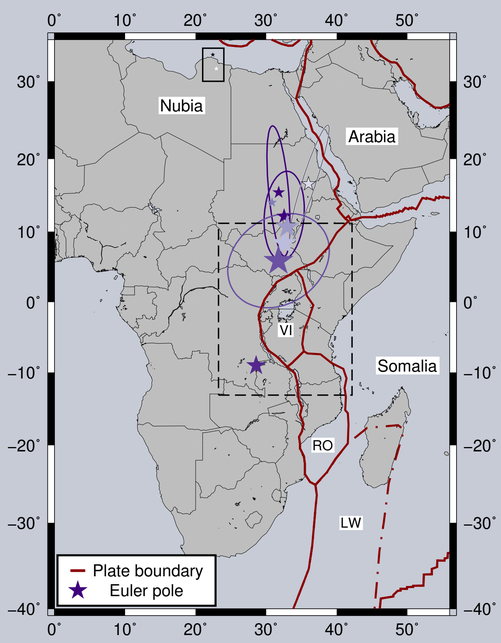


**Fig. 7** Predicted Victoria microplate Euler poles (white and black stars in black box) after 2 My compared to geodetically derived poles[4] (purple stars).

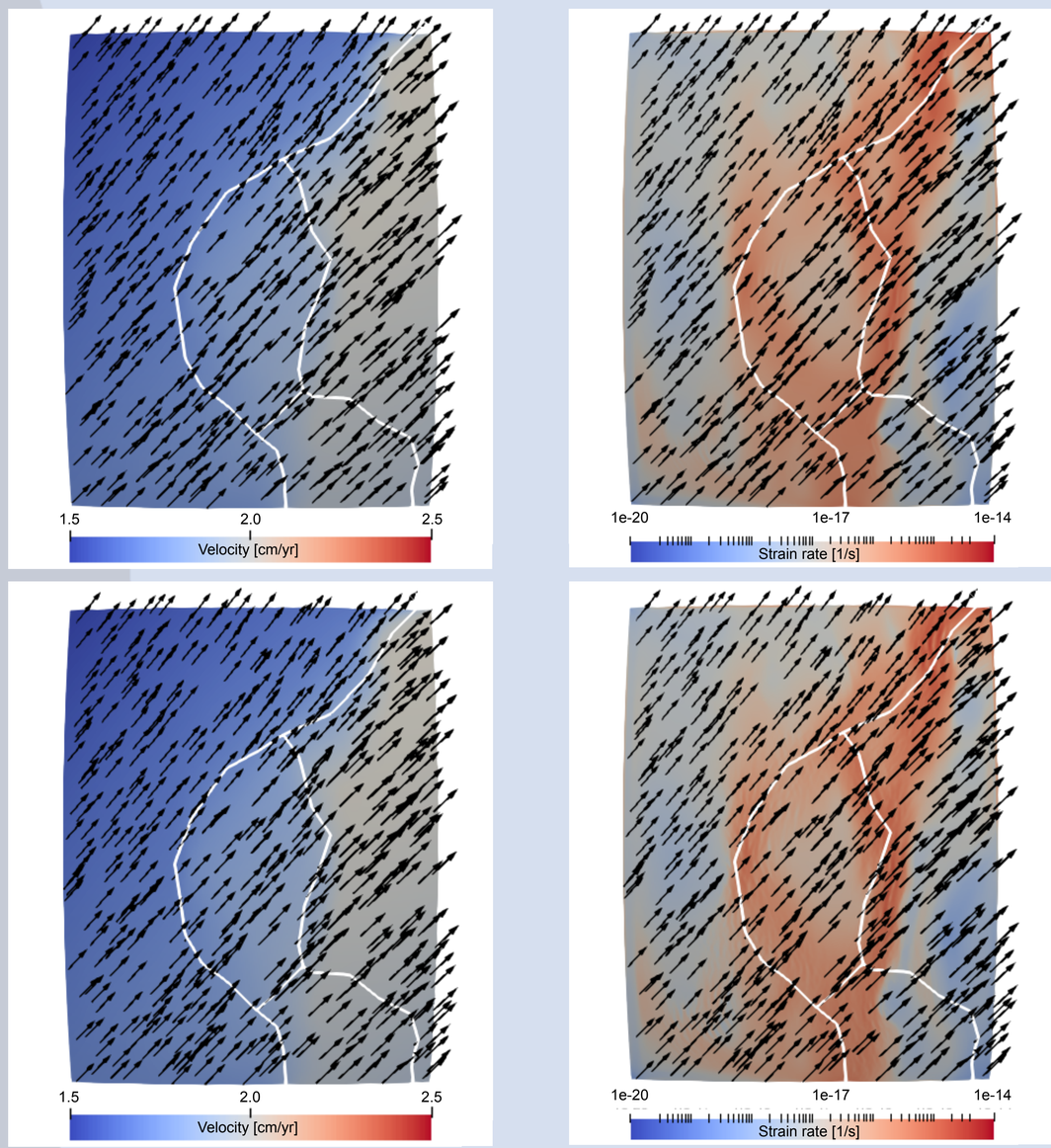


**Fig. 6** Top view of model results at 5 km depth after 2 My of extension. White lines outline the plate boundaries from the geodetic block model[4]. Left column: plate motions as represented by the velocity field and vectors. Right column: Strain rate field and velocity vectors. Top row: no initial damage (plastic strain). Bottom row: initial plastic strain between 0-0.5 in the upper 50 km along the Proterozoic mobile belts of the EARS.

### 3. References


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