

## Active Kinematics of Lithospheric Extension Along the East African Rift

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Theme: Infrastructure to support GPS EAR Transects

The East African Rift (EAR) has been identified as a “focus site” for the GeoPRISMS RIE Initiative. In addition, the GeoPRISMS Community has recognized that geodetic observations, particularly GPS and InSAR are already providing important constraints on the distribution of strain across the EAR and that such observations are an essential component for future research on the kinematics and dynamics of rift initiation and evolution. Because of the great length of the EAR system (~3000 km), the GeoPRISMS Program will select specific “discovery corridors” traversing the rift for focused geophysical and geological studies. Since distance along strike is a reasonable proxy for the extent of rift development, selecting “corridors” for focused geodetic observations along the full strike of the EAR (Afar to the southernmost rift in Malawi) will allow comparison of the spatial distribution of strain across the rift at different stages of evolution, addressing fundamental questions about how continental rifting evolves to full ocean spreading. In addition, selecting rift segments at similar stages of development, but different tectonic settings (e.g., magmatic vs. amagmatic environments) will provide opportunities to investigate the role of magmatic and other geologic processes (e.g., pre-existing structures) in rift initiation and evolution.

In contrast to other geophysical observations, geodetic monitoring of secular deformation requires sufficient time to allow motions to “grow” beyond the accuracy of the observational technique. Deformation rates along the EAR reach ~20 mm/yr across the Afar in the north (related directly to S Red Sea extension and Danakil block rotation) and vary from ~ 7 mm/yr across the northernmost rift in central Ethiopia (10°N), to ~5 mm/yr in southern Ethiopia/Kenya (distributed between the E and W rift branches in Kenya and Tanzania), to <3 mm/yr across the amagmatic Malawi Rift (-10 to -20°S) and the highly magmatic Massawa Rift in Eritrea (Kogan et al., 2012; McClusky et al., 2010; Stamps et al., 2008) (Figure 1). Sub-mm/yr, 95% confidence levels for current GPS observations require a minimum of 3-5 years of continuous, or 4-6 years of annual, multi-day survey observations. Since we are interested in constraining the spatial distribution of strain, we will need to determine site velocities to roughly an order of magnitude better than the total extension rate across the rift. Accordingly, under the best circumstances (stable monuments stable atmospheric conditions), it will require 5-10 years to determine the distribution of strain across the EAR at a range of evolutionary stages.

The most cost- and time-effective approach to constraining the kinematics of rifting along the EAR, and hence the evolution of rifting, is to build on earlier GPS observations to allow useful results to be obtained quickly, and a full set of geodetic constraints to be developed during the proposed life of the GeoPRISMS Program. Figure 1 shows the locations of survey sites (minimum of 2 occupations) and continuous GPS stations for which data are available along the EAR. These include data collected by the authors of this White Paper in collaboration with host-country partners, and others available through a range of data sharing agreements. Evaluating, integrating, and uniformly processing and analyzing these data to determine their utility for geodynamic studies will provide the basis for developing dense geodetic transects along strike of the EAR.

Based on our earlier studies and most recent analyses, for the purpose of contributing to the discussion, we suggest a series of 7 transects as follows (see Figure 1):

- 1- Massawa Rift in Eritrea (incipient rift [ $\sim 5$  Ma], slow [ $\sim 2$ -3 mm/yr], highly magmatic);
- 2- Afar Rift (ocean-like rift, fast [ $\sim 20$  mm/yr], highly magmatic);
- 3- Northern Ethiopia Rift (well developed continental rift, intermediate rate [ $\sim 7$  mm/yr]);
- 4- Southern Ethiopia and Kenya (E and W branches) rifts (early continental rift, intermediate rates [5-7 mm/yr; in Kenya distributed between E and W]);
- 5- Kenya/Uganda Rift (early continental rift, intermediate rates [5-7 mm/yr], distributed between E and W branches);
- 6- Tanzania Rift (early continental rift, intermediate rates [4-6 mm/yr], distributed between E and W branches);
- 7- Malawi Rift (incipient rift, slow [ $\sim 2$ -3 mm/yr], amagmatic).

Comparisons of the slow spreading Malawi and Massawa rifts (transects 1, 7) will allow investigation of the role of magmatic intrusions in rift initiation. The rapid extension across the Afar (in relation to other rift segments) (transect 2) offers opportunities to evaluate the influence of magmatic processes for the latest stage of crustal extension prior to full-ocean spreading. The kinematics for the relatively simple continental rift in northern and southern Ethiopia (3, 4) will provide constraints on the distribution of extension across well developed (north) and earlier stages of rifting. In Kenya and Tanzania, the distribution of extension between the W and E branches (5, 6) will provide opportunities for evaluating the importance of pre-existing crustal structures in focusing crustal extension and for comparison with faster continental extension in Ethiopia. The overall character of rift development along the full strike of the EAR will undoubtedly provide further, unanticipated insights into the dynamics of rift initiation and evolution.

*Broader Impacts* of geodetic studies of the EAR over the long term include enhancing geodetic and geophysical expertise in Africa through direct collaborations, developing geodetic constraints for basin models for resource exploration, geothermal development, and hazard mitigation (earthquakes, volcanic events) through cooperation with government geological surveys and nonprofit emergency response organizations, such as the Aga Khan Development Network, with whom we have partnered elsewhere in the world, and the GEM Foundation ([www.globalquakemodel.org](http://www.globalquakemodel.org)), a public-private partnership to improve global geologic risk assessment. In addition, position data developed during the course of the GeoPRISMS initiative will be provided to government mapping and cadastral agencies for infrastructural development and will contribute to establishing a modern reference frame for the African continent (AFREF). The GeoPRISMS geodetic initiative will provide opportunities for student and postdoctoral involvement in international research.

## References

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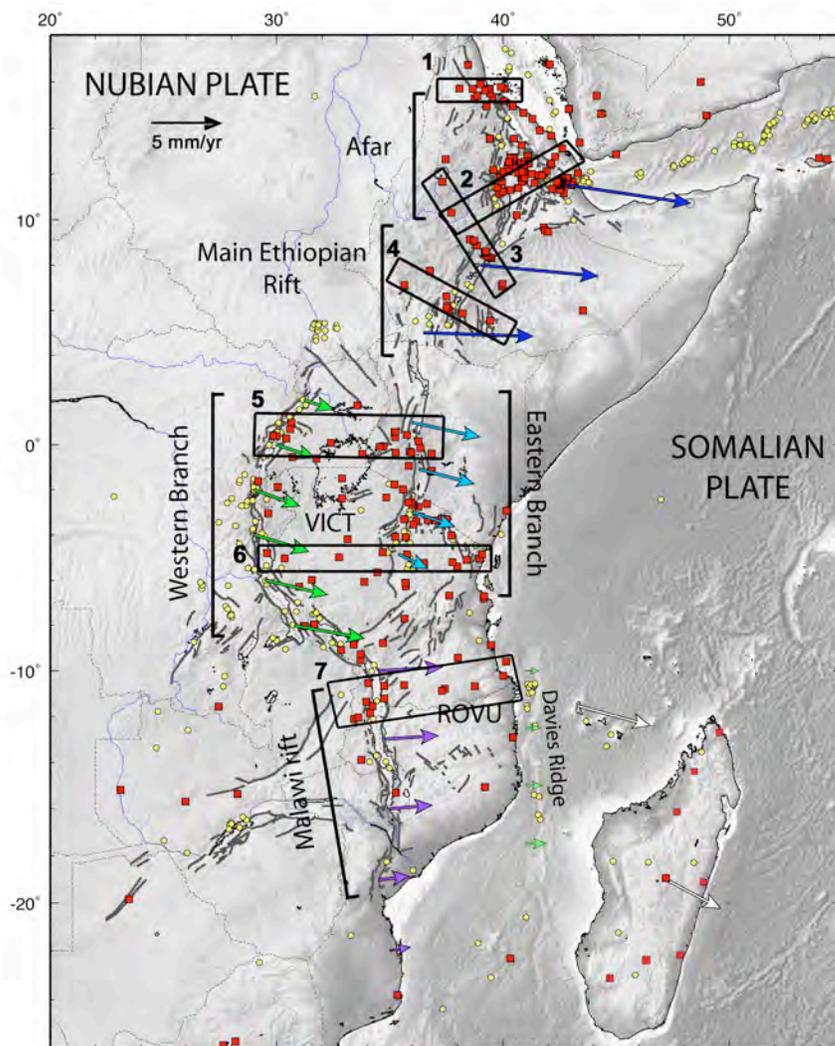


Figure 1. Main features of the East African Rift. Black lines show major faults, yellow circles are  $M > 5$  earthquake epicenters (NEIC catalog), red squares are GPS stations where at least two occupations have been performed, arrows show estimated velocities across plate or micro-plate boundaries (Nubia, Victoria (VICT), Rovuma (ROVU), and Somalia) according to Stamps et al. (2008).