Constraining magmatism and migration patterns between the Ethiopia-Yemen & E. African plateaux from new seismic and geodetic data

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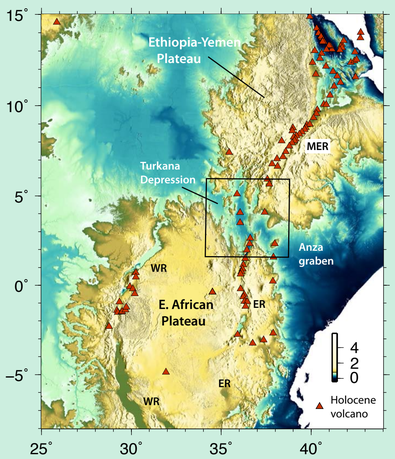


Introduction

Does a rift sector with low GPE evolve as a rift sector atop broad, dynamically supported plateau?

Turkana Depression at Kenya-Ethiopia border provides unique opportunity to test rifting models. **Turkana Rift Arrays to Investigate Lithospheric Structure (TRAILS)** deployed 32 seismometers and 9 continuous GPS in January, 2019.

Objectives

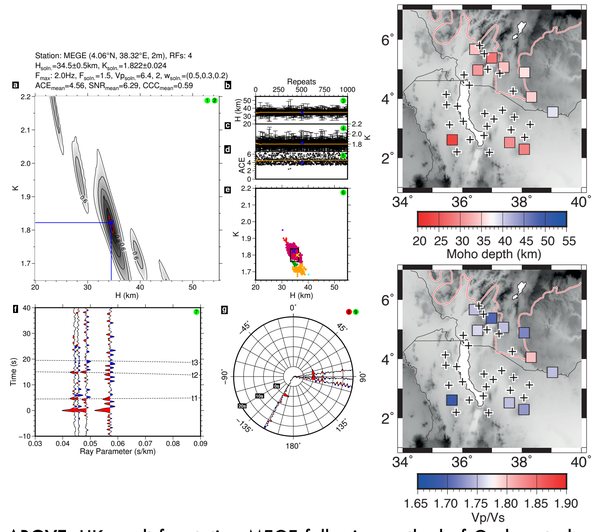
TRAILS – acquisition of seismic and geodetic data for lithospheric imaging, earthquake source mechanisms, surface kinematics.

Data and models will test :

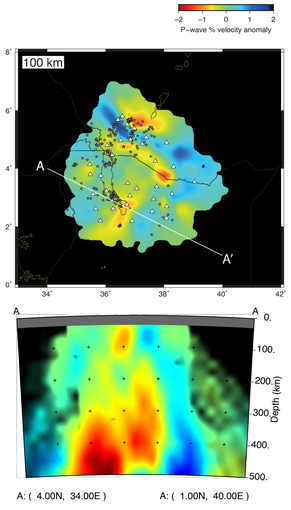
A1) Gravitational Potential Energy (GPE) from isostatic and dynamic topography strongly influences the location, magnitude of surface deformation;
A2) Lateral variations in material properties strongly influence the location and magnitude of surface deformation.

B1) Two mantle plumes support the two plateaux with minimal dynamic support of the Turkana Depression;
B2) One super-plume underlies both the plateaus, and the Turkana Depression is a highly stretched and magmatically-modified zone that channels mantle flow.

Crust and mantle seismic structure



ABOVE: HK result for station MEGE following method of Ogden et al., (2019). (b-e) Cluster analysis selects a final solution from 1000 individual H–κ results, each calculated using randomly selected receiver functions, and H–κ input parameters. (f) Receiver functions plotted by horizontal slowness and (g) backazimuth. **RIGHT:** Moho depth and bulk crustal Vp/Vs ratio across the TRAILS network. Black crosses are stations where insufficient data are available so far to obtain a stable solution.

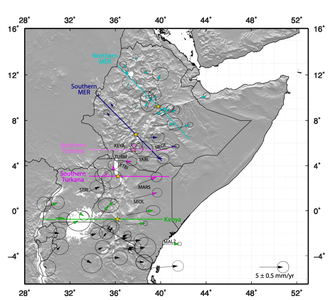


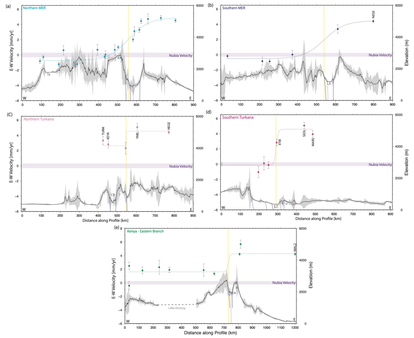
ABOVE: 100km depth slice (top) and cross section (bottom) through a P-wave tomographic model of the Turkana upper mantle. 3849 P-wave relative arrival-times have been inverted to generate the model.

Conclusions & Future Plans

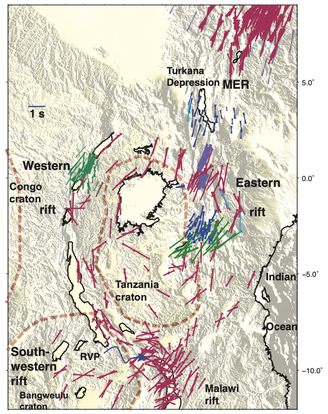
- Active deformation (GPS, seismicity) and volcanism localized to narrow zones north and south of the NW-SE trending mantle lithospheric high velocity zone
- Strain and magmatism migrated eastward from Archaean craton edge at 30-25Ma to modern zone – influence of pre-existing mantle lithospheric structure?
- Largest amplitude anomalies appear deep - superplume related. Evidence for focused upwelling is lacking. Fast wave speeds at 100 km are potential evidence for Pan African mantle lithospheric suture.
- Future work will compare active and tine-averaged deformation behavior, and spatial and temporal distribution of hazards and resources associated with rifting.

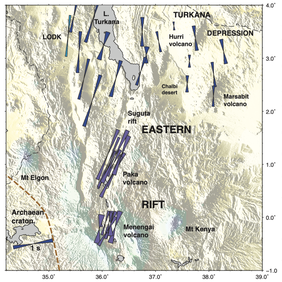
GPS, SKS-Splitting Results





Velocity solution in Nubia-fixed reference frame with 95% confidence ellipses. Transects represented by colored lines and stations are shown below. Stars indicate the location of maximum strain rate defined by the inflection point in the sigmoid fit (Knappe et al., JGR, 2020). We find no evidence for the broad zone of strain predicted in rift inheritance models (Brune et al., 2017), but instead infer a time migration from W to E.





Joint splitting analysis results with wedges indicating 95% confidence limits. Method simultaneously minimizes transverse energy on all components to produce one set of splitting parameters. Small delay times occur in the area of < 2 My shield volcanoes east of Lake Turkana, which lie above the lowest velocities imaged in the mantle at depths > 200 km.

Working model: Weak extension but voluminous magmatism E of L. Turkana above deep mantle velocity anomaly. Most extended lithosphere in Suguta-S Turkana. Aligned melt and along-axis flow explain anisotropy patterns.

Shear-wave splitting results (blue) with respect to craton boundaries and earlier analyses (Tepp et al., 2018; Walker et al., 2004; Gao et al. 1997; Homuth et al., 2016; Bagley et al., 2013; Reed et al., 2017). Smaller splitting delays, % nulls, and rotation of splitting direction occur at Tanzania and Bangweulu craton edges. Splitting rotates from NE direction parallel to plate motion to rift parallel (N-S, NNE) beneath rift thin zones where along-axis flow and melt-filled cracks are inferred. Splitting delay times increase northward in the Suguta –S Turkana rift and Ethiopia where melt volume in lithosphere increases, based on tomography and H-κ stacking.