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The DRIAR Project: Dry-Rifting In the Albertine-Rhino Graben, Uganda

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SCIENTIFIC MOTIVATION

The DRIAR project was funded by the NSF Frontier Research in Earth Sciences in late 2020 to investigate continental rifting, which is a process integral to plate tectonic theory. As such, continental rifts have been intensely investigated to understand the physical processes that initiate and sustain continental break-up. The leading paradigm for rift initiation suggests "magma-assisted (wet)" rifting is required to weaken strong lithosphere such that only small tectonic stresses are needed for rupture to occur (e.g., Buck, 2004; Wright et al., 2006; Muirhead et al., 2016; Jones et al., 2019). However, numerous examples of "magma-poor (dry)" rifting exist worldwide that do not show surface expressions of magmatism and challenge the magma-assisted model.

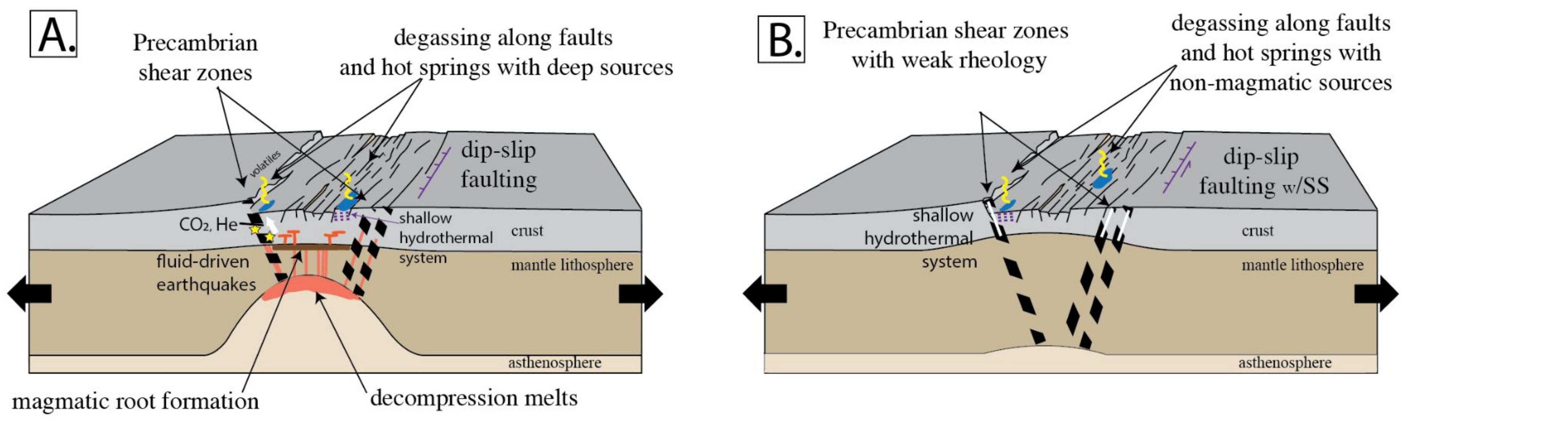

Figure 1. A. Conceptual model of magma-poor rifting with melt at depth. B. Model of magma-poor rifting with no melt at depth. Based on Muirhead et al. (2016, 2018).

Hypotheses for magma-poor rift segments:

1) Despite the lack of surface volcanism, melt is present at depth and has weakened the lithosphere, allowing for strain localization during the onset of rifting.
2) The lack of surface volcanism is indicative of a lack of magmatism at depth, and pre-existing structures weaken the lithosphere allowing.

STUDY AREA

We test our hypotheses by studying the magma-poor northern Western Branch of the East African Rift System (EARS; Figure 2), which comprises the Lakes George-Edward Graben and the Albertine-Rhino Graben. This setting provides an unprecedented opportunity to study the hypothetical along-axis transition from wet (magma-assisted) to dry (magma-poor) rifting, and to rift termination.

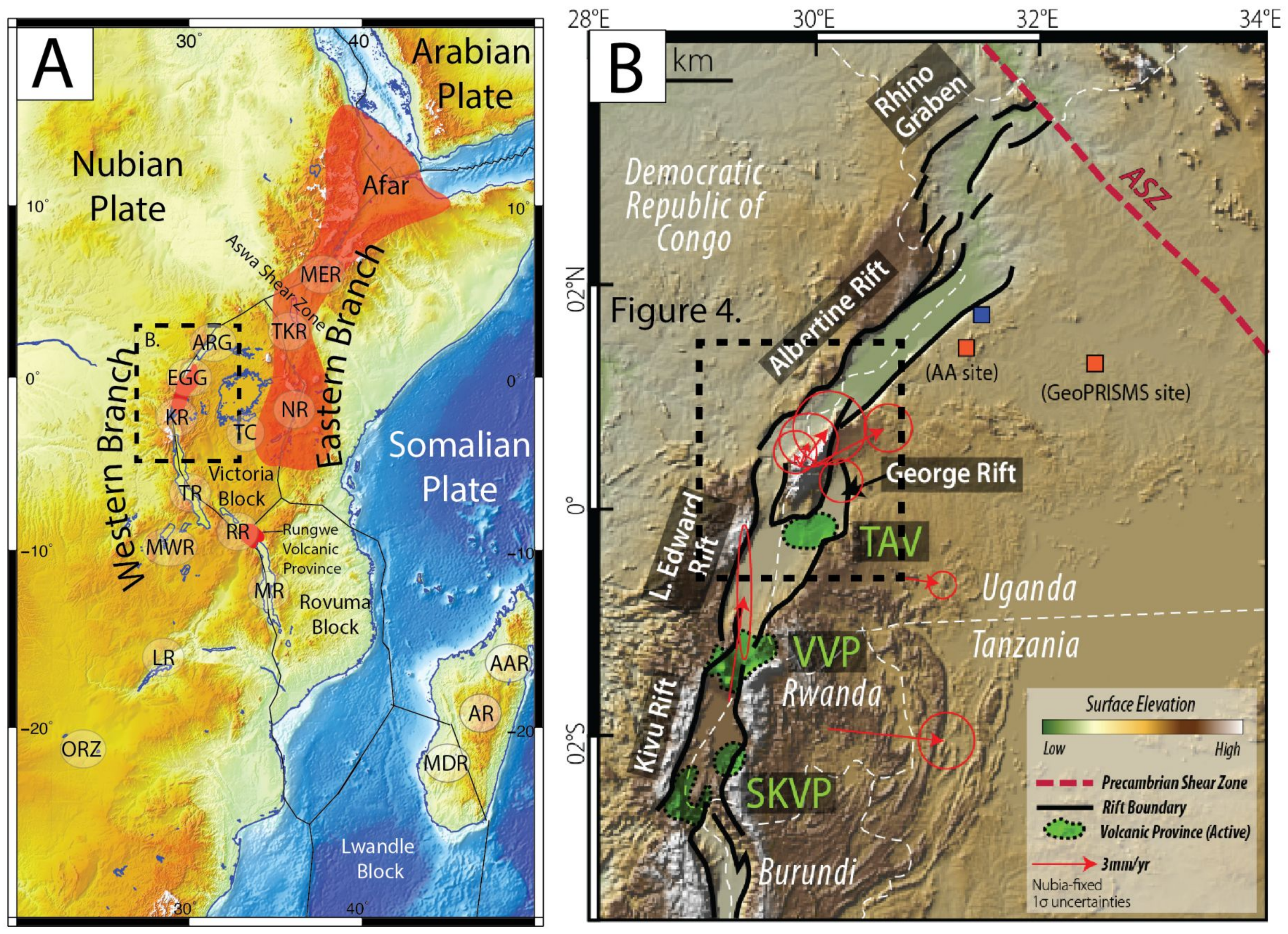

Figure 2: (A) Active rifts and key features of the EARS. Red zones are approximate zones of magma-assisted rifting. Hashed lines are zones of deformation from Stamps et al. (2021). MER = Main Ethiopian Rift. EGG = Lakes Edward-George Graben. ARG = Albertine-Rhino Graben. TC = Tanzania Craton. MWR = Mweru Rift. TKR = Turkana Rift. NR = Natron Rift. AAR = Alaotra- Ankay Rift. AR = Ankarata Rift. MDR = Morondava Rift. RR = Rukwa rift. MR = Malawi Rift. LR = Luangwa Rift. ORZ = Okavango Rift Zone. (B) GPS velocity solution from Stamps et al. (2018) showing new campaign and continuous GNSS sites as blue and orange squares, respectively. This work entails using these new sites. Quaternary volcanoes as green triangles. TAV = Toro-Ankole Volcanic Field. VVP = Virunga Volcanic Province.

PROJECT OBJECTIVES

1. Use magnetotellurics (MT), gravity, and passive-source broadband seismology to determine lithospheric thickness, map the rigidity and density of the lithosphere, mantle-flow direction from deep anisotropy, potentially frozen lithospheric anisotropy, and to assess the presence or absence of melt at depth.
2. Use magnetics, gravity, and seismology to determine the thermal structure and thickness of the crust beneath the rift zone.
3. Constrain surface motions with new GNSS observations.
4. Collect geomorphic samples for Quaternary geochronology of landforms cut and offset by the rift-bounding and intra-basinal faults to determine their fault slip rates.
5. Conduct detailed field observations to examine the geometry and kinematics of rift related structures and pre-rift (Precambrian) structures. Use these observations to evaluate the extent to which the Precambrian structures have been reactivated during rift evolution and possible seismic risks of these structures.
6. Use industry seismic reflection data constrained by well data to investigate fault evolution, as well as, strain migration and evolution through time.
7. Use the geochemistry of hot springs and measurements of magmatic gas fluxes along faults and non-faulted areas to identify mantle magmatic signatures and their variability along strike, and to establish the presence or absence of shallow magma chambers and how fluids/volatiles assist faulting. Simultaneously, quantify the variability of tectonic CO_2 flux to the atmosphere.
8. Use the helium isotope data from recent lavas and xenoliths from the rift axis to determine the magmatic sources beneath the northern Western Branch of the EARS.
9. Jointly use our observations to simultaneously determine temperature, density, and compositional heterogeneities, as well as, use these products as input to develop a new class of geodynamic models for magma-poor rifting.

FIELDWORK AND BROADER IMPACTS

The DRIAR team plans to initiate fieldwork in January 2022 with a temporary seismic deployment (PASSCAL), magnetotelluric observations, structural geologic fieldwork, campaign GNSS observations, and the installation of 4 new continuous GNSS stations (Figure 3). In summer 2022, we also plan to conduct the first of two field schools to train our African collaborators and a few US participants in the techniques that are being used for this project. The field school is part of our comprehensive broader impacts plan that encompasses capacity building, societally relevant scientific outcomes, communicating broadly our results through educational videos and open access data, and by providing professional development and mentoring guidance to students participating in the DRIAR project (Figure 4).

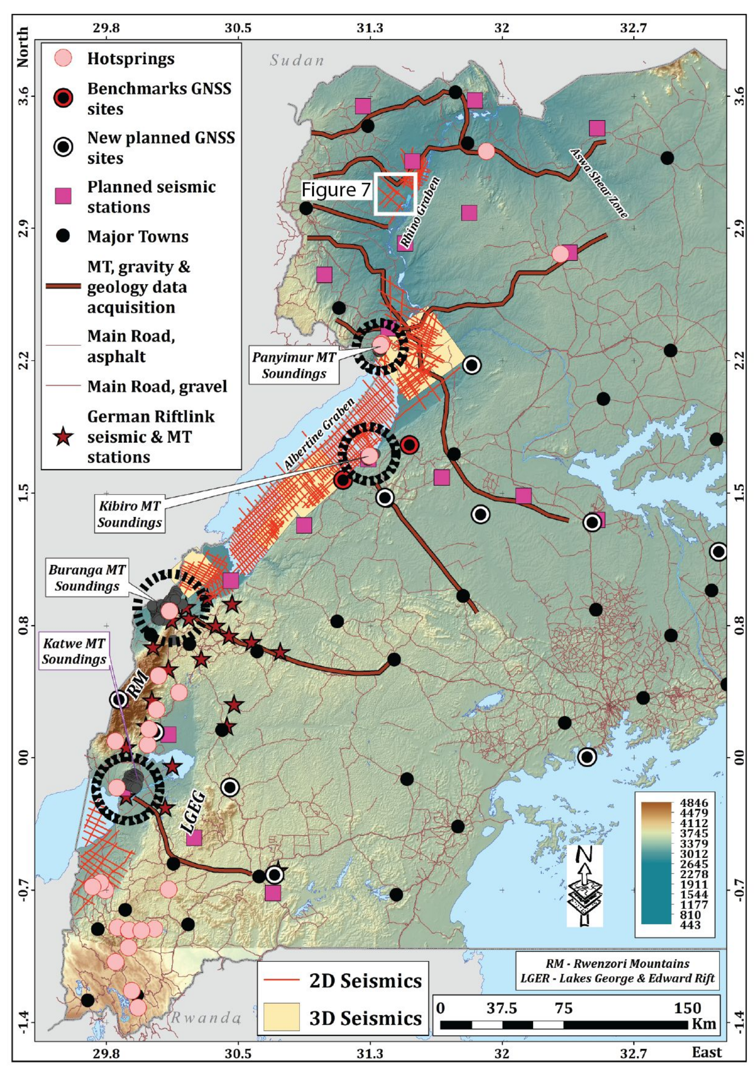

Figure 3. A map of the study area (only in Uganda) showing topography, hot springs, streams, lakes, and major towns. Also shown are proposed transects for the acquisition of geological and geophysical data and seismic profiles. Where possible, the transects will also be used to collect gas samples in addition to samples taken at hot springs.

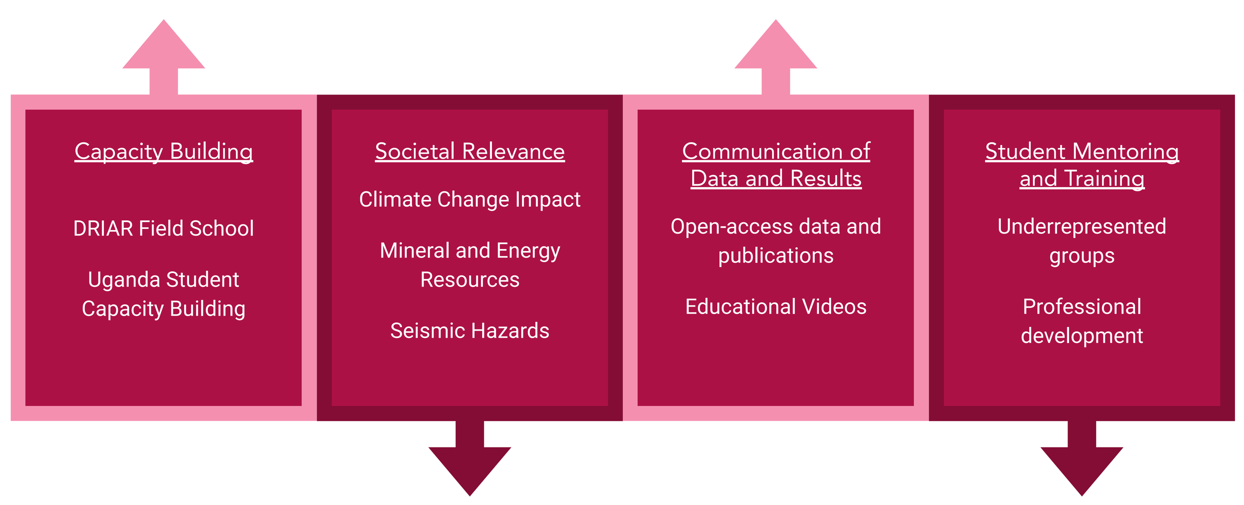

Figure 4. Diagram outlining the broader impacts components of the DRIAR project.

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