Thermochronology and Evolution of the Malawi Rift (Ref IAP2-18-90)

University of St Andrews
In partnership with University of Glasgow

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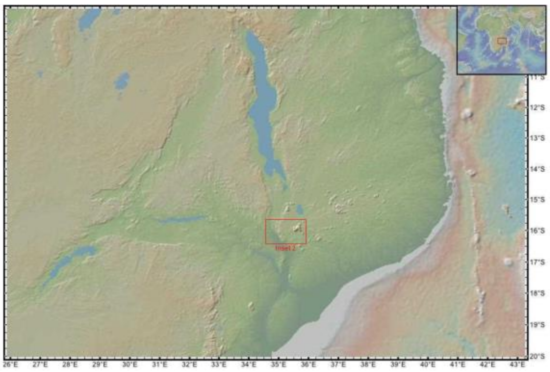
Key Words	1. Geothermal energy, seismic hazard, water resources, continental tectonics, East African Rift.

Overview

The Malawi rift forms the southernmost, actively propagating tip of the East African Rift (EAR) system. Whereas most of EAR shows punctuated volcanic effusion evolving through time and continuing to the present day, the Malawi rift is notionally non-volcanic, formed of listric normal fault systems cutting Precambrian crystalline basement in an alternating half-graben geometry.

Nonetheless, ~20 hot springs ascend to the Malawian landsurface (Dulanya et al., 2010) suggesting as-yet unerupted magma chambers at shallow to moderate depth (Branchu et al., 2005). The potential for these magma chambers to provide geothermal energy from high-geothermal gradient locales (either hot dry rocks or hot saline aquifers); or for the hot springs themselves to offer opportunities for low-enthalpy geothermal direct use are currently the focus of much scientific attention (Dulanya, 2006; Gondwe et al., 2016; current World Bank investment programme bringing forward two sites to Phase-II Geothermal Feasibility study).

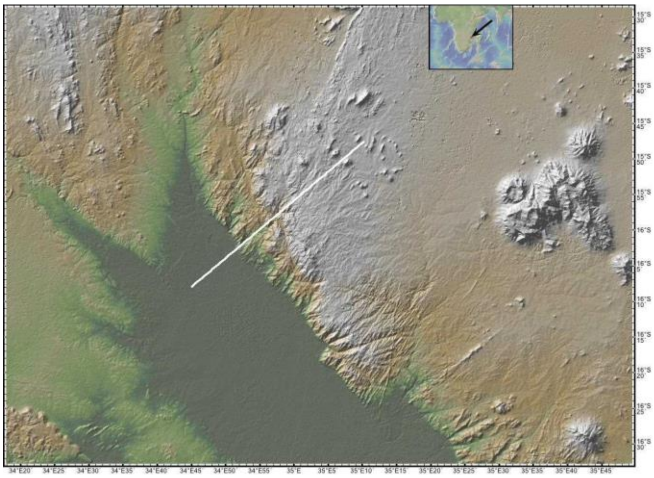
Malawi currently derives 95% of its electricity from hydropower, which makes it highly vulnerable to natural cycles and societal demand on water resources. Diversification of its energy production profile to multiple renewable strategies could help Malawi develop economically and model scalable strategies for adoption throughout East Africa.



Inset 1: SRTM-based digital terrain model of southernmost EAR, Lake Malawi extending south to the Zambezi drainage. Inset 2 study area in red outlined box.

This studentship will evaluate the geothermal energy resource potential of Malawi; will discern the water balance in sedimentary aquifers containing hot springs; and it will address the seismic hazard in Malawi's most-deprived and hence most-vulnerable geographic districts, Chikwawa and Nsanje. It will do this by measuring noble gas geochemistry (concentrations, ratios, and isotopic composition of He, Ne, and Ar) of hot spring waters to address mixing ratios of connate, deep-seated, and meteoric-recharge waters; and to assess heat sources as magmatic, mantle-derived, and/or radiogenic (hot granite).

It also will use (U-Th-Sm)/He thermochronology of apatite and zircon and fission-track thermochronology of apatite to assess the age and rate of exhumation across Malawi's highest-relief tectonic escarpment, the Thyolo Scarp, comprised of listric faults soling into a fundamental normal fault which either is the unbroken continuation of the Nsanje fault, which broke further to the south with magnitude M_w 5.6 on 8 March 2018; or else is an on-strike en-echelon fault in the same network.

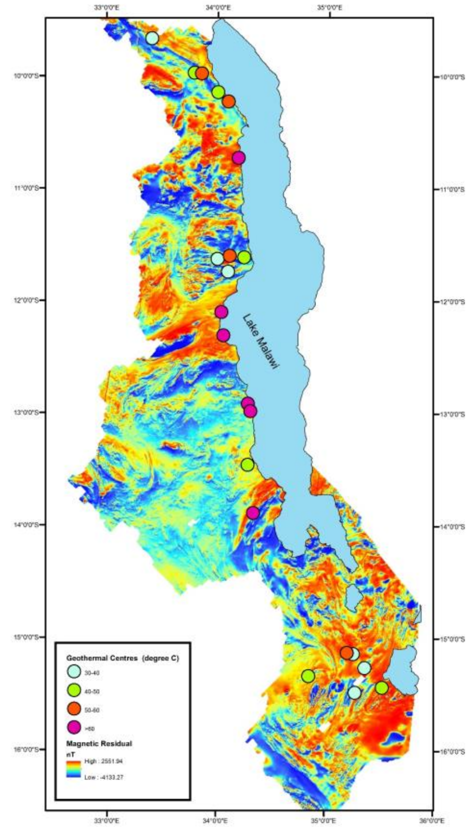


Inset 2: Thyolo Scarp descending 1200 m from ~1300 m.a.s.l. atop Malawian highlands at top right of inset to the floor of Chikwawa graben, ~90 m.a.s.l. in lower centre of inset. The fault network forming this huge scarp is along-strike with recently-broken, Magnitude 5-6 seismogenic faults some ~50 km to the south and east. The population centre of Blantyre is just off this inset to the immediate north. (U-Th-Sm)/He thermochronology would be performed across this escarpment along the profile indicated in white.

An earthquake of similar magnitude breaking further north, near the Chikwawa study area of this project, would impact on >25% the population of Malawi, including earthquake-vulnerable structures housing >1 million residents of Blantyre, the nation's finance, commercial, and legal centre.

This studentship will use UAV (drone)-based structure-from-motion algorithms to create high-resolution digital elevation models of the Thyolo Scarp and critical hot springs, in order to fully describe the interplay between fault network geometry and hydrogeologic flow.

Using GIS, physical parameters of the geothermal resource will be mapped atop social parameters (population density, electrical grid proximity, heat demand) to inform the ongoing World Bank Geothermal Feasibility Study for Malawi.



Inset 3: Aeromagnetic anomaly image of Malwi with 22 hot springs colour-coded by temperature. Noble gas systematics of these hot springs will reveal derivation of heat from mantle, crustal magma chamber, and/or radiogenic origin; and water balance of deep-sourced versus meteoric-recharge flow.

Methodology

Noble gas geochemistry will be undertaken in Glasgow at the Noble Gas Isotope Facilities Gas Lab and Helium Thermochronology Lab at the Scottish Universities Environmental Research Centre (SUERC), where Professor Fin Stuart is Director. Stuart has active research interest in the thermochronology of continental rifts, active faults, and the East African (including Malawian) rift (Luszczak et al., 2017; Mortimer et al., 2016; Torres Costa et al., 2015).

Geological and geophysical interpretation will take place at University of St Andrews with Dr Tim Raub, collaborating with colleagues in Malawi.

At University of Malawi-Chancellor's College (Zomba), Dr Blackwell Manda of the School of Geography and Geology is a former Principal Geologist of the Malawi Geological Survey and specialises in basement geology and geodynamics of Malawi and the East African Orogen. Dr Zuze Dulanya, former Malawi Geological Survey geologist now in the UM-CC Geography and Geology School, is a hydrogeologist and has authored several publications on the water resource management and geothermal energy potential of Malawi.

Drs Manda, Dulanya, and Raub will supervise and assist fieldwork in Malawi. They have been collaborating over three field seasons and two years so far, studying granitoid geodynamics, hydroclimatology, and geothermal energy in Malawi. Impact reports linked at: http://geophysicistatlarge.blogspot.com/2017/09/malawi-geothermal-2017.html
and
https://www.scotland-malawipartnership.org/files/1115/0937/4752/St_Andrews_Geothermal_Malawi_Handout.pdf.

Timeline

Year 1: Autumn: Noble gas study, existing hot springs water samples; **Winter:** rangefinder age-dating, preliminary Chikwawa transect granitoid samples (n=4). **Winter and Spring:** Drone certification qualification. **Summer:** Field season in Malawi, collection of all remaining hot springs water samples and ~8 additional (U-Th-Sm)/He thermochronology samples. **Throughout:** Participation in team activities developing geology and geophysical/geodynamic synthesis of Malawian basement terrains. Submission of co-authored manuscripts.

Year 2: Autumn: Mineral separation of new samples and noble gas geochemistry of all hot springs water samples. **Winter:** Submission of First-authored manuscript #1 on hot springs noble gas geochemistry with geothermal and water resource implications. **Spring:** Thermochronology on all samples. **Summer:** Submission of First-authored manuscript #2 on exhumation of Thyolo highlands and development of Chikwawa Scarp

Year 3: Autumn-Winter: Synthesis of southern/Malawian EAR thermochronology and implications for seismic hazard and neotectonics of the Shire/Zambezi Rifts. **Spring/Summer:** research arising from prior work programme

Year 3.5: write-up, defence

Training & Skills

The student will gain certification as a licensed UAV (drone) operator and will develop credentialed skills in matlab. The student also will develop experience planning and executing fieldwork in remote conditions and working with social science and policy stakeholders.

References & Further Reading

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