SEGMeNT: An NSF-Continental Dynamics project to study the weakly extended Malawi (Nyasa) Rift

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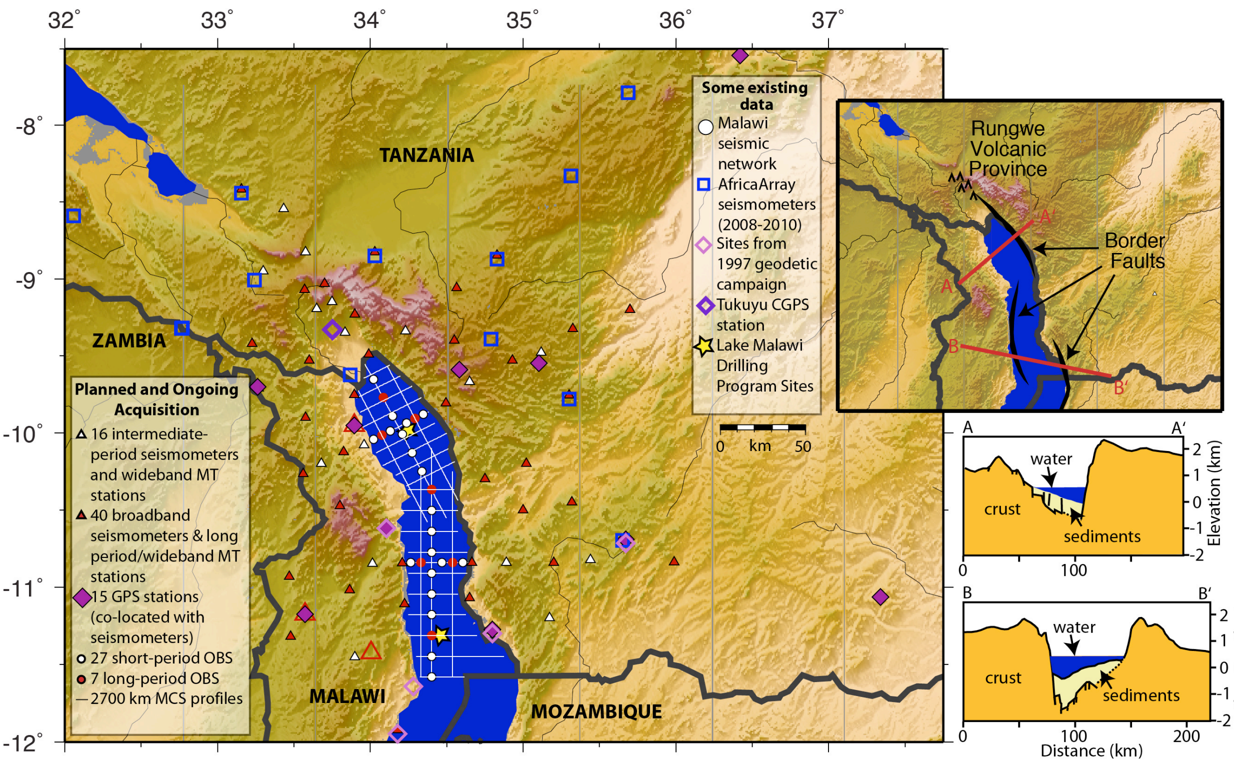
We are beginning a multidisciplinary, multinational study focused on the northern Malawi (Nyasa) rift that includes characterizing deformation and magmatism in the crust and mantle lithosphere along 2-3 rift segments, quantifying temporal patterns in deformation, and evaluation of the source of magmas. The northern Lake Malawi (Nyasa) region in the East African Rift System is an excellent locality to examine early-stage rifting at slow rates in strong, cold lithosphere. Only a small amount of stretching has occurred (<15%)[Ebinger, 1989], and extension is estimated to be proceeding relatively slowly at ~3.5 mm/yr [Stamps *et al*., 2008], but model constraints are very sparse. It exhibits pronounced tectonic segmentation, which is defined in the upper crust by ~100-km-long border faults [Ebinger *et al*., 1987]. The length scales of segments together with flexure associated with faulting [Ebinger *et al*., 1991], occurrence of deep seismicity [Jackson and Blenkinsop, 1993; Foster and Jackson, 1998] and inferred mafic lower crust [Nyblade and Langston, 1995] suggest that rifting is occurring in relatively strong, cold lithosphere. Very little volcanism is associated with rifting, providing a serious test for recent models that require intrusive magmatism to initiate rifting in cold, strong continental lithosphere [Buck, 2004]. Strikingly, the only surface expression of magmatism in this system occurs in an accommodation zone between segments rather than in a segment center [Furman, 2007], in clear contrast to MORs and mature rifts. This relationship is also observed elsewhere in the Western Rift of the East Africa Rift system and in other early-stage rifts, but the 3D distribution of magma at depth and its role in extension are unknown in all cases.

In the SEGMeNT (**S**tudy of **E**xtension and ma**G**matism in **M**alawi a**N**d **T**anzania) program, we will acquire a suite of geophysical, geological and geochemical data to better understand this rift system. Active and passive seismic data and magnetotelluric (MT) data will reveal the 3D structure of the crust and lithosphere at a variety of length scales, from the architecture of border faults and accommodation zones to the distribution of deformation and magma (if present) in the mantle lithosphere. Geochronology, thermobarometry and geochemistry of volcanic rocks will yield constraints on the origin of magmatism, including variable contributions from sub-lithospheric plume and asthenospheric versus lithospheric sources. Integrated with surface deformation, seismicity, and rift stratigraphy, this will yield constraints on the evolution of deformation and magmatism at a range of time scales. New details of syn-rift stratigraphy will be correlated to a high-resolution chronologic framework developed from scientific drilling in Lake Malawi, and will provide constraints on the relationships between rift topography and regional climate. Comparisons of active and cumulative deformation patterns may enable us to evaluate the importance of episodic, seismic and/or magmatic events in accommodating extension and how they relate to segmentation. We hope that this powerful combination of temporal and spatial constraints will produce unique insights into the initiation of segmentation and magmatism during continental rifting.

In July 2012, a network of continuous GPS stations was deployed across the rift (see abstract of Elliott et al and map below), and will remain deployed for the next five years. Fieldwork in the Rungwe volcanic province was carried out in August 2012 to collect samples for geochemical analysis. We plan to deploy the passive seismic network and acquire MT data in the summer of 2013, and acquire active-source seismic data in Lake Malawi (Nyasa) in early 2014.



A core part of the GeoPRISMS RIE science plan concerns the initiation of rifting and the evolution of early-stage rifts. Key questions concern the origin and role of magma during earliest rifting, the formation and evolution of rift segmentation and its manifestation at depth in the crust and lithosphere, and the temporal style of deformation (episodic versus steady-state). The SEGMeNT program is strongly aligned with GeoPRISMS RIE objectives, and there are several ways in which our program and other studies in the Malawi (Nyasa) rift can contribute to GeoPRISMS science in the EAR. First, we would be excited to initiate new collaborations that build on or are complementary to our funded CD program. Additionally, by comparing regions within the EAR that have undergone different amounts of extension, our community can illuminate the evolution of extensional provinces from inception to breakup. For example, a funded CD program by Estella Atekwana and colleagues targets the extensional province beneath the Okavango delta, where rifting is just commencing (see Atekwana white paper). Comparing patterns of deformation and magmatism beneath the poorly known, weakly extended rifts of the Okavango Delta and Lake Malawi (Nyasa) with the well-studied, mature rifts in Ethiopia and Afar would reveal the progression of magmatism and deformation with increasing amounts of cumulative stretching, and provide vital constraints on the structure and rheology of extending continental lithosphere.

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