The Lake Tanganyika Drilling Project: A potential ~10Ma continuous record of integrated tectonic and climatic history for the western African rift.

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Proposed Site: Lake Tanganyika, East Africa
Themes addressed: GeoPrisms Draft Science Plan Overarching Themes: *3.3 Climate-Surface-Tectonic Feedbacks* and 3.5 *Plate Boundary Deformation and Geodynamics*; Rift Initiation and Evolution Initiative Themes: 5.2. How do fundamental rifting processes (such as tectonics, magmatism, and erosion, transport, and sedimentation), and the feedbacks between them, evolve in time and space?; 5.3. What controls the structural and stratigraphic architecture of rifted continental margins during and after breakup? and 5.4 What are the mechanisms and consequences of fluid and volatile exchange between the Earth, oceans, and atmosphere at rifts and rifted margins?

Key existing and forthcoming data/infrastructure

- NSF-supported East African Lakes Drilling Workshop (Providence Nov 2011) has already chosen Lake Tanganyika (Fig. 1) as its highest priority drilling target for the East African Rift (Russell et al., 2012).Three prior seismic stratigraphic and four coring campaigns since the 1980s have demonstrated very thick sediment accumulation and areas of slow (~0.1mm/yr) accumulation in this lake, suggesting that 10 My of lake history could be recovered in some areas (e.g. Rosendahl, 1988; Scholz et al., 2007; McGlue et al, 2008; Tierney et al., 2008; Burnett et al., 2010) (Fig. 2) .
- We will have access to new industry seismic reflection data currently under collection by several hydrocarbon exploration companies and may be able to piggyback on their exploration efforts for locally focused studies (collaborations established at the Providence meeting).
- There is a strong likelihood of cofunding through the International Continental Scientific Drilling Program because of multiple, compelling science questions to be addressed (tectonics, paleoclimate, lacustrine faunal evolution in isolation, implications for human origins).

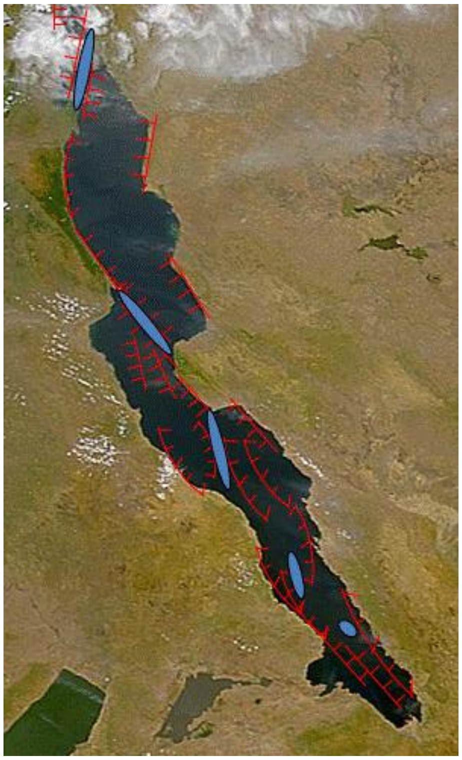
Lake Tanganyika (LT) is the largest (~34000km^2) deepest (~1500m), and oldest (estimated 9-12Ma, Cohen et al., 1993) of the African rift lakes. It provides a compelling target for scientific drilling for many reasons, and in particular, should be an attractive target for consideration within the context of the GEOPRISMS-East African Rift initiative. A variety of targets within the lake would provide opportunities to examine different types of questions. The longest and most continuous records would be collected from intrabasin highs in deep water (atop horst blocks on accommodation zones) where extremely slow sedimentation rates, coupled with water depths great enough to avoid episodic desiccation during lake level low stands could yield records covering much of LT's history and would lack turbidite or mass flow complications Cores from similar settings in anoxic lake basins reveal annual varves lacking bioturbation that provide an exquisite record of changing climate and tectonics (e.g., Tiercelin et al., 1994; Cohen et al., 2006). Alternatively, records from basin flanks would be shorter in duration but could sensitively record local watershed events, thermochronologic histories of rift margin uplift, and climatic/tectonic interactions affecting sedimentation rates and vegetation records. With existing and targeted new seismic lines it will be possible to stratigraphically link the horst and deep basin sites.

LT is a dynamic rift in cratonic lithosphere far from subducting slabs, providing an ideal setting for rift initiation studies. Stratigraphic records in the Tanganyika area suggest that rift-related volcanism may have occurred at 25 Ma (Roberts et al., 2012), but has far less resurfacing from volcanism than lakes to the north (e.g. Turkana). The long, large-offset border faults define a profound along-axis segmentation that persists throughout repeated cycles, and most strain in the LT basin is localized along a few fault systems, which allows for relatively “easy” reconstructions of rift architecture through time.. LT has the greatest seismic energy release in the EAR, and entire 100 km-long border faults may rupture during discrete earthquakes (e.g., Jackson and Blenkinsop, 1996), providing insights into the initiation and maintenance of rift segmentation.. With the detailed time-history record afforded by cores, these characteristics could facilitate fault slip rate/paleoseismicity studies discussed below. The high-resolution, long time span of LT core records would provide an unprecedented laboratory for examining the initiation and linkage of faults across and along the length of the rift, the rates of vertical crustal movements, and earthquake cycles, all of which produce the pronounced along-axis basin asymmetry. These results, in turn, could be compared with historic records to improve our understanding of time-averaged vs instantaneous deformation rates, and lithospheric rheology. Data from well sited drill cores at Lake Tanganyika could address the overarching question of “How do rifts initiate and evolve?” by providing specific data on rates of border fault slip and basin subsidence, and repeat time of major earthquakes using seismite records (e.g. Boës and Fagel, 2008), which would have both theoretical and applied implications. A long core from LT could record how basin systems evolve as border fault segments are linked (e.g., Scholz et al., 1998; Densmore et al., 2004; 2006), and to test models of strain localization during progressive rifting episodes (e.g., Ebinger, 2005). Down hole experiments could be conducted in the borehole to determine stress states and to measure heat flow.

A long borehole record from LT has the potential to be used to understand a wide array of source to sink processes in an active rift. The LT rift has uplifted flanks rising more than 2 km above the 1000 km-wide EAR plateau that have fundamentally changed drainage and vegetation patterns. A combination of provenance studies (using detrital zircon chronology and petrography), paleoerosion studies (through cosmogenic radionuclides and detrital low temperature thermochronology methods (e.g. Balco and Shuster, 2009; Stock et al, 2006; Rahl et al., 2007), and landscape vegetation history (through pollen and charcoal analysis) would provide an unparalleled opportunity to integrate our understanding of how rift flank exhumation couples with climate (locally affected by orographic uplift) to impact erosion rates and patterns. We could then ask questions about how orographic relief is created and maintained in continental rifts over geologically long intervals, given the high preservation potential of an LT record. Through careful integration of the drill cores with the seismic stratigraphic record available for LT we could extend our conclusions about rates of exhumation and rift basin infill far from the individual drill sites. By extending this approach along the rift axis (LT covers ~600km) and through multiple lake level phases we could eventually develop a full 4-D understanding of rift lake basin evolution as it interacts with changing climate regimes.

Basin analysis studies of the modern rift at LT could have applied implications of great interest to potential industry partners, which could in turn reduce the cost of the project to NSF considerably. Exploration wells in nearby Lake Albert demonstrate that sediments <10 My in age can host a robust hydrocarbon system. An LT borehole could allow us to ask whether fault planes are open or whether aqueous, hydrocarbon, and or magmatic fluids are flowing along stratigraphic horizons. How are high wax oils trapped at shallow levels? How does fault architecture control permeability and fluid pathways? And is there a potential to date oils in a high heat flow but relatively young basin?

A drill coring campaign at LT will engage a wide range of scientists outside of the GEOPRISMS community, making the funding base for this project much broader. The potential of a continuous environmental record spanning the last 10Ma from tropical Africa would excite paleoclimatologists and climate modelers interested in long term interactions of E. African uplift, and oceanic gateway impacts on the Indian Ocean’s thermal history, the evolution of the monsoon, and even N Atlantic hurricanes (e.g., Cane and Molnar, 2001; Feakins et al., 2007). Lake Tanganyika is one of the global hotspots of lacustrine endemic biodiversity (especially among its cichlid fish, molluscs and crustaceans). A lake core record there holds the promise of documenting and understanding the dynamics of speciation in the context of both an evolving rift basin system and changing climate regimes (Cohen, 2011). And finally, there is potential synergy with the paleoanthropology community’s interest in obtaining a continuous record of environmental history from a single area covering the entire span of human evolution (e.g. deMenocal, 2004; Feakins et al., 2005).



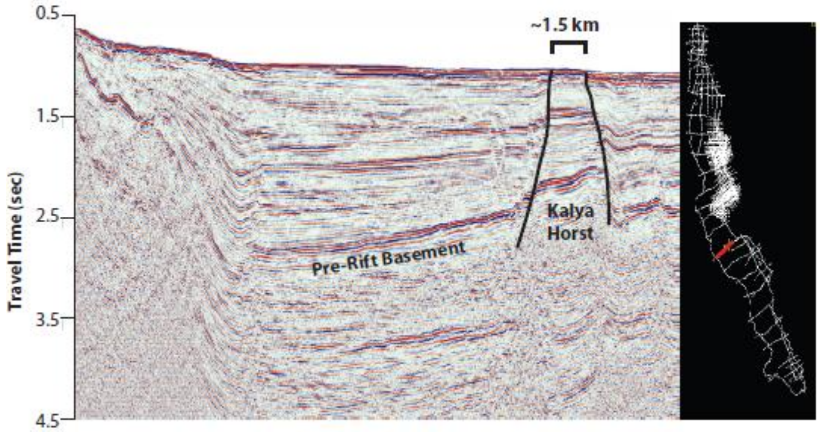


Figure 1 (left). Lake Tanganyika, showing major faults and accommodation zone highs (horsts-purple).
Figure 2 (above). Seismic section from the northern end of the Kalya horst; location of the seismic section within lake Tanganyika illustrated by the red line within the seismic grid at right. Note the presence of a continuous and condensed sedimentary sequence above pre-rift basement on the Kalya horst, indicated by the bracket. Data are from Project PROBE (Rosendahl, 1988). Figure from Russell et al. (2012).

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