Studying early stage of rifting in Northern Tanzania

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The breakup of continents and creation of new oceans is a fundamental yet poorly understood plate tectonic process. The identification of the processes linked to continental break-up is however not only essential in terms of fundamental Earth Sciences because they result in the formation of new plate boundaries, but their clear identification is also a major economic challenge, as they control the formation, location and storage of energy resources (hydrocarbons, geothermal). As human settlement expands to more and more remote regions, and as we obtain longer historical records, we find that earthquake, volcanic and landslide hazards in continental rift zones have major societal impacts on the rapidly growing human populations living within or near rift zones worldwide.

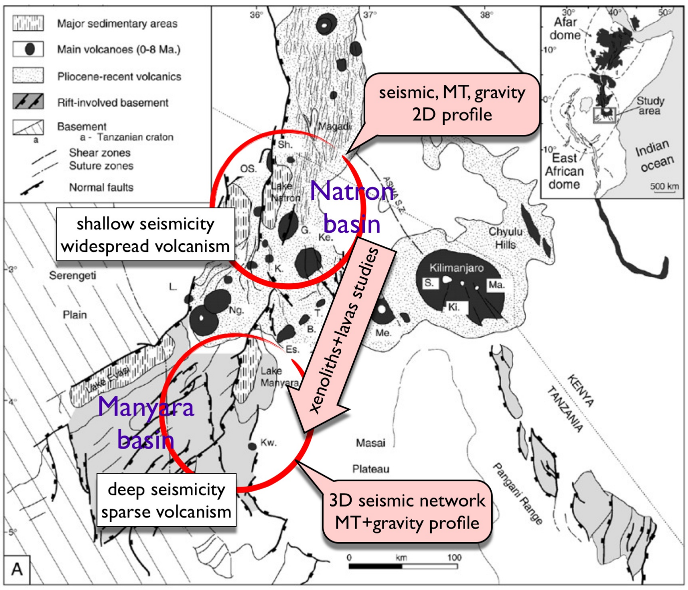
In classical rifting models, lithospheric stretching leads to upwelling and adiabatic decompression melting of asthenosphere, resulting in magmatism after significant lithospheric thinning (e.g. Sengör & Burke 1978; White & McKenzie 1989). Yet, many continental rift sectors experience magmatism coincident with rift initiation (e.g. Ebinger et al. 2008), implying that magmatism may be a key driving force, as opposed to a consequence, of lithospheric thinning (e.g. Buck 2006). Recent models of rifting also insist on complex interaction between asthenospheric dynamism and far field stresses, between deep processes and local inherited fabrics (Huismans et al. 2001; Petit et al. 2008).

Largely 2D geophysical, structural and geochemical studies of evolved continental rifts and successfully rifted margins document the modification of the crust due to plate stretching and magmatic processes (e.g. Keir et al. 2009; Leroy et al. 2008). Yet in those cases, the time sequence of magma production, storage, eruption and interaction with tectonic processes are impossible to deconvolve. Moreover, rifts develop in heterogeneous continental lithosphere and are thus inherently three-dimensional. Their interaction with pre-existing lithospheric structures (composition, rheology, thickness) may contribute to their localisation. Although the contribution of inherited lithospheric thickness, composition, and structural variations and rheology may seem obvious (Vauchez et al. 1997; Tommasi & Vauchez 2001; Ebinger 2005), its influence on the localisation of the deformation, its temporal relationship with magmatism and rupture during rift inception have yet to be examined.
Many fundamental questions regarding inception and development of a continental rift in thick lithosphere still remain unanswered:

- What are the spatial and temporal relationships between magmatism and faulting?
- How do these interactions affect the strain localisation?
- What are the effects of magmatism in terms of rheological weakening of the lithosphere?
- How do the inherited structures at the lithosphere-asthenosphere boundary (LAB) through to the crust control the localisation of the deformation and magmatism?

The large number of ongoing projects demonstrates the growing interest of the international Earth Sciences community to identify the processes responsible of the lithospheric weakening that leads to strain localisation and the continental break-up (e.g. Buck 2006; Bialas et al. 2010, AfricaArray 2005-2010). The recent EAGLE and DoRA projects (NERC, NSF and ANR, respectively) greatly helped to characterize the late stage of magmatic rifting processes (e.g. Ebinger and Casey 2001; Keir et al. 2006; Rowland et al. 2007). However, they focus on systems already extremely influenced by significant lithospheric thinning and resultant magmatism. Our understanding of continental rifting processes also comes from 2D studies of inactive rift basins (e.g. YOCMAL ANR project) buried beneath *ca* 10 km of post-rift sedimentary strata where the thermal-mechanical response of the lithosphere to

stretching and heating has long since decayed. Moreover, along magmatic margins where large volumes of magma are intruded into the plate, the timing of magma emplacement is very poorly constrained in these deep water settings (Leroy et al. 2008). Part of us participated to those projects and we are thus fully aware of these obstacles to apprehend the onset of continental rifting, particularly how thick (>100 km) lithosphere dissects while it should be too strong to rift by plate motion stresses alone (e.g., Bott 1991; Bialas et al. 2010).
For these reasons, we target the first 5 My of a magmatic rift initiating in thick (>150 km) continental lithosphere, **where we can directly image and detect fault and magma interactions, as well as the role of inherited and rheological heterogeneities** of the lithosphere on rift localisation. In this context, **the North Tanzania system** provides an exceptional laboratory, as it is the location of the least evolved stage of magma-assisted continental rift in the East African rift system (Dawson, 1992; Le Gall et al. 2008).
We intent to fully characterize the early stages of magma-assisted continental rifting with a multidisciplinary study with coupled data acquisition and modelling tasks.
A 3D seismic, structural, and volatile geochemistry part of this project is already funded through NSF program for years 2012-2015 (Lead PI Simon Kattenhorn), and includes the Magadi basin in southern Kenya. We propose here to advantageously complement this with additional geophysical and geochemical studies in two target areas (Natron, Manyara) that span **the transition from incipient rifting with deep seismicity and sparse magmatism to shallow seismicity and widespread magmatism.**



We propose here to acquire new field, geophysical (gravity, MT, seismic), geochemical and petrophysical data in a rifting inception place, the Tanzania rift, to constrain and test 2D and 3D models of continental lithospheric extension associated with repeated episodes of magma intrusion. This combination of data acquisition, novel inversions and models will allow us to: (1) map the spatial distribution of strain in space and time using geophysical and geodetic methods; (2) constrain crust and upper mantle structure; (3) characterize the chemistry and spatial distribution of crustal fluids and magma; (4) quantify the volume of magma intruded into the crust through seismic data interpretation combined with InSAR, and (5) distinguish the role of the different processes involved in continental rifting through numerical modelling. The active collaborations between American, French, Tanzanian, and Kenyan institutions will ensure the success of this multidisciplinary project both scientifically and in terms of formation.

Project partners:

University of Dar-es-Salaam
Nelson Mandela Institute, Tanzania
University of Nairobi
Geothermal Development Corporation, Kenya
University of Idaho
University of New Mexico
University of Rochester
Rensselaer Polytechnic Institute