Tectonics of the incipient continental rifting

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Rifting incorporates the fundamental processes concerning the breakup of continental lithosphere and plays a significant role in the formation and evolution of sedimentary basins. In spite of numerous geoscientific studies, the mechanisms responsible for the initiation and development of continental rifts are still poorly understood. In order to decipher the characteristics of rifting at its earliest stage, 50 PASSCAL broadband seismic stations were installed for the SAFARI (Seismic Arrays For African Rift Initiation) experiment from 2012 to 2014 across the Malawi (MRZ), Luangwa (LRZ), and Okavango (ORZ) rift zones (Fig. 1). The studies summarized herein represent the first local teleseismic investigations to examine crustal/mantle structure and anisotropy using a dense array among any of the three rift zones.

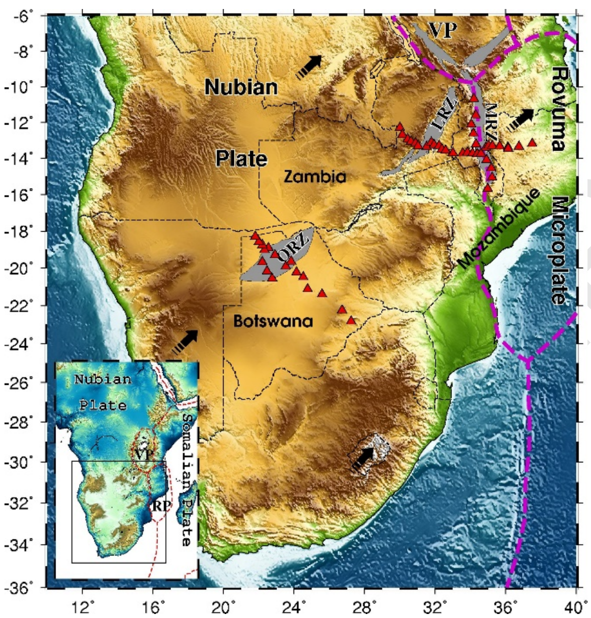

Figure 1. Seismic stations (red triangles) belonging to the SAFARI experiment situated across the MRZ of the Southern Branch and the LRZ and ORZ of the Southwestern Branch of the East African Rift System. Black arrows denote the absolute plate motion (APM) from the MORVEL plate model. Magenta dashed lines are plate boundaries. Insert: Topographic map of Africa showing the area of study with plate boundaries (dashed red lines). RP: Rovuma Microplate; VP: Victoria Microplate

Inversions of receiver function (RF) stacking and gravity modeling indicate that the crust/mantle boundary beneath the ORZ is uplifted by 4-5 km, which is related to lithospheric stretching and potential decompression melting. High ratios of the P-to-S wave velocities (Vp/Vs) beneath the border faults of both the ORZ and the MRZ are indicative of fluids percolating along major faults within the crust. Systematic NE-SW fast orientations from shear wave splitting analyses of the ORZ, LRZ and MRZ are consistent with absolute plate motion (APM) models of the African Plate constructed under the assumption of no-net rotation. Spatial coherence analysis of the splitting parameters and correspondence between the observed fast orientations and the trend of tectonic features indicate that the main source of observed anisotropy is most likely in the upper asthenosphere, probably due to simple shear associated with the relative movement of the lithosphere against the asthenosphere. RF analyses of the mantle transition zone (MTZ) beneath all three rift zones reveal an essentially ubiquitous unperturbed transition zone with a mean thickness on par with the global average. These findings suggest that it is unlikely for a low-velocity province to reside within the upper mantle or MTZ beneath the nonvolcanic southern EARS, which is also supported by the absence of significant low-velocity anomalies revealed from P-wave tomography. We postulate that the incipient segments of the East African Rift System are driven primarily by passive extension within the lithosphere attributed to the divergent rotation of the Somalian plate relative to the Nubian plate, and that contributions of thermal upwelling from the lower mantle are insignificant in the initiation and early-stage development of rift zones in southern Africa.