Lithospheric structure of an incipient continental rift: converted wave imaging of the Malawi Rift, southern East African Rift System

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The East African Rift is the textbook example of active continental rifting, devolving from a well-developed rift in the north to a slowly extending, incipient rift in the southernmost portion of the Western Branch, the Malawi Rift. There is no volcanism in this portion of the rift outside of the Rungwe Volcanic Province, which sits to the northwest of Lake Malawi. This region has a fabric of weaker, orogenic belts sandwiched between strong cratonic blocks. It is thought that these pre-existing weaknesses may strongly localize present extension, and may, indeed, be the only reason such deformation is possible despite little melt being present. In order to investigate this enigmatic rift, the SEGMeNT experiment (Study of Extension and magmatism in Malawi aNd Tanzania) deployed a network of 48 broadband seismometers, both on land and in Lake Malawi itself. Here, we use data from these stations and all other available local broadband stations to image the lithosphere with converted waves. Converted waves are sensitive to sharp changes in velocity with depth. To interpret such data in context, a high resolution local tomography model is required. We compare our results to recent surface wave imaging using SEGMeNT data [Accardo et al., 2017].

We observe a negative velocity gradient in the uppermost mantle, interpreted as the lithosphere-asthenosphere boundary, that shallows by up to 50 km beneath the rift lake. This lithospheric thinning is symmetric at the northernmost tip of the lake, adjacent to the low velocities of the Rungwe Volcanic Province. However, moving south, the rift becomes asymmetric. Thinned lithosphere is centered east of the North Basin beneath the Ubendian Belt, a Proterozoic orogenic belt with a strong northwest-southeast fabric parallel to the strike of the North Basin. The observed asymmetric thinning fits well with the local surface wave imaging of Accardo et al. In the Central Basin, between the poorly oriented Irumide Belt and Karoo-aged Ruhuhu Basin, P-to-S wave imaging suggests crustal thinning is more localized than elsewhere in the study region – the phase interpreted as the Moho shallows by up to 10 km over approx. 70 km laterally. At uppermost mantle depths, the shallowest negative velocity gradient is centered to the west of the surface rift axis, similar to the asymmetry seen by surface wave imaging around the Central Basin. These patterns may reflect the control exerted on this rift by pre-existing weaknesses: the shift in the asymmetry of the rift between the North and Central Basin reflects the different strength of the terranes hosting the rift basin. In contrast, the symmetry of the thinned lithosphere beneath the northernmost part of Lake Malawi may reflect the relative ease of deforming the lithosphere adjacent to the hot, low velocity anomaly underlying the Rungwe Volcanic Province. Alternatively, this complex deformation pattern may reflect more fundamental extensional processes in strong, cold lithosphere.