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What's melt got to do with it? Constraints on the thermomechanical state of the upper mantle beneath two end member localities in the East African Rift System using seismic observables

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We present absolute shear velocities and estimates of temperature, melt content, and grain size for the uppermost mantle beneath two end-member localities in the East Africa Rift System to address the fundamental question of how strong continental lithosphere ruptures. Our study focuses on the Main Ethiopian Rift (MER), the type location for mature continental rifting above a hotspot, and the Malawi Rift (MR), an immature rift where surface magmatism is limited to a single volcanic province north of the rift (the Rungwe Volcanic Province). By constraining the thermomechanical state of the upper mantle in these locations we aim to elucidate the role of magma on the initiation and evolution of continental rifting.

For this study we leverage more than a decade of seismic instrumentation collected within and around the MER, and the newly acquired SEGMeNT (Study of Extension and maGmatism in Malawi and Tanzania) seismic dataset focused on the northern portion of the MR. The SEGMeNT dataset now includes over 2 years of dense on-shore passive source acquisition, as well as seven unique "lake-bottom" broadband seismometers that provide continuous data coverage across the center of the MR beneath Lake Nyassa/Malawi.

To constrain shear velocity structure beneath both regions, we first employ a multi-channel cross-correlation algorithm to obtain inter-station phase and amplitude information from Rayleigh wave observations between 20-100 s period. These observations are inverted for phase-velocity maps at each period, accounting for the effects of wavefield focusing. Further, we retrieve estimates of phase velocity between 9-20 s period using spectral fitting of ambient noise cross-correlograms. Phase velocities are inverted for 3D variations in absolute shear velocities in the crust and upper mantle using a linearized inversion with starting models created via a combined grid-search Monte Carlo method. Using these models, we then estimate temperature, melt content, and grain size beneath these locations, exploiting newly developed relations between thermodynamic state variables and seismic wave-speed via the Andrade anelastic model.

Preliminary results suggest that spatial variations in shear velocity are remarkably similar between the MER and MR, with widespread low-velocity mantle overlain by higher-velocity layers associated with plateau regions. However, the absolute velocities of the upper mantle beneath the central rift valleys in these locations are drastically different, with the lowest velocities imaged within the MER reaching ~ 4.0 km/s while the lowest velocities found within the MR are limited to > 4.15 km/s. This difference extends broadly throughout the low-velocity portion of the upper mantle beneath both regions, suggesting that the asthenosphere beneath the MER is consistently slower than that beneath the MR. The lowest velocities in the MR region are strongly localized to the Rungwe Volcanic Province whereas they are more broadly distributed within the MER and surrounding western plateau. These observations suggest substantial differences in thermal state and/or melt content beneath the MR and MER, which we will quantify using our thermodynamic modeling analysis.