Plumes, plate thinning, and magmatism in the East African Rift

Tyrone O. Rooney

The East African Rift System is among the most magmatically active continental rifts, exhibiting a wide diversity of products that includes flood basalts, highly alkaline lavas, explosive silicic eruptions, stratiform rift basalts, and aligned chains of cinder cones. The generation of these products derives from the melting of thermo-chemically anomalous material in the East African upper mantle, and decompression of the upper mantle caused by lithospheric thinning during rift evolution. The central focus of this project is the interaction of these two processes during advanced rifting.

Geochemical and geophysical studies of East Africa have converged on the necessity for the presence of hot and chemically distinct material in the East African upper mantle likely derived from one of two antipodal thermo-chemical anomalies located in the deep mantle – the African Large Low Shear Velocity Province. Derivation of material from this common source helps resolve the considerable debate over the number, composition, and location of these anomalies in East Africa. As part of this project, a synthesis of existing isotopic data has been undertaken throughout East Africa that has revealed a common endmember in lava suites from Rungwe in the very south of the East African Rift System to Afar in the north. This common geochemical endmember resembles the existing hypothesized composition for the Afar plume and implies that material rising from the African Large Low Shear Velocity Province has this composition. These results confirm that the upper mantle beneath East Africa is contaminated with material derived from the deep mantle.

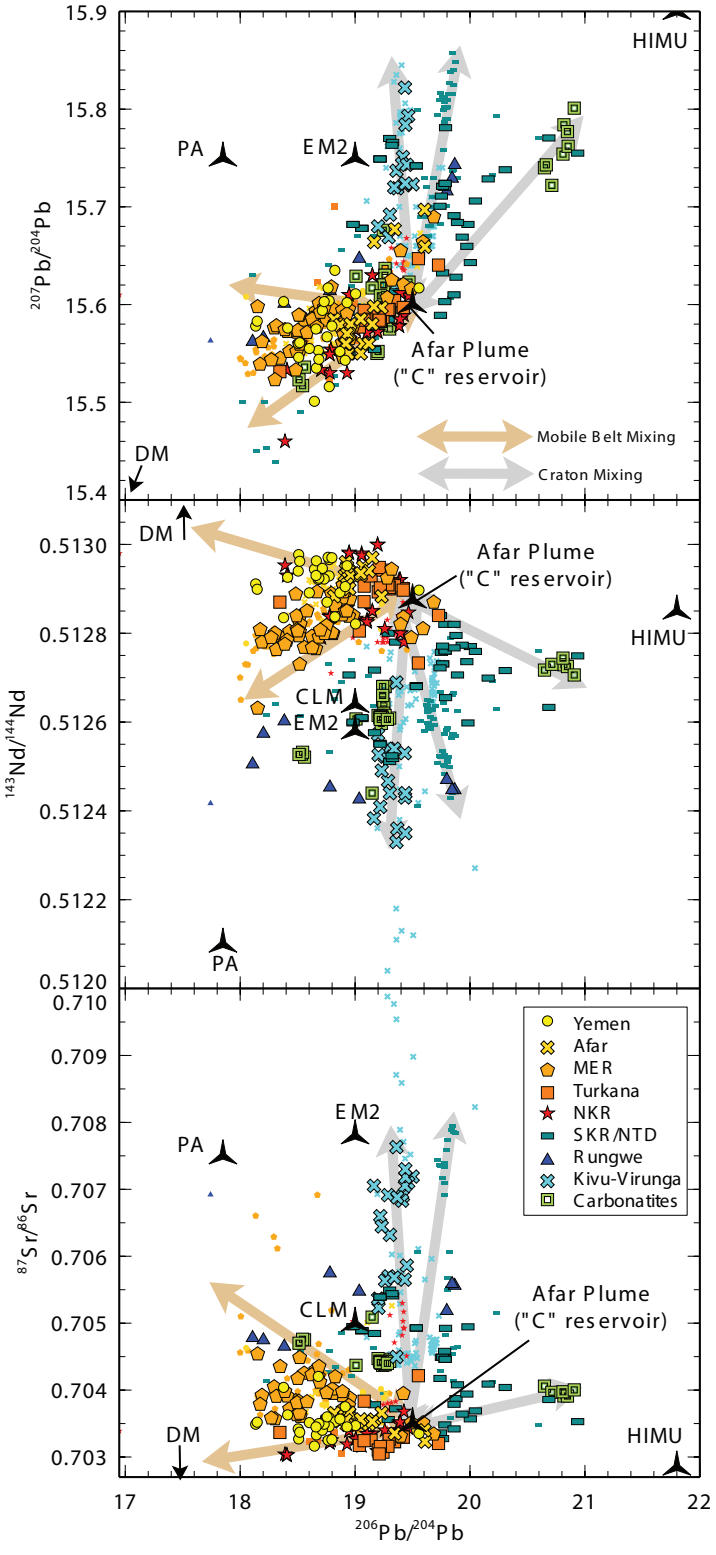

Figure 1. Quaternary Data: Isotopic variation of samples erupted 0.5 Ma to present in East Africa showing a convergence in mixing arrays on the Afar Plume isotopic composition. Samples erupted in regions influenced by the Craton are shown in cool colors, while warm colors are for those erupted within the Mobile belt. Mixing arrays (drawn by hand) are also shown as grey and orange arrows. The Pan African Lithosphere (PA), Afar Plume, CLM, HIMU, and Enriched Mantle 2 (EM2) are hypothetical endmembers derived from the existing literature. The Depleted Mantle (DM) endmember is not shown in these plots due to the compressive impact on the plotting of the dataset. These endmembers are shown as discrete points but in reality these are regions of isotopic space and are shown as the center points for clarity. Small symbols represent samples that are either 5 wt. % MgO. Figure is modified from Rooney (2020)

Continued work on this project examines the link between extensional events in the East African Rift System and the location and timing of volcanism. Research undertaken as part of this project has already identified distinct pulses of basaltic magmatism that correlate with known episodes of extension (Early Miocene, Mid Miocene, and Pliocene). Our ongoing work is focused upon Pliocene stratiform basalts from the Turkana and Afar Depressions and the transition to more focused magmatism at both locales. The aim of this ongoing work is to develop a conceptual model that uses magma generation processes as a probe of plate thinning during rifting. ■

Rooney, T. (2020). The Cenozoic magmatism of East Africa: Part II – Rifting of the mobile belt . Lithos, 360-361, 105291, doi: 10.1016/j.lithos.2019.105291

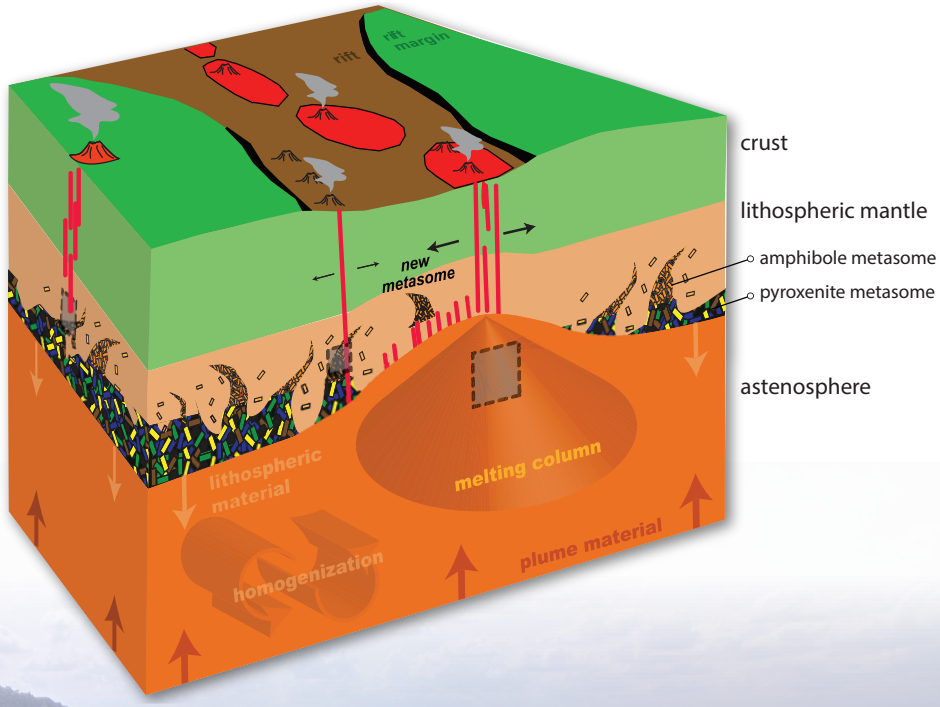

Figure 2. Cartoon depicting of melt generation processes within the Eastern Branch of the East African Rift System. The lithospheric mantle has been enriched with pyroxenite-bearing metasomes (deeper) and amphibole-bearing metasomes (shallower) generated by chromatographic metasomatism as fluids/melts passed through the lithospheric mantle. The asthenosphere in this area has been hybridized and homogenized by mixing initially with lithospheric materials (depicted as down going arrows). Figure is modified from Rooney (2020)