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Flow, melt and fossil seismic anisotropy beneath Ethiopia

James Hammond (1), J-Michael Kendall (2), James Wookey (2), Graham Stuart (3), Derek Keir (4), and Atalay Ayele (5)

(1) Department of Earth Science and Engineering, Imperial College London, London, UK, (2) School of Earth Science, University of Bristol, Bristol, UK, (3) School of Earth and Environment, University of Leeds, Leeds, UK, (4) National Oceanography Centre, Southampton, University of Southampton, Southampton, UK, (5) Institute of Space Science, Geophysics and Astronomy, Addis Ababa University, Addis Ababa, Ethiopia

Ethiopia is a region where continental rifting gives way to oceanic spreading. Yet the role that pre-existing lithospheric structure, melt, mantle flow or active upwellings may play in this process is debated. Measurements of seismic anisotropy are often used to attempt to understand the contribution that these mechanisms may play. In this study we use new data in Afar, Ethiopia along with legacy data across Ethiopia, Djibouti and Yemen to obtain estimates of mantle anisotropy using SKS-wave splitting. We show that two layers of anisotropy exist, and use shear-wave splitting tomography to invert for these. We show that fossil anisotropy with fast directions oriented northeast-southwest may be preserved in the lithosphere away from the rift. Beneath the Main Ethiopian Rift and parts of Afar, anisotropy due aligned melt due to sharp changes in lithospheric thickness dominate the shear-wave splitting signal in the mantle. Beneath Afar, away from lithospheric topography, melt pockets associated with the crustal magma storage dominate the signal and little anisotropy is seen in the uppermost mantle suggesting melt retains no preferential alignment, possibly due to a lack of mantle lithosphere. These results show the important role melt plays in weakening the lithosphere and imply that as rifting evolves passive upwelling sustains extension. A dominant northeast-southwest anisotropic fast direction is observed in a deeper layer across all of Ethiopia. This suggests that a conduit like plume is absent beneath Afar today, rather a broad flow from the southwest dominates in the upper mantle.