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Mapping the evolving strain field during continental breakup from crustal anisotropy in the Afar Depression

D. Keir (1), M. Belachew (2), C. Ebinger (2), M. Kendall (3), J. Hammond (4), G. Stuart (5), A. Ayele (6), and J. Rowland (7)

(1) University of Southampton , (2) University of Rochester, (3) University of Bristol , (4) Imperial College London , (5) University of Leeds, (6) University of Addis Ababa , (7) University of Auckland

Rifting of the continents leading to plate rupture occurs by a combination of mechanical deformation and magma intrusion, yet the spatial and temporal scales over which these alternate mechanisms localize extensional strain remains controversial. Here we quantify anisotropy of the upper crust across the volcanically active Afar Triple Junction using shear-wave splitting from local earthquakes to evaluate the distribution and orientation of strain in a region of continental breakup. The pattern of S-wave splitting in Afar is best explained by anisotropy from deformation-related structures, with the dramatic change in splitting parameters into the rift axis from the increased density of dyke-induced faulting combined with a contribution from oriented melt pockets near volcanic centres. The lack of rift-perpendicular anisotropy in the lithosphere, and corroborating geoscientific evidence of extension dominated by dyking, provide strong evidence that magma intrusion achieves the majority of plate opening in this zone of incipient plate rupture.