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Multiple mantle upwellings beneath the Northern East-African Rift System from relative P- and S-wave traveltime tomography

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Mantle plumes have been invoked as the likely cause of East African Rift volcanism and extension. However, the nature of mantle upwelling is debated, with proposed configurations ranging from a single broad plume, the African Superplume, connected to the LLSVP beneath Southern Africa, to one or more distinct lower-mantle sources along the rift. We present a new relative travel-time tomography model that images detailed P- and S-wave velocities from P,S and SKS phases below the northern East-African, Red Sea and Gulf of Aden rift. Data comes from stations that cover the area from Tanzania to Saudi Arabia. The aperture of the integrated dataset allows us to image for the first time structures of $\sim$100 km length scale down to depths of 900 km beneath this region. Our images provide evidence of at least two low-velocity structures with a diameter of $\sim$200 km that continue through the transition zone and into the lower mantle: the first extends to at least 900 km beneath Afar, and a second reaching at least 750 km depth just west of the Main Ethiopian Rift, a region with off-rift volcanism. Taking into account seismic sensitivity to temperature and thermally controlled phase boundary topography, we interpret these features as multiple focused upwellings from below the transition zone with excess temperatures of 100$\pm$50 K. The scale of the upwellings is smaller than any of the previously proposed lower mantle plume sources. This suggests the ponding or flow of deep-plume material below the transition zone may be spawning smaller upper-mantle upwellings.