Lava architecture and vent distribution in an active rift (Manda-Hararo, Afar, Ethiopia)

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The Manda-Hararo rift segment in Afar (Ethiopia) has been actively undergoing a period of dyke injection, extension and volcanism since an initial fissure event in 2005. We present the results of a detailed mapping, remote sensing, geochemistry and geochronology project to characterise the spatial and temporal distribution of volcanism in this rift segment and the interplay between tectonism and magmatism in this active extensional setting at the continental-oceanic crust transition.

Characterisation of the morphology of individual lavas and the architecture of stacking multiple lavas within a province requires a unique indentifying feature for each individual flow field. In the absence of a unique chemostratigraphic, palaeomagnetic, or petrologic fingerprint, field investigation and good exposure may be the only way of tracing a single lava flow from its source to the distal reaches of a flow field. High-resolution mapping at the scale of individual lavas in Afar, a poorly accessible region, required the development of a mapping methodology. The mapping approach involved remote sensing and three-dimensional image analysis of topography and surface rock chemistry based on mineral maps generated from false colour composites of Landsat ETM+, ASTER and hyperspectral (Eagle and Hawk) imagery together with aerial photographs. We combined the datasets with DEMs derived from LiDAR, SPOT5 and ASTER within GeovisionaryTM software for interpretation within an immersive visualisation suite enabling simulation of a fieldwork-based investigation. Interpretations derived from this approach were ground-truthed by targeted field studies and samples were acquired for 40Ar-39Ar dating.

Results from the mapping establish the eruption history of the Manda-Hararo rift at the scale of individual eruption units and enables identification of the structures, textures and spectral signatures of volcanic complexes that can be combined with fieldwork to ground validate the composition, character and age of lavas. The investigation shows a spread of eruption sites, vent character, and young volcanic ages (<10 ka) dispersed around the axis of the rift segment suggesting that crustal accretion may not be limited to the central spreading centre. Linear basaltic fissure vents dominate the topographic rift axis whilst point source basaltic vents are located up to 7 km away from the rift axis. Recent volcanism and observation (from high-resolution geophysics and satellite geodesy) of dyke emplacement in the last 7 years suggests focused magmatic accretion in the rift axis. However, our mapping reveals that abundant cinder cones and vents are also located off-axis suggesting past activity of this segment has included the development of oblique and off-axis magmatic plumbing systems. This observation is similar to models of slow-spreading magmatic mid-ocean ridge (MOR) segments, and contrasts with repetitive eruptions from central fissure vents in fast-spreading MORs.