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Volcanic field elongation, vent distribution and tectonic evolution of continental rift: The Main Ethiopian Rift example

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Magmatism and faulting operate in continental rifts and interact at a variety of scales, however their relationship is complex. The African rift, being the best example for both active continental rifting and magmatism, provides the ideal location to study the interplay between the two mechanisms. The Main Ethiopian Rift (MER), which connects the Afar depression in the north with the Turkana depression and Kenya Rift to the south, consists of two distinct systems of normal faults and its floor is scattered with volcanic fields formed by tens to several hundreds monogenetic, generally basaltic, small volcanoes and composite volcanoes and small calderas.

The distribution of vents defines the overall shape of the volcanic field. Previous work has shown that the distribution of volcanic vents and the shape of a field are linked to its tectonic environment and its magmatic system.

In order to distinguish the impact of each mechanism, we analyzed four volcanic fields located at the boundary between the central and northern MER, three of them (Debre Zeyit, Wonji and Kone) grew in the rift valley and one (Akaki) on the western rift shoulder. The elongation and shape of the fields were analyzed based on their vent distribution using the Principal Component Analysis (PCA), the Vent-to-Vent Distance (VVD), and the two dimensional symmetric Gaussian kernel density estimate methods. We extracted from these methods several parameters characterizing the spatial distribution of points (e.g., eccentricity (e), eigen-vector index (evi), angular dispersion (Da)). These parameters allow to define at least three types of shape for volcanic fields: strong elongate (line and ellipse), bimodal/medium elongate (ellipse) and dispersed (circle) shapes.

Applied to the natural example, these methods well differentiate each volcanic field. For example, the elongation of the field increases from shoulder to rift axis inversely to the angular dispersion. In addition, the results show that none of the analyzed fields has its shape parallel to the actual trend of youngest and active faulting and volcanism. The alignment analysis shows that the feeders located along the actual rift axis (Wonji and Kone) are parallel to the NNE trend of the youngest fault system. This parallelism decreases as we move to the rift border.

Our results suggest that the shape of volcanic fields is controlled mainly by large crustal to lithosphere scale structures (main border faults of the rift) and/or by the Lithosphere-Asthenosphere-Border (LAB) geometry, whereas diking, occurring at shallower levels, is principally controlled by upper crustal stress and strain state.