Geophysical Research Abstracts
Vol. 18, EGU2016-16013, 2016
EGU General Assembly 2016
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Sill emplacement and corresponding ground deformation processes at the Alu-Dalafilla volcanic centre in the Danakil Depression, Ethiopia

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A consensus has emerged from a variety of disciplines over the past 15 years that Quaternary magmatism in Ethiopia is almost entirely dominated by dike intrusion. Focused dike intrusion within 60 km long, 20 km wide, rift zones is considered to mark the present day locus of extension in Ethiopia, and represent the proto-ridge axis location of an incipient ocean spreading centre. However, it has been suggested on the strength of Moho depths and Quaternary eruptive volumes in northernmost Ethiopia, that the final transition from continental rifting to incipient oceanic spreading may instead be characterised by an abrupt, rheologically driven, late-phase of crustal thinning. Development of a sedimentary basin and mantle decompression melting occurring in the Danakil Depression, driven by this late-phase crustal thinning, should result in a markedly different style of magmatism in the upper crust: i.e. field observations, high-resolution seismic reflection studies, and experimental modelling suggest that interconnected networks of sill intrusions dominate in sedimentary basins. Here, we present the first evidence from the Danakil Depression that links surficial structures, observed at the Alu-Dalafilla volcanic centre, to the ongoing emplacement of an underlying sill. In particular, we use satellite imagery to examine a dome-shaped fold, associated fracture patterns, and surrounding lava flows, which we suggest likely formed in response to roof uplift above and extrusion from a saucer-shaped sill; i.e. a sub-horizontal inner sill encircled by an inward-dipping, transgressive inclined rim. InSAR observations by Pagli et al. (2012) of ground uplift and deflation occurring during the eruption of basaltic lava at Alu-Dalafilla in 2008 capture what we believe to be the first real-time evidence for intrusion-induced forced folding dynamics above a saucer-shaped sill. InSAR data further suggest that intrusion occurred at a depth of $\sim$1 km, likely placing the sill within an evaporitic host rock sequence. Important consequences of the shift to sill-dominated magmatism in the Danakil Depression include: (i) roof uplift induced by sill intrusion may not directly relate to the emplaced magma volume if intrusion promotes ductile deformation of the host evaporitic sequence (Schofield et al. 2014), implying that InSAR studies of ground deformation, crucial to volcanic hazard assessment, may under-estimate intruded magma volumes; and (ii) sill volumes are not incorporated into total melt volume estimates, which are used to constrain lithospheric processes active during continental break-up.