Geophysical Research Abstracts
Vol. 18, EGU2016-4869, 2016
EGU General Assembly 2016

Magma genesis, storage and eruption processes at Aluto volcano, Ethiopia: lessons from remote sensing, gas emissions and geochemistry

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One of the most intriguing aspects of magmatism during the transition from continental rifting to sea-floor spreading is that large silicic magmatic systems develop within the rift zone. In the Main Ethiopian Rift (MER) these silicic volcanoes not only pose a significant hazard to local populations but they also sustain major geothermal resources. Understanding the journey magma takes from source to surface beneath these volcanoes is vital for determining its eruption style and for better evaluating the geothermal resources that these complexes host. We investigate Aluto, a restless silicic volcano in the MER, and combine a wide range of geochemical and geophysical techniques to constrain magma genesis, storage and eruption processes and shed light on magmatic-hydrothermal-tectonic interactions.

Magma genesis and storage processes at Aluto were evaluated using new whole-rock geochemical data from recent eruptive products. Geochemical modelling confirms that Aluto's peralkaline rhyolites, that constitute the bulk of recent erupted products, are generated from protracted fractionation (>80 %) of basalt that is compositionally similar to rift-related basalts found on the margins of the complex. Crustal melting did not play a significant role in rhyolite genesis and melt storage depths of ∼5 km can reproduce almost all aspects of their geochemistry. InSAR methods were then used to investigate magma storage and fluid movement at Aluto during an episode of ground deformation that took place between 2008 and 2010. Combining new SAR imagery from different viewing geometries we identified an accelerating uplift pulse and found that source models support depths of magmatic and/or fluid intrusion at ∼5 km for the uplift and shallower depths of ∼4 km for the subsidence. Finally, gas samples collected on Aluto in 2014 were used to evaluate magma and fluid transport processes. Our results show that gases are predominantly emanating from major fault zones on Aluto and that they display a clear magmatic carbon signature of –4.2 to –4.5 ‰. This provides compelling evidence that the magmatic and hydrothermal reservoirs of Aluto are physically connected.

Bringing the new data sets together provides an integrated picture of the plumbing system of this restless rift volcano. Aluto's silicic magmas are generated and stored at depths of ∼5 km. Magmatic intrusion and/or fluid injection in the cap of this magmatic reservoir drives edifice wide inflation while subsequent deflation is related to magmatic degassing and/or cooling of the geothermal reservoir at shallower depths. Tectonic faults that dissect the complex are a key component of this plumbing system and by connecting the deep reservoirs to the surface they not only provide important degassing pathways but will almost certainly be exploited during future eruptive events.