The formation of geothermal systems in the context of magma-assisted continental rifting: Magnetotelluric models from the Main Ethiopian Rift (MER)

L. Dambly[1a], F. Samrock[1], A.V. Grayver[2], H. Eysteinsson[3], M.O. Saar[1]

[1]ETH Zurich, Institute of Geophysics, Geothermal Energy and Geofluids Group, [a]luise.dambly@erdw.ethz.ch
[2]ETH Zurich, Institute of Geophysics, Earth and Planetary Magnetism Group
[3]Reykjavik Geothermal, Ltd., Reykjavik, Iceland

SUMMARY

The rise of geothermal development in Ethiopia has been strongly supported by magnetotelluric (MT) measurements. For placement of geothermal wells, the majority of MT studies focused on imaging the clay cap structure of volcano-hosted high-temperature geothermal systems. Most recent studies have succeeded to image the deeper magmatic feeding systems including the shallow magma reservoirs that drive geothermal systems in the MER, by applying modern 3-D inversion codes and by inverting MT phase tensors that are free of galvanic distortions.

To gain further insight into the geological setting of geothermal systems in the MER we constructed two new models obtained from 3-D inversion of MT data at Aluto and Corbetti volcanoes. Both geothermal systems play an important role in the Ethiopian energy development strategy. Although they have been thoroughly studied, open questions remain concerning their formation in the geological context of magma-assisted rifting. At Aluto the transcrustal distribution of magma was imaged by a local-scale MT survey, while at Corbetti evidence for the presence of a shallow intrusion was found, yet the intrusion was not yet imaged in 3-D.

To obtain a multi-scale model of the regional transcrustal distribution of melt beneath Aluto volcano we analyze two combined local- and regional-scale MT datasets. The datasets comprise regionally distributed stations across the rift valley (33 stations, 2000 km^2) and locally distributed stations measured at Aluto's volcanic edifice (165 stations, 145 km^2). In order to analyze the MT data we applied a modern 3-D inversion approach, based on a combination of impedance and phase tensor inversion. Doing so, we succeeded to obtain a 3-D multiscale subsurface model that images the lower crustal magma ponding zone in about 30 km depth beneath the rift. Furthermore, the model shows that this zone is connected to the shallow upper crustal magmatic heat source of Aluto's geothermal system via a structurally controlled transcrustal magma channel.

To shed light on the current state of the magma reservoir beneath Corbetti, we performed a 3-D phase tensor inversion utilizing a local dataset (127 stations, 340 km^2) covering the Corbetti caldera. In doing so, we could image for the first time a shallow intrusion, approximately 10 km deep, that acts as a heat source for the geothermal system of Corbetti. The location of this intrusion is in overall great agreement with previous predictions by InSAR surface deformation observations and geodetic and gravimetric modelling studies.

Our studies demonstrate the capability of MT to provide holistic images of volcano-hosted high-temperature geothermal systems from small scales relevant for geothermal drilling to large scales showing their formation in the context of an actively evolving rift.

Keywords: volcano imaging, geothermal exploration, 3-D multiscale inversion, Main Ethiopian Rift