Geophysical Research Abstracts
Vol. 19, EGU2017-17959, 2017
EGU General Assembly 2017

Integrated geophysical imaging of the Aluto-Langano geothermal field (Ethiopia).

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The Aluto-Langano geothermal system is located in the central part of the Main Ethiopian Rift, one of the world's most tectonically active areas, where continental rifting has been occurring since several Ma and has yielded widespread volcanism and enhanced geothermal gradient. The geothermal system is associated to the Mt Aluto Volcanic Complex, located along the eastern margin of the rift and related to the Wonji Fault Belt, constituted by Quaternary NNE-SSW en-echelon faults. These structures are younger than the NE-SW border faults of the central Main Ethiopian Rift and were originated by a stress field oblique to the rift direction. This peculiar tectonism yielded local intense rock fracturing that may favour the development of geothermal reservoirs. In this paper, we present the results of an integrated geophysical survey carried out in 2015 over an area of about 200 km2 covering the Mt Aluto Volcanic Complex. The geophysical campaign included 162 coincident magnetotelluric and time domain electromagnetic soundings, and 207 gravity stations, partially located in the sedimentary plain surrounding the volcanic complex. Three-dimensional inversion of the full MT static-corrected tensor and geomagnetic tipper was performed in the 338-0.001 Hz band. Gravity data processing comprised digital enhancement of the residual Bouguer anomaly and 2D-3D inverse modelling. The geophysical results were compared to direct observations of stratigraphy, rock alteration and temperature available from the several deep wells drilled in the area. The magnetotelluric results imaged a low-resistivity layer which appears well correlated with the mixed alteration layer found in the wells and can be interpreted as a low-temperature clay cap. The clay-cap bottom depth is well corresponds to a change of thermal gradient. The clay cap is discontinuous, and in the central area of the volcanic complex is characterised by a dome-shape structure likely related to isotherm rising. The propilitic alteration layer, pinpointed as the 80-Ohm-m isosurface, shows two dome-shape highs. The first is NNE-trending, and may be interpreted as an upflow zone along a fault of the Wonji belt. Two productive wells are located along the borders of this area, as well as the alignements of fumaroles and altered grounds. The second is linked to a wide resistive area, located at shallow depth, where no clay cap was detected. It could be interpreted as a fossil high-temperature alteration zone reaching shallow depths, and it is associated to several fumaroles. Modeling of 2D/3D gravity data shows that the anomalies are due to shallow density variations likely related to lithology. The deep lateral variations due to structural lineaments inferred from well stratigraphy have no detectable signature. However, the trend analysis performed on the residual Bouguer anomaly (via horizontal and tilt derivative computations), allowed to identify five lineaments. Three of them exhibit NNE-SSW strike, corresponding to the Wonji Fault Belt Trend, whereas two have NNW-SSE strike, corresponding to the Red Sea Rift trend, which in this area is of minor evidence. The signature of shallow structures is then indicative of major regional structures. One of the lineaments marks the presence of a major fumarolic zone.