

## Integrated Geophysical Model for Suswa Geothermal Prospect using Resistivity, Seismics and Gravity Survey Data in Kenya

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### ABSTRACT

Magnetotelluric (MT) method is preferred for sub-surface exploration of geothermal areas. The MT method is effective for delineating geothermal reservoirs that are characterized by high resistivity contrast between the reservoir and the overlying cap rock (clay caps). The transient electromagnetics (TEM) was used to resolve the static shift problem in MT due to its good resolution near the surface. In this study, we investigate the geothermal potential over the Suswa geothermal prospect through correlation of electromagnetic, seismics and gravity survey results. The three data sets show quite a good correlation and thus helps us confirm there exists a geothermal system at Suswa. A look at the resistivity maps reveal a low-resistivity anomaly at depth which is probably the deeper conductor acting as a heat source on the northern and the southern part of the prospect. This is confirmed by a high-density body seen on the gravity survey at similar locations of the prospect and also micro seismic events at depth reveal the same trend thus reducing ambiguities in the interpretation of either data set.

### 1. INTRODUCTION

The Suswa geothermal prospect is associated with a trachytic volcano located along the Kenyan rift valley (Figure 1). Geophysical surveys were undertaken in Suswa to give a structural image of the subsurface. The electrical resistivity method was used as its data are strongly affected by geothermal processes and may indicate the presence of a geothermal system. The magnetotelluric (MT) method is preferred for exploration of geothermal. The method is effective for delineating geothermal reservoirs, which are characterized by high-resistivity contrast between the reservoir and the cap rock (clay caps) that are located on top.

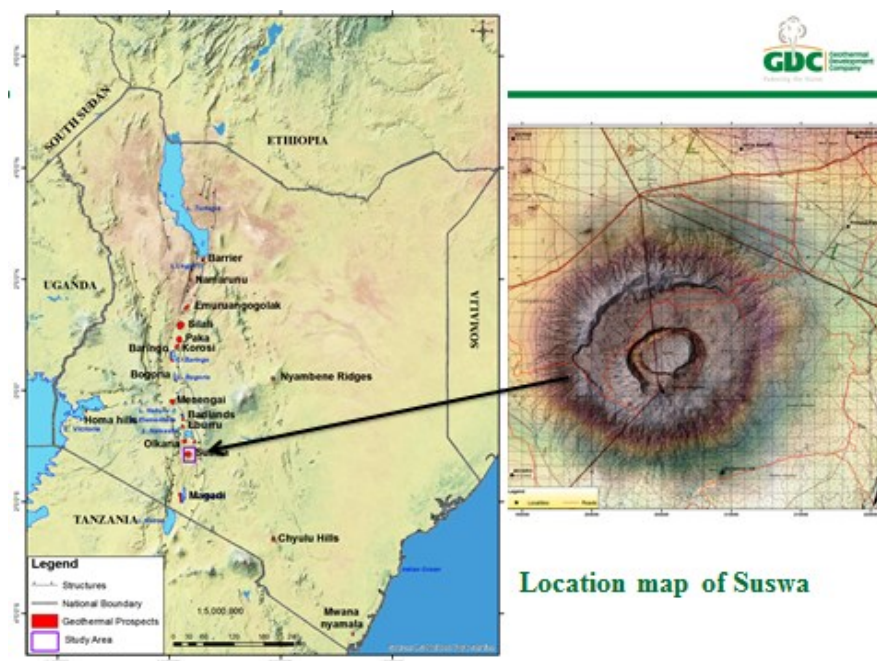


Figure 1: Location map of Suswa prospect in Kenyan rift valley.

The transient electromagnetics (TEM) was used to resolve the static shift problem in MT due to its good resolution near the surface. The hypothesis used is that an increased fluid content due to fracturing, and the development of more conductive alteration clay minerals can give rise to an electrical resistivity contrast which with reliable mapping can increase chances of discovering geothermal resources and defining the extent of geothermal reservoirs. This is done through imaging the controlling structures of geothermal systems, and in locating and characterizing permeable fracture zones. Apparent resistivity data from MT and TEM surveys were analysed to understand the resistivity structure within the prospect. Gravity surveys carried out by Geotermica Italiana (1989) suggest that a positive anomaly related to shallow bodies made of dense lava flows and negative anomalies are related to deeper sources. Gravity data is consistent with volcanological and geophysical evidence suggesting that the area of late quaternary caldera volcanoes are thermally privileged sites (Cantini, 1990). A high-density body seen on the gravity survey at similar locations

Magnetotelluric uses natural electromagnetic waves induced by magnetosphere or ionosphere currents. The signals are used to image the resistivity structure of the earth, Vozoff, 1991; Jiracek et al, (1995). Since the source is far away from the earth's surface, MT waves can be treated as planar, Zhdanov and Keller, (1998). The MT wave is comprised of electric and magnetic fields which are recorded orthogonally using two electric and three magnetic channels.

## 2.1 TEM and MT joint inversion

### 3. MICRO-SEISMICS SURVEY

#### 4. GRAVITY SURVEY

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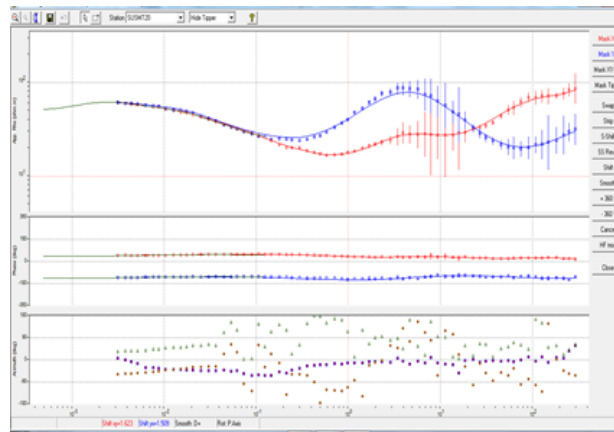


Figure 3: Joint 1-D inversion of TEM and MT soundings.

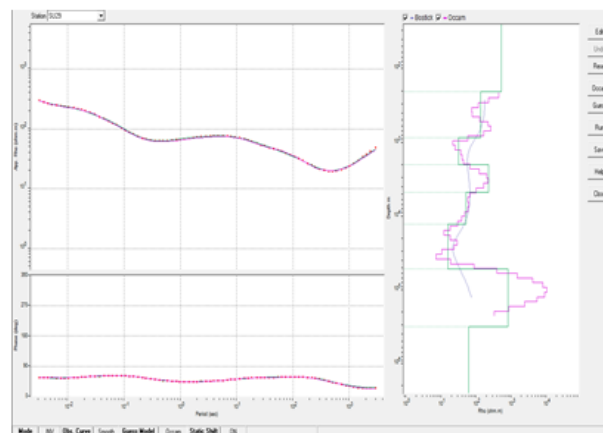


Figure 4: Shows the results of the 1-D resistivity inversion model.

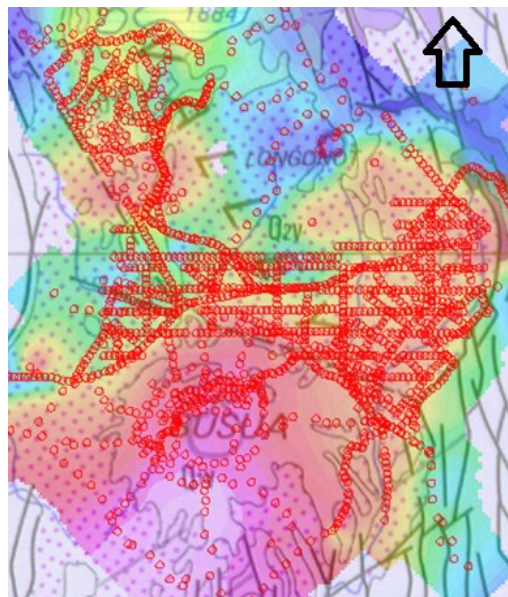


Figure 5: Red circles show locations of the gravity survey network overlain the Suswa geological map.

## 5. RESULTS

Various MT cross sections (Figure 6 and 7) taken on the northern and southern part of the prospect show a typical resistivity structure of a high-temperature geothermal system. Both are characterised by a shallow layer of high resistivity near the surface due to unaltered formations, overlying a low-resistivity anomaly due to hydrothermal alteration, followed by a fairly high-resistivity

associated with the reservoir level due to hydrous minerals found at that level, this is underlain by a low-resistivity anomaly associated with the possible heat source controlling the Suswa system. Figure 8 shows the different cross sections projected in a 3-D view which gives a good picture of the resistivity structure in the prospect. Figure 9 shows a resistivity map taken at 6000 mbsl and the structural orientation correlates quite well with the seismic event location and bouguer anomaly map (Figure 10 and Figure 11). Gravity high (Red) where we have the low resistivity anomalies (Red) in the southern part of the resistivity map and dense seismic events reveal a magmatic body below the prospect and which is the heat source for the geothermal system.

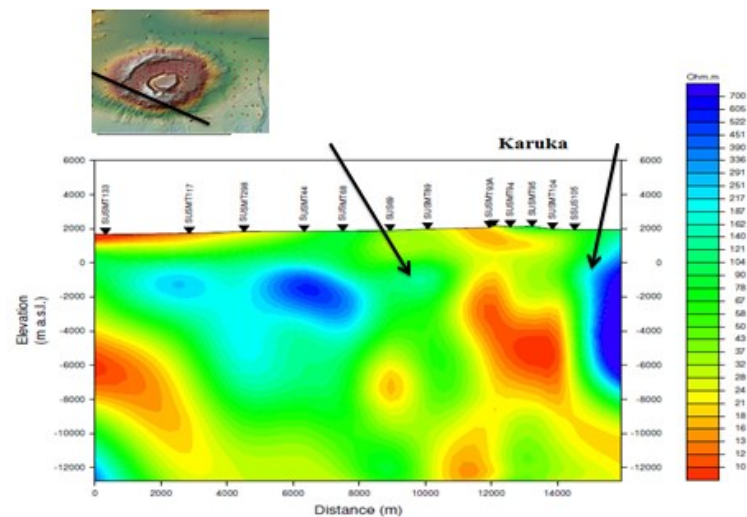


Figure 6: Resistivity cross section along NW-SE direction

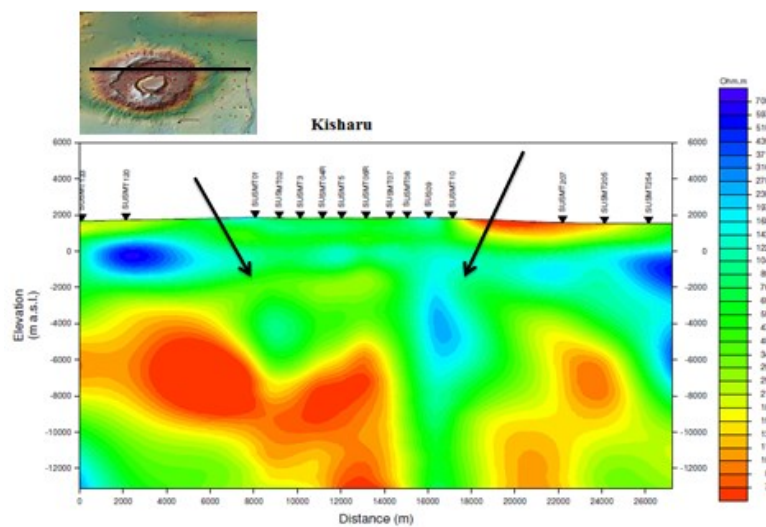


Figure 7: Resistivity cross section along W-E direction

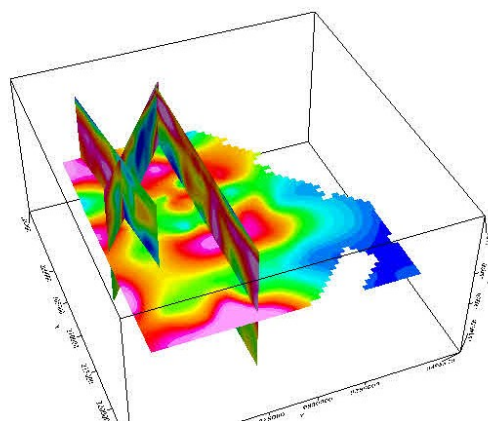


Figure 8: 3-D visualization of resistivity cross sections



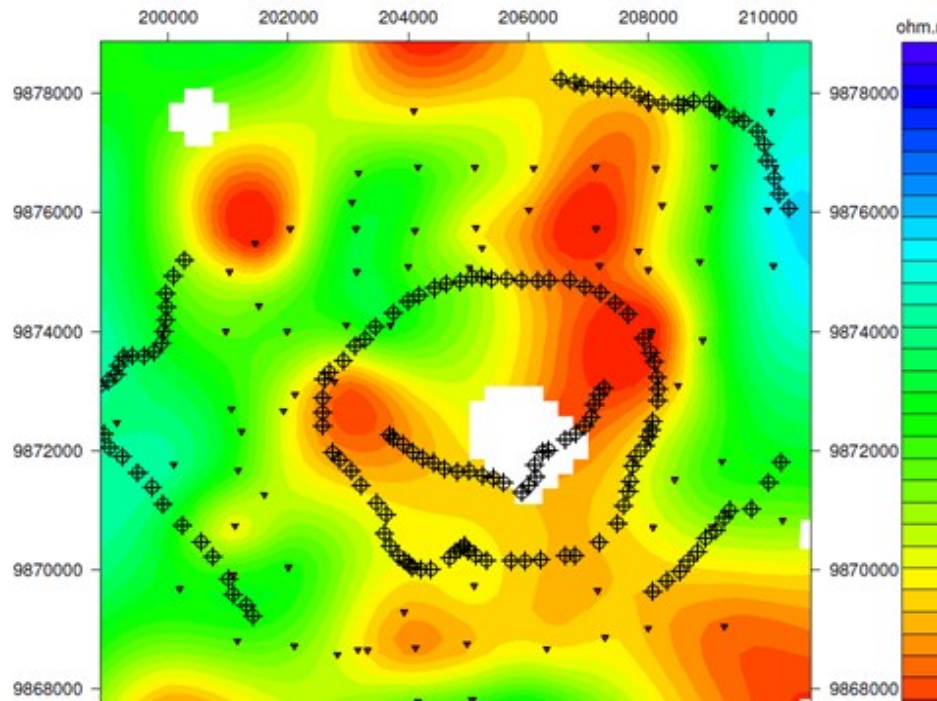


Figure 9: Resistivity map at 6000 mbsl (Red is low resistivity, yellow moderate and green fairly high, pale blue is high).

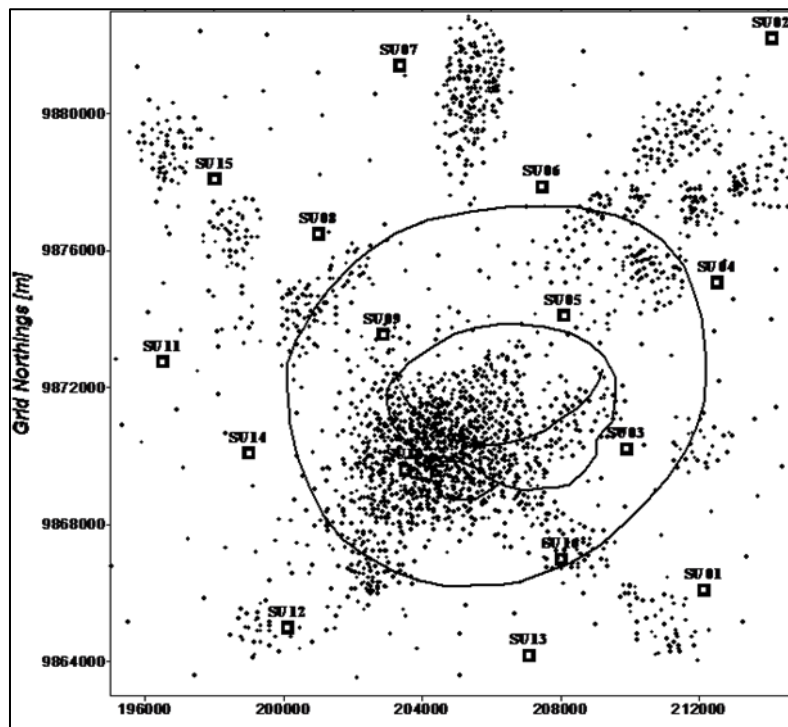
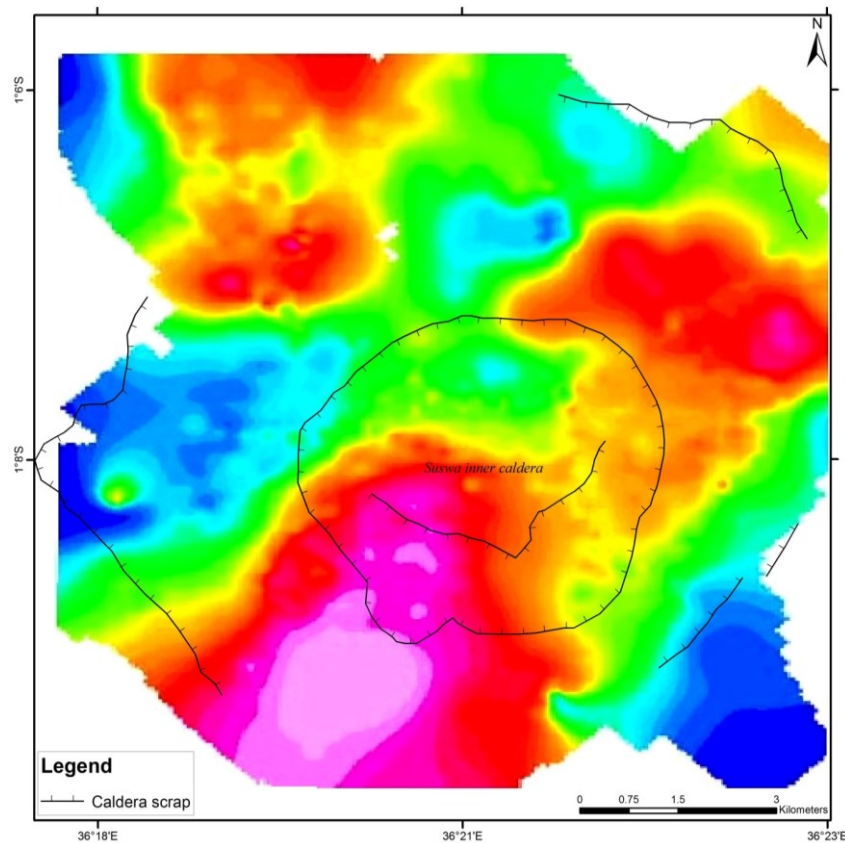


Figure 10: Map of Suswa showing event locations, inner and outer caldera and recording stations (after Simiyu 1997).

## 6. CONCLUSIONS

The geophysical surveys completed at the Suswa geothermal prospect show that:-

1. Resistivity, seismics and gravity results are in good correlation.
2. Correlating the data sets helps reduce ambiguity on either data set, which is useful in making final interpretations, in other words, it increases confidence when it comes to decision making.
3. Therefore its good to use joint geophysical imaging techniques for a reliable interpretation then correlate with the surface geology too.



**Figure 11: Suswa Bouguer anomaly map (Red is gravity high, green moderate and blue low)**

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