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# Magnetotelluric Exploration at Tendaho high temperature geothermal field in North East Ethiopia

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## SUMMARY

Tendaho is one of the high temperature geothermal areas in Afar depression in north east Ethiopia. A total of 129 MT sites were acquired from Tendaho high temperature field. The 2D inversion of MT data from Tendaho high temperature field revealed three main resistivity structures down to a depth of 10 km: low resistivity surface layer underlain by a resistive layer followed by good conducting structure. The low resistivity surface layer show areas with either sediments, lateral flow of geothermal fluids or zeolite-clay alteration zone. Below the conductive layer, is a high resistivity zone that can be correlated to Afar stratoid basalts or epidote alteration zone .The high resistivity structure has been associated with the deep reservoir of the geothermal system. The deep good conductive body is probable heat source of the geothermal system.

**Key words: Magnetotellrics, 2D inversion, High Temperature Geothermal, Tendaho, and North East Ethiopia**.

## INTRODUCTION

Magnetotelluric (MT) survey was conducted at Tendaho high temperature geothermal field in 2010/11 as a joint collaboration project between Ministry of Mines of Ethiopia (MME), through Geological survey of Ethiopia (GSE), and German Federal Institute of Geosciences and Natural Resources (BGR) - GEOTHERM programme.

The Tendaho geothermal field is located in the central part of Afar Depression about 600 km from Addis Ababa in the north-eastern part of Ethiopia (Figure 1). The approximate geographical location of the MT studied area as a whole is 40° 55'36.92" E and 41° 44'38.3" longitude and 11° 57'22.574"N and 11° 43'7.16" latitude presented in Figure 1.

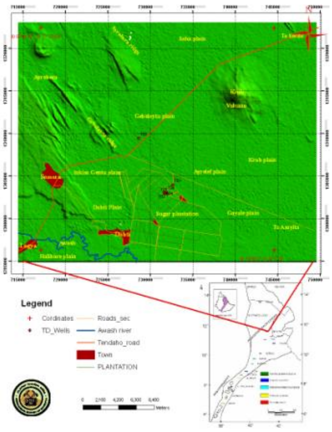

**Figure 1: Location Map of Tendaho Geothermal Field.**

## MT DATA ACQUISATION AND PROCESSING

5-channel MT data acquisition system (MTU-5A) from Phoenix Geophysics Ltd was used to record the MT data. The induction coil MTC-50 used covers frequency ranges from 0.0001 Hz up to 400 Hz. The electrodes used are composed of $PbCl_2$ solution in a ceramic container that is designed to ensure a good contact between the outside wires and the soil. The dipole length between the electrodes used was 100 m; with some exception of 50 m. A total of 129 MT soundings were collected in Tendaho geothermal field along seven profiles (Figure 2). The direction of the seven profiles was chosen approximately perpendicular to the known geologic strike direction of the Tendaho graben. The station spacing on the profiles is mostly about 1 Km.

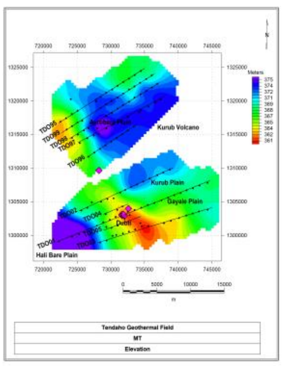

**Figure 2: Elevation map of Tendaho area showing MT profiles.**

The impedance and geomagnetic transfer functions were obtained using the robust processing program SSMT2000 provided by Phoenix Geophysics-Canada (Phoenix Geophysics, 2005). To analyze dimensionality of the MT data, impedance polar diagram was used. A typical example of impedance polar diagram from the 129 MT sites at a frequency of 0.01 Hz is shown in Figure 3. The polar diagram was plotted from measured data.

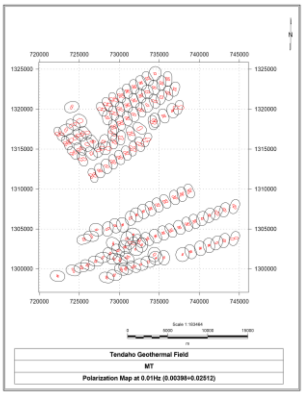


**Figure 3: Impedance Polarization map for MT sites. |Zxx| =red colour and |Zxy|= black colour in the polar diagram.**

The dimensionality information from the polar diagrams on Figures 3 show mostly 2D resistivity structure at the frequencies and soundings considered. The geoelectric strike direction was analyzed using the program strike by McNeice and Jones (2001). The multi-site, multi-period analysis of the regional strike direction resulted in N25°W dominant strike direction. Therefore, 2D inversion of the MT data was carried out.

Prior to 2D inversion, the MT data were rotated to -25°. The program developed by Randy Mackie (2001) was used for the 2D inversion. The 2D inversion of the MT data was done using a smooth model inversion routine. This routine finds regularized solution to the 2D inverse problem for MT data using the method of nonlinear conjugate gradients (Rodi and Mackie, 2001).

## RESULTS FROM 2D INVERSION

2D MT cross section TDO01, (Figures 2 and 4), runs from Hali Bare Plain in SW and ends Kurub plain in the NE with a total distance of about 24 km. A good conducting (≤ 4 Ωm) surface layer which is about 1 km thick, underlain by high resistivity layer (≥ 8 Ωm) (Figure 4). Below the resistive layer, low resistivity (≤ 4 Ωm) is observed. The good conducting surface layer is interpreted here as sediments, lateral flow of geothermal fluid or zeolite/smectite alteration zone. The resistive second layer can be associated with Afar stratoid series basalts or chlorite-epidote alteration zone. The conductive body (< 4 Ω m) at depth of about 4.5 km is presumably associated with the heat source of the geothermal system. The resistivity cross section also revealed possible fracture zones/faults in the Afar staratoid basalts (shown by vertical lines in Figure 4). This fracture zone may give rise to higher permeability and high temperature and presumably indicate upflow of geothermal fluids into the system.

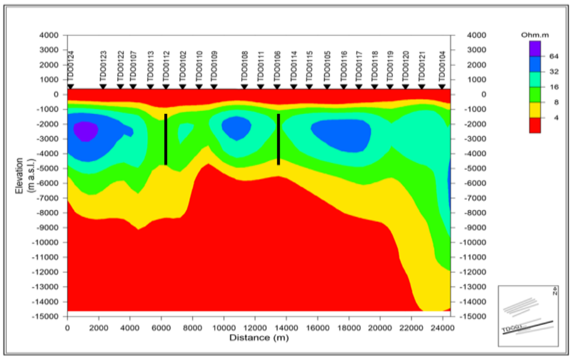


**Figure 4: 2D MT cross section TDO01**

## CONCLUSIONS

The 2D inversions of MT data from Tendaho geothermal field revealed three main resistivity structures down to a depth of 10 km. The low resistivity surface layer is either sediments, lateral flow of geothermal fluids or zeolite-clay alteration zone (Aquater, 1996). Below the conductive layer, high resistivity (> 8 Ωm) is observed, is correlated to Afar stratoid basalts or epidote alteration zone as confirmed from alteration zones of well TD1, TD2 and TD3 (Aquater, 1996). The high resistivity structure can be the deep reservoir of the geothermal system. The deep conducting layer is associated with the heat source of the geothermal system.

## ACKNOWLEDGMENTS

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