APPLICATION OF TRANSIENT ELECTROMAGNETICS IN STATIC SHIFT CORRECTION FOR MAGNETOTELLURICS DATA OF SUSWA GEOTHERMAL PROSPECT IN KENYA.

Raymond Mwakirani
Geothermal Development Company Ltd,
P. O. Box 1770 Nakuru, 20100
rmwakirani@gdc.co.ke

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ABSTRACT
Suswa is the southernmost of the quaternary volcanoes in the axis of the Kenyan rift. Suswa is unique in having two calderas; the outer and the inner. Although magnetotellurics (MT) method is preferred for sub-surface exploration for geothermal resource. The MT 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 of the reservoir zone. Often, dc shift “static shift“ on the apparent resistivity on MT plots at all frequencies may be caused by shallow or near surface conductivity heterogeneity due to local geology and rugged topography often related with volcanic fields such as the Suswa volcano. There are various techniques proposed to solve for static shift on MT data, which include the use of topographical data during data inversion process and the use of complimentary resistivity data from methods such as direct current (DC) method or the Transient electromagnetic method (TEM).

In this study, we investigate for static shift on the MT data collected over the Suswa geothermal prospect and the application of TEM data to correct for static shift on MT data caused by near surface conductivity heterogeneities at the MT station. The static shift values in this region were found to range from 0-2 an indication that the MT apparent resistivity curves were shifted up or down indicating either higher (shift up) or a lower (shift down) of the true apparent resistivity values. A look at the cross-sections reveal a shallow layer of low resistivity values which is probably the sub-surface heterogeneities responsible for the shift and if its not corrected leads to errors in the final interpretation of resistivity structure.

1. INTRODUCTION

Geophysical surveys in Suswa prospect were undertaken to give a structural image of the underground from data collected on the surface. The electrical resistivity method was used as it is strongly affected by geothermal processes and would thus indicate the presence of a geothermal system. 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 curves were analysed to understand the resistivity structure within the prospect.

2. MAGNETOTELLURICS (MT)

Magnetotellurics (MT) 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. The fields are recorded orthogonally, using two electric channels and three magnetic channels as shown in Figure 1.

3. TRANSIENT ELECTROMAGNETICS (TEM)

In the transient electromagnetic method (TEM), an electrical current is induced in the ground and a magnetic field created is measured at the surface, from which the resistance of the underground rocks is determined. The current in the ground is generated by a time varying magnetic field. Yet, unlike MT-soundings, the magnetic field is not the randomly varying natural field but a field of controlled...
magnitude generated by a source loop. A loop of wire is placed on the ground and a constant magnetic field of known strength is built up by transmitting a constant current into the loop. The current is then abruptly turned off (Figure 3). The decaying magnetic field induces electrical current in the ground. The current distribution in the ground induces a secondary magnetic field decaying with time. The decay rate of the secondary magnetic field is monitored by measuring the voltage induced in a receiver coil (or a small loop) at the centre of the transmitter loop see Figure 2.

Figure 2: Transient current flow in the ground (from Hersir and Björnsson, 1991)

Figure 3: Basic nomenclature and principles of the TEM method; (a) shows the current in the transmitter loop; (b) is the induced electromotive force in the ground; and (c) is the secondary magnetic field measured in the receiver coil. For the graphs of the induced electromotive force and the secondary magnetic field, it is assumed that the receiver coil is located in the centre of the transmitter loop (Christensen et al., 2006)

4. MAGNETOTELLURICS STATIC SHIFT

Static shift is as a result of distortion of the electric field a phenomenon produced by the presence of shallow and local bodies or heterogeneities, which are much smaller than the targets of interest and skin depths (Figure 4). These bodies cause charge distributions and induced currents that alter the magnetotellurics responses at the studied or regional scale (Kaufman, 1988; Chave and Smith,
The term “static or telluric shift” is used because apparent resistivity is distorted by a multiplicative constant, $S$, and hence by a shift when presented on a log scale this means that if not properly corrected, interpretation can lead to very misleading interpretation(Figure 5). Shifts as low as $S = 0.1$ have been observed which would lead to 10 times too low resistivity values and 3 times too shallow depths to resistivity boundaries (Árnason 2008).

The vertical shift of the apparent resistivity curves can lead to errors in the inverted model because the resistivities and depths of the final model will be scaled by $s$ and $(s)^{1/2}$ respectively, for a 1D layered model. Correction for this effect is then of first importance before any interpretation of MT data.

In this case, the best static shift parameters for MT data were determined after joint inversion with the TEM then extracted from the jointly inverted models and plotted to show the spatial distribution around the prospect area. From figure 6 it’s evident that most of the MT tensors were not shifted at all which shows a normal distribution trend but a few soundings were shifted either up or down, an indication of near surface inhomogeneities which led to the galvanic distortion.

A total of 96 MT tensors used in this report only 48 MT tensors had pairs for joint inversion with the TEM. The remaining MT tensors were inverted with static shift values extracted from the gridded static shift map figure 7, which is based on the spatial distribution of shifts extracted from the matching pairs of MT and TEM, which may not be correct as static shifts can vary from one sounding location to another, leading to errors in interpretation. The spatial distribution of static shifts is not localized at every sounding location and is representative with nearest stations due to the similar topography near the stations making near surface distortion to be even. The solution to this is measuring TEM data at every MT site and in this report the effect of static shift on MT impedance tensors has been demonstrated.

5. MT STATIC SHIFT ANALYSIS IN SUSWA PROSPECT

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Figure 6: A histogram of the shift parameters for determinant apparent resistivity in the Suswa prospect.

Figure 7: Spatial distribution of static shift parameters for determinant apparent resistivity in the Suswa prospect.

6. TEM AND MT JOINT INVERSION

The joint 1-D inversion of TEM and MT soundings was carried out by shifting the MT model to fit an equivalent 1D MT model generated from the TEM data acquired at the same site. The invariant (which is an average if the TE and TM resistivity modes) was used to carry out 1D modeling of MT data after static shift correction (Figure 8). 1D modelling was carried out using a layered model and Occam smooth model. In the layered model approach, a maximum of 8 layers were used to invert for both resistivities and thickness. In the Occam inversion, the layer thickness a fixed on log scale and the inversion is carried out on the resistivity values of the layers.
7. CONCLUSIONS

The remedy to static shift correction for MT apparent resistivity curve is by jointly inverting them with a TEM sounding measured at the same site. The TEM technique has been proved in determining the scaling factor that the MT sounding has suffered due to inhomogeneities hence its correction. This is made possible by the fact that TEM measures the decaying field and not electric current, so the TEM sounding is not affected by static shift.

REFERENCES


