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Application of Electrical Resistivity Method (ERM) and Aeromagnetic Methods in Mapping Ground Water Potentials: A Case Study of Fune and Nangere Areas of Yobe State.

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ABSTRACT

This study aims to investigate the ground water potential in Fune and Nangere Local Government Area of Nigeria. Source Parameter Imaging (SPI) method was applied to the Acquired aeromagnetic data to produce the depth to basement rocks ranging from 300 m at the northern part to 300 m at the southern part. The geoelectrical survey is represented by 2 sections comprising of 4 Vertical Electrical Sounding (VES) which were collected by using Schlumberger configuration of AB/2 ranged (from 1.5 to 200 m). The results of quantitative interpretation of the subsurface sequence consists of dominantly three to four geoelectrical units. The first unit consists of top soil with high resistivity and thin thickness. While the second one consists of sand and gravel with thickness ranging from 10 to 50 m of moderate to high resistivity. The third one consists of sandstone of low resistivity ranging from 75 to 50 ohmm and thickness ranging from 10 to 70 m; this unit represents the aquifer of the study area for the three layer section. The last geoelectrical unit consists of low resistivity layer of less than 40 ohmm and thickness ranging from 30 to 80m, this unit represents the aquifer of the study area for the three layer section.

Keywords: *Fune, Ground Water, Magnetic, Nangere, Resistivity, Source Parameter Imaging*

Introduction

Ground water becomes the readily available option for exploration in areas where surface water shortages exist. However, the over-exploration of this resource has moved ground water research to forefront of the geosciences in trying to answer the questions of ground water recharge, discharge in aquifers and optimal depth of exploration. These questions become increasingly relevant as we continue to test the limits of ground water resource sustainability in areas of complex geology like Nangere through the application of geophysical method.

Geophysics concept has to do with the applications of laws of physics to study the earth and its surroundings atmosphere, (Umera, 2011). Different geophysical tools such as magnetic and resistivity exist for groundwater exploration (Araffa et al., 2019, George et al., 2020). The electrical resistivity geophysical techniques have been increasingly to search for ground water (Bagare et al., 2019). Electrical resistivity method has advantage of mapping resistivity variations for layered formations and structures such as fractures within rocks and groundwater exploration. Low resistivity values signified potential zones for ground water. (Lucy et al., 2016)

The aim of the magnetic survey is to investigate subsurface geology on the basis of anomalies in the Earth's magnetic field resulting from the magnetic properties of the underlying rocks (Narimi et al., 2019). Magnetic surveys can be carried on land, at sea and in the air. The technique is widely used, and the speed of operation of airborne surveys makes the method very attractive in the search for types of ore deposit that contain magnetic minerals (Kearey *et al.*, 2013, Adetona & Abu, 2013). With respect to ground water prospecting, the depth to basement plays an important role in ground water exploration. Several techniques of mapping basement as a source of magnetic anomaly is being practiced by many authors. These are grouped into graphic and computer modeling techniques, (Ndikilar *et al.*, 2019). The source parameter imaging (SPI), has been widely used in recent years to estimate the basement depth, source parameter imaging function is a quick, easy and powerful method for calculating the depth of magnetic sources. Its accuracy has been shown to be in good percentage in test on real data sets with drill whole control. SPI has the advantage of producing more complete set of coherent solution points and it is easier to use,(AL-Banna & Daham, 2019).

Therefore, this study focus on the use of the source parameter imaging to unveil the overburden thickness and electrical resistivity for layer characterization in Fune and Nangere Local Government Area of Nigeria.

Location and geology of the study area

The study area is the southern part of Yobe state, located at Latitudes $11^{0}46^{'}15^{''}$W, Longitudes $11^{0}5^{'}35^{''}$E and $11^{0}40^{'}39^{''}$N $11^{0}20^{'}04^{''}$E, it falls within the Sudan savannah vegetation zone and is characterized by a hot and dry climate for most of the year, (Naibbi *et al.*, 2014). The study area is part of the sediments of the Chad Basin, comprising such rock types as, sands and sandstones, clay/shale intercalations. The formations varies rapidly both laterally vertically,(Dawoud & Raouf, 2009). The volcanic in the area are represented by basalts, trachyte and rhyolites,(Kwaya *et al.*, 2017).

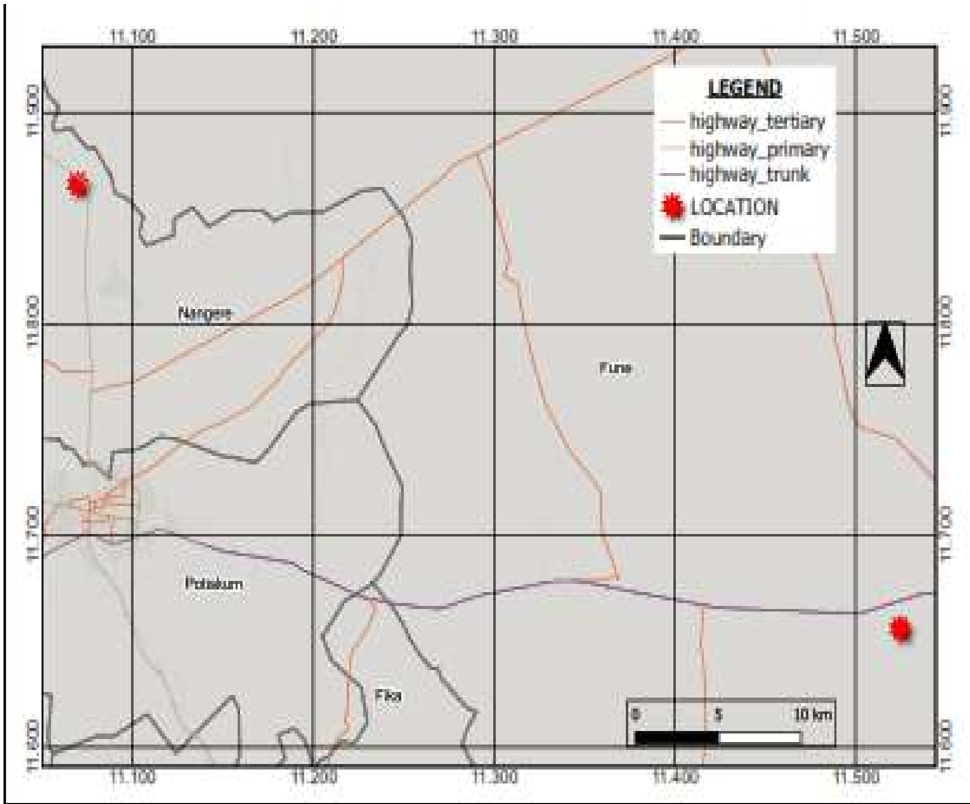

Figure 1. Location of the Study Area.

Electrical Method

VESs (vertical electrical soundings) were carried out in the study area adopting Schlumberger electrode configuration. These method has been successful in delineating lithological units and groundwater explorations. These methods are clearly shown in the works (Lucy et al., 2016, Bagare et al., 2019). Futher more IPI2WIN and Surfer 17 were used for the processing and interpretation of the collected data.

Table 1. Resistivity Range of Values

RESISTIVITY RANGE OF VALUES (OHMM)	LAYER TYPE
1-30	Silt or clay, damp to moist
30-75	Silt or clay, dry to damp top soil; gravelly clays; clayey gravels
75-150	Clayey gravels; silty sand and gravel; saturated clean sand and gravel: interlayered sand, gravel and silt
150-1000	Salty sand and gravel: saturated clean sand and gravel: dry, clean sand and gravel
30-1300	Shale
10-1700	Sandstone

Aeromagnetic Method

The high-resolution aeromagnetic dataset used for this study was obtained from the Nigerian Geological Survey Agency as a part of the nation-wide aeromagnetic survey between 2005 and 2010. The survey was flown in drape mode using real time global positioning system at a sensor mean terrain clearance of 80100m. Traverse and Tie line spacing was 2000m NE directions and the data were recorded at a sampling interval of 100m (NGSA, 2010) and stored in grid form. The data were initially pre-processed by Fugro Airborne Survey and Consultant teams, pre-processing operation included micro leveling, and removal of cultural effects as well as filtering for noise contents. The pre-processed data were quality controlled for isolated spikes and other spurious data which bear no correlation with geology. Butterworth filtering processing was applied to remove any possible cultural noise and other outrageous noise in order to increase the signal to noise ratio while minimizing other noise energies in the data, (Odidi *et al.*, 2020). The stated goal of SPI method is that the resulting images can be interpreted by an expert in local geology, (Salako, 2014).

The Source Parameter Imaging (SPI) is a technique using an extension of the complex analytical signal to estimate magnetic depths. This technique is sometimes referred to as the local

Wavenumber method, it is a profile or grid- based method for estimating magnetic source depths. The method utilizes the relationship between source depth and the local wavenumber (k) of the observed field, which can be calculated for any point within a grid of data via horizontal and vertical gradients.

Interpretation of an anomalous magnetic response involves determining the parameters that characterize the source of the anomaly. The depth to the top of the structure is a parameter that is commonly sought, and the source parameter imaging (SPI) method is one way of determining this depth estimate. One advantage of the SPI method is displaying the depths map as an image. The SPI technique assumes a step type source model. The following formula holds:

$$\text{Depth} = 1 / k\ \text{max} \qquad (1)$$

Where k max represent the peak value of k which is located over the step source

$$k = \sqrt{\left[\frac{dA}{dX}\right]^2} + \left[\frac{dA}{dY}\right]^2 \qquad (2)$$

Tilt derivative (A) is described as

$$A = a\tan\left[\frac{dM}{dZ}\right] / \sqrt{\left[\frac{dM}{dX}\right]^2} + \left[\frac{dM}{dY}\right]^2 \qquad (3)$$

M = total magnetic value, (AL-Banna & Daham, 2019). For the dipping contact, the maxima of k are located directly over the isolated contact edges and are independent of the magnetic inclination, declination, dip, strike and any remnant magnetization (Akiishi *et al.*, 2018). The depth is estimated at the source edge from the reciprocal of the local wave number, (Odidi *et al.*, 2020). The SPI uses an extension of the complex analytical signal to estimate magnetic source depths, source geometries, the dip and susceptibility contrast , (Akiishi *et al.*, 2018).The SPI function is a method for calculating the depth of potential field sources, (Okwesili *et al.*, 2019). Oasis Montaj software was used to accomplish the SPI technique.

Results and discussions

The reduced to equator TMI map of the study area is illustrated in Figure 2. The magnetic anomaly signature can be divided into two contrasting areas, that is, the northern and the southern anomaly. The TMI map offers a high magnetic susceptibility distribution throughout the northern part of the study area. To the south, there is a low magnetic susceptibility distribution throughout the northern part of the study area.

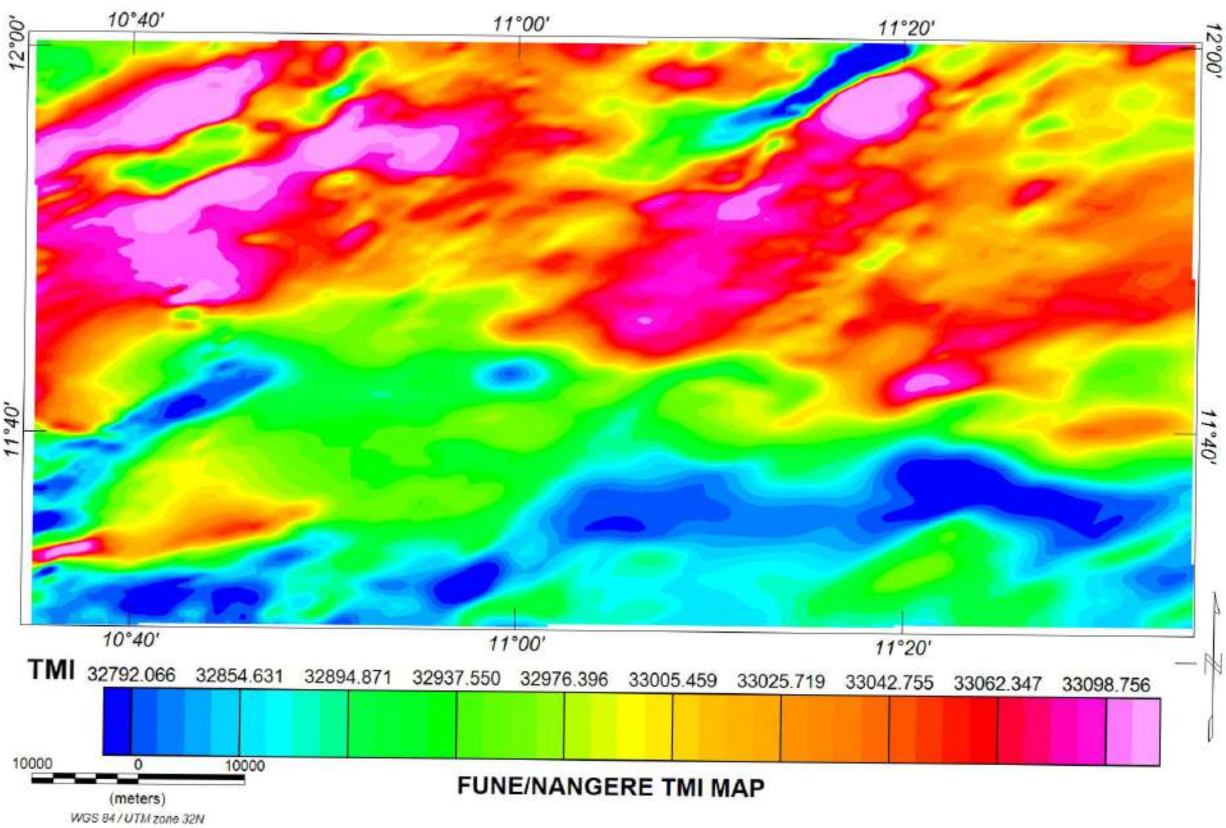

Figure 2. Total Magnetic intensity Map of the Study Area reduced to Equator

Source Parameter Imaging

The source parameter imaging of the study area is characterized by a range of depth of magnetic ensembles as depicted in (Figure 2) with deepest area in the south eastern region. The deepest sources have a depth of about 3000m and probably correspond to either a hidden intrusive body or to the uplifted magnetic basement in the south eastern part of the study area. The intermediate sources have an average depth of 1500m and probably correlate with weathered strata, it has a complex pattern distributed between the high and low depth region of the study area. These magnetic source depth estimates show that the magnetic basement in the study area dips from north to south as can be shown in profiles 1 through three.

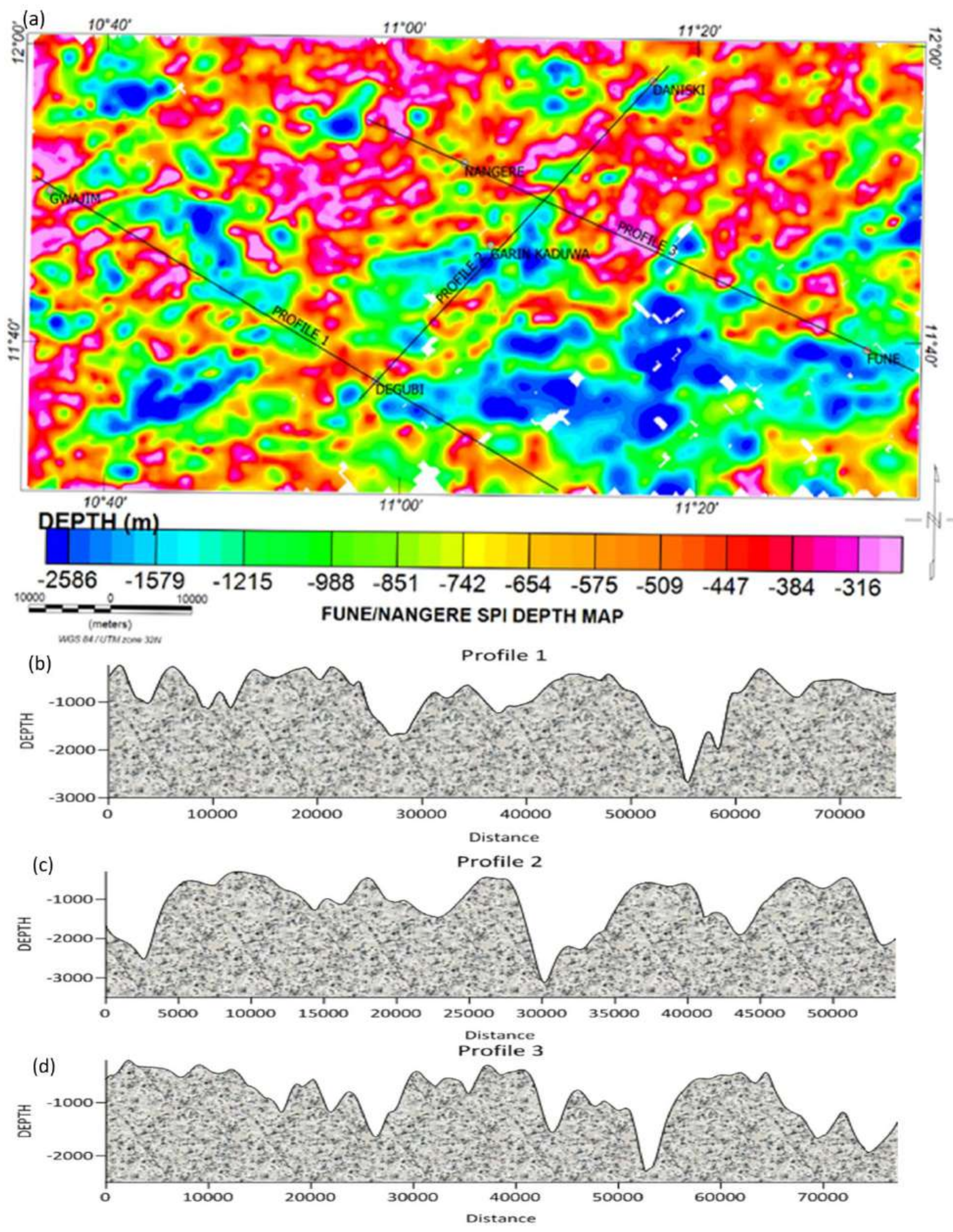

Figure 3. Source Parameter Imaging Map of the Study Area

Resistivity curves

The result from the six sounding revel three resistivity curve types A, AH and K. the vertical electrical sounding at Degubi and Daniski show a three layer A type resistivity curve with characteristic resistivity of $\rho_1 > \rho_2 > \rho_3$, they have a very low resistivity third layer with an average thickness of 45m and a depth of 10m. The AH type resistivity curve type was observed only at Garin Kaduwa, it has a thick fourth layer of more than 100m and a characteristic resistivity of $\rho_1 > \rho_2 < \rho_3 > \rho_4$. The K types were visible at Garga, Gwajim and Daniski comprising of three vertical electrical sounding points thereby making it the dominant curve type of this survey. It has a characteristic resistivity of $\rho_1 > \rho_2 < \rho_3$ and a thickness of averagely 50m at a depth of 7m. Layers were deduced based on the resistivity range of values from Table 1.

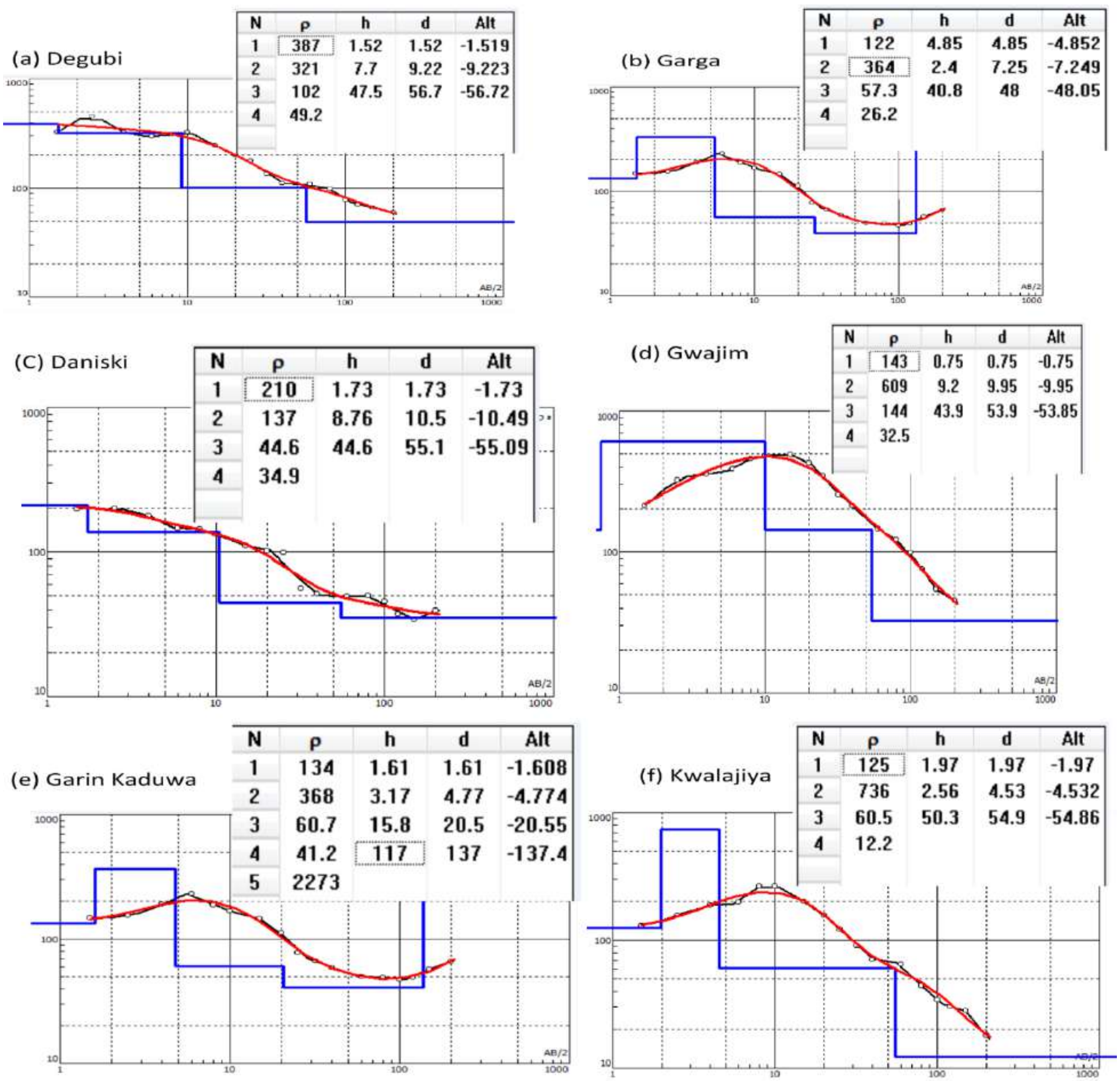

Figure 4. Modeled Resistivity curves and Tables

Resistivity Section

Two sections were generated using the VES data to vividly represent the strata. The first section comprises of 2 VES from Gwajim and Degubi oriented north west-south east. Three layers were deduced from the interpretation of this section, the top layer corresponds geologically to top soil with high resistive near surface and moderate resistive to a depth averagely 20m. The second layer correlates with the sand and gravel with clayey intercalations and has moderate resistivity with its deepest part extending to 50 m. The third layer due to its low resistivity may correlates with porous sediments or wet clay with resistivity ranging below 70 ohmm, this layer has the potential for ground water accumulation.

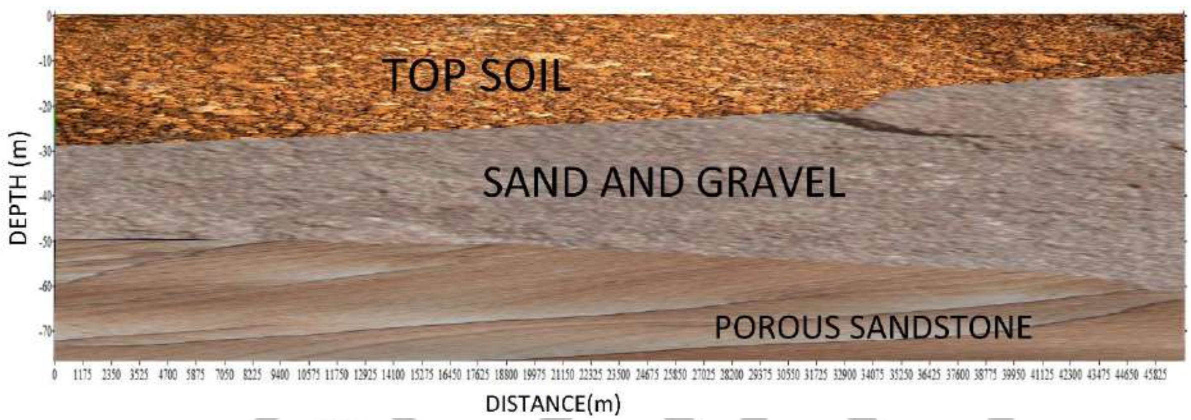

Figure 5. Resistivity Section 1

Section 2 was formed by joining VES from Degubi and Garin Kaduwa and Daniski oriented south west to north east. The interpreted section 1 is made up of four layers, the top layer corresponds geologically to top soil with high resistive near surface and moderate resistive to a depth averagely 10m. The second layer correlates with the sand and gravel with clayey intercalations and has moderate resistivity with its deepest part extending to 60 m. The third layer due to its low resistivity may correlates with semi porous sediments or wet clay with resistivity ranging between 53 and 85 ohmm, this layer has the potential for ground water accumulation. The fourth layer having the lowest resistivity of less than 50 ohmm may consist of porous sediments, therefore making it the most potential aquifer source.

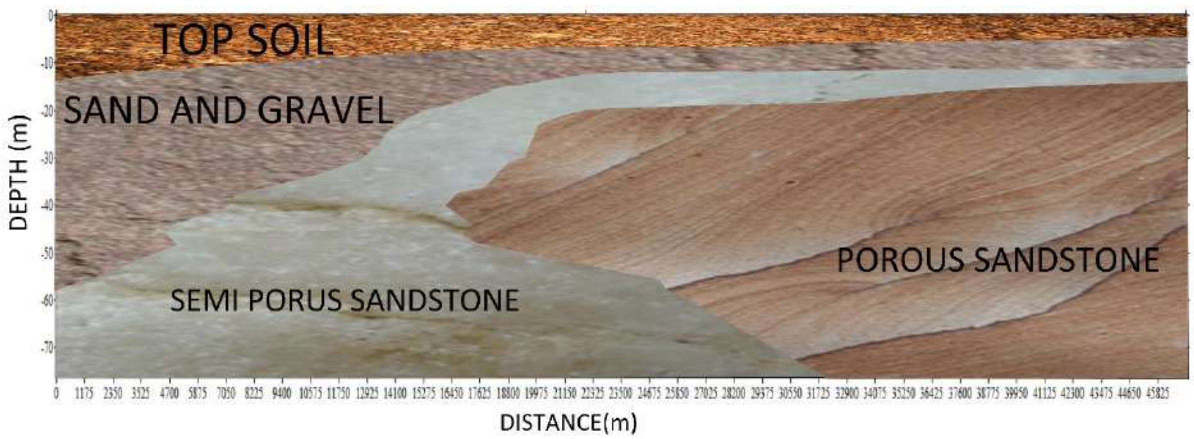

Figure 6. Resistivity section 2

Conclusion

Source Parameter Imaging (SPI) was employed in this work for the processing of the aeromagnetic data. The depth to basement rocks ranging from 300 m at the northern part to 300 m at the southern part. The geoelectrical survey is represented by 2 sections comprising of 4 VESs which were collected by using Schlumberger configuration of AB/2 ranged (from 1.5 to 200 m). The results of quantitative interpretation of the subsurface sequence consists of dominantly three to four geoelectrical units. The first unit consists of top soil with high resistivity and thin thickness. While the second one consists of sand and gravel with thickness ranging from 10 to 50 m of moderate to high resistivity. The third one consists of sandstone of low resistivity ranging from 75 to 50 ohmm and thickness ranging from 10 to 70 m; this unit represents the aquifer of the study area for the three layer section. The last geoelectrical unit consists of low resistivity layer of less than 40 ohmm and thickness ranging from 30 to 80m, this unit represents the aquifer of the study area for the three layer section. It is therefore recommended that for domestic exploitation of the resources within the area, assessment of groundwater quality should be carryout to an average depth of 40m for significant penetration of the aquifer.

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