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Geophysical Investigation of Part of Ahmadu Bello University Farm, Nigeria

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Abstract

Geophysical methods are becoming an increasingly valuable tool even for agricultural applications. Agricultural geophysics investigations are commonly focused on delineating small- and/or large-scale objects/features within the soil profile (~ 0 to 2 m depth) over very large areas. The study was carried out at a farm site in Ahmadu Bello University, to delineate subsurface structures with depth. It revealed the lithological units in the study area. The analyses has revealed various lithological units from the results of the inverted sections along the profiles. The study area has shown clearly two distinct layers, overburden and weathered basement. The overburden layer is clayey sand, sandy clay, and laterite. This laterite soil show very high resistivity anomaly that may be referred to as consolidated laterite. The weathered layer which contains medium grained sand with clay and feldspar materials also has the presence of fractured part that could act as the aquifer in the area. From the subsurface properties, this farm land may have low agricultural yield or may limit the cultivation potential of the region, but the region may be good for underground water yield.

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1. Introduction

Geophysical investigations of the earth involves the study of physical properties of the earth, thereby providing vital information of characteristics of subsurface material. Geophysical investigation can generally be classified as

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shallow (residual) or deep (regional) study. However, analysis of these measurements can reveal how the physical properties of the earth's interior vary vertically and laterally, reflecting the subsurface geology [1]. Most techniques of geophysical probes are noninvasive (Resistivity, electromagnetic induction, ground penetrating radar, seismic, gravity, radioactive nuclear magnetic resonance, etc.) but with some very few exceptions like cone penetrometer and borehole geophysical methods.

In comparison to the scope of geophysical research in the mining and petroleum industries, the extent of geophysics applications to agriculture is incredibly modest and ranges from the earth surface to a few centimeters below the earth. In fact, geophysical imaging of the interior of a tree trunk is one application of agricultural geophysics where the scale can actually be as small as a few centimeters [2].

In agriculture, geophysical techniques have often been utilized primarily for some kind of soil analysis. As a result, agricultural geophysics is frequently primarily concerned with depths between the ground's surface and 2 meters, which is the range typically containing the soil profile and the entire crop root zone [1], [3]. This relatively shallow depth of interest (2 m) is undoubtedly advantageous for agricultural geophysics applications since most geophysical technologies have capabilities to probe deeper. Electrical resistivity method and ground penetrating methods are some of the best methods of probing such shallow depths.

In this study, the electrical resistivity method is used to examine the subsurface structure of some part of the Ahmadu Bello University farm. A wide range of soil phenomena with an impact on agriculture and the environment are being studied with an increasing demand for near-surface observing technologies, from the analysis of time-dependent changes in water content to the detection of pollutants, to the analysis of soil salinization and fertility to the study of soil-root plant interactions [1, 3].

The Electrical Resistivity method calculates the electrical conductivity or apparent resistivity of a bulk volume of soil that lies directly below the earth surface. Details of this method can be found in shallow investigations like; [4-6].

The aim of this project is to delineate the earth's subsurface structure of a farm land using a non-invasive geophysical techniques.

2. Location and Geology of the Study Area

The Ahmadu Bello University farm is situated in Shika, along Zaria-Funtua Road, North of Ahmadu Bello University main campus. It lies within latitudes $11^o\ 11'\ 47''$ N and $11^o\ 11'\ 57''$ N and longitudes $07^o\ 35'\ 26''$ E and $07^o\ 35'\ 44''$ E as shown in Figure 1. It is bordered by Bomo village in the northeast and Ahmadu Bello University Teaching Hospital (ABUTH) in the south Accessibility of the university farm is by the Zaria-Funtua Road which is a prominent Federal Road. The farm is about 3 km from A.B.U. Main entrance.

Geologically, the past events have led to the classification as Basement complex and Sedimentary basin [7] regions in Nigeria. The study area is in the Basement complex region and consist of rocks like; Biotite gneisses, migmatites, metasediments quartz, schist and some intercalation of amphibolites [6]. The study area belongs to the Nigeria Basement Complex which according to [7], is composed of four distinct rock types. The rocks typically found within the basement complex include gneisses, migmatites, metasediments and some intercalation of amphibolites. The basement complex rocks occupy more than 50% of the total land surface of Nigeria. The basement complexes accommodate the metasediments and are made up of gneisses. Exposures are scanty and highly weathered. The rock types are biotite, gneisses, granite gneisses and in parts with subordinate migmatites. The contact between the gneisses and metasediments are gradational, Dahomeyan-Birrimian in age [7]. The Zaria crystalline rocks are part of the Nigerian Basement Complex. Oyawoye [8] has shown that there is a structural relationship between this Basement Complex and the rest of the West African basement. This is partly due to the fact that the whole region was involved in a single set of the orogenic episode, the Pan African orogeny, which left an imprint of structural similarity upon the rock units.

3. Methodology

3.1. Electrical Resistivity Tomography

The Terrameter SAS 4000 with an electrode selector is used. This equipment works based on the principle of the conventional four electrodes (two current electrodes and two as potential electrodes) technique. For a better resolution,

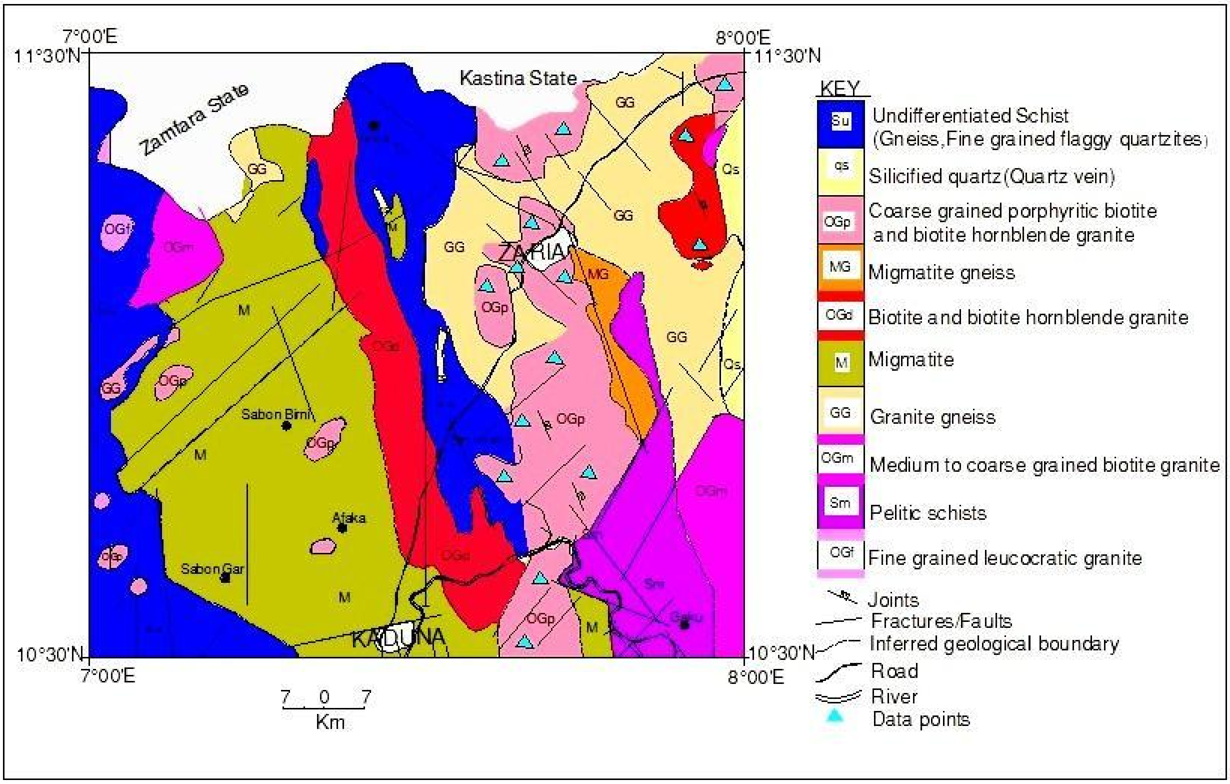

Figure 1. Geological map of part of Kaduna state, showing the study area

the dipole-dipole array was used. A total of forty-two (42) electrodes of 5 m interval are connected to the electrode selector along the profile line. A computer-controlled system is then used to automatically select the active electrodes for each measure [9]. The raw data were processed and interpreted using RES2DINV software. The data were filtered to remove bad datum points and inverted to estimate the true resistivity of the subsurface. Model refinement option of the "Inversion" menu was used to take care of the large resistivity variations near the ground surface. Measurements were made along 6 profiles, separated by 10 m interval were measured as shown in Figure 2.

4. Results

Figures 3-8 shows the two-dimensional inversion result for all the profiles, with a 4.8 % absolute root mean square (RMS) error for profile 1 (Figure 3), 12.2 % error for profile 2 (Figure 4), 4.5 % error for profile 3 (Figure 5), 4.0 % error for profile 4 (Figure 6), 8.6 % error for profile 5 (Figure 7) and 5.2 % error for profile 6 (Figure 8). The error shows that a good fit has been achieved between the calculated and measured apparent resistivity values.

The apparent resistivity results were correlated with lithology information obtained from borehole logs dug around the study area.

5. Discussion

The Electrical Resistivity Imaging (ERI) shows the variation in the distribution of the soil resistivity at different depth along each profile. From visual inspection, the ERI can be classified into two major layers; the overburden layer and the weathered basement layer. This six profile all show this two major classifications; the section above the black line is the overburden while the section below the black line is the weathered basement layer.

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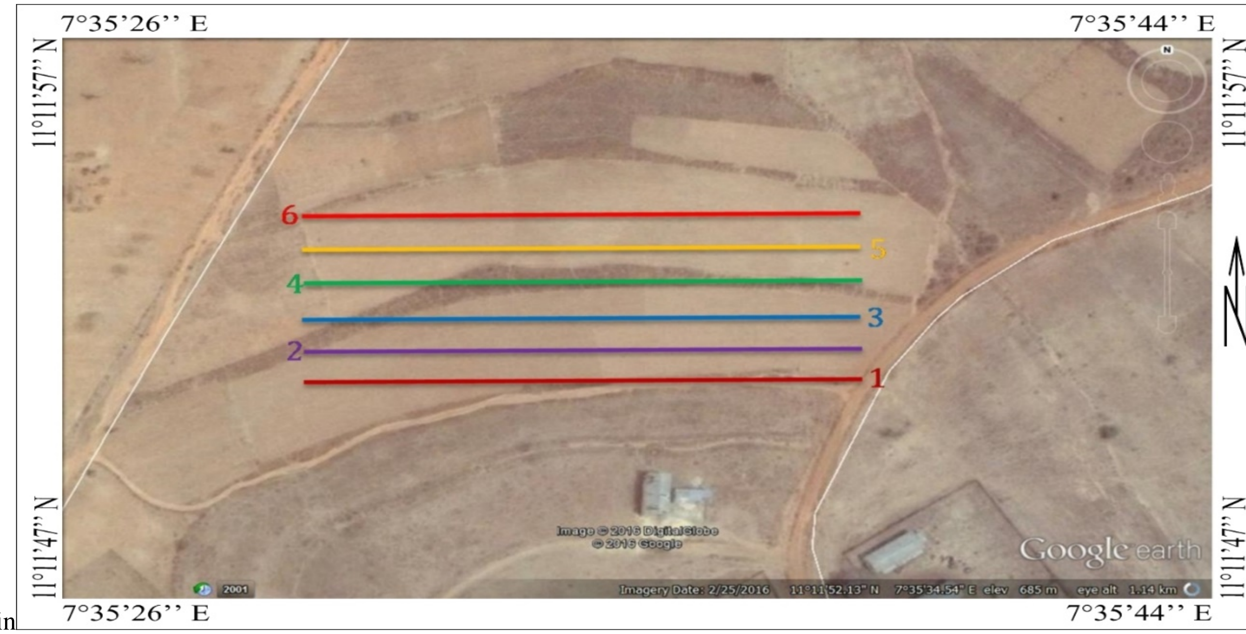

Figure 2. An illustration of the 2-D profiles layout superimposed on the Google earth map used for the study area

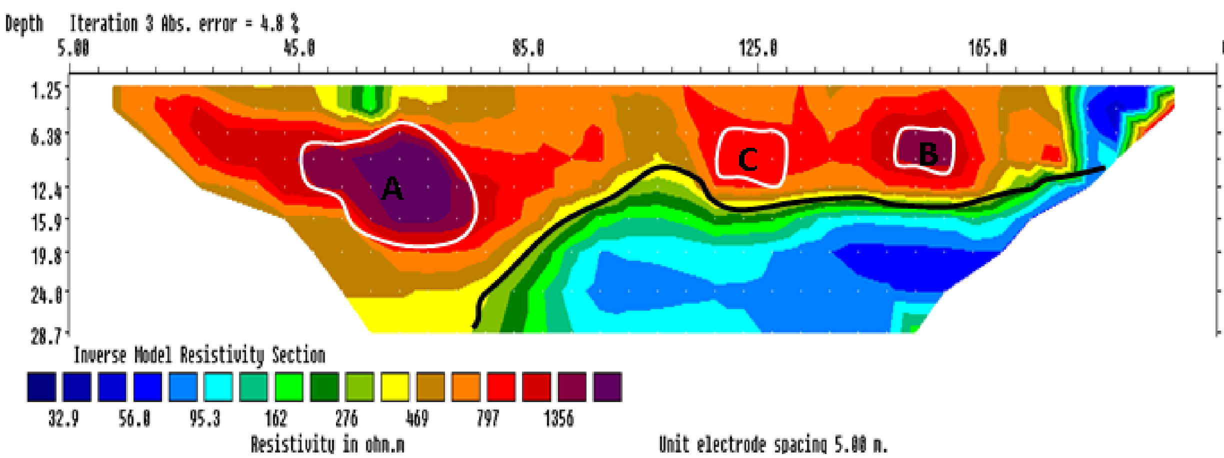

Figure 3. Result of 2-D inversion of the data along profile 1

This classification correlates with the geological borehole log obtained for the region [10]. The overburden contains pockets of very high resistivity anomalous body that are continuous in all the profiles. This shows that the overburden consists of reddish-brown soil (suspected to be majorly Lateritic clay), fine partly silty clay and brown sandy clay [10].

Generally, the distribution of the subsurface soil resistivity in the inversion models shows a wide variation in the soil resistivity with depth along the profiles. The ERI revealed that the overburden layer is characterized by relatively high resistivity values across the study site with the resistivity values ranges between 450 Ωm to 2,000 Ωm with thickness ranging from 12.4 m at the end of the profile to about 30.0 m at the beginning of the profiles. The variation in the resistivity values depicts the nature of the inhomogeneity of the layer. The subsurface heterogeneity comes from the presence of clayey sand, sandy clay and laterite soil. Within the overburden also, there exist a very high resistivity anomaly ¿ 900 Ωm at a depth between 5 m – 20 m, this was interpreted as consolidated bodies that has weathered over

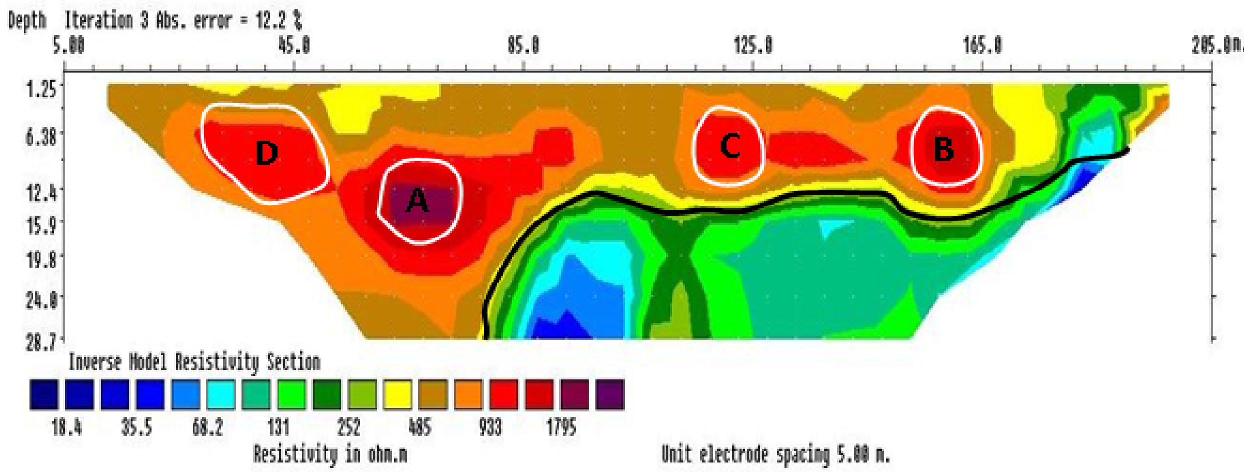

Figure 4. Result of 2-D inversion of the data along profile 2

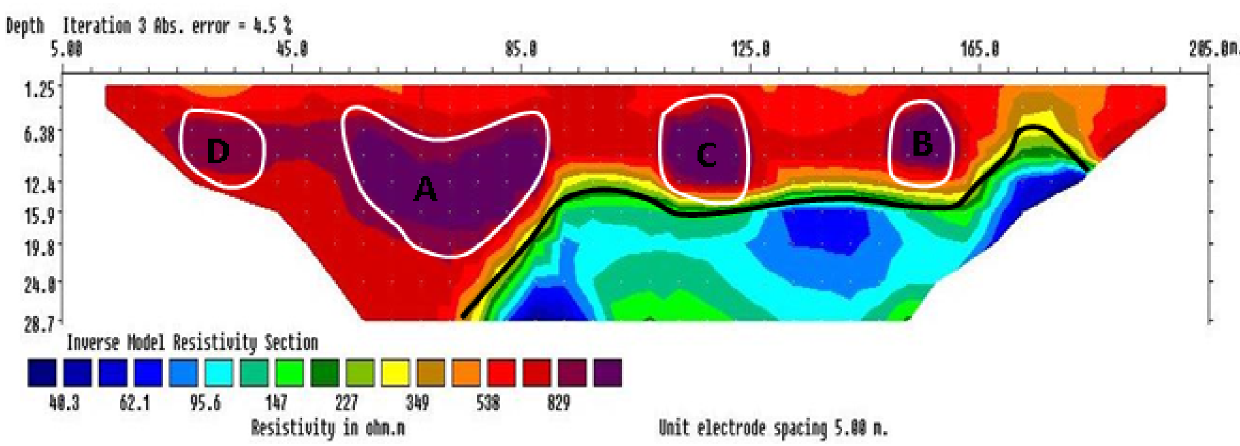

Figure 5. Result of 2-D inversion of the data along profile 3

time. The consolidated bodies appears to have conical shapes (A, B, C, D, and E) and are believed to be continuous cylindrical bodies. It is also possible that the whole of the overburden layer was once a solid plate lying horizontally and the activities of weathering has fragmented the body through fracture lines coming from beneath the layer. The section marked "A" appears in all the profile (which shows continuity) and has resistivity value greater than 1000 Ωm in most of the profiles. This body is biggest in profiles 3 and 4 (Figure 6 and 7). This could mean slower weathering activities around this area. The section "B" with resistivity value > 1000 Ωm in all the profiles except profiles 1 and 2 (Figures 3 and 4). Profiles 4, 5, and 6 (Figures 6, 7, and 8) has shown high weathering activities from the surface between the anomalous sections "B" and "C", this could also be a fractured line that has extended to the surface. This might also be the case for the section "A" which has further fragmented into "D" and "E" in profiles 2, 3 and 5.

The weathered basement which shows high degree of fracture, may consisting of gravel, brownish fine to medium grained sand with clay and feldspar [10]. This layer has resistivity values ranging between 18 Ωm to about 470 Ωm and occurs from the depth of about 8.0 m (at the end of the profiles) to a greater depth of 30.0 m (at the beginning of the profiles). However, Figures 3, 4, 6, 7 and 8 has shown weathering exposed to the surface. Figure 6 and 8 has shown large region of saturation below the black line. It is obvious that weathering has extended to the surface in Figures 3 and 4 (at a lateral distance of about 55 m to around 180 m) and Figures 6, 7 and 8 (at a lateral distance of about 45 m and 135 m).

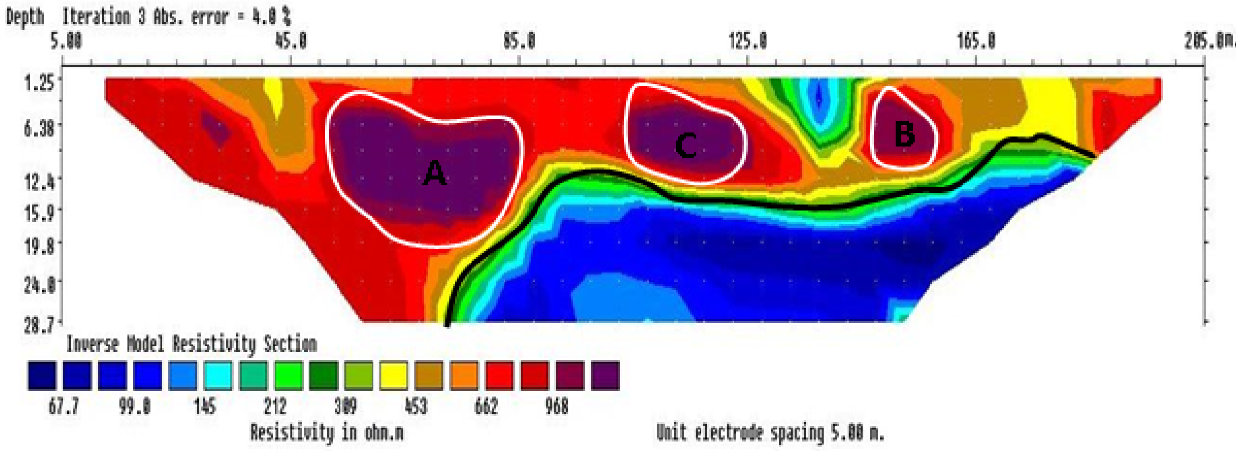

Figure 6. Result of 2-D inversion of the data along profile 4

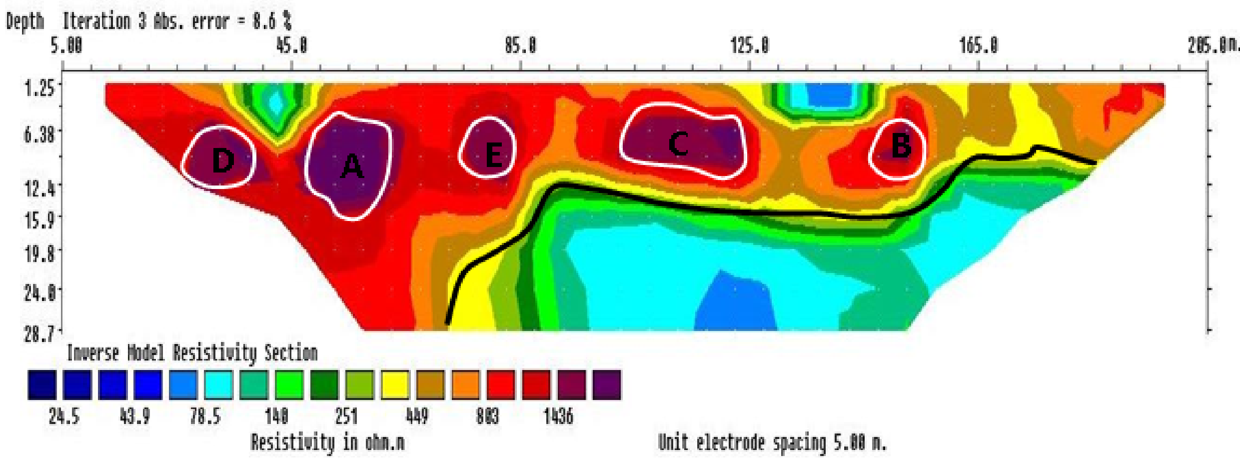

Figure 7. Result of 2-D inversion of the data along profile 5

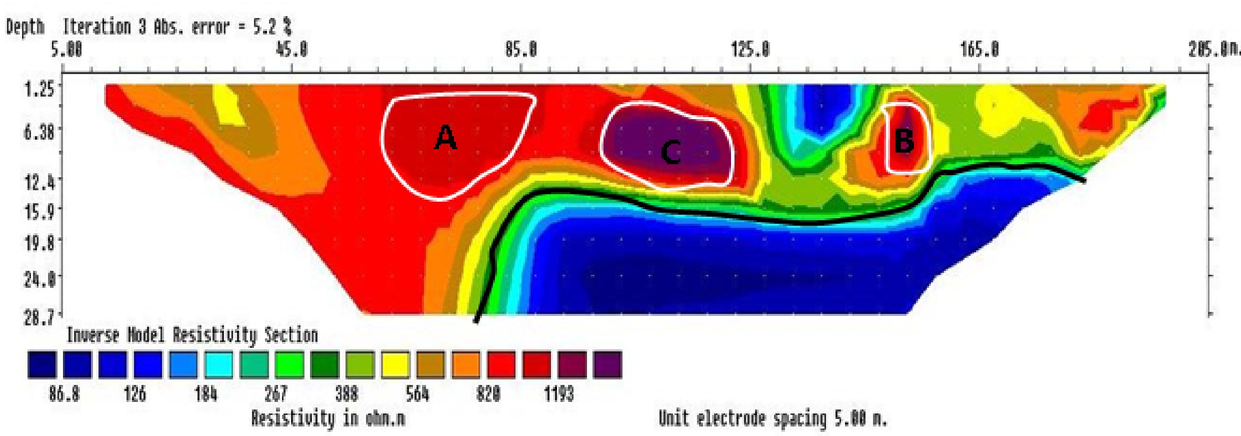

Figure 8. Result of 2-D inversion of the data along profile 6

Typically, metamorphic rocks in basement complexes form laterites, which are brownish coloured soils and are known to have high consolidation properties [11], as shown in the overburden layers of all the profile. Also, result has shown very saturated weathered basement but hard and consolidated overburden, another property of laterite which reduces the water retention of the soil there by causing shrinkage and cracking [12]. This unstable nature of the subsurface could also be due to the presence of large quantity of clay [13]. From the subsurface properties, this farm land may have low agricultural yield or may limit the cultivation potential of the region, but the region may be good for underground water yield.

6. Conclusion

The Electrical resistivity method has been used to delineation the subsurface structures of part of a farm land. It has shown presence of fractures that are highly weathered. The results shows lithological structure of the rock and soil apparent resistivity, based on the resistivity contrast with the host rocks. This was classified into two distinct geological layers of overburden and weathered basement layers. In correlation with a borehole log, the overburden layer is believed to have clayey sand, sandy clay, and laterite soil. This laterite soil show very high resistivity anomaly that may be referred to as consolidated laterite. Also from borehole log correlation, the weathered layer is believed to contain medium grained sand with clay and feldspar materials and presence of fractured part that could act as the aquifer in the area. The result further shows that the high resistivity at the subsurface are consolidated laterite which display an unstable characteristic and consequently, may not be a good framing cultivation. The top soil also shown a low water retention ability and hence lowers the soils potential for agriculture. However the area has a good water potential that may be promising for irrigation farming.

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