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ELECTRICAL RESISTIVITY IMAGING SURVEY FOR SHALLOW SITE INVESTIGATION AT UNIVERSITY OF IBADAN CAMPUS SOUTHWESTERN NIGERIA

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ABSTRACT

A geo-electrical imaging survey was conducted at Abadina area of University of Ibadan, Ibadan, south-western Nigeria for shallow site investigation in order to determine the applicability of 2-D resistivity imaging in studying the weathered profile, which in turn determines how feasible the area would be in terms of erection of structures that will stand the test of time. The area is underlain mainly by augen gneiss with minor intrusion of dolerite dyke. Geophysical survey was carried out using 2-D electrical resistivity imaging technique. The Wenner array was employed. Field data were obtained for eight electrical imaging lines. The field data was subjected to inversion in order to remove geometrical effects from the pseudosection and produce an image of true depth and true formation resistivity. This layer has a range of resistivity from 10 to 100 Ohm-m. Partially weathered basement were observed on some of the traverses with relatively high resistivity anomalies. The image lines depict clearly that the subsurface material differs in terms of their competence. This is reflected in the weathering pattern where part of the image line was showing deeply weathered material towards one side whereas the other side is showing very shallow overburden at less than 2 m. In conclusion, site investigation using 2-D electrical resistivity imaging is an essential step to be taken before the erection of any structure for minimum damage because a balanced interaction of soil and structure is the hall-mark of a successful design of foundation. Further studies such as soil test should be carried out to ascertain the suitability of the soil for future planning of the site.

Keywords: electrical imaging, site investigation, wenner array, clay layer, competent rock, Ibadan.

INTRODUCTION

Geoelectrical measurements are an important and integral component of geophysical investigations connected with environmental problems. In recent years, electrical resistivity surveys have progressed rapidly from the conventional sounding survey, which provides layer depths and resistivities at a single place, to techniques which provide two-dimensional electrical pictures of the subsurface. The purpose of electrical surveys is to determine the subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity of the subsurface can be estimated. This development started with the introduction of practical electrical tomography field systems, like the geoelectrical Wenner pseudosection and was soon followed by effective processing and inversion software. The imaging technique is particularly powerful and useful in the study areas of complex geology, in groundwater problems and in many other shallow subsurface investigations (Dahlin, 1996). 2-D electrical imaging method gives good results when the resistivity contrast is high.

Within the weathering profiles, the primary rock minerals are destroyed or altered in response to atmospheric and biospheric conditions. The effect of weathering in areas of crystalline rock is to alter the hard parent material with very low porosity and primary permeability into softer and eventually quite earthy materials with very high porosity and storativity. The weathered profile developed above crystalline basement rocks in low latitude regions comprise, from top to bottom, the soil layer, the saprolite (product of insitu chemical weathering of the bedrock), the saprock (fractured bedrock) and the fresh bedrock (Olayinka and Olayiwola, 2001). Barker *et al*., (2001) used electrical resistivity imaging technique to delineate contaminated zone near Dindigul town in India. The imaging over the contaminated areas, although providing interesting information, can only be interpreted qualitatively and that electrical images provide a more detailed view of the subsurface structure than can be obtained using other geophysical technique and therefore lead to a better understanding of the subsurface. Mondal *et al*., (2008) demonstrated that electrical resistivity imaging (ERI) method can give a better picture of the concealed structures, than the conventional maps of true and/or apparent resistivity contours using the vertical electrical sounding method. From their study, concealed lineaments within the granitic terrain of India were identified which further proved the resistivity imaging technique to be a powerful tool in the study of concealed lineaments as well as groundwater exploration.

Weathering and fracturing depend on the lithology and texture of the parent rock and the extent of the weathered overburden and the presence of joints and fractures in the underlying bedrock (Acworth, 1987). Deep weathering has proved to be the most important single factor in geological environments (Le Grand, 1962; Asseez, 1972) especially in the humid tropics by providing an overburden of relatively more porous and more permeable materials from the rocks. There is ample evidence that there is a considerable weathering depth in

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many parts of the Nigeria basement (De Swardt, 1955; Thomas, 1966; Jeje, 1972) which Ibadan part is of. The development of thick clay in basement complex terrain leads to failure in constructions. Other prevailing environmental factors such as topography, vegetation and climate favour engineering construction.

The study of weathering profile, its vertical variation, spatial distribution, textural characteristics of the constituent materials are essential step towards a better understanding of shallow site investigation in basement complex areas. To locate a successful site for construction in Precambrian basement terrain is problematic due to the heterogeneous nature of the subsurface and so the geology of the sobesurface needs to be investigated in considerable details. This knowledge has led to the application of geophysical methods mostly resistivity sounding in site investigation. Due to the limitations of the conventional resistivity sounding and profiling, electrical resistivity imaging (2-D) was used in this study for mapping the subsurface layers at Abadina area of University of Ibadan because it is capable of yielding adequate information on subsurface rock types and distribution.

MATERIALS AND METHODS

Site description

The University of Ibadan campus is located in the north central part of Ibadan metropolis, Southwestern Nigeria (Figure-1). It lies between Latitudes $7^0 26.00^1$N and $7^0 27.7^1$N and Longitudes $3^0 53.00^1$E and $3^0 54.12^1$E. It covers an area of approximately 3.4 by 3.6 square kilometers. The area is characterized by a gently undulating relief with elevation ranging between 180 m and about 230 m. The mean annual rainfall ranges between 788 mm and 1884 mm while the mean annual temperature is 26.6^0C. There is fluctuation in the volume of River Ona and the Oba dam with the weather conditions, the highest being recorded during the rainy season between the month of April and October. From November to February, the water level is very low.

Geology of the study area

Ibadan, a region in the Southwestern part of Nigeria is dominated by rock types such as granite and granitic schist of the metasedimentary series, banded gneiss and granite gneiss, augen gneiss and migmatite complex (Figure-2). (Okunlola *et al*., 2009). Quartzite outcrops occur as ridges with relatively high elevation and are commonly schistose in form. Their strike line runs in the north-south direction between 340^0 and 350^0 consistently dipping eastwards with characteristic cross-cutting features (Olayinka, 2001).

The University of Ibadan Campus is underlain by quartz schists, granite gneisses and augen gneisses (Figure-3). The quartz schists occur in the western part of the campus while the eastern part is underlain by augen gneiss. They are separated by the granite gneiss which extends from southern part to a point towards the north. The quartz schists and augen gneiss outcrop in various parts of the campus but the former are more extensively weathered and fractured (Oladunjoye, 2010).

Foliation planes are well developed and the general strike direction is north-south. The rocks are gently dipping with dip values ranging from 10^0 to 50^0.

Methods of study

In order to achieve the objectives of the present study; the field survey consists of reconnaissance survey to ascertain the rock types, so as to locate the possible area for the resistivity measurements using 2- D electrical imaging survey. For the geophysical survey, field resistivity data were obtained along eight imaging lines using Wenner configuration and a maximum of eight levels were attained for each of the traverse. The lines were aligned in the N-S and W-E azimuths. Five of the traverses which are 1, 2, 3, 4 and 5 were oriented along N-S azimuth while the remaining three traverses 6, 7 and 8 were oriented along W-E azimuth. The field layout of the traverses is shown in Figure-4.

2-D resistivity data were acquired along 100 m long profile, using an electrode spacing ranging from 2-16 m for each traverse. To be able to give a two-dimensional picture of the resistivity distribution within the subsurface as well as show a qualitative picture of the resistivity data obtained, the resistivity measurements obtained were used to construct a pseudosection and then contoured.

The measured apparent resistivity data were inverted to create a model for the subsurface resistivity using an iterative smoothness-constrained least square inversion.

The Diprowin software was used for the inversion and an acceptable model is normally arrived at within 5 iterations. It is a 2-D inversion program that needs no previous knowledge of the subsurface as the initial guess model is constructed directly from field measurements.

RESULTS AND INTERPRETATIONS

The results of the 2-D electrical resistivity imaging surveys are presented as contoured pseudo and inverted sections. A contoured pseudosection conveys a qualitative two-dimensional variation of resistivity within the subsurface. The pseudosections of the measured and calculated apparent resistivity as well as the section of the inverted resistivity model for traverses 1 to 8 are shown in Figures 5 to 12. The inverted sections create models for the subsurface resistivity using an iterative smoothness-constrained least square inversion.

Image line 1

The inverted section (Figure-5) clearly shows a relatively thin layer of resistive materials as the topsoil (about 2 m thick). Below this unit is a conductive layer about 6 m thick and towards the north is another layer of resistive material ranging from 6 m to 8 m between electrodes position 0 to 50 m. The weathered basement in the northern part shows resistivities less than 100 Ohm-m indicating clayey soil. The high resistivity anomalies

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observed at the depth range of 6 m to 8 m at the northern part of the section shows that the subsurface materials are relatively resistive. Towards the southern part of the line, the weathering is deeper as indicated by the low resistivities at depth. This is a clear indication that the degree of weathering is not uniform along the image line.

Image line 2

This section (Figure-6) shows relatively low resistivity at less than 100 Ohm-m towards the northern part. The low resistivities (< 100 Ωm) are typical of clay-rich lithology which is similar to the range established for similar geological provinces (Wright, 1992; Barker *et al*., 1992; Olayinka *et al*., 1999).

There is a dome-like rock body with high resistivity values toward the southern part of the section at electrode position of about 66 m to 84 m. This image line depicts clearly that the subsurface material differs in terms of their competence and this will definitely have implication on any structure which would be erected in such area.

Image line 3

The resistivity section of Line 3 (Figure-7) shows a dome like structure observed towards the northern part of the section which is an indication of basement high. Generally, across the line, a thin layer of resistive material constitutes the top soil and towards the northern part, there is a pocket of conducting material forming a closure. At electrode position of about 20 m to 40 m, overburden is very shallow at about 4 m. towards the southern part; there is an indication of deep weathering. The weathering pattern is not uniform. Erection of structure (building) on this type of site will result in one side of the building resting on competent bed and the other side on an incompetent layer (clay).

Image line 4

The inverted section of Line 4 (Figure-8) clearly shows a thin layer of resistive material of about 1m thick. Towards the northern part of the section is a conductive material (<100 Ohm-m) of about 6 m thick. Towards the southern part at electrode position 24 - 34 m is a dome like structure with higher resistivity values which is also an indication of basement high. At electrode positions 42 - 66 m is a conductive layer with resistivity values of less than 70 Ohm-m with decreasing resistivities with depth.

Image line 5

This section (Figure-9) shows a thin layer of resistive material which constitutes the top soil. This is followed by conductive material (< 100Ohm-m) of about 6 m thick. At electrode position of about 38 m to 68 m, overburden is very shallow at about 2 m with increasing resistivities with depth.

Image line 6

The inverted section (Figure-10) shows a thin layer of resistive material forming the top soil at electrode position from 18 m. To the western part of the section, is a closure of weathered material of about 6 m thick with resistivity values of less than 80 Ohm-m. The resistivity values towards this part increases with depth and it shows that the subsurface materials are relatively resistive. Towards the central part of the section, a layer with low resistivity values was observed below the thin layer of resistive top soil which is about 6 m thick. Towards the eastern part of the image line, there is a closure of conductive layer (50 - 70 Ohm-m) overlying the resistive material with increasing resistivities as the depth increases.

Image line 7

The inverted section (Figure-11) shows a thin layer of resistive material forming the top soil. This is followed by a conductive layer (< 100 Ohm-m). Towards the western part of the section, high resistivity (>300 Ohm-m) anomalies was observed on the traverse at increasing depth which indicates that the subsurface materials are relatively resistive as compared to the central part of the section in which the resistivities decrease with depth. Towards the eastern part of the section, there is a small closure of weathered basement (<60 Ohm-m) within the resistive materials, which may indicate pocket of clayey soil. The basement shows a dome-like resistive structure.

Image line 8

Figure-12 shows the inverted section of line 8. This section shows distinctively resistive top soil which ranges between 0-4 m. The top soil is underlain by less resistive material which has varying thickness across the section. The image shows that the degree of weathering is deeper at the central parts of the line.

DISCUSSIONS

A 2-D electrical resistivity imaging survey using Wenner array has revealed the pattern of resistivity variations within the study area. The top soil of the survey area is generally resistive as a result of the relative high resistivity values observed on some of the traverses. This may be related to different degree of compaction in the area. The low resistivity anomalies observed with increase in depth along the traverses could be due to changes in moisture contents and degree of weathering which could cause the subsurface to have varying resistivities. The high resistivity anomalies observed on some of the traverses at the depth range of 6-8 m shows that the subsurface materials are relatively resistive. This probably suggests that the basement is shallow as compared to those in which the resistivities decrease with depth. The decrease in resistivity may indicate that overburden is relatively thick tending towards sandy-clay/clayey material at depth. All the inverted sections in the survey area depict an uneven subsurface topography reflecting different degree of weathering which is a common characteristic of crystalline basement rocks. The poorly weathered/fresh part of the basement in the area shows resistivities above

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184 Ohm-m and is generally undulating indicating uneven weathering.

High resistivity anomaly in some of the traverses indicates resistive subsurface materials. However, low resistivity anomaly may be due to the presence of saturated clayey materials at shallow depth.

In the study area, overburden is thick on some traverses because of decreasing resistivity with depth and shallow on the other traverses because of increasing resistivity with depth. This is an indication of uneven weathering pattern of the subsurface crystalline rocks.

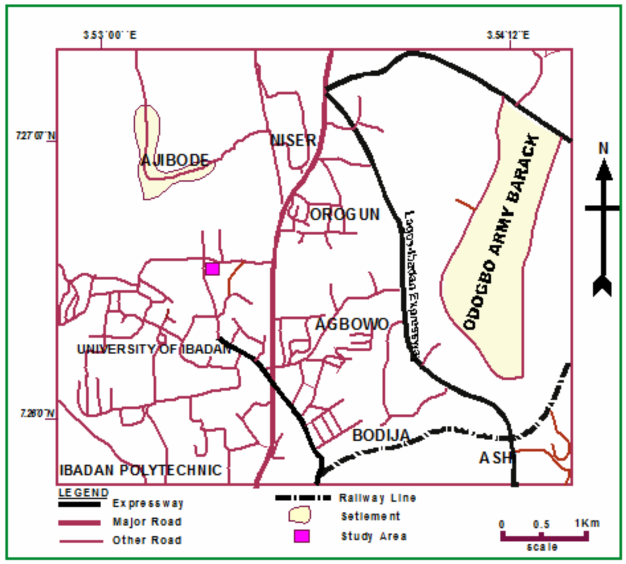

Fig. 1: Map of the study area showing location and accessibility
(Source :Map depot, Ministry of works Oyo State Nigeria)

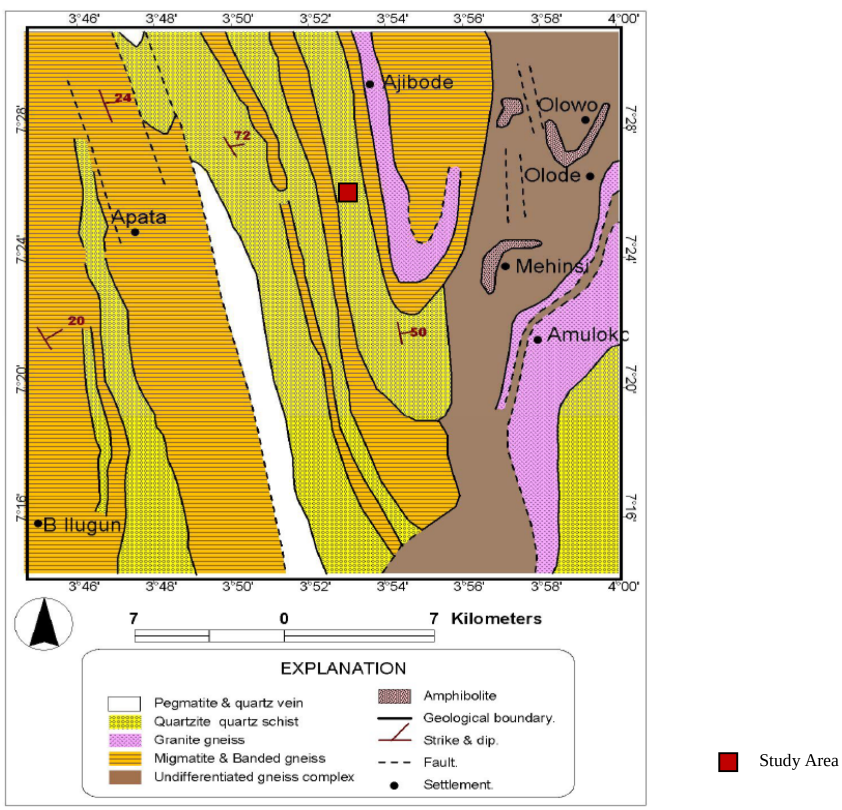

Figure-2. Geological map of Ibadan (After Okunlola *et al*., 2009).

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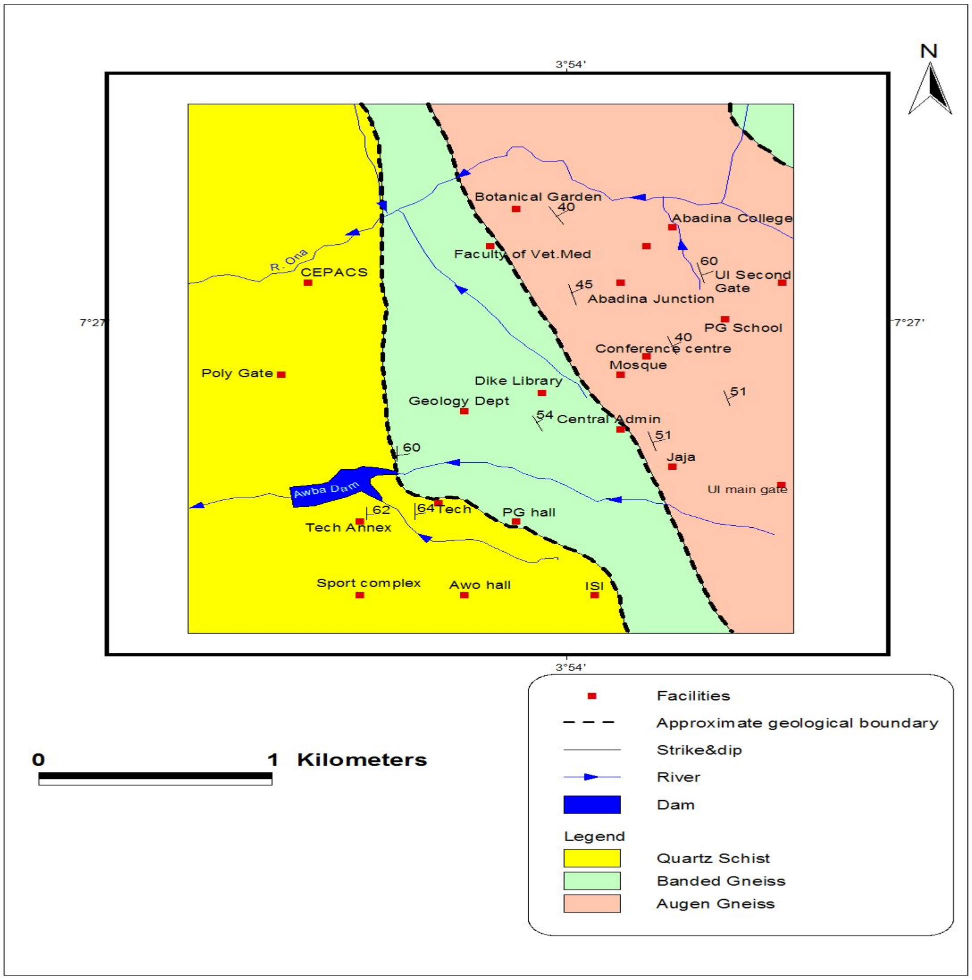

Figure-3. Geological map of university of Ibadan (After Oladunjoye, 2010).

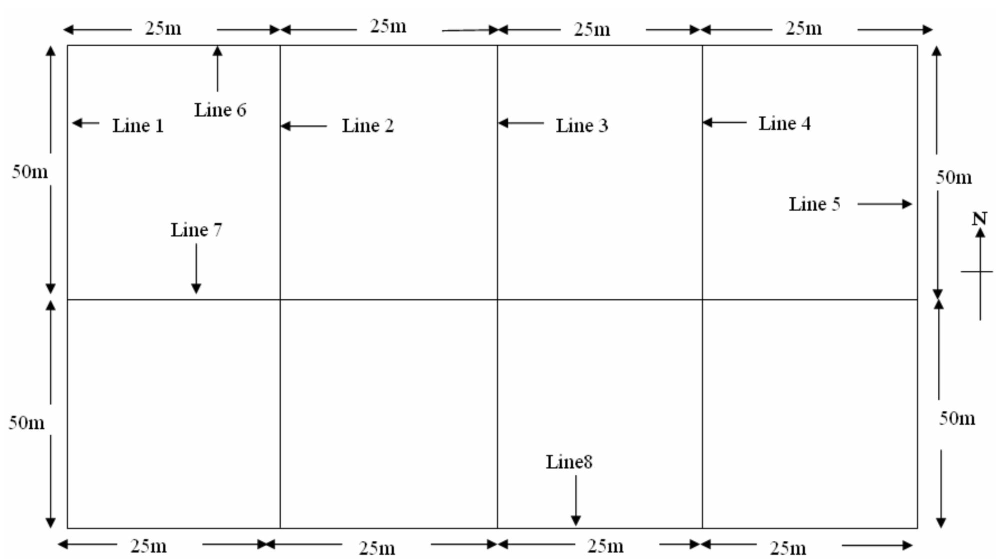

Figure-4. The field layout of the traverses.

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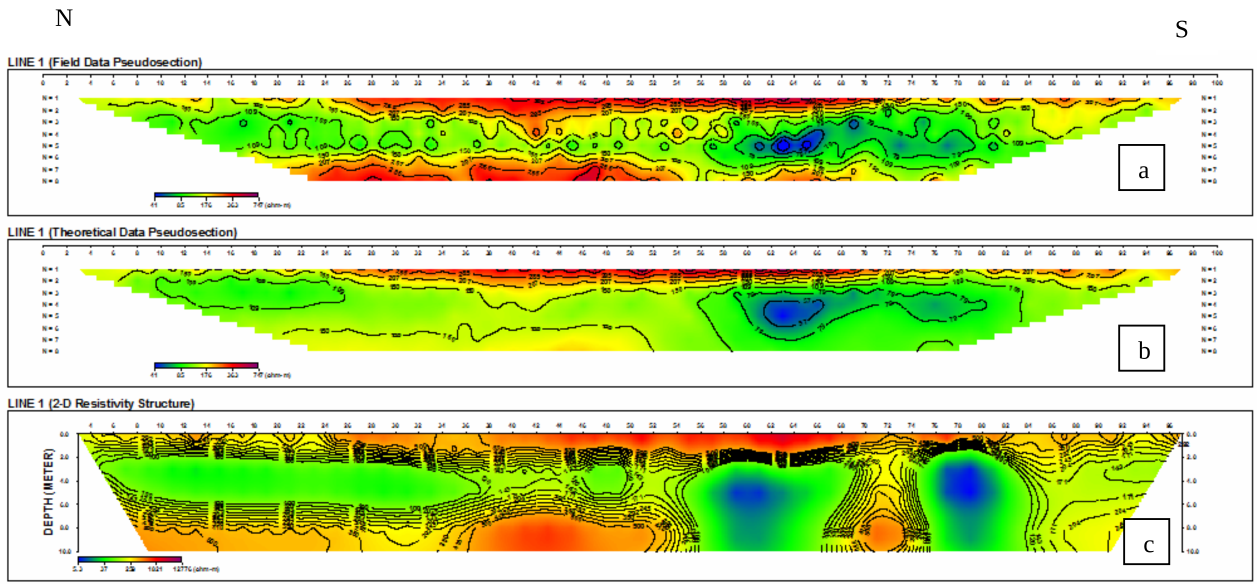

Figure-5. (a) The measured apparent resistivity pseudosection, (b) the calculated apparent resistivity pseudosection and (c) the inverse model resistivity section for traverse 1.

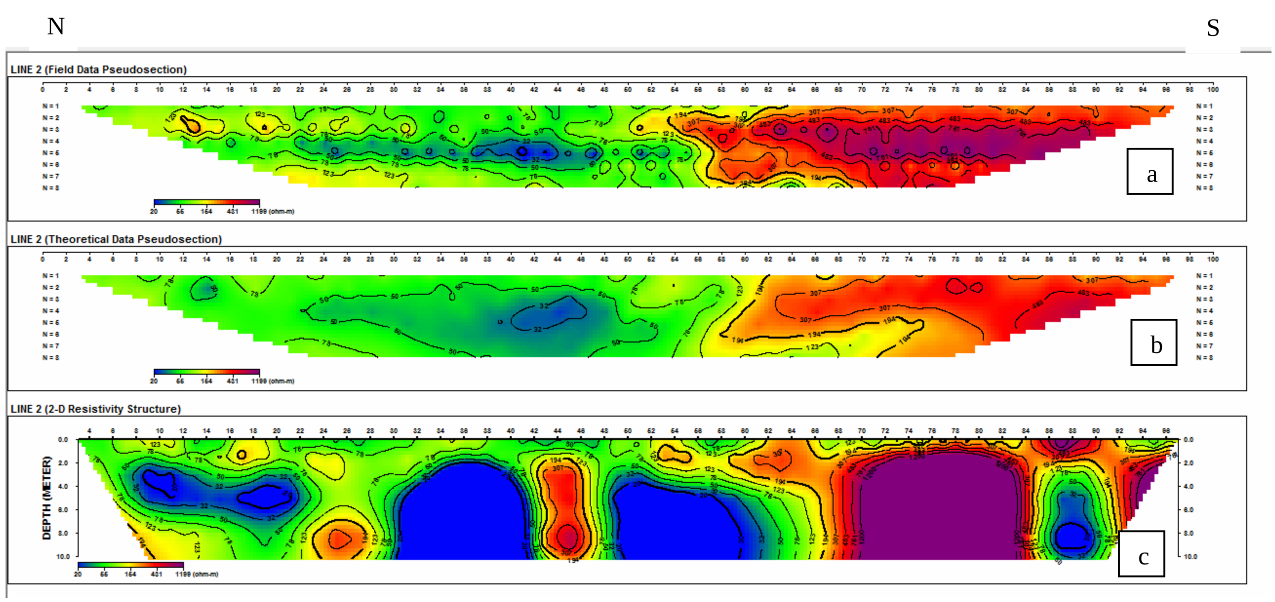

Figure-6. (a) The measured apparent resistivity pseudo section, (b) the calculated apparent resistivity pseudosection and (c) the inverse model resistivity section for traverse 2.

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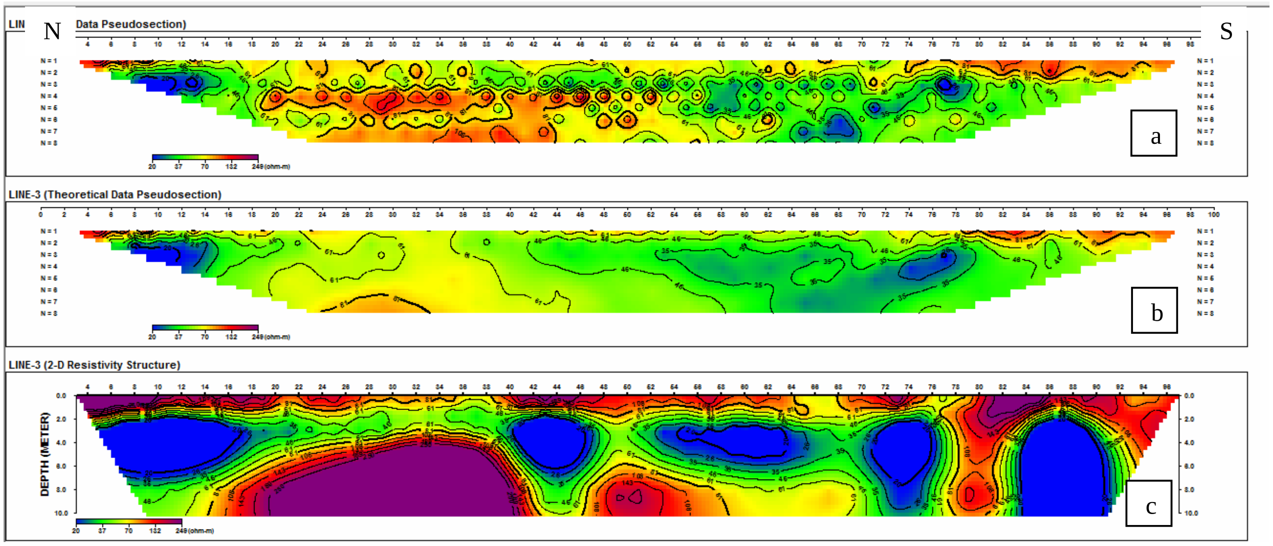

Figure-7. (a) The measured apparent resistivity pseudo section, (b) the calculated apparent resistivity pseudo section and (c) the inverse model resistivity section for traverse 3.

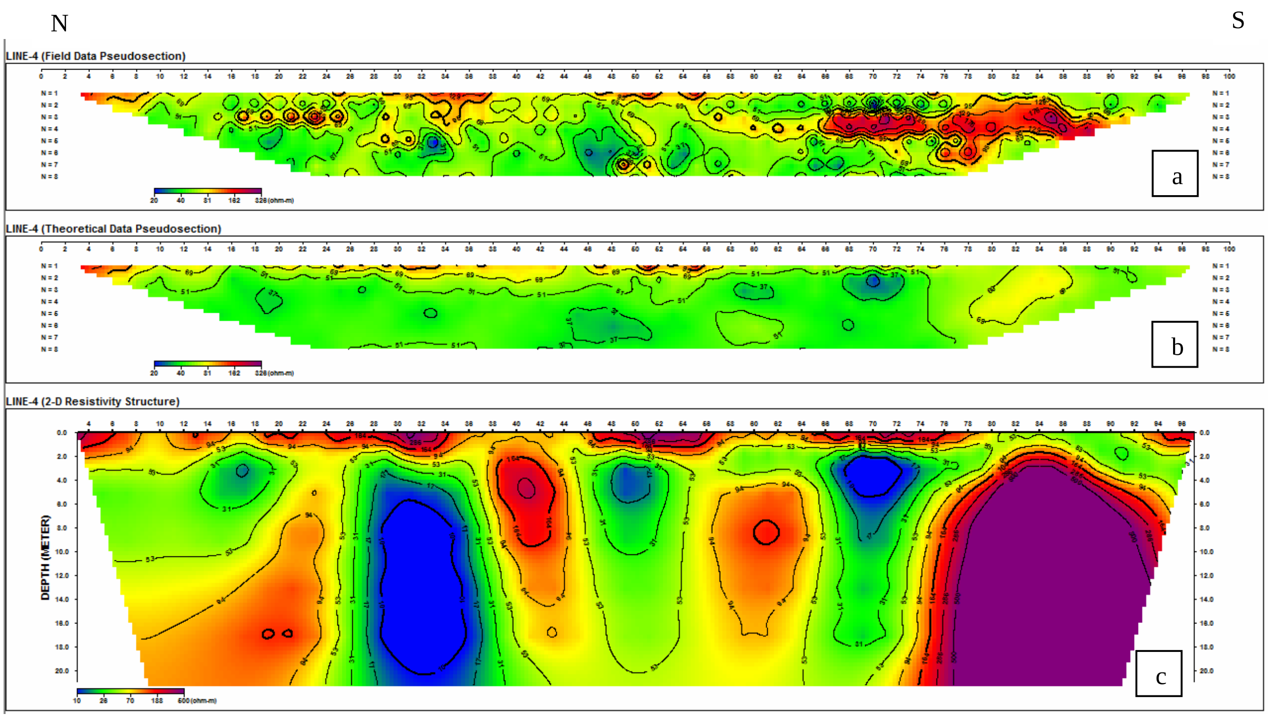

Figure-8. (a) The measured apparent resistivity pseudo section, (b) the calculated apparent resistivity pseudo section and (c) the inverse model resistivity section for traverse 4.

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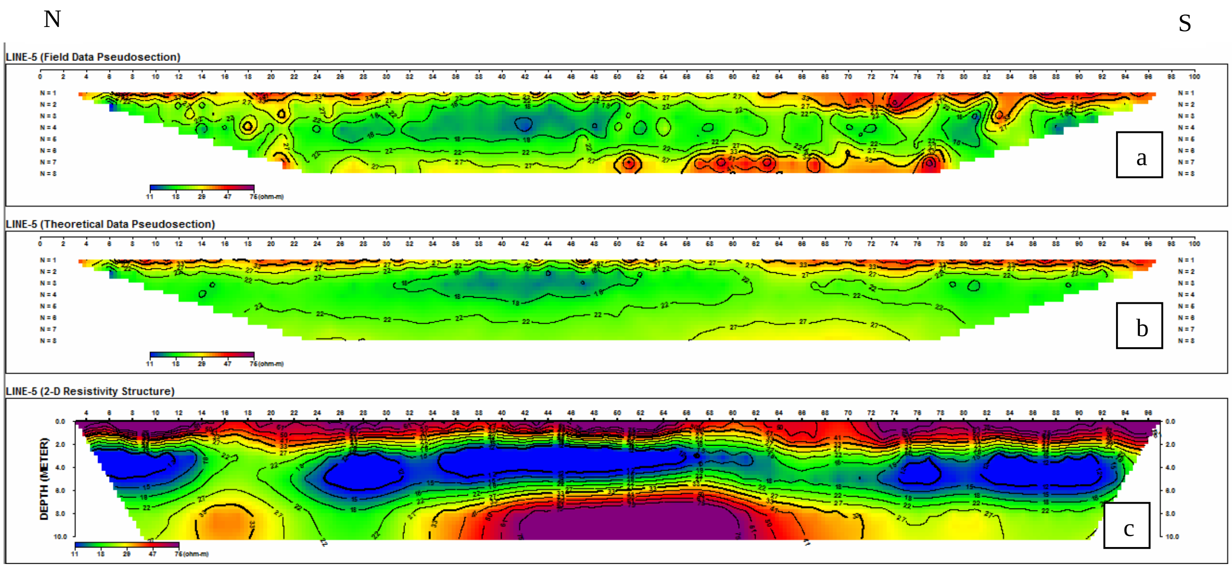

Figure-9. (a) The measured apparent resistivity pseudo section, (b) the calculated apparent resistivity pseudo section and (c) the inverse model resistivity section for traverse 5.

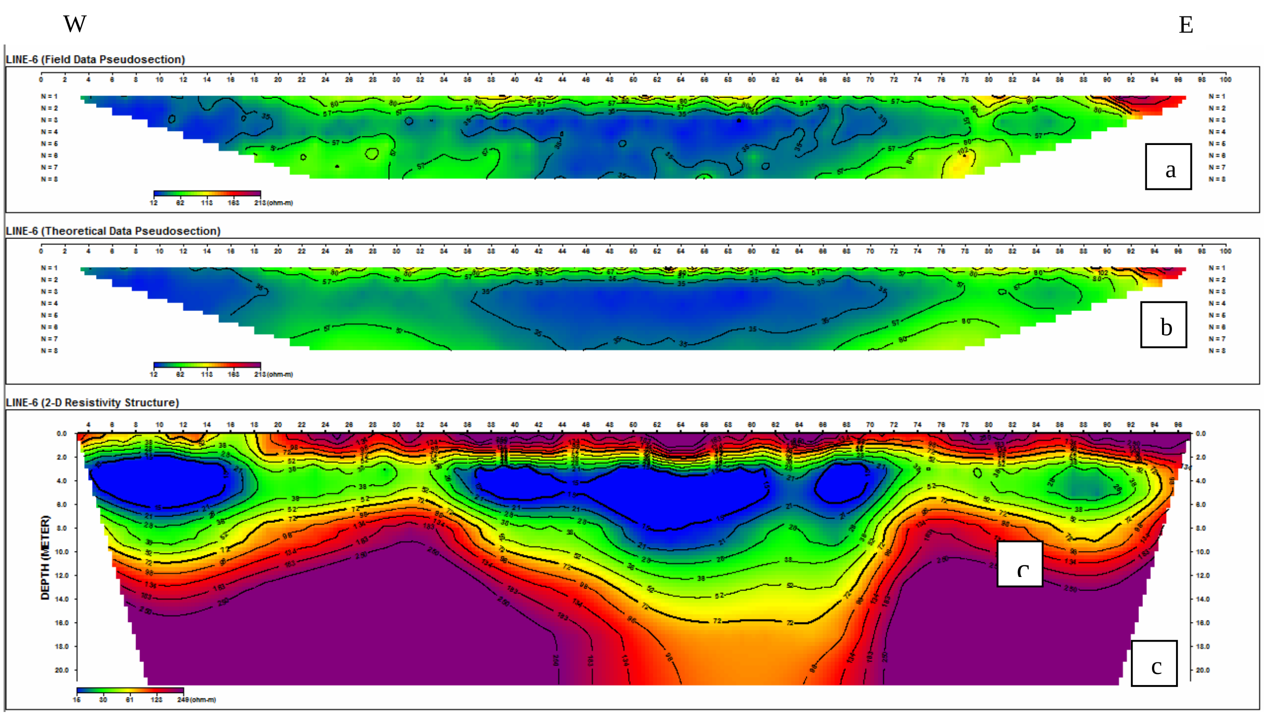

Figure-10. (a) The measured apparent resistivity pseudo section, (b) the calculated apparent resistivity pseudosection and (c) the inverse model resistivity section for traverse 6.

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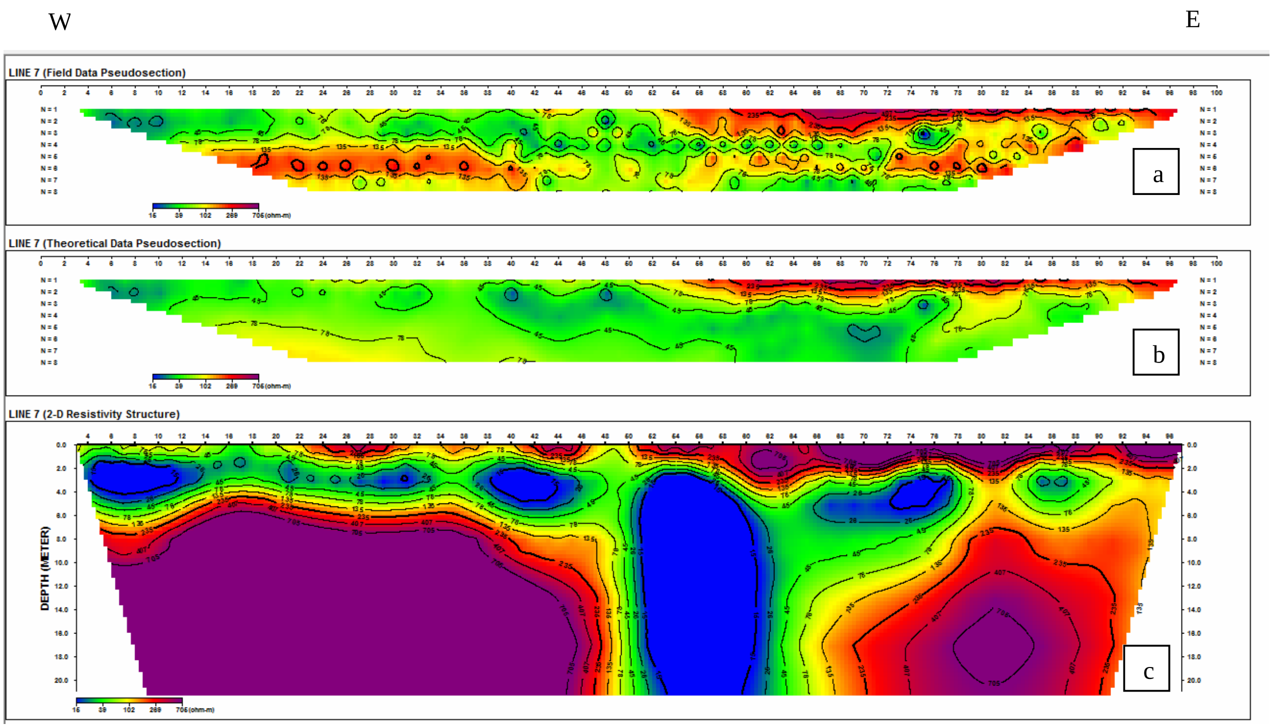

Figure-11. (a) The measured apparent resistivity pseudosection, (b) the calculated apparent resistivity pseudosection and (c) the inverse model resistivity section for traverse 7.

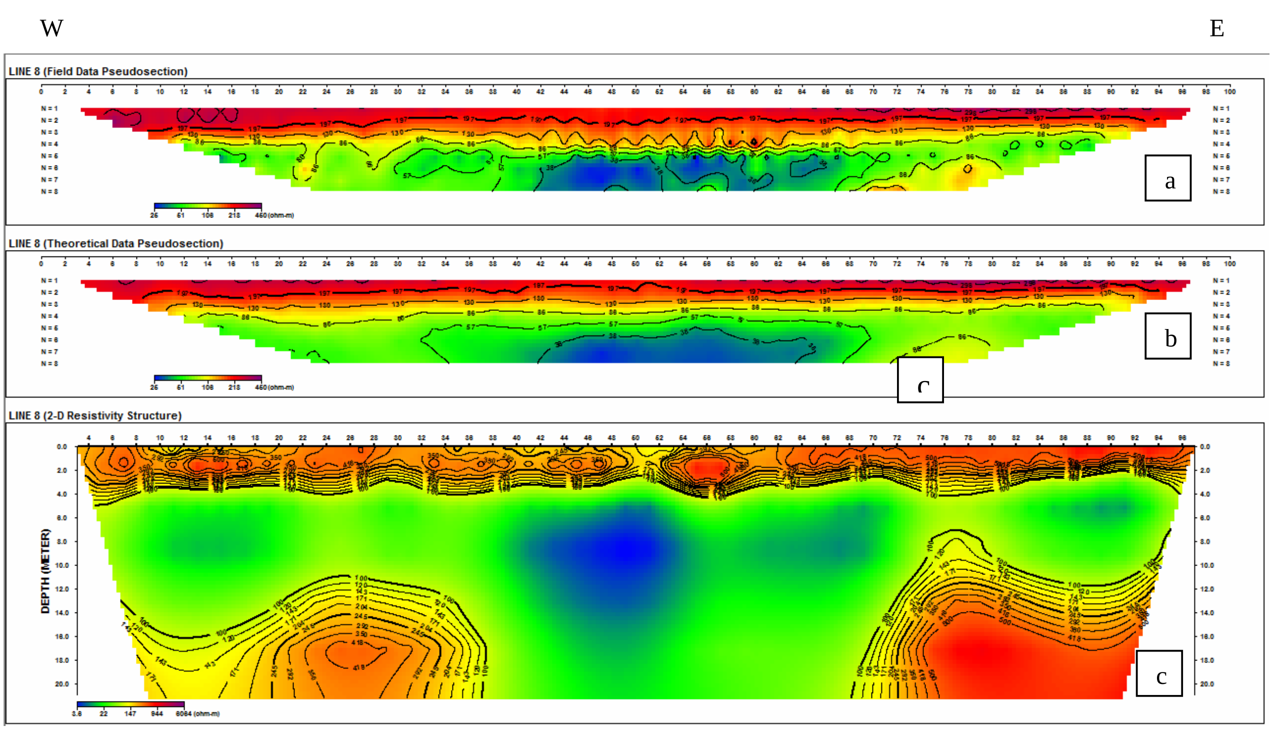

Figure-12. (a) The measured apparent resistivity pseudosection, (b) the calculated apparent resistivity pseudosection and (c) the inverse model resistivity section for traverse 8.

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CONCLUSIONS

Site investigation using 2-D electrical resistivity imaging is an essential step to be taken before the erection of any structure for minimum damage because a balanced interaction of soil and structure is the hall-mark of a successful design of foundation. Based on the findings, the weathering pattern is not uniform and the basement is shallow on some traverses whereas it is thicker on the other traverses. This indicates that the use of 2-D electrical imaging will be more beneficial in site investigation than carrying out spatial sounding because it gives detail information about the subsurface.

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