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APPLICATION OF QUASI-3D ELECTRICAL RESISTIVITY IMAGING TECHNIQUES TO SITE INVESTIGATIONS IN MOSOGAR ETHIOPE WEST LGA, SOUTH-SOUTH NIGERIA.

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ABSTRACT

The nature of the subsurface was investigated using 2D and 3D electrical resistivity imaging techniques to determine whether it was suitable for the development of engineered structures. The objectives were to determine the Lithostratigraphy and the presence of fractures, voids, clay and overburden soil that may pose a danger to the structure. A total of six 2D lines were acquired at the site using Petro-zenith Earth resistivity meter. The Wenner array configuration method was adopted for this research. The 2D apparent resistivity data were processed with the RES2DINV program and the results of each surveyed line were collated into a 3D data set and inverted using RES3DINV software. The final results showed that the topsoil of these profiles was inferred to be Laterite, Coarse Sand and clayey sand and the low-resistivity materials at the base in profiles 1,2,3 and profiles 4,5,6 were indicative of the possible presence of Clay therefore it is not suitable for the construction of high rise buildings and Bridges, except it is excavated to remove the suspected clay and filled with the appropriate soil materials before construction.

INTRODUCTION

The Electrical Resistivity Imaging (ERI) technique has become a widely used technique for environmental and engineering site study. It is also used for hydrogeologic research [3–4], the characterization of geologic and manmade structures [1–2] and environmental studies. ERI offers a non-invasive, reasonably priced method of creating models of the sub-surface's physical characteristics. A site investigation is an essential first step that needs to come before any development project. A suitable foundation is also an essential component of construction since these sanctuaries need to be carefully developed and founded over appropriate Earth materials.

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Every structure must be built on rocks or soil. When doing a site investigation, a geophysical survey can be a useful tool for selecting from a range of potential project locations and for thoroughly evaluating the site at a selected location. Site investigation is usually required to assess the variation in thickness and nature of the subsurface rocks and overburden soil within the area of the proposed project. Geophysical tools are intended to supplement the direct methods, such as drilling and trenching but not to substitute these methods. These direct investigation methods are often limited by access, cost and ground damage [5]. However, the spatial distribution of all subsurface physical characteristics and geological features is intrinsically three-dimensional. The three-dimensional effects of subsurface structures are more pronounced in environmental and engineering investigations where the geology is highly heterogeneous and subtle. As a result of 3D effects and breaking the 2D assumption, images obtained from 2D resistivity surveys frequently contain misleading features. This typically results in a misperception of the position and size of the reported anomalies [6]. Therefore, in theory, the most accurate and trustworthy results should come from a 3D survey combined with a 3D interpretation model that allows the resistivity to fluctuate in all directions, particularly under delicate heterogeneous subsurface conditions.

THE STUDY AREA

The site chosen for this study is at Mosogar Community located in Ethiope West LGA, *Delta State* southern part of Nigeria and lies between latitudes N5°52’34.2’’ to N5°52’41.8’’ and longitudes E5°43’49.6’’ to E5°43’55.1’’. It falls within the tropical equatorial climate. Geologically, the area is situated in the Niger Delta basin and lies within the aquiferous Benin formation of the Niger Delta, The Benin formation consists of thick continental sands [7] and [8]. It extends from the west across the whole of the Niger- Delta area and southward beyond the present coastline. The Benin Formation contains abundant aquifer in the area and it is composed of more than 90% massive, porous, coarse sands with isolated clay/shale interbeds [9, 10].

Figure 1: Map of Delta State Showing the study Location [11]

MATERIALS AND METHODS

A total of six 2D profiles lines were measured with the aid of a Petrozenith Earth resistivity meter using the Wenner array configuration method. Three parallel lines of 60m in length and 3 orthogonal lines of 100m in length were taken, at the proposed site. The apparent resistivity values (ρ), were calculated using the observed resistance values (R) obtained. A manual data collection technique was employed the equation for Wenner configuration expressed by

$$\rho = 2\pi aV / I \qquad (1)$$

where a is the electrode spacing, V is the potential difference and I is the current. The equation can be rewritten as

$$\rho = 2\pi aR \qquad (2)$$

The distance between each of the measured profiles was 10m. After the acquisition, the data were processed with the RES2DINV program, software. Using apparent resistivity measurements, the software automatically generates a 2D resistivity model of the subsurface through non-linear least-square optimization. The subsurface is divided into multiple rectangular blocks by the computer based on the distribution of observed data. In the iterations, the modeled calculated data are adjusted to correlate with the observed data. The goal of the inversion problem is to determine the block resistivity that will minimize the discrepancy between the apparent resistivity values that are measured and those that are calculated. Since the smoothness-constrained least-squares inversion produces the best results when the subsurface shows smooth variation, it was chosen.

The 2D pseudo-sections data files were later combined into a 3D data file in the RES2DINV program and inverted using the RES3DINV program The smoothness-constrained least-squares inversion was applied for the 3D inversion for the same reasons. The 10m interval between the profiles was chosen to comply with the sensitivity of the 3D inversion for the Wenner array.

RESULTS AND INTERPRETATIONS

Profile 1

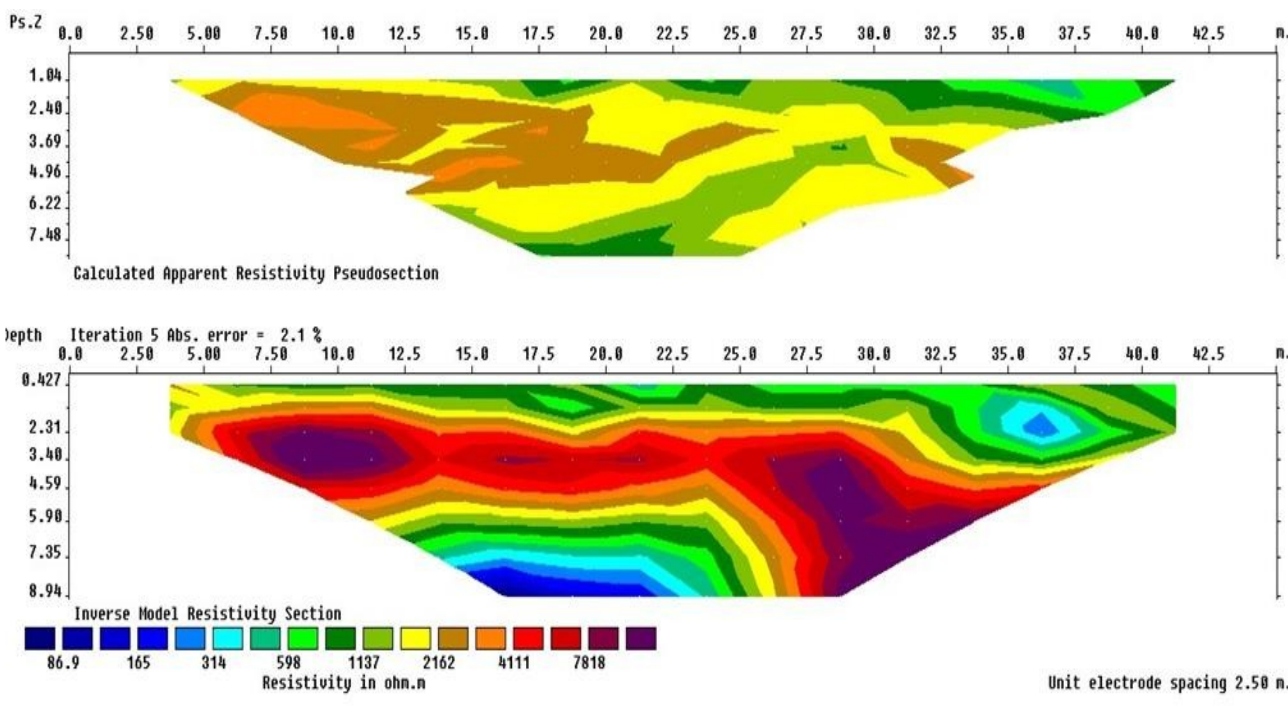

Figure 2: Inverse 2D Model Resistivity section along Profile 1

Profile 2

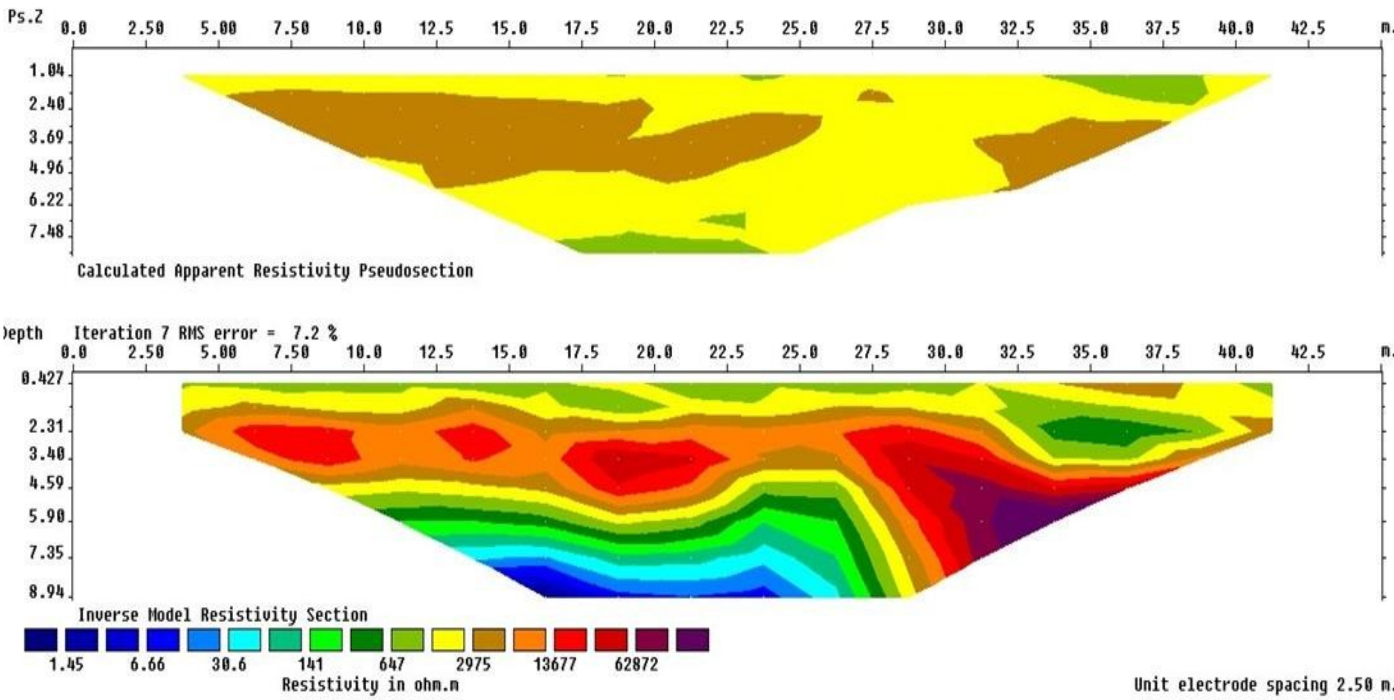

Figure 3: Inverse 2D Model Resistivity section along Profile 2

Profile 3

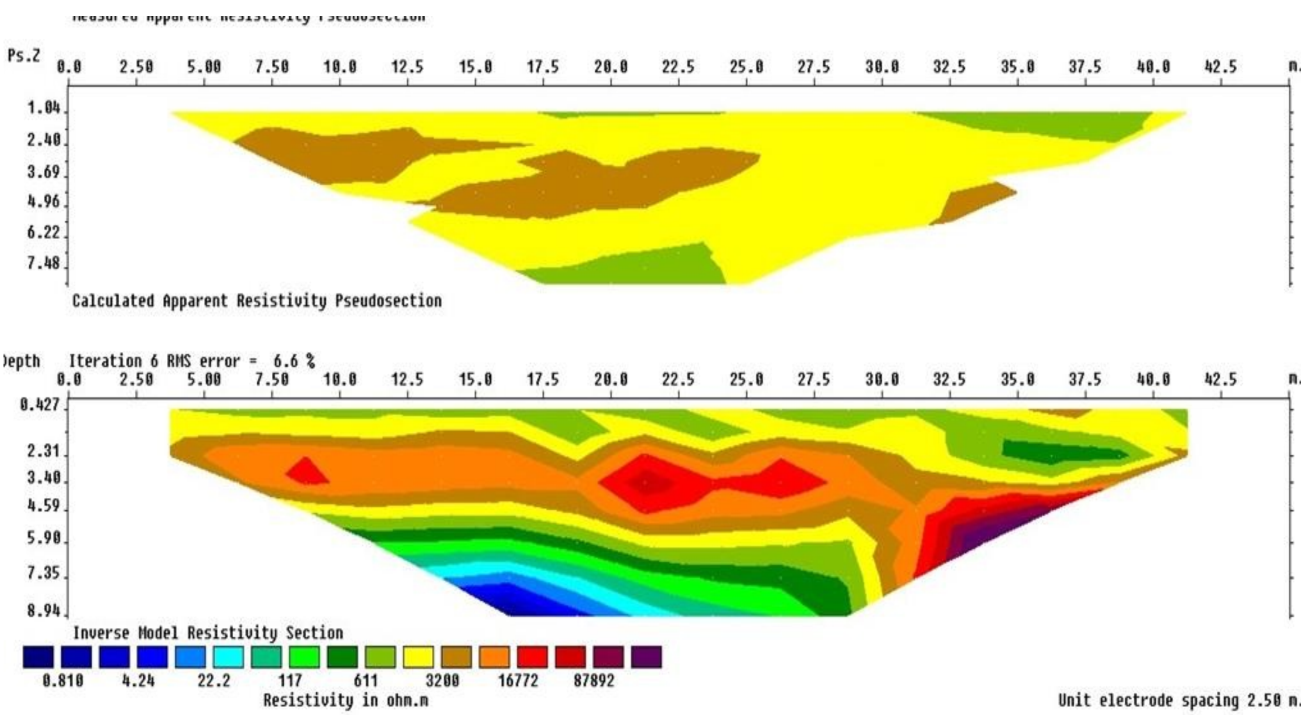

Figure 4: Inverse 2D Model Resistivity section along Profile 3

Profile 4

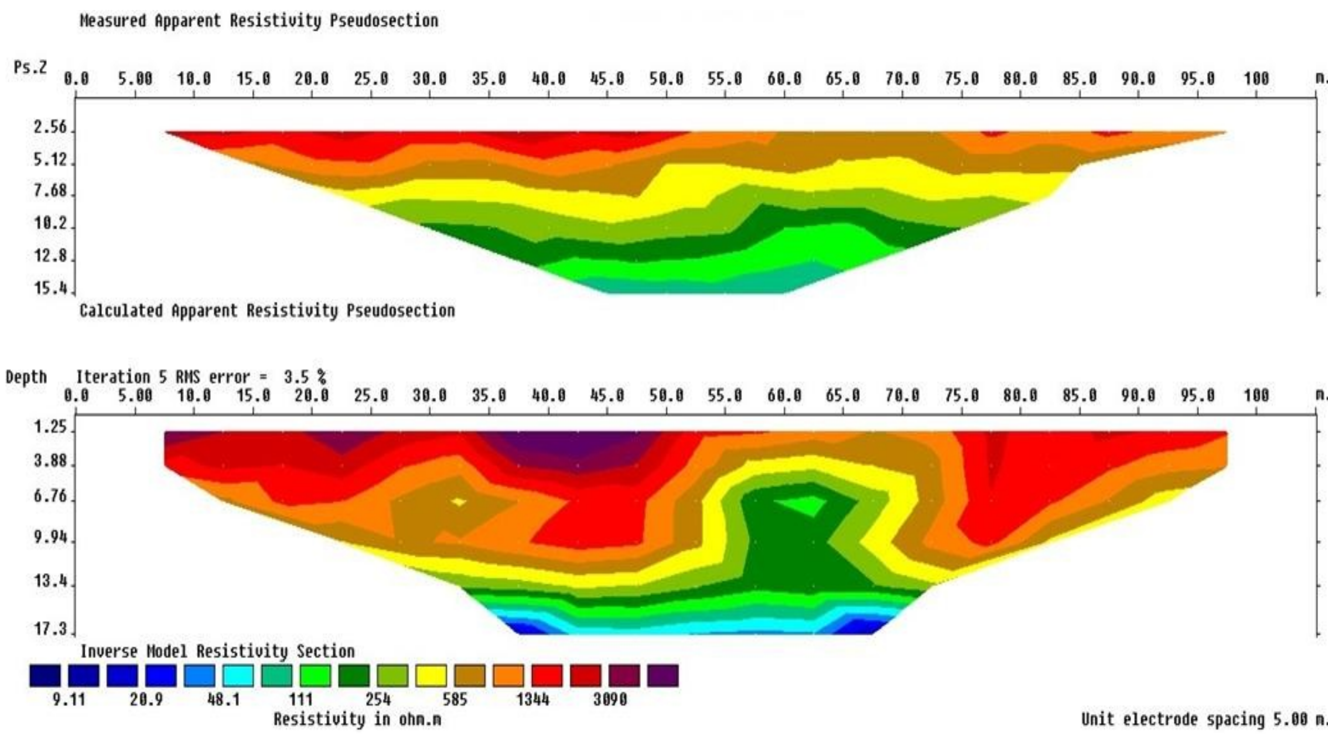

Figure 5: Inverse 2D Model Resistivity section along Profile 4

Profile 5

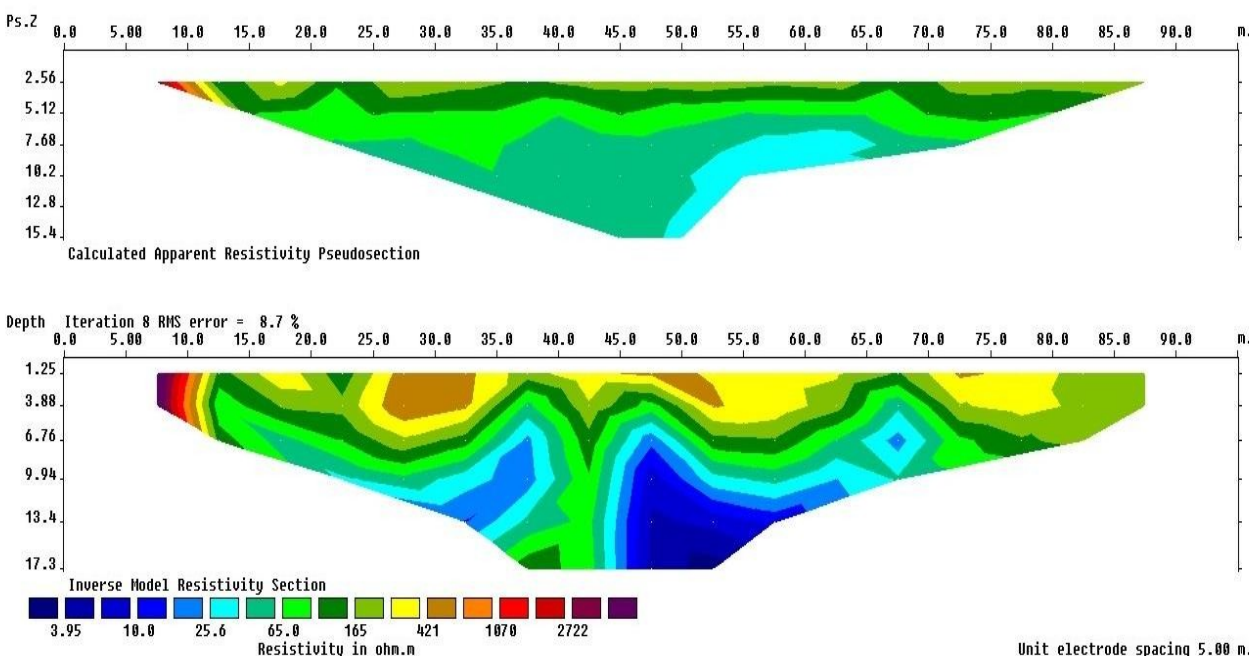

Figure 6: Inverse 2D Model Resistivity section along Profile 5

Profile 6

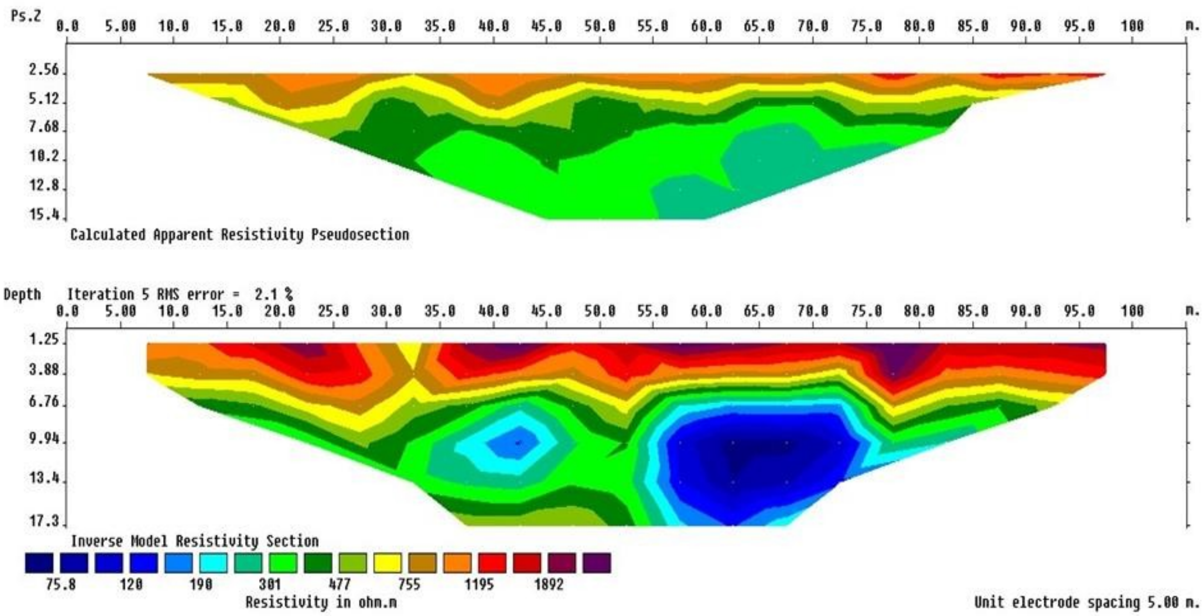

Figure 7: Inverse 2D Model Resistivity section along Profile 6

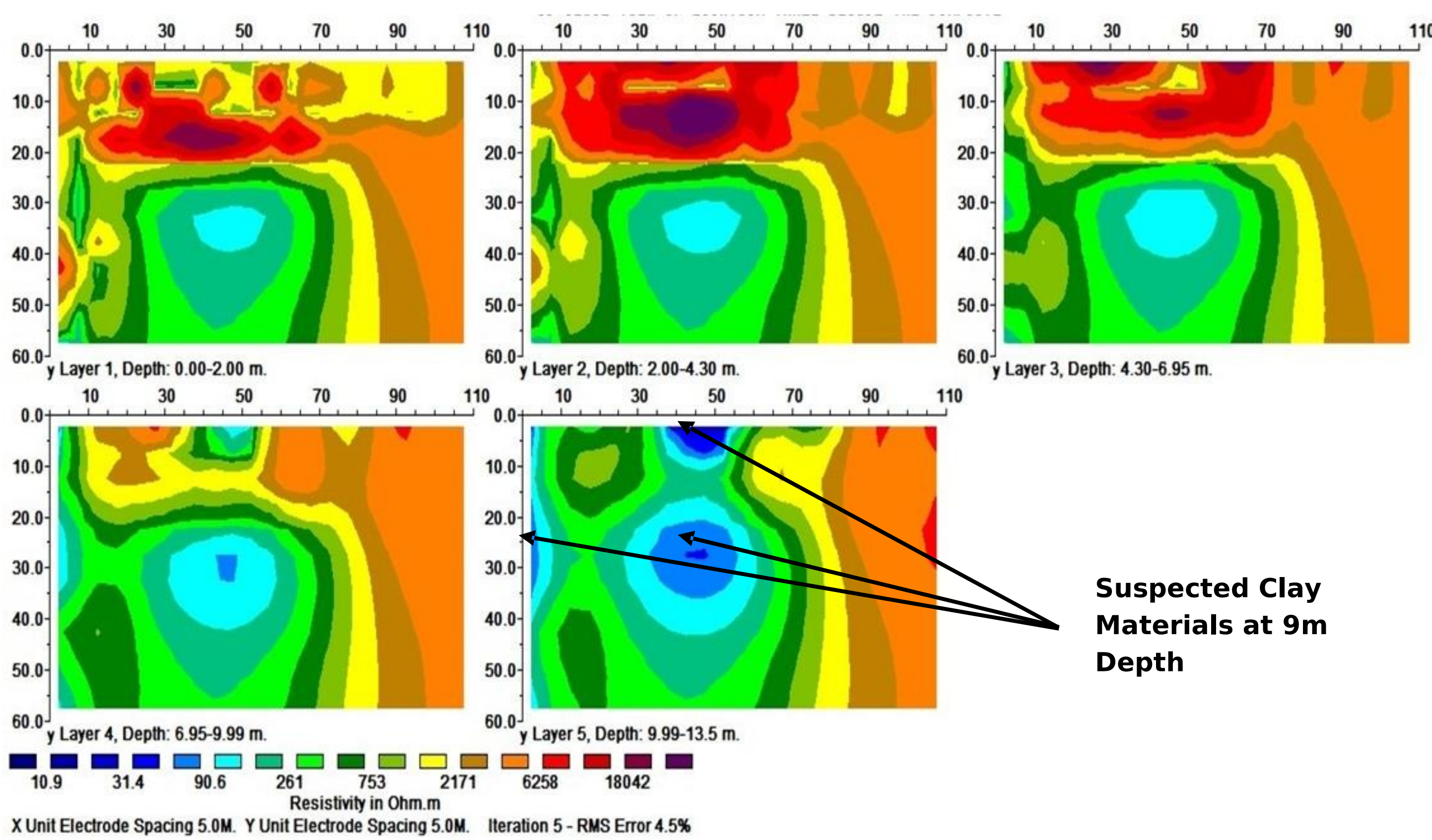

Figure 9: 3D Resistivity Model of the surveyed area

DISCUSSION OF RESULTS

The Inverse resistivity of the surveyed area are presented as models in figures 1-6. The root mean square errors obtained in the inverted models were between a minimum of 2.1% to a maximum of 8.0%. There is a good correlation between the subsurface and resistivity distributions of the subsurface soils in the surveyed area. The profiles showed similar variations of resistivity at different depths characterized by low-resistivity materials at the base in Figures 2-7. The 2D inverse resistivity models presented in figures 2 to 7 generally show that the topsoil is characterized by high resistivity values that range from 300ohm.m to 8000ohm.m from a depth of 1m to 4m with a thickness of about 3m in Profiles 1 to 4 This layer is largely composed of laterites and sandstones. Profile 1,2,3 had a lateral distance of 50m and an average depth of 8.9m. The topsoil of these profiles was inferred to be Laterite and clayey soil with resistivity ranging from 120ohm.m to 1500ohmm. It was seen from the inverse model that there was a sharp increase in the resistivity of the second Layer from 2m in depth to about 8m in depth at the eastern end of the survey. This was inferred to be lateritic soil and Compacted Coarse sand with a resistivity range of 2000ohmm to 5000ohmm and Compacted Ferruginous Sandstones with resistivity ranging from 5000ohm.m and above.

Profiles 4,5,6 showed a survey length of 100m each with a depth of 17.8m. These profiles exhibited low to moderate resistivities ranging from 100ohm.m to 15000ohm.m indicative of the possible presence of Clayey soil, and Laterite up to a depth of 7m in profiles 5, 6, and 13m in profile 4. It was seen from the inverted images that all the Profiles showed Low resistivity of 100ohm.m and below to a depth of 17.3m in profiles 4,5,6 and 9m and below in profiles 1,2,3. This is indicative of the possible presence of Clay at this depth. The 3D image model block was sliced into 5 layers at varying depth distance beginning from the surface to the achieved depth. The inverse 3D model in Figure 8 shows the horizontal sections of the model obtained after 5 iterations. The 5 layer sections show the various geological depths at the survey site beginning from the surface to 13.5m in depth. The heterogeneous earth can be seen clearly in the 3D model compared to that of the 2D resistivity models. The first and second layers show complex subsurfaces which are more heterogeneous. Layers 1 to 4 also show the lateral extent of the compacted Coarse and ferruginous Sandstones at the eastern end of the survey. The low resistivity zones clearly seen in the fifth layer also correspond to what were shown in the 2D Slices indicative of possible accumulation of clay materials at this depth.

CONCLUSION

It was found that the resistivity values correlate quite well with the geological formations revealed by both the 2D and 3D images in the survey area. This then lends credence to the fact that electrical imaging is a powerful technique in the study of subsurface.

This research however has been able to show that though the site characteristics is favorable for Low-cost housing, It would be disastrous for building engineers to construct high-rise buildings at the surveyed site without first excavating up to the depth where there is suspected clay and filling it with sands that can withstand building with such strength.

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