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Application of Electrical Resistivity Methods to Determine the Lithological Parameters of Utese Community, Edo State, Nigeria

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ABSTRACT

Lithological parameters of Utese using electrical resistivity methods was carried out, using vertical electrical sounding (VES) and electrical resistivity imaging (ERI), two (2) VES data and three (3) ERI data were acquired at different locations in the community, the VES data acquired were analysed and interpreted using WINRESIST computational software that helps in plotting depth against the resistivity value. In a similar way, the 2D data acquired were interpreted using EARTH IMAGER software which helps to automatically obtain the image of the 2D inversion model of the subsurface. The results obtain from the survey classified the lithology into topsoil, clay sand, weathered bedrock, sand stone and sand, the maximum depth of aquifer in this community is 126.8 m, with aquitard thickness of 95m at VES A, and a shallow depth of 44.4 m and aquitard thickness of 38.8 m at VES B. The aquiferious zone and a zone of thick clay layer at depth range of 15 m to 60 m from the image of the 2D ERI model was deduced, the resistivity value in this layer of thick clay ranges from 2500 Ωm to 11000 Ωm.

Keywords: *Lithology, Characteristics, Electrical Resistivity, Aquifer*

1. INTRODUCTION

Electrical Resistivity has contributed immensely to the geophysical investigation of the subsurface and the choice of the right research method is very important because of the geology of the area of study.Application of a collaborative method using geophysical method is highly advised [1,2,3]. Geophysical methods may be applied to a wide range of investigations from studies of the entire Earth [4] to exploration of a localized region of the upper crust for engineering or other purposes [5,6]. An alternative method of investigating subsurface geology isby drilling boreholes, but these are expensive and provide information only at discrete locations. Geophysical surveying, although sometimes prone to major doubts or uncertainties of interpretation, provides a relatively rapid and cost-effective means of deriving a really distributed information on subsurface geology[7]. In the exploration for subsurface resources the methods are capable of detecting and delineating local features of potential interest that could not be discovered by any realistic drilling programme.In the electrical resistivity method, electric currents generated artificially are sent into the earth using currents electrodes and the resulting potential differences are measured at the surface [7].The lithological identification of the subsurface and groundwater features of an area can be efficiently determined by drilling of numerous boreholes and understanding of the soil and water samples collected [8].In this research,the electrical method of geophysical investigation is used to explorethe subsurface properties of Utese Community.

2. GEOLOGY OF THE STUDY AREA

Utese a suburban area is located inOvia North East Local Government Area of Edo State, Nigeria. Neighbouring communities/small towns include Egbeta, Ugbowe, Uhen, Ogbese and Okada. The top soil in this area is lateritic clay sand with reddish brown coloration, why the bed rock is underlined by limestone.The various formations in the geology of Edo State are the Benin, Bende Ameki, Ogwashi-Asaba, Imo and Nsukka. The geology of the study areas is characterized by deposits laid during the tertiary and cretaceous periods. The area is underlain by sedimentary rock constituting part of the Benin formation which is made up of over 90% massive, porous, coarse sand with thick clay/shale interbeds having high groundwater retention capacity.

3. MATERIALS AND METHODS

The electrical resistivity method used in this work is a combination of both the one-dimensional (1D) vertical electrical sounding (VES) and the two-dimensional (2D) electrical resistivity imaging (ERI). A total of two (2) Schlumberger vertical electricalsoundings (VES) were carried out in this community. The current electrode(AB/2) spacing ranged from 1.0 m – 350.0 m while the potentialelectrode (MN/2) varied between 0.25 m and 10.0 m. This method has been proven to be very effective. Severalexploratorymethods are generallyused in assessing the spatial spreading of aquifer parameters [9–20].

Similarly, 2D electrical resistivity survey was also carried with a total of three (3) electrical resistivity imaging traverse were acquired using the Wenner electrode configuration. Electrode spacing of 10m was adopted for this survey and the profile length of 300 m was adopted. The necessary equipments for data acquisition include:

PASSI 16 GL-N Earthresistivity meter, electrodes (four stainless steel metallic electrodes were used, a pair of two each for current and potential electrodes measuring between 0.4 m to 0.5 m), Cables made up of multi-strand copper wires insulated with PVC (these are connected to the electrodes and the resistivity meter. It is used to transmit and receive current), PVC Tape for taking distance measurement, GPS for location marking and topographical heightening of the sampling point, Hammer to drive the electrodes into the ground to ensure firm contact and Spare multi-meter for error detection.The VES data acquired were analysed and interpreted using WINRESIST computational software that help in plotting depth against the resistivity value. In a similar way, the 2D data acquired were interpreted using EARTH IMAGER software which helps to automatically obtain the 2D inversion model of the subsurface. For a conducting cylinder of resistance δR, length δL and cross-sectional area δA the resistivity r is given by

$$\rho = \frac{\delta R \delta A}{\delta L} \quad (1)$$

For a single current electrode implanted at the surface of a homogeneous medium of resistivity ρ, current flows away radially. The voltage drop between any two points on the surface can be described by the potential gradient $(-\frac{\delta V}{\delta x})$, which is negative because the potential decreases in the direction of current flow. The current density *(J)* is the current (*I*) divided by the area over which the current is distributed (a hemisphere,$2\pi r^2$), and so the current density decreases with increasing distance from the current source. The potential difference (δV) across a hemispherical shell of incremental thickness δr is given by:

$$\frac{\delta V}{\delta r} = -\rho . J = -\rho \frac{I}{2\pi r^2} \quad (2)$$

Thus the voltage V_r at a point r from the current point source is given as

$$V_r = \int \delta V = -\int \rho \frac{I}{2\pi r^2} \delta r = \frac{\rho I}{2\pi} . \frac{1}{r} \quad (3)$$

If, however, a current sink is added, a new potential distribution occurs (figure 1). For a current source and sink, the potential V_P at any point P in the ground is equal to the sum of the voltages from the two electrodes, such that

$$V_p = V_A + V_B \quad (4)$$

Where V_A and V_B are the potential contributions from the two electrodes, $A(+i)$ and $B(-i)$.

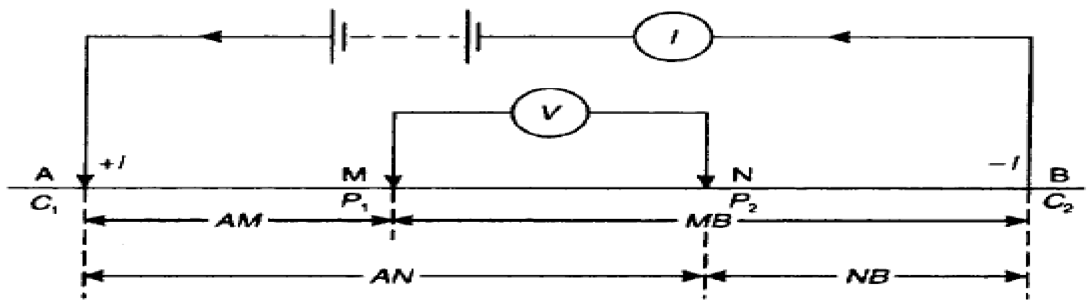


Figure 1: Generalised form of electrode configuration in resistivity surveys

The potentials at electrode M and N are:

$$V_M = \frac{\rho I}{2\pi}\left[\frac{1}{AM} - \frac{1}{MB}\right], \quad V_N = \frac{\rho I}{2\pi}\left[\frac{1}{AN} - \frac{1}{NB}\right] \quad (5)$$

However, it is far easier to measure the potential difference,

$$\delta V_{MN} = V_M - V_N = \frac{\rho I}{2\pi}\left\{\left[\frac{1}{AM} - \frac{1}{MB}\right] - \left[\frac{1}{AN} - \frac{1}{NB}\right]\right\} \quad (6)$$

Rearranging this so that resistivity ρ is the subject:

$$\rho = \frac{2\pi \delta V_{MN}}{I}\left\{\left[\frac{1}{AM} - \frac{1}{MB}\right] - \left[\frac{1}{AN} - \frac{1}{NB}\right]\right\}^{-1} \quad (7)$$

Where the K-factor or geometric factor from equation (7) is given as

$$K=2\pi \left\{\left[\frac{1}{AM} - \frac{1}{MB}\right]-\left[\frac{1}{AN} - \frac{1}{NM}\right]\right\}^{-1} (8)$$

Substituting K for equation (2) we have that

$\rho = \frac{\delta V}{I} . K$ (9)

From Ohm's law, we have that

$$R = \frac{\delta V}{I} (10)$$

So that equation (7) becomes

$\rho = R \times K (11)$

$$K = \frac{\rho}{R} (12)$$

Where: ρ is the resistivity, K is the geometric factor, R is the resistance, δV is the potential difference and I is the current.

4. RESULTS

The results of the VES and the ERI data are presented in the geoelectric sections and the 2D model below.

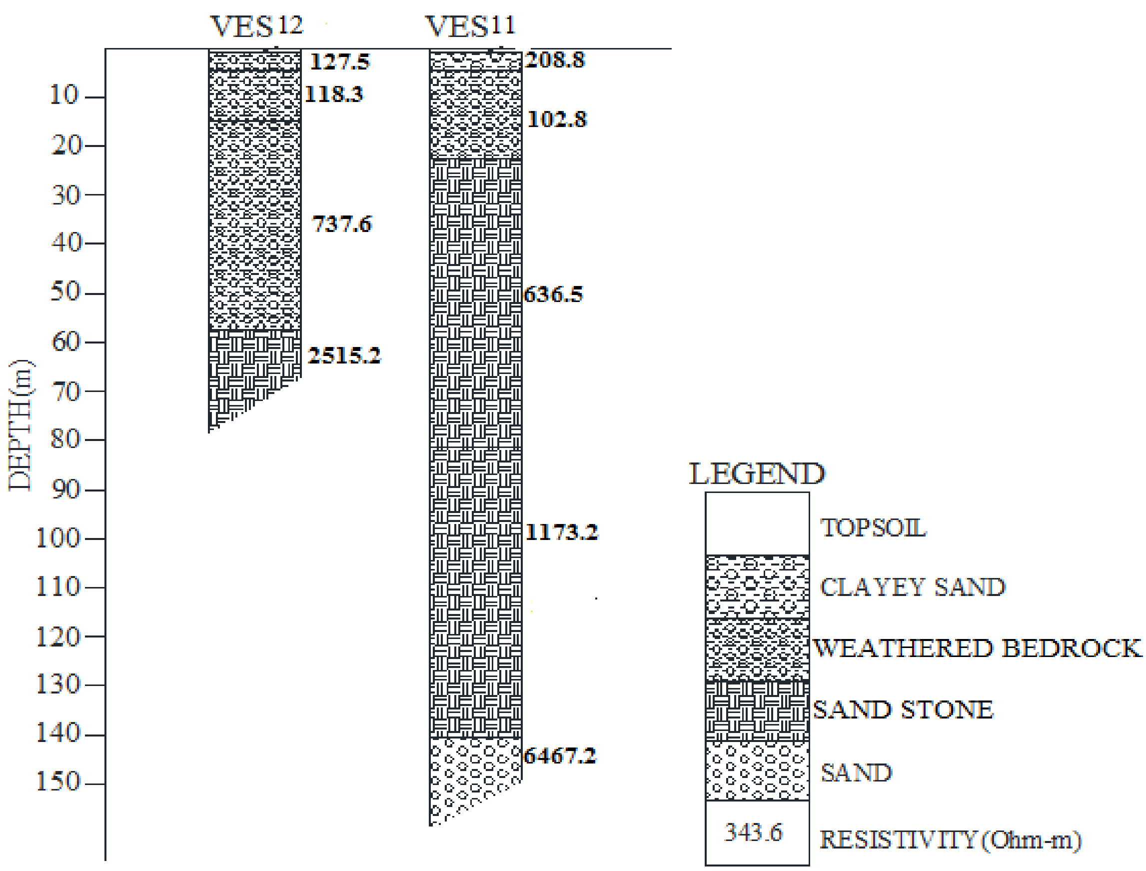
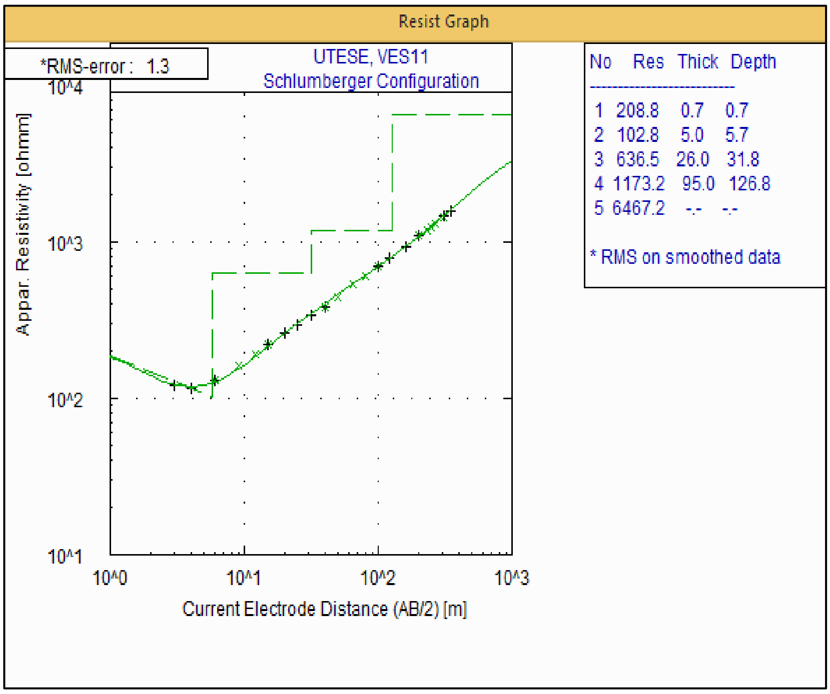


Figure 2: Geoelectric Sections of the 1D Sounding

VES A



VES B

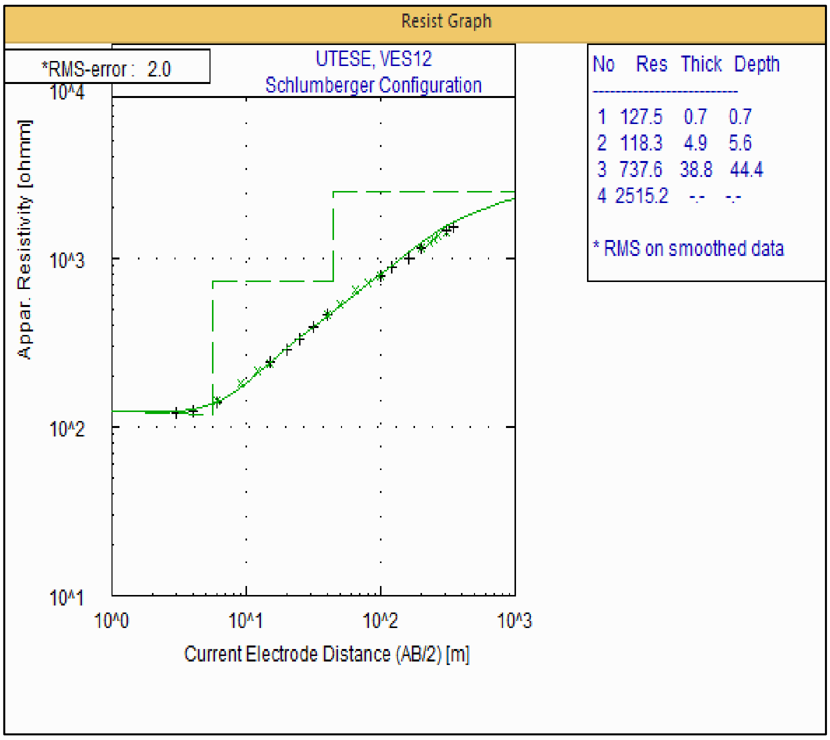
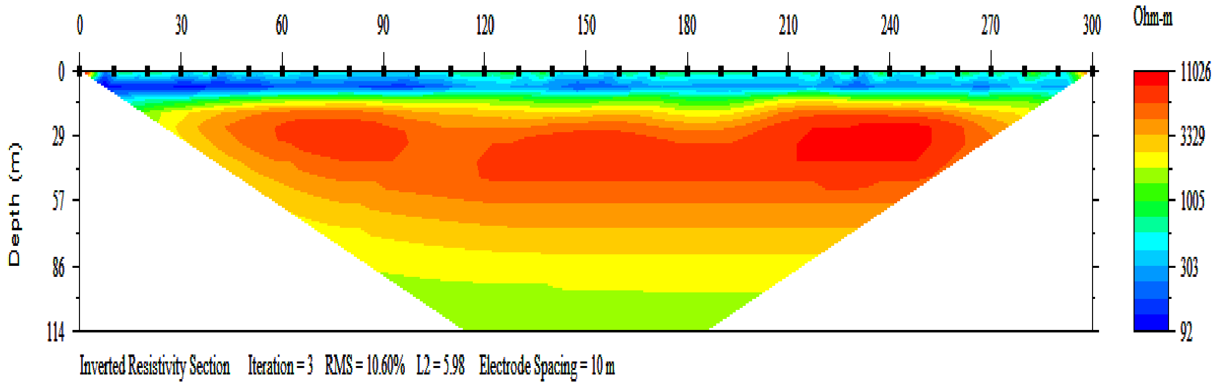
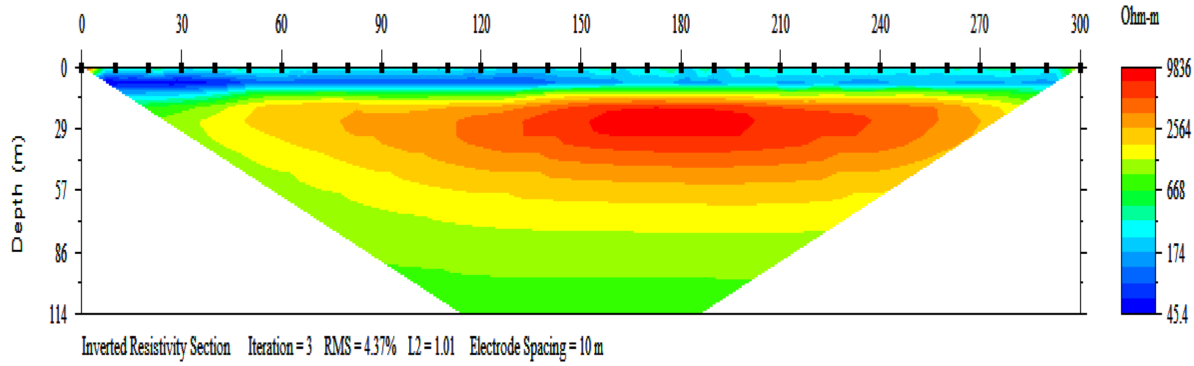


Figure 3: VES Curves for 1D Sounding

Location 1



Location 2



Location 3

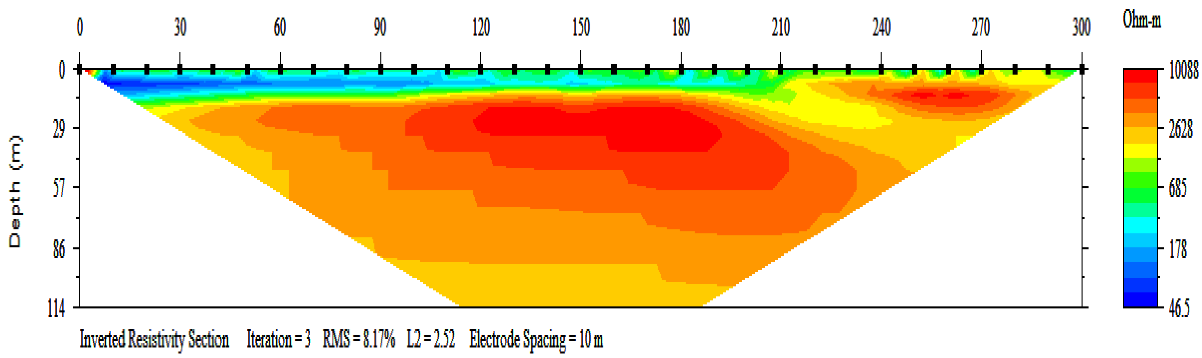


Figure 4: ERI Models for the 2D Survey

5. DISCUSSIONS

The results as shown in figure 2 above reveal the geoelectric sections of the survey areas, with the lithology characterise into the topsoil, clay sand, weathered bedrock, sand stone and sand, the maximum depth of aquifer and aquitard thickness in this area is at 126.8 m and 95 m on the VES A respectively and a shallow depth of 44.4 m, with thickness of aquitard at 38.8 m on VES B, as shown from figure 3. The curve types from figure 3 are HAK and HA for VES A and VES B respectively.

The images of the ERI model for the 2D survey in figure 4 further confirm the results of the 1D VES surveys. The 2D ERI model for location one (1) to three (3) assume similar trend in the subsurface properties, as the they divided into three distinct layers, The uppermost layer with resistivity range of 92 Ωm to 2000 Ωm, and depth range of 0 m to 15 m. This layer is composed of the topsoil, the clay sand and the lateritic clay sand. This region has a very high porosity and high conductivity, especially during the wet season, but has little groundwater retention capability. The middle layer with resistivity range of between 2500 Ωm to >11000 Ωm and depth range of between 15 m to 60 m, is composed of sandstone, thick clay and highly complex sediments, with high weathering activities, the conductivity in this zone is poor and the resistivity is very high, water retention capability here is very low because of the high resistivity value and the compacted nature of the zone.

The last layer is a region with resistivity value ranging from 600 Ωm to 2000Ωm, the depth range in these area lies between 60 m to 114 m. The material compositions in thiszone are fine sand, coarse sand, sand stone and the basement rock. This region has a very high conductivity because of it high level of porosity, and lower resistivity, compared to the middle layer. This area has high potential for groundwater retentions, but movements of groundwater to this zone has to be through cracks and pores space, this is because of the thickness exhibited by the layer above it.

6. CONCLUSION

In conclusions, the lithological Characteristics of Utese Community has been successfully stratified using the combined electrical resistivity methods of vertical electrical sounding (VES) and the electrical resistivity imaging (ERI). The aquiferious zone with the help of the 2D imaging and depth of aquifer in this location using the 1D sounding and the curve types has been clearly identified.

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