Subsurface Characterization of the Vice-Chancellor's Quarter, Ugbowo Main Campus, University of Benin, Benin-City, Edo State, Using Electrical Resistivity (Dipole-Dipole) Method

***Ochu, A. and Dieokuma, T.**
Department of Physics, Faculty of Physical Sciences, Federal University, Otueke, Bayelsa State.

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Abstract

2-D resistivity inversion survey technique of electrical resistivity method was undertaken at Vice-Chancellor's, Dipole-dipole configuration covering the entire area was conducted using the ABEM Terrameter SAS 1000 and inter-electrode spacing of 5m were used in the traverse. The program res2dinv software was used for this processing. Before the inversion process to obtain a true model resistivity continuous distribution of calculated electrical resistivity in the subsurface, the apparent resistivity data were subjected to moving averaging filtering using Origin Pro8. The software computes, by inversion, the true resistivity of the subsurface that agrees with the measured apparent resistivity values from the survey.2D inversion of the first profile shows a lithology between Laterite and Sandy clay, with Laterite seen between depths of 0.85-2.65m and covers a lateral distance between 0 and 30m with resistivity range 1000-1323 Ωm, as a result of change in earth material resistivity is seen to increase downward. In the second profile, the 2D inversion shows that between 0-40m laterally and 0-6.79m vertically there was a range of resistivity value between 229-452 Ωm (Weathered laterite) and resistance 492-1813 Ωm (Dry Sand) respectively. The third profile, the 2D inversion shows that between 0-100m laterally and 0-2.79m vertically there was a range of resistivity value between 229-592 Ωm (Weathered laterite) and resistance 1242-1498 Ωm (Dry Sand) respectively. The profile is largely characterized by Laterite and sand (as seen from the range of resistivity values given from the 2D inversion.

***Corresponding Author: Ochu, M**.: Ochuaa@fuotuoke.edu.ng

Introduction

Resistivity measurements are associated with changing depths depending on the separation of the current and potential electrodes in the survey, and can be interpreted in terms of a litho logic and/or geo-hydrologic model of the subsurface. Measurement of resistivity (inverse of conductivity) is, in general, a measure of water saturation and connectivity of pore space (Cardimona,2002). Air, with naturally high resistivity, results in the opposite response compared to water when filling voids. Whereas the presence of water will reduce resistivity, the presence of air in voids will increase subsurface resistivity (Cardimona, 2002). The goal is to predict the electrical properties of medium or subsurface rock formations, especially its ability to conduct or inhibit electricity. This research uses the dipole-dipole configuration by injecting the current into the earth. The material with varying resistivity will provide information about the material structure passed by the current. The reason for the wide use of electrical method is due to the fact that it is inexpensive, fast and it is a non-invasive technique that yields useful information about subsurface conditions (Binley, 2010). The use of dipole-dipole array in electrical prospecting has become common. In terms of logistics on the field, it is the most convenient especially for large spacing. This is because other arrays require significant lengths of wire to connect the power supply and voltmeter to their respective electrodes and this wire must be moved for every change in spacing as the array is either expanded for a sounding or moved along a line. (Ghtman, 2003)

Location and Geology of the study area

The study area which is Vice-Chancellor's district area University of Benin, Ugbowo Edo State of Nigeria is underlined by Benin formation (Ikhile, 2016). Details of the geology and hydrogeology of the Benin formations have been documented (Kogbe, 1976). The area lies between longitude E5o37'32.83'' and E 5o37'36.9'' between latitude N 6^0 23' 56.69''N and N 6^0 24' 00.8'' approximately 350km SW of Abuja . The topography of the area are plane surface which has the following rock types, top soil, laterite, clay, sandy clay and clean sand which is in close agreement with the Benin formation that ranges from Miocene to recent (Ekpelu, 2018). The inhabitant of these survey are majorly farmers and petit traders

Materials and Methods

ABEM Terrameter SAS 1000 T, was used to take measurement of resistivity. Coordinates of the Vertical Electrical Sounding (VES) position. were made using Global positioning system (GPS). A reconnaissance study of the area was taken to know the places to be sounded . Coordinate points were marked on the base map. Electrical profiling, known as constant separation traversing (CST), was used to determine lateral resistivity variations in the shallow subsurface at a more or less fixed depth of investigation. The current and potential electrodes are moved along a profile with constant spacing between electrodes.

Theory of electrical resistivity method

Many electrode configurations are used in geophysics to measure subsurface resistivity. A common factor in these configurations is a set of current input electrodes usually labeled A and B and a set of voltage measurement electrodes usually labeled M and N. The dipole-dipole method places the A and B electrodes to one side with a spacing between them denoted as "a".

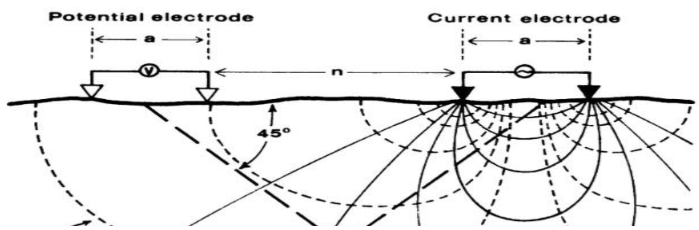

Figure 1: Dipole-dipole configuration, including electric field lines (solid) and resultant equipotential surfaces (dashed)

The resistance of a resistive object determines the amount of current through the object for a given potential difference across the object, in accordance ohm's law

$$I = \frac{V}{R} \ldots\ldots\ldots\ldots(1)$$

From Ohm's law,

$$R = \frac{\Delta V}{I} \ldots\ldots\ldots\ldots(2)$$

The resistance R, of a conductor of uniform cross-section can be computed as

$$R = \frac{\rho L}{A} \ldots\ldots\ldots\ldots(3)$$

Where,

L is the length f the conductor, measured in metres (m)

A is the cross-sectional area, measured in square metres (m^2)

ρ is the electric resistivity (also called specific electrical resistance) of the material, measured in Ohm meter (Ωm).Resistivity is a measure of the material's ability to oppose electric current.

Comparing equations (2) and (3), we have

$$\frac{\Delta V}{I} = \frac{\rho L}{A}$$

$$\rho = \frac{\Delta V A}{I L} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Equation (4) can be used to determine the resistivity of any homogenous and isotropic medium provided the geometry is simple. For semi – infinite medium, however, the resistivity at every point must be defined. If we allow parameters (A) and (L) to infinitesimal size then:

$$\rho = \frac{\to 0 \frac{\Delta V}{L}}{A \to 0\, L} = \frac{E}{J} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where E = Electric field and J = Current density.

$$\therefore J = \frac{E}{\rho} = \sigma E \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

But E is the gradient of a scalar potential

i.e $E = -\nabla V$

$$j = -\sigma \nabla V$$

Current crossing the spherical body of surface area A is

$$I = JA = 4\pi r^2 J \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

$$I = 4\pi r 2P \frac{\partial v}{\partial r}$$

$$\therefore \partial v = \frac{\partial}{\partial r}$$

$$\therefore v = -\int \frac{IP}{4\pi r^2} \partial r$$

$$v = \frac{IP}{4\pi r^2} \partial r$$

In practice, the earth structure is an approximate of hemisphere than current density

$$J = \frac{I}{A} = \frac{I}{2\pi r^2}$$

$$E = \frac{IP}{2\pi r^2}$$

$$\partial v = \frac{IP}{2\pi r^2} \partial r$$

$$V = -\int \frac{IP}{2\pi r^2}$$

$$V = \frac{IP}{2\pi r}$$

This is the potential of P due to a current at C, the surface of the earth.

Data Acquisition and Presentation

For the geophysical investigation of subsurface characterization carried out in this area, an ABEM Terrameter SAS 1000, electrodes, reels of wire, cell, were used to carry out the field procedure. Dipole-dipole array was used in the procedure on the field to obtain horizontal soundings within the location with Inter- electrode spacing of 5m in all the traverses. The program res2dinv software was used for the processing of the data before the inversion process to obtain a true model resistivity continuous distribution of calculated electrical resistivity in the subsurface, the apparent resistivity data were subjected to moving averaging filtering using Origin Pro8 and the noise and spiking values were edited. Models for 2D resistivity inversion program comprise rectangular blocks (cell). The bottom of a block corresponds to a data point which is approximately equal to its effective depth (Loke, 2004). The software computes, by inversion, the true resistivity of the subsurface that agrees with the measured apparent resistivity values from the survey. Apparent resistivity measurements recorded during the survey were entered into a text file in a format compatible with the res2dinv and read into the computer with the software running. The software produces a pseudosection of the subsurface by contouring the apparent resistivity values from the geophysical survey and this is presented as the first image of the figure. The calculated apparent resistivity values was also produced, contoured and presented as the second image of the same figure. Pseudosection gives very approximate picture of the true subsurface resistivity distribution. However, the pseudosection gives a distorted picture of the subsurface because the shape of the contours depends on the type of array used and the true subsurface resistivity (Loke, 2004). The third image of the same figure is the inverse model resistivity section (smoothed) which represented the most accurate picture of the subsurface that can be produced from the measured or observed apparent resistivity distribution.

Results and Discussion

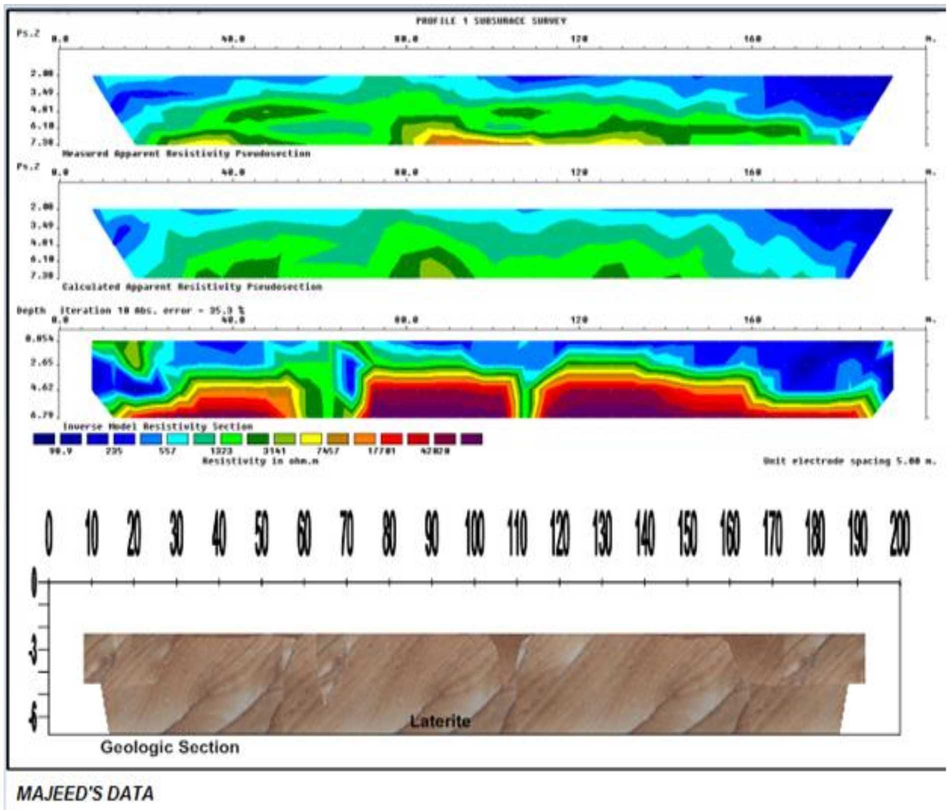

Fig 2 2D inversion of Dipole-Dipole profile 1(Diprowin**)**

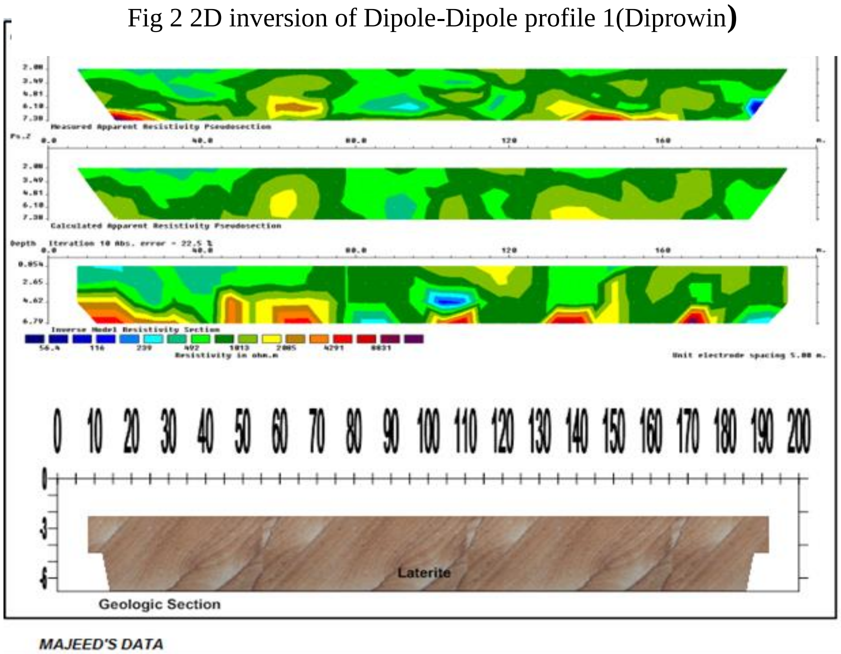

Fig 3 2D inversion of Dipole-Dipole profile 2 (Diprowin)

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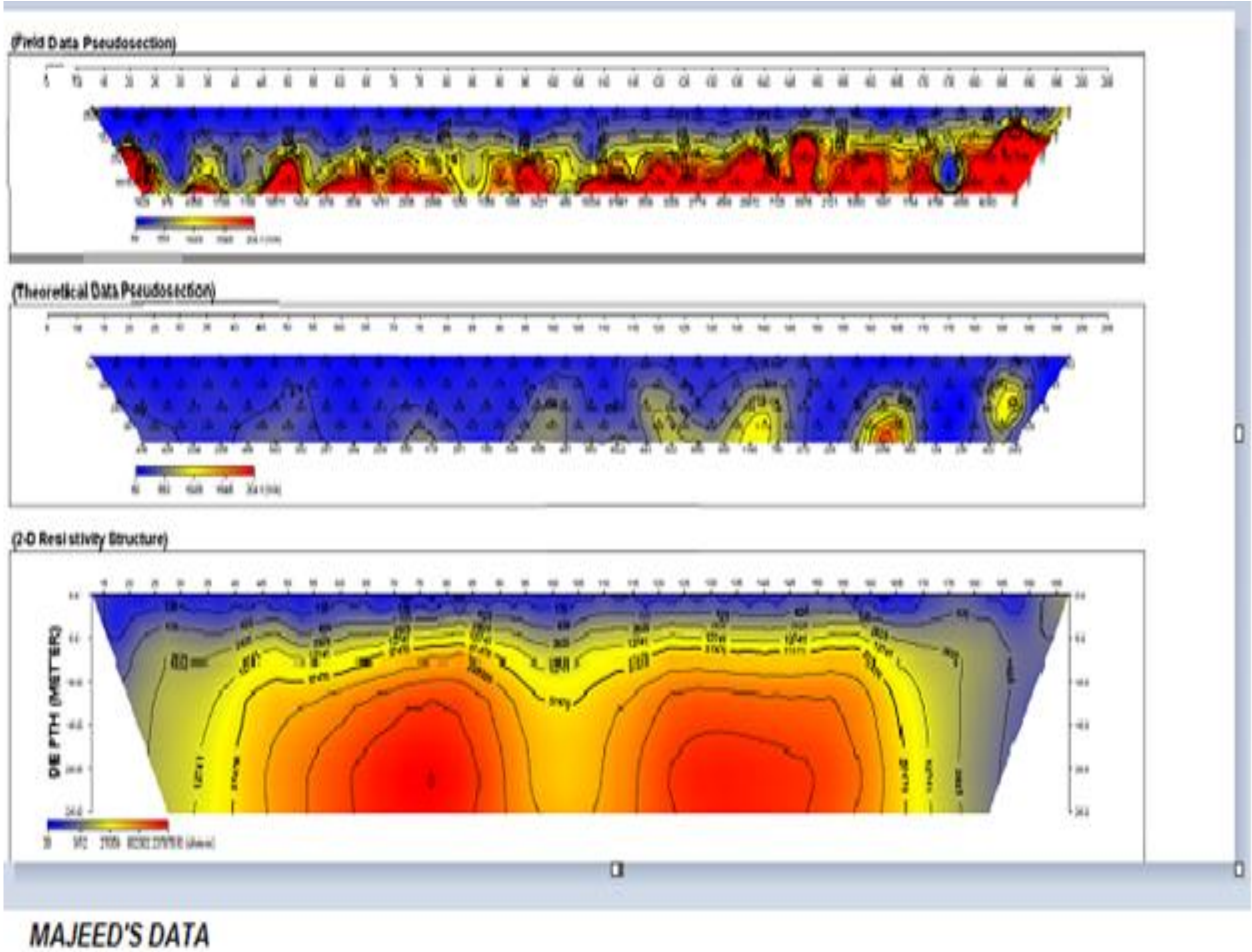

Fig 4 2D inversion of Dipole-Dipole profile 3

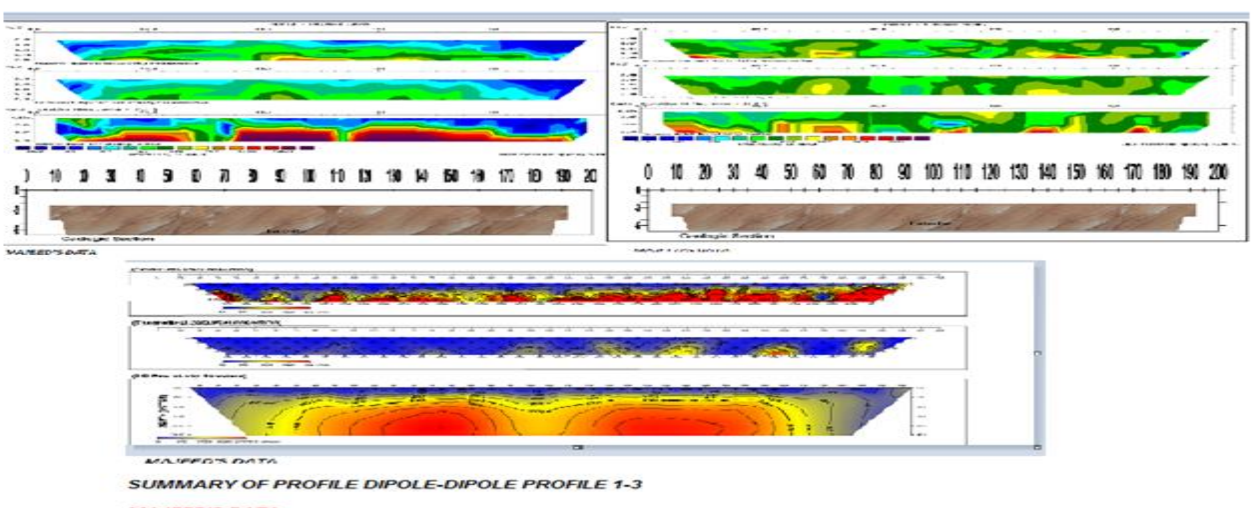

Fig 5.Summary of Dipole-Dipole Profile 1-3

The electrical imaging survey was conducted to provide two-dimensional electrical pictures of the subsurface section made up of lateritic soil/laterite. It is seen from the electrical images that there is rapid laterally and vertically variation of the electrical property. This is indicated by many different color fillings. Within the pictured section of the laterite layer, is most likely that it does not change vertically and laterally to another soil lithology. So, variations in the electrical resistivity in the section most likely reflect variation in water content and mineralogical composition. There is increment in the conductivity value of lateritic soil with the increase in water content, degree of saturation and dry density (Calamita *et al.,* 2012) and (Bai *et al.,* 2013). Lateritic soil has many unfavourable properties, such as shrinkage, cracks, water sensitivity and uneven distribution (Bai *et al.*, 2013).The geologic section of the electrically imaged portion of the subsurface was drawn in surfer13 software, and no delineation of portion saturated with producible water, as laterite is not normally sediment (under-saturated and water held under capillary forces) forming aquifer.

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Conclusion

The electrical resistivity data gave reasonable results that can be used to understand the subsurface layers and groundwater potential. Two different types of soil namely; Laterites and sand were observed from the 2-D resistivity data representation along the traverse. A uniform layer of Laterite is shown on the traverse from the depth between 0 to 6.79m. The profile is generally characterized by Laterite and sand.

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