LITHOSTRATIFICATION OF THE SUBSURFACE USING 2-DIMENSIONAL ELECTRICAL RESISTIVITY SURVEY IN UNIVERSITY OF BENIN, EDO STATE, NIGERIA

BY

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PSC1608021

DEPARTMENT OF PHYSICS

FACULTY OF PHYSICAL SCIENCES

UNIVERSITY OF BENIN

BENIN CITY

JULY, 2021

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A PROJECT SUBMITTED TO
THE DEPARTMENT OF PHYSICS, FACULTY OF PHYSICAL
SCIENCES, UNIVERSITY OF BENIN, BENIN CITY, IN
PARTIAL FUFILMENT OF THE REQUIREMENTS FOR THE
AWARD OF BACHELOR OF SCIENCE DEGREE
IN PHYSICS

JULY, 2021

CERTIFICATION

We the undersigned, hereby certify that this research project was carried out by USIOBOR EWOMAZINO JEREMIAH

of the Department of Physics, Faculty of Physical Science, University of Benin and do approve that it is adequate in scope and quality in partial fulfilment of the award of Bachelor of Science (B.Sc.) degree in Physics, University of Benin, Benin City.

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(External Examiner)

Date: …………………….

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DEDICATION

This research is dedicated to God Almighty for His love and grace that enabled me to carry out this project successfully.

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ABSTRACT

A 2-D geoelectrical resistivity survey was carried out on two different locations (hall 2 and hall 3) in University of Benin, Benin City, Edo State, Nigeria, for subsurface lithology. The Wenner array configuration and Pasi Earth resistivity meter was engaged for the acquisition of fields datasets. The data were subjected to an inversion using RES2DINV software for analysis and interpretation. The lateral spacing used was 160m and the total depth for the first and second locations were 136m and 64m respectively. The resistivity of the various surveys ranges from 57Ωm to 1261Ωm for survey line 1 and 1Ωm to 631Ωm for survey line 2. The geological interpretation of survey line 1 reveals the presence of possibly clayey sand and sand having resistivity values of 50Ωm - 500Ωm and 800Ωm - 1200Ωm respectively. Survey line 2 reveals the presence of possibly laterite soil, clay, alluvium soil having resistivity values of 10Ωm - 88Ωm, 50Ωm - 100Ωm, and 200Ωm - 800Ωm respectively. Results for this study shows that buildings can be erected in the survey line 1 which has large deposit of sand. For survey line 2, excavations and sand filling of the area should be done before erecting buildings to prevent building collapse because of the large deposit of clay.

CHAPTER ONE

INTODUCTION

1.0 GENERAL OVERVIEW

Geophysics is the science that applies the principles of physics to the study of the Earth (usually the earth's subsurface). In order to achieve this, measurements are made at or near the earth's surface to obtain data arising from the vertical and/or lateral variations of the distribution of subsurface physical properties of earth materials (rocks and minerals). The interpretation of this data is capable of detecting and delineating local and regional features that could be of economic interest and/or aid in the unravelling of the Earth's interior. Most geologic features that would be of economic interest as natural resource comprise the concentrations of specific minerals or pore fluids. Such concentrations are not usually common in nature. Hence geophysics seeks to detect areas of this **"UNCOMMON"** concentrations usually referred to as **ANOMALIES**. Geophysical method of subsurface investigation provides a relatively rapid and cost effective means of deriving large area information coverage of subsurface geology (*Shell Intensive Training Programme Geophysics*)

There is a broad spectrum of geophysical methods of survey presently in use for the study of the earth irrespective of scale. However, differences exist in the scale of instrumentation and logistics for the various objectives of study.

1.1 GEOPHYSICAL EXPLORATION METHODS

The various geophysical exploration methods available include:

1. Magnetic method
2. Gravity method
3. Radiometric method
4. Seismic method (reflection and refraction)
5. Electrical resistivity method
6. GPS

Geophysical methods sometimes involve tedious data acquisition procedures and usually require fairly advanced mathematical manipulation for interpretational analysis but considerable amount of geologic information is often obtainable from them. All the various methods enumerated earlier have their different operational parameters at data collection stage; calculated parameters at data processing /analysis stage; inferred parameters (lithologies, structures and pore fluids) at the interpretation stage.

A table showing the various geophysical methods and the accompanying related parameters (as discussed above) and their various applications is shown in Table .1 below.

Method	**Parameter Contrast or operative physical property**	**Measured Parameter**	**Measured parameter**	***Main applications***
Seismic	Density and elastic moduli, which determine the propagation velocity of seismic waves (time of travel)	Travel times of reflected/refracted seismic waves	Velocities, depths and dips of reflectors and refractors	Exploration for hydrocarbons, Geologic structures, Ground water, Determination of engineering foundation parameters
Gravity	Density/Mass which determine gravitational acceleration	Spatial variations in the Earth's gravitational field	Residual Anomalies, depths, dimensions and orientation of causative bodies	Delineation of Sedimentary Basins, salt domes and intrusives.
Magnetic	Magnetic susceptibility and remanence which determine magnetizability	Spatial variations in the strength of the geomagnetic field		Delineation of Sedimentary Basins magnetic materials, metalliferrous mineral, Faults, Intrusives, Basement Topography

Electrical Resistivity	Electrical Potential which determine the conductivity or resistivity	Earth resistance	Resistivities and thicknesses of layers	Exploration for metalliferous mineral deposits, Groundwater, Salt deposit, Fresh/Saline water Interface, Buried conductors
Induced Polarisation	Electrical capacitance which determines quantity of voltage that can develop	Polarisation voltages or frequency dependent ground resistance	Quantity and duration of induced voltages	Exploration for metalliferous minerals
Self-potential	Electrical potential for conductivity or resistivity	Electrical Potentials	Resistivity and thickness of bed	Exploration for metalliferous mineral deposits
Electromagnetic	Electrical conductivity and magnetic induction	Response to electromagnetic radiation	Resistivity and skin depth	Exploration for metalliferous mineral deposits

			Emission	Exploration for

Radiometrics	Radioactivity	Radioactivity Radioactive emissions rate	count rate of K, Th, U and their various ratios.	Radioactive materials (Nuclear Energy), Determination of Radioactive levels

Table 1 Geophysical Survey Methods and their related parameters(Shell Intensive Training Programme Geophysics)

1.2 LOCATION AND GEOLOGY OF THE STUDY AREA

University of Benin is a public research university located inOvia North East, Edo State, SouthSouth Nigeria. The area is bounded by latitude6°20.022'N and longitude 5°36.009'E.Figure 1 shows the geological map of the study area.

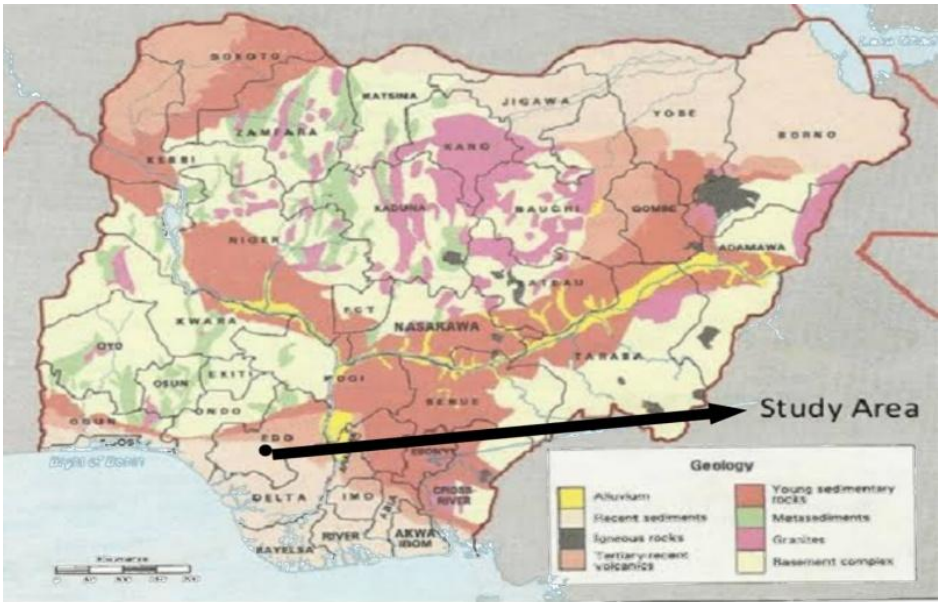

Figure 1: Geologic map of Nigeria sowing the location of the study area

(Balogun 2000)

1.3 AIM OF STUDY

The aim of the study is to carry out a geophysical investigation using 2D resistivity imaging to find out the lithological characterization of the study area.

1.4 OBJECTIVE OF STUDY

The objectives are therefore to;

i. acquire 2-D electrical resistivity data within the study area.
ii. use the 2-D data generated to characterize the subsurface within the study area.

1.5 JUSTIFICATION OF STUDY

Lithological distribution, as a direct geological reflection, has been widely used in petroleum and geological projects.The knowledge of subsurface geology and thecharacterization of the spatial distribution ofsubsurface physical properties are important foreffective delineation of an area under survey(Ahzegbobor, 2010) and (Aigbogun, 2010).

CHAPTER TWO

LITERATURE REVIEW

2.0 PREVIOUS GEOPHYSICAL AND GEOLOGICAL INVESTIGATIONS IN NIGERIA.

1D and 2D electrical resistivity methods were combined to investigate the subsurface properties of Egbeta community for minerals and groundwater potential. The Vertical electrical sounding (VES) and Electrical resistivity imaging (ERI) data were acquired with the aid of PASSI-16L-N Earth resistivity meter, using Schlumberger and Wenner array configuration respectively. The VES geoelectric sections were drawn using AutoCAD 2007 version after the data were interpreted with WINRESIST computational software. The 2D data acquired were interpreted using EARTH IMAGER software which helps to automatically obtain the 2D inversion model of the subsurface. The results from the VES survey six layers: sandy topsoil, lateritic clayey sand, sand stone, gravel/coarse sand and sand. The result of the ERI from the 2D inversion model divides the 2D image of the inversion model into three horizontal cross-sections, the first zone having resistivity range of 34.3 Ωm to 850 Ω, with depth range between 0 m to 15 m and lateral extent > 250 m. The middle zone has resistivity range between 600Ωm to 8689Ωm, with depth range between 15 m to 86 m. The lateral extent of this region is over 280 m. The third region which is in the deepest part of the subsurface has resistivity range between 580Ωm to 1200Ωm and lateral extent > 200 m.(Adegbite et, al)

A geoelectrical imaging survey was conducted at Ekiugbo in Uhunmwode Local Government Area of Edo State, Nigeria, for Shallow site investigation in order to determine the subsurface lithology using Pole-Dipole arrayand SAS 1000 Terrameter for the acquisition of field data. Global position system (GPS) was used to geolocate the position of the data acquisition as longitude 005006’20.6”, latitude 05039’24.7”. The data were subjected to an inversion using RES2DINV computer software for analysis and interpretation. The lateral spread was 280 m and the vertical penetration was 184 m. The resistivity of the various lithological profiles ranges 138 Ωm – 54938 Ωm

2.1LITHO-STRATIFICATION

The study of stratified rocks is called stratigraphy. It’s the branch of geology that deals with the description, correlation, and interpretation of stratified sediments and stratified rocks on and in the Earth. Inasmuch as by far the greatest part of the uppermost zone of the earth’s bedrock is sedimentary rock, stratigraphy is an important branch of Earth science.

Lithostratigraphy is define as the description and systematic organization of the subsurface (soil, rock etc.) into distinctive named units based upon lithological character of the rocks and statigraphic relations. It is the core stratigraphic technique and has been utilized in many forms.

Despite the common use of lithostatigraphy, successful use of the technique can be limited by the complexity of glacial sequences which are often fragmented disparate and heterogeneous in nature

Lithology refers to a type of rock in the earth crust. It is the used as a gross identification for the rock layer in the subsurface. Different kinds of rock exists in the subsurface but not all are conducive for hydrocarbon accumulation. For a subsurface rock to be good hydrocarbon accumulation, the rock should be sedimentary with pore spaces. Accurate determination and understanding of lithology, pore fluid, pore shapes, and sizes are fundamental to other petro physical analysis. These pore spaces can be filled with hydrocarbons.

Lithological soil type includes alluvial soil, basaltic soils, boulder clay soil, calcareous soil, chalk soil, clay soil, diorite soils, glacial till soil, granite soils, loess soil, sandy soil, schist soil, shale soil, and volcanic soil.

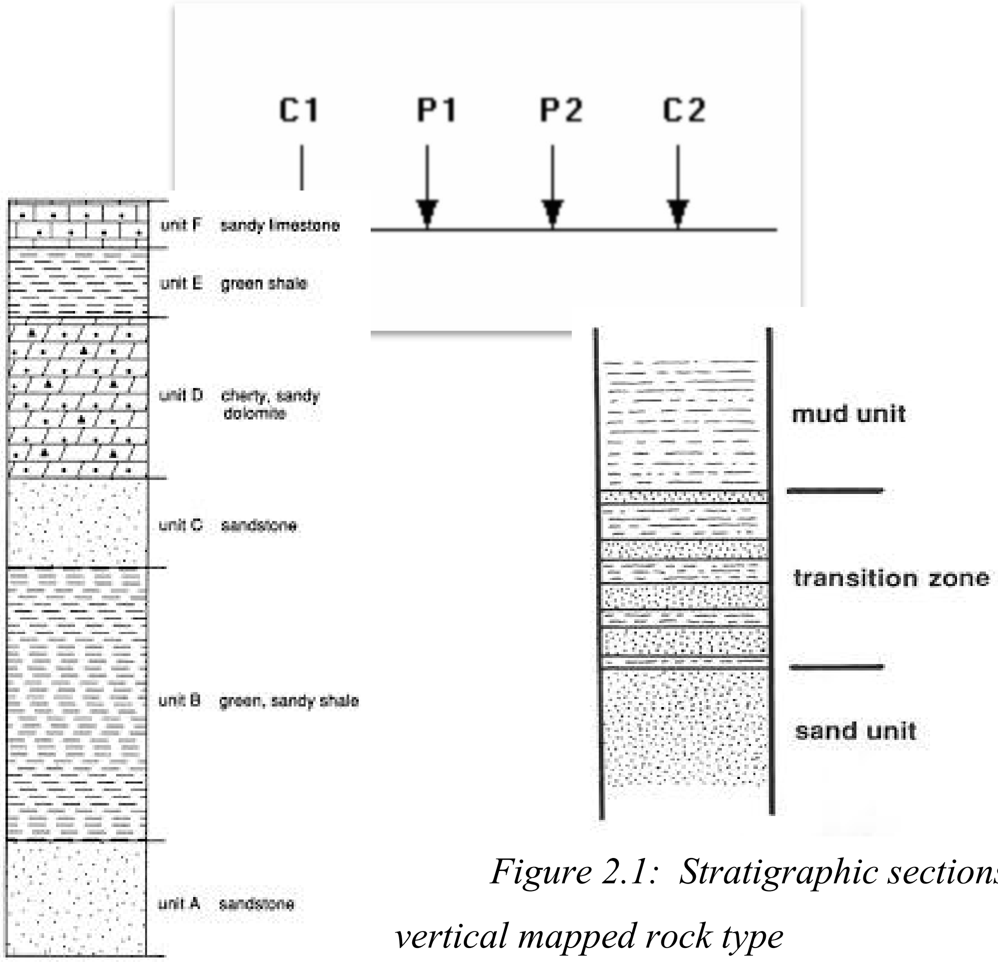

Figure 2.1: Stratigraphic sections—vertical mapped rock type

2.2 ELECTRICAL RESISTIVITY SURVEY

The resistivity method has its origin in the 1920's due to the work of the Schlumberger brothers. For approximately the next 60 years, for quantitative interpretation, conventional sounding surveys (Koefoed 1979) were normally used. In this method, the centre point of the electrode array remains fixed, but the spacing between the electrodes is increased to obtain more information about the deeper sections of the subsurface.

Figure 2.2 Conventional four electrode array to measure the subsurface resistivity.

The resistivity method is one of the oldest geophysical survey techniques (Loke 2011). 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. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock. Electrical resistivity surveys have been used for many decades in hydrogeological, mining, geotechnical, environmental and even hydrocarbon exploration (Loke*el al.* 2011, Loke *et al*. 2013a).

Electrical and electromagnetic methods make up a large portion of all geophysical methods used. They also include some of the oldest methods used to explore the subsurface. Electrical methods can be used to measure different quantities including current flow, electrical potential and electromagnetic fields. The first electrical method to be used in this course will be direct current (DC) resistivity.

2.3 BASIC THEORY OF ELECTRIC SURVEY

In a homogeneous earth, current flows radially outward from the source to define a hemispherical surface. The current distribution is equal everywhere on this surface which is also called an equipotential surface. Starting with Ohm's law (*V* = *IR*) and defining the resistance *R* in terms of the resistivity ρ and the area of the shell (equipotential surface), thepotential difference across the shell is

$$dV = \iota(R) = I\left(\rho\,\frac{L}{A}\right) = I(\rho\,\frac{dr}{2\pi r^2})$$

Where *V* is the voltage (or electrical potential), *I* is the current, $\rho$is the resistivity, and *r* is the radius of the equipotential surface. Integrating the above equation and setting the potential at infinity to zero, the electric potential at a distance *R* from the source is given by

$$V = \frac{\rho I}{2\pi R}$$

Resistivity has units of *ohm m* and is not to be confused with *resistance* which has units of *ohms*. The *resistivity* of a material is defined as $\rho\frac{RA}{L}$ where *R* is the resistance of the material, *A* is the cross-sectional area through which current flows and *L* is the length on the material.

The potential has been derived due to a single current source. The goal in resistivity surveying is to measure the potential different between two points due to the current from two current electrodes. The potential at each electrode is determined due to the current sources

$$V_{P1} = \frac{I\rho}{2\pi r_1} - \frac{I\rho}{2\pi r_2}$$

$$V_{P1} = \frac{I\rho}{2\pi r_3} - \frac{I\rho}{2\pi r_4}$$

Where the $r_{i's}$are shown in Figure 1. The potential difference $\triangle V = V_{P_1} - V_{P_2}$which is simplifies to

$$\triangle V = \frac{I\rho}{2\pi}(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4})$$

The above equation can then be solved for the resistivity. In a non-homogeneous earth, the resistivity which is measured is not actually the true resistivity of the subsurface. For an earth with more than one layer, the *apparent resistivity* measured will be an average of the resistivities of the additional layers. The apparent resistivity data needs to be interpreted in terms of a subsurface model in order to determine the actual resistivities of the layers.

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Materials	Resistivity(•m)	Conductivity (Siemen/m)
Igneous and Metamorphic Rocks		
Granite	5x10^{3} – 10^{6}	10^{-6} - 2x10^{-4}
Basalt	10^{3} – 10^{6}	10^{-6} – 10^{-3}
Slate	6x10^{2}- 4x10^{7}	2.5x10^{-8}- 1.7x10^{-3}
Marble	10^{2}- 2.5x108	4x10^{-9}– 10^{-2}
Quartzite	10^{2}- 2x108	5x10^{-9}– 10^{-2}
Sedimentary Rocks		
Sandstone	8 - 4x10^{3}	2.5x10^{-4}- 0.125
Shale	20 - 2x10^{3}	5x10^{-4}- 0.05
Limestone	50 - 4x10^{2}	2.5x10-3 - 0.02
Soils and waters		
Clay	1 - 100	0.01 - 1
Alluvium	10 - 800 1	.25 x10^{-3}- 0.1
Groundwater (fresh)	10 - 100	0.01 - 0.1
Sea water	0.2	5
Chemicals		
Iron	9.074x10^{-8}	1.102x10^{7}
0.01 M Potassium chloride	0.708	1.413
0.01 M Sodium chloride	0.843	1.185
0.01 M acetic acid	6.13	0.163
Xylene	6.998x10^{16}	1.429x10^{-17}

Table 2.Resistivities of some common rocks, minerals and chemicals.

2.4 2D ELECTRICAL IMAGING

We have seen the greatest limitation of the resistivity sounding method is that it does not take into account horizontal changes in the subsurface resistivity. A more accurate model of the subsurface is a two-dimensional (2-D) model where the resistivity changes in the vertical direction, as well as in the horizontal direction along the survey line. In this case, it is assumed that resistivity does not change in the direction that is perpendicular to the survey line. In many situations, particularly for surveys over elongated geological bodies, this is a reasonable assumption. In theory, a 3-D resistivity survey and interpretation model should be even more accurate. However, at the present time, 2-D surveys are the most practical economic compromise between obtaining very accurate results and keeping the survey costs down. Typical 1-D resistivity sounding surveys usually involve about 10 to 20 readings, while 2-D imaging surveys involve about 100 to 1000 measurements. In comparison, 3-D surveys usually involve several thousand measurements. The cost of a typical 2-D survey could be several times the cost of a 1-D sounding survey, and is probably comparable with a seismic survey. In many geological situations, 2-D electrical imaging surveys can give useful results that are complementary to the information obtained by other geophysical method. For example, seismic methods can map undulating interfaces well, but will have difficulty (without using advanced data processing techniques) in mapping discrete bodies such as boulders, cavities and pollution plumes. Ground radar surveys can provide more detailed pictures but have very limited depth penetration in areas with conductive unconsolidated sediments, such as clayey soils. Two-dimensional electrical surveys should be used in conjunction with seismic or GPR surveys as they provide complementary information about the subsurface.

One of the new developments in recent years is the use of 2-D electrical imaging/tomography surveys to map areas with moderately complex geology (Griffiths and Barker 1993). Such surveys are usually carried out using a large number of electrodes, 25 or more, connected to a multi-core cable. A laptop microcomputer together with an electronic switching unit is used to automatically select the relevant four electrodes for each measurement. At present, field techniques and equipment to carry out 2-D resistivity surveys are fairly well developed. The necessary field equipment is commercially available from a number of international companies. Some institutions have even constructed “home-made” manually operated switching units at a nominal cost by using a seismic cable as the multi-core cable.

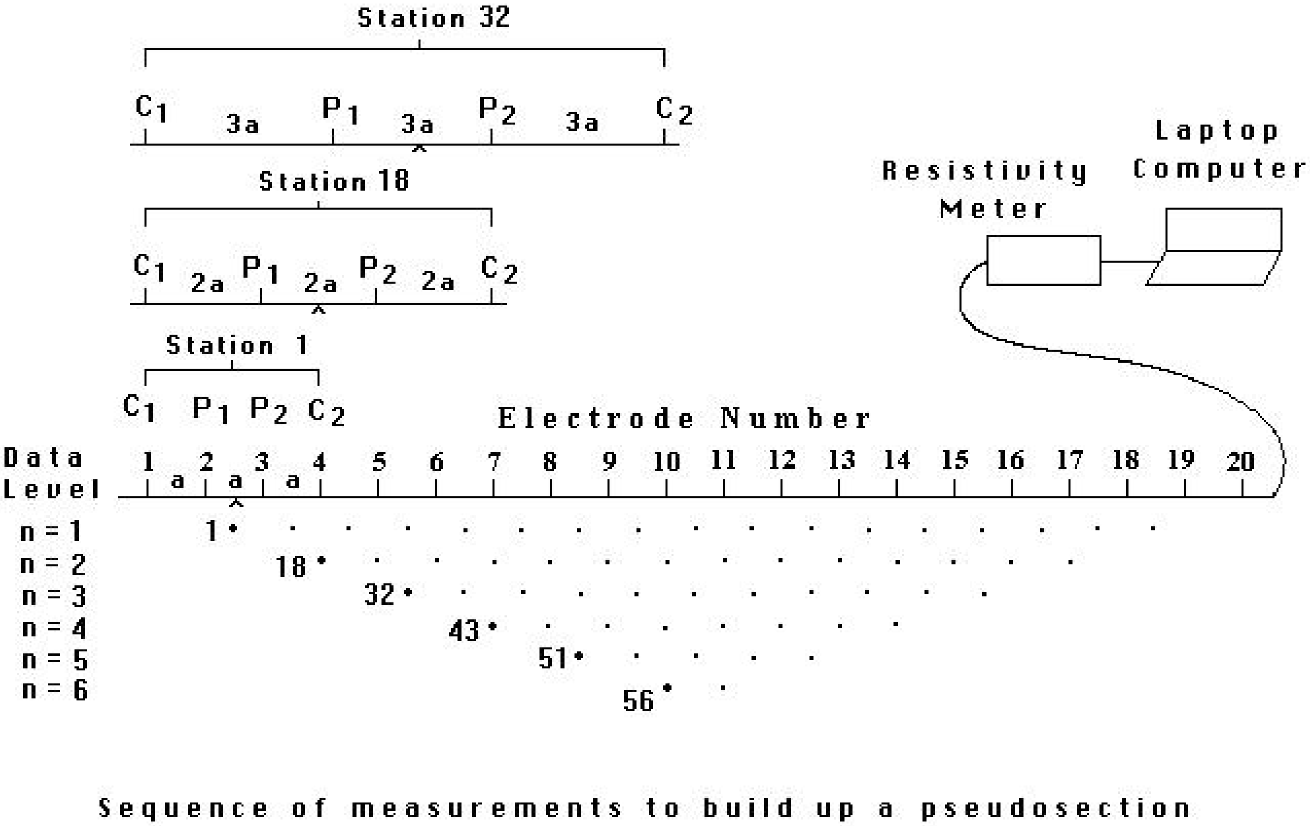

Figure 4: The arrangement of electrodes for a 2-D electrical survey and the sequence of measurements used to build up a pseudosection.

2.41 COMPUTER INTERPRETATION

After the field survey, the resistance measurements are reduced to apparent resistivity values. Practically all commercial multi-electrode systems come with the computer software to carry out this conversion. In this section, we will look at the steps involved in converting the apparent resistivity values into a resistivity model section which can be used for geological interpretation.

2.42 DATA INPUT AND FORMAT

To interpret the data from a 2-D imaging survey, a 2-D model for the subsurface which consists of a large number of rectangular blocks is usually used. A computer program is then used to determine the resistivity of the blocks so that the calculated apparent resistivity values agree with the measured values from the field survey. The computer program RES2DINV.EXE will automatically subdivide the subsurface into a number of blocks, and it then uses a least-squares inversion scheme to determine the appropriate resistivity value for each block. The location of the electrodes and apparent resistivity values must be entered into a text file which can be read by the RES2DINV program. The program manual gives a detailed description of the data format used.

CHAPTER THREE

METHODOLOGY AND INSTRUMENTATION

3.0 ELECTRICAL RESISTIVITY METHOD

The electrical resistivity method is an active geophysical method. It employs an artificial source which is introduced into the ground through a pair of electrodes. The procedure involves measurement of potential difference between other two electrodes in the vicinity of current flow. Apparent resistivity is calculated by using the potential difference for the interpretation. The electrode by which current is introduced into the ground are called **Current Electrodes** and electrodes between which the potential difference is measured are called **Potential Electrode.**

In geoelectrical resistivity tomography (near-surface), a large number of electrodes are inserted into the ground and a computer-based system scans the whole array, thus realizing a combined sounding and profiling. If the target in a proposed survey area is narrow and extends over a long distance (the 2D case), the technique effectively investigates a series of depth range on a profile line, resulting in a pseudosection of apparent resistivities.Tomographic surveys normally employ arrays of electrodes on the surface of the ground for data collection. The survey technique involves measuring a series of constant separation traverses with the electrode separation being increased with each successive traverse. Since increasing separation leads to information from greater depth, the measured apparent resistivities may be plotted as a contoured section, which reflects qualitatively the spatial variation in resistivity in the vertical cross-section. Length of profile, depth of penetration and resolution required determine the unit electrode spacing.

3.1 TYPES OF ELECTRODE CONFIGURATION

The electrode configuration or array is determined by the mode of arrangement of the current and potential electrodes and the common arrays are ;

1. Schlumberger Array
2. Dipole-Dipole Array
3. Pole-Dipole Array
4. Wenner Array
5. Pole-pole Array
6. Square Array
7. Lee- Partition Array
8. Crossed – square Array
9. Gradient Array

3.10 Schlumberger Array

In Schlumberger array the electrodes are collinearly arranged i.e. arranged along a straight line with 2 outer current electrodes and two inner potential electrodes. Four electrodes C_1, P_1, P_2 and C_2 are placed at the surface and current electrode are spread much further apart than the potential electrodes.

In depth probing the potential electrode remains temporarily fixed while the current electrode spacing is expanded systematically about the centre of the spread. For large values of L, it may be necessary to increase l also in other to maintain a measureable potential.

But, the distance (2l) between the potential electrodes is small compared to the distance (2L) between the current electrodes, with L $\geq$ 5l. The inter-electrode spacing in the generalized resistivity equation becomes.

$r_1 = r_4 = L - l$,

$r_2 = r_3 = L + l$

So that the generalized apparent resistivity equation for Schlumberger configuration (ρ_{as}) becomes;

$$\rho_{as} = 2\pi R \left[\frac{1}{\frac{1}{L-l} - \frac{1}{L+l} - \frac{1}{L+l} + \frac{1}{L-l}} \right] \ldots\ldots\ldots\ldots\ldots\ldots (2.31)$$

$$= 2\pi R \frac{\left(L^2 - 1^2\right)}{4l} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.32)$$

$$\rho_{as} = \frac{\pi R(L^2 - l^2)}{2l}$$

But If L >>l, then $L^2 - l^2$ will be approximately equal to L^2

$$\rho_{as} = \frac{\pi R L^2}{2l} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.33)$$

Or

$$\rho_{as} = \frac{\pi R(AB/2)^2}{MN} \qquad (2.34)$$

Where L, *l*, AB and MN are as defined in Figure. 2.4

The depth of investigation for Schlumberger is 0.25AB

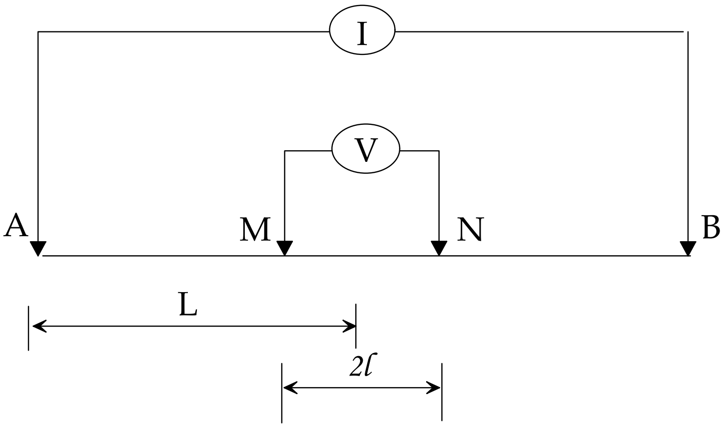

Figure.3.1: Schlumberger electrode configuration (Mid-point of line AB is the spot been measured)

3.11Dipole-Dipole

Dipole-Dipole configuration was used to measure the lateral and vertical variations in the ground apparent resistivity values. The electrodes are collinearly arranged. The two(pair) current electrode comes before the two potential electrode and are separated by constant (na) where n=1,2,3,4,5,6,7,8….. and ‘a’ is the distance between the electrodes, which is 10m for this study. It is only the distance between the inner current electrode and inner potential electrode that varies, other are at equidistance to each other.

In the dipole-dipole array, the typical field procedure is to transmit on a current dipole while measuring the voltages on up to five of the adjacent potential dipoles. When the data collection is completed for the particular transmitter dipole, the entire array is moved by a distance equal to one dipole separation and the process is repeated.

Where n= expansion factor

a=electrode spacing

ρ_{dda} = The apparent resistivity of dipole dipole, it is calculated by using;

$$\rho a = 2\pi R\left(\frac{1}{\frac{1}{r_1}-\frac{1}{r_2}-\frac{1}{r_3}+\frac{1}{r_4}}\right) ------------------ (2.38)$$

$$r_1 = na + a = a(n+1)$$

$$r_2 = na$$

$$r_3 = na + 2a = a(n+2)$$

$$r_4 = na + a = a(n+1)$$

$$\rho_{dda} = 2\pi R\left[\frac{1}{\frac{1}{a(n+1)}-\frac{1}{na}-\frac{1}{a(n+2)}+\frac{1}{a(n+1)}}\right] -------- (2.39)$$

$$\rho dda = 2\pi R\left[\frac{1}{\frac{n(n+2)-(n+1)(n+2)-n(n+1)+n(n+2)}{a(n+1)(n+2)n}}\right]$$

$$\boldsymbol{\rho} dda = 2\pi R\left[\frac{1}{\frac{n^2+2n-\left(n^2+2n+n+2\right)-\left(n^2+n\right)+\left(n^2+2n\right)}{a(n+1)(n+2)n}}\right]$$

$$\rho dda = 2\pi R\left[\frac{1}{\frac{n^2+2n-\left(n^2+3n+2\right)-n^2-n+n^2+2n}{a(n+1)(n+2)n}}\right]$$

$$\rho dda = 2\pi R\left[\frac{1}{\frac{n^2+2n-n^2-3n-2-n^2-n+n^2+2n}{a(n+1)(n+2)n}}\right]$$

$$\rho dda = 2\pi R\left[\frac{1}{\frac{-2}{a(n+1)(n+2)n}}\right]$$

$$\rho dda = 2\pi R\left[\frac{a(n+1)(n+2)n}{-2}\right] ---------- (2.40)$$

$$\rho dda =- \pi Rna(n+1)(n+2) ---- (2.41)$$

Theoretical depth of investigation is 0.195AB.

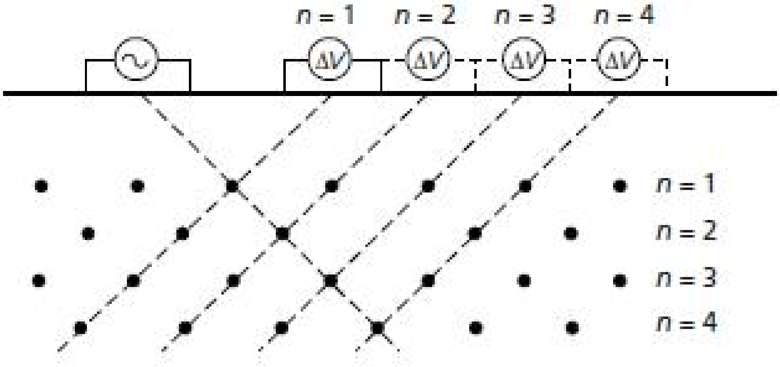

Figure 3.2: Dipole-Dipole Array

3.12 Pole-Pole Array

This array is not as commonly used as the Wenner, dipole-dipole and Schlumberger arrays. In practice the ideal pole-pole array, with only one current and one potential electrode, does not exist. To approximate the pole-pole array, the second current and potential electrodes (C2 and P2) must be placed at a distance which is more than 20 times the maximum separation between C1 and P1 electrodes used in the survey. The effect of the C2 (and similarly for the P2) electrode is approximately proportional to the ratio of the C1-P1 distance to the C2-P1 distance. If the effects of the C2 and P2 electrodes are not taken into account, the distance of these electrodes from the survey line must be at least 20 times the largest C1-P1 spacing used to ensure that the error is less than 5%. In surveys where the inter-electrode spacing along the survey line is more than a few metres, there might be practical problems in finding suitable locations for the C2 and P2 electrodes to satisfy this requirement. Another disadvantage of this array is that because of the large distance between the P1 and P2 electrodes, it is can pick up a large amount of telluric noise which can severely degrade the quality of the measurements. Thus this array is mainly used in surveys where relatively small electrode spacing (less than 10 metres) are used. It is popular in some applications such as archaeological surveys where small electrode spacing are used. This array has the widest horizontal coverage and the deepest depth of investigation. However, it has the poorest resolution, which is reflected by the comparatively large spacing between the contours in the sensitivity function plot.

3.13 Pole-Dipole Array

The pole-dipole array also has relatively good horizontal coverage, but it has a significantly higher signal strength compared with the dipole-dipole array and it is not as sensitive to telluric noise as the pole-pole array. Unlike the other common arrays, the pole-dipole array is an asymmetrical array and over symmetrical structures the apparent resistivity anomalies in the pseudosection are asymmetrical. In some situations, the asymmetry in the measured apparent resistivity values could influence the model obtained after inversion. One method to eliminate the effect of this asymmetry is to repeat the measurements with the electrodes arranged in the reverse manner. By combining the measurements with the “forward” and “reverse” pole-dipole arrays, any bias in the model due to the asymmetrical nature of this array would be removed. The pole-dipole array also requires a remote electrode, the C2 electrode, which must be placed sufficiently far from the survey line. For the pole-dipole array, the effect of the C2 electrode is approximately proportional to the square of ratio of the C1-P1 distance to the C2- P1 distance. Thus the pole-dipole array is less affected by the C2 remote electrode compared with the pole-pole array. If the distance of the C2 electrode is more than 5 times the largest C1-P1 distance used, the error caused by neglecting the effect of the C2 electrode is less than 5% (the exact error also depends on the location of the P2 electrode for the particular measurement and the subsurface resistivity distribution). Due to its good horizontal coverage, this is an attractive array for multi-electrode resistivity meter systems with a relatively small number of nodes. The signal strength is lower compared with the Wenner and Wenner-Schlumberger arrays but higher than the dipole-dipole array. For IP surveys, the higher signal strength (compared with the dipole-dipole array) combined with the lower EM coupling (compared with the Wenner and Wenner-Schlumberger arrays) due to the separation of the circuitry of the current and potential electrodes makes this array an attractive alternative.

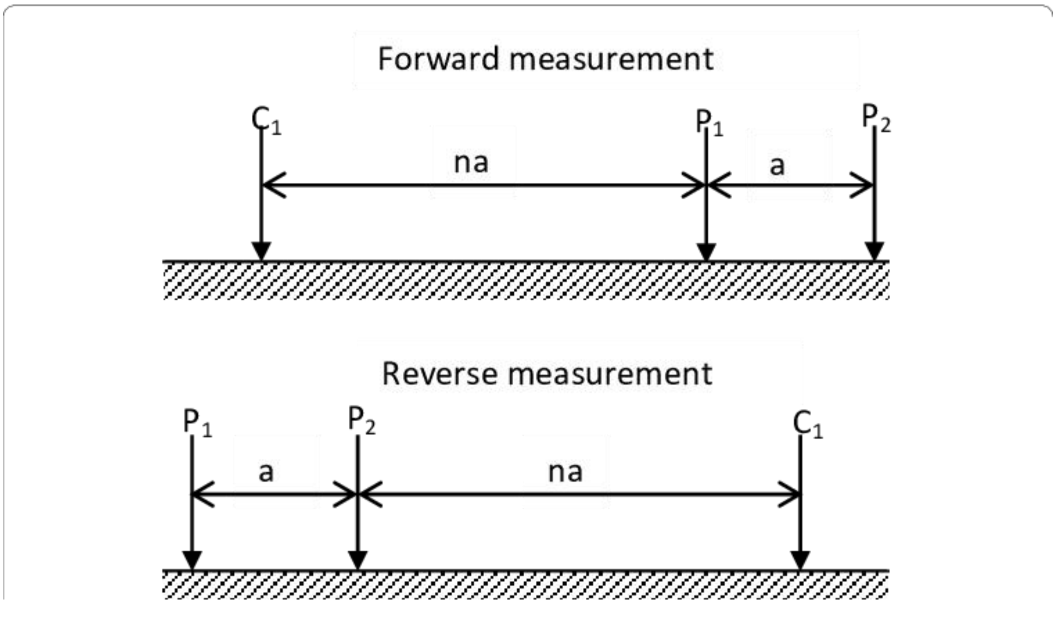

Figure 3.3: The forward and reverse pole-dipole arrays

The signal strength for the pole-dipole array decreases with the square of the "n" factor. While this effect is not as severe as the dipole-dipole array, it is usually not advisable to use "n" values of greater than 8 to 10. Beyond this, the "a" spacing between the P1-P2 dipole pair should be increased to obtain stronger signal strength.

For the course of this project work, the wenner array configuration was employed.

3.14 Wenner Array

It is a co-linear array i.e. all the electrodes are arranged in a straight line with the potential electrodes arranged inside the current electrodes. The inter electrode spacing is uniform (the same). In Wenner array, current is passed through the earth by means of pair of current electrodes C_1 and C_2 while measuring potential difference by the potential electrodes P_1 and P_2, which are placed at an equal distance or interval "a" along the traverse (or profile) being measured, as shown in figure 3.6. Series of current values (I) and potential difference (Δv) were taken. The ratio of potential difference to the current gives the resistance, R.

The apparent resistivities of the subsurface media were calculated by using;

Recall,

$$\rho a = 2\pi R \left(\frac{1}{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}} \right) ----------------- (2.35)$$

Where,

$$r_1 = a$$

$$r_2 = 2a$$

$$r_3 = 2a$$

$$\rho wa = 2\pi R\left(\frac{1}{\frac{1}{a}-\frac{1}{2a}-\frac{1}{2a}+\frac{1}{a}}\right)-----------------(2.36)$$

$$= 2\pi R\left(\frac{1}{\frac{2-1-1+2}{2a}}\right)$$

$$= 2\pi R\left(\frac{1}{\frac{1}{a}}\right)$$

$$\therefore \rho wa = 2\pi Ra ------------------------ (2.37)$$

Pwa is Wenner apparent resistivity. “a” is the constant electrode spacing, for this study it is 10m.

The theoretical depth of penetration $\geq \cong$ 0.115AB or $\frac{a}{3}$

3.2 EQUIPMENTS FOR THE FIELD WORK

The equipment used for the field work are listed below.

- Resistivity Meter (Terrameter)
- Electrodes
- Reels of cables
- Hammer
- Measuring tape
- Recording sheets
- DC Battery (power source)

- Hammers

- ***Terrameter***

This is a computerized system which is at the heart of the entire field operation. There are numerous and these have been discussed analytically in the preceding section (section 3.2).

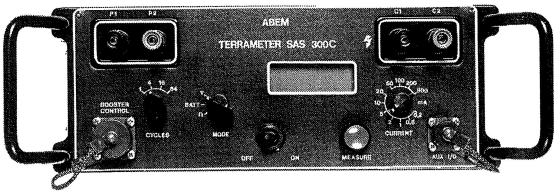

Figure 3.4: Pasci resistivity meter

- ***Electrodes***

Four stainless non-polarizing steel electrodes were used, the electrodes has angular shape at the base for easy penetration into the ground. They were driven into the ground via a hammer during the field work, two were used to send current into the ground when connected with the current portion of the Terrameter- current electrode, while the inner two electrodes measures the potentials.

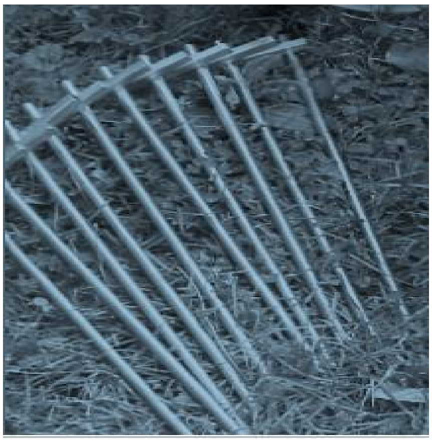

Figure 3.5: The stainless steel Electrodes

- ***Reels of cable***

Insulated cables with crocodile clips at the end of the cable are used to connect the electrode and the battery to the resistivity meter.

Figure 3.6: Reels of Cable

- ***Measuring Tape***

This is used to measure the position of the electrodes.

- ***Recording sheets***

These are sheets of paper that has been formatted for used on the field.

- ***Dc Battery***

The battery used as source of power for the Terrameter was a direct current 12v battery always attached to the base of the Terrameter.

- ***Hammers***

To drive the electrodes into the ground to ensure firm contact.

3.3 FIELD PROCEDURE OF WENNER ARRAY

The Wenner electrode array is the simplest of arrays; in it, the four electrodes—A, M, N, and B—are placed in line and spaced equidistant from each other. The two outer electrodes, A and B, are current electrodes, and the two inner electrodes, M and N, are potential electrodes. With the Wenner array, the resistivity of subsurface layers is found by increasing the distance between the electrodes while maintaining the location of the center point of the array. This method is called **vertical electrical sounding (VES)** or electrical drilling. Detection of horizontal changes of resistivity is achieved by moving the four electrodes across the surface while maintaining constant electrode separation. This method is called profiling or sometimes electrical trenching. (**Source**)

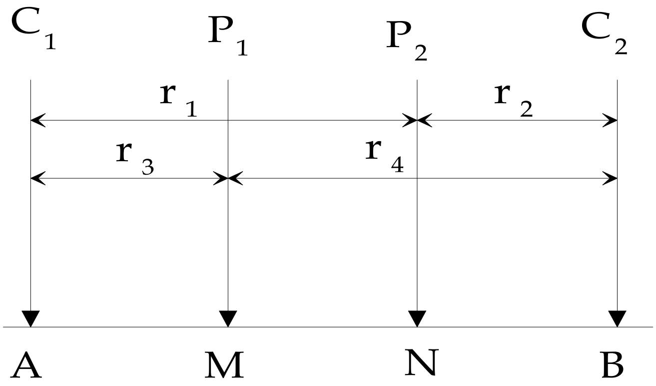

Figure 3.7: Wenner Electrode Configuration.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 RESULTS

SURVEY DATA FOR HALL 3 ENVIROMENT

ARRAY TYPE	**Wenner Array**	**DATE**	**02/02/2021**
INSTRUMENT USED	**ABEM SAS 300C Earth Resistivity meter**	**STATE**	**EDO**
LOCATION	**University of Benin**	**LGA**	**Ovia North East**
LINE NUMBER	**L1**		
POSITION COORDINATES	**Wenner traverse 1 Long 003˚22’10.0”Lat 06˚29’17.8”Elev 5.8**	**OBSERVER**	**EdebeatuEkene**

Traverse 1 a = 10m					
C1	P1	P2	C2	R(Ω)	ʆ(Ωm)
0	10	20	30	1.6	100.54
10	20	30	40	0.642	40.34
20	30	40	50	0.145	9.11
30	40	50	60	0.108	6.78
40	50	60	70	0.049	3.079
50	60	70	80	0.276	17.34
60	70	80	90	5.9	370.75
70	80	90	100	3.3	207.37
80	90	100	110	0.259	16.27
90	100	110	120	2.700	169.66
100	110	120	130	0.831	52.22
110	120	130	140	0.75	47.13
120	130	140	150	0.839	52.72
130	140	150	160	1.1	69.12
140	150	160	170	0.922	57.93
150	160	170	180	0.065	4.08
160	170	180	190	0.12	7.54
170	180	190	200	0.028	1.75

Traverse 1 a = 20m					
C1	P1	P2	C2	ᶋ(Ω)	ᶋ(Ωm)
0	20	40	60	0.532	66.86
10	30	50	70	1.200	150.81
20	40	60	80	1.100	138.24
30	50	70	90	0.922	115.87
40	60	80	100	0.667	83.82
50	70	90	110	0.205	25.76
60	80	100	120	0.542	68.11
70	90	110	130	0.825	103.68
80	100	120	140	0.471	59.19
90	110	130	150	0.308	38.70
100	120	140	160	0.315	39.58
110	130	150	170	0.292	36.69
120	140	160	180	0.207	26.01
130	150	170	190	0.253	31.79
140	160	180	200	0.323	40.59
Traverse 1 a = 30m	Column1	Column2	Column3	Column4	Column5
C1	P1	P2	C2	ᶋ(Ω)	ᶋ(Ωm)
0	30	60	90	0.527	99.35
10	40	70	100	1.300	245.07
20	50	80	110	0.160	30.16
30	60	90	120	0.225	42.41
40	70	100	130	0.074	13.95
50	80	110	140	0.878	165.52
60	90	120	150	0.552	104.06
70	100	130	160	0.02	3.77
80	110	140	170	0.079	14.89
90	120	150	180	1.9	358.18
100	130	160	190	0.357	67.30
110	140	170	200	0.35	65.98
Traverse 1 a = 40m	Column1	Column2	Column3	Column4	Column5
C1	P1	P2	C2	ᶋ(Ω)	ᶋ(Ωm)
0	40	80	120	0.292	73.39
10	50	90	130	0.232	58.31
20	60	100	140	0.716	179.97
30	70	110	150	0.204	51.27
40	80	120	160	0.298	74.90
50	90	130	170	0.232	58.31
60	100	140	180	0.047	11.81
70	110	150	190	0.144	36.19

80	120	160	200	3.600	904.80
Traverse1 a=50	Column1	Column2	Column3	Column4	Column5
C1	P1	P2	C2	ᶊ(Ω)	ᶊ(Ωm)
0	50	100	150	0.511	160.55
10	60	110	160	0.486	152.70
20	70	120	170	0.082	25.76
30	80	130	180	0.027	8.48
40	90	140	190	0.0047	1.47
50	100	150	200	0.922	289.69
Traverse 1 a = 60m	Column1	Column2	Column3	Column4	Column5
C1	P1	P2	C2	ᶊ(Ω)	ᶊ(Ωm)
0	60	120	180	0.632	238.28
10	70	130	190	0.284	107.07
20	80	140	200	0.039	14.70

SURVEY DATA FOR HALL 2 ENVIROMENT

ARRAY TYPE	**Wenner Array**	**DATE**	**02/02/2021**
INSTRUMENT USED	**ABEM SAS 300C Earth Resistivity Meter**	**STATE**	**EDO**
LOCATION	**University of Benin**	**LGA**	**Ovia North East**
LINE NUMBER	**L2**		
POSITION COORDINATES	**Wenner traverse 2 Long 06˚23’58.0”Lat 005˚37’09.2”Elev 99.3**	**OBSERVER**	**EdebeatuEkene**

Traverse 2 a = 10m					
C1	P1	P2	C2	§(Ω)	§(Ωm)
0	10	20	30	10.9	684.95
10	20	30	40	11.3	710.09
20	30	40	50	8.9	559.27
30	40	50	60	0.096	6.03
40	50	60	70	0.399	25.07
50	60	70	80	0.259	16.27
60	70	80	90	0.366	22.99
70	80	90	100	0.082	5.15
80	90	100	110	0.062	3.89
90	100	110	120	17.000	1068.28
100	110	120	130	14.9	936.31
110	120	130	140	12.9	810.63
120	130	140	150	16.8	1055.71
130	140	150	160	17.7	1112.26
140	150	160	170	19.8	1244.23
150	160	170	180	27.6	1734.38
160	170	180	190	22.6	1420.18
170	180	190	200	0.81	50.90

Traverse 2 a = 20m					
C1	P1	P2	C2	§(Ω)	§(Ωm)
0	20	40	60	4.900	615.83
10	30	50	70	5.500	691.24
20	40	60	80	7.400	930.03
30	50	70	90	6.700	842.05
40	60	80	100	1.100	138.24
50	70	90	110	6.700	842.05
60	80	100	120	0.498	62.58
70	90	110	130	8.400	1055.71
80	100	120	140	8.900	1118.55
90	110	130	150	7.200	904.89
100	120	140	160	7.500	942.60

110	130	150	170	0.530	66.61
120	140	160	180	11.200	1407.61
130	150	170	190	13.700	1721.81
140	160	180	200	13.900	1746.95
Traverse 2 a = 30m					
C1	P1	P2	C2	ᶊ(Ω)	ᶊ(Ωm)
0	30	60	90	4.000	754.08
10	40	70	100	5.300	999.15
20	50	80	110	5.400	1018.00
30	60	90	120	5	942.60
40	70	100	130	5.2	980.304
50	80	110	140	5.6	1055.71
60	90	120	150	6.700	1263.08
70	100	130	160	6	1131.12
80	110	140	170	5.9	1112.26
90	120	150	180	5.6	1055.71
100	130	160	190	4.7	886.04
110	140	170	200	10.2	1922.90
traverse 2 a=40					
C1	P1	P2	C2	ᶊ(Ω)	ᶊ(Ωm)
0	40	80	120	3.900	980.30
10	50	90	130	4.900	1231.66
20	60	100	140	5.500	1382.48
30	70	110	150	5.700	1432.70
40	80	120	160	0.876	220.19
50	90	130	170	3.000	754.08
60	100	140	180	7.900	1985.74
70	110	150	190	5.300	1332.20
80	120	160	200	3.400	854.62
traverse 2 a=50					
C1	P1	P2	C2	ᶊ(Ω)	ᶊ(Ωm)
0	40	80	120	4.200	1055.71
10	50	90	130	3.600	904.89
20	60	100	140	4.800	1206.52
30	70	110	150	0.425	106.82
40	80	120	160	1.400	351.90
50	90	130	170	0.651	163.63

traverse 2 a=60					
C1	P1	P2	C2	ᶊ(Ω)	ᶊ(Ωm)
0	40	80	120	4.300	1080.84
10	50	90	130	0.749	188.26
20	60	100	140	3.600	904.89

4.1DATA PROCESSING AND DISPLAY

The program, RES2DINV was used for this processing. 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 software 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 represents the most accurate picture of the subsurface that can be produced from the measured or observed apparent resistivity distribution.

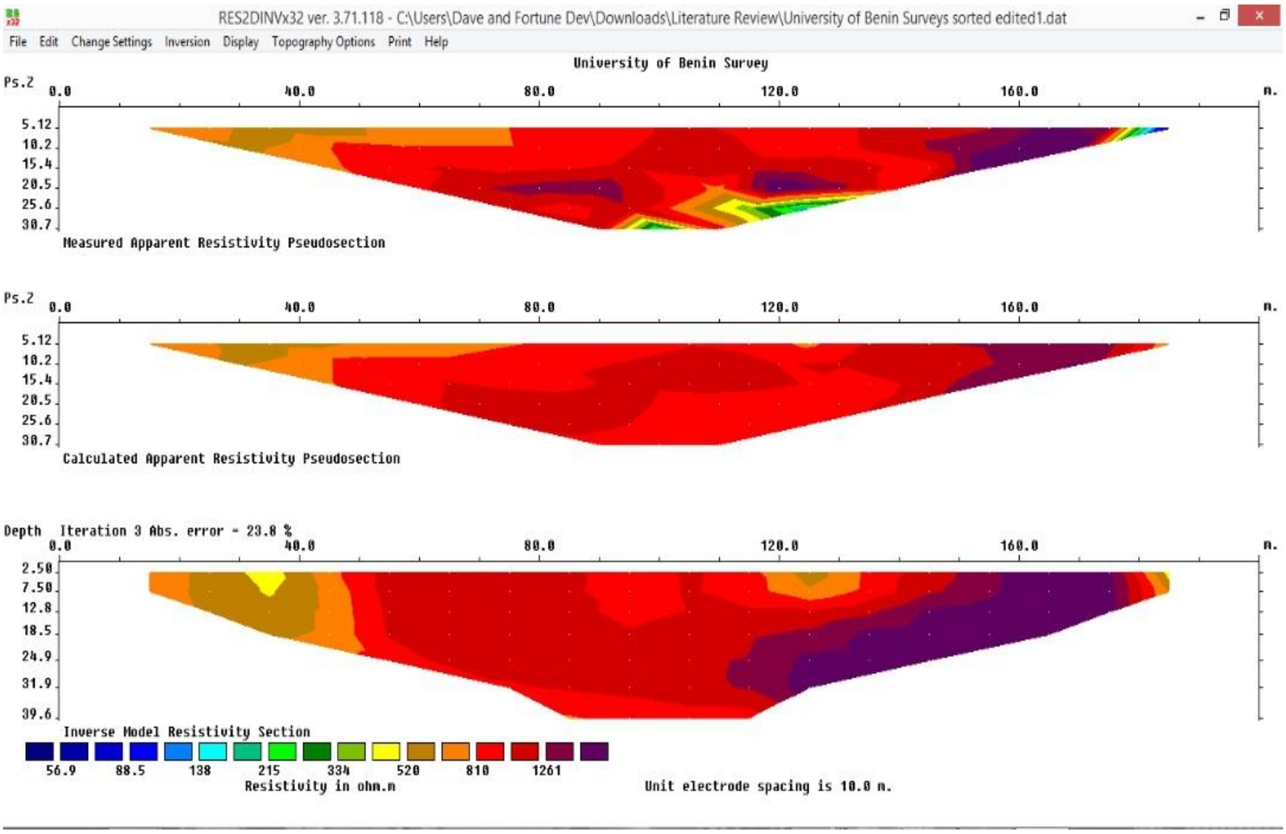

Fig 4.1: 2-D measured, calculated and resistivity survey for wenner

The numerous colour shades signifies different geo-electric materials present in the resistivity block model with resistivity ranges between 50Ωm – 1270Ωm showing geoelectrical layers composed of lateral soil, clay, clayey sand, limestone etc.

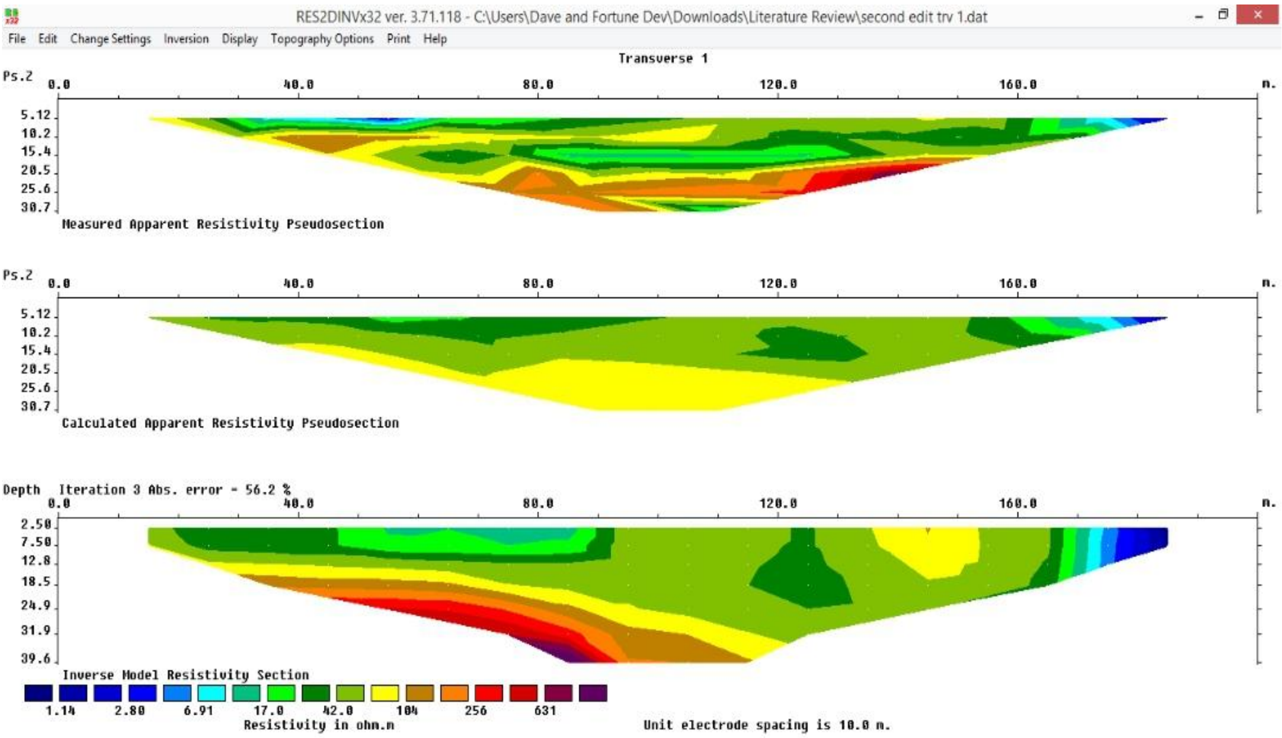

Fig 4.3: 2-D measured, calculated and resistivity survey for wenner

The resistivity block model displays different colour shades, noting that there are different geo-electric materials present in the sub-surface with resistivity ranges between 1Ωm - 800Ωm showing geological layers composes of lateral soil, clay, clayey sand, etc.

CHAPTER FIVE

CONCLUSION, RECOMMENDATION AND REFRENCES

5.0 CONCLUSION

In conclusion, after results of the carried out resistivity survey was obtained using Wenner Array. Anomalies which were suspected to be clay deposits were indicated by the geoelectric image. From profile 1, the maximum depth was 39.6m. The yellow colour code ranging between 350 Ωm to 520 Ωm from a depth of 2.50m to 7.50m is suspected to have a small layer of clayey sand. The red colour code ranging between 800 Ωm to 1261Ωm from a depth of 2.50m to infinity is suspected to have a large layer of shale.

For profile 2, maximum depth of 39.6m is imaged with clay suspected to be present at a lateral depth of 12.8m to 31.9m. The blue colour code ranging between 1Ωm to 17Ωm from a depth of 2.50m to 12.80m is suspected to have a small layer of lateral soil. The green colour code ranging between 17Ωm to 50Ωm from a depth of 12.50m to 31.90m is suspected to have a large layer of clayey sand. The yellow colour code ranging between 50Ωm to 104Ωm from a depth of 12.80m to infinity is suspected to have a small layer of clay. The red and purple colour code ranging between 250Ωm to 800Ωm from a depth of 25.9 to infinity is suspected to have a large layer of alluvium soil.

5.1 RECOMMENDATION

- Wenner is good in resolving vertical changes (i.e horizontal structures), but relatively poor in detecting horizontal changes.
- Wenner array should be used for moderate depth investigations.
- The RES2DINV software should be worked upgraded in other to achieve a more accurate reading with lesser errors, the error due to overlapping of values tends to affect the inversion and causes poor interpretation.

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