GEOPHYSICAL INVESTIGATION OF SUBSURFACE LITHOLOGICAL STRUCTURES USING 2D ELECTRICAL RESISTIVITY IN THE UGBOWO AREA, UNIVERSITY OF BENIN, EDO STATE, NIGERIA

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ABSTRACT

This study aimed to investigate subsurface lithological structures at the University of Benin, Benin City, Nigeria, using the 2D electrical resistivity method. Field data was acquired using the Wenner-Alpha configuration, and processed using RES2DINV software to generate 2D resistivity models. The results revealed a multi-layered subsurface structure, typically consisting of an upper layer of alluvium (soil) with varying amounts of clay, underlain by layers of shale and sandstone. The resistivity values ranged from 131 Ωm to 6239 Ωm. Vertical Electrical Sounding (VES) data provided further insights, identifying five distinct layers and providing more accurate depth and thickness information compared to the Wenner array. The study demonstrates the effectiveness of the 2D electrical resistivity method in characterizing subsurface structures and provides valuable information for construction planning and geological assessments in the study area.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

The geophysical detection of subsurface lithological structures plays a crucial role in geological investigations, environmental assessments, and resource exploration. Among the various geophysical methods available, the 2D electrical resistivity method stands out as a powerful tool for imaging subsurface geological features and characterizing lithological structures. By measuring the electrical resistivity distribution of the subsurface, this method provides valuable insights into the spatial variations in lithology, bedrock composition, and fluid content.

The 2D electrical resistivity method is based on the principles of electrical conduction through the Earth's subsurface materials. Different rock types and geological formations exhibit distinct electrical resistivity values due to variations in their mineral composition, porosity, and pore fluid conductivity (Loke et al., 2013). By deploying arrays of electrodes on the ground surface and measuring the electrical potential differences resulting from injected currents, resistivity surveys generate data that can be used to construct detailed subsurface resistivity models.

This introduction aims to provide an overview of the application of the 2D electrical resistivity method for detecting subsurface lithological structures. It will discuss the principles underlying the method, highlight its advantages and limitations, and showcase its potential in various geological and environmental investigations.

Geological structures such as faults, folds, fractures, and stratigraphic layers influence the distribution of electrical resistivity in the subsurface. Understanding these structures is essential for delineating geological boundaries, identifying potential mineral deposits, and assessing groundwater resources (Haldorsen et al., 2001). The 2D electrical resistivity method offers the capability to visualize these structures in two dimensions, providing valuable information for geological mapping and subsurface characterization.

Moreover, the non-invasive nature of the 2D electrical resistivity method makes it suitable for environmental assessments and engineering applications. It allows for the detection of underground contaminants, mapping of subsurface infrastructure, and monitoring of groundwater flow patterns (Dahlin and Zhou, 2004). Additionally, the method's versatility enables it to be deployed in various terrain conditions, ranging from urban environments to remote wilderness areas.

The 2D electrical resistivity method offers a valuable means of detecting subsurface lithological structures and characterizing geological formations. Its ability to provide detailed imaging of the subsurface makes it a versatile tool for a wide range of geological, environmental, and engineering applications. The following sections will delve deeper into the principles, applications, and advancements of this method, highlighting its significance in subsurface exploration and resource management.

1.2 RELATIONSHIP BETWEEN LITHOLOGICAL PARAMETERS AND THE PHYSICAL PROPERTIES OF SUBSURFACE ROCKS

The relationship between lithological parameters and the physical properties of subsurface rocks is crucial for interpreting geological structures and planning engineering projects. Lithological parameters include rock type, grain size, porosity, and mineral composition, all of which influence the physical properties such as density, magnetic susceptibility, electrical resistivity, and mechanical strength of rocks. Here’s how these relationships are commonly understood, supported by relevant citations:

1. Porosity and Permeability

Porosity, the volume of voids in a rock, directly influences its permeability, which is the ability of a rock to transmit fluids. Highly porous rocks, such as sandstones, typically exhibit higher permeability compared to denser, less porous rocks like granite. Porosity and permeability are essential for understanding fluid flow in hydrogeology and petroleum geology (Domenico and Schwartz, 1998).

2. Mineral Composition and Density

The density of a rock is significantly influenced by its mineral composition. For instance, rocks rich in heavy minerals like magnetite or hematite (iron oxides) have higher densities compared to those dominated by lighter minerals such as quartz or calcite. This variation in density is crucial for geophysical exploration using gravity methods (Telford et al., 1990).

3. Grain Size and Mechanical Strength

The grain size of sedimentary rocks affects their mechanical strength and weathering behavior. Coarser-grained rocks, like conglomerates, tend to have higher porosity but may be mechanically weaker compared to fine-grained rocks like shale, which might be harder but less porous. These properties are significant for construction projects where the mechanical stability of the ground is crucial (Bell, 2007).

4. Rock Texture and Elastic Properties

The texture of a rock, which describes the size, shape, and arrangement of grains or crystals, influences its elastic properties such as Young's modulus and Poisson's ratio. These properties determine how rocks deform under stress and are vital for engineering and geophysical applications (Mavko, Mukerji, and Dvorkin, 2009).

5. Chemical Weathering and Resistivity

Chemical composition affects how rocks interact with fluids, impacting their resistivity and susceptibility to weathering. For example, rocks containing conductive minerals or fluids have lower resistivity, making them more detectable by electrical and electromagnetic methods in geophysical surveys (Telford et al., 1990).

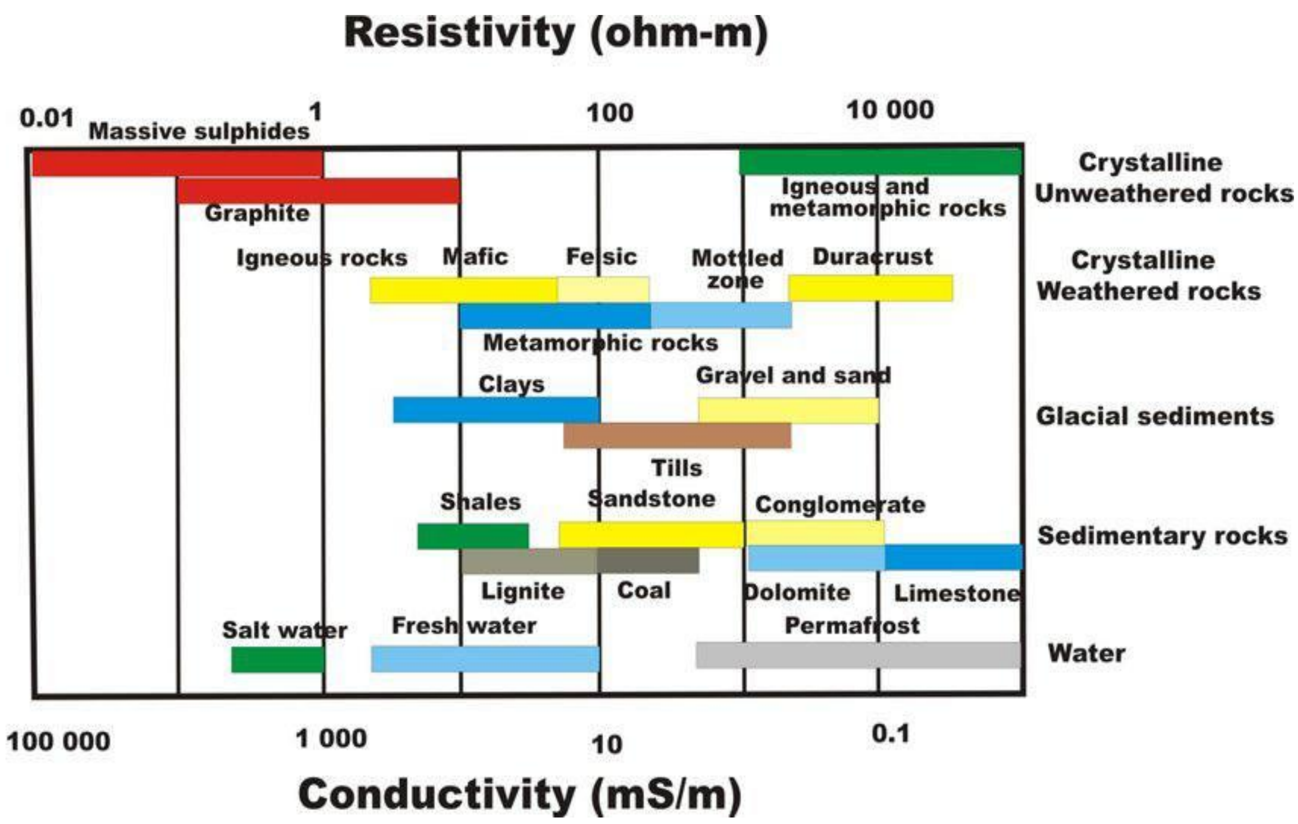


Figure 1.1: Resistivity of rock types (www.researchgate.net)

1.3 SUBSURFACE LITHOLOGY IN CIVIL ENGINEERING, ENVIRONMENTAL STUDIES, AND HYDROGEOLOGY

Understanding subsurface lithology the composition, structure, and properties of rocks and sediments beneath the Earth's surface is crucial in various fields, including civil engineering, environmental studies, and hydrogeology. Some of the importance of subsurface lithology are;

1. Civil Engineering

Subsurface lithology data helps engineers assess the stability and bearing capacity of the ground to design suitable foundations for structures (Fellenius, 1936). Knowledge of lithology aids in planning and executing excavations, tunnels, and underground structures by predicting ground conditions and potential hazards (Chesnaux and Martel, 2011).

Material Selection: Understanding lithology helps engineers select appropriate construction materials and methods to ensure the durability and integrity of infrastructure projects (Powell and Sarikaya, 2008).

2. Environmental Studies

Subsurface lithology influences the movement and fate of contaminants in groundwater and soil, affecting environmental quality and human health (Freeze and Cherry, 1979).

Site Remediation: Knowledge of lithology is essential for designing effective remediation strategies to mitigate environmental contamination and restore degraded sites (McCarthy and Zachara, 1989). Understanding subsurface lithology helps identify environmentally sensitive areas and inform land use planning decisions to minimize environmental risks and impacts (Thornthwaite and Mather, 1957).

3. Hydrogeology

Subsurface lithology data guides hydrogeologists in locating and characterizing aquifers, determining groundwater flow patterns, and estimating groundwater resources (Fetter, 2001). Lithology influences the vulnerability of aquifers to contamination and depletion, making it essential for assessing and managing groundwater quality and quantity (Fetter, 2001). Knowledge of lithology is critical for designing and constructing wells that efficiently extract groundwater while minimizing risks of borehole collapse, formation damage, and contamination (Fetter, 2001).

1.4 THE LIMITATIONS OF TRADITIONAL METHODS LIKE DRILLING AND CORE SAMPLING

Traditional methods like drilling and core sampling have been widely used in geological and geotechnical investigations for decades. While they provide valuable information about subsurface conditions, they also have several limitations.

1. Cost and Time-Intensiveness

Traditional methods such as drilling and core sampling can be costly and time-consuming, especially when conducting extensive investigations over large areas or at great depths (Davis and DeWiest, 1966). The expenses associated with equipment, personnel, and site preparation can significantly impact project budgets and timelines.

2. Limited Spatial Coverage

Drilling and core sampling provide point measurements at specific locations, resulting in limited spatial coverage of subsurface information. This lack of spatial continuity can lead to uncertainties in geological interpretations and may overlook important geological features or anomalies (Diessel, 2010).

3. Disruption of Site Environment

Drilling operations can disrupt the natural environment and ecosystems, causing habitat disturbance, soil erosion, and landscape alterations (Dresen et al., 2003). Core sampling may also involve the removal of significant volumes of material, leading to soil degradation and visual impacts on the site.

4. Inaccessibility to Certain Locations

Drilling and core sampling may be impractical or impossible in certain locations, such as densely populated urban areas, environmentally sensitive regions, or offshore locations (Stewart et al., 2013). These limitations restrict the ability to obtain subsurface information in critical areas.

5. Depth Limitations

Traditional drilling methods are often limited in their depth penetration capabilities, especially in hard rock formations or deep geological settings (He et al., 2019). Deep drilling requires specialized equipment and expertise, increasing costs and logistical challenges.

6. Sampling Bias and Variability

Core samples may suffer from sampling bias and variability, particularly in heterogeneous geological formations. Variations in lithology, fracture density, and mineralization can affect the representativeness of core samples, leading to uncertainties in geological interpretations (Sims et al., 2012).

1.5 ELECTRICAL RESISTIVITY (ER) METHOD AS A NON-DESTRUCTIVE GEOPHYSICAL TECHNIQUE

The electrical resistivity (ER) method is a non-destructive geophysical technique used to investigate subsurface structures and properties by measuring the electrical resistivity of the Earth's materials. Here's an explanation of the ER method, supported by citations: The ER method relies on the principle that different materials have varying electrical resistivities. When an electrical current is introduced into the ground through a pair of electrodes, the resulting potential differences are measured at other electrode pairs. By analyzing these measurements, it's possible to infer the distribution of electrical resistivity within the subsurface (Loke, 2014). In ER surveys, electrodes are placed at predetermined positions on the ground surface or in boreholes, forming electrode arrays such as Wenner, Schlumberger, or dipole-dipole. The spacing and configuration of electrodes determine the depth of investigation and resolution of the survey (Reynolds, 2011). The ER method has numerous applications in various fields, including environmental studies, engineering, archaeology, and resource exploration. It is used to delineate subsurface features such as bedrock, soil layers, groundwater, geological structures, and buried objects (Society of Exploration Geophysicists, 2002).

1.5.1 Advantages of the ER Method

Non-Destructive: The ER method is non-destructive, meaning it does not alter the subsurface and can be applied in environmentally sensitive areas or areas with cultural heritage significance.

Versatility: ER surveys can be conducted in different terrains and environments, including urban areas, forests, deserts, and underwater, making it a versatile technique for subsurface investigations.

Cost-Effective: ER surveys are relatively cost-effective compared to other geophysical methods, such as seismic surveys or drilling, making them suitable for preliminary site investigations or large-scale surveys.

1.5.2 Limitations of the ER Method

Depth Limitations: The depth of investigation in ER surveys is limited, and the method may not be suitable for deep targets or highly resistive materials.

Interpretation Challenges: Interpreting ER data requires expertise and may be influenced by factors such as electrode spacing, geological complexity, and subsurface heterogeneity.

1.6 AIM AND OBJECTIVES

The aim of this work is to estimate subsurface lithological structures using 2D electrical resistivity method in the University of Benin, Benin City Using Geoelectrical Method.

The objectives of this work are to;

1. collect field data using Wenner-Alpha configurations with a Pasi Earth Resistivity Meter.

2. process the acquired data using RES2DINV software to obtain 2-Dimensional true resistivity profiles.
3. characterize the subsurface layers based on resistivity and depth values, including topsoil, dry sand, and silty sand.
4. interpret the 2D resistivity imagery to identify potential building construction areas and assess the absence of clay formations.

1.7 LOCATION OF STUDY AREA

The physical characteristics of the Benin Region which are relevant for the purpose of this investigation are hereby discussed in terms of those factors which [1]-[3] identified as the environment of weathering. They include the geological foundation and rock types, types and density of plant cover, availability of readily weatherable rocks, and tropical humid climate with seasonality of rainfall or alternating wet and dry seasons and topography amongst others. The geology and geomorphologic processes and landforms of the Benin Region have their interplay interconnections with weathering. In a broad term, the geomorphology includes aspects of the geology and relief while the hydrology embraces aspects of the drainage and water resources. These are discussed below under the following headings: Geology, Physiography (Relief) and Geomorphology, Geomorphic Processes, Weathering, Drainage Processes, Landforms, Surface Water Hydrology and Water Resources. These aspects have not been fully documented by research workers in this region. This paper therefore examines these aspects as they affect the landscape of the region.

1.8 GEOLOGY

The Benin Region is underlain by sedimentary formation of the South Sedimentary Basin. The geology is generally marked by top reddish earth, composed of ferruginized or literalized clay sand. (Parkinson, 1907) first used the term Benin sand to describe the reddish earth underlain by sands, sandy clays and ferruginized sandstone that mark the Paleo-Coastal Environment of Paleocene-Pleistocene Age. These sediments spread across the southern fringes of the Anambra Basin and marking the upper fancies off-flaps of the Niger Delta. (Tattam, 1943) used the name Coastal plain sands to describe the formation of red earth underlain by sands and clays that mark an ancient coastal plain environment now exposed in Calabar, Owerri, Onitsha and the Benin Region with the age Oligocene-Pleistocene.

However (Reyment, 1965) reinstated the name Benin formation to identify the reddish-brown-yellow generally white sands often with clayey and pebbly horizons with type-locality around Benin. This is also referenced at Calabar and other parts of South Eastern Nigeria. The formation was further established by well logging of Etete 1, well drilled on-shore east of River Niger by Shell Nigeria. Petroleum Development Company (SPDC) and described by (Short and Stauble, 1967). The formation is about 1830 m thick at the seashore but thins landwards. The sedimentary suits of the Benin Formation dip 2˚ - 8˚ south.

Geologically, the Benin Region comprises of:

1) the Benin formation;

2) alluvium

3) drift/top soil

4) Azagba-Ogwashi (Asuba-Ogwashi) formation.

1. The Benin Formation

It is assigned to the Oligocene-Pleistocene period in the continent of Africa and to the Oligocene-Pleistocene recent at the sub-oceanic (Short and Stauble, 1967). The formation is characterized by top reddish to reddish brown lateritic massive fairly indurate clay and sand. This is often marked with reticulate muderacks. This caps the underlying more friable pinkish-yellowish white often gravelly-pebble sands clayey soils, sands and clay (Akujieze, 2004). The sedimentary sequences are poorly bedded with discontinuous clay horizons at various depths. It is estimated to be about 800m thick under Benin City and about 1,830m near the sea shore sections of the formation. They are exposed at various erosion sites, sand quarry sites, and road cuttings. The Benin formation covers 95% of the region.

2. Alluvium

These are found along Ikpoba and Ovia flood plains. They are made up of grayish-dirty white yellowish-white sands, silts, clayey sands, gravels and even wood-plant materials. These have been washed down the river valley and deposited at the river banks. They are recent deposits.

3. Drift/Top Soil

Drifts are sediments still in the process of transportation or movement. They are made up of light brown-yellowish silt, mudflows and sands derived from the weathering of the parental Benin Formation. Drifts are washed down by fluvial agents especially the storms and floods dominating the wet season of the region. The drifts are not part of the solid geology. But they are mainly derived and reworked materials and loads dropped by moving floods. Drifts cover roadsides; fill up areas, concealing the underlying geology. Drifts vary from very thin veneers to up to 0.55 m. The drifts cover about 2% of the urban area. Where the drifts are stabilized soil profile formation is developed.

4. Azagba-Ogwashi (Asaba-Ogwashi) Formation

The Azagba-Ogwashi formation has been missing spelt as Ogwashi-Asaba formation (Reyment, 1965). It consists of clays, sands and grits and seams of lignite alternating with gritty clays. It grades upwards into the Benin Formation. The Ogwashi-Asaba formation is exposed in stream channels at the northern parts of the Benin Region, west of Ekiadolor-Iwu and 4 km east of Utekon and north of Azalla (Akujieze, 2004).

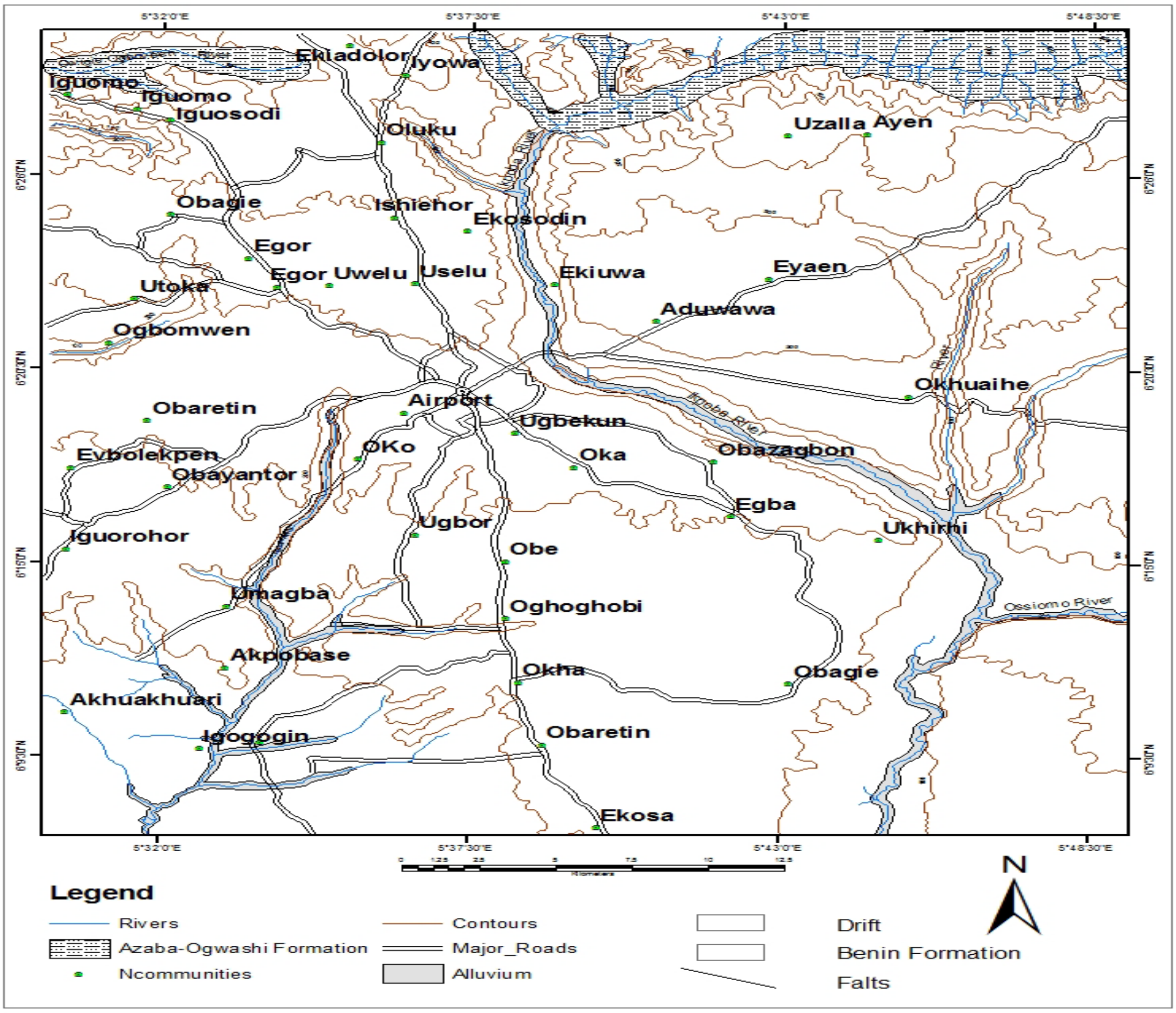


Figure 1.2: Benin region geological formation (source: Akujieze, 2004).

CHAPTER TWO

LITERATURE REVIEW

2.1 SOME LITERATURES REVIEWED

Ahzegbobor (2013) used induced polarisation and electrical resistivity imaging to measure the salinity of the soil. The physical parameters of subsurface soil in Covenant University Farm, located in southwest Nigeria, were evaluated for spatial variability using 2D imaging techniques, which included geo-electrical resistivity and time domain induced polarisation. Using a Wenner array, the apparent resistivity and chargeability of the induced polarisation effect were evaluated simultaneously along six traverses. After processing the obtained data, 2D inverse models of the chargeability and resistivity of the subsoil were created. Additionally, samples of soil were gathered, and their conductivity and salinity levels were examined. The findings indicate that the laboratory test and the salinity level in the sections were combined to qualitatively evaluate the salinity, level of compaction, and thickness of the soil on the farm. Inferred were other petrophysical characteristics related to soil conductivity, such as organic matter, moisture content, and clay volume. The study shows that geo-electrical resistivity imaging can be a helpful method for accurately determining how the soil quality varies over broad areas of land in order to support precision farming.

Electrical resistivity was employed by Atakpo (2013) to calculate the overburden protection capacity in the Delta State area of Amukpe. A maximum electrode separation of 1000 metres was used for vertical electrical soundings (VES). The first order geo-electric parameters were obtained by quantitatively interpreting the data by computer iteration using the Resist Software, which was shown as VES curves. The lithologic logs of a borehole bored in the research area were connected with the interpreted geo-electric data. To assess an area's overburden protection capacity, the total longitudinal unit conductance values were employed. The research area's aquifer is susceptible to contamination, particularly from hydrocarbons, due to its poor protective capacity value.

The concept of electrical resistivity imaging was used by Okezie and Ayolabi (2014) to look into groundwater pollution. Resistivity variations in both vertical and horizontal directions along the survey lines are shown by the use of Wenner and Gradient arrays with a minimum electrode spacing of 2 metres. The 2-D resistivity data was processed and reprocessed using Earth Imager software. The resistivity of the soil material that makes up the subsurface ranges from 42 to 15,000 Ohm-m, reflecting the different conductivities that are linked to changes in lithology and fluid type. The presence of hydrocarbons in the subsurface can be linked to high resistivity formations, indicating contaminated shallow aquifers in the research area. In the research region, the water level is between 4 and 5 metres below the surface. After conducting geophysical investigations, deep wells measuring approximately 45 metres are advised due to the high resistivity formations found in most areas.

Unekeet et al., (2015) created a straightforward model to track the longitudinal migration of leachates in soil using moisture content and the electrical resistivity approach. An developing method for characterising soil is soil electrical resistivity. Soil moisture density and moisture content are important determinants of it. In this investigation, soil electrical resistivity measurements were made both near and far from a municipal waste disposal site, and soil moisture content was measured in a lab. The goal of the regression study was to find a linear relationship between resistivity. The results indicate that while moisture content reduced, resistivity rose with increasing distance from sources of leachate generation.

The electrical resistivity approach was used by Koda et al., (2017) to look at possible channels for pollution movement inside areas of both current and former landfill sites. The purpose of the study was to assess the spatial movement of pollution and interpret the findings in order to build reclamation and restoration plans going forward. The ability to precisely determine contaminated zones through airborne investigations is made possible by a clear association between pollution indicators like electrical resistivity and salt compounds.

At the proposed building site in Ibese, Southwest Nigeria, Falae (2014) used Vertical Electrical Sounding (VES) to conduct a geophysical investigation in order to identify the geophysical parameters that can be used to evaluate the subsurface geological characteristics of the site's structural competence for building development and construction. The Schlumberger setup was used to collect the data. Numerical inversion of the individual DC resistivity was performed in one dimension to enhance the processing of the data and better fulfil the goal of the study. Models produced from the 2D inversion of each VES were used to construct geo-electric sections that showcased the principal geo-electric features of the local geological units. The geo-electric sections consist of three or four layers: sand/limestone, pebble clay, limestone, and topsoil, based on the interpretation results. The layers' resistivities and thicknesses range from 33 to 160 Ohm-m, 2-210 Ohm-m/0.8 to 9.2 m, and 11 to 404 Ohm-m/0.4 to 1.5 m, respectively. The analysis's findings indicated that shallow foundations for small- to medium-sized engineering buildings should be built using the sand/limestone lithology.

2.2 THEORY OF THE ELECTRICAL RESISTIVITY METHOD

The electrical resistivity (ER) method is a widely used geophysical technique for investigating the subsurface. It relies on the principle that different geological materials exhibit varying electrical resistivity values (Telford et al., 1976). This variation allows us to map and characterize subsurface features based on their electrical response. Ohm's Law, a cornerstone of electrical theory, lays the foundation for understanding the ER method (Reynolds, 1997). It states that the potential difference (voltage, ΔV) across a conductor is directly proportional to the current (I) flowing through it and inversely proportional to the conductor's resistance (R):

$$\Delta V = I \times R \qquad (2.1)$$

Resistance (R) of a conductor depends on its geometry and the material's inherent resistivity (ρ). The relationship between these properties is expressed as:

$$R = \rho \times (L / A) \qquad (2.2)$$

Where:

L is the length of the conductor (m)

A is the cross-sectional area of the conductor (m^2)

Resistivity (ρ), measured in ohm-meters (Ωm), is a material's intrinsic property that reflects its ability to resist the flow of electric current. Materials with low resistivity readily conduct electricity (e.g., metals), while those with high resistivity impede current flow (e.g., insulators). In the field, ER surveys involve injecting electric current into the ground through a pair of electrodes (current electrodes) and measuring the resulting potential difference between two other electrodes (potential electrodes) (Dahlin and Loke, 1998). The measured potential difference (ΔV) and the injected current (I) are then used to calculate the apparent resistivity (ρ_a) using the following equation:

$$\rho_a = k \times (\Delta V / I) \qquad (2.3)$$

where k is a geometric factor that depends on the specific electrode configuration used in the survey (e.g., Wenner array, Schlumberger array). The geometric factor accounts for the arrangement of the electrodes and their spacing (Griffiths and Barker, 1993).

It's important to note that apparent resistivity (ρ_a) is a theoretical value representing the average resistivity of the subsurface along the current path (Aizebeokhai et al., 2010). This is because the current doesn't necessarily travel in a straight line between the electrodes but through a complex volume of Earth material.

Delving into Resistivity Variations and Subsurface Characterization, The key to utilizing the ER method lies in interpreting the variations in apparent resistivity observed in the field data. Different geological materials typically exhibit distinct resistivity ranges (Omosuyi et al., 2007). For example, saturated sands and gravels generally have lower resistivity values compared to dry soils or bedrock due to the higher conductivity of water. Clayey soils often fall between these extremes. By analyzing the spatial distribution of apparent resistivity values obtained from the survey, geophysicists can infer the presence and boundaries of various subsurface formations. This allows for the creation of 2D or 3D resistivity models that depict the subsurface electrical properties (Loke, 2003).

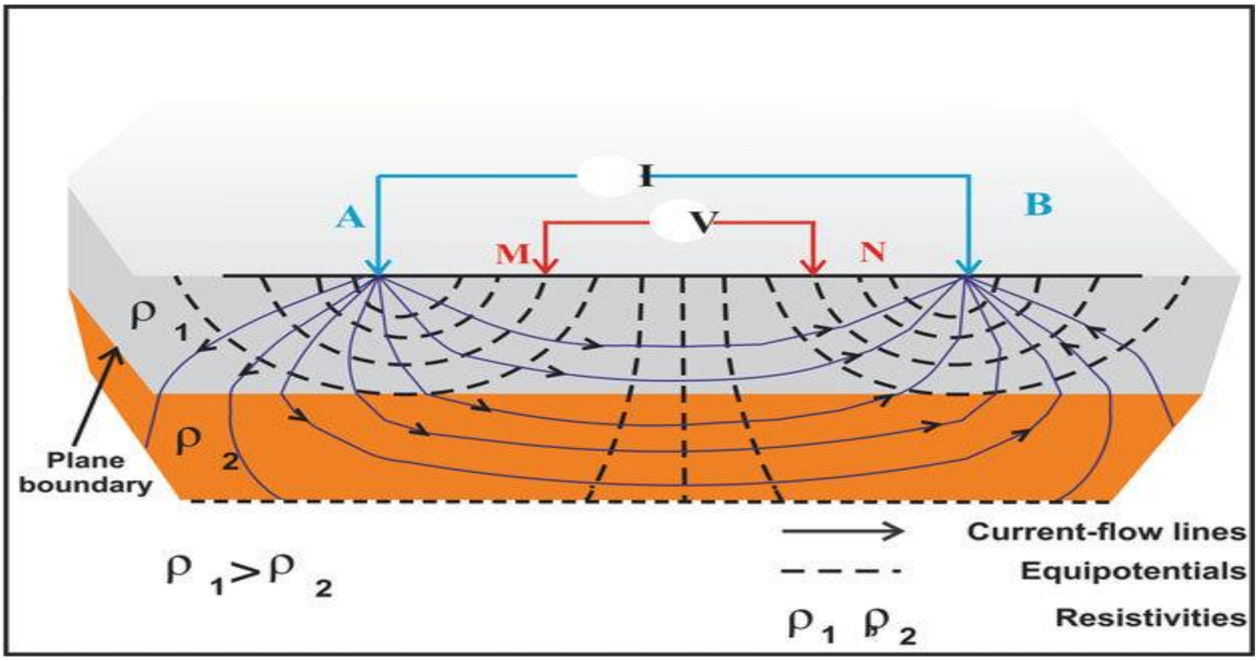


Figure 2.1: Theory of the Electrical Resistivity Method in two Dimension

However, it's crucial to remember that resistivity alone cannot uniquely identify specific rock or soil types. Other factors like pore water salinity and clay content can also influence resistivity values (Keary and Brooks, 1991). Therefore, successful interpretation often involves integrating ER data with other geological information and potentially using borehole data for confirmation. The electrical resistivity method, built upon the fundamental principles of Ohm's Law and material resistivity, offers a valuable tool for non-destructive subsurface exploration. By measuring the electrical response of the Earth, geophysicists can gain valuable insights into the composition and structure of the hidden world beneath our feet. Building upon the foundational concepts, let's delve deeper into the electrical resistivity (ER) method and explore its practical applications.

2.2.1 Electrode Configurations and Current Flow Paths

In field surveys, ER measurements rely on various electrode configurations, each with its own advantages and limitations (Reynolds, 1997). Common configurations include:

Wenner Array: This popular choice involves four electrodes arranged in a straight line with equal spacing between them. It offers good depth penetration but may lack resolution in shallow zones.

Schlumberger Array: This configuration utilizes a central current electrode pair flanked by two far-spaced potential electrodes. It provides better resolution for shallow features but has a limited investigation depth compared to the Wenner array.

Dipole-Dipole Array: This versatile configuration uses four non-collinear electrodes, offering a balance between depth penetration and resolution across various depths.

The choice of electrode configuration depends on the specific survey objectives and the target investigation depth.

Current, injected through the current electrodes, doesn't necessarily travel in a straight line but distributes itself within the subsurface along a complex path (McNeill, 1991). This current flow path depends on the resistivity distribution of the subsurface materials. Higher resistivity zones tend to deflect the current, while lower resistivity zones offer less resistance and experience a stronger current concentration.

2.2.2 Current Flow in Layered Media versus Current Electrode Spacing

Imagine that we conduct a series of four electrode experiments, each centered about the same point. Let's assume that the potential electrodes remain centered between the current electrodes and that their separation is held fixed. Initially, the current electrodes are placed close together and we measure current and voltage from which we compute apparent resistivity. Then we perform the same experiment, but we systematically increase the current electrode spacing while holding the potential electrode spacing fixed. What will happen?

Consider the earth model shown below: a high resistivity layer over a lower resistivity layer.

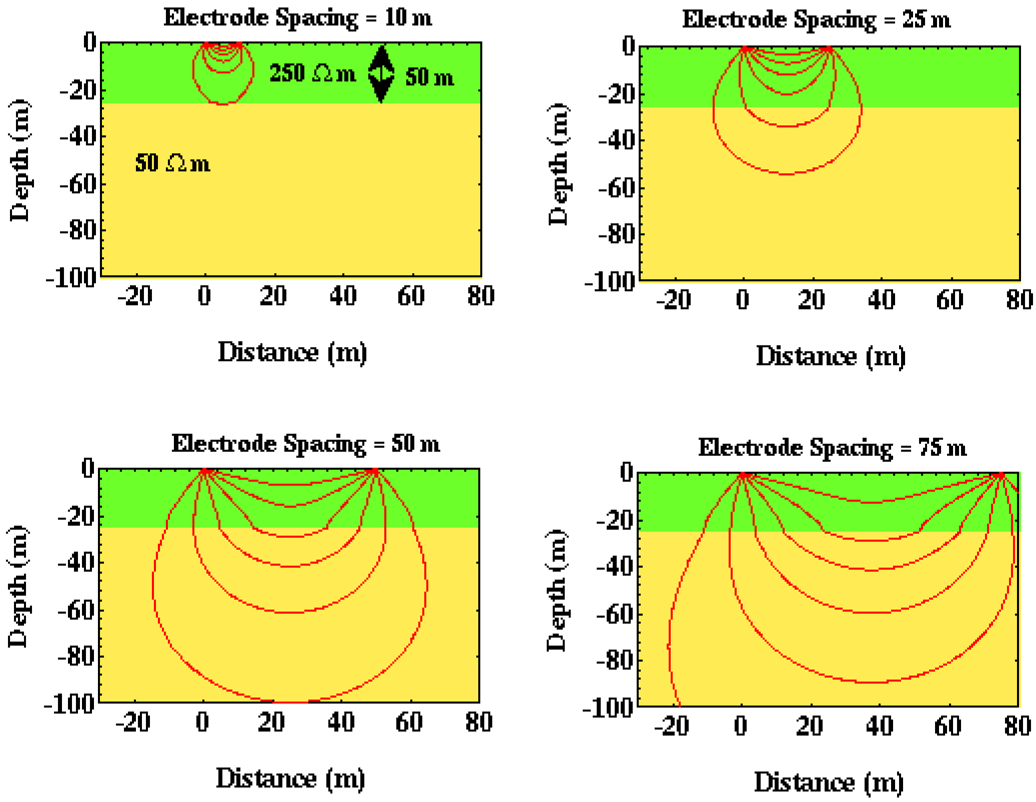


Figure 2.2: Homogeneous Earth Model

When the current electrodes are closely spaced, in the region surrounding the potential electrode positions (between the two current electrodes), most of the current flows through the upper layer along paths that are close to those that they would have flown along if the model were homogeneous. That is, in this electrode configuration, current flow is not perturbed enough near the potential electrodes for us to be able to distinguish between this layered model and a homogeneous Earth model with a resistivity equal to the resistivity of the top layer. Thus, the computed apparent resistivity will be close to the resistivity of the upper layer, 250 ohm-m.

Now, we increase the current electrode spacing and repeat the same experiment. At larger current electrode spacings, the current flow near the potential electrodes is significantly altered by the presence of the subsurface boundary. In this case, current is preferentially drawn downward into the lower resistivity layer, decreasing the current density between the two current electrodes where we will measure the voltage with our two potential electrodes. This decrease in current density will cause our computed value of apparent resistivity to decrease from 250 ohm-m.

At very large current electrode spacings, underneath our potential electrodes, the pattern of current flow is again similar to that which we would observe in a homogeneous Earth model. In this case, however, the media has a resistivity of 50 ohm-m, not 250 ohm-m. Thus, if we were to compute and plot apparent resistivity for a variety of current electrode spacings while holding the potential electrodes fixed, we would generate a plot similar to that shown below.

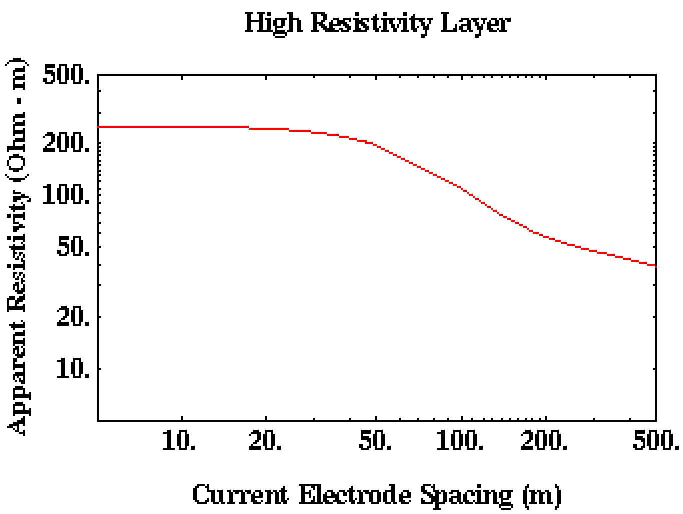


Figure 2.3: Apparent Resistivity for a Variety of Current Electrode Spacings

As is common for curves of this type, notice that this plot is a ***Log-Log*** plot. Instead of plotting apparent resistivity versus current electrode spacing, we have plotted the Log (base 10) of the apparent resistivity versus the Log (base 10) of the current electrode spacing. This is done because, in practice, we will find that both the apparent resistivities and the current electrode spacings will vary over two to three orders of magnitude (e.g., spacings can commonly increase from 0.25 m to 250 m). Using Log-Log plots provides us with a means of compressing the relevant information into a single graph. In the example shown above, notice that the apparent resistivity does not approach the resistivity of the lower layer until the electrode spacing approaches 500 m! Thus, large electrode spacings are required to see deep structure. A good rule of thumb is that you will need current electrode spacings on the order of 10 times the depth to which you would like to see.

2.2.3 Apparent Resistivity vs. True Resistivity

The concept of apparent resistivity (ρ_a) introduced earlier is a crucial aspect of ER measurements. As mentioned, it represents an averaged value along the current path, not the true resistivity of a specific subsurface layer (Sharma, 1997). For a simple layered Earth model with distinct resistivity zones, advanced inversion techniques can be applied to the collected data. These techniques mathematically model various subsurface scenarios and iteratively adjust them to find the model that best explains the measured apparent resistivity values. Through this process, a more accurate representation of the true resistivity distribution, often presented as a 2D or 3D resistivity model, can be obtained (Loke, 2003). However, interpreting real-world scenarios with complex subsurface structures can be challenging. Geophysicists often employ various inversion algorithms and rely on their experience to arrive at a geologically plausible interpretation that best fits the data (Zhdanov, 2009).

While ER offers a valuable tool for subsurface exploration, it's essential to acknowledge its limitations:

1. **Non-uniqueness:** As mentioned previously, a single resistivity value can correspond to different material types. Additional information like borehole data or other geophysical methods can aid in more definitive interpretations.
2. **Anisotropy:** Some Earth materials exhibit anisotropic resistivity, meaning their resistivity varies depending on the direction of current flow. This can complicate data interpretation in certain geological settings.
3. **Electrode-Soil Contact:** Ensuring good electrical contact between the electrodes and the ground is crucial for obtaining reliable data. Wetting the soil around the electrodes may be necessary in dry conditions.

2.2.4 Applications of the Electrical Resistivity Method

Despite these limitations, the ER method finds numerous applications in various fields:

1. **Groundwater Exploration:** Identifying potential aquifer zones by mapping variations in resistivity associated with water-saturated formations.

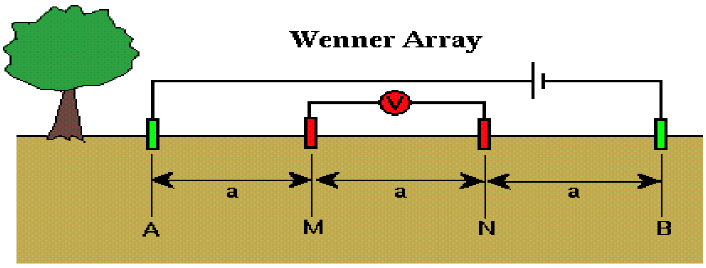
2. **Environmental Investigations:** Delineating the extent of contaminant plumes based on resistivity contrasts between contaminated and uncontaminated zones.
3. **Geotechnical Engineering:** Assessing subsurface conditions for foundation design and identifying potential geohazards like landslides.
4. **Archaeological Surveys:** Mapping buried structures and archaeological features based on resistivity anomalies.

The electrical resistivity method, with its theoretical foundation rooted in Ohm's Law and material resistivity, provides a powerful tool for non-destructive subsurface exploration. By understanding the concepts of apparent resistivity, electrode configurations, and data inversion, geophysicists can interpret resistivity variations to infer the composition and structure of the hidden world beneath the surface. However, acknowledging the limitations and potential ambiguities necessitates a thoughtful approach that often integrates ER data with other geological and geophysical information.

2.3 SURVEY TYPES OVERVIEW: SOUNDINGS AND PROFILES

1. Resistivity Soundings

When doing resistivity sounding surveys, one of two survey types is most commonly used. For both of these survey types, electrodes are distributed along a line, centered about a midpoint that is considered the location of the sounding. The simplest in terms of the geometry of electrode placement is referred to as a Wenner survey. The most time effective in terms of field work is referred to as a Schlumberger survey. For a Wenner survey, the two current electrodes (green) and the two potential electrodes (red) are placed in line with each other, equidistant from one another, and centered on some location as shown below.

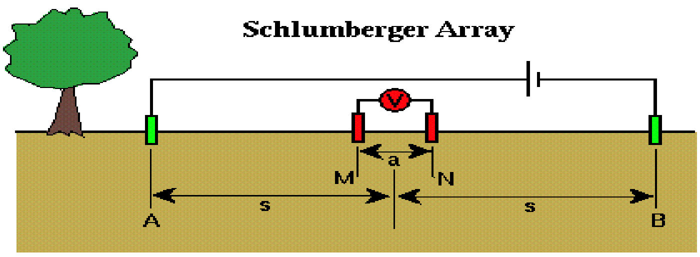


$$\rho_a = 2\pi a \frac{\Delta V}{i}$$

Figure 2.4: Wenner survey

The apparent resistivity computed from measurements of voltage, ΔV, and current, i, is given by the relatively simple equation shown above. This equation is nothing more than the apparent resistivity expression shown previously with the electrode distances fixed to a. To generate a plot of apparent resistivity versus electrode spacing, from which we could interpret the resistivity variation with depth, we would have to compute apparent resistivity for a variety of electrode spacings, a. That is, after making a measurement we would have to move all four electrodes to new positions.

For a Schlumberger survey, the two current electrodes (green) and the two potential electrodes (red) are still placed in line with one another and centered on some location, but the potential and current electrodes are not placed equidistant from one another.



$$\rho_a = \frac{\pi(s^2 - a^2/4)}{a} \frac{\Delta V}{i}$$

Figure 2.5: Schlumberger survey

The current electrodes are at equal distances from the center of the sounding, s. The potential electrodes are also at equal distances from the center of the sounding, but this distance, a/2, is much less than the distance s. Most of the interpretational software available assumes that the potential electrode spacing is negligible compared to the current electrode spacing. In practice, this is usually interpreted to mean that a must be less than 2s/5.

In principle, this implies that we could set a to be less than 2s/5 for the smallest value of s that we will use in the survey and never move the potential electrodes again. In practice, however, as the current electrodes are moved outward, the potential difference between the two potential electrodes gets smaller. Eventually, this difference becomes smaller than our voltmeter is capable of reading, and we will need to increase a to increase the potential difference we are attempting to measure.

Table 2.1: Strengths and Weaknesses of Schlumberger and Wenner Sounding Methods.

Schlumberger	Wenner
Advantage	Disadvantage
Need to move the two current electrodes only for most readings. This can significantly decrease the time required to acquire a sounding.	All four electrodes, two current and two potential, must be moved to acquire each reading.
Because the potential electrode spacing is small compared to the current electrode spacing, for large current electrode spacings, very sensitive voltmeters are required.	Potential electrode spacing increases as current electrode spacing increases. Less sensitive voltmeters are required.
Because the potential electrodes remain in fixed locations, the effects of near-surface lateral variations in resistivity are reduced.	Because all electrodes are moved for each reading, this method can be more susceptible to near-surface, lateral variations in resistivity. These near-surface lateral variations could potentially be misinterpreted in terms of depth variations in resistivity.

In general, interpretations based on DC soundings will be limited to simple, horizontally layered structures.	In general, interpretations based on DC soundings will be limited to simple, horizontally layered structures.

2. Resistivity Profiles

As was mentioned on the previous page, the data collected from resistivity soundings is usually interpretable only for horizontally stratified structures. If you are employing resistivity methods to find vertical structures, one would typically use resistivity profiles instead of resistivity soundings.

As described previously, resistivity profiles are resistivity surveys in which the electrode spacing is fixed for all readings. Apparent resistivity is computed for different electrode center points as the entire electrode spread is moved. Usually, the center point is moved along the line of the electrodes, although this does not have to be the case.

Shown below is geologic structure involving a vertical boundary between a higher resistivity material to the left and a lower resistivity material to the right. Below the geologic model is the apparent resisitivity you would observe using a Wenner array as the array is moved from left to right. Note that the distance shown along the bottom of this plot is the distance between the vertical fault and the current electrode farthest to the left of the array.

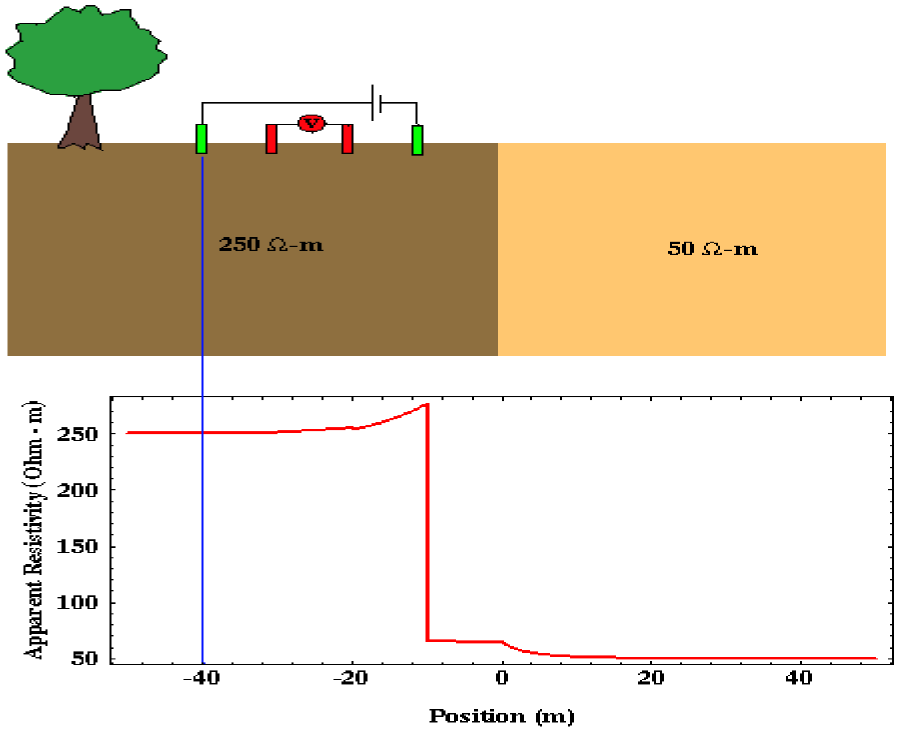


Figure 2.6: Resistivity Profiles

As you would expect, if the electrode array is far removed from the vertical fault, the measured apparent resistivity is equal to the resistivity of the underlying rock. As the array approaches the fault, the resistivity varies in a discontinuous fashion. That is, the change in resistivity with electrode position does not vary smoothly. The discontinuities in the resistivity profile correspond to array locations where electrodes move across the fault. The specifics of how the apparent resistivity varies as the electrode array moves across the fault depend on the type of array used. These notes will not contain a detailed discussion of these features of the apparent resistivity curve. Suffice it to say that using this profiling technique, vertical contrasts in resistivity can be identified.

How does one determine the electrode spacing to be used in a profile survey? If the vertical feature does not extend to the surface, the electrode spacing must be large enough to impart sufficient electrical current to depths below which the vertical contrast exists. Usually, electrical soundings will be performed well removed but on either side of the vertical structure that you wish to map. By examining the depth variation in resistivity interpreted from each of these soundings, an electrode spacing for the profile is determined.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 DC RESISTIVITY EQUIPMENT

Compared to the equipment required for gravity surveying and magnetic surveying , that required for DC resistivity surveying is much less exotic. In fact, it is rather mundane consisting of nothing more than a source of electrical current, an ammeter, a voltmeter, some cable, and electrodes. Given the nature of the measurements that we are making, however, there are some considerations that must be taken into account given the equipment used to perform the measurements.

1. **Pasi Earth Resistivity Meter***:* It is light weight and has waterproof, rugged cast aluminum casing. It is a Signal Averaging System. This is a method whereby consecutive readings are taken automatically and the results are averaged continuously.
2. **Current Source**: A source of DC current is required. In general, batteries are not capable of producing the DC currents required, so that if a pure DC source is used, it has to be produced by a portable electric generator. If, as is commonly done to eliminate the effects of electrode potentials and telluric currents, a slowly varying AC current is used, portable, battery driven sources can be employed for DC resistivity surveys commonly used in engineering and environmental applications.
3. **Electrodes**: To avoid problems associated with electrode potentials, sophisticated electrodes known as porous pots can be used. But, because spurious electrode potentials can be mitigated through the use of a slowly varying AC source, these electrodes are not commonly used for DC resistivity measurements. If the conditions in the survey are extremely dry and contact between the electrode and the ground can not be maintained, one might consider using porous pots.

For DC resistivity surveys, the most commonly used electrodes are nothing more than aluminum, copper, or steel rods about two feet in length. These rods are driven into the ground and connected with cables to the current source or the voltmeter. Under dry conditions, contact between the rod and the ground can be enhanced by wetting the ground surrounding the electrode.

Cables: To connect the electrodes to the various electrical components, cables must be employed. These cables are typically nothing more than insulated wires with stranded, copper-cored conductors. Although long cable lengths may need to be employed, given the high resistivity of the ground, resistance in the cables is typically negligable. A more significant problem is current induction in the cables used to make the voltage measurement from the current flowing in the cables going to the current electrodes. This source of noise is easily avoidable by simply keeping the voltage cables at a distance (a few feet) from the current cables. For easy deployment, cables are usually stored on reels.

3.2 FIELD PROCEDURE FOR ERT SURVEY METHOD

The first step involves marking a straight and accessible 200-meter line using a measuring tape. Then, electrodes are positioned along the line at equal intervals, with a total spacing of 3a between the first and last electrode. The report recommends deciding on an appropriate spacing (a) based on the desired investigation depth and practicality. For example, a 10-meter spacing (a) would result in a total electrode span of 30 meters. This spacing can be adjusted to cover the entire line with multiple measurements.

Once the electrodes are positioned, they are connected to the resistivity meter according to the manufacturer's instructions. The data collection process involves starting at one end of the line and taking measurements. For each setup, the resistance is measured using the resistivity meter. The report emphasizes logging the electrode positions, resistance values, and any relevant environmental conditions in a field notebook or directly into a data logger.

After each measurement, the electrodes are moved forward by a set interval (e.g., 10 meters) and the measurement is repeated until the entire line is covered.

Field precautions include regularly checking connections for security and ensuring good electrode contact with the ground. The report advises avoiding surveying during or immediately after rain due to its impact on resistivity measurements. Additionally, it highlights being aware of and avoiding areas with potential electrical interference, such as near power lines or underground cables.

For data processing using DIPPRO software, the recorded resistivity data (electrode positions and corresponding resistance values) are entered. The software settings are then configured to match the survey setup, including the Wenner array and electrode spacing. The inversion tool in DIPPRO is then used to convert the resistance data into a model of subsurface resistivity. This involves an iterative process to minimize the difference between the measured data and the model's response. The processed data is presented as 2D or 3D resistivity images, which are then analyzed to identify variations in resistivity that could indicate different subsurface materials or features.

Finally, a report is prepared that includes the methodology, raw data, processed images, and interpretation of the findings. The report should discuss any anomalies or significant features identified in the resistivity profile.

3.3 FIELD PROCEDURE

The pre-survey planning involves determining the survey line's location and equipment check to ensure proper functioning. Then, the electrodes are laid out along a straight line, and initial measurements are taken with a small electrode spacing to probe shallow subsurface features. As the spacing between electrodes is incrementally increased, corresponding adjustments are made to measure the potential difference and injected current continually. The surveyor advised repeating measurements at each electrode configuration to average out any noise or errors. Continuing the measurements until the maximum spacing is reached, typically at a distance where AB/2 reaches about 100 meters for a total line length of 200 meters, helps probe deeper structures. Throughout the survey, meticulous documentation of measurement data and environmental conditions is essential.

Regarding data processing using Res2DInv software, the surveyor emphasized the need to format the collected data according to the software requirements. Once imported, the software parameters are set, and the inversion process is executed, with close monitoring for convergence. Upon completion, the inverted resistivity profiles are carefully analyzed to interpret subsurface structures, and detailed reports including resistivity profiles, inversion parameters, and geological interpretations are generated.

Overall, the described process provides a comprehensive framework for conducting a VES survey and analyzing the obtained data using Res2DInv software.

Figure 3.1: ERT field equipment

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 ERT RESULTS AND INTERPRETATION

1. Field Data: The field data for the geophysical survey behind the Maingate shopping complex was collected using an ABEM 300 terrameter (SAS). The Wenner array configuration was utilized with a spacing parameter (a) of 10m, and a total of 5 electrodes (n) were employed. The lateral distance covered during the survey was 200m, starting from 0m. The coordinates for the survey points were recorded as follows:

At 0m: 6°23'44.00"N, 5°36'36.00"E

At 100m: 6°23'47.00"N, 5°36'36.00"E

At 200m: 6°23'51.76"N, 5°36'33.25"E

2. Theoretical Data: The theoretical data refers to the expected resistivity values based on the geological model and the chosen electrode configuration. These values are typically calculated using mathematical models and geological assumptions.

3. Pseudo Section (2D Resistivity Structure): The pseudo section represents a graphical representation of the resistivity structure beneath the survey area. It is constructed by plotting the measured apparent resistivity values at different electrode configurations along the survey line. This pseudo section provides a visual depiction of subsurface variations in resistivity and helps in interpreting geological features such as faults, fractures, and lithological boundaries.

Table 4.1: 2D DATA SHEET OF 200M TRAVERSE 2

2D DATA SHEET OF 200M TRAVERSE AT 10m UNIT ELECTRODE SPACING (WENER ALPHA)						
N1						
C1	P1	P2	C2	R (Ohms)	K	App Res
0	10	20	30	11.44	62.84	718.8896
10	20	30	40	9.13	62.84	573.7292
20	30	40	50	7.93	62.84	498.3212
30	40	50	60	4.08	62.84	256.3872
40	50	60	70	3.95	62.84	248.218
50	60	70	80	3.67	62.84	230.6228
60	70	80	90	3.54	62.84	222.4536
70	80	90	100	4.3	62.84	270.212
80	90	100	110	9.19	62.84	577.4996
90	100	110	120	6.13	62.84	385.2092
100	110	120	130	6.45	62.84	405.318
110	120	130	140	9.56	62.84	600.7504
120	130	140	150	9.69	62.84	608.9196
130	140	150	160	10.11	62.84	635.3124
140	150	160	170	6.69	62.84	420.3996
150	160	170	180	9.4	62.84	590.696
160	170	180	190	5.36	62.84	336.8224
170	180	190	200	4.86	62.84	305.4024
N2						
0	20	40	60	5.86	125.68	736.4848

10	30	50	70	6.45	125.68	810.636
20	40	60	80	4.53	125.68	569.3304
30	50	70	90	3.43	125.68	431.0824
40	60	80	100	3.73	125.68	468.7864
50	70	90	110	2.72	125.68	341.8496
60	80	100	120	4.62	125.68	580.6416
70	90	110	130	4.68	125.68	588.1824
80	100	120	140	4.43	125.68	556.7624
90	110	130	150	4.87	125.68	612.0616
100	120	140	160	5.79	125.68	727.6872
110	130	150	170	9.43	125.68	1185.1624
120	140	160	180	5.02	125.68	630.9136
130	150	170	190	4.85	125.68	609.548
140	160	180	200	3.69	125.68	463.7592
N3						
0	30	60	90	4.39	188.52	827.6028
10	40	70	100	5.55	188.52	1046.286
20	50	80	110	3.43	188.52	646.6236
30	60	90	120	4.03	188.52	759.7356
40	70	100	130	4.44	188.52	837.0288
50	80	110	140	5.29	188.52	997.2708
60	90	120	150	4.97	188.52	936.9444
70	100	130	160	4.96	188.52	935.0592
80	110	140	170	3.73	188.52	703.1796
90	120	150	180	4.32	188.52	814.4064

100	130	160	190	4.6	188.52	867.192
110	140	170	200	3.89	188.52	733.3428
		N4				
0	40	80	120	3.99	251.36	1002.9264
10	50	90	130	3.47	251.36	872.2192
20	60	100	140	3.67	251.36	922.4912
30	70	110	150	3.93	251.36	987.8448
40	80	120	160	3.96	251.36	995.3856
50	90	130	170	3.8	251.36	955.168
60	100	140	180	4.63	251.36	1163.7968
70	110	150	190	4.29	251.36	1078.3344
80	120	160	200	4.26	251.36	1070.7936
		N5				
0	50	100	150	3.19	314.2	1002.298
10	60	110	160	3.49	314.2	1096.558
20	70	120	170	3.56	314.2	1118.552
30	80	130	180	3.9	314.2	1225.38
40	90	140	190	4.62	314.2	1451.604
50	100	150	200	4.76	314.2	1495.592

Table4.2: 2D DATA SHEET OF 200M TRAVERSE 3

2D DATA SHEET OF 200M TRAVERSE AT 10m UNIT ELECTRODE SPACING (WENER ALPHA)						
		N1				
C1	P1	P2	C2	R (Ohms)	K	App Res
0	10	20	30	9.27	62.84	582.5268
10	20	30	40	9.72	62.84	610.8048
20	30	40	50	7.07	62.84	444.2788
30	40	50	60	7.57	62.84	475.6988
40	50	60	70	5.7	62.84	358.188
50	60	70	80	4.74	62.84	297.8616
60	70	80	90	5.8	62.84	364.472
70	80	90	100	10.77	62.84	676.7868
80	90	100	110	9.74	62.84	612.0616
90	100	110	120	7.64	62.84	480.0976
100	110	120	130	7.69	62.84	483.2396
110	120	130	140	6.56	62.84	412.2304
120	130	140	150	8.15	62.84	512.146
130	140	150	160	6.93	62.84	435.4812
140	150	160	170	7.65	62.84	480.726
150	160	170	180	8.59	62.84	539.7956
160	170	180	190	6.74	62.84	423.5416
170	180	190	200	5.65	62.84	355.046
		N2				
0	20	40	60	5.18	125.68	651.0224

10	30	50	70	3.58	125.68	449.9344
20	40	60	80	3.48	125.68	437.3664
30	50	70	90	4.1	125.68	515.288
40	60	80	100	3.92	125.68	492.6656
50	70	90	110	3.8	125.68	477.584
60	80	100	120	4.51	125.68	566.8168
70	90	110	130	3.64	125.68	457.4752
80	100	120	140	7.06	125.68	887.3008
90	110	130	150	3.81	125.68	478.8408
100	120	140	160	3.74	125.68	470.0432
110	130	150	170	4.56	125.68	573.1008
120	140	160	180	3.85	125.68	483.868
130	150	170	190	3.13	125.68	393.3784
140	160	180	200	2.71	125.68	340.5928
		N3				
0	30	60	90	3.36	188.52	633.4272
10	40	70	100	9.49	188.52	1789.0548
20	50	80	110	4.18	188.52	788.0136
30	60	90	120	4	188.52	754.08
40	70	100	130	3.26	188.52	614.5752
50	80	110	140	2.99	188.52	563.6748
60	90	120	150	1.972	188.52	371.76144
70	100	130	160	5.2	188.52	980.304
80	110	140	170	3.06	188.52	576.8712
90	120	150	180	3.08	188.52	580.6416

100	130	160	190	3.17	188.52	597.6084
110	140	170	200	2.73	188.52	514.6596
		N4				
0	40	80	120	6.89	251.36	1731.8704
10	50	90	130	6.37	251.36	1601.1632
20	60	100	140	3.54	251.36	889.8144
30	70	110	150	3.15	251.36	791.784
40	80	120	160	3.2	251.36	804.352
50	90	130	170	3.5	251.36	879.76
60	100	140	180	3.05	251.36	766.648
70	110	150	190	2.91	251.36	731.4576
80	120	160	200	2.93	251.36	736.4848
		N5				
0	50	100	150	3.66	314.2	1149.972
10	60	110	160	3.28	314.2	1030.576
20	70	120	170	3.18	314.2	999.156
30	80	130	180	1.638	314.2	514.6596
40	90	140	190	3.42	314.2	1074.564
50	100	150	200	3.03	314.2	952.026
		N6				
0	60	120	180			
10	70	130	190			
20	80	140	200			

4.1.1 Discussion

The 2D Electrical Resistivity models are shown in Figures 4.1 to 4.2. In this model, the results is presented in a colour-coded presentation depicted with contour lines indicating the Inverted 2D

Resistivity structure obtained from the study area. The horizontal scale on the section is the lateral distance while the vertical scale is the depths, which are both in meters. A maximum spread of 200 m were modelled with the corresponding depth of 30.0 m investigated on all the profiles as show from Figures 4.1 to 4.2

WENNER PROFILE2 (2-D Resistivity Structure)

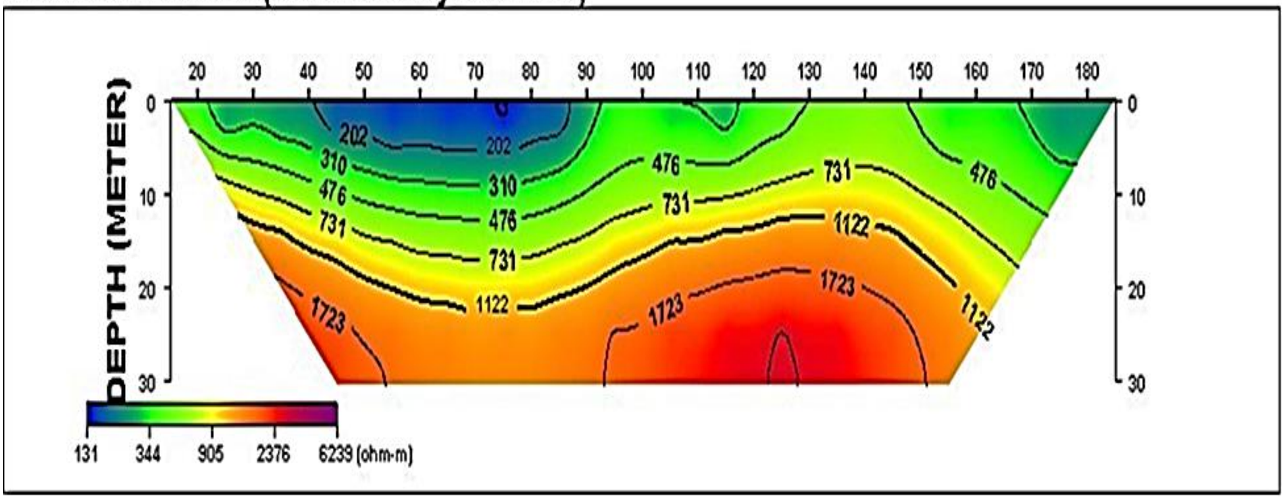


Figure 4.1: Inverted 2D resistivity model obtained for traverse 2

Figure 4.1 represents the 2D resistivity image obtained for profile two with a horizontal distance of 200 m and a depth of 30 m, with resistivity values ranging from 131 Ωm – 6239 Ωm across the profile showing geoelectric model layers composed of alluvium, laterite, shale, sandstone with a little quantity of clay.

The profile was divided into four (4) major layers, which are all seen to be generally characterized by moderate to high resistivity values. At the top layer, we can infer from the low resistivity value that is characterized by alluvial soil, which has a resistivity range between 130 Ωm and 800Ω m, mixed with patches of clay, across the horizontal profile having a lateral continuity down to a depth of 15m. Shale and consolidated stand stone suspected to have a resistivity value 2000Ωm to 6239Ωm having a lateral continuity was inferred at a depth of 20m down to the last depth.

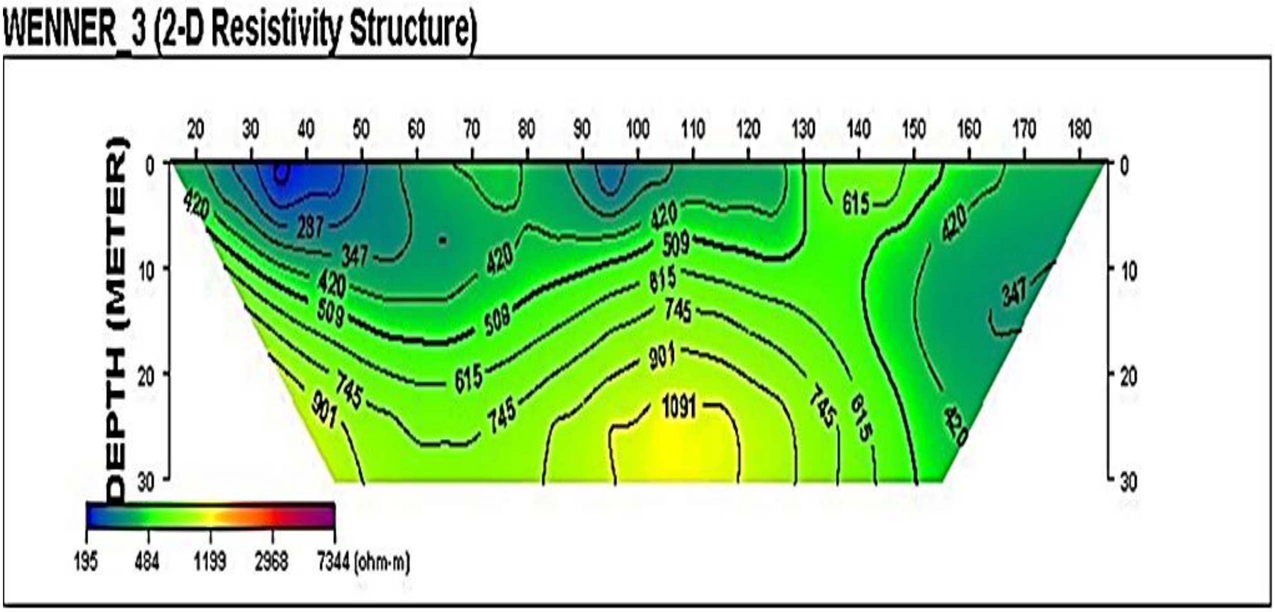


Figure 4.2: Inverted 2D resistivity model obtained for traverse 2

Figure 4.2 represents the 2D resistivity image obtained for profile two with a horizontal distance of 200 m and a depth of 30 m, with resistivity values ranging from 195 Ωm – 7344 Ωm across the profile showing geoelectric model layers composed of alluvium, laterite, shale, sandstone with a little quantity of clay.

four (4) major layers were delineated in the profile which is seen to be generally characterized by moderate to high resistivity values, at the top layer we can infer from the moderate resistivity value that is characterize by alluvium followed by laterate and some patches of clay deposit at a distance of 30m to 50m and 90m to 100m across the horizontal profile. Shale and unconsolidated sandstone with resistivity values of 400 Ωm to 2000 Ωm where suspected spreading across the horizontal profile having a lateral continuity down to the last depth of 30m.

4.2 VES RESULTS AND INTERPRETATION

$Date = \ 12/11/2024$

Elevation $(m) = 112$

6˚ N23˚ E28˚

5˚ N36˚ E34˚

Table 4.3: VES data sheet

MN/2[m]	AB/2[m]	Resistance[Ωm]	G.F	Adj. Resistivity [Ωm]
0.20	1.00	204.00000	7.541	1538.3232
0.20	1.47	112.90000	16.660	1880.876687
0.20	2.15	53.10000	35.996	1911.363041
0.20	3.16	25.20000	78.123	1968.691738
0.20	4.64	10.65000	168.801	1797.728605
0.20	6.81	4.14000	363.970	1506.836071
0.20	10.00	1.58000	785.186	1240.593564
2.00	10.00	18.76000	75.408	1240.593564
2.00	14.70	7.61000	166.597	1267.800849
2.00	21.50	3.33000	359.955	1198.651399
2.00	31.60	1.71300	781.227	1338.241645
2.00	46.40	0.94300	1688.008	1591.791619
10.00	46.40	4.51000	322.520	1591.791619
10.00	68.10	2.40000	712.859	1710.860474
10.00	100.00	0.98000	1555.290	1524.1842
10.00	147.00	0.34000	3379.064	1148.881726

4.2.1 Discussion

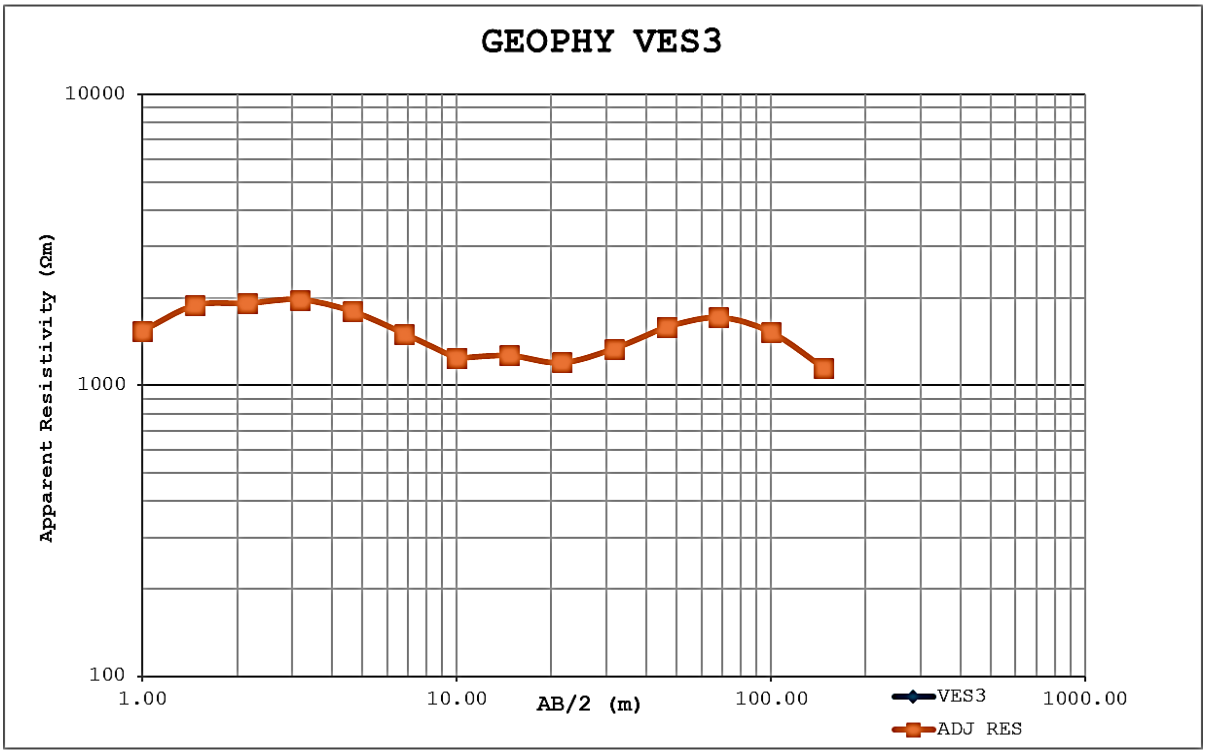


Figure 4.3: VES graph

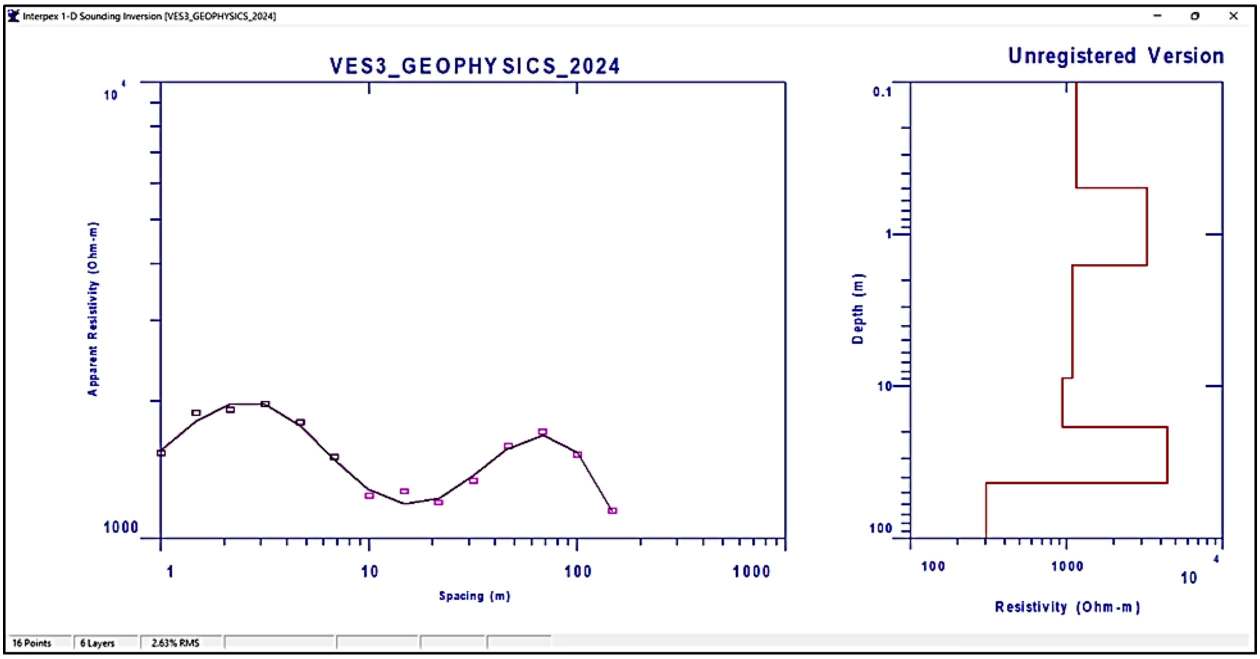


Figure 4.4: VES

In the Vertical Electrical Sounding (VES) a total of distance of 200 m was covered laterally. The results of interpreted resistivity data for the investigation are presented as curves. This is shown in

Figure 4.3. Computer interpretation of the observed curve resolved the penetrated layers beneath the VES.

Figure 4.3 and 4.4 reveals the images obtained from Vertical Electrical Sounding (VES) using IX!D software whereby the apparent resistivity is plotted against the distance on a log- log graph producing an AHAK curve revealing an increase of apparent resistivity with depth.

Table 4.4: The result as captured from VES

Resistivity Model

Surface Elevation: 112.00 Fitting Error: 2.6283

Use Depth Instead of Thickness Units: (meters)

#	Rho	Fix?	Thick	Depth	Elev	Fix?
1	1151.3		0.49476	0.49476	111.51	
2	3264.0		1.1120	1.6068	110.39	
3	1092.7		7.1908	8.7976	103.20	
4	943.27		9.6645	18.462	93.538	
5	4399.1		24.721	43.183	68.817	
6	306.50					
7						
8						
9						
10						
11						
12						

Insert Cell | Insert Row | Column Math: | Forward

Delete Cell | Delete Row | Add To | One Iteration

OK | Multiply By | More Iterations

Table 4.3 above shows the result as captured from VES. Five (5) resistivity layers where delineated showing the resistivity values ranging from moderate to high resistivity values of 1151.3Ωm to 4399.1 Ωm ranging from a depth of 0.49476m to 43.183m. The thickness and depth of each layers where captured which indicate the inferred lithology of different layers. From the table Alluvium (Topsoil) and laterite where inferred at a depth of 0.49476m and 8.7976m respectively, meanwhile shale and sandstone (unconsolidated and consolidated) where suspected at a depth of 18.462m to 43.183m having a thickness of 9.6645m and 24.721m respectively. The results obtained from VES was observed to be in anology with the result from wenner in regards to their lithology. The advantage from this result obtain from VES over wenner is that VES was able to capture more layers and their accurate thickness.

CHAPTER FIVE

FINDINGS, CONCLUSION AND SUGGESTIONS FOR FURTHER STUDIES

5.1 FINDINGS

1. The 2D resistivity image (Figure 4.1) shows a four-layer structure from 131 Ωm to 6239 Ωm. The top 15 meters are low-resistivity alluvium with clay, while deeper layers are higher-resistivity shale and consolidated sandstone.
2. Figure 4.2 suggests a deeper layer of unconsolidated sandstone with resistivity between 400 Ωm and 2000 Ωm.
3. VES data (Table 4.3) identifies five layers with resistivities from 1151.3 Ωm to 4399.1 Ωm to 43 meters, starting with alluvium and laterite, progressing to shale and sandstone.
4. VES results align with Wenner array findings in lithology and provide more detailed layer information.

5.2 CONCLUSION

The aim of this research was to estimate subsurface lithological structures using the 2D electrical resistivity method at the University of Benin, Benin City, utilizing Geoelectrical Method. The objectives included collecting field data using Wenner-Alpha configurations, processing the acquired data with RES2DINV software to obtain 2-Dimensional true resistivity profiles, characterizing subsurface layers based on resistivity and depth values, and interpreting the 2D resistivity imagery to identify potential building construction areas and assess the absence of clay formations. The findings of the research revealed a four-layer subsurface structure with resistivity values ranging from 131 Ωm to 6239 Ωm. The top layer, down to 15 meters depth, was inferred to be alluvium (soil) with some clay patches, exhibiting low resistivity. The underlying layer, suspected to be shale and consolidated sandstone, showed moderate to high resistivity. Similar four-layer structures were observed in different profiles, with variations in resistivity values and layer compositions. The Vertical Electrical Sounding (VES) data identified five layers with moderate to high resistivity down to a depth of 43 meters, providing more detailed information about layer thickness compared to the Wenner array results.

Overall, the findings from both the Wenner array and VES generally agreed in terms of identified lithology, highlighting the effectiveness of the 2D electrical resistivity method in characterizing subsurface structures and providing valuable insights for potential construction projects and geological assessments.

5.3 SUGGESTIONS FOR FURTHER STUDIES

1. Borehole data acquisition would provide ground truth information about the actual subsurface lithology and validate the inferred compositions from the resistivity surveys.
2. Expanding the survey area using the Wenner array or VES could provide a more comprehensive picture of the subsurface across a larger region.
3. Investigating the possibility of using other geophysical techniques, such as seismic refraction, could offer complementary data for a more robust subsurface characterization.

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