

**GEOPHYSICAL INVESTIGATION USING 2-DIMENSIONAL RESISTIVITY
METHOD FOR SUBSURFACE LITHOLOGY AT BLOCKS OF FLAT
UNIVERSITY OF BENIN.**

BY

AYA AFOKE

PSC1909011

**A PROJECT SUBMITTED TO THE DEPARTMENT OF PHYSICS,
FACULTY OF PHYSICAL SCIENCES, IN PARTIAL FUFILLMENT OF
THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF
BACHELOR OF SCIENCE (B.SC.) OF THE UNIVERSITY OF BENIN,
BENIN CITY, EDO STATE, NIGERIA.**

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CERTIFICATION

I hereby certify that this project was carried out under my supervision by **AYA AFOKE**, a final year student of department of physics, Faculty of physical sciences, University of Benin, Benin city, Edo state, Nigeria.

PROF. C. O. AIGBOGUN
Supervisor

Date

PROF. O.D. OSAHON
Head of Physics Department

Date

.....
EXTERNAL EXAMINER

.....
Date

DEDICATION

I dedicate this endeavor to the Divine Providence for granting me existence and the opportunity to accomplish this task. I extend my heartfelt appreciation to my exemplary parents, Mr. and Mrs. Aya, whose unwavering encouragement and financial assistance have been instrumental in manifesting my aspirations. Gratitude also goes to my beloved Aunties, Uncles, siblings, and all supporters for their affection and blessings.

CERTIFICATION OF DISSERTATION ON PLAGIARISM

We the undersigned attest and declare that the dissertation of **AYA AFOKE** titled
**“GEOPHYSICAL INVESTIGATION USING 2 DIMENSIONAL
RESISTIVITY METHOD FOR SUBSURFACE LITHOLOGY
CHARACTERIZATION AT BLOCKS OF FLAT, UNIVERSITY OF BENIN”**
was carried out has successfully passed the anti-plagiarism test and doesn't violate
any copyright.

ACKNOWLEDGEMENT

I wish to extend my sincere gratitude to my exceptional and dependable supervisor, Professor C. O. Aigbogun, for providing invaluable guidance and support throughout the completion of this project.

Furthermore, I am deeply thankful to my heavenly father and my parents, Mr. and Mrs. Aya, for their unwavering love, care, and financial assistance, which have been pivotal in my academic journey.

I am also indebted to the numerous lecturers in the Physics Department at the University of Benin for their contributions and expertise.

ABSTRACT

Geophysical surveys utilizing 2-Dimensional Resistivity method was conducted at Blocks of Flats, University of Benin, Benin City Nigeria, to characterize subsurface lithology and create a comprehensive base map of the area. Two parallel traverses were undertaken for the 2-D Electrical Resistivity Imaging (ERI) using the Wenner Schlumberger array configuration. The 2-D Electrical Resistivity data underwent processing through inversion of the 2-D apparent resistivity data using RES2DINVS64 software to generate the 2-D inverted resistivity section. The outcomes of the 2-D ERI delineated three to five resistivity structures across the two traverses, indicating the presence of clay/clayey sand, sand, and sandstone within a lateral distance of 200m and depths ranging from 39.6 to 57.3m across each traverse. Resistivity values generally ranged from 16.8 to 75542 Ω m across Traverse 1 and 2. The clay/clayey sand, clayey sand, sand, and sand/sandstone exhibited resistivity values ranging from 24.7 to 227 Ω m, 95.5 to 291 Ω m, and 322 to 7554 Ω m, respectively.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Characterizing the shallow subsurface is a crucial requirement for a wide range of applications and disciplines, including those relevant to hydrogeology, agriculture, civil and structural engineering, and in environmental studies (Ehirim, 2010). Geophysical methods offer relatively fast, efficient and cost effective tools for diagnosing the subsurface state to assess their capability to sustain social infrastructures such as high rise buildings, roads and railways, and for environmental monitoring to follow lateral and temporal evolution of plumes in polluted soils, which serve as fundamental basis for successful remediation of such polluted zones. These methods, employed independently or integrated with other geophysical or non-geophysical methods, have been used successfully to determine the suitability of soils for various applications (Atekwana, 2000). Electrical resistivity tomography survey techniques are increasingly being applied to environmental and engineering investigations especially characterization of dumpsites, contaminated land and preconstruction investigations (Alile, 2017). The theory of 3D electrical resistivity tomography is consistent with the common electrical method.

Resistivity is a physical property of materials. It is the ability to resist a flow of charges; it is the measurement of how strongly a material resists the flow of electric current (Denchik, 2005). The purpose of electrical surveys is to determine

the subsurface resistivity distribution by making measurements on the ground surface. The 2D resistivity measurements are normally made by injecting current into the ground through two current electrodes and measuring the resulting voltage difference at two potential electrodes (Nordiana, 2012). Resistivity imaging technique depends on Ohm's law, which states that the electric current in a material is proportional to the potential difference across it (Abdelwahab, 2013).

From these measurements, the true resistivity of the subsurface can be estimated (Loke, 2012). Geo electrical resistivity imaging has played an important role in addressing a wide variety of hydrogeological, environmental and geotechnical issue. A more accurate model of the subsurface is a two dimensional (2D) model where the resistivity changes in the vertical direction, as well as in the horizontal direction along the survey line (Abdelwahab, 2013). However, at the present time, 2D surveys are the most practical economic compromise between obtaining very accurate results and keeping the survey costs down (Dahlin, 1996).

Electrical resistivity imaging technique has the ability to present the changes in electrical resistivity values of the compounds during a period of time, thus it is applicable in the environmental pollution (Kaya, 2007). This development started with the introduction of practical electrical imaging field systems, like the geoelectrical Wenner pseudosection and was soon followed by effective processing and inversion software (Omowumi, 2012). The imaging technique is particularly powerful and useful in the study areas of complex geology, in groundwater problems and in many other shallow subsurface investigations (Dahlin, 1996). Electrical resistivity is known to be highly variable among other physical

properties of rock (Adli, 2010). The resistivity of the 2D model is assumed to vary both vertically and laterally along the survey line but constant in the direction perpendicular to the survey line (Aizebeokhai, 2010). Thus, a given rock type can have a large range of resistivity, from about 1000 to 10 million $\Omega\cdot\text{m}$, depending on whether it is wet or dry (Loke, 2004).

Presently, four main techniques can be adopted in electrical resistivity investigations. These include; 1-D, 2-D, 3-D and 4-D techniques. The 4-D technique incorporates the time component and is usually called time-lapse technique. The resistivity of a soil or rock is dependent on several factors that include amount of interconnected pore water, porosity, and amount of total dissolved solid such as salts and mineral composition (clays) and degree of water saturation in the rock (Srinivasamoorthy, 2009).

1.2 LITHOLOGY

Lithology is a fundamental geological concept that describes the physical characteristics of rocks, such as mineral content, grain size, texture, and color (Blatt and Tracy, 1996). These characteristics provide geologists with crucial clues about the rock's origin, history, and potential uses. Understanding lithology is crucial for various applications in geology, engineering, and environmental science.

Lithology refers to the study and description of rocks, particularly their physical and visual characteristics. It is primarily concerned with the rocks' composition and texture and how these factors influence rock behavior and interaction with natural processes (Folk, 1974).

1.2.1 Components of Lithology

1. **Mineral Composition:** This involves identifying the minerals that make up a rock, which affects its color, hardness, and chemical reactivity. The mineral composition is vital for determining a rock's suitability for specific uses, such as building materials or ore extraction (Blatt et al., 2006).
2. **Texture:** Rock texture includes the size, shape, and arrangement of the minerals or grains within the rock. Textural features can indicate the rock's formation environment and history. For example, the size of the grains in a sedimentary rock can tell us about the energy of the environment where the sediment was deposited (Twiss and Moores, 2007).
3. **Color:** While often not as scientifically telling as mineralogy or texture, the color of a rock can provide clues about its composition and the conditions under which it was formed. For instance, red sandstone typically indicates iron oxide presence, suggesting oxidizing conditions during formation (Marshak, 2014).

1.2.2 Applications of Lithology

1. **Petroleum Geology:** Lithology determines reservoir quality by influencing porosity and permeability, which are critical for storing and transmitting fluids like oil and natural gas (Selley, 1998).
2. **Environmental Geology:** Lithologic information helps in assessing soil contamination risks and groundwater movement, informing environmental protection and cleanup strategies (Fetter, 2001).
3. **Engineering:** Understanding the lithology of an area allows engineers to design appropriate foundations for buildings, roads, and other structures and predict and mitigate issues such as landslides and subsidence (Das, 2007).

To determine lithology, geologists often use tools such as petrographic microscopes, X-ray diffraction, and field assessments. Advanced techniques include geophysical logging in boreholes, which can provide continuous records of lithology at depth without extensive drilling (Rider, 2002). Lithology is a core aspect of geology that informs many practical applications from resource extraction to environmental management and infrastructure development. By understanding the detailed characteristics of rocks, professionals can make informed decisions that affect economic ventures and public safety.

1.3 STRATIGRAPHY

Stratigraphy involves the study of rock layers (strata) and layering in the earth's subsurface, which is essential for understanding geological structures, mapping the distribution of minerals and hydrocarbons, and assessing environmental conditions. Geophysical techniques are crucial tools in stratigraphy because they allow geologists and geophysicists to characterize the subsurface without extensive drilling. Stratigraphy generally refers to the study of rock layers and layer sequences. In geophysics, stratigraphy focuses on interpreting these layers to reveal the history of sediment deposition and to predict the locations of minerals, oil, and gas. This discipline integrates principles of sedimentology, petrology, and paleontology to understand the spatial and chronological relationships among rocks (Boggs, 2006).

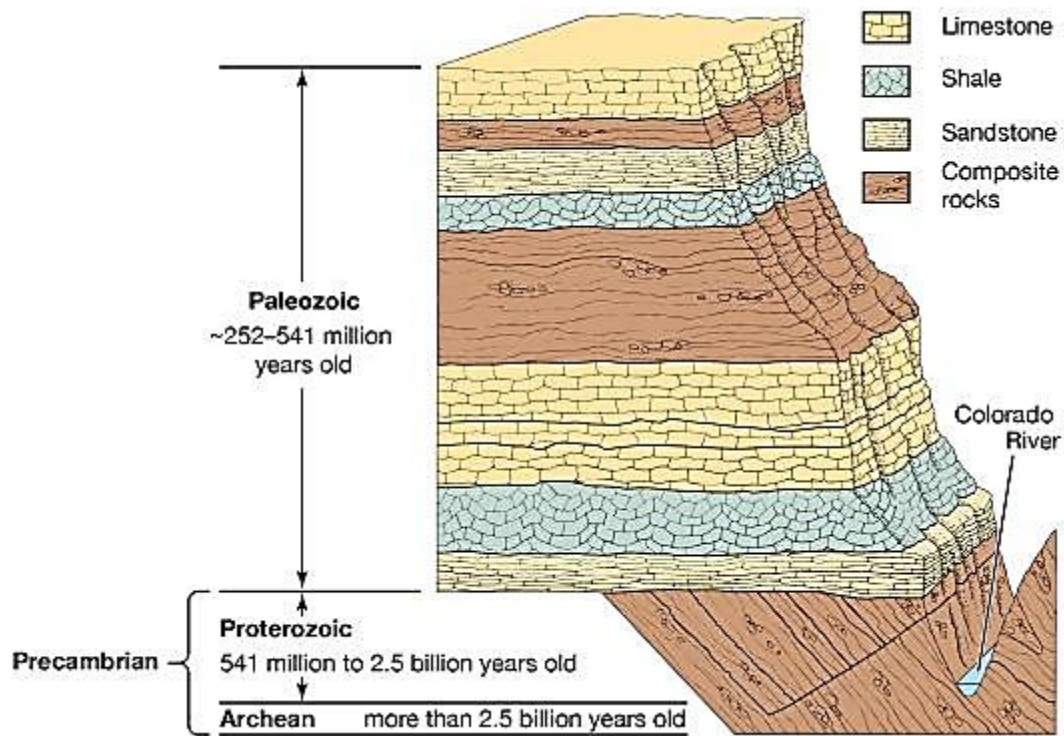


Figure 1 1: Stratigraphy

1.3.1 Techniques in Stratigraphic Analysis

1. Seismic Reflection Methods: This is the primary tool in hydrocarbon exploration and involves sending sound waves into the ground and analyzing the echoes that return from the subsurface layers. Variations in the echoes help identify different rock layers and structures, such as folds, faults, and stratigraphic traps (Sheriff, 1991).
2. Ground Penetrating Radar (GPR): GPR is effective for shallow stratigraphic investigations. It is used extensively in environmental assessments, archaeological site investigation, and civil engineering projects to map the depth and structure of the subsurface layers (Daniels, 2004).
3. Electrical Resistivity Tomography (ERT): This method is used to image subsurface stratigraphy by measuring the electrical resistivity of different materials. It is

particularly useful in delineating aquifers and clay layers in the subsurface (Loke, 2004).

1.3.2 Applications of Stratigraphy in Geophysics

- **Hydrocarbon Exploration:** Stratigraphy helps in identifying and mapping reservoir rocks and seal rocks, which are crucial for trapping hydrocarbons (Selley, 1998).
- **Water Resources:** Stratigraphic studies can delineate aquifers and confining units, aiding in sustainable groundwater management (Fetter, 2001).
- **Environmental Geology:** Stratigraphy assists in understanding the spread of contaminants through different layers of the earth and in planning remediation strategies (Fetter, 2001).
- **Archaeology and Paleontology:** Geophysical stratigraphy can help locate and map archaeological sites or fossil layers without disturbing them (Renfrew and Bahn, 2004).

1.3.3 Challenges and Considerations

The accuracy of stratigraphic interpretation from geophysical data can be limited by the resolution of the technique and the complexity of the subsurface geology. Moreover, different geophysical methods might provide varying results depending on the physical properties of the geological materials, requiring cross-validation and integration of data from multiple sources (Milsom, 2003).

Stratigraphy in geophysics is an indispensable field that plays a vital role in natural resource exploration, environmental science, and historical geology. By leveraging

various geophysical techniques, geoscientists can interpret the earth's subsurface in ways that are non-invasive, cost-effective, and comprehensive.

1.4 SUBSURFACE CHARACTERIZATION

Subsurface characterization is a critical component of geophysical exploration and environmental assessments, aimed at understanding the properties and distribution of soil, rock, and fluids beneath the Earth's surface. This field employs a variety of techniques to gain detailed insights into subsurface conditions, which are essential for mineral and hydrocarbon exploration, civil engineering projects, groundwater management, and environmental remediation.

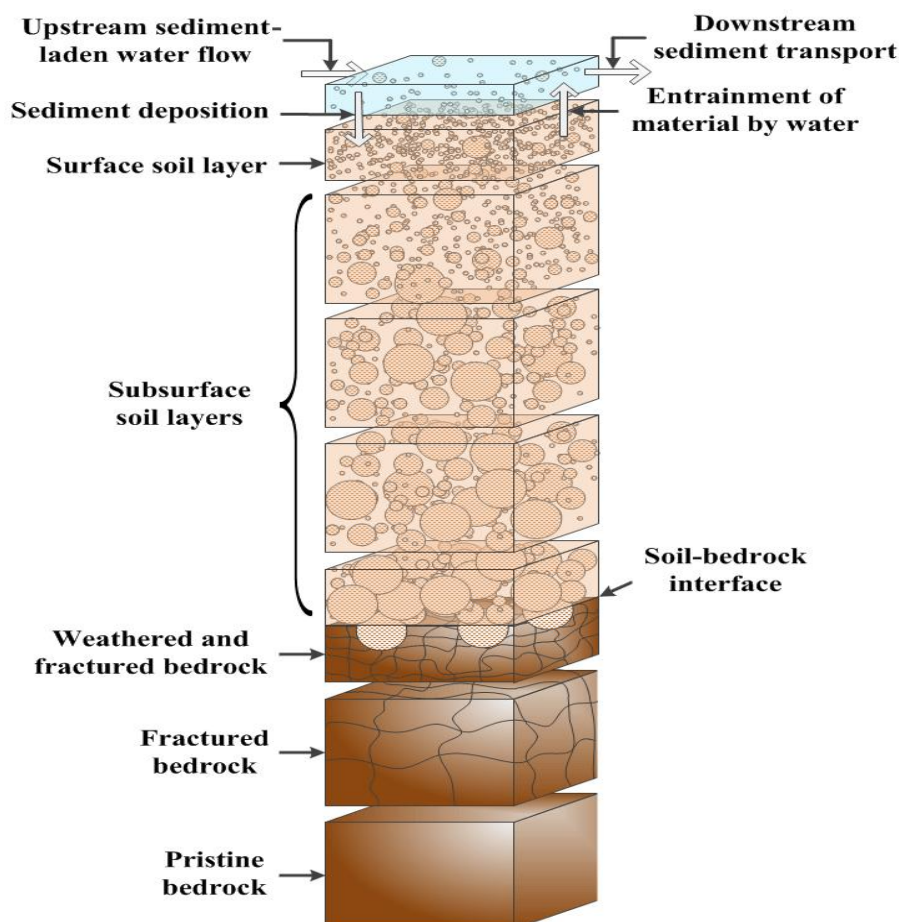


Figure 1 2: Subsurface Soil Profile

Figure 1.2: Subsurface Soil Profile

1.4.1 Techniques and Approaches

1. **Seismic Methods:** These are among the most commonly used techniques for subsurface characterization, employing the propagation of seismic waves to interpret the geological structures and properties of the subsurface. Reflection seismology, in particular, is crucial for delineating stratigraphic features and mapping hydrocarbon reservoirs (Sheriff, 1991).

2. **Electrical Resistivity Tomography (ERT):** ERT measures the electrical resistivity of subsurface materials to identify variations in composition, porosity, and saturation, which are important for detecting aquifers, pollution plumes, and clay barriers (Loke, 2004).

3. **Ground Penetrating Radar (GPR):** This non-invasive method uses radar pulses to image the subsurface. GPR is effective in environments with minimal conductive materials and is commonly used in environmental and engineering applications to map subsurface features and utilities (Daniels, 2004).

4. **Magnetic Methods:** These involve measuring variations in the Earth's magnetic field caused by subsurface magnetic minerals. Magnetic surveys are used to identify mineral deposits and geological structures (Telford et al., 1990).

1.4.2 Applications

1. **Resource Exploration:** Subsurface characterization is fundamental in the exploration of oil, gas, and minerals, providing data critical for locating deposits and designing extraction strategies (Selley, 1998).

2. Environmental Studies: It helps in assessing pollution spread, identifying contaminated sites, and designing remediation systems. For instance, ERT can delineate landfill leachate plumes in groundwater (Benson et al., 1997).
3. Civil Engineering: Geophysical methods assist in site investigation for construction projects, ensuring stability and the integrity of structures by revealing subsurface anomalies like voids or unstable soil (Knill, 2003).

1.4.3 Challenges and Limitations

The interpretation of geophysical data for subsurface characterization can be complex and is dependent on local geological conditions. Misinterpretations can occur due to anisotropy, heterogeneity of materials, and interference from ambient noise (Milsom, 2003). Additionally, the resolution of geophysical methods may not always meet the requirements for certain detailed investigations.

Subsurface characterization forms the backbone of multiple disciplines, enabling safer and more effective exploration and development of subsurface resources. The integration of multiple geophysical techniques often yields the best results, providing a comprehensive understanding of subsurface conditions.

1.5 LOCATION STUDY AREA

The survey area is located within longitudes $5^{\circ}36'5.28''\text{E}$ and latitudes $6^{\circ}20'9.04''\text{N}$. an elevation of 80.2 Meters (263.14 Feet). The study location (the University of Benin blocks of flat) is situated in Ovia-North East Local Government Area. The area also occupies the Southern part of Edo State which is a sedimentary terrain and is underlain by sedimentary rocks of Paleocene to recent age. The sedimentary rock contains about 90% of sandstone and shale intercalations (Alile et al., 2011). Edo

State is situated in the Southwestern part of Nigeria. It is an important sedimentary basin in Nigeria due to its closeness to the oil fields within the Niger Delta region.

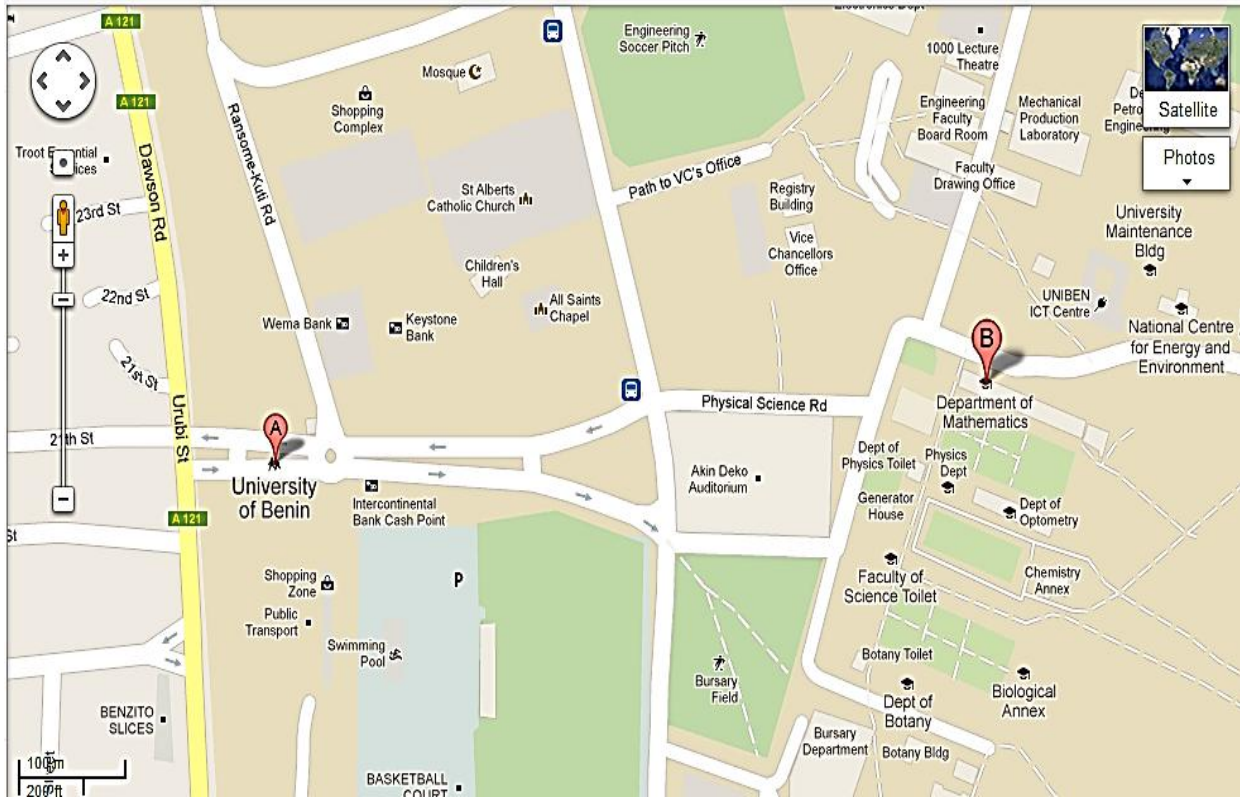


Figure 1 3: A picture of the study area. (Source: Google – Earth)

1.6 GEOLOGY OF BENIN

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 mudcracks. 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).

1.7 AIM AND OBJECTIVES OF THE WORK

The aim of this study is to apply 2 Dimensional Electrical Resistivity Tomography for Subsurface Lithology Characterization at Blocks of Flat, University of Benin, Benin City.

The objectives of this study are to;

1. conduct 2D ERT surveys at the University of Benin to gather subsurface resistivity data campus-wide.
2. analyze ERT data to interpret subsurface lithological features, including sedimentary deposits and geological structures beneath the University.

CHAPTER TWO

LITERATURE REVIEW

2.1 ELECTRICAL PROSPECTING METHODS

Electrical prospecting methods are widely used in geophysics to characterize subsurface properties based on the electrical conductivity and resistivity of geological materials. These methods involve measuring the response of the Earth to applied electrical currents or fields and are invaluable for various applications, including mineral exploration, groundwater assessment, and environmental studies. Here's an explanation with citations:

1. Electrical Resistivity Tomography (ERT)

ERT measures the electrical resistivity of subsurface materials by injecting electrical currents into the ground and measuring the resulting potential differences. Contrasts in resistivity are indicative of variations in lithology, moisture content, and fluid saturation. ERT is extensively used in environmental studies to delineate contaminant plumes, map groundwater resources, and characterize subsurface structures such as bedrock and faults (Loke, 2004).

2. Vertical Electrical Sounding (VES)

VES involves measuring the vertical distribution of electrical resistivity by varying the electrode spacing and depth of investigation. It provides information on the layering and resistivity structure of the subsurface. VES is commonly employed in mineral exploration to identify ore bodies, as well as in hydrogeological studies to determine aquifer thickness and geometry (Keller and Frischknecht, 1966).

3. Induced Polarization (IP)

IP measures the time-dependent voltage response of the Earth to a current pulse. It provides information on the surface properties of minerals and the presence of disseminated sulfide minerals, clay minerals, or organic matter. IP is widely used in mineral exploration for detecting sulfide ore deposits, as well as in environmental studies to identify contaminated sites and characterize subsurface lithology (Barker and Slater, 2000).

4. Self-Potential (SP) Method

SP measurements detect naturally occurring electrical potentials generated by electrochemical processes within the subsurface. These potentials can be indicative of groundwater flow, mineralization, or geological structures. SP is used in groundwater exploration to locate potential aquifer boundaries and in geothermal exploration to identify subsurface fluid flow paths (Johnson et al., 2005).

Electrical prospecting methods offer valuable insights into subsurface properties, aiding in resource exploration, environmental assessment, and engineering projects. By integrating these methods with other geophysical techniques, geoscientists can achieve comprehensive subsurface characterization for diverse applications.

2.2 PREVIOUS WORK DONE

Alagbe and Faleye (2020) conducted research in Akure, southwestern Nigeria, aiming to evaluate the subsurface lithology at a construction site. They integrated 2D electrical resistivity imaging (ERI) and vertical electrical sounding (VES) techniques to assess the site's suitability for engineering structures. By utilizing both horizontal profiling (Wenner array) and vertical soundings (Schlumberger configuration), they

were able to analyze the lithological composition at various depths. The findings revealed the presence of multiple geo-electric layers with varying resistivity values, indicating the prevalence of clay-rich layers in areas designated for foundation placement. This study suggests that while shallow foundation may not be suitable for massive engineering structures due to the prevalence of clay materials, it may be feasible for smaller projects.

Abiola et al. (2017) conducted their study at Iba Nursery/Primary School in Ojo, Southwest, Nigeria, with the goal of mapping subsurface lithology and understanding its implications on engineering structures. They employed 2D resistivity imaging and vertical electrical sounding techniques to delineate subsurface layers and assess their suitability for construction. Through qualitative interpretation of the data, they identified various subsurface layers and highlighted challenges for massive engineering structures due to the presence of clay materials close to the surface. However, the study suggested that small to medium-sized structures could be constructed with proper consideration of subsurface conditions.

Eke and Umuokoro (2020) focused their research on determining subsurface lithology and suitable depths for structural foundations at Ignatius Ajuru University of Education in Port Harcourt, Nigeria. They utilized electrical resistivity techniques, including vertical electrical sounding (VES) and borehole logging, to characterize subsurface conditions. By examining lithostratigraphy sequences and soil resistivity values, the study aimed to identify optimal foundation depths and soil types for construction. The findings indicated that the studied area comprised silty sands,

laterite, and coarse sands, which could support structures with foundations close to the earth's surface.

Ayuni et al. (2018) emphasized the importance of subsurface investigation for construction safety in Nigeria. Using Vertical Electrical Sounding (VES), they aimed to characterize subsurface lithology for foundation purposes. Through computer iteration process and qualitative interpretation of the data, they identified three to four-layered lithology, highlighting the suitability of top lateritic soil and the second layer for small to medium engineering structures. The study recommended foundation depths of 1-2 meters to avoid unsuitable layers, thus ensuring the stability and safety of constructed structures.

2.3 THE ELECTRICAL RESISTIVITY METHOD

The electrical resistivity method is a geophysical technique used to image the subsurface by measuring its ability to conduct electrical current. The fundamental principle governing the electrical resistivity method is Ohm's Law, which states that the current (I) flowing through a conductor is directly proportional to the potential difference (voltage, V) across it and inversely proportional to the resistance (R) of the conductor:

$$I = V / R \quad (2.1)$$

In the context of earth materials, resistivity (ρ) is a measure of a material's opposition to electrical current flow. It's the equivalent of electrical resistance for a unit volume of material.

Consider a current (I) flowing in a cylindrical conductor of length L , cross-sectional area A .

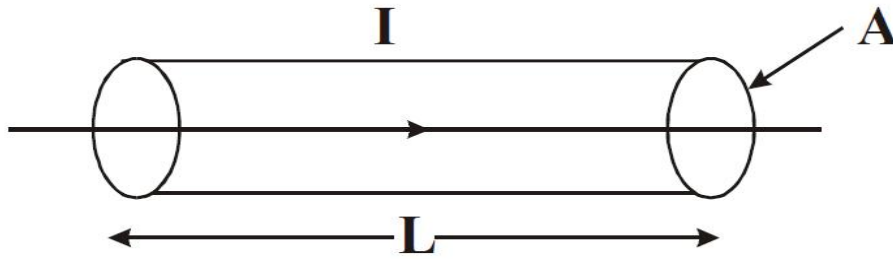


Figure 2 1: Cylinder used to Show the Flow of Current through a Body

Where,

I = Current flowing in the conducting medium between points measured in amperes

A = Area of the cylinder (Cross sectional area)

L = Length of the cylinder

The electrical resistance R can be expressed as:

$$R \propto \frac{L}{A} \quad (2.2)$$

$$R = \rho \frac{L}{A} \quad (2.3)$$

Where ρ is the constant of proportionality called resistivity.

But from ohms law:

$$R = \frac{\Delta V}{I} \quad (2.4)$$

Combine equations 2.3 and 2.4

$$\frac{\Delta V}{I} = \rho \frac{L}{A} \quad (2.5)$$

$$\therefore \rho = \frac{\Delta V A}{I L} \quad (2.6)$$

Where: ΔV = Potential difference between any two points measured in volts.

ρ = The resistivity in ($m\Omega$)

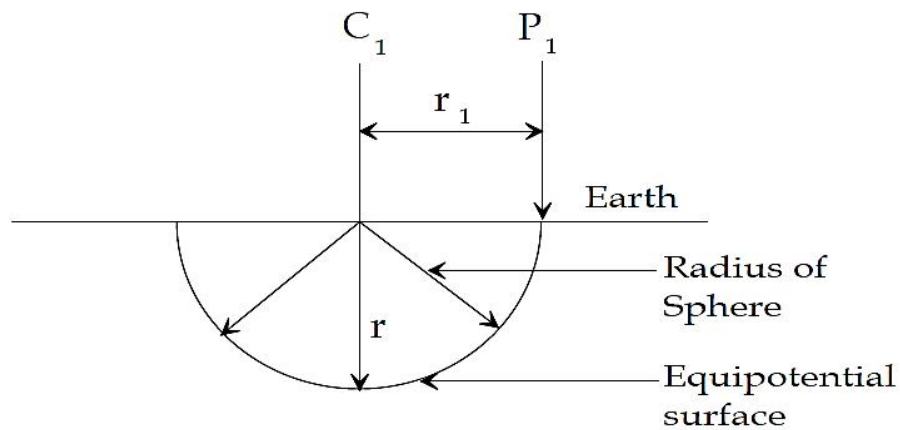


Figure 2 2: Showing the Passage of Current through the Earth

Method Workflow:

- **Current Injection:** Electrical current is injected into the ground through two current electrodes. A battery or a generator serves as the current source.
- **Potential Measurement:** The potential difference (voltage) is measured between two separate potential electrodes placed in the vicinity of the current flow. Ideally, no current flows between these potential electrodes.
- **Apparent Resistivity:** The measured voltage and current values are used to calculate an apparent resistivity (ρ_a). This apparent resistivity represents an average resistivity of the subsurface volume influenced by the current flow path.

The calculated resistivity value (ρ_a) is termed apparent resistivity because it reflects the average resistivity of the entire volume of earth sampled by the current. This volume depends on the spacing and configuration of the electrodes used.

2.3.1 Factors Affecting Resistivity

1. Material Composition: Different rock and soil types have varying electrical resistivity values. For instance, clay-rich soils are typically less resistive than sandy soils due to the presence of water in the clay pores, which conducts electricity better.

2. Porosity and Water Saturation: The amount of water in the pore spaces of a material significantly affects its resistivity. Higher water content generally leads to lower resistivity.

3. Clay Content: Clay minerals have a strong affinity for water and can significantly influence the overall resistivity, especially in clayey soils.

4. Dissolved Salts: The concentration of dissolved salts in the pore water can also affect resistivity. Saltier solutions conduct electricity better, resulting in lower resistivity values.

2.3.2 Applications of Electrical Resistivity

- **Subsurface Mapping:** Mapping variations in subsurface lithology (rock types) based on their resistivity contrasts.
- **Groundwater Exploration:** Identifying and characterizing freshwater aquifers by exploiting the resistivity difference between freshwater and saltwater.
- **Environmental Investigations:** Mapping potential contaminant plumes or locating buried waste based on resistivity variations.
- **Geotechnical Engineering:** Assessing subsurface conditions for construction projects by identifying potential weak zones or bedrock depth.

- **Archaeological Surveys:** Locating buried structures or archaeological features based on resistivity anomalies.

By employing different electrode configurations and interpreting the measured resistivity data, geophysicists can gain valuable insights into the subsurface. The electrical resistivity method is a non-destructive, relatively quick, and cost-effective technique, making it a popular choice for various geoscientific applications.

CHAPTER THREE

MATERIALS AND METHODOLOGY

1.1 RESISTIVITY SURVEYS

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 and geotechnical investigations. More recently, it has been used for environmental surveys.

The resistivity measurements are normally made by injecting current into the ground through two current electrodes (C_1 and C_2 in Figure 3.1), and measuring the resulting voltage difference at two potential electrodes (P_1 and P_2). From the current (I) and voltage (V) values, an apparent resistivity (p_a) value is calculated.

$$p_a = k V / I \quad (3.1)$$

Where k is the geometric factor which depends on the arrangement of the four electrodes. Resistivity meters normally give a resistance value, $R = V/I$, so in practice the apparent resistivity value is calculated by

$$p_a = k \times R \quad (3.2)$$

The calculated resistivity value is not the true resistivity of the subsurface, but an “apparent” value which is the resistivity of a homogeneous ground which will give the same resistance value for the same electrode arrangement. The relationship

between the “apparent” resistivity and the “true” resistivity is a complex relationship. To determine the true subsurface resistivity, an inversion of the measured apparent resistivity values using a computer program must be carried out.

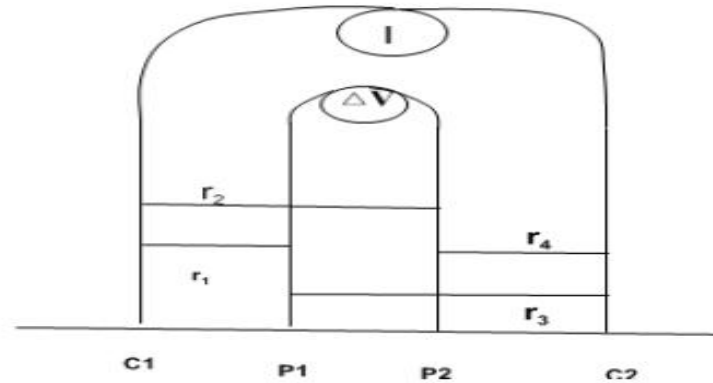


Figure 3 1: Shows the Generalized Electrode Configuration for Electrical Resistivity

3.1.1 Generalized Electrode Configuration for Resistivity Survey

The potential at the current surface semi finite earth is given as:

$$V = \frac{I\rho}{4\pi r} \quad (3.3)$$

In practise we use four electrodes.

Where;

- r_1 is the distance between P_1 and C_1
- r_3 is the Distance between P_1 and C_2
- r_2 is the Distance between C_1 and P_2
- r_4 is the Distance between P_2 and C_2
- C_1 and C_2 are Current Electrodes
- P_1 and P_2 are Potential Electrodes

- The potential at P₁ due to current at C₁ is:

$$V_{11} = \frac{I\rho}{2\pi r_1}$$

The potential at P₁ due to current at C₂ is;

$$V_{12} = \frac{I\rho}{2\pi r_2}$$

The sum total of potential at P₁ due to current at C₁ and C₂ is;

$$V_{11,12} = \frac{I\rho}{2\pi r_1} + \frac{-I\rho}{2\pi r_2}$$

$$V_{11,12} = \frac{I\rho}{2\pi r_1} - \frac{I\rho}{2\pi r_2}$$

$$V_{11,12} = \frac{I\rho}{2\pi} \left[\frac{1}{r_1} - \frac{1}{r_2} \right] \quad (3.4)$$

Similarly,

Potential at P₂ due to current at C₁ is

$$V_{21} = \frac{I\rho}{2\pi r_3}$$

$$V_{22} = \frac{-I\rho}{2\pi r_4}$$

The sum total Potential of P₂ due to current at C₁ and C₂ is;

$$V_{21,22} = \frac{I\rho}{2\pi r_3} - \frac{I\rho}{2\pi r_4}$$

$$V_{21,22} = \frac{I\rho}{2\pi} \left[\frac{1}{r_3} - \frac{1}{r_4} \right] \quad (3.5)$$

But the potential difference ΔV between P₁ and P₂ can be obtained by subtracting equation (2.13) and (2.14)

$$\Delta V = V_{11,12} - V_{21,22}$$

$$\Delta V = \left[\frac{I\rho}{2\pi r_1} - \frac{I\rho}{2\pi r_2} \right] - \left[\frac{I\rho}{2\pi r_3} - \frac{I\rho}{2\pi r_4} \right]$$

$$\rho = \frac{2\pi V \Delta V}{I} \left[\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4} \right]^{-1} \quad (3.6)$$

Recall, from ohms law that $R = \Delta V / I$

Therefore, $\rho = GR$

Where G is the Geometric Factor

1.2 ELECTRODE ARRAY OR CONFIGURATION

This is the arrangement of the current and potential electrode in the electrical resistivity method. The commonly use configuration include Wenner, Schlumberger, Dipole-dipole, Pole-Pole and Pole-Dipole. The most used is the Wenner, Schlumberger and Dipole-Dipole.

1. Schlumberger Array

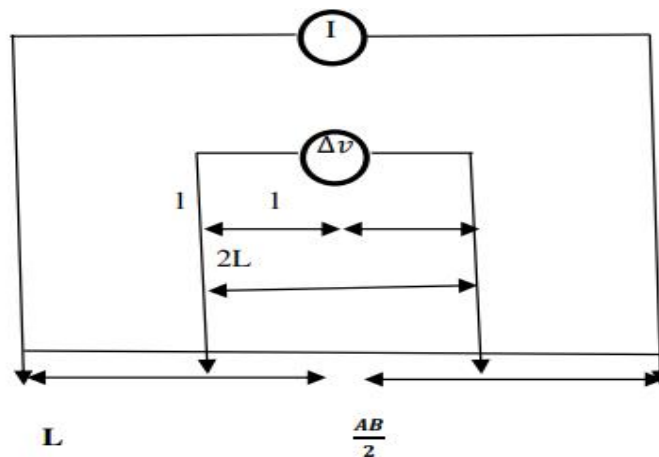


Figure 3 2: A diagrammatic representation of Schlumberger array.

Four electrodes are used and the measurements of apparent resistivity are made by increasing the distance between the current electrode while the potential electrode remain constant, such that the distance AB between the electrode is five times greater than or equal to the separation distance between the potential electrode MN. It is used to study the variation of resistivity with depth.

$$AM = L - I, AN = L + I, MB = L + I, NB = L - I$$

$$\rho = \frac{2\pi\nabla V}{I} \left[\frac{1}{AM} - \frac{1}{AN} - \frac{1}{MB} + \frac{1}{NB} \right]^{-1}$$

$$\rho = \frac{2\pi\nabla V}{I} \left[\frac{1}{L - I} - \frac{1}{L + I} - \frac{1}{L + I} + \frac{1}{L - I} \right]^{-1}$$

$$\rho = \frac{2\pi\nabla V}{I} \left(\frac{4I}{L^2} \right)^{-1} \quad (3.7)$$

For large values of L, it will be necessary to increase I, to maintain a measurable potential.

Usefulness of Schlumberger Array

- It requires less manpower since one person can operate the potential electrodes and at the same time take reading
- Field curves are generally smoother and steep free
- Laying of field equipment is relatively easy

2. Wenner Array

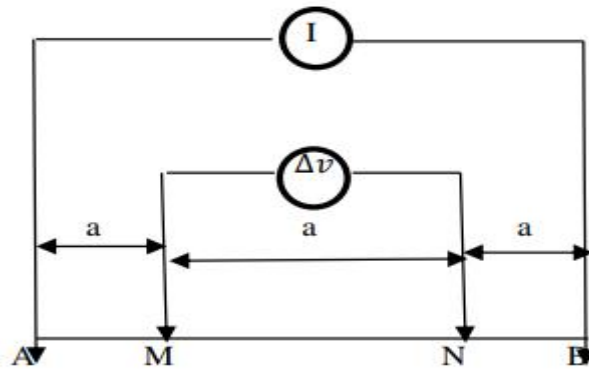


Figure 3 3: A diagrammatic representation of Wenner array

This is a collinear array in which all the four electrodes are arranged along a straight line with the potential electrode MN located between the two current electrode AB with equal inter electrode separation such that

$$AM = MN = NB = a$$

For the generalized resistivity equation, the apparent resistivity equation for wenner is

$$\rho = \frac{2\pi\nabla V}{I} \left[\frac{1}{a} - \frac{1}{2a} - \frac{1}{2a} + \frac{1}{a} \right]^{-1}$$

$$\rho = \frac{2\pi\nabla V}{I} \left(\frac{1}{a} \right)^{-1}$$

$$\rho = 2\pi r a \tag{3.8}$$

3. Dipole-Dipole

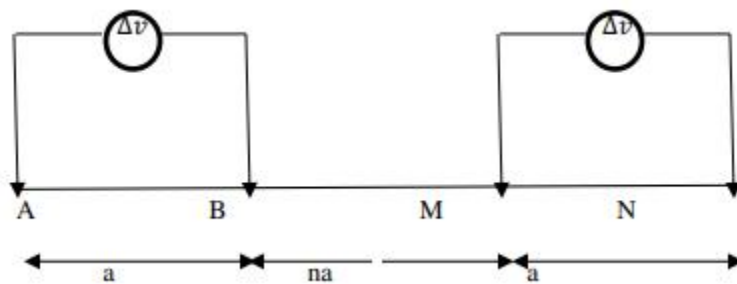


Figure 3 4: A diagrammatic representation of dipole-dipole array

This is also a collinear array in four electrodes. The electrodes are arranged in the order AB and MN having the same separation or the two dipoles are separated by a distance na where n is an expansion factor.

$$r_1 = a(n+1), \quad r_2 = na, \quad r_3 = a(n+2) \quad r_4 = a(n+1)$$

$$\rho = \frac{-\nabla V \pi n}{I} (n+1)(n+2)a \quad (3.9)$$

Where $(n)(n+1)(n+2)a$ is the geometric factor

1.3 FIELD SURVEY METHOD

The data for this project work was acquired using the PASI Earth Resistivity meter (Terrameter). The Wenner-Schlumberger hybrid array was employed. The results were used to create 2D images of sub-surface geology along a profile with RES2DINV software. Apparent resistivity results gathered by the 2D dc-resistivity equipment were processed to generate a model-section of subsurface resistivity that represents the true subsurface resistivity variation.

Wenner-Schlumberger configuration is a configuration with a constant system of spacing rules with a note of factor "n" as this configuration is the comparison of the distance between C_1 - P_1 (or C_2 - P_2) electrodes with spaces between P_1 - P_2 . If the distance between electrodes the potentials (P_1 and P_2) are :a" than the distance between the current electrode (C_1 and C_2) is $2na + a$. The resistivity determination process uses 4 electrodes placed in a straight line. This configuration is a combination of the Wenner configuration and Schlumberger configuration. In the measurement by the spacing factor $(n) = 1$, the Wenner-Schlumberger configuration is similar to the measurement in the Wenner configuration (distance between electrode = a), but on

the measurement with $n = 2$ and so on, the Wenner-Schlumberger configuration is the same as the Schlumberger configuration. The current electrode and the potential electrode are greater than the distance between the potential electrodes).

The 2D electrical resistivity study includes the utilization of PASI 16GL model Terrameter resistivity meter which is upheld by an outer battery (12 V, 60 Ah Battery), one Global Positioning System (GPS) for taking the directions of the investigation territory.

1.4 MEASUREMENT PROCEDURE

For Wenner-Schlumberger array configuration, the distance between the (C_1) and (P_1) is the same as the distance between (P_2) and (C_2). The geometric factor (K) for Wenner-Schlumberger equals $\pi a n(n + 1)$. Measurements commenced at one end of the traverse line with electrode spacing $a=10$ m at electrode positions 1, 2, 3 and 4. Next each electrode (C_1 , P_1 , P_2 and C_2) was shifted a distance of 10 m, the active electrode positions being 2, 3, 4 and 5. The minimum electrode spacing used was 10m (for data level $n=1$), while the maximum electrode spacing used was 60m (for data level $n=8$). The four electrodes are at equidistant for $n=1$ (Wenner array method) electrodes are in a straight line. For $n = 2, 3, 4\dots$ the distance between C_1 and P_1 increases and P_2 and C_2 increases respectively. While the distance between P_1 and P_2 remains constant for all measurement of n after $n = 1$

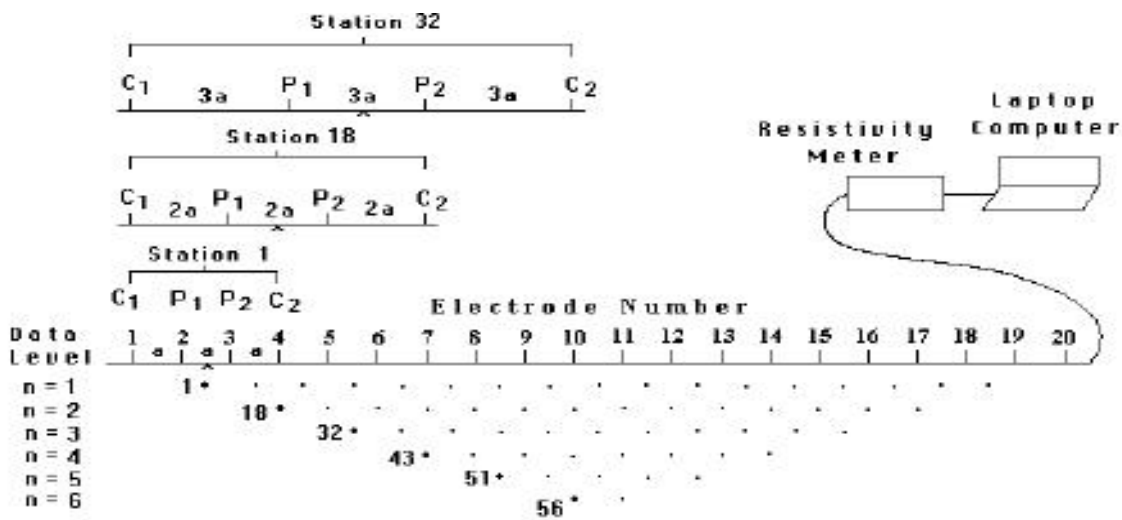


Figure 3 5: The arrangement of electrodes for a 2-D electrical survey and the sequence of measurements used to build up a pseudosection.

3.4.1 Field calculations

Field calculation of the Wenner Shlumberger geometric factor, Resistivity should be carried out using the field sheet. Calculations involve finding the average of measurements RD1 and RD2 multiplying by $\pi n (n+1) a$ ($a = \text{spacing}$). Plot values on log-log graph paper and draw a curve to fit the plotted points.

3.4.2 Need for calibration

- Reliability is improved by measuring soundings at points where a depth or material property is known e.g. Water table position, Freshwater lens thickness and Geology
- Interpreted resistivity values can be considered for similar soundings

3.5 INSTRUMENT



Figure 3 6: Terameter, electrode selector, multicore cables, clips, electrodes and battery.

1. Transmitters

High power and reliable constant current are the primary requirements. For small scale work, transmitters capable of sourcing up to several hundred milliwatts of power might be adequate. For larger scale work, it is possible to obtain transmitters that can source up to 30,000 watts. Current is usually injected as a 50% duty cycle reversing square wave; that is, current is on for several seconds, off for several seconds, on with reversed polarity, off, etc. Decay voltages in IP surveys (measured during a time domain transmitter's "off" stages) are often two orders of magnitude smaller than primary voltages. Therefore, very high-power transmitters are often desirable. For mineral exploration in conductive ground (where potentials will be small), it is possible to obtain transmitters capable of sourcing tens of kilowatts of power. Needless to say, these are rather dangerous systems, and definitely not portable! The figures below show several currently available transmitters.

2. Electrodes

In general, current injection and potential measurement electrodes are not interchangeable. However, automated acquisition systems using smaller source currents do employ the same stainless steel electrodes, both for sourcing current and measuring potentials. This becomes more and more difficult as source currents increase because the ground can become altered by high current densities. For injecting current, low impedance is required - i.e. good contact resistance is the primary concern. Stainless steel stakes, sheets of foil, wetted (and perhaps salted) ground, are all possible approaches to improving contact resistance. For measuring potentials, low noise, non-polarizing (not necessarily low impedance) electrodes are the primary concern. Small lead plates buried in the soil will often do the trick. In more difficult situations, wet electrodes made from porous ceramic jars containing copper sulfate solution are required. See Corwin, 1990 for a good discussion of electrodes for this type of galvanic work.

3. Cables

Ordinary insulated wire on reels (possibly on a back-pack) for easy handling are most common (figure to the right).

- For small scale work, some systems are available that use multiconductor cable, and possibly "smart" electrodes that can be switched between input and measurement functions by computer.
- For large scale work, this is not practical because of the large currents involved (up to a hundred Amps or so in some cases). Multiconductor cables with individual wires capable of carrying that current would be prohibitively heavy

for mineral exploration surveys, which commonly involve profile lines several kilometres long.

- However, there are some systems that use multiconductor seismic cable for the potentials while requiring the normal single, heavy gauge wire for the current source.

4. Measuring Tape

This is used to measure the length of spread of both the potential and current electrodes. It is calibrated in centimeter, meter and feet. In cases where the length of the spread is exhausted and there are still distances to be measured, measured distances on the ground can be marked and the remainder of the distance, measured

5. Hammer

This is used to hit the electrodes into the earth for greater penetration in areas of highly compacted soil structure.

6. Battery

This is used to power the terrameter. It is also the source of the current which is sent into the earth, from which the potential difference across the potential electrodes is measured.

7. Cutlass:

This is used in rough terrain. It is used to clear off weeds, grasses and all unwanted obstruction along the walk-way or on points disturbing the placement of electrodes.

8. Global Positioning System (GPS)

This is used to obtain knowledge of geographical location (longitude and latitude) of the survey area. It is very important, in that it tells us the elevation of the surface

layer with respect to the sea level. This is needed for accurate analysis of the position of subsurface anomalies.

3.6 FIELD PRECAUTIONS

When conducting electrical resistivity surveys in the field, some precautions to consider include:

1. Always wear appropriate safety gear such as rubber gloves, safety glasses, and insulated footwear to prevent electric shock.
2. Inspect the survey site for any potential hazards such as overhead power lines or underground utilities before starting the survey.
3. Ensure proper grounding of equipment to prevent electrical hazards and interference.
4. Avoid conducting surveys during thunderstorms or in wet conditions to minimize the risk of lightning strikes and equipment damage.
5. Regularly calibrate instruments to ensure accurate measurements and reliable data.
6. Ensure that all personnel involved in the survey are properly trained in electrical safety procedures and the operation of survey equipment.
7. Establish clear communication protocols and emergency procedures in case of accidents or electrical hazards.
8. Regularly inspect and maintain survey equipment to prevent malfunctions and ensure safe operation.

9. Obtain necessary permits and permissions before conducting surveys in sensitive or restricted areas.
10. Have appropriate first aid kits and emergency response plans in place in case of accidents or injuries.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESULTS

Utilizing an Earth resistivity metre, resistivity data was extracted from the subsurface following the survey utilising the Werner Schlumberger array setup. The transverse section's 2D resistivity profile was then created using the RES2DINVX64 programme. The profiles that were produced are shown below.

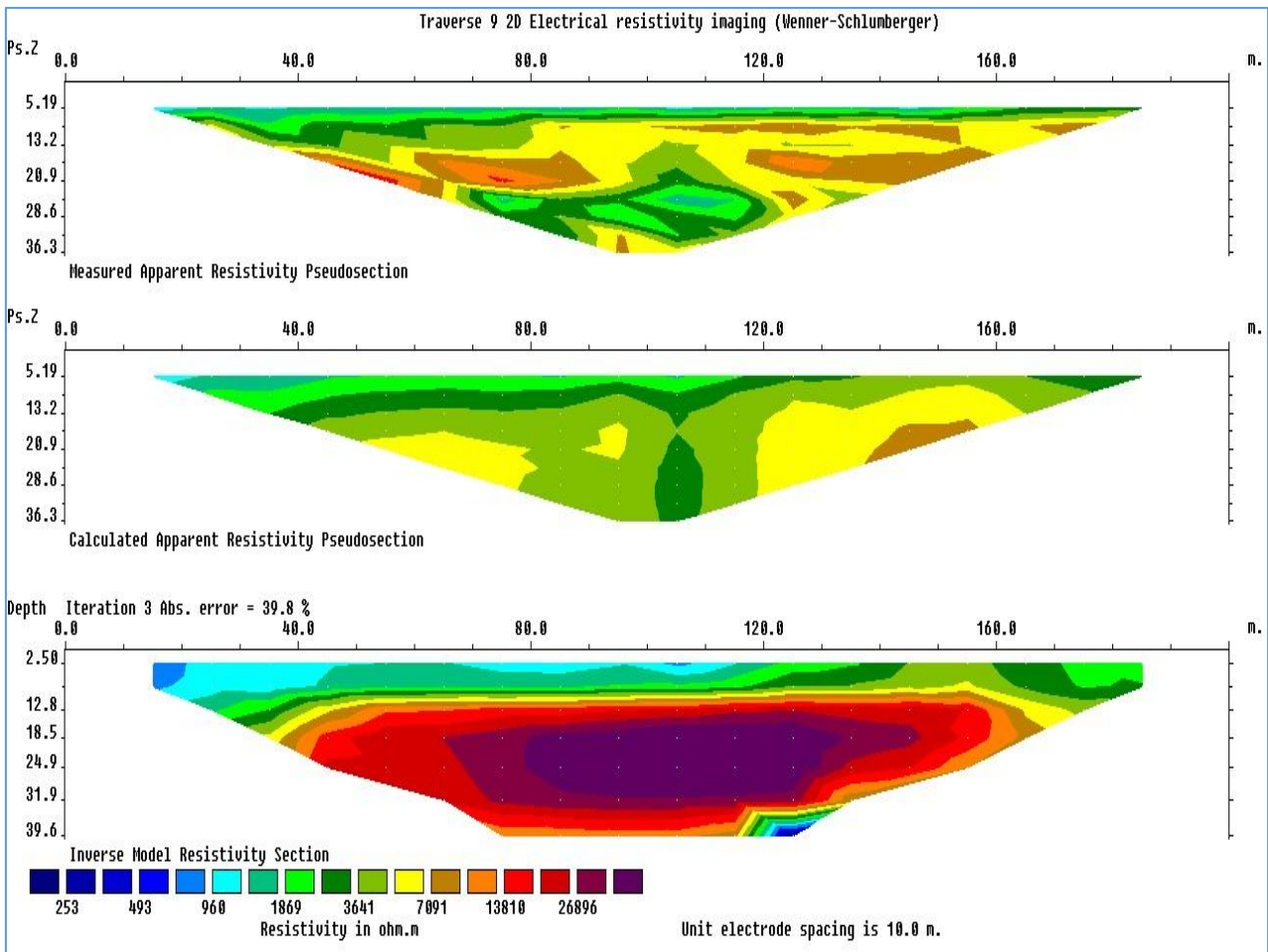


Figure 4 1: 2D Electrical Resistivity Imaging of the first profile.

The subsurface lithology characterization, which depicts the make-up of the rock and sediment layers at various depths, is shown in Figure 4.1.

From 0m to 2.50m, the profile indicates moderate to high resistivity values (253 Ω m - 7091 Ω m), suggesting the presence of alluvial deposits. These are typically loose sedimentary materials deposited by flowing water. Between 2.50m and 18.5m, the lithology is described as a mixture of different rock types, including alluvial, laterite, sandstone, and shale, with similar resistivity values. This suggests a heterogeneous layer with varied sedimentary and weathered rock formations.

From 18.5m to 39.6m, the profile reveals a distinct lithological composition characterized by very high resistivity values (13810 Ωm - 26896 Ωm). This indicates the presence of consolidated sandstone, shale, and other rocks. The high resistivity suggests the presence of denser and more consolidated materials, possibly forming a cave-like structure, with minor quantities of clay interspersed within the rock matrix. Overall, the profile depicts a layered subsurface structure with varying lithological formations, ranging from loose alluvial deposits near the surface to more consolidated rock formations at greater depths, potentially indicating complex geological processes and environments.

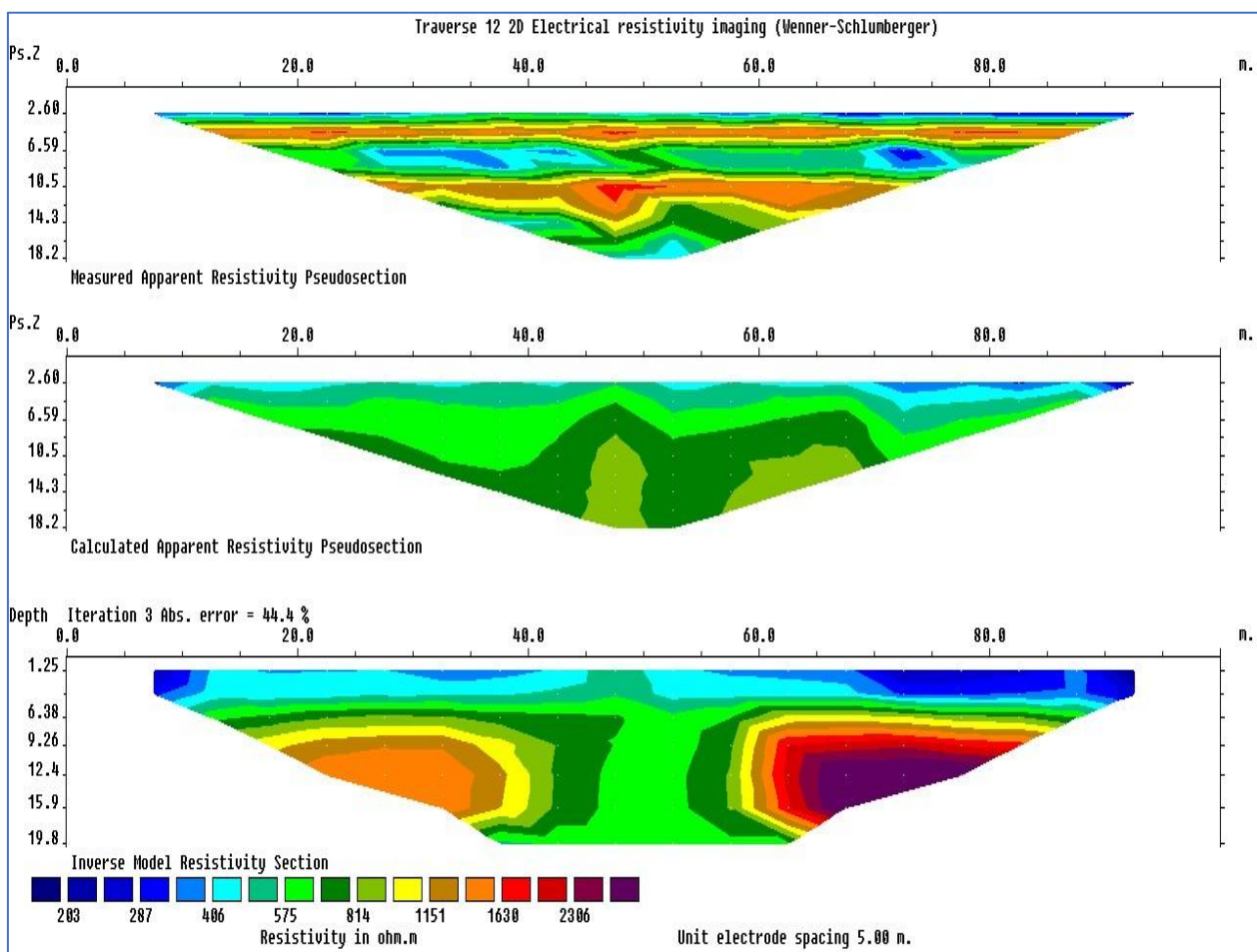


Figure 4 2: 2D Electrical Resistivity Imaging of the second Profile.

The subsurface lithology characterization of the profile in figure 4.2 reveals a stratified composition with varying lithological formations across different depth intervals. Moderate to high resistivity values are consistently observed throughout the profile, indicating the presence of potentially alluvial and laterite deposits in the uppermost layers (0m - 1.25m and 1.25m - 9.26m). In the deeper layers (9.26m - 15.9m), high resistivity values suggest the presence of unconsolidated sandstone, shale, and clayey sand. Overall, the profile exhibits a diverse lithological composition, including alluvial, laterite, and unconsolidated sandstone, shale, and clayey sand at different depths.

CHAPTER FIVE

FINDINGS, CONCLUSION AND SUGGESTION TO FURTHER STUDY

5.1 FINDINGS

1. 2D ERT surveys at the University of Benin Teaching Hospital revealed varying resistivities: moderate to high (253 - 7091 Ωm) in the upper 0 - 2.50 m layers suggested alluvial deposits.
2. Intermediate layers (2.50m - 18.5m) showed mixed rock types with similar resistivities, while deeper layers (18.5m - 39.6m) with high resistivities (13810 Ωm - 26896 Ωm) indicated consolidated sandstone, shale, and possible cave formations.

5.2 CONCLUSION

The 2D Electrical Resistivity Tomography (ERT) surveys conducted at the University of Benin Teaching Hospital and its environs have provided substantial insights into the subsurface lithological structure. This research has successfully delineated the varying lithological formations at different depths, contributing significantly to the geological and environmental understanding of the area.

The findings from the ERT surveys indicated the presence of alluvial deposits characterized by moderate to high resistivity values in the shallow subsurface (0m - 2.50m). These deposits are likely the result of sedimentation by flowing water, typical of the alluvial environments. As the depth increases to between 2.50m and 18.5m, the subsurface shows a mixture of different rock types including alluvial materials, laterite, sandstone, and shale, suggesting a complex interplay of sedimentary and weathered rock formations. This heterogeneity is crucial for understanding soil stability and groundwater flow within these layers.

Deeper subsurface layers from 18.5m to 39.6m displayed very high resistivity values, indicative of consolidated rock formations such as sandstone and shale, which may incorporate denser and more consolidated materials, possibly forming cave-like structures with minor clay intrusions. This suggests a significant geological transition, potentially relevant for advanced geological studies and engineering applications, including construction and resource extraction.

Overall, the application of 2D ERT at the University of Benin Teaching Hospital has revealed a detailed stratigraphy that enhances our understanding of the subsurface lithology. This information is invaluable for future environmental assessments,

geological research, and practical applications in engineering and resource management. The project successfully meets its objectives by not only mapping the subsurface but also by providing a model that reflects the complex lithological diversity of the study area.

5.3 SUGGESTIONS FOR FURTHER STUDIES

1. Conduct detailed geological mapping and core drilling to validate the lithological interpretations obtained from the ERT surveys.
2. Investigate the hydrogeological implications of the identified lithological formations, particularly regarding groundwater flow patterns and aquifer characteristics.
3. Extend the study area to encompass surrounding regions for a more comprehensive understanding of the subsurface geology and lithological variability.

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