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TWO – DIMENSIONAL ELECTRICAL RESISTIVITY SURVEY FOR DETECTION OF ANCIENT BURIED STREAMS IN JESSE TOWN, DELTA STATE, NIGERIA.

***[1]Avwenaghegha, O. J., [2]Ekone, N. O., [1]Anthony, P. O. and [1]Malumi, S. O.**

[1]*Department of Physics, Southern Delta University, Ozoro, Delta State, Nigeria.*
[2]*Department of Geology, Southern Delta University, Ozoro, Delta State, Nigeria.*

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ABSTRACT

A 2D electrical resistivity survey using the Wenner-Schlumberger array was conducted at four sites in Jesse town, Delta State, Nigeria. The goal was to identify potential subsurface features, like an ancient buried stream, linked to ongoing road pavement failures. Data collected with a Petro Zenith Earth Resistivity meter were processed using RES2DINV software. Results revealed low-resistivity anomalies in Locations 1 and 2, interpreted as possible fractures or a buried paleochannel. Specifically, anomalies at ~45m and 60m in Location 1 and around 50m in Location 2 suggest zones where water inflow could weather the underlying laterite, contributing to pavement failure. These interpretations are preliminary and require validation through drilling or hydrogeological investigation to confirm the causes of the anomalies

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1. INTRODUCTION

Ancient buried streams (also known as Paleochannels or buried valleys) are terms used to describe previous river systems that existed several years ago [1]. In other words, ancient buried streams, are former waterways which have now been concealed by soil, buildings, roads, as a result of urban development. Although buried streams are not visible, they continue to function beneath the surface and can pose significant challenges to road and building infrastructure, as well as the surrounding environment. Buried streams play a key function in shaping the landscape especially during the Pleistocene Epoch, during which time glacial activity was predominant in different parts of the world [2]. Generally, ancient streams are formed as a result of the natural evolution and movement of river channels over geologic time.

*Corresponding author: AVWENAGHEGHA, O. J.
E-mail address: oghenenyorejude@gmail.com
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These processes happen due to changes in climate, tectonic activity, fluctuations in the sea level and so on. Abandoning a stream can make it become buried by sediments from overbank flooding, aeolian processes or glacial till. The sediment layers protect and preserve these features, making them time capsules of past hydrologic activity [3].

Ancient buried streams in Nigeria were formed essentially during the late Pleistocene to Holocene epochs when the climate was significantly wetter than today. During these wetter periods, rivers flowed actively across what are now arid or semi-arid regions. Over the course of time, as the climate moved toward aridity (especially during the Holocene aridification – about 5,000 years ago) many of these rivers have dried up. Their courses were afterwards buried under layers of aeolian (wind-blown) sands and alluvial deposits [4].

Buried stream channels are extremely useful in recreating the geological and climatic history of a region. Their stratigraphy and associated fossil records can divulge ancient ecosystems and weathering patterns. Also, investigating these channels enable geologists to comprehend fluvial dynamics, like river meandering, sediment transport, and channel migration over time. These channels usually contain coarse sediments such as gravel and sand, which are quite different from the surrounding finer sediments. The difference in material composition helps identify paleochannels via drilling and geophysical methods [5].

Buried streams can sabotage the stability of roads and highways, since water will continue to flow underneath the surface, it can diminish the soil gradually and generate voids below the road pavement structures [6]. After a period, this could lead to the deterioration of roadbeds, giving rise to sagging, cracking and in more severe cases, unexpected collapses or sinkholes. In most developing cities with deteriorating infrastructures, the channels or pipes that transmit these streams can corrode, break open, or become blocked with debris, thereby enhancing the possibility of road failure.

Furthermore, the cost of rehabilitation and maintenance of roads built over buried streams are quite exorbitant. Government may need to fortify foundations, redirect traffic during such repairs, and also invest in regular monitoring to identify likely subsurface movement.

Despite these challenges, buried streams are essential for groundwater resource development in Northern Nigeria for example. This is because these paleochannels often consist of coarse-grained materials such as sands and gravels. They serve as effective aquifers, holding large volumes of groundwater. In actual fact, many rural water supply projects in the arid zones of Nigeria rely on identifying these paleochannels for borehole drilling [7].

Moreso, understanding the distribution of buried streams helps in reconstructing paleoclimatic conditions. These findings confirm that regions now classified as deserts once experienced much wetter climates, supporting complex ecosystems and even early human settlements.

During environmental planning, investigating buried stream channels can help in preventing excessive-extraction of groundwater, control contamination risks, and plan continued land use practices. Buried stream channels can also serve as pathways for contaminant transport, particularly if linked to surface water or shallow aquifers

In Nigeria, one major area with buried streams which have been mostly studied is the Chad Basin in Northeastern Nigeria. Hitherto, this basin supported an extensive river network, including contributions from ancient rivers such as the paleo-Komadugu and paleo-Yobe. Also, satellite imagery, geophysical surveys, and borehole data have revealed the presence of ancient stream channels underneath the desert sands of Borno and Yobe States [8]. Similarly, in the Sokoto Basin (Northwestern Nigeria), ancient stream networks have been discovered beneath thick layers of sediment. These buried channels are remnants of ancient river systems that transported sediments during periods of enhanced monsoonal rainfall [9].

Identifying and studying ancient buried streams demands a multidisciplinary approach. Conventional fieldwork is usually accompanied with more sophisticated technologies, such as: Ground-penetrating radar (GPR), Seismic reflection techniques, Electrical resistivity imaging (ERI), Remote sensing and satellite imagery. In particular, Electrical Resistivity Tomography (ERT) and Ground Penetrating Radar (GPR)—have been significantly used in mapping subsurface structures [4]. In addition, sedimentological studies and borehole data have confirmed the presence of channel deposits at various depths.

The application of geophysics in investigating possible causes of road failure has gained increasing relevance in recent years. A notable example is the study by Avwenaghegha et al. [10], which involved a geophysical investigation of pavement failure along the new Eku Road, Sapele, Delta State, Southern Nigeria. Their results revealed low resistivity values, characteristic of expansive clay and clayey materials, at various segments along the surveyed profiles—suggesting a link between these materials and road instability.

Geophysical methods have also been applied to detect ancient river systems buried beneath modern desert surfaces, transforming the understanding of Africa's climatic history. When integrated with archaeology and paleoclimatology, studies of buried streams can offer insights into how ancient civilizations adapted to shifting water resources.

Among the geophysical methods used in urban archaeological investigations, **Ground Penetrating Radar (GPR)** [11], [12], **magnetic techniques** [13], and **Electrical Resistivity Tomography (ERT)** [14] are most commonly employed. These techniques are used to identify features such as walls, cavities, and foundations. In many cases, combining multiple methods improves reliability in interpreting these complex subsurface environments.

For instance, **Negri and Leucci** [11] combined 2D ERT to study walls and cavities beneath an ancient temple with 3D GPR imaging to detect modern man-made structures. Similarly, **Drahor et al.** [15] applied magnetic gradiometry, GPR, and ERT to characterize subsurface features and assess structural damage beneath a church floor.

Although techniques such as seismic and microgravity are less commonly used because of challenges in acquiring data in urban environments [16], [17], they can still provide valuable subsurface information. Detecting tunnels, especially in urban settings, remains challenging. Methods such as GPR, gravity, ERT, electromagnetic induction (EMI), and seismic surveys have all been employed with varying success. Their effectiveness depends on factors like soil properties, contrast between tunnel materials and surrounding media, tunnel depth and preservation, and surface environmental conditions [18].

In this study, the two dimensional (2D) electrical resistivity tomography (ERT) was conducted in Jesse Town, Ethiope West Local Government Area, Delta State, Southern Nigeria, to determine the possible presence of ancient buried streams in the location, which might be the cause of incessant road pavement failure in the study location.

Statement of the Problem

Recurring road pavement failures such as sagging, cracking, and partial collapse have been reported in Jesse Town, Ethiope West Local Government Area, Delta State despite repeated rehabilitation efforts. Preliminary observations and existing literature suggest that these failures may be associated with ancient buried stream channels beneath the affected areas. To date, however, no comprehensive geophysical investigation has been conducted to validate this hypothesis. A thorough understanding of the subsurface conditions is crucial for devising sustainable strategies for road construction and maintenance in the region.

Objectives

To investigate the subsurface conditions in Jesse town using electrical resistivity tomography (ERT) in order to identify the possible presence of ancient buried stream channels and assess their impact on road pavement stability.

The specific objectives of this study are to:

1. Carry out two-dimensional (2D) Electrical Resistivity Tomography (ERT) surveys in selected areas of Jesse Town to investigate subsurface conditions;
2. Identify and interpret buried stream channels or paleochannel structures from the resistivity data, and correlate these features with observed road pavement failures;
3. Evaluate the implications of the identified subsurface features for road stability and provide recommendations to improve road construction and maintenance.

Location of the Study Area

Different profile lengths were investigated in failed portions of selected paved roads which exist within Jesse Town, Ethiope West Local Government Area, Delta State, Southern Nigeria. During the period of this research, the above roads were experiencing some massive cracks, potholes, rippling, depressions etc. which has led to the overall failure or collapse of the roads. The selected roads (profiles) for this research are as follows:

PROFILE 1: **EFEMINI ROAD, JESSE**
Latitude: 05.749.06^{0}N **Longitude: 05.869.09^{0}E** **Average Elevation: 13.2.m**

Plate 1: Photo shot of part of Efemini Road, Jesse town where profile 1 was taken

PROFILE 2: **OLYMPIA ROAD, JESSE**
Latitude: 05.766.66^{0}N **Longitude: 05.851.18^{0}E** **Average Elevation: 15.1m**

Plate 2: Photo shot of part of Olympia Road, Jesse where profile 2 was taken

PROFILE 3: MARKET ROAD, JESSE
Latitude: $05.719.08^0$N Longitude: $05.673.43^0$E Average Elevation: 12.7m

Plate 3: Photo shot of part of Market Road, Jesse where profile 3 was taken

PROFILE 4: GARAGE ROAD, JESSE
Latitude: $05.726.08^0$N Longitude: $05.688.41^0$E Average Elevation: 11.9m

Plate 4: Photo shot of part of Garage Road, Jesse town where profile 4 was taken

Figure 1 is a map of Nigeria and highlighted in red circle is the state (Delta State) in which the study area is located. Also, figure 2 is a map of Delta state highlighting the local government area of the study location. Figure 3 is a Google earth map showing the study area (Idjerhe kingdom), which is now popularly called Jesse kingdom. The various latitudes and Longitudes of the different profiles surveyed are given in the results section.

Figure 1: A map of Nigeria showing the location of Delta State

Figure 2: A map of Delta State showing the various Local Governments.

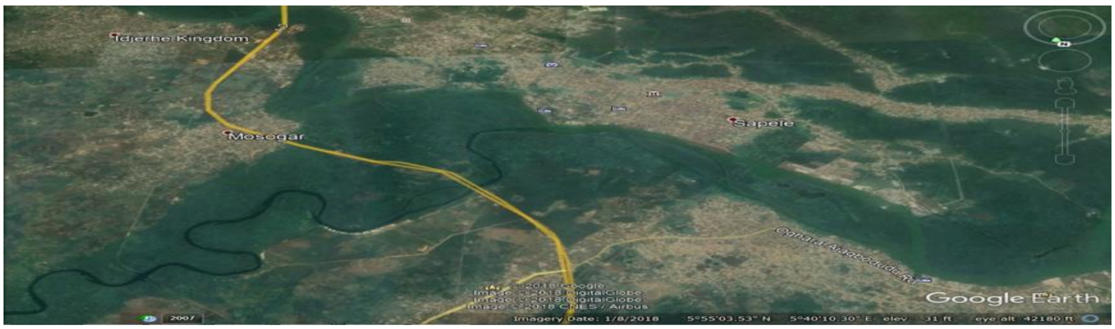


Figure 3: Google Earth Map showing the study Area

MATERIALS AND METHODS

Study Area and Field Design

Field experiments for this study was conducted in Delta state in Jesse town which is located in Ethiope West Local Government area of the state. Each field experiments were undertaken on the site and used a special method to address a particular condition and goal of each field experiments. The geophysical investigation technique employed was the 2D (two – dimensional) electrical resistivity imaging applying a combination of the Wenner and Schlumberger arrays (otherwise called the Wenner – Schlumberger array). This array was used for acquiring the resistivity data because it is partly and to an acceptable level, responds to horizontal and vertical structures. The minimum electrode spacing used for each of the profile was 5 metres (5 m). Each profile was aligned as closely as possible to a straight line._In all, a total of 4 profiles were surveyed with varying lengths for each profile parallel to the failed sections of the paved roads.

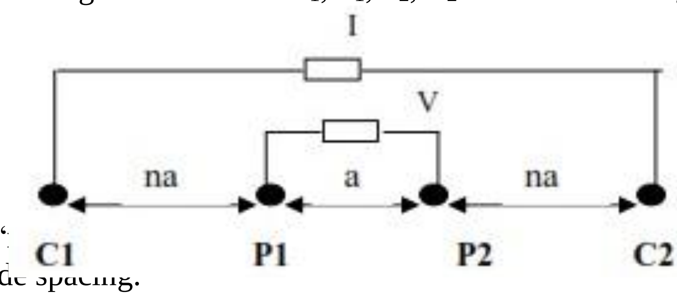
Field Equipment

The geophysical field survey was conducted using a standard suite of electrical resistivity equipment. The primary instrument used for data acquisition was the Petro–Zenith Earth Resistivity Meter. This was complemented by a set of stainless steel electrodes, cable reels, and crocodile clips for making secure electrical connections during measurements. Additional accessories included a hammer for field preparation, measuring tapes for layout accuracy, and a handheld Global Positioning System (GPS) device for spatial referencing. Field observations and measurements were recorded manually using writing pads before digital processing. All equipment used in the field survey met standard geophysical survey requirements and ensured reliable data acquisition under prevailing site conditions.

Data Acquisition / Field Procedure

In a typical resistivity survey (as was the case in this particular field work), the major task is in setting and arranging the electrodes and cables. Once completed, the readings are acquired from

the resistivity meter and stored either in a data sheet or directly on a computer. At least five persons were used for the fieldwork. The first four were each needed to monitor and control the four electrodes alongside its cable, while the fifth person operated and handled the recording equipment, thus completing the five-man data collection crew for this survey.
The Wenner – Schlumberger configuration has a spacing rule which is constant with a factor "n" and the electrodes arranged in the order C_1, P_1, P_2, C_2 as indicated in figure 4.



…iguration electrode

In this array, the "… $-C_2$) electrode spacing to the P_1-P_2 electrode spacing.

Firstly, a series of measurements was taken throughout the profile length with the electrodes equally spaced at an interval of **a** = 5m and the spacing factor **n** = 1. After completing this sequence of measurements, subsequent measurements were taken in the same pattern and procedure as the first, but in each case, the spacing between C_1-P_1 and P_2-C_2 was increased to 2**a**, 3**a**, 4**a**, and so on while the spacing between P_1-P_2 remained constant at **a** = 5m (that is, n = 2 for the 2nd series of measurements, n = 3 for the 3rd series of measurements and so on). A schematic representation of this procedure is depicted in figure 5.

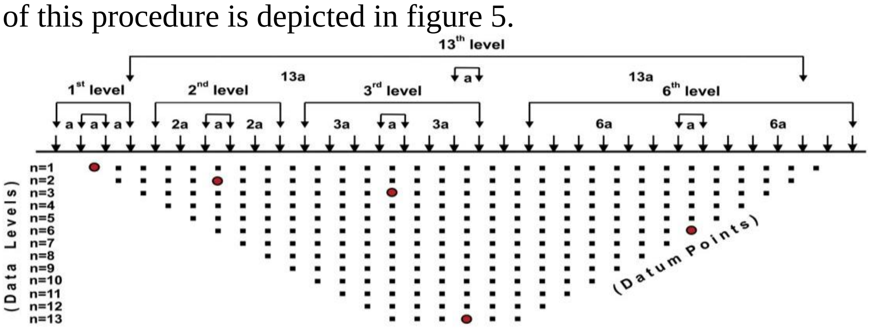


Figure 5: A conventional representation of the Wenner – Schlumberger array with electrode configuration and datum points

The Wenner - Schlumberger configuration described above is simply an amalgamation of Wenner and Schlumberger arrays. During the measurements, when n = 1, the configuration is just like the Wenner array, but for n = 2 and greater, it becomes similar to the Schlumberger configuration. That is, C_1-P_1 (or P_2-C_2) distance is more than the P_1-P_2 distance.

From the several measurements taken, it was then possible to generate a series of data which were recorded in a data sheet or writing pad and thereafter inputted into a computer for computerized inversion with the Res2Dinv software. After data processing, interpretation of data was performed by correlating the data processing with basic knowledge of apparent resistivity of rocks and minerals and geological conditions of the study area.

RESULTS

The results obtained from the field work (the processed result are presented as pseudo-sections, providing an approximately depiction of the subsurface characteristics). The images as well as the apparent resistivity range obtained were used for a detailed exposition and analysis of the different profiles.

Profile 1

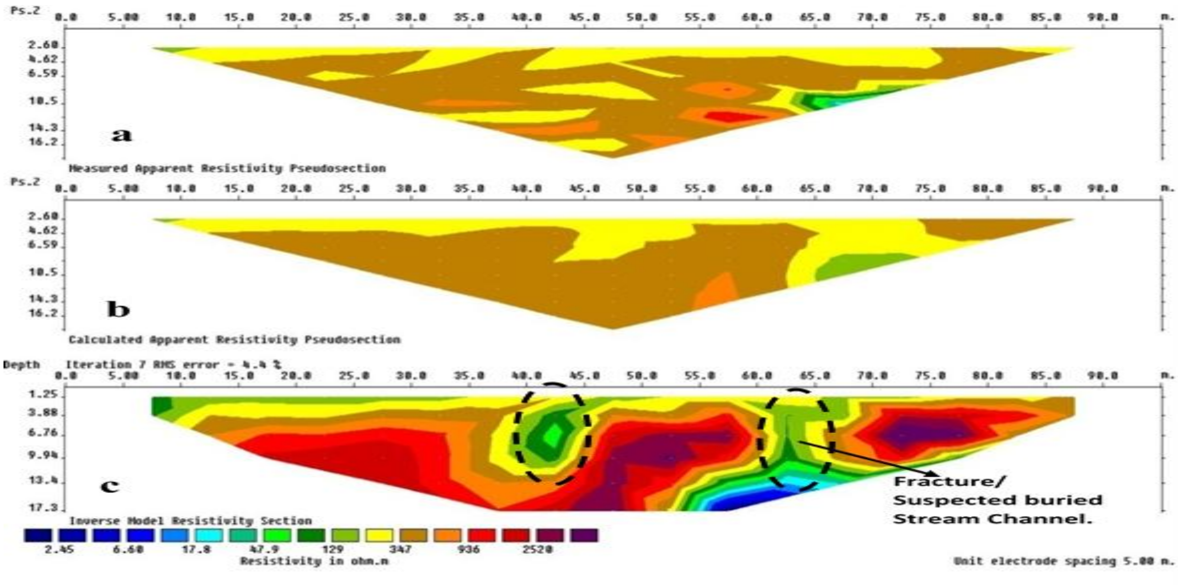


Figure 6: Pseudo-section plots of apparent resistivity data for profile 1 showing

(a) Measured apparent resistivity of profile 1
(b) Calculated apparent resistivity of profile 1
(c) Inverse model resistivity section of profile 1

Profile 2

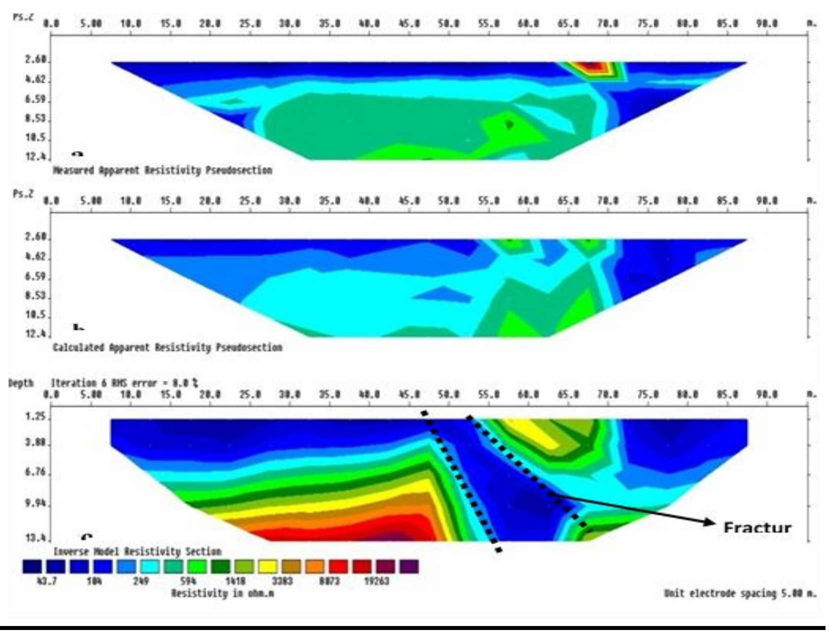


Figure 7: Pseudo-section plots of apparent resistivity data for profile 2 showing
(a) Measured apparent resistivity of profile 2
(b) Calculated apparent resistivity of profile 2
(c) Inverse model resistivity section of profile 2

Profile 3

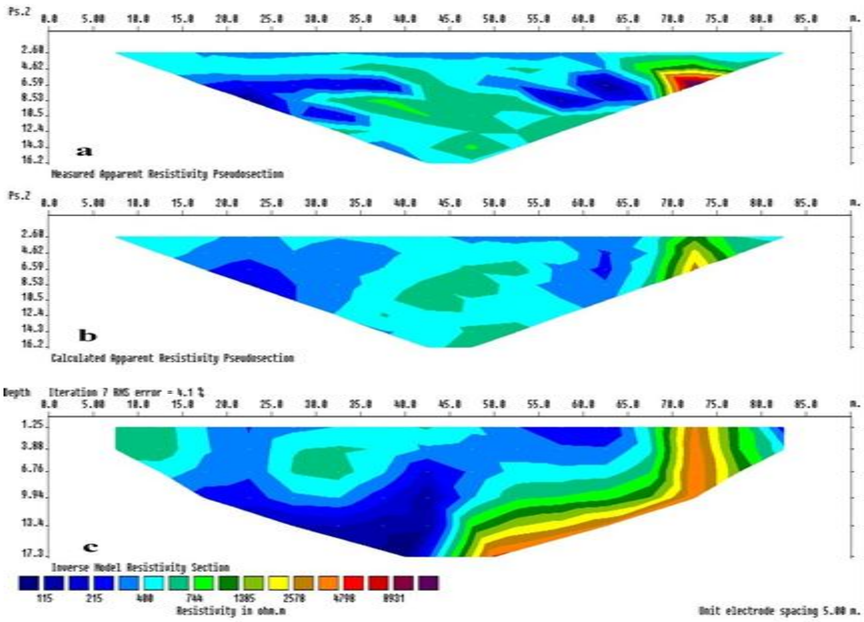


Figure 8: Pseudo-section plots of apparent resistivity data for profile 3 showing

(a) Measured apparent resistivity of profile 3
(b) Calculated apparent resistivity of profile 3
(c) Inverse model resistivity section of profile 3

Profile 4

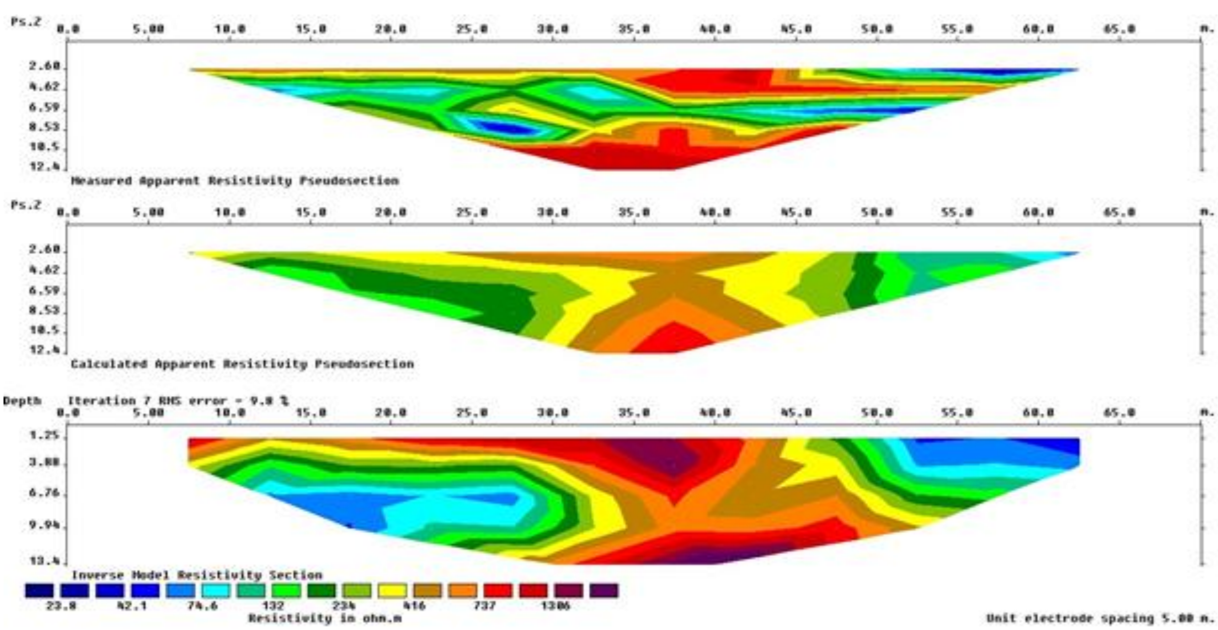


Figure 9: Pseudo-section plots of apparent resistivity data for profile 4 showing

(a) Measured apparent resistivity of profile 4
(b) Calculated apparent resistivity of profile 4
(c) Inverse model resistivity section of profile 4

Table 1: Apparent resistivity range and lithology variations for distinctive zones across geologic sections using the inverse resistivity section for the various profiles.

Profile Number	Location	Resistivity Range (Ωm)	Depth (m)	Profile Length (m)	Inferred Lithology
1	EFEMINI ROAD, JESSE	2.45 – 120	12.0 – 17.3	55.0 – 67.0	Clay, water, sand
		347 - 2520	1.25 – 9.94	70.0 – 85.0	Laterite and Sandstone
2	OLYMPIA ROAD, JESSE	43.7 – 200	1.25 – 6.76	7.0 – 45.0 70.0 – 87.0	Clay
		8073 - 20000	12.0 – 13.4	20.0 – 45.0	Laterite/ Sandstone
3	MARKET ROAD, JESSE	115 – 215	9.94 – 17.3	15.0 - 45.0	Clayey soil
			1.25 – 3.00	54.0 – 64.0	
		744 - 4000	1.25 – 9.94	63.0 – 78.0	Sandstone, Silt Sand, Shale
4	GARAGE ROAD, JESSE	23.8 – 120	1.25 – 5.00	50.0 – 63.0	Clay
		737 - 1400	1.25 – 5.00	20.0 – 42.0	Laterite/Sandstone

DISCUSSION

PROFILE 1: This profile shows a much different result from the others. The Road pavement has been completely washed off as seen in plate 1. After the investigation and interpretation of the geologic model shown in figure 6 (c), it was determined that the top soil is lateritic with relatively high resistivity values ranging from approximately 300 Ωm to 2520 Ωm. However, at distances 45 m and 60 m along the profile length, there is a fracture or possibly a buried ancient stream channel which reveals a region of low resistivity where there is possible inflow or percolation of water into the soil thereby gradually causing weathering of the lateritic layer.

PROFILE 2: Figure 7(c) displays the inverse resistivity model for this profile, which extends about 85 m in length and reaches a penetration depth of 13.4 m. In this profile, the top soil consists of low resistive material of low resistivity values ranging from about 43 Ωm – 200 Ωm which stretches almost across the profile length and underlain by high resistive rocks whose values ranges from 1500 Ωm to about 20000 Ωm. Also, a fracture is seen at about the 50 m mark of the profile length. The low resistivity zone could be classified as clayey soil with low permeability.

PROFILE 3: Figure 8(c) presents the resistivity section for Profile 3, which spans from 100 m in length to 17.3 m in depth. In this profile, a top weathered layer of low resistivity earth materials with values ranging from 115 Ωm – 215 Ωm was noticed at an approximate depth between about 9.94 m − 17.3 m spanning a length of 15 m – 45 m the profile. This low resistivity values were also observed at distances between 54 m – 64 m to a depth of around 3.00 m below the top soil. This depicts signatures of sandstone, clay and sandy clay. This is underlain by competent bedrock of high resistivity above 9000 Ωm from the southern side of the survey and spans all the way to the top at the 70 m mark of the profile.

PROFILE 4: The resistivity section of Profile 4 is depicted in Figure 9(c). In this profile, it was observed that there exists a thin top region of high resistive soil with resistivity values in a range of 700Ωm to about 2000Ωm which stretches about 80% of the total length of the profile probably from surface fill during construction of the road. It further stretches downwards to the base at distances between 35 m – 48 m along the profile length. However, there are patches of low resistivity soil with values ranging from 23.8 Ωm – 120 Ωm just below this top layer from about 4m to 10m in depth. Also, at a distance between 50 m – 63 m, this low resistivity values were observed to a depth around 5.00 m below the top surface soil. This is suspected to be clay/clayey soil. This profile shows that this particular area does not have enough competence to sustain heavy vehicular movement and could eventually lead to failure as seen on the sections along this road

CONCLUSION

A geophysical investigation involving the Wenner - Schlumberger electrical resistivity tomography (Imaging) has been carried out in selected roads in Jesse town, Delta State, Southern Nigeria, so as to ascertain the presence of buried ancient streams in relation to the incessant road pavement failures in the study area.

The study has shown and re-validated the fact that Electrical resistivity tomography (or Imaging) is a very significant tool for the investigation of road, buildings and other engineering structures, as well as fractures and ancient buried streams.

The results reveal the presence of a possible buried stream or fracture in locations 1 and 2. At location 2, a fracture appears near the 50 m mark along the survey length. In location 1, fractures or possible buried ancient stream channels are present at 45 m and 60 m, indicated by low resistivity zones that suggest water infiltration and gradual weathering of the lateritic layer.

This investigation has therefore revealed the presence of clayey soil below the road pavements, as well as the presence of geological features such as faults, fractures, ancient buried streams which may have contributed immensely to the road failures in the study area. Appropriate drilling work needs to be carried out on the affected locations to ascertain the cause(s) of these anomalies. Also, proper remediation must be carried out before further construction are done in the surveyed locations.

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