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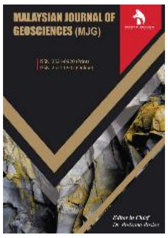

RESEARCH ARTICLE

APPLICATION OF ELECTRICAL RESISTIVITY TOMOGRAPHY IN ENGINEERING SITE CHARACTERIZATION: A CASE STUDY OF IGARRA, AKOKO EDO, SOUTHWESTERN NIGERIA

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ABSTRACT

To better understand the subsurface geological composition (relief, fault, fracture, discontinuities, orientation of structures) of the surrounding environment that anticipates infrastructural development in the near future due to population explosion, an Electrical Resistivity Tomography (ERT) survey was conducted in Igarra, Akoko Edo area of Edo state, Nigeria. The depth to bedrock, possible geologic structures (faults, fractures, voids) were some of the properties investigated. To determine the orientation and continuity of the underlying geological features, 2D resistivity surveys were conducted along three parallel traverses (S-N orientation) with a total length of 205m and an inter-traverse spacing of 50m. The ERT results demonstrate that there are constant areas of low resistivity along the three traverses. Stations between 70 m - 90 m and 110 m - 150 m revealed low resistivity values, indicating possible geological structure. As seen in the resistivity pseudo-section, competent beds can be found at around 5 m and about 10 m in some stations (70 – 90 m and 110 – 150 m). It is generally accepted that geological features (fault, fracture) that pose a risk to geotechnical and engineering projects can be found in the regions with low resistivity. According to the research, pervasive underground geological structures are to blame for most road failures. Since electrical resistivity tomography is useful in describing an engineering site, further geophysical investigation for hydrogeological objectives should be undertaken on the identified faulted and fractured zones to establish its hydrologic importance and reserved for such.

KEYWORDS

Electrical Resistivity Tomography, Resistivity, Site Characterization, Geologic Structure, Dipole-Dipole

1. INTRODUCTION

In the last three decades, the application of geophysics in engineering site characterization has gained more prominence. Although in the early days of construction up to recent years the fundamentals of engineering site characterization or evaluation only adopts the general geotechnical test approach. Geotechnical engineering as a branch of civil engineering evaluates the behavior of earth under stress by adopting the principles of soil and rock mechanics, while it thrives on the knowledge of geology, hydrology and geophysics. As a ground truth, reliable and proven method, the application of geo-techniques in engineering site characterization extends to the military, mining engineering, petroleum engineering, coastal engineering and offshore construction. Some of the methods; California bearing ratio (CBR), cone penetration test (CPT), standard penetration test (SPT), atterberg limit test, liquid limit test, plasticity index test, American Association of State Highway and Transportation Officials test (AASHO) basically provide point information which does not provide quantitative information about a large subsurface environment. Such point information based on the density or interval/frequency of sampling could miss out on vital subsurface structures such as presence of cavity, faults, fractures and other buried artifacts which could negatively impact the engineering structure erected on such area of land leading to several degrees of social and economic losses including loss of lives.

The main purpose in the design of geotechnical engineering is to define the shear strength and settlement of the soil through methods of analysis for deformed soil, as well as the flow that fluids follow in structures that are either supported or made of soil, or even structures buried into the soil (Philotheos et al., 2021). Due to the varying moisture levels, the soil's characteristics can change from season to season. All loads from structures must be securely transferred to the ground. Therefore, it is important to accurately assess the soil's safe bearing capacity. Geotechnical engineering includes various studies required for the development of pavements, tunnels, earthen dams, canals, and earth retaining structures in addition to determining safe bearing capacity for building foundations. It includes investigating ground-improvement techniques as well. This area of civil engineering is crucial because the stability of every structure depends on how safely loads are transferred to the ground. However, despite all these relevance of geotechnical engineering, the method is highly expensive, limited to obtaining point information and could not account for large area at once, hence a need for geophysical method in electrical resistivity tomography.

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Geophysical methods including ERT are rapid, less expensive, and non-invasive methods that provides insight to subsurface geology and configuration once the methodology is rightly chosen (Falade et al., 2019). According to Asem et al., (2018), the presence of natural and man-made structures on engineering construction sites, such as pipes and sinkholes, causes serious geotechnical and geo-environmental issues. Tomography investigation of the earth's subsurface at sites designated for construction engineering has drawn the attention of experts because, near-surface structures, cavities, sink holes, voids, fractures, faults among others and/or in-homogeneities in the foundation geo-materials pose major risk to civil engineering structures. Geophysics, therefore, had been used extensively including prediction of earthquakes, also geophysical techniques have been applied to structural engineering problems and they now form a significant component of non-destructive testing (NDT) (McDowell et al., 2002).

The purpose of the resistivity method therefore is to detect underground inhomogeneities and interpret them as modifications in underground materials or structures (Amin and Hamidreza, 2016). Sirwa et al., (2013), integrated 2D (ERT) method and boreholes data to determine the subsurface geological deficiencies that could endanger engineering construction. Some researchers used Electrical resistivity method (ERT) in mapping subsurface geologic sequence and concealed geological structures (Amosun et al., 2018; Olorunfemi et al., 2015). Features corresponding to major and minor linear fractures within the basement rocks were identified as the root cause of incessant road failure using combined electromagnetics and electrical resistivity method (Osinowo et al., 2011). Based on the assumption of electrical resistivity contrast, the 2D electrical resistivity tomography had been used to locate subsurface cavity underlying an engineering site in Thailand, conducted (Rungroj and Mark, 2014). Further studies, by on a site for prospective Pishva hospital in Iran had detected resistivity anomaly corresponding to Qanat tunnel and aqueduct shaft underlining the proposed site that constitutes weak zones underneath (Amin and Hamidreza, 2016).

The electrical resistivity tomography (ERT) is a proven insightful tool that provides reliable information on internal structure of altered/disrupted subsurface (Ayolabi et al., 2012; Syed et al., 2020; Al-Awsi and Abdulrazzaq, 2022). In UK, the 2D and 3D electrical resistivity tomography (ERT) were successfully applied in determining the geometry of a buried quarry within an abandoned dolerite quarry and landfill (Jonathan et al., 2006). Some researchers successfully adopt ERT to determine seepage zones through earthen embankments of wastewater treatment pond systems (Rungroj and Mark, 2015). An investigation into the causes of landslide in Western Nepal identified cracked, weathered, sheared, and fractured bedrock as root cause of landslide in the area (Ashok and Radha, 2020). According to a study, identified subsidence hazard zone due to cavity limestone, conforms to the N-S elongated fracture pattern found in the research area (Wilopo et al., 2022).

As a vast method of engineering site investigation, the electrical resistivity methods of geophysics can be used as a pre-construction site investigation tool, or post construction investigation tool. The aim of this study is to provide insight into the subsurface geologic environment that is responsible for incessant road failure along Igarra-Auchi road and map subsurface geological features underlying the adjoining sites that anticipate engineering construction in the study area. By understanding more about the lateral and vertical subsurface geologic variation, the study conducts geophysical investigation to identify areas that could potentially threaten engineering construction while also suggesting appropriate remedies in accordance with their engineering competence.

2. GEOLOGY OF THE STUDY AREA

The Igarra schist belt is located in the southwestern segment of the Precambrian Basement Complex of Nigeria (Figure 1). The study area (about 230 km^2) is delimited by latitudes 07° 15' to 07° 20' 12''N and longitudes 06° 00' to 06° 12'E. The Older Granite suite is well exposed in scenic hills, while the metasediments occur in plains and low-lying areas especially stream channels such as river Onyami. Secondary structural features such as fractures and folds are often ubiquitous (Ogbe et al., 2018).

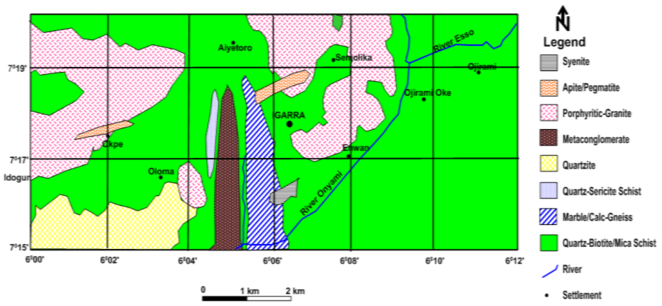

Figure 1: Geological map of Igarra and surrounding areas

3. METHODOLOGY

The Electrical Resistivity method involving dipole-dipole array was used to investigate the possibility of subsurface geological structures like cavities, faults, fractures and to produce a subsurface image in order to identify the locations of these geological structures that may impair present and future structural development. Three parallel traverses of 205m length and 50m inter-traverse separation were established (Figure 2). The station-to-station interval of 10m along each traverse was adopted for the survey. Dipro - Win software was used to process the electrical resistivity (dipole-dipole) data.

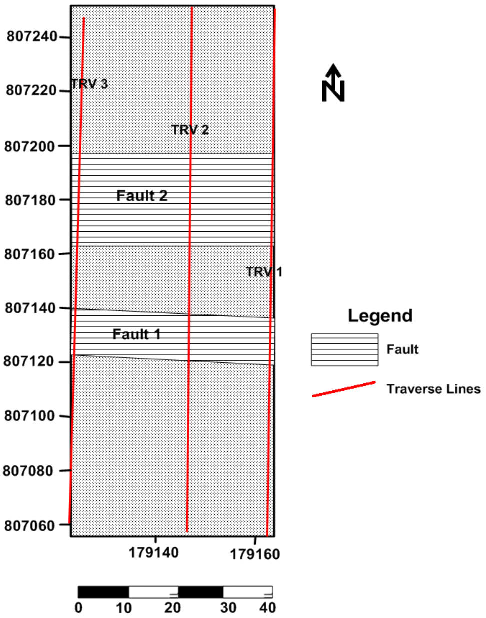

Figure 2: Data acquisition Map of the study area

4. RESULTS AND DISCUSSION

4.1 Electrical Resistivity Tomography

The apparent resistivity along traverse 1 is presented in pseudo-section (Figure 3) and it proved to be the onset of geological structures observed in the study area. At offsets 80 m, 120 – 150 m low resistivity value of 27.7 Ω-m, 122 Ω-m, 17.67 Ω-m, 15.27 Ω-m and 14.47 Ω-m which typically suggests the presence of geological structures was interpreted to be faults, or fractures. However, competent formation was encountered at about 7m depth at different offsets while onset of structures encountered at 10m deep. The pseudo-section (Figure 4) embodies apparent resistivity along traverse 2 and continuation of geological structure (fault) as observed between stations 20 m -60 m, 80 m – 90 m and 120 m – 130 m which exhibits low resistivity values 21.9 Ω-m - 46.7 Ω-m, 41.3 Ω-m - 29.1 Ω-m and 56.9 Ω-m - 39.8 Ω-m respectively. The values are suggestive of the presence of conductive body, typical of cavities, faults, fractures etc. The subsurface images reveal the presence of fault, or fractures indicated by the obvious depression zones. The pseudo-section in figure 5 along traverse 3 demonstrates the continuation of the intercepted geological structure. Low resistivity values at stations 70m to 90m and 110m to 150m show low resistivity values of 26.4 Ω-m - 9.8 Ω-m, and 46.7 Ω-m - 24.8 Ω-m respectively, which are suggestive of the presence of cavities, faults and fractures.

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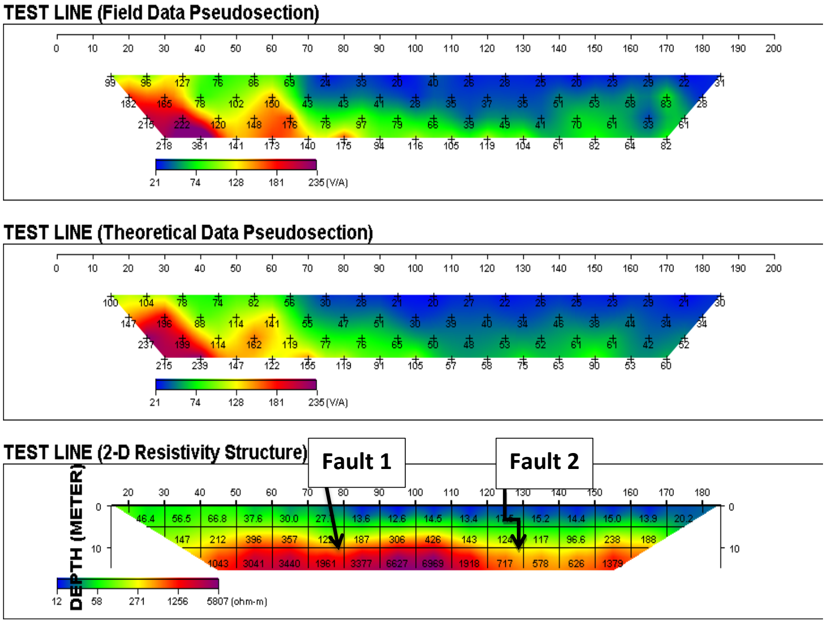
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Figure 3: Dipole-dipole pseudo-section for Traverse 1

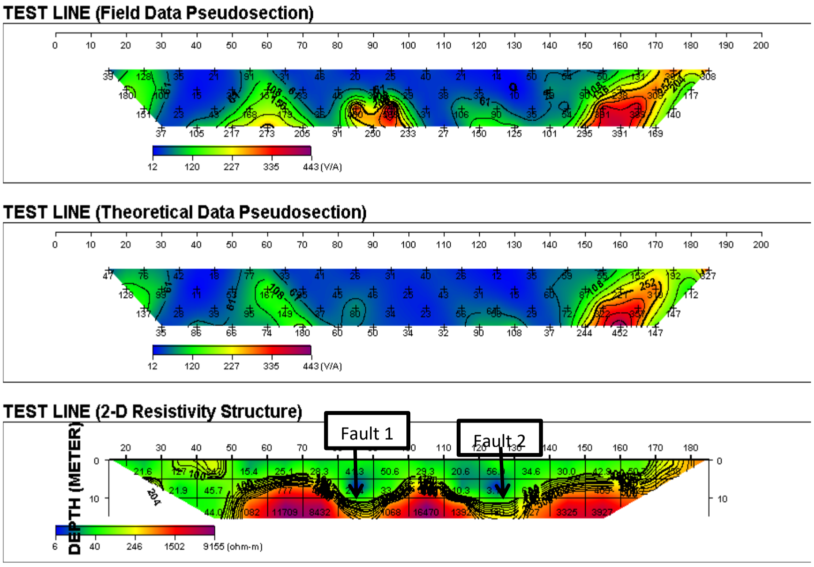
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Figure 4: Dipole-dipole pseudo-section for Traverse 2

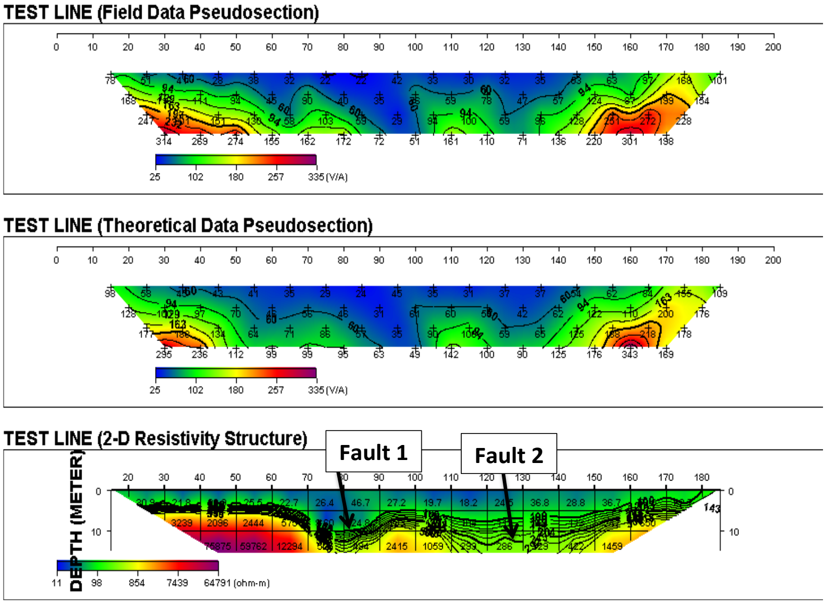
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Figure 5: Dipole-dipole pseudo-section for Traverse 3

5. CONCLUSION

The investigation conducted across the three established traverses intercepted the geological structures and revealed the range of topsoil depth between 0 – 5 m and occasionally up to 10m along the traverses. Along traverse 1, slight depression is observed between stations 70 m and 90 m considered as the onset of the geological structure, while stations between 110 m and 150 m revealed a larger geological structure. In traverse 2, depression is observed between station 70 m and 90 m, and station 110 m – 140 m to deeper depths. In traverse 3, depression suggestive of geological structure is observed between station 70 m and 90 m, and stations 110 m – 150 m. The information along the three traverses shows consistency of the identified geological structures in the study area. Depth 0 – 5 m depicts the topsoil and subsequently competent formation suitable for engineering and constructions purposes except for stations 70 m to 90 m and stations 110 m to 150 m where the structures are obvious and clearly pronounced.

Siting structures on faulted/fractured zones could lead to degrees of distress, ranging from multiple cracks, sinking of building, and partial or complete differential settlement. The faulted zones between stations 70 m – 90 m and stations 110 m – 150 m could be considered weak zones usually suitable for groundwater development. The resulting subsurface image of the investigation helps to relate the subsurface with respect to its geotechnical and environmental engineering relevance. The area identified competent for engineering purpose should be marked out by further confirming the depth of the competent formation and given the appropriate treatment for such purpose. The identified geological structures (faults and fractures) could be dedicated to groundwater development due to it hydrogeological significance. Neither test borings nor geophysical methods alone provide all the information needed in subsurface investigation. Non-destructive geophysical methods prior to a test boring program assist in the proper location of borings and reduce the number of boreholes. The investigation demonstrates the use of Electrical Resistivity Tomography method as a supplemental, cost-effective technique in subsurface investigations.

AUTHORS CONTRIBUTION

Temitope Oni: Conceptualization, Methodology, Software, Visualization, Investigation, Supervision. Ayodele Falade: Visualization, Investigation, Software, Validation, Writing- Reviewing and Editing. Olumuyiwa Oso: Writing- Reviewing and Editing

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