

2025

**Federal University of
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Nigerian Journal of Technological Research

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NIGERIAN JOURNAL OF TECHNOLOGICAL RESEARCH

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Philosophy: As a strictly scientific and technological journal, it tends to provide information on problem-solving technology to its immediate environment and the international community.

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EDITORIAL COMMENTS

This edition of the Nigerian Journal of Technological Research is the second for the year 2025, which was a remarkable year for the Editorial Board. The large number of submissions and the quality of the manuscripts are a huge encouragement to us. The Board organised a retreat for academic and administrative staff including our reviewers and thesis supervisors on the ethical use of Artificial Intelligence in academic writing. The knowledge gained through the workshop was brought to bear on the selection of articles published in this edition.

This volume features seventeen papers spanning agricultural science, food safety, biomedical research, and applied engineering. Agricultural management and ecology form a key focus, with contributions investigating integrated pest management and insect forecasting for cashew and cocoa crops, carbon sequestration in plantations, and botanical bioactive compounds for sustainable storage. Food safety and chemical analysis are addressed through quality assessments of commercial yoghurts, leafy vegetables, and market food colorants, alongside studies on functional colorant mechanisms and the therapeutic potential of *Terminalia catappa* seed extracts for sickle cell disease. In the physical and applied sciences, the research covers subsurface electrical resistivity imaging for road infrastructure, meteorological modelling of solar irradiance, and the dynamics of the relativistic restricted three-body problem. The issue concludes with assessments of local institutional and environmental systems, examining ambient air quality, climate-responsive architectural designs for housing and urban food sovereignty, and the impact of online learning platforms on public university development.

As usual, the Editorial Board is ever grateful to the University Management for the immense support and encouragement provided to them. Also, the Board is appreciative of the support of TETFUND. The financial assistance received consistently from the Tertiary Education Trust Fund (TETFUND) has enabled the Journal to adopt the Diamond Open Access Policy. Authors no longer pay the Article Processing Fee. We hope to sustain this policy as long as we continue to receive funding from TETFUND.

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2-DIMENSIONAL SUBSURFACE IMAGING OF AUCHI-IGARRA ROAD USING ELECTRICAL RESISTIVITY METHOD

Jamiu A. Sikiru¹, Osakpolor M. Omorogieva¹, Michael E. Okiotor¹, Oyintare Brisibe¹, Joshua German¹ & Yemi S. Onifade²

¹Department of Marine Geology, Nigeria Maritime University, Okerenkoko, Warri 332104, Delta State, Nigeria

²Department of Physics, Federal University of Petroleum Resources, Effurun 330102, Delta State, Nigeria

Correspondence: jamiu.sikiru@nmu.edu.ng, +2348138065538

ABSTRACT

We conducted a 2D Electrical Resistivity Imaging (ERI) survey along a section of the Auchi-Igarra Road, opposite the proposed Momoh University, to investigate the cause of existing road failures. Four ERI profiles, two on each side of the road, were acquired to cover both the failed and relatively stable sections. The profiles had lengths of 60 m, 72 m, 48 m, and 36 m. The ERI results revealed anomalously low resistivity values beneath the failed road sections, suggesting the presence of highly conductive subsurface materials. Profile 1: Showed extremely low resistivity (down to 395 Ωm), indicating high conductivity. Profile 2: Resistivity values ranged from 352 to 1758 Ωm , significantly lower than the surrounding material. Profile 3: Featured a low resistivity zone between 5.81 and 31.8 Ωm . Profile 4: Resistivity varied between 15.6 and 3133 Ωm . The road failure is likely due to the presence of moisture-sensitive, highly conductive clay materials beneath the pavement. The consistently low resistivity zones across the failed areas were interpreted as evidence of conductive clay minerals in the subsurface. These materials are susceptible to freeze-thaw phenomena (swelling during the rainy season and shrinking in the dry season), which compromise the road's structural integrity. We recommend that the suspected clay mineral under the failed section be excavated and replaced with competent, engineered materials or crushed rocks geotextiles capable of withstanding the highway's vehicular load.

Keywords: Auchi-Igarra Road, Imaging, Assessment, Surveying, Public Infrastructure

1.0 INTRODUCTION

The Auchi-Igarra expressway, a roughly 35-kilometer road built on weathered basement rocks, is experiencing significant failure (figures 2 and 3). The primary causes of this degradation are a combination of the road's underlying geology, high traffic from heavy-duty vehicles, and potentially the use of substandard construction materials. The road shows extensive signs of distress, evidenced in numerous potholes and failed sections, which impede vehicular traffic. To investigate the root causes of the road's failure, a 2-D Electrical Resistivity Imaging (ERI) survey was conducted approximately 5 kilometers before Igarra Township, near the proposed Momoh University site (Arekumo & Lawrence, 2023). This geophysical survey involved acquiring four profiles: two on each side of the road, running parallel to the highway. The ERI method is used to map subsurface resistivity variations, which can help in identifying weak

zones, material inconsistencies, and the depth of weathered layers (Mohammed, 2021).

The failure of the Auchi-Igarra road can be attributed to several interacting Geological factors; the road was built on weathered basement rocks (Omorogieva & Okiti, 2022). These rocks have been exposed to physical and chemical weathering processes over time, which can significantly reduce their strength and load-bearing capacity. When these weakened rock layers form the foundation of a road, they can deform under load, leading to cracks, settlement, and ultimately, failure of the pavement. Traffic Loading, the road serves as a major route for heavy-duty articulated vehicles transporting quarried rocks and industrial minerals. The continuous passage of these overloaded trucks exerts immense stress on the road's structure, accelerating the fatigue and failure process. This constant heavy-load traffic exacerbates the issues caused by the weak sub-grade. Construction Materials: The type and quality of materials used during the

road's construction could also be a contributing factor. If the aggregates, sub-base materials, or asphalt mix were not of the required standard, they would be unable to withstand the cumulative stress from traffic and the unstable underlying geology, leading to premature failure.

The 2-D Electrical Resistivity Imaging (ERI) survey was a critical step in diagnosing the problem. This non-invasive geophysical method involves injecting an electric current into the ground and measuring the resulting potential difference. By analyzing these measurements, geophysicists can create a cross-sectional image (pseudo-section) of the subsurface, revealing different layers and features based on their electrical resistivity. The four profiles were strategically placed to provide a comprehensive view of the

subsurface along the road's path. By placing two profiles on either side of the road and parallel to it, the survey detected lateral and vertical variations in the soil and rock layers that might be contributing to the road's instability. The ERI data helped in mapping the depth and extent of the weathered basement rock. This shows how deep the weak, unstable layer extends, identifying zones of low resistivity, which often indicate areas with high moisture content or clay-rich materials—both of which can significantly weaken the sub-grade. Locating potential voids, fractures, or areas of loose fill that may have contributed to the road's settlement and failure.

The results of this survey provide crucial data for engineers to propose effective and long-lasting remedial measures for the road's repair and reconstruction.

1.1 Study Location and Geology

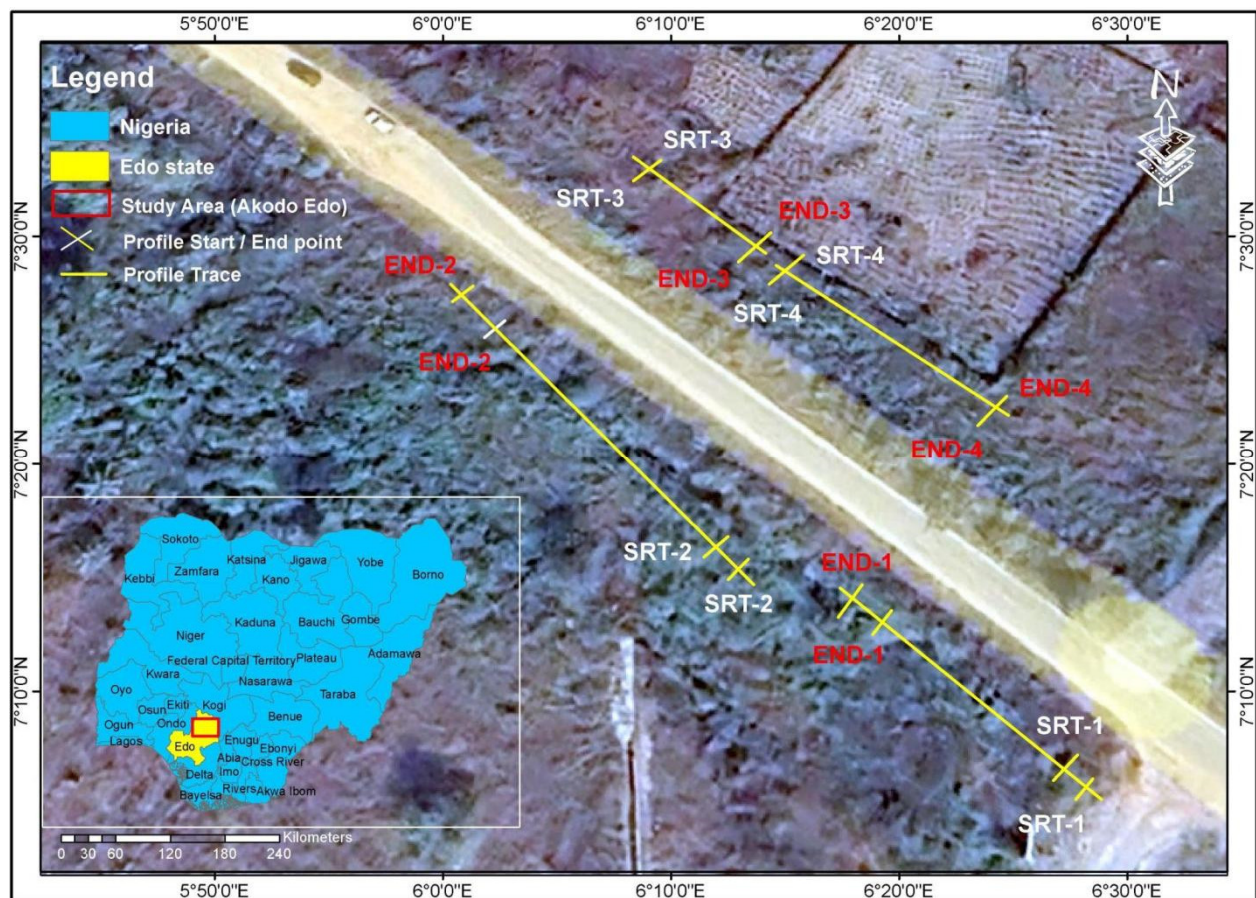


Figure 1: Map of the Study Location

The study area is situated within the Igarra region, which is the headquarters of the Akoko-Edo LGA in the northern part of Edo State, Southwestern Nigeria. Along the Auchi-Igarra road, which is part of a major road network that also connects to Ibillo and serves as a vital north-south route in the region. The area is bounded by Kogi and Ondo States. Characterized by a rocky landscape, Igarra is almost totally surrounded by rugged, rocky hills that are part of the Kukuruku Hills chain. The study area's position along the road suggests it lies on the flatter or gently sloped sections between the higher rocky elevations. The image shows four 2-D electrical resistivity imaging profiles (SRT-1 to SRT-4), each consisting of a linear array of measurement points (indicated by 'X' for start/end points and 'END-1' to 'END-4' for profile ends). The profiles were acquired along the road surface (for SRT-2 and SRT-4) just by the road shoulder/verge (for SRT-1 and SRT-3). The general trend of the profiles and the road itself is roughly NW-SE (Figure 1).

The Igarra region lies within the Precambrian Basement Complex of Southwestern Nigeria and specifically forms the most eastern extent of the Nigerian Schist Belts, known as the Igarra Schist Belt (Turner, 1989; Salami et al., 2023). The geology is a complex record of multiple deformation and metamorphic events, primarily associated with the Pan-African Orogeny (around 650 ± 150 Ma) (Oyawoye, 1972). The lithology of the Igarra Schist Belt is broadly classified into two main groups:

Metasediments (Schist Belt Rocks); these are rocks formed from the metamorphism of ancient sedimentary sequences. They constitute the dominant rock unit and are often found in plains and low-lying areas. Key rock types include: Schist, the most extensive rock, often quartz-biotite schist or quartz-sericite schist, exhibiting foliation (layering). Marble and Calc-silicate Rocks: Significant deposits that are often quarried for industrial use. Quartzite and Metaconglomerates (Rahaman, 1988). The second group is the Intrusive Igneous Rocks (Older Granites): These are post-tectonic plutonic rocks that intruded the metasediments during the Pan-African event (Oloto & Anyanwu, 2013). They are typically well-exposed in the scenic, high-rising hills. Key intrusive rocks include: Granite: Porphyritic (large crystals in a finer matrix) or non-porphyritic, ranging from grey, pink, and white in color. Syenite Dykes; unmetamorphosed and considered to be some of the youngest intrusive events in the area. Pegmatites and Quartz Veins. The rocks have undergone polyphase deformation, resulting in complex structures such as foliations, cleavages, folds, joints, and faults (including strike-slip faults). The metamorphism ranges from greenschist to amphibolite facies, indicating low to medium-grade heat and pressure conditions. The presence of abundant fractures and joints in the intrusive rocks, like the Older Granites, often leads to better exposure and rugged topography, which is characteristic of the Igarra landscape.



Figure 2: Relatively Stable Part of the Road

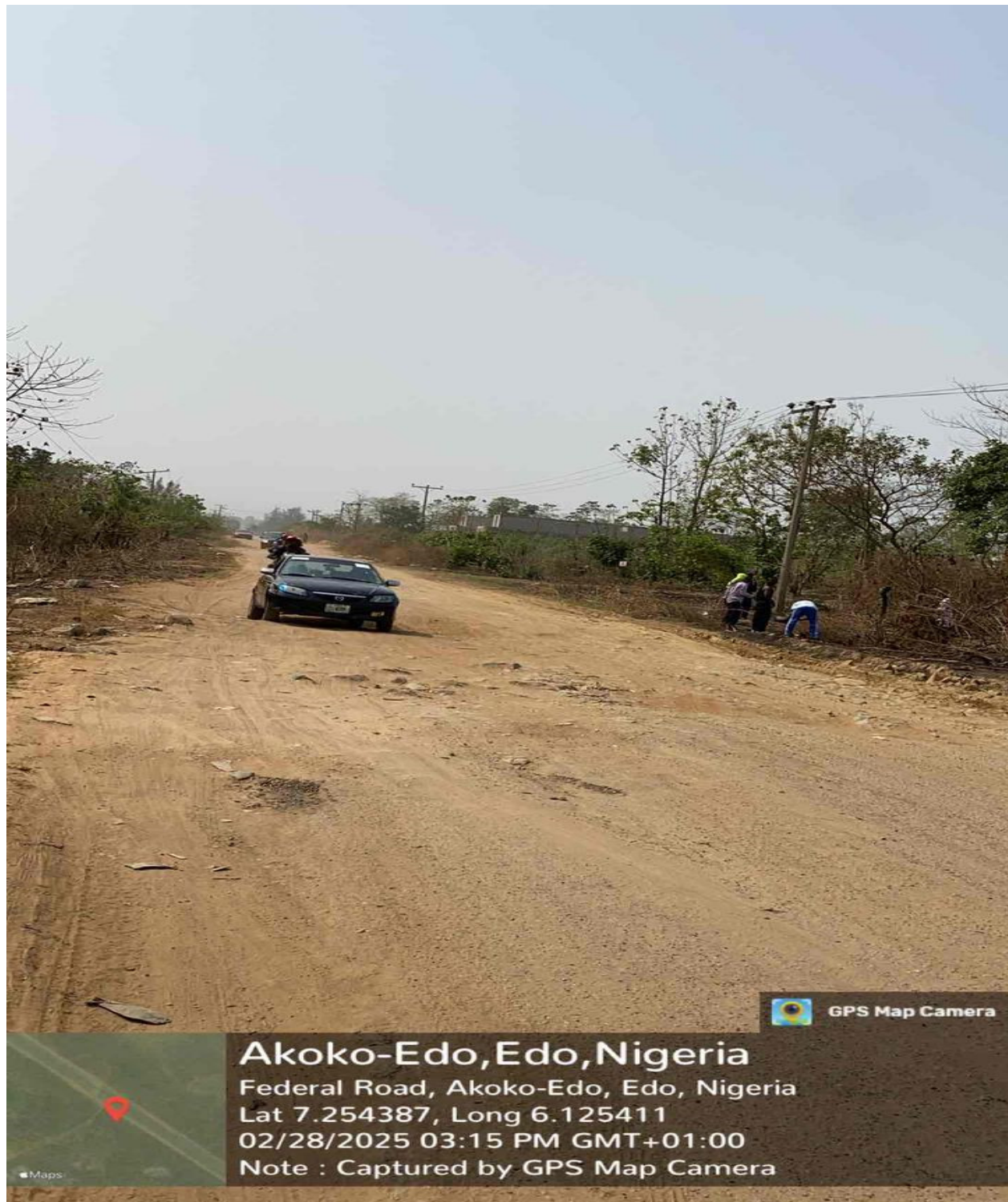


Figure 3: A failed Section along Auchi-Igarra Federal Road

2.0 LITERATURE REVIEW

Express roads are vital public infrastructure, facilitating the movement of people, goods and services and connecting diverse localities, states, and nations. By traversing different regions, they often foster cultural and social cohesion. In Nigeria, road ownership is

primarily divided between the Federal Government and State Governments. Federal roads typically link different states, whereas state-owned roads predominantly connect cities and localities within a single state. Road design and execution are intrinsically tied to the geologic condition of the ground surface upon which they are constructed.

There are two primary types of road pavements: flexible and rigid. Flexible pavements, which utilize asphalt, are designed to adapt to minor ground movements, such as settlements or those caused by freeze-thaw cycles and temperature variations. Rigid pavements, conversely, are composed of reinforced or non-reinforced concrete. Globally, flexible paved roads are the dominant type, primarily because of their lower initial construction and maintenance costs and their ability to better tolerate the swelling and shrinking of sub-grade materials (JOUAV, 2024).

Sun et al. 2025 applied Electrical Resistivity Tomography (ERT), a geophysical method based on porous media's conductive theory, to detect abandoned refractory clay mining tunnels along the planned Yuanling-Chenxi Expressway in China. Using a Wenner electrode array across five survey lines, the researchers created 2D inversion profiles which showed low-resistivity anomalies (less than 70 Ωm) initially interpreted as subsurface cavities, likely water-filled due to recent rainfall. Subsequent borehole verification confirmed the presence of a total of eight water-filled cavities, including six abandoned mining tunnels in the mudstone formation (Zone-2) and two karst caves in the limestone formation (Zone-1). A key finding and weakness/gap in the ERT interpretation was the "masking effect": multiple closely spaced, water-filled tunnels within the fractured, high-water-content mudstone and sandy shale strata often appeared as a single, large low-resistivity anomaly in the inversion profiles, which reduced the resolution and made it difficult to distinguish individual tunnels without borehole data. The successful integration of ERT with borehole and geological data allowed for the construction of a 3D model, providing a crucial reference for the subsequent remediation of the Goaf area.

Okeniyi et al. (2022), employed the Two-Dimensional Electrical Resistivity Imaging (2D ERI) method using the Wenner configuration on three 100 m traverses to map the subsurface at stable and unstable road sections. The study found that stable road portions exhibited higher apparent resistivity

values and had permeable soil formations that allowed water to drain. In contrast, the unstable portion (Traverse A) showed low apparent resistivity and had impermeable clayey soil that traps water, a major contributor to road instability. A key critical insight revealed that while the impermeable clay layer is the primary geological weakness, the differing stabilities of two geologically similar sections (Traverse A and B) were strongly attributed to the dynamics of heavily loaded versus offloaded industrial trucks plying the axis. The authors conclude that the fundamental weakness is the subsurface condition, which needs to be addressed with additional measures incorporated into road construction to achieve a sustainable road network at the industrial hub.

Two-Dimensional (2D) Electrical Resistivity Imaging (ERI) method using the Constant Separation Traversing (Wenner array) configuration to survey five troubled sections of the highway: Iyana Isashi, Iyana Era, Agbara, Magbon, and Oko Afo. The results demonstrated that the causes of road pavement collapse were primarily due to waterlogged sands and a mixture of clay topsoil/subgrade soils with characteristically low resistivity values (ranging from 3.79 Ωm to 83.3 Ωm). This low resistance indicates water ingress, which, combined with a thin pavement, makes the road unable to withstand the lane's pressure. A major implied weakness or limitation of the existing road design is the inadequate geotechnical advice received before construction, as the geophysical evidence strongly suggests that the sub-grade materials are inadequate for a highway, leading to incessant failure despite previous rehabilitation efforts (Ogungbe et al. 2021).

Krami et al. (2024) utilized the Electrical Resistivity Tomography (ERT) method in a Wenner configuration for two geophysical campaigns—one before (November 2022) and one during (February 2023) the winter season—to measure the electrical resistivity of soil supporting the road pavements in four different sections of Morocco. The results consistently showed a decrease in electrical resistivity values during the winter season across all road sections, which the authors

attribute to asphalt pavement cracking, water infiltration, and the characteristics of the supporting soil. The study identified that defective pavement areas, such as in Road Section 1, had considerably lower resistivity (50 to 95 Ωm) compared to non-defective areas (150 to 360 Ωm) before the winter, with this conductive zone expanding during the winter due to rainwater infiltration, making the area prone to degradation. A key weakness identified as contributing to the advanced deterioration of the pavement in certain sections (like Road Sections 2 and 3) was the insufficient thickness of the bituminous layer, which, combined with water circulation facilitated by fractured limestone or clayey loam sub-grade, makes the structure incapable of effectively resisting damage.

Okior & Ogueh 2021 established the impact of clay mineral to the engineering stability of the Auchi-Igarra Road (which runs through parts of the Benin Flank of the Anambra Basin) because of the identified presence of expansive clay minerals. The study establishes a direct link to the area by noting that one of the Mamu Formation's "best exposures" is at Igodor on the Benin Flank, near Auchi. This confirms that the problematic clay-rich shales and siltstones of the Mamu Formation form the underlying subgrade material (or source material) for the Auchi-Igarra road segment. The presence of Smectite and Illite clays, characterized by their high Cation Exchange Capacity (CEC), is the primary concern for road failure. These clay types have an unstable crystal structure that readily absorbs large amounts of water (high CEC) when wet, causing the soil volume to swell (heave). Conversely, they lose water and shrink (subsidence) when dry. The constant seasonal cycle of swelling and shrinking in the subgrade generates tremendous internal stresses beneath the road pavement, leading to classic road failures like potholes, rutting, cracking, and eventual complete collapse of the road structure.

3.0 MATERIALS AND METHOD

We used an Earth Resistivity Meter (ERM) as the primary instrument for generating and measuring electrical signals. These signals were then induced into the subsurface to gather data. The ERM was connected to the ground using several stainless steel electrodes, each 50 cm long, which served as the interface between the instrument and the earth. Flexible cables (2 mm diameter) facilitated the proper transmission of electrical current from the ERM to the electrodes. The cable reels, which resembled a pulley system, were used to manage the cables by winching them before and after use. Hammers were essential for driving the electrodes firmly into the ground to ensure good electrical contact. To maintain accurate records, we used data sheets for recording field measurements. A fiberglass tape was used to precisely measure the spacing between electrodes. We also used a Geographic Positioning System (GPS) to accurately determine the coordinates of each survey point. Finally, safety equipment, including hand gloves, safety boots, and helmets, was worn by all personnel to ensure physical protection and safety throughout the fieldwork.

Field data acquisition was carried out using the Wenner electrode configuration method. This method involves a specific arrangement of four in-line electrodes to measure subsurface resistivity. For each of the four survey profiles, we started with a minimum inter-electrode spacing of 3.0 meters. This initial spacing was maintained for the first reading across the entire profile. For subsequent readings, we progressively increased the spacing by a factor of two, then three, and so on, up to the n-th reading. This systematic increase in spacing allowed us to probe different depths into the subsurface, with a greater spacing providing a deeper investigation. The number of readings taken on each profile depended on both the profile's length and the available space at the site.

4.0 RESULTS AND DISCUSSION

4.1 Results

Table 1: Summary of interpreted resistivity ranges and their corresponding engineering implications along the Auchi-Igarra highway.

Profiles	Identified Lithology	Resistivity Ranges (Ωm)	Engineering Implication
1	Clay/lateritic Soil	34.5-395	Unstable: High Risk of Road Failure Zone
2	Relatively weathered Basement Rocks	352-10194	Stable: Moderately Competent Foundation
3	Clay	5.81-298	Unstable: Active failure zone/high plasticity
4	Clay vs. Fresh Rock*	15.6-> 10,000	Critical: High differential settlement risk

*Note: In Profile 4, the upper limit value represents a non-conductive "infinite" basement.

The geophysical investigation highlights a direct correlation between the low-resistivity clay zones ($< 40 \Omega m$) identified in Profiles 1, 3, and 4 and the visible surface deformation (rutting and subsidence) observed along those specific chains of the Auchi-Igarra road. This confirms that the primary cause of failure is geogenic, rooted in the incompetent nature of the clayey subgrade rather than surface drainage issues alone (Table 1).

Interpretation of the sections (Figures 4-7) shows three distinct layers of data. The top two

are the measured and calculated apparent resistivity pseudo-sections, while the bottommost section, the Inverse Model Resistivity Section, is the most crucial for a proper interpretation. This final section provides a geological cross-section of the subsurface, showing the distribution of true resistivity values with depth. The color scale at the bottom of the image, ranging from blue (low resistivity) to purple (high resistivity, or red), corresponds to the varying resistivity values in ohm-meters, Ωm

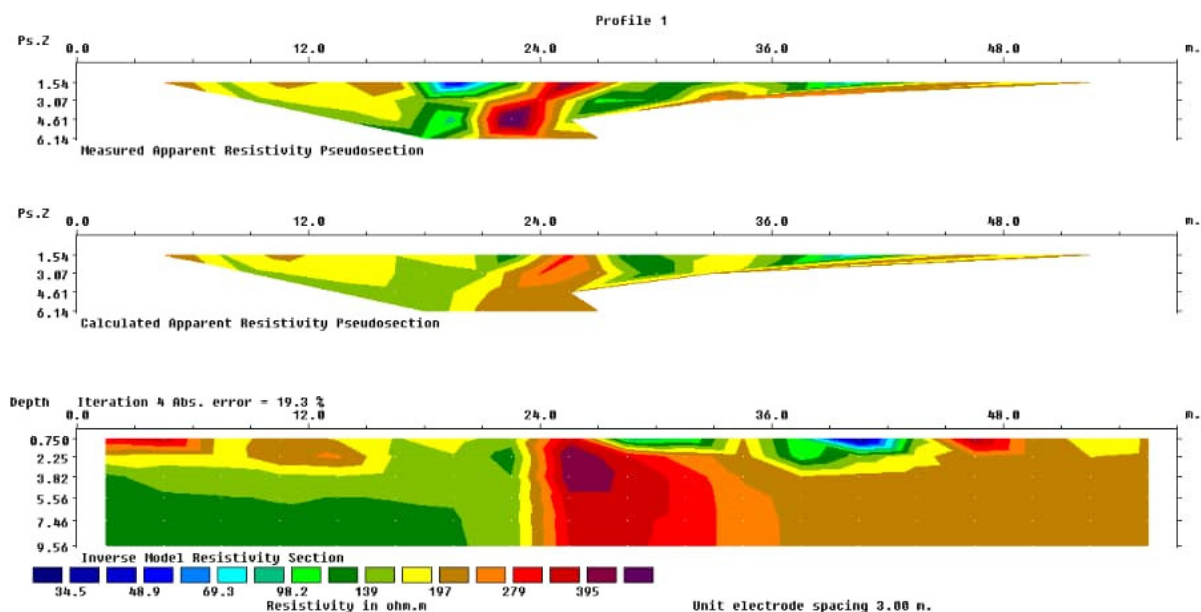


Figure 4: Profile 1 ERI Section

Interpretation of Profile 1 (figure 4) reveals that the highway section is founded upon a

mechanically unstable subgrade characterized by low-resistivity clayey lenses ($< 60 \Omega m$). The

presence of a high-resistivity vertical anomaly (395 Ωm) at the 24m mark introduces a point of significant stiffness contrast, which facilitates differential settlement and is the likely geogenic cause of the observed pavement distress in this specific corridor. The profile is dominated by low to medium resistivity values (blue to green zones), ranging from approximately 34.5 Ωm to 139 Ωm . This confirms the presence of clayey and lateritic soils as noted in Table 1. The blue zones (< 50 Ωm) at shallow depths (around 0.75 m to 3.0 m) indicate high moisture-retention areas. This moisture softens the subgrade, leading to a loss of bearing capacity and eventual pavement subsidence.

Clay or shale are fine-grained rocks, and soils typically have low resistivity due to their mineral composition and ability to hold water. Water, particularly if it contains dissolved salts, drastically lowers the resistivity of the surrounding soil and rock. The extremely low resistivity values suggest that this zone is highly saturated with water. The sharp, vertical boundary of this low-resistivity zone suggests a structural feature like a fault or fracture zone that acts as a conduit for groundwater flow. This geological weakness would not only reduce the bearing capacity of the soil but also allow for the accumulation of water, leading to the observed low resistivity (Figure 4).

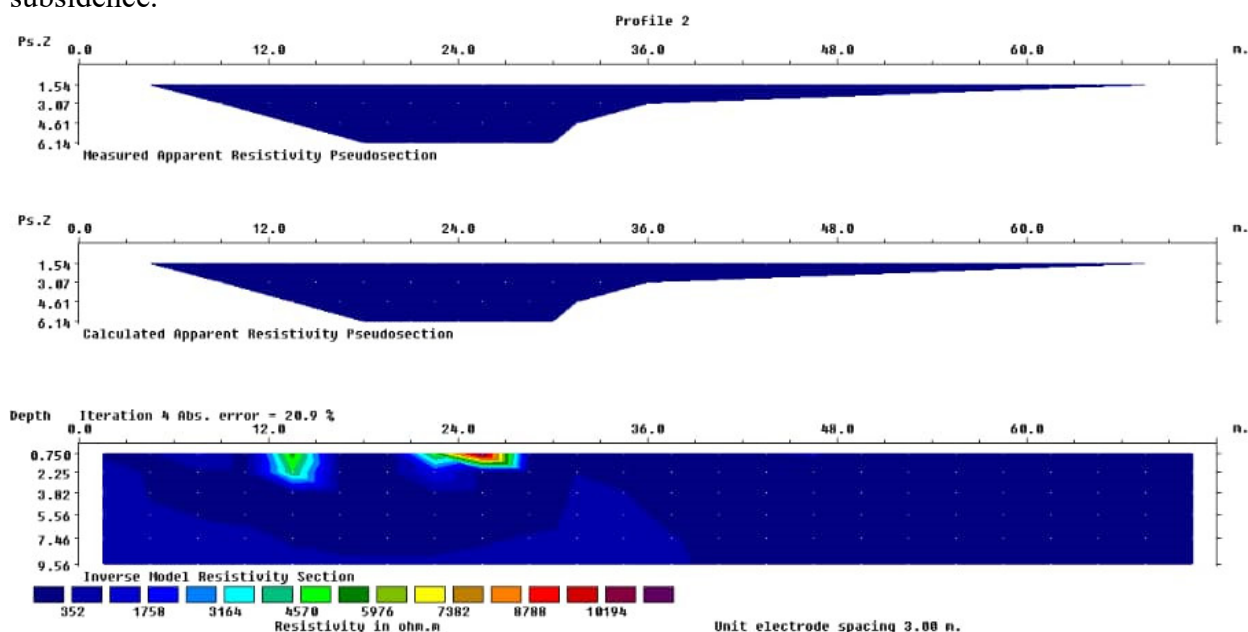


Figure 5: Profile 2 ERI Section

From figure 5 above, Resistivity Anomaly, the most prominent feature is a zone of low resistivity (blue to light blue colors) located between the 18- and 30-meter mark on the horizontal axis and extending from the surface to about 5 meters in depth. The resistivity values in this area are significantly lower than the surrounding material, falling in the range of 352 to 1758 Ωm . Cause of Low Resistivity; in the context of road engineering and geology, low resistivity values typically indicate the presence of water-saturated zones or high-clay content materials. Water, especially with dissolved salts, is a good conductor of electricity, thus lowering the ground's resistivity. Similarly, certain clay minerals are

conductive. High Resistivity Zones; the surrounding areas (e.g., at the 12-meter and beyond the 30-meter mark) show higher resistivity values (green, yellow, and red colors), indicating the presence of more competent, less saturated, or drier materials, such as weathered basement rocks, laterite, or sands.

The inverse resistivity model directly links the subsurface anomaly to the road failure. The weak zone identified is susceptible to failure for several reasons: Reduced Bearing Capacity, the presence of water and/or clay in the subgrade significantly reduces its bearing capacity. When saturated, these materials

become weak and lose their ability to support the weight of the road pavement and traffic, leading to pavement cracking, rutting, and eventual collapse. Poor Drainage, the low resistivity zone likely represents a pocket of poor drainage. Water accumulation from rainfall or a high water table saturates the subgrade, leading to a loss of strength.

Differential Settlement, the sharp contrast in material properties between the weak, conductive zone and the surrounding, more competent ground can cause differential settlement. The weak zone settles more under load than the surrounding stable ground, creating stresses on the pavement that result in cracking and failure.

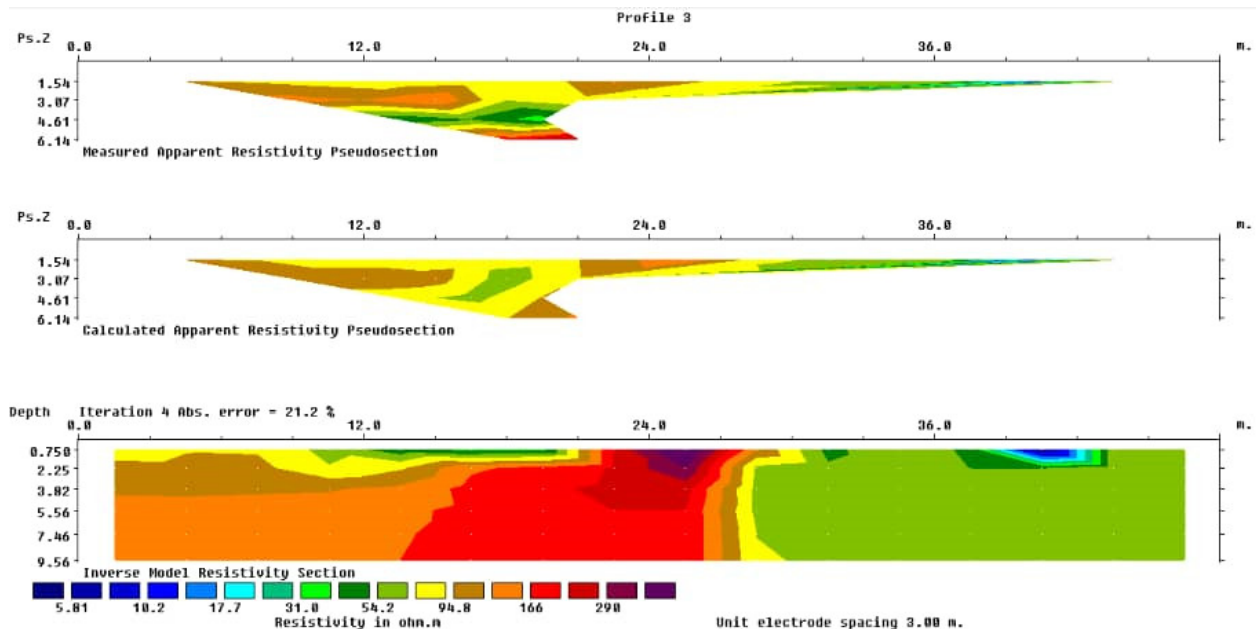


Figure 6: Profile 3 ERI Section

Based on the resistivity pseudo-section (Figure 6), the road failure along the Auchi to Igarra Express is likely caused by geological instability, specifically the presence of a highly conductive and potentially water-saturated clayey or weathered lateritic formation at shallow depths. This is often associated with the presence of Igarra schists, a common rock type in the region. The Inverse Model Resistivity Section provides a more accurate representation of the subsurface geology and is the key to interpretation. This section shows a clear lateral and vertical variation in resistivity values. The low resistivity zone (colors from deep blue to light blue and green, representing

values from approximately 5.81 to 31.8 Ωm) is concentrated at depths between 0.75m and 5.56m, particularly from the 12m to 24m horizontal mark. These low resistivity values are indicative of clayey formations, water-saturated sands, or highly weathered schist and lateritic formations. The high resistivity zones (colors from red to purple, representing values from 166 to 290 Ωm) are visible at greater depths (below 6m) and on the far left and right ends of the profile. These high values suggest the presence of competent, dry bedrock or less weathered materials like fresh basement rock or dry laterites.

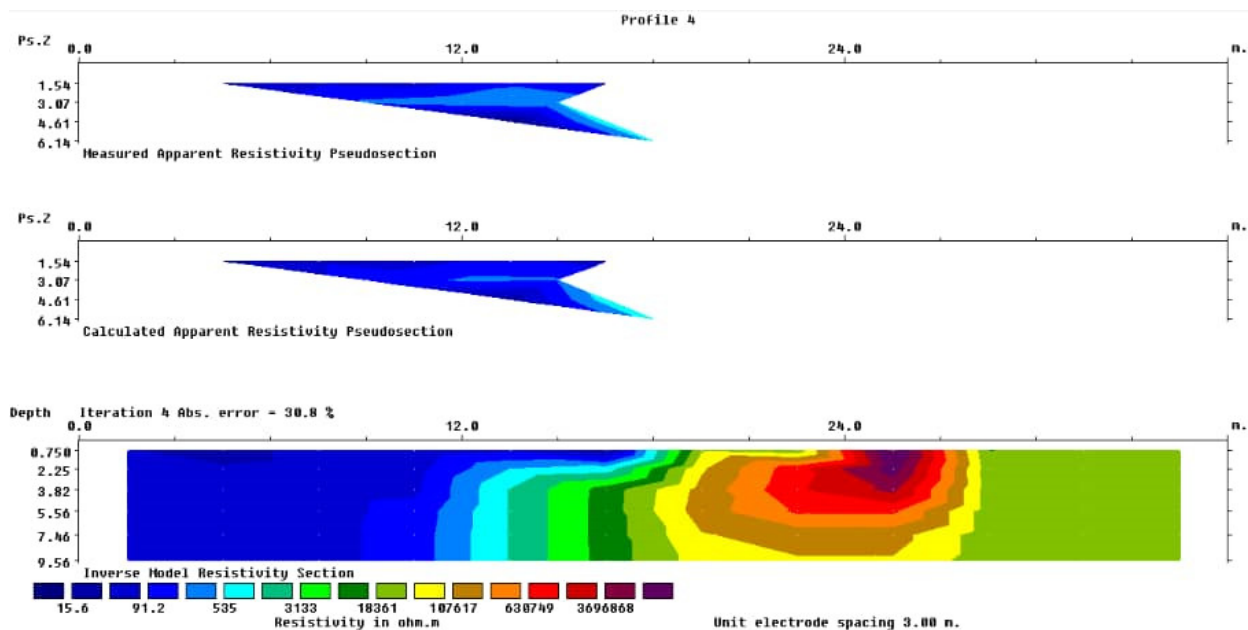


Figure 7: Profile 4 ERI Section

The image (Figure 7) is an Inverse Model Resistivity Section, a type of visualization used in geophysical surveys, specifically Electrical Resistivity Tomography (ERT). This scientific method maps the subsurface by measuring the electrical resistivity of the ground. The image shows a two-dimensional cross-section of the Earth, with the horizontal axis representing the distance along a survey line and the vertical axis showing depth. Color-coded Resistivity: the different colors correspond to varying levels of electrical resistivity, measured in ohm-meters (Ωm). Low resistivity (blue/green); this indicates areas that are electrically conductive. In a geological context, this often points to the presence of clay-rich soils, which are highly conductive, or water-saturated zones, such as a shallow water table or areas where groundwater has accumulated. High resistivity (yellow/red); this represents materials that are electrically resistive. These zones typically correspond to dry soils or fresh, un-weathered bedrock like granite or quartzite, which are poor conductors of electricity.

Subsurface Layers: the profile delineates distinct subsurface layers. You can see a surficial layer of varying resistivity and deeper, more resistive zones, which likely represent the bedrock. The interface between these layers appears irregular and undulating. The scientific data from this type of geophysical survey is

directly related to the persistent problem of road failure in Igarra, a town in Nigeria's Basement Complex. The geological and geotechnical properties of the subsurface, as revealed by the resistivity profile, are a major cause of this structural instability.

4.2 Discussions

The ERI sections provide compelling evidence that the road failure is not merely a superficial issue but is directly linked to a significant subsurface geological anomaly (Igwenagu et al. 2025). The presence of a low-resistivity, highly saturated zone, likely a fault or fracture, has created an unstable foundation that is unable to support the road's structure, especially under the heavy loads of traffic. This constant water saturation and weakened substratum are the primary culprits for the observed road failure. The high absolute error of 20.9% mentioned in the inverse model, while notable, is an acceptable margin for this type of geotechnical survey and does not invalidate the overall interpretation. The data clearly identify a localized weak zone directly beneath the area of the road failure, confirming that the subsurface conditions, particularly the presence of saturated or clay-rich ground, are the primary cause of the road's distress (Figures 4 to 7).

4.3 Possible Cause of Road Failure

The road failure is directly linked to the presence of a low-resistivity, conductive, and likely water-saturated zone. Swelling Clays and Weathered Laterites; the low resistivity zone likely represents a clay-rich or highly weathered lateritic soil layer. Clays and laterites, especially when exposed to water, can swell and lose their bearing capacity. This is because their mineral structure absorbs water, causing them to expand. When the moisture content fluctuates, they shrink and swell, leading to a phenomenon known as "shrink-swell" behavior (Kavur et al. 2023). This repeated movement weakens the underlying road pavement, causing it to crack and deform. Poor Subgrade Strength: The presence of a water-saturated, clayey subgrade (the layer directly beneath the road's base) provides an unstable foundation for the road. The road's weight and the stress from traffic cannot be properly supported, leading to settlement, rutting, and eventual collapse of the pavement structure. Igarra Schists; the geology of the area is characterized by the Igarra Schists, which are part of the Younger Metasediments of the Nigerian Basement Complex. These schists are prone to deep weathering, producing a thick mantle of lateritic and clayey soils. The low-resistivity zone in the image is consistent with the geological signature of such weathered schist formations. The road's construction on this inherently weak and unstable geological formation makes it highly susceptible to failure, particularly during periods of rainfall when the subgrade becomes saturated.

5.0 CONCLUSION

In conclusion, the scientific data presented in the resistivity profile illustrate that the inherent geological and geotechnical conditions of the Igarra area, specifically the presence of expansive clay, an irregular bedrock topography, and water-saturated zones are significant underlying factors for the recurring problem of road failure. The road failure is likely due to the presence of moisture-sensitive, highly conductive clay materials beneath the pavement. We recommend that the suspected clay mineral under the failed section be

excavated and replaced with competent, engineered geomaterials capable of withstanding the highway's vehicular load.

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REFERENCES

- Arekumo, T., & Lawrence, O. O. (2023). Investigation of Road Failures along Imiringi Road Bayelsa State Using Electrical Resistivity Imaging (ERI). *World Scientific News*, 183, 48- 59.
- Igwenagu, U. T. I., Debnath, R., Ahmed, A. A., & Alam, M. J. B. (2025). An integrated approach for Earth infrastructure monitoring using UAV and ERI: A *Systematic Review Drones*, 9(3), 225.
- [JOUAV.COM/blog/road-contruction.html](https://www.jouav.com/blog/road-contruction.html) accessed on 26th September, 2025
- Kavur, B., Štambuk Cvitanović, N., Jug, J., & Vrkljan, I. (2023). Conceptual Model of Expansive Rock or Soil Swelling. *Geosciences*, 13(5), 141.
- Krami, K., Benamara, A., Radouani, M., Ettayeb, M., & Tarik., L. (2024). Study of Asphalt Pavement Cracking in Different Road Sections of Morocco Using Electrical Resistivity Tomography. *International Journal of Geophysics*, 1-11. <https://doi.org/10.1155/2024/1312619>
- Mohammed, M. Z. (2021). Electrical resistivity imaging and magnetic surveys for evaluating highway failures along

- Ogbagi-Ikare, Southwestern Nigeria. *Environment Sciences*, 2(4).
- Ogungbe, A. S., Afolabi, T. O., Onori, E. O., & Ogabi, C. O. (2021). Geophysical Investigation of road failure along Lagos Badagry expressway using electrical resistivity imaging *Journal of Physics: Conference Series*, 1734 (21) 012041. Doi: 10.1088/1742-6596/1734/1/012041
- Okeniyi, E. T., Adagunodo, T. A., & Okeniyi, J. O. (2022). Electrical resistivity application for road failure assessment at an industrial hub in Ogun State, Nigeria. *IOP Conf. Series: Earth and Environmental Science* 993. doi:10.1088/1755-1315/993/1/012020.
- Okior, M. E., & Ogueh, E. D. (2021). Geochemical Characteristics of the Campano- Maastrichtian Sediments of the Anambra Basin, Southeastern Nigeria - Implication for Provenance, Paleo-depositional Environment, Maturity and Tectonic Setting. *SPE-207170-MS. Presented at the Nigeria Annual International Conference and Exhibition*, Lagos, Nigeria, 2–4 August 2021.
- Oloto, I. N., & Anyanwu, D. (2013). Petrology of Ibillo-Mangongo Area of Igarra, Edo State, Nigeria. *Advances in Applied Science Research*, 4(2), 221-228.
- Omorogieva, O. M., & Okiti, I. (2022). Geotechnical appraisal and geological influence on road failure: a new perspective in geotechnical engineering. *International Journal of Earth Sciences Knowledge and Applications*, 4(1), 124-132.
- Oyawoye, V. O. (1972). The Basement Complex of Nigeria. *African Geology* (pp. 109–120). Ibadan University Press.
- Rahaman, M. A. (1988). Recent Advances in the Study of the Basement Complex of Nigeria. In *Precambrian Geology of Nigeria* (pp. 11–41). Geological Survey of Nigeria.
- Salami, I., Okwueze, B. O., & Ibekwe, H. (2023). Hydrogeochemical Assessment of Groundwater Quality and Geological Influence in Igarra and environs, Southwestern Nigeria. *Journal of Applied Sciences and Environmental Management*, 27(5), 903-912.
- Sun, M.; Ou, J.; Li, T.; Cao, C.; Liu, R. (2025). Application of Electrical Resistivity Tomography (ERT) in Detecting Abandoned Mining Tunnels Along an Expressway. *Applied Science*, 15, (2289). <https://doi.org/10.3390/app15052289>
- Turner, D. C. (1989). The Nigeria Shield. The Geology of Nigeria (2nd ed., pp. 91–98). Elizabethan Publishing Company.