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Hydrogeophysical Investigation of Groundwater Potential in Tumfure and Environs, Akko LGA, Gombe State, Northeastern Nigeria

Bello Abubakar Dauda, Victor Vitalis, Umar Ibrahim Ashaka

***Abstract:** This study was conducted to evaluate the groundwater potential of Tumfure and its environs in the Gongola Arm of the Upper Benue Trough, Northeastern Nigeria, in response to increasing dependence on groundwater for domestic water supply and the limited availability of surface water resources. The research applied hydro geophysical techniques to determine the distribution of the subsurface aquifer. Groundwater conditions were investigated using twenty (20) Vertical Electrical Sounding (VES) measurements acquired with the Schlumberger array (AB/2 of 200 meters) and interpreted using WINRESIST software. Results reveal predominantly three- to four-layer subsurface models comprising topsoil, clay, sandy clay, sandstone, and conglomerate. Despite favourable lithologic compositions, the absence of impermeable layers (aquitards/aquicludes) at depth limits groundwater accumulation. This study underscores the need for more comprehensive, multi-method geophysical surveys to enable compelling groundwater exploration in the area.*

***Keywords:** Vertical Electrical Sounding, Topsoil, Clay, Sandy Clay*

Nomenclature:
VES: Vertical Electrical Sounding

I. INTRODUCTION

Groundwater is a vital and hidden natural resource that augments domestic water supplies, supports agriculture and industry, and sustains ecosystems. Access to safe and adequate drinking water is a fundamental human necessity, and groundwater remains the primary source of potable water for many communities worldwide, particularly in developing regions where surface water quality is unreliable (Villholth et al., 2018) [7].

A. Literature Review

Geophysical techniques, particularly the electrical resistivity method, are widely used to delineate subsurface lithological units and assess groundwater potential across diverse geological environments. The electrical resistivity method is very effective in groundwater studies because subsurface resistivity variations are strongly influenced by lithology, porosity, degree of weathering, and groundwater saturation, which control aquifer properties (Oyeyemi et al., 2022 [5]; Konwea et al., 2023) [3].

In Nigeria, Vertical Electrical Sounding (VES) has been extensively applied to characterise aquifers and evaluate groundwater potential in both crystalline basement and sedimentary terrains. Recent studies demonstrate that the resistivity method reliably helps to identify weathered and fractured zones that serve as productive aquifers, while also providing estimates of aquifer thickness and depth to the water-bearing layers (Falade et al., 2019 [1]; Konwea et al., 2023). These applications are particularly valuable in areas where borehole failure is common due to complex subsurface conditions.

In northeastern Nigeria and the Upper Benue Trough, electrical resistivity surveys have contributed significantly to understanding aquifer parameters, groundwater distribution, and yield potential within sedimentary formations. Studies conducted in similar geological settings indicate that sandstone and clayey sandstone units exhibit variable resistivity responses depending on compaction, cementation, and saturation levels, which directly affect groundwater storage and transmissivity (Yusuf et al., 2020 [6]; Getachew & Abdulkadir, 2024) [2]. The Gombe Sandstone and Kerri-Kerri Formation, which underlie parts of Akko LGA including Tumfure, are characterized by heterogeneous lithology and variable porosity, resulting in spatial variations in groundwater potential.

The integration of geoelectric data with hydrogeological knowledge has improved groundwater evaluation and significantly reduced the risk of unsuccessful borehole drilling. A combined interpretation of resistivity parameters, such as layer resistivity and thickness, enhances aquifer delineation and supports sustainable groundwater development (Oyeyemi et al., 2022; Getachew & Abdulkadir, 2024). Despite the proven effectiveness of electrical resistivity methods, certain limitations remain, including reduced resolution at greater depths and challenges in distinguishing lithologies with similar resistivity values. Consequently, recent studies recommend integrating resistivity surveys with complementary geophysical methods or geological data to improve subsurface imaging and more reliable groundwater assessments (Konwea et al., 2023; Getachew & Abdulkadir, 2024).

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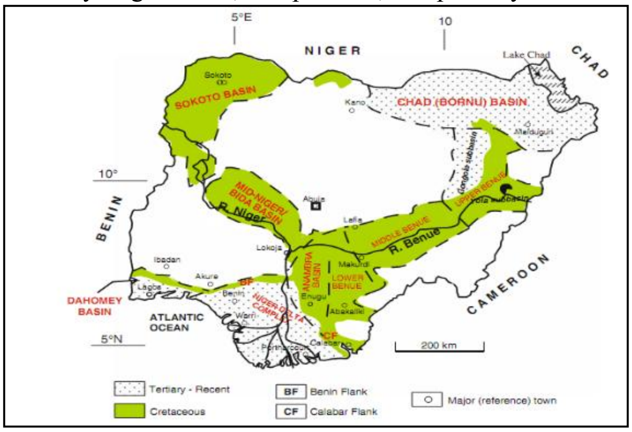
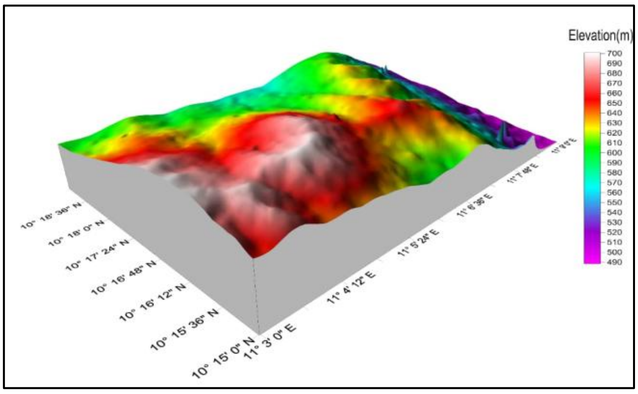
II. GEOLOGICAL AND HYDROGEOLOGICAL SETTING

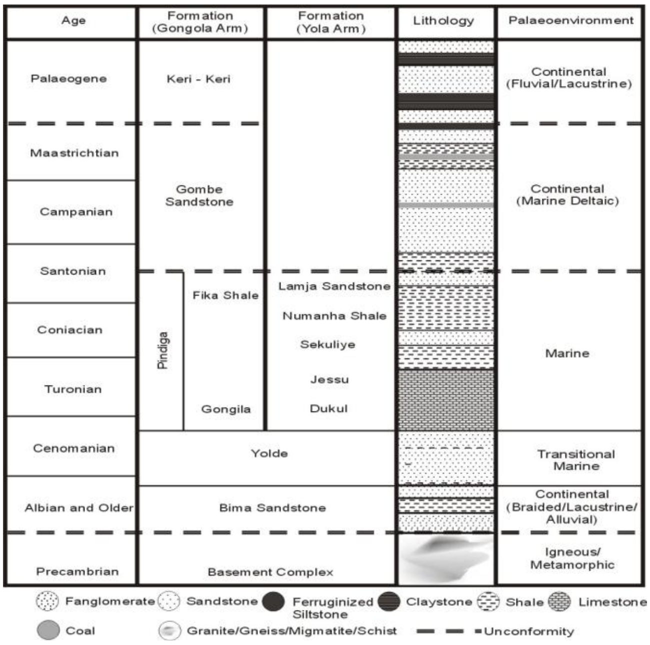
Tumfure lies within North Eastern Nigeria's sedimentary basin, commonly known as the Gongola arm of the Upper Benue Trough, underlain by the Maastrichtian Gombe Sandstone and the Palaeocene Kerri-Kerri Formation. These units vary in grain size, composition, and porosity.



[Fig.1: Geological Map of Nigeria Revealing the Case Study Area (Modified After Yusuf et al., 2020)]



[Fig.2: Spatial Distribution of Relief Within the Study Area (Elevation Ranges Between 490 And 700 Meters Above Sea Level)]



[Fig.3: Stratigraphic Succession of the Upper Benue Trough (Modified After Obaje et al., 2015) [4]]

III. MATERIALS AND METHODS

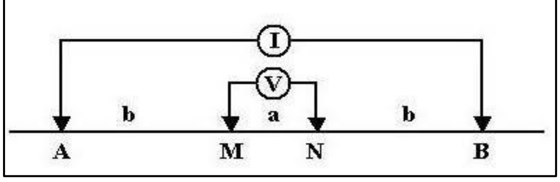
A. Field Equipment

i. Ohmega Terrameter
ii. Steel electrodes
iii. Cable wires, hammers, measuring tapes, and GPS
iv. WINRESIST software for modelling

B. Methodology

The Schlumberger array configuration was used. VES data were collected across 20 random points and interpreted using both manual curve matching and computer-based inversion.

$$\rho_A = \frac{V}{I}\pi\frac{b(b+a)}{a} \approx \frac{V}{I}\pi\frac{b^2}{a} \quad \text{if } a << b$$

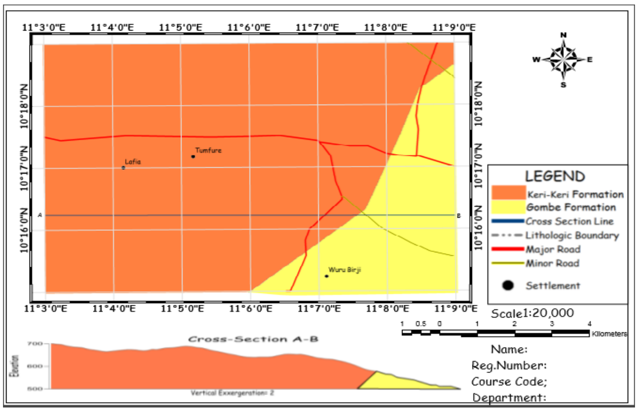


[Fig.4: Schlumberger Array Configuration]

Plate I: Field Setup for VES Data Acquisition (Operators Taking VES Readings Using the Schlumberger Array)

IV. RESULTS AND DISCUSSION

A. Geology of the Study Area



[Fig.5: Google Map Showing Geoelectric Section Lines]

Two rock types underlie the study area. The Gombe formation which dominate the North Western and South Western part of the study area (Figure 4) variable succession of well-bedded, fine to medium grained sandstones which are brownish in colour and sandy and silty

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micaceous shales with occasional mudstones are observed and Keri Keri formation dominate North Eastern and South Eastern part of the study area (Figure 4) unit consisting of poorly consolidated, medium-coarse-grained Arkosic sands that are whitish grey in colour and grits with interbeds of sandy gravels, good exposures are encountered along stream channels within the study area (Plate II and III).

Plate II: Very Coarse-Grained Kerri-Kerri Sandstone Exposure

Plate III: Conglomerate Exposure in Stream Channel

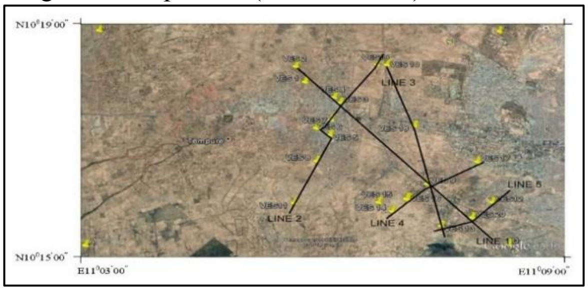
B. Lithologic Layers and Resistivity

i. Interpretation showed:

- **Topsoil:** 10–400 Ωm
- **Clay/Clayey Sand:** 30–150 Ωm
- **Sandstone:** 240–2166 Ωm
- **Conglomerate:** >2000 Ωm up to 38,000 Ωm

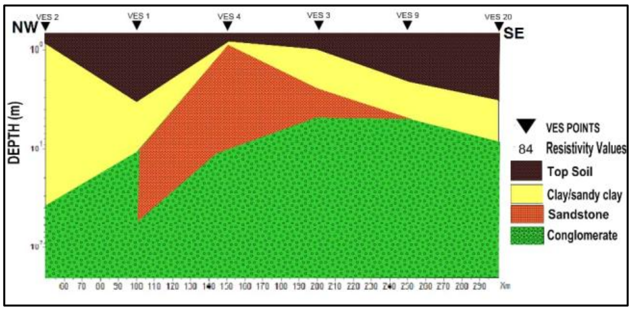
C. Geoelectric Sections

Five geoelectric profiles (Line 1–Line 5) were drawn.



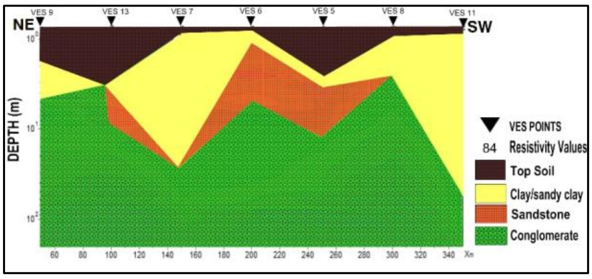
[Fig.6: Five Geoelectric Profiles (Line 1–Line 5) Were Drawn]

i. Geoelectric Section Along LINE 1



[Fig.7: Geoelectric Section Along Line 1 (Four Layers: Topsoil, Sandy Clay, Sandstone, Conglomerate)]

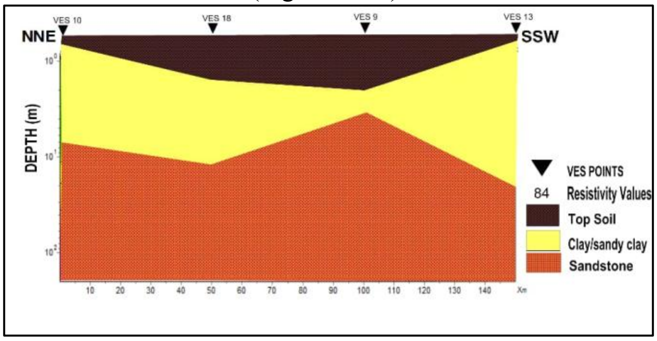
ii. Geoelectric Section Along LINE 2



[Fig.8: Geoelectric Section Along Line 2 (Four layers: Topsoil, Sandy Clay, Sandstone, and Conglomerate)]

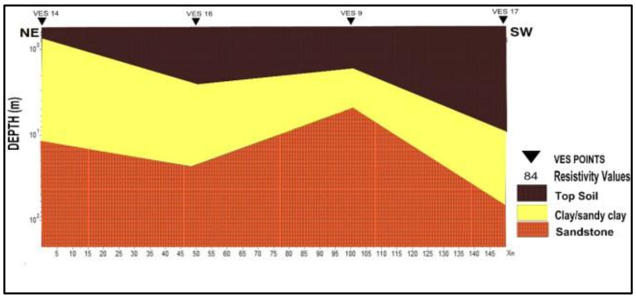
iii. Geoelectric Section Along LINE 3

Geoelectric section along a NNE–SSW profile connecting VES points 10 → 18 → 9 → 13. It illustrates subsurface lithological layers interpreted from resistivity data. The profile reveals a typical three-layer system, with the sandstone unit serving as the primary potential aquifer. The clay/sandy-clay layer may influence recharge and flow dynamics, whereas the topsoil is largely insignificant hydrogeologically. The uplifted sandstone near VES 9 suggests better prospects for shallow groundwater abstraction in that area (Fig 8 Line 3).



[Fig.9: Geoelectric Section Along Line 3 (Three Layers: Topsoil, Sandy Clay, and Sandstone)]

iv. Geoelectric Section Along LINE 4



[Fig.10: Geoelectric Section Along Line 4(Three layers: Topsoil, Sandy Clay, and Sandstone)]

v. Geoelectric Section Along LINE 5

- **Geoelectric Section** (or 2D subsurface profile) derived from Vertical Electrical Sounding (VES) data collected along a NE–SW transect (VES 13 → VES 20 → VES 12). It shows the variation in subsurface layers based on their resistivity values and inferred lithologies.

The section shows a three-layer system with increasing groundwater potential in the deeper sandstone unit. The clay/sandy-clay layer may impede direct recharge in

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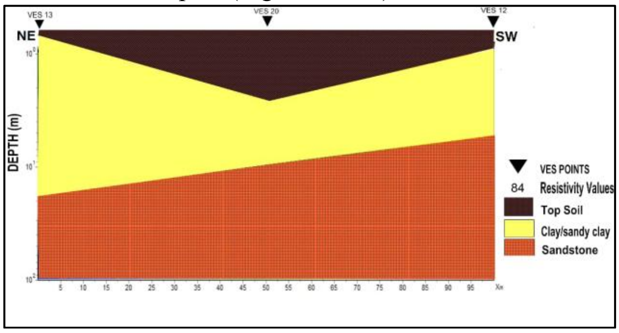
some areas but could also contribute to water retention. The sandstone unit presents the most promising target for groundwater exploration, especially near VES 12, where it is thickest and deepest (Fig.10 Line 5).



[Fig.11: Geoelectric Section Along Line 5 (Three Layers: Topsoil, Sandy Clay, and Sandstone)]

V. CONCLUSION

Despite the presence of potentially permeable lithologies such as sandstone and conglomerate, the absence of impermeable confining layers (aquitards) limits groundwater accumulation and storage. No significant aquifer systems were identified within the 200 m depth range investigated.

RECOMMENDATIONS

- Investigate beyond 200 m depth using deeper resistivity or borehole logging.
- Apply complementary geophysical techniques like Audio Magnetotelluric (ADMT) and seismic.
- Consider hydrochemical analysis to assess water quality if groundwater is found.

DECLARATION STATEMENT

The authors declare that they are fully accountable for the content of this article. All authors contributed substantially to the research, analysis, interpretation of data, and preparation of the manuscript. Each author has reviewed and approved the final version of the paper before submission.

As the article's author, I must verify the accuracy of the following information after aggregating input from all authors.

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- **Funding Support:** This article has not been funded by any organizations or agencies. This independence ensures that the research is conducted with objectivity and without any external influence.
- **Ethical Approval and Consent to Participate:** The content of this article does not necessitate ethical approval or consent to participate with supporting documentation.
- **Data Access Statement and Material Availability:** All data generated and analyzed during this study are available upon reasonable request from the corresponding author. Processed resistivity data, VES curves, inversion models, and GIS files can be accessed through the authors' repository. There are no restrictions or limitations on data accessibility.
- **Author's Contributions:** Each author has individually contributed to the article. Bello Abubakar Dauda: Conceptualization, field data acquisition, data interpretation, manuscript drafting, preparation of figures and plates. Victor Vitalis: Methodology design, literature review, data interpretation, manuscript editing. Umar Ibrahim Ashaka: Geological framework description, stratigraphic interpretation, review and critical revision of the manuscript. All authors read and approved the final manuscript and take full responsibility for its content.

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AUTHOR'S PROFILE

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