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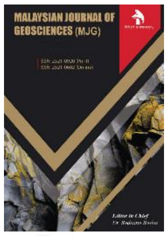

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RESEARCH ARTICLE

HYDROGEOPHYSICAL INVESTIGATION FOR GROUNDWATER RESOURCE POTENTIAL IN MASAGAMU, MAGAMA AREA, FRACTURED BASEMENT COMPLEX, NORTH-CENTRAL NIGERIA

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ABSTRACT

Vertical Electrical Sounding (VES) was conducted in Salbi farm in the fractured Basement Complex, North-Central Nigeria to determine the groundwater resource potential to serve for agricultural purposes. Four VES stations using Schlumberger electrode configuration with a maximum current electrode spread of 300m were employed for data acquisition. ZHODY software was employed in computing resistivities, depths and thicknesses of the various layers and curve types. Results indicate that the area is characterized by 3 distinct geoelectric layers inferred differently at the VES locations. One potential groundwater aquifer zone was delineated at VES 1, 2, and 4 within the fractured/weathered basement columns having depths ranging between 48.8 – 59.60m and resistivities ranging between 213 - 513 Ωm. These results suggest that boreholes for sustainable groundwater supply in Salbi farm should be sited either at VES 1, 2 or 4 location and screened at a depth ≥60.0m. Wells to develop this resource should be drilled to an effective depth of 40 to 60 m for optimum yields. It is recommended that pumping test be done in order to further determine the aquifer efficiency and productivity in the area. However, the aquifers at these locations have potentials for groundwater but may be vulnerable to contamination.

KEYWORDS

Vertical Electrical Sounding, Aquifer, Salbi Farm, Fractured Basement Complex, Masagamu.

1. INTRODUCTION

Investigating the groundwater resource potential to meet the need of good water supply for farming activities in Masagamu, Magama Local Government Area, Niger State, North-Central Nigeria is very essential in the absence of natural water supply such as lakes, basins, streams and rivers or public water utility system. Masagamu is witnessing rapid increase in farming activities. There is a shift from subsistence to commercial farming in this area leading to high demands for potable water to serve the agricultural activities. As at the time of this survey, the source of water supply to the area is a non-motorized borehole in Salbi farm which is of moderate yield and may not meet the rising demand. The aim of this research which includes reconnaissance survey followed by geological/hydrogeophysical survey is to locate geological structures that are associated with groundwater that could lead to sinking of well or borehole. The objective is to determine thicknesses, depths, resistivities and lithologies of different rock types that constitute viable aquifers using the VES method.

Hydrologically, groundwater within the Basement Complex is found within fixtures such as cracks, joints and weathered overburden which are majorly dependent on rain water recharge, and other sources such as rivers, lakes or basins. These fixtures are necessitated majorly by chemical weathering and tectonic activities; which could be deeply buried. But in the instance of a deeper weathered overburden, it provides good condition for groundwater occurrences. Electrical resistivity survey provides a suitable method to easily access groundwater in these geological structures. Vertical electrical sounding (VES) which is an electrical resistivity technique for measuring vertical variations of electrical resistance in the ground, has proven to be more convenient for hydrogeophysical and hydrogeological surveys in the Basement Complex.

Various researches have been conducted in search of prolific aquifer in the basement complex of Northern Nigeria. Alaminiokuma and Chaanda, 2020, employed the vertical electrical sounding technique to explore for the groundwater potential in Mando, located within the Crystalline Basement Complex of Nigeria. Results show that the area is characterized by four to five geoelectric subsurface layers inferred differently at the VES traverses. An unconfined shallow aquifer zone is delineated. This potential groundwater aquifer zone found at all the VES locations has shallow overburden depth ranging between 7.1–10.9m with coarse-grained sand columns having thicknesses ranging between 6.0–9.6m. These results suggest that groundwater occurrence in Mando lies within the weathered overburden (WO) composed of coarse-grained sands which forms a level below the loose clayey laterite. These WO consist of sands or gravels derived from the weathering of the crystalline rocks. Based on these results, it is suggested that boreholes for sustainable groundwater supply in the study area should be drilled to a depth of about 10.0m. Bawallah et.

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al., 2019 investigated aquifer in order to determine its groundwater potential in Camic Garden Estate, Ilorin Metropolis, North-Central Basement Complex of Nigeria. Very Low Frequency-Electromagnetic (VLF-EM) and Ground Magnetics (GM)were used for structural evaluation/delineation combined with Electrical Resistivity Method (ERM)using the Vertical Electrical Sounding (VES) Technique were employed to produce results which showed predominant three-layer earth model: top soil, clayey/weathered layer and fresh basement. The clayey/weathered layer constitutes the major auriferous unit in the area, and are characterized by moderately low resistivity value which ranged between 23.00 and 200.00 Ωm while the thickness varies from 13.2 to 61.0 m. The study reveals that 83% of the study area may be of low water bearing/yield owing to the thick clayey column that characterized the weathered layer without fractured basement. Markus et. al. 2018 investigated of groundwater potential of part of Rafin-Yashi, Minna, North Central, Nigeria using Electrical Resistivity Profiling (ERP) and Vertical Electrical Sounding (VES). Results revealed about 95% H- type curve and 5% K- type curve with three distinct geoelectric layers namely: the top soil, weathered/fractured basement and the fresh basement. The apparent resistivity of the first layer ranged between 18.5 – 706.6Ωm with a corresponding thickness of 1.1 m – 4.8m, second layer has apparent resistivity values of 16.8 – 591.6Ωm with corresponding thickness of 4.8 – 15.3m and the third layer has apparent resistivity values of 19.2 – 7299.1Ωm with an infinite thickness. Bulus et. al., 2017 studied the porous zones of Kwal and its environs employing Forty (40) vertical electrical sounding data using the Schlumberger configuration in the study area. Results revealed three geo-electric layers with varying thickness and levels of weathering. The three geo-electric layers were interpreted to be clayey sand, weathered basement with resistivity values ranging between 18.9 to 498.2Ωm indicating porous zones due to secondary porosity or water content while the third layer is interpreted to be fresh basement, this layer revealed high resistivity values that ranges between 521.6 and 6148.2Ωm.

In view of the serious demand for water for domestic and agricultural purposes in Masagamu, this research provides the basis for determining prolific aquifers for siting boreholes. When such boreholes are satisfactorily drilled and completed, they will be greatly utilized for farming purpose.

2. Geological Framework

Nigerian portion of the Precambrian Trans-Saharan Pan-African orogeny lie within the mobile belt which separated the West African and Congo Cratons. It is related to Aïr, Hoggar, Cameroun and Borborema Pan-African (Brasiliano) regions (Ferre et al., 1998). The total area of Nigeria is covered is nearly of the same ratio by basement and sedimentary lithologies (Rahaman, 1988). The Basement rocks are divided into Basement Complex, Younger Granites and Tertiary-Recent volcanic rocks (Kogbe, 1989). The Nigerian Precambrian Basement Complex is made up of the Migmatite - Gneiss complex, Schist belts and Older Granites with the largest area of Basement Complex in north-central Nigeria [Figure 1] (Obaje et al., 2006; Obaje 2009, Ajibade et al., 2008).

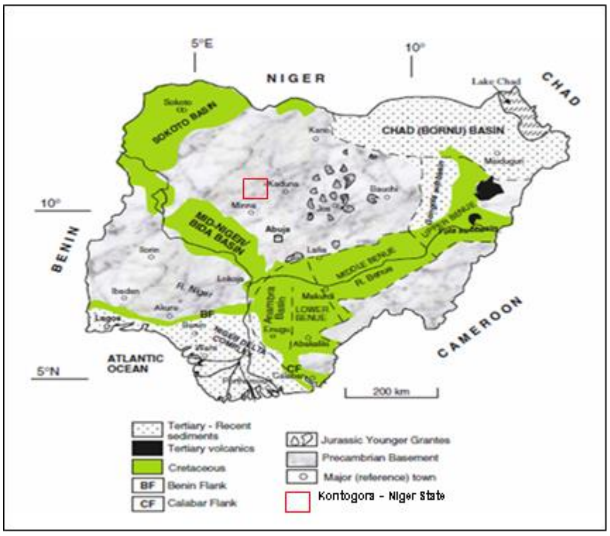

Figure 1: Geological Map of Nigeria (Modified from Obaje, 2009)

3. Location & Acessibility, Physiography, Drainage, Vegetation and Climate of The Study Area

3.1 Location and Accessibility

The area under investigation is the Salbi farm located at Masagamu in Magama Local Government Area of Niger State. The farm is accessible by a tarred road (Kontagora- Kebbi road) (Figure 1).

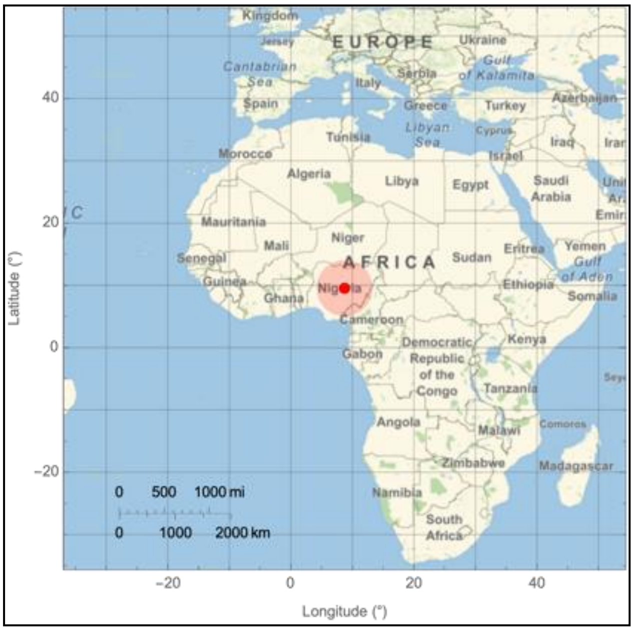

Figure 2: Map showing the Location of the Study Area

3.2 Physiography, Drainage Vegetation and Climate

The study area is located on a relatively flat to undulating land. Drainages are structurally controlled with some rugged terrain to the east and southern part of the study area. Ajibade et al. (2008) noted that these water channels in the area are mostly controlled by lithologic and structural units. The vegetation is of typical Guinea Savannah mosaic zone of the West African Sub-region (Ileoje, 1981) which is characterized with tall grasses and scattered trees. This comprises shrubs, thorny trees and other trees of moderate to high heights as well as different species of tall and short grasses. Examples include locust beans/mango trees, elephant/carpet grasses among others. The Weather/climate condition of the area is simply considered as steppe climate (NIMET, 2018). The average annual temperature ranged from 28 °C to 31°C classified as BSh (Kotten et al., 2006) while the annual average precipitation rages from 1270mm to 1524mm (Ileoje, 1981), with least amount of rainfall in January and highest precipitation of about 230mm in July/August every year.

4. Methodology

4.1 Field Data Acquisition

Ohmega Digital Terrameter was employed in acquiring the Vertical Electrical Sounding data along 4 traverses (Figure 3).

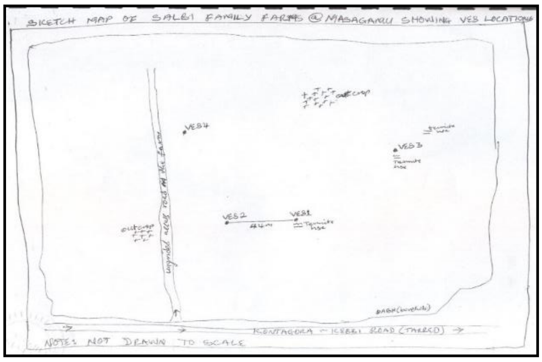

Figure 3: Map showing the 4 VES traverses in the study area

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Schlumberger configuration (Figure 4) with a maximum current electrodes' separation of 300m was employed to achieve a penetration depth of 120m. Two current electrodes were placed linearly at the same mid-point with two potential electrodes but at different distances from one another. The current electrodes were placed at equal distance, ***s*** from the mid-point of the array while the potential electrodes were similarly placed at equal distance but at $a/2 < s$. Different spreads of current electrodes, AB were achieved, thereby resulting in different probe depths.

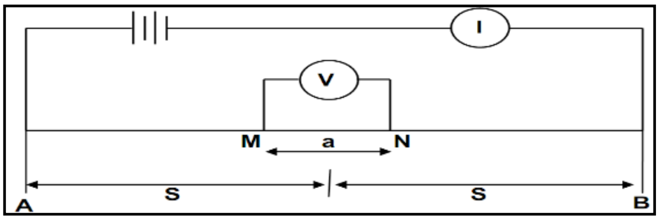

Figure 4: Schematic of Schlumberger Array for Data Acquisition

4.2 Computation of Soil Apparent Resistivity, ρ_a

Apparent resistivities were obtained from field resistance values using the equation:

$$\rho_a = \frac{2\pi R}{k} \quad (1)$$

Where ρ_a is apparent resistivity, R is the measured resistance, AB= Distance between current electrodes, MN=Distance between potential electrodes and the geometric factor, K is given as:

$$K = [\frac{1}{AM} - \frac{1}{AN} - \frac{1}{BM} + \frac{1}{BN}] \quad (2)$$

Therefore, ρ_a becomes:

$$\rho_a = \frac{2\pi R}{[\frac{1}{AM} - \frac{1}{AN} - \frac{1}{BM} + \frac{1}{BN}]} \quad (3)$$

5. Data Interpretation

The apparent resistivity, ρ_a values were fitted against half current electrode spread, AB/2 employing the ZHODY software. The resistivities, thicknesses and depth of the various layers were computed and the curve types were determined.

6. Results

Figures 5 - 8 show the geoelectric sections for the four VES stations. Generally, the AK type curve was observed in the study area. Figure 8 shows the lithologic cross section for the study area.

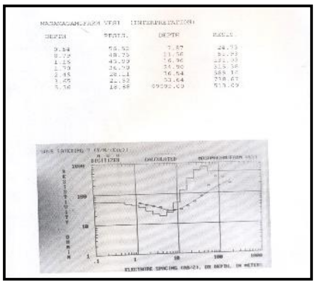

Figure 5: Geoelectric Section for VES 1

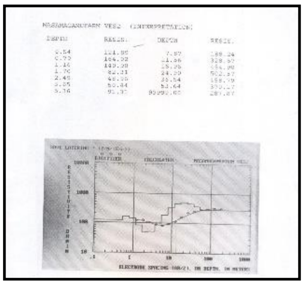

Figure 6: Geoelectric Section for VES 2

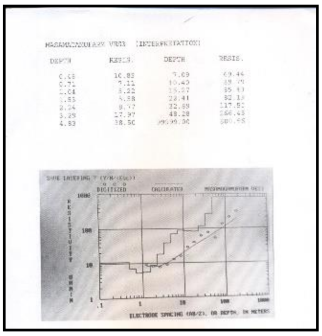

Figure 7: Geoelectric Section for VES 3

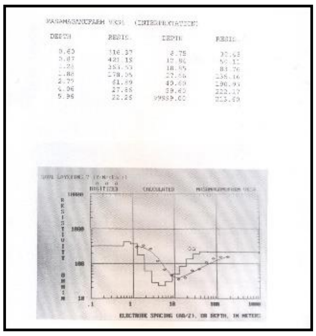

Figure 8: Geoelectric Section for VES

Table 4 is a summary of the interpretation of the results of the Vertical Electrical Sounding in the study area while Table 5 is the lithologic cross-section for the study area. The results show that the area is characterized by four geoelectric subsurface layers.

Table 4: VES Data Interpretation Results in the Study Area

Sounding Locations	Geoelectric Layers	Resistivity, ρ(Ωm)	Depth, D(m)	Thickness, *h*(m)	Inferred Lithostrata	Curve Type
VES 1 Long: 5⁰13'21.27" Lat: 10⁰27'23.83"	**I**	18 – 56	0 – 11.56	11.56	Weathered overburden	AK
	II	131 -738	11.56 – 53.64	42.08	Weathered basement, harden with depth	
	III	513	53.64 - ∞	-	Weathered/fractured Basement	
VES 2 Long: 5⁰13'22.69" Lat: 10⁰27'23.44"	**I**	48 – 164	0 – 5.36	5.36	Weathered overburden	AK
	II	188 – 502	5.36 – 53.64	48.28	Weathered/fractured basement	
	III	287	53.64 - ∞	-	Weathered/fractured Basement	
VES 3 Long: 5⁰13'16.79" Lat: 10⁰27'17.60"	I	5 – 10	0 – 2.24	2.24	Topsoil	AK
	II	17 – 266	2.24 – 48.28	46.04	Weathered basement	
	III	800	48.28 - ∞	-	Weathered Basement, harden with depth	
VES 4 Long: 5⁰13'23.08" Lat: 10⁰27'15.72"	**I**	22 – 421	0 – 18.85	18.85	Weathered overburden	AK
	II	135 – 222	18.85 – 59.60	40.75	Weathered basement	
	III	213	59.60 - ∞	-	Weathered/fractured Basement	

Table 5: Lithologic cross section for the study area

VES 1 Section			
Depth	***Thickness***	***Description of lithology***	***Infered Lithostrata***
0 – 11.56	11.56	Weathered overburden	
11.56 – 53.64	42.08	Weathered basement, harden with depth	
53.64 - ∞	-	Weathered/fractured Basement	
VES 2 Section			
Depth	***Thickness***	***Description of lithology***	***Infered Lithostrata***
0 – 5.36	5.36	Weathered overburden	
5.36 – 53.64	48.28	Weathered/fractured basement	
53.64 - ∞	-	Weathered/fractured Basement	
VES 3 Section			
Depth	***Thickness***	***Description of lithology***	***Infered Lithostrata***
0 – 2.24	2.24	Topsoil	
2.24 – 48.28	46.04	Weathered basement	
48.28 - ∞	-	Weathered Basement, harden with depth	
VES 4 Section			
Depth	***Thickness***	***Description of lithology***	***Infered Lithostrata***
0 – 18.85	18.85	Weathered overburden	
18.85 – 59.60	40.75	Weathered basement	
59.60 - ∞	-	Weathered/fractured Basement	
Key/Legend			
	Top Soil		
	Weathered overburden		
	Weathered Basement		
	Weathered/Fractured Basement		

7. Discussion

VES 1: Three geoelectric layers of AK curve type are delineated at this location. Inferred lithologies are characterized by an 11.56m thick weathered overburden with resistivity between 15.0 - 56.0 Ωm to a depth of 11.56m. Below this formation is a 42.08m thick weathered basement hardened to a depth of 5.64m. This has a resistivity value between 131-738Ωm. Following the hardened weathered basement is the weathered/fractured basement with resistivity value of 513Ωm with undetermined thickness and depth since it makes up the last layer. These layers are probable water-bearing geological structures.

VES 2: Three geoelectric layers of AK curve type are delineated at this location. The 5.6m thick top layer to a depth of 5.6m is characterized by weathered overburden materials with resistivity between 48 – 164Ωm. Underlying this layer is a 48.28m thick weathered/fractured basement to a depth of 53.64m with resistivity between 188 – 502Ωm. Below this zone is also a layer of weathered/fractured basement with resistivity of 287Ωm and undetermined thickness and depth. Layer I is probable water-bearing while Layers II and III are probable aquiferous geological structures.

VES 3: Three geoelectric layers of AK curve type are delineated at this location. Soil layers here are characterized by a porous and permeable 2.24m thick topsoil with resistivity between 5.0 – 10.0 Ωm and depth of 2.24m. Below this layer is a 46.04m thick weathered basement to a depth of 48.28m. This is zone has resistivity value between 17.0 – 266.0Ωm. Below this zone is a layer of weathered basement hardened with depth with resistivity of 800.0Ωm and undetermined thickness and depth. Layer I is dry top soil, Layer II is probably aquiferous while Layer III is probably water-bearing geological structures.

VES 4: Three geoelectric layers of AK curve type are delineated at this location. Lithologies here are characterized by an 18.85m thick weathered overburden with resistivity between 22.0 – 421.0Ωm to a depth of 18.85m. Underlying this layer is a 40.75m thick weathered basement to a depth of 59.60m. This has resistivity value between 135.0 – 222.0Ωm. Beneath this zone is a layer of weathered/fractured basement with resistivity of 213Ωm and undetermined thickness and depth. Layer I is water-bearing, Layer II is probably water-bearing while Layer III is probably aquiferos.

8. Conclusion

The hydrogeophysical investigations conducted in Salbi farm in Masagamu, Magama area, North-Central Nigeria delineated the presence of three subsurface geoelectric layers which are the top soil, weathered overburden and weathered/fractured basement. These layers correspond to the AK-type curve which is a characteristic of the basement complex environment. This research also revealed the presence of possible aquifers for groundwater storage in the area. The study area is predicted to have moderate to good groundwater potential, and this is supported by the occurrences and concentration of fractures which can constitute weathered/fractured aquifers around these regions.

9. Recommendation

Groundwater exploitation in the study area should be conducted at VES stations I, II and IV as they have higher concentration of fractures, and hence possibility of weathered/fractured basement aquifer. The wells to develop this resource should be drilled to an effective depth of 40 to 60 m for optimum yields. It is also recommended that pumping test be carried out on the drilled wells in order to further determine the aquifer efficiency and productivity in the area.

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