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HYDROGEOLOGICAL MAPPING OF A SECTION OF JANRUWA KAMANZO KADUNA STATE.

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ABSTRACT

Vertical Electrical Sounding (VES) method of Electrical Resistivity was carried out at a section of Janruwa-Kamanzo, Kaduna metropolis, using the Schlumberger array, with maximum electrode separation, AB/2 of 100m on 20 VES stations, having 20m offsets to each other. The survey was carried out to obtain information on the subsurface condition, which can be of great assistance in underground water exploitation. From the interpreted data, geoelectric and geologic sections and indeed some specialized maps were produced. It is suggestive that the area is underlain by three to five layers. The first layer also known as topsoil varies from 0.3 m – 4.7 m in thickness and 63 Ωm – 1601 Ωm in resistivity. This geoelectric derivation suggests that the topsoil is highly lateritic in nature. The weathered/fractured basement varies from 73 Ωm – 639 Ωm and 3.9 m – 58 m respectively. The derived geologic suggests that the weathered layer varies in composition (silty/sandy clay, clay and sand) with an average resistivity and thickness values of 305 Ωm and 17 m respectively. The regions of low subsurface apparent electrical resistivity with deep aquifer are suggested for borehole installation for groundwater development. The last layer, which is at infinite thickness, is found to have high resistivity values ranging from 555 Ωm to 3333 Ωm. The observed regions of low resistivity in this layer suggest that the basement rocks may have under fracture and are slightly weathered. The observed relatively high resistivity zones range from 73 Ωm – 639 Ωm with an average aquifer thickness of 32m suggesting high aquifer potential zone targets for siting boreholes.

Keywords: *Electrical Sounding, g*roundwater, aquifer potential, deep aquifer

1. Introduction

The hydrogeology of an area is controlled by the geological and climatic factors of the region. This is because the ecological formation underlying an area and its structures determine the type of aquifers that would be developed and how they would be recharged (Alao, 2023; Alao, et al., 2024a). The climate determines the amount and the rate of recharge of the aquifer. Thus, the hydrogeology of Kaduna state like that of any other place is to a large extent a function of the geologic setting (Dogara, et al., 2017a). The climatic and hydrologic conditions control the surface and subsurface waters in the area. The surface water, which is directly governed by the underlying geology, has its infiltration, evaporation, run-off and other flow components as major factors responsible for groundwater recharge and accumulation in the area (Omeiza & Dary, 2018).

Water remains a scarce natural resource that requires special treatment due to its necessity for human survival (Alao, et al., 2022a). While this resource is widely dispersed across nature, its amount and quality differ depending on the location (Alimi, et al., 2022). This can be attributed to factors such as natural population growth, rising urbanization, rising basin development, and climate-related hazards. The availability of water for human use is rapidly declining. Because surface water is so limited, groundwater has emerged as a substitute supply of water for human use. Because groundwater is accessible throughout dry seasons and less susceptible to pollution, it is now widely relied upon for a variety of residential and commercial applications, including drinking, agriculture, and industrial operations worldwide (Abdullahi, et al., 2010; Alao, et al., 2023a). Groundwater localization within the Basement Complex occurs either in the weathered mantle or in the fracturing, fissuring and jointing systems of the bedrock (Aboh, 2001; Alao, et al., 2022a). These unconsolidated materials are known to reflect some dominant hydrologic properties, and the highest groundwater yield in Basement Complex areas are found in areas of thick overburden overlying fractured zones and are characterized by relatively low resistivity (Jatau, et al., 2013).

A study applied the VES technique to investigate the subsurface layering of some selected villages in Chikun LGA of Kaduna State, to determine the configuration of the aquifer underlying the region. The result of the interpreted VES data suggested that the area is underlain by three to five layers (Aboh, 2009). The geologic sections derived from the analyzed geoelectric section suggested that the alluvial deposits of sand, silt and sandy clay as well as the weathered and fractured basement rocks constitute the aquifer in the areas. The average thickness of the aquifer was found to be 25m. The geoelectric section generated also suggests that the resistivity values of the aquifer components range from 100Ωm to 250Ωm for the alluvial deposits to an average of 50Ωm to 350Ωm for the weathered/fractured basement formations. Kaduna, where the study area is located is underlain by the Crystalline Basement rocks (Eduvie, 2003; Dogara, et al., 2017; Alao, et al., 2019). At present, the quantity of groundwater for both drinking and domestic purposes at the Janruza area is generally moderate. However, the current influx of people as well as other prominent potential groundwater use, that may be attracted to the populace may likely pose threat to groundwater. The work aimed at applying electrical resistivity to determine to map the hydrogeological nature of the study area for future planning.

2. Site Description

The geography of Kujama agriculture is perfect. The precise location of the location is at latitude and longitude $10^0\ 27'986``\ N$ and $07^0\ 28'84``\ \mathrm{E}$. It covers a total landmass of 160,000 m^2. The studied region is made up of metamorphic rocks that form a crystalline basement complex. The primary aquifer component of the basement complex is found in the worn, fractured basemen. The rocks in the study region are thought to be capped by laterites, sandstones, silty clay, and clay sand (Aboh, et al., 2016; Alao, 2024). The laterites are often well consolidated, particularly near the surface, and weather into lateritic nodules mixed with silty and sandy clays. However, it was noted that the presence of some hard-resistant granite outcrops in the terrain is typically caused by Precambrian rocks that have occasionally been exposed to erosion weathering (McCurry, 1970; Oyawoye, 1970; Dan-Hassan & Olorunfemi, 1990). Studies has shown that there is a strong connection the climatic conditions and the weather activities (Ayejoto, et al., 2023). The average annual rainfall of the state is about 1500mm with the highest amount recorded in the months of August/September. High evaporation during the dry season causes water shortage problems in many of the Local Government Areas of Kaduna state. Night temperatures as low as 10^{o}C have been recorded in January, and daytime temperatures as high as 40^{o}C in April (Ajibade & Okwori, 2009). The dominant rock types are the migmatite-gneiss complex and the Older Granites which intruded the host gneissic rocks. Prolonged in-situ weathering of the Crystalline Basement rocks under tropical conditions has produced a sequence of unconsolidated material (laterites) whose thickness and lateral extent vary extensively. There are three major types of aquifers in the study area namely weathered overburden aquifer, fractured bedrock aquifer and the stream alluvial deposits aquifer (NGSA, 2016). The basement complex rocks are crystalline rocks of low porosity and permeability. In this geologic environment groundwater accumulation depends on the (i) degree of weathering and thickness of the overburden, (ii) degree and nature of fracturing of the rocks, (iii) the presence and absence of clays above the weathered zone and its effect on rate of infiltration of water into the aquifer, and (iv) the hydrological continuity (permeability) of the weathered zone.

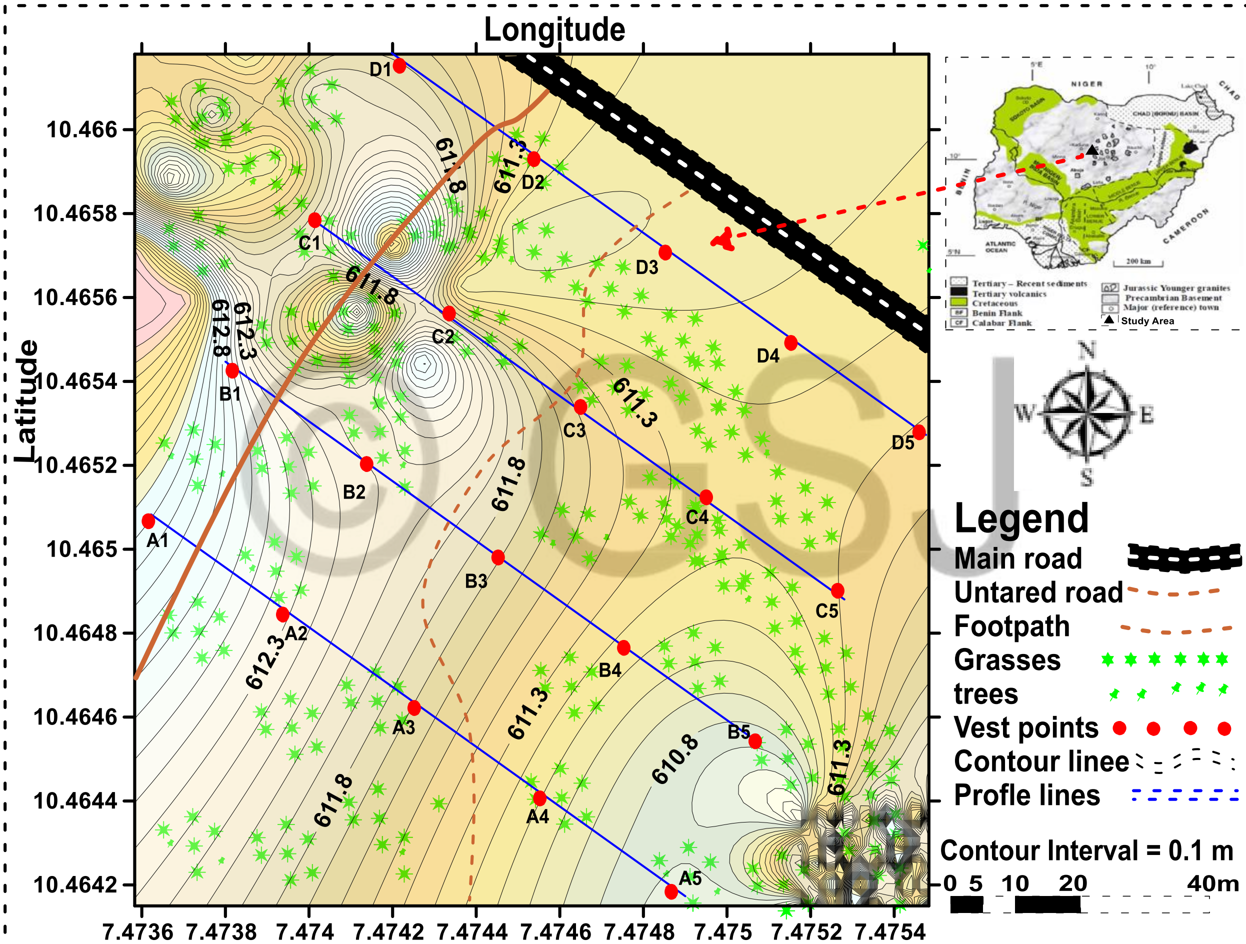

Fig 1: Map of Study Area Showing the VES Points.

3. Methodology

The use of geophysical techniques is growing in popularity as a useful tool for groundwater exploration (Alao, et al., 2023b). Electrical resistivity techniques which use Ohm's law were carefully selected for this investigation to obtain the subsurface resistivity distribution over the twenty (20) VES locations. By Ohm's law, electrical resistivity measurements are often performed by measuring the voltage difference at two potential electrodes (C and D) and injecting current into the ground through two current electrodes (A and B in Fig. 2) (Telford, et al., 1990; Loke, 2000). That is:

$$V = IR \qquad \Rightarrow R = \frac{\Delta V}{I} \qquad (1)$$

Because the actual current flow is highly influenced by conductive layers (Dogara & Alao, 2017a; Dogara & Alao, 2017b), thus, the value measured is known as the "apparent resistivity" and is donated by ρ_a. That is:

$$\rho_a = \frac{RA}{L} \qquad (2)$$

From the Schlumberger array (Fig 2), the geometry factor 'K' is defined as:

$$K = \frac{A}{L} = 2\pi \left[\left(\frac{1}{r_A} - \frac{1}{r_B} \right) - \left(\frac{1}{R_A} - \frac{1}{R_B} \right) \right]^{-1} \quad (3)$$

The value of K depends on the arrangement of the four electrodes (A, B, C, & D) is defined in Fig. 2 as

Solving Equation (3), we have:

$$K = \frac{A}{L} = 2\pi \left[\frac{(r_{AC})(r_{AD})}{r_{CD}} \right] \qquad (4)$$

From equation (2) and (4), the apparent resistivity (ρ_a) becomes:

$$\rho_a = \frac{RA}{L} = 2\pi R \left[\frac{(r_{AC})(r_{AD})}{r_{CD}} \right] \qquad (5)$$

Where R is resistivity. Thus, equation (5) becomes:

$$\Rightarrow \rho_a = RK \qquad (6)$$

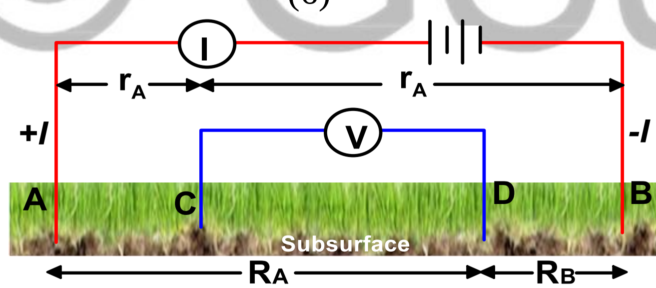

Fig. 2: Schlumberger Configuration

4. Results Presentation and Discussion

Fig 3 is the geoelectric section of the study area showing all the layer structures including the weathered/fractured basement respectively with average resistivity and thickness values of 305Ωm and 23m. The thickest part of the aquifer was found to be the region around VES points $P_{1/4}$, $P_{1/5}$, and $P_{3/2}$ with thicknesses of 35.5 m, 31 m and 34.5 m respectively. The noted area of high aquifer thickness may be considered good enough for borehole siting. According to previous studies, the area with thick aquifer units of 15m and above may generally appears good enough for drilling productive boreholes depending on the underlain materials such as electrical resistivity, sand-to-clay ratio and the degree of saturation (Abdullahi & Udensi, 2008; Alao, et al., 2023c). Based on this information, the observed relatively high resistivity zones range from 73Ωm – 639Ωm with an average aquifer thickness of 32m suggesting high aquifer potential zone targets for siting boreholes. The lower aquifer thickness region (depicted by both yellow and green colours) covers most of the study area. These regions could be considered as regions of low aquifer potential zones and they may be relatively vulnerable to near-surface contamination due to their relatively shallow nature. Considering the aquifer thickness and resistivity values (11m - 41m and 73Ωm - 639Ωm respectively), the study area appears fairly good region for siting of boreholes. In summary, the blue, green and red colours signified average, lower poor aquifer potential zones.

Fig 4 shows the surface contour map produced by contouring the resistivity values and overburden thickness of the basement rocks to reveal the variation in the fresh basement and the degree of weathering and fracture of the study area. The map shows that the depth to the basement and the basement resistivity vary from 16m to 52m and 1000Ωm to 7500Ωm respectively. Previous studies noted that when the bedrock with relatively low resistivity (<750Ωm), could indicate fracturing and high aquifer potentials (Aboh, 2002; Aweto, 2012). It was also noted that the variation in resistivities of the basement is a function of the degree of weathering of the basement (Omeiza & Dary, 2018; Nur, et al., 2022). Based on this information, the area depicted in blue colour could indicate fractured and thus increase the aquifer potential of the study area. In general, the map shows that the study area is underlain by fractured/fresh basement rock. On the other hand, the deepest part (range from 26m to 48m) depicted in blue colour is the region already suggested for groundwater exploitation in this work. According to a recent study, one of the most significant parameters in geophysical investigations is accurate depth estimation for proper planning (Alao, et al., 2024c). The finest area for delineation for borehole installation for regional groundwater development occurs within a deep basement about a depth of 25 m and above.

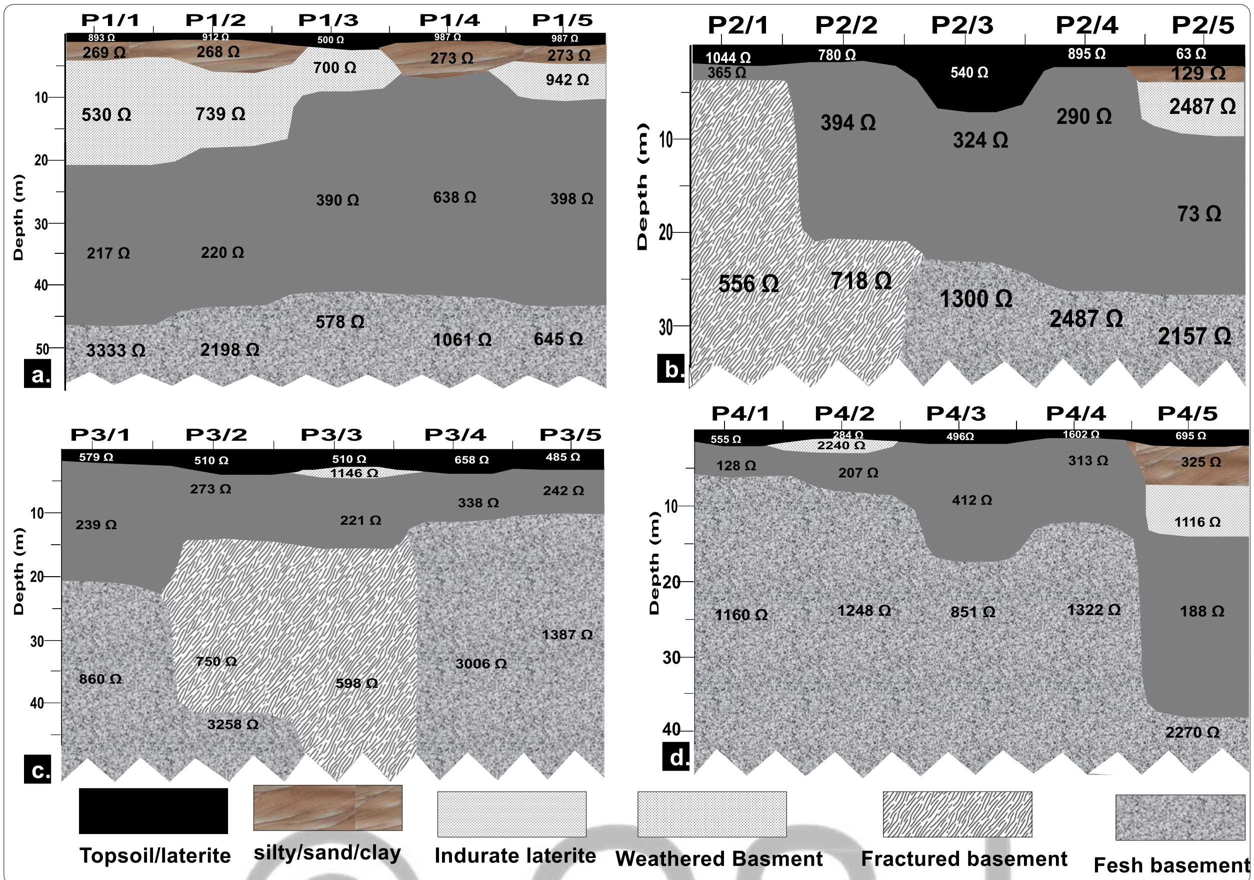

Fig. 4: Geoelectric/geologic section of all four Profiles for Aquifer Evaluation showing the keys. (a) profile 1, (b) profile 2, (c) profile 3, and (d) profile 4

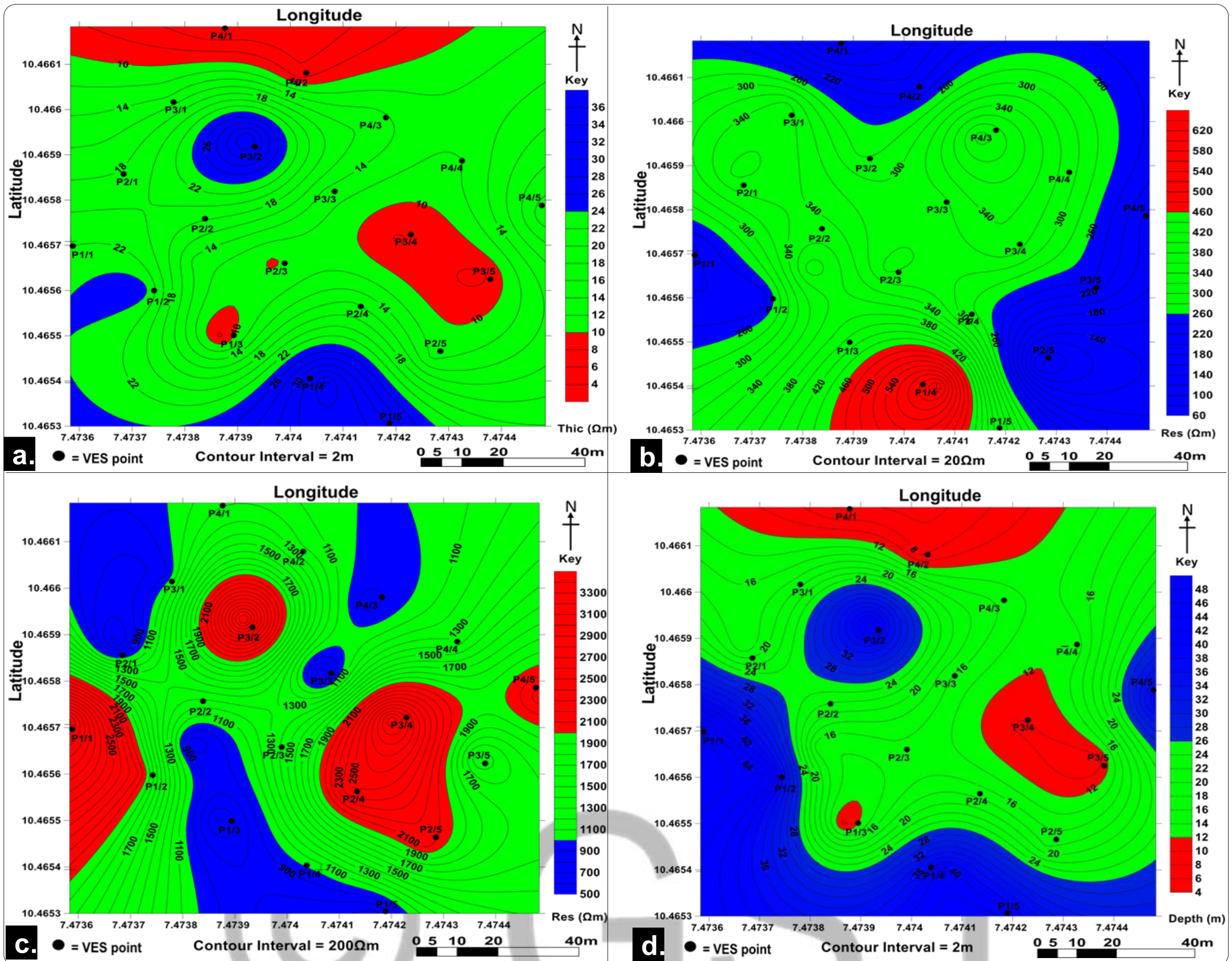

Fig. 5: The surface contour map of subsurface parameters (a) Isopach Map of Weathered Layer, (b) Iso-resistivity Map of Weathered Basement Layer, (c) Iso-resistivity Map of Basement Rock, and (d) Depth to the Basement (Overburden Thickness) Map.

5. Conclusion and Recommendations

The high thick weathered basement with a relatively low resistivity that covers a small region depicted in blue colour in the whole study area has been successfully identified as a potential aquifer zone target for groundwater exploitation and it may not be considered large enough to harbour a substantial quantity of water demand that may be arising in the study area. The dc-resistivity method has proved very successful in the identification of strata and exploitation of groundwater within the crystalline basement rocks. In conclusion, the following recommendation is made for future researchers: (i) the area of study taken is relatively small. Thus, the a need to carry out more geophysical research to cover more areas within Janruwa Kamanzo, and (ii) another geophysical research using a different method, like

Seismic. The techniques used in this study are also applicable to other regions of Nigeria, particularly the northern states where water scarcity is a serious threat.

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