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Geophysical Characterization of Basement Rock and Groundwater Potential Using Integrated Techniques in Odeda General Hospital, South – West, Nigeria

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Abstract:
Background: *Assessment of groundwater potential zone is extremely important for groundwater management. This study was carried out to characterize the basement rocks and groundwater potentials by delineating the resistivity and overburden thickness of the subsurface lithology of Odeda General Hospital, Southwest, Nigeria.*
Materials and Methods *An integrated geophysical survey involving the Very Low Frequency Electromagnetic (VLF-EM) and Electrical Resistivity using Schlumberger electrode arrangement were adopted for this study. The VLF-EM data were acquired along five traverses using VLF-EM 34 Meter while ten VES surveys were carried out at areas with anomalous conductivity delineated by the VLF-EM survey using Campus Ohmega resistivity meter. The maximum current electrode spread and potential electrode separation were 200m and 10m respectively.*
Result
The VLF – EM survey results were filtered with Karous – Hjelt (KH) filtering software, however, the VES data were analyzed using WIN-RESIST software. The resulting geoelectric section from the interpretation of the computer iterated VES curves indicate the presence of maximum of five lithologic layers, which includes the top soil, sandy clay, weathered layer (clay), fractured basement, and fresh bedrock, with varying resistivities and thicknesses. The overburden thickness varies from 12.1 to 55.7. The VES interpretation was also used to generate Dar Zarrouk parameters, which includes the coefficient of anisotropy ranging from 0.72 to 1.83, and the reflection coefficient, which varies from 0.6 to 1.0. The area is classified into low, medium and high yield groundwater potential zones. Generally, the study area does not boast of excellent groundwater prospects since most of the VES location falls under the medium yield with the overburden thickness less than 13 m and reflection coefficient greater and equal to 0.8.
Conclusion: *From this study, only VES 9 has a high productive aquiferous zone. The integrated geophysical approach has proven to be productive in delineating areas with groundwater potential in a typical basement complex at Odeda General Hospital, Southwest, Nigeria.*
Keywords: *Electrical resistivity, Electromagnetic method, Groundwater potential*

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I. Introduction

Groundwater is one of the most valuable natural resources, which supports human health, economic development and ecological diversity. It is the water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations. Groundwater represents the second-most abundantly available freshwater resources after surface water, which is the first and constitutes about 30% of fresh water resources of the globe (Subramanya, 2008). Over the years the growing importance of groundwater based on an increasing need has led to unscientific exploitation of groundwater creating a water stress condition (Waikar and Nilawar, 2014).

The basement complex of south western Nigeria comprises of different types of crystalline rocks with different origins, of which the gneiss-migmatite is predominant. Due to the diversity in the formations of these rocks, it presents a difficulty in groundwater exploration especially considering the increased failures of borehole in the area (Olayinka and Olorunfemi, 1992). Nonetheless, groundwater use in the territory is progressively turning out to be depended upon because of urbanization of most rural regions that rely entirely upon stream, hand-burrowed wells. Absence of quality portable water supply also plays a role in the dependence of groundwater in these areas. Groundwater occurrence in basement rocks is attributed to the upper weathered section and fractured portion of the underlying fresh bedrock (Olorunfemi and Fasuyi, 1993).

Delineating an aquiferous zone for borehole development often poses a problem because the basement aquifer are often limited both laterally and vertically (Satpathy and Kanugo, 1976). There are various geophysical methods which can be used to detect groundwater potential zones. The choice of method depends largely on the depth of investigation and sometimes cost (Todd, 2004; Majumdar and Das 2011). Of all these methods used in exploring groundwater, the electrical resistivity profiling and electromagnetic method have been the most widely used (Molua and Emagbetere, 2005). This is because the operation of the field instrument is not complicated and the analysis of data is economical (Iseshien – Emekeme *et al.,* 2004; Ezeh and Ugwu, 2010; Anomohanran, 2011a, b; Atakpo and Ofomola, 2012).

II. Materials and Methods

The study area is Odeda General Hospital and its environs situated within Odeda town, along Abeokuta – Ibadan express road. It lies between longitude 3^0 31' 23"E and 3^0 31'39"E and between latitude 7^0 14' 06"N and 7^0 14' 43"N. The Climate is tropical, typical of the sub-equatorial belt of the South-Western Nigeria, with an average annual temperature in the range of 25°C – 27°C. The climate in this region is characterized by two seasonal climate regimes: the wet and dry seasons. These climate regimes are dependent on two prevailing air masses blowing over the Nigeria nation. The two air masses are the Tropical Maritime (Tm) and the Tropical Continental (Tc). The study area experiences rainfall all year round. Although the rainfall pattern varies significantly from year to year, the dry months are mostly dry (November to March). The onset of rains begins in April while the retreat is usually around November. The study area is part of the basement complex of south-western Nigeria. It is underlain by the Migmatite-gneiss-quartzite complex rocks. The two main rock types in the area are banded gneiss and quartzite. The outcrops of both rock types are highly weathered and fractured. In most parts of the study area, they are covered by the superficial overburden derived from the weathering of the basement rocks. Occurrence of groundwater is rather shallow and its movements are controlled largely by topography. At Bedrock depressions in a typical Basement Complex area in Nigeria are groundwater collecting centres. They also show relatively high overburden thickness while bedrock ridges are characterized by thin overburdens. Consequently the groundwater flows away from the crest of the basement ridges into bedrock depressions (Ariyo, 2005).

III. Procedure Methodology

Two Geophysical techniques were used for this work; Very Low Frequency Electromagnetic (VLF-EM) and Vertical Electrical Sounding (VES). The VLF-EM served as a reconnaissance tool to initially delineate areas with conductive or fractured zones while the resistivity method (VES) served in imaging the subsurface to confirm the presence, depth of emplacement and thickness of identified fractures. The VLF-EM survey was carried out at different stations and were surveyed at 5m interval along five traverses approximately east-west direction ranging from 0 to 200 metres in length using GEONICS 34 VLF-EM unit. And for VES survey, ten points were selected within the VLF-EM area of study (Figure 1). At each point, VES using Schlumberger array was carried out. Each electrode spacing ranges from 1m to 100m while that of potential electrode spacing ranges from 0.25m to 10m. The principal instruments used for this survey are VLF-EM 34 and Campus Omega resistivity meter.

IV. Results

From the result Very Low Frequency-Electromagnetic Method (VLF-EM) was adopted field data were filtered via the Karous – Hjelt (KH) filtering method and presented on 2-D contoured sections. On the interpreted sections, highly conductive zones are depicted as hot (red) while regions with very low conductivity are depicted

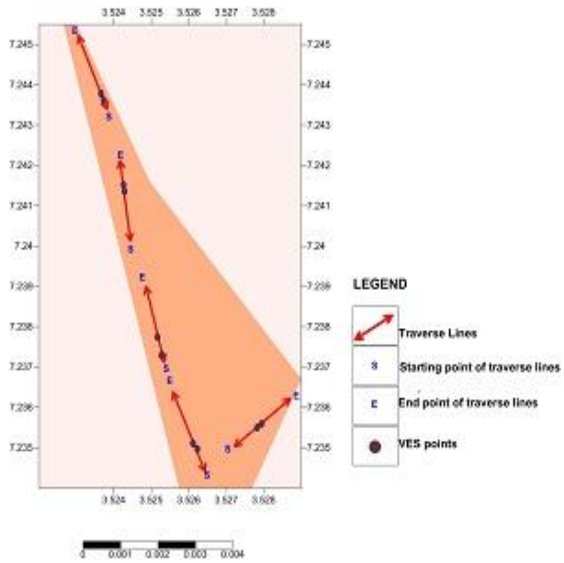

Figure 1: Ten VES survey points along VLF-EM profile

The high conductivity zones with red signatures could be due to the presence of fracture or build-up of clayey materials (McNeil and Labson, 1992)

The VLF-EM survey serves as a preliminary investigation for the VES. The areas delineated as high conductive/fracture zones along the traverse were considered as point of interest in the VES survey. The interpretation of the VES data is both qualitative and quantitative in which the thickness, resistivity of different layers and their inferred lithologies based on their resistivity and reflection coefficient was determined. The geoelectric parameters of the various litholoies are shown in Table 1.

The geoelectric interpretation of the study area revealed maximum of five lithologic layers namely: the top soil, sand clay, weathered layer (Clay), fractured basement, and fresh bedrock. The fractured basement was differentiated from the fresh basement using the resistivity values and the values of the reflection coefficient. The reflection coefficient was obtained by formula proposed by Olayinka, (1996). The reflection coefficient shows the degree of freshness of the rock at the bedrock interface and can be defined as:

$$r = \frac{(\rho_n-(n-1))}{(\rho_n + \rho\ (n-1))} \qquad \ldots\ldots \quad 1$$

Where ρ_n is the resistivity of the nth layer and (n-1) is the resistivity of layer overlying the nth layer. The formula was used to calculate the reflection coefficient and it shows a value ranging from 0.63 to1.00. The calculated reflection coefficient was used to produce a reflection coefficient map (Figure 4). According to Olayinka, (1996); Bayewu (2017), reflection coefficient greater than 0.8 exhibits weathered or fractured basement, which, thus, favours a high groundwater potential. In a typical basement complex, the decreasing reflection coefficient and relatively high overburden thickness are worthy parameters to accurately determine areas with groundwater potential (Olorunfemi and Olorunniwo1985).

The overburden thickness of the study area varies from 12.1 to 55.7. The overburden thickness map (fig 3) shows thick overburden thickness in the extreme northwest and south west of the study area with the overburden thickness ranging from 48 to 55.7. Appreciable overburden thickness is also noticeable in the central part of the study area south, and the south eastern part of the study area, with the overburden thickness ranging from 24.1 to 32.5. Shallow overburden also exists in the north-western part of the study, close to the areas with thick overburden and in the extreme southern and northern part of the study area with the values ranging from 6.2 to 12.1. Therefore, groundwater availability in this area will depend on the areas with presence of fractures with thin overburden thickness and areas with thick overburden thickness.

V. Discussion

The evaluation of the groundwater potential of the study area is based on the geoelectric parameters derived from the VES interpretation result. Among the parameters considered for the groundwater potential evaluation includes the overburden thickness, the reflection coefficient and the presence of fracture or weathered rock, which, however is summarized in table 2.

Based on the aforementioned parameters, the groundwater potential of the study area is classified into three; low, medium and high groundwater potential areas. These criteria are the basis in evaluating excellent points for groundwater potential in the study area.

Areas with high yield are areas where the overburden thickness is greater than 13 m and/or reflection coefficient is less than 0.8. Medium yield areas are areas with overburden thickness greater than 13 m but less than 30 m and with reflection coefficient greater than or equal to 0.8.The low medium is the last criteria and these are areas characterized with overburden thickness less than 13 m and the reflection coefficient greater than or equal to 0.8.

Table no 1: Summary of Geo-electrical Parameters in the study area

No. VES	No. of Layers	Resistivity	Thickness	Depth	Description
1	1 2 3 4	76.8 33.1 12.7 3670	0.6 11.3 16.6 Infinite	0.6 11.9 28.5 Infinite	Top soil Sand clay Clay Fresh basement
2	1 2 3 4 5	136.6 13.2 578.9 46.3 12875.3	0.4 0.4 0.6 31.1 Infinite	0.4 0.9 1.5 32.6 Infinite	Top soil Clay Lateritic soil Sand clay Fresh basement
3	1 2 3 4	61.2 334.7 17.9 5727.8	6.2 5.3 12.6 Infinite	6.2 11.5 24.1 Infinite	Top soil Lateritic soil Clay Fresh basement
4	1 2 3 4	54 389.2 18.2 2951	5.7 7.1 20.0 Infinite	5.7 12.7 32.7 Infinite	Top soil Lateritic soil Clay Fresh basement
5	1 2 3 4	221 18.5 123 10276	0.5 0.4 47.1 Infinite	0.5 0.9 48.0 Infinite	Top soil Clay layer Sand clay layer Fresh basement
6	1 2 3 4	164 63.5 141 11119	0.6 2.0 53.1 Infinite	0.6 2.6 55.7 Infinite	Top soil Clayey sand layer Sand layer Fresh basement
7	1 2 3	189.4 35 13065.3	0.6 11.2 Infinite	0.6 11.8 Infinite	Top soil Clayey sand layer Fresh basement
8	1 2 3	321.7 107.2 8822.2	0.7 25.2 Infinite	0.7 25.9 Infinite	Top soil Sand clay layer Fresh basement
9	1 2 3 4	154 10.3 75.2 332	0.5 0.3 11.3 Infinite	0.5 0.8 12.1 Infinite	Top soil Clayey layer Sand clay layer Fractured basement
10	1 2 3 4	305 110 199 19714	0.5 4.8 43.0 Infinite	0.5 5.3 48.3 Infinite	Top soil Sand clay layer Sand layer Fresh basement

Table no 2: Groundwater Potential across the 10 VES stations

No. VES	Overburden thickness	Reflection coefficient	Presence of fractured/weathered rock	Remark
1	28.5	0.99	-	Medium yield
2	32.5	0.99	-	Medium yield
3	24.1	0.99	-	Medium Yield
4	6.2	0.99	-	Low yield
5	48	0.98	-	Medium yield
6	55.7	0.98	-	Medium Yield
7	11.8	1	-	Low Yield
8	25.9	0.98	-	Medium Yield
9	12.1	0.63	Fracture available	High Yield
10	48.3	0.98	-	Medium Yield

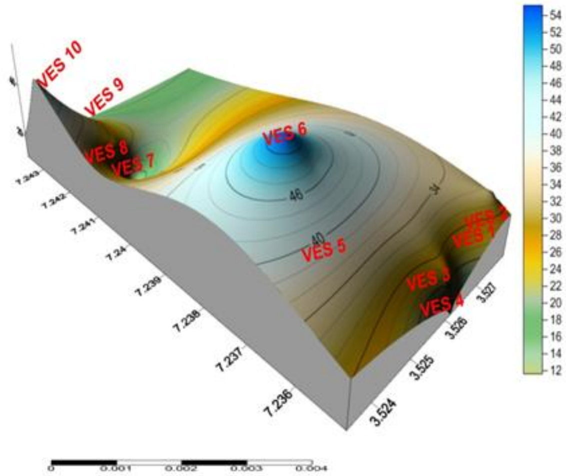

Figure 2: Map showing 3D Overburden thickness of the study area

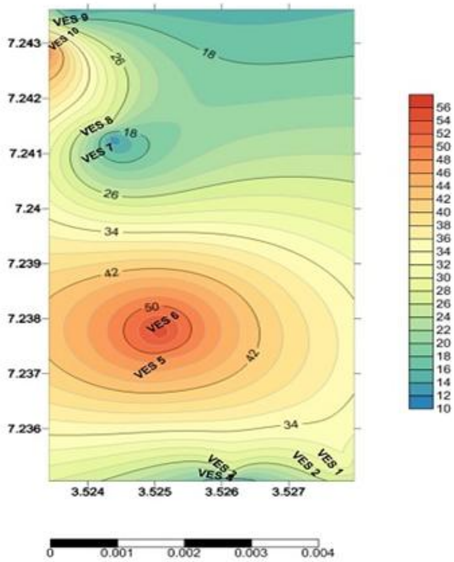

Figure 3: Map of the Overburden thickness

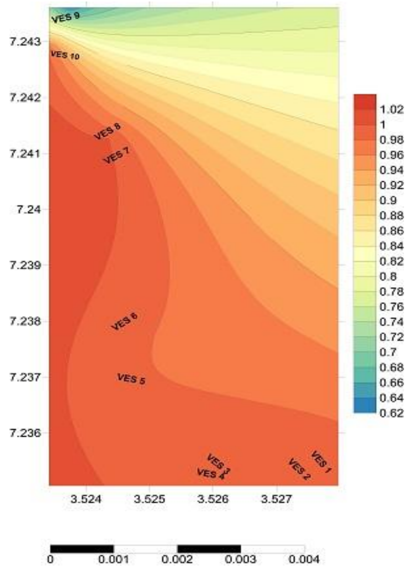

Figure 4: Reflection coefficient map of the study area

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