JASEM ISSN 1119-8362

Full-text Available Online at
www.ajol.info and
www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage. *Dec,* 2017
Vol. 21 (7) 1291-1296

Geo-Electrical Investigation for Groundwater Potential of Ihievbe Ogben, Edo North, South Western Nigeria

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ABSTRACT: This study was carried out within Ihiebe Ogben community in Akoko Edo LGA, Nigeria to investigate the ground water potential of the Basement Complex rocks using Vertical Electrical Sounding (VES) that deploys Schlumberger Array configuration. Evaluation of hydrogeological parameters shows fractured/ weathered basement thickness, resistivity values of the fractured basement, overburden thickness and basement relief having values between 1.5-7.9m, 64.5-503.9 Ωm, 5.2-15.7m and 136.8-160.7m respectively. Prospectivity ranking map was generated from these parameters and was used to rank the area around the VES stations. The results show that the most prospective areas with the highest ranking of 8,7 and 6 correspond to areas around VES station 6,1 and 2 respectively, restricted to the Eastern – Northwestern region of the study area.

DOI: **https://dx.doi.org/10.4314/jasem.v21i7.12**

Received 17 October 2017; received in revised form 17 November 2017; accepted 10 December 2017

Keywords: Groundwater, Vertical Electrical Sounding, Fractured basement, prospectively ranking

The ease of developing groundwater in Nigeria is restricted by the fact that most part of the country is underlain by Basement Complex rocks. (Kazeem,2007). Development of secondary porosity and permeability by weathering in such terrains bring about the occurrence of groundwater. The aquifers are inherently discontinuous; hence, the need to conduct geophysical investigation to locate areas with abundance of such fractures capable of holding economic quantity of water in place for productive borehole placement.

Various geophysical methods have been applied successfully to explore for ground water in basement terrains. Some of these methods include electrical, magnetic, electromagnetic etc. Of all these methods, electrical resistivity method has been the most widely used for groundwater exploration (Alile et al., 2008). The VES (Vertical Electrical Sounding) is an electrical resistivity method that is commonly used for depth sounding due to its simplicity and reliability.(Olawuyi and Abolarin, 2013). It is used to evaluate the vertical variation of electrical resistivity below the earth surface since the electrical resistivity of most rocks is dependent on the amount of water in the pore spaces within the rocks, the distribution of these pores and the salinity of the water in the pore spaces.

The study area is underlain by Precambrian Basement Complex rocks, characterized by low porosity and permeability. The highest groundwater yield in such terrains are found in areas where thick overburden overlies fractured zones; these zones are often characterized by relatively low resistivity values (Olorunfemi et al., 1990). Locations of such zones are valuable sites to place wells for portable groundwater production devoid of pollutants (Alabi et al., 2010). The people of this community typically depend on various forms of water source such as streams and hand dug wells known for their vulnerability to pollution, thereby making them prone to water borne diseases.(Ologe et al., 2014).

The need to provide portable water sources for Ihievbe Ogben community, to reduce their adverse health exposure level constitutes the objevtive of this study.

MATERIALS AND METHODS

The geophysical prospecting method adopted for this study is the Vertical Electrical Sounding (VES) techniques of the Electrical resistivity method deploying the Schlumberger array configuration. The ABEM SAS-1000 Terrameter along with necessary accessories equipment were used. According to (Olawuyi and Abolarin, 2013), in the schlumberger array, the spacing between the potential electrode (MN) was recommended for reliable readings, not to exceed 40% of half the distance of the spacing (AB) of the current electrodes. The current survey comprise of 8 VES stations (Figure 2), acquired deploying the schlumberger array with a maximum current electrode separation (AB/2) of 100m.

The apparent resistivity electrical response measured from the field were then plotted on double logarithmic graph sheet against half the current-electrode spacing (AB/2) to produce the observed field curve which was eventually initially interpreted by partial curve matching to give an estimate of the layers resistivity and thickness. These results serve as starting point for the iterative computer assisted interpretation that was later done. Geo-electric section and Subsurface maps were generated using parameter such as the overburden thickness, weathered/Fractured zone thickness, Resistivity response of the weathered/ Fractured layer, Basement relief, Clay thickness and Prospectively ranking, to aid our interpretation and evaluation of the ground water potential of Ihieve Ogben Community.

STUDY AREA

The study area is Ihievbe Ogben, and it is located in Edo State, southwestern Nigeria. It lies between latitude 7^0 09'45" and 7^0 11'40" N and longitude 6^0 08'45" and 6^0 11'15" (Figure 2). The study area falls within the Igarra schist belt, which is part of the South Western Nigeria Basement Complex rocks (Figure 1). The Basement complex rocks underlying the study area is classified into four main lithologies (Oyawoye, 1972), namely: The Older Granite; The Migmatite Complex; The Metasediment series; Miscellaneous rock rock types.

The mapped lithologies around the VES vicinity are basically typical of the rocks types found within the Igarra schist belt. Therefore the study area falls within the third lithological group classification of Oyawoye 1972.

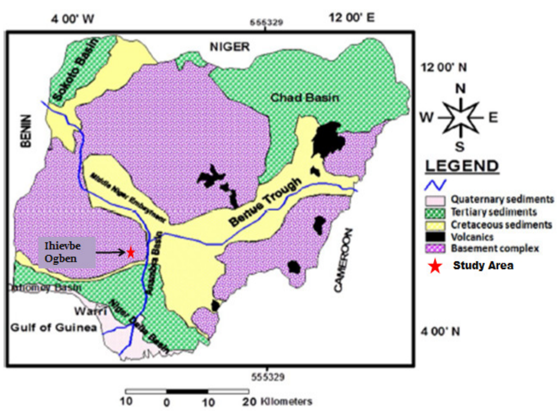

Fig1: Geological Map showing major rock distribution in Nigeria and the position of the study area. (Modified after

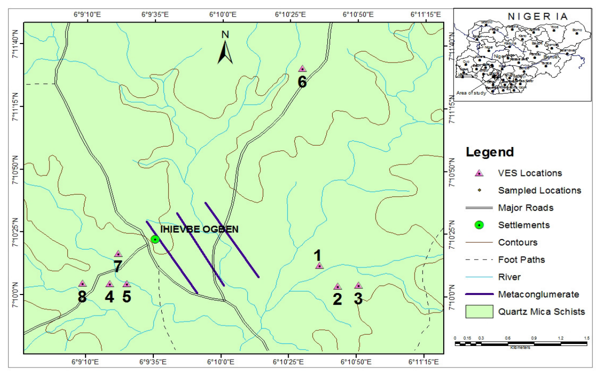

Fig 2: Map showing rock types and location of the study area with VES station distribution

RESULTS AND DISCUSSIONS

Eight (8) depth sounding points using Schlumberger array were conducted within the study area. The aquired field data and interpreted results are presented in tables, charts, VES profile curves, geo-electric sections and subsurface maps. Hydrogeological parameters evaluated to understand the groundwater potential around the study area include basement relief, overburden thickness, fractured zone thickness, fractured zone isoresistivity distribution. Four geoelectric layers were interpreted applying both partial curve matching and computer software iterative technique (Table 1). These layers correspond to the top soil, clay, weathered/fractured basement and fresh basement typical of the geological layering characteristics of the basement terrain.

The geo electrical parameters interpreted from the 8 VES stations are present in Table 1. Four different curve types were interpreted; KH ($P1 < P2 > P3<P4$), HA ($P1 < P2 > P3<P4$), QH ($P1 > P2 > P3<P4$) and QA ($P1> P2 > P3<P4$) (Figure 4). The interpreted VES results were used to model the subsurface rock in 2-D geo-electric sections. (Figure 5). The model gave insights into the geometry and thickness variation of the various lithologic units along the cross section. Four major layers that correspond comparatively to the top soil, clay, weathered/ fractured basement and fresh basement, typical of the four basic lithological units defined in basement hydrogeology were interpreted, (Bayode et al., 2005). From Table 1, it is observed that for more than 50% of the sounding points, the resistivity of the bedrock is not less than 5000Ωm. As demonstrated by Hezell et al.(Hezell et al., 1992), the bedrock can be described as incompetent and mostly fractured.

The first layer on the geo- electric section is the top soil characterized by clayey sand with resistivity value between 34.9-284.9Ωm (Abiola et al., 2013) and thickness ranging between 0.44-1.20m. The second layer described as clay has resistivity values between 36.7-76.3Ωm and thickness between 2.4-9.2m. The third layer is defined as the weathered basement, and constitutes the main potential aquifer in the study area, with resistivity values between 64.5-503.9Ωm, and thickness between 1.48 and 7.9m. The fourth layer is the fresh basement which extends to infinity into the subsurface. It has resistivity value between 278.3 -15501Ωm. This can extend to infinity with depth because of its crystalline nature.

Table1: parameters estimated from acquired VES data interpretation

			Specific Layer Resistivity, Ωm					Layer Thickness, m				Depth to bottom of Layers, m			
VES Station Number	Location	No of Layers	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	h_1	h_2	h_3	h_4	d_1	d_2	d_3	d_4
1	Ihievbe Ogben	5	50.50	36.71	8.02	154.97	278.33	0.58	2.77	3.86	7.01	0.58	3.35	7.21	14.22
2	Ihievbe Ogben	5	150.01	36.82	14.76	64.48	3244.80	1.20	2.80	6.40	4.60	1.20	4.01	10.40	14.96
3	Ihievbe Ogben	5	112.32	37.95	11.24	149.90	11440.0	0.69	1.62	1.97	2.94	0.69	2.31	4.28	7.21
4	Ihievbe Ogben	5	129.60	56.11	145.67	8813.90	1676.20	0.98	2.59	1.66	14.69	0.98	3.57	5.22	19.91
5	Ihievbe Ogben	5	34.94	76.27	10.75	503.90	13624.0	0.44	1.08	2.43	3.57	0.44	1.52	3.95	7.52
6	Ihievbe Ogben	5	286.94	53.24	38.78	197.42	1914.90	0.99	1.57	5.18	7.93	0.99	2.56	7.74	15.68
7	Ihievbe Ogben	5	117.22	49.72	142.00	1793.5	3380.00	0.98	2.53	1.48	4.29	0.98	3.51	4.99	9.28
8	Ihievbe Ogben	5	112.75	44.97	10.21	153.05	15501.0	0.66	1.29	1.92	2.76	0.66	1.95	3.87	6.63

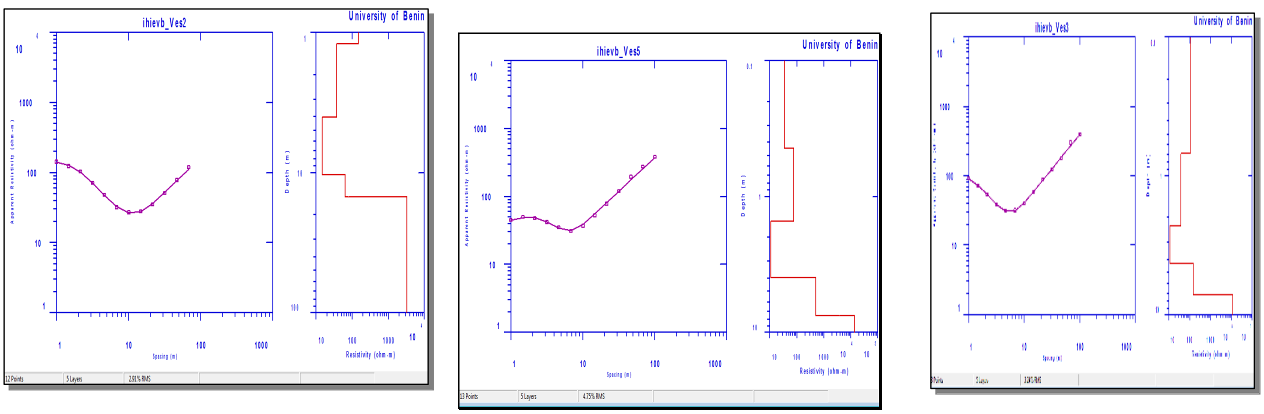

Fig 4: Some of the Software generated VES curves

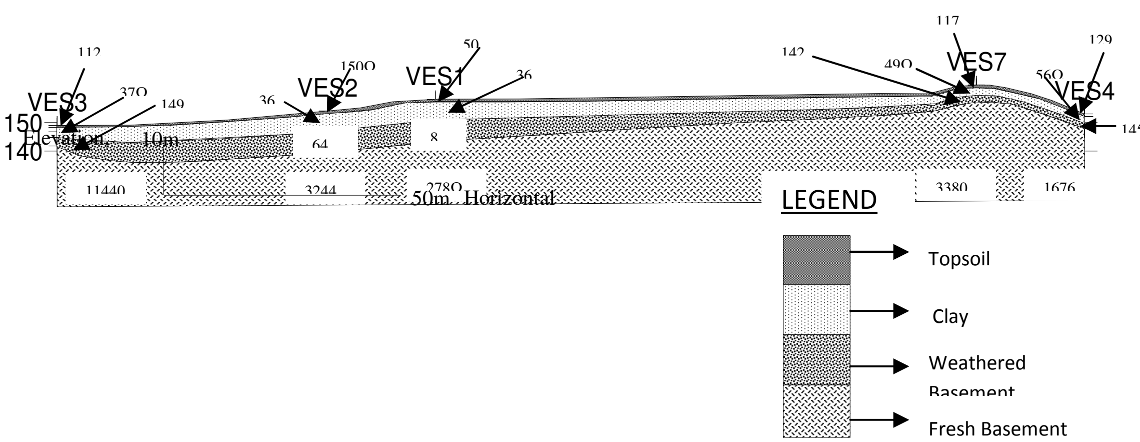

Fig 5: Northwest to Southeast cross section of VES location in Ihievbe-ogben showing VES 3,2 ,1, 7 and 4.

Subsurface maps were generated with parameters in Table2, for effective interpretation of the estimated hydrogeological parameters, and visualization of spatial distribution of data across the study area. The subsurface maps generated for this study include Basement relief map, Overburden thickness maps, Weathered/fractured zone resistivity and thickness maps, Clay thickness map and prospectivity ranking map. The basement relief map was obtained by subtracting the overburden thickness from the respective VES station elevations. This is very important becauses it reveals areas of basement depression that coincide with low elevation and areas of basement highs, related to high elevation.

Table 2: Parameters used to generate subsurface maps

	ELEV	Northings	Eastings	Weathering front/Fractured zone Thickness	Regolith/ Overburden	Basement Topography	Clay Thickness	Productivity Ranking	Depth to top of fractured zone	Fractured window resistivity
VES1	162	25812.6	22177.1	7.01	14.22	147.78	3.86	7	7.21	154.97
VES2	154	25811.6	22181.6	4.56	14.96	139.04	9.2	6	10.40	64.48
VES3	144	25806.9	22188.7	2.94	7.21	136.79	3.59	4	4.27	149.9
VES4	153	25823.0	22158.0	1.66	5.22	147.78	2.59	2	3.56	145.67
VES5	157	25824.0	22165.9	3.57	7.52	149.48	2.43	5	3.95	503.9
VES6	158	25831.3	22172.2	7.93	15.68	142.32	5.18	8	7.75	197.42
VES7	170	25815.0	22160.0	1.48	9.28	160.72	2.53	1	7.8	142
VES8	159	25821.0	22187.0	2.76	6.63	152.37	3.21	3	3.87	153.05

Areas of basement depression are important potential prospective zone with good groundwater potential. This implies that areas with the greatest depression has the potential of having the greatest overburden thickness, fractured zone thickness and clay thickness, which are very important hydrogeological parameters to consider in groundwater prospectivity. The basement relief map in Figure 7 shows the basement elevation that falls in the range 137-161m. It aslo reveals the eastern-northwestern streatch as having the least elevation of less than 155m , which coincide with the region of greatest basement surface depression in the study area.

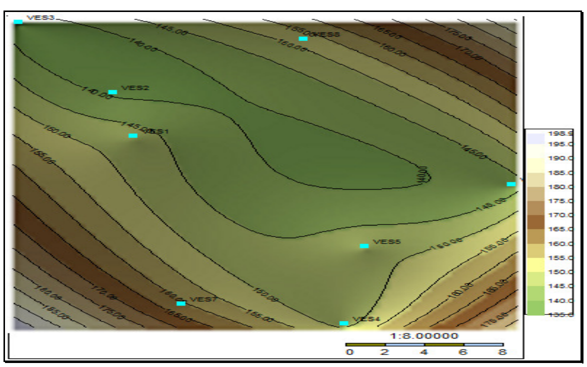

Fig 7: Basement relief map

The overburden represent all materials above the presumed fresh basement (Abiola et al. 2013). As a rule of thumb, regions with thick overburden always coincide with basement depression. Such areas are known to have high groundwater potential (Okhue and Olorunfemi, 1991). The thickness of the overburden as shown in Figure 8 varies between 5.2-15.7m. The thickest area being around the central region of the study area where VES 1 and VES 6 are located, and the northcentral region where VES 2 was stationed. The nothern and southern region of the map area have the thinest overburden.

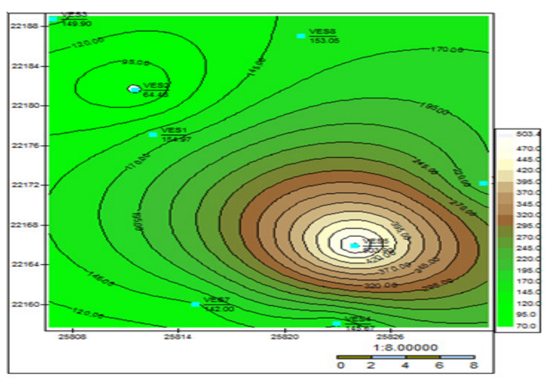

Fig 8: Overburden thickness

Figure 9 is the map of the weathered/ fractured layer, considered to be the main aquiferous zone in the study area(Wright, 1992) . The thickness vary between 1.5-8m, with the eastern and western part having the greatest thickness around VES1 and VES6. The most weathered part of the basement occurs around VES1, VES2 and VES6, which corresponds to the central part of the map, trending East- West of the study area. Generally, the thickess falls below 10m and therefore boreholes drilled into this aquiferous zone may lack the potential to serve as commercial sources of water, but they can sufficientlyserve domestic purposes.

The resistivity values of the weathered zone is one of the most important hydrogeological parameters to be considered for groundwater prospectivity in basement terrain because it gives an insight as to whether the fractures are water bearing or not. The resistivity value of this layer varies between 64.5 and 504 Ωm, and the distribution of values in most part of the map area falls within the range of 100-450Ωm (Figure 10), considered as having a good potential for groundwater (Adiat et al., 2009).

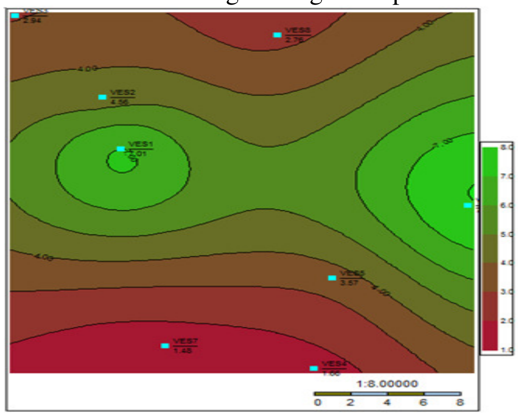

Fig 9: Fracture zone thickness map

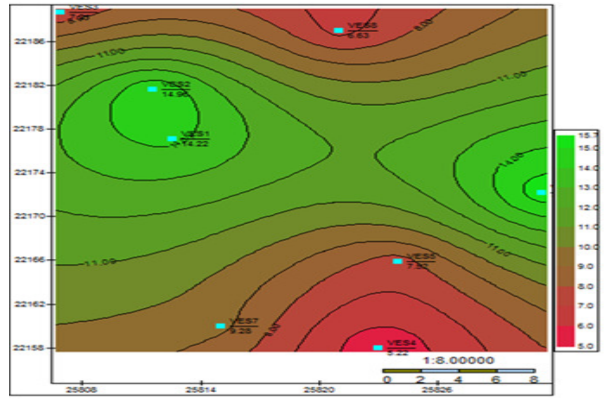

Fig 10: Fracture zone Resistivity map

The clay thickness map in Figure 11 shows that the northwestern portion of the map area has the greatest thickness of about 9m, while the northern and southern part has values less than 3m. The thickness range between 3.5-10m covers the eastern - northwestern stretch of the map within the vicinity of VES 1, 2 and 6. The implication and importance of clay thickness evaluation lies in its natural filtering effect of water infiltrating and percolating into the ground water thereby protecting the water from contaminant that may result from anthropogenic activities at the surface or near surface.

The natural Iso-electric response and thickness of the weathered/fractured layer are among the most important parameters to consider in evaluating the ground water potential in a basememt complex terrain (Bala and Ike, 2001). The ground water potential is ranked between 1 and 8, with 8 being the region with the highest groundwater potential and 1 the least. Figure 12 shows the ranking map of the prospective areas established by considering the following key parameters condition, to define the best prospective area: Weathered/fractured basement thickness greater than 4m, resistivity values between 64.5 and 503.9m, overburden thickness greater than 9m, Clay thickness greater or equal to 3.5m and basement relief elevation less than 150m.

Area around VES6, VES1 and VES2 best meet most of the aforementioned hydrogeological conditions. Hence, they are ranked 8,7, and 6 respectively as the best prospective areas and spans the eastern - north western zone of the study area. This zone described above represent the best location to site a borehole for groundwater production (Figure 12) .

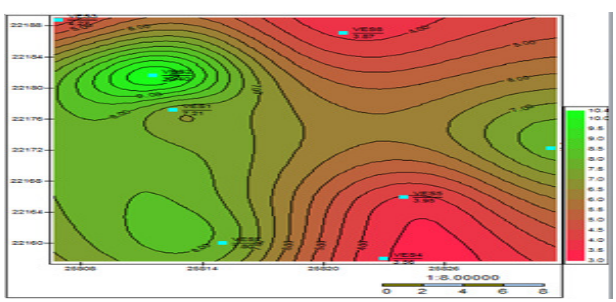

Fig 11: Clay thickness Map

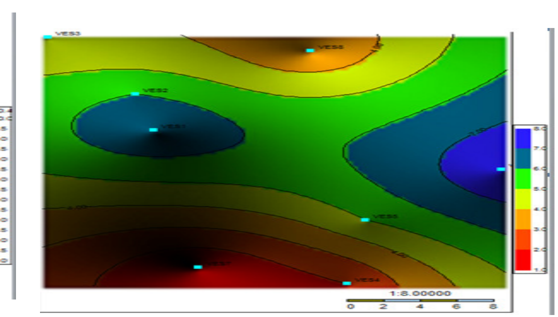

Fig 12: Prospectivity ranking map

Conclusion: The importance and application of the Electrical resistivity method for groundwater evaluation in a basement area has been demonstrated in this study carried out within basement terrain of the Ihievbe Ogben community. The eight VES interpreted revealed four basic subsurface layers in the community. They include the top soil, clay layer, weathered/fractured basement and the fresh basement. The weathered/fractured basement was identified as the water bearing layer as demonstrated by Olurunfemi et al. 1990. The study revealed the eastern- northeastern zone to be the most prospective region with the best hydrogeologic conditions for borehole siting especially around VES 6, 1 and 2. The northern and southern region has the least potential for groundwater prospectivity.

It is important to state here that although the overburden and clay thickness in these proposed locations are favourable for the natural filtering process for good groundwater quality, (Alabi et al., 2010), the thickness of the weathered basement across the study area (less than 10m) is not so favourable enough for commercial borehole project. Therefore, the community should only be considered for domestic borehole development.

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