

Groundwater Potential of Olojuoro-Olode-Gbayo, Part of Southwestern Nigeria

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Abstract

This study aims at identification of aquiferous layers for high groundwater yield, which could serve the ever-increasing population because of the increasing mining activities at Olojuoro-Olode-Gbayo, Ibadan, south-western Nigeria. In this study, a simple relatively inexpensive and reliable electrical resistivity method was used. Twenty-four VES (vertical electrical sounding) using Schlumberger configuration with maximum current electrode separation (AB/2) of 100 m were carried out over the area in order to understand the subsurface geologic settings that could lead to successful exploration for groundwater. Interpretation of geo-electrical data involved use of curve-matching technique and computer-iterations. The interpreted geoelectric sections showed the lithology to consist of top soil, lateritic clay, weathered bedrock, fractured basement, and fresh basement. The geo-electric parameters (layer resistivities and thicknesses), which are known to be of hydro-geologic importance were inferred from the VES interpretation and were used to generate maps (basement resistivity, overburden thickness, and reflection coefficient maps). These maps were synthesized and integrated to delineate areas with possible good yield of groundwater. Analysis of interpreted results shows that majority of the curves are 'H' types. The overburden thickness ranges from 3.5 - 29.7 m, whereas basement resistivities and reflection coefficients are estimated to vary between 150 - 1678 Ω m, and 0.39 to 1.5, respectively. The interpreted maps identified geo-electric parameters favorable for groundwater occurrence. It could be inferred that central part of the study area has high potential for groundwater development, compared to northeastern part where conditions are less favorable. In conclusion, the study area has a very good potential for groundwater development which can serve the communities and increasing population of the miners.

Keywords: Groundwater, Electrical resistivity, Basement Complex, Nigeria.

INTRODUCTION

Population growth is usually associated with areas of intensive mining activities. This is essentially the case at Olode-Olojuoro-Gbayo area, where aquamarine mining is ongoing (Abudulawal et al., 2017). Water is used mainly for domestic purposes as well as agricultural development and in manufacturing industries. Since water is essential to all living organisms, it promotes health and life. Consequently, there is need to provide potable water for the miners as well as the communities in the area. This in turn necessitated the need for extensive search for groundwater potential of the basement rocks in the area. In the basement complex, groundwater occurs in faults, joints, fractures, as well as in overlying weathered overburden, which typically has high recharge during rainy season (Acworth, 1987). Due to its better spatial extension and distribution, groundwater is a preferred source because of its quality (Olorunfemi and Olorunniwo, 1985; Wright, 1992). Unfortunately, it is not readily available like surface water and its exploitation demands cost and technical know-how.

Workers like Olorunfemi and Fasuyi (1993), Olayinka et al. (2004), and Abudulawal et al. (2015), among others, have noted that detailed knowledge of geology of subsurface, weathering depth, and structural disposition through geological and geophysical investigations is inevitable in revealing discontinuous nature of the aquifer system of the basement complex. Olayinka (1992) observed that fracture zones in hard rocks play important and critical roles in fluid flow within the subsurface. Also, permeability

and secondary porosity development have been identified as other factors that aid movement of groundwater in hard rocks. For example, Wright (1992) and Oladunjoye (2013) concluded that searching for ground in basement rocks should typically aim at mapping secondary structures.

Various researchers have carried out studies on the occurrences of groundwater in the basement complex rocks of southwestern Nigeria, using geophysical techniques (Ajayi, and Adegoke-Anthony, 1988; Olorunfemi and Fasuyi, 1993; Olayinka et al., 2004; Abudulawal et al., 2015). For example, Ajayi and Adegoke-Anthony (1988) presented case studies of use of electrical resistivity for estimating aquifer potential in crystalline rocks of southwestern Nigeria and concluded that geophysical method was a preferred method for groundwater exploration. Also, Oladunjoye et al. (2013) were able to highlight critical areas of ground water development in parts of the basement complex by injecting electrical current into the ground.

In order to evolve a more practical and scientific planning for development and management of groundwater resources in Olojuoro-Olode-Gbayo, in Ibadan, southwestern Nigeria, a hydro-geophysical evaluation of groundwater potential was carried out. The study is expected to greatly contribute to understanding of hydrogeology of the basement complex, in addition to delineation of fractured and weathered basement aquifers that can be developed for sustainable water supply for the people in the area and adjacent communities.

MATERIALS AND METHODS

Description of the project area

The study area Olode-Olojuoro-Gbayo and its environs are located within Ibadan suburbs in Oyo State, Nigeria. It lies within Longitudes 03°56'00"E and 05°59'00"E, and Latitudes 07°11'00"N and 07°13'00"N (Fig. 1). The study area is generally accessible by road. The major road in the area is the old Ibadan-Ijebu-Igbo road, which runs from the northwestern part of the area through Olojuoro in the southeastern part. A network of narrow, gently meandering, ephemeral and perennial streams, dissects and drains the study area and forms dendritic drainage patterns. Geologically, the study area lies within Nigerian Basement complex that is characterized by crystalline rocks of Pre-Cambrian age.

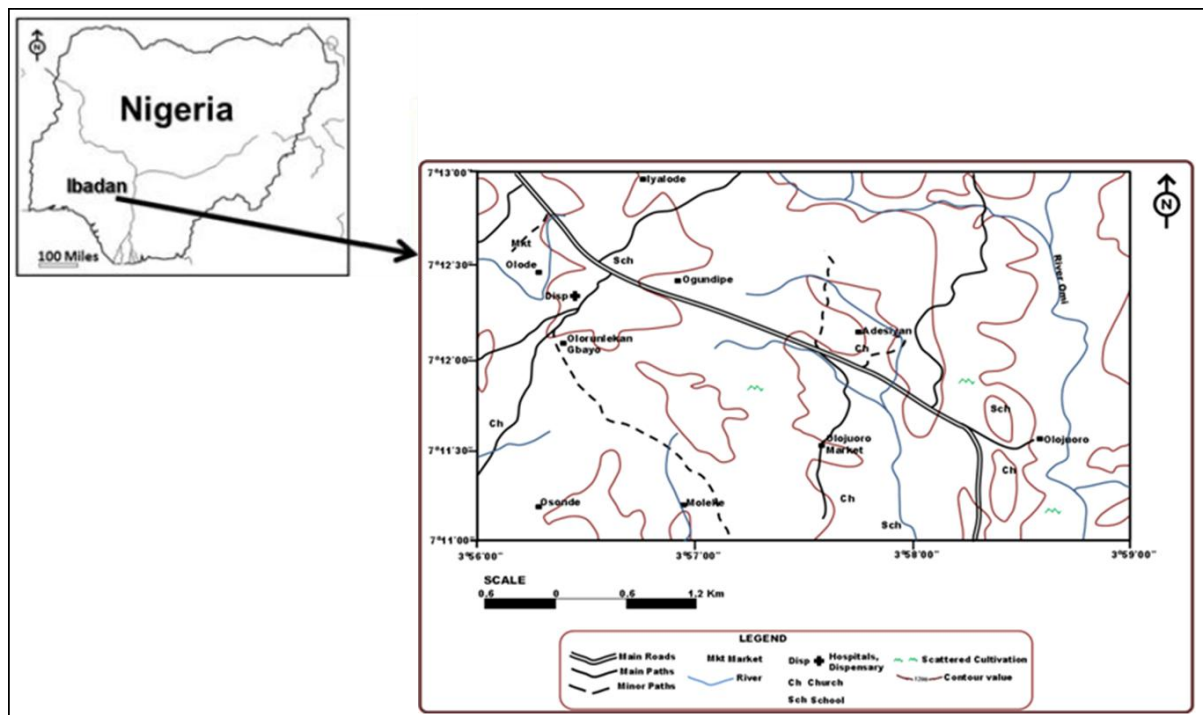


Figure 1: Location map of the study area showing road network and drainage patterns

(Rahaman, 1976). Local geological mapping showed that the rock groups in the area are porphyritic granite, porphyroblastic gneiss and undifferentiated gneiss complex. Prominent locations in the study area are known to harbor precious rocks and gemstones, in which important host rocks are pegmatites (Abudulawal et al., 2017). The folding and faulting features observed on some of these rocks, as seen in situ, affirm the fact that there had been repeated phases of deformation and recrystallization. Abundance of ferromagnesian minerals in the rocks give it the melanocratic appearance. Most of the mineralized pegmatites in this area occur as minor intrusion within the gneissic rocks as evidenced by elevated level of mining activities in the study area.

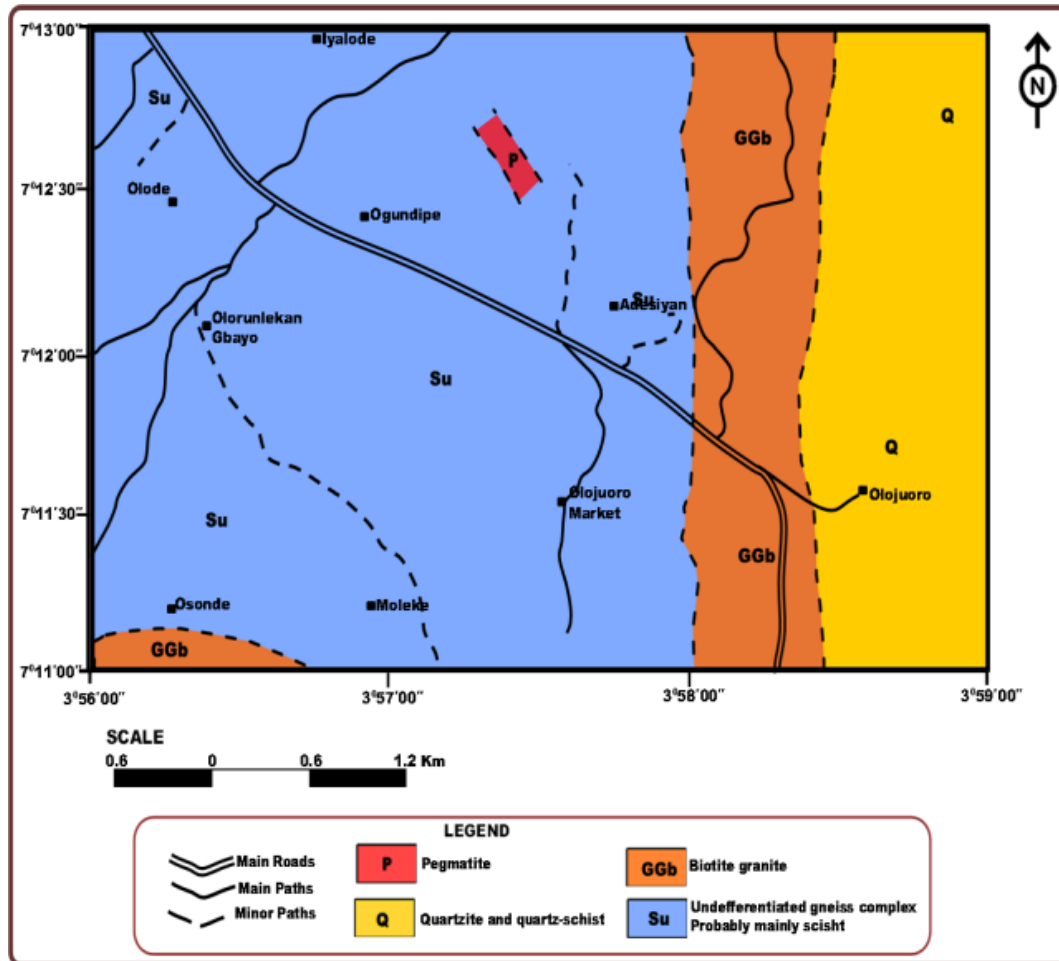


Figure 2: Geological map of Olojuoro-Olude (Adapted from NGSA, 1967)

Data acquisition and Interpretation

The geophysical investigation was carried out using Omega resistivity meter. Electrical resistivity method was applied with the use of Schlumberger array. Current source for the meter was a movable 12.5 V car battery. A total of twenty-five VES were carried out in the area using a maximum spread (AB) of 200 m. Following Orellana and Mooney (1966), apparent resistivity data was plotted against half electrode spacing on a log-log scale. Conventional partial curve matching and drawing of auxiliary point diagram was first used before computer iteration. The essence of the vertical electrical sounding is to determine number of layers denoted as “n” and resistivity of each layer denoted as “e” which are measured in “m” and “ohm-m” respectively. This was based on the principle of Zohdy (1989) and Telford et al. (1990), who used point of maxima and minimum as representative of lithologies. Next, the results were used to calculate reflection coefficient (RC) for each of the VES curves. The calculation was based on the method of Bhattacharya and Petra (1968) and Olayinka (1996):

$$\gamma = \frac{\rho_n - \rho_{n-1}}{\rho_n + \rho_{n-1}} \quad (1)$$

where γ is reflection coefficient, ρ_n is layer resistivity of nth layer and ρ_{n-1} is resistivity of the layer overlying the nth layer. Finally, overburden thickness, basement resistivity, and reflection coefficient maps were constructed using results of resistivity interpretations.

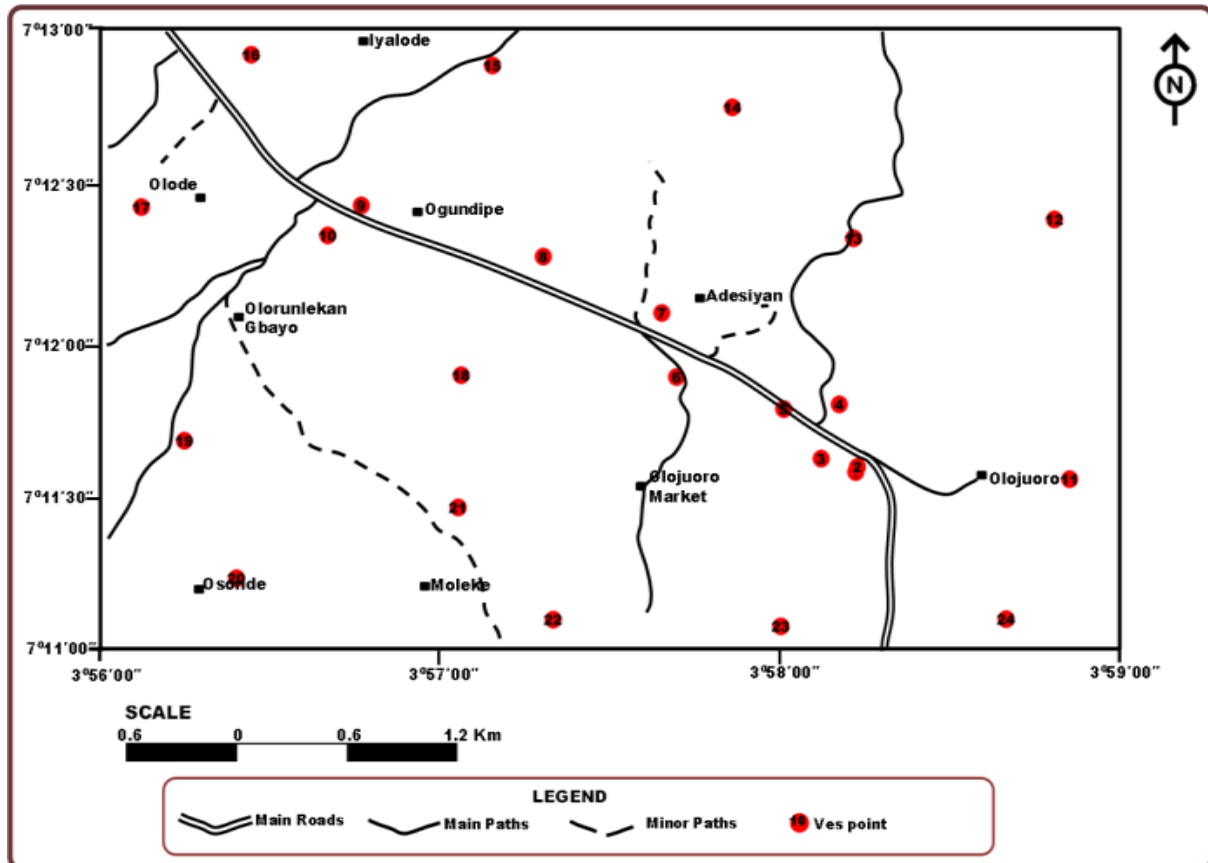
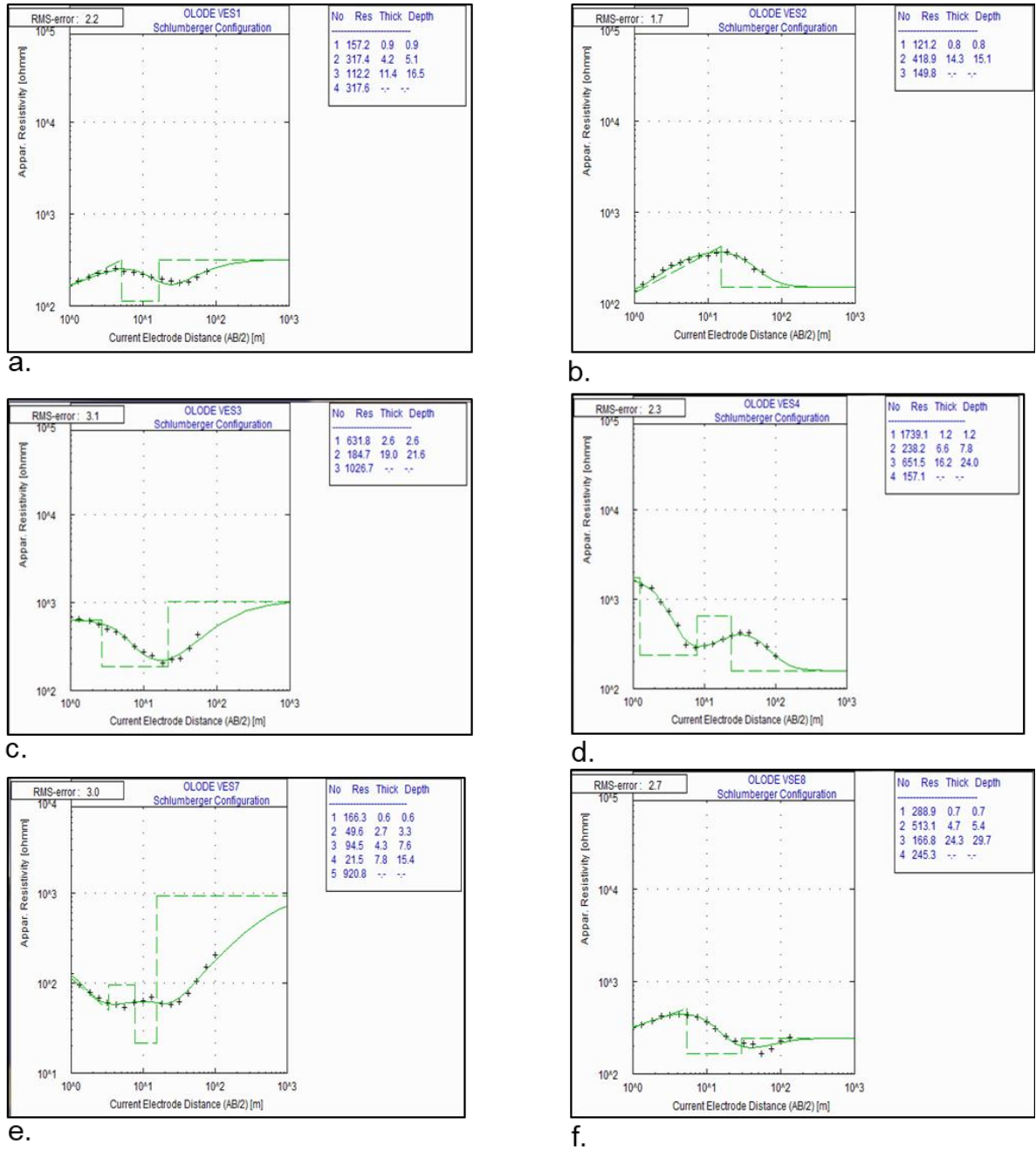


Figure 3: Location Map of the study area showing the distribution of the VES across the area

RESULTS

The VES results are summarized in Table 1. Figure 4 shows examples of VES curves that were interpreted from the acquired geoelectric data in the study area. The VES curves could be categorized into: H, K, KH, HK and HKH-type curves. The dominant curves are the H-types, which constitute about 54% whereas KH-types constitute about 29%. The H-types and K-types show a system of three geoelectric layers consisting top-soil, weathered basement, and fractured/fresh basement (Fig. 4b, c and e). The KH and HK-types, which were also interpreted, show a system of four geoelectric layers of top soil, lateritic clay, weathered bedrock, and fractured basement (Fig. 4a, d, and F). For the HKH-type, five-geoelectric layers were interpreted namely, top-soil; sandy clay; lateritic clay; fractured basement; and weathered bedrock (Fig. 4e).



Figures 4: Representative samples of the VES curves that were interpreted from the resistivity data: (a) KH - curve type (b) K – curve type (c) H – curve type (d) HK – curve type (e) KHK – curve type (f) HKH – curve type

Table 1: Summary of Geoelectric parameters obtained from VES data interpretation

VES NO.	Layer	Resistivity (ohms-m)	Layer Thickness (m)	Depth (m)	Curve Type	Reflection Coefficient	Probable Lithology
1	1	157	0.9	0.9	KH	0.5	Top-soil
	2	317	4.2	5.1			Lateritic clay
	3	112	11.4	16.5			Weathered basement
	4	318					Fractured basement
2	1	121	0.8	0.8	K	-	Top-soil

	2	419	14.3	15.1			Lateritic clay
	3	150					Fractured basement
3	1	632	2.6	2.6	H	0.7	Top-soil
	2	185	19.0	21.6			Weathered bedrock
	3	1027					Fractured basement
4	1	1739	1.2	1.2	HK	-	Top-soil
	2	238	6.6	7.8			Sandy clay
	3	652	16.2	24.0			Lateritic clay
	4	157					Fractured basement
5	1	157	0.6	0.6	KH	0.8	Top-soil
	2	416	2.2	2.8			Lateritic clay
	3	99	3.3	6.1			Weathered bedrock
	4	1678					Fractured basement
6	1	140	2.5	2.5	H	0.8	Top-soil
	2	78	21.5	24.0			Weathered bedrock
	3	699					Fractured basement
7	1	166	0.6	0.6	KHK	0.95	Top-soil
	2	50	2.7	3.3			Sandy clay
	3	95	4.3	7.6			Lateritic clay
	4	22	7.8	15.4			Weathered bedrock
	5	921					Fractured basement
8	1	289	0.7	0.7	KH	0.2	Top-soil
	2	513	4.7	5.4			Lateritic clay
	3	167	24.3	29.7			Weathered basement
	4	245					Fractured basement
9	1	162	1.7	1.7	H	0.8	Top-soil
	2	30	15.5	17.2			Weathered bedrock
	3	286					Fractured basement

10	1	190	2.3	2.3	H	0.76	Top-soil
	2	42	15.3	17.6			Weathered bedrock
	3	307					Fractured basement
11	1	142	1.3	1.3	H	0.70	Top-soil
	2	77	7.9	9.2			Weathered bedrock
	3	439					Fractured basement
12	1	82	1.1	1.1	H	0.80	Top-soil
	2	33	3.4	4.5			Weathered bedrock
	3	423					Fractured basement
13	1	91	1.0	1.0	H	0.57	Top-soil
	2	50	2.5	3.5			Weathered bedrock
	3	184					Fractured basement
14	1	100	0.7	0.7	KH	0.9	Top-soil
	2	180	2.3	3.0			Lateritic clay
	3	23	6.5	9.5			Weathered bedrock
	4	37					Fractured basement
15	1	100	0.6	0.6	KH	0.9	Top-soil
	2	191	1.5	2.1			Lateritic clay
	3	21	5.0	7.1			Weathered bedrock
	4	535					Fresh basement
16	1	216	0.5	0.5	H	0.8	Top-soil
	2	24	6.7	7.2			Weathered bedrock
	3	345					Fractured bedrock
17	1	108	1.1	1.1	H	0.8	Top-soil
	2	86	7.6	8.7			Weathered bedrock
	3	775					Fractured basement
18	1	103	3.6	3.6	H	0.6	Top-soil
	2	59	3.3	6.9			Weathered bedrock

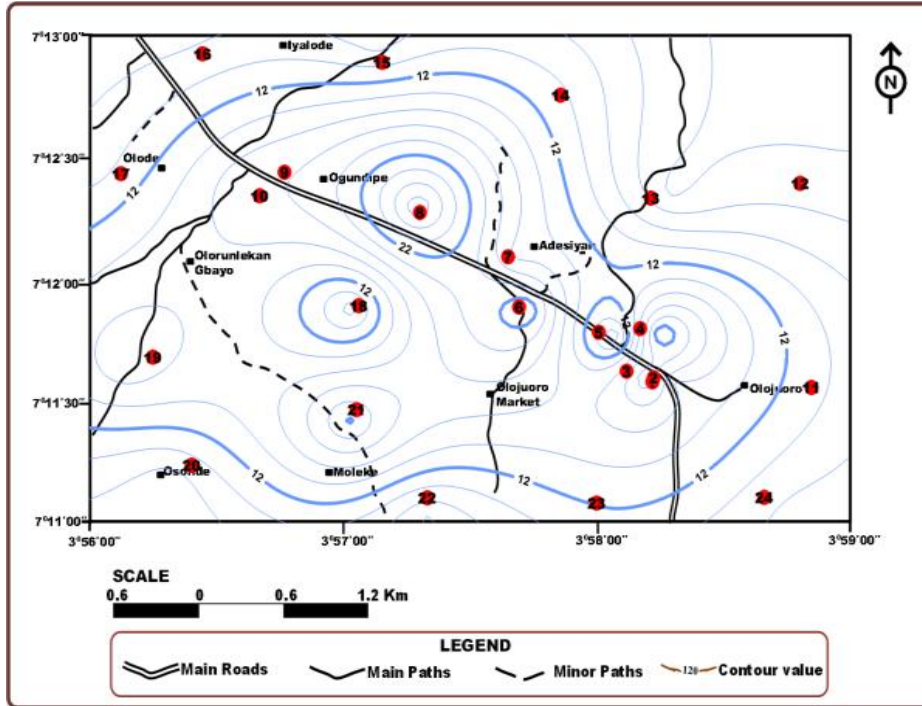
	3	263					Fractured basement
19	1	166	0.8	0.8	KH	0.5	Top-soil
	2	542	4.8	5.6			Lateritic clay
	3	181	12.1	17.7			Weathered bedrock
	4	594					Fractured basement
20	1	192	0.9	0.9	H	0.6	Top-soil
	2	121	5.7	6.6			Weathered bedrock
	3	526					Fractured basement
21	1	189	0.6	0.6	HKH	0.8	Top-soil
	2	48	1.4	2.0			Sandy clay
	3	278	7.6	9.6			Lateritic clay
	4	46	12.9	22.5			Weathered bedrock
	5	461					Fractured basement
22	1	174	1.0	1.0	H	0.9	Top-soil
	2	68	4.8	5.8			Weathered bedrock
	3	1282					Fresh basement
23	1	78	0.6	0.6	KH	0.9	Top-soil
	2	180	2.7	3.3			Lateritic clay
	3	45	8.1	11.4			Weathered basement
	4	374					Fractured basement
24	1	181	1.0	1.0	H	0.48	Top-soil
	2	89	6.0	7.0			Weathered bedrock
	3	255					Fresh basement

Overburden thickness, basement resistivity, and reflection coefficient maps were inferred from the interpretation of the VES data (Fig. 5). Generally, average thickness of overburden in the study area is around 12 m (Fig. 5a). Within the central part of area under study, average overburden thickness is around 22 m whereas overburden thickness is lower in other areas especially in the far northeastern part, where overburden thickness is less than 4 m. The basement resistivity and reflection coefficient maps (Figs. 5b and c) show the basement resistivity and reflection coefficients as inferred from the VES interpretation results. The resistivity values of the basement vary from 150 Ω m (VES 2) to around 1678 Ω m (VES 5), whereas the reflection coefficient ranges from 0.2 – 0.9.

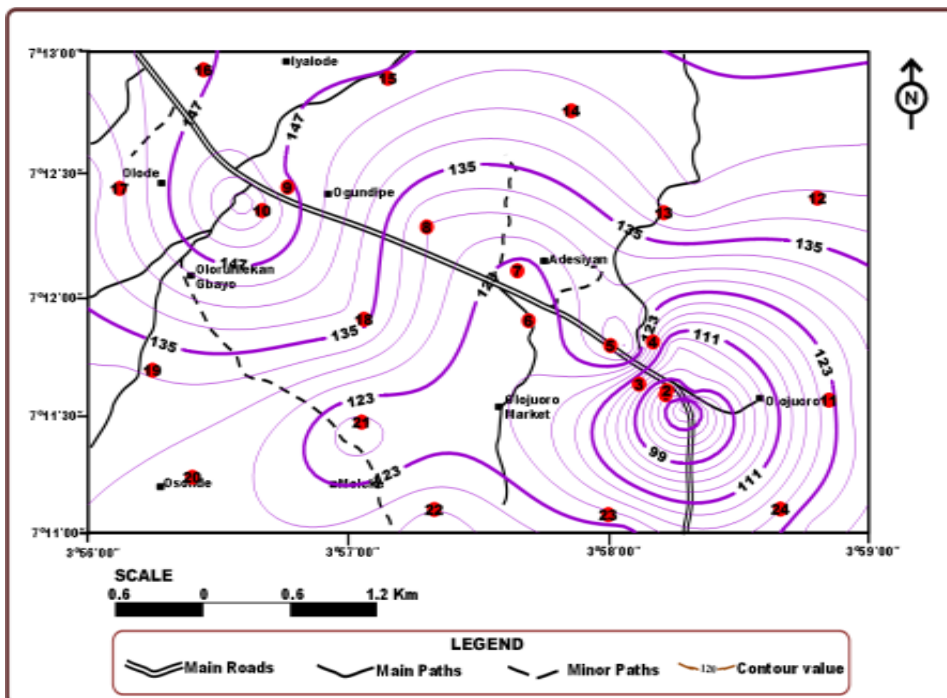
DISCUSSION

The groundwater potentials of Olode and its adjoining villages situated within Ibadan suburbs were studied using electrical

resistivity method. Vertical electrical sounding method was adopted using the conventional Schlumberger array. Good quality data were obtained with the observational errors being less than 5%. Geo-electrical properties of the area were determined from the resistivity data and these were used to obtain overburden thickness, basement resistivity, and reflection coefficient. These results were used to evaluate potential of groundwater in the area. Overburden thickness map shows relatively thick overburden in central part whereas overburden thickness is lower in other parts, especially in northeastern part of the study area. Thus, with occurrence of relatively thick overburden and fractured zones in the basement, there is high feasibility of getting good groundwater yield, especially in the central part of the study area (Olorunfemi and Okhue, 1992; Dan-Hassan and Olorunfemi, 1999).



(a) Overburden thickness



(b) Basement resistivity (ohm-m)

REFERENCES

- Abudulawal L., S. A. Amidu, K. A. Apanpa KA, O. A. Adeagbo, O. A. Akinbiyi. 2015. Geophysical Investigation of Subsurface Water of Erunmu and its Environs, Southwestern Nigeria using Electrical Resistivity Method. *Journal of Applied Science*. 15:741-751.
- Abudulawal L., S.A. Amidu, O.A. Adeagbo, and S.A. Adejumo, 2017. Overburden Thickness and Potential Tonnage Estimate of Olode-Gbayo Pegmatite Deposit, Southwestern Nigeria, Using Electrical Resistivity Method. *Journal of Geography, Environment and Earth Science International*. 10(2): 1-12.
- Ajayi, O. and C. W. Adegoke-Anthony. 1988. Groundwater Prospects in the Basement Complex Rocks of Southwestern Nigeria. *Journal of African Earth Sciences (and Middle East)*. 7:227-235.
- Dan-Hassan, M. A. and M. O. Olorunfemi. 1999. Hydrogeological Investigation of a Basement Terrain in the North-Central part of Kaduna State, Nigeria. *Journal of Mining and Geology*. 35(2): 189-206
- Ekwueme, B.N. 1993. *An Easy Approach to Metamorphic Petrology*. University of Calabar Press, Calabar, Nigeria
- Krishnamurthy, N. S., D. Kumar, V. Rao Anand, S. C. Jain, S. Ahmed. 2003. Comparison of Surface and Sub-surface Geophysical Investigations in Delineating Fracture Zones. *Current Science*, 84 (9): 1242-1246.
- Obaje, N. G. 2009. *Geology and Mineral Resources of Nigeria*. Lecture Notes in Earth Sciences. Springer, New York, NY.
- Oladunjoye, M. A., A. O. Akanji O. T. Akingbesote. 2013. Groundwater Exploration in Alakuta- Awotan Area of Ibadan, Southwestern Nigeria. *Journal of Geol. Geosci*. 2: 24. DOI: 10.4172/2329-6755.1000124
- Olorunfemi, M.O. and M. A. Olorunniwo, 1985. Goelectric Parameters and Aquifer Characteristics of Some Parts of Southwestern Nigeria. *Journal of Mining and Geology*. 20: 99-109.
- Olorunfemi, M.O and Okhue, E.T. (1992). Hydrogeologic and Geologic Significance of a Goelectric Survey at Ile-Ife, Nigeria. *Journal of Mining and Geology*. 28:221-229
- Olorunfemi, M. O. and S. A. Fasuyi. 1993. Aquifer Types and the Goelectric Hydrogeologic Characteristics of Parts of the Central Basement Terrain of Nigeria, Niger State. *Journal of African Earth Sciences (and Middle East)*. 6:309-317.
- Olayinka, A.I. 1992. Geophysical Siting of Boreholes in Crystalline Basement Areas of Africa. *Journal of African Earth Sciences (and Middle East)*. 14:197-207.
- Olayinka, A. I. 1995. A Comparative Study of the Geophysical Data at Some Low and High Yielding Borehole Sites in the Area around Ilorin and Okene, Southwestern Nigeria. *Nigerian Journal of Science*. 29:147-158
- Olayinka, A. I. and M. O. Olorunfemi. 1992. Determination of Goelectric Characteristics in Okene Area and Implications for Borehole Siting. *Journal of Mining and Geology*. 28:403-411
- Olayinka, A.I., 1996. Non-uniqueness in the Modelling of Bedrock Resistivity and its Hydrogeological Implications. *Journal of Water Resources*. 7: 49-55
- Olayinka AI, Amidu SA, Oladunjoye MA. 2004. Use of Electromagnetic Profiling and Resistivity Sounding for Groundwater Exploration in the Crystalline Basement Area of Igbeti, Southwestern Nigeria. *Global Journal of Geological Sciences*. 2:243-253.
- Orellana E, and H. M. Mooney HM. 1966. *Master Tables and Curves for Vertical Electrical Sounding over Layered Structures*. Interscience. Madrid. 193p
- Rahaman, M. A. 1976. Review of the Basement Geology of South-Western Nigeria. In: Kogbe C. A, editor. *Geology of Nigeria*. 2nd Ed. Elizabethan Publishers, Lagos. Nigeria.
- Telford W. M., L. P. Geldart, and R. E. Sheriff. 1990. *Applied Geophysics*. 2nd Ed. Cambridge University Press, USA.
- Wright, C. P. 1992. The Hydrogeology of the Crystalline Basement Aquifers in Africa. In: C. P. Wright and W. C. Burgess (eds). *Hydrogeology of Crystalline Basement Aquifers in Africa*. Geological Society of London Special Publication. 66:1-27
- Zohdy, A. A. R. 1989. A New Method for the Automatic Interpretation of Schlumberger and Wenner Sounding Curves. *Geophysics*. 54:245-253.