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Original Research Article

Geo-Electrical Exploration for Groundwater in Eiyenkorin, Ajelanwa and Owa-Otun Communities in Kwara State, Nigeria

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ABSTRACT

Schlumberger Vertical Electrical Soundings (VES) for groundwater exploration in Eiyenkorin, Ajelanwa and Owa-Otun communities in the Basement Complex terrain of the southwestern Nigeria were carried out with a view to establishing the different subsurface geoelectric layers and the aquifer units. Data were collected from 4, 5 and 15 VES stations at Ajelanwa, Owa-Otun and Eiyenkorin communities respectively. From the quantitative interpretations of the data collected, using the usual method of curve matching with the Orellana-Mooney Master curves and 1-D forward modeling with WinResist 1.0 version software, between four and five lithologic units were identified in these Communities. These include: the topsoil, the lateritic layer, the weathered layer, the partly weathered/fractured basement and the fresh basement. The weathered layer and the partly weathered/fractured basement constitute the main aquifer units. The depth to bedrock at the chosen VES locations vary from 3.7 to 23.8 m at Eiyenkorin, 6 to 30 m at Ajelanwa, and 7 to 13 m at Owa Otun communities. Some lobes or areas of low resistivity which constitute the prospective zones for water exploration in these areas have been delineated.

1. INTRODUCTION

The ever increasing population in the developing world, especially in the sub-Sahara Africa, coupled with increasing agricultural and industrial development warrants greater demand for essential public utilities, most especially water supply for domestic and agricultural purposes (Fashae, *et al.,* 2014). Communities located on Basement Complex terrains commonly have problems of potable groundwater supply due to the crystalline nature of the underlying rocks which lack primary porosity. Groundwater storage capacity in those areas is dependent on depth of weathering and intensity of fracturing of the underlying rocks. For Basement Complex rocks to become good aquifers, they must be highly fractured and/or deeply weathered (Anudu, *et al.,* 2008).

Groundwater occurrence in Basement rocks is limited to the upper weathered section and fractured portion of the underlying fresh rocks (Olorunfemi and Fasuyi, 1993). The location of potential groundwater zones in the Basement is often problematic, so to overcome these problems, many boreholes were drilled in the rural areas by Kwara State, National and International agencies (e.g. FGN/EEC Middlebelt Programme) for groundwater exploration**.** The boreholes drilling was preceded by detailed geophysical investigations in order to evaluate the geologic and geoelectric characteristics of the aquifers. The Vertical Electric Sounding (VES) method was preferred for its simplicity, easy interpretation and rugged nature of the associated instrumentation (Sharma and Baranwal, 2005).

2. MATERIALS AND METHODS

2.1. The Study Area

The study areas include: Eiyenkorin, Ajelanwa and Owa Otun Communities in Kwara State in the Basement Complex terrain of the Middle-Belt Region of Nigeria (Figure 1). Eiyenkorin is a fastly growing community located at the outskirts of Ilorin along Ogbomosho road (with Centre at Lat. 8.393185°N and Lon. 4.463279°E). Ajelanwa is located beside Kulende Estate along the old Ilorin-Jebba road (with Centre at Lat. 8.512881°N and Lon. 4.582780°E) in Ilorin East Local Government Area of Kwara Central Senatorial District. It is bounded by the Kulende Estate, Rail road and a stream in the North, West and South respectively, while Owa Otun community is located (with Centre at Lat. 8.098211°N and Lon. 5.238096°E) in Osi - Isapa area, north of the Egbe – Omu-aran road. The study locations fall within the tropical savannah climate and exhibit a well-marked rainy season and a dry season. Temperatures are above 18 °C (64 °F) throughout the year and the vegetation is that of woodland and tall grass savannah. The study locations fall within the Pre-Cambrian Basement Complex of Southwestern Nigeria which consists of migmatite, gneisses, schist and quartzite into which has been an emplacement of granitic, and to a lesser extent, more basic materials (Rahaman, 1981). The major fracture zones in Ajelanwa are Northeast- Southwest trending which coincide with the river channels.

2.2. Geophysical Investigation

The geophysical investigation employed the electrical resistivity method involving 1D vertical electrical sounding (VES) technique. The Ohmega^{TM} earth resistivity meter was employed in the acquisition of the VES data using Schlumberger array in the study area. The VES Schlumberger current electrode spacing was varied from 1 to a maximum of 200 m. The electrode spreading followed the description (Kearey *et al.,* 2002) where half electrode spacing (AB/2, Figure 2) range of 1 – 100 m was used to generate maximum information about the subsurface lithology and overburden thickness. Data were collected from 4, 5 and 15 VES stations at Ajelanwa (Figure 3), Owa-Otun (Figure 4) and Eiyenkorin (Figure 5) communities respectively. Apparent resistivity (Pa) for the Schlumberger array was computed from Equation (1) (Sharma, 1997).

$$\text{Pa} = \frac{\pi L^2}{2l}\frac{\Delta V}{I} \quad (1)$$

where (L) is half the distance between current electrodes (AB), (l) is half the distance between the potential electrodes (MN), ΔV/I is the resistance of the ground and I is the input current.
The interpretation of the 1D VES data involved partial curve matching (William, 2007) and computer-assisted 1D forward modeling with WinResist 1.0^{TM} software (Vander Velpen, 1988).

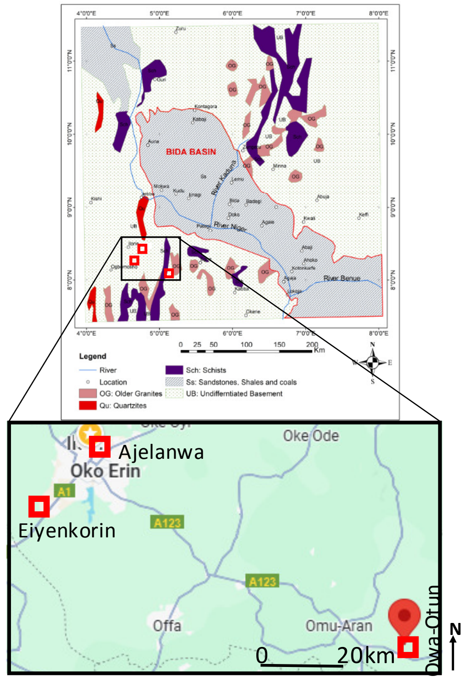

Figure 1: Sketch map of the Eiyenkorin, Ajelanwa and Owa-Otun study area (Inset is the Geological map of Bida Basin (Adapted from Obaje et al., 2011)

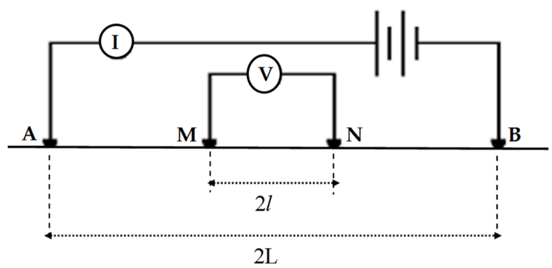

Figure 2: Diagram of VES Schlumberger configuration

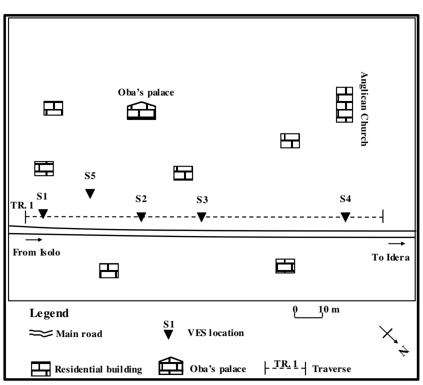

Figure 3: A sketch map of Ajelanwa community showing the VES sites

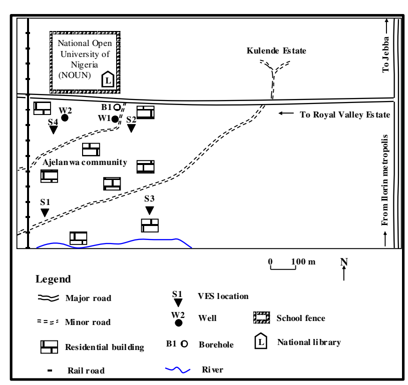

Figure 4: A sketch map of Owa-Otun community showing the VES sites

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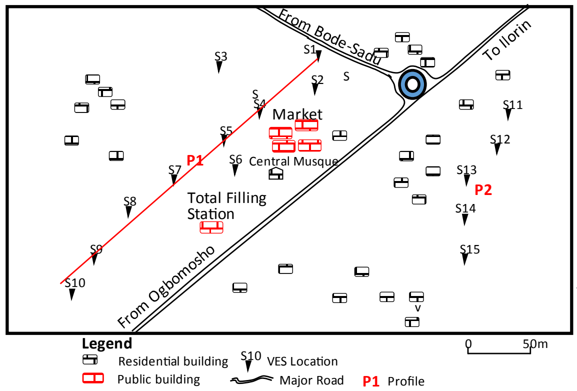

Figure 5: A sketch map of Eiyenkorin community showing the VES sites

3. RESULTS AND DISCUSSION

3.1. The VES Curves

The typical VES curves and interpreted geoelectric models are displayed in Figures 6-8 while Table 1 is the summary of the result for Eiyenkorin study area. The VES interpretation results at Eiyenkorin (Figure 6), indicated four to five major lithologic units: the top soil, the lateritic layer, the weathered layer, the fractured basement and the fresh bedrock. The topsoil has thickness ranging between 0.5 and 4.3 m with resistivity ranging from 85 to 5504 Ω-m, the lateritic layer has thickness ranging between 0.4 and 3.0 m with resistivity ranging from 81 to 3122 Ω-m, the weathered layer is made up of sandy clay/clayey sand with thickness of 0.9 -17.9 m while resistivity ranged from 12 to 3024 Ω-m, the fractured basement has a thickness of 0.9 – 20.2 m and resistivity of -42 to 230 Ω-m while the fresh bedrock had resistivity ranging from 450 to 96005 Ω-m. The weathered layer and the fractured basement constitute the main aquifer units (Olorunfemi *et al.,* 2020; Akintorinwa *et al.,* 2020 and Olawuyi and Bawallah, 2022) and there exists two lobes of highly prospective groundwater potential at locations S7, S9 and S10 below profile 1 in the Eiyenkorin Community.

The VES interpretation results at Ajelanwa (Figure **7**), indicated four major geologic units: the top soil, the weathered layer, the partly weathered/fractured basement and the highly resistive bedrock. The topsoil is composed of silt, clayey sand and sand with thickness ranging between 1.6 and 11 m and resistivity ranging from 40 to 130 Ω-m; the weathered layer is made up of sandy clay/clayey sand with thickness of approx. 15 m while resistivity ranged from 18 to 50 Ω-m; the partly weathered/ fractured basement has a thickness of 15 - 25 m and resistivity of 18 - 20 Ω-m while the fresh basement or bedrock had resistivity ranging from 2000 Ω-m and above. The weathered layer and the partly weathered/fractured basement constitute the main aquifer units (Olorunfemi *et al.,* 2020 and Olawuyi and Bawallah, 2022) and the groundwater potential at VES 1 in the Ajelanwa Community is high.

The VES interpretation results at Owa Otun (Figure 8), indicated four major geologic units: the top soil, the weathered layer, the partly weathered/fractured basement and the highly resistive bedrock. The topsoil is composed of clayey sand and sand, its thickness ranged between 0.5 and 0.8 m while resistivity ranged from 375 to 1,110 Ω-m; the weathered layer is made up of sandy clay/clayey sand, its thickness ranged between 2.3 and 9.9 m while resistivity ranged from 144 to 300 Ω-m; the partly weathered/ fractured basement has a thickness of 8.5 m and resistivity of 345 Ω-m while the fresh basement or bedrock had resistivity ranging from 1120 Ω-m and above. The weathered layer and the partly weathered/fractured basement constitute the main aquifer unit (Bayode *et al.,* 2006 and Obasi *et al.,* 2013), however, the partly weathered/ fractured basement is localized beneath VES 1 only and the groundwater potential at this location in Owa Otun Community is low.

3.2. Geoelectric Section

The geoelectric section across profile 1 at the Eiyenkorin study area is shown in Figure 9. The overburden is not generally very thick, which is usual for the southwestern Nigeria basement complex (i.e. ≤ 20m) but the weathered basement is generally thick, with almost uniform thickness across profile 1 (Olorunfemi and Fasuyi, 1993), while the fractured basement exists as two lobes of highly prospective groundwater potential zones at locations S7, S9 and S10.

3.3. Pseudosections

The pseudosections presented as field and theoretical data pseudosections as well as the 2-D resistivity structure along traverse 1 at Owa Otun study area (Figure 10) delineated some areas and zones with different resistivities reflecting some subsurface geoelectric characteristics. The relatively thick areas and zones with low resistivity (e.g. < 300 Ω-m), especially where there are closures are more likely to have highest groundwater potential if the low resistivity is not caused by the presence of excessive clay. These areas are associated with weathered or fractured basement mainly. In the basement terrain, the areas having thick overburden overlying fractures zones are known to favour groundwater yield (Olorunfemi and Fasuyi, 1993). The zone containing the lobe of low resistivity below VES 1 (Figure 9) will definitely be a better zone for water prospecting in the area because all the information obtained there show that the lobe constitutes the best prospective area for water exploration. On the other hand, the areas and zones with high resistivity (e.g. > 1000 Ω-m) could be showing un-weathered or un-fractured or fresh bedrock.

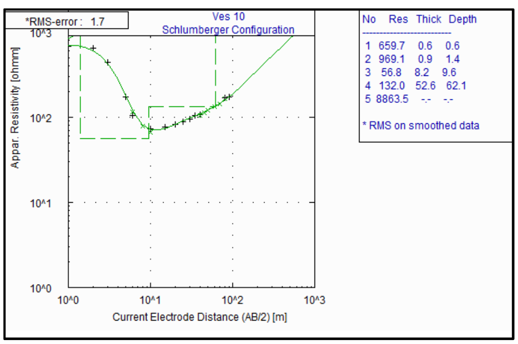

Figure 6: Typical VES curve obtained at Eiyenkorin study area

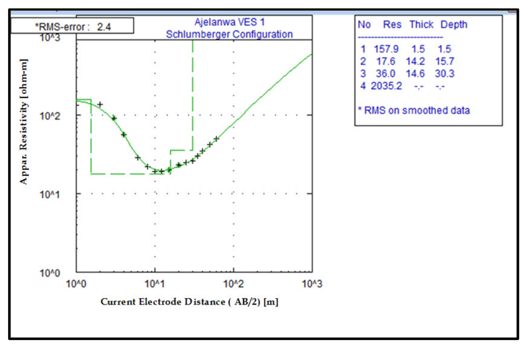

Figure 7: Typical VES curve obtained at Ajelanwa study area

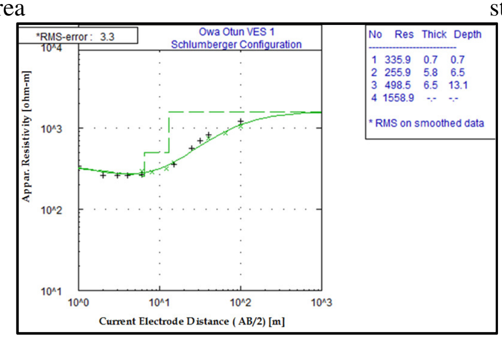

Figure 8: Typical VES curve obtained at Owa Otun study area

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Table 1: Summary result table for Eiyenkorin study area

VES station	No. of layers	Resistivity (Ωm)	Thickness	Depth to Bedrock	Curve type	Remark
VES 1	3	673.0 75.7 61028.0	4.3 14.5 --	18.8	H	Topsoil Weathered Basement Fresh Basement
VES 2	4	4800.0 478.0 39.6 10836.0	0.9 1.6 17.9 --	20.4	QH	Topsoil Laterites Weathered Basement Fresh Basement
VES 3	3	229.1 398.7 2268.0	0.9 3.0 --	3.9	A	Topsoil Weathered Basement Fresh Basement
VES 4	4	102.6 526.5 11.5 11125.0	0.6 0.8 7.8 --	9.3	KH	Topsoil Laterites Weathered Basement Fresh Basement
VES 5	3	600.0 15.6 230.0	1.4 2.3 ---	3.7	H	Topsoil Weathered Basement Fractured Basement
VES 6	4	257.9 1765.1 161.9 48233.1	0.6 0.9 4.73 --	6.73	KH	Topsoil Laterites Weathered Basement Fresh Basement
VES 7	5	85.9 238.7 16.7 62.5 1745.8	0.5 0.8 2.3 20.2 --	23.8	KHK	Topsoil Laterites Weathered Basement Fractured Basement Fresh Basement
VES 8	4	134.0 250.0 125.0 450.0	0.6 3.0 5.90 --	9.5	KH	Topsoil Laterites Weathered Basement Fresh Bedrock
VES 9	3	1026.1 24.6 196.0	1.5 6.8 --	8.3	H	Topsoil Weathered Basement Fractured Basement
VES 10	5	659.7 969.1 56.8 132.0 8863.5	0.6 0.9 8.2 5.26 --	15.4	KHK	Topsoil Laterites Weathered Basement Fractured Basement Fresh Basement
VES 11	4	483.0 3024.4 109 2506.2	0.5 0.9 13.1 --	14.5	KH	Topsoil Weathered Basement Fractured basement Fresh Basement
VES 12	3	5503.6 388.1 4086.4	1.0 5.6 --	6.6	H	Topsoil Weathered Basement Fresh Basement
VES 13	3	185.7 27.8 9745.6	0.5 7.4 --	8.0	H	Topsoil Weathered Basement Fresh Basement
VES 14	4	479.8 3121.9 76.7 4522.5	0.8 0.9 9.9 --	11.7	KH	Topsoil Laterites Weathered Basement Fresh Basement
VES 15	5	948.5 81.0 658.4 41.8 96005.5	0.5 0.4 1.4 4.7 ---	6.9	HKH	Topsoil Laterites Weathered Basement Fractured Basement Fresh Basement

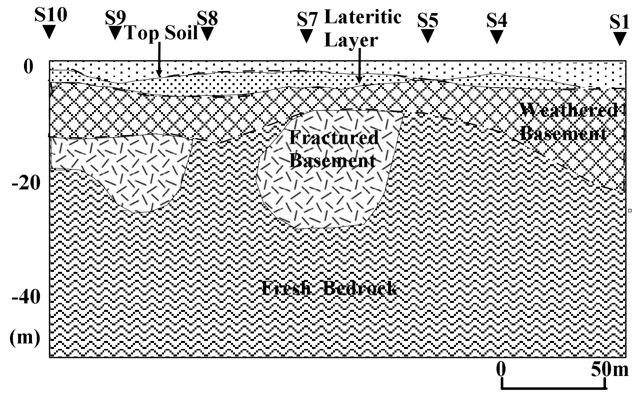

Figure 9: Geoelectric section across profile 1 at Eiyenkorin

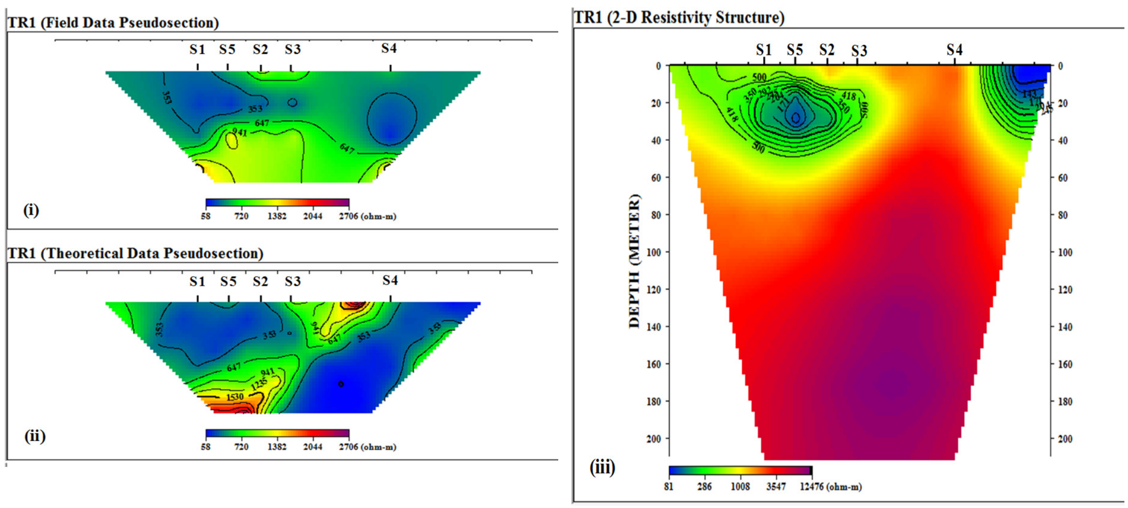

Figure 10: (i) Field data pseudosection (ii) Theoretical data pseudosection and (iii) 2-D Resistivity structure along traverse 1 at Owa Otun

4. CONCLUSION

Geophysical investigation for groundwater exploration in Ajelanwa, Owa Otun and Eiyenkorin Communities in the Basement Complex terrain of Kwara State, Nigeria has revealed four to five major lithologic units. These include: the topsoil, the lateritic layer, the weathered layer, the partly weathered/fractured basement and the fresh bedrock. The weathered layer and the partly weathered/fractured basement constitute the main aquifer units. At the three study areas, the depth to fresh basement varies from 3.7 to 30 m. The geoelectric interpretations of the electrical resistivity data obtained in the study areas have elicited lobes or areas of low resistivity which constitute the prospective zones or areas for water exploration. Basement depression zones which correspond to area with relatively thick overburden materials and areas having thick weathered and fractured basement are priority zones for possible groundwater development most especially when the clay content is low. The study areas have been delineated into prospective high and low groundwater potential zones based on geoelectric characteristics.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Akintorinwa, O. J., Atitebi, M.O. and Akinlalu, A. A. (2020). Hydrogeophysical and Aquifer Vulnerability zonation of a typical Basement Complex Terrain: A case study of Odode Idanre Southwestern Nigeria. Heliyon 6 (8).

Anudu, GK, Onwuemesi, AG, Ajaegwu, NE, Onuba, LN and Omali, AO. (2008). Electrical Resistivity investigation for Groundwater in the Basement Complex terrain: A Case Study of Idi-Ayunre and its Environs, Oyo State, Southwestern Nigeria. *Natural and Applied Science Journal,* 9(2), pp. 1 – 12.

Bayode, S.S., Ojo, J.S. and Olorunfemi, M.O. (2006). Geoelectric Characterization of Aquifer Types in the Basement Complex Terrain of Parts of Osun State, Nigeria. Global Journal of Pure and Applied Science, 12(30, pp. 277- 385.

Fashae, OA, Tijani, MN, Talabi, AO and Adedeji, OI. (2014). Delineation of Groundwater Potential Zones in the Crystalline Basement Terrain of SW-Nigeria: An Integrated GIS and Remote Sensing Approach. *Applied Water Sci*ence 4, pp. 19 - 38.

Kearey, P., Brooks, M. and Hill, L. (2002). An Introduction to Geophysical Exploration, Third Edition Blackwell Science, Oxford.

Obaje, N. G., Moumouni, A., Goki, N. G., and Chaanda, M. S. (2011). Stratigraphy, Paleogeography and Hydrocarbon Resource Potentials of the Bida Basin in North-Central Nigeria. Journal of Mining and Geology, 47(2), pp. 97-114.

Obasi, R. A., Ademilua, O.L. and Eluwole, A. B. (2013). Geoelectric Sounding for Groundwater Potential Appraisal around the Northeastrn -Southeastern Parts of the Federal Polytechnics, Ado-Ekiti Campus, Southwestern Nigeria. Research Journal in Engineering and Applied Sciences 2(3), pp. 211-219.

Olawuyi, A. K. and Bawallah, M, A. (2022). Integrated Geophysical Method and Techniques for Studying the Perennial Springs in Ikanje-Share, Kwara State, Nigeria. Nigeria Journal of Basic and Applied Sciences, 30 (1), 68-76. http://dx.doi.org/10.4314/njbas.v3011.10

Olorunfemi, M. O. and Fasuyi, S. A. (1993). Aquifer Types and the Geoelectric/ Hydrogeologic Characteristics of Part of the Central Basement Terrain of Nigeria (Niger State). *Journal of African Earth Science* 16, pp. 309-317.

Olorunfemi, M. O. Oni, A. G., Bamidele, O. E. *et al*. (2020). Combined Geophysical Investigations of the Characteristics of a Regional Fault Zone for Groundwater Development in a Basement Complex Terrain of South-west Nigeria. SN Applied Sciences. 2, 1033. https://doi.org/10.7007/s42452-020-2363-6

Olorunfemi, MO and Fasuyi, SA. (1993). Aquifer Types and the Geoelectric/ Hydrogeologic Characteristics of Part of the Central Basement Terrain of Nigeria (Niger State). *Journal of African Earth Sciences* 16, pp. 309-317.

Rahaman, MA. (1981). Recent Advances in the Study of Basement complex of Nigeria. First Symposium on the Precambrian Geology of Nigeria, Summary.

Sharma, P. V. (1997). Environmental and Engineering Geophysics. Cambridge University Press. Cambridge. U.K. 474.

Sharma, SP and Baranwal, VC. (2005). Delineation of Groundwater Bearing Fracture Zones in Hard Rock Area Integrating Very Low Frequency Electromagnetic and Resistivity Data. *Journal of Applied Geophysics*, 57, pp. 155 – 166.

Vander Velpen, B. P. A. (1988). "WinResist Version 1.0 ". M. Sc. Research Project. ITC: Delft, Netherlands.

William, L. (2007). Fundamentals of Geophysics. Cambridge University Press. Second Edition. pp. 263 – 265.