ISSN 2229-5518

The Application of Geophysical Methods in Determining the Causes of Borehole Failure: A Case Study of Dextol Hostel, Abeokuta, South Western Nigeria.

**Adeolu Aderoju O., Hansen-Ayoola A.O., Olanrewaju Olajuwon

Abstract

Boreholes adjudged successful or high yielding after drilling have been known to fail - a term used to describe the deteriorating condition of a borehole in terms of quantity and quality. The Four (4) boreholes within the study area were determined to be failed as a result of low or non-yield. The subsurface characterization with a view to understanding the ground water potential of the study area through the determination of the aquiferous units, overburden material, and bedrock was done. Vertical Electrical Sounding (VES) and Horizontal Profiling (HP) survey using Schlumberger and Wenner configuration respectively were conducted in the study area. DGGeo-ERM 01 Resistivity meter with accessories was used for data acquisition. Geo-electric Profiling using Wenner configuration was carried out in order to delineate regions of anomaly within the basement rock and then VES followed. Maximum spread AB of 120m was maintained for the two VES and distance a = 60m was observed for the horizontal profiling while the electrodes were being moved at the interval of 3 meters. The subsurface of the study area is characterized by thick overburdens, perched aquifers, minor and major fractures. It was determined that the cause of failures was as a result of poor decision by the drillers to drill into perched aquifers and minor fractures.

Index Terms: Borehole, Drill, Fractures, Horizontal Profiling, Perched aquifer.

1 INTRODUCTION

WATER is life, as a good percentage of human activities are either directly or indirectly dependent on water. Therefore, having good and easy access to portable water is key to a good and vibrant life both on the industrially or domestically. Over the years, the demand for quality water increases on annual basis. As the population of the country is growing, pollution and urbanization is reducing or affecting access to portable water. Therefore, every day, more and more companies and families turn to borehole water/underground water to meet their manufacturing and drinking needs.

In a quest for this, a field of study that unveils the subsurface structures and settings such as geophysical exploration is required in order to delineate subsurface formations and to locate a viable aquifer that would serve such needs for water.

Borehole failures are usual occurrences in basement complex regions where the targeted aquifer is fractures in hard rocks, these are also known as secondary porosity. Factors that are responsible for borehole failures are numerous. Some of the speculations for the causes of Borehole failures are; failure to carry out drilling operations to specifications or efficiently, borehole completion problems (improper casing of the overburden rock unit), problems associated to post drilling such as failure in borehole maintenance, damage to submersible pumps, blocked or leaking pipelines or damaged reservoir tanks or inability to drill into water bearing units. Borehole failure could also be geology related, examples are; seasonal variations in water level and inability for the encountered aquifer to deliver water. This research work was carried out in order to determine the reason for the borehole failures encountered at Dextol Hostel (A massive student building) and efforts were made using geophysical exploration methods in order to determine another viable point to carry out the borehole drilling.

Comprehensive geophysical exploration with accurate data acquisition can reduce greatly the risk of having failures in drilled boreholes and increase our chance of getting good water for our daily needs. The prior borehole failure experienced in the study area called for a comprehensive study of the subsurface in order to locate a viable aquifer that can serve the huge compound.

2 STUDY AREA

2.1 Physiography/Geology

The study area falls within the ancient city of Abeokuta. Abeokuta is the largest city and state capital of Ogun State in southwest Nigeria (Figure 1). It is situated on the east bank of the Ogun River, near a group of rocky outcrops in a wooded savannah; 77 kilometres (48 mi) north of Lagos by railway, or 130 kilometres (81 mi) by water.

Abeokuta lies in fertile country of wooded savannah, the surface of which is broken by masses of grey granite. It is spread over an extensive area, being surrounded by mud walls 18 miles in extent.

2.2 Relief and Drainage

Ogun State has a wide area of undulating lowlands belonging to the coastal sedimentary rocks of western Nigeria. There are scattered hills that are interfluves between the different river valleys. Some remnants of a large planation in the state include the out crop inselbergs found at Abeokuta, the Olumo Rock at the southern edge of the Western uplands.

2.3 Climate: Ogun State is located in the moderately hot, humid tropical climatic zone of southwestern

ISSN 2229-5518

Nigeria. There are two distinct seasons in the state, namely, the rainy season which lasts from March/April to October/November and the dry season which lasts for the rest of the year, October/November till March/April.

Figure 1: The Study Area on the Map of Nigeria [10]

3 GEOLOGY OF THE STUDY AREA

The gneiss-migmatite complex is the most widespread rock formation within the study area. It comprises gneisses, quartzite, calc-silicate, biotite-hornblende schist and amphibolites [8]. The older granites in and around Abeokuta, are of late Precambrian to early Paleozoic in age and are magmatic in origin [4].

Abeokuta falls within the basement complex of the geologic setting of south-western Nigeria (Figure 2). The basement complex rocks of Pre-Cambrian age are made up of older and younger granites, with the younger and older sedimentary rocks of the both tertiary and secondary ages. The area is underlain by basement rocks, which cover about 40% of landmass in Nigeria (Figure 3) [6].

4 DESCRIPTION AND STATE OF SITUATION OF THE STUDY AREA

The Study area is a massive four winged complex (Figure 4). Four (4) boreholes have been drilled in the compound, two of the boreholes are not serving at all (Borehole 1 and 2) (i. e. completely failed) while the other two which are close to each other are serving but the water yield is very low (Borehole 3 and 4) (yield is less than 400 litres/24 hours). So they were considered to be failed boreholes. The four wells are drilled almost on the same traverse line with less than 15 meters distance between each well. It was first suggested that the boreholes must have failed due to their inability to access a water bearing fracture that could serve the compound.

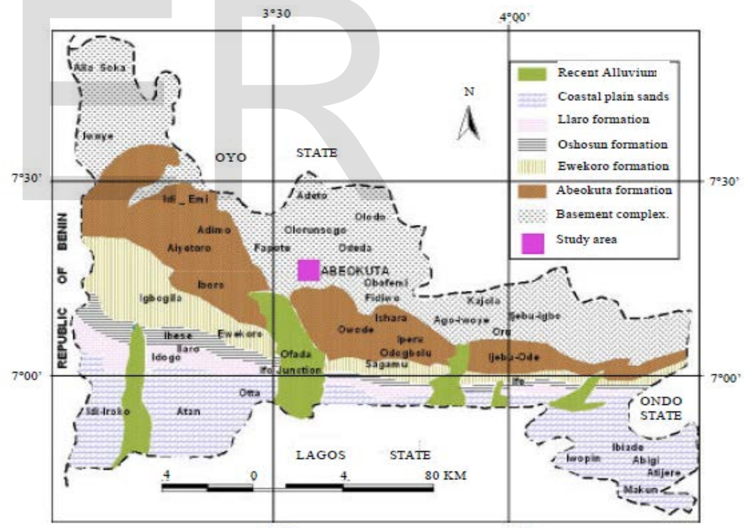


Figure 2: The Geological Map of Ogun State Showing the Study Area [7].

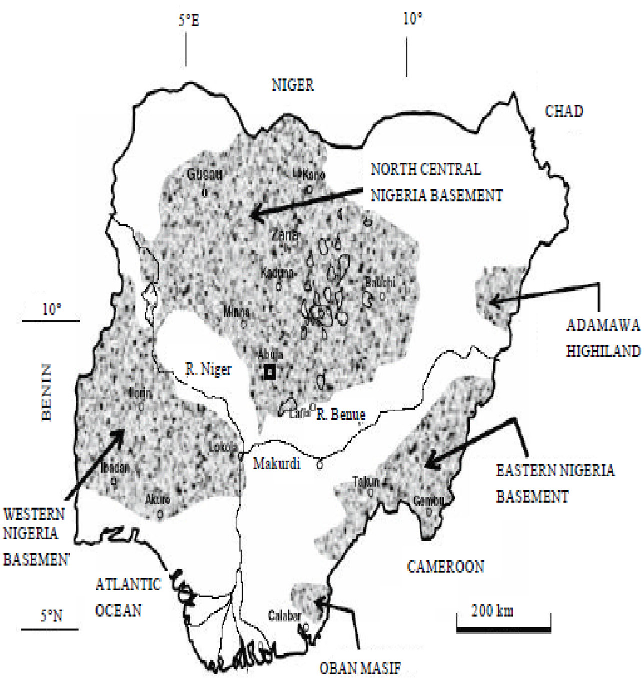


Figure 3: The Geological Map of Nigeria Showing the Basement Complex Settings [6].

Figure 4: Satellite View of the Study Area with the VES Locations and Borehole Locations [5]

5 LITERATURE REVIEW

Borehole failures have been researched by many authors and a myriad of factors are responsible for this occurrence. Ron et al [9] investigated the well field in southeast Botswana, and determined that poor construction and completion were responsible for failure. Eduvie [2], Eduvie and Olabode [3], and Afuwai et al [1] also present some causes of borehole failures.

6 ELECTRICAL RESISTIVITY METHOD

The resistance offered by the opposite faces of a unit cube of a material to direct current is termed electrical resistivity. Unit of resistivity in geophysical literature is connoted as the ohm·m. The resistance (R) of the material having a resistivity (ρ) over a length (L) and surface area of current flow (A) is represented by

$$R = \rho \frac{L}{A}.$$

The above relation is known as Ohm's law, which governs the resistivity of the geological formation. Resistivity is generally high under dry conditions and decreases with moisture or clayey material. Presence of water in voids, cracks, or fractures even in minor amounts eases the path for current passage and makes the geological formations relatively conductive.

6.1 Acquisition and Processing of Resistivity Data.

The resistivity of the subsurface formation is measured using four electrodes, two metal bars for passing current into the ground (current electrodes) and two non-polarizable porous pots for potential variation measurements (potential electrodes).

The current of electrical intensity (*I*) is introduced between current electrodes which can be identified as A and B. The potential difference produced as a result of current flow is measured with potential electrodes represented as M and N.

The acquired resistivity data of a vertical electrical sounding (VES) is plotted on a double log sheet, in order to accommodate both the spacing and apparent resistivity variations. While the horizontal profiling is plotted on a linear graph using Microsoft excel software.

7 METHODOLOGY

Geo-electric sounding i.e Vertical Electrical Sounding (VES) and Horizontal Profiling (HP) surveys using Schlumberger and Wenner configuration respectively were conducted in the study area. DGGeo-ERM 01 Resistivity meter with accessories was used for data acquisition. Two geo-electric sounding was carried out in study area, the first was carried out at the point where Borehole 3 was sited while the second geophysical VES was 120m away from the traverse line of the existing four boreholes. Before VES 2 was done, a Geo-electric Profiling using Wenner configuration was carried out in order to delineate regions of anomaly within the basement rock.

Maximum spread AB of 120m was maintained for the two VES and distance a = 60m was observed for the horizontal profiling while the electrodes were being moved at the interval of 3 meters.

7.1 Interpretation of Resistivity Data

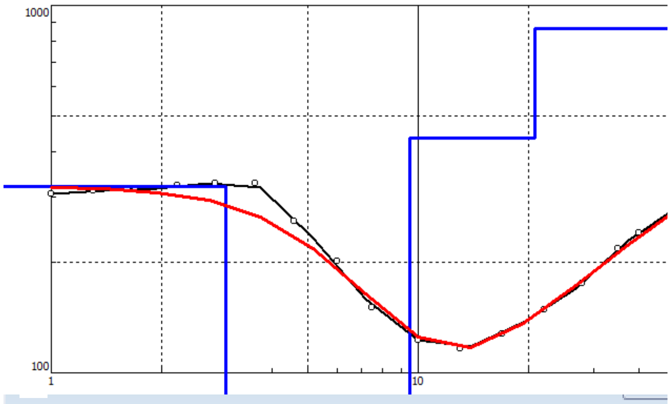
The data acquired from VES survey is subjected to quantitative interpretation so as to attain fairly good information about the subsurface (depth-wise lithostratigraphic sequence) at the centre of each VES. IPI2Win software Version 3.0.1, was used for further computations and a model of the layered sequence was obtained. The geo-electric layered sequence was then related to Geology for further considerations and decision making.

8 RESULTS AND DISCUSSIONS

The results from the first VES that was carried out at BH 3 revealed that the subsurface has four geo-electric layers. The first layer predicted to be the top soil with resistivity value of 321 Ωm and thickness of 2.99m while the second layer being a sandy clay unit shows a decrease in its resistivity value to 61.4 Ωm with a thickness of 6.5 m, the third layer which was considered to be a moderately weathered basement rock has an increased resistivity value of 435 Ωm to the depth 20.8m, the last layer which is considered as fresh basement has resistivity value of 865 Ωm with an infinity thickness (Figure: 5 and 8a)

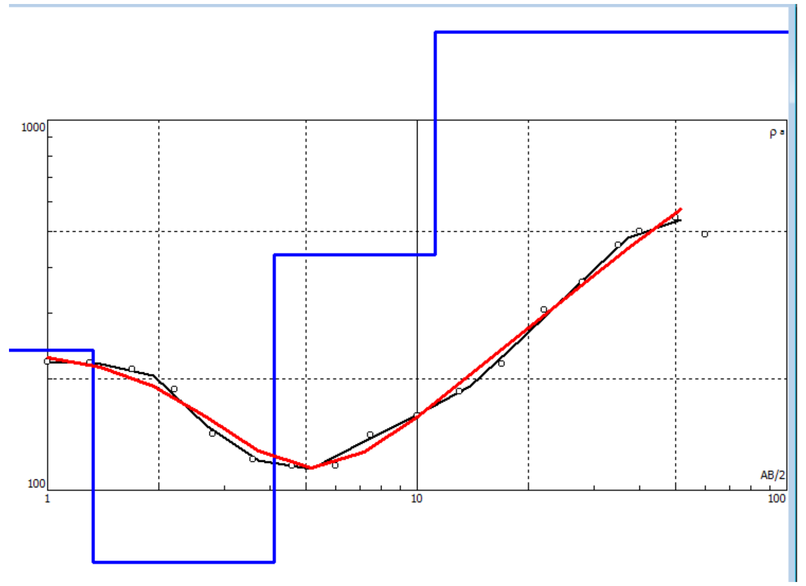
The horizontal profiling along the traverse line that cuts through the second sounded point revealed an obvious anomaly which is indicative of fracture at AB/2 = 39 m, this point was sounded and the fracture was confirmed to be existing at the section (Figure 6).

The VES 2 also shows a curve with four geo-electric layers, the first layer is predicted to be the top soil with the following properties; apparent resistivity: 239 Ωm, thickness of 1.33 meters, the second layer is considered to be a sandy clay unit with resistivity value of 63.8 Ωm, and 2.73 m, the third layer is considered to be a moderately weathered basement rock with resistivity value of 433 Ωm and a thickness of 7.0 m. the last geo-electric layer is considered to be a fractured basement rock with resistivity value of 1729 Ωm to an infinity depth.



N	1	2	3	4
ρ	321	61.4	435	865
h	2.99	6.5	11.3	
d	2.99	9.49	20.8	
Alt	-2.99	-9.486	-20.8	

Figure 5: Graph and Results display of VES 1



N	1	2	3	4
ρ	239	63.8	433	1729
h	1.33	2.78	7.08	
d	1.33	4.1	11.2	
Alt	-1.328	-4.104	-11.19	

Figure 7: Graph and Results display of VES 2

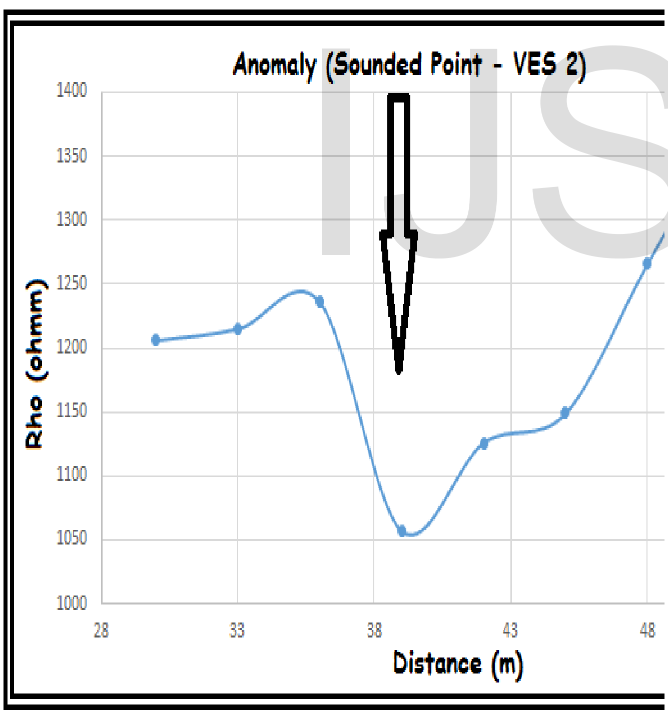


Figure 6: Horizontal Profiling graph with anomaly at AB/2 = 39 m

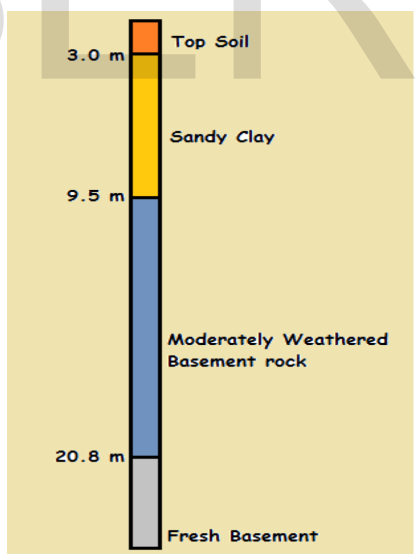


Figure 8a: Geo-Electric Section of VES 1

ISSN 2229-5518

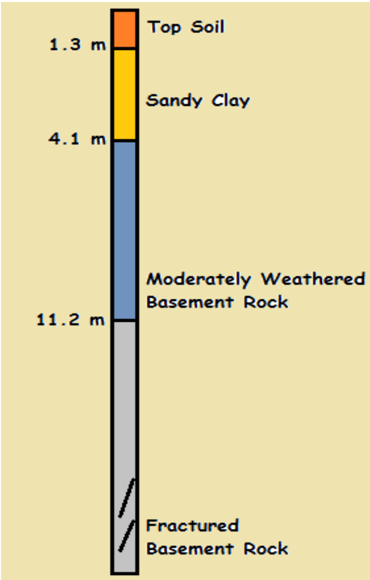


Figure 8b: Geo-Electric Section of VES 2

9 CONCLUSION

The two results obtained revealed that the subsurface has similar or close geologic settings, the overburden soil for the first VES is thicker and has better propensity for bearing water although such water may not be substantial. This explains the reason why Borehole 3 and 4 were still producing very little water when pumped. Conversely, VES 2 has a thin overburden (loosed earth materials), this may be phreatic aquifer. The geo-electric layering reveals that there are two fracture aquifers in the fourth layer of the section, the first projected fracture is a minor one at depth 24 – 28 m, the second fractured aquifer was projected to be at 45 – 50 m.

The second VES was recommended for drilling, the report stated that the well be drilled to a depth of 60 – 70 m, wherein upon encounter with viable aquifer before the stipulated depth, the driller can terminate using his discretion. When the borehole was drilled, the first minor fracture predicted produced very little water upon drilling while the second fractured aquifer had a good yield rate. Upon well completion, the water production rate was considered okay to serve the compound (2, 500 litres was pumped in 20 minutes).

REFERENCES

[1] Afuwai, G.C., Lawal, K.M., Sule, P., Ikpokonte, A.E. (2014): Geophysical Investigation of the Causes of Borehole Failure in the Crystaline Basement Complex: A Case Study of Kaura Area of Kaduna State, Nigeria. Journal of Environment and Earth Science. Vol.4, No.23.

[2] Eduvie, M. (2008). Difficult Groundwater Terrains of Nigeria in relation to Drilling Cost, A paper presented at the stakeholders workshop for developing Term of Reference for the study of Public and Private Borehole Drilling in Nigeria.

[3] Eduvie, M. and Olabode O. (2012). A critical Review of Hand pump Utilization for Rural Water Supply: Case studies from part of Nigeria. Water Resources (2012)22, Journal of the Nigerian Association of Hydrogeologist. Pp.51-59.

[4] Jones, H.A. and Hockey, R.D. (1964): The Geology of Part of South-Western Nigeria. Geological Survey of Nigeria Bulletin No. 31, Geological Survey of Nigeria, Kaduna.

[5] Google Earth: Satellite view of Dextol Hostels, Abeokuta, Ogun State, Nigeria.

[6] Obaje, N.G. (2009): Geology and Mineral Resources of Nigeria. Springer, Dordrecht Heidelberg London New York, 221 pp.

[7] Olowofela, J.A., Akinyemi, O.D., Idowu O.A., Olurin O.T., Ganiyu S.A. (2012): Estimation of Magnetic Basement Depths Beneath the Abeokuta Area, South West Nigeria from Aeromagnetic Data Using Power Spectrum. Asian Journal of Earth Sciences. Volume 5(3): 70 – 78.

[8] Rahaman, M. A. (1976): Review of the basement geology of South-western Nigeria, a review in Geology of Nigeria, edited by C. A. Kogbe, pp. 39-56, Elizabeth Publications Co., Lagos.

[9] Ron T.C., Berhanu F.A., Loago M., Oteng M. Moreomongwe (2006): Investigating the causes of water-well failure in the Gaotlhobogwe wellfield in southeast Botswana. Journal of Applied Science and Environmental Managemment. Vol. 10 (3) 59 – 65.

[10] Wikipedia: Location map of Abeokuta, Nigeria.

Appendix

Dextol VES 1

AB/2	MN/2	RHO
1	0.25	308.25
1.3	0.25	313.15
1.7	0.25	313.44
2.2	0.25	323.56
2.8	0.25	325.45
3.6	0.25	325.63
4.6	0.25	257.32
4.6	1	258.21
6	1	202.58
7.5	1	152.61
10	1	120.51
13	1	116.75
13	3	116.59
17	3	125.98
22	3	148.85
28	3	174.54
35	3	217.38
40	3	239.59
40	6	243.84
50	6	279.25
60	6	300.57

Dextol VES 2

AB/2	MN/2	RHO
1	0.25	221.98
1.3	0.25	220
1.7	0.25	212.15
2.2	0.25	187.21
2.8	0.25	142.13
3.6	0.25	121.02
4.6	0.25	103.62
4.6	1	131.21
6	1	116.7
7.5	1	140.82
10	1	158.8
13	1	182.3
13	3	186.19
17	3	219.94
22	3	307.08
28	3	365.59
35	3	460
40	3	487.07
40	6	513.41
50	6	546.05
60	6	490

HP:A=60m,d=3m

AB/2	RHO
30	1205.78
33	1214.78
36	1235.89
39	1056.8
42	1125.78
45	1148.8
48	1265.78
51	1378.56