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Causes of Borehole Failure in Complex Basement Terrains: ABUAD Case Study, Southwestern Nigeria

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ABSTRACT : *A preliminary assessment of primary causes of borehole failure has being conducted using Afe Babalola University as a case study. A total of fourteen boreholes (namely borehole 1-14) were studied, vertical electrical soundings, depth sounding, flushing and pump testing were conducted on each of the boreholes to establish their status at the time of the study and possible evaluation of the groundwater potential of the wells. Four out of the fourteen boreholes (borehole 1-4) are productive and in-use, while the remaining ten (borehole 5-14) are out-of-use and abandoned for various. The productive holes were able to support continuous flow of water for over 3 hours without drop in volume of water flow. Seven of the holes (boreholes 5, 6, 8, 9, 11, 12 & 14) failed and were abandoned because of low yield (could not flow beyond 5 minutes), while the remaining three (boreholes 7, 10 & 13) failed and were abandoned due to wrong location and improper completion, caving/formation problems, and wrong installation/completion respectively. Proper well completion is essential in areas prone to caving and other formation related problems. Air drilling should be avoided in areas with thick and loose overburden. Right mixture of drilling mud should be applied to secure the hole wall while flushing should be continuous throughout drilling in such formation. Casing should be done immediately and such holes should be lined and grouted. Timers should be installed on low yield wells and regulated/programmed for 5 or 10 minutes flow depending on the recharge rate. Pump rating for installation should be strictly based on well recharge rate. Productive wells should be properly maintained and monitored for optimal performance.*

KEYWORDS: *Caving, Loose overburden, Improper completion, Grouting, Optimal performance.*

I. INTRODUCTION

The rate of borehole failure has been alarming in recent time. High expectations from borehole yield and the huge amount of resources involved in sinking a borehole are making such failures unbearable and unacceptable. The unprofessional approach of many drillers are partly responsible for the failure while the role of poor maintenance culture and practices are also hindering optimal well performance. The need for careful, detailed geophysical study in citing borehole location and appropriate completion design cannot be overemphasized. Groundwater exploration reports around Ado-Ekiti suggest low fracture in most part of this state capital. This results in low yield in most of the boreholes own by private individual and public.

Several workers such as Dutcher and Garret (1965), Clerk (1985), Olorunfemi and Olorunniwo (1985), Olorunfemi (1990), Olayinka and Olorunfemi (1992) Olorunfemi and Olayinka (1992), Olorunfemi and Fasuyi (1993), Oladipo et al, (2005) Olayinka and Weller (1993), Rehil and Birk (2010), Ojo et al, (2011), Talabi (2013) have carried research in various aspect of groundwater exploration/investigation, evaluation and structural delineation using geophysical methods in several location within the basement complex terrain around the world.

Groundwater exploration in the basement aquifers posed a serious challenge resulting from complexity of rocks and minerals and their attendant heterogeneous grain size distribution. Olayinka and Olorunfemi (1992) emphasized the need to conduct a surface geophysical survey such as Vertical Electrical Resistivity Sounding in identifying the localized aquiferous zones before siting boreholes. Electrical resistivity method has been used extensively in groundwater investigation especially in the basement complex terrains (Grant and West, 1965, Olorunfemi and Olorunniwo, 1985. Olorunfemi, 1990. Olorunfemi and Olayinka, 1992). Recently, Ademiluwa and Eluwole 2013 evaluated groundwater potential of some part of the university and concluded that weathered basement and fractured basement constitute the main aquifer types within the study area based on their layer thicknesses and resistivity.

Afe Babalola University (ABUAD) has a total of 30 boreholes to cater for the daily water requirement of the University; however, some of the boreholes have failed due to various reasons. This study therefore aims at assessing the primary causes of borehole failure in basement complex using ABUAD as a case study

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II. LOCATION AND GEOLOGY OF THE STUDY AREA

2.1 Location

Afe Babalola University is located in Ado-Ekiti along Ijan road, opposite The Federal Polytechnics. The study area is randomly selected within the university campus. The terain is gently undulating, with topographic elevation ranging from 345m to 370m above sea level. Ado Ekiti is underlain by crystalline rocks made of Older granite, Migmatite and Charnockites, with little or no fracture in most location and shallow overburden.

2.2 Climate, Geology and Hydrogeology of The Area

The area is situated within the tropical rain forest region, with a climate characterized by dry and wet seasons. Average annual rainfall in this area is 1300 mm, with average wet days of about 100. The annual temperature varies between 18^{0}C to 34^{0}C. The study area lies within the basement complex of south-western Nigeria and is made up of; older granite, Migmatite and Charnockites. The overburden is relatively shallow within the study area with average of 9.6m. The groundwater is found within the overburden and fractured basement while the area is drained by the river Ogbese which flow SW-NE direction. The basement complex rocks are poor aquifers as they are characterized by low porosity and negligible permeability, resulting from their crystalline nature.

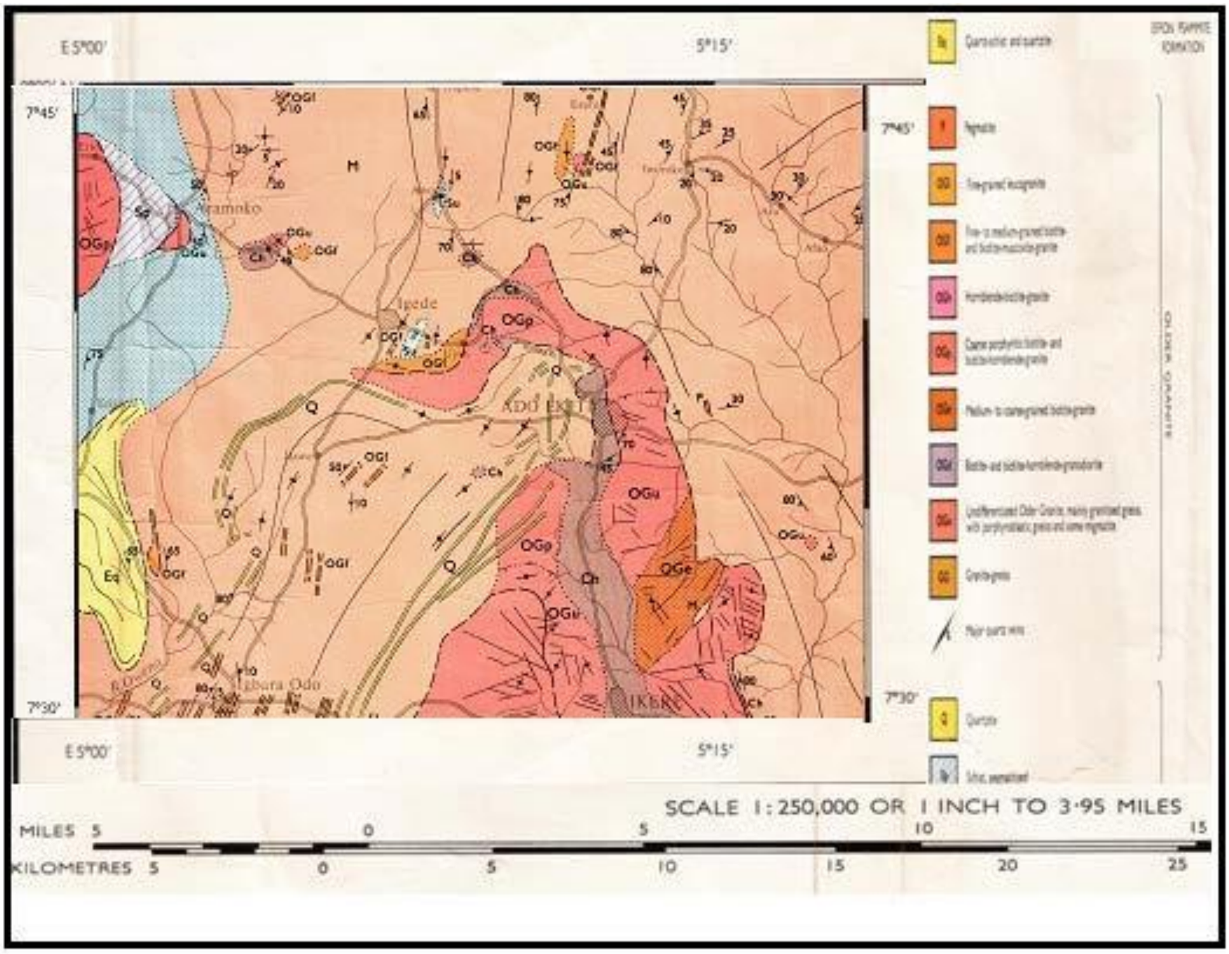


Fig. 1. Geological Map of the study area (Adapted from NGSA)

III. Methodology, Data acquisition and Interpretation

A reconnaissance survey of study area was carried out for site familiarization, planning and selection of the wells for the study. This was followed with geophysical investigation of the wells, flushing, depth sounding and pump testing. Resistivity sounding was adopted in resolving resistivity variation with depth, thus sounding helped in delineating the various subsurface lithological units, aquiferous layers and their hydrogeological significance.

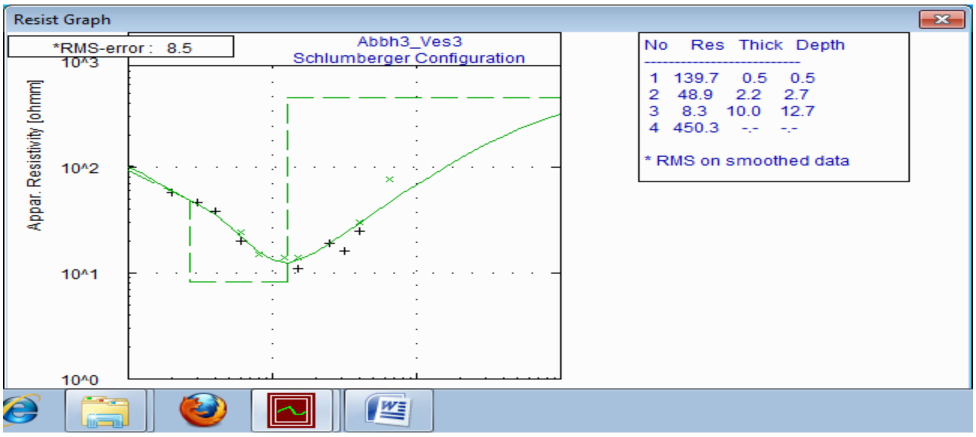
IV. RESULTS AND DISCUSSIONS

4.1 Vertical Electrical Sounding

A total of 14 selected boreholes across the study area were sounded. The processed data were interpreted, resulting curve types were assessed, existing subsurface lithologic units were established, and the geoelectric properties of the various subsurface layers were used in delineating the aquiferous units in the study area. Field observations were made, flushing and pump testing were conducted on the boreholes. Status of each of the boreholes at the time of the study were established. The results are presented in the form of table (Table 1), geoelectric curves (Figure 2a, b, c & d) and sections (Figure; 3a, b, c & d).

Two curve types were obtained from the study area namely; HA and HK. Five geo-electric layers were delineated from the sounding curves namely; top soil, sandy clay, weathered basement, fractured basement and basement. A correlation table was generated by comparing different geo-electric layers revealed by the sounding curves (Table 1). The top soil, sandy clay and weathered basement layers constitute the overburden. Basement is relatively shallow in this area with an average depth-to-basement of 10.8m.

A summary of the results of interpretation, on which the findings were hinged, is shown in figure 2 below.



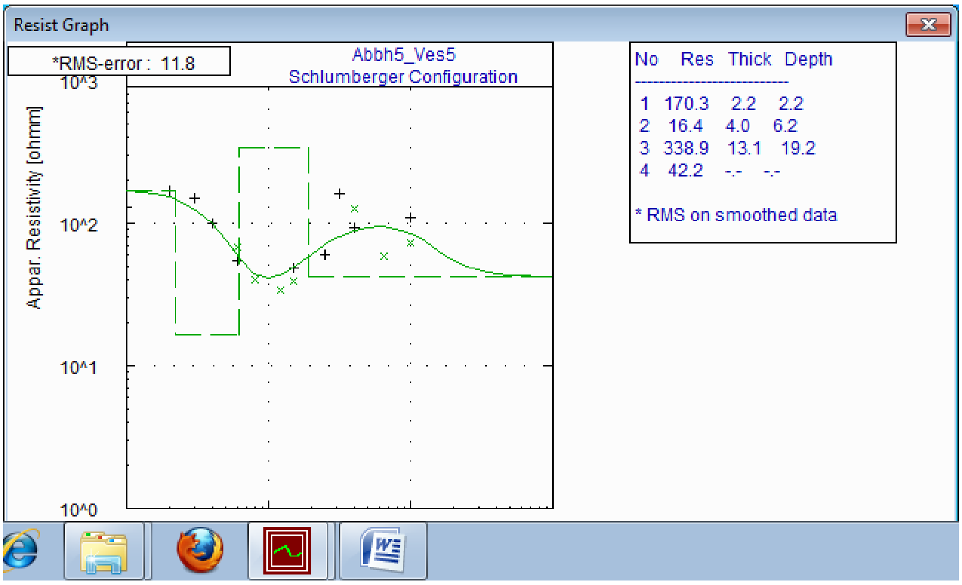


Fig. 2. Typical Geoelectric curves from the study area

Table 1a: Correlation Table

VES POINT		1	2	3	4	5	6	7
CURVE TYPE		HA	HA	HA	HK	HA	HA	HA
LITHOLOGY								
TOP SOIL	TOP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	BASE	1.0	1.0	3.0	2.0	1.0	1.0	1.0
	THICKNESS	1.0	1.0	3.0	2.0	1.0	1.0	1.0
	Ωm	123	140	70	170	95	80	110
CLAYEY SAND	TOP	1.0	1.0	3.0	2.0	1.0	1.0	1.0
	BASE	16.0	13.0	11.0	6.0	17.0	16.0	20.0
	THICKNESS	15.0	12.0	8.0	4.0	16.0	15.0	19.0
	Ωm	49	49	65	16	85	90	60
WEATHERED BASEMENT	TOP	-	-	-	6.0	-	-	-
	BASE	-	-	-	19.0	-	-	-
	THICKNESS	-	-	-	13.0	-	-	-
	Ωm	-	-	-	339	-	-	-
FRACTURED BASEMENT	TOP	-	-	-	19.0	-	-	-
	BASE	-	-	-	-	-	-	-
	THICKNESS	-	-	-	-	-	-	-
	Ωm	-	-	-	42	-	-	-
BASEMENT	TOP	16.0	13.0	11.0	-	17.0	16.0	20.0
	Ωm	256	450	1042	-	397	312	374

Table 1b: Correlation Table

VES POINT		8	9	10	11	12	13	14
CURVE TYPE		HA	HA	HA	HA	HA	HA	HA
LITHOLOGY								
TOP SOIL	TOP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	BASE	1.0	3.0	1.0	1.0	1.0	1.0	1.0
	THICKNESS	1.0	3.0	1.0	1.0	1.0	1.0	1.0
	Ωm	173	152	39	42	78	47	33

CLAYEY SAND	**TOP**	1.0	3.0	1.0	1.0	1.0	1.0	1.0
	BASE	10.0	15.0	12.0	7.0	7.0	13.0	14.0
	THICKNESS	9.0	12.0	11.0	6.0	6.0	12.0	13.0
	Ωm	**30**	**79**	**44**	**54**	**37**	**35**	**14**
WEATHERED BASEMENT	**TOP**	-	-	12.0	-	-	13.0	14.0
	BASE	-	-	-	-	-	-	-
	THICKNESS	-	-	-	-	-	-	-
	Ωm	**-**	**-**	**183**	**-**	**-**	**163**	**120**
FRACTURED BASEMENT	**TOP**	-	-	-	-	-	-	-
	BASE	-	-	-	-	-	-	-
	THICKNESS	-	-	-	-	-	-	-
	Ωm	**-**	**-**	**-**	**-**	**-**	**-**	**-**
BASEMENT	**TOP**	10.0	15.0	-	7.0	7.0	-	-
	Ωm	**274**	**505**	**-**	**349**	**794**	**-**	**-**

The correlation tables presents the summary of the different inferred subsurface layers as revealed by the sounding curves.

4.1.1 Geoelectric Units

The geoelectric sections (Figures 3a, b, c & d) show the variations of resistivity and thickness values of layers within the depth penetrated in the study area. Five subsurface layers were revealed: Lateritic Topsoil, Clayey-sand, weathered Basement, Fractured Basement and presumed Fresh basement.

Topsoil

The topsoil is relatively thin across the study area with an average resistivity and thickness values of 97Ωm and.1.1m respectively.

Clayey-sand

Clayey-sand was encountered across the area with average resistivity and thickness values of 51Ωm and 13.5m respectively.

Weathered Basement

The weathered basement was encountered in only four of the locations with average resistivity value of 201Ωm.

Fractured Basement

The fractured basement was encountered in only one of the locations and the resistivity value is 42Ωm.

Basement

The basement is the fresh bedrock and is the last layer. It is relatively shallow in the study area, it was encountered in ten locations and the average resistivity and depth values to the top of basement are 475Ωmand 13.2m respectively.

Overburden

The overburden in assumed to include all materials above the presumably fresh basement and they constitutes the aquiferous units within the study area.

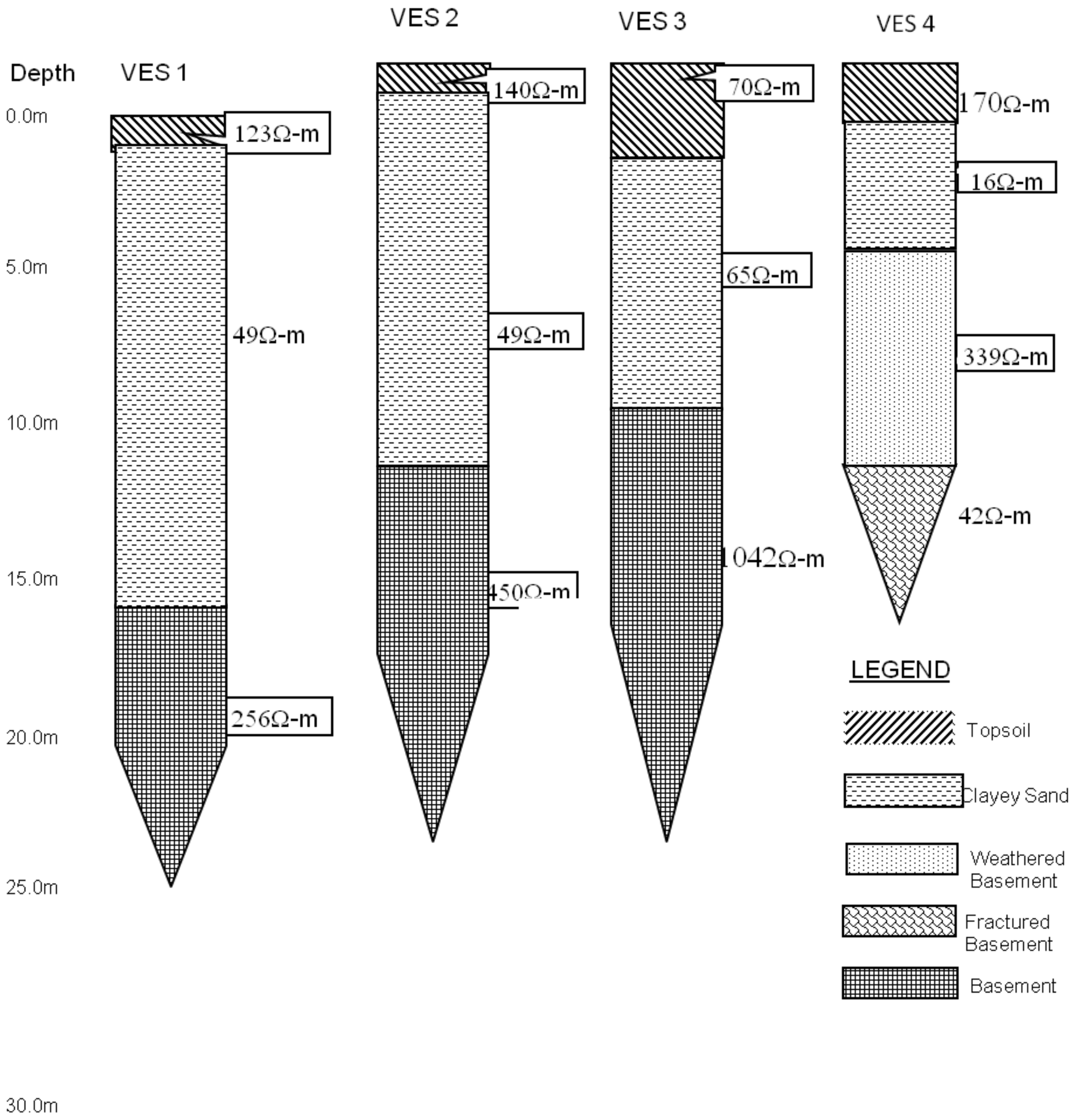


Fig. 3a: Geoelectric Section of VES 1 – 4.

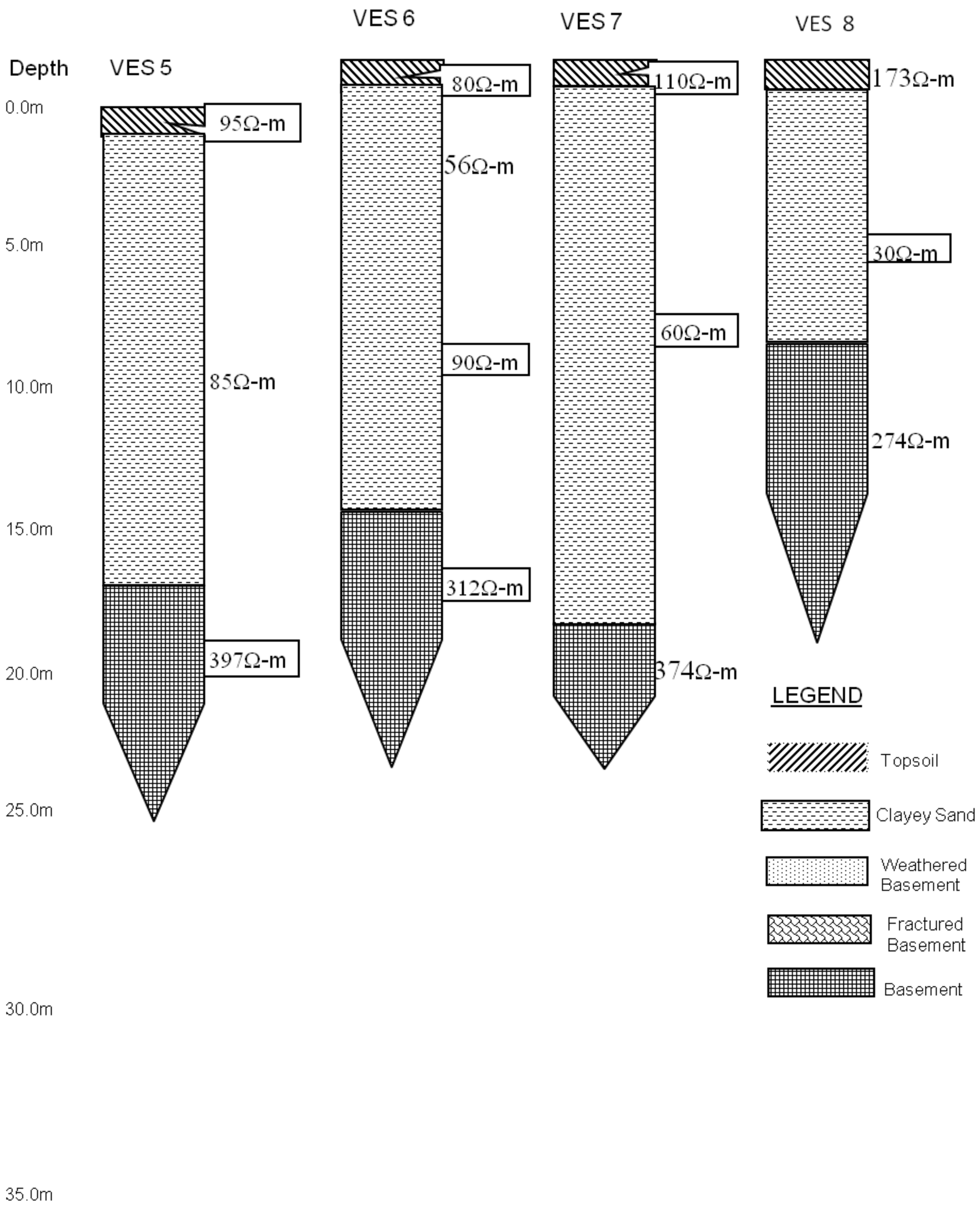


Fig. 3b: Geoelectric Section of VES 5 - 8.

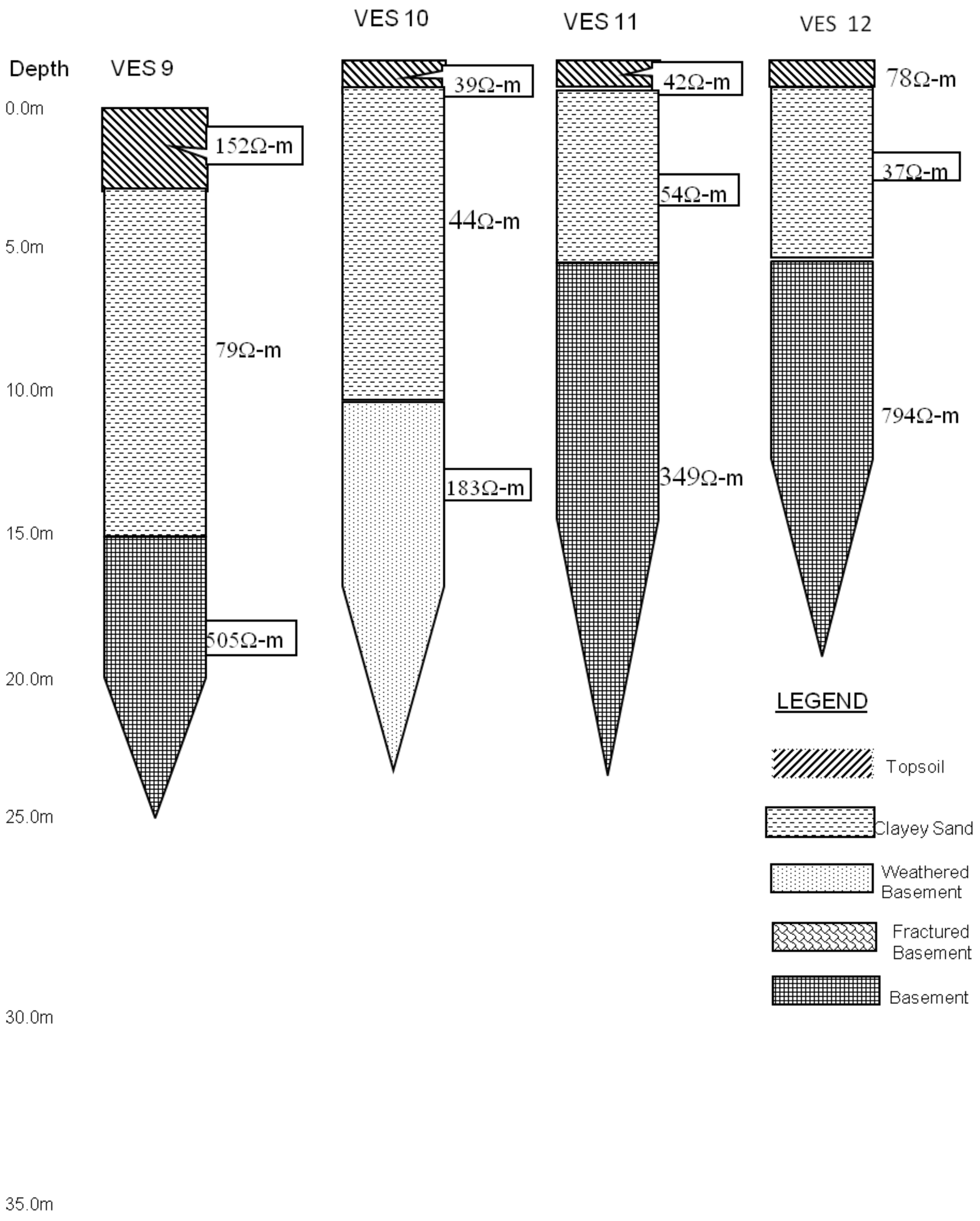


Fig. 3c: Geoelectric Section of VES 8 - 12.

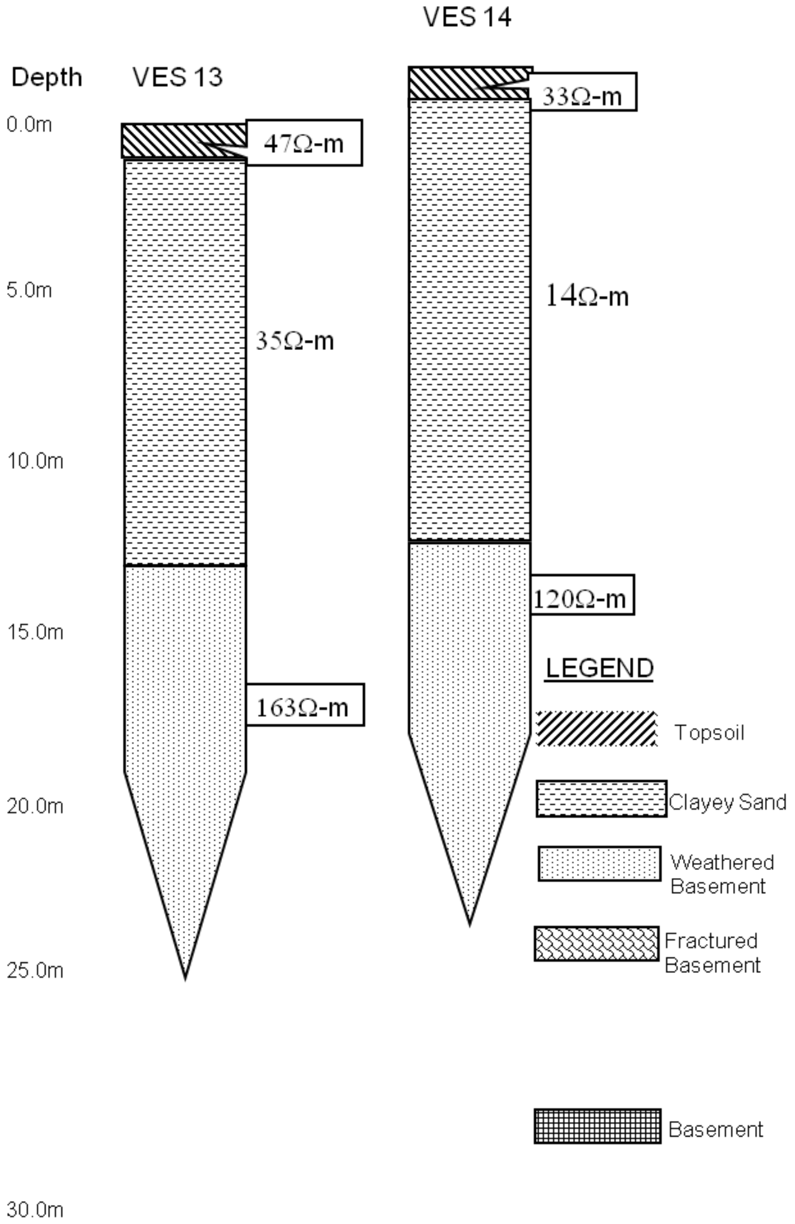


Fig. 3d: Geoelectric Section of VES 11 & 12.

The geoelectric sections correlate the various vertical subsurface layers revealed by the sounding curves of the study area.

4.2 DISCUSION

Fourteen boreholes were investigate The top soils are generally thin (within 0.5 – 2.5 m, with the average of 1.1m) in most parts and the average apparent resistivity value is 97Ω-m while the sandy clay layers are relatively thick (within 4.0 – 18.7 m, with an average of 11.5m). The sandy clay average apparent resistivity value is very low (51Ω-m) across the study area. The combination of the top soil, sandy clay and weathered basement zones constitute the overburden units within the study area with an average thickness of 13.5m.

The overburden materials and the fractured basement constitute the aquiferous units within the study area with low to medium groundwater potential (sandy clay units have low water yield and prone to caving, while fractured basement zones have medium groundwater potential).

Four out of the fourteen boreholes (boreholes 1 – 4) are productive and in-use, while the remaining ten boreholes (boreholes 5 – 14) are out-of-use and abandoned for various reasons. The four productive boreholes were able to support continuous flow of water for 1 hour. Seven of the boreholes (boreholes 5, 6, 8, 9, 11, 12 and 14) failed and were abandoned because of low yield (could not flow beyond 5 minutes), while the remaining three (boreholes 7, 10 and 13) failed and were abandoned due to wrong location and completion, caving/formation/completion problem, and wrong installation/completion respectively.

4.3 RECOMMENDATIONS

Detail and extensive geophysical studies are prerequisite for citing borehole locations. Proper completion should be ensured in areas prone to caving and other formation problems. Air drilling should be avoided in areas with thick and loose overburden, right mixture of drilling mud should be applied to secure the hole wall while flushing should be continuous throughout drilling in such formation. Casing should be done immediately and such holes should be lined and properly grouted. Timers should be installed on low yield wells and regulated/programmed for 5 minutes flow and 10 minutes recharge. The productive wells should be properly maintained and monitored for optimal performance.

4.4 CONCLUSION

The failed boreholes were partly due to low groundwater potential of the area, wrong location of some of the boreholes (boreholes 5, 6, 8, 9, 11, 12 and 14), improper installation, completion and formation problem (boreholes 13 and 10) and poor maintance culture (borehole 7). With proper maintenance and monitoring of the productive wells and reactivation of the abandoned ones, there will be improved performance from the existing wells.

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