Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol. 3, No.9, 2013

Evaluation of Groundwater Potential of Crystalline Basement Area of Kogi State Polytechnic, Osara Campus, North-Central Nigeria using Electrical Resistivity Method

[1*] O.K. Musa, [2] D.A. Ogbodo [3] S.S. Jatto [4] E.A. Kudamnya
[*1]Department of Geology, Federal University Lokoja, P.M.B 1154, Kogi State; [2] Department of Mineral Resources Engineering, Kogi State Polytechnic, Lokoja, Nigeria; [3]Centre for Atmospheric Research, (NASRDA), Abuja; [4]Department of Geology, Ahmadu Bello University Zaria
[*]E-mail of the corresponding author: Kizi.musa@gmail.com

Abstract
Hydrogeophysical study was carried out in the Basement Complex area of Kogi State Polytechnic, Osara Campus, to investigate the groundwater potential of the subsurface layers. Acute water shortage and challenges of abortive and non-functional open and closed wells has prompted this study on the development of the groundwater resources. This work involves using the electrical resistivity method to investigate concealed fractures within the area with the aim of delineating near surface/subsurface geological layers to determine the depths, thickness, structural trends and spatial distribution of basement rocks as potential sources of groundwater. A total of thirty six vertical electrical sounding (VES) using the Schlumberger configuration was employed for the study. The depth and resistivity of the subsurface layers were determined. The interpreted results of the geo electrical sections indicates the presence of four subsurface layers: top soil of thickness and resistivity values ranging from 0.2 – 5.0m and 169 – 3728 ohms meter, weathered basement ranging from 5 – 12m and 100 – 914 ohms meter, fractured basement ranging from 6.2 – 196 meters and 42 - 196 ohms meter the fresh rock bedrock ranging from infinity in thickness and 741 – 3691 ohms metres. Geo electric sections, overburden Isopach maps of the area were drawn with basement depressions and elevations, the basement depressions are the priority areas for groundwater abstraction within the study area.
Keywords: Osara, Groundwater, Electrical Resistivity, Fracture, Geoelectrical sections.

1. Introduction

The need to develop groundwater resources for potable use in Kogi State Polytechnic Lokoja, Osara Campus is highly considered as a result of population increase at the institution and the fast expansion of the institution. The Osara town where the essential for sustainable development of the groundwater resources within this area.The study area school is located depends mainly on water from the hand – dug wells of epileptic and inadequate supply during the dry season. Groundwater abstraction at only one location in the institution can no longer sustain the increased population, as villagers from the Osara town also rely on the water at the Campus for their domestic use. Attempts made to drill more wells t the Osara Campus have all failed as the wells are either epileptic or non-functional. Hence, detailed evaluation of the groundwater potential within the campus is underlain by crystalline rocks of the basement complex where aquifers are continuous, isolated and compartmentalised. These rocks in their undeformed state have little or no primary inter granular porosity and permeability and thus, ground water occurrence depends on the presence of secondary porosity and permeability by weathering and/or fracturing of the parent rocks (Acworth, 1981; Olorunfemi and Fasuyi, 1993). In the basement complex area of Nigeria, the exploitation of groundwater is highly control by the nature and the type of fracture that occurs within the basement complex. Delineation and distribution of such fractures is therefore very necessary to exploit the groundwater resources. This Delineation was possible by surface geophysical methods such as resistivity technique.

2. Site Description and Geology

The study area is located between latitudes 7^0 47’ to 7^0 51` North and longitudes 6^0 40' to 6^0 45' East (Figure 1). Kogi State Polytechnic Lokoja, Osara Campus. The study area is accessible through federal trunk a road from Abuja via Lokoja to Okene. The area is characterized by rainy and dry seasons. The rainfall starts in April and lasts until November. The rainy season on average lasts for 217 days while the dry season starts from November-March and lasts for 151 days (Walter, 1977). The vegetation is guinea savannah consisting of tall grasses and low trees and shrubs. In the wet season, this vegetation grows to become thick and impenetrable in some parts. In the dry season however, the grasses becomes dry and are burnt annually.

The study area falls within the basement complex of the south-western part of Nigeria made up of hilly plateau, dipping gently in the north-eastern and eastern directions. Southwestern Nigeria is mainly underlain by four main rock units which have been adequately studied by various workers (Rahaman, 1989) Ajibade et al., in Kogbe C.A (1980), Oladele et al., (1978). The Basement Complex rocks of Nigeria are composed predominantly of migmatite gneiss complex; slightly migmatised to unmigmatised para-schists and meta-igneous rocks; charnockitic, older granite suites and dolerite dykes (Rahaman, 1976). The Precambrian Basement rocks of Okene area, Southwestern Nigeria comprise of schists and gneisses which have been subjected to major supracrustal tectonic events such as the Dahomeyan (3000± 200Ma), Eburnean (1850 ± 250Ma), Kibaran (1000± 100Ma), and Pan-African (550± 100Ma) (Ezepue and Odigi, 1993).

4. Methodology

The Vertical Electrical Sounding is used to measure vertical variations in electrical properties beneath the earth surface with respect to a fixed Centre of the array. It is done by increasing the electrode spacing linearly about a central position whose vertical resistivity variation is sought. Resistance measurements are made at each expansion and multiplied by the respective geometric factor (K) to give the resistivity. A total of thirty six VES soundings were carried out along six profiles at a separation of 200 metres within Osara town using the ABEM tetrameters SAS 1000. A total of six soundings spaced at a station interval of 100m were taken on each profile (figure 3). A maximum current electrode spacing (AB) of 300m was used with the aim of probing a depth of at least 1/3 of AB. The VES station were marked, two current electrodes (C1 and C2) of equal distances on the opposite side of the VES station were measured and hammered into the ground. Similarly, two other electrodes (P1 and P2) of equal distances at VES point between the current electrodes were measured.

5. Results

The results of the Vertical Electrical sounding are presented in Tables 1 to 6. From the results obtained from VES stations along profiles. In Profile AA', the top soil shows average layer resistivity and thickness values ranging from 267 – 3728 ohms metres and 1.14 – 2.91m in Profile AA', 267 – 3728 ohms metres and 1.14 – 2.91m for Profile BB', 245 – 373 ohms metres and 0.37 – 1.43m for Profile CC' 238 – 604 ohms metres and 1.25 – 6.08m for Profile DD' 445 – 1596 ohms metres and 0.60 – 3.31m for Profile EE' and 196 – 352 ohms metres and 1.17 – 3.95m for Profile BB' FF.

The weathered basement ranges from 268 – 6106 ohms metres and 1.14 – 2.91metres in Profile AA', 347 – 688 ohms metres and 1.15 – 18.96metres in Profile BB', 473 – 526 ohms metres and 6.05 – 12.8metres in Profile CC', 231 – 520 ohms metres and 2.72 – 10.6metres in Profile DD', 179 – 358 ohms metres and 1.70 – 3.32metres in Profile EE', 245 – 645 ohms metres and 0.69 – 2.56metres in Profile FF'.

The fractured basement ranges from 117 – 1432 ohms meter and 11.6 – 24.2 metres in Profile AA', 117 – 268 ohms meter and 4.57 – 36.03 metres in Profile BB', 126 – 221 ohms meter and 2.02 – 26.3 metres in Profile CC', 104 – 204 ohms meter and 1.37 – 36.4 metres in Profile DD', 98 – 152 ohms meter and 6.20 – 38.9 metres in Profile EE', and 113 – 176 ohms meter and 7.53 – 17.5 metres in Profile FF metres in Profile AA', 42 – 1432 ohms meter and 11.6 – 24.2 metres in Profile AA', 42 – 1432 ohms meter and 11.6 – 24.2 metres in Profile AA'.

The Fresh bedrock ranges from 227 – 1564 for Profile AA', 1345– 1564 for Profile BB', 1251– 3691 for Profile CC', 1236– 3307 for Profile DD', 1456– 3421 for Profile EE', 1329– 2112 for Profile FF'. 1345– 1564 for Profile AA, 1345– 1564 for Profile AA, 1345– 1564 for Profile AA. The thickness values for profile AA' – FF' are at infinity.

6. Discussion

The 2D geoelectric/geologic sections along the 6 profiles are shown in Figures 3to 9. Four geo-electric/geological subsurface layers comprising the top soil, weathered layer, partly weathered/fractured basement and the fresh bedrock have been delineated. The top soil is composed of sandy clay or clayey sand with resistivity values of 180-300Fm and thickness of between 0.50-4.0 metres. With the exception of profile BB, CC and DD the entire top layer of the others are generally less than 2 metres thick. The second layer is the weathered basement with resistivity values that vary between 84-170Fm and thickness of between 0.60-25.0 metres. It indicates a high degree of saturation, suggesting that the layer corresponds to the aquiferous zone in the area. However, due to the low resistivity of some of the VES point for this layer, there is indication of possible of clay materials within the weathered basement. The third layer is the partly weathered/fractured basement with resistivity and thickness values of 200-450 Fm and 9.0-35 metres respectively. From the 2D geo electrical/geologic sections, there are indications of confine fractures within the basement especially in profile A-C. The fresh basement shows very high resistivity value, greater than 500 ohm-m indicating non porous and permeable media. This forms the bedrock rock of the entire study area.

The prominent fracture zones are restricted within a depth of 8.0 to 35.0 metres below the ground level. Since the study area shows a four layered case, the 2nd and 3rd layers are interpreted as potential ground water horizons from which a good amount of ground water can be exploited. In this case, the second layer represents weathered zone and the third layer represents partially weathered zone or fractured zone. From the geophysical investigation results obtained, it is inferred that the thickness of the aquifer varies from place to place. In most part of the study area the thickness of the aquifer materials is more than 25.0 metres. The potential aquifers are confined to weathered and fractured migmatite rocks of the basement complex of the North Central Nigeria. The geophysical investigation of the area reveals that, it has high potentiality for exploitation of ground water through different kinds of groundwater structures. However, depending on the depth to massive bedrock, suitable ground water structures may be developed. The depth to the fresh basement within the study area was between 8.0 metres to 34.0metres (figure 12). It was also observed predominantly within the study area that the depth to the fresh bedrock was generally above 16.0 metres.

The Isopach map of the weathered basement is as shown in Figure13. From the map,the thickness of the weathered basement ranges from 2 to 26m. This thickness is reliable for groundwater accumulation especially within the areas where the thickness is generally above 12 metres. Figure 14 show the isopach map of the fractured basement. It is clearly seen from the map that the thickness of the fractured basement ranges from 0 to 26 meters which are confined within to the study area. However some unconfined fractures exist. These fractures show some North-East South-West trend where there are absences of fractures. From Figure 15, it can be noticed that the depth to basement is generally greater than 16 metres except for the portion where the major road pass through. This shows that the overburden burden covering the fresh basement is thick enough to accumulate enough water for groundwater exploitation activities. Also it can be deduced that the road pavement is been sited on a solid foundation which geo technically, the road is free from most geological factors that aid road pavement failure.

7. Conclusion

This study has been able to highlight the importance of resistivity method in effective hydrogeological characterisation and groundwater exploration. The geophysical investigation carried out delineates the presence of four subsurface layers which comprised the top soil, weathered basement, fractured basement and the fresh bedrock. It can be concluded that the low resistivity and significantly thick weathered and the fractured basement constitute the aquifer in this area. Also the thickness of the weathered layers was reasonable to support continuous supply of water from any borehole within the area. However the North-West portions of the area lack sufficient fractures and the thickness of the overburden is also thin for groundwater abstraction.

Acknowledgement

The authors wish to acknowledge the school of Mining Engineering, Kogi State polytechnic Lokoja for making available the equipment used for this research.

References

Acworth, R. I. (1987): The development of crystalline basement aquifers in a tropical environment. Q. J. Eng. Geol., 20, 265–272.

Ajibade, A.C., & Woakes, M.W. (1980: Proterozoic crustal development in pan African regime of Nigeria. In: C.A. Kogbe(ed), Geology of Nigeria, 2nd revised edition, Rock view Nig. Ltd. Pp. 57 – 69.

Akpa, F.A., Ayuba, F., & Lekdukun, M.O. (2011): Preliminary assessment of corrosion and encrustation potentials of groundwater in Itakpe, North Central Nigeria. *Journal of Mining and Geology*, Vol. 47(1)2011, pp 19 -25

Ezepue, M.C., and Odigi, M.I. (1993): *Journal of mining and geology* vol. 29 (1), pp.41-50.

Olade, M.A. (1978): General features of precambrian iron ore deposit, and its environment at Itakpe ridge, Okene Nigeria. Trans. Instn. Min and Metal Sec. B, PP. 88 – 87P.B9

Olorunfemi, M.O., & Fasuyi S.A. (1993): Aquifer types and the geoelectrical/ hydrogeologic characteristics of parts of the central basement terrain of Nigeria. *Journal of African earth sciences,* 16: 309 – 317.

Rahaman, M.A. (1989): Review of the basement geology of Southwest Nigeria. *In*: Kogbe, C.A., (ed) Geology of Nigeria, Rock View (Nig.) Limited, Jos, Nigeria, pp. 39-56. Rahaman, M.A. (1976): A review of the basement geology of Southwest Nigeria. In: Kogbe, C.A., (edition) Geology of Nigeria, Elizabethan publishing, Lagos. Page 41-58.

Walter, M.W. (1977): The length of rainy season in Nigeria. *Agricultural Meterology, Volume 18*

Table 1: Summary of the Resistivity Survey along Profile AA'

Ves Station	Layer Resistivity	Thickness	Depth	Remark
1	267	1.26	1.26	Top Soil
	418	1.72	3.00	Weathered Basement
	42	11.71	14.75	Fractured Basement
	688	Infinity	Infinity	Fresh Bedrock
2	265	1.21	1.21	Top Soil
	400	1.83	3.04	Weathered Basement
	45	10.70	13.74	Fractured Basement
	788	Infinity	Infinity	Fresh Bedrock
3	3728	1.14	1.14	Lateritic Top Soil
	6106	1.03	2.18	Weathered Basement
	551	22.1	24.2	Fractured Basement
	871	Infinity	Infinity	Fresh Bedrock
4	326	1.52	1.52	Top Soil
	778	4.91	6.45	Weathered Basement
	204	15.55	21.98	Fractured Basement
	797	Infinity	Infinity	Fresh Bedrock
5	765	1.30	1.30	Top Soil
	315	3.40	4.70	Weathered Basement
	116	17.9	22.5	Fractured Basement
	477	Infinity	Infinity	Fresh Bedrock
6	1126	2.91	2.91	Top Soil
	268	2.80	5.79	Weathered Basement
	1432	5.97	11.76	Fracturd Basement
	227	Infinity	Infinity	Frsh Bedrock

Table 2: Summary of Resistivity Survey along Profile BB'

VES Station	Layer Resistivity	Thickness	Depth	Remark
1	8178	1.88	1.88	Lateritic Top Soil
	398	8.96	10.84	Weathered Basement
	276	36.03	46.88	Fractured Basement
	1453	Infinity	Infinity	Fresh Bedrock
2	2207	1.61	1.61	Lateritic Top Soil
	415	1.69	3.30	Weathered Basement
	117	4.57	7.87	Fractured Basement
	1564	Infinity	Infinity	Fresh Bedrock
3	2135	3.32	3.32	Lateritic Top Soil
	401	6.78	10.31	Weathered Basement
	268	25.06	28.88	Fractured Basement
	1467	Infinity	Infinity	Fresh Bedrock
4	337	1.06	1.06	Top Soil
	688	1.15	2.21	Weathered Basement
	136	17.1	19.3	Fractured Basement
	1345	Infinity	Infinity	Fresh Bedrock
5	439	1.22	1.22	Top Soil
	347	2.09	3.30	Weathered Basement
	196	6.70	10.0	Fractured Basement
	1432	Infinity	Infinity	Fresh Bedrock
6	160	2.76	2.76	Top Soil
	473	8.2	10.94	Weathered Basement
	125	11.5	21.02	Fractured Basement
	1432	Infinity	Infinity	Fresh Bedrock

Table 3: Summary of Resistivity Survey along Profile CC'

VES Station	Layer Resistivity	Thickness	Depth	Remark
1	245	1.25	1.25	Top Soil
	196	6.05	7.31	Weathered Basement
	126	26.3	33.6	Fractured Basement
	1615	Infinity	Infinity	Fresh Bedrock
2	276	1.06	1.06	Top Soil
	522	12.8	13.9	Weathered Basement
	251	11.0	24.9	Fractured Basement
	1597	Infinity	Infinity	Fresh Basement
3	286	0.37	0.37	Top Soil
	162	5.1	5.48	Fractured Basement
	3691	Infinity	Infinity	Fresh Bedrock
4	199	6.58	6.58	Top Soil
	2935	Infinity	Infinity	Fresh Bedrock
5	245	1.24	1.24	Top Soil
	190	2.02	3.26	Fractured Basement
	1376	Infinity	Infinity	Fresh Bedrock
6	373	1.43	1.43	Top Soil
	473	6.8	8.23	Weathered Basement
	221	17.0	25.3	Fractured Basement
	1251	Infinity	Infinity	Fresh Bedrock

Table 4: Summary of Resistivity Survey along Profile DD'

VES Station	Layer Resistivity	Thickness	Depth	Remark
1	238	1.25	1.25	Top Soil
	520	10.6	11.80	Weathered Basement
	1520	Infinity	Infinity	Fresh Bedrock
2	261	6.08	6.08	Top Soil
	3307	Infinity	Infinity	Fresh Bedrock
3	272	1.87	1.87	Top Soil
	228	2.72	4.60	Weathered Basement
	1362	Infinity	Infinity	Fresh Bedrock
4	395	1.26	1.26	Top Soil
	114	1.37	2.62	Fractured Basement
	1287	Infinity	Infinity	Fresh Bedrock
5	604	1.35	1.35	Top Soil
	231	6.17	7.51	Weathered Basement
	204	36.4	43.9	Fractured Basement
	1236	Infinity	Infinity	Fresh Bedrock
6	575	1.59	1.59	Top Soil
	105	4.62	6.21	Fractured Basement
	1564	Infinity	Infinity	Fresh Bedrock

Table 5: Summary of Resistivity Survey along Profile EE'

VES Station	Layer Resistivity	Thickness	Depth	Remark
1				
	1251	*0.60*	1.64	Top Soil
	358	*2.5*	4.14	Weathered Basement
	152	*17.1*	27.2	Fractured Basement
	1497	Infinity	Infinity	Fresh Bedrock
2	1596	*1.63*	1.63	Top Soil
	179	2.03	3.66	Weathered Basement
	100	7.77	11.4	Fractured Basement
	3217	Infinity	Infinity	Fresh Bedrock
3	1299	*3.31*	3.31	Top Soil
	280	*3.32*	6.02	Weathered Basement
	120	*12.83*	16.15	Fractured Basement
	1456	*Infinity*	Infinity	Fresh Bedrock
4	680	1.40	1.40	Top Soil
	214	2.50	3.90	Weathered Basement
	98	38.9	42.8	Fractured Basement
	3421	Infinity	Infinity	Fresh Bedrock
5	1241	1.59	1.59	Top Soil
	116	6.20	7.79	Fractured Basement
	1867	Infinity	Infinity	Fresh Bedrock
6	445	1.14	1.14	Top Soil
	287	1.70	2.85	Weathered Basement
	123	6.35	11.20	Fractured Basement
	1988	Infinity	Infinity	Fresh Bedrock

Table 6: Summary of Resistivity Survey along Profile FF'

VES Station	Layer Resistivity	Thickness	Depth	Remark
1	280	1.17	1.17	Top Soil
	648	2.56	3.73	Weathered Basement
	141	7.53	11.3	Farctured Basement
	1889	Infinity	Infinity	Fresh Bedrock
2	286	1.34	1.34	Top Soil
	423	1.16	2.5	Weathered Basement
	176	8.68	11.2	Fractured Basement
	1475	Infinity	Infinity	Fresh Bedrock
3	196	1.33	1.33	Top Soil
	245	0.78	2.11	Weathered Basement
	152	10.2	12.3	Fractured Basemnt
	1960	Infinity	Infinity	Fresh Bedrock
4	557	2.64	2.64	Top Soil
	1410	Infinity	Infinity	Fresh Bedrock
5	280	3.95	3.95	Top Soil
	169	17.5	21.4	Fractured Basement
	2112	Infinity	Infinity	Fresh Bedrock
6	352	1.23	1.23	Top Soil
	429	0.69	1.93	Weathered Basement
	113	9.69	11.6	Fractured Basement
	1329	Infinity	Infinity	Fresh Bedrock

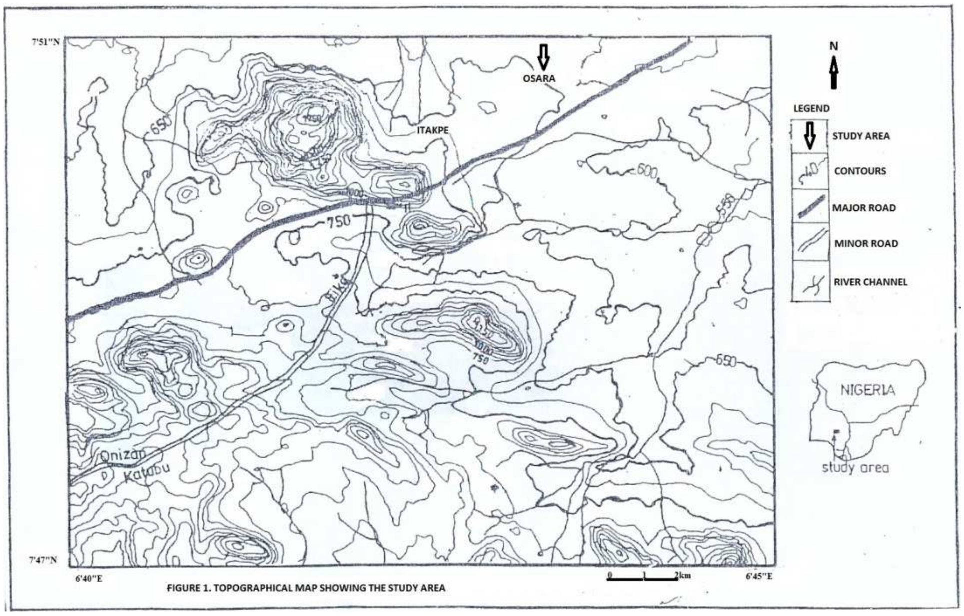


FIGURE 1. TOPOGRAPHICAL MAP SHOWING THE STUDY AREA

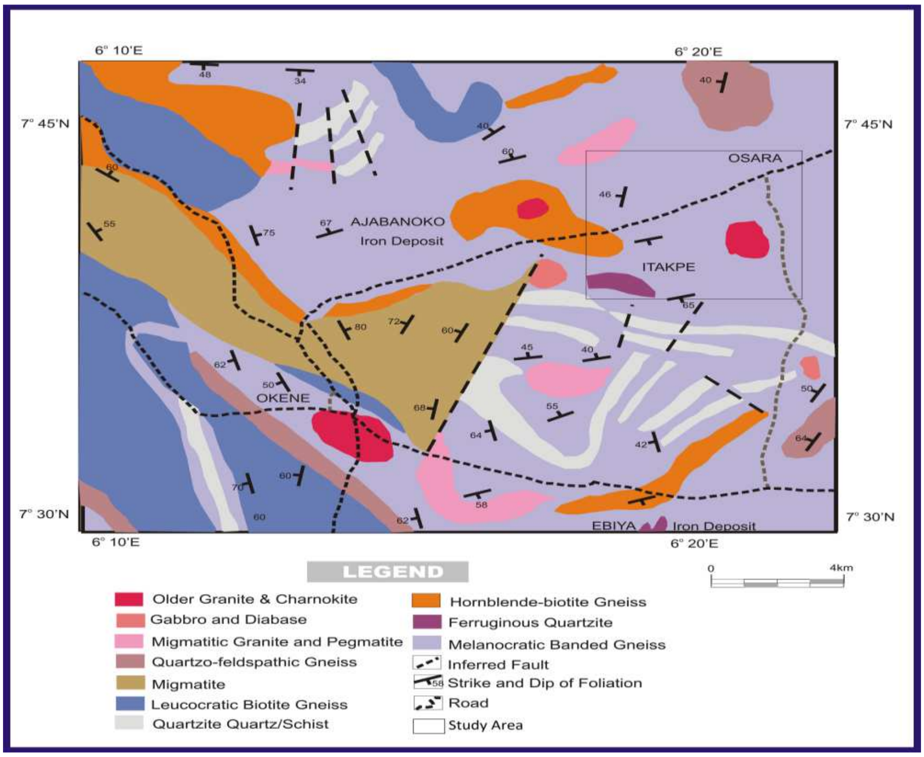


Figure 2: Geological Map of the Okene Area (after Akpa *et al*, 2011)

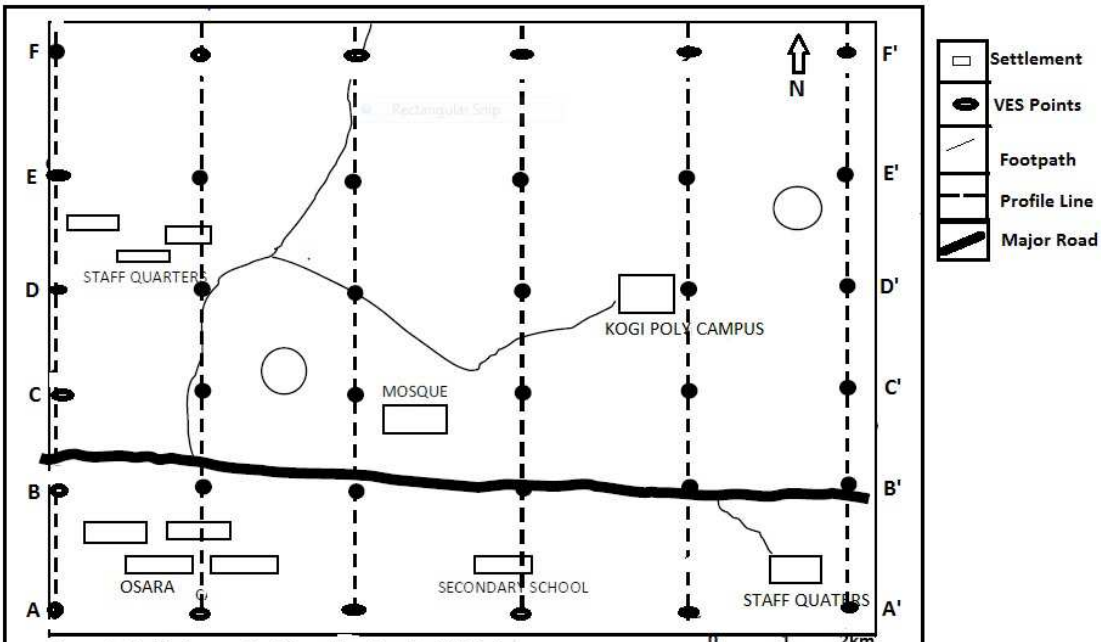
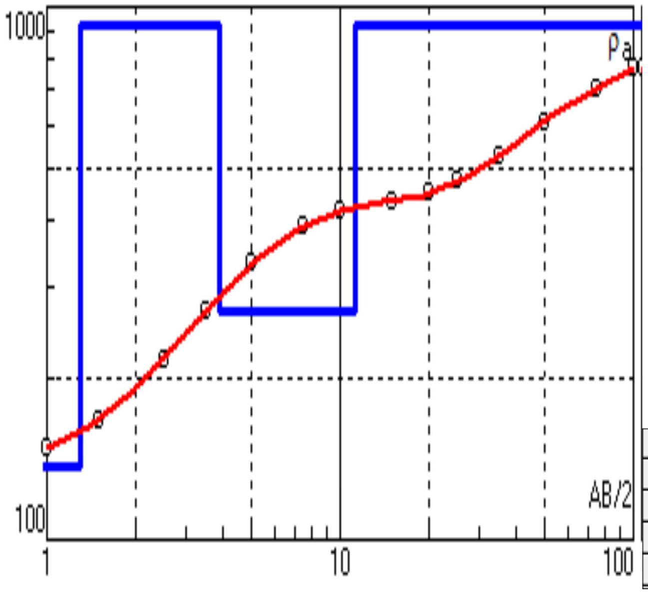
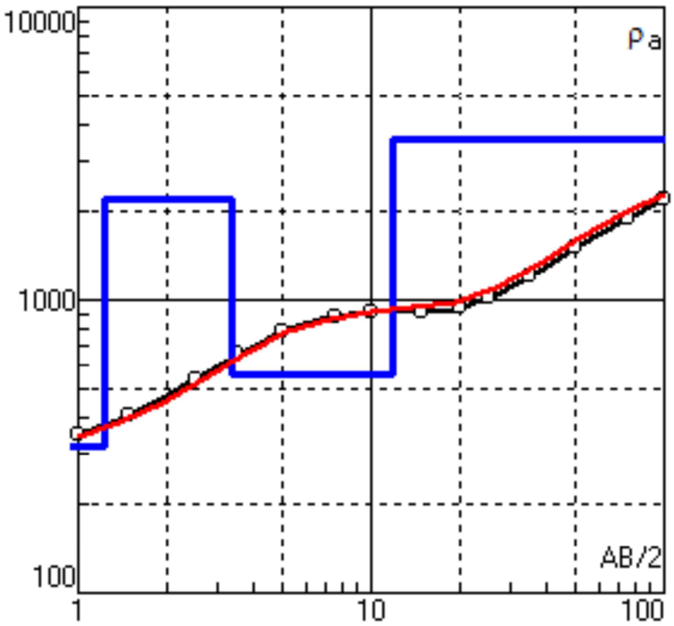


Figure 3. Profile Layout Positions Showing the VES Points



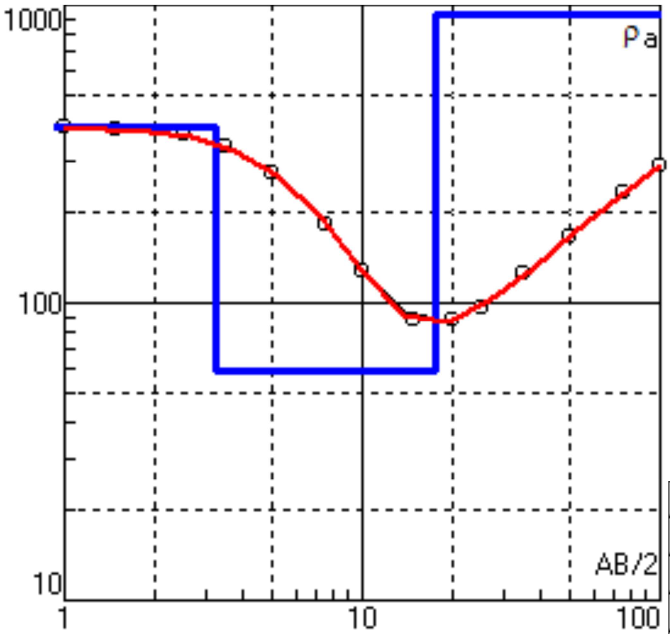
N	ρ	h	d
1	137	1.3	1.3
2	924	2.6	3.9
3	266	7.4	11.3
4	924		

Figure 3: Example of sounding Curve Obtained



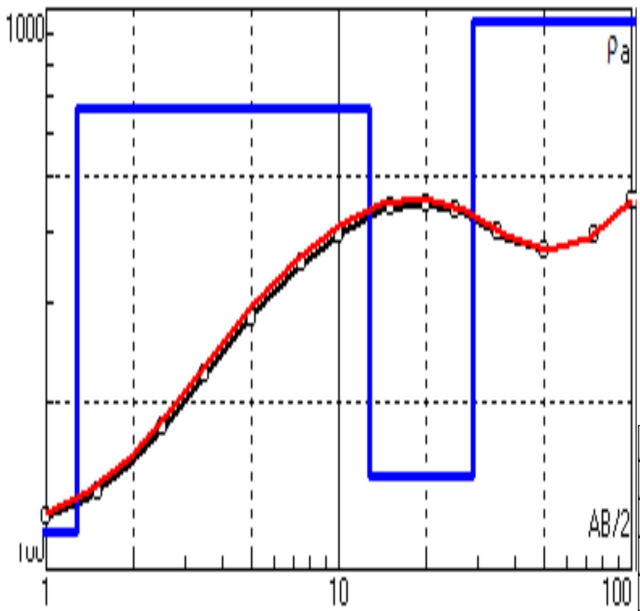
N	ρ	h	d
1	316	1.2	1.2
2	2209	2.1	3.3
3	559	8.5	11.8
4	3542		

Figure 4: Example of sounding Curve Obtained



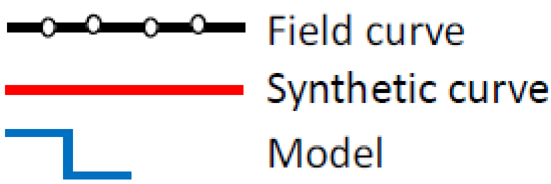
N	ρ	h	d
1	389	3.2	3.2
2	59	14.4	17.6
3	927		

Figure 5: Example of sounding Curve Obtained



N	ρ	h	d
1	116	1.3	1.3
2	665	11.5	12.8
3	145	16.1	28.9
4	950		

Figure 6: Example of sounding Curve Obtained



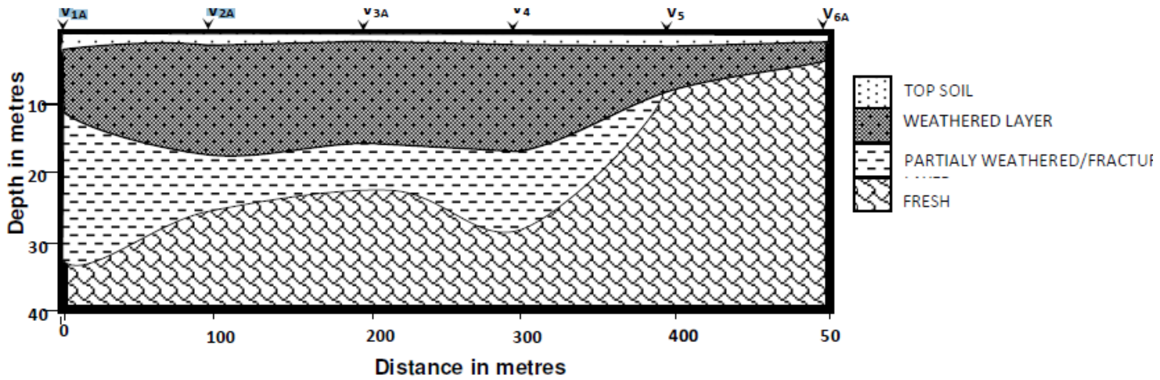


Figure 7 Geo electric/Geologic Sections along Profile AA'

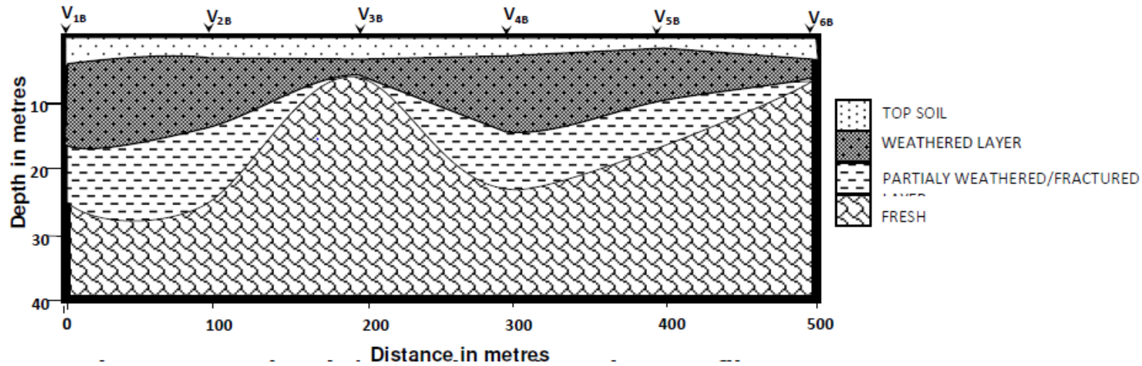


Figure 8 Geo electric/Geologic Sections along Profile BB'

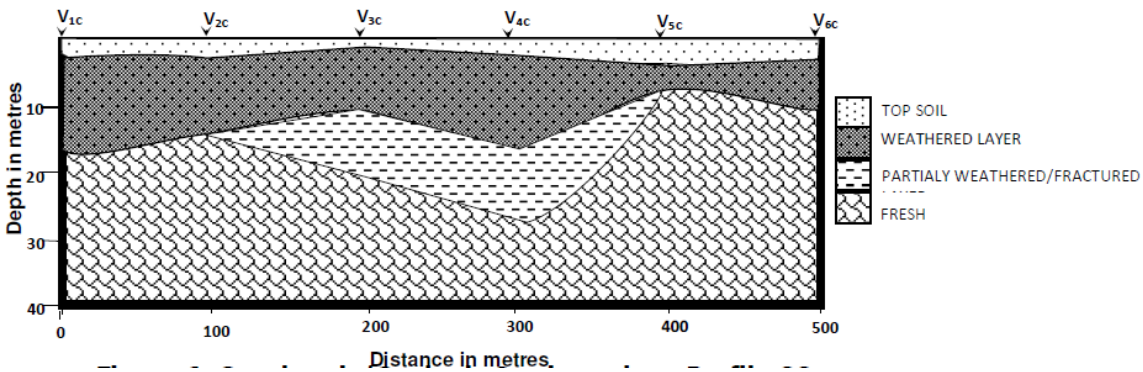


Figure 9 Geo electric/Geologic Sections along

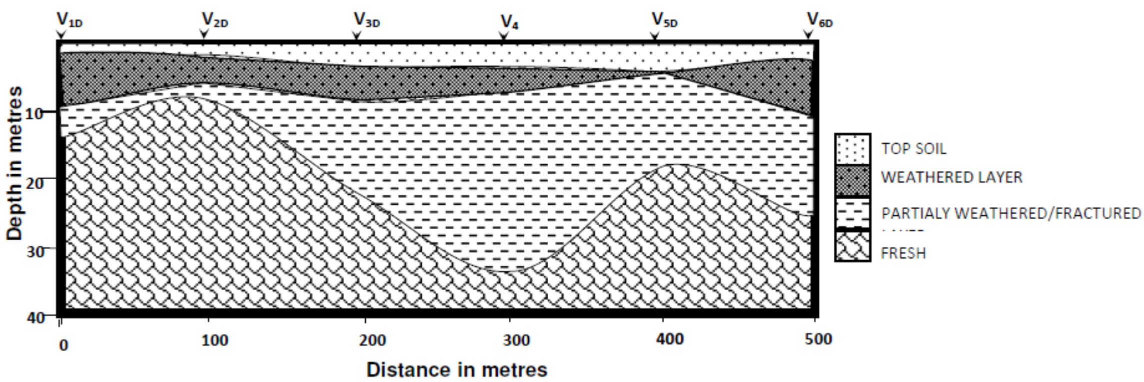


Figure 10 Geo electric/Geologic Sections along Profile DD'

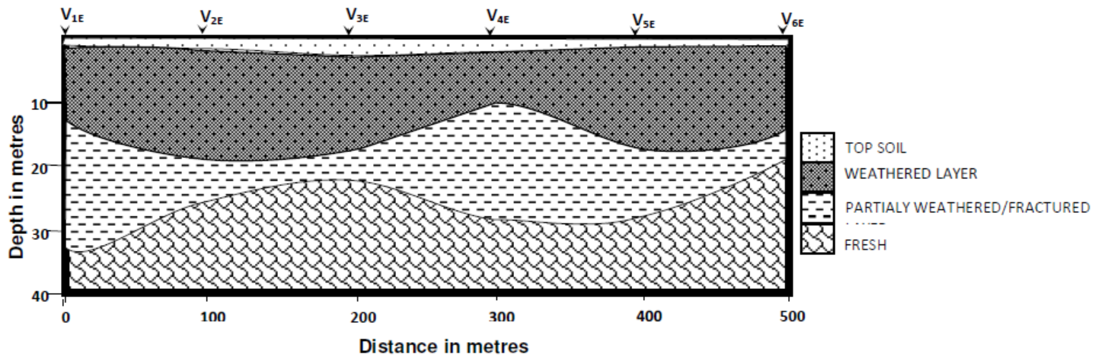


Figure 11 Geo electric/Geologic Sections along Profile EE'

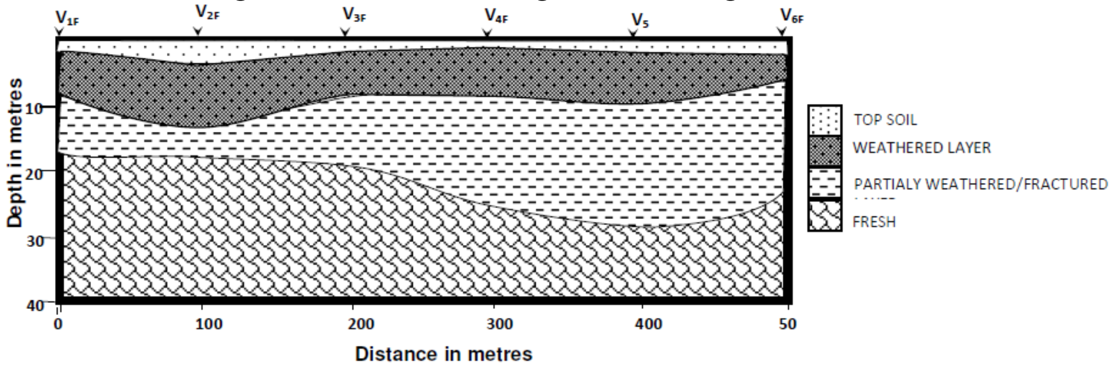


Figure 12 Geo electric/Geologic Sections along Profile FF'

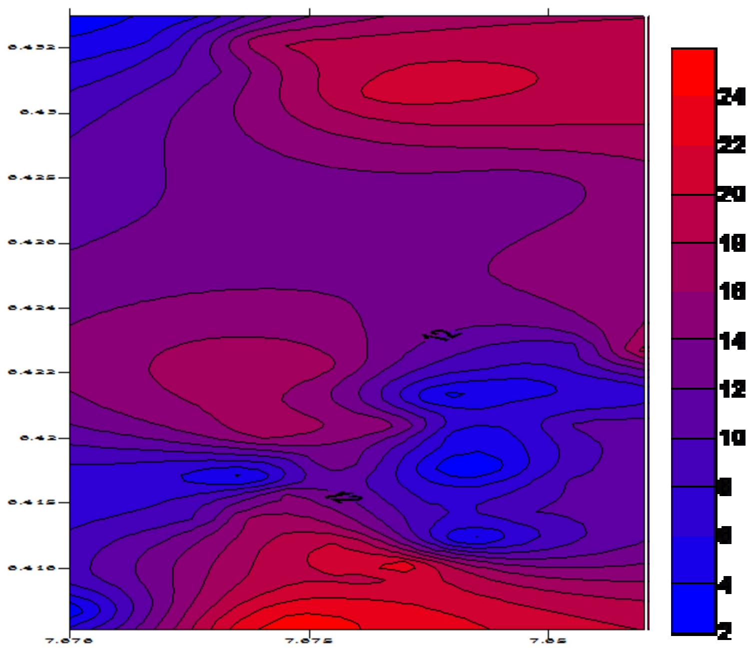


Figure 13: Thickness of the Weathered Basement

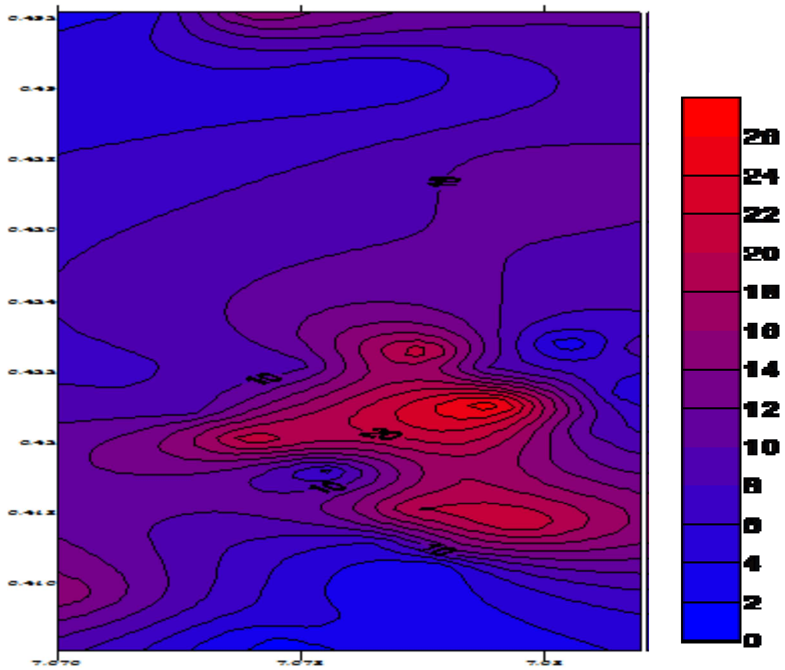


Figure 14: Thickness of the Weathered Basement

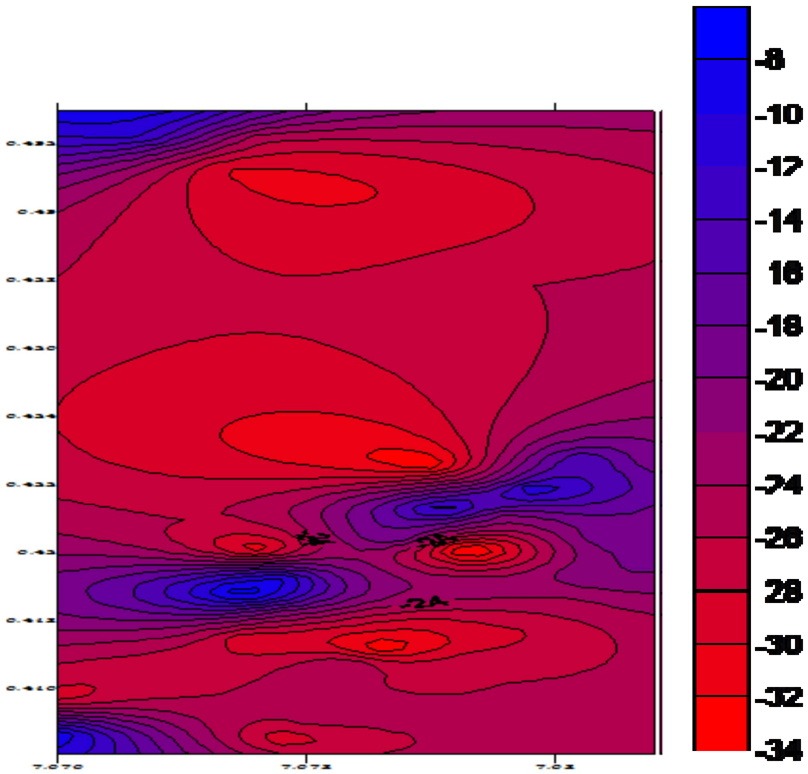


Figure 15: Thickness of the Weathered Basement