

A Geophysical Approach to Site Characterization for Construction and Related Purposes; Case Study of ABUAD Teaching and Research Farm, Ado - Ekiti, Southwest Nigeria.

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Abstract
Geophysical survey involving the VLF Electromagnetic and the Electrical resistivity methods using the Schlumbeger Electrode Configuration have been carried out at the Afe Babalola University Teaching and Research Farm, Ado Ekiti. The interpretation and modelling of the reconnaissance VLF –EM data acquired along 17 West- East Traverses had earlier been used in an earlier study in the area to delimit the farm area into 29 VES stations from where detailed study using the electrical resistivity method were carried out. The results from the 2-D interpretation of the VES data were used to prepare the geoelectric sections along five cross sections AA^{I}, BB^{I}, CC^{I}, DD^{I} and EE^{I} so as to reveal the subsurface lithologic successions vis-à-vis their geoelectric characteristics. The resistivity curve types obtained include the H-,KH-, HA-, KHA-, A-, K-, QH-, and the HKH-types in decreasing order of frequencies. The preponderance of H-and its' combination type- curves is indicative of the dominance of the weathered layer lithology, and as anticipated in the study area, being a basement complex environment. The general lithological sequence include the topsoil, lateritic clay, sandy clay, weathered basement and fresh basement. From these, it was revealed that section DD ^{I} has the thinnest sequence of loose overburden materials spread over the longest lateral distance and is considered most favourable and suitable for siting heavy engineering infrastructures,such as agricultural products processing plants and industries, this is because the fresh basement is at the shallowest depth here, thus requiring the least excavatory work. This is followed in order of merit by sections CC^{I}, BB^{I}, EE^{I} with the least being AA^{I} , in addition, siting of waste dump and incinerating plant will be best here because the least concrete blinding will be required for the thinnest weathered sequence for the prevention of leachate infiltration in the prevention of pollution to the groundwater aquifer in the farm . In addition, further studies involving cone penetrometer and or auger boring tests is recommended to be carried out to confirm the detailed competence levels of the rocks along the specified section as necessarily required.
Keywords: VLF-Electromagnetic, Type-curves, Fresh Basement, Geoelectric characteristics, cross-section

1. Introduction

Electrical resistivity surveys have been used for many decades in hydrogeological, mining and geotechnical investigations. It is routinely used in engineering and hydrogeological investigations to investigate the shallow subsurface geology (Kearey and Brookes, 1996). Electrical resistivity survey is based on the response of the earth to the flow of electrical current. Artificially generated electric currents are introduced into the ground and the resulting potential differences are measured at the surface (Telford et al., 1990; Lowrie 2007). All materials, including soil and rocks, have an intrinsic property- resistivity that governs the relation between the current density and the gradient of the electrical potential. In general, the main principle in any geophysical explorations is to non-intrusively gather data on the area of interest (Scollar et al., 1990). A building constructed at a site without properly considering the underground strata or its load-bearing capacity may settle excessively or differentially, causing development of cracks in the building which may ultimately lead to its failure and collapse. subsurface geological features such as fractures, voids, and nearness of water table to the surface are among the inconveniences that pose considerable constraints to building constructions especially to their foundations (Andrews et al., 2013). Geophysical investigation was carried out at the Teaching and Research Farm of the Afe Babalola University, Ado Ekiti to determine the geophysical parameters that can be used to appraise the structural competence of the subsurface geological strata as a means of characterising the farm area for construction purposes and building development. Though there are existing structures on the site, however, there is need for the development of new structures to meet the rapid developmental growth of the Agricultural Faculty programmes of the institution,especially in the areas of extension and engineering, research, crop production and allied objectives. In view of this, a pre-construction investigation was carried out for evaluation of the farm area as a primary tool for further geotechnical site investigation.

2.1 Site Location And Geology

Afe Babalola University Teaching and Research farm is located in the western part of the main campus of the University which itself is situated in the along Federal Polytechnic- Ikare road in Ado-Ekiti .The farm could be found within latitudes 7^0 36′ 53’’N and 7^0 37’ 12’’ N and longitudes 5^0 17′ 45’’ E and 5^0 18’ 10’’E, and it is situated on a vast area of low-land cultivated in part and comprising of several agricultural plants like mango, gmelina and teak trees, palm trees, a fish pond and other ancilliary infrastructures. A fairly thick overburden covers the area with varying thicknesses. Underlying the overburden are crystalline rocks consisting of granitic rock, which is equally exposed along the course of the river that flows across the area (Rahaman,1988; Ajibade and Umeji 1989). The geologic setting of the area is typical of the migmatite gneiss complex rocks of the Precambrian Basement Complex of southwestern Nigeria (Rahaman, 1988), comprising of undifferentiated granite, charnockitic rocks, medium to coarse granite and migmatite gneiss rocks (Fig. 1). The River Ogbese which is situated at the southern part of the farm and which flows eastward in the area constitute the major drainage network as well as the veritable source of recharge in the area. The topography of the area is of relatively flat to a gently sloping terrain while the vegetation in the area is of rainforest type, characterized by short dry season and long wet season, with high annual rainfall of about 1,300 mm. Annual mean temperature is between 180 C and 330 C with relatively high humidity (NIMET, 2007).

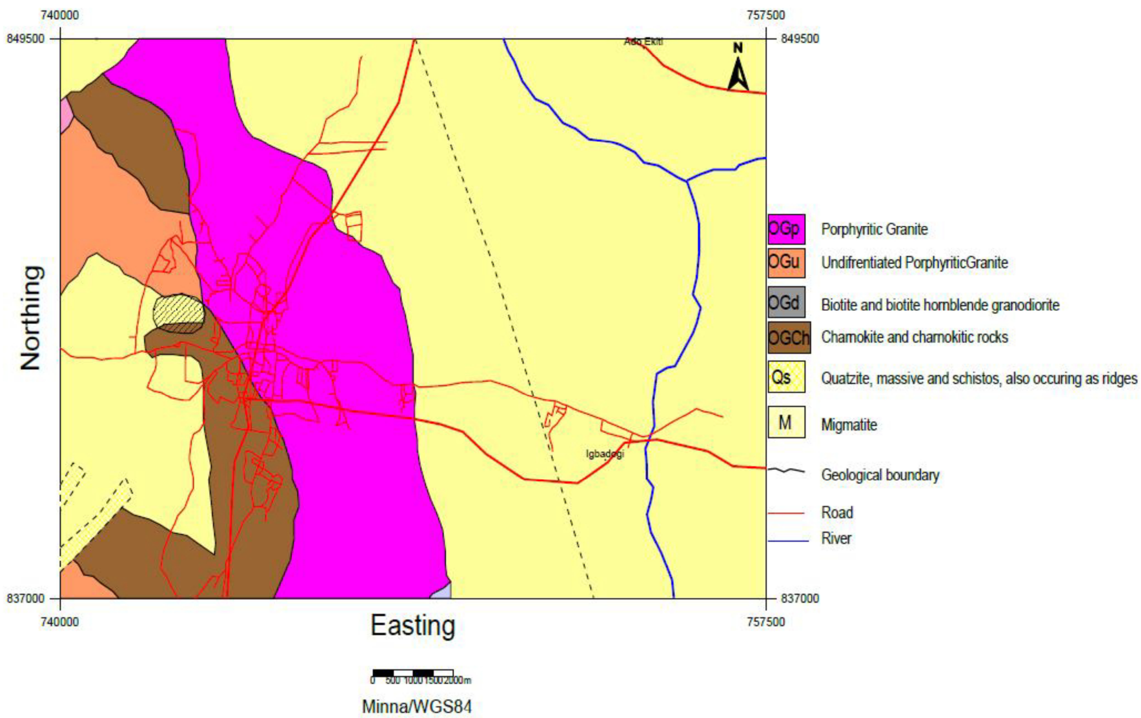


Fig.1: A section of the migmatite gneiss complex rocks of the Precambrian Basement Complex of southwestern Nigeria (curled from Minna WGS84)

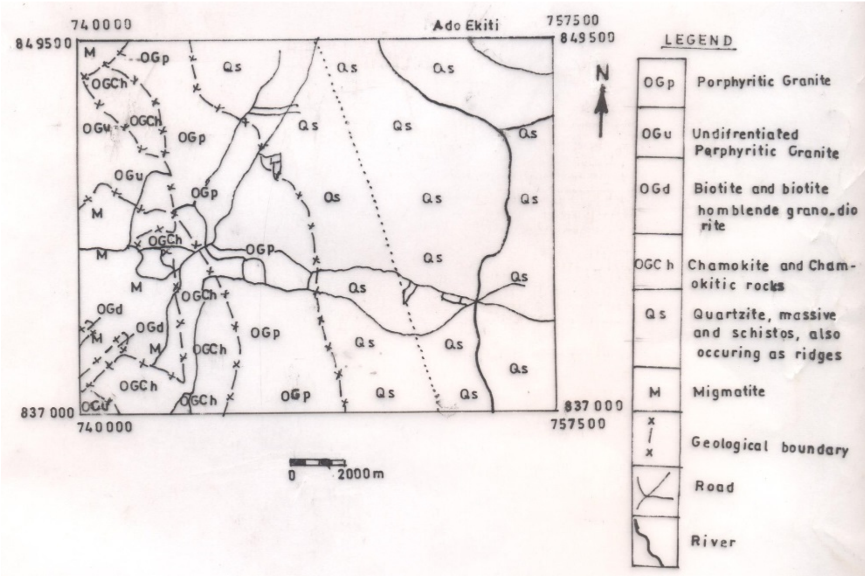


Fig.2:Geological map of Ado Ekiti (curled from geological map of Sheet 56)

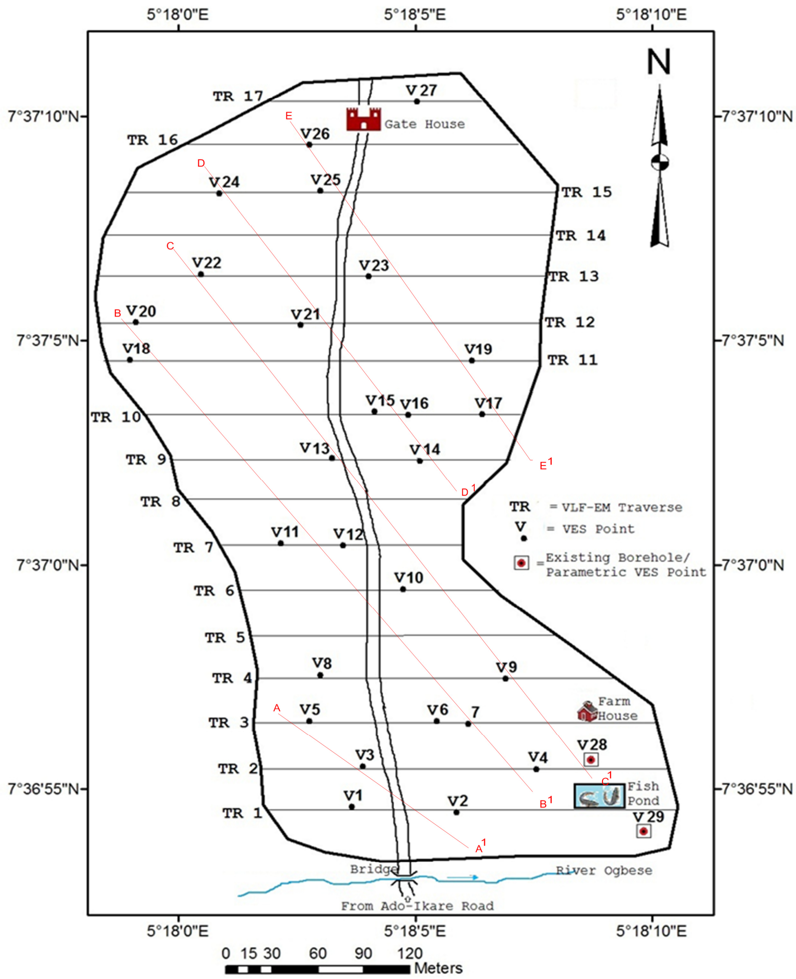


Figure 3; Base Map of the study area showing VLF Traverses , VES points and Cross-Sections

3.0 Materials And Methods

This study adopts the initial approach and results from the earlier work of Ademilua et al (2014) . The 17 West- East VLF-Electromagnetic Traverses spaced at 5m interval established for the previous work were adopted for the current study and the modeling and interpretation results from these were used to delimit the farm area into 29 points from where Vertical Electrical Soundings were carried out for further detailed study using the Schlumberger electrode array (Fig.3). The equipments used include the ABEM SAS-300B terrameter, four electrodes, measuring tape and hammers. The Schlumberger electrode configuration with maximum electrode spacing (AB/2) of 75m was used. The potential electrodes remained fixed and the current electrodes were expanded simultaneously about the center of the spread. When the distance between the current electrodes was large, the distance between the potential electrodes was increased to have a measurable potential difference. The location of each sounding station was recorded in Universal Traverse Mercator (UTM) coordinates with the aid of a GARMIN personal navigator (GPS) unit. The soundings were performed parallel to the traverse lines and the apparent resistivity values were calculated. The data derived from VES measurements were processed using IPI2 WIN software. The VES results were used to prepare 2-D geo-electric sections AA^I, BB^1, CC^1, DD^1 and EE^1 taken along NW – SE direction of the survey area to reveal the subsurface lithological succession and their structural disposition in the arae.

4.0 Results And Discussion

Table 1 shows the layer thicknesses and their corresponding resistivity values obtained from VES curves (Fig.4). The VES results were used to prepare 2-D geo-electric sections taken along NW – SE direction of the survey area to reveal the subsurface lithology of the area.

4.1 General Characteristic of the VES curves

Eight curve types were identified in the area of investigation. The H curve occurred most in the area, accounting for about 34% of the total curves, followed by KH curve with about 31% degree of occurrence; A, K, QH and HKH constitute about 3% each while AH and KHA constitute about 13% and 6% respectively (Table 2). The histogram of the frequency of the curve types is illustrated in Figure 5. These curves establish the fact that the surveyed area is a typical basement terrain. The steeply rising segment of the curves at large electrode separations is indicative of fresh bedrock (Olayinka, 1990).

4.2 Geoelectric and Lithological Characteristic

The VES results were used to prepare 2-D geo-electric sections (Figs. 6a-e) which were along the cross-section lines AA^1, BB^1, CC^1, DD^1 and EE^1. The sections revealed the geo-electric/geologic characteristics of the subsurface layers. The top soil, lateritic clay, sandy clay, weathered / fractured basement and the fresh basement constitute the five layer configuration. The four layer configuration consists of the top soil, sandy clay, weathered / fractured basement and the fresh basement, while the three layer configuration comprises of the lateritic topsoil, sandy clay/weathered basement and the fresh basement. The resistivity of the topsoil ranges from 51.8Ωm to 1110Ωm and its thickness between 0.5m and 3.62m. It is made up of variably loose to compact coarse grained sand. The top soil is underlain by lateritic clay / sandy clay with resistivity values ranging from 18Ωm to 16915Ωm and thickness ranging from 0.47m to 3.62m. The weathered layer/fractured basement which is the layer overlying the fresh basement has resistivity values ranging from 15.6Ωm to 422Ωm with thicknesses between 1.99m and 27.7m. The bedrock resistivity ranges from 728Ωm to 99210Ωm.

4.3 Geoelectric section along AA^1

This geoelectric section comprises of VES positions 5, 3, 1 and 2 (Fig.6a). The first layer constitutes the topsoil with layer resistivity values ranging from 66.2Ωm to 516Ωm. The layer thickness ranges from 0.6m to 1.2m. The second layer varied in composition for the four VES stations. While VES 3 and VES 1 have clayey materials with resistivity values of 41.9Ωm and 18Ωm respectively as their second layer with average thickness of 2.3m, a more resistive lateritic hard pan of resistivity value 2122Ωm form the second layer in VES station 1. It has a thickness of about 2m. Directly beneath the topsoil at VES 5 is a weathered lateritic material of resistivity value 297Ωm and thickness 6.1m. Weathered basement with resistivity values ranging from 308Ωm to 422Ωm and thickness ranging from 6.5m to 29m form the third layer in VES 3, 1 and 2. In these points, the fourth layer is fresh basement with average resistivity value of 46576Ωm while it corresponds to the third layer in VES 5. Construction of high building along this area without excavation of clayey materials and introduction of piling for the structure to rest directly on the competent bed may lead to differential settlement of the building which may cause some major cracks on the building.

4.4 Geoelectric section along BB[1]

This section encompasses VES 4, 7, 11, 18 and 20 with the highest number of layers attributed to VES 11 which has 5 different geoelectric layers (Fig. 6b). The resistivity of the top soil ranges from 75.4Ωm to 1110Ωm and its thickness varies from 0.5m to 1.5m. Sandy soil extend from VES 11 to VES 18 as second layer with resistivity values of 522Ωm and 855Ωm respectively having average layer thickness of about 3m. Weathered layer form the second layer for VES 4, 7 and 20 but third layer for VES 11 and 18 with resistivity values ranging from 51.4Ωm to 104Ωm and thickness ranging from 4.7m to 10.4m. The weathered layer in VES 11 was underlain by fractured basement which extended to a depth of 21m beneath the weathered layer. The last geoelectric layer beneath these VES points constitutes the fresh bedrock with resistivity ranging from 2419Ωm to 99210Ωm. The geoelectric section revealed that fresh bedrock is close to the surface at VES 4, 7 and 20. Heavy structures like farm-based industrial machineries can be sited at this area without much threat to their foundation well being.

4.5 Geoelectric section along CC[1]

The geoelectric section along CC[1] cuts across five VES stations (Fig. 6c). The top soil has resistivity values that vary from 51.8Ωm to 1027Ωm. The thickness of this layer varies from 1.1m to 1.8m. Lateritic clay forms the second layer in VES 10 and 28 with average resistivity of 310Ωm and average thickness of 1.6m. Clay with resistivity value of 44.7Ωm and thickness 4m is found directly below the top soil in VES 22. Underlying this layer is the relatively thick weathered basement of resistivity 349Ωm. It extends to a depth of 31m from the base of the second layer. This weathered layer forms second layer in VES 13 and VES 9. It forms fourth and third layer in VES 10 and VES 28 respectively. Considering the significant thickness and the occurrence at shallow depth to the surface of weathered layer between VES 22 and VES 9 along the section, the area may not be able to support heavy structures, alternatively a groundwater abstraction facility e.g. a borehole may be suitably sited around the area to harness its ground water potential.

4.6 Geoelectric section along DD[1]

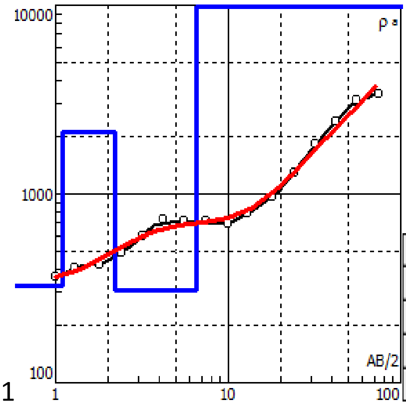
Five VES stations, VES 24, 21, 15, 16 and 14, arranged in this order, are along this section DD[1] (fig. 6d). The resistivity of topsoil varies from 198Ωm to 327Ωm.while its thickness varies from 0.5m to 1.9m. Relatively resistive sandy soil underlay the topsoil from VES 21 to VES 14 along the section. It has resistivity values that vary from 660Ωm to 1445Ωm. Its thickness varies from 1.1m to 1.9m. Weathered layer forms second layer in VES 24 and extend from VES 21 to VES 14 as third layer with resistivity ranging from 17.3Ωm to 37.2Ωm and thickness ranging from 3.3m to 7.5m. Fractured basement with resistivity value 188Ωm and thickness 14.9m underlay the weathered layer in VES 16. Sandy clay layer is usually a competent geo-material for engineering structures foundation supports, particularly when the sand aggregates are coarse enough to absorb and bind the clay material together in the presence of water. Owing to the presence of sandy material near the surface along this section, shallow foundation may be feasible in the area. This section DD [I] has the thinnest sequence of loose overburden materials spread over the longest lateral distance is most favourable and suitable for siting heavy engineering infrastructures,such as agricultural products processing plants and industries, this is because the fresh basement is at the shallowest depth here, thus requiring the least excavatory work. In addition, siting of waste dump and incinerating plant will be best here because the least concrete blinding will be required for the weathered sequence for the prevention of leachate infiltration into the groundwater aquifer systems beneath the farm . Here, a shallow foundation may be feasible in this section because the clay material and weathered layers are fairly thin along the section as well being close to the surface. Construction of heavy engineering structures like agricultural processing industry being anticipated for the farm could be sited at the topmost Northern parts along this section after confirmatory engineering competence tests involving the cone penetrometer and the auger boring ((Falae (2014); Oyedele and Ekpaette (2011)).

4.7 Geoelectric section along EE[1]

Five different VES stations make up this geoelectric section which includes: VES 17, 19, 23, 25 and 26 (Fig. 6e). The maximum number of geoelectric layers delineated at VES 26 is four while three geoelectric layers are delineated beneath each of the remaining four VES stations . The lithologies delineated are topsoil, clay, weathered basement and fresh basement. Topsoil has thicknesses ranging from 1.3m to 2.2m with corresponding resistivities from 160Ωm to 453Ωm. Clay with resistivity of 22.9Ωm and thickness of 2m forms the intermediate layer between the topsoil
and weathered basement in VES 26. Weathered layer constitute the second layer in VES 17, 19, 23 and 25, however it extends to VES 26 as the third layer. This layer has resistivity that varies from 30.1Ωm to 88.5Ωm and thickness which varies from 5m to 11.7m. The last geoelectric layer beneath these VES points constitutes the fresh bedrock with resistivity ranging from 1083Ωm to 65405Ωm. The near surface materials constituting the weathered layer are known to be incompetent for the base functions of heavy engineering structure siting ((Gang (2007) ; Adegbola et al (2010)). In view of these incompetence, deep foundation in which piles carry super-structural loads to competent rock at 12m depth is recommended for this site.

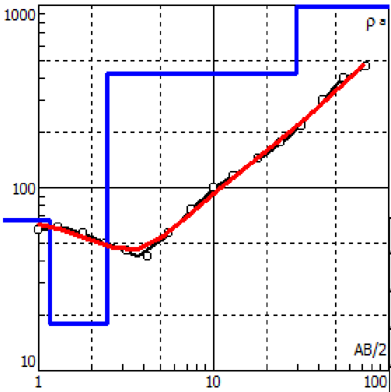
5.0 Conclusion And Recommendations

Geophysical survey involving the VLF Electromagnetic and the Electrical resistivity methods have been carried out in the study area, the interpretation and modeling of the reconnaissance VLF –EM data acquired along 17 West- East Traverses had been used to delimit the study area into 29 VES stations from where detailed study using the electrical resistivity method were carried out. The results from the interpretation of the VES station were used to prepare the geoelectric sections along five cross sections AA^I, BB^I, CC^I, DD^I and EE^I so as to reveal the subsurface lithologic successions vis-à-vis their geoelectric characteristics. The resistivity curve types obtained include the H-,KH-, HA-, KHA-, A-, K-, QH-, and the HKH-types in decreasing order of frequencies. The preponderance of H- and its' combination type- curves is indicative of the dominance of the weathered layer lithology, and as anticipated in the study area, being a basement complex environment. The general lithological sequence include the topsoil, lateritic clay, sandy clay, weathered basement and fresh basement. From these, it was revealed that section DD ^{I} has the thinnest sequence of loose overburden materials spread over the longest lateral distance is most favourable and suitable for siting heavy engineering infrastructures,such as agricultural products processing plants and industries, this is because the fresh basement is at the shallowest depth here, thus requiring the least excavatory work. This is followed in order of merit by sections CC^I, BB^I, EE^I with the least being AA^I , in addition, siting of waste dump and incinerating plant will be best here because the least concrete blinding will be required for the thinnest weathered sequence for the prevention of leachate infiltration in the prevention of pollution to the groundwater aquifer in the farm . Generally, shallow foundation may not be feasible in this area because of the presence of clay material and weathered layer that could be said to be on the average, close to the surface. Construction of simple structure may be appropriate in the study area due to relatively low thickness of sandy layer. Therefore, in order to construct a super or giant structure in the study area, the area along section DD1 should be considered first while further study involving cone and or auger penetrometer tests should be carried out to determine the detailed competence levels of the rocks as necessarily required.



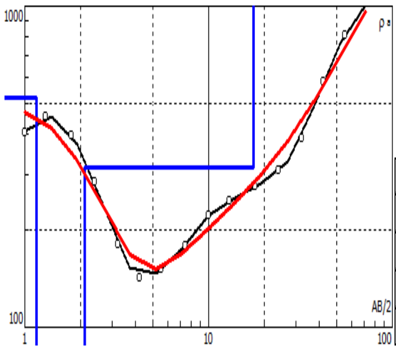
VES 1

N	1	2	3	4
ρ	328	2122	308	45018
h	1.1	1.11	4.32	
d	1.1	2.21	6.53	
Alt	-1.104	-2.211	-6.535	



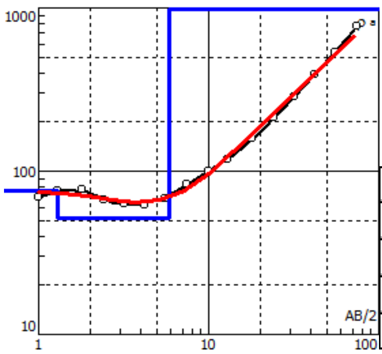
VES 2

N	1	2	3	4
ρ	66.2	18	422	47355
h	1.17	1.28	27.2	
d	1.17	2.45	29.7	
Alt	-1.169	-2.454	-29.68	



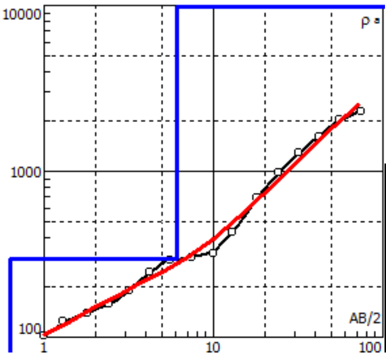
VES 3

N	1	2	3	4
ρ	516	41.9	314	146830
h	1.16	0.962	15.5	
d	1.16	2.12	17.6	
Alt	-1.156	-2.118	-17.61	



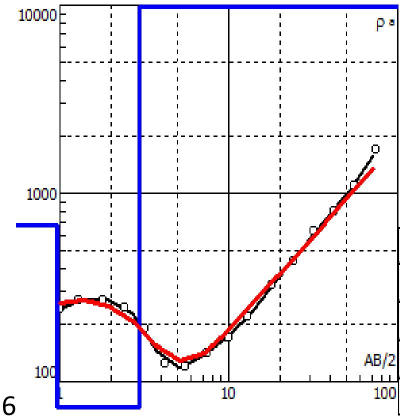
VES 4

N	1	2	3
ρ	75.4	51.4	27818
h	1.3	4.55	
d	1.3	5.86	
Alt	-1.301	-5.855	



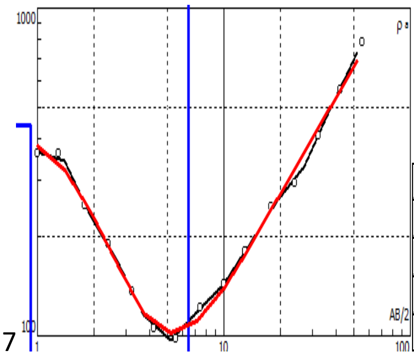
N	1	2	3
ρ	77.2	297	37747
h	0.625	5.51	
d	0.625	6.13	
Alt	-0.6255	-6.132	

VES 5



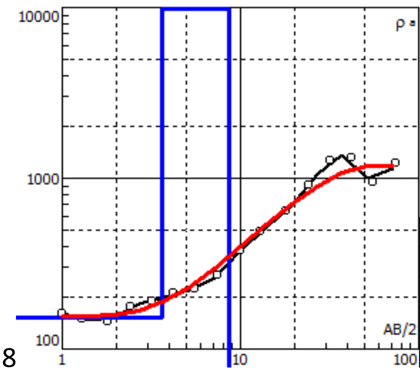
N	1	2	3	4
ρ	212	682	39.7	97222
h	0.5	0.472	1.99	
d	0.5	0.972	2.97	
Alt	-0.5	-0.9724	-2.966	

VES 6



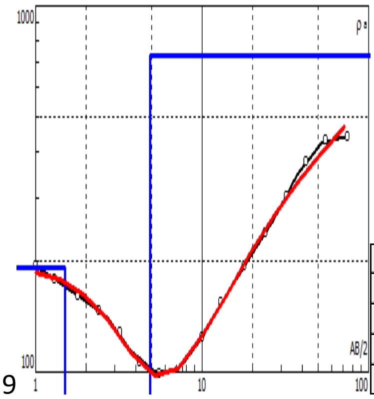
N	1	2	3
ρ	439	77.4	32547
h	0.917	5.53	
d	0.917	6.45	
Alt	-0.917	-6.446	

VES 7



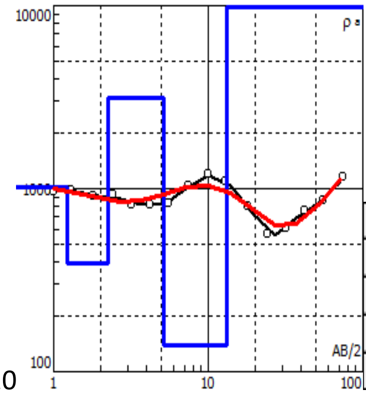
N	1	2	3
ρ	153	16915	14.1
h	3.62	5.02	
d	3.62	8.64	
Alt	-3.62	-8.644	

VES 8



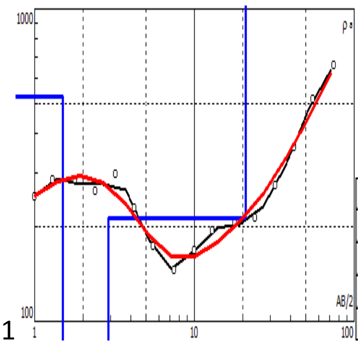
VES 9

N	1	2	3
ρ	194	54.4	728
h	1.5	3.38	
d	1.5	4.88	
Alt	-1.503	-4.878	



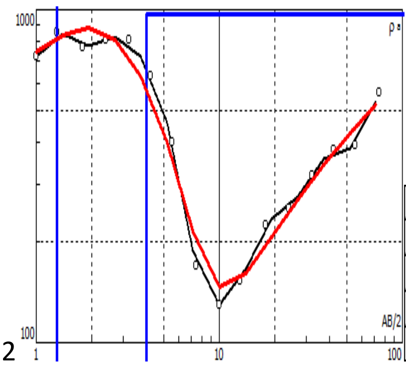
VES 10

N	1	2	3	4	5
ρ	1027	393	3108	139	86485
h	1.22	1.01	2.87	8.16	
d	1.22	2.24	5.11	13.3	
Alt	-1.224	-2.239	-5.111	-13.28	



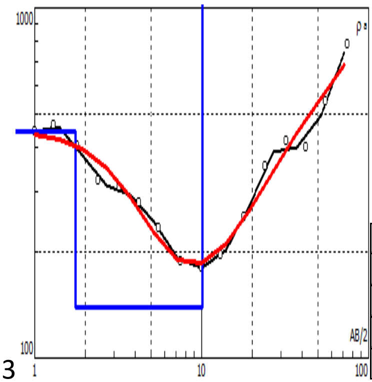
VES 11

N	1	2	3	4	5
ρ	194	522	52.6	214	99210
h	0.5	1	1.38	18.1	
d	0.5	1.5	2.89	21	
Alt	-0.5	-1.503	-2.886	-21.03	



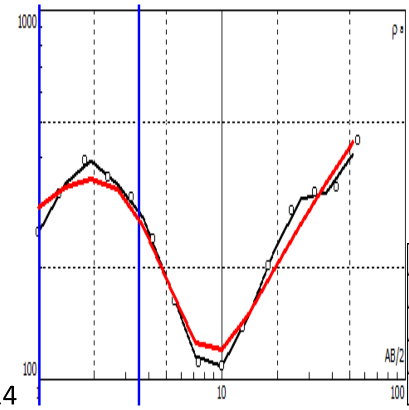
VES 12

N	1	2	3	4
ρ	527	2219	36.3	972
h	0.5	0.8	2.7	
d	0.5	1.3	4	
Alt	-0.5	-1.3	-3.997	



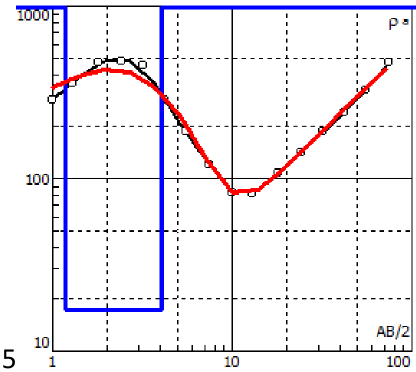
VES 13

N	1	2	3
ρ	444	140	1465
h	1.75	8.33	
d	1.75	10.1	
Alt	-1.749	-10.08	



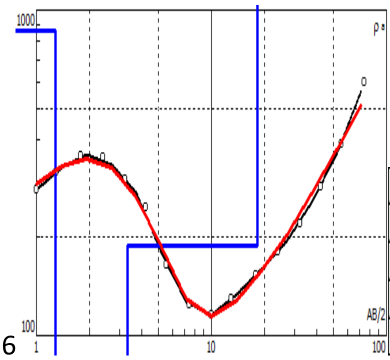
VES 14

N	1	2	3	4
ρ	198	1311	31.3	1291
h	0.5	0.512	2.53	
d	0.5	1.01	3.54	
Alt	-0.5	-1.012	-3.537	



VES 15

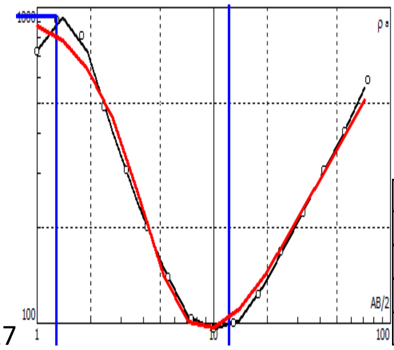
N	1	2	3	4
ρ	222	1445	17.3	58178
h	0.5	0.67	2.87	
d	0.5	1.17	4.04	
Alt	-0.5	-1.17	-4.036	



VES 16

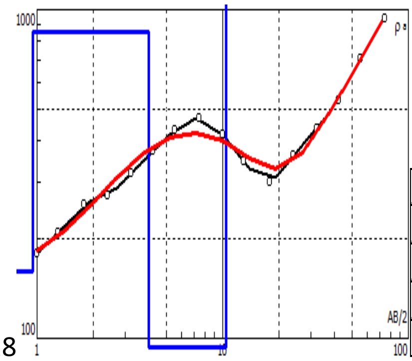
N	1	2	3	4	5
ρ	206	865	36.7	188	25283
h	0.5	0.779	2.05	14.9	
d	0.5	1.28	3.33	18.2	
Alt	-0.5	-1.279	-3.327	-18.22	

VES 17



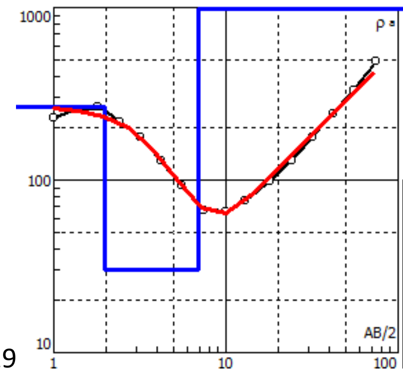
N	1	2	3
ρ	938	78.6	65405
h	1.28	10.9	
d	1.28	12.2	
Alt	-1.283	-12.17	

VES 18



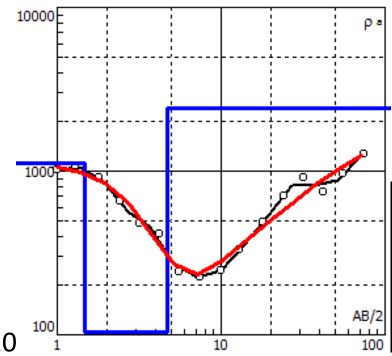
N	1	2	3	4
ρ	160	855	94.1	71988
h	0.948	3.05	6.4	
d	0.948	4	10.4	
Alt	-0.9478	-4.001	-10.4	

VES 19

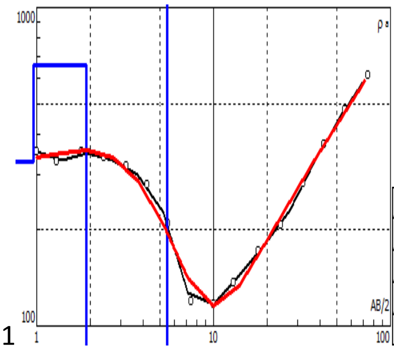


N	1	2	3
ρ	264	30.1	27101
h	1.98	4.97	
d	1.98	6.95	
Alt	-1.98	-6.946	

VES 20

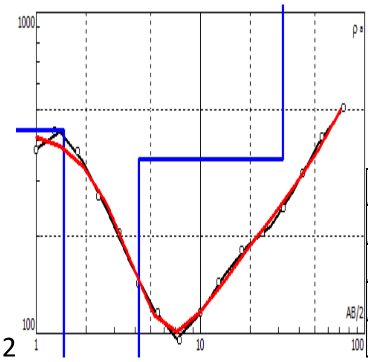


N	1	2	3
ρ	1110	104	2419
h	1.46	3.24	
d	1.46	4.71	
Alt	-1.464	-4.707	



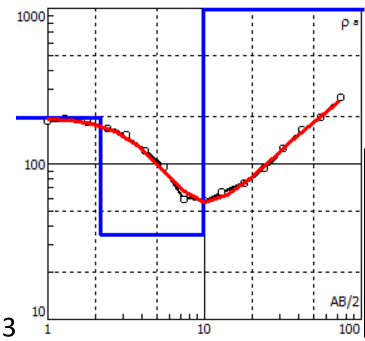
VES 21

N	1	2	3	4
ρ	327	660	36.6	3187
h	0.956	0.949	3.57	
d	0.956	1.9	5.48	
Alt	-0.9561	-1.905	-5.478	



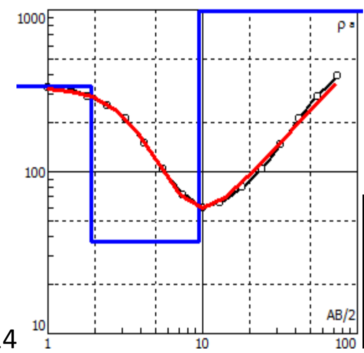
VES 22

N	1	2	3	4
ρ	430	44.7	349	29618
h	1.48	2.74	27.7	
d	1.48	4.21	31.9	
Alt	-1.475	-4.215	-31.94	



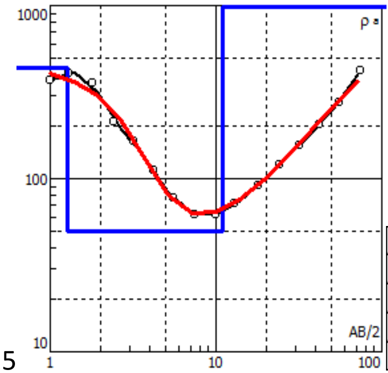
VES 23

N	1	2	3
ρ	198	35.1	1083
h	2.16	7.6	
d	2.16	9.77	
Alt	-2.163	-9.766	



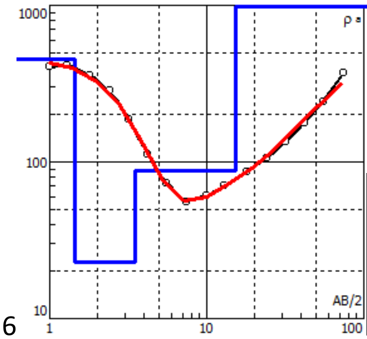
VES 24

N	1	2	3
ρ	334	37.2	29547
h	1.89	7.54	
d	1.89	9.43	
Alt	-1.892	-9.435	



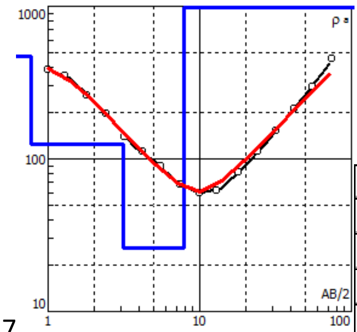
N	1	2	3
ρ	434	49.7	33111
h	1.26	9.67	
d	1.26	10.9	
Alt	-1.262	-10.93	

VES 25



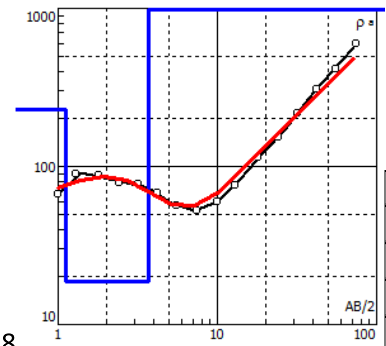
N	1	2	3	4
ρ	453	22.9	88.5	36330
h	1.45	2.06	11.7	
d	1.45	3.51	15.2	
Alt	-1.453	-3.515	-15.24	

VES 26



N	1	2	3	4
ρ	470	125	26	34225
h	0.774	2.37	4.69	
d	0.774	3.14	7.84	
Alt	-0.7743	-3.143	-7.838	

VES 27



N	1	2	3	4
ρ	51.8	228	18.8	26930
h	0.5	0.627	2.57	
d	0.5	1.13	3.7	
Alt	-0.5	-1.127	-3.7	

VES 28

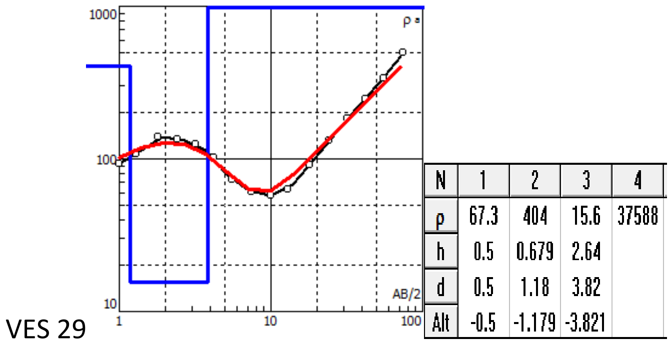


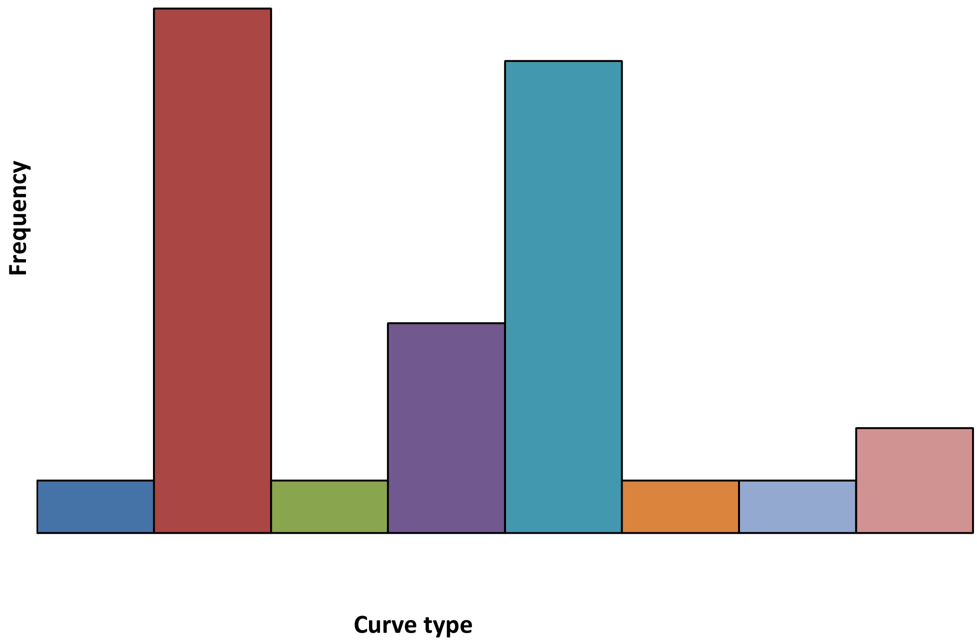
Fig. 4 : The VES curves

Table 1: Summary of Resistivity values and Layer Thicknesses

VES No	r_1(Ωm)	r_2(Ωm)	r_3(Ωm)	r_4 (Ωm)	r_5(Ωm)	h_1 (m)	h_2 (m)	h_3 (m)	h_4 (m)
1	328	2122	308	45018		1.1	1.11	4.32	
2	66.2	18	422	47355		1.17	1.28	27.2	
3	516	41.9	314	146830		1.16	0.962	15.5	
4	75.4	51.4	27818			1.3	4.55		
5	77.2	297	37747			0.625	5.51		
6	212	682	39.7	97222		0.5	0.472	1.99	
7	439	77.4	32547			0.917	5.53		
8	153	16915	14.1			3.62	5.02		
9	194	54.4	728			1.5	3.38		
10	1027	393	3108	139	86485	1.22	1.01	2.87	8.16
11	194	522	52.6	214	99210	0.5	1	1.38	18.1
12	527	2219	36.3	972		0.5	0.8	2.7	
13	444	140	1465			1.75	8.33		
14	198	1311	31.3	1291		0.5	0.512	2.53	
15	222	1445	17.3	58178		0.5	0.67	2.87	
16	206	865	36.7	188	25283	0.5	0.779	2.05	14.9
17	938	78.6	65405			1.28	10.9		
18	160	855	94.1	71988		0.948	3.05	6.4	
19	264	30.1	27101			1.98	4.97		
20	1110	104	2419			1.46	3.24		
21	327	660	36.6	3187		0.956	0.949	3.57	
22	430	44.7	349	29618		1.48	2.74	27.7	
23	198	35.1	1083			2.16	7.6		
24	334	372	29547			1.89	7.54		
25	434	49.7	33111			1.26	9.67		
26	453	22.9	88.5	36330		1.45	2.06	11.7	
27	470	125	26	34225		0.774	2.37	4.69	
28	51.8	228	18.8	26930		0.5	0.627	2.57	
29	67.3	404	15.6	37588		0.5	0.679	2.64	

Table 2: Classification of curve types

Curve types	Frequency
A	1
H	10
K	1
HA	4
KH	9
QH	1
HKH	1
KHA	2



A- H- K- HA- KH- QH- HKH- KHA-

Fig. 5: Histogram of the VES curve types in the study area.

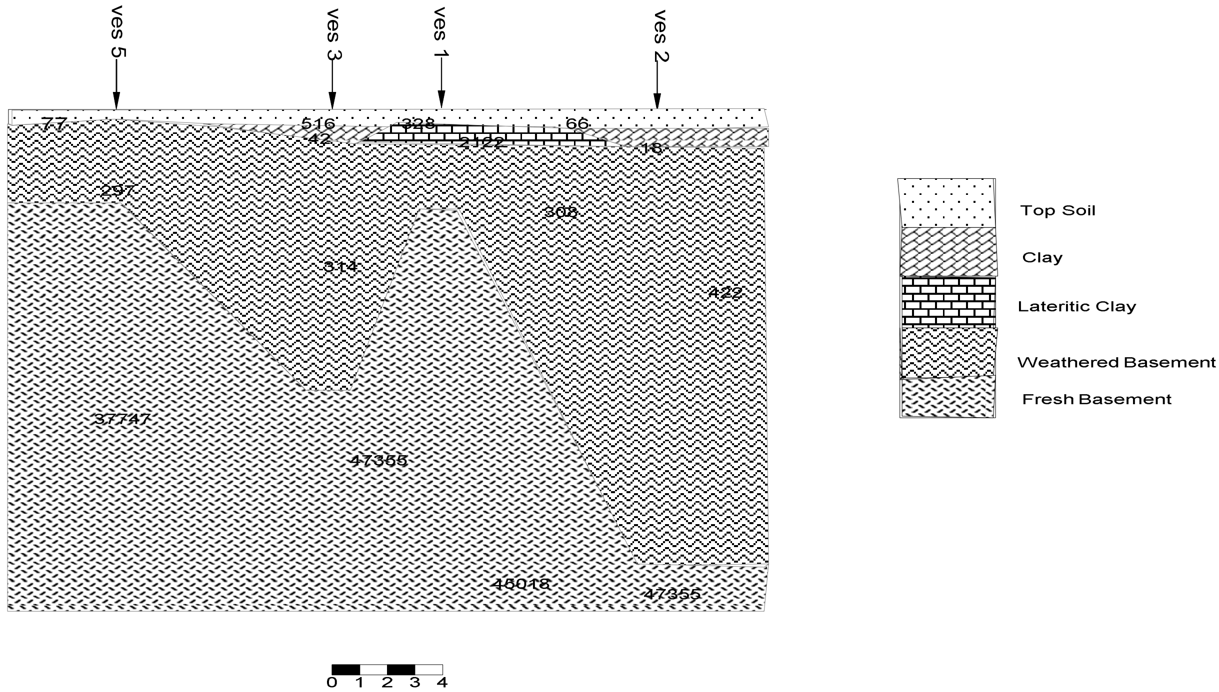


Fig.6a: Geoelectric section along cross-section AAõ

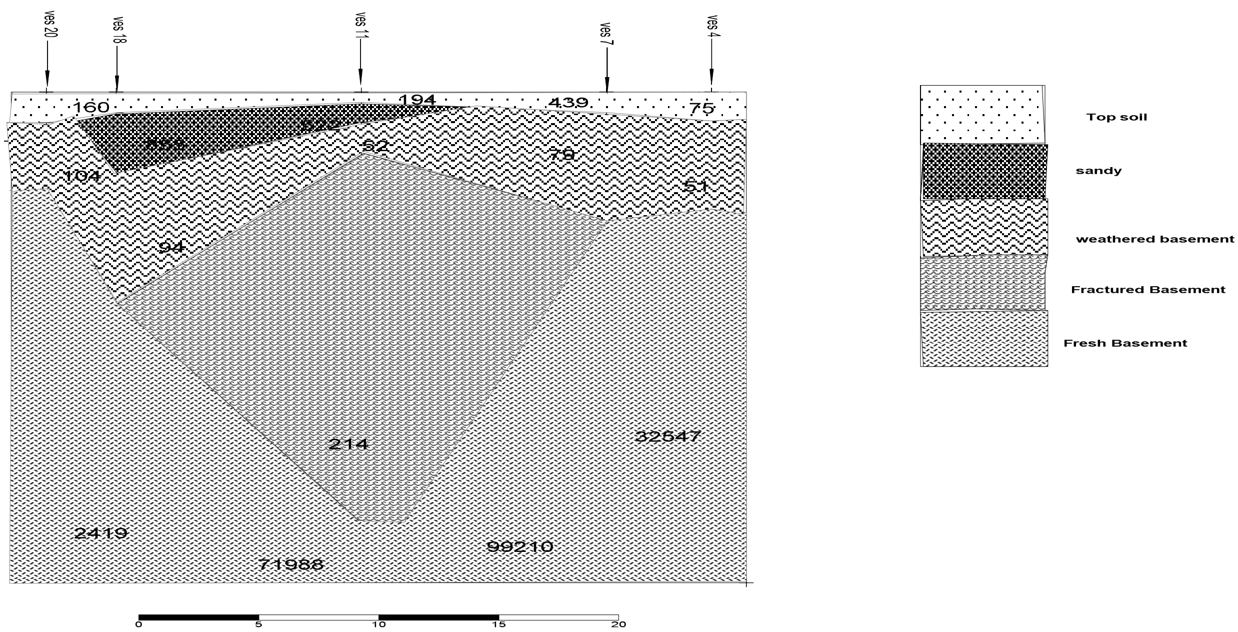


Fig.6b: Geoelectric section along cross-section BB^{1}

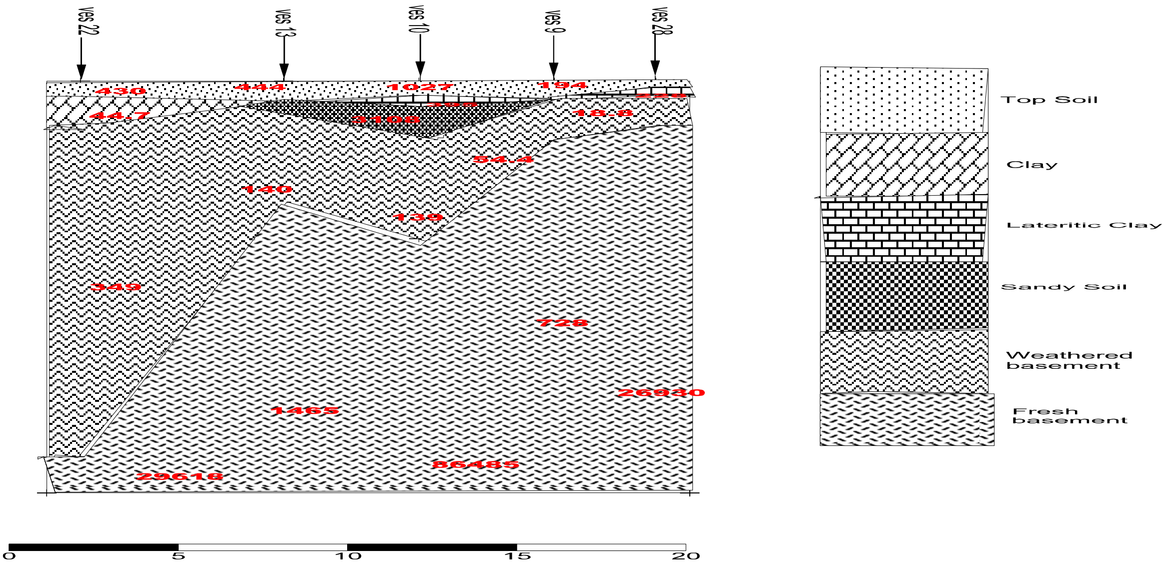


Fig.6c: Geoelectric section along cross-section CC[1]

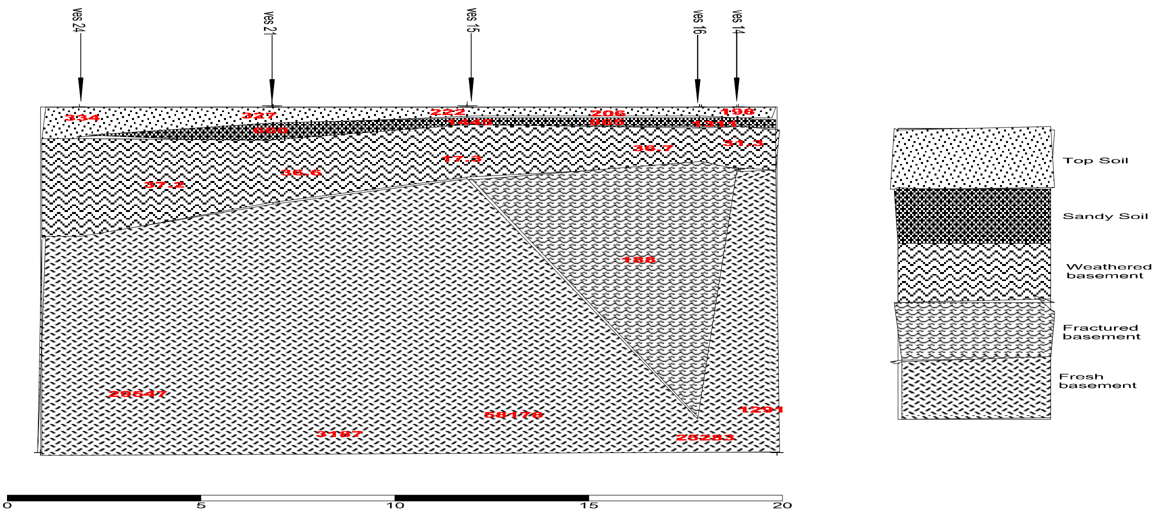


Fig.6d: Geoelectric section along cross-section DD[1]

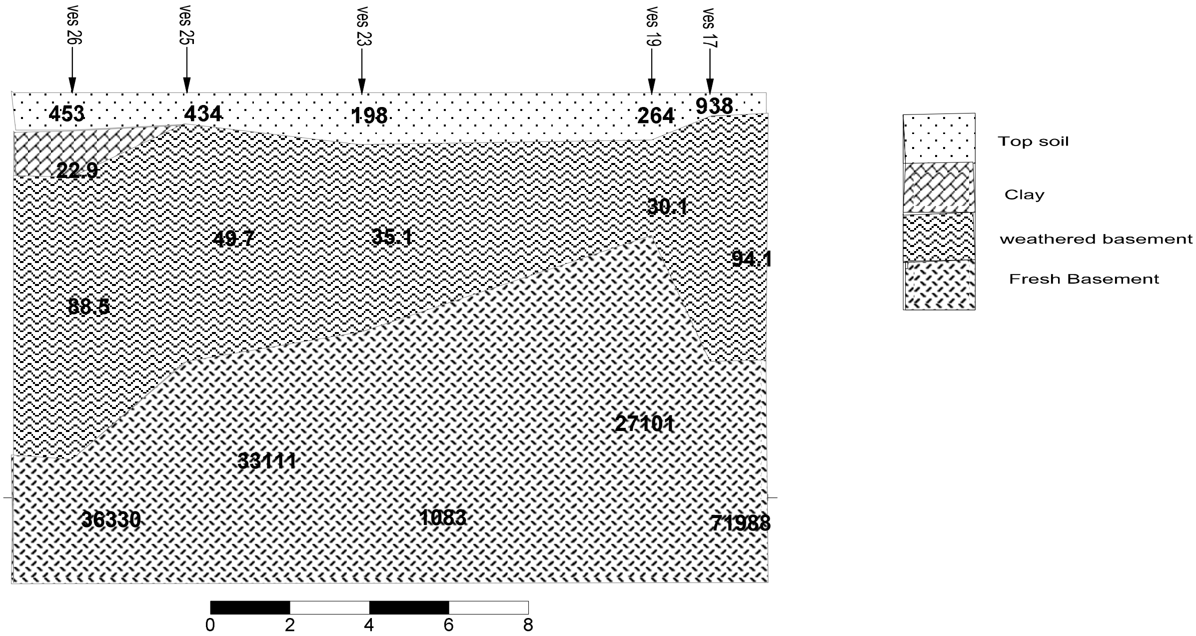


Fig.6e: Geoelectric section along cross-section EE[1]

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