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Research Paper

Geoelectrical Resistivity Investigationover the Sedimentary Claystone Deposit in The Area Around Aloji in The Anambra Sedimentary Basin of Nigeria

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Abstract
Geophysical investigation using the vertical electrical resistivity sounding survey technique was carried out on the sedimentary claystone occurrence exposed in the Aloji area, Anambra Basin of Nigeria to determine its thickness. The result revealed five litho - stratigraphic layers in the study area. The claystone in the area has a varying thickness ranging from 0.82 m to 6.75 m. The litho-stratigraphic sequence in the areaconsists essentially of a thin top soilabout 0.30 m thick composed of loose laterite underlain by a lateritic claystone with a thickness varying from 0.37 m to 1.25 m, which is underlain by a compactedclaystone layerwith a thickness ranging from 0.82 m to 6.75 m. This claystone layer is underlain by a sandy claystone layer with a thickness ranging from 4.08 m to 35.3m. Beneath thislayer is a lateritic shale layer which is the basal unit in the Mamu Formation and defines the boundary between the Mamu Formation and the Nkporo/Enugu shale.

Key Word: *Sequence, thickness, claystone, layer, lateritic*

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I. Introduction

Clay is a natural earthy fine-grained material which behaves like plastic when mixed with a limited amount of water. Clay deposits may form primarily in place as residual clay or as a result of a secondary sedimentary deposition process after they have been eroded and transported from their original location of formation. Sedimentary clay deposits are typically associated with very low energy depositional environments such as large lakes and marine basins. Clay minerals include kaolinite, montmorillonite – smectite and illite. Chemically, clay minerals are essentially crystalline hydrous aluminium silicates sometimes with variable amounts of magnesium or iron replacing wholly or in part the aluminium in some of the clay minerals (Velde, 1995)

1.1 Location and Accessibility

The study area, Aloji, is located in Ofu Local Government Area of Kogi State and is part ofthe northern sub-basin of the Anambra sedimentary basin of Nigeria. It lies between longitudes 6° 56' 04.7"E and 06° 56' 27.9" E and latitudes 7° 24' 33.6" N and 7° 24' 59.8" N. The area is part of the topographical map sheet(Sheet 248) produced on a scale of 1:250,000. The area is accessible by a major road, the Anyigba – Itobe road which cuts through the clay deposit thereby exposing good sections at both sides of the road. There are other minor roads and foot paths that traversed the area (Figure 1).

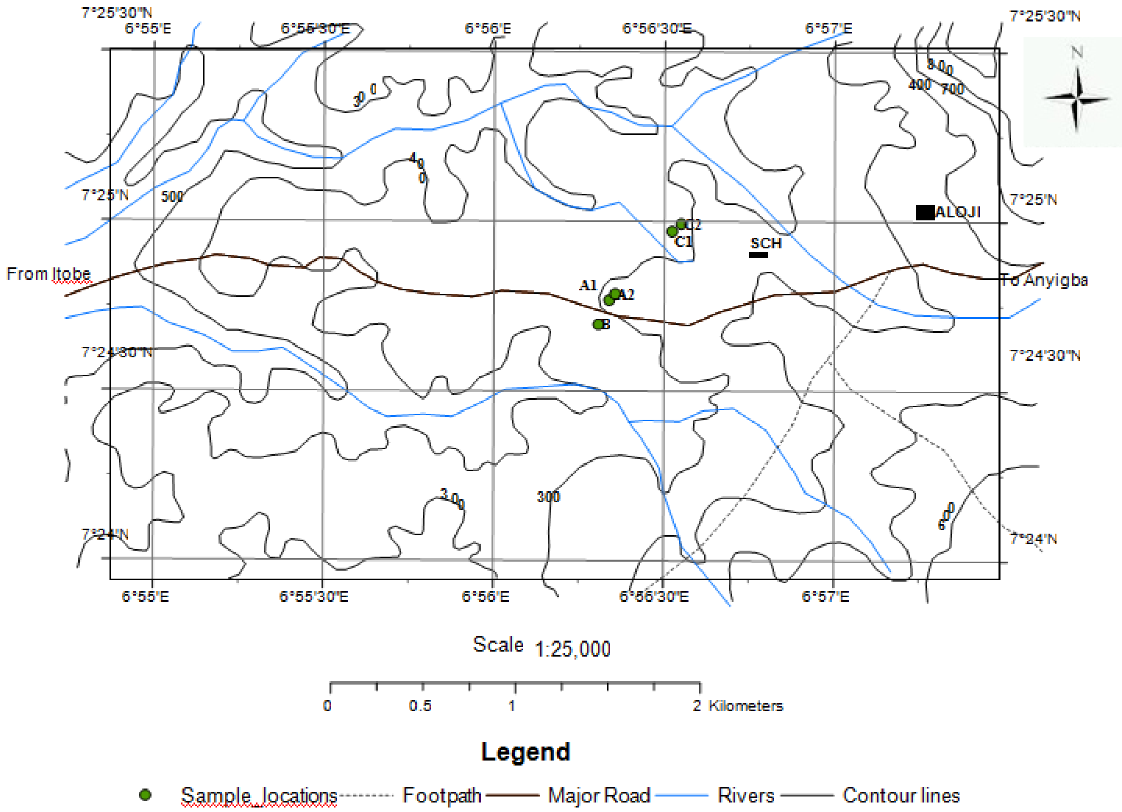


Figure 1 Topographic map of the study area showing clay sample points(modified after NGSA, 1965).

1.2Previous geophysical studies on clay deposits in Nigeria.

Previous studies on geophysical investigations of clay deposits include those by Ogundana *et al* (2015) who carried out a geophysical evaluation of the lateral continuity of the Ikere kaolin deposit. It reported four lithological units namely: topsoil, laterite, kaolin and basement rock. The kaolin layer is characterized by a relatively low resistivity with an average value of 61Ωm.

Geophysical study of clay attributes in Iruekpen village of Edo state was carried out by Ezomo (2012) using the electrical resistivity method. Three to five lithologic layers were established consisting of clay, shale, sandstone and limestone. The resistivity of the clay layer ranges from 48.4Ωm – 113.4Ωm with a thickness ranging from 0.71m to 1.48mVertical Electrical Sounding (VES) survey using the Schlumberger configuration was used to quantify the reserve of the kaolin deposit in Ukwu-Nzu and Ubulu-Uku areas of Aniocha-North of Delta State (Egbai, 2013). The result revealed 4-8 geoelectric layers consisting of clayey laterite, kaolin, sandy clay, gravelly sand and coarse gravel. The resistivity of the kaolin ranges from 52.8Ωm – 447.6Ωm with thickness ranging from 1.4m – 34.5m.The estimated reserve of the kaolin deposits are 401,235.8 tonnes and 69,535.4 tonnes respectively.

Geophysical resistivity survey mapping and reserve estimation of the clay deposit in Ajebo town near Abeokuta in southwestern Nigeria revealed the presence of 3 to 5geolelectric layers as follows: the top soil (0.5 – 1.4m), lateritic clay (1.7 – 4.7m), indurated clay (4.4 – 11.3m), clayey sand (9.3 – 18.3m), saturated clay (>6.3m) with a total clay reserve estimate of 9.5 x 10^4 tonnes (Ehinola*et al,* 2009)

Badams *et al* (2009) in a study on the geophysical evaluation of the kaolin deposit of Lakiri Village, southwestern Nigeria using the vertical electrical sounding survey revealed 3 – 5 geoelectric layers with resistivity values varying between 1099 – 22037Ωm and thickness varying between 0.4 – 17m.

This study seeks to determine the variation in thickness of the claystone in the Aloji area and the lithologic layers underlying and overlying the claystone

1.3 Methodology

The apparent resistivity of the lithological layers beneath the study area was obtained using the Vertical Electrical Soundings (VES) survey technique. The Schlumberger electrode configuration was employed. The current electrodes were expanded from a minimum current electrode spacing (AB/2) of 0.5m to a maximum of 73.5m using potential electrodes spacing (MN/2) of 0.1m, 0.5m and 1.0m. Data from nine (9) VES points were obtained from nine different locations (Figure 1). The data obtained from the 9 vertical electrical sounding (VES) points are shown in table 9 - 17. Using ohms law:

Apparent resistivity ℓ= G × V/I, Where V/I= resistance of the formation, G is the geometric factor and for Schlumberger array it is given by:

$$G = \pi (L^2 - a^2)/4a$$

Where a, is the distance between the potential electrodes and L is thedistance between the current electrodes(Philip *et al*, 2002)

The IPwin2 software was used to plot the apparent resistivity data against the current electrode spacing and the geo-electric layer parameters (resistivity and thickness) of each sampled location are shown in figures 13 to 21.

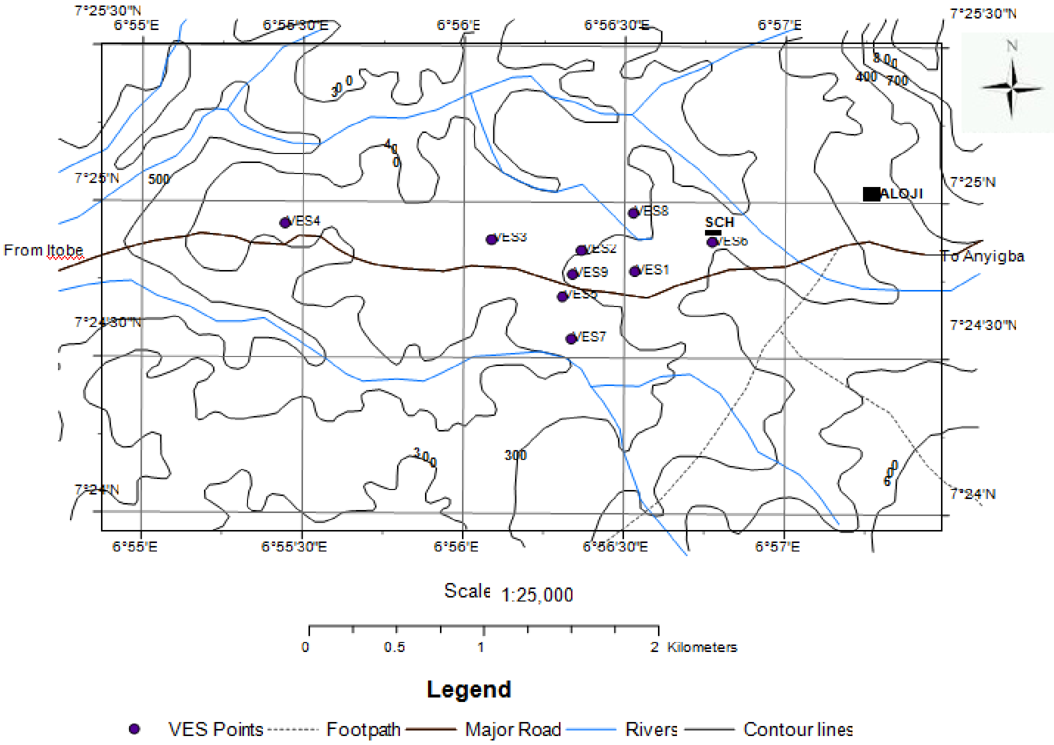


Figure 1: Topographic map of the study area showing the VES points

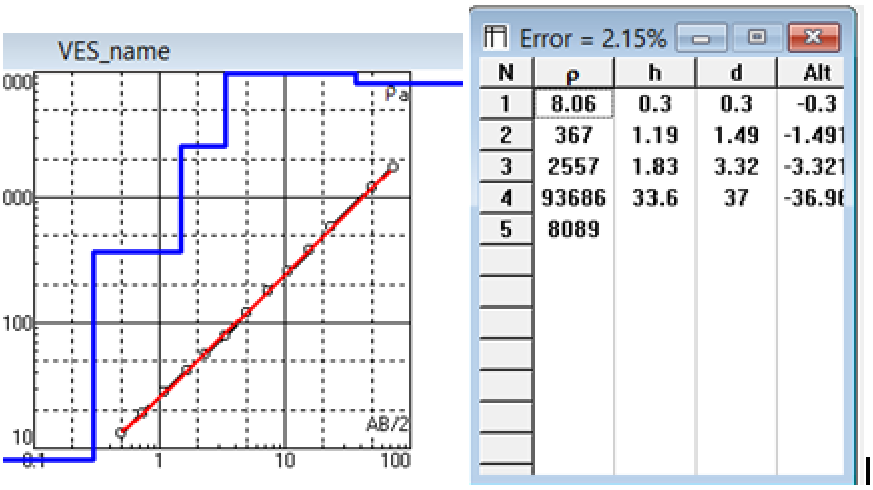
4.1 Field occurrence and stratigraphy of the study area

Aloji clay falls within the Mamu Formation in the northern part of the Anambra sedimentary basin. There are two main exposures of the clay deposit in the area; one along Anyigba – Itobe road on longitude E006°56'21.3"and latitude N07°24'43.3" with an average thikness of 12m and extending in a N-S direction over a distance of 315m and the other behind Aloji village on longitude E006°56'30.4" and latitude N07°25'01.11" with an average thickness of 19m and extending in a N-S direction over a distance of 330m. The lower part of the clay exposed along the Anyigba – Itobe road is dirty white in color with traces of iron stains. This layer is overlain by a greyish –white clay of 0.6m thickness, which in turn is overlain by a highly compacted lateritic clay layer of 1.4m thickness and is in turn capped by a fine – coarse grained lateritic overburden about 0.4m thick. Similarly, the clay exposure behind the village is brownish – white clay at the bottom and is overlain by a greyish –white clay of 3mthickness which in turn is overlain by a highly compacted lateritic clay of 2m thickness, and capped by an overburden layer of fine – coarse grained laterite of 1m thickness. At the extreme north of the study area on longitude E006°55'24.5" and latitude N07°24'58.5" along Anyigba – Itobe road is an exposure of shale. This is believed to be the bottom layer of the Mamu Formation and defines the boundary between the Mamu Formation and Nkporo/Enugu shale of the Anambra sedimentary basin.

4.2 Results of Geophysical Resistivity Survey and Interpretation

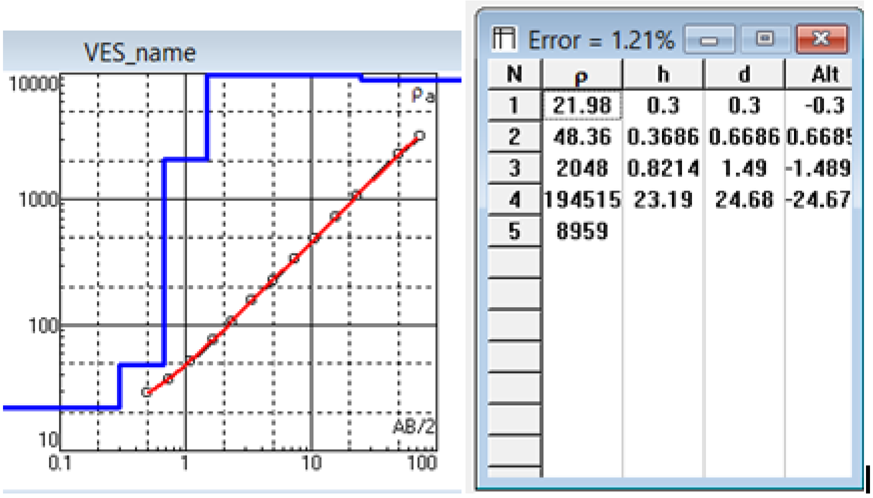
Table 1: Vertical Electrical Sounding (VES) data obtained from the study area

LONGITUDE		6°56' 32.2"E	6° 56' 20.9"E	6° 56' 04.6"E	6° 55' 26.9"E	6° 56' 16.3"E	6° 56' 44.9"E	6° 56' 19.3"E	6° 56' 31.8"E	6° 56' 17.5"E
Latitude		07°24'49.0"N	07°24'49.9"N	07°24' 49.9"N	07°24'58.1"N	07°24'43.4"N	0724'43.4"N	07° 24'32.9"N	07° 25' 006"N	07° 24' 44.9"N
Elevation (m)		272	229	220	206	220	248	221	215	226
Electrode Spacing		Apparent Resistivity (Ωm)								
AB/2 (M)	MN/2 (M)	VES 1	VES 2	VES 3	VES 4	VES 5	VES 6	VES 7	VES 8	VES 9
0.50	0.10	1.78	24.78	978.32	1091.34	2311.91	1108.34	1114.98	3.88	1107.78
0.73	0.10	3.92	9.71	1669.75	2451.75	3802.95	1456.13	1774.18	5717.36	1649.31
1.08	0.10	9.17	41.84	1957.45	2919.19	4227.98	1267.19	1639.84	7341.23	6276.83
1.65	0.10	12.01	60.89	2420.21	3836.69	5193.31	1298.03	1731.24	5104.25	7633.58
2.32	0.10	34.79	401.56	2725.70	5017.41	5758.11	1523.76	2821.91	1269.29	10020.81
3.40	0.10	21.63	460.16	3066.32	6602.60	6428.95	1877.46	2105.73	137.54	24907.64
5.00	0.10	124.84	1738.94	2730.11	6993.21	5236.37	1969.23	1773.84	4668.68	3155.17
7.35	0.50	363.97	1406.36	1298.77	3965.59	5153.65	1859.13	1220.71	781.61	6824.06
10.75	0.50	1363.48	12221.80	1483.19	3033.37	4827.06	11941.01	1028.71	470.82	657.11
15.80	0.50	356.37	32459.80	1853.95	2442.65	5626.10	5927.86	966.62	9739.90	6031.41
23.20	0.50	10777.06	7618.79	105.14	2409.95	8615.43	2699.67	639.97	0.00	0.00
50.00	1.00	1202.90	15465.42	50153.76	486.30	1580.58	6500.22	8203.62	0.00	0.00
73.50	1.00	85753.05	110640.61	133576.54	5409.59	7499.28	5079.00	45097.14	0.00	



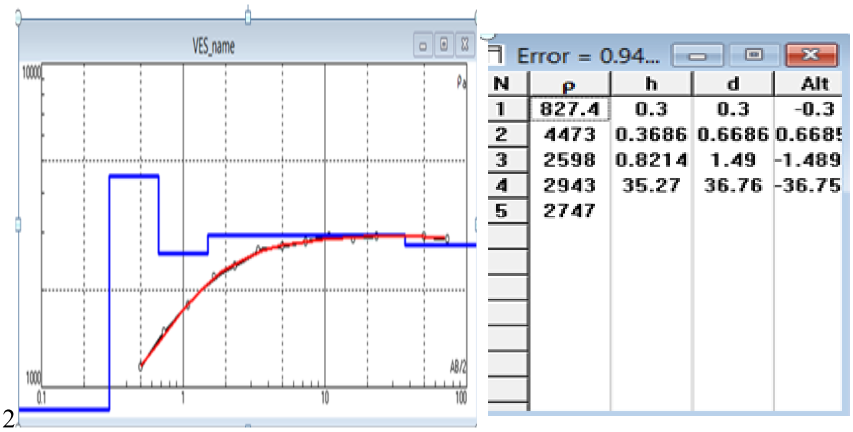
N	ρ	h	d	Alt
1	8.06	0.3	0.3	-0.3
2	367	1.19	1.49	-1.491
3	2557	1.83	3.32	-3.321
4	93686	33.6	37	-36.9
5	8089			

Figure 3: Computer modelled curve for VES 1



N	ρ	h	d	Alt
1	21.98	0.3	0.3	-0.3
2	48.36	0.3686	0.6686	0.668
3	2048	0.8214	1.49	-1.489
4	194515	23.19	24.68	-24.67
5	8959			

Figure 4: Computer modelled curve for VES



N	ρ	h	d	Alt
1	827.4	0.3	0.3	-0.3
2	4473	0.3686	0.6686	0.668
3	2598	0.8214	1.49	-1.489
4	2943	35.27	36.76	-36.75
5	2747			

2

Figure 5: Computer modelled for VES 3

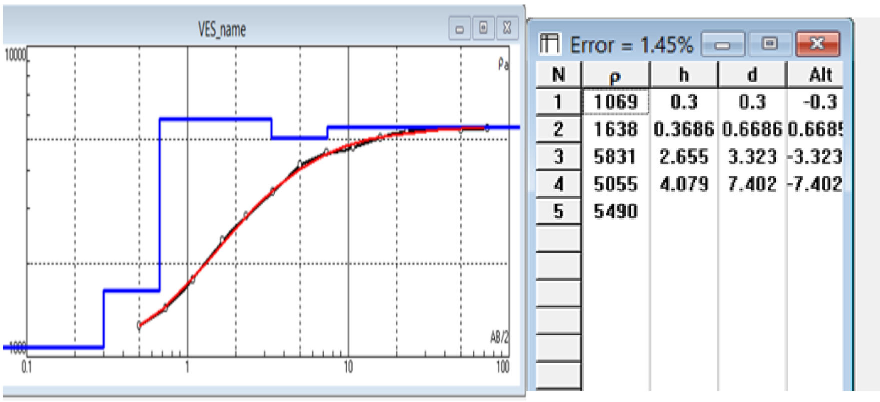


Figure 6: Computer modelled curve for VES 4

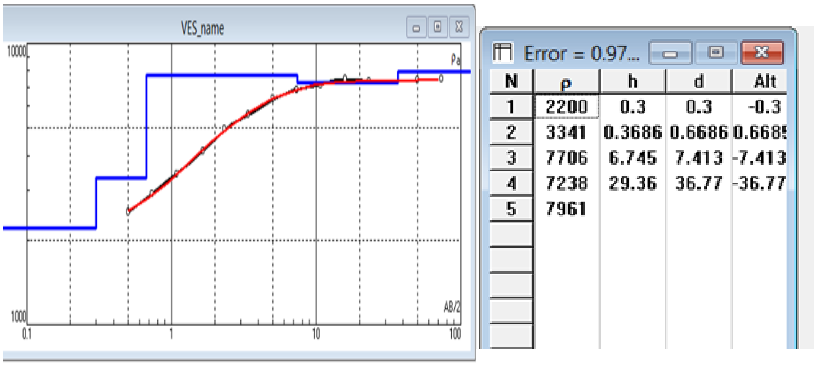


Figure 7: Computer modelled curve for VES 5

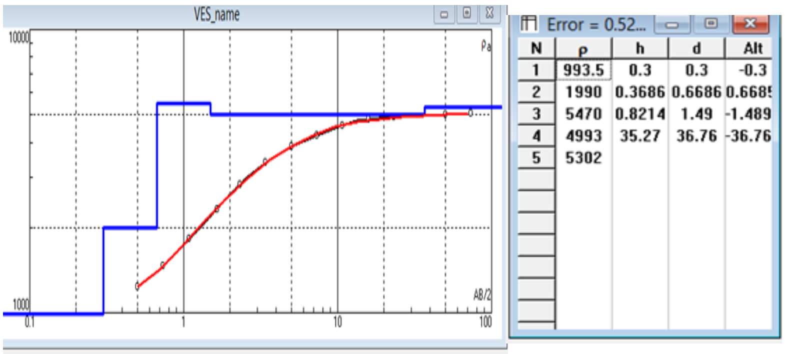


Figure 8: Computer modelled curve for VES 6

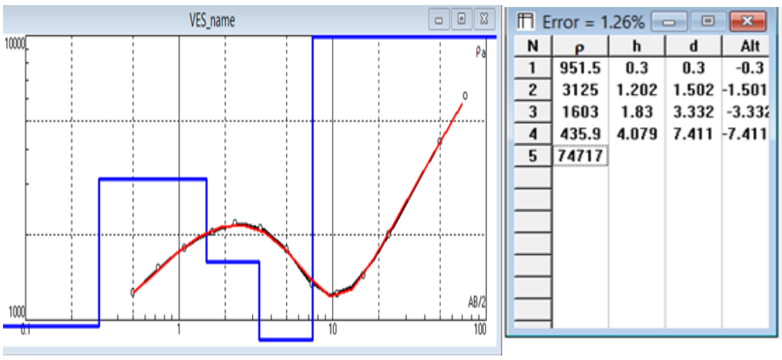


Figure 9: Computer modelled curve for VES 7

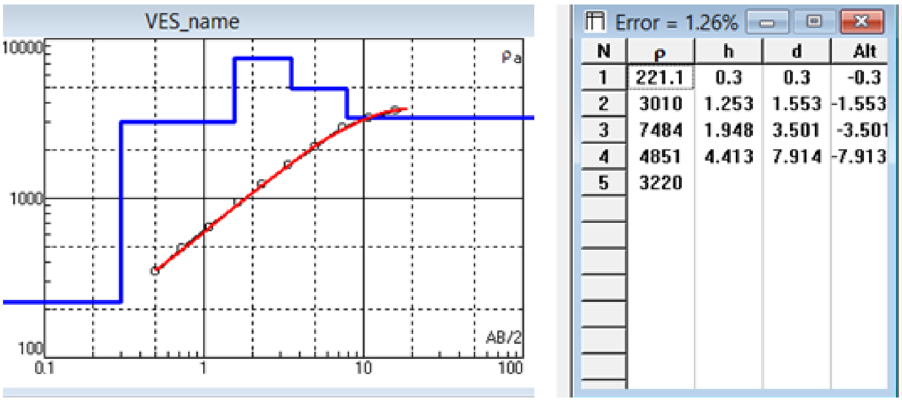


Figure 10: Computer modelled curve for VES 8

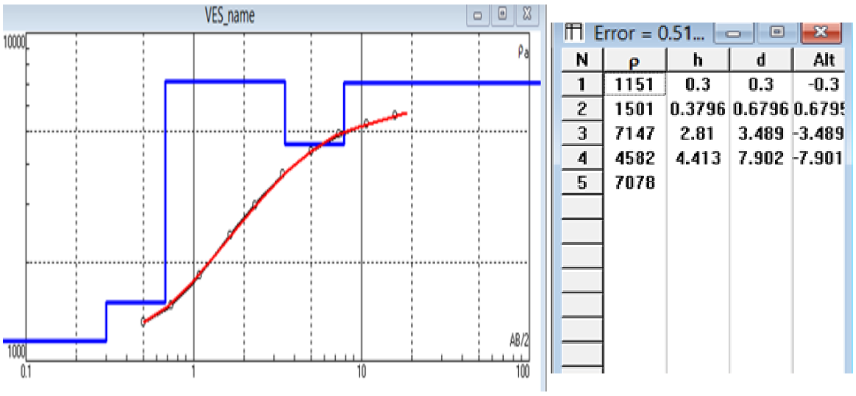


Figure 11: Computer modelled curve for VES 9

Interpretation of the VES survey data in the study area (Table 2) shows five litho - stratigraphic layers with similar lithology except for VES points2, 5, 8 and 9 which show a slight variation. Though the resistivity values of the claystone layer are relatively high which is attributed to the presence of silt in the claystone, it is should be noted that the VES points 8 and 9 were run directly on the claystone outcrop as control surveyto determine its resistivity which was then used in the interpretation of other VES points.

The lithology of the study area as interpreted from the geo-electric layer parameters are a thin top layer (loose clayey laterite) 0.3m thick which is underlain by lateritic claystonewith thickness ranging from 0.37m to 1.25m overlying a highly compacted claystone of thickness ranging from 0.82m to 6.75m. Underlying this is a thick layer of sandy claystone with thickness ranging from 4.08m to 35.27m. Beneath this layer is a lateritic shale layer believed to be the basal layer of the Mamu Formation and forms the boundary between the Mamu Formation and Nkporo/Enugu shale Formation. Though there are similarities in the litho - stratigraphy of the VES points but the thickness of the corresponding layers varies from point to point. The layer of interest which is the claystone is relatively thicker at VES points 4, 5, 7, 8 and 9 with thicknesses of 2.66 m, 6.75m,1.83 m, 1.95m and 2.81m respectively. The claystone tends to thin out from the point of maximum thickness at VES 5 to the point of least thickness at VES 2 (0.82 m), VES 3 (0.82 m) and VES 6 (0.82m) (Table 2)

The resistivity values of the litho -stratigraphic layers vary across the VES locations. The resistivity value of the layer of interest (claystone layer) is relatively very high and tends to increase with depth ranging from 1603Ωm to as high as 7147Ωm. This high resistivity may be attributed to the relatively high content of silica in the claystone as observed from the gritty feel of the claystone between the palms and results of XRF analysis of the claystone in the study area (Alege *et al, 2014*) which shows a high mean silica content (69.2 %)

Table 2: A Summary of the Interpretation of the Geo-electric Parameters of the VES Data

VES	LAYER	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	PROBABLE LITHOLOGY
1	1	8.06	0.30	0.3	Top soil
	2	367	1.19	1.49	Lateritic clay
	3	2557	1.83	3.32	Claystone
	4	93686	33.6	37	Sandy claystone
	5	8089	-	-	Lateritic shale
2	1	21.98	0.30	0.30	Top soil
	2	48.36	0.37	0.67	Clay
	3	2048	0.82	1.49	Claystone
	4	194515	23.19	24.68	Sandy claystone
	5	8959	-	-	Lateritic shale
3	1	827.4	0.30	0.30	Top soil
	2	4473	0.37	0.67	Lateritic claystone
	3	2598	0.82	1.49	Claystone
	4	2943	35.27	36.76	Sandy claystone
	5	2747	-	-	Lateritic shale
4	1	1069	0.30	0.30	Top soil
	2	1638	0.37	0.67	Lateritic claystone
	3	5831	2.66	3.32	Claystone
	4	5055	4.08	7.40	Sandy clay
	5	5490	-	-	Lateritic shale
5	1	2200	0.30	0.30	Claystone
	2	3341	0.37	0.67	Lateritic claystone
	3	7706	6.75	7.41	Highly compacted Claystone
	4	7238	29.36	36.77	Sandy claystone
	5	7961	-	-	Lateritic shale
6	1	993.5	0.30	0.30	Top soil
	2	1990	0.37	0.67	Lateritic clay
	3	5470	0.82	1.49	Claystone
	4	4993	35.27	36.76	Sandy clay
	5	5302	-	-	Lateritic shale
7	1	951.5	0.30	0.30	Top soil
	2	3125	1.20	1.50	Lateritic claystone
	3	1603	1.83	3.33	Claystone
	4	435.9	4.08	7.41	Sandy claystone
	5	74717	-	-	Lateritic shale
8	1	221.1	0.30	0.30	Claystone
	2	3010	1.25	1.55	Lateritic claystone
	3	7484	1.95	3.50	Highly compacted Claystone
	4	4851	4.41	7.91	Sandy claystone
	5	3220	-	-	Lateritic shale
9	1	1151	0.30	0.30	Claystone
	2	1501	0.38	0.68	Lateritic claystone
	3	7147	2.81	3.49	Highly compacted Claystone
	4	4582	4.41	7.90	Sandy claystone
	5	7078	-	-	Lateritic shale

Five litho-stratigraphic layers with resistivity values ranging from 8.06Ωm to 194515Ωm were encountered beneath the VES points in the study area. VES points 8 and 9 were run directly on the claystone exposure as controlpoints for interpreting the VES data from the sounding points where the claystone is not exposed at the surface. The resistivity values of the claystone exposed at VES stations 8 and 9 (control points) are 7484 Ωm and 7147 Ωm respectively.The lithologic succession in the area is made up of a thin top soil (laterite) with a thickness of 0.3m.This is underlain by lateritic claystone with a thickness ranging from 0.4m to 1.2m whichin turn overlies a claystone layer with a thickness range of 0.82m to 6.75m thick. The claystone is underlain by a sandy claystone layer of thickness ranging from 4.1m to 35.3m which in turn overlies the lateritic shale layer believed to be the basal unit of the Mamu Formation.

5.2 Conclusion

Field geological and geophysical investigation of the Aloji clay deposit of the Mamu Formation in the northern sub basin of the Anambra sedimentary Basin of Nigeria reveals the following. The Aloji claystone is a sedimentary deposit formed from detrital sediments transported by dendritic streams that characterize the study area.The claystonecolor varies from dirty white to reddish white with intercalations of lateritic layers. The discoloration in the white colour in the claystone is attributed to leaching of iron from the laterite that caps the claystone due to the tropical conditions of high rainfall and high temperature of the study area. The thickness of the claystone deposit ranges from 0.82m to 6.75m and thinsout steeply from the point of maximum thickness (VES 5).The claystone contains a lot of silt as revealed by the relatively high resistivity value of the claystone horizon at the control VES locations where it outcrops and by the relatively high silica content (69.2 %) as revealed from XRF analysis of the claystone (*Alege et al*, 2014)

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