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Preliminary Lithologic Deductions for Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria, using Vertical Electrical Sounding Method

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ABSTRACT

This work is about geoelectric investigation involving forteen vertical electrical sounding carried out in Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. The total current electrode spread varied from 400 to 500 m and this depended on access roads, topography and general infrastructure. The survey was aimed at investigating the resistivity of consolidated and unconsolidated formations of the study area and the depth of the Aquifer. The ABEM Terrameter, signal averaging system (SAS) 4000 was used in carrying out the soundings. Data obtained were interpreted using the RESIST software. The usual high and low resistivities of the Benin Formation caused by changes in lothologies were obtained. Aquifer resistivity varied from 249.70 to 4192.30 Ωm. The number of layers ranged from four to six in the area, while the total thickness ranged from 9.20 to 484.50 m. The curve types significantly obtained in the area were: A, HA, HK, KH, AK, HAK, KHA, and HKH. The curve models distributed fairly in the area have good prospect for groundwater potential due to low resistivity values obtained from H- and K-curve types which can translate into saturated sand beds of significant water wells. Three litho-and hydro-resistivity cross sections were drawn which shows that the area has four distinctive layers defined as; top loamy, lateritic sand, medium grained sand (water bearing formation) and the conducting layer which is clay formation. Efforts should be made to check the quality of water in such a region, since aquifer in the region is located at shallow depths from the surface of the earth.

Keywords: Vertical electrical sounding (VES), aquifer, resistivity, lithology, terrameter

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INTRODUCTION

Of all the natural resources, water permeates perhaps most deeply into all aspects of life. Water is no doubt one of the most essential needs of human beings, for drinking and other domestic purposes. Its presence or lack of it determines to a great extent the nature of the natural environment in which life and majority of our economic activities depend on [1]. Water availability is govrned by the water cycle, in which rainfalls from the clouds flows over the land or sinks through the ground, where it may be stored as groundwater in underground aquifers, and finally flows through rivers, lakes and dams towards the sea. Evaporation from surface water and transpiration of plants and trees feed the clouds and the cycle continues[1].

Groundwater cannot be directly observed or managed from the surface. Therefore groundwater surveying consists of the application of a range of indirect techniques. Successful groundwater exploration depends on the selection of a combination of techniques appropriate to the area under investigation. The increased interest in recent years in underground sources of water has led to the need for more intensive studies of the geometry and properties of aquifers. The most important objective of any geophysical survey for groundwater prospecting is to translate the result of geophysical interpretation in terms of the subsurface hydrogeology. For this purpose, a geological cross-section, geological correction and location map of potential sites for drilling of groundwater are usually prepared [2, 3].

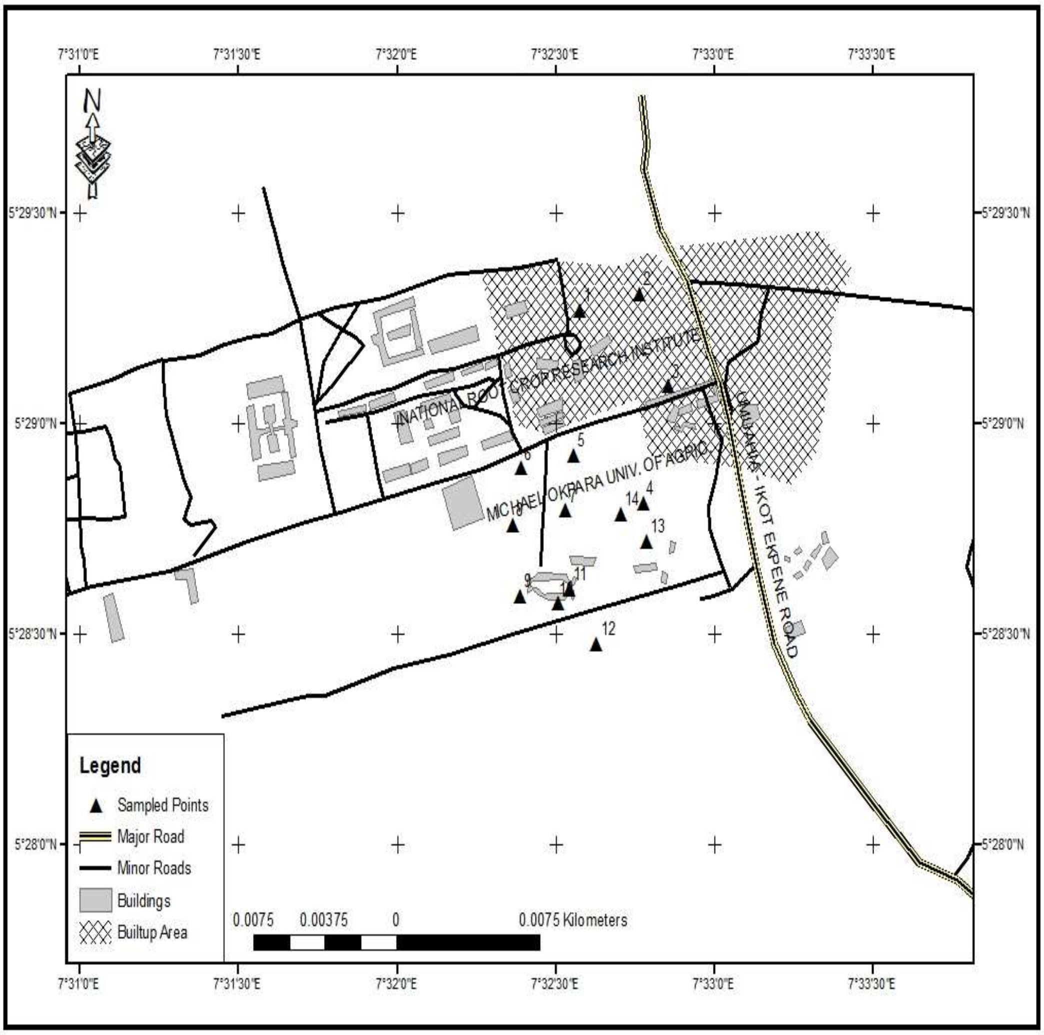

Fig. 1: Map of the study area showing VES points

Generally researches conducted in recent times using the surface electrical methods are fundamentally geared towards determining lithology [4, 5, 6, 7], groundwater potential [8, 9] and saltwater fresh water interface [10, 11]. This study was carried out to ascertain the formation strata and aquifer characteristics in Michael Okpara University of Agriculture, Umudike.

Location and Geology of the Study area

Michael Okpara University of Agriculture, Umudike (MOUAU) is located in Ikwuano Local Government Area of Abia State, Southeastern Nigeria. It is located within the deltaic marine sediments of Cretaceous to recent age, at about latitude $5^{0}28^{1}$ and $5^{0}30^{1}$N and between longitude $7^{0}31^{1}$ and $7^{0}33^{1}$E [12]. The Geology of the area is the deltaic marine sediment of Cretaceous to Recent age. There are two principal formations in the area namely: the Bende-Ameki and the coastal plain sands otherwise known as the Benin Formation. The Bende-Amaki Formation of Eocene to Oligocene age consists of medium to coarse-grained white sandstone, which may contain pebbles, gray-green sandstone, bluish calcareous silt, with mottled clays and thin limestone. Considerable lateral variation in lithology has also been observed. The lower part of the formation consists of fine-coarse-grained lenses of sandstone with abundant calcarceous shales and thin shelly limestone. The Bende-Ameki Formation overlies the impervious Imo shale group of Paleocene age, which is characterized by lateral and vertical variations in lithology.

The coastal plain sand otherwise known as the Benin Formation overlies the Bende-Ameki Formation and dips southwestward. The Formation sediments were deposited during the late Tertiary-early Quaternary period [13]. The

Formation is shallow and has an expected thickness of about 200m [14]. The lithology consists of unconsolidated loosely medium to coarse-grained cross-bedded sands occasionally pebbly with localized clays and shales. Umudike soil is acidic with average pH range of 4.5 – 5.7[15]. Figure 1 shows the map of the study area.

The two principal geological formations: the Bende-Ameki and the coastal plain sands otherwise known as the Benin Formation have comparative groundwater regime. They both have reliable groundwater that can sustain regional borehole production. The Bende-Ameki Formation has little groundwater when compared to the Benin Formation. The high permeability of the Benin Formation, the lateritic overburden earth and the weathered top of this formation as well as the underlying clay-shale member of the Bende-Ameki series provide the hydrologic conditions favouring aquifer formation in the area. The area has elevation range of 60 to 180 m above mean sea level.

MATERIALS AND METHODS

Variation of electrical conductivity is investigated here with the help of electrical resistivity sounding. Forteen Schlumberger vertical electrical soundings (VES) were collected using a maximum current electrode separation of AB/2 of 400 m. Digital averaging equipment, the ABEM SAS 4000 Terrameter, was used for direct current (DC) resistivity work. The instrument displays directly the apparent resistivity of the subsurface under probe. It has an in-built dc power source. Four stainless metal stakes were used as electrodes [16, 17].

The Schlumberger electrode configuration was used in all the soundings. In the Schlumberger configuration, all the four electrodes are arranged collinearly and symmetrically placed with respect to the centre. In this array the potential electrode separation is very small compared to the current electrode separation (Figure 2), where “b” is the distance between the current electrode and station midpoint, “a” is the distance between potential electrodes and “2b” is the current electrode separation. The distance between the potential electrodes is increased only when the signal is too small to measure. Apparent resistivity ρa is given by

$$\rho_a = \pi R \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right] \quad (1)$$

where AB/2 is half the current electrode separation and MN/2 is half the potential electrode separation [18]. The apparent resistivity is plotted against half the current electrode spacing on a double logarithmic graph. To get the layer parameters (resistivity and thickness) of the subsurface, these sounding curves are first interpreted with the help of theoretically computed master curves by partial curve matching and drawing auxiliary point diagrams [16, 19, 20]. Based on this preliminary interpretation, initial estimation of the resistivities and thicknesses of the various geoelectric layers were obtained. These were later used as starting point models for a fast computer assisted interpretation. Computer aided interpretation of the field data was done using Resist software. The results of the manually smoothed field data were fed into this programme and iteration was done. The Resist inversion programme generated the final models for resistivity, thicknesses and depth. The results of this computer modeled data and curves are shown in Table 1 and in Figures 3, 4, 5 and 6.

RESULTS AND DISCUSSION

Table 1 shows primary and significant parameters like formation resistivity, curve type, depth to bottom and thickness of layers which are needed to define the characteristics of formation in the area. The geoelectric parameters shown on the table are resistivity (ρ), thickness (h) and depth to bottom.

The number of layers ranges from four to six in the area, while the total thickness ranges from 9.20 m at MU_2 (piggery farm) to 484.5 m at MU_6 (VC’s lodge). The top layer resistivity values range from 83.30 Ωm at MU_1 (forest base) to 3799.7 Ωm at MU_2 (Afrihub). The low resistivity top layer enhanced the current penetration into the deeper layer and the detection of the deeper layer. The second layer has resistivity values ranging from 7.60 Ωm at MU_2 (piggery farm) to 3894.60 Ωm at MU_5 (Liman hall). The third layer has resistivity values ranging from 144.00 Ωm at MU_2 (piggery farm) to 85677.50 Ωm at MU_8 (mechanic workshop). Layer four has resistivity values ranging from 51.00 Ωm at MU_{12} (Afrihub) to 4100000.00 Ωm at MU_5 (Liman hall) and MU_6 (VC’s lodge). Layer five has resistivity values ranging from 1063 Ωm at MU_6 (VC’s lodge) to 100000.00 Ωm at MU_9 (petrol station).

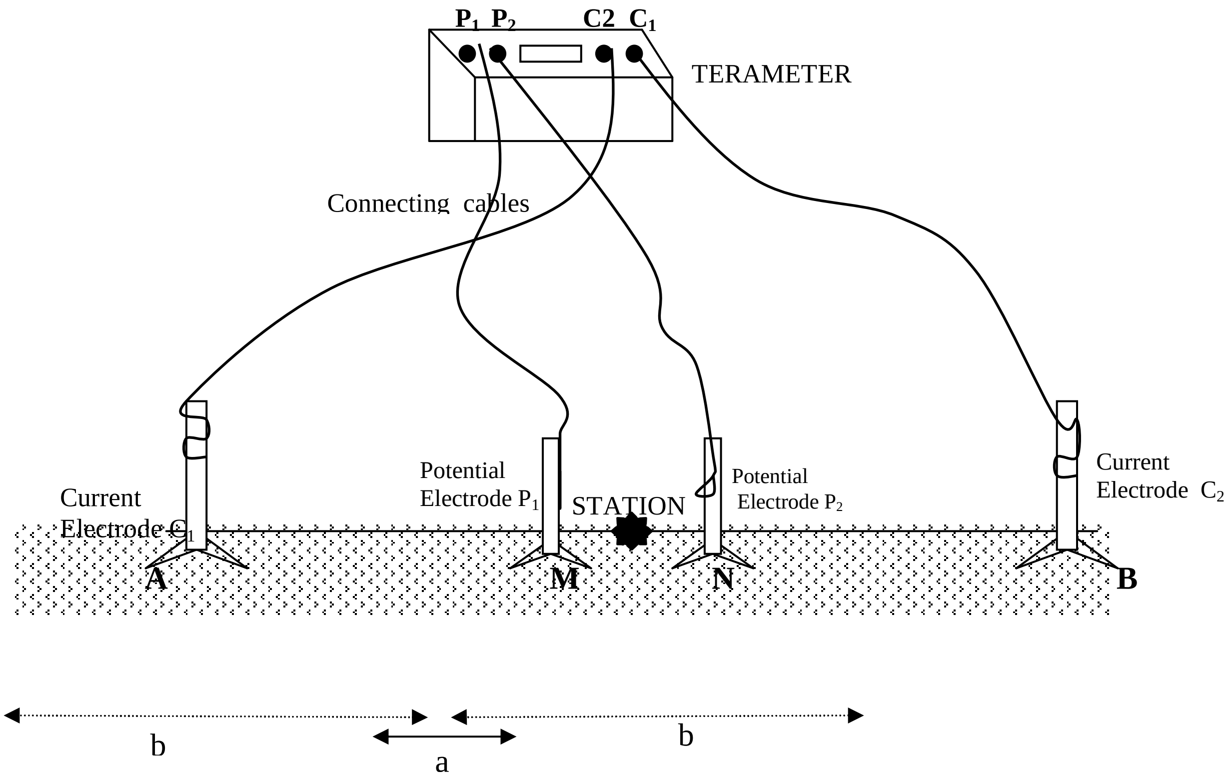

Fig. 2: General four-electrode configuration for VES survey using Schlumberger array.

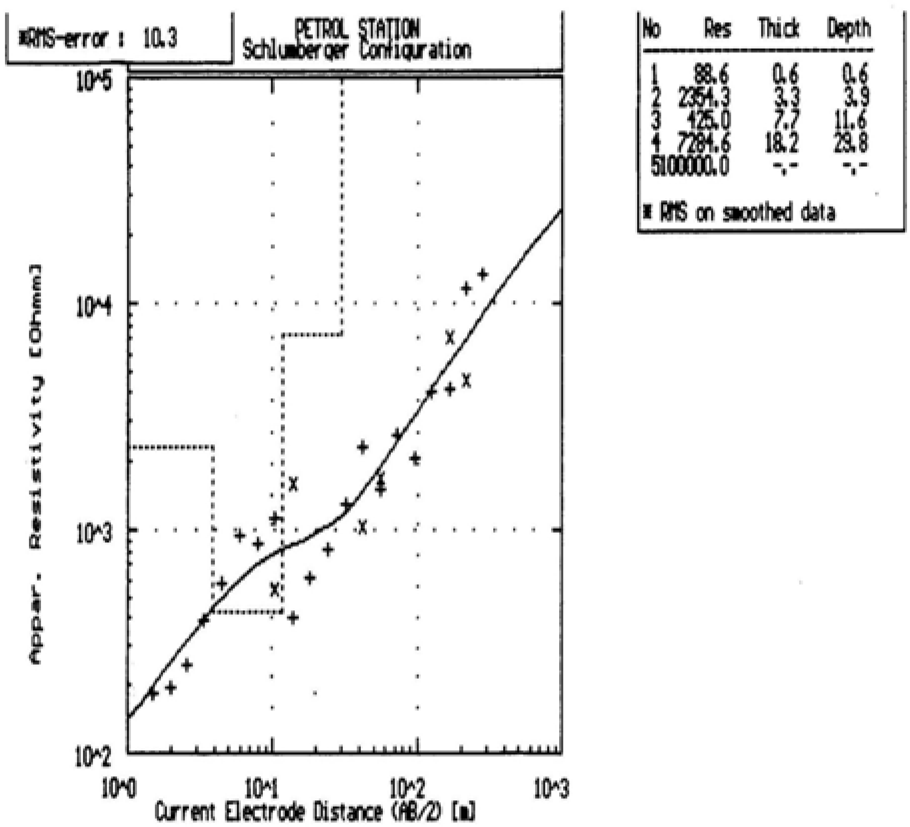

Fig. 3: Typical model representing (KH, KHA) curve types at MU_9

The curve types significantly obtained in the area are: A, HA, HK, KH, AK, HAK, KHA, and HKH. Figs. 3 – 6 show the curve models that are obtained in the area. The emergence of these significant curve types in this profile has significant inference on the lithologic compositions and saturated aquiferous zone. The curve models shown in Table 1 distributed fairly in the area have good prospect for groundwater potential due to low resistivity values obtained from H- and K-curve types which can translate into saturated sand beds of significant water wells.

Table 4.1: Interpreted layer parameters from vertical electrical soundings (ρ, resistivity in Ωm, h thickness in (m) and d depth in meters)

VES No	Location	Elevation (m)	Latitude Longitude	No of layers	ρ_1 h_1	ρ_2 h_2	ρ_3 h_3	ρ_4 h_4	ρ_5 h_5	ρ_6 h_6	Depth (m)	Curve type
MU$_1$	Forest Base	111.0	5.4799 7.5422	4	83.30 1.10	9.90 2.00	2862.80 7.10	38626.40 ---	--- ---	--- ---	10.20	HA
MU$_2$	Pigery farm	112.9	5.4794 7.5394	5	145. 30 0.80	7.60 1.30	144.00 1.20	7147.30 6.00	100000.00 ---	--- ---	9.20	HA
MU$_3$	Stadium junction	115.6	5.4763 N7.5418	4	183.60 1.20	77.6 2.70	13123.60 30.00	678.90 ----	--- ---	--- ---	33.90	HK
MU$_4$	College of engineering	106.6	5.4765 7.5398	5	83.70 1.40	507.70 1.20	3981.20 5.70	4192.30 11.60	5640.70 ---	--- ---	19.80	A
MU$_5$	Liman hall	114.5	5.4768 7.5424	4	835.40 2.00	3894.60 5.02	249.7 16.60	4100000.00 ---	--- ---	--- ---	23.80	KH
MU$_6$	VC's lodge	136.8	5.4848 7.5476	5	704.70 1.20	14.90 1.80	804.40 2.60	4100000.00 478.90	1063.50 ---	--- ---	484.50	HAK
MU$_7$	University Gate	129.4	5.4803 7.5461	5	135.90 1.60	97.00 2.20	308.50 1.60	17161.50 12.10	38638.0 ---	--- ---	17.60	HA
MU$_8$	Mechanic workshop	136.8	5.4787 7.5464	5	136.40 1.10	15.40 2.10	85677.50 377.50	1344.70 48.10	2177.90 ---	--- ---	428.80	HKH
MU$_9$	Petrol station	120.2	5.4831 7.5451	5	88.60 0.60	2354.30 3.30	425.00 7.70	7284.60 18.20	100000.00 ---	--- ---	29.80	KHA
MU$_{10}$	American quarters	138.9	5.4878 7.5429	5	113.90 1.00	1104.80 20.90	294.50 9.20	526.50 22.70	41182.30 ---	--- ---	53.80	KHA
MU$_{11}$	VC's lodge(back)	126.3	5.4885 7.5461	5	744.00 1.10	210.20 5.90	2268.00 10.90	16528.30 108.00	8985.90 ---	--- ---	125.90	HAK
MU$_{12}$	Afrihub	121.3	5.4821 7.5426	6	3799.70 0.40	65.40 0.80	666.80 2.30	51.00 6.70	3276.10 12.40	61787.50 ---	22.60	HKHA
MU$_{13}$	Umbrella tree	102.3	5.4816 7.5400	4	247.00 0.70	1029.30 16.70	4649.30 42.20	287.80 ---	--- ---	--- ---	59.60	AK
MU$_{14}$	Bishop's house	90.9	5.4746 7.5438	5	130.10 0.60	1199.30 3.30	219.60 8.50	8387.60 23.20	46697.90 ---	--- ---	35.60	KHA

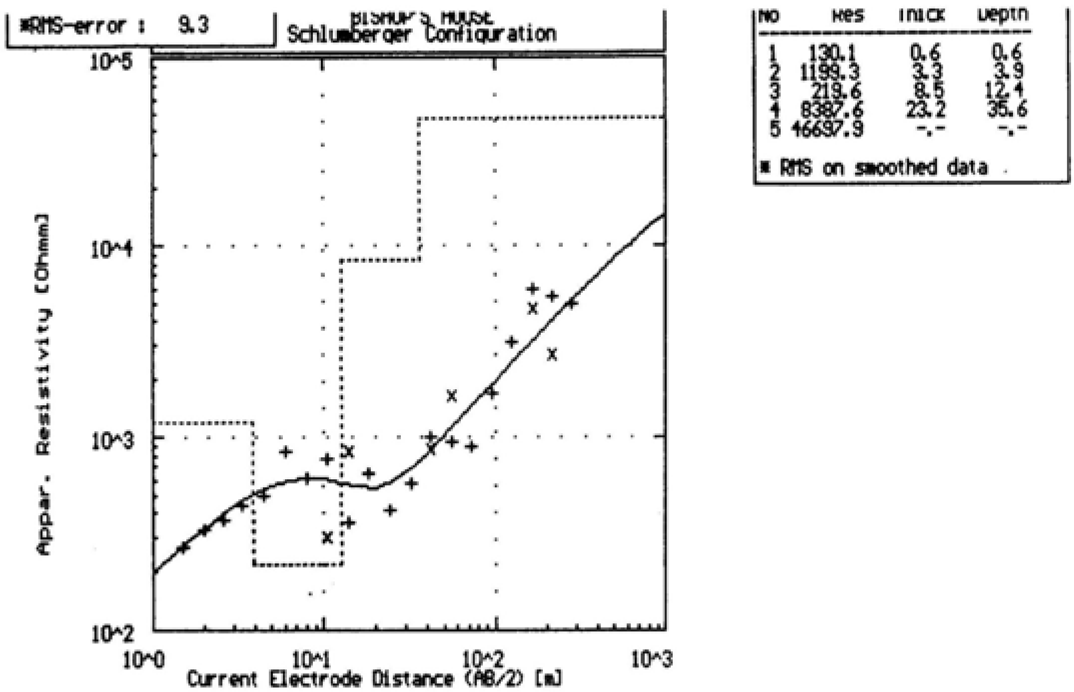

Fig. 4: Typical model representing (KH, KHA, AK) curve types at MU$_{14}$

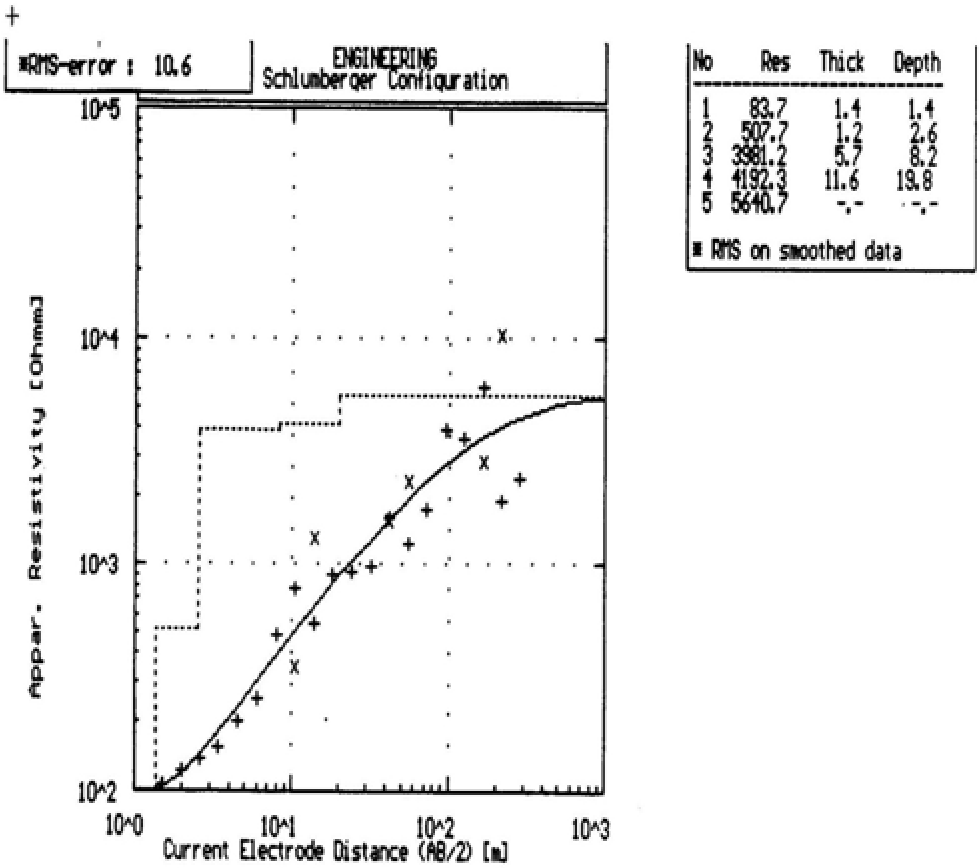

Fig. 5: Typical model representing (A) curve types at MU_4

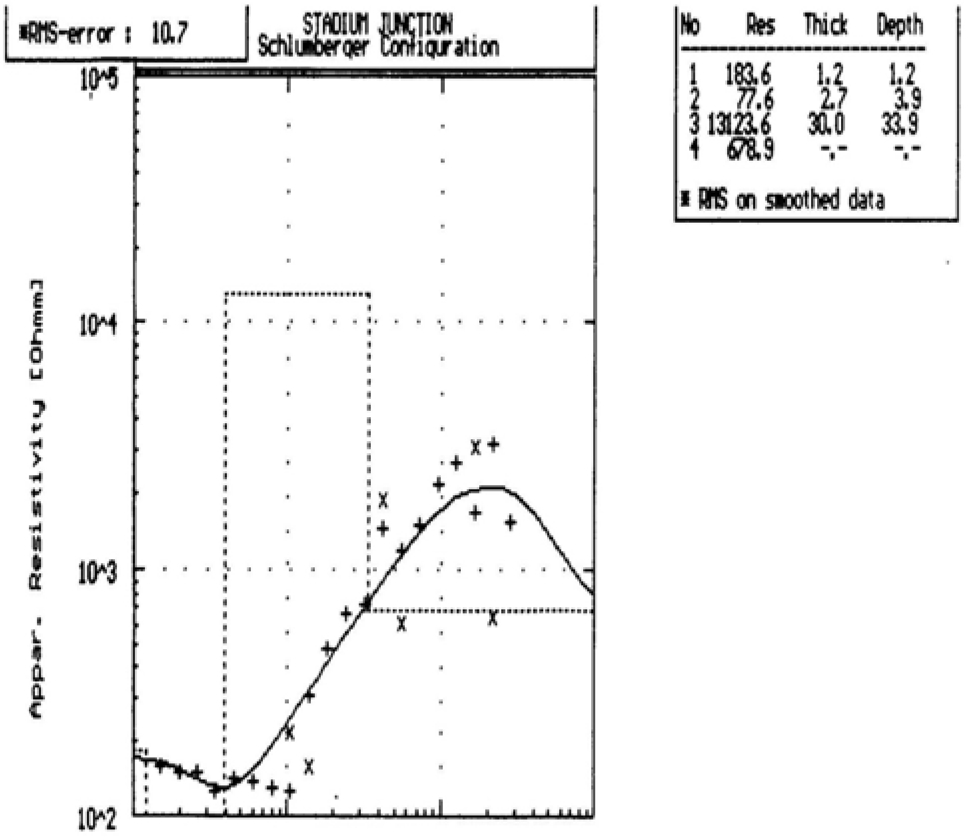

Fig. 6: Typical model representing (HK, HKH, HKHA) curve types at MU_3

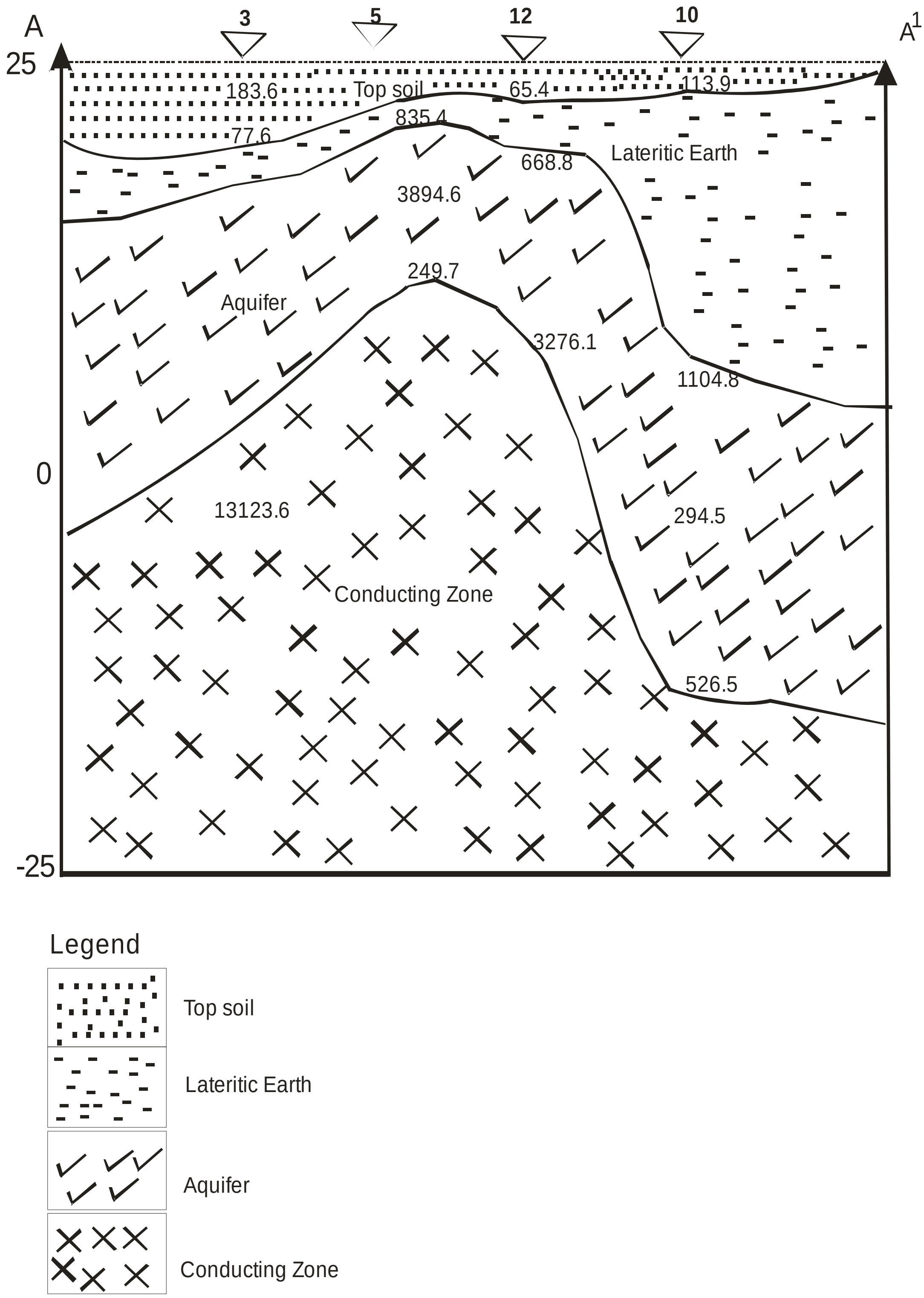

Fig. 7: Geoelectric section along AA[1] traverse in the area

In general, the knowledge of typical resistivity values for different types of subsurface materials (Table 1) and the geology of the study area is significant in converting resistivity picture into geologic information. Figs. 7-9 are the geologic sections drawn along the different profiles chosen within the study area. The lithologic log shown in Fig. 10 indicates broadly the depth penetrated and the lithologic sections. Correlating the geoelctric sections in Figs. 7-9 drawn from the resistivity value with the lithologic log shown in Fig.10, shows the depth of penetration and lithologic succession

In the study area where close interval readings were taken, three litho-and hydro-resistivity cross sections were drawn with each covering traverse AA[1], BB[1] and CC[1] as shown in Figs 7-9. The drawing of the profile was done through the use of resistivity values and depth from top to bottom.

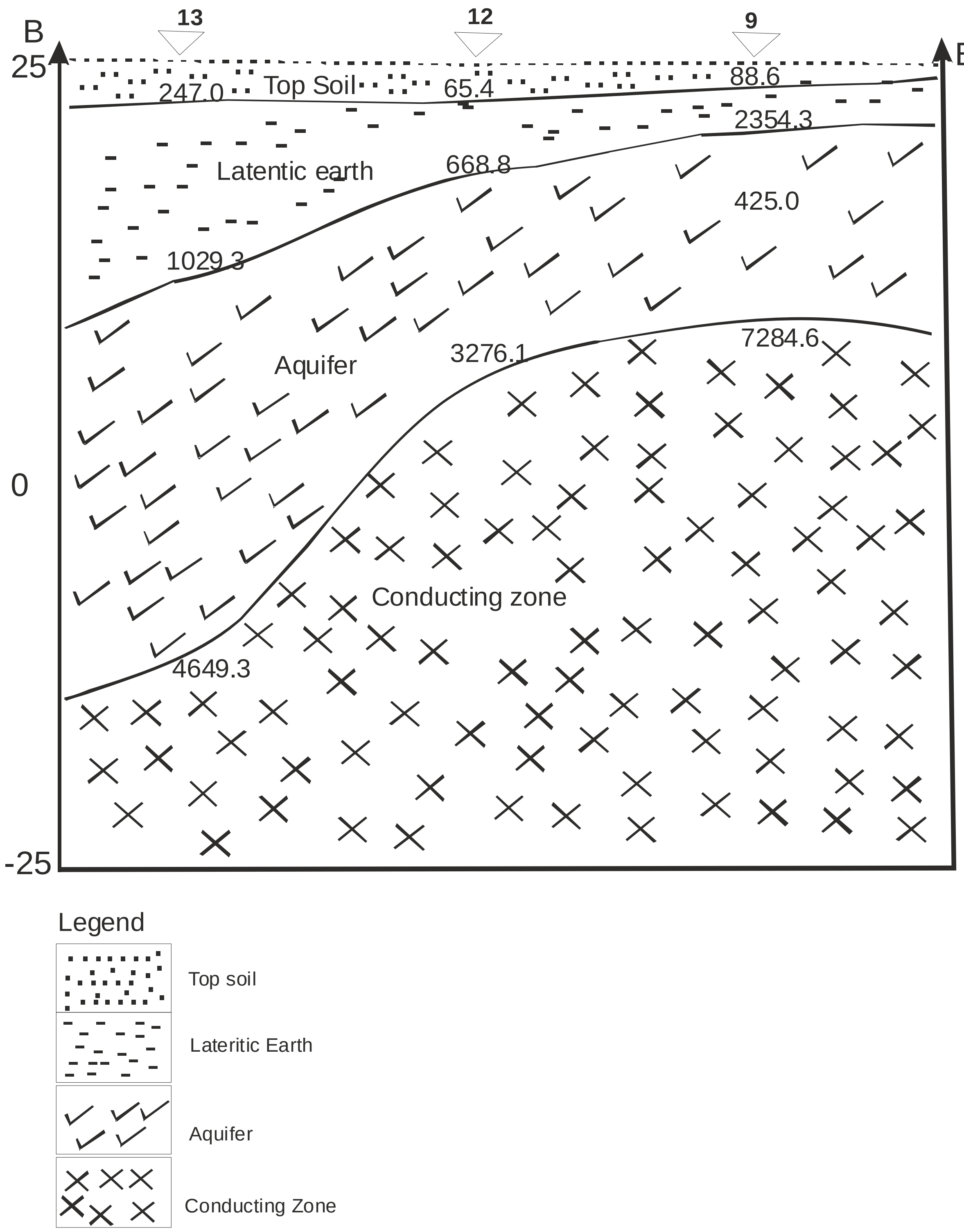

Fig. 8: Geoelectric section along BB[1] traverse in the area

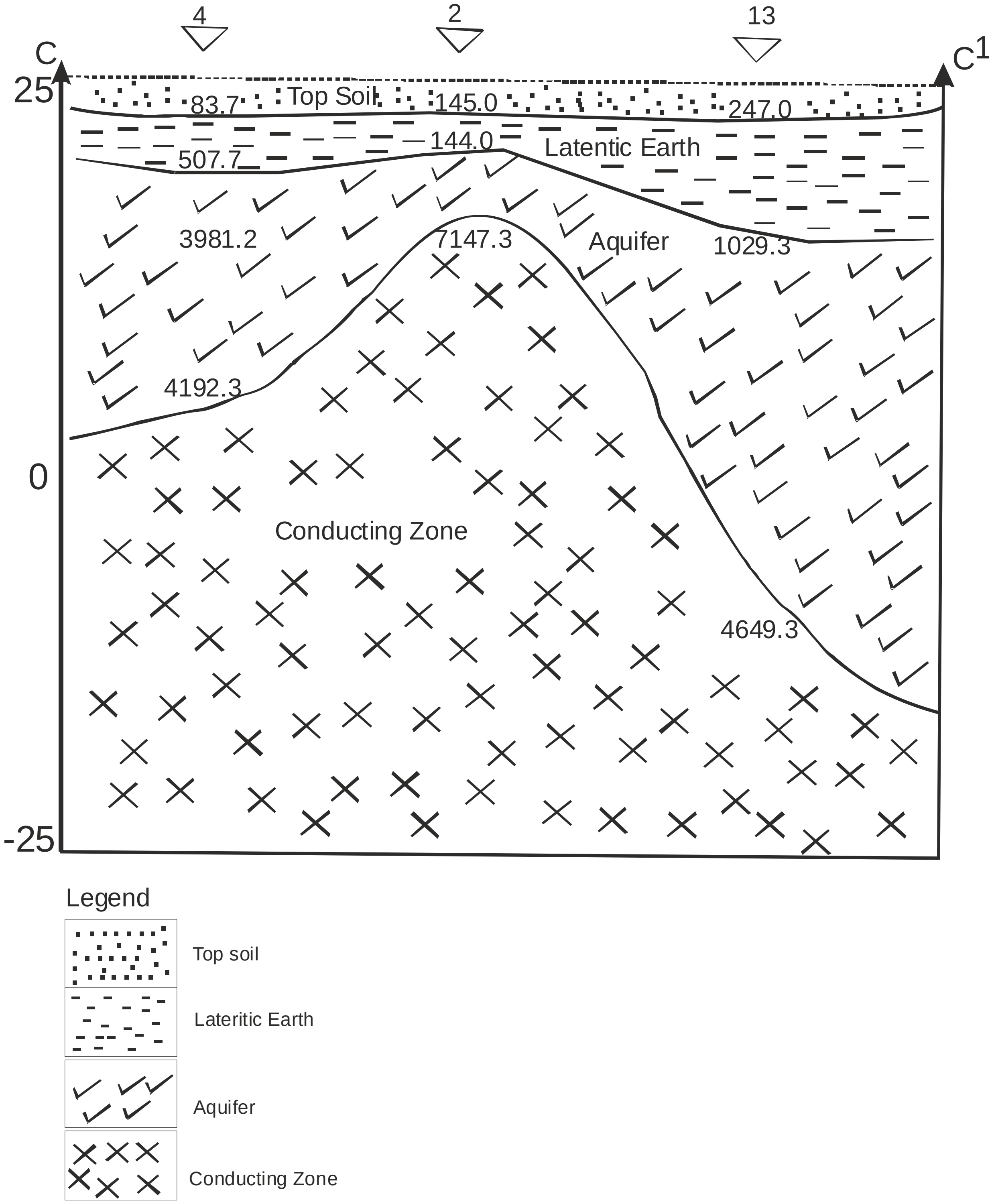

Fig. 9: Geoelectric section along CC[1] traverse in the area

AA[1] profile traverses the S-N of the study area covering four VES points (MU_3, MU_5, MU_{12} and MU_{10}). AA[1] profile shows four geoelectric layers and is characterized with HK, KH, HKHA and KHA curve types. The profile total thickness ranged from 22.60 to 53.80 m. The top layer has low resistivity values ranging from 65.40 to 183.60 Ωm, which is defined to be loamy. The second layer has resistivity values ranging from 668.80 to 835.40 Ωm which is lateritic sand. The third layer has resistivity values ranging from 249.70 to 3894.60 Ωm. The third layer is defined as medium grained sand (water bearing formation). The forth layer is defined as the conducting layer which is clay formation.

BB[1] profile traverses the W-E of the study area covering three VES points (MU_{13}, MU_{12}, and MU_9). BB[1] profile shows four geoelectric layers and is characterized with AK, HKHA and KHA curve types. The profile total thickness ranged from 22.60 to 59.60 m. The top layer has low resistivity values ranging from 88.60 to 247.00 Ωm, which is defined to be loamy. The second layer has resistivity values ranging from 668.80 to 2354.30 Ωm which is lateritic sand. The third layer has resistivity values ranging from 425.0 to 3276.10 Ωm. The third layer is defined as medium grained sand (water bearing formation). The forth layer is defined as the conducting layer which is clay formation.

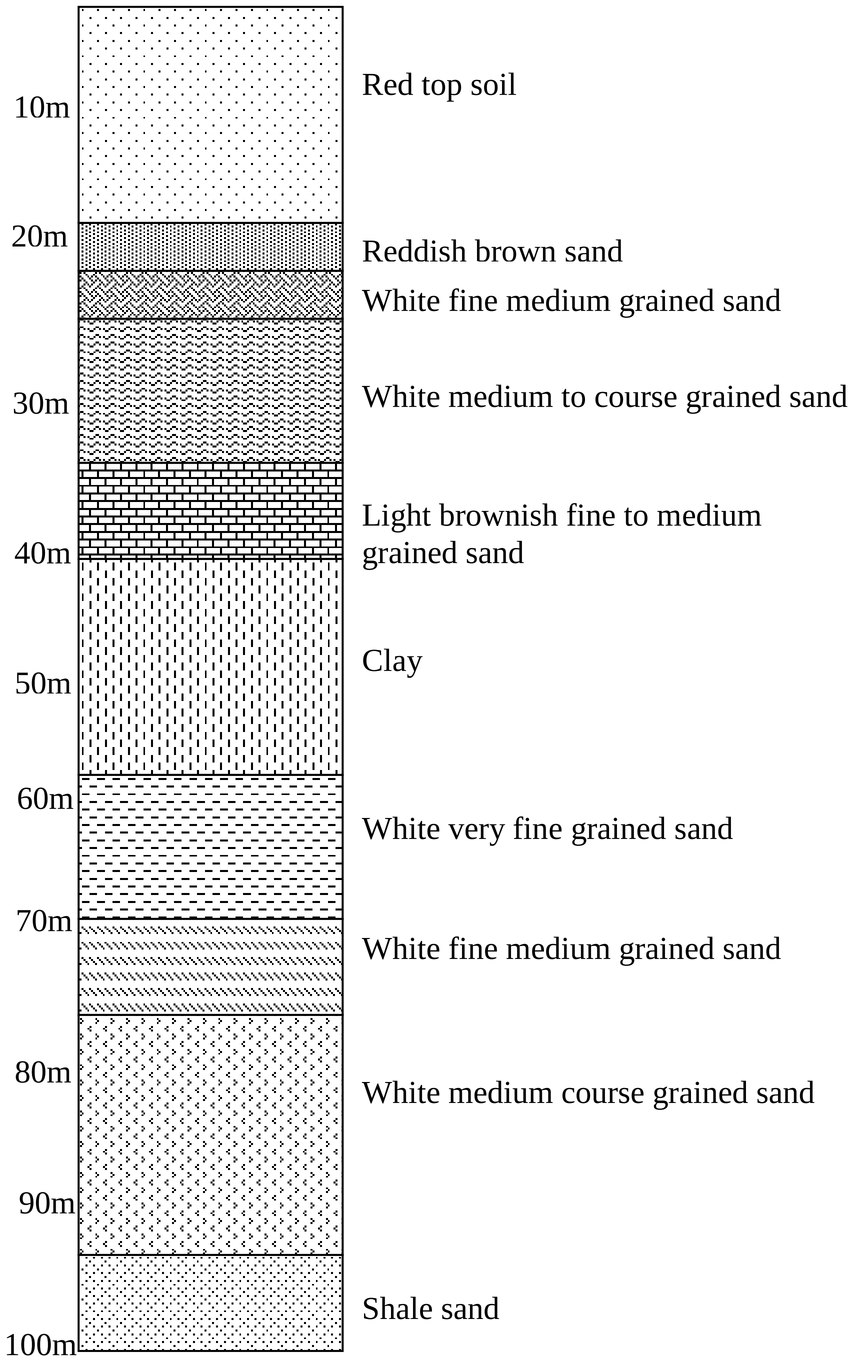

Fig. 10: Litholog of borehole at Michael Okpara University of Agriculture, Umudike (after Ebilah, 1994)

CC[1] profile traverses the SW-NE of the study area covering three VES points (MU_4, MU_2, and MU_{13}). CC[1] profile shows four geoelectric layers and is characterized with A, HAA and AK curve types. The profile total thickness ranged from 9.20 to 59.60 m. The top layer has low resistivity values ranging from 88.70 to 247.00 Ωm, which is defined to be loamy. The second layer has resistivity values ranging from 144.00 to 507.70 Ωm which is lateritic sand. The third layer has resistivity values ranging from 1029.30 to 4192.30 Ωm. The third layer is defined as medium grained sand (water bearing formation). The forth layer is defined as the conducting layer which is clay formation with resistivity values ranging from4649.30 to 7147.39 Ωm.

CONCLUSION

The lateral and vertical variations in the geoelectric columns which agree with the lithologic log indicate that VES profiles are useful method to investigate the lateral and vertical variation of subsurface lothology as well as subsurface hydrology. The high and low ranges of resistivities found in the geosections give the clue to the fact that the Benin Formations that are obvious in all the profiles are intercalations of different sandy units. Efforts should be made to examine the quality of water in the area because of the shallowness of aquifers in the area.

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