The Use of Vertical Electrical Sounding (VES) for Earthling Protection Design

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Abstract: *Application of Electrical Resistivity Method involving Shallow Vertical Electrical Sounding (VES) was carried out in four (4) selected locations within the premises of Federal University of Technology, Akure using the wenner array configuration with the aim of establishing suitable earthling medium in the area. At each location, five (5) vertical electrical soundings with a total spread of AB/3 = 12m were occupied with 'a' varying from 1m to 12m. The result reveals between three (3) to five (5) geo-electric layers which comprise of top soil, clay, sandy clay, and clayey sand and sand layer. The layer resistivity and thickness ranges between 10 -648 ohm-m and 0.04-5.94m respectively. The curve types obtained from the study area were predominantly H and KH types. The results reveal the points characterized by a reasonable clay horizon thickness that may serve the purpose of a good earthling medium/protective soil material in some of the locations.*

Keywords: *Wenner Configuration, Earthling medium and Clay horizon.*

1. INTRODUCTION

In electricity supply systems, an earthing system defines the electrical potential of the conductors relative to the Earth's conductive surface. Most electrical systems connect one supply conductor to earth (ground)[1].

The process of electrically connecting to the earth itself is often called "earthling". While electrical grounding may have originally been considered only as a safety measure, with today's advances in electronics and technology, electrical grounding has become an essential part of everyday electricity. Computers, televisions, microwave ovens, fluorescent lights and many other electrical devices, generate lots of "electrical noise" that can damage equipment and cause it to work less efficiently. Proper grounding can not only remove this unwanted "noise", but can even make surge protection devices work better.[2] Soil resistivity is the key factor that determines the resistance or performance of an electrical grounding system. It is the starting point of any electrical grounding design. Soil resistivity varies dramatically throughout the world and is heavily influenced by electrolyte content, moisture, minerals, compactness and temperature.[3]

The present study aim at evaluating the suitability of the area for the design of earthling system.

The objectives of the study are as follows:

- Delineating the subsurface geologic layers and determining the nature of the identified layers;

- To determine the thickness of the geoelectric layers within the study area.

- To determine the thickness of the low resistivity layer.

- To estimate the depth extent to the top of the low resistivity layer

- To determine from soil resistivity measurements, the nature of the soil and its suitability as an electrical system earthling medium

- On the basis of above evaluate the feasibility of the area for the design of earthling system.

2. SITE DESCRIPTION

The surveyed site (Figure.1) is situated at different locations within the Obanla of Federal University of Technology, Akure, Ondo State. The locations are back of Library, School of Environmental

Technology (SEET) car park, FUTA power substation and the front of Ogomudia research Laboratory denoted as locations 1 to 4 respectively (figures 2 &3). The location is linked by major and minor roads.
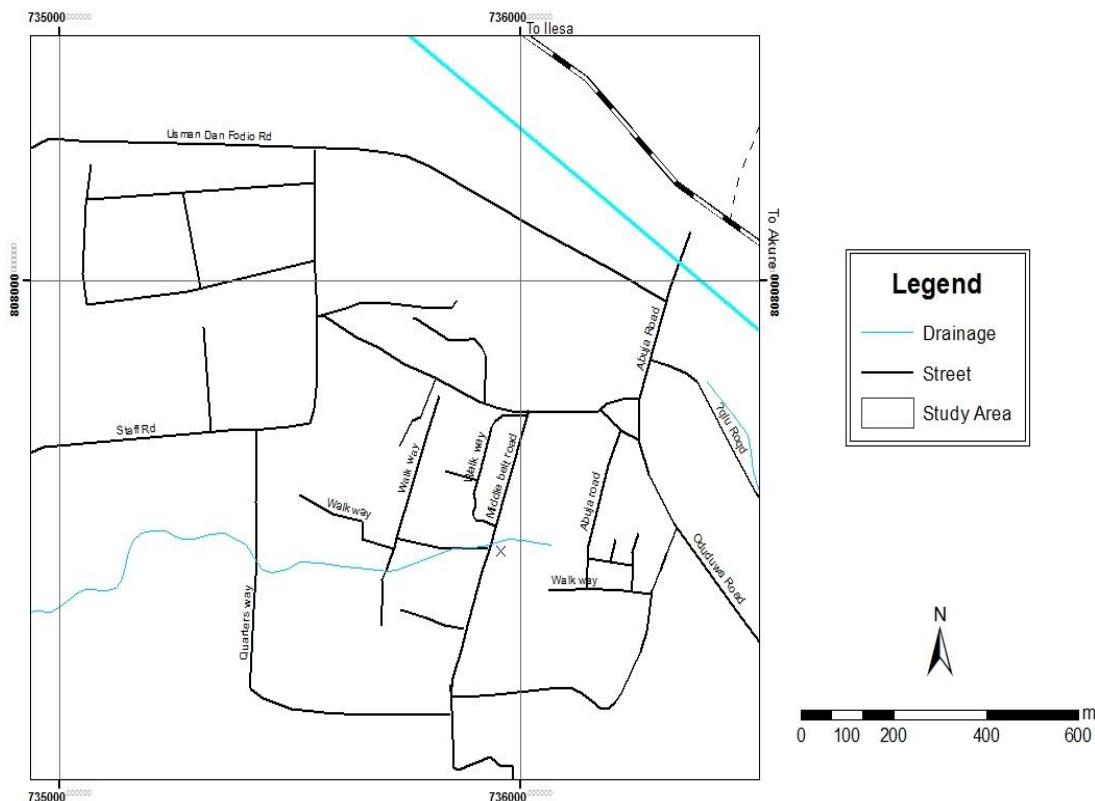

Fig1. *Location Map of Federal university of Technology, Akure*

3. GEOLOGY/GEOMORPHOLOGY

The area is underlain by the Precambrian Basement Complex rocks. The identified lithological units include quartzite bands, migmatite gneiss and biotite-granite. Locations 1 and 2 are predominanltly biotite granite while locations 3 and 4 are underlain by migmatite gneiss. The area is drained by small streams and its tributaries.
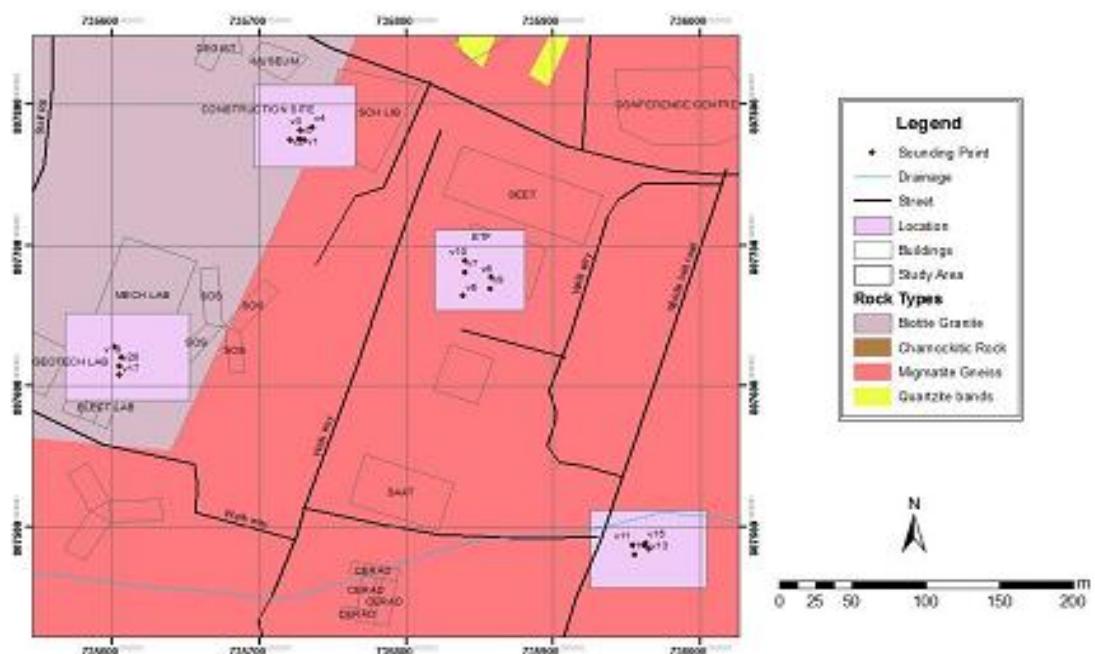

Fig2. *Geological map showing the rock types and the study locations. (Modified after Kareem,1995)*

4. METHODOLOGY

4.1. Geoelectrical Survey

Twenty (20) Vertical Electrical Soundings were conducted within the study area (Figure 3) using Ohmega resistivity meter. Wenner array was employed with electrode separations (AB/3) ranging from 1 to 12 m. The location of each sounding station was recorded in Universal Traverse Mercator (UTM) coordinates with the aid of a GARMIN 12 channel personal navigator (GPS) unit.

The soundings were spatially performed on each of the four locations and the apparent resistivity values were calculated. The apparent resistivity measurements at each station were plotted against electrode spacing (AB/3) on bi-logarithmic graph sheets. The curves were inspected to determine the number and nature of the layering. Partial curve matching was carried out for the quantitative interpretation of the curves. The results of the curve matching (layer resistivities and thicknesses) were fed into the computer as a starting model in an iterative forward modeling technique using RESIST version 1.0.[5] From the interpretation results (layer resistivities and thicknesses), were determined.
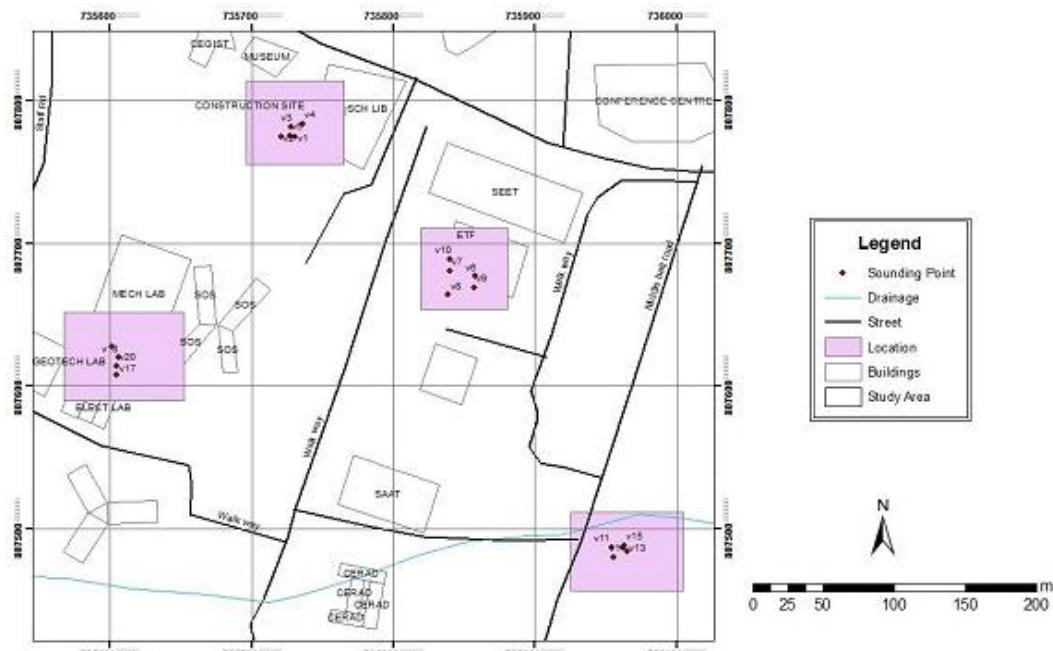
Fig3. *Data Acquisition map of the study Locations.*

4.2. Data Acquisition

The data acquisition involved two major field techniques viz: profiling and depth profiling. The geophysical methods utilized for the study is the Electrical Resistivity Sounding (ERS) Method. Twenty (20) Wenner VES stations were occupied scattered throughout the study (Figure 3). Measurements of ground resistance were made with the Ohmega resistivity meter. The VES data were interpreted quantitatively by partial curve matching technique. The multi-layered field curves were interpreted segment-by-segment using theoretically generated master curves and associated auxiliary curves. The interpretation results from partial curve matching were used as started model parameters in 1-D forward modeling involving RESIST version 1.0 software. The final interpretation results were used to prepare 1-d columnar sections. The Electrical Resistivity Sounding (ERS) utilized the Wenner configuration using Ohmega resistivity meter. The Current electrode spacing AB/3 range from 1m to maximum of 12m.

4.3. Data Presentation and Interpretation

The VES data were plotted as depth sounding curves and interpreted qualitatively and quantitatively. The qualitative interpretation was carried out by way of visual inspection to characterize the curves according to their signatures, which mirror the layering of the subsurface. The quantitative interpretation was effected through partial curve matching followed by computer iteration. The iteration was done with the aid of RESIST computer software.

4.4. Result Presentation

The geophysical data are presented as table, profiles, curves and maps. The VES data are presented as sounding curves i.e. plots of apparent resistivity as a function of the electrode spacing on the log-log paper. The depth sounding curves are shown in figure 4. The sounding curves are essentially H and KH types with maximum of three to five geoelectric layers. Other curve types in the locations include HA, QH, HK, HKH, A, and KHA. The interpretation of the sounding curves is quantitative. This involved partial curve matching and computer iteration methods which is based on Ghosh model.[4]

The layer parameters provide information on the layer resistivity and the layer thickness which is relevant in depth estimates of the overburden, the nature of the geologic layers and depth extent of relative low resistivity layer.

5. RESULTS AND DISCUSSION

The results of the study were presented as Sounding Curves, columnar sections, Maps, and profiles.

5.1. Vertical Electrical Sounding

The vertical electrical sounding curves were interpreted in terms of the subsurface geoelectric parameters (layer resistivity and thickness) at each of the four locations. These enabled the determination of the geoelectric layer thicknesses or depths to the rock head (or bedrock) beneath all the VES stations. The depths to the rock head beneath the sounding stations vary from 0.1 to 7.25m (Table 1). The overburden thickness is relatively shallow as a result of the length of spread and also penetrates deep enough to delineate the possible layer suitable for earthling.

5.2. Isoresistivity and Isopach Maps of the Study Area

Figures 5 and 6 show the isoresistivity and Isopach maps of the conductive layer which in most cases falls within the second and third layer. The maps were produced for each of the locations. The layer consists of clay, sandy clay, clayey sand and sand layer. Locations with relatively low resistivity (usually less than 100 ohm-m) in conjunction with appreciable thickness of greater than 2.5 m are areas suggested to support the design of the earthling system.
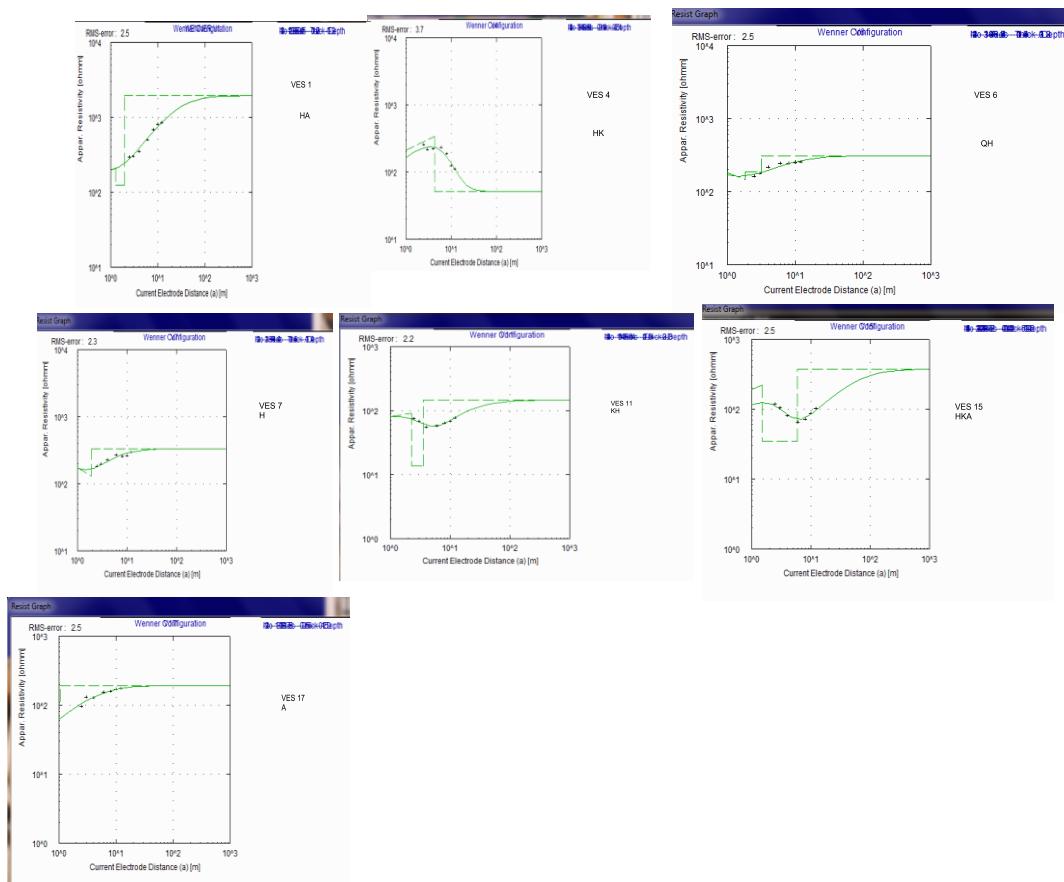

Fig4. *Typical Sounding Curves on the study area*

5.3. Isoresitivity and Isopach Map of the Second Layer

Figure 5 show the Isoresistivity and Isopach map of the second layer respectively for locations 1 to 4. At location 1, the resistivity of the second layer varies from 20 – 70 ohm-m with thickness ranging from 0.55 -3.75m. This reveals that the layer is predominantly clay. However, only VES 1 and VES 5 with resistivity 26 ohm-m , 23 ohm-m and thickness 3.75m and 3.22m respectively is suitable as an earthling medium in this location on the basis of their thickness.

The second layer resistivity of location 2 vary from 82-133 ohm-m with thickness ranging from 1.6-3.34m. VES 6-10 occupy this location. The second layer is composed of clay to sandy clay in this location. Due to the thin layers of clay medium in location 2, the VES positions are not suitable for earthling. However, VES 9 with resistivity of 133 ohm-m and thickness 3.34m could be made to be more conductive and thereby increasing its suitability as an earthling medium. The resistivity of the second layer in location 3 ranges from 34 to 300 ohm-m with layer thickness of 0.28 to 2.3m. From the information obtained from the second layer, this location is not suitable for earthling medium. The second layer of location 4 consist of VES 16 to VES 20 with resistivity ranging from 66 to 189 ohm-m and thickness 0.04 to 0.62m. The second layer in this location comprises of clay and sandy clay. The thickness of the second layer in this location suggest that the layer is too thin to be suitable as an earthling medium irrespective of the conductivity of the medium.
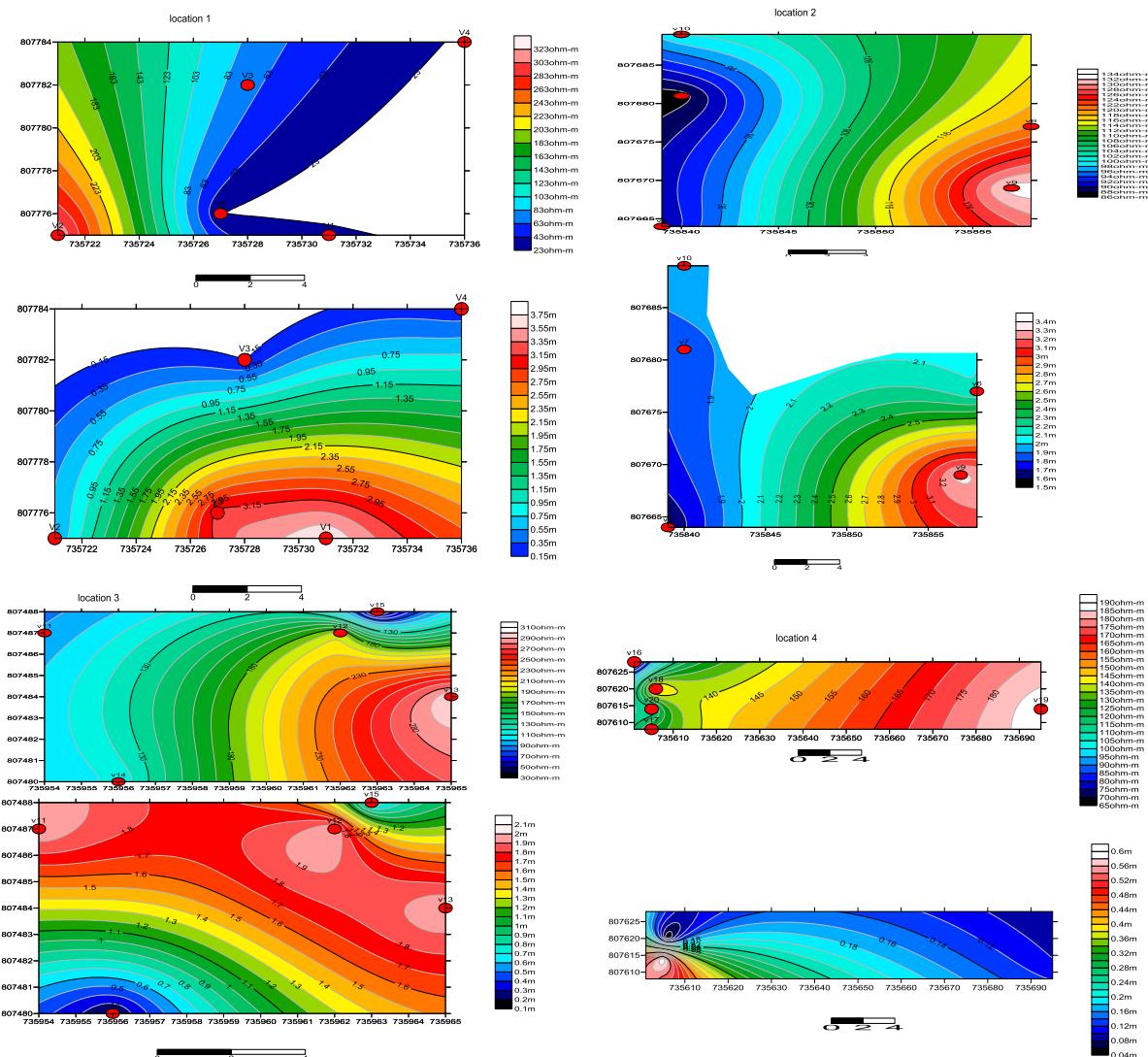
Fig5. *Soresistivity and Isopach maps of the second layer in locations 1 to 4*

5.4. Isoresitivity and Isopach Map of the Third Layer

Figure 6 show the Isoresistivity and Isopach map of the third layer respectively for locations 1 to 4. The resistivity of the third layer at location 1 varies from 10 – 204 ohm-m with thickness ranging from 2.73 -5.94m. This reveals that the layer is predominantly clay with VES 4 comprising of clayey

sand This suggest that location will serve as a good location for earthling medium especially VES 2 and VES 5. Location 2 third layer resistivity vary from 104-610 ohm-m with thickness ranging from 1.81m -∞. The thickness of the last layer is not defined beneath VES7 to VES 9 due to the third layer serving as the last layer. VES 6-10 occupy this location. The third layer is composed of predominantly sand except for VES 6 which is sandy clay. The higher resistivity value of the third layer (sand layer) is not suitable effectively to serve as a medium for an earthling system.

At location 3, the third layer resistivity vary from 16 to 237 ohm-m with thickness ranging from 1.1 to 3.3m. The layer composition ranges from clay to clayey sand with VES 11 to 13 predominantly clay with resistivity of 16 ohm-m, 16 ohm-m and 31ohm-m respectively with layer thickness of 1.10m, 2m and 3.3m respectively. On the basis of the medium being conductive and relatively thick, the third layer of VES 13 is the most suitable point that can serve as earthling medium in this location.

The third layer of location 4 consist of VES 16 to VES 20 with resistivity ranging from 26 to 400 ohm-m and thickness 0.21m to ∞. The third layer in this location is predominantly sandy except for VES 18 and VES 19 that is sand. The third layer in this location is not suitable as an earthling medium on the basis of the sand composition and thinness of the layers that are conductive.
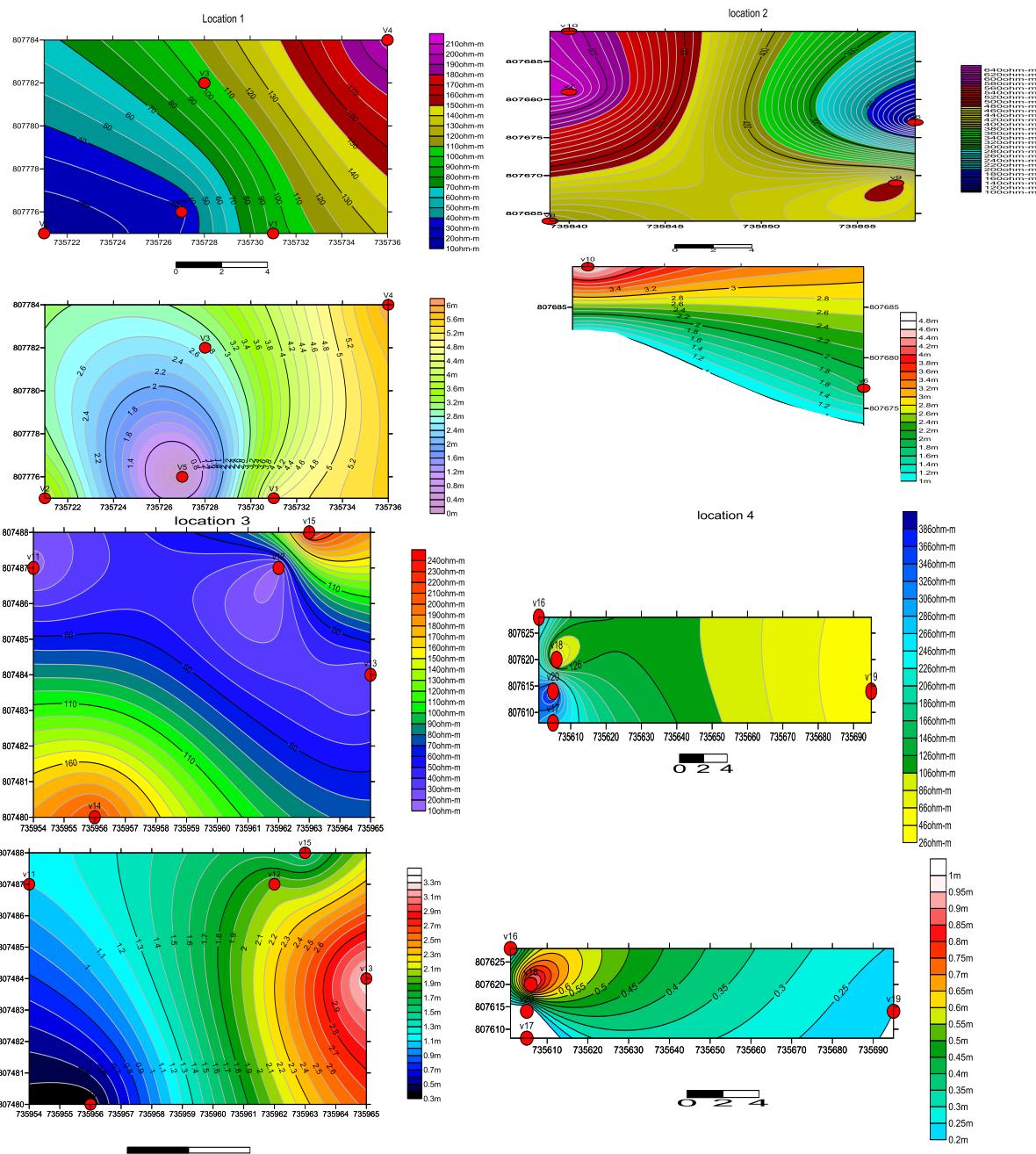

Fig6. *Isoresistivity and Isopach maps of the third layer in locations 1 to 4*

Table1. *Layer Parameters of the study area.*

Layer	Resistivity (ohm-m)	Thickness (m)	Depth (m)	Lithology	Curve Type	VES Point
1	130	0.25	0.25	Top soil	HA	1
2	26	3.75	4	Clay		
3	93	4.76	8.76	Clay		
4	135	–	–	Sandy clay		
1	146	0.32	0.32	Top soil	KH	2
2	321	0.55	0.87	Sand		
3	10	3.91	4.78	Clay		
4	210	–	–	Clayey sand		
1	90	0.50	0.50	Top soil	HA	3
2	70	0.15	0.65	Clay		
3	103	2.73	3.38	Sandy clay		
4	163	–	–	Sandy clay		
1	100	0.50	0.50	Top soil	HK	4
2	20	0.21	0.71	Clay		
3	204	5.94	6.65	Clayey sand		
4	180	–	–	Clayey sand		
1	70	0.34	0.34	Top soil	H	5
2	23	3.22	3.56	Clay		
3	27	–	–	Clay		
1	300	0.27	0.27	Top soil	QH	6
2	120	2.11	2.38	Sandy clay		
3	104	1.81	4.19	Sandy clay		
4	226	–	–	Clayey sand		
1	260	0.37	0.37	Top soil	H	7
2	87	1.85	2.22	Clay		
3	648	–	–	Sand		
1	160	0.23	0.23	Top soil	H	8
2	90	1.60	1.83	Clay		
3	400	–	–	Sand		
1	240	0.23	0.23	Top soil	H	9
2	133	3.34	3.57	Sandy clay		
3	490	–	–	Sand		
1	140	0.45	0.45	Top soil	HK	10
2	100	2.00	2.45	Clay		
3	610	4.80	7.25	Sand		
4	76	–	–	Clay		
1	66	0.30	0.30	Top soil	KH	11
2	92	2.00	2.30	Clay		
3	16	1.10	3.40	Clay		
4	164	–	–	Sandy clay		
1	140	0.80	0.80	Top soil	KH	12
2	196	2.00	2.80	Clayey sand		
3	16	2.00	4.80	Clay		
4	164	–	–	Sandy clay		
1	100	0.10	0.10	Top soil	KH	13
2	300	0.18	0.28	Sand		
3	31	3.30	3.58	Clay		
4	375	–	–	Sand		
1	140	0.24	0.24	Top soil	HKH	14
2	112	0.60	0.84	Sandy clay		
3	213	0.32	1.15	Clayey sand		
4	126	3.30	4.45	Sandy clay		
5	342	–	–	Sand		
1	100	0.25	0.25	Top soil	HKH	15
2	34	0.23	0.48	Clay		
3	237	1.50	1.98	Sand		
4	38	5.10	7.08	Clay		
5	336	–	–	Sand		
1	30	0.15	0.15	Top soil	A	16
2	66	0.20	0.35	Clay		
3	300	–	–	Sand		
1	42	0.40	0.40	Top soil	A	17
2	126	0.53	0.93	Sandy clay		
3	260	–	–	Sand		
1	50	0.15	0.15	Top soil	KHA	18
2	150	0.04	0.19	Sandy clay		
3	26	1.00	1.19	Clay		
4	300	0.51	1.70	Sand		
5	450	–	–	Sand		
1	54	0.18	0.18	Top soil	KHA	19
2	189	0.10	0.28	Clayey sand		
3	47	0.21	0.49	Clay		
4	329	0.30	0.79	Sand		
5	480	–	–	Sand		
1	30	0.22	0.22	Top soil	A	20
2	110	0.62	0.82	Sandy clay		
3	400	–	–	Sand		

6. CONCLUSIONS AND RECOMMENDATION

The geophysical results show three to five layers within the study locations. It is also worthy of note that the sounding did not get to the basement in most of the locations on the basis of the AB/3 being limited to 12m. This is because the aim of the research is restricted to a shallow depth of investigation. The geo-electric layers include the topsoil (Clay, clayey sand and sandy clay). The second and third layer (clay, sandy clay, clayey sand and sand). The fourth and fifth layer are generally clayey sand and sand in the locations. On the basis of the second layer, VES 1 and VES 5 are suitable earthling points in location 1 while locations 2, 3 and 4 are not suitable locations for earthling medium due to their relatively high resitivities (clayey sand and sand) and low layer thicknesses. However, the third layer suggest a better scenario where VES 1, VES 2 and VES 5 are suitable earthling points in location1. Location 2 has no suitable point that can serve as an earthling medium. At location 3, VES 13 is suitable as an earthling point while at location 4, no point is suitable as an earthling point. It is pertinent to note that in areas around the school of environmental car park (SEET) at location 2 and areas around Ogomudia Laboratory (location 4), the resistivity of the second and third layer which is supposed to accommodate the earthling electrode is resistive. Therefore, the conductivity of this medium in areas of low layer thickness and high resistivity can be enhanced. Any earthling materials buried in a resistive medium may not protect the instrumentation when there is a lighting or thunder-storm.

The results of the geophysical investigation has once again reveal the efficacy of geophysics as a tool in choosing suitable earthling medium and solving geological problems in our environment.

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