Integrated Geophysical Investigation Of Structural Failure Of A Building At Ido Local Government Secretariat Ibadan, Nigeria.

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Abstract: The House of Chief Building at Ido Local Government Council Secretariat Ibadan, which was commissioned in April 2008, has developed several cracks on its walls and floors, making it uninhabitable. The integration of Very Low Frequency (VLF) Electromagnetic and Electrical Resistivity methods were used to establish the effect of foundation on the failure of the building. Eight VLF traverses were laid across the building and its immediate surrounding for profiling in the N-S direction from where thirteen station points were selected for Vertical Electrical Sounding (VES) using the Schlumberger configuration. Three subsurface layers were delineated; the topsoil, clayey layer and weathered basement with resistivity values ranging from 88–416Ωm, 28–155Ωm and 256–7635Ωm respectively. The thicknesses of the top soil and the clayey layer ranged from 0.7–2.1m and 6.1–14.8m. Around the vicinity of the building, the resistivity of the weathered layer beneath the foundation was found to be low, ranging from 28–75Ωm typical of clayey materials. The compressible clayey formation underneath the building has led to differential sinking of the foundation which led to the cracks on its walls and floors.
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Keywords: Integrated Geophysical Investigation; Structural Failure; Building; Ido; Local Government; Secretariat Ibadan; Nigeria

Introduction

Structural failure in buildings has been a common occurrence in Nigeria in recent time particularly in the coastal cities with Lagos being at the fore front. The frequent collapse of some buildings in major cities in Nigeria can be attributed to the absence of a geotechnical investigation of the project site before, during and after the construction exercise (Amadi et. al., 2012). Oyewande (1992) observed that structural failure in buildings can be classified as design faults (50%), faults on construction site (40%) and product failure (10%). However, survival, durability and maintenance ability of a building are largely a function of the subsurface structure comprising the soil and the rocks on which the foundation is seated. This is because the live and dead loads of any structure are ultimately transmitted to the subsurface structures. Geophysical methods offer a fast, cheap and cost effective technique of investigating the subsurface formation for pre and post foundation studies. In Geophysical methods, the principles of Physics are applied to take systematic measurements near or at the surface of the earth to obtain information about the subsurface properties.

Various research works have been carried out in recent time with the use of electromagnetic and electrical resistivity methods in delineating the sub-structural formation. Ofomola et al. (2011) used the methods to investigate the cause of gradual failure of a section of Obanla Staff Quarters Buildings at Federal University of Technology, Akure, Nigeria and found that it was due to the presence of clayey sandy soil underneath the structure. Aigbedion (2007) used the VLF-EM method to investigate the incessant road failure along Opoji-Uwenlenbo-Ileh in Ekpoma, Nigeria. Popoola and Okhaifo (2012) evaluated the highway failure of part of Ibadan-Iwo road, a typical basement terrain, using the integration of VLF-EM and electrical resistivity methods. They discovered that the clayey formation of the failed portion of the road was the major cause of the incessant failure of the sections delineated. Raimi et al. (2012) used vertical electrical sounding for determining suitable sites for construction of boreholes for irrigation. Adiat, et al. (2009) also used VLF-EM and Schlumberger Vertical Electrical Sounding (VES) for road failures investigation in Igbara-Oke-Ibuji road which is also a typical basement complex in South-Western Nigeria. Hence Very Low Frequency Electromagnetic Method and Electrical Resistivity Method are found to be useful in site investigation, groundwater development especially in basement complex areas and also in foundation studies of building and roads.

This study was carried out to find out the effect of the sub-surface materials on the structural failure observed on the House of Chief Building at Ido Local Government Secretariat. The building (fig. 1) which was commissioned in 2008 has since developed several cracks on its walls and floor (fig. 2-4) and has been vacated owing fear of sudden collapse. A notable horizontal crack (fig. 2) on part of the wall seemed to be an indication of partial sinking of the foundation which could be due to insufficient load bearing capacity of the material underneath.

Figure 1: Grasses growing on the crack floors

Figure 2: Sign of differential settlement

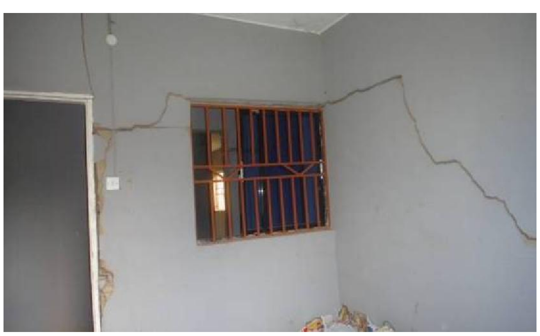


Figure 3: Cracks in one of the rooms

Figure 4: Cracks on the outside wall

Site Location

The House of Chief Building is one of the structures at Ido Local Government Secretariat, Ibadan, south-western Nigeria (fig. 5). The study area which comprised the building and its immediate surrounding occupies an area of about 100m by 100m. It lies within 3.7632^{0}E, 7.4737^{0}N and 3.7640^{0}E, 7.4741^{0}N. The elevation above sea level ranges from 211m to 229 m. The study area falls within the Precambrian Basement Complex rocks of South Western Nigeria characterised by mostly quartzite, granites, schist, gneisses, marble/limestone among others. The area is within the tropical rain forest belt, characterised by alternating wet and dry seasons with a mean annual rainfall of 1420.06mm. Relative humidity is about 74.55% and the mean maximum and minimum temperatures are 26.46°C and 21.42°C respectively (Wikipedia, 2007).

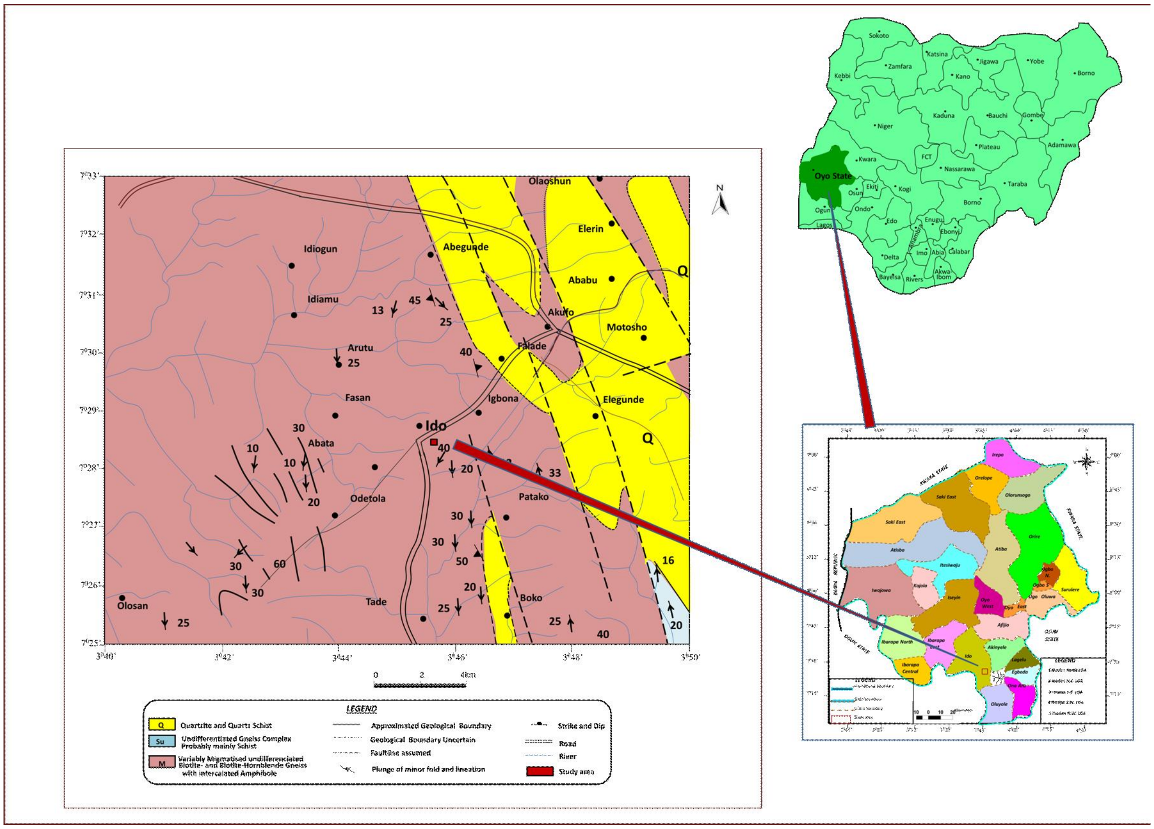


Figure 5: Geographical Location of the study area on the Nigerian map

Materials And Method Of Data Acquisition

The reconnaissance survey of the study area including the building and its immediate surrounding was carried as depicted in figure 6. The instrument employed for the VLF survey was the **ABEM WADI**, which measures the in-phase (Real) and quadrature (Imaginary) components of the induced vertical magnetic field as a percentage of the horizontal primary field. For the purpose of the investigation, eight geophysical traverses (T1–T8) were established. Traverses T1-T6 were laid across the distressed building while T7 and T8 were laid at distances 60m and 10m respectively away from the distressed building to serve as control traverses. The profiling technique was employed for the VLF-EM using a station separation of 5m along the traverses, perpendicular to the transmitter signal direction.

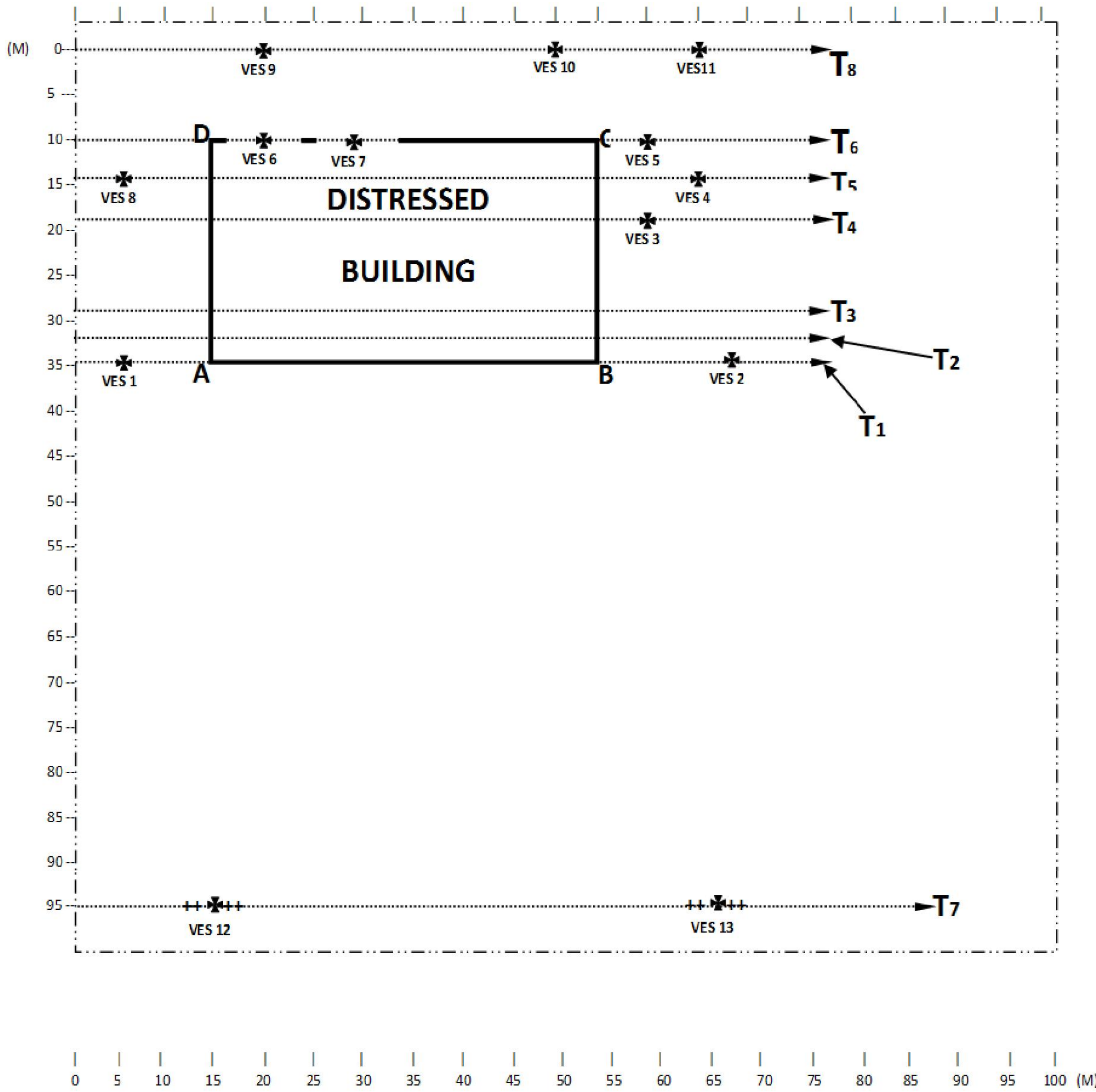
The equipment employed for the resistivity field data measurements was the **Resistivity Meter** (**Geopulse Meter)**. The vertical electrical sounding (VES) technique involving the Schlumberger array was adopted at selected points that showed high conductivity zones on the VLF profiles. Half current electrode separations (AB/2) varying from 1m to a maximum of 42m were used so as to be able to determine the depth to a competent level of the subsurface.

The **Global Positioning System (GPS)** meter was used to identify the geographical coordinates of each station point.

Data Processing And Analysis

Real and imaginary components of the VLF-EM measurements were obtained on with the WADI equipment and were treated in two stages using Microsoft Excel and Karous-Hjelt filtering software (KHFILT) to obtain the VLF-EM anomaly curves. Notable anomaly peaks (indication of high conductivity) along these profiles which fell outside the building were selected as VES station points (fig. 7-12).

The VES data were presented as geoelectric sounding curves by plotting the apparent resistivity ρ_a (Ωm) against the electrode spacing (AB/2). The curves were plotted on a bi-log paper and traced out on a transparent paper, all of which were iterated thereafter with WinResist software to generate theoretical curves (sample curves are shown in fig. 13-15). Matching the field curve with theoretical model curves gave the quantitative interpretation of the VES data. Surfer 9. lnk was used to generate the geoelectric sections underneath the distressed building by linking VES points along and across different VLF traverses.



LEGEND

✠ VES

++✠++ CONTROL VES

T_1 VLF TRANSVERSE

Note: THE TRAVERSE ARE IN NORTH-SOUTH DIRECTION

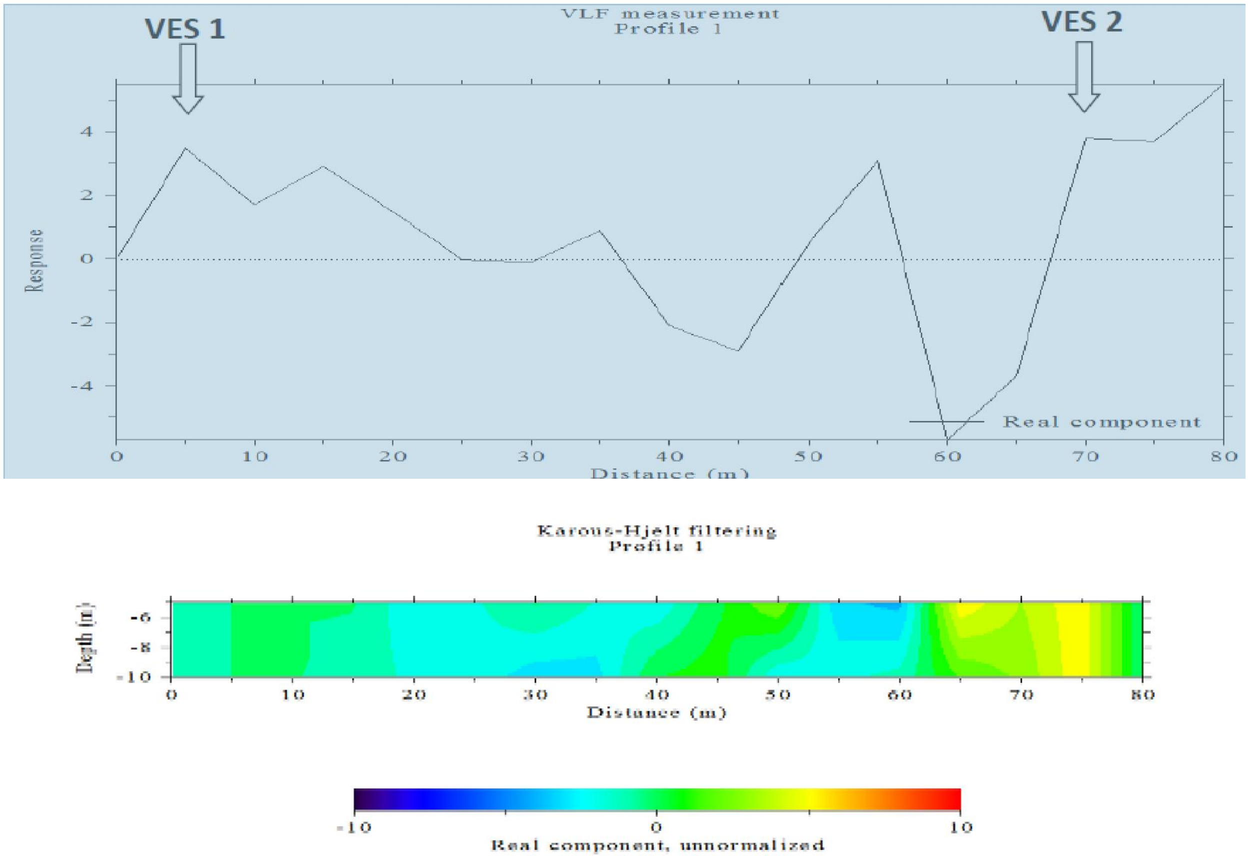


Figure 7: Profile 1 showing VES points and the Pseudo Section

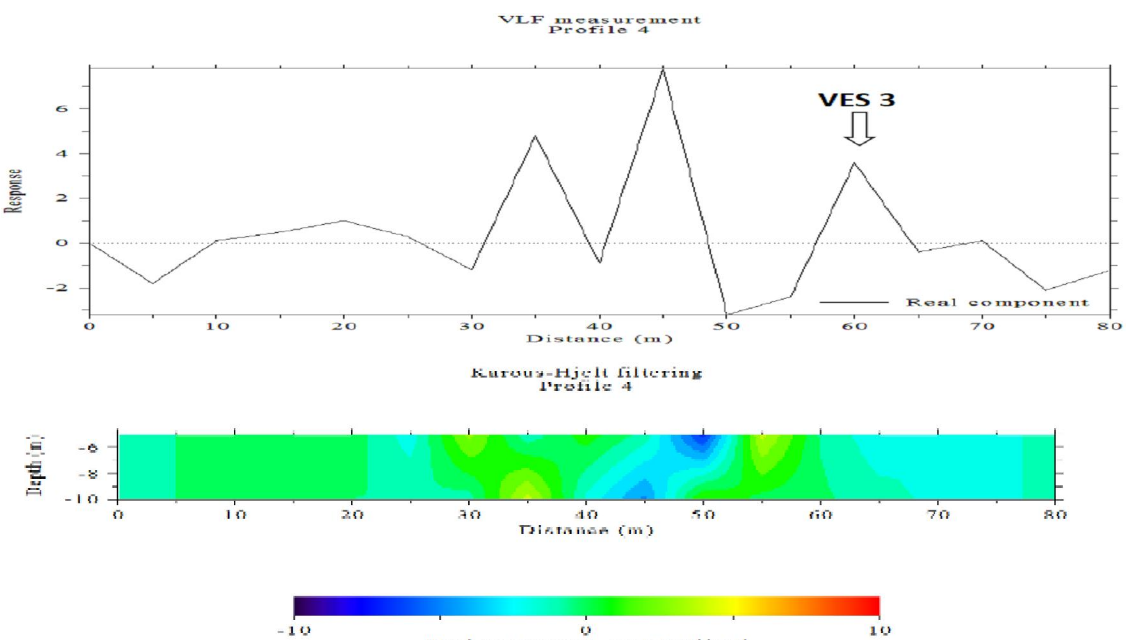


Figure 8: Profile 4 showing VES point and the Pseudo Section

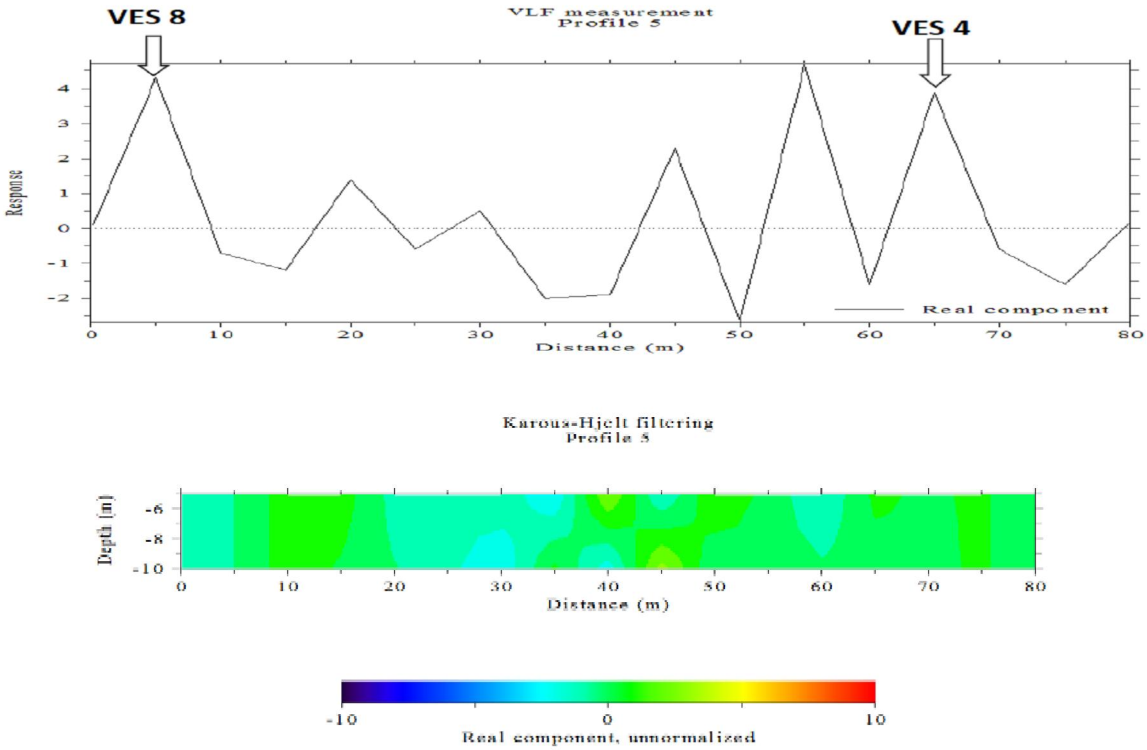


Figure 9: Profile 5 showing VES points and the Pseudo Section

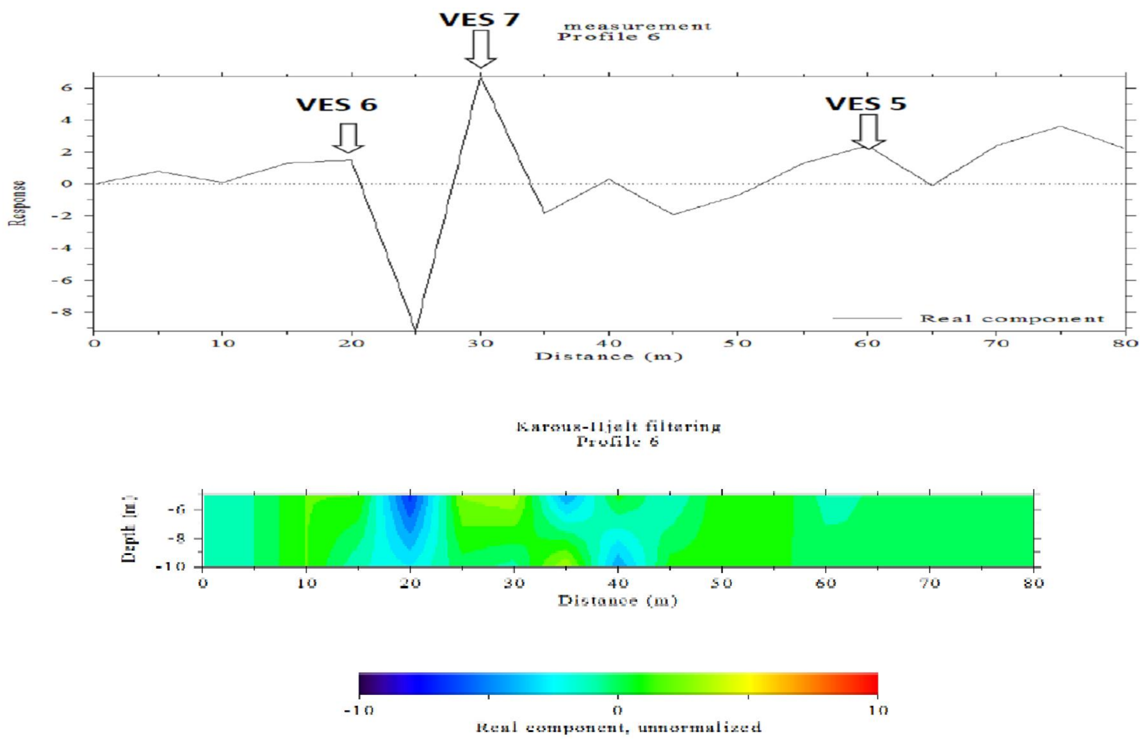


Figure 10: Profile 6 showing VES points and the Pseudo Section

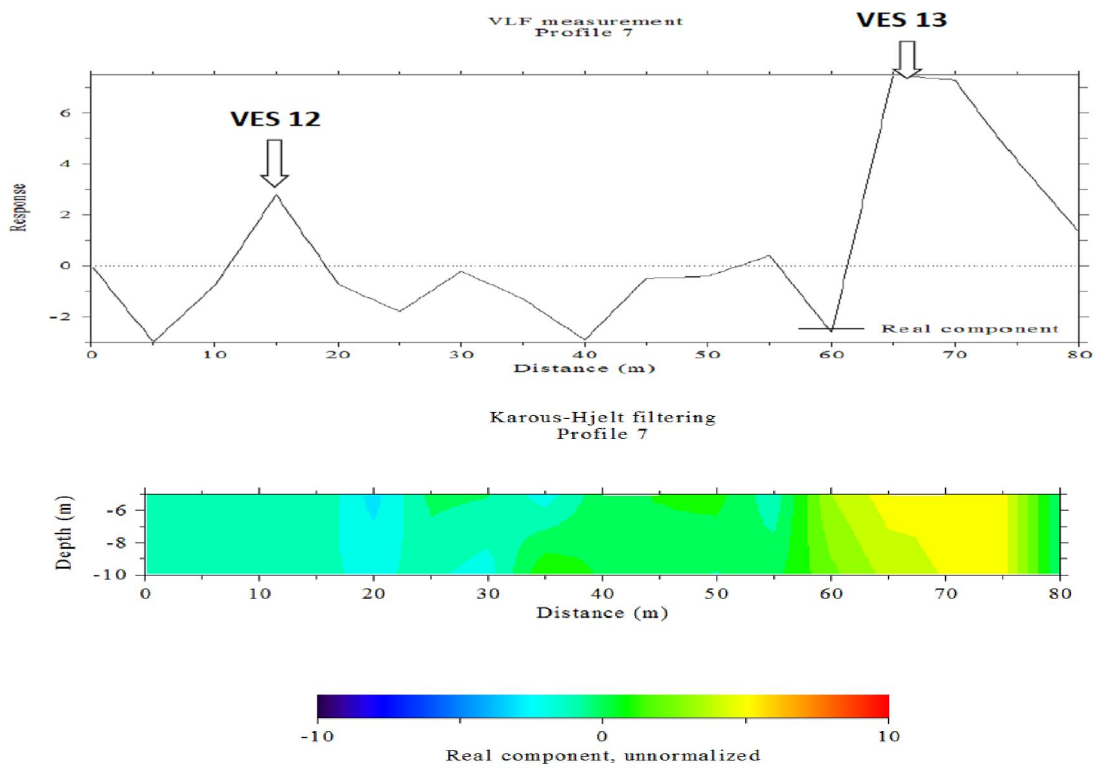


Figure 11: Profile 7 showing VES points and the Pseudo Section

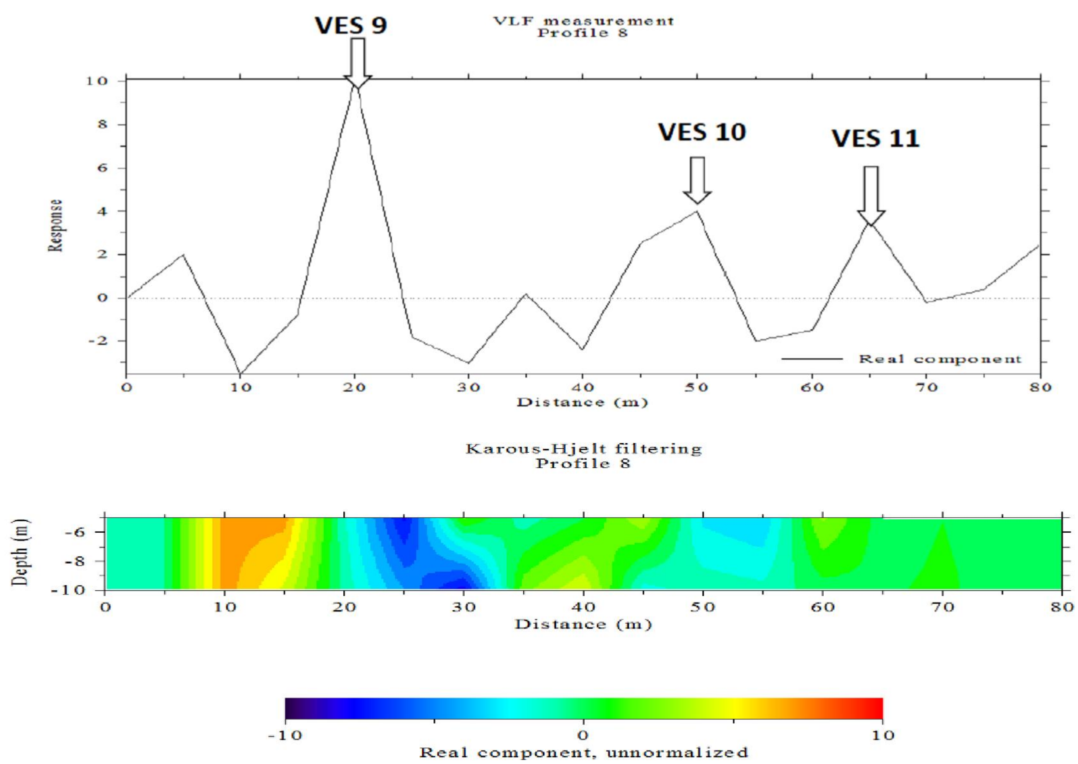


Figure 12: Profile 8 showing VES points and the Pseudo Section

Table 1: Lithological Interpretation of resistivity measurements.

VES	Layer	Apparent Resistivity/Ωm	Thickness/m	Depth /m	Lithologic Description	Curve Type
1	1	88.7	1.0	1.0	Top soil	H
	2	38.5	9.0	10.0	Sandy Clay	
	3	255.6			Weathered Basement	
2	1	111.6	1.5	1.5	Top soil	H
	2	47.8	7.9	9.4	Clayey sand	
	3	701.8			Weathered Basement	
3	1	347.6	1.3	1.3	Top soil	H
	2	47.3	6.8	8.1	Clayey Sand	
	3	2436.3			Fresh basement	
4	1	346.1	1.6	1.6	Top soil	H
	2	74.4	11.6	13.2	Clay Soil	
	3	3247			Fresh basement	
5	1	241.3	1.8	1.8	Top soil	H
	2	60.5	11.4	13.2	Clayey Sand	
	3	2451.4			Fresh basement	
6	1	155.2	1.2	1.2	Top soil	H
	2	49.5	10.9	12.1	Clayey Sand	
	3	1382.8			Fresh Basement	
7	1	135.1	2.1	2.1	Top soil	H
	2	28.6	6.1	8.2	Clay	
	3	377.2			Weathered Basement	
8	1	100.1	1.4	1.4	Top soil	H
	2	55.5	11.3	12.7	Clayey Sand	
	3	906.6			Weathered Basement	
9	1	104.6	1.3	1.3	Top soil	H
	2	68.4	15	16.3	Clayey Sand	
	3	933.1			Weathered Basement	
10	1	140.8	1.8	1.8	Top Soil	H
	2	57.6	11.6	13.4	Clayey Sand	
	3	1298.8			Fresh Basement	
11	1	415.7	1.2	1.2	Top Soil	H
	2	83.3	10.2	11.4	Clayey Sand	
	3	7635.3			Fresh Basement	
12	1	167.6	1.5	1.5	Top Soil/ Clay	H
	2	46.6	14.8	15.3	Clay Soil	
	3	621.6			Weathered Basement	
13	1	62.1	0.7	0.7	Top Soil	K H
	2	155.3	1.4	2.1	Clayey sand	
	3	31.5	6.9	8.0	Sandy Clay	
	4	1370.9			Fresh Basement	

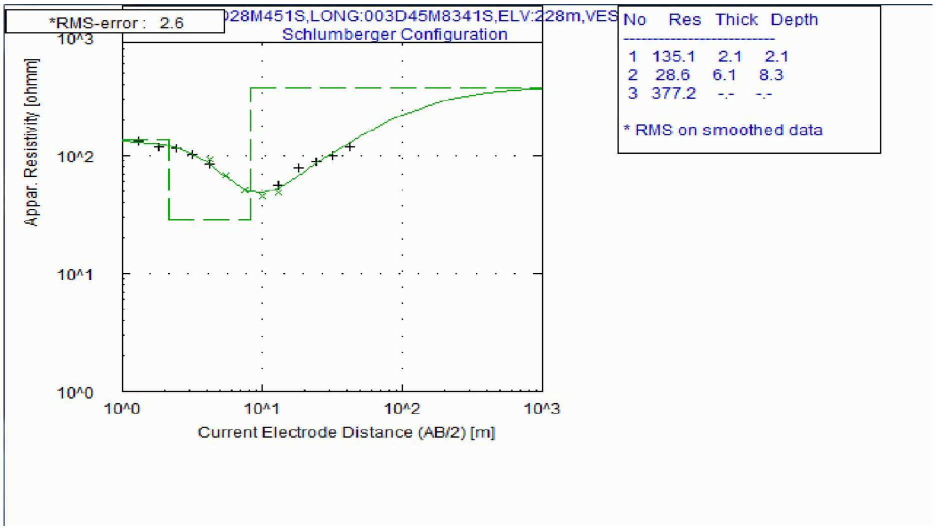


Figure 13: Sample vertical electrical sounding (VES 3) curve obtained

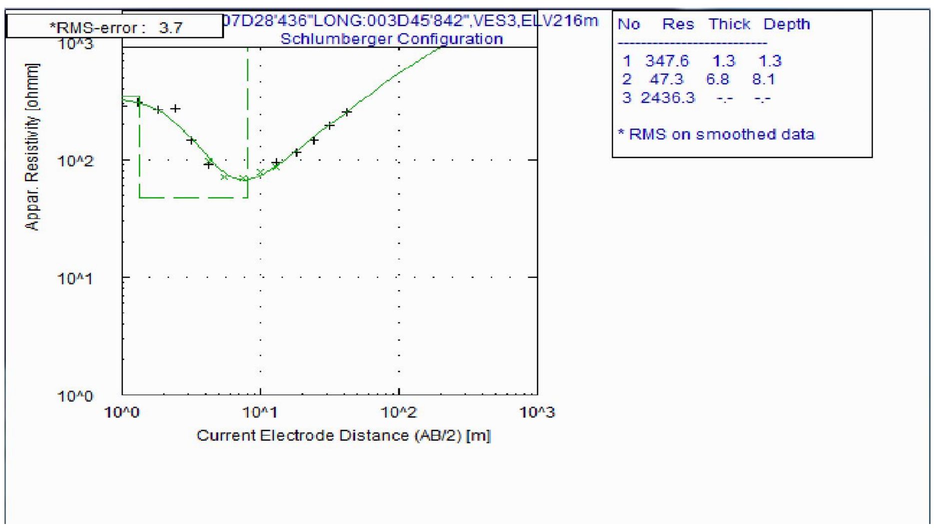


Figure 14: Sample vertical electrical sounding (VES 5) curve obtained

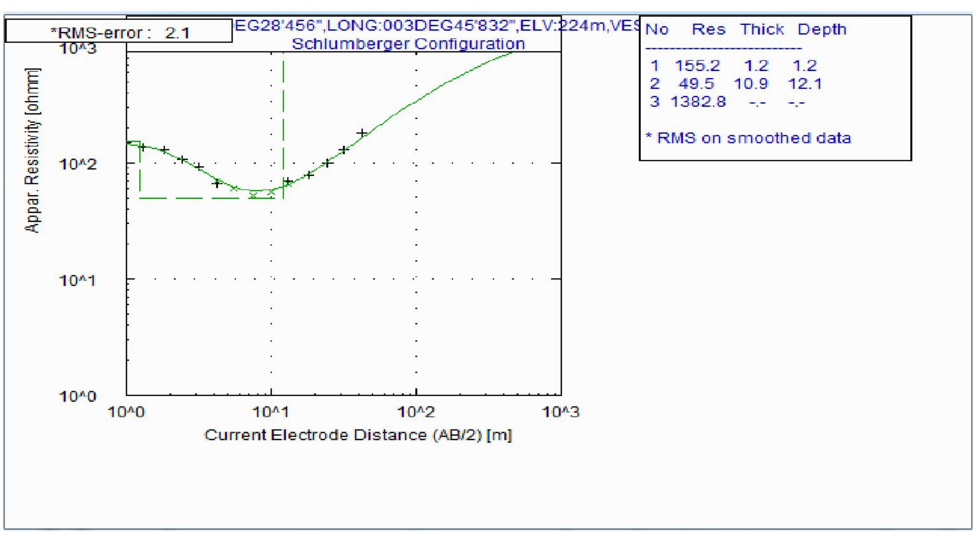


Figure 15. Sample vertical electrical sounding (VES 7) curves obtained

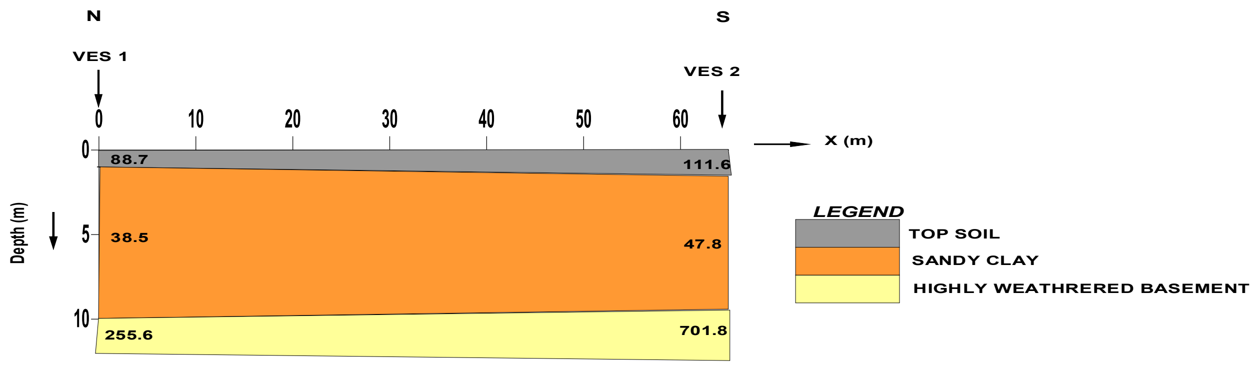


Figure 16: Geoelectric Section along Traverse 1

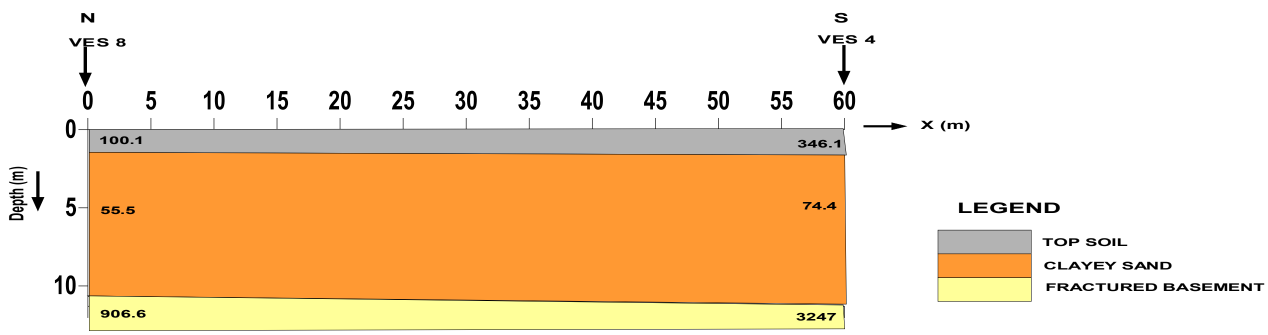


Figure 17: Geoelectric Section along Traverse 5

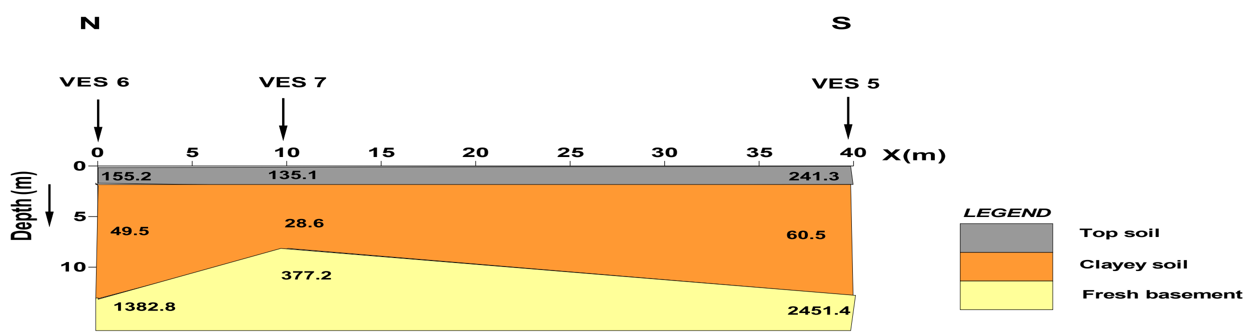


Figure 18: Geoelectric Section along Traverse 6

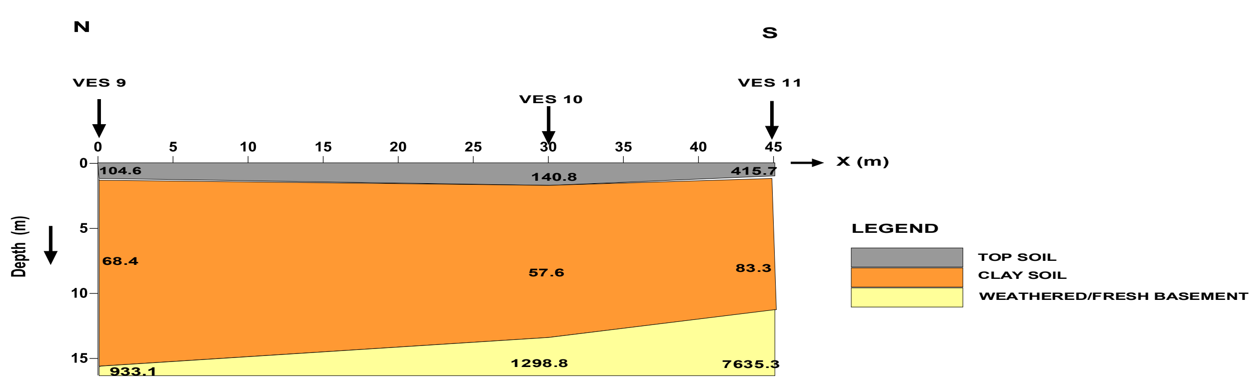


Figure 19: Geoelectric Section along Traverse 8

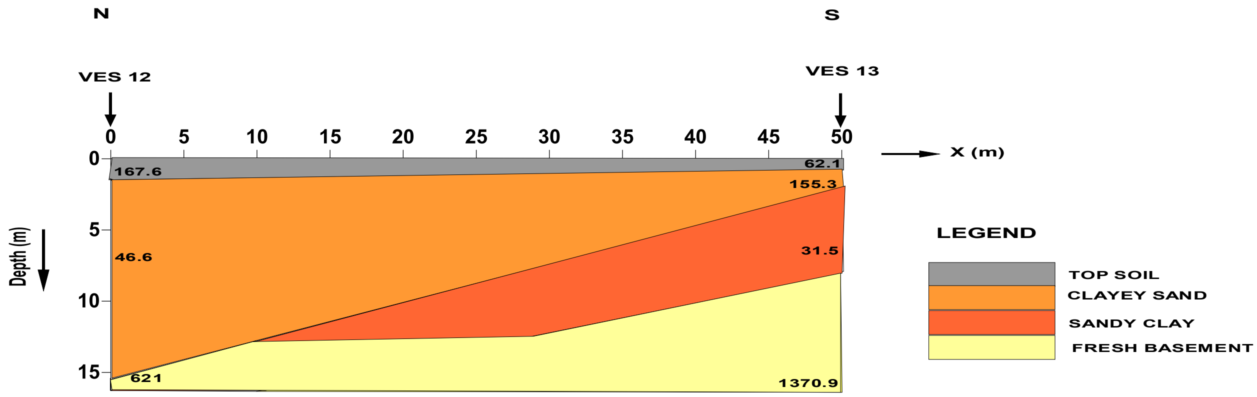


Figure 20: Geoelectric Section along Traverse 7

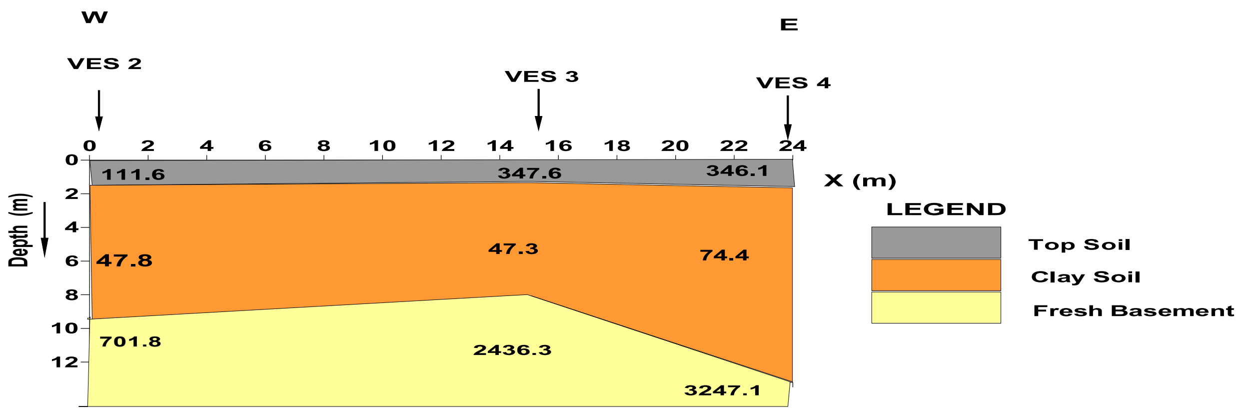


Figure 21: Geoelectric Section across Traverse 1, 4 and 5

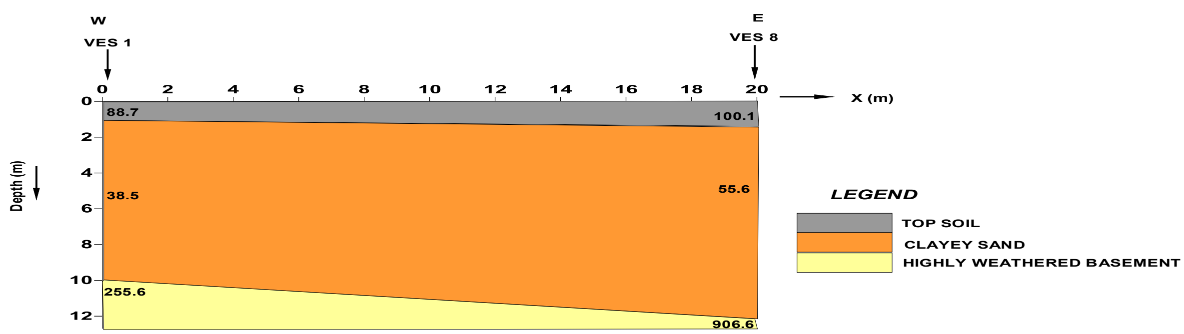


Figure 22: Geoelectric Section across Traverse 1 and 5

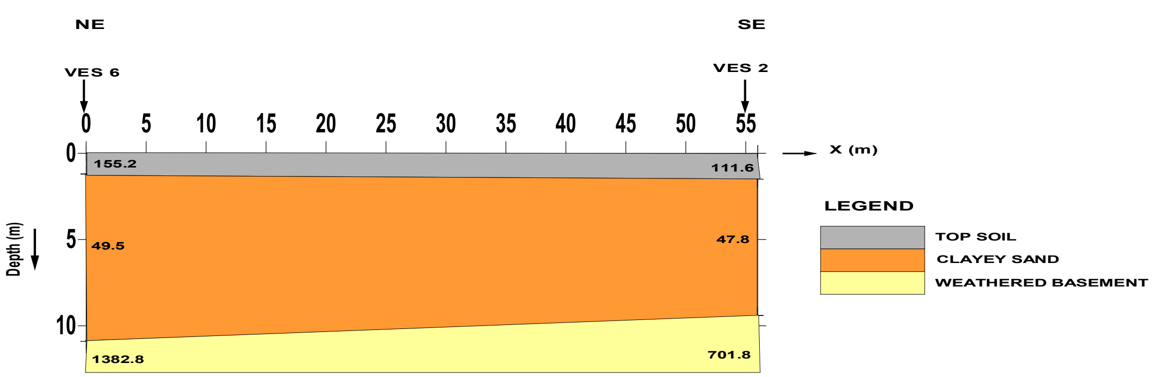


Figure 23: Geoelectric Section of VES 6 and 2

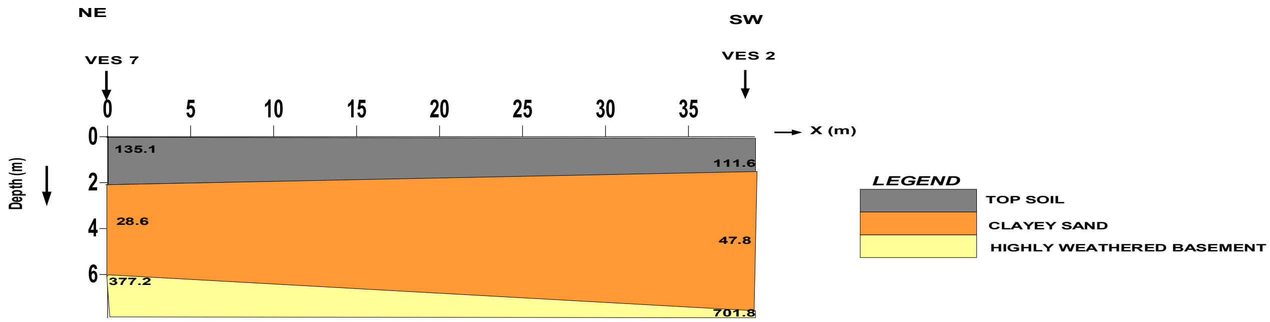


Figure 21: Geoelectric Section for VES 7 and 2

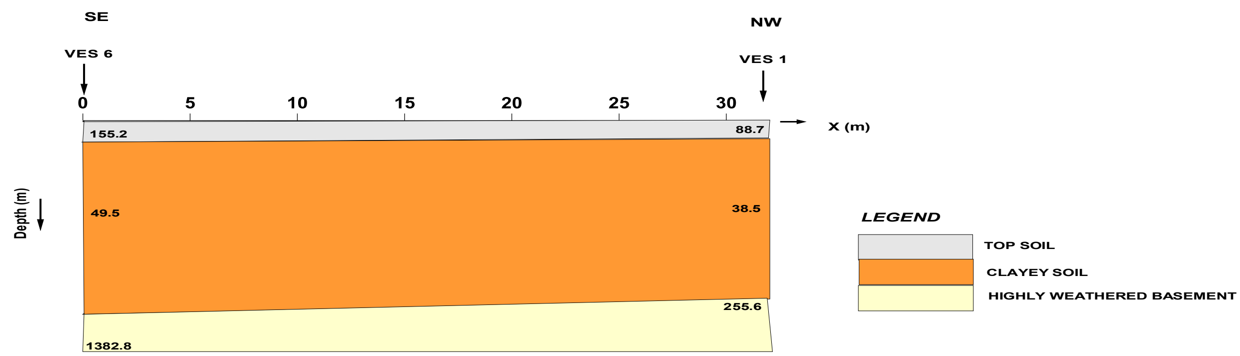


Figure 22: Geoelectric Section for VES 6 and 1

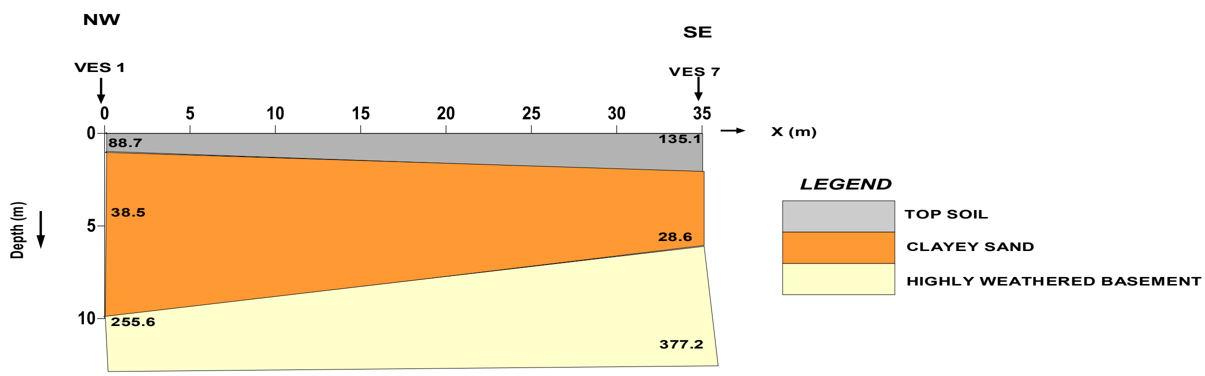


Figure 23: Geoelectric Section for VES 7 and 1

Results And Discussion

Samples of resistivity curves obtained from vertical electrical soundings are shown in figures.

13 -15. Two types of resistivity sounding curves, H (VES 1-12) and KH (VES 13) were obtained (table 1). The interpretations of vertical electrical soundings were based on the following assumptions:

i. All layers are horizontally stratified.
ii. The earth subsurface is made of layers with approximately constant resistivity values separated from one another by plane interfaces.
iii. Standard model of soil resistivity was used to deduce soil types from VES resistivity values.

The VLF survey revealed that the conductive zones were concentrated at the eastern section of the building along traverses T4, T5, T6 and T8. These were confirmed by the results of electrical resistivity measurements since the VES points all revealed layers with considerably low resistivity values. In particular, VES 7 spot which contained a layer of least resistivity of 28.6 Ω m and the highest peak on the VLF graph.

The geoelectric sections (fig. 16-23) provide the one dimensional imaging of the subsurface layers beneath and in the vicinity of the distressed building to a maximum depth of about 15 m Topsoil Layer Resistivity Map.

The resistivity of the topsoil varied generally from 62 – 416 ohm-m while the thickness varied from 0.7 – 2.1m. Underneath the distressed building, the topsoil layer resistivity varied from 88.7 – 28028 ohm-m. Zones within the topsoil where the resistivity values were less than 300 ohm-m are considered geotechnically incompetent to carry large engineering structures (Adesida and Omosuyi, 2005) At the depth of 5 m, resistivity varied from 28.6 to 155 Ωm around the distressed building. This is typical of clayey materials. Therefore at this depth, the Eastern part of the study area in which the distressed building is located is geotechnically incompetent to bear construction load. This material extended further to a depth of 10 m.

Conclusion

The interpretation of the geoelectric sections revealed the following as the possible cause of the failure:

1. Clayey nature of the soil on which the building was constructed. Clay, though highly porous, is less permeable owing to poor connectivity of its pores, retains water without releasing it thus makes it swell up and collapse at the exertion of pressure thereby leading to foundation failure.

2. Presence of near surface linear features such as faults, fracture and joints etc. in the subsoil beneath the building foundation which led to structurally weak zones that enhanced ground water accumulation and hence foundation failure.

3. Closeness of the weathered layer to the surface implies that the building foundation is resting within the water table.

Recommendations

1. It is recommended that the building should be marked for demolition to avert self destruction which may lead to loss of lives and property.

2. For reconstruction, the foundation must be reinforced with piles up to about 10m deep and a German-flooring is highly recommended. This will block seepage of water into the building floor.

3. To avert future occurrence, the services of the geotechnical experts should be engaged for pre foundation studies, which will act as a guide for the civil engineers before and during construction.

Reference

1. Adiat, K.A.N., A.O. Adelusi, and M.A. Ayuk. (2009). Relevance of Geophysics in Road Failures Investigation in Typical Basement Complex of South Western Nigeria". *Pacific Journal of Science and Technology.* 5(1):528-539.
2. Aigbedion I. (2007). Geophysical Investigation of Road Failure using Electromagnetic profiles Along Opoji, Uwenlenbo and Ileh in Ekpoma-Nigeria. *Middle-East Journal of Scientific Research* 2 (3-4): 111-115.
3. Amadi A. N., Eze C. J.Igwe C. O., Okunlola I. A. & Okoye N. O.(2012). Architect's and Geologist's View on the Causes of Building Failures in Nigeria. *Modern Applied Science.* 6(6): 31-38.
4. Ofomola, M.O., K.A.N. Adiat, G.M. Olayanju, and B.D. Ako. (2011). Integrated Geophysical Methods for Post Foundation Studies, Obanla Staff Quarters of the Federal University of Technology, Akure, Nigeria. *Pacific Journal of Science and Technology*. 10(2): 93-111.
5. Popoola O.I. and Okhaifo B.O. (2012). Evaluation of Highway Failure of a Portion of Ibadan Iwo Road, South Western Nigeria, using very low frequency Electromagnetic and Resistivity methods. *EJGE* Vol. 17: 2541-2554.
6. Raimi J., M. S. Abdulkarim., Hamidu I. and A. S. Arabi. (2011). Application of Schlumberger Vertical Electrical Sounding for Determination of Suitable Sites for Construction of Boreholes for Irrigation Scheme within a Basement Complex. *International Journal of Multidisciplinary Sciences and Engineering.* 2(6): 81-84.
7. Oyewande, B. (1992). A Research for Quality in the Construction Industry (June- July ed.). *Builder's Magazine*, Lagos: 120-161.

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