Geophysical Investigation into the Cause(S) of Structural Failure within Bacosa and Faculty of Science Buildings, Bowen University Temporary Site, Iwo

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ABSTRACT

Cracks on concrete and walls could be bothersome for quality of life and for property claims. Geophysical investigations was carried out around Faculty of Science and BACOSA buildings of Bowen University Temporary site, Iwo with a view to establish the possible cause(s) of failure of buildings within the study area.

The geophysical methods used for the investigation were the Very Low Frequency Electromagnetic (VLF-EM) and the Electrical Resistivity (ER) methods. The VLF-EM measurements were taken at an interval of 10m along six traverse lines in the E-W and S-N directions. From the result of the VLF-EM, six VES stations were occupied in the study area involving Schlumberger configuration with half current electrode separation (AB/2) varying from 1 to a maximum of 65m. The 2-D VLF-EM models generated showed a network of suspected linear (geological) structures such as fractures, faults and contacts within the study area.

The VES curve types obtained in the area include HA, KH, QH and AA with HA type curve dominating. Four subsurface geologic layers were delineated in the study area. These include the topsoil, weathered layer, clayey sand and fresh basement with resistivity ranging from 121.3 to 771.2 ohm-m, 134.4 to 595.8 ohm-m, 81.6 to 951.9 ohm-m and 1474.7 to 5134.4 ohm-m respectively. The thickness range from 0.5 to 2.4m, 1.8 to 9.8m and2.7 to 24.5m. Depths to the bedrock are generally less than 40m. The resistivity of the weathered layer beneath the topsoil in which the foundation is seated was found to be low within the study area, ranging from 134.4 to 595.8 ohm-m typical of clayey materials.

From the models generated from VLF-EM and resistivity data, the distressed structures were found to be situated within the areas with a fairly high concentration of fractures, faults and contacts and relatively low resistivity values(less than 1000 ohm-m) typical of incompetent clayey formation.

Keywords: Geophysical investigation, Structural failure, Electrical resistivity, Depth to bedrock, Foundation, Very low frequency electromagnetic, VLF-EM

1. INTRODUCTION

The incessant incidence of foundation failure of structure is becoming alarming in Nigeria. This failure has been attributed to a number of factors such as inadequate information about the soil and the subsurface geological material, poor foundation design and poor building materials (Fatoba et al. 2010). This has led to the loss of life and lots of goods and properties worth millions of naira aside from the cost of rehabilitation or complete redesign and reconstruction at much higher cost.

Structural failure is said to have taken place when there are unacceptable differences between expected and observed performance of any structure (Egwuonwo, 2012). Structural failure ranges from settlement, upthrust and total collapse. Some earth materials, due to their nature, cannot support solid and rigid structure; among these are clay and clay-bearing earth. Similarly, earth materials such as sands and fresh basement rock provide firm support for solid foundation.

Common structural failures in the world today include the failure of bridges, dams and the failure of buildings, which is the most common of all. Building failures can be considered to have occurred in a component when that component can no longer be relied upon to fulfill its principal functions. Limited deflection in a floor which causes a certain amount of cracking and distortion in portions could reasonably be considered as defects, whereas excessive deflection resulting in serious damage to partitions, ceilings and floor finishes could be classified as utter failure (Akintorinwa et al.2010, Akintorinwa and Abiola, 2011).

Foundation of any structure is meant to transfer the load of the structure to the ground without causing the ground to respond with uneven and excessive movement. Investigation into structural failures are therefore not only expected to identify trends leading to structural safety problems but are also expected to suggest solution(s) against the trend. To this end, geophysical methods besides geotechnical approaches are routinely used for foundation investigation. The geophysical methods that suites such investigation are the electrical resistivity, seismic refraction, gravity, magnetic and very low frequency electromagnetic methods (Sunmonu and Alagbe, 2011).

In this study, electrical resistivity and very low frequency electromagnetic methods were used to investigate the likely causes of structural failures which manifest themselves as vertical cracks on the wall of buildings around BACOSA and Science Laboratory Buildings (Figures 1to 8). The electrical resistivity method usually furnishes the engineers information about the depth to the bedrock, the composition of geoelectric layers and the trend/nature of geological fissures that can jeopardize or threaten the life span of the structure while the VLF is used to study the distribution of fractures which normally reveal themselves as conductive zones within the subsurface (Alagbe, et al, 2013).

2. MATERIALS AND METHODS

2.1. Very Low Frequency Electromagnetic (VLF - EM) Method

The instrument used for the VLF profiling is the Abem Wad. A total of six transverse were established in either west to east or north to south directions. The reading was recorded at an interval of 10metres.

VLF-EM is an inductive exploration technique that is used in mapping shallow subsurface structural features in which the primary EM waves induces current flow (Sharma, 1997, Adelusi et al, 2009). Although both the real and quadrature component of the VLF-EM were measured, the real component data which are usually more diagnostic of linear features were processed for qualitative interpretation.

The VLF data i.e. real and filtered real components of the EM fields measured were subjected to Fraser (1983) filtering to increase the signal to noise ratio of the data set and enhance the anomaly signature. The real and filtered real (Karous and Hjelt, 1983) components were plotted against station positions. A 2-d inversion of real component data was also carried out using the same software.

2.2. Electrical Resistivity Method

The electrical resistivity method utilized the vertical electrical sounding (VES) method involving the Schlumberger array. Six sounding stations were established on the observed fault or weak zones revealed by the VLF-EM method. The current electrode spacing (AB/2) was varied from 1m to 65m. The apparent resistivity measurements were plotted against electrode spacing on bi-logarithmic graph sheets.

Partial curve matching was carried out using WinGLink software for the quantitative interpretation of the sounding curves. The results of the curve matching (layer resistivities and thickness) were used as starting model parameters for 1-D forward modeling using a computer iterating software WinResist to check RMS-error. The VES interpretations were used for the construction of geoelectric sections along the various segments.

3. THE STUDY AREA

The study was conducted within the BACOSA and the Faculty of Science buildings of Bowen University Temporary site in Iwo Southwestern Nigeria (Figure 9), located between latitude $_{1}$ to $8°00'$ and longitude $4°00'$ to $5°00'$ in south western Nigeria precambrian basement complex comprising predominantly migmatized and undifferentiated gneisses, schist and quartzite. Locally, the rock sequence in the study area consists of fine grained biotite gneiss, quartzite's schist complex of Precambrian age (jones and hockey 1964).

The gneiss complex underlain the northern and southern part of the study area and constitute a considerable larger area with rock exposures. The rocks appear to be readily weathered and give rise to an undulating topography dipping in a north-south direction and cross cutting by numerous bands and lenses of pegmatites at several locations.

The topsoil association of the site is the Fasola and Ajawa groups with great fertilities, which support good agricultural practice. They have fine texture and are of variety of colour ranging from brown to brownish red, fairly brownish yellow and white clay, and are of average thickness of 50mm (Akinloye, et al, 2002). Generally Iwo is located in southwest Precambrian basement complex of Nigeria, predominantly composed of; oldergranite, migmatite gneiss complex, dolorite dykes and charnockitic rocks.

4. RESULT AND DISCUSSION

4.1. Very Low Frequency Electromagnetic (VLF-EM) Method

The measured raw real and the filtered real data extracted from the raw field data were plotted to generate anomaly curves which enabled qualitative identification of linear features. These linear features (suspected geological interface/fault zones) are usually delineated as points of coincident crossovers and positive peaks of the raw real and filtered real anomaly curves.

Figures 10a to 15a display VLF-EM plots (raw real and filtered real) along profiles 1to 6 (BACOSA 1-6) alongside the Fraser filtered and corresponding Karous-Hjelt filtered current density pseudosection (Figures 10b to 15b). The 2-D inversion shows the variation of apparent current density and change in conductivity with depth. With such apparent current density cross-section plots, it is possible to qualitatively discriminate between conductive and resistive structures where a high positive value usually denoted by red colour, correspond to conductive subsurface structure and low or negative values are related to resistive subsurface structures (KHFFILT, 2004).

Figure 10a shows the raw and filtered real profile along BACOSA 1. Three positive peaks mapped as fractures, joints, contacts, or faults at distances between 10-30m, 40-65m and 82-110m on the filtered real are shown with two well pronounced positive peaks at distances between 40-65m and 82-110m.These are zones of interest in fault and fracture detection in basement terrain. Figure 10b shows the corresponding K-H pseudosection on the profile. The pseudosection is a measure of conductivity of the subsurface as a function of depth. The conductivity is shown as colour codes with the zones of high conductivity coded with red colour. Different features of varying degree of conductivity were delineated on the profile with two highly conductive zones clearly revealed (Red colour). Several other closures of conductive bodies represented with colour codes are present on the section with each conductive body coinciding with the points already identified on the profile as fractures and joints.

Figure 11a, also shows the raw and filtered real profile along BACOSA 2. Four positive peaks which were zones of interest are again mapped as fractures, joints, contacts, or faults at distances between 10-40m, 60-70m, 90-105m and 130-140m on the filtered real as shown with two well pronounced positive peaks at distances between 40-65m and 85-110m. Figure 11b shows the corresponding K-H pseudosection on the profile with two very distinct zones of high conductivity (red colour coded).

Figure 12a, also shows the raw and filtered real profile along BACOSA 3. Two pronounced positive peaks were observed and mapped as possible fractures, joints, contacts, or faults zones at distances between 40-90m and 110-140m on the filtered real. Figure 12b shows the corresponding K-H pseudosection on the profile with the two zones of high conductivity (red colour coded).

Figure 13a, dipicted the raw and filtered real profile along BACOSA 4. Two positive peaks were observed with only one very pronounced at a distance between 70-120m which serves as point of interest. Figure 13b equally shows the corresponding K-H pseudosection on the profile with only one point of high conductivity (red colour coded).

Figure 14a, also shows the raw and filtered real profile along BACOSA 5. Two pronounced positive peaks were observed and mapped as possible fractures, joints, contacts, or faults zones at distances between 40-100m and 120-150m on the filtered real,but only one at distance 120-150m is well revealed as this could be observed on the corresponding K-H pseudosection (Figure 14b).

Observed on Figure 15b is the raw and filtered real profile along BACOSA 6. Three positive peaks mapped as zones of interest at distances between 0-20m, 40-70m and 110-155m on the filtered real as shown with two well pronounced positive peaks at distances between 40-70m and 110-155m. Figure 15b shows the corresponding K-H pseudosection on the profile with two highly conductive zones clearly revealed (Red colour).

4.2. Vertical Electrical Sounding (VES) Method

The resistivity sounding curves of the six VES stations (Figures 16 to 21) obtained from the survey area consist of four geoelectric layers, with VES 1-3 (HA type);VES 4 (KH type); VES 5, (QH type) and VES 6 (AA type). The curves were characterized according to their signatures, which mirror the layering of the subsurface. The four geoelectric layers that were delineated include the topsoil, weathered layer, clayey sand and fresh basement with resistivity ranging between 121.3 to 771.2 ohm-m, 134.4 to 595.8 ohm-m, 81.6 to 951.9 ohm-m and 1474.7 to 5134.4 ohm-m respectively. The thickness ranges from 0.5 to 2.4m, 1.8 to 9.8m and2.7 to 24.5m. Depths to bedrock are generally less than 4om. It was however observed from the six VES stations which circles around the distressed building (Figures 1to 8) showed that the weathered layer has resistivity values of 216.9, 165.2, 134.4, 163.1, 196.5, 595.8 ohm-m and thickness 9.8, 9.4, 8.7, 4.8, 1.8 and2.1m respectively. Since the topsoil with thickness varying from 0.5 to 2.4m will be excavated during foundation construction, this layer is believed to act as support for foundation. From the resistivity values, the weathered layer in this study area is seen to be characterized of clayey materials of thickness ranging from 1.8 to 10.2m. Therefore, probable reason for the structural defect on the buildings could be the problem of swell and shrinkages of clayey soils. Seasonal variation in the level of saturation of clayey soils is expected to have given rise to the seasonal swelling and shrinkages of buildings subsurface. The swell and shrink might have caused the ground movement which invariably should have cause defect (cracks) and foundation instability of the buildings. The contrast between the shrinking clay and non-shrinking zone might have also contributed to the ground movement which in turn could bring about risk on the structure.

5. CONCLUSION

The results of the investigation showed that the possible cause(s) of the structural failure in the study area are due to the presence of geologic features mapped as fractures, faults, contacts and clayey formations present in the study area. Therefore, in order to avert future geotechnical problems and to minimize resources used in repairing or total reconstruction of failed and distressed structures in the University, the services of the geophysist should be engaged for pre-foundation studies, which will act as a guide for the civil engineers before and during construction.

REFERENCES

Adelusi, A.O; Adiat, K.A.N and Amigun, J.O (2009): Integration of surface electrical prospecting methods for fracture detection in Precambrian basement rocks of Iwaraja area Southwestern Nigeria. Ozean Journal of Applied Sciences 2(3), 265-280.

Akinloye, M K; Fadipe, D O; Adabanija; M A (2002). A Radiometricmapping of the Ladoke Akintola University Compus, OgbomosoSouthwestern Nigeria. *Science Focus;* 1, 55-61

Akintorinwa, O.J; Ojo, J.S and Olorunfemi, M.O (2010): Geophysical investigation of pavement failure in a basement complex terrain of southwestern Nigeria. The Pacific Journal of Science and Technology 11(2), 649-663.

Akintorinwa, O.J and Abiola, O (2011: Subsoil evaluation for pre-foundation study using geophysical and geotechnical approach. Journal of emerging trends I engineering and applied sciences 2(5), 858-863.

Alagbe, O.A; Sunmonu, L.A and Adabanija, M A (2013): Fracture distribution within Bowen University Permanent site and its hydrogeologic implication. Research Journal of Physical Sciences 1(3), 1-5.

Egwuonwo, G.N (2012): Application of geophysical imaging in investigation of structural failure of buildings; Case study of three building sites in Zaria area, Northwestern Nigeria. The Pacific Journal of Science and Technology 13(1), 580-589.

Fatoba, J.O; Alo, J.O and Fakeye, A.A (2010): Geoelectric imaging for foundation failure investigation at Olabisi Onabanjo University mini campus, Ago Iwoye, Southwestern Nigeria. Journal of Applied Sciences Research 6(12), 2192-2198.

Karous, M.R and Hjelt, S.E (1983): “Linear filtering of VLF dip- angle measurements”. Goephysical prospecting 31, 782-894.

KHFFILT (2004): Karous-Hjelt and Fraser filtering of VLF measurements, version 1.1a. Markku Pirttijarvi

Sharma, S.P and Baranwal, V.C (2005): Delineation of groundwater-bearing fracture zones in a hard rock area integrating very low frequency electromagnetic and resistivity data. Journal of Applied geophysics 57, 155-166.

Sunmonu, L.A and Alagbe, O.A (2011): Groundmagnetic study to locate buried faults (A case study of abandoned Local Government Secretariat in Ogbomoso). International journal of physics 3(1), 70-75.

Figure 1: Distressed Building in the Study area Showing Cracks on the wall of BACOSA building

Figure 2: Distressed Building in the Study area Showing Cracks on the wall of BACOSA Extension I

Figure 3: Distressed Building in the Study area Showing Cracks on the wall of a fence behind BACOSA Extension I

Figure 4: Distressed Building in the Study area Showing Cracks on the wall of BACOSA Extension II

Figure 5: Distressed Building in the Study area Showing Cracks on the wall of fence behind MICOM Lab.

Figure 6: Distressed Building in the Study area Showing Cracks on the wall of General Lab

Figure 7: Distressed Building in the Study area Showing Cracks on the wall of 200Level Physics Lab.

Figure 8: Distressed Building in the Study area Showing Cracks on the wall of Faculty of Science building

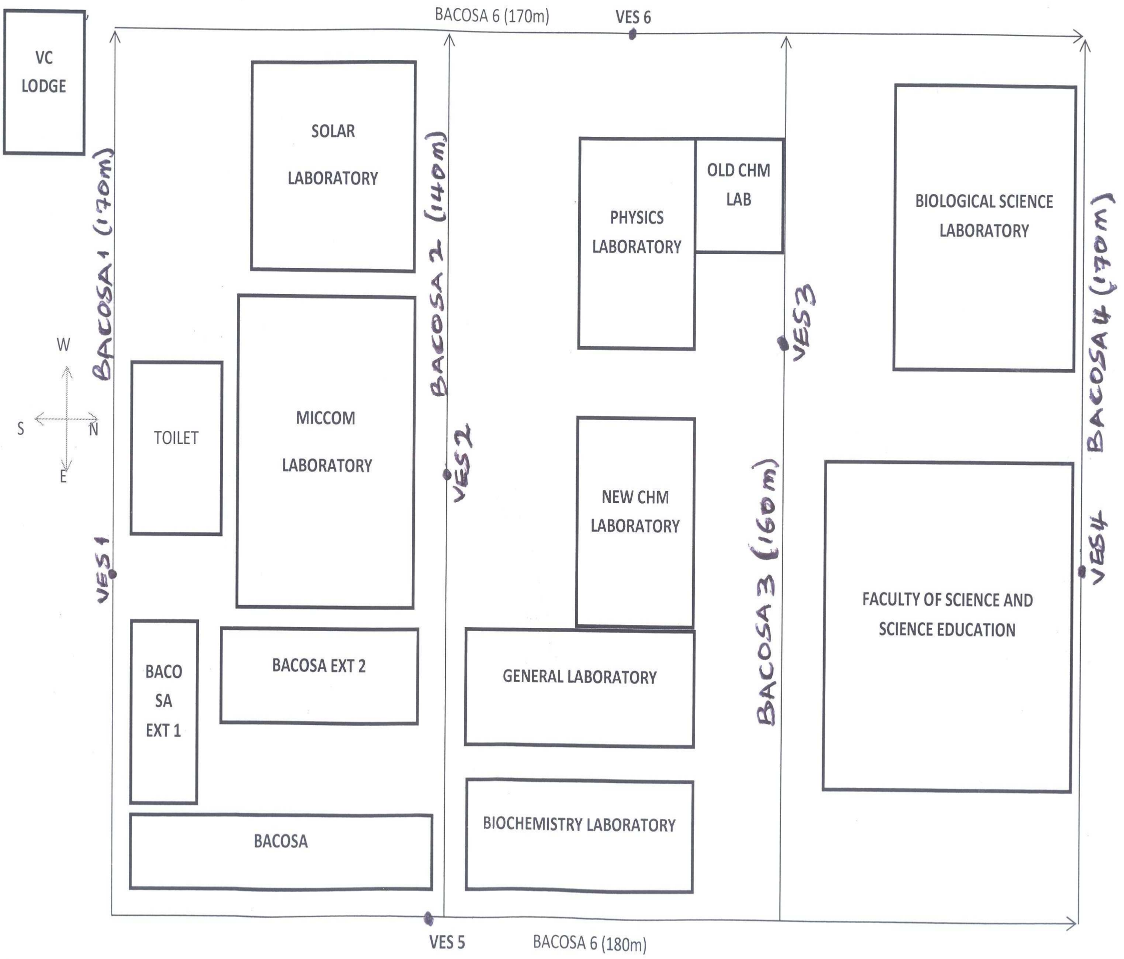


Figure 9: Map of the study area

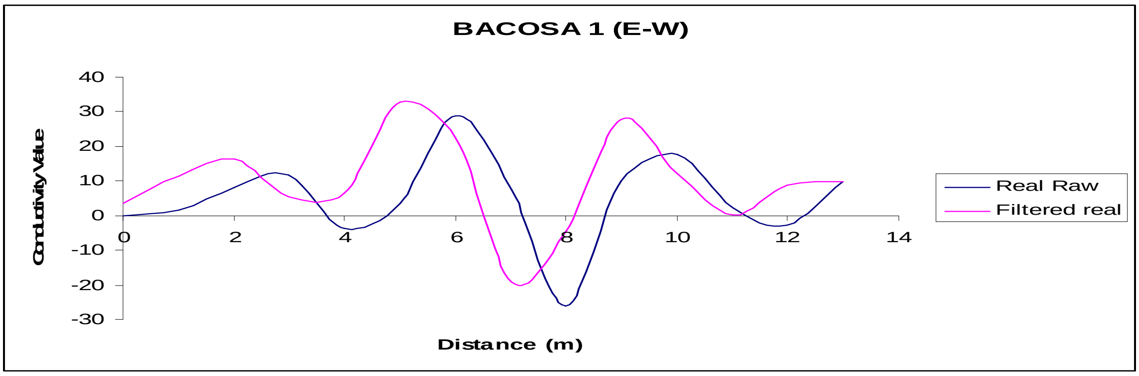


Figure 10a: Raw and Filtered real profile along BACOSA 1

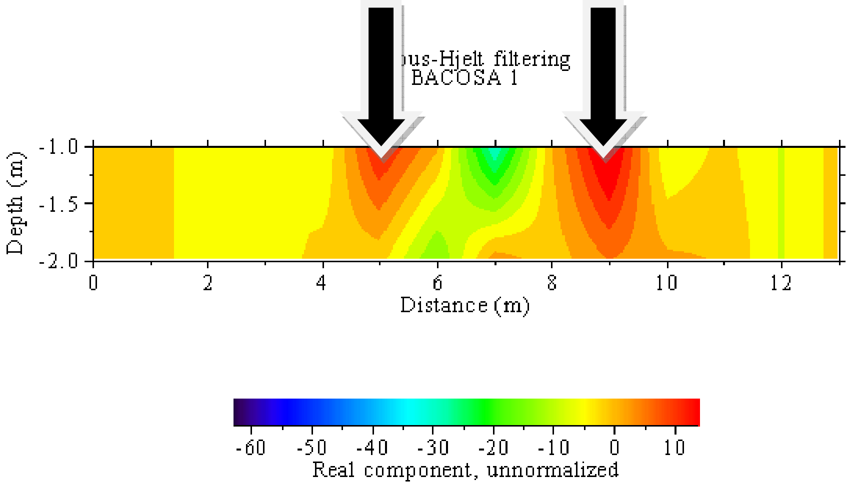


Figure 10b: Karous and Hjelt pseudo section along BACOSA 1

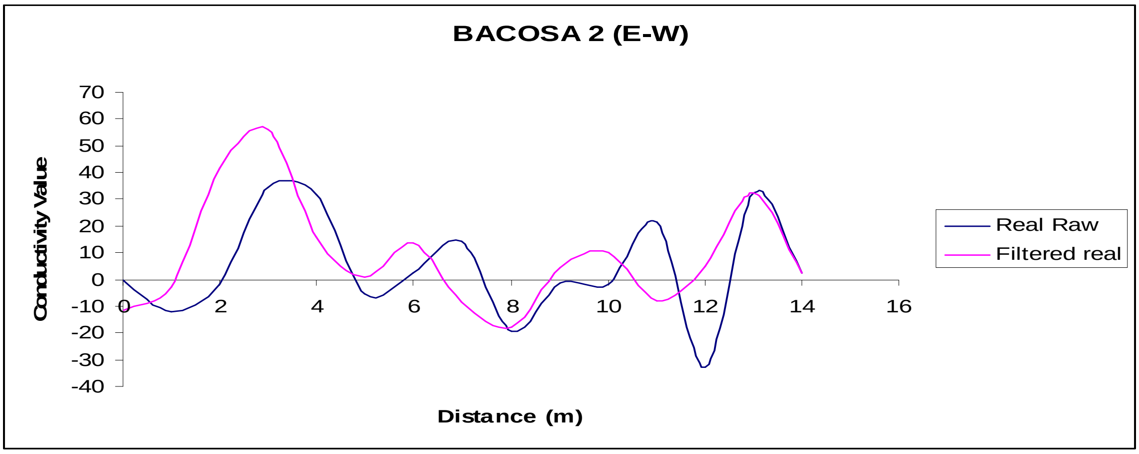


Figure 11a: Raw and Filtered real profile along BACOSA 2

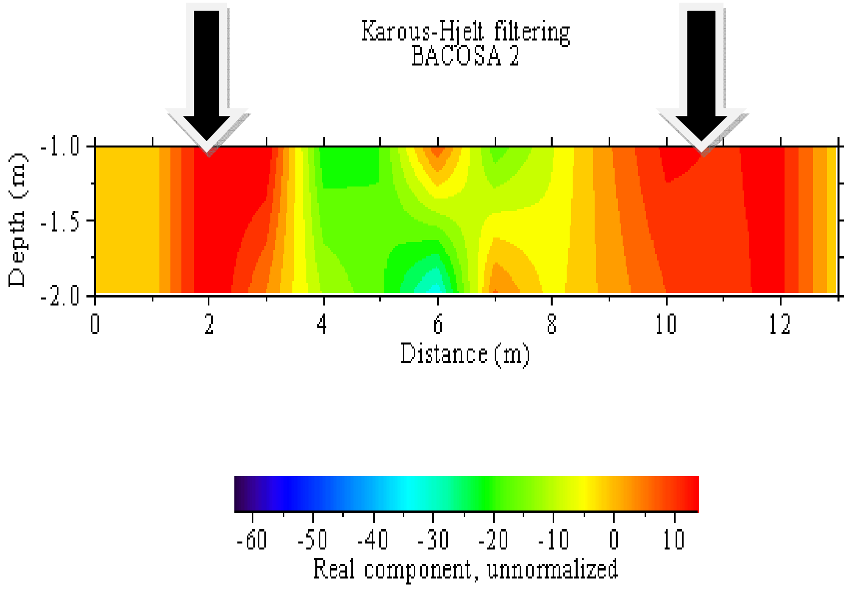


Figure 11b: Karous and Hjelt pseudo section along BACOSA 2

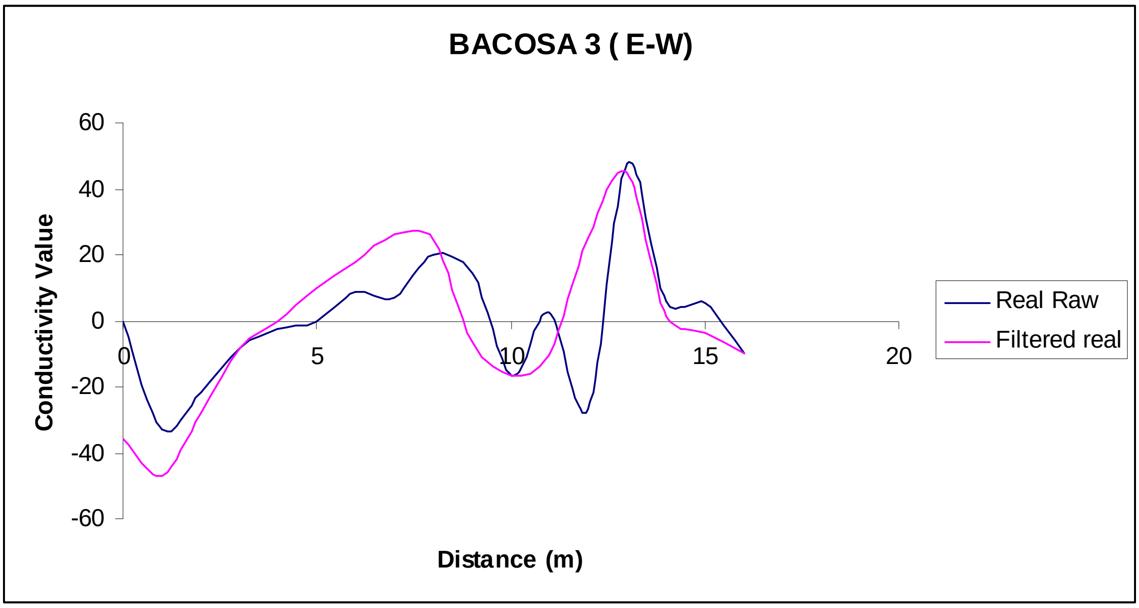


Figure 12a: Raw and Filtered real profile along BACOSA 3

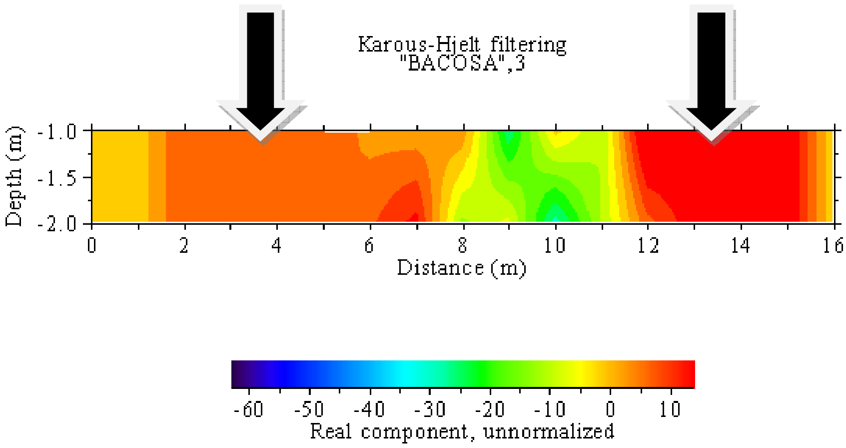


Figure 12b: Karous and Hjelt pseudo section along BACOSA 3

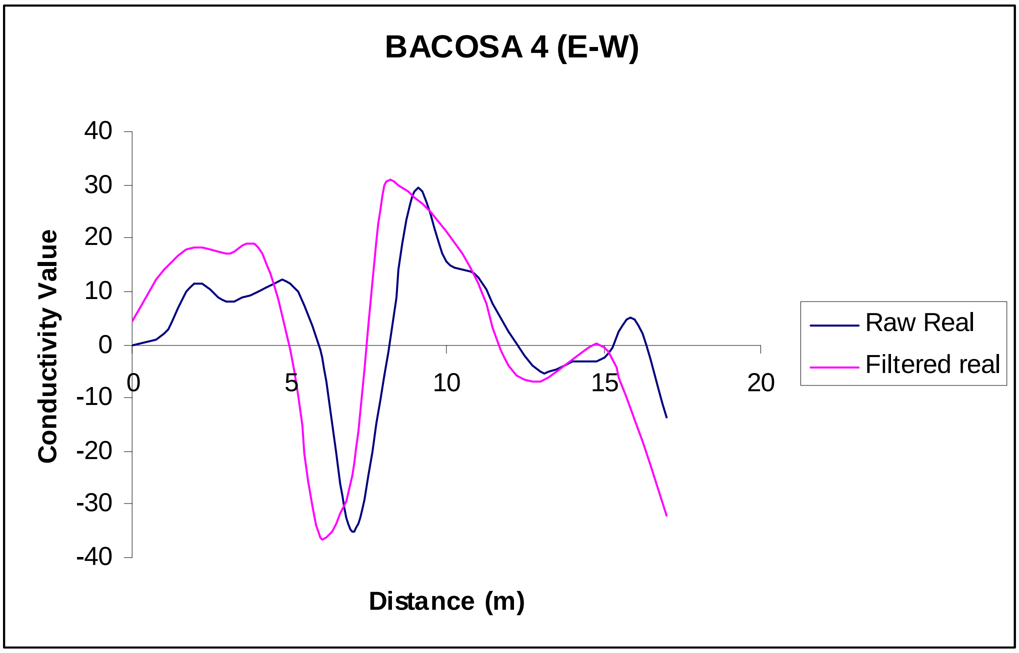


Figure 13a: Raw and Filtered real profile along BACOSA 3

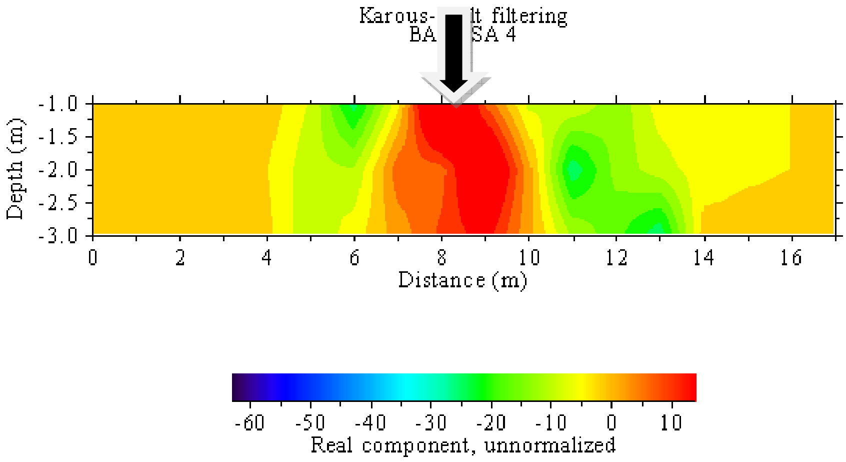


Figure 13b: Karous and Hjelt pseudo section along BACOSA 3

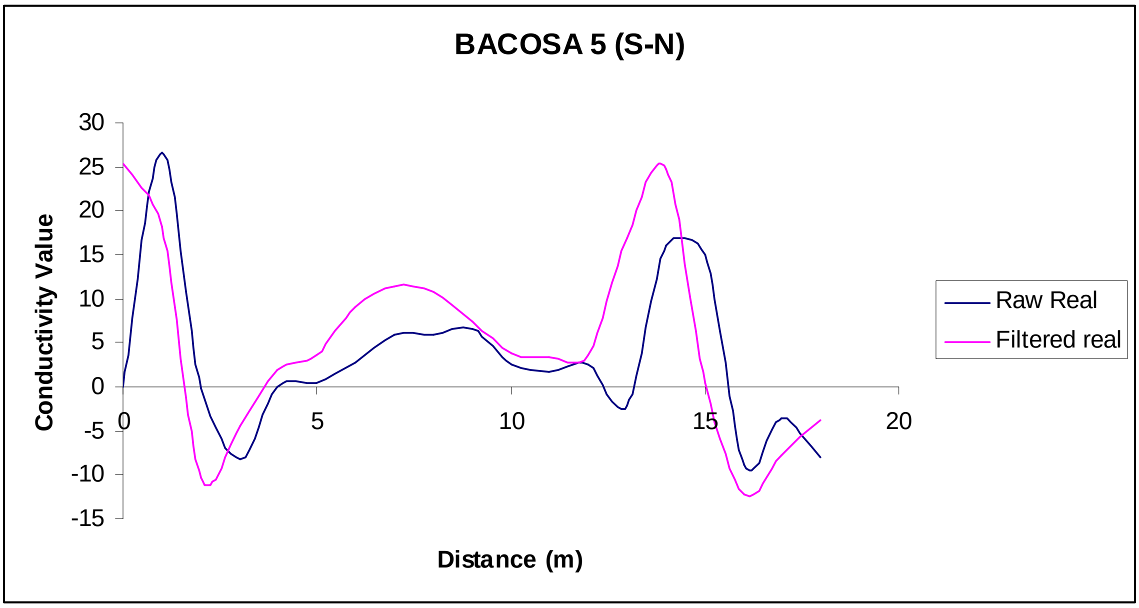


Figure 14a: Raw and Filtered real profile along BACOSA 5

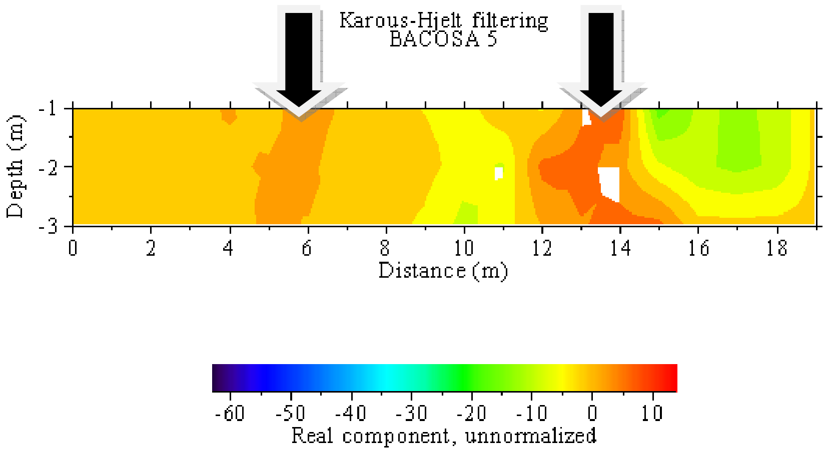


Figure 14b: Karous and Hjelt pseudo section along BACOSA 5

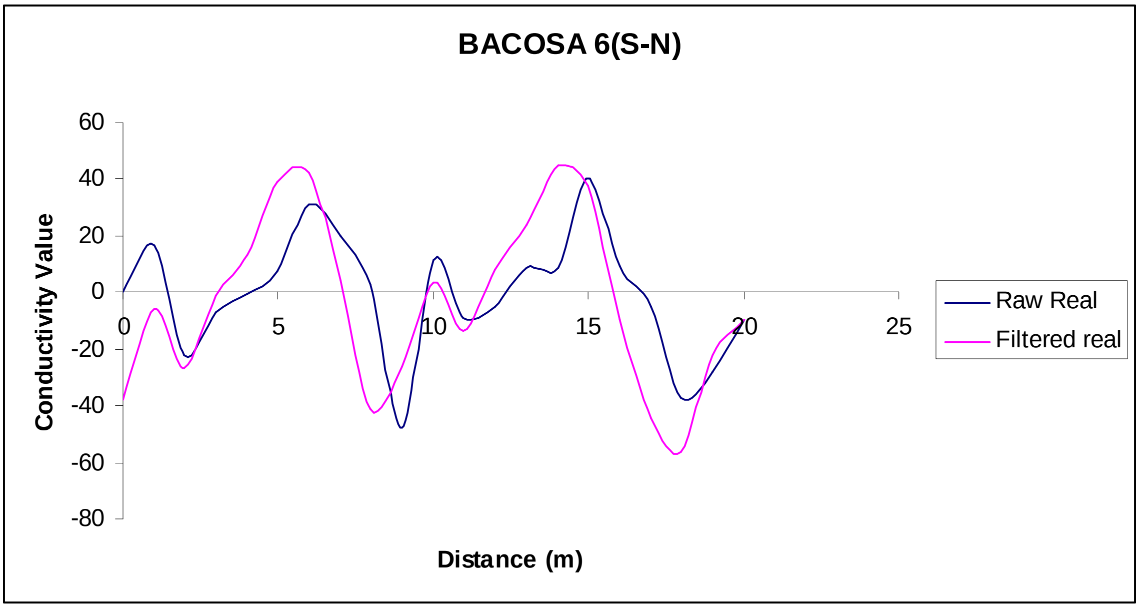


Figure 15a: Raw and Filtered real profile along BACOSA 6

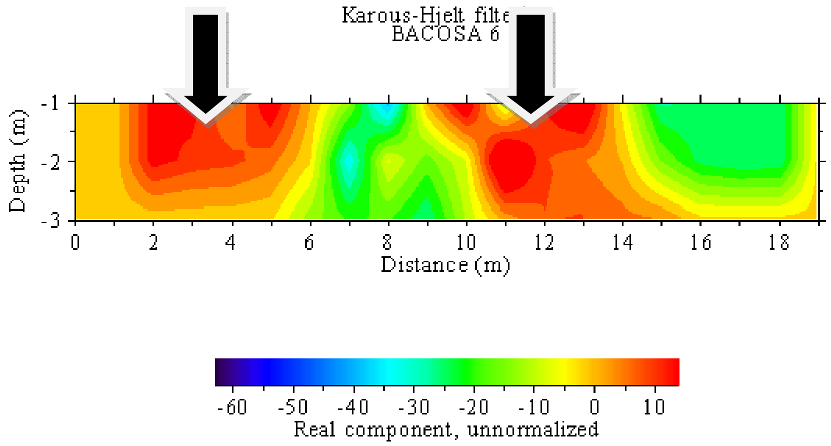
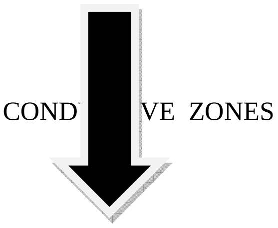
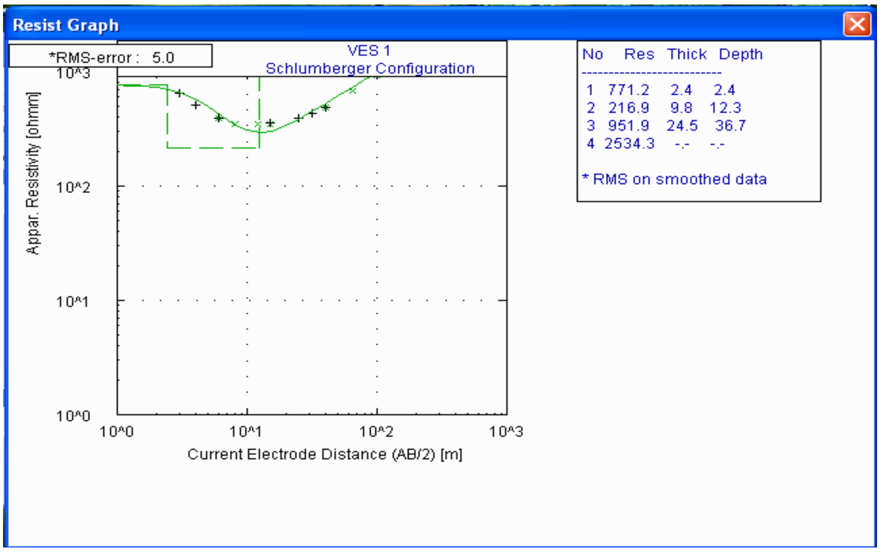


Figure 15b: Karous and Hjelt pseudo section along BACOSA 6





*RMS-error : 5.0

```
No   Res  Thick  Depth
---------------------------
 1  771.2   2.4    2.4
 2  216.9   9.8   12.3
 3  951.9  24.5   36.7
 4 2534.3   -.-    -.-

* RMS on smoothed data
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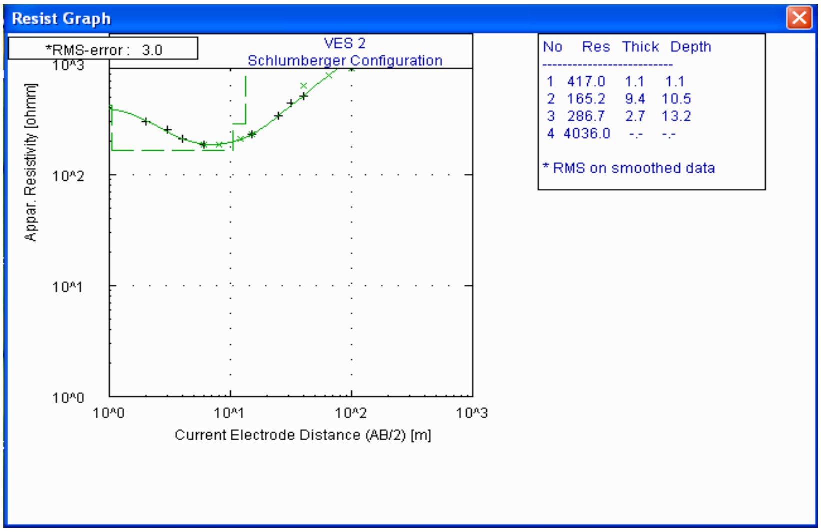
Figure 16: The Sclumberger Depth Sounding beneath VES 1 at BACOSA

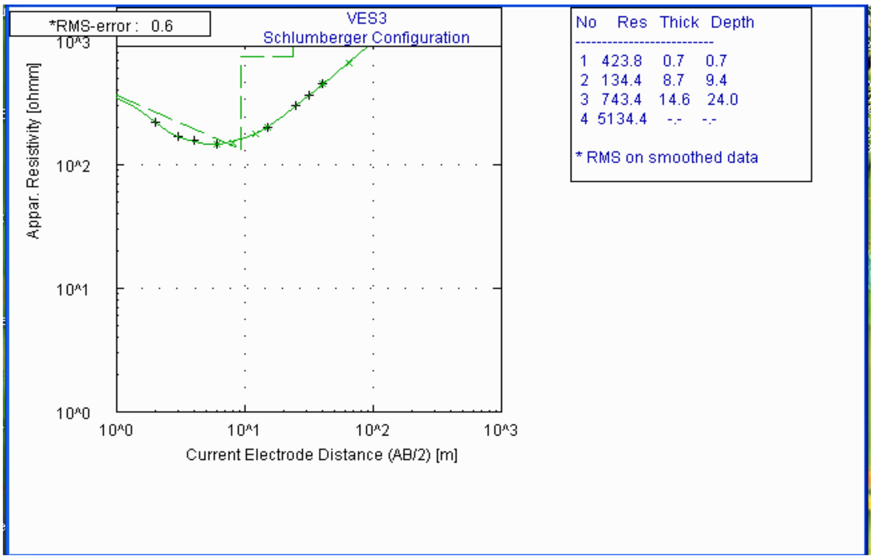


*RMS-error : 3.0

```
No   Res  Thick  Depth
---------------------------
 1  417.0   1.1    1.1
 2  165.2   9.4   10.5
 3  286.7   2.7   13.2
 4 4036.0   -.-    -.-

* RMS on smoothed data
```

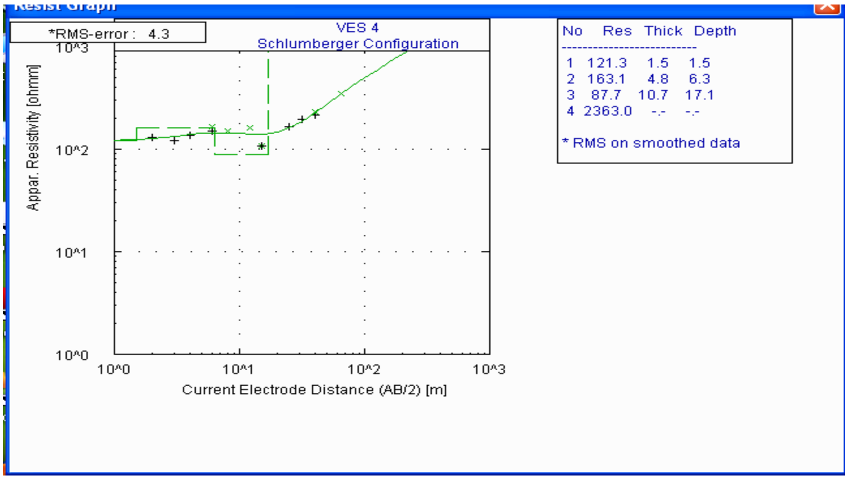
Figure 17: The Sclumberger Depth Sounding beneath VES 2 at BACOSA



```
No    Res   Thick  Depth
--------------------------
 1   423.8   0.7    0.7
 2   134.4   8.7    9.4
 3   743.4  14.6   24.0
 4  5134.4   -.-    -.-

* RMS on smoothed data
```

Figure 18: The Sclumberger Depth Sounding beneath VES 3 at BACOSA



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No    Res   Thick  Depth
--------------------------
 1   121.3   1.5    1.5
 2   163.1   4.8    6.3
 3    87.7  10.7   17.1
 4  2363.0   -.-    -.-

* RMS on smoothed data
```
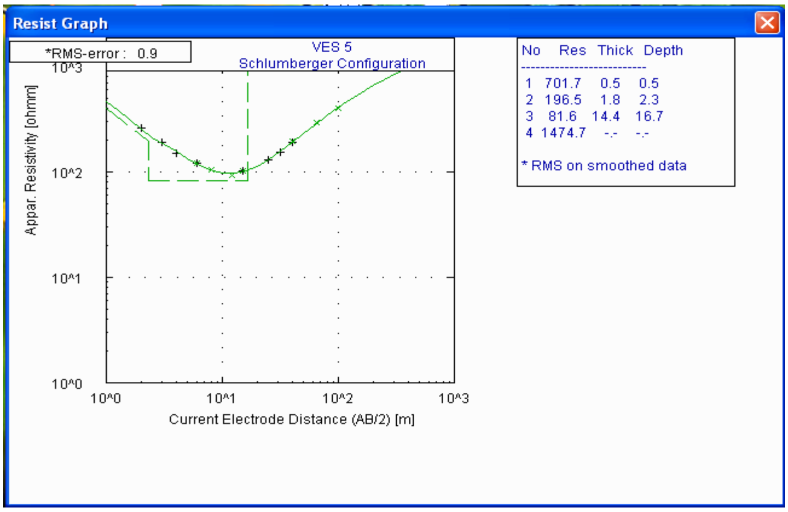

Figure 19: The Sclumberger Depth Sounding beneath VES 4 at BACOSA

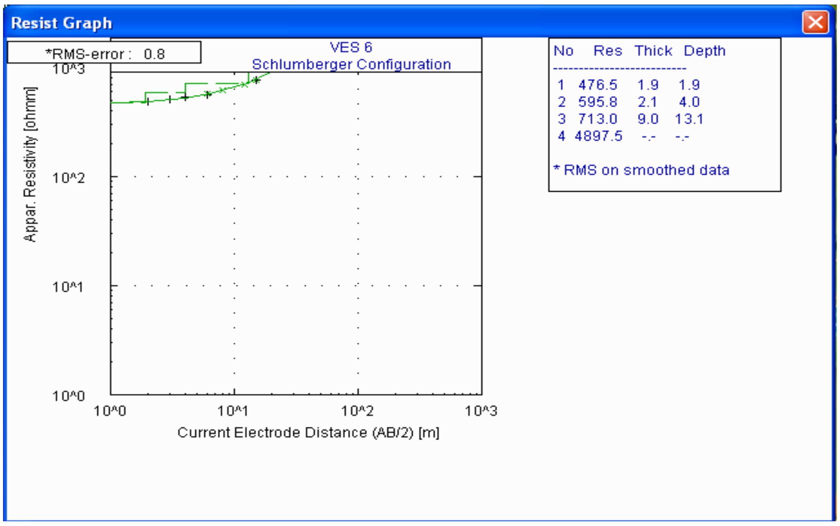


*RMS-error : 0.9

No	Res	Thick	Depth
1	701.7	0.5	0.5
2	196.5	1.8	2.3
3	81.6	14.4	16.7
4	1474.7	-.-	-.-

* RMS on smoothed data

Figure 20: The Sclumberger Depth Sounding beneath VES 5 at BACOSA



*RMS-error : 0.8

No	Res	Thick	Depth
1	476.5	1.9	1.9
2	595.8	2.1	4.0
3	713.0	9.0	13.1
4	4897.5	-.-	-.-

* RMS on smoothed data

Figure 21: The Sclumberger Depth Sounding beneath VES 6 at BACOSA

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