Applications of 1D and 2D Electrical Resistivity Methods to Map Aquifers in a Complex Geologic Terrain of Foursquare Camp, Ajebo, Southwestern Nigeria

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Applications of 1D and 2D Electrical Resistivity Methods to Map Aquifers in a Complex Geologic Terrain of Foursquare Camp, Ajebo, Southwestern Nigeria.

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ABSTRACT

Ajebo Foursquare Camp was surveyed to locate sites for water supply tube-wells and to adduce reason(s) for failure of most boreholes drilled there. Results from twenty four (24) VES points show 3–4 geoelectric layers, which are weathered/Fractured rocks of resistivity range from 68–394Ωm with thickness range of 3.4–14.8m. Only two VES stations have aquifer thickness above 14m. However, results of eight (8) 2D resistivity imaging in the areas show about two points where productive boreholes could be sited. These points were not covered during VES survey. Thus, tomography/2D resistivity imaging gives a better lateral view of the subsurface layers than geoelectric section from 1D because of its ability to give a continuous record of subsurface image.

(Keywords: wells, groundwater, VES, geoelectric layers, resistivity, tomography, subsurface imaging)

INTRODUCTION

In order to locate a water supply tube-well that can serve the congregation of thousands of worshippers patronizing the camp on weekly basis, a major geophysical mapping of the camp was carried out. This involved both 1D and 2D surveys. 1D electrical method using Vertical Electrical Sounding has been employed over the years to characterize aquifer in different geologic environments and to map fractures in basement areas (Koefoed, 1979, McDowell, 1979, Ayolabi *et al*, 2003).

Recently, attention is shifting to a more accurate method of imaging the subsurface. 2D and 3D resistivity images are created by inverting hundreds to thousands of individual resistivity measurements (Loke and Barker, 1996a, b) to produce an appropriate model of the subsurface resistivity. Thus, electrical resistivity imaging has been a veritable tool in delineating bedrock depression, fracture, synclinal water accumulation zone and aquifer layer (Singh *et al*, 2006, Ayolabi *et al*, 2008).

THE STUDY AREA

The study area is a conference centre where participants are drawn from all works of life for a retreat. Besides, as a community where people inhabit, availability of potable water becomes an imperative. The area lies within latitudes 7^0 N to 7^0 30' N and longitudes 3^0 30' E and 4^0 0' E. In addition, it falls within the basement Complex of Southwestern Nigeria which has been adequately studied by various workers (Rahaman, 1989, Caby, 1989). Local geology is made up of granite gneiss and mica schist. Hence, it hydrogeology lies mainly on location of fractures and/or weathered basement.

METHOD

Twenty four VES points were occupied and eight (8) 2D resistivity imaging profile lines were carried out widely distributed in the area. The traverses TR4, TR6, TR7, and TR8 are located at the precincts of the areas while others are within to enhance a vivid coverage of the entire land mass. The VES points are widely distributed along the 2D traverses, Figure 1.

A Schematic diagram of the distribution of the 2D resistivity imaging profiles and VES points is shown in Figure 2.

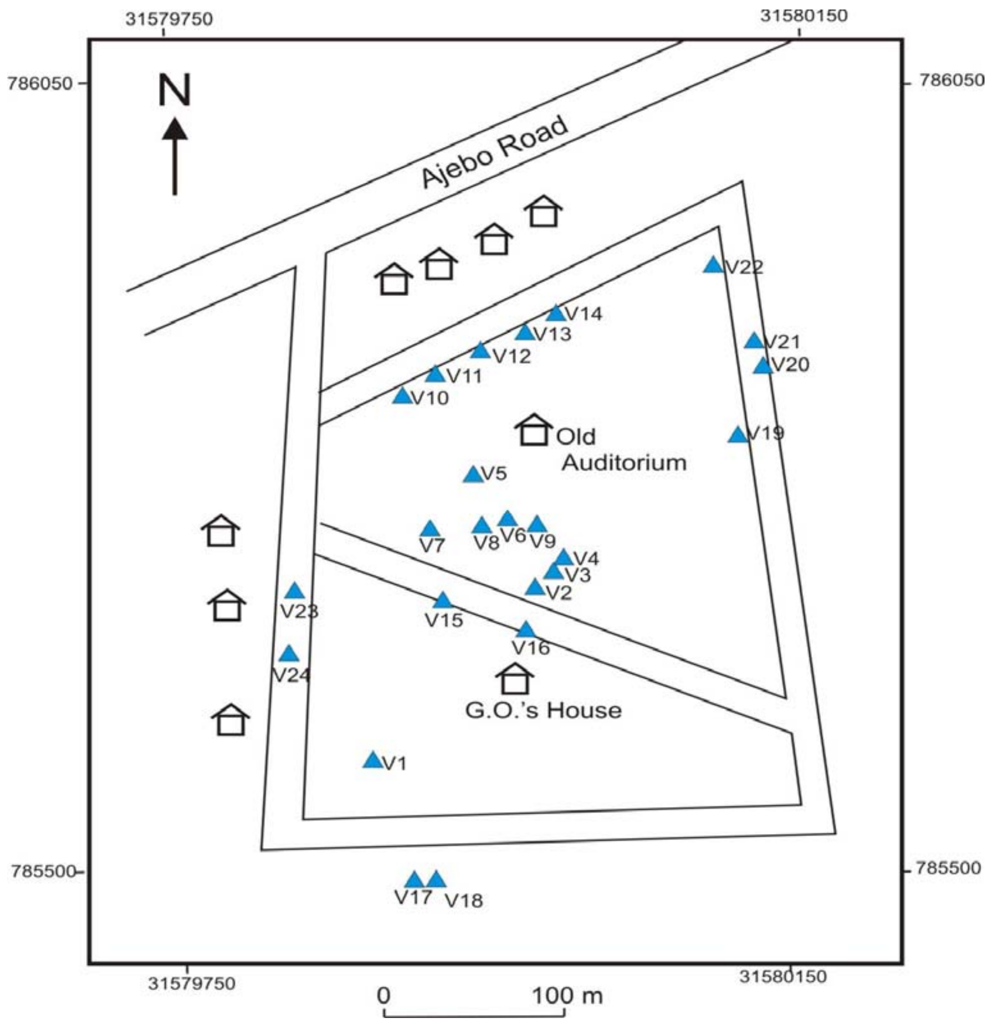

Figure 1: Data Acquisition Map Showing the VES Points.

The VES were carried out using a Schlumberger array with a maximum electrode spacing (AB/2) of 150m while the apparent resistivity data from the 2D were acquired using a Wenner geometry with a maximum of 21 electrodes (spaced at a=10m with n = 1, …, 5) to give a total profile length range of 140m – 370m.

In each case, ground resistivity data acquisition were made using ABEM Terrameter – Signal Averaging System (SAS) – 1000. It is highly sensitive and has a high signal to noise ratio. It has been used over the years for several geophysical surveys – environmental, engineering, structural mapping, and hydrogeology.

RESULTS

The VES data was plotted on a log – log paper and curve matched. The curves were interpreted quantitatively by computer iteration using the RESIST software. This generates the geoelectric parameters (the layer resistivity and thickness).

From the result 3 – 4 geoelectric layers were delineated which are: top soil made up of lateritic clay, sand and sandy clay. Other lithologies are Laterite, weathered or fractured rocks and fresh basement. Three (3) hydrogeological horizons were encountered from the VES result.

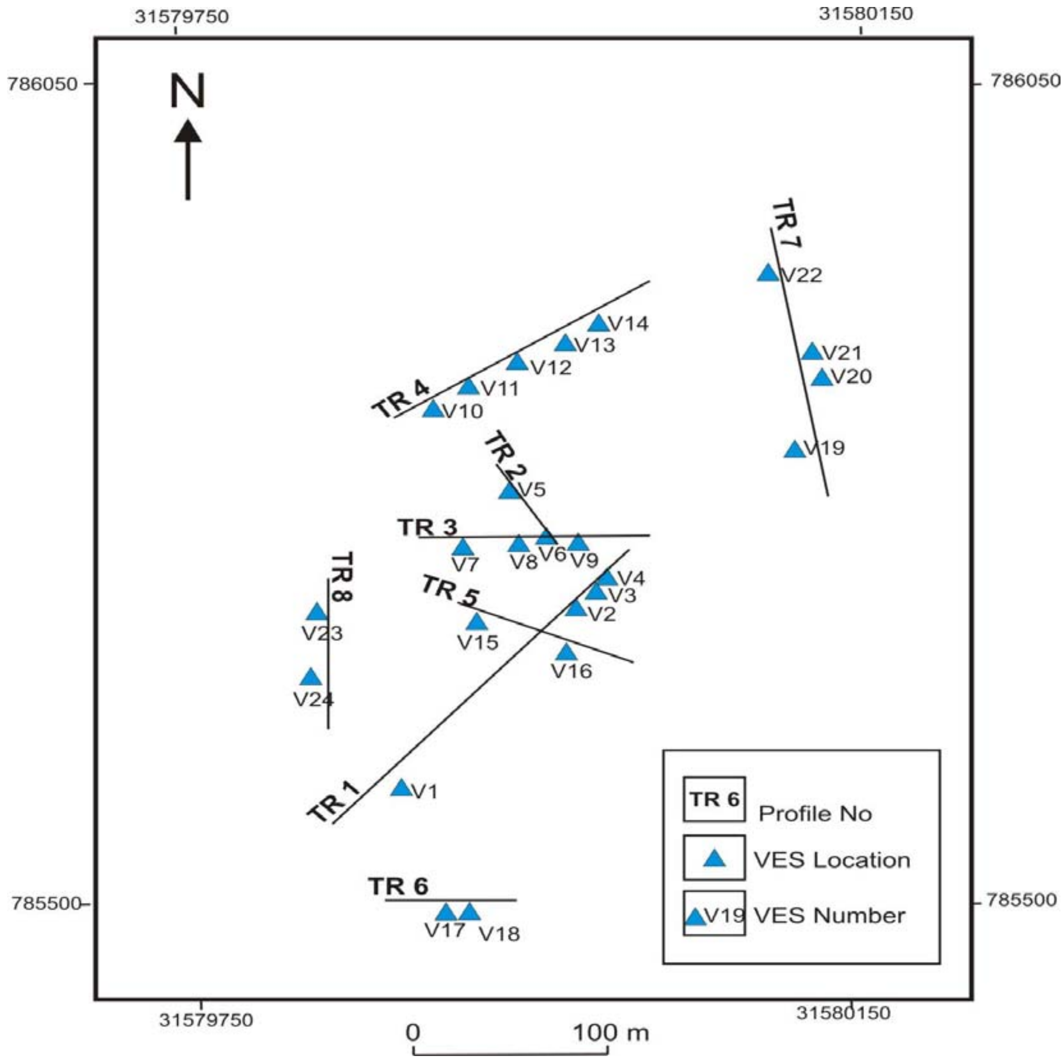

Figure 2: Schematic Diagram Showing Traverses TR1 – TR8.

These are clay/ clayey sand of resistivity 38 – 52Ω m and thickness 3.3 – 3.8m; weathered and fractured rocks of resistivity 56 – 100Ω m and 109 - 394 Ω m and thickness 3.4 – 14.8 m and 6.3 – 12.1m respectively (Table 1). However, the clay/ clayey sand horizon may hold water but could not transmit it effectively. Thus, the two VES points where this is encountered could not be recommended for borehole development, or else the well's life span will be very short.

There are existing boreholes and hand-dug wells in the area but most have failed possibly owing to the reason stated above. All attempts made to get the log data of the wells failed due to lack of proper records but we noticed that overburden and aquifer thickness are generally thin in this are except in some selected locations. Thus this could also account for the failure and / or erratic behavior of drilled holes in the camp.

For example a drilled borehole close to VES 10 is partially functioning and seasonal. The depth to weathered layer here is 0.9m and aquifer thickness is less than 7m. It is most likely that the well is being recharged from the surface run off during the rainy season which dries off in the dry season.

Table 1: Summary of VES Results in the Study Area.

VES Points	Layer Resistivity (Ωm)					Layer Thickness (m)				Depth to Bedrock (m)
	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	h_1	h_2	h_3	h_4	
1	730	175	977	39		0.7	3.5	8.6		
2	856	92	1446			1.3	11.7			11.7
3	973	89	830			1.4	10.5			11.9
4	765	93	971			1.5	10.1			11.6
5	758	201	1038			1.7	11			12.7
6	1469	394	793			1.8	12.3			14.1
7	1383	250	2499	369		1.3	2.0	12		
8	765	109	1278			1.4	9.5			10.8
9	1613	78	890			1.7	8.2			9.9
10	252	92	1008			0.9	6.8			7.7
11	273	95	1067			1.3	8.0			9.3
12	100	213	67	1908		0.8	3.2	3.4		7.4
13	146	241	79	1407		0.8	3.7	6.6		11
14	107	164	100	1970		0.6	4.6	3.5		8.7
15	235	116	1731			1.5	6.3			7.7
16	490	156	1879			0.9	6.5			7.4
17	164	38	1793			0.8	3.8			4.6
18	160	52	2161			0.7	3.3			3.9
19	462	92	1310			1.7	14.8			16.5
20	237	56	1083			1.4	13.3			14.5
21	256	68	1022			1.2	14.1			15.3
22	274	72	1801			1.4	9.5			10.8
23	1360	325	2850	122	1085	1.1	2.9	11.4	12.1	27.5
24	1245	140	1303			1.5	13.8			15.3

ELECTRICAL RESISTIVITY TOMOGRAPHY RESULTS

In area with complex geology, electrical resistivity imaging has proven to be effective in locating site for water – supply tube well (Sign et al 2006). Thus, eight (8) 2D traverses well distributed in the camp were carried out to provide better information and possibly give clue to ground water condition/situation of the area. 2D data was inverted using DIPPRO for Window software program. The distribution of resistivity along inverted model resistivity pseudosection perfectly agrees with 3 – 4 geoelectric layers identified from VES results. However, a few of the traverses give remarkable information useful for borehole sitting.

Traverse (TR 1) positioned at ground position 105 to 120m produced an hollow-like bedrock depression of resistivity below 300Ωm (Fractured rock) with appreciable overburden thickness above 20m and aquifer thickness above 20m. TR3 profile between ground positions 90m to 140m indicated a basin-like structure which could have been suggested for borehole siting but for lack of appreciable overburden and aquifer thickness. The same result is obtained from VES 8 & 9 located on the profile. TR 7 survey line at 300m to 320m on the ground surface could be suggested for borehole but this may also be seasonal.

TR 8 survey profile between surface positions 120m–140m is a good bedrock depression – a groundwater collection centre – that can be developed to producing borehole. VES 23 sited on the survey line reveals that a water-filled fractured zone of 12 m thickness is overlain by a highly resistive layer of resistivity 2850Ωm, interpreted as fresh basement rock and underlain by another fresh basement (country rock, possibly gneiss).

The upper layer is interpreted as granitic rock intruding into the pre-existing gneiss. Both surveys (1D and 2D) agree perfectly as to the location and thickness of the fracture layer.

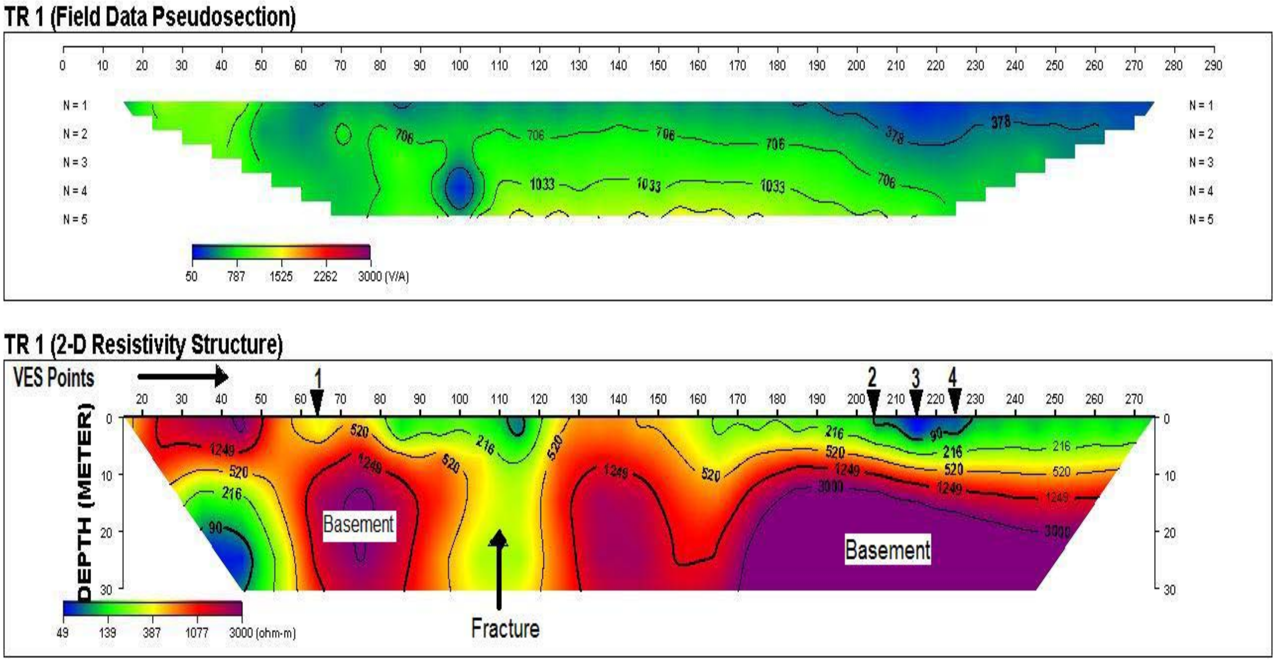

Figure 3: Wenner Configuration Inverted Resistivity Section along Traverse 1 and the Corresponding VES Points.

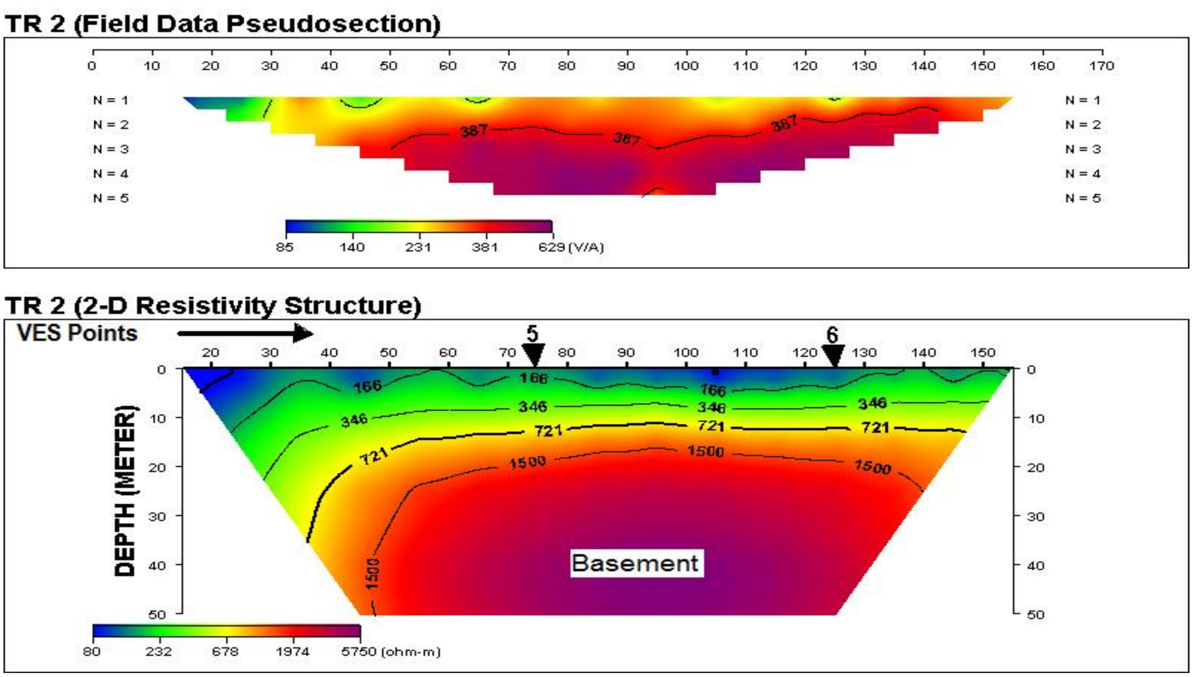

Figure 4: Wenner Configuration Inverted Resistivity Section along Traverse 2 and the Corresponding VES Points.

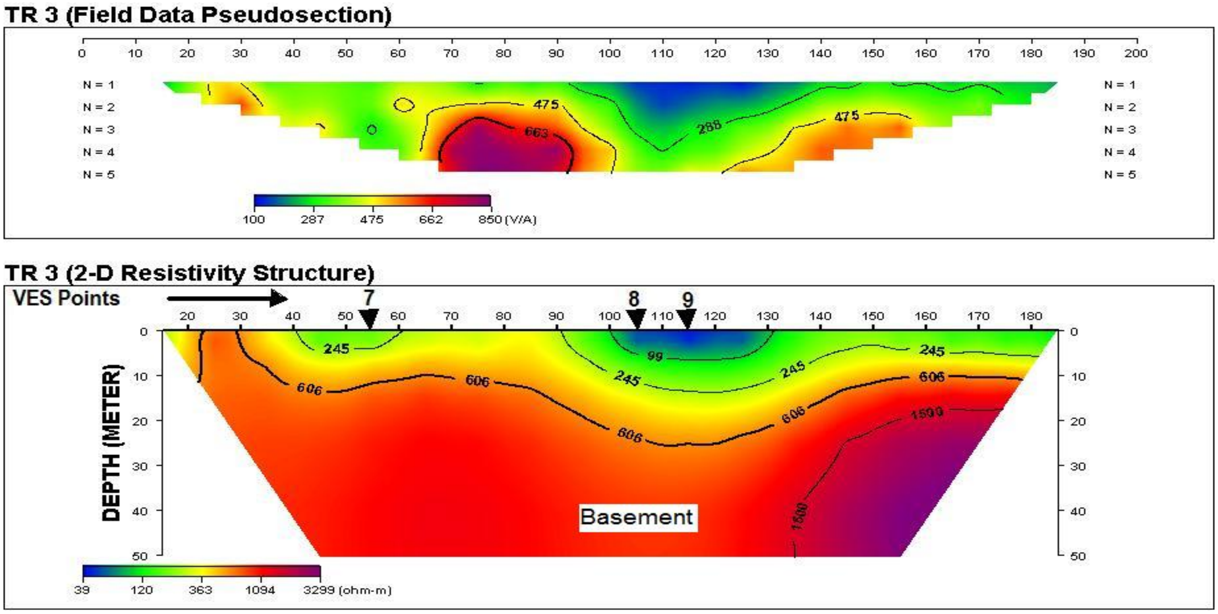

Figure 5: Wenner Configuration Inverted Resistivity Section along Traverse 3 and the Corresponding VES Points.

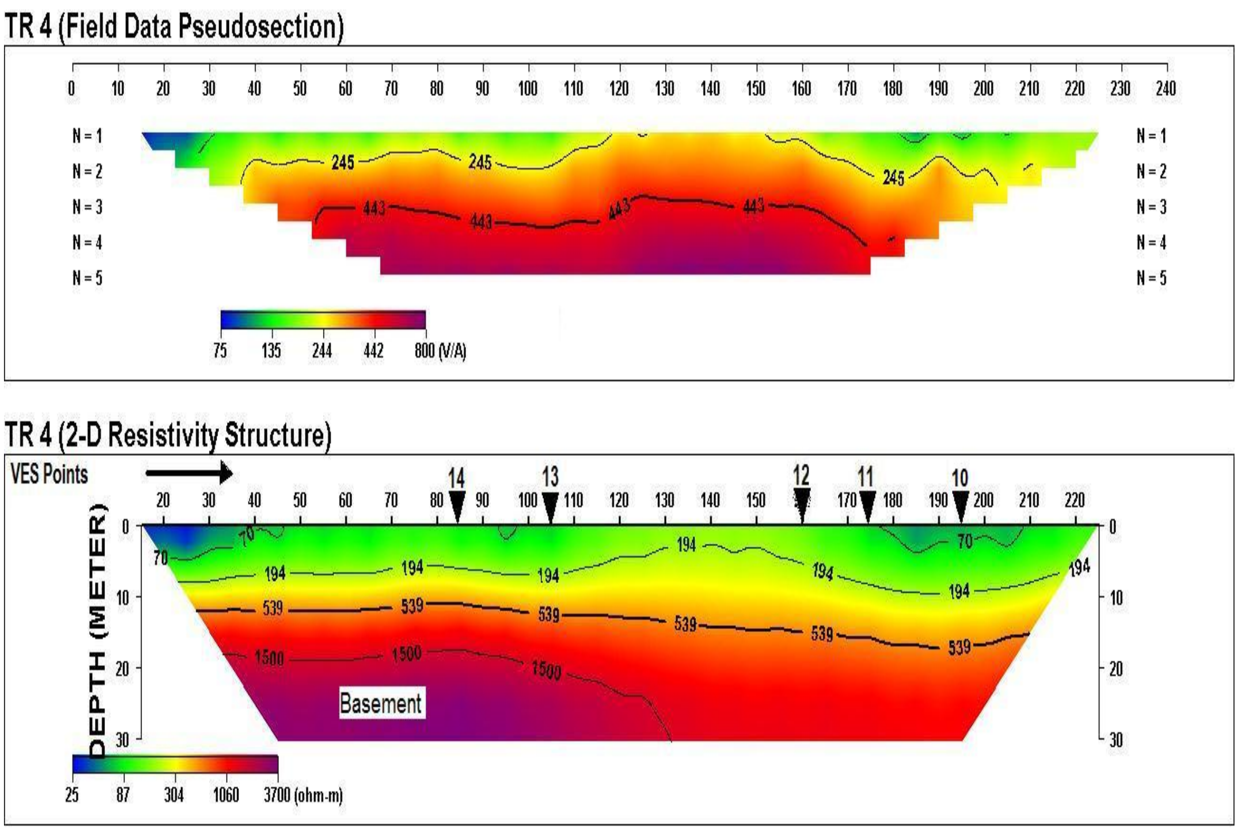

Figure 6: Wenner Configuration Inverted Resistivity Section along Traverse 4 and the Corresponding VES Points.

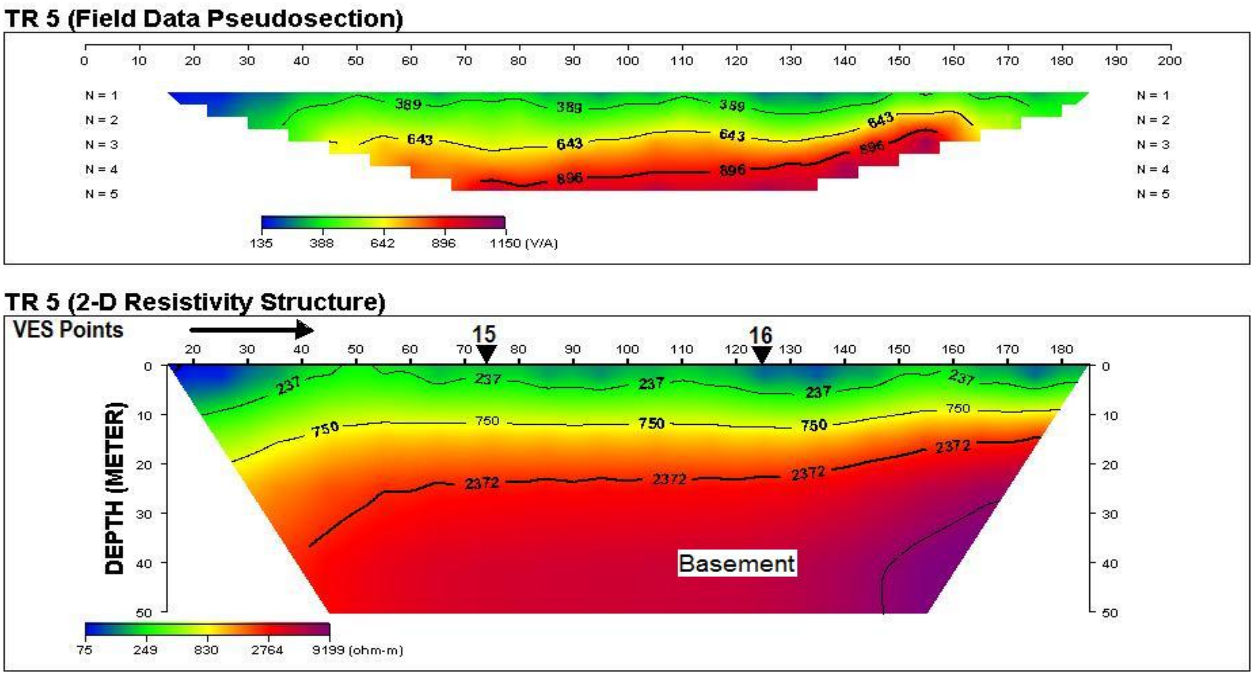

Figure 7: Wenner Configuration Inverted Resistivity Section along Traverse 5 and the Corresponding VES Points.

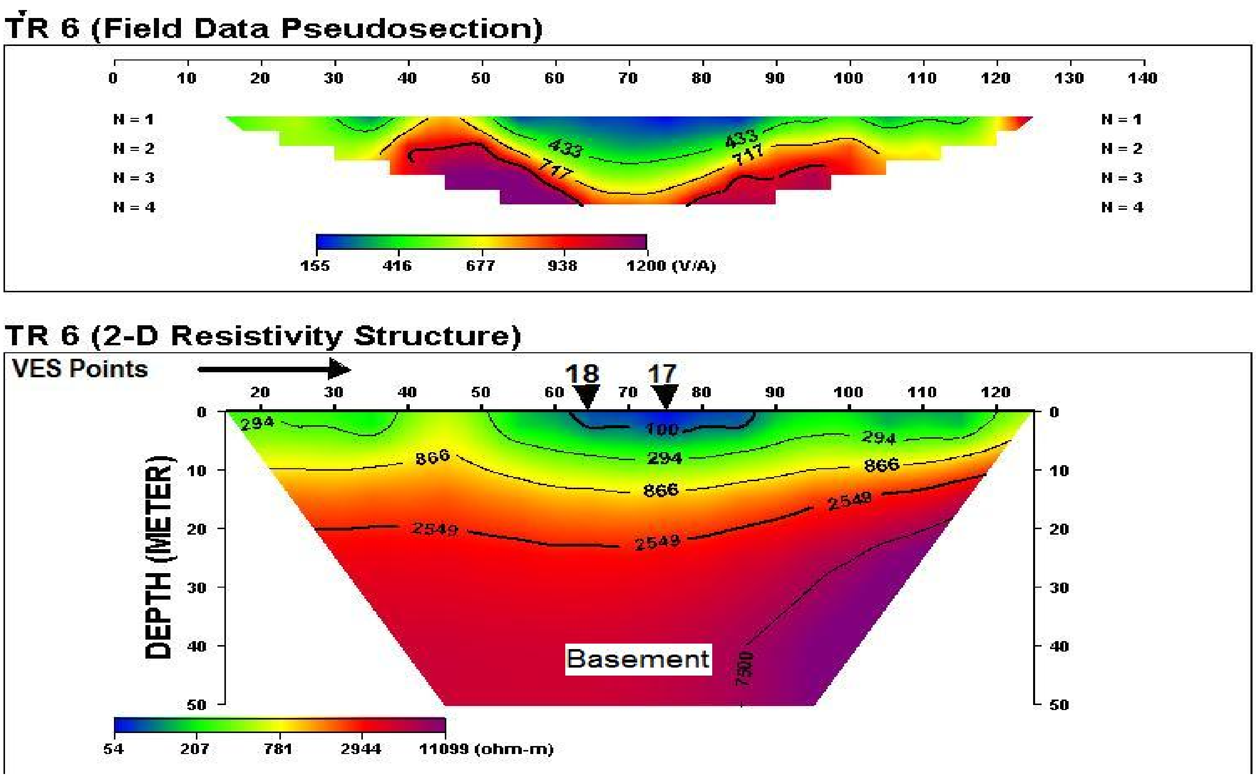

Figure 8: Wenner Configuration Inverted Resistivity Section along Traverse 6 and the Corresponding VES Points.

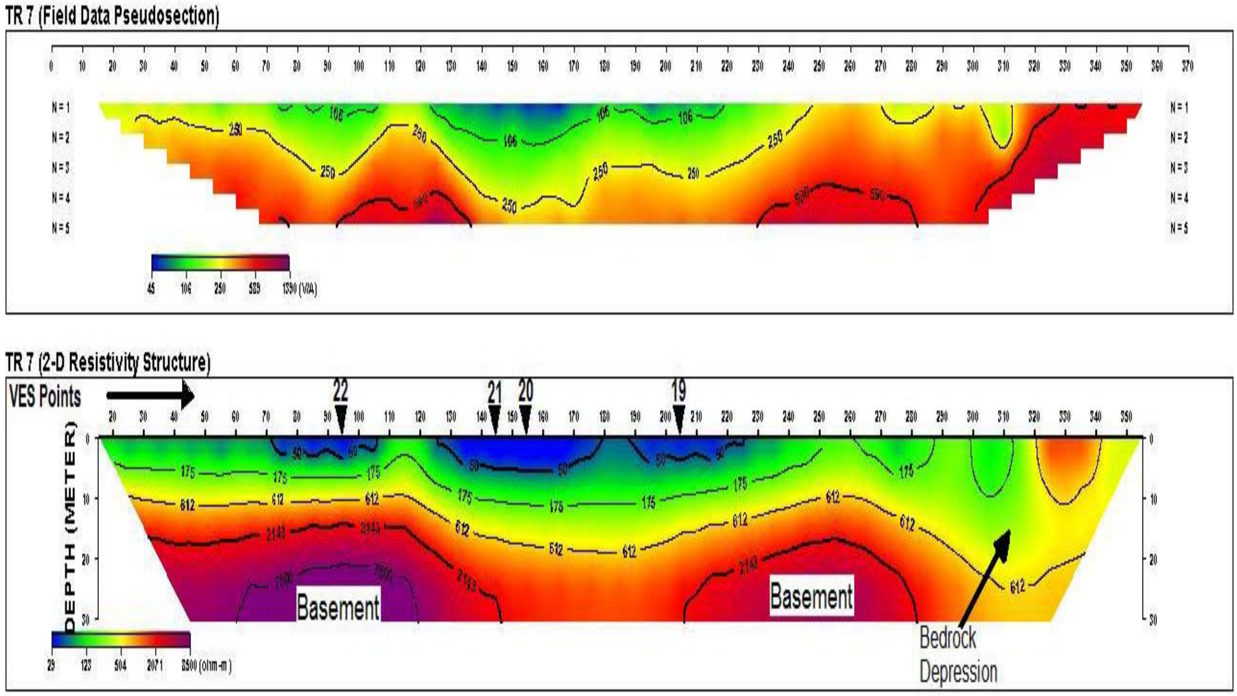

Figure 9: Wenner Configuration Inverted Resistivity Section along Traverse 7 and the Corresponding VES Points.

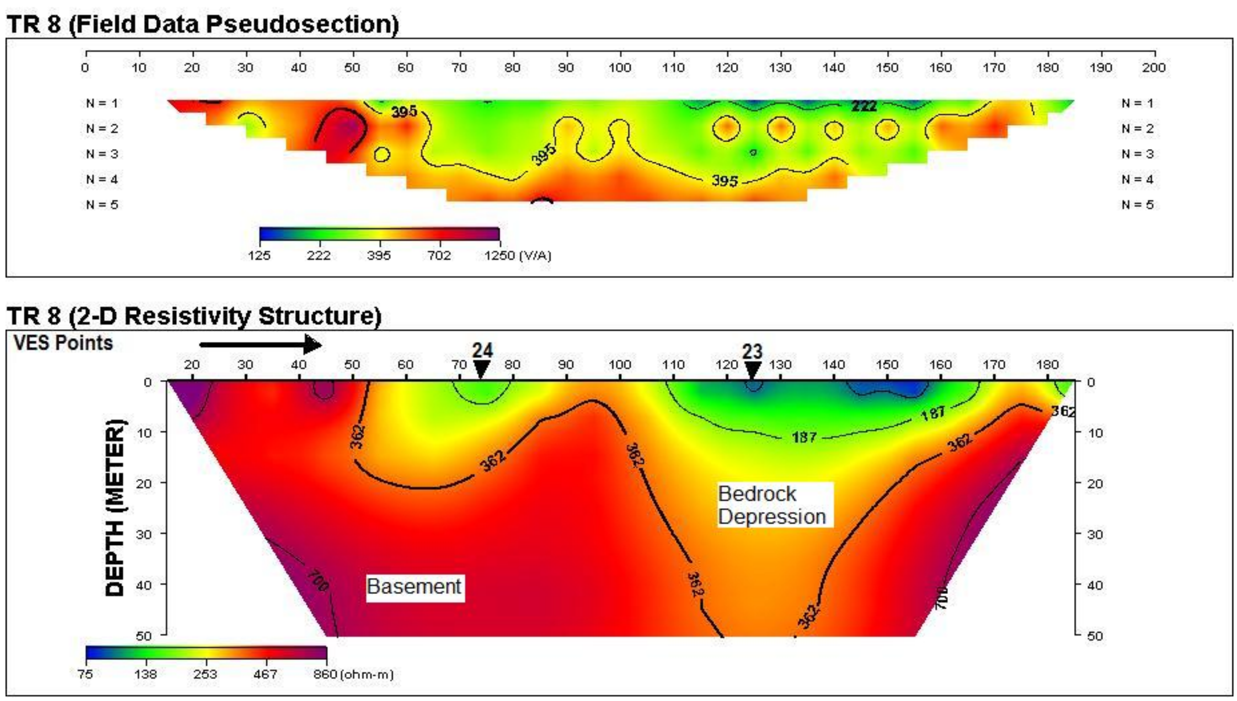

Figure 10: Wenner Configuration Inverted Resistivity Section along Traverse 8 and the Corresponding VES Points.

COMPARISON BETWEEN VES AND 2–D RESULTS

One of the numerous advantages of Electrical Resistivity Tomography (ERT) over ID sounding is noticed in traverse TR 1 (Figure 3). None of the four VES points on this profile delineate the fracture observed on the 2D structure. No place could have been recommended if not for the ERT that produces continuous vertical and lateral imaging along the profile. Thus geoelectric section from VES does not depict the subsurface layers as often imagined, only ERT with continuous imaging along a traverse is reliable.

Other 2D profiles agree in pattern with corresponding ID obtained along the profile, especially TR8 and VES 23 where both surveys delineate a fracture zone/bedrock depression. Only few points give hope of tapable groundwater. This account for the reasons why most boreholes drilled in the camp either failed or is erratic i.e. seasonal.

CONCLUSIONS

ID and 2D surveys of Ajebo camp have been carried out. The result indicated that the area has a complex geology. The results of VES gives scanty hope as water filled horizons are either thin having depth to bedrock above 15m in just two stations or made up of clay horizon. However, the result of ERT show areas favorable for siting productive borehole especially in profile TR1 at surface position 120m interpreted to be water filled fractured rock and profile TR 8 at ground position 130 m as a good bedrock depression where subsurface water accumulates.

It was also discovered that 2D survey gives a better result than 1D because of its ability to image the subsurface vertically and laterally which enhances continuity. Geoelectric layers from two VES points separated by a distance would not give a comprehensive imaging as the 2D does.

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