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Determination of Aquifer Layer by the Application of Electrical Resistivity and Electromagnetic Method of Exploration at Ojoo Town Oyo State Southwestern Nigeria

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ABSTRACT

Geophysical method of exploration involving electrical resistivity and electromagnetic profiling was employed in order to determine the groundwater potential at ojoo. Vertical electrical sounding were carried using the Schlumberger electrode array configuration, 2D electrical resistivity using Wenner array and Electromagnetic profiling using Geonics EM 34-3 were deployed along the area. Ten vertical electrical sounding stations and eleven electromagnetic traverses with one 2D profile were carried data sets were acquired. The qualitative analysis of the electromagnetic data identified relatively high conductive regions indicating possible fracture zones or weathered layer along traverse 1, 5, 6, 7 and 8. The geoelectric section obtained from the sounding curves delineates four subsurface layers which are top soil, weathered basement layer, fractured basement and fresh basement. The weathered layer and the fracture basement constitute the aquifer units across the area, but their insignificant thinness suggest they may not be good for appreciable groundwater development. The 2D Profiling has characterize the topsoil/weathered basement with resistivity range of 27.2 to 537Ωm and depth range of 3 to 8m. Possible fracture zone underlying the basement is represented by electrical resistivity range of 54.9 to 295Ωm at depth of 13.5m this fracture zone is also delineated by traverse C-C' on VES station 8, 9 and 10. Electrical resistivity and electromagnetic methods are suited in mapping and better understanding of basement depression or fracture zones. Geophysical methods should hence form an integral part of groundwater exploration programme in solving problem associated with groundwater occurrence

Key words: *Aquifer layer, Electrical resistivity, Electromagnetic Profiling, Fracture zone, Ojoo*

INTRODUCTION

Groundwater is characterized by some physical parameters that are determined by geophysical methods like electrical resistivity, magnetic and gravity. These parameters are the permeability, porosity, transmisivity and conductivity. This work however involved the application of electromagnetic and electrical resistivity to investigate the groundwater potential at ojoo and environs. Electromagnetic and electrical resistivity methods of exploration for groundwater in a basement terrain have proven to be reliable. Previous studies have shown that the depth of aquifer differ from place to place due to variation in geothermal and geostructural occurrence (Ekine and Osobonye 1996) Groundwater exploration is multidisciplinary in approach, if it is to be effective. The geomorphological investigation encompasses the study of the surface topography of an area, its surface water resources, drainage pattern and the vegetation pattern. The geological/hydrogeological investigation may involve interpretation of remotely sensed data (e.g. aerial photographs, landsat imageries etc.) for regional reconnaissance mapping of lineament and major geological structures. This is followed up with localized ground geologic mapping of the area, for the identification of the lithologic unit, microstructures and the general strike of the geology (Edet et al 1994) Ojoo and environs, south western Nigeria is characterized by extensive outcrop of crystalline basement rock, largely of granite gneiss petrology. Inadequate municipal water supply coupled with hydrogeological difficult nature of the terrain, individual and cooperate bodies indiscriminately sink wells and boreholes within the unconsolidated overburden materials with glaring lack of concerns for the vulnerable status of aquifers and possible environmental risk. In basement terrain, groundwater is generally believed to occur within the overlying unconsolidated material derived from the in-situ weathering of rocks and the fractured fault bed rock (Clark 1985). Geophysical survey involving Electrical resistivity and Electromagnetic methods constitute the most reliable means outside direct mechanical drilling through which basement structures such as fracture or weathered zone that are of hydrogeological significance can be mapped (Vanderberghe 1982)

MATERIALS AND METHOD

Electromagnetic profiling method

The basic field equipment used for the EM survey, consist of a battery, a transmitter coil about 800mm in diameter, a distance measuring device, a receiver coil and a volt meter connected to the receiver coil. The distance between transmitter and receiver is measured electronically and set at 10, 20 and 40m spacing. The coils are placed at a known distance apart and coupled, either both horizontally or vertically on the ground. The transmitter is turn on, the distance between the transmitter and the receiver is adjusted and the apparent terrain conductivity is read directly off the receiver. When both coils are placed horizontally on the ground, the transmitter generates an electrical field with a vertical dipole, so this is called the vertical dipole mode. Similarly when the coils are vertical the equipment is in the horizontal dipole mode. The vertical dipole mode has a greater penetration than the horizontal dipole mode. With a 40m coil spacing and the coil in vertical dipole mode, the quipment can penetrate to a maximum depth of 60m. The electromagnetic profiling was conducted along eleven profiles along the study area

Vertical Electrical sounding method

The field equipment employed for the resistivity field data measurement is the Allied Omega Terrameter. The equipment measures resistivity values digitally as computed from Ohm's law. The Terrameter is powered by a 12.5V DC power source. Other accessories to the equipment include the booster, four metal electrode, cables and hammers spread, Schlumberger array was employed. Generally the array consists of a pair of potential electrode and a pair of current electrode. These are driven into the earth in a straight line to make a good contact with the ground. The current electrode spacing is expanded over a range of values for measurement in the field. The value AB/2 increases as the measurement progresses while the potential electrode separation are guided accordingly. The maximum current electrode separation AB/2 was 75m while the maximum potential electrode separation MN/2 was 5m. A total of ten Vertical Electrical Sounding points were occupied. The field resistivity data were first curve marched manually and then subjected to computer iteration and inversion with the aid of WingLink software. The curves were interpreted with a minimum number of layers that are deemed necessary, and that are qualitatively recognizable on the field curves. It is possible that more layers than the recognizable ones are present, which was then declare as being electrically suppressed. Suppressed layers were added only if borings or models from adjacent soundings suggest their existence and if they produce an acceptable fit. Also, the degree of uncertainty of the computed model parameters and the goodness of fit in the curve fitting algorithm are expressed in terms of root mean square error. The resistivity of the different layers and the corresponding thicknesses were reproduced by a number of iterations until the model parameters of all the VES curves were totally resolved with minimum root mean square error (r.m.s), at this stage, the final subsurface 1-D resistivity image geoelectric sections were generated. The apparent resistivity is given by

$$\rho_a = \frac{\pi}{2l}\frac{(L^2 - x^2)^2}{(L^2 + x^2)}\frac{\Delta V}{l} \text{ x}$$

is the separation of the mid—points of the potential and current electrodes.

When used symmetrically, x = 0

$$\rho_a = \frac{\pi L^2}{2l}\frac{\Delta V}{l}$$

Where L= AB/2 and l= MN/2. AB is the current electrode space in (m) and MN is the potential electrode space (m). ΔV/I is the resistance in Ohms (Ω). (Telford 1984)

2D Electrical resistivity method

The field equipment used for the 2D resistivity survey is the allied Omega Terrameter on Wenner array configuration. The whole set up consist of two current electrodes and two potential electrodes that are equally spaced apart from 5 to 20m. The Wenner configuration measures the lateral variation of ground resistivity at a fixed depth. The resistivity field data was processed with the aid of RES2DINV software to obtain a 2D profile of the ground conductivity.

RESULT AND DISCUSSION

Electromagnetic Profiling

The data obtained from both vertical and horizontal coil configurations were plotted as apparent conductivity (mmho/m) against respective station positions (m). The results are presented in (Figure 1.0-1.4). The apparent conductivity of the subsurface obtained from the various coil spacing of 10, 20 and 40m at both vertical and horizontal dipole profiles, identified five relatively high conductive regions along traverse 1, 5, 6, 7 and 8. These conductive regions depict weathered region and possible fracture zones. The apparent conductivity profiles derived from the various coil spacing indicates that the low conductive regions are associated to the basement region and relatively high conductive regions are associated to weathered basement or possible fracture zones. The horizontal and vertical orientation of Geonics EM 34-3 has different responses with depth (McNeil 1980). At 10m coil orientation depth of penetration is 7.5m on horizontal dipole and 15m on vertical dipole. At 20m coil orientation depth of penetration is 15m on horizontal dipole and 30m on vertical dipole. At 40m coil orientation depth of penetration is 30m on horizontal dipole and 60m on vertical dipole.

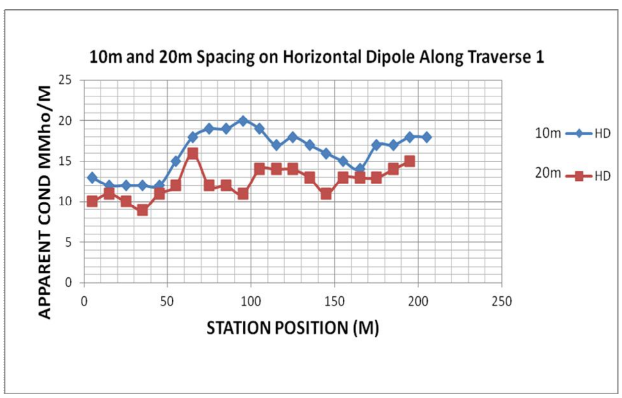
Along traverse 1 (Fig 1.0) 10m coil orientation at a lateral distance of 90m possible fracture zones was delineated at a depth of 7.5m on horizontal dipole and at a lateral distance of 85m at a depth of 15m on the vertical dipole. On 20m coil orientation at lateral distance of 65m possible fracture zone was delineated at a depth of 15m on horizontal dipole and at lateral distance of 95 and 135m at a depth of 30m on vertical dipole.

Along traverse 5 (Fig1.1) 10m coil orientation at a lateral distance of about 40m possible fracture zone was delineated at a depth of 7.5m on horizontal dipole and at a depth of 15m at lateral distance of about 70m on the vertical dipole. On 20m coil orientation at a lateral distance of 22m possible fracture was delineated at a depth of 15m on horizontal dipole and lateral distance of 42m at a depth of 30m on vertical dipole. On 40m coil orientation at a lateral distance of 42m possible fracture zone was delineated at a depth of 30m on horizontal dipole and at a lateral distance of 22m at a depth of 60m on vertical dipole.

Along traverse 6 (Fig 1.2) 10m coil orientation at a lateral distance of 60m, possible fracture was delineated at a depth of 7.5m on horizontal dipole and lateral distance of 22m at a depth of 15m on vertical dipole. On 20m coil orientation at lateral distance of 20 and 50m, possible fracture was delineated at depth of 15m on horizontal dipole and a lateral distance of 18 and 64m at a depth of 30m on vertical dipole. On 40m coil orientation at lateral distance of 44m, possible fracture was delineated at a depth of 30m on horizontal dipole and lateral distance of 36m at a depth of 60m on vertical dipole.

Along traverse 7 (Fig 1.3) 10m coil orientation at a lateral distance of 24m, possible fracture was delineated at a depth of 7.5m on horizontal dipole and lateral distance of 48m at a depth of 15m on vertical dipole. On 20m coil orientation at a lateral distance of 24m, possible fracture was delineated at a depth of 15m on horizontal dipole, and lateral distance of 34m at a depth of 30m on vertical dipole. On 40m coil orientation at a lateral distance of 25m, possible fracture was delineated at a depth of 30m on horizontal dipole, and lateral distance of 13m at a depth of 60m on vertical dipole.

Along traverse 8 (Fig 1.4) 10m coil orientation at a lateral distance of 50m, possible fracture was delineated at a depth of 7.5m on horizontal dipole, and at lateral distance of 32m at a depth of 15m on vertical dipole. On 20m coil orientation at a lateral distance of 15 and 45m, possible fracture was delineated at a depth of 15m on horizontal dipole, and at lateral distance of 28 and 50m, possible fracture was delineated at a depth of 30m on vertical dipole. On 40m coil orientation at a lateral distance of 25m, possible fracture was delineated at a depth of 30m on horizontal dipole and at depth of 60m on vertical dipole.



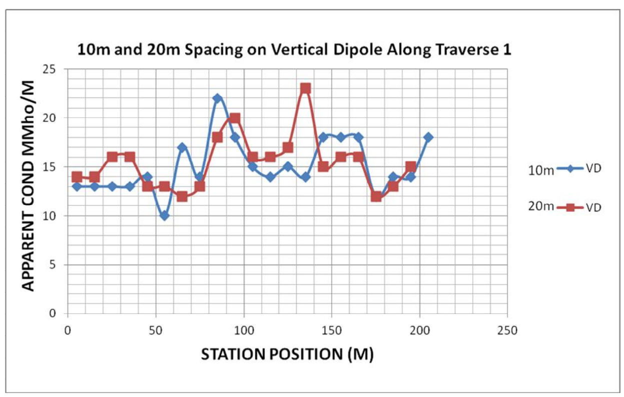


Fig 1.0. 10m and 20m coil spacing on horizontal and vertical dipole along traverse 1

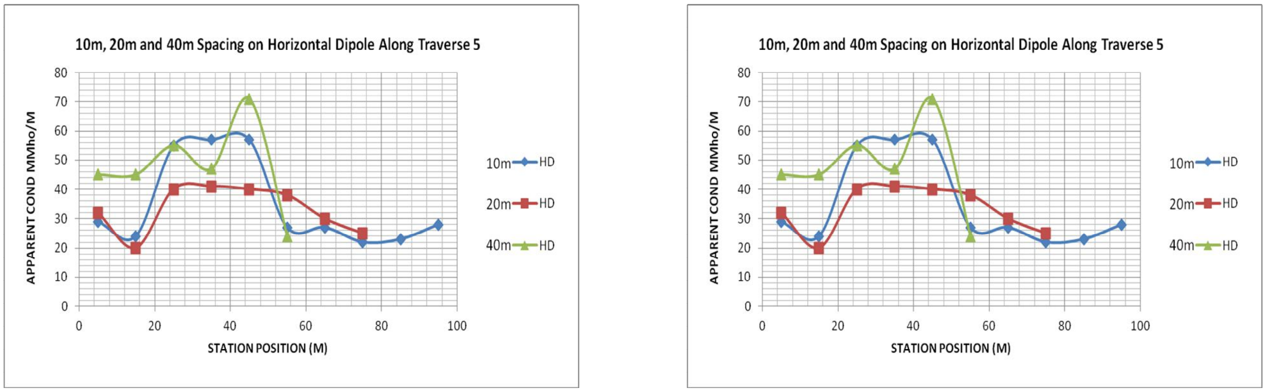


Fig 1.1. 10m, 20m and 40m coil spacing on horizontal and vertical dipole along traverse 5

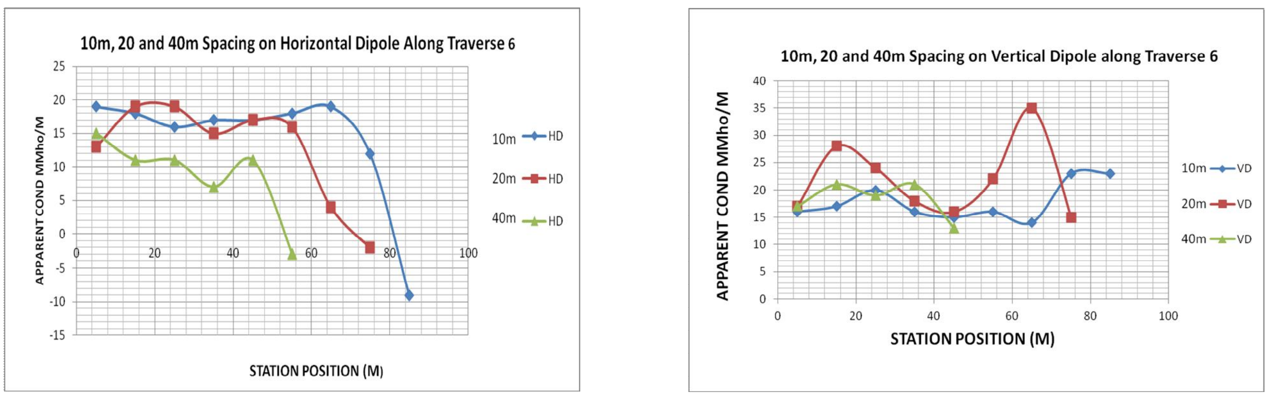


Fig 1.2. 10m, 20m and 40m coil spacing on horizontal and vertical dipole along travers 6

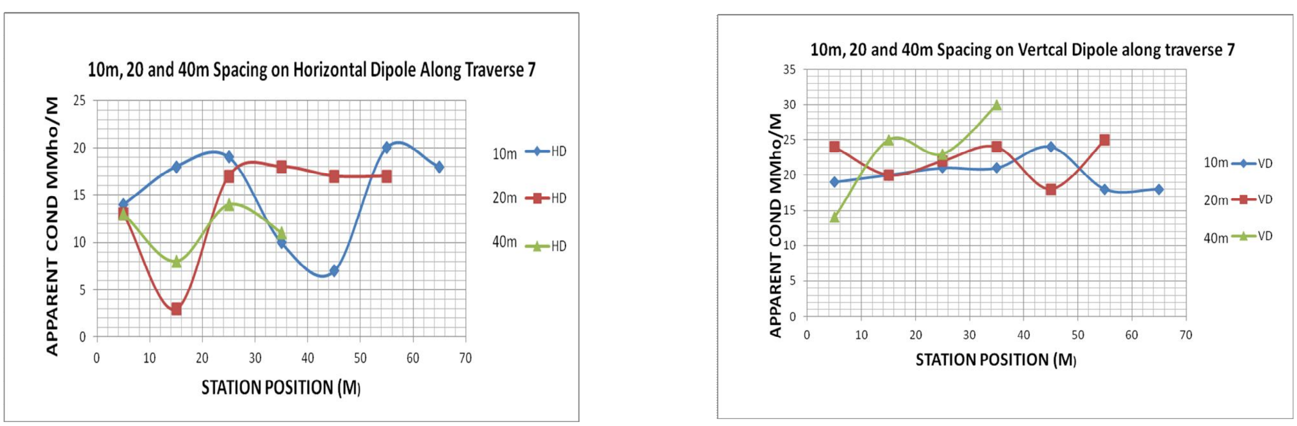
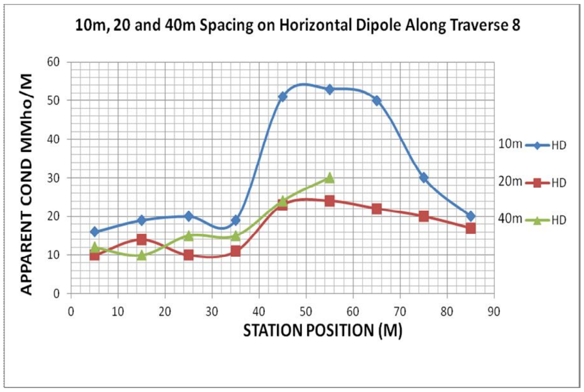


Fig 1.3. 10m, 20m and 40m coil spacing on horizontal and vertical dipole along traverse 7



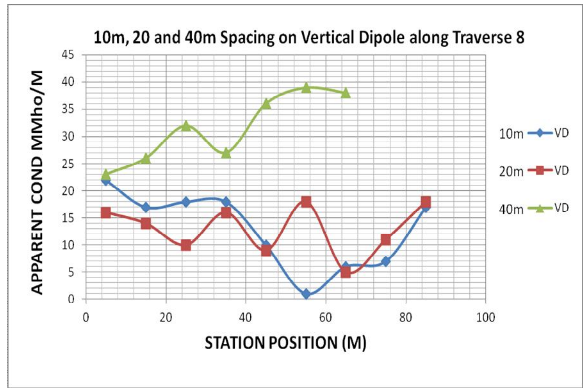


Fig 1.4.10m, 20m and 40m coil spacing on horizontal and vertical dipole along traverse 8

Vertical Electrical Sounding

TRAVERSE A-A'

The first layer on this traverse is characterized by electrical resistivity value of 66 to 286Ωm and thickness of 0.5 to 1.1m, and it was designated as topsoil. The second layer is characterized by electrical resistivity value of 49 to 80Ωm and thickness range of 0.8 to 4.4m. The second layer is descriptive of weathered layer which may include Silt Sand, Clay, Clayey Sand or conglomeratic stone dispersed in lateritic Clay. The third layer is represented by electrical resistivity value of 114 to 537Ωm and thickness of 0.8 to 2.5m. The third layer is indicative of the weathered basement and was interpreted as the aquifer in the study area. The degree of weathering and thickness of the weathered basement is related to its sustainability, storativity, yield and transmisivity. The fourth layer is with electrical resistivity range of 2057 to 7605Ωm descriptive of the basement.

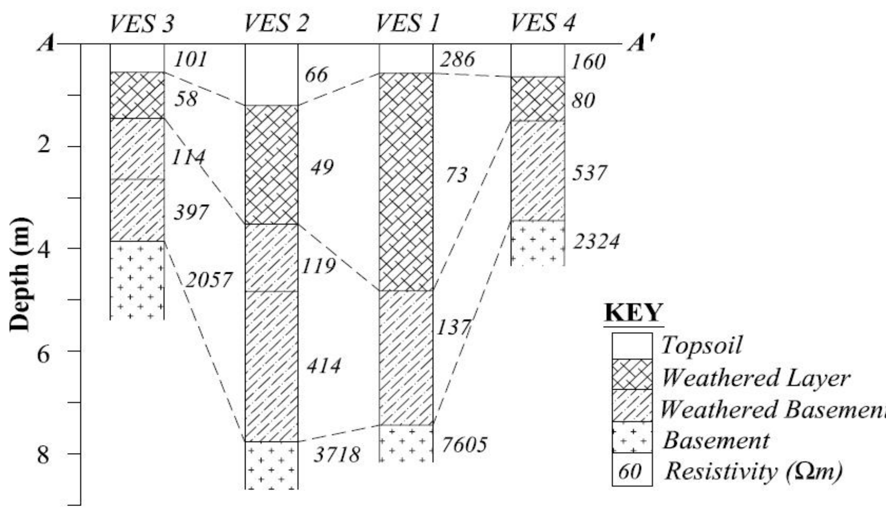


Fig 2.0. Geosection for Traverse A-A'

TRAVERSE B-B'

The first layer is the topsoil with electrical resistivity value range of 36 to 50Ωm and thickness range of 0.4 to 0.7m. The second layer is with electrical resistivity value range of 79 to 131Ωm and thickness range of 0.5 to 2.7m. The second layer is associated to weathered basement on stations 5, 6 and 7. The third layer is represented by electrical resistivity value range of 61 to 5229Ωm of which relatively high electrical resistivity value of 5229Ωm on station 5 is indicative of basement. The third layer is descriptive of weathered basement on station 6 and 7. The fourth layer is with electrical resistivity value range of 2023 to 2068Ωm and descriptive of the basement.

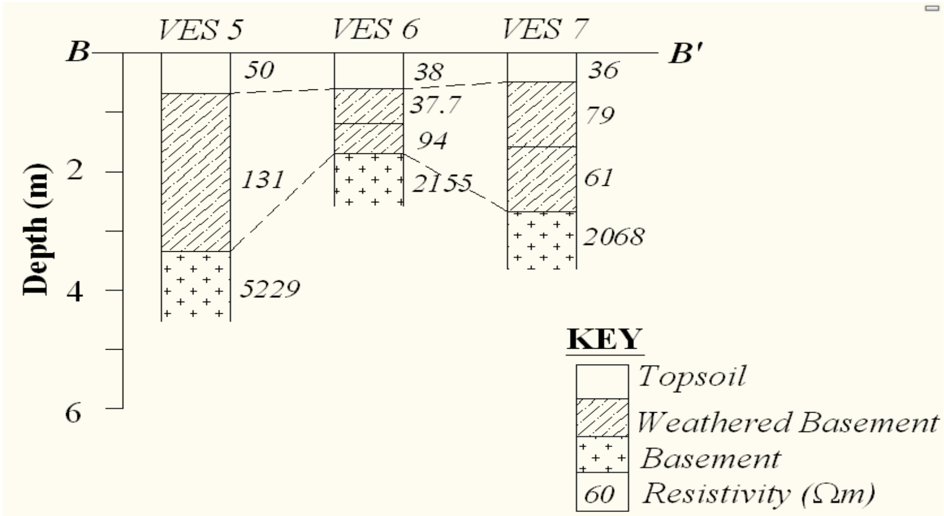


Fig 2.1. Geosection for Traverse B-B'

TRAVERSE C-C'

The first layer on traverse C-C' is with electrical resistivity value range of 151 to 382Ωm and thickness range of 0.5 to 0.7m which constitutes the topsoil. The second layer is with electrical resistivity value range of 62 to 514Ωm and thickness range of 0.8 to 5.6m. The second layer is descriptive of weathered basement on stations 8, 9 and 10. The third layer according to its electrical resistivity representation is with electrical resistivity value range of 113 to 1262Ωm and thickness range of 3 to 13.5m. The third layer is indicative of weathered basement on station 8 and 9 but as basement on station 10. The fourth layer is with electrical resistivity value range of 225 to 8819Ωm and undetermined thickness. The relatively high electrical resistivity signature on station 8 and 9 indicates fresh basement. The relatively low electrical resistivity value of 225Ωm on station 10 is indicative of fractured basement which should be the most prolific point to sink borehole in the study area.

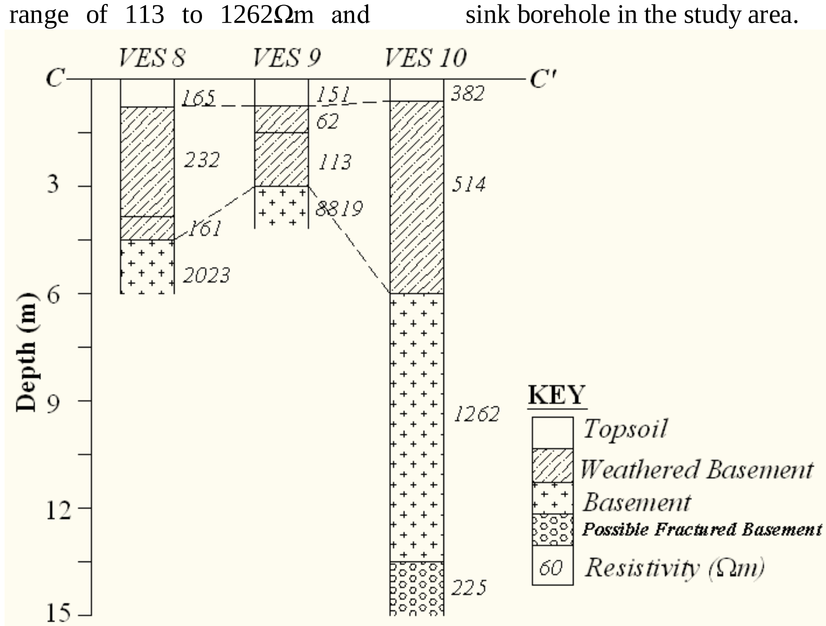


Fig 2.3. Geosection for Traverse C-C'

2D Electrical Resistivity

The 2D Electrical Resistivity Section on Profile 1 is presented in Fig 3. The region with electrical resistivity value range of 169 to 905Ωm and depth range of 6.8m constitutes the topsoil and weathered basement. Fresh basement is characterized by electrical resistivity value range of 905 to 2777Ωm at depth range of 1.25 to 17.3m. Within the lateral distance of 22.5 to 53m and depth range of 8.5 to 17.3m the basement region is underlain by relatively lower electrical resistivity value range of 96.2 to 517Ωm associated to weathered or faulted basement. The faulted or fractured region should serve as the best point to site borehole for ground water development in the study area

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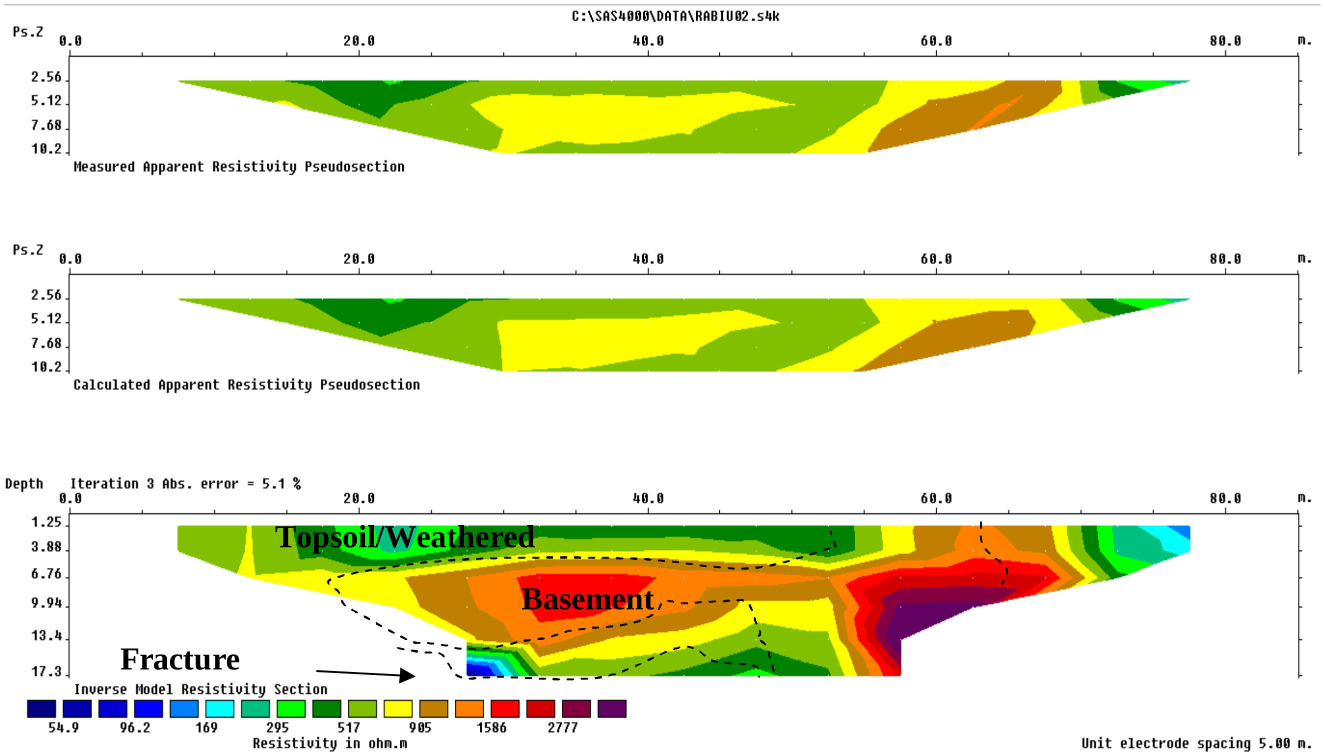
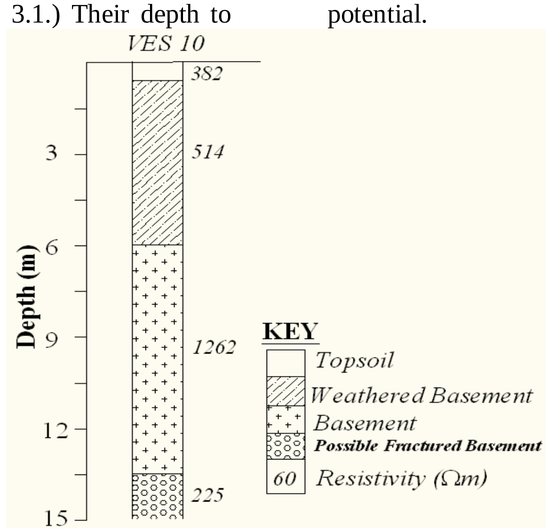


Fig 3. 2D Inverse Model Resistivity Section on Profile 1

Correlation between VES and 2D Profile

VES station 10 indicates possible fault underneath the basement which is equally indicated on the Profile 2D Psuedosection along the same line (Fig 3.1.) Their depth to fractured basement is significantly similar. Therefore it may suggest that borehole at this point will have high groundwater potential.



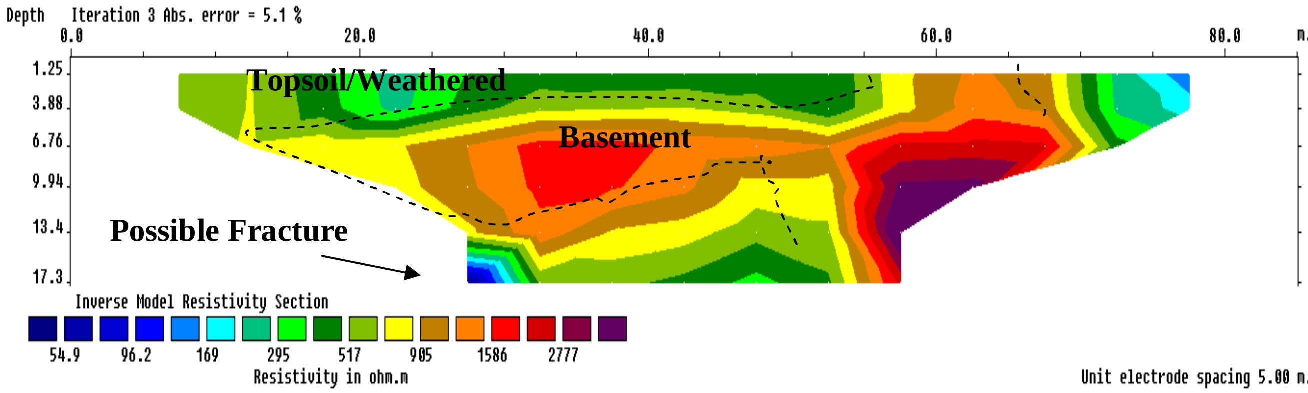


Figure 3.1. Correlation between VES and 2D Profile

CONCLUSION

Geophysical survey involving the application of Electrical resistivity and Electromagnetic profiling was conducted at ojoo town southwestern Nigeria in order to identify the aquifer layer for groundwater development. The quantitative interpretation of the Electromagnetic profiles detected high conductive areas which identifies possible fracture zones or basement depression. The qualitative interpretation of the VES data revealed four subsurface geoelectric layers. These layers are topsoil weathered Basement layer, Partly Weathered/Fracture Basement and Fresh Basement. The first layer (topsoil) has resistivity values ranging from 36 to 382Ωm and thickness value of 0.4 to 1.1m. The resistivity value of the second layer (weathered zone) ranges from 37 to 514Ωm and thickness of 0.5 to 5.6m. The third layer which is the Fractured Basement has resistivity value of 537 to 131Ωm and thickness of 0.5 to 3.2m. The fresh basement which is the forth layer is characterized by high resistivity value of up to 8819 Ωm. Possible fracture region was delineated beneath VES 10 which is also delineated by Profile 1 on 2D electrical resistivity section as possible fracture zone within a similar depth. This is also around the region indicated by the Electromagnetic profile as possibly fractured. Hence this could be the best point to drill a borehole for prolific groundwater development.

RECOMMENDATION

The integrated geophysical technique has helped in the identification and better understanding of the aquifer dimension. It has been deduced from the study, that electrical resistivity and electromagnetic profile method are suited for estimating thickness, mapping of bed rock and fracture zone. It is therefore recommended that geophysical method should form an integrated part of groundwater exploration programme in solving geophysical problems associated with ground water occurrence

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