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Application of 1D and 2D Electrical Resistivity Methods to Investigate the Subsurface Properties of Egbeta, Edo State, Nigeria

Adegbite, Joseph T* Olorunsola, Kuforijimi Omofonmwan, O. John O. J.
Department of Physics, University of Benin, Benin City, Edo State, Nigeria

Abstract
1D and 2D electrical resistivity methods were combined to investigate the subsurface properties of Egbeta community for minerals and groundwater potential. The Vertical electrical sounding (VES) and Electrical resistivity imaging (ERI) data were acquired with the aid of PASSI-16L-N Earth resistivity meter, using Schlumberger and Wenner array configuration respectively. The VES geoelectric sections were drawn using AutoCAD 2007 version after the data were interpreted with WINRESIST computational software. The 2D data acquired were interpreted using EARTH IMAGER software which helps to automatically obtain the 2D inversion model of the subsurface. The results from the VES survey six layers: sandy topsoil, lateritic clayey sand, sand stone, gravel/coarse sand and sand. The result of the ERI from the 2D inversion model divides the 2D image of the inversion model into three horizontal cross-sections, the first zone having resistivity range of 34.3 Ωm to 850 Ω, with depth range between 0 m to 15 m and lateral extent > 250 m. The middle zone has resistivity range between 600 Ωm to 8689 Ωm, with depth range between 15 m to 86 m. The lateral extent of this region is over 280 m. The third region which is in the deepest part of the subsurface has resistivity range between 580 Ωm to 1200 Ωm and lateral extent > 200 m.
Keywords: Electrical, Resistivity, Subsurface Properties, Zones, Aquifer, Minerals

Introduction

The need to attract foreign direct investment to the mining sector is highly imperative to shift attention away from the over reliance on crude oil which is now a falling product in the international market. Exploitation of mineral resources has assumed prime importance in several developing countries including Nigeria (Aigbedion and Iyayi, 2007). Nigeria is blessed with abundant mineral resources, which have contributed greatly to the nation's wealth. Mineral resources are integral part of the growth and economic developments of any nation, as an important source of generating revenue and wealth creation, but before they are harnessed, they must pass through the stages of exploration, mining and processing (Dogara and Aloa, 2017; Ndinwa and Ohwona, 2014). The method adopted during the exploration of mineral resources varies because of the geological situation of the area of consideration. Electrical resistivity imaging employed in this survey has been an authentic tool in delineating bedrock depression, fracture, synclinal water accumulation zone and aquifer layer (Singh *et al.*, 2006, Ayolabi *et al.*, 2008). Geophysical mapping techniques have progressed from 1D to 2D to 3D, still, the capability of the 1D method in subsurface mapping has not been fully utilized, mostly the mapping and estimation of in-place intrusive rock for commercial quarry development (Nwachukwu *et al*., (2017). This shows that 1D method is still relevant in the subsurface mapping. Two-dimensional (2D) geoelectrical resistivity imaging has been extensively employed to map areas with moderately complex geology (Griffiths and Barker 1993; Griffiths *et al*., 1990; Dahlin and Loke 1998; Olayinka 1999; Olayinka and Yaramanci 1999; Amidu and Olayinka 2006). Loke (2001) stated that the major limitation of the 2D geoelectrical resistivity imaging is that measurements made with large electrode spacing are often affected by the deeper sections of the subsurface as well as structures at a larger horizontal distance from the survey line. It is most distinct when the survey line is placed near a steep contact with the line parallel to the contact. Both methods (1D and 2D) are employed in this study because it has been discovered that 2D survey gives a better result than 1D due to its ability to image the subsurface vertically and laterally which enhances continuity (Ayolabi *et al*., 2009). This paper aims at using 1D and 2D electrical resistivity methods to investigate the subsurface properties of Egbeta community in Edo state, Nigeria.

Location and Geology of the Study Area

Egbeta, a suburb area is in Ovia North East Local Government Area of Edo State, Nigeria. The several formations in the geology of Edo State are the Benin, Bende Ameki, Ogwashi - Asaba, Imo and Nsukka. The geology of the study areas is characterized by deposits laid during the tertiary and cretaceous periods (Reyment, 1965). The area is underlain by sedimentary rock constituting part of the Benin formation which is made up of over 90% massive, porous, coarse sand with thick clay/shale interbeds having high groundwater retention capacity (Kogbe, 1976). Figure 1 below shows the location of Egbeta on the satellite imagery and the neighbouring communities, while Figure 2 shows the geological map of the study area.

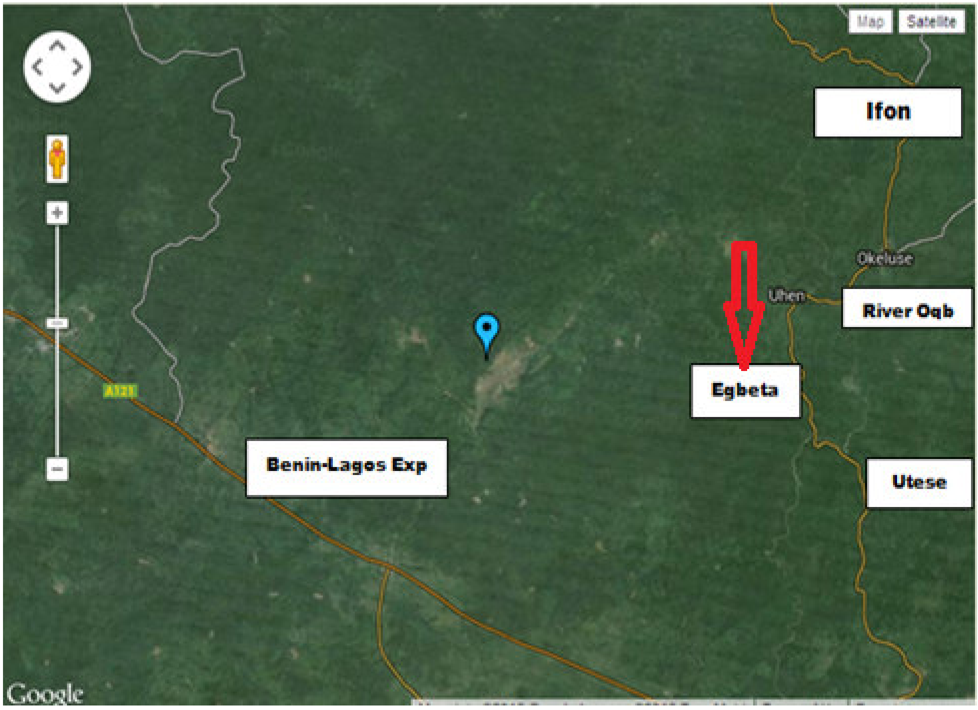

Figure 1: Satellite Image of the Study location indicated with Red Arrow

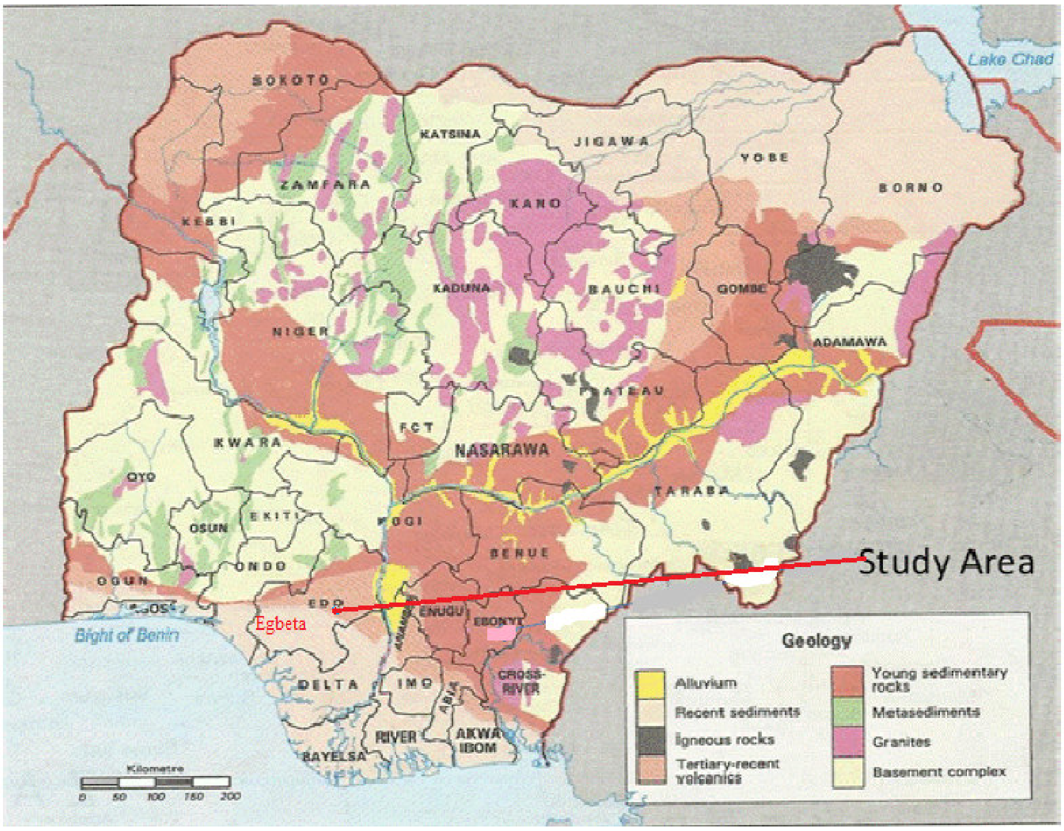

Figure 2: Geologic Map of Nigeria showing the Location of the Study Area (Balogun, 2000)

Materials and Methods

In this research, both one dimensional (1D) and two dimensional (2D) electrical resistivity methods of geophysical survey investigation were adopted. A total of six (6) vertical electrical soundings (VES) surveys were carried out using Schlumberger configuration along the 2D profile lines at different locations. The current electrode (AB/2) spacing ranged from 1.0 m – 350.0 m while the potential electrode (MN/2) varied between 0.25

m and 10.0 m. Three (3) 2D electrical resistivity imaging (ERI) survey data were acquired using the Wenner electrode configuration. Electrode spacing of 10 m was adopted for this survey and the profile length of 300 m. PASSI 16 GL-N Earth resistivity meter was used for the data acquisition. The VES data acquired were analysed and interpreted using WINRESIST computational software that helps in plotting depth against the resistivity value and the geo-electrics sections for the VES data obtain were drawn using AutoCAD 2007. In a similar way, the 2D data acquired were interpreted using EARTH IMAGER software which helps to automatically obtain the 2D inversion model of the subsurface. It is assumed that the surface is homogeneous and isotropic (Abdullahi and Udensi, 2008), and this was taken into consideration during the data processing.

Results

The results from this survey at the different locations in the community are presented in figures 3 to 8 below
Location A

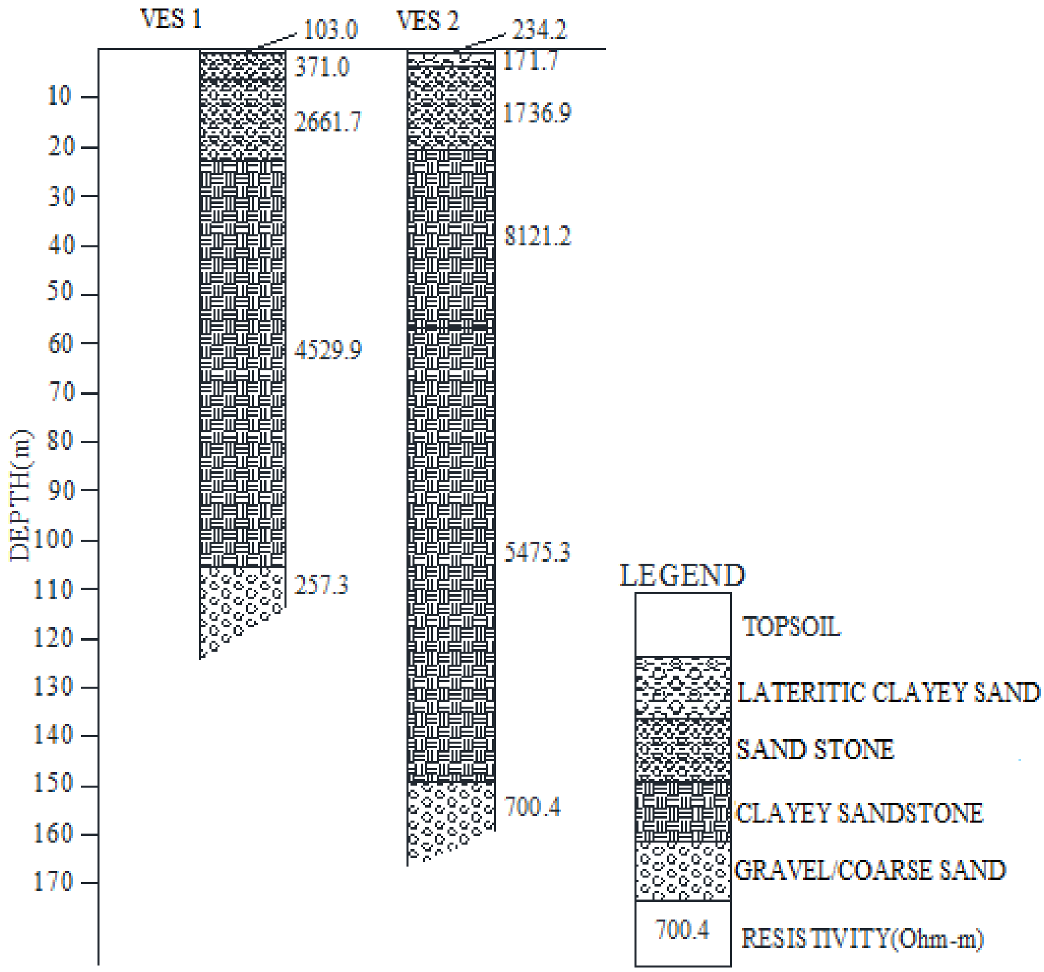

Figure 3: Geoelectric Section for location A

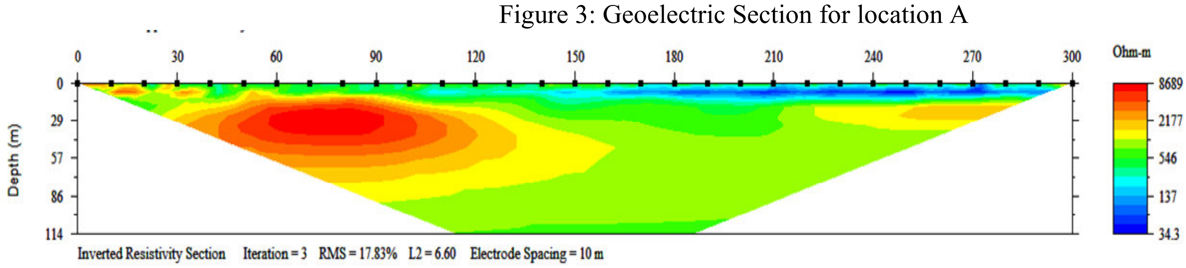

Figure 4: ERI Model for Location A

Location B

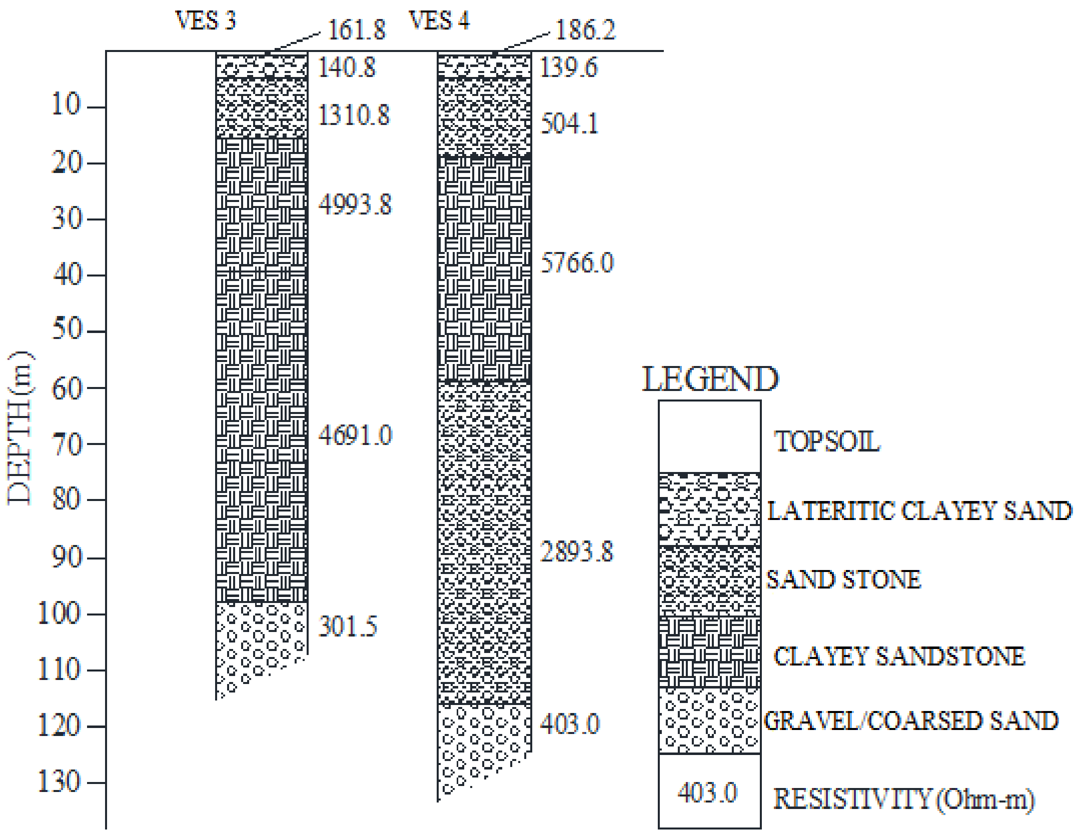

Figure 5: Geoelectric Section for Location B

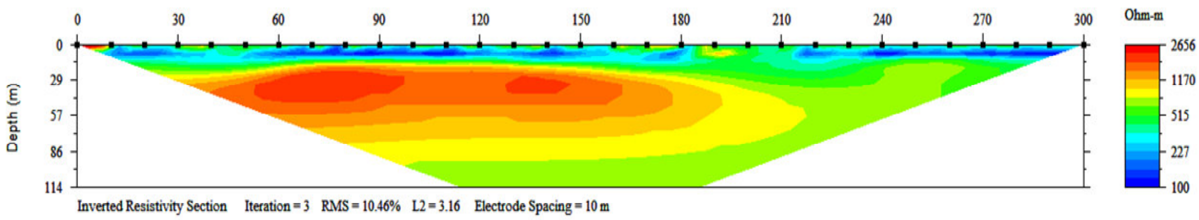

Figure 6: ERI Model for Location B

Location C

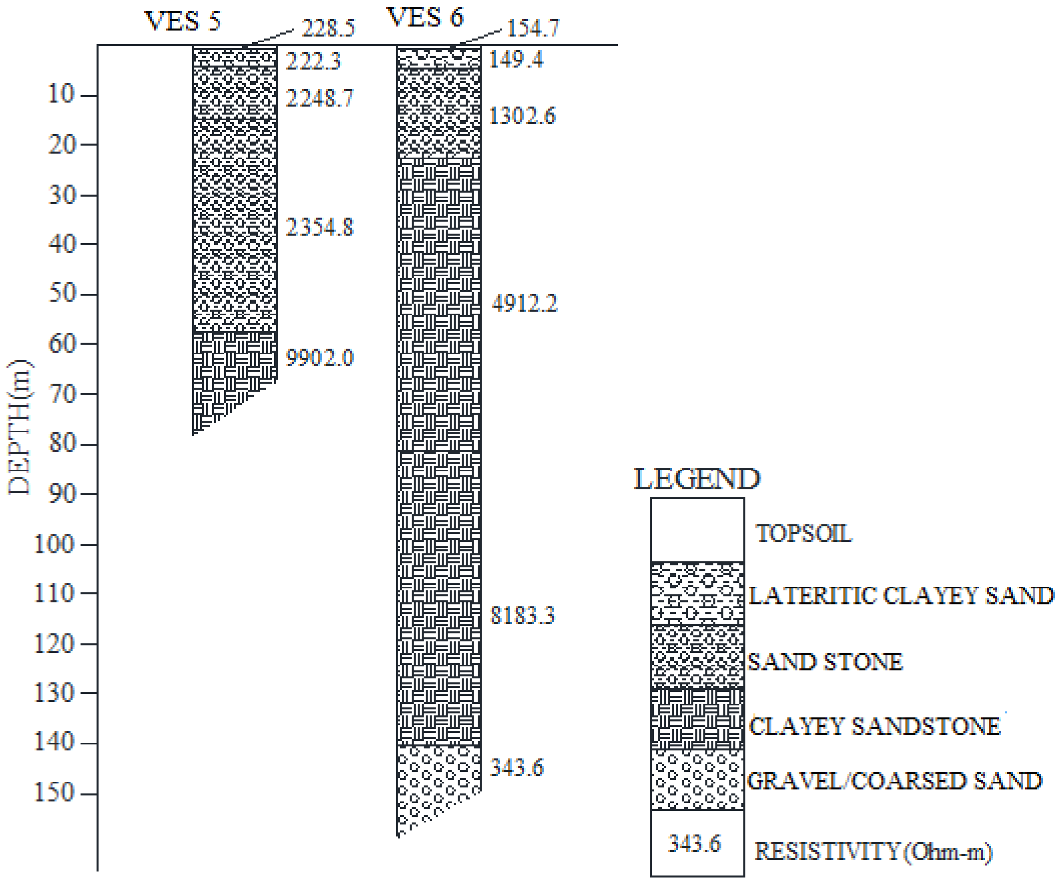

Figure 7: Geoelectric Section for Location C

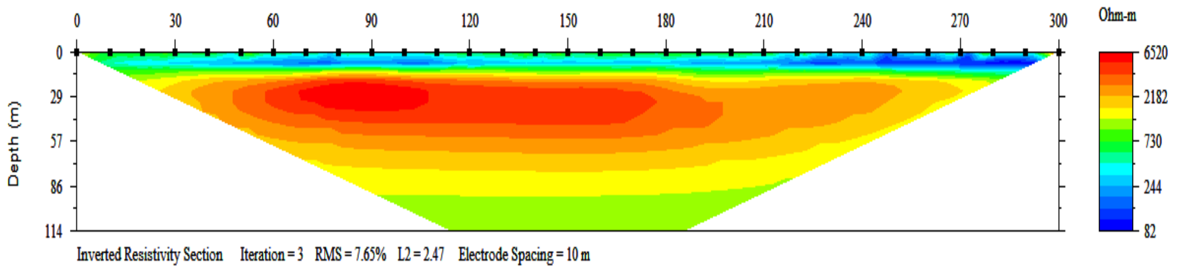

Figure 8: ERI Model for Location C

Discussion

The analytical results presented by the geoelectric sections for the VES survey revealed in figures 3, 5 and 7 above give six sub-layers as follows: The sandy topsoil occupying the first layer has a depth range of 0.5 m to 0.8 m, thickness range of 0.5 m to 0.8 m, and resistivity range of 103 Ωm to 228 Ωm. The second layer which is composed of lateritic clayey sand has resistivity range of 139.6 Ωm to 371.1 Ω, thickness range of 3.0 m to 5.4 m and depth range of 3.5 m to 6.1 m. The third layer composing of sand stone has resistivity range of 504.1 Ωm to 2661.7 Ωm, thickness range of 10.4 m to 18.2 m and depth range of 14.7 m to 22.8 m. The fourth layer at depth range of 39.1 m to 105 m, thickness of 23.7 m to 82.2 m and resistivity of 2354.8 Ωm to 8121.2 Ωm has clayey sandstone. The fifth layer with depth range of 97.8 m to 149.2 m, thickness range of 57.4 m to 92.9 m and resistivity range of 257.3 Ωm to 9902 Ωm has gravel/coarse sand. The deepest layer of depth and thickness undefined has resistivity range of 301.5Ωm to 403 Ωm, this layer is characterised with sand, and it is the lower aquifer zone.

Analytical results from the image of the 2D ERI model presented in figures 4, 6 and 8 above are divided into three horizontal cross-sections. The first zone with resistivity range of 34.3 Ωm to 850 Ω, with depth range of between 0 m to 15 m, and lateral extent > 250 m. The minerals in this region includes: the sandy top soil, lateritic clayey sand and sandstone. This region is highly porous with high conductivity because of the low resistivity of the materials in the region. The middle zone has resistivity range of between 600 Ωm to 8689 Ωm, with depth range between 15 m to 86 m. The lateral extent of this region is over 280 m. This zone has lower conductivity, and the probability of getting water bearing aquifer in this zone is low, this is because of the high resistivity of the zone and the mineral compositions of the zone which are mainly sandstones, clayey sandstones and gravel. The third region which is in the deepest part of the subsurface has resistivity range between 580 Ωm to 1200 Ωm and lateral extent > 200 m. The mineral compositions of the zone are: gravel, coarse sand and sandstone. This is the lower aquifer zone with high conductivity and lower resistivity values compared to the middle zone which has a very high resistivity.

Conclusion

The subsurface properties of Egbeta community has been successfully investigated using 1D and 2D electrical resistivity methods to ascertain the natural resources deposits. Both surveys (1D and 2D) agree seamlessly as to the depth of the aquiferous zones. The results did not show any complex geology in the study area. From the geologic data and resistivity interpretation, the lithologic units in this community are: Sandstones (a clastic sedimentary rock composed of quartz or feldspar) some of which are already weathered or fractured, clay minerals and laterite. They are available in large commercial quantities as revealed from the 2D ERI models presented in the figures. Also, the delineated aquifers were classified into zones. The third region with the lower aquifer zone is porous and has high probability of groundwater retention capability unlike the other zones. It is expected that the groundwater potential in this zone to range from moderate to high.

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