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GEOELECTRICAL INVESTIGATIONS FOR GROUNDWATER EXPLORATION IN CRYSTALLINE BASEMENT TERRAIN, SW NIGERIA: IMPLICATIONS FOR GROUNDWATER RESOURCES SUSTAINABILITY

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ABSTRACT

This research involves the subsurface geological characterization for groundwater potential assessment within the campus of the Polytechnic of Ibadan, southwestern Nigeria. The study is directed towards groundwater resources exploration, development and management in the campus. Five 2D resistivity imaging traverses were conducted using Wenner array in addition to five VES surveys using Schlumberger array that provide layering information and geoelectrical parameters. Three geologic layers delineated from the 2D resistivity inversion models include predominantly clayey sand/ sandy clay top soil (overburden), partly weathered or fractured basement and fresh basement. Their inverse model resistivity values ranges 6.68 – 98.6 Ωm*, 68.0 – 929* Ωm *and* ≥ 2252 Ωm *with bottom depths ranges 3.8 – 6.4 m and 6.4 – 10 m respectively. 1D model inversion from VES results also delineate three lithologies classifying both topsoil and some part of the partly weathered basement as overburden with resistivity and thickness range 483 – 1746.9* Ωm*, 1.1 – 1.8 m; partly weathered or fractured basement 60.3 – 93.5* Ωm*, 8.4 -12.9 m and fresh basement 984.6 – 2078.9* Ωm*. The saturated portion of the partly weathered or fractured basement at depth will favour groundwater exploration and development in this area, while the relatively shallow overburden thickness would serve as the protective layer and recharge for the fractures.*

Key words: Geoelectrical resistivity, Basement aquifer, Groundwater exploration, Subsurface characterization, Groundwater sustainability.

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1. INTRODUCTION

The heavy reliance on groundwater as a source of affordable water for both industrial and domestic use throughout the world demands that the water occurrence within the subsurface is of significant quantity and high quality. Subsurface geological characterizations using surficial geoelectrical resistivity technique are sufficient to address variety of problems related hydrological investigations in complex geological terrains such as crystalline basement. Several works have been carried out on the assessment, abstraction, development and management of groundwater within the hard rock terrain of Nigeria [1-15]. In this research, Electrical resistivity imaging (ERI) and vertical electrical soundings (VES) were combined for subsurface characterization as part of preliminary studies for groundwater resource evaluation and management in a basement complex, southwestern Nigeria.

2. METHODOLOGY

2.1. Geologic and Hydrogeologic Setting

Most parts of Ibadan and other neighbouring towns within the southwestern Nigeria are underlain by gneiss-migmatites complex and the metasedimens underlie [16]. The gneiss-migmatite complexes within this region include minor quartizites and calc-silicate bearing units. The major rock types present in the study area are predominantly granites and schists of metasedimentary scores (such as mica schist, quartizite and quartz-schist), biotite, biotite-hornblende gneiss, banded gneiss and granite gneiss, and migmatite gneiss (Figs 1a and b). The minor rock types within the area include augen-gneiss pegmatite and amphibolite. The gneisses that are rich in mafic minerals may undergo weathering, resulting to rigoliths and clayey soils overlying the coarse grained granitic components soil with more varying texture and lower clay contents [17].

2.2. Data Acquisition and Processing

The data acquisition were done manually using Omega resistivity meter in the investigation site within the Polytechnic of Ibadan campus, Ibadan southwestern Nigeria (Fig. 2). Five resistivity soundings were carried out along the five lines with maximum half-current electrode spread (AB/2) of 75.0 m using Schlumberger array, which is enough for the anticipated depth of investigation (DOI). Likewise, five 2D electrical resistivity profile lines in the West-East and North-South direction were conducted with each 2D resistivity profiles being 110 m length (Fig. 2). Wenner array with least electrode spacing of 5.0 m was adopted for the surveys reaching 5 data level of 5 for each profiles. The Wenner configuration was adopted for the 2D ERT survey due to its easy application, strongest signal strength, and greater sensitivity to vertical resistivity variation or structures lying horizontally with respect to the country rocks [18].

The processing of the acquired soundings (VES) data were done by plotting the apparent resistivity against half–current electrode spacing (AB/2) on a log–log graph sheets. The estimated geoelectric parameters (resistivities and thicknesses) from the partial curve matching were later adopted as the initial inputs for several iteration on a Win-Resist software program to get final model parameters for subsurface geoelectric layers. Also, apparent resistivity data observed for the 2D electrical resistivity tomography (ERT) were processed and inverted using RES2DINV inversion code [19, 20].

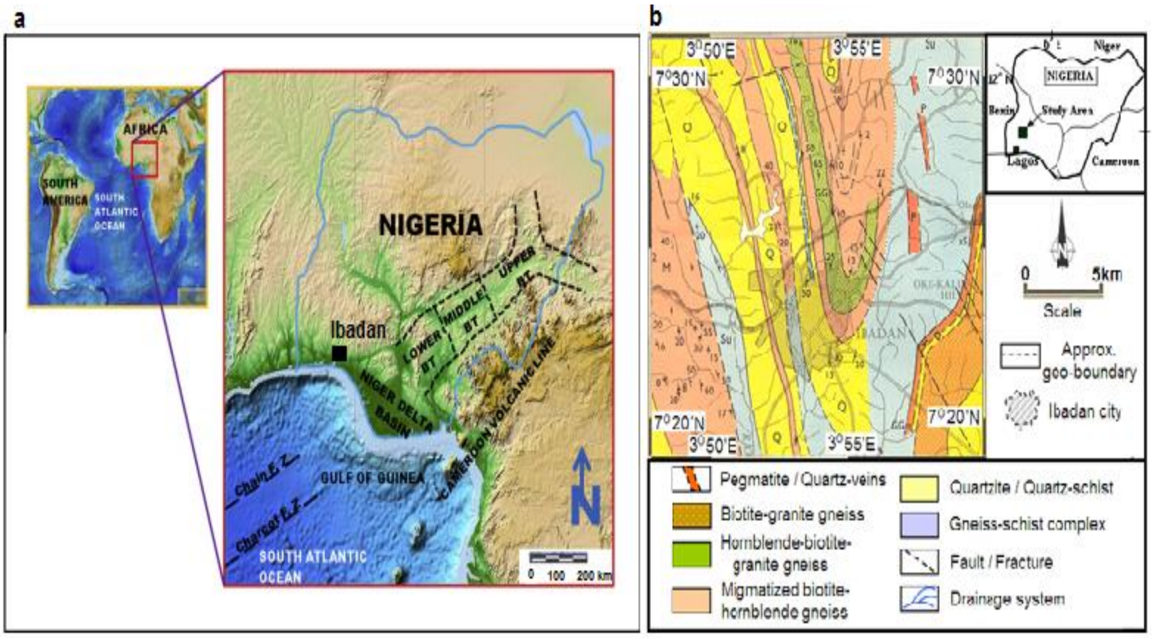

Figure 1 Map showing the Nigeria relief and adjoining areas with extracted and modified Ibadan, using ETOPO1 global relief model [21]. **b.** Geological map of Ibadan (After NGSA, 2009).

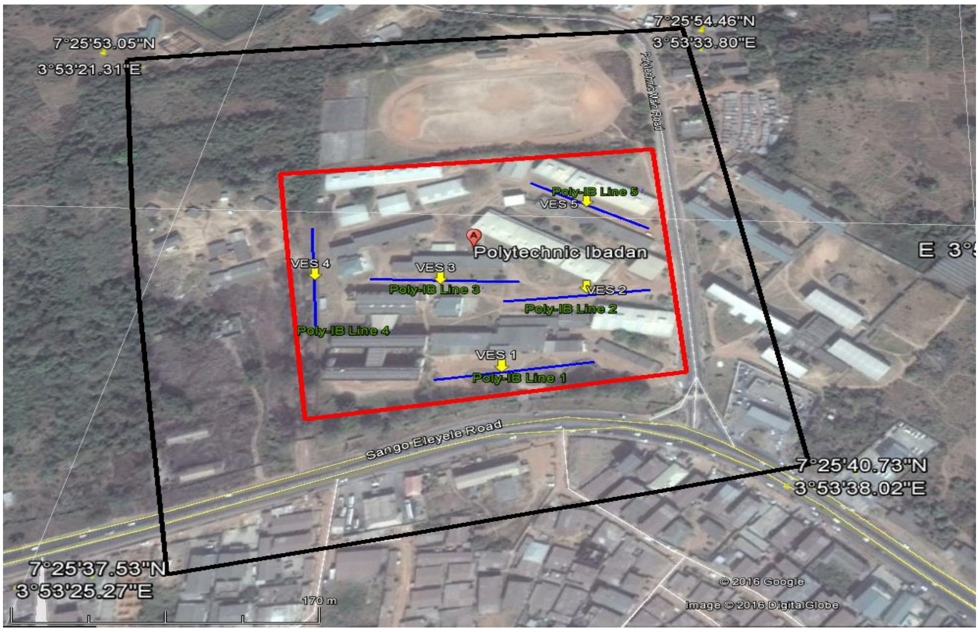

Figure 2 Satellite imagery map of the study site in Ibadan indicating the 2D resistivity profile lines (blue) and VES points (yellow arrows)

3. RESULTS AND DISCUSSION

3.1. Vertical Electrical Sounding

The derived geoelectric parameters from several iterations of the resistivity vertical electrical soundings are shown in Figs. (3 and 4) and Table 1. Three geoelectrical layers were identified from the iterated curves. Large consistency of the geoelectric parameters were observed in the VES curves. Based on the local geology of the area and the information available from the boreholes and hand-dug wells, the delineated subsurface strata are: overburden layer (mainly sandy clay units) with model apparent resistivity ranging between 1746.3 (Ωm) and 483.3 (Ωm) and thickness range 1.1 – 1.8 metres; intercalation of partly weathered and fracture basements with model resistivity range of 60.3 – 93.5 (Ωm) as well as thickness range of 8.4 – 12.4 metres; fresh basement with model resistivity ranging from 784.6 to 2078.9 (Ωm). The second layer is interpreted as the water-saturated aquiferous zone in the area of study. The fresh portion of the basement is inferred to be the lowermost infinitely thick layer with very high resistivity values. The outcomes of the VES surveys serve as great imput to better understanding the hydrogeological setting in the study area. The water saturated fractured and weathered basement should be the target for sustainable water supply in the study area.

3.2. Interpretations of 2D Resistivity Models

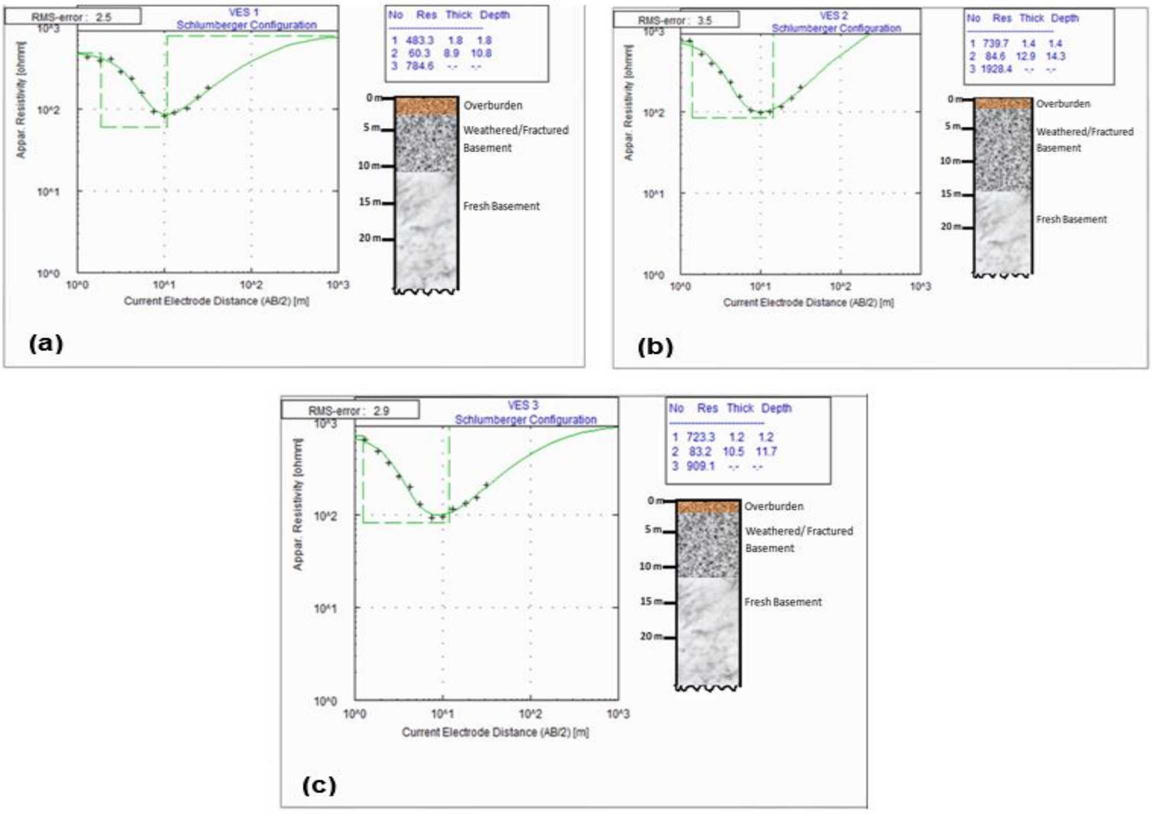

Figure 3 VES curves and geoelectrical parameters obtained for (**a**) VES 1, (**b**) VES 2 and (**c**) VES 3.

The 2D inverse models of the apparent resistivity distribution within the subsurface with depths obtained from the smoothness constrained inversion are presented in Figs. 5 and 6. The inversion models reveal a range of both relatively low resistivity and high resistivity zones within the area of study. The 2D inverse models resistivity values range from about 9.18 – 10133 Ωm, 6.68 – 40441 Ωm, 17.7 – 7219 Ωm, 15.1 – 20382 Ωm, and 10.1 – 19610 Ωm

for traverses 1 – 5 respectively. The variations in inverse models resistivity values 2D geoelectrical imaging to the tune of tens of thousands Ohm-metre higher than those of the 1D VES points denote the greater sensitivity and resolution of 2D electrical resistivity imaging [22-25]. The geoelectrical parameters for the three identified geoelectric layers such as the inverse resistivity models values and thicknesses obtained from the soundings agree reasonably with those obtained from the 2D resistivity imaging.

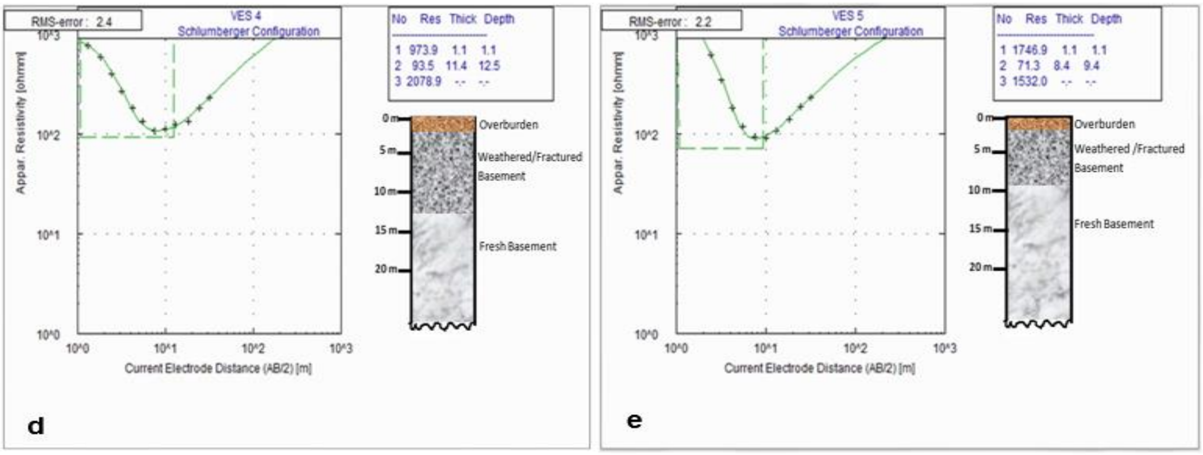

Figure 4 VES curves and geoelectrical parameters for (**d**) VES 4 and (**e**) VES 5.

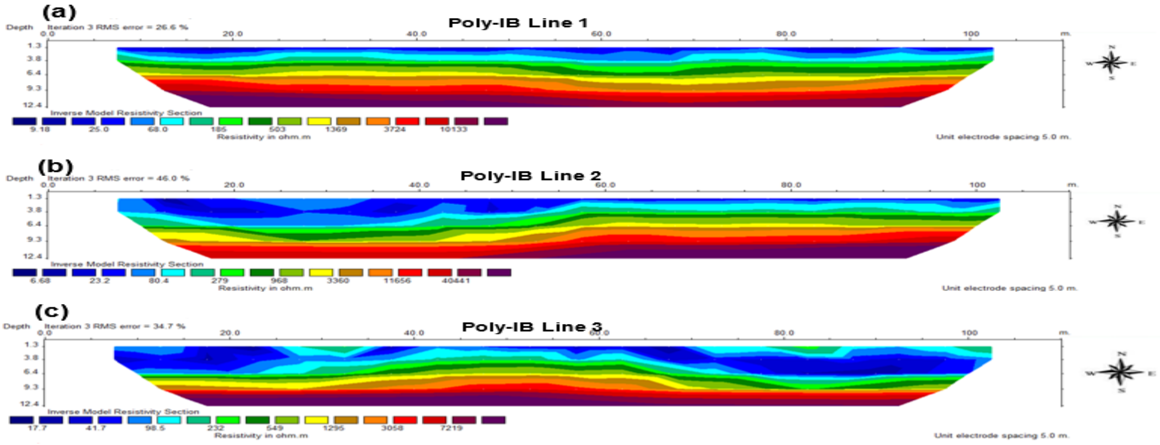

Figure 5 2D inverse resistivity model for Poly-IB profiles 1, 2 and 3.

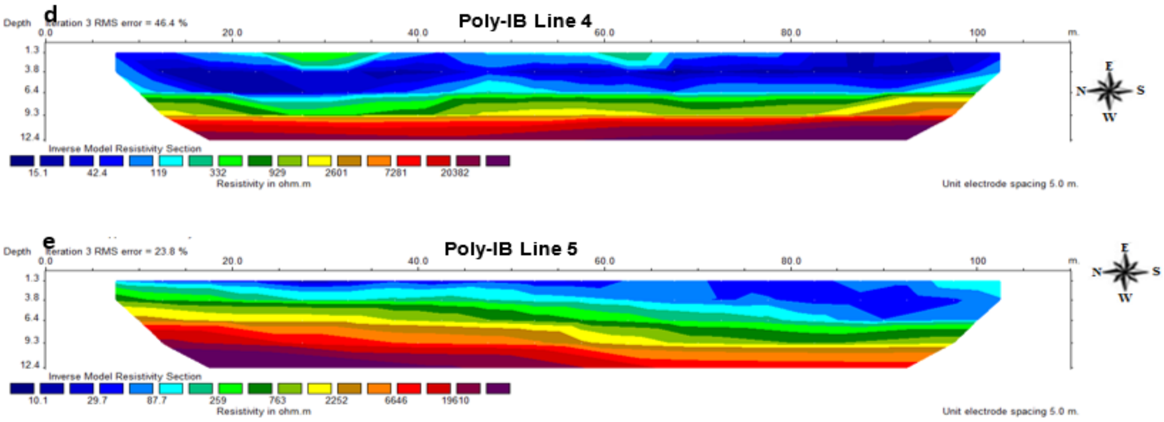

Figure 6 2D inverse model resistivity sections for Poly-IB profiles 4 and 5.

Table 1 Interpreted geoelectric layered parameters from the VES (1-5)

Layer		VES 1	VES 2	VES 3	VES 4	VES 5	Lithology
1	Resistivity (Ωm)	483.3	739.7	723.3	973.9	1746.9	Overburden (Sandy Clay)
	Thickness (m)	1.8	1.4	1.2	1.1	1.1	
	Bottom Depth (m)	1.8	1.4	1.2	1.1	1.1	
2	Resistivity (Ωm)	60.3	84.6	83.2	93.5	71.3	Weathered /Fractured basement
	Thickness (m)	8.9	12.9	10.5	11.4	8.4	
	Bottom Depth (m)	10.8	14.3	11.7	12.5	9.4	
3	Resistivity (Ωm)	784.6	1928.4	909.1	2078.9	1532	Fresh Basement

Depth-to-base of the geoelectric layers reveals quick assessment of their lateral thickening.

4. CONCLUSIONS

Geoelectrical resistivity surveys involving vertical electrical soundings and ERT have been used to evaluate the groundwater potential in a crystalline basement terrain and to delineate target locations for sitting boreholes in the study area. The analyses of the soundings resistivity models and the 2D inversion models clearly shows three geoelectric layers; top layer, which is inferred to be sandy clayey/ clay; water-saturated weathered and fractured basement with clayey materials serving as the aquifer unit, and fresh basement. The electrical soundings delineate higher bottom depth for the water-saturated aquiferous unit, however with little or low lateral resolution. Lateral heterogeneity of clay content within this layer was evident in the 2D electrical resistivity imaging. The rigoliths (weathered basement) unit within the area with bottom depth up to 10 metres from 2D imaging but about 14.1 metres from the VES results. Thus, groundwater exploration and development in the area should target the weathered and fractured basement layer.

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