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Full Length Research Paper

Geo-electrical data analysis to demarcate groundwater pockets in Ado – Ekiti, southwest, Nigeria

Oyedele, E. A. A.[1]*, Oyedele, T.[2] and Oyedele, K.[3]

[1]Physics Department, University of Ado - Ekiti, Nigeria.
[2]Geological Services, Ogun State Ministry of Commerce and Industry, Abeokuta, Nigeria.
[3]Omega – Inlands and Associates, Abeokuta, Nigeria.

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Geo-Electrical Analysis of data obtained from Vertical Electrical Sounding (VES) measurements conducted in Ado-Ekiti has been carried out to demarcate groundwater pockets in the metropolis within the Basement Complex of Southwest, Nigeria. 49 'vertical electrical soundings' were carried out. The layer parameters of resistivity and thickness were determined and used to generate spatial distributions of relevant geo-electric parameters including overburden thicknesses, the bedrock relief and the weathered basement thickness/resistivity. The depth – to – bedrock varied from 3.8 to 56.2 m with a mean of 21.04 ± 14.62 m. The weathered basement has resistivity values ranging from 6.5O to 1214 Ω-m with weathered basement thickness ranging from 3 to 39.5 m. The basement rocks were observed to be variably fractured. Groundwater potential zones such as valley fills/basement depressions, weathered zones and fractured zones were delineated in the study area based on the geoelectrical data.

Key words: Groundwater, geoelectric, saprolite, bedrock, basement.

INTRODUCTION

The exploration for groundwater in hard rock terrains is a complex task. The crystalline basement rocks are generally of low porosity and permeability, and as such, have no water storage capacity in their fresh (unaltered) form; consequently, their groundwater resources are limited and commonly restricted to features produced by weathering and tectonic processes (Olayinka and Olorunfemi, 1992). The application of the Vertical Electrical Sounding (VES) lends itself as an efficient and effective method for mapping potential zones that are relevant to the development of groundwater resources. The electrical resistivity method is a non-invasive geophysical method. VES measurements are useful in groundwater studies as neither the structure nor the dynamics of the soil is disturbed (Adiat et al., 2009; Ariyo and Adeyemi, 2009). Ado-Ekiti, Southwest Nigeria, is underlain by the Precambrian basement Complex Rocks of Southwestern Nigeria with heavy dependence on rain water, surface water and groundwater for its water supplies (Rahaman, 1988). In tropical and equatorial regions, weathering process creates superficial layers, with varying degrees of porosity and permeability. The unconsolidated superficial materials often constitute reliable aquifer units if significantly thick and appropriately porous and permeable. The concealed basement rock may contain faulted areas, incipient joints and fracture systems derived from tectonic events earlier experienced. The detection and delineation of these hydrogeologic structures may facilitate the location of groundwater prospect zones in a typical basement setting (Omosuyi et al., 2003).

Increasing population with the attendant human activities geometrically leads to increasing demand for groundwater resources. The surface water, where available and accessible, cannot guarantee the required water quality status required for most domestic activities.

*Corresponding author. Email: akinakin02@yahoo.com.

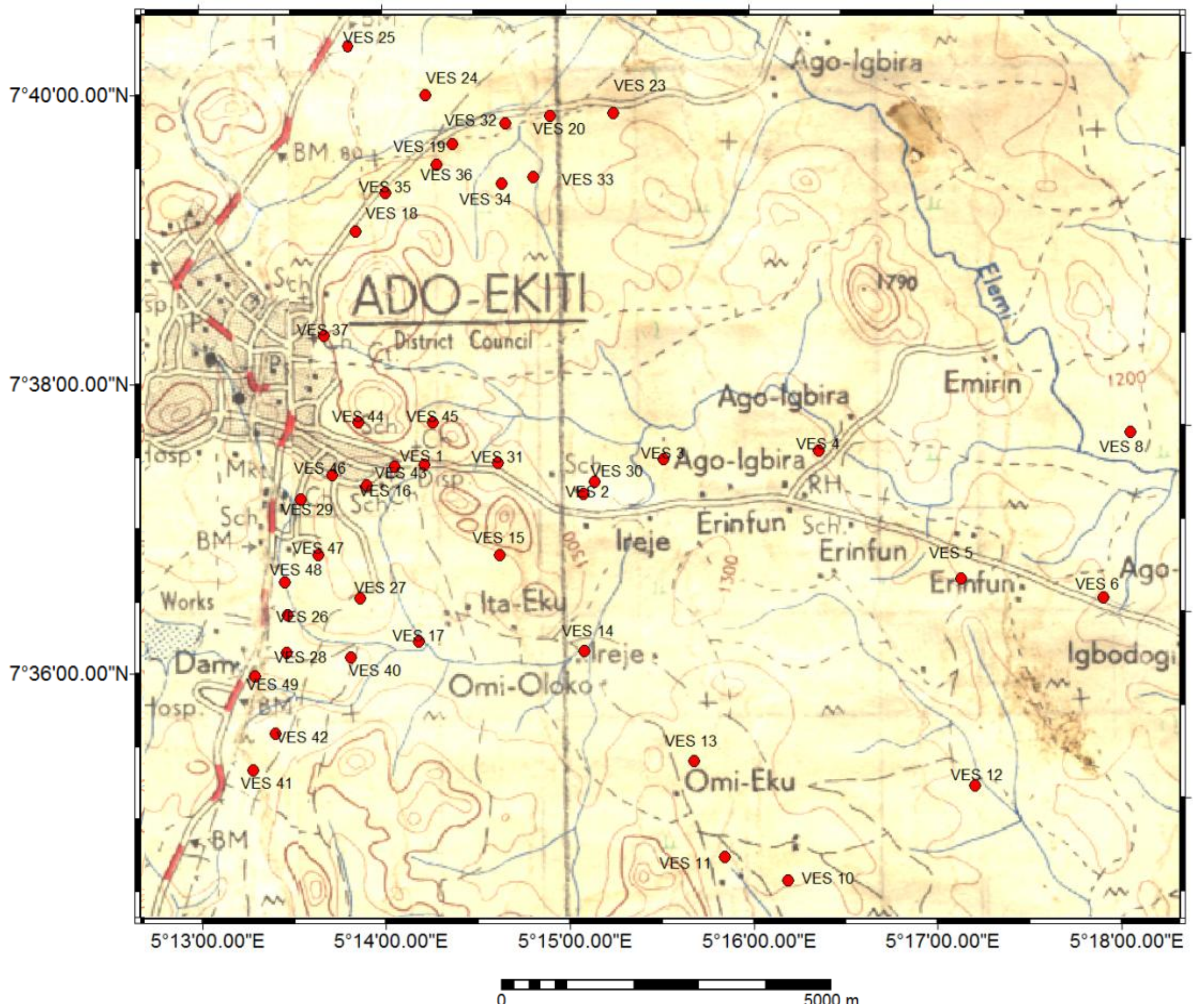

Figure 1. Map of the study area showing the vertical electrical sounding (VES) locations (Federal surveys, 1966).

This underlines the natural recourse to groundwater (Adeyeye and Abulude, 2004). This study was undertaken to delineate groundwater potential zones in Ado-Ekiti using geo-electrical analysis of VES data.

LOCATION AND GEOLOGY/HYDROGEOLOGY

Ado-Ekiti is located (within latitude 7° 33' and 7° 42' N and longitude 5° 11' and 5° 20' E) in South Western Nigeria on a low-land surrounded by several isolated hills and inselbergs. The highlands are separated sometimes by extensive lowlands. The centre portion of the metropolis is a high-rise thus contributing to the drainage pattern observed in the area. The topography (Figure 1) of the area is rugged due to the presence of crystalline basement rocks like charnockite and quartzite ridges which rise abruptly above the surrounding country rocks (Figure 2). The area is underlain by the Precambrian basement complex rocks of South-western Nigeria and drained by River Ireje, Elemi, Omisanjana and Awedele Stream. They flow into River Ose and Owena and empty into the Atlantic Ocean (Rahaman, 1988; Ebisemiju, 1993). The crystalline basement rocks generally lack primary porosity and permeability. As such, secondary porosity (joints, lineaments and the weathered zone) is the main source for groundwater occurrence, movement and transmission. Groundwater occurs under unconfined conditions in shallow, moderately weathered zones and in semi-confined conditions in joints, fissures, and fractures that extend beyond the weathered zones (Olayinka and Olorunfemi, 1992; Olorunfemi et al., 1999; Adelusi et al., 2004).

MATERIALS AND METHODS

The geoelectric data acquisition was carried out using vertical electrical sounding (VES) technique. The instrument used for the

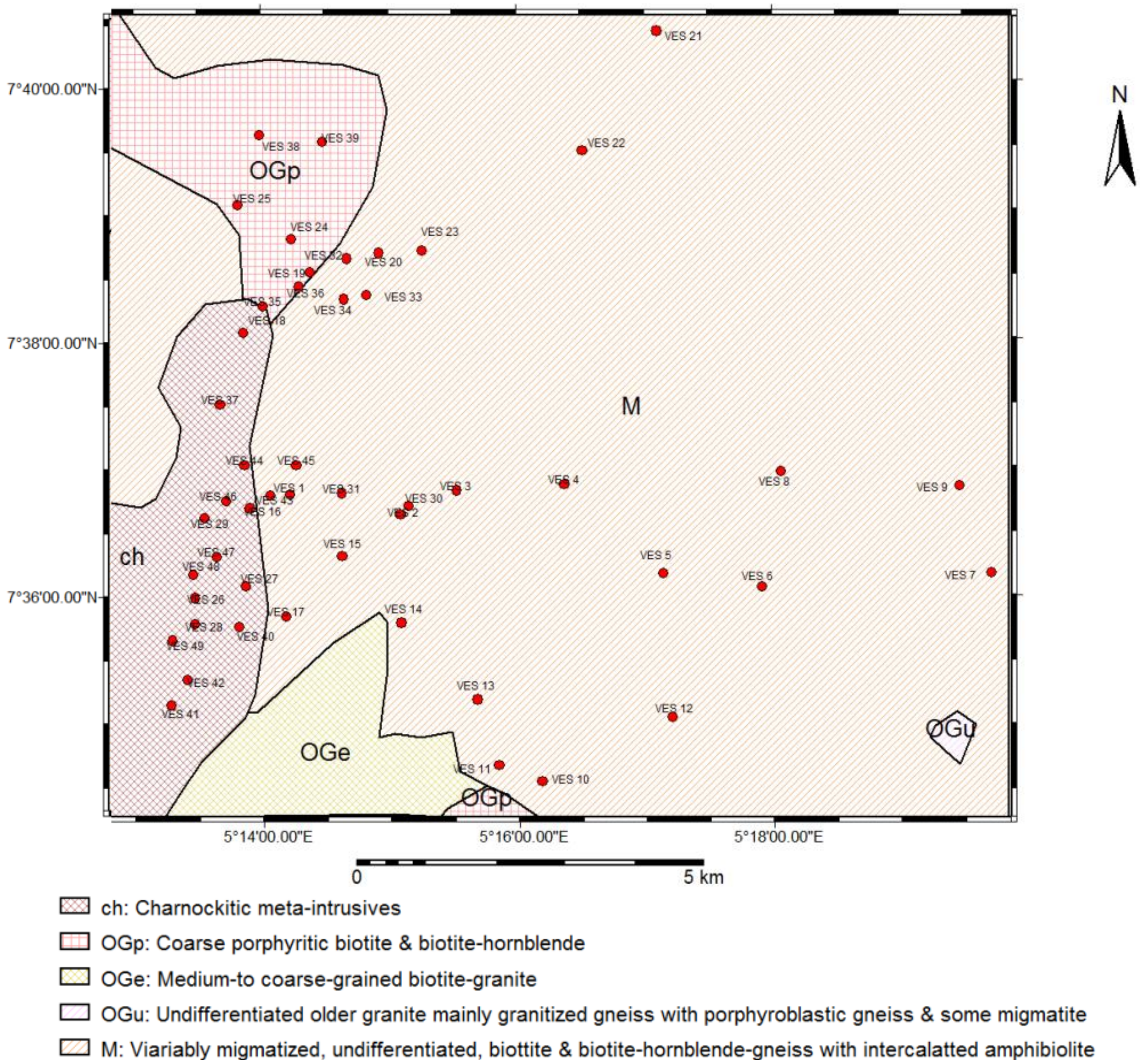

Figure 2. Geological map of Ado Ekiti and VES locations (geological map of Akure sheet 56).

resistance measurement was the ABEM Terrameter Signal Averaging System, SAS 300B with ABEM 2000 Booster. A total of 49VES points were fully occupied as shown in Figures 1 and 2. The VES data were acquired using the Schlumberger array with maximum electrode separation (AB/2) of 100 m. This has been decided based on well inventory data. A few soundings were however conducted up to (AB/2) of between 120 and 150 m. The apparent resistivity obtained from the field was plotted against half the current electrode separation (AB/2) on the bilogarithmic graph paper to obtain the initial parameters, which were used as inputs in a computer program, RESIST Version 1.0, to obtain the final parameters (Vander Velpen, 1988). The geoelectric parameters of layer thickness and resistivity obtained were used for the analysis (Olorunfemi and Okhue, 1992; Sheriff et al., 2002). Global positioning system (GPS) survey was run through the VES stations using a GERMIN CHANNEL 12 GPS Unit to obtain the vertical and horizontal positions (elevations and horizontal coordinates). All the processed geoelectric parameters and GPS data were used to generate the relevant maps using Surfer 8. Analysis of the maps would form the basis of the discussions.

RESULTS AND DISCUSSION

The results of the study are presented as coverage maps as shown in Figures 3 to 7. These maps are discussed in turn.

The isopach map of the overburden in the study area

The isopach map of overburden of the study area was produced as shown in Figure 3 with a contour interval of 5 m. The overburden encompasses all materials above the presumably fresh bedrock. It is defined as the total depth from the surface to the top of bedrock at each of the VES station. The map provides a general view of the geometry of the aquifers in the study area. The depth - to – bedrock varies from 3.8 to 56.2 m with a mean of

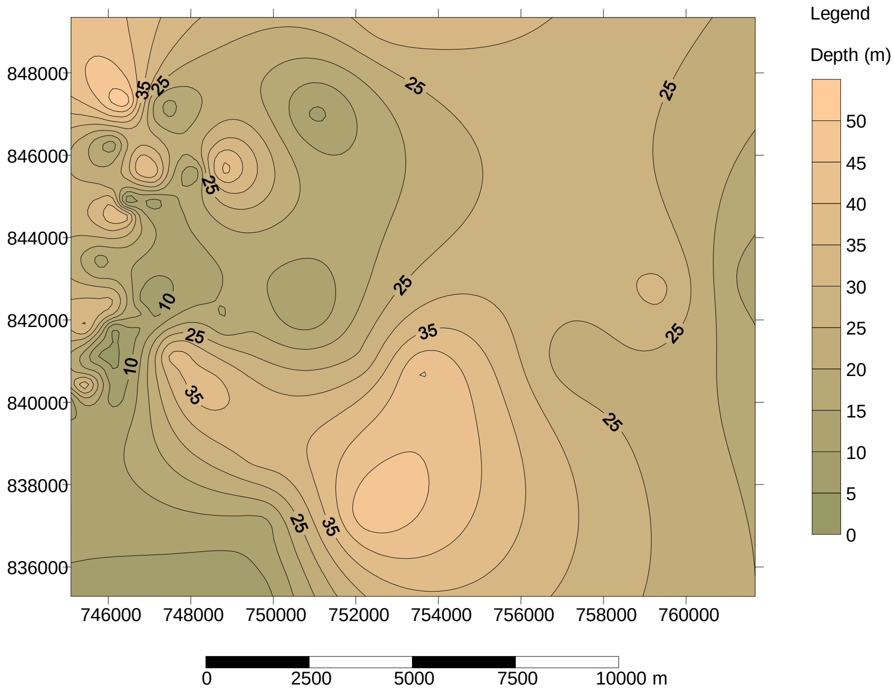

Figure 3. The isopach map of the overburden in the study area.

21.04 ± 14.62 m. The result agrees with Okhue and Olorunfemi (1991) which predicted a range of 4.0 to 79.2 m as possible overburden thickness in a similar geological terrain of the basement complex area of Ile - Ife, Southwest, Nigeria. It is evident from the map that the bedrock is not a smooth and continuous surface, rather, it exhibits undulating configuration. This depth is zero where the basement rocks outcropped (Mallam and Emenike, 2008).

A sizeable percentage of the study area has overburden cover ≥ 25 m. The isopach map of the overburden shows areas with thick overburden cover (H ≥ 30 m) in the North Western/Southern flanks of the study area. Pockets of such points also occur in the Western and Central parts of the area. These areas correspond to basement depression zones while zones with relatively thin overburden which are indicative of basement highs/ridges occur on the Western/Eastern and Southwestern flanks.

Generally, areas with thick overburden cover and less percentage of clay in which the intergranular flow has either dominant or important role are known to have high groundwater potential particularly in the basement complex area. These points are priority zones for groundwater development in the study area (Olorunfemi and Okhue, 1992; Mallam and Emenike, 2008).

The weathered basement thickness distribution map of the study area

The weathered basement thickness map (Figure 4) is a veritable tool to analyse and identify promising/potential aquifers. The map shows the variation of the weathered basement layer across the study area. The thickness of the layer ranges from 3 to 39.5 m with a mean of 15.40 ± 10.53 m. The weathered basement layer is seen to be thickest around the Southern/South Western portions with isolated portions along the Western/North Western portions of the study area. As the weathered basement layer is believed to be the major aquifer, the said regions offer strong appeal for groundwater development. In particular, average weathered basement layer thickness of about 34.04 m recorded at VES 12, 14, 15, 18, 19, 23 and 29 demarcates those zones of the study area as promising aquifers.

The weathered basement resistivity distribution map of the study area

The resistivity values of weathered basement at the various VES stations occupied in the area were contoured to give the ‘weathered basement resistivity map’ as shown in Figure 5. The resistivity values range from 6.5 to 1214 Ω-m. This indicates that the material composition is largely clay/sandy clay/clayey sand (Olayinka and Olorunfemi, 1992; Adelusi et al., 2004; Mallam, 2004). The basement rocks of the study area have varieties of texture of granites ranging from coarse to fine grained materials. The coarse grained granites weathered into water bearing residuals soil with a good water yield while the fine grained type weathered into clayey residual soil, which has poor water-yielding

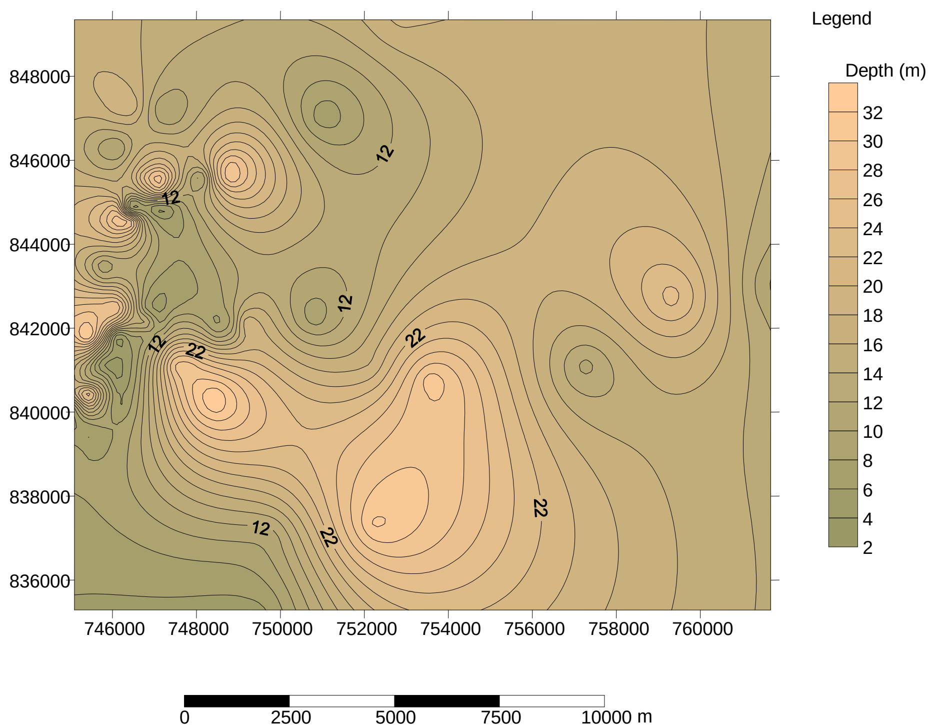

Figure 4. The weathered basement thickness distribution map of the study area.

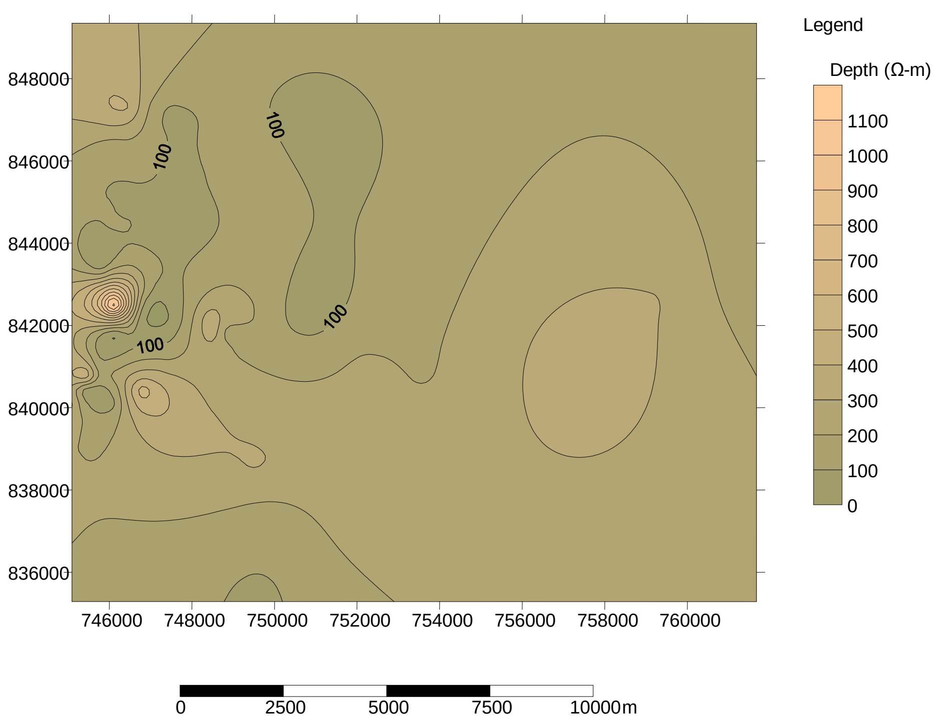

Figure 5. The weathered basement resistivity distribution map of the study area.

aquifer unit wherever if forms underlying basement rock. The map discriminated between high water bearing weathered basement zones and the low water bearing ones. It also indicated the variations in the degree of weathering/saturation across the study area. The low resistivity values characterizing the “low weathered

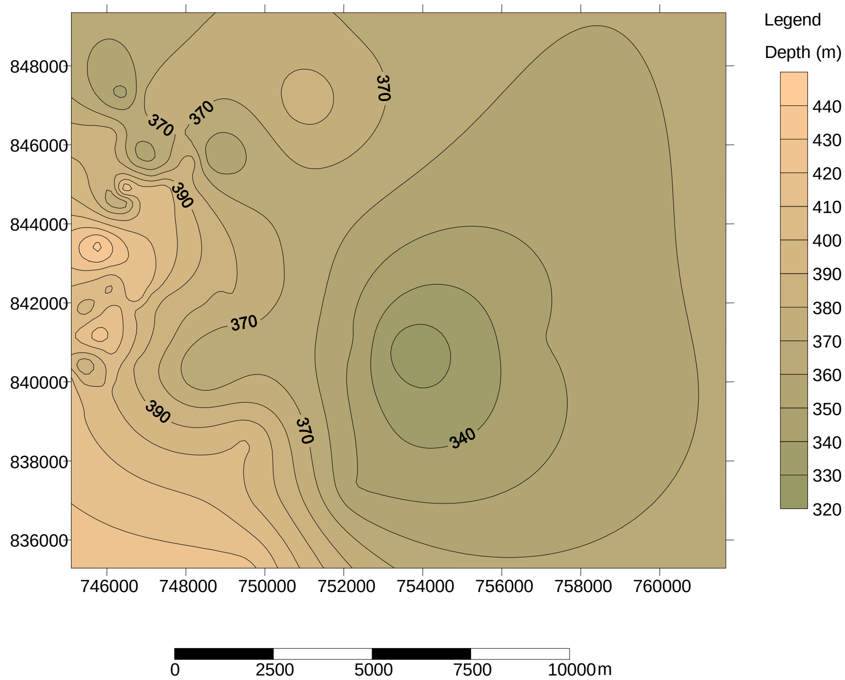

Figure 6. The bedrock relief map of the study area.

basement resistivity zones" are probably due to the highly weathered nature of the weathered basement layer at such points, tending towards clay and also due to the fact that the weathered basement layer is saturated with water at the zones. The very thin nature of the weathered basement layer across the zones and the presence of substantial amount of clay, render the potentials for groundwater low.

The zones underlain by thick overburden cover and less percentage of clay with appreciable degree of satuation as delineated on the map hold high potentials for groundwater exploitation (Okhue and Olorunfemi, 1991; Shemang, 1993).

The bedrock relief map of the study area

The bedrock relief map (Figure 6) is a contoured map of the bedrock elevation beneath all the VES stations. These elevations were obtained by removing the overburden thickness from the surface elevation at the VES stations. The bedrock relief map reflects the bedrock topography and its disposition. The map delineates a series of bedrock ridges and depressions within the surveyed area. The bedrock ridges show relatively thin overburden cover while the depressions are characterized by thick overburden. The depressions also exhibit low resistivity values. The bedrock depressions are diagnostic of groundwater collecting centres. They are thus demarcated as priority areas for groundwater development (Olorunfemi and Idornigie, 1992; Mallam and Emenike, 2008).

Bedrock resistivity distribution map of the study area

Over 50% of the area is underlain by fresh unfractured basement rocks with resistivities ≥ 5000 Ω-m (Figure 7). The basement rocks were observed to be variably fractured. The fractured nature of the rocks in other parts of the survey area is displayed by their low bedrock resistivity values. Aquiferous units in the basement complex terrain are mainly found in the thick and porous weathered overburden (saprolite zone) and the fractured part of the bedrock. The presence of these fractures further support the groundwater potentials of those zones (Shemang, 1993; Aboh and Osazuwa, 2000; Mallam, 2004).

Conclusion

Geo-electrical analysis of data obtained from vertical electrical sounding (VES) measurements has been carried out to demarcate groundwater pockets in Ado - Ekiti, Southwest, Nigeria. Feasible groundwater pockets like valley fills/basement depressions, weathered zones and fractured zones were delineated in the study area. The bedrock relief maps delineated a series of bedrock ridges and depressions within the surveyed area. The isopach map of the overburden showed relatively high overburden thicknesses (of up to 56.2 m) within the depressions. The bedrock depressions are observed to be variably fractured. The relatively low resistivity weathered basement constitutes the main aquifer unit. The highest groundwater yield is to be found in area

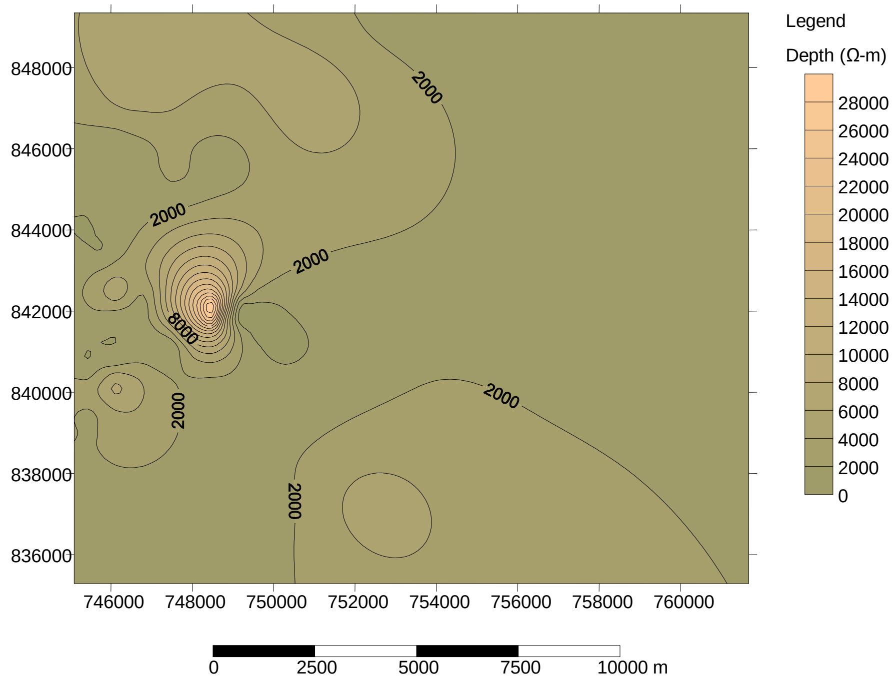

Figure 7. Bedrock resistivity distribution map of the study area.

where thick, weathered layer overburden (saprolite zone) with relatively low resistivity overlies the fractured basement. These zones were delineated in the study area.

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REFERENCES

Aboh HO, Osazuwa IB (2000). Lithological deductions from Regional Geoelectric Investigation in Kaduna, Kaduna State Nigeria. Nig. J. Phys. 12:1-7.

Adelusi AO, Ayuk MA, Oyedele AA (2004). Hydrogeophysical Analysis of Owode Area around Oba-Ile near Akure, SW Nigeria. Afr. J. Develop. Stud. 4(1&2):11-14.

Adeyeye EI, Abulude EO (2004). Analytical Assessment of some surface and groundwater resources in Ile–Ife, Nigeria. J. Chem. Soc. Nig. pp. 98-103.

Adiat KAN, Olayanju GM, Omosuyi GO, Ako BD (2009). Electromagnetic Profiling and Electrical Resistivity Soundings in Groundwater Investigation of a Typical Basement Complex – A Case Study of Oda Town Southwestern Nigeria. Ozean J. Appl. Sci. 2(4): 333-359.

Ariyo SO, Adeyemi GO (2009). Role of Electrical Resistivity Method for Groundwater Exploration in Hard Rock Areas: A Case Study from Fidiwo/Ajebo Areas of Southwestern Nigeria. Pac. J. Sci. Technol. 10(1):483-486.

Ebisemiju FS (1993). Ado-Ekiti Region - A Geographical Analysis and Master Plan. Alpha Prints, p. 15-30.

Mallam A (2004). Fresh Basement: Revealed from Resistivity Method. Zuma J. Pure Appl. Sci. 6(1): 6-9.

Mallam A, Emenike EA (2008). Preliminary Findings of Subsurface Characteristics From Direct Current Resistivity Survey of The Federal Capital Territory (FCT), Nigeria. Int. J. Pure Appl. Sci. 2(2):68-76.

Okhue ET, Olorunfemi MO (1991). Electrical Resistivity Investigation of a Typical Basement Complex Area -The Obafemi Awolowo University Campus Case Study. J. Min. Geol. 27(2):63-69.

Olayinka AI, Olorunfemi MO (1992). Determination of Geoelectric Characteristics in Okene Area and Implications for Borehole Siting. J. Min. Geol. 28(2):403-411.

Olorunfemi MO, Idornigie AI (1992). A Geoelectric Mapping of Basement Structures of South – Central Part of Bida Basin and its Hydrogeological Implication. J. Min. Geol. 28:94-98.

Olorunfemi MO, Ojo JS, Akintunde OM (1999). Hydro-geophysical Evaluation of the Groundwater Potentials of the Akure Metropolis, Southwestern Nig. J. Min. Geol. 35(2):207-228.

Olorunfemi MO, Okhue EJ (1992). Hyrogeologic and Geologic significance of a Geoelectric Survey at Ile–Ife, Nig. J. Min. Geol. 28:242-350.

Omosuyi GO, Ojo JS, Enikanselu PA (2003). Geophysical Investigation for Groundwater around Obanla – Obakekere in Akure Area within the Basement complex of South-Western Nigeria. J. Min. Geol. 39(2):109-116.

Rahaman MA (1988). Recent advances in the study of the basement complex of Nigeria. In Precambrian Geology of Nigeria. Geological Survey of Nigeria, Kaduna South, pp. 11 - 43.

Shemang EN Jnr (1993). Groundwater Potentials of Kubanni River Basin, Zaria, Nigeria from DC Resistivity Study. Water Resour. 4(1&2):36-42.

Sheriff MA, Malgwi DI, Hassan H (2002). Geoelectrical Depth Sounding Using Schlumberger Array in Yimirshika Area of Borno State, Nigeria. Zuma J. Pure Appl. Sci. 4(2):127-133.

Vander V (1988). RESIST Version 1.0. MSc Research Project. Delft, Netherlands.