Application of Electrical Resistivity Imaging (ERI) For Investigation of Groundwater in Iwajaye, Southwestern Nigeria

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Abstract

Reliance too much on surface water resources in the face of uncertainty of climatic condition is very risky, hence there is need to carry out exploration for another source of portable water mostly groundwater in the study area, Iwajaye area, Southwestern Nigeria. Hence, the work is aimed of mapping the subsurface lithology for determining the groundwater potential of the area. The area under investigation is located within the Crystalline Basement of Southwestern Nigeria with a local geology underlined by Pegmatite. A total of three (3) 2D electrical resistivity imaging was established using the ABEM resistivity meter adopting the Dipole-dipole electrical configuration with a profile length of 500m and electrode spacing of 10m. The measured apparent resistivity value was inputted into the RES2DINV software and was subjected to inversion process to generate the resistivity structural image of the subsurface. The interpretation of the resistivity lithological generated from Profile 1 reveals the presence of weathered unit, fractured basement, and fresh basement with resistivity value range of (40Ωm – 85Ωm), (125Ωm – 310Ωm), (500Ωm – 2000Ωm) respectively. Profile two reveal presence of weathered layer, fractured zone, basement blocks with resistivity rage of (26 Ωm – 120 Ωm), (622 Ωm – 675Ωm) and (709Ωm to 2403Ωm) respectively. Profile 3 shows the presence loose alluvium, moderately resistive blocks, partially weathered basement, and basement blocks with resistivity value (106Ωm – 210Ωm), (306Ωm – 620Ωm), (110Ωm – 210Ωm), (55Ωm – 230Ωm). The geological inference of this lithology on groundwater exploration reveals both the weathered overburden layer and fracture basement as the aquiferous unit in the study area. Conclusively, the occurrence of fracture basement region in profile 1 and 2 reveals the regions has a good groundwater prospect in the study area at depth of 55m and 65m respectively.

Keywords: *- Groundwater, Basement, Fracture, Resistivity, Imaging.*

INTRODUCTION

Groundwater exploration has been a vital concern to human because of its importance for several activities. Its importance has necessitated its exploration using several geological and nongeological approach. It is of best knowledge to understand the hydrogeological condition of an environment before embarking of groundwater exploration process. It is therefore regarded as an indispensable resource and the most available reservoir of fresh water; hence availability of quality water resources will continue to be the primary concern of societies, hydrogeologists, Geoscientists, and researchers on its acquisition for the purpose of a reliable and safest source of drinking water (Akinbinu, 2015). Increase in population growth and industrialization globally has even subjected regions of more abundant rainfall to face the problem of quality and quantity water. It is a general believe that surface water cannot be fully dependable throughout the year because of seasonal rainfall system in Nigeria, this give a clue that there is need to search for other alternatives to augment this insufficient. Because of unpredictable availability of surface water, the society must depend on the largest available source of quality fresh water which lies underground, and this is referred to as Groundwater and this make more than 53% of all population relies on it as a source of drinking water (Daniel *et al*., 2015).

Groundwater can therefore be defined freshwater occurring within the saturated voids of rocks beneath the ground or a subsurface water which fully saturates the pore spaces of the aquifer (Strahler, 1973, Ariyo *et.al*.,2021).Other than these reasons; Groundwater is also widely used as a source for irrigation in food production (Zekster and Everett, 2004).Due to this important usefulness of groundwater, there is need to understand the geological phenomena such as the subsurface lithology and also the aquifer configuration on an area for the successful exploration of Groundwater in an area because it is believed that the movement of water from earth surface infiltration to underground water through recharge processes is determine by the nature of the aquifer present in the area (Bashir *et. al.*, 2014).

Most of the Earth's liquid freshwater is found in underground within aquifer zone and in lakes and rivers. Indeed, these units called aquifer provide a valuable base for groundwater flow to rivers during periods of no rainfall. A formation or rock unit can be defined as an aquifer if it has significant porosity and permeability to store and likewise able transmit sufficient amounts of groundwater. Rock that lacks porosity and permeability are referred to as aquicludes, or basement rocks. An aquifer is classified as unconfined if it's bounded above and below by aquicludes. Aquitards is a type of layers that tend to slow down groundwater flow, these include layers such as clays, shales, glacial tills, and silts, are. Hence, thickness and the other properties of the aquifers where the water is tapped from are very important and can only be made known through geophysical surveys. According to Makinde (2002), groundwater is related to the nature of earth rocks. Information on these rocks can be provided by a number of physical techniques which includes seismic reflection and refraction, electrical resistivity techniques, well-logging etc. The vertical electrical sounding (VES) method is a depth sounding galvanic method and has proved very useful in groundwater exploration due to simplicity, reliability of the method and ease of interpretation of acquired data (Ariyo and Adeyemi, 2016). Lithology and fluid contents of a rock are major factors that determine its electrical resistivity.

Over the years, Electrical Resistivity Method via Vertical Electrical Sounding technique has been employed to characterize aquifer in different geologic environments and to map fractures in basement areas which are important for groundwater extraction (Koefoed, 1979, McDowell, 1979, Ayolabi *et al*, 2003, Ariyo and Adeyemi., 2016, Coker *et.al*., 2018). But recent development is looking on another method that gives means of imaging the subsurface. 2D and 3D earth resistivity images are created by inverting hundreds to thousands of individual resistivity measurements (Loke and Barker, 1996) to gives an appropriate model of the subsurface earth resistivity. Thus, the method has been an important tool in delineating bedrock depression, fracture, synclinal water accumulation zone and aquifer layer (Singh *et al*, 2006, Ayolabi *et. al.,* 2008). Hence this makes this research work focus on the 2D Resistivity Imaging for a successful delineation of the subsurface aquiferous zone. The research work is aimed to investigate groundwater potential zone using electrical resistivity imaging with the objectives of detecting the surface layers thickness and resistivity, delineate the possible geological information that is capable of hosting groundwater. Geologically, the study area is underlain by Granite and pegmatite rocks of Southwest basement complex.

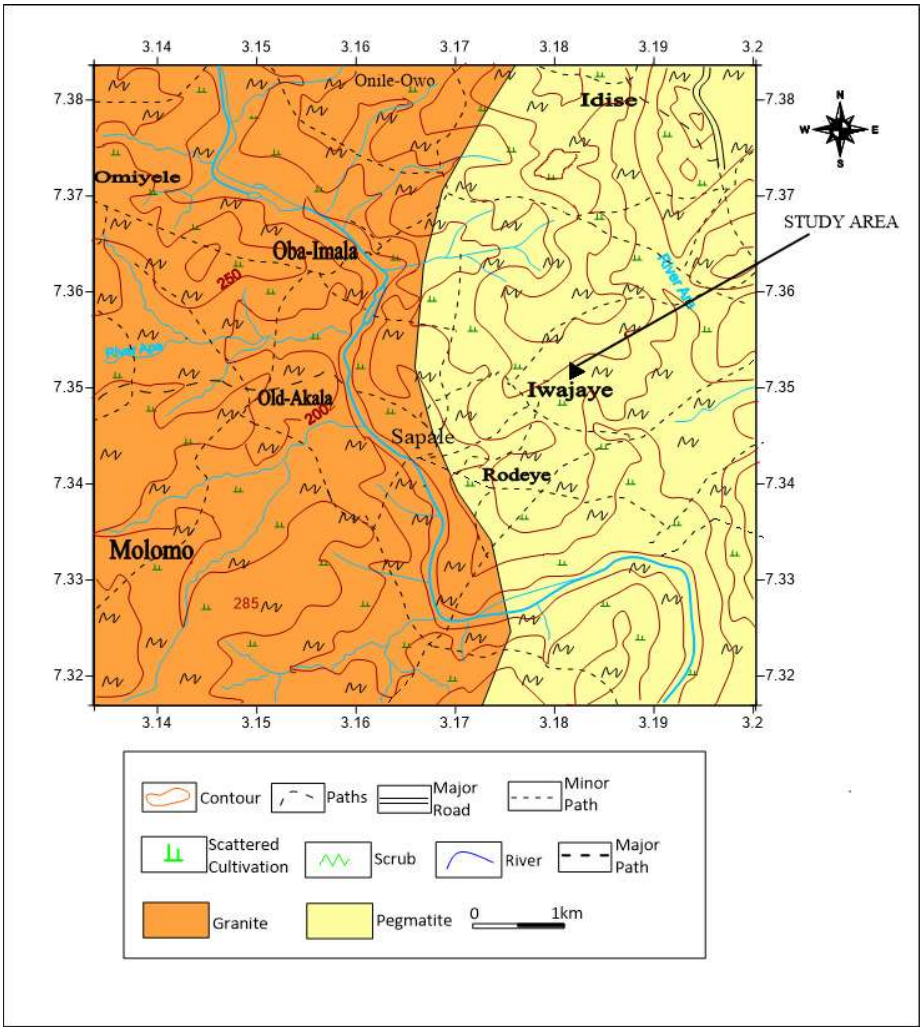

Figure 1: Geological Map of the Study Area

MATERIALS AND METHODS

Two procedures are commonly employed when employed this method during field operation regardless of the specific electrode spread employed. The method to be used depends on whether one is interested in resistivity variation with depth or with lateral extent. The 2D Resistivity Imaging was obtained during the field process using Dipole-dipole electrode arrays. The field data was model using the RES2DINV version 4.0 software whereby the raw data obtained was processed using the computer programmes RES2DINV. Interpretation of a 2D set of data requires a 2D model of the subsurface. The 2D model used by the programme divides the surface into a number of rectangular blocks. The programme then determines the resistivity of the rectangular block resistivity) which agrees with the actual measurement. A finite-difference forward modeling subroutine was used to calculate the apparent resistivity values. A nonlinear least-squares optimization technique (Loke and Barker, 1996) was used for the inversion routine. The objective function minimized by the inversion is based on (DeGroot-Hedlin and Constable 1990) with the starting model being the average apparent resistivity values for the respective data set. The optimization method adjusts the resistivity of the model blocks and iteratively tries to reduce the difference between the calculated and measured apparent resistivity values. A measure of the difference is expressed as RMS (root mean square) error. According to Nwangi, 1982, “best” model is found where the RMS error does not change significantly.

RESULTS AND DISCUSSION

An intricate basement setting resulted on the resistivity sections imaged within the area. Both gradual and anomalous variation patterns are depictable on the sections (Figures 2, 3 and 4). From quantitative dimension, the resistivity value is of less 90 Ωm from depth of 0 to 10m indicating presence of clay overburden. Below the depth range of 10m – 20m shows a large resistivity value ranging from 20Ωm – 2000Ωm characterized indiating irregularly deformed basement. None of the basement expanse along the three profiles survived tectnonism. Geologic structures within the basement architecture as perceived on the resistivity section reveal a good subsurface lithology for groundwater resources.

Profile One: Three geoelectric units are presented on the resistivity section of profile one (Fig. 2). From top to base of the section, the resistivity of the units varied between 40Ωm – 85Ωm for weathered unit, 500Ωm – 2000Ωm for fresh basement, and 125Ωm – 310Ωm for the fractured basement (Fig. 2). The weathered unit have a thikness is 11 m to 16m thick; and occur as a nearly planar clay layer.

Fresh basement occur as the second layer in the profile; occuring between depth-interval 18m to 69m. Thickness of the fresh basement on the section ranges from 30.8m (0 – 160m on distance axis) to over 54 m (beyond the 250m mark of distance axis). The perceived architecture of the basal part of basement on the section is unconnected to topography but rather due to tectonisms.

Deeper down the section into the third geo-electric layer, subsurface resistivity dropped to a range of 129Ωm – 290Ωm (Fig. 2), indiating a fractured basement rock. The emergence of the fracture zone can be structurally related to the vertical or nearly vertical stresses that had acted upon an initially fresh basement sheild.

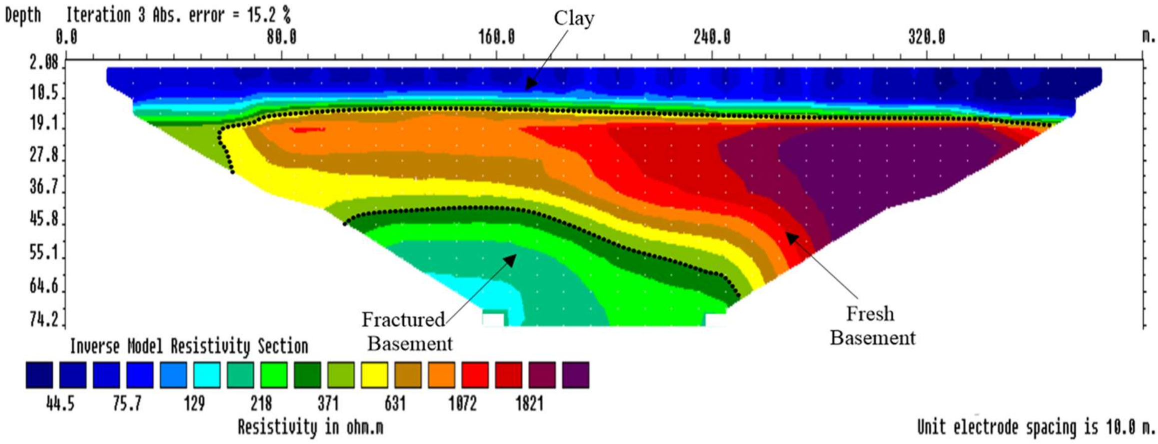

Figure 2: Resistivity Section along Profile 1

Profile Two: Abrupt vertical and lateral resistivity changes are observed on the resisitivity section of profile 2 (fig. 3). The uppermost part of the section, as expected, is occupied by weakly resistive geo-electric units (26Ωm – 120Ωm) inferred as heterogenous weathered layer of clay and sandy clay. Thickness of the weathered layer ranges between 7m – 15m (right from 0 to the 240m mark on distance-axis). Between the 240m to 340m eletrode spacing, the weathered layer became appreciably thicker, attaining a fairly uniform thickness of about 25m. Beyond this electrode position, its thickness gradually drop to a minimum of 10m towards the end of the profile.

Next beneath the weathered layer, is a relatively more resistive zone, characterized by a resistivity range of 156Ωm – 303Ωm, and a thickness range of 1.5m to 22m (fig. 3). It is by inference, a zone of partial or minor weathering of the basement block. The partially weathered zone is obviously very thin except around the 220m – 250m distance mark, where it wedged out as an impressive 22m thick block.

At slightly greater depth, the basement block became relatively more resistive in a rather divergent pattern (fig. 3). Resistivity range of the divergent blocks similarly ranges from 709Ωm near the centre of the profile to 2403 Ωm at the extreme; corresponding to a separated basement blocks. The inclined zone of separation between the two blocks possesses a nearly uniform resistivity value of 622Ωm inferred as zone of structural discontinuity easily recognized as fractured zone (fig. 3). It is large scale fractured zone; 40 m wide along its centre but became broader deeper down the base of the section.

The fractured zone, depending on its permeability and vertical extent, may pool up a very large volume of groundwater resource, or drain off the available underground water within the saproliticzone, deeper down the crust.

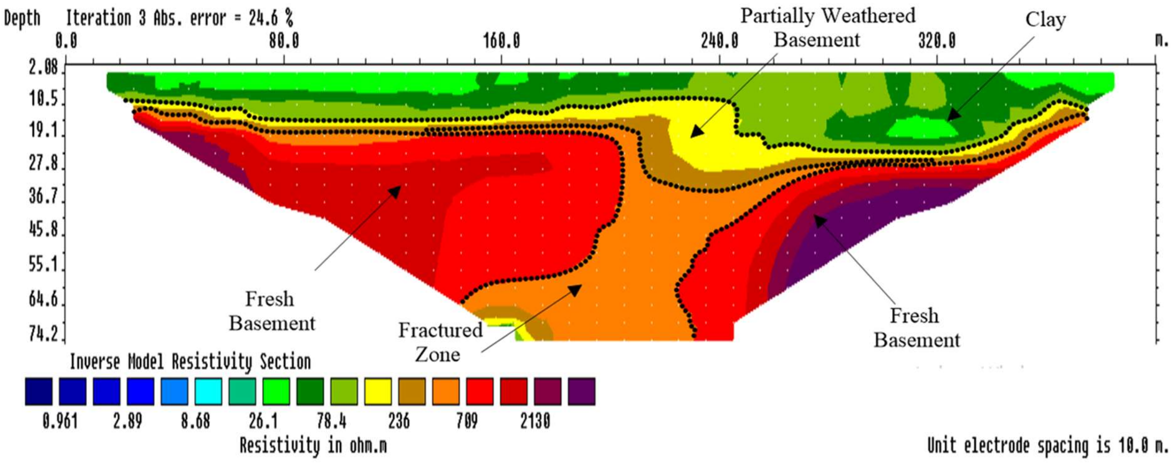

Figure 3: Resistivity Section along Profile 2

Profile Three: Highly complex geologic setting is revealed on the resistivity section of profile three, as similar structural scenerio of crustal divergence is observed beneath the profile (Fig. 4). Thin lateral bands of heterogenous geo-electric units characterized the uppermost section of the resistivity section. Resistivity of the geo-electric units ranges from 25Ωm – 90 Ωm for clay and/or weathered pegmatite (between mark 0 to 240m), and 106Ωm – 210Ωm for the loose aluvium – from a distance of 250m to the end of the profile. A thickness range of 4m – 7m for the aformentioned units althogeter indicate a very shallow regolith cover. The clay layer is underlain around the starting and central part of the profile by a relatively better resistive (110Ωm – 210Ωm) partially weathered basement.

Occurring further below, are three moderately resistive blocks (306Ωm – 620Ωm) severely detached by two broad zones of very low resistivity (55Ωm – 230Ωm). The drifted blocks is resolutely inferred as separated fresh basement rocks while the opened structural gap is delineated as fractured zone.

Anomalous occurrences of conductive closure within the fractured zone (between the 80m – 160m distance mark), and resistive closure within the large central basement block is possibly indicative of ore emplacement during the late stage crystallization of the pegmatitic fluid.

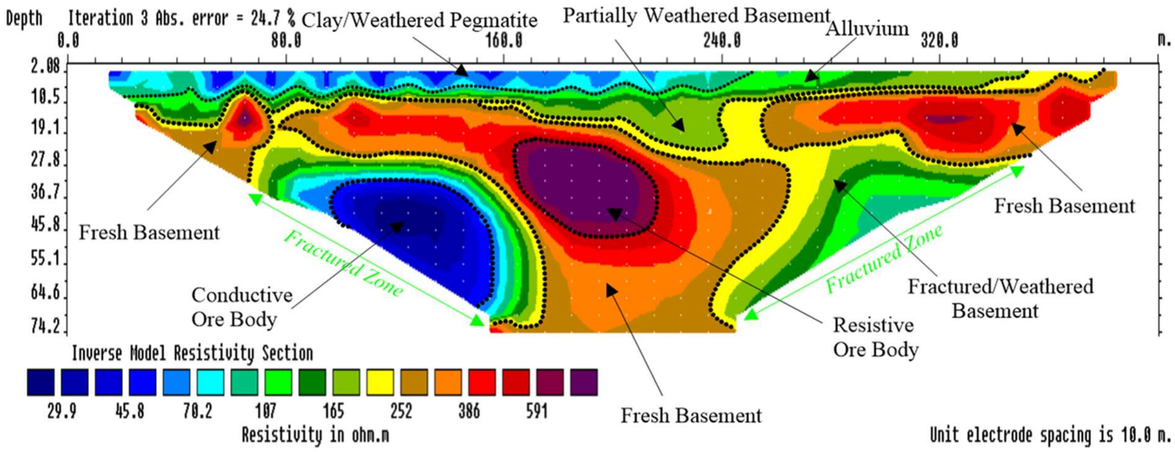

Figure 4: Resistivity Section along Profile 3

CONCLUSION

The study indicates a wide range of resistivirty variation in the study area. The Profile 1 in the study area shows the weathered unit, fractured basement, and fresh basement ranges 40Ωm – 85Ωm, 125Ωm – 310Ωm, and 500Ωm – 2000Ωm respectively. Profile 2 reveal presence of weathered layer, fractured zone and fresh basement blocks with resitivity rage of 26Ωm – 303Ωm, 622 Ωm-672Ωm, 709Ωm to 2403Ωm respectively while profile 3 reveal presence of loose alluvium, partially weathered basement, moderately resistive blocks and basement blocks with resistivity vaue range of 106 Ωm – 210Ωm, 110Ωm – 210Ωm, 306Ωm – 230Ωm and 709Ωm - 2403Ωm respectively. Conclusively, the presence of fracture basement region in profile 1 and 2 reveal the region as a good groundwater prospect in the study area at the depth of 55m and 65m respectively.

It can be recommended that the further geophysical exploraton method such as the use of remote sensing approach and magentic method can be used to examine the fracture system of the study area and other subsurface geological structures which can improve groundwater exploitation in the study area. Also, the traditional elctrical resistivity sounding tehniques can be used to correlate the result of ths present study.

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