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Electromagnetic Imaging for Groundwater Prospecting in Basement Complex Terrain, Offa, Southwestern Nigeria

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Abstract
Groundwater potentials in Basement Complex rocks were accessed using the electromagnetic prospecting method. The electromagnetic curve and profile maps generated from the measured potential difference have been analyzed to access the groundwater potentials in the study area. The three traverses used in this research showed distinct vertical fractures indicated with 'red-lines' on both the profile and curve maps. The results obtained showed the potential borehole locations in 'red-lines' which were points of potential difference drop ranging from 0.00 mV to 0.54 mV. Out of all the potential probing points, P4, P6 and P10 were drilled. The yields of P4, P6 and P10 boreholes as calculated were 100 L/min, 166 L/min and 125 L/min, respectively. The study concluded that groundwater is usually accumulated within fractured basement and less dense rocks usually overburden materials as revealed by very low potential difference values obtained at all the drilled borehole locations. Among the drilled boreholes in the study area, P6 was the best in term of yield. For further studies, 3 different parallel profiles that are 1 m apart starting from the same initial point along the same traverse, should be employed for a better understanding in the continuity of the interpreted subsurface geologic structures at the same probing point. Thus, the idea of how extensive the geologic structures are, can be seen.

Keywords: Potential difference, Geologic Structures, Equidistance, yield, probing point, traverse

Introduction

Rapid population growth and infrastructural development in Offa and its environs has imposed more demand in potable water supply in the area. Therefore, groundwater source must be engaged to reduce the demanding pressure on other sources of water supply. Several geophysical methods have been employed within the basement complex terrain around the world to access groundwater potential and geologic structural delineation by eminent researchers (Olayinka & Weller, 1997; Olayinka & Olorunfemi, 1992; Ojo *et al.*, 2011; Rehil & Birk, 2010; Oladipo *et al.*, 2005; Talabi, 2013). The most commonly used geophysical methods in groundwater prospecting are electrical resistivity and electromagnetic methods due to their uniqueness in measuring the conductivity of the geologic structures in the subsurface. Groundwater development in crystalline basement rocks is of importance despite its poor hydrogeological nature (Du Preeze & Barber, 1965). Up to 50 % of the total water required by rural populace in Nigeria is provided by basement complex aquiferous units (Offodile, 2002). These aquiferous units in basement complex are the overburden materials and fractured basement rocks (Ademiluwa & Eluwole, 2013; Ogundana & Talabi, 2014). Groundwater occurrence is the safest source of water due to several successions of strata that were superimposed on it (Ogundana & Talabi, 2014). The aim of this research is to explore for groundwater potentials in the study area through the depicted geologic structures such as fractures, joints and faults from variation or sharp drop in potential difference values usually shown by V, L, W and U shape on the curve map.

Geology of the Area

The study area (Offa) is situated within Southwestern Nigeria. It is located at latitude 8º 08' 56.80'' N and longitude 4º 43' 14.66'' E. The Southwestern parts of Nigeria consist mainly of Precambrian basement rocks which are polycyclic and have been severely altered by tectonic activities aging from Archaean to Late Proterozoic (Adelana *et al.*, 2005). Offa town is underlain by biotite gneiss with bands and lenses of biotile schists and pegmatite intrusion (Adelana *et al.*, 2005).

The following rock types were recognized as part of Migmatitic gneiss complex: banded gneisses, augen gneisses and pegmatite (Oyawoye, 1965). The Migmatite gneiss complexes are Archaean (Brugier *et al.*, 1994; Kroner & Ekwueme, 2006; Dada, 2008).

Materials and Methods

A feasibility study was conducted to familiarize with the local geology of the study area. In accessing the groundwater prospecting zones of the study area, three (3) traverses were conducted for data acquisition using an electromagnetic tool (PQWT S-300).

The working principle of this exploration tool (PQWT S-300) involves a perpendicular injection of an electromagnetic wave into the ground to generate an induction electromagnetic field of the same frequency as natural field source. At different frequencies of electric field strength, different geologic structures are depicted at different depths due to variation in measured properties (potential difference (mV)). PQWT S-300 has the ability to select probing depth limits of 100 m / 150 m / 300 m.

A leap-frogging electrode array was deployed in data acquisition process. The available pairs of potential electrodes (M and N) were connected through cable to the host machine and grounded into the ground using an equidistance electrode spacing of 10 m for the completion of each traversing (Fig. 1). After the first reading, both electrodes were leap-frogged by 1 m each i.e. M was moved from 0 to 1 m and N was moved from 10 m to 11 m, until the end of each traversing. The measured points are the mid-points or probing points (MN/2) of the electrode spacing, which are 1 and 2, respectively. The probing points were shifted towards the direction of traversing has shown below (Fig. 1).

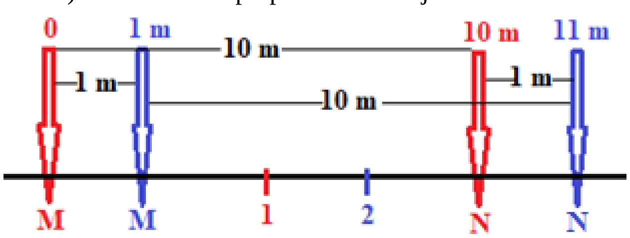

Figure 1: An Annotated Diagram Illustrating a Typical Movement of Potential Electrodes along a Traverse

Where:
MN = equidistance of 10 m of the potential electrode spacing
MN/2 = mid-point of MN along the traverse.

The potential difference (Pd) in millivolts (mV) resulted in the process were automatically recorded by the host machine by a push of a button and simultaneously plotted to generate both the profile and curve maps of the corresponding traverses which can be interpreted qualitatively.

Results and Discussion

Any of the probing points on the maps are equivalents to plus 4 m of its representation on the ground. Since, 10 m equidistance electrode spacing was used throughout the data acquisition in all the 3 traverses. The traverses are 17 m, 25 m and 25 m long, respectively. From the results obtained in traverse 1, electromagnetic curve and profile maps were plotted (figure 2 & 3). The point on the profile indicated with 'red line' has distinct vertical fractures depicted by V-shape on the curve map, which is area with sharp drop in potential differences ranging from 0.00 mV to 0.21 mV. The results obtained in traverse 2, electromagnetic curve and profile maps were plotted (Figures 4 & 5). From the maps, the point(s) on the profile indicated with 'red lines' have distinct vertical fractures depicted by V-shape on the curve map, which are areas with sharp drop in potential differences ranging from 0.00 mV to 0.11 mV. The results obtained in traverse 3, electromagnetic curve and profile maps were plotted (figure 6 & 7). From the maps, the point(s) on the profile indicated with 'red lines' have distinct vertical fractures depicted by V-shape on the curve map, which are areas with sharp drop in potential differences ranging from 0.00 mV to 0.54 mV. The potential borehole locations indicated in 'red-lines' in all profiles having potential difference drops ranging from 0.00 mV to 0.54 mV. The low potential difference values and geologic structures from the results obtained in the study area show higher groundwater potentials in the study area. In all the sorted shapes (V, L, W and U) indicating a sharp drop in potential differences, only the V-shape is present in the results used in this study. Out of all the potential probing points (MN/2) indicated with 'red lines' on the available profiles, three preferred points were drilled (P4, P6, and P10). An averagely deep well of 75 m, 85 m and 85 m is expected to be drilled for the observed geologic structures to be captured in any of the selected borehole locations, respectively. The vertical axis on the profile map representing depth in metres and this can easily be used by comparing the same probing point on both maps to see the depth extent and the conductivity property of the geologic structures. The depth at the completion of the three drilled borehole locations were 65 m, 80 m, and 85 m which is still within the proposed depth, respectively. 5 m sumps were drilled in all the three boreholes. Their yields were calculated to be 100 L/min, 166 L/min and 125 L/min, respectively. Most of the drilled boreholes were terminated before the total proposed depth because the encountered fractures were sufficient in producing adequate water and there is no need of wasting more capital in acquiring more depth.

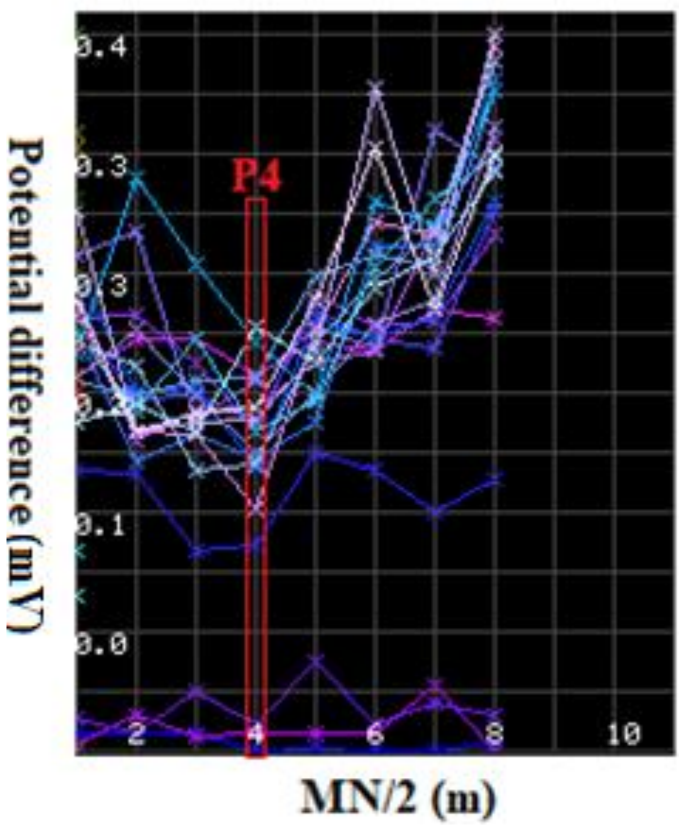

Figure 2: An Electromagnetic Curve Map of Traverse 1 Showing P4

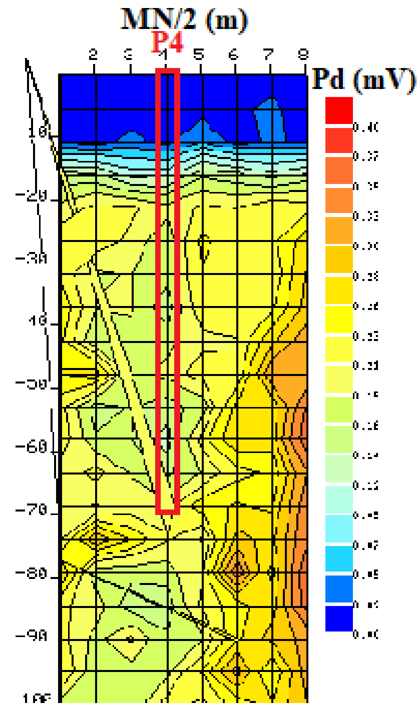

Figure 3: An Electromagnetic Profile Map of Traverse 1 Showing P4

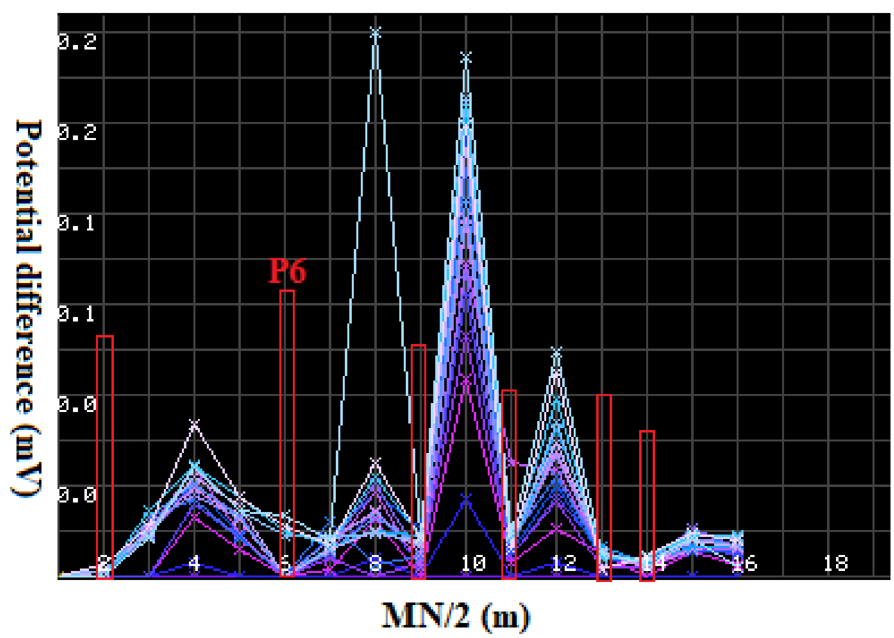

Figure 4: An Electromagnetic Curve Map of Traverse 2 Showing P6

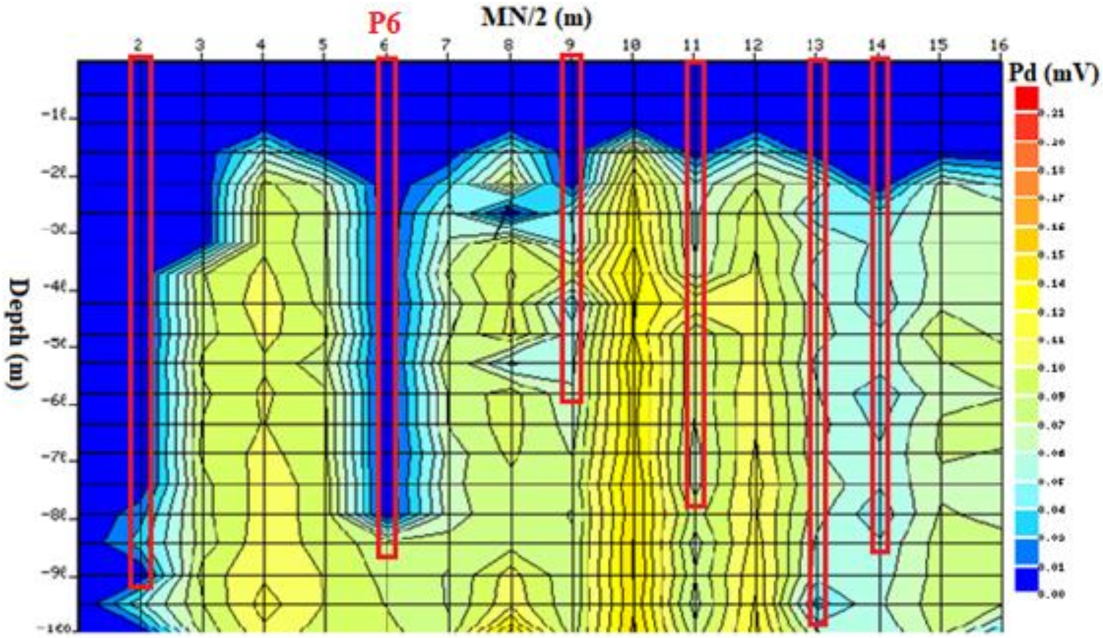

Figure 5: An Electromagnetic Profile Map of Traverse 2 Showing P6

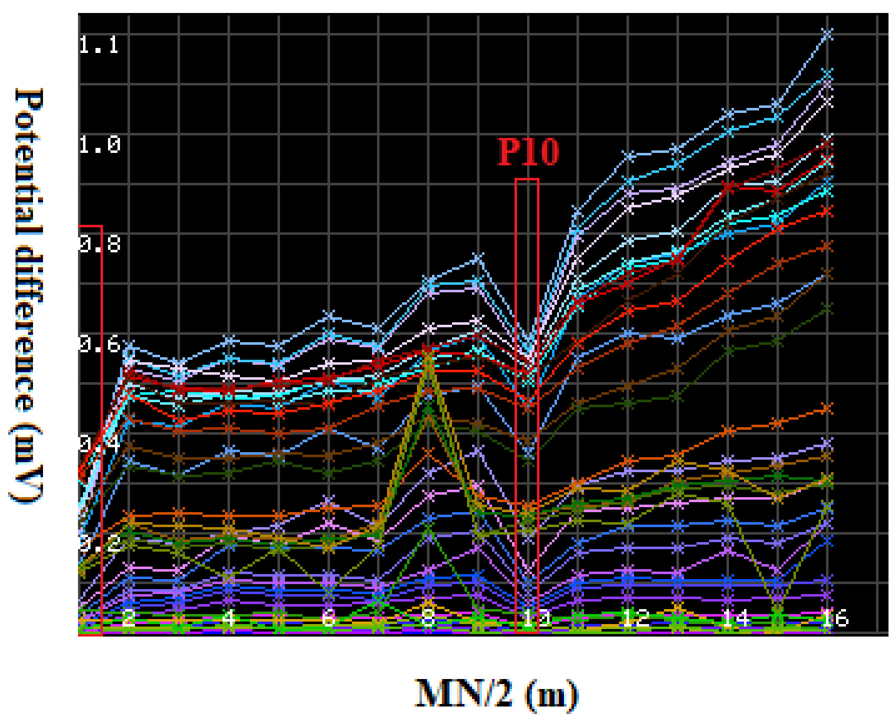

Figure 6: An Electromagnetic Curve Map of Traverse 3 Showing P10

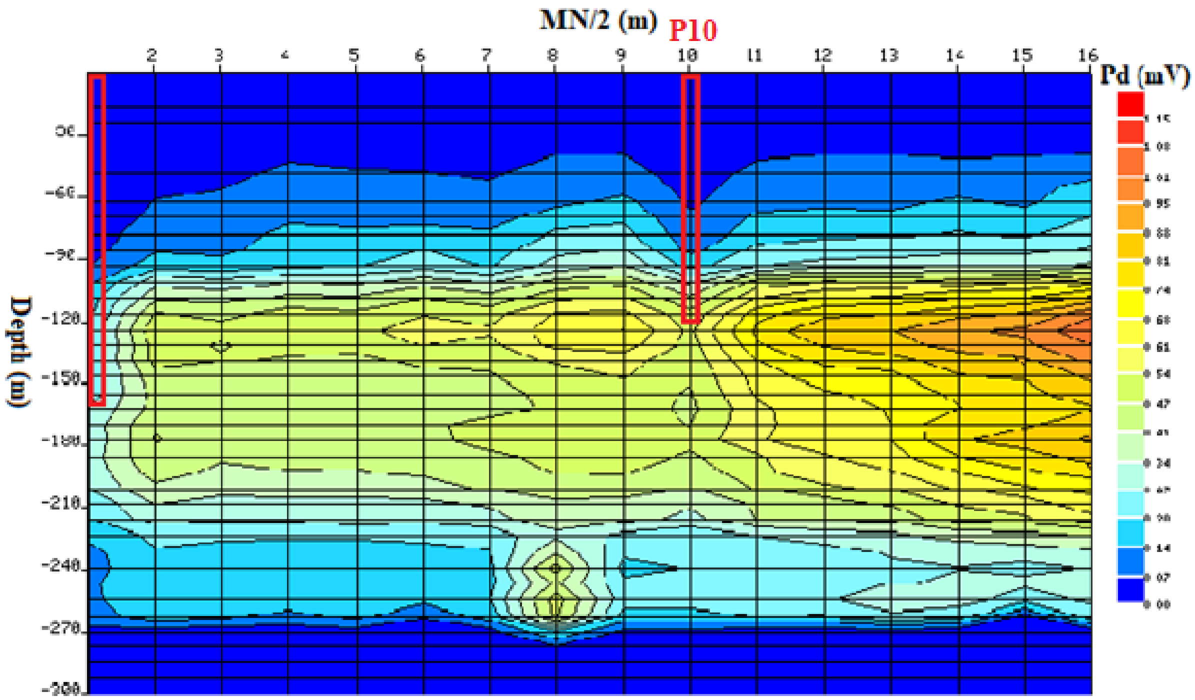

Figure 7: An Electromagnetic Profile Map of Traverse 3 Showing P10

Conclusion

The combination of both the electromagnetic profile and curve maps in the interpretation process makes it more accurate by viewing the same point on both maps to see where the anomalous values extend to through a sharp drop in potential differences depicted by V-shape on the curve maps.

The study concluded that groundwater are usually accumulated within fractured basement and less dense rocks usually overburden materials revealed by very low potential difference values which were confirmed at all the drilled borehole locations. All the 3 drilled boreholes (P4, P6, and P10) have moderately high yield ranging from 100 L/min, 166 L/min and 125 L/min, respectively and P6 being the best among the 3 drilled boreholes in the study area in term of yield.

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