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RELATIONSHIP BETWEEN THE DEPTHS OF TERMINATION OF DRILLING AND BOREHOLE FAILURE IN THE CRYSTALLINE BASEMENT COMPLEX OF NORTH-WESTERN NIGERIA

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ABSTRACT

An Electrical Resistivity survey of a non-functional borehole was carried out at Bondong, Southern part of Kaduna state. Six (6) VES Points were sounded along a profile of 150m which passes through a Borehole with intervals of 30m from each VES Point. The borehole was drilled to a depth of 25m. The profile has four underlying layers: the first layer constitutes of Clay with resistivity range of 10-100Ωm at a depth of 4m. This is taken as the Topsoil layer. The second layer constitutes of sand/laterites with resistivity range of 200-1000Ωm which is taken as the weathered layer which has a depth of 25m and a thickness of 21m. The third layer is the fractured layer which compose of gravels and coarse grain sand with resistivity range of 300-2000Ωm and has a depth of 85m and a thickness of 64m, this layer is suspected to constitute of high water content. The fourth layer is the fresh basement which is taken as the porphyritic granite rock with resistivity value greater than 6000Ωm at a depth of 100m from the Topsoil. A critical examination of the tomogram explains the fact that the borehole failed not because it was poorly sited but rather the depth at which the drilling was terminated was not adequate, which is at 25m. The drilling would have gone further to a depth of about 65m.

Keywords: *Electrical Resistivity, Borehole, Aquifer, Topsoil*

INTRODUCTION

Bondong is located at Kaura which lies between latitudes $9^{0}30'$ N and $9^{0}45'$N and longitudes $8^{0}20'$E and $8^{0}35'$E in the southern part of Kaduna state Nigeria. The borehole under consideration lies at latitude $09^{0}37^{I}13.78^{II}$N and longitude $08^{0}33^{I}15.96^{II}$E. The borehole is motorized. The borehole is non-functional. Six (6) VES Points were sounded along the profile of 200m length in the N-S direction. The calculated apparent resistivities of these VES points were inverted to produce an image of the profile. The borehole was drilled between VES4 and VES5 to a depth of 25m; the initial recorded yield was 6.5 litre/min and the static water level was 6m (KSWB, 2006). The area has a history of failure water boreholes (Afuwai et al., 2014). The study area is located in the tropics within the Guinea Savannah region. Rainfall is seasonal and moderate with a mean annual amount of 1524 mm (Yanet, 2012). Rainfall usually commences in March and ends in October and for the rest of the year dry season prevails. Temperatures vary between less than 15^{0}C around December/ January and 32^{0}C in March and April with its annual mean between 24^{0}C and 28^{0}C. The relative humidity varies with the season with highest values in the rainy season and lowest values during the harmattan. The mean annual relative humidity is 57%. The vegetation consists of broad-leaved savannah woodland and when properly developed, the trees may attain heights of 10-15m. The dominant trees within are *Isoberlina doka* while *Khaya senegalensis*, *Danielia oliveri*, *Perkia* and *Ficus sycomotus* are common. There are abundant grasses with annual types dominating the uplands while the perennial type such as *Hyparrhenia spp* and *Andropogon spp* are also common. Sugarcane and other garden crops, mostly vegetable, are cultivated along streams courses. Dominant food crops found in the area include root crops e.g. yams and cassava while stem tubers include potatoes. These are sometime intercropped with millet and maize.

Porosity generally decreases with depth; permeability however, has a more complicated relationship, depending on the extent of fracturing and the clay content (Chilton and Foster, 1995). In the soil zone, permeability is usually high, but groundwater does not exist throughout the year and for places where it exists, it dries out soon after the rains end. Beneath the soil zone, the rock is often highly weathered and clay rich, therefore permeability is low. Towards the base of the weathered zone, near the fresh rock interface, the proportion of clay significantly reduces. This horizon, which consists of fractured rock, is often permeable, allowing water to move freely. Wells or boreholes that penetrate this horizon can usually provide sufficient water (Jones, 1985). Deeper fractures within the basement rocks are also an important source of groundwater, particularly where the weathered zone is thin or absent. These deep fractures are tectonically controlled and can sometimes provide supplies of up to one or even five litre/s (Hamidu et al, 2014). Sands and gravels eroded from basement rocks and deposited in valleys can also be important sources of groundwater. The groundwater resources within the regolith and deeper fracture zones depend on the thickness of the water-bearing zone and the relative depth of the water table. The deeper the weathering, the more sustainable the groundwater (Afuwai et al., 2011). However, due to the complex interactions of the various factors affecting weathering, water-bearing horizons may not be present at all at some locations. Different methods have been used to abstract groundwater from basement aquifers. The most common are boreholes and dug wells (Figure 1).

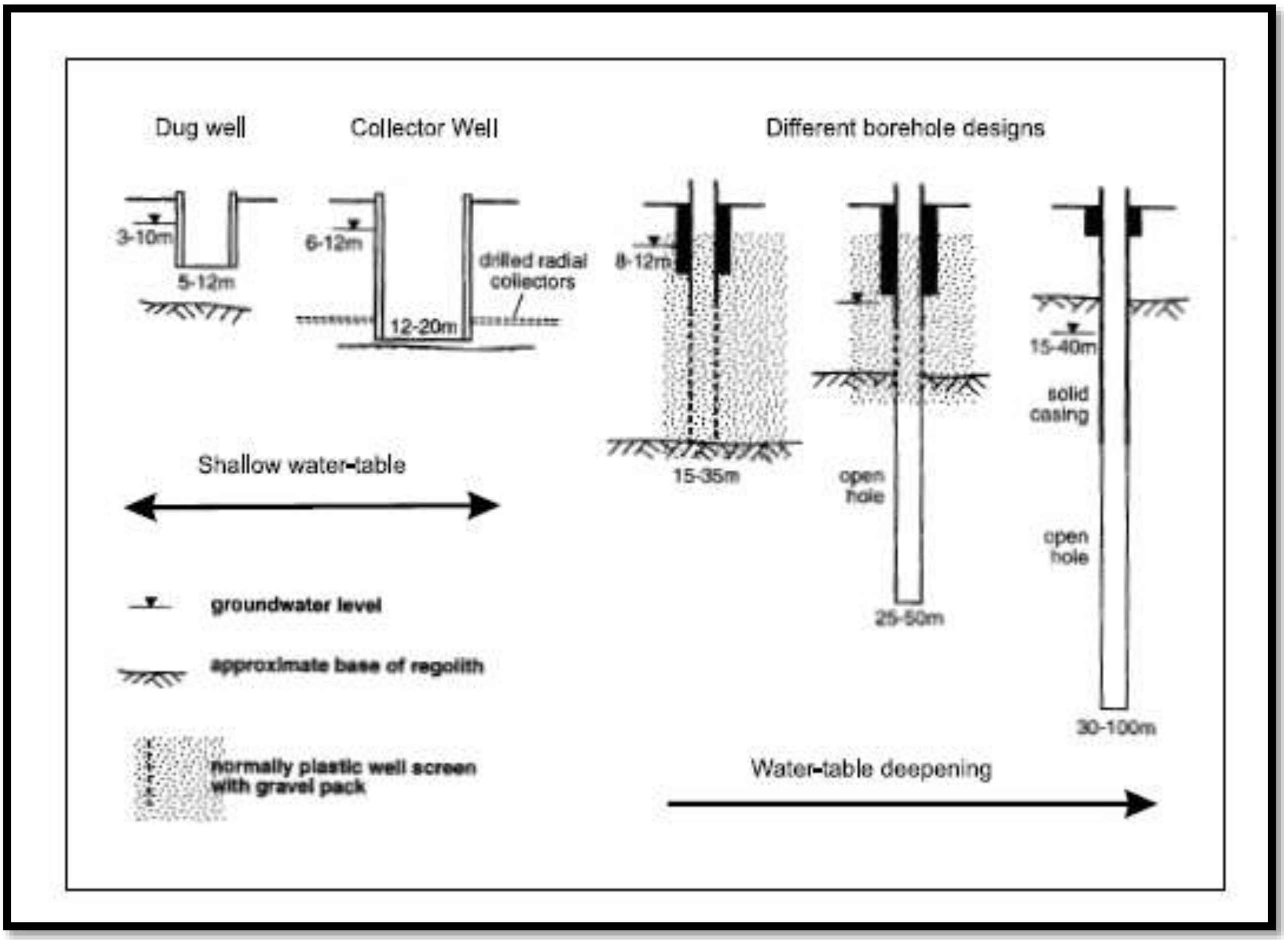

Fig.1: Different designs of wells and boreholes for basement, depending on the hydrogeological conditions (Foster et al., 2000)

GEOLOGY OF THE SURVEY AREA

The study area is made up of the rocks of the Migmatite-Gneiss Complex, Older Granites, Younger Granites and Newer Basalts. Basement rocks that occur in the study area are part of the rocks within Kaduna state (Figure2) and can be classified into:

1. Newer Basalts.
2. Younger Granites
3. Older Granites
4. Undifferentiated Schists
5. Migmatites-Gneiss Comple

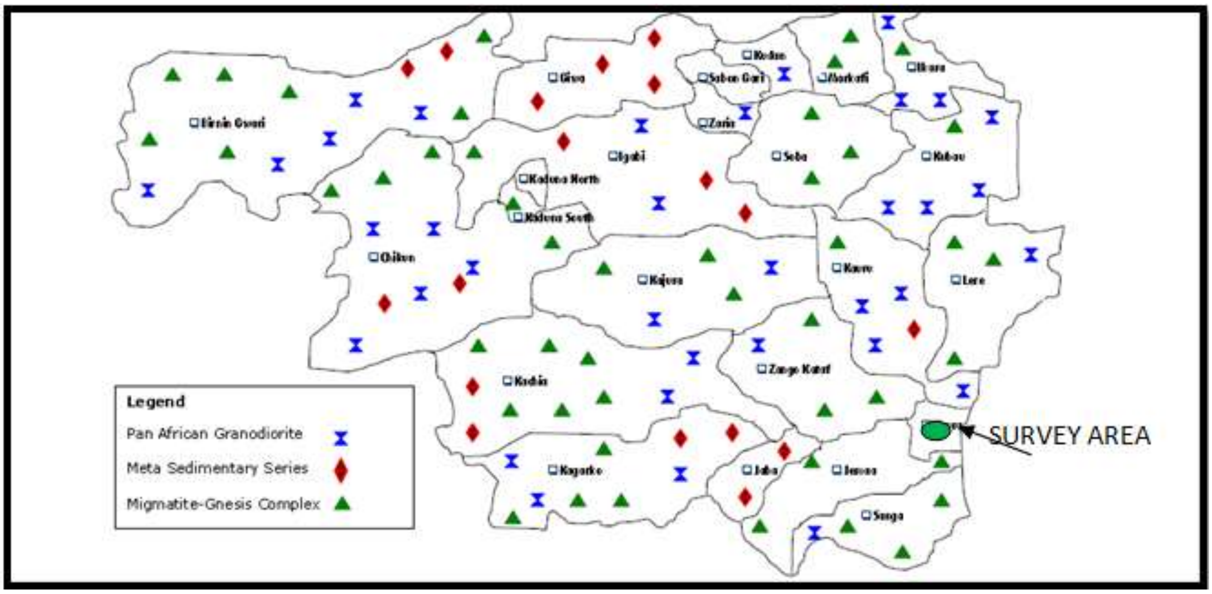

Fig. 2: Geologic map of Kaduna

METHODOLOGY

Electrical Resistivity Survey is the method employed in this study. By using a continuous vertical electrical sounding technique we established Six (6) VES points along a profile of 150m at 30m interval. This is a survey technique developed for the investigation of areas of complex geology, it involves measuring a series of constant separation traverses with the electrode spacing being increased with each successive traverse. Since increasing separation leads to greater depth of penetration, the measured apparent resistivities may be used to construct a vertical contoured section displaying the variation of resistivity both laterally and vertically over the section.

The resistivity method is based on measuring the potentials between one electrode pair while transmitting direct current (DC) between another electrode pair. The depth of penetration is proportional to the separation between the electrodes, in homogeneous ground, and varying the electrode separation provides information about the stratification of the ground.

However, if the ground is inhomogeneous, the calculated resistivity varies as the electrode spacing is varied or the array is moved about. This calculated resistivity is called "apparent resistivity ρ_a", given by

$$\rho_a = K(\frac{\Delta V}{I}) \quad (1)$$

where K is called the geometric factor. For this work, using schlumberger array, if $2b$ is potential electrode spacing and L is half the maximum current electrode spacing $\frac{AB}{2}$ then

$$K = \pi(\frac{L^2}{2b}\ \frac{b}{2}) \quad (2)$$

The apparent resistivity is the ratio of the potential obtained in-situ with a specific array and a specific injected current by the potential which will be obtained with the same array and current for a homogeneous and isotropic medium of 1Ωm resistivity (Dobrin, 1976). The apparent resistivity measurements give information about resistivity for a medium whose volume is proportional to the electrode spacing. Resistivity is affected more by water content and quality than the actual rock material in porous formations. Since the measured resistivity is usually a composite of the resistivity of several layers, the apparent resistivity may be smaller or larger than the real resistivities or in rare cases identical with one of the two resistivity values in a homogeneous surface. The apparent resistivity is the same as the real resistivity in a homogeneous subsurface, but normally a combination of contributing strata. The value of the apparent resistivity obtained with small electrode spacing is called the surface resistivity. Terrameter SAS300 was the primary equipment used in this study.

RESULTS AND DISCUSSIONS

The profile has four underlying layers: the first layer constitutes of clay with resistivity range of 10-100Ωm. This is taken as the Topsoil layer. The second layer constitutes of sand with resistivity range of 200-1000Ωm which is taken as the weathered layer which has a depth of 25m and a thickness of 21m. The third layer is the fractured layer which compose of gravels and coarse grain sand with resistivity range of 300-2000Ωm and has a depth of 85m and a thickness of 64m, this layer is suspected to constitute of high water content. The sum of the thicknesses of the weathered and fractured layers equals the thickness of the Aquifer. The fourth layer is the fresh basement which is taken as the porphyritic granite rock with resistivity greater than 6000Ωm at a depth of 100m with infinite thickness. The depth to basement rock along the profile is averagely 40m. A critical examination of the tomogram (Figure 3) explains the fact that the borehole failed not because it was poorly sited but rather the depth at which the drilling was terminated was not adequate, which is at 25m. The drilling would have gone further to a depth of about 65m into the structure near its bottom that appears like a fault or weak zone, in the hard rock zone, around this horizon where permeability is high, the borehole wouldn't have failed.

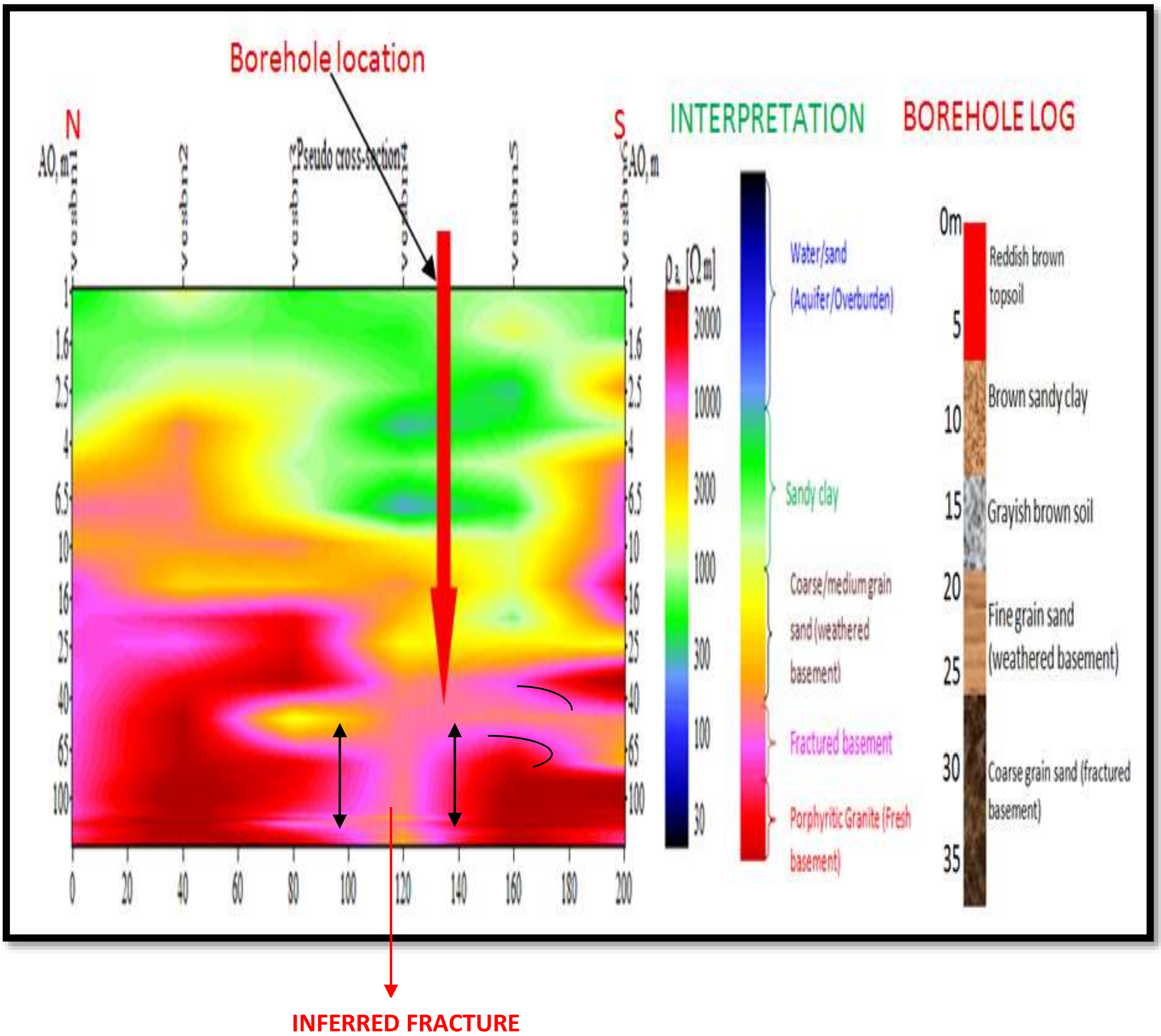

Fig. 3: Resistivity tomography section for Bondong Profile

CONCLUSION

The Geoelectric section generated at Bondong across the non-functional borehole explains the fact that the borehole failed not because it was poorly sited but rather the depth at which the drilling was terminated was not adequate. The drilling would have gone further into the fractured zones which compose of gravels and coarse grain sand with resistivity range of 300-2000Ωm and has a depth of 85m and a thickness of 64m, the borehole wouldn't have failed. Because around this horizon permeability is very high, the layer is suspected to constitute of high water content.

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