

ORIGINAL ARTICLE

Geo-electrical Exploration for Groundwater in Jimba-Oja, Ifelodun Local Government Area of Kwara State, Nigeria

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ABSTRACT

Vertical Electrical Soundings (VES) and Horizontal Profilings (HP) for groundwater exploration in the Agricultural and Rural Management Training Institute (ARMTI) and National Centre for Agricultural Mechanization (NCAM), both located at Jimba-Oja, Ifelodun Local Government Area (LGA) of Kwara state, were carried out with a view to establishing the different subsurface geo-electric layers, the aquifer units and their hydrogeologic parameters. Data were collected from 25 VES stations situated within latitudes $4^{\circ} 39'$ and $4^{\circ} 41'$ and longitudes $8^{\circ} 22'$ and $8^{\circ} 23.5'$, three of which have been drilled. From the quantitative interpretation of the data collected, using the usual method of curve matching with the Orellana-Mooney Master curves and 1-D forward modeling with WinResist 1.0 version software, four lithologic units were identified. These include: the topsoil, the lateritic layer, the weathered/fractured layer and the fresh basement. The weathered/fractured basement constitutes the main aquifer unit. The isopach map of the overburden shows depth to the bedrock varying from 2.8 to 28m. The geoelectrical interpretation of data obtained in this area has permitted the delineation of a lobe of low resistivity which constitutes the prospective zone for water exploration in the area.

Keywords: Aquifer, Geoelectrical, Hydrogeologic parameters, Lithologic unit, Lobe.

INTRODUCTION

The ever increasing demand for essential public utilities, most especially water supply for domestic and agricultural purposes in the developing world, particularly in the sub-Saharan Africa where there is prolonged dry season coupled with untidy and polluted surface water make the need to augment the available surface water with groundwater arise and hence a proper approach for groundwater development becomes imperative (Dan-Hassan and Olorunfemi, 1999 and Olutoyinet *al.*, 2013).

Geophysical studies for groundwater development in ARMTI and NCAM in Jimba-Oja, Ifelodun LGA of Kwara State was carried out. The paper describes the results of geophysical study using direct current (d.c.) resistivity methods. The goals of this study include: (i) To avert a recurrence of boreholes abandonment necessitated by quartzite encountered at shallow depth (e.g. NCAM site) and (ii) To have a more detailed understanding of the

hydrogeology of this area and delineate zones which are more favourable for groundwater exploration.

The study area is underlain by the Crystalline Basement Complex rocks of Nigeria (Fig. 1), where groundwater occurs either in the weathered mantle or in the joint and fracture systems in the unweathered rocks (Ako and Olorunfemi, 1989 and Olayinka and Olorunfemi 1992). The highest groundwater yield in the basement terrains is found in areas where thick overburden overlies fractured zones (Olorunfemi and Fasuyi, 1993). These zones are often characterized by relatively low resistivity.

The geophysical study is one of the most effective ways of evaluating the environment without interfering with the hydrogeologic system. Omosuyi, *etal.*(2008) opined that in view of the discontinuous (localized) nature of basement aquifers, drilling programmes for groundwater development should generally be preceded by detailed hydro-geophysical investigations.

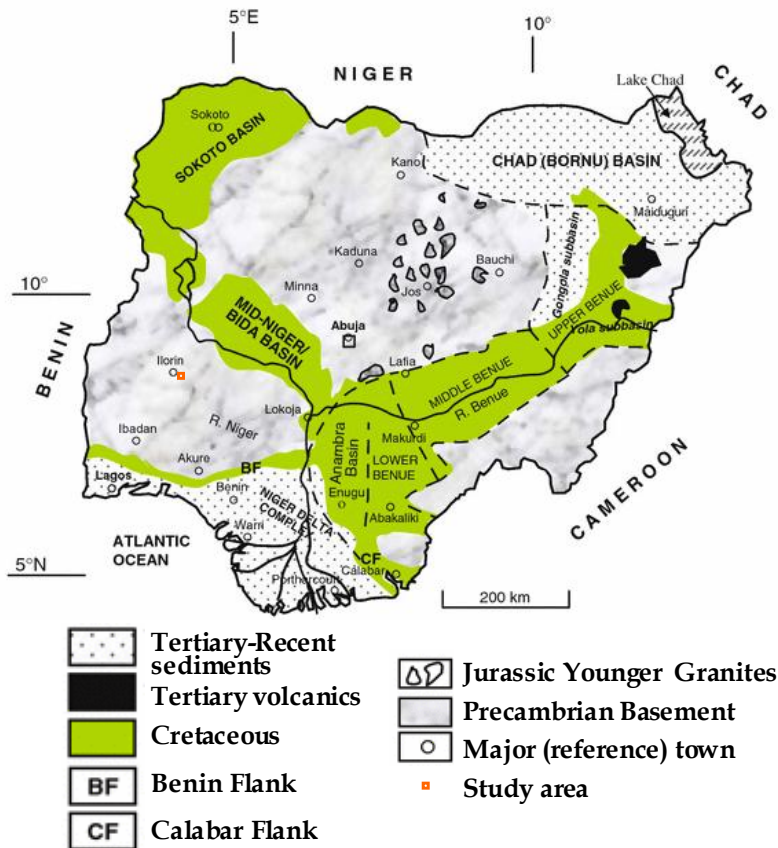


Figure 1: Geological Sketch Map of Nigeria Showing the Major Geological Components (Basement, Younger Granites and Sedimentary Basins) and the Study Area (After Obaje, 2009).

The Geology, Hydrogeology and Physiography

Geological map of the study area which lies between latitudes $4^{\circ} 39'$ and $4^{\circ} 41'$ and longitudes $8^{\circ} 22'$ and $8^{\circ} 23.5'$ is shown in Fig. 2. The area under study falls within the

crystalline basement complex rocks of Nigeria. Oyawoye (1972) classified the basement complex into four main rock groups using lithology. These include; (i) the older granites (ii) the migmatite complex (iii) the metasedimentary

series and (iv) the miscellaneous rock types. The lateritic and weathered overburden are the main rocktypes observable in the study area, except a few occasional exposure of hard rocks as boulders in the study area. A classification of the basement rocks using structures was done by Annor (1983) who established two major groups of rocks. These include; (i) the late supracrustal -intrusive group, which is composed of late intrusive suite (granites, granodiorites, syenites, charnockitic rocks and pegmatite and younger metasediment (Paraschists and metavolcanics) and (ii) the gneiss complex which are described as large scale sheeted rock body which is composed of granitic orthogneisses, paraschists, paragneisses, orthogneisses and metavolcanics.

MATERIALS AND METHODS

Twenty-five vertical electrical soundings (VES) and six horizontal profilings (HP) were conducted in the study area (Fig.2). The VES locations were chosen based on the existing boreholes, thick

overburden areas obtained from HP result and proximity to the two existing institutes and their host community. Out of the three completed boreholes in the area, two are located within the ARMTI premises while the remaining one is in NCAM premises. For horizontal profiling, Wenner array was used. The arrangement of electrodes in Wenner array is different from that of the Schlumberger array in the sense that the distance between one electrode and the next is a third of the current electrode separation.

VES is based on the fact that the current penetrates continuously deeper with increasing separation of the current electrodes and thereby reflects information about the resistivity variation with depth (Sharma, 1997). Figure 3 illustrates a simple arrangement involved in the principle of electric sounding.

In the Schlumberger array the spacing between the potential electrodes must not exceed 40% of half the distance of the spacing (AB) of the current electrodes (Adewumi, *et al.*, 2005). Apparent resistivity (ρ_a) for the

Schlumberger array is computed from the following equation (Sharma, 1997):

$$\rho_a = \frac{nL^2}{I} \frac{\Delta v}{2l} \quad (1)$$

Where $(2L)$ is the distance between the current electrodes (AB), $(2l)$ is the distance between the potential

electrodes (MN), $\frac{\Delta v}{2l}$ is the surface gradient of potential at the midpoint between M and N, and I is the input current.

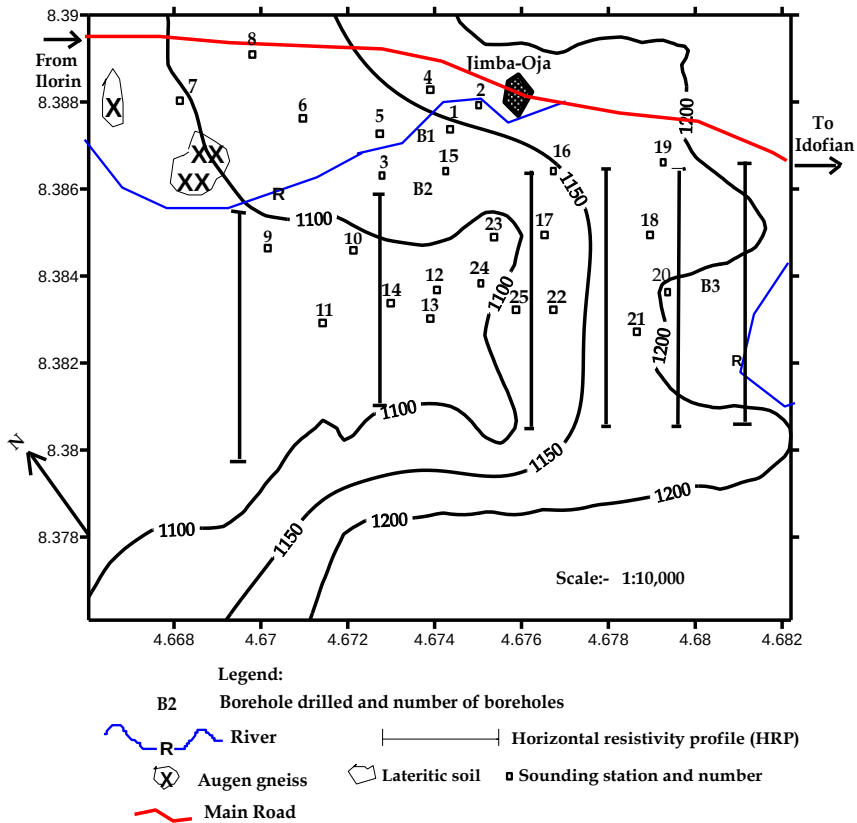


Figure 2: Geological Map and Sounding Stations

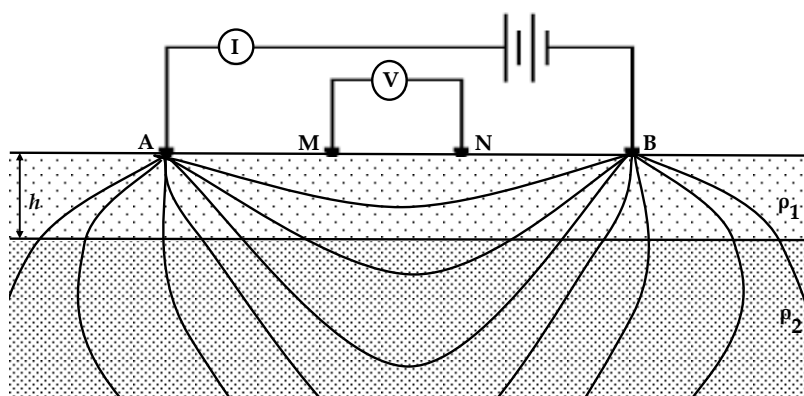


Figure 3: Principle of electric sounding. For small current electrode separation the current is virtually confined to the surface layer (resistivity ρ_1) and the measurement of p.d. between ρ_1 and ρ_2 gives information about ρ_1 . As the separation AB increases a greater fraction of the current penetrates deeper into the substratum (resistivity ρ_2) and the measurements give more information about ρ_2 (After Sharma, 1997).

The current from battery was sent into the ground through the outer electrodes. The potential difference generated by this current was measured using a voltmeter. The apparent resistivity value for each electrode spacing was calculated by multiplying the resistance obtained at the point with the geometric factor.

In the case of vertical electrical soundings, the maximum spread of the current electrodes was four hundred metres to give room for maximum penetration into the basement rock. The VES curves

were quantitatively interpreted by partial curve matching and computer iteration techniques (Sharma, 1997). The partial curve matching involved segments by segment matching of the field curves with two layers model curves and their corresponding auxiliary curves. Typical sounding curves are shown in Fig. 4. The geoelectric layers for the sounding curves vary from three to four in the area (Reynolds, 1997).

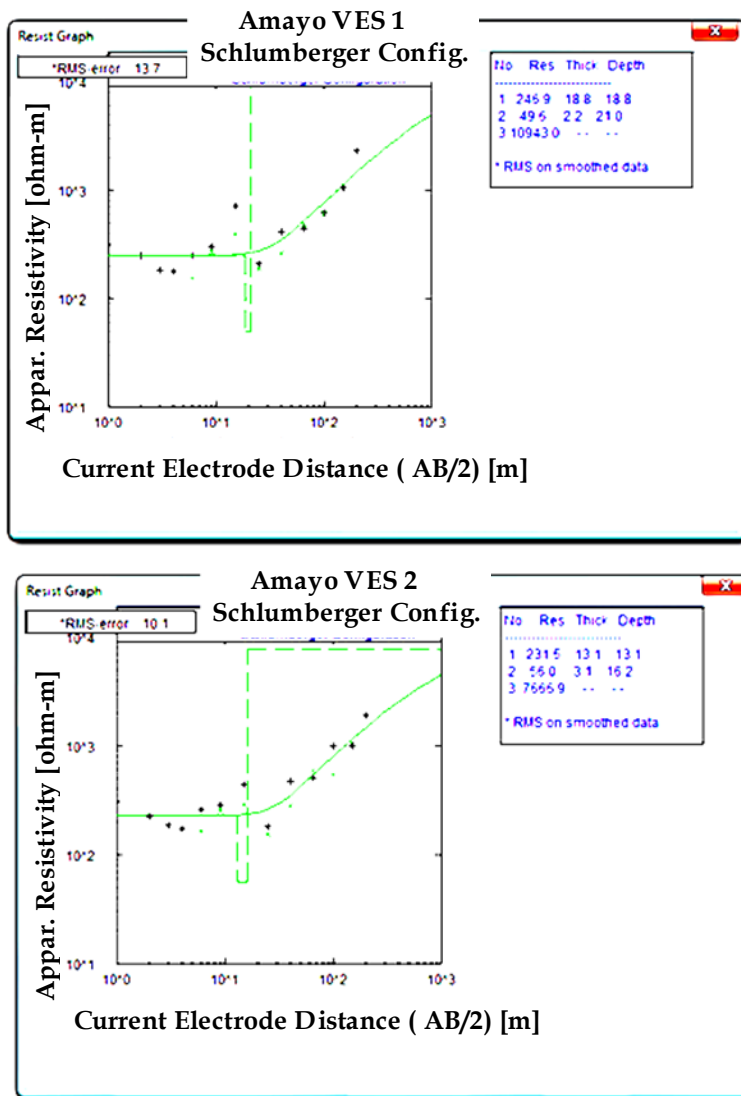


Figure 4: Typical Schlumberger Sounding Curves Obtained in the Study Area

RESULTS AND

DISCUSSIONS

Geo-Electric Sequences and Resistivity Histograms

The VES interpretation results indicated three to four major geologic units: the top soil, the lateritic layer, the weathered/fractured zone and the highly resistive bedrock. The top soil and the lateritic layer are merged in places especially where the two units share identical electrical properties.

Fig. 5a shows the top soil resistivity histogram. The resistivity values vary from 6.0 to 700 ohm-m with the highest frequencies in the 6.0 to 250 ohm-m range. The low resistivity end (<250 ohm-m) is diagnostic of clay-sandy clay and clayey sand, while the high resistivity end (>250 ohm-m) typifies compact sand and laterites. The layer thickness varies from 1.5 to 6.0 m (Fig. 6a). This layer is composed of clay, lateritic clay, sandy clay, clayey sand and sand. This accounts for the wide resistivity range.

The resistivity values for the second layer (laterite) (Fig. 5b) vary from 0.40 to 60.0 ohm-m with the most frequently occurring resistivity values in the 0.4 to 10.0 ohm-m range. The low resistivity end (<10.0 ohm-m) is typical of clay-sandy clay and clayey sand while the moderate resistivity (10 ohm-m) typifies compact sand and laterites. The layer thickness varies from 0.95 to 21.60 m (Fig. 6b)

The resistivity values for the weathered basement vary from 4.85 to α (infinity) as shown in fig 5c. The most frequently occurring layer resistivity value lies between 4.85 to 500 ohm-m. The low resistivity end (< 500 ohm-m) is typical of lateritic clays with welded gravels while the high resistivity end (>500 ohm-m) indicates compact sands. The thickness of this horizon varies from 2.3 to 20 m (Fig. 6c). The electrical resistivity of this layer depends on the sand to clay ratio and the degree of saturation. The sandy clay-clay layer with high

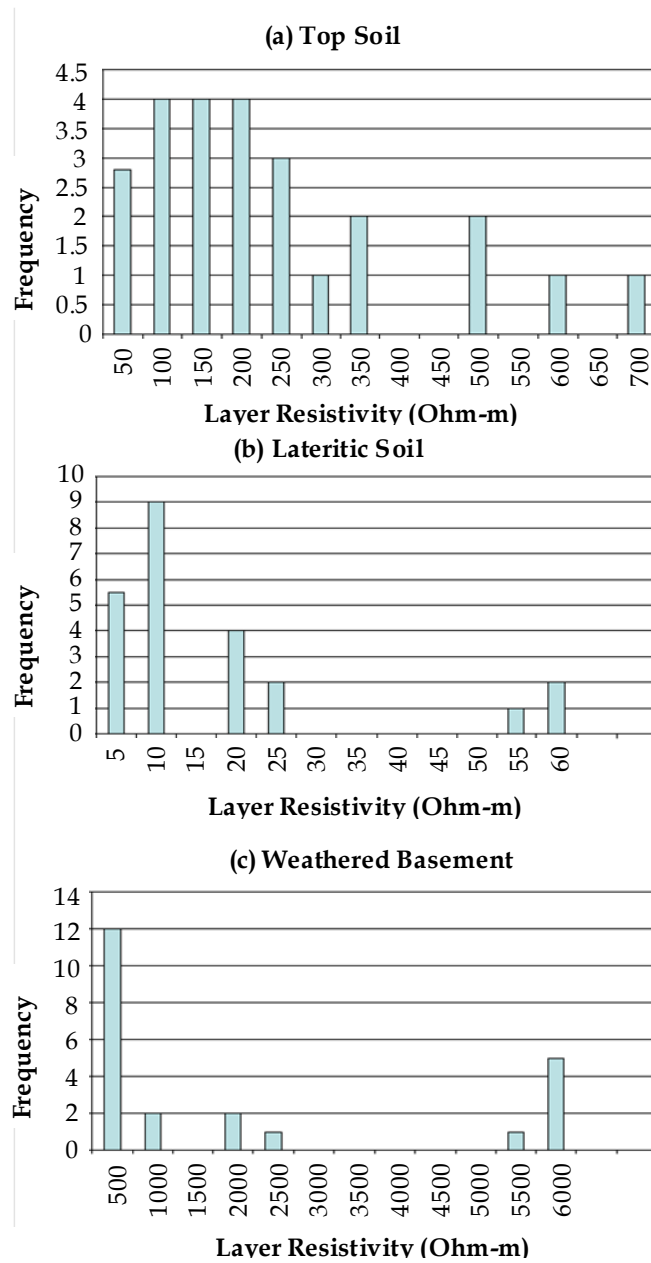


Figure 5: Histogram of Layer Resistivity

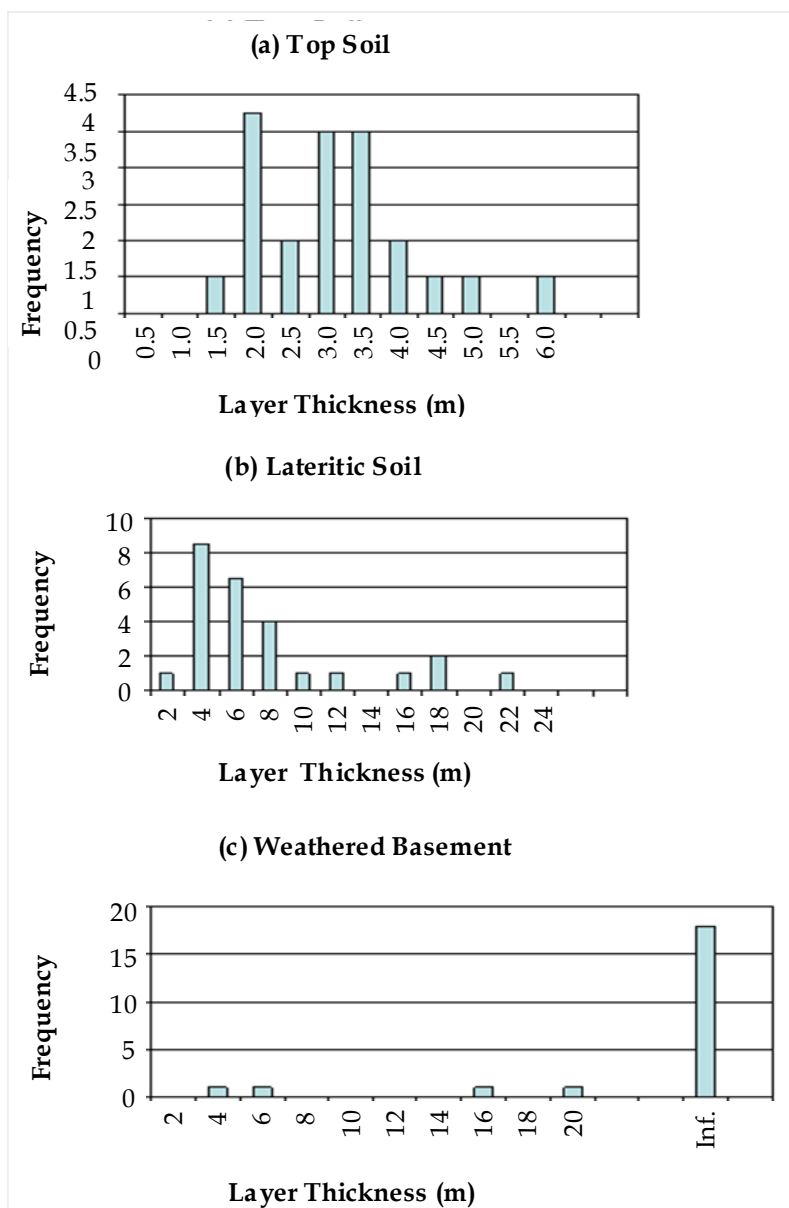


Figure 6: Histogram of Layer Thickness

clay content imposes some confining characteristics on the aquifer zone. A high degree of saturation could also account for some reduction in resistivity. The weathered layer constitutes the major aquifer unit. In some places, fractured zones occur immediately beneath the weathered horizon. Where the fractured zone is saturated, a relatively high groundwater yield can be obtained from boreholes penetrating such sequence.

The map of apparent resistivity for $AB/2 = 100$ m (Fig. 7) shows a lobe of low resistivity to the South/South-Eastern part of the area under study. Also the area with high resistivity is to the North. The portion with maximum depth

where valley exists is around the centre of the area under study. The fractured zone constitutes a major component of the aquifer in a Basement Complex area. The depth to bedrock varies from 2.5 to 28 m. This is due to differential weathering of the basement rocks. It is interesting to note that the area with high resistivity (Figs. 7 and 8) is to the North and it corresponds with areas having shallow depth (Figs. 9 and 10), while the lobe of low resistivity (Fig. 7) tallies with area having maximum depth to the basement (Figs. 9 and 10). Also the geological map of the area (Fig. 2) shows that the outcrops in this area are in the North.

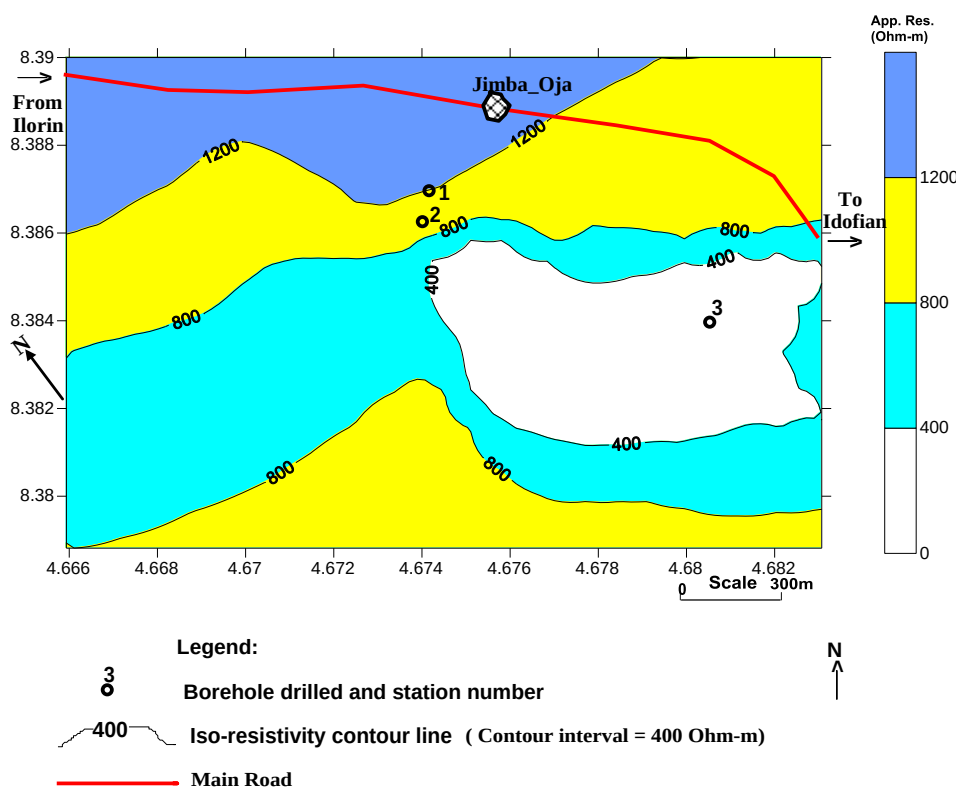


Figure 7: Apparent Resistivity Map of the Study Area ($AB/2= 100$ m)

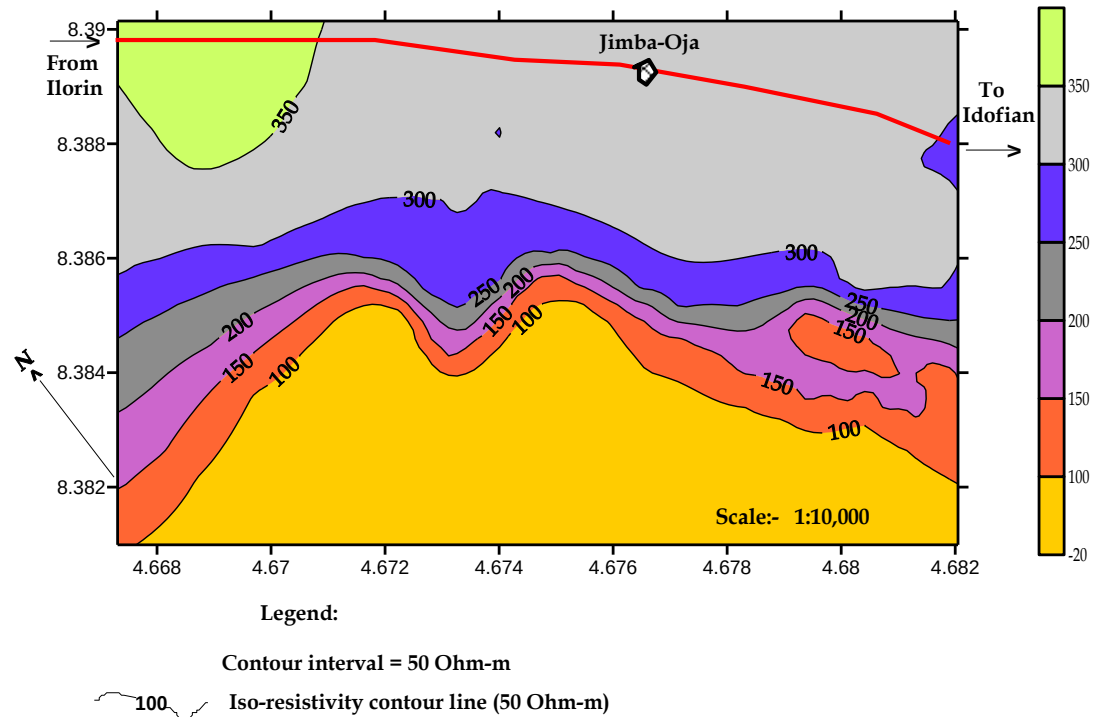


Figure 8: Apparent Resistivity Map (AB/2= 10 m)

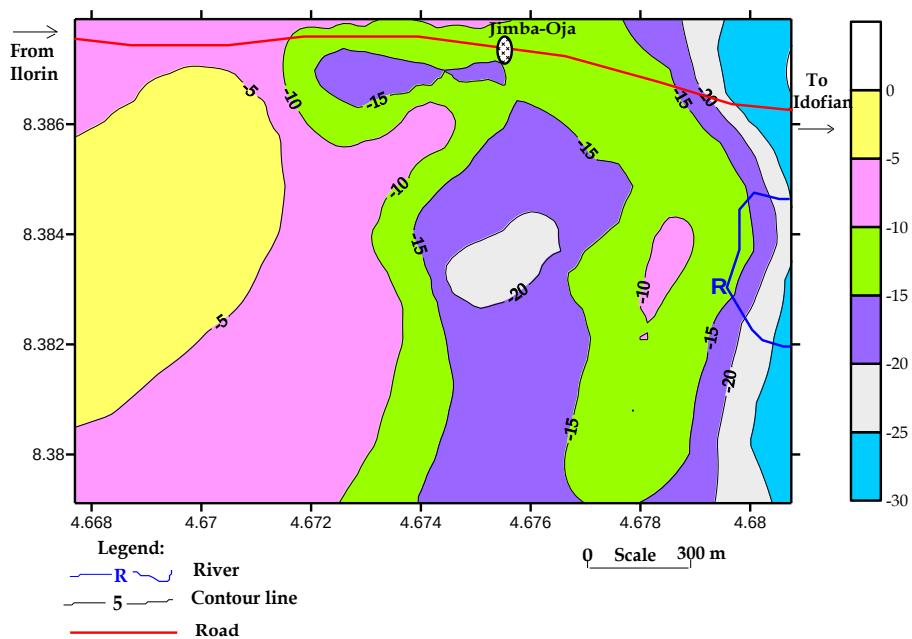
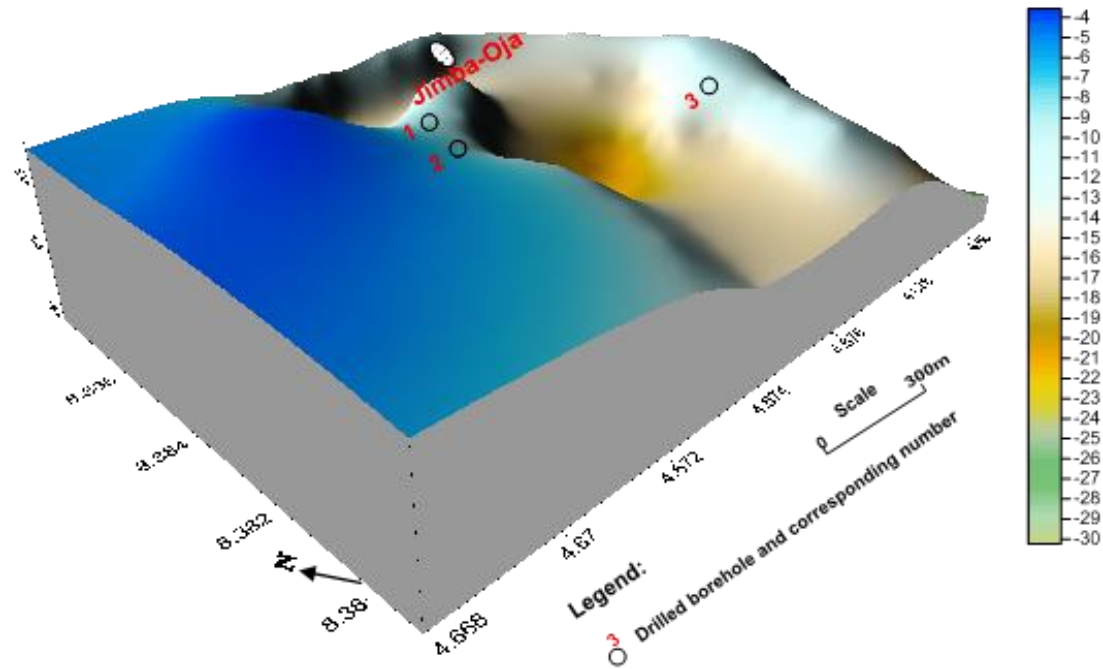


Fig. 9: Map of Depth to Last Layer (Bedrock)



This further confirms the high resistivity values obtained to the North (Figs. 7 and 8). The deep seated basement with thick overburden containing the lobe of low resistivity (Fig. 7) will definitely be a better zone for water prospecting in the area because all the information obtained in Figs. 7, 9 and 10 show that the lobe constitutes the main prospective area for water exploration.

The depths to the fresh bedrock (overburden thickness) beneath the sounding stations shown in Figs. 9 and 10 include the topsoil, the lateritic horizon and the weathered/fractured basement. The depth to the bedrock varies from 2.85 to 32m. Okhue and Olorunfemi (1991) opined that, generally areas with thick overburden (Figs. 9 and 10) and low percentage of clay in which the intergranular flow has either a dominant or important role are known to have high groundwater potential particularly in a Basement Complex area.

CONCLUSIONS

The hydro-geophysical investigation of ARMTI and NCAM, Jimba-Oja in Ifelodun L.G.A of Kwara State, Nigeria for groundwater exploration has revealed four major geoelectric units. These include: the top soil, the lateritic layer, the weathered/fractured basement and the fresh basement unit. The weathered/ fractured basement constitutes the main aquifer unit in the study area.

The isopach map of the overburden shows that depths to the fresh basement vary from 2.85 to 28.0 m. The geoelectric interpretation of the electrical resistivity data obtained in the area has elicited a lobe of low resistivity (Fig. 7) which constitutes the prospective zone for water exploration. Boreholes located within basement depression zones which correspond to area with relatively thick overburden (Figs. 9 and 10) give relatively high yields. Such areas with thick overburden materials are priority

zones for possible groundwater development most especially when the clay content is low. The study area has been delineated into

prospective high and low groundwater potential zones based on geoelectric characteristics.

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