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# Determination of Porous Zones Using Vertical Electrical Sounding Data from Basement Rocks of Kwal, Kanke, North-Central Nigeria

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***ABSTRACT:*** *This work was undertaken to study the porous zones of Kwal and its environs, Forty (40) vertical electrical sounding data using the schlumberger configuration with current electrode with a maximum electrode spacing of AB/2 = 125m were carried out in the study area. The field data were smoothened and interpreted using computer software (WinResist inversion) in order to estimate the porosity and determine the porous zones. The interpreted results revealed three geo-electric layers with varying thickness and levels of weathering. The three geo-electric layers were interpreted to be clayey sand, weathered basement with resistivity values ranging between 18.9 to 498.2 Ωm indicating porous zones due to secondary porosity or water content while the third layer is interpreted to be fresh basement, this layer revealed high resistivity values that ranges between 521.6 Ωm to 6148.2 Ωm.*

***Keywords:*** *Porosity, Weathered Basement, Sounding, Resistivity, and Geo-electric layer*

## I. INTRODUCTION

Kwal is situated in the north-central part of Nigeria and lies between latitude 9.3643°N to 9.3928°N and longitude 9.6010°E to 9.6375°E (Fig 1). The area is underlain by crystalline basement rocks, where its porosity is secondary as a result of weathering and/or fracturing of the parent rocks. Crystalline basement rocks occupy 40 % of the land area of sub-Saharan Africa (MacDonald and Davies, 2000).

Weathering is also an important factor that determines the presence of porosity and permeability, especially in basement complex rocks. (Acworth, 1987; Oluorunfemi and Fasuyi, 1993; Edet and Okereke, 1997).Several authors have therefore delineated shallow aquifers and estimated aquifer hydraulic parameters using surface geophysical methods in different parts of the world. (Ekwe and Opara, 2012, Onyekurk, 2010). Permeability and porosity in the weathered zone of crystalline rocks vary throughout the rock profile (Fig 2). Porosity generally decreases with depth while permeability possesses a complicated relationship, depending on the extent of fracturing and the clay content (Chilton and Foster, 1995). In some cases the bedrock has disintegrated into an extensive and relatively thick layer of unconsolidated, highly weathered rock with a clayey residue of low permeability (Morris et al., 2003). This work is therefore intended at determining the effect of secondary porosity on electrical resistivity and to also analyse the result of depth on the porosity of the crystalline basement rocks of Kwal, north central, Nigeria.

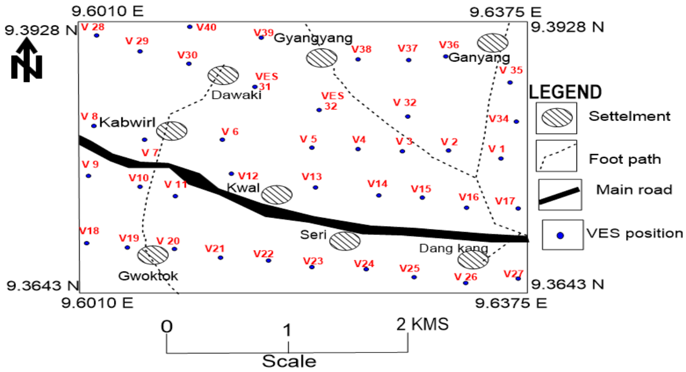


**Figure 1:** Location map of the study area showing VES points

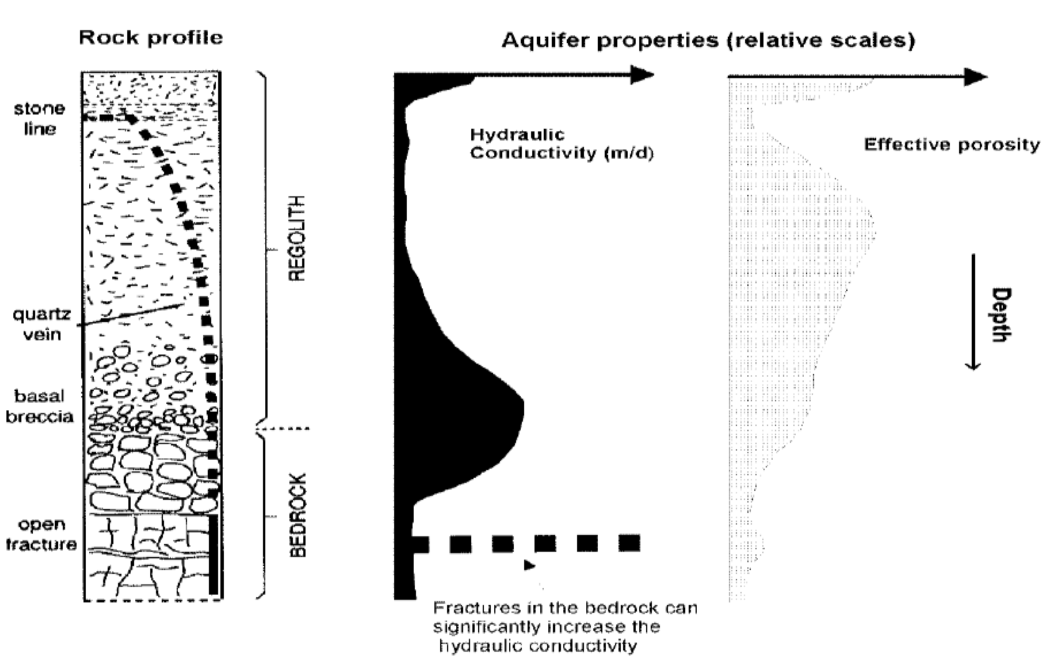


**Figure 2:** Variation of permeability and porosity with depth in basement aquifers (After Chilton and Foster, 1995)

## II. GEOLOGY OF KWAL AREA

The geologic sequence of the Jos-Plateau consists almost entirely of plutonic and volcanic rock belonging to four (4) major age groups. (Macleod et al., 1971) suggested the generalized succession given below (table 1); Kwal area is underlain by four rock units. This includes migmatites, Older granite, aplo-pegmatitic granite and Quaternary Basalts. The migmatite constitutes 65% of the study area and is basically a metamorphic rock made up of metamorphic minerals of high temperature, injected with granitic materials. In addition, migmatites are commonly interpreted to be partially melted rocks in which the granitic partial melt has not segregated from the complementary residue. Some petrologists believe migmatites represent residues of production of granitoid plutons, but other possibilities exist. This rock covers the entire part of the study area. Mineralogically migmatites are composed of feldspar, hornblend, and quartz with or without biotite. The older granite covers about 15% of the study area and is located at the north-western part of the study area. This rock is composed of fine-grained and light colored with injections of some mafic minerals. Unlike migmatite that are mostly exposed along river channels, these are seen as high level outcrops and also as minor outcrops and as veins on the predominant Migmatite. These rocks, most likely intruded the basement during the Pan-African Orogeny. The aplo-pegmatitic granite constitutes about 10% of study area. This rock is composed mainly of quartz and feldspars with very coarse crystals. An extensive pegmatite field characterized the South western margin of the study area with variable thickness of about 90-200m Aplo-pegmatitic granite field assumes a NW-SE trend (Fig 3). Basalts are extrusive igneous rocks with a glassy texture. They constitute one of the youngest rocks in the study area since they are Quaternary in age. Columnar basalts were encountered at the Northwestern part of the study area. This gives clue to the fact that the basaltic intrusion was previously jointed. Conversely, some basalts trending NW-SE are seen as boulders within a basalt field with no joints.

**Table 1:** Table of the geological sequence of the Jos-Plateau

| S/No | Age | Rock type | Description |
|---|---|---|---|
| 1 | Quaternary | Newer Basalts | Lava flows and volcanic cone |
| 2 | Cretaceous | Sedimentary rocks | Sediments |
| 3 | Jurassic | Younger Granite | Granite, Porphyries |
| 4 | Precambrian to lower Paleozoic | Crystalline Basement | Migmatite, Gneisses Pan-African “older Granite” |

Macleod et al., (1971)

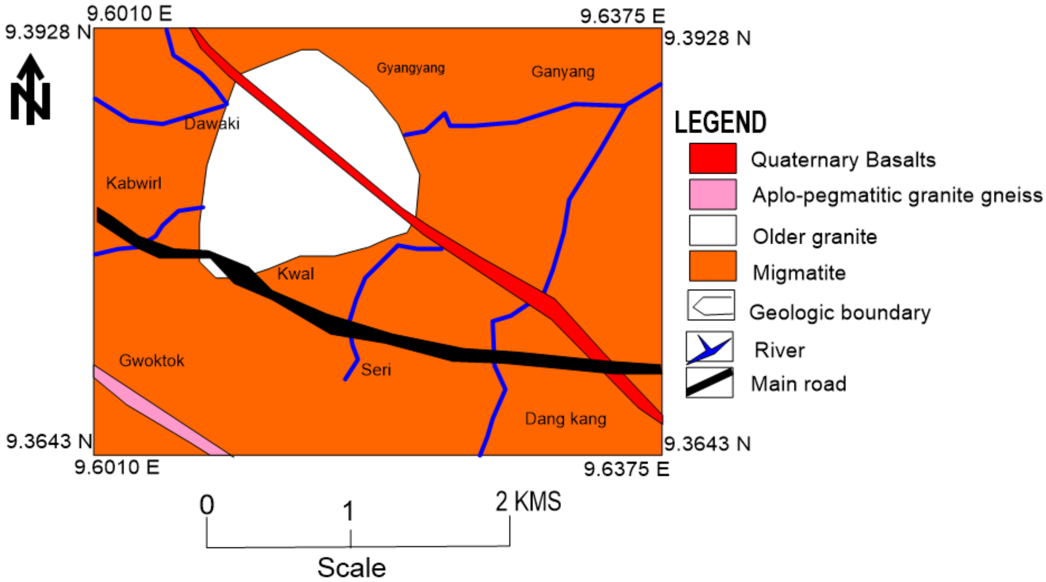


**Figure 3:** Geological map of study area

**Data acquisition and interpretation**

Resistivity methods have been used extensively to locate vertical and horizontal fractures and weathered zones in West and East Africa (Chilton and Foster, 1995). In this study forty Vertical Electrical Sounding (VES) were carried out in the area (Fig 1). The Schlumberger configuration was adopted with current electrode separation of AB/2 = 125 m. The instrument used for the acquisition of the data was the ABEM SAS 300C Terrameter which measures the variation in the electrical resistivity of the subsurface by introducing electric current through current electrodes (AB) and picking the potential difference from the potential electrodes (MN). The data collected were then processed through curve matching to produce the initial models for the computer interpretation using WinResist inversion software to create the thickness and electrical resistivity values of the subsurface layers (Telford et al., 1990). The final results of the analysis are revealed in Table 2. Fig. 1 shows the Site locations of the VES points within study area.

**Table 2:** Interpreted results of geoelectric parameters of Kwal area.

| | Thickness of layers (m) | | | | Resistivity of layers (Ω-m) | | | |
|---|---|---|---|---|---|---|---|---|
| VES no | $h_1$ | $h_2$ | $h_3$ | | $\rho_1$ | $\rho_2$ | $\rho_3$ | $\rho_4$ |
| 1 | 7 | 1 | 16 | | 36 | 69.2 | 596.5 | 547.5 |
| 2 | 0.8 | 16.5 | | | 146.4 | 69.1 | 34.5 | |
| 3 | 1.6 | 8.4 | | | 74.3 | 31.1 | 40.4 | |
| 4 | 1.9 | 12.7 | | | 180.4 | 73.9 | 31.6 | |
| 5 | 1.2 | 5.4 | 25.3 | | 108.8 | 37 | 133.5 | 337.8 |
| 6 | 0.7 | 5.9 | 14.3 | | 172.3 | 28.3 | 159.9 | 1538.4 |
| 7 | 2.5 | 17.2 | | | 17.3 | 4957.8 | 6148.2 | |
| 8 | 2.6 | 4 | | | 14.9 | 76.6 | 4603.1 | |
| 9 | 9.7 | 17.5 | | | 453.9 | 428.5 | 1394.7 | |
| 10 | 5.6 | 4.3 | | | 134.6 | 328.7 | 856 | |
| 11 | 3.2 | 5.4 | | | 121 | 47.8 | 929.7 | |
| 12 | 0.9 | 2 | 3.6 | | 163.1 | 18.9 | 315.7 | 738.6 |
| 13 | 7.2 | 3.3 | 16.4 | | 52.5 | 222 | 1161.5 | 1122.5 |
| 14 | 7.2 | 2.6 | 12.2 | | 45.9 | 159.2 | 1294.3 | 2187.4 |
| 15 | 7.6 | 2.6 | | | 243.7 | 395.2 | 621 | |
| 16 | 6.3 | 29.6 | | | 261.8 | 521.6 | 729.5 | |
| 17 | 7.5 | 6.5 | | | 224.4 | 417.9 | 594.7 | |
| 18 | 9.7 | 26.6 | | | 184.3 | 498.2 | 636.9 | |
| 19 | 5 | 9.3 | 19.8 | | 142.2 | 696.9 | 360.1 | 1224.7 |
| 20 | 4.9 | 6 | 20.9 | | 79.3 | 312 | 338.9 | 1122.5 |
| 21 | 5.2 | 6.2 | | | 15.2 | 269.4 | 4030.5 | |
| 22 | 1.3 | 6.3 | 11.5 | | 133 | 54.3 | 697.4 | 2670 |
| 23 | 1.4 | 5.6 | 10.7 | | 160.4 | 52.7 | 704.4 | 3209.2 |
| 24 | 1.2 | 6.8 | 12.9 | | 107.8 | 55.3 | 691.2 | 1827.6 |
| 25 | 6.3 | 7.7 | | | 48.3 | 328.2 | 475.5 | |
| 26 | 1 | 13.3 | | | 162.4 | 45.9 | 621.9 | |
| 27 | 1 | 13.1 | | | 323.7 | 91.5 | 1217.2 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 28 | 0.9 | 13.5 | 16.2 | | 95.1 | 287.6 | 632.3 | 126.4 |
| 29 | 11.6 | 17.6 | | | 170.4 | 398.5 | 425.7 | |
| 30 | 7.2 | 3.8 | | | 27 | 93.4 | 1023.7 | |
| 31 | 0.7 | 3.4 | 16.2 | | 107.2 | 33.7 | 261.2 | 823.1 |
| 32 | 5.8 | 6.1 | 12.7 | | 71.2 | 219.6 | 561.2 | 2437.6 |
| 33 | 0.6 | 7 | 15.4 | | 243.2 | 57.6 | 248.5 | 1460.2 |
| 34 | 3.6 | 3.5 | 19.4 | | 163.6 | 335.5 | 881.5 | 342.2 |
| 35 | 6.3 | 24.1 | | | 113.2 | 724.6 | 297.6 | |
| 36 | 2.7 | 3.1 | 4.5 | | 65.2 | 23.4 | 351.8 | 2328 |
| 37 | 6.4 | 3.4 | | | 85.4 | 183.3 | 688.1 | |
| 38 | 1.5 | 19 | 10.6 | | 56.4 | 160.5 | 237.1 | 1943.9 |
| 39 | 7.7 | | | | 83.3 | 510.1 | | |
| 40 | 9.6 | 9.6 | | | 170.1 | 281.7 | 443.9 | |

## III. DISCUSSION ON THE RESULTS

The first geoelectric layer which is the top soil varies in thickness from between 0.6 to 11.6 m at VES 33 and VES 29 respectively, while the resistivity ranges from 14.9 at VES 8 to 453.9 Ωm at VES 9. Areas with high resistivity values indicates the presence of sand as top soil, while those with relatively low resistivity values point to the existence of clay or intercalation of clay with sand (Telford et al., 1990) The second geoelectric layer was interpreted to be weathered basement with the exception of VES points 7, 16, 19, 35 and 39 with resistivity values of 4957.8 Ωm,521.6 Ωm, 696.9 Ωm, 724.6 Ωm and 510.1 Ωm respectively which reveal the presence of unaltered bedrock in the electrostratigraphic sequence. The remaining thirty five VES points revealed varying degrees of weathering (porosity) with resistivity values ranging from18.9 to 498.2 Ωm indicating porous zones due to secondary porosity or water content. The thickness of these layers also varies from 3 to 31.9 m. The resulting weathered zone can vary in thickness from few metres in arid areas to over 90 m in humid tropics (MacDonald and Davies, 2000). A layer is slightly weathered if the resistivity values are relatively high or on the other hand a highly weathered zone has relatively low resistivity values (Telford et al., 1990). Therefore, the reduction in the resistivity values of the second geoelectric layer is due to secondary porosity induced by secondary processes such as weathering or fracturing in the parent rocks. The third geoelectric layer revealed fresh basement rocks not affected by the effect of secondary processes. Below the weathered zone, the rocks become progressively less weathered and more consolidated and therefore act as the contact between the weathered zones and the fresh basement rock. This layer revealed high resistivity values that ranges between 521.9 to 6148.2 Ωm with the thickness ranging from 9.3 to 29.6 m.

## IV. CONCLUSION

Three main geoelectric layers were identified from the forty VES data obtained from the study area. The first layer was interpreted to be clayey sand; the second layer revealed weathered basement rocks while the third layer is fresh basement rocks. The data obtained from the geophysical survey and its subsequent interpretation has thrown more light on our initial knowledge of the subsurface geology of the area and therefore helped at limiting its porosity and water retention and transmission capacity without option to any sedimentological studies. The intrusive igneous crystalline rocks of the area have very little (if any) primary porosity, but secondary porosity has been identified to be the major source of porosity in the parent rocks of Kwal area.

## REFERENCES


[1]. Acworth, R. I., 1987. The development of crystalline basement aquifers in a Tropical environment.

[2]. Quarterly Journal of engineering Geology.Vol. 20, pp. 265-272.

[3]. Chilton, R. C. and Foster, S.S.D. 1995. Hydrogeological characterization and water supply potential of basement aquifers in tropical Africa. Hydrogeology journal. Vol. 3(1), pp. 36-49.

[4]. Edet, A. E and Okereke, C. S. 1997. Assesment of hydrogeological conditions in basement aquifers of the Precambrian Oban massif south-eastern Nigeria. Journal of applied geophysics. Vol. 36(4), pp. 195-204.

[5]. Ekwe, A. C. and Opara, A. I. 2012. Aquifer Transmissivity from Surface Geoelectrical Data: A Case Study of Owerri and Environs, Southeastern Nigeria, Journal of the Geological Society of India, Vol. 80, No. 1, pp. 355-378.

[6]. MacDonold, A.M. and Davies, J. A. 2000. Brief review of groundwater for rural water supply in sub- Saharan Africa. British Geological Survey. Technical report WC/00/33.

[7]. Macleod, W.N., Turner, D.C and Wright, E. P (1971). The Geology of the Jos Plateau: vol.1. Geology, Bull. Geol. Survey, Nigeria No.32.pp 91-95.

[8]. Morris, B.L., Lawrence, A.R.L., Chilton, P.J.C., Adams, B., Calow, R.C. and Klinck, B.A. 2003. Groundwater and its susceptibility to degradation: A Global Assessment of the problem and option for management. Early warning and assessment report series, RS. 03-3 United Nations environment programme, Nairobi, Kenya.

[9]. Olorunfemi, M.O.and Fasuyi, S.A. 1993. Aquifer types and the geoelectrical/hydrogeologic characteristics of part of central basement terrain of Nigeria. Journal of African Earth Science. Vol. 16(3), pp 309-317.

[10]. Onyekuru, S., 2010. Depositional patterns of Upper Cretaceous Sediments in the Southeastern part of Anambra Basin Southeastern Nigeria, Unpublished Ph.D. Thesis, Federal University of Technology, Owerri, 2010, 280 p.

[11]. Telford, W. M., Geldart, L. P. and Sheriff, R. E. 1990. Applied Geophysics, Cambridge University Press. 770 p