FULL LENGTH RESEARCH ARTICLE

A REGIONAL GEOELECTRIC INVESTIGATION FOR GROUNDWATER EXPLORATION IN MINNA AREA, NORTH WEST NIGERIA.

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ABSTRACT

A Regional Geoelectric survey using the Vertical Electrical Resistivity (VES) was used to investigate the land mass covering Minna and it's environ in Nigeria aimed at assessing the lithology beneath the area, delineate the aquiferous formations and its depths and thicknesses. The area was grided into 13 profiles spaced at 3 km intervals with each having 13 stations for the VES. A total of 169 VES points were occupied. The Global Positioning System (GPS) equipment was used for locating the stations on ground. The interpretation of the field data was carried out using the Zhody soft-ware, which converts the apparent resistivity as a function of electrode spacing to the true resistivity as a function of depth in two dimensions. The rocks of the area are largely of crystalline rocks, which include gneisses, migmatites and metasedimentary schists. The results show that the area is underlain by three layer lithologic sections. In some sections where the basement had probably suffered severe weathering and or fracturing, four or five layer models were obtained. The weathered/fractured layers along the transitional zones form the aquiferous formations in the area with a maximum thickness of about 45m.

Keywords: Vertical Electrical Sounding, Apparent resistivity, formations, lithology, layers, depths, fracturing, rocks, global positioning system, delineate

INTRODUCTION

Minna, the main town in the area is the capital of Niger State Nigeria. It is a metropolitan city that is densely populated and whose population is on the rise because of its proximity to the Federal Capital Territory (FCT).

The progressive population growth has led to severe shortage of portable drinking water for the area which poses as a great challenge to both the citizens and the government. The present investigation is aimed at producing data which could serve as a basis for more detail groundwater exploitation activities for the area.

The result will provide a geophysical survey data containing basic information necessary for identifying zones for siting better yield boreholes. The result of the survey will also serve as basis for more detailed geophysical and geotechnical studies in the area as well provide other geophysical parameters for carrying out geotechnical activities. At present information on regional geoelectric investigation for the area is scanty.

MATERIALS AND METHOD

The Study Area: The study area is a vast land on the Minna topographic map sheet SW 164, located at latitudes 9°30'N and longitudes 6°25'E (Fig. 1). It covers a total landmass of approximately 1300 km² (Adeniyi 1985).

The Geology/Hydrogeology of the Study Area: Minna area falls within the larger northwestern Nigerian basement complex, which is made up of crystalline rocks consisting of gneisses and migmatatites, and meta sedimentary schists. Trustwell & Cope (1963) recognized three formations in the area. First is the Kusheriki Psamite formation at the base of successions made of rocks of varying lithology, texture and structure and showing different degree of granitization and migmatization. The metamorphic host rocks are pegmatite, feldspathic, and granitic material with relics of quartzite and an upper more extensive unit of quartzo feldspathic rocks which are distingushed as members of the Zungeru granulite. Embrechitic migmatites is well exposed at a cut in Kwakwa village, about 12km² from Suleiman-Minna road.

The second classes of rocks are mainly the Kushaka schist formation considered to be the stratigraphic equivalence of the Kushaka Formation.

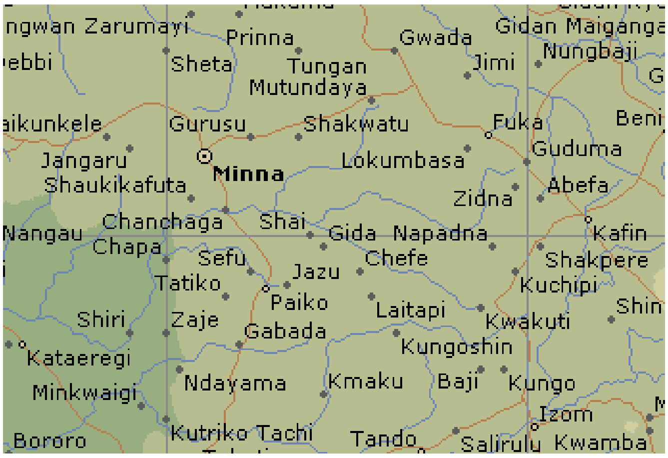

FIG. 1 TOPOLOGY MAP SHOWING THE SURVEY AREA.

This forms the narrow belts in the western half of Nigeria and has been variously described as "newer metasediments' by Oyawole (1972) or as younger meta-sediments by McCurry (1972). Lastly are the older granites which was first introduced by Falconer (1911) to distinguish the Pan-African granites in Nigeria from the Mesozoic tin-bearing volcanic granitic ring complexes of the Jos plateau which were emplaced into the migmatite-gneiss complex and the schist belts (Fig 2).

The area is situated within the crystalline hydro geological province. The hydro geological province is made up of two interconnected aquifers, namely: - the soft overburden aquifer and the partial weathered/fractured basement aquifer. The average thickness of the soft overburden in Minna and its environs is about 30m and the average yield of borehole in the aquifer is about 0.5 liters per second (Adeniyi 1985).

The partially weathered/fractured basement formation is the secondary aquifer and the more reliable aquifer in this area. An average yield of 5 liters per second of borehole can be gotten when carefully sited in the fractured zone. The groundwater in the area is primarily service by the surface precipitation and by the lateral groundwater movement. The depth to the water tables lies on the average between 3 - 15m below the surface in the crystalline basement (Adeniyi 1985).

Locating the stations: The Terrameter model SAS 300c was used to acquire one hundred and sixty-nine (169) YES stations using the Global Positioning System (GPS) to locate the stations. The Schlumberger configuration method was used in taking the data. The Schlumberger array involves the use of the two potential electrodes P1& P2 fixed about a center '0' as the point of inscription, while the current electrodes C1& C2 are moved in steps collinearly with P1&P2.

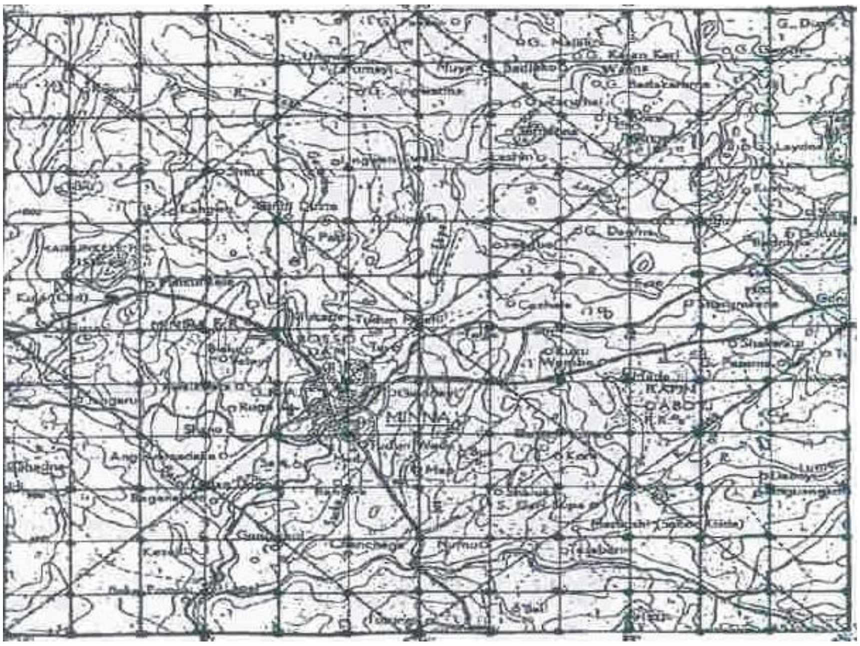

FIG. 2. GEOLOGY MAP SHEET 42 SUPERIMPOSED ON THE TOPOLOGY MAP SHEET SWIM OF MINNA.

The principle is that current is introduced into the ground by means of two current electrodes and the potential drop between a second pair of electrodes (potential electrodes) placed in line in between the pair is measured. Fig. 3 shows the current and the potential distribution within a homogeneous isotropic ground in a vertical plane through the current electrodes. Pattern would be the same in any plane through these electrodes.

A proportion of the current penetrates deeply into the ground and the depth of penetration increases with increasing electrode spacing.

In a heterogeneous ground in which there exists a vertical variation in resistivity with depth, the apparent resistivity rather than the true resistivity is measured. The flow of the current in such a ground is influenced by the density, porosity and salinity of the fluid contained in the ground.

From equation (1), the resistivity ρ can be expressed as:

$$\rho = \frac{2\pi\Delta V}{I}\left(\frac{1}{r1}-\frac{1}{r2}-\frac{1}{r3}+\frac{1}{r4}\right)^{-1} \quad \text{... (2)}$$

= KR

Where R corresponds to the resistivity of the volume of the ground between the potential surfaces passing through the potential electrodes and K is called the geometric factor which depends on the electrode configuration.

The Schlumberger configurations are giving by r = r3 - rl = r2 - r4 and L = r1 + r2 = r3 + r4 where V and I are in millivolts and milliameter respectively.

Here,

$$K=\left(\left(\frac{\pi}{2r}\right)\frac{L}{r}\right)^{-1} \quad \ldots(3)$$

The field data which is the resistivity of the subsurface is converted to the apparent resistivity in ohm-meters. These computed values of apparent resistivity are a function of electrode spacing. The apparent resistivity values are plotted against the spacing by means of a computer program developed by Zodhy (1989). The interpreted curves obtained provide means for comparing the resistivity variation with depth. The comparison is done by contouring points of equal resistivity at a given depth as iso resistivity of cross-sections or points of equal resistivity with depth as iso-resistivity of vertical section. In an attempt to achieve a comprehensive interpretation, along the aim of this work, the following steps were adopted:

(i) Twelve profiles of interest were chosen through the latitudes, longitudes and the diagonals of the survey area. These are: latitudes 9°30'N, 9° 40'N, 9°45'N, longitudes 6°30'E, 6°35'E, 6°40'E, CG', EA', GC', AE', and CG"

(ii) Regional contour map of the aquifer thickness for the entire area was produced. The approximate average resistivity values associated with rocks and water types in the basement complex is given in Table 1.

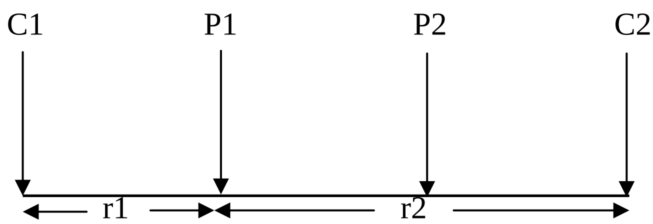

FIG. 3 ELECTRODES CONFIGURATION

TABLE 1. APPROXIMATE RESISTIVITY RANGES FOR VARIOUS ROCK AND WATER TYPES IN THE BASEMENT COMPLEX AREA (After Telford *et al.* 1976)

ROCK TYPE	RESISVITY (O-M)
Clay and Marl	1-67
Topsoil	67 - 100
Clayey soil	100 - 133
Sandy soil	670 - 1330
Limestone	67 - 1000
Sandstone	33 - 6700
Sand and gravels	100 - 180
Schist	10 - 1000
Granite	25 - 1500
Surface water (in igneous rock)	30 - 500
Groundwater (in igneous rock)	30-150
Weathered laterite	200 - 500
Fresh laterite	500 - 600
Weathered/Fractured basement	100-500
Fresh basement	>1000

RESULTS
The results of the interpretation of the sounding on the profiles sampled are summarized in the aquifer thickness map shown in Fig. 4. Typically, the surfacial layer, which is the first layer is made up of low resistivity and consists of clayey soil in some sections and high resistive fresh laterites mixed with loose sands and gravels in others. The average resistivity value of this layer varies between 10 - 900 Q-m. The average resistivity value of the second layer underlying the area is in the range of about 28 - 400 Q-m. This layer is the aquiferous formation in the study area, and has an average thickness that varied between 5-20m. Its maximum thickness of about 45 m is found where it is deeply seated. In some sections where the basement fractures are pronounced, delineation of adjourning layers becomes less apparent. This layer together with the overlaying layer forms the basic aquifer formation of this study area.

The fresh parent rock underlying this layer forms the bedrock and has relatively high resistivity value ranging between 1000 - 20000 Q-m. The bedrock has infinite thickness in all sections of the area. It is found to outcrop in some areas. The fresh basement rocks forms the third layer in most sections of the study area.

The aquifer map Fig. 4 was produced by considering the thicknesses of both the weathered layers and the transitional zones from each VES stations. The average value of the aquifer's thickness is about 24m although a maximum thickness of 45 m is found around Shadna, west of Minna and east of Gotube. Areas with aquifer thickness less than the average include Minna municipality, Bosso, GRA, Dutse Kura, Tudun Fulani, Maikunkele, Petta Sheta Shakwatu, Chanchaga, and Tutungo. It is suggested that the zones with the thickest aquifer and deep basement will have the most productive boreholes while the

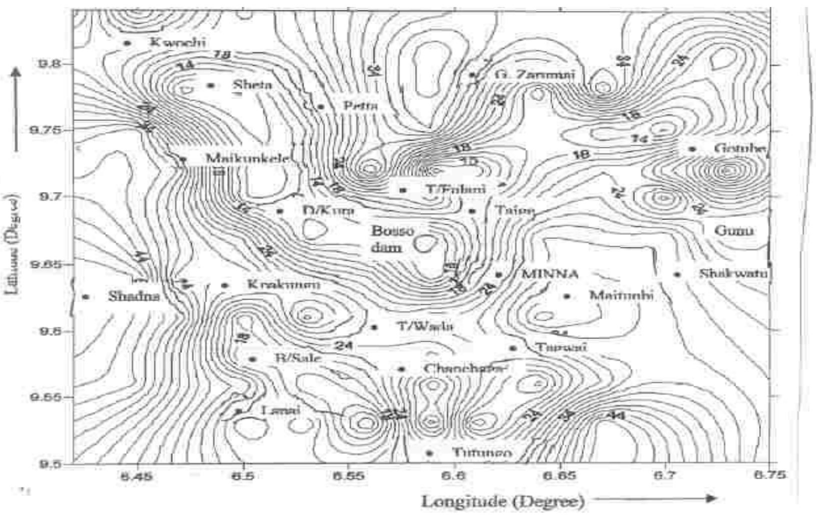

FIG.4 CONTOU MAP OF AQUIFER THICKNESS (CONTOU THICKNESS 2m)

zones having shallower aquifer and basement will serve as groundwater recharge areas, especially when located near a river or stream.

In this work, 169 VES stations were established on defined profiles covering a landmass of about 1300 km^2. The results of the VES interpretation show a maximum of five layer configuration for the area. The weathered/fractured basement terrain, of varying depth and thickness, forms the main aquifer with an average thickness of 24m.

The result from this study has provided a useful guide towards locating sites of productive boreholes. In addition, strong and weak zones, typified by their characteristics high and low resistivity values respectively, have been delineated. These are useful parameters considered while considering possibilities of construction of high rise structures, location of roads as well as situation of industries. Minna municipality and its suburbs are characterized by shallow basement of high resistivity values. This implies that the area is favorable for the construction high-rise structures. A geotechnical investigation is however, necessary to evaluate other useful geotechnical parameters.

For acquisition of other useful aquifer parameters, surveys such as seismic refraction investigations, and radial type of sounding are recommended. Also, to assess the quality of the underground water, geochemical study of the area is recommended.

REFERENCES
Adeniyi, D. R. 1985. Geophysical Investigation of the Central Part of Niger State, Nigeria. Ph.D Thesis, University of Wisconsin, Madison, USA.

Falconer, J. D. 1911. *The Geology and Geography of Northern Nigeria.* Macmillan Publication, London.

McCurry, P. 1975. *The Geology of the Pre-Cambrian to Lower Paleozoic Rocks of Northern Nigeria.* Geology of Nigeria, (ed. C. A Kogbe

Oyawoye, M. O. 1964. The Geology of Nigerian Basement Complex. *Journal of Mining and Geology* (1):16.

Telford, N. W. Geldart, L. P., Sheriff, R. S. & Keys, D. A. 1976. *Applied Geophysics.* Cambridge University Press.

Trustwell, F. J. & Cope, R. N. 1963. The Geology of Parts of Zaria and Niger Provinces of Northern Nigeria. *GSN Bulletin* 29.

Zhody, A. R. R. 1989. A New Method for the Automatic Interpretation of Schlumberger and Wenner Sounding Curves. *Geophysics,* (2):245-253.