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An investigation of groundwater condition in Agbede by Geelectrical resistivity method.

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Abstract

Vertical soundings (VES) for the purpose of drilling groundwater boreholes for the inhabitants were conducted in Agbede to determine: the depth to the aquifer (Ajali Formation which consists of porous and permeable coarse sandstones); the thickness of overlying aquiclude (Imo Shale which consists of non porous/ permeable thick clays) and to locate where the small lenticular sands within the Imo Shale called perched aquifer exists. Perched aquifers are hydraulically separated, are relatively small, and they occur above the water table when there is an impermeable layer of rock (aquiclude) above the main aquifer. The VES curves of the area were qualitatively interpreted and the result showed an ascent at the first decade (dry top soil), a decent at the second decade (Imo Shale) and with the right most segment ascending int6o the third decade which is an indication of the presence of the Ajali Formation below the Imo Shale. The geoelectric section from the from the VES revealed that the Ajali Formation could not be encountered even at a depth of 494.03m, indicating that the clay is as thick as 500m. Also perched aquifer could be encountered between the depths of 52.76-55.43m with thicknesses 9.89-10.86m but not in all locations.

1.0 Introduction

The superiority of the geoelectric method over others in the groundwater research is confirmed by the work of Pulawaski and Kurth [1]. The ability of the receptivity method to furnish information on the subsurface geology unobtainable by other methods in groundwater studies was demonstrated by Zohdy and co-workers [2, 3]. They also attested to the ability of the electrical method to provide information on the depth of the fresh/salt water interface. The resistively techniques have been successfully utilized in: assessing water supply potential in basement aquifers [4], exploring aquifer boundaries in the plains of Yemen [5], and the assessment of the groundwater resources potentials within the Obudu basement area of Nigerian [6].

The previous workers demonstrated the success of VES for ground water assessment. However, the fact that no successful borehole has been drilled in a terrain such as Agbede which is underlain by thick clay is an evidence that the thickness of the clay above the Agbede which is underlain by thick clay is an evidence that the thickness of the clay above the Ajali Formation (the main aquifer) has not been estimated situation which led to the aborted borehole after drilling through 34m thick of clays.

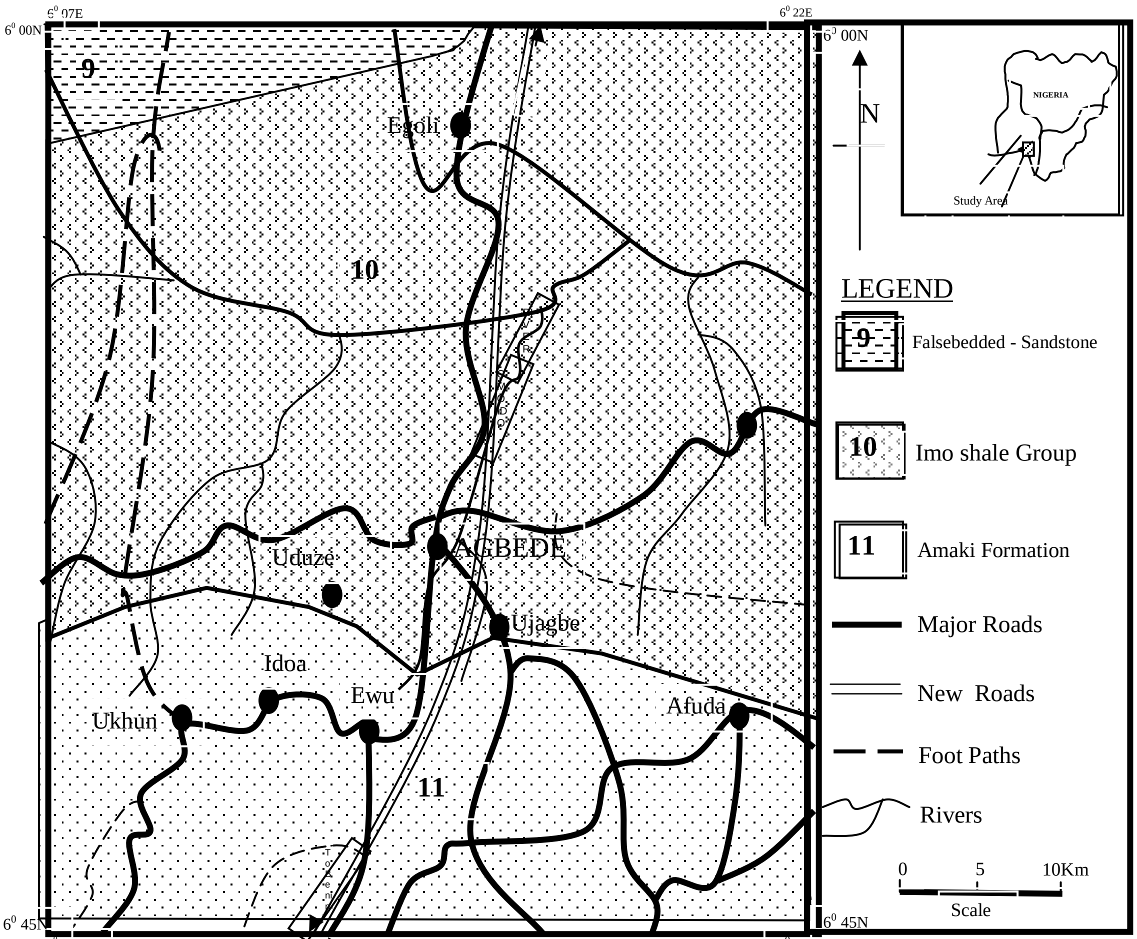
This study reported here was carried out primarily using VES to proffer solution to this problem by investigating ground water condition of the area.

2.0 Brief Geology of the Study Area

Agbede is underlain by Tertiary sediments consisting of siltstone, silty clay, clay stones and shale generally of the Imo Clay-shale Formation and partly of the Bende-Ameki Formation (Figure 1).

Hand dug wells, road cuts, trenches and freshly dug soak-away pits revealed a top reddish to reddish-brown lateritic capping varying from 0. 5-2.5m underlain by yellowish brown, often iron stained mottled siltstone randing from 2.5-6.5m thick. Between Km 101 and 104 along the Benin-Auch Road (from around Ewujunction to Agbede) measured strike of the siltstone beds range from $210^0 - 280^0$ azimuth with dip magnitudes of $3^0 - 5^0$ towards the south and southeasterly directions. An abortive borehole at the Agbede Primary School showed a subsurface lithology (table 1) essentially of argillaceous materials.

Geological Map of Agbede and Environs



3.0 Theory

The fundamental theory behind the resistively method was expounded by Maillet [7] and the theory has been expanded by other workers [8-10]

The connection between $\underline{E}$ and $\underline{J}$ is produced by 0hm's law which states that the current density is proportional to the electric field strength.

$$\underline{J} = \sigma \underline{E} \qquad (3.1)$$

The proportionality constant is called conductivity (σ). For an isotropic medium, the conductivity is a scalar quantity so that $\underline{J}$ and $\underline{E}$ are in the same direction. In general $\underline{J}$ and $\underline{E}$ are not in the same direction because conduction might be in one direction rather than another. Such a medium is said to be anisotropic and the conductivity is a tensor of second rank, σ_{il} where i and j may be any of the x, y, z spatial directions in a rectangular coordinate system. Thus 0hm, s law becomes:

$$\underline{J} = \sigma_{ij} \underline{E} \qquad (3.2)$$

The resistively method operates in the absence of a field of induction and is based on observations of an electric field maintained by direct current. For source free regions of the earth, form the Maxwell's equations we can write:

$$\underline{\nabla} \; x \; \underline{E} = 0 \qquad (3.3)$$

$$\underline{\nabla} \; x \; \underline{J} = 0 \qquad (3.4)$$

And equation (3.3) suggests that the electrics field strength may be expressed as the gradient of a scalar potential.

$$\underline{E} = -\underline{\nabla} \; \underline{V} \qquad (3.5)$$

Combining equations (3.2), (3.4) and (3.5), a differential equation which is the basis of all resistively prospecting with direct current can be written as:

$$\nabla \sigma_{ij} \; \nabla V = 0 \qquad (3.6)$$

In the isotropic case when the conductivity at a point in the ground is independent of direction, equation (6) reduces to Laplace's equation:

$$\nabla^2 V = 0 \qquad (3.7)$$

The solutions to equations (3.6) and (3.7) may be developed for a particular model of the earth by selecting a co-ordinate system to match the geometry of the model and by imposing appropriate boundary condition.

By applying separation of variables to Laplace's equation in cylindrical co-ordinate [11] arrived at a general solution for the potential at the surface of an n-layer earth having arbitrary resistivities and thicknesses;

$$V(r) = \frac{I\ell_1}{2\pi}\left[\frac{1}{r} + 2\int_0^\infty \theta_n(\lambda) J_0(\lambda r) d\lambda\right] \qquad (3.8)$$

.where $V(r)$ is the potential at the surface of the earth at a distance, r from the current I, source, ℓ_1 is the resistivety of the first layer, J_0 is the zero-order Bessel function of the first kind and θ_n called kernel function is a function of the thickness and reflection coefficients for an assumed earth model. By differentiating equation (8), the Schlumberger apparent resistivity over an n-layered earth becomes;

$$\ell_a(r) = \ell_1\left[1 + 2r^2 \int_0^\infty \lambda \theta_n(\lambda) J_1(\lambda r) d\lambda\right] \qquad (3.9)$$

where J_1 is the first order Bessel function of the first kind. The evaluation of the integral in equation (3.9) has been done in a number of ways.

A novel approach to the problem of computing, sounding curves for stratified models by starting with the integral formula of [11] was introduced by [12] and equation (3.9) can be expressed as follows:

$$\ell_a(r) = r^2 \int_0^\infty \lambda T(\lambda) J_1(\lambda r) d\lambda \qquad (3.10)$$

where $T(\lambda) = \ell_1[1 + 2\theta_n(\lambda)]$

The function $T(\lambda)$ is called the resistivity transform because it is defined by a Hankel transformation

$$T(\lambda) = \int_0^\infty r^{-1} \ell_a(r) J_1(\lambda r) dr \qquad (3.11)$$

Equation (3.11) is a convolution integral. Therefore, it is possible to determine a linear digital filter $\{b_i\}$ which converts resistivity transform samples into apparent resistivity values for theoretical models:

$$\ell_a(i) = \sum_j b_i T_{m-i} \qquad (3.12)$$

This model is accurate, fast simple in operation and has small computer storage requirements. In addition, depths are no longer restricted to integral multiples and may take any arbitrary values.

4.0 Experimental Work

The field work was carried out in Agbede town. A total of five (5) Schlumberger Vertical Electrical Soundings were conducted using ABEM SAS 300C Tetrameter and the SAS 2000 Booster along some selected streets. Array spread for current electrode spacing range between 1362m to 2000m depending on the available straight open spaces. All the VES were located along the old and new Benin-Auchi roads whose alignments are approximately straight in the north-south direction.

The end result of the field measurements is the computation of the apparent resistivity in 0hm-m. These were then plotted against half the current spacing (AB/2) in meters using a log-log sheets. This was interpreted quantitatively using the partial curve matching method and later subjected to computer assisted iterative method. Moreover, the logs of an available abortive norehole were studied and geologic section was derived.

5.0 Results and Discussion

In Figure 2, all the curves except VES 5 showed an initial rise indicating top dry sands, a middle wide descent (broad bowl shape) indicating thick clay (Imo Shale) and an ascent at the rightmost end indicating the occurrence of the Ajali Formation below the clay. In VES 5, the second ascent preceding the wide descent indicates the presence of the shallow aquifer tapped by hand dug wells.

In Table 2, the near surface sand above the clay is thin (1. 01-26m thick) and the thickness of the clay intercepted is 483.73-498.13m. The sands of thickness, 9.89-10.86m, encountered in only VES1and VES4 at depths 54.93-55.43m is the perched aquifer. This aquifer does not exist everywhere; therefore it is of small lateral. And because of its smallness in terms of thickness, width and length, this aquifer holds small volume of water and any terminating in it dries up within short period of time after well completion hence this water source has not been recommended anywhere for any borehole even at the rural level because of urban-rural drift. The Ajali Formation is the main in the because of its large lateral extent (its exists everywhere under the thick clay in the area). This aquifer was encountered at depths 498.13m and 494.03m in VES 2 and VES 5 locations respectively, this makes the recommended depths for boreholes to be more than 500m.

Notably, the results for VES 3 in Table2 showed the presence of clay of thickness above 335m and a top soil of 6m thick above it. This thick shale is reflected by the long descending middle segment in all the VES curves between the second and the third decade (i.e. AB/2 values 10-316m) as shown in Figure 2. It is interesting to note from Table 1 that logs of the abortive borehole close to VES 3 also indicated clay of thickness 338m with a top soil thickness of the clay in VES 1, 3 and 4 is in excess of 329m. Moreover, in Table 2 the shallow thin sand (12.45m thick and 2.76m deep) in VES 5 is the aquifer (source of water) for the hand dug wells during the wet season as it dries up during the dry season. It is worth noting that the fact that all the VES showed the presence of a thick clay which agrees with the geology of the area, is an indication of the viability of the VES technique for the purpose of this study.

Table 1: Lithology of the abortive borehole at Agbede Primary School.

(m)	Lithology
0.8	- soil (reddish brown
8-44.5	- clay (grayish)
44.5-75.3	- clay (hard grayish)
73.3 – 100.2	- silt
100.2 – 184.5	-clay (grayish plastic)
184.5-255.8	- silt
255.8-302.3	- clay (dark grayish)
302.3 – 346.0	- clay (bottom unknown)

6.0 Conclusion

The study has shown that useful delineation of the subsurface can be developed with high accuracy using VES. Although the clay is thick any sharp resistivity contrast within it is a useful parameter for predicting the thickness and depth of perched aquifer (VES 1 and VES 4). Therefore,

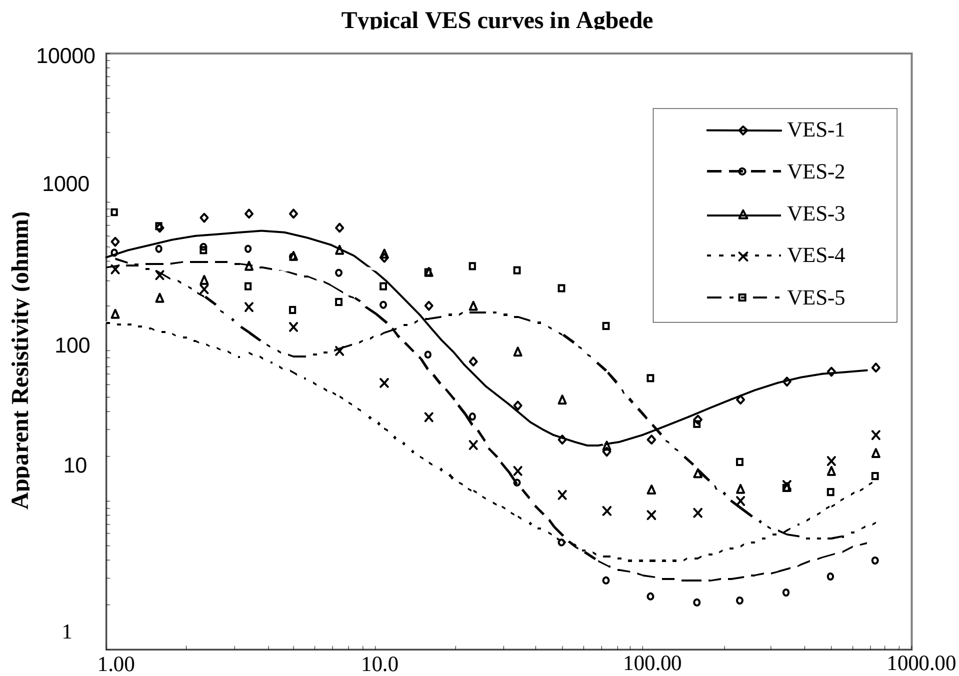


Figure 2: Typical VES Curves for Agbede.

Table 2: Summary of the lithology derived from the VES curves in Agbede

VES No.	Thickness of sand above the Imo-Shale	Thickness of the Imo Shale (m)	Sands within the Imo-Shale (perched aquifer)		Sand below the Imo-Shale	Total Depth Penetrated (m)
			Depth (m)	Thickness (m)	Depth (m)	
1	3.50	>95.37	55.43	10.86	Not penetrated	109.79
2	5.76	498.13	Nome	None	498.13	521.32
3	6.26	>328.82	None	None	Not penetrated	335.08
4	1.01	>252.39	54.93	9.89	Not penetrated	253.04
5	1.09	483.73	2.76	12.45	494.03	498.94

based on the VES a result drilling of deep conventional boreholes in excess of 500m is recommended since the Imo Shale Formation is very pervasive and thick in Agbede.

However, in order to achieve success in any domestic or rural water supply projects, we also strongly recommend the possibility of exploiting surface water source which is not as expensive as drilling deep boreholes that are capital intensive and of high technical involvement in drilling through the thick clay to penetrate the Ajali aquifer. A systematic study and discharge measurement of the Odomo River most be well conducted so as to ascertain the year round supply of water for the surface water option which is more economical drilling deep boreholes.

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