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THE VERTICAL ELECTRICAL SOUNDING: A VIABLE TOOL FOR THE INVESTIGATION OF CLAY DEPOSITS.

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ABSTRACT

The presence of clay deposits in Ozalla and Sabongida-ora both of Owan West Local Government area of Edo State was investigated using the electrical resistivity method. The Vertical Electrical Sounding (VES) was used for the investigation using the Schlumberger electrode configuration. Interpretation of data was by curve fitting in order to generate initial model for computer iterative technique. Borehole data were also collected using spontaneous potential method as well as driller's log.

The result shows that at Ozalla the overburden sand is over 35m whereas the overburden sand is 3.8m at Sabongida-ora with a clay thickness of over 50m. These results agreed very well with borehole records.

INTRODUCTION

The mining and production of individual minerals for the use of various industries is an activity that has not received adequate entrepreneurial attention in Nigeria. This has its historical basis in the fact that virtually all Nigerian industrialists depend on foreign sources for both plants and equipment as well as the raw materials for their industries.

With the current drive towards the attainment of self- reliance in the local sourcing of industrial raw materials, it is thus possible to set up profitable ventures for the supply of raw materials as feedstock to industries without direct involvement in actual manufacturing.

Clay falls into one of the industrial minerals that are needed for the manufacturing of industrial products. Hence this investigation is aimed at determining the existence and thickness of clay deposits in and around Ozalla and Sabongida-ora both in Owan West Local Government Area of Edo State using the Vertical Electrical Sounding technique.

THEORIES

Maillet (1947), expounded the fundamental theory behind the resistivity method and the theory has been adequately covered by Keller and Frischknecht (1966), Grant and West (1965), and Bhattacharya and Patra (1968).

Ohm's law provides the relationship between electric field strength $\underline{E}$ and current density $\underline{J}$ as;

$$J = \sigma E$$

This proportionality constant is called conductivity. Note that for an isotropic medium, the conductivity will be a scalar quantity so that $\underline{J}$ and $\underline{E}$ will be in the same direction. In general $\underline{J}$ and $\underline{E}$ are not in the same direction because conduction might be easier in one direction rather than another. Such a medium is said to be anisotropic and the conductivity is a tensor of second rank, σ_{ij}; the subscripts i and j may be any of the X, Y or Z spatial directions in a rectangular co-ordinate system. Ohm's law becomes

$$\underline{J} = \sigma_{ij} \underline{E}$$

or, more fully :

$$\begin{pmatrix} J_X \\ J_Y \\ J_Z \end{pmatrix} = \begin{pmatrix} \sigma_{XX} & \sigma_{XY} & \sigma_{XZ} \\ \sigma_{YX} & \sigma_{YY} & \sigma_{YZ} \\ \sigma_{ZX} & \sigma_{ZY} & \sigma_{ZZ} \end{pmatrix} \begin{pmatrix} E_X \\ E_Y \\ E_Z \end{pmatrix}$$

Hence a differential equation which is the basis of all resistivity prospecting with direct current can be written as:

$$\nabla . \sigma_{ij} \nabla v = 0 \qquad (1)$$

In the isotropic case where the conductivity at a point in the ground is independent of direction, equation (1) reduces to Laplaces equation

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

Solutions to equation (1)and (2) 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 conditions.

Note however that resistivity theory and interpretation have long been biased **toward an earth model of horizontal, homogeneous and isotropic layers. This is often a reasonable approximation to the real earth, especially in ground water environments, because of the natural mechanism of sedimentation.**

By applying separation of variables to Laplace's equation in cylindrical co-ordinates, Stefanesco, Schlumberger and Schlumberger (1930) were able to arrive at a general solution for the potential at the surface of an n-layer earth having arbitrary resistivities and thickness:

$$V(r)=\frac{I\,\ell_1}{2\Pi}\left(\frac{1}{r}+\quad 2\int_0^{\infty}\theta_n(\lambda)J_0(\lambda r)d\lambda.\right) \tag{3}$$

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 resistivity 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.

In particular, for 2- and 3- layer models, the kernel function is given by

$$\theta_2(\lambda)=\frac{K_1\exp(-2\lambda\,h_1)}{1-K_1\exp(-2\lambda\,h_1)}$$

$$\theta_3(\lambda)=\frac{K_1\exp(-2\lambda h_1)+K_2\exp(-2\lambda(h_1+h_2))}{1\;+\;K_1K_2\exp(-2\lambda h_2)-K_1\exp(-2\lambda h_1)-K_2\exp(-2\lambda(h_1+h_2))}$$

By differentiating equation (3), the Schlumberger apparent resistivity over an n-layered earth becomes:

$$\ell_a(r)=\ell_1\left(1+2r^2\int_0^{\infty}\lambda\theta_n J_1(\lambda r)d\lambda\right) \tag{4}$$

where J_1 is the first- order Bessel function of the first kind. The evaluation of the integral in equation (4) has been done in a number of ways.

Ghosh (1971) introduced a novel approach to the problem of computing sounding curves for stratified models by starting with the integral formula of Stefanesco et al. (1930), equation (4), and expressing it as

$$\ell_a(\mathrm{r})=\mathrm{r}^2\int_0^{\infty}\lambda\,\mathrm{T}(\lambda)\mathrm{J}(\lambda\mathrm{r})\mathrm{d}\lambda \tag{5}$$

where

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

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

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

Equation (5) 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:

$$\ell_a(i) = \sum_i b_i T_{m-i}$$

This method 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.

EXPERIMENTAL WORK

Ozalla, one of the towns where this research was carried out is situated around $6^0\ 48^1$N and $6^0\ 00^1$E while Sabongida-ora the second town is situated around $6^0\ 54^1$N and $5^0\ 53^1$E. The Schlumberger electrode configuration was used for data acquisition, Osemeikhian and Asokhia (1994). The ABEM TERRAMETER SAS 300B manufactured in Sweden was used for taking surface resistivity readings. This equipment contains a borehole logging component that is attached for the purpose of logging the nearby boreholes. The mode of logging was the spontaneous potential method.

RESULTS AND DISCUSSION

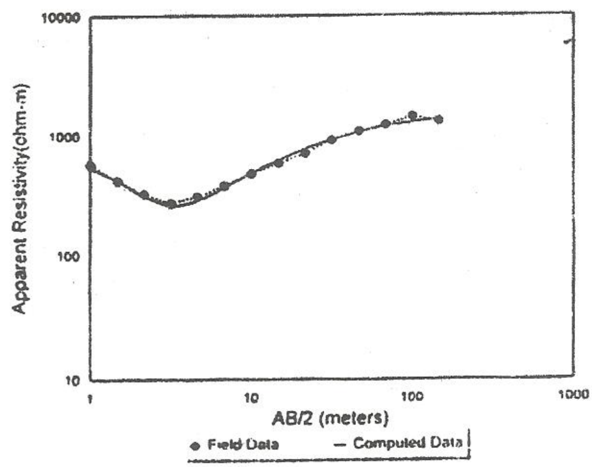
The apparent resistivity curve for Ozalla is the HA-curve type $\ell_1 > \ell_2 < \ell_3 < \ell_4$ as shown in VES 1. Ozalla belong to the sedimentary environment with a fairly resistive topsoil underlain by a less resistive layer which in turn is underlain by a very resistive layer. The substratum indicates the highest resistivity in all the layers. Hence at Ozalla, the overburden sand presents a much higher thickness of over 35m. The driller's log and the SP log, fig.1 (a) and fig.1 (b) agree well with this interpretation.

On the other hand the apparent resistivity curve for Sabongida-ora is the QH-curve type $\ell_1 > \ell_2 > \ell_3 < \ell_4$ as shown in VES2. It also belongs to the sedimentary environment with the surface layers considerably higher in resistivity than successive underlying layers with a corresponding resistive substratum. Note that, the broadness of the initial segment of the curve depicts a higher thickness for the resistive surface layer indicative of laterite and sand. Thereafter, the resistivity curve continued to fall sharply, indicative of the presence of clay. Thus at Sabongida-ora, after probing into a depth of 54m, the clay thickness was about 50m indicating large deposit of clay in the area. The driller's log and SP log for Sabongida-ora fig.2(a) and fig2(b) are indicative of the presence of clay minerals. The SP log is positive for Ozalla, indicative of low salinity but negative for Sabongida-ora, indicative of high salinity.

CONCLUSION

The vertical electrical sounding used for the investigation of clay deposits is very reliable. The result of the high correlation between the driller's log and SP log for the two towns in Owan West Local Government Area of Edo State indicates that no risk is involved in using this method to determine the presence of clay in any other location

PROJECT: Field and theoretical curve for VES 1
SITE: Ozalla



Project.

Resistivity Sounding Interpretation

Field and Theoretical Data

AB/2 values (metres)	Observed values (ohm metre)	Computed values (ohm-metre)	Log difference
1.00	567.00	[illegible]	0.02
1.47	419.00	424.44	-0.01
2.15	328.00	309.44	0.03
3.16	272.00	253.72	0.03
4.64	311.00	281.95	0.04
6.81	382.00	268.64	0.02
[illegible]	481.00	[illegible]	-0.00
14.70	583.00	623.42	-0.03
21.50	703.00	771.00	-0.04
31.60	908.00	923.66	-0.01
46.40	1086.00	1065.17	0.01
[illegible]	1219.00	1188.74	0.01
[illegible]	1447.00	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Model Parameters

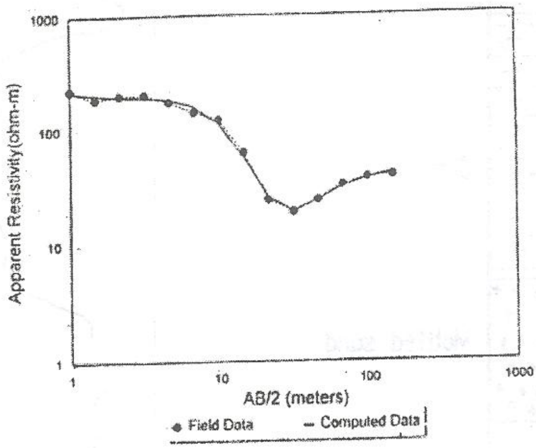
Geoelectric Layer	Specific Resistivity (ohm-metre)	Thickness (metres)	Cumulative Thickness (metres)
1	646.00	0.80	0.80
2	129.00	1.70	2.50
3	1345.00	34.50	37.00
4	1511.00	infinity	infinity

Field Measurements by Ujuanbi O.

Computer Interpretations by Ujuanbi O.

RMS error [illegible]

PROJECT: Field and theoretical curve for VES 2
SITE: Sabongida-Ora



Project:

Resistivity Sounding Interpretation

Field and Theoretical Data

AB/2 values (metres)	Observed values (ohm-metre)	Computed values (ohm-metre)	Log difference
1.00	221.00	211.65	0.02
1.47	185.00	203.34	-0.04
2.15	199.00	193.83	0.01
3.16	201.00	189.04	0.03
4.64	174.00	183.31	-0.02
6.81	142.00	159.22	-0.05
10.00	121.00	110.52	0.04
14.70	62.90	57.24	0.04
21.50	[illegible]	25.81	-0.03
31.60	18.80	18.96	-0.00
46.40	23.90	23.99	-0.00
58.10	32.30	30.90	0.02
100.00	37.70	37.12	0.01
147.00	39.10	41.64	-0.03

Model Parameters

Geoelectric Layer	Specific Resistivity (ohm-metre)	Thickness (metres)	Cumulative Thickness (metres)
1	219.00	1.10	1.10
2	80.10	0.40	1.50
3	348.00	1.60	3.10
4	103.00	3.10	6.20
5	4.70	6.60	12.80
6	88.20	40.50	53.30
7	34.10	infinity	infinity

Field Measurments by: Ujuanbi O

Computer Interpretations by: Ujuanbi O

RMS error (%) 2

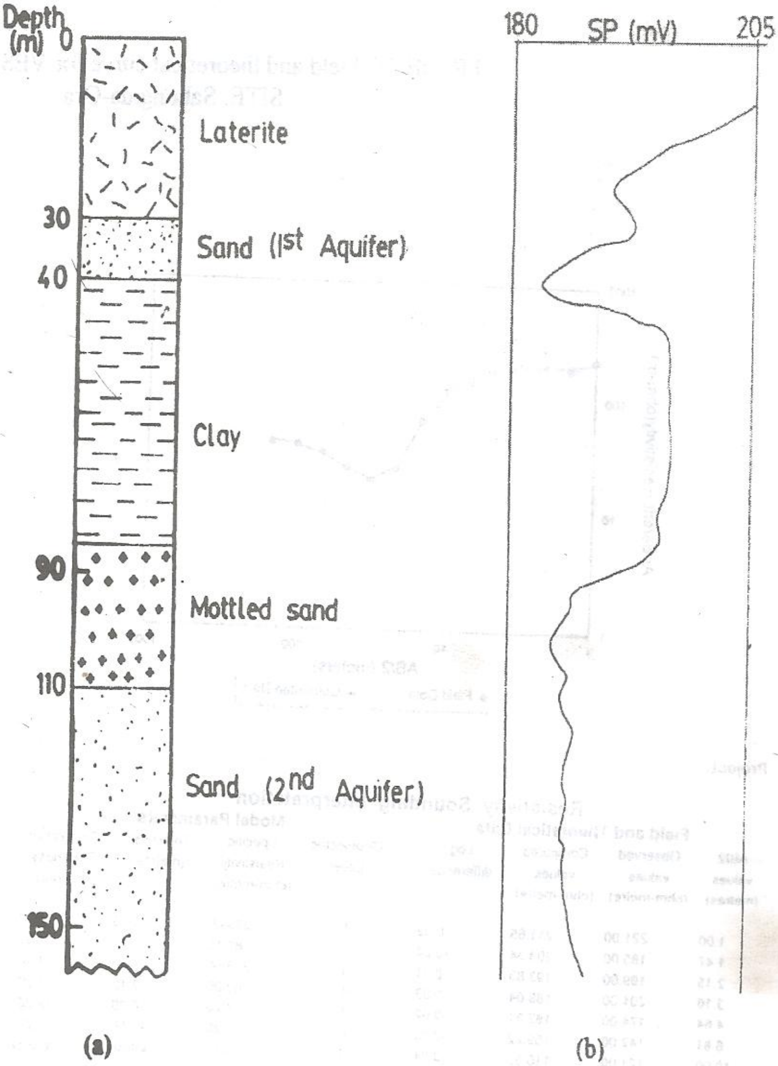
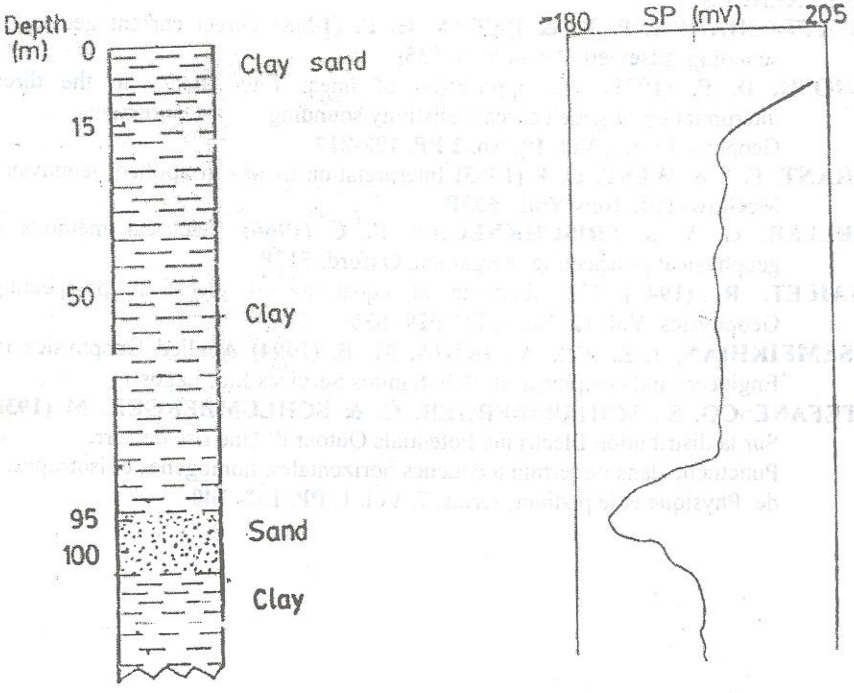


Fig. 1. Driller's/SP log in Ozalla



(a) (b)

Fig. 2: Driller's/SP log in Sabongida-Ora

REFERENCES

BHATTACHARYA, P. K. & PATRA, H. P. (1968) Direct current geoelectric sounding. Elseviert, Amsterdam **135p**

GHOSH, D. P. (1971) The application of linear filter theory to the direct interpretation of geoelectrical resistivity sounding measurements. Geophys. Prosp., **Vol. 19, No. 2 PP. 192-217**

GRANT, F. S & WEST, O. F (1965) Interpretation theory in applied geophysics. McGraw- Hill, New York, **583P**

KELLER, G. V & FRISCHKNECHT, F. C (1966) Electrical methods in geophysical prospecting. Pergamon, Oxford, **517P**

MAILET, R. (1947) The fundamental equations of electrical prospecting. Geophysics, **Vol. 12, No. 4, PP. 529- 556**

OSEMEIKHIAN, J. E. A & ASOKHIA, M. B. (1994) Applied Geophysics for Engineers and Geophysicist, Pub. Samtos Services Ltd. Lagos

STEFANESCO, S., SCHLUMBERGER, C. & SCHLUMBERGER, M (1930) Sur la distribution Electrique Potentials Qutour d' Une rise de terre Ponctuelle dans un terrain a couches horizontales, homogenes et isotropes. J. de. Physique et le padium, series, 7, **Vol. 1, PP. 132- 140**