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Geophysical Investigation for the Delineation of Lithology at Novena University, Ogume, Delta State Using the Vertical Electrical Sounding (VES) Method and Electrical Profiling

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Abstract
Lithology is the basis of subdividing rock sequences into individual lithostratigraphic units for the purposes of mapping and correlation between areas. Geophysical investigation for the delineation of lithology has been carried out at Novena University, Ogume, Delta State using the Vertical Electrical Sounding (VES) method and electrical profiling. The major aim of this research work is to obtain the internal distribution of physical properties of a subsurface geological structure or materials within the study area so as to guide against the challenge of dry water wells, effective drainage channels and other geotechnical issues. The VES was acquired using Schlumberger array. For Profiling, data acquisition was executed with 5m inter electrodes spacing in Wenner configuration. The Petrozenith Earth Resistivity Meter was used for the field measurement in both cases. For the VES, the apparent resistivity data were input into IP2WIN software running on personal computer. The data was inverted to obtain the subsurface true resistivity. The VES reveals that at a probing point of about 10.11m, a resistivity less than 100Ωm was encountered originating from the surface. This suggests that the near surface layer is made up of sandy clay / clay just underlain by an unsaturated coarse sand. Beneath it is a high resistivity material of 6857Ωm. The high resistivity is probably due to very low water content since the upper layer, sandy clay and clay has very low permeability for water to reach the coarse sand layer. The line plot gotten from the profiling indicates that the near- surface geologic section investigated is not homogeneous. The curve of profile 2 is more irregular than that of profile1. This is most likely due to lateral changes in water content, sand grading, clay content and mineralogical compositions or texture of near surface sand changes laterally.

Keywords: *Lithology, Vertical Electrical Sounding, Electrical Profiling, Resistivity*

Introduction

The lithology of a rock unit is a description of its physical characteristics visible at outcrop, in hand or core samples, or with low magnification microscopy. The lithology of the parent materials determines a soil's physical and mineralogical properties (Repe et al., 2017; Jenny, 1994; Sumner, 2000; Bardgett, 2005; Daher, 2019). Physical characteristics include; colour, texture, grain size, and composition (US Geological survey, 2010; Bates and Jackson, 1984; Allaby and Allaby, 1999). Lithology assessment helps to solve the challenges arising from dry water wells, effective drainage channels and other geotechnical issues. Geophysical investigation using the electrical resistivity methods amongst others, is one method used for the delineation of lithology and rock characterization.

Geophysical investigation of the subsurface of the earth involves taking measurements on or beneath the earth's subsurface or vertically in a borehole to obtain internal distribution of physical properties of a subsurface geological structure or material. Various geophysical methods are applied to environmental site investigations. Geophysical methods are employed in the exploration of geological structures and are implemented in a wide range of applications ranging from building, groundwater investigation to the inspection of dams and dike (Klimis et al., 1999; Luna and Jadi 2000; Othman, 2005; Savaidisi et al., 1999; Soupios et al., 2006; Vencateswara et al., 2004), aiming towards the exploration of geological structure and the determination of physical parameters of the rock formations/units.

The electrical resistivity methods involving Schlumberger electrode configuration has been used as a resource quantification of a kaolin deposit at Ikere in Ekiti State of Nigeria (Afolabi et al., 2004). In the work of Adegboa, (2010) On Subsurface Characterization and its environmental implications using the electrical resistivity survey: The resistivity method was carried out with a view to characterize different subsurface geological units and to provide the engineering/ environmental geophysical characterization of the study area.

The resistivity method has been adopted in this research work because of the influence of resistivity or conductivity on the electrical and chemical nature of the various physical and geologic formations. The delineation of lithology using the Electrical Resistivity methods was carried out in the football pitch of the Novena University, Ogume, Delta State.

Site Description/Location

The Study location, Novena University, Ogume, Delta State is in Amai kingdom, Ukwuani Local Government Area of Delta State. It is in the Southern part of Nigeria known as the Niger Delta and lies within latitudes (5.96^0 to 6 $.04^0$) N and longitudes (6.48^0 to 6.59^0) E with an elevation of about 23m above sea level as depicted in Figure 1. The study location is bounded on the North by Obiaruku, on the South by Ezeonum, on the West by Arhagba and on the East by Ogume. Amai has two major roads which are tarred. These are the Obiaruku -Amai road and Ogume-Amai road with some network of roads that are not tarred. Amai is also home to the Novena University and the Konum farms limited. The occupation of her settlers is mainly farming. The line co-ordinates for the study locations are presented in table1. The base map for the location is shown in figure 1.

Table 1: Profile line co-ordinates

LINES	CO-ORDINATES	LATITUDE	LONGITUDE
LINE PL 1	Coordinate	N5^O 44' 57.9''	E006^O 12' 22.9''
LINE PL 2	Begin coordinate End coordinat	N5^O 44' 56'' N5^O 44' 58''	E006^O 12' 26'' E006^O 12' 26''

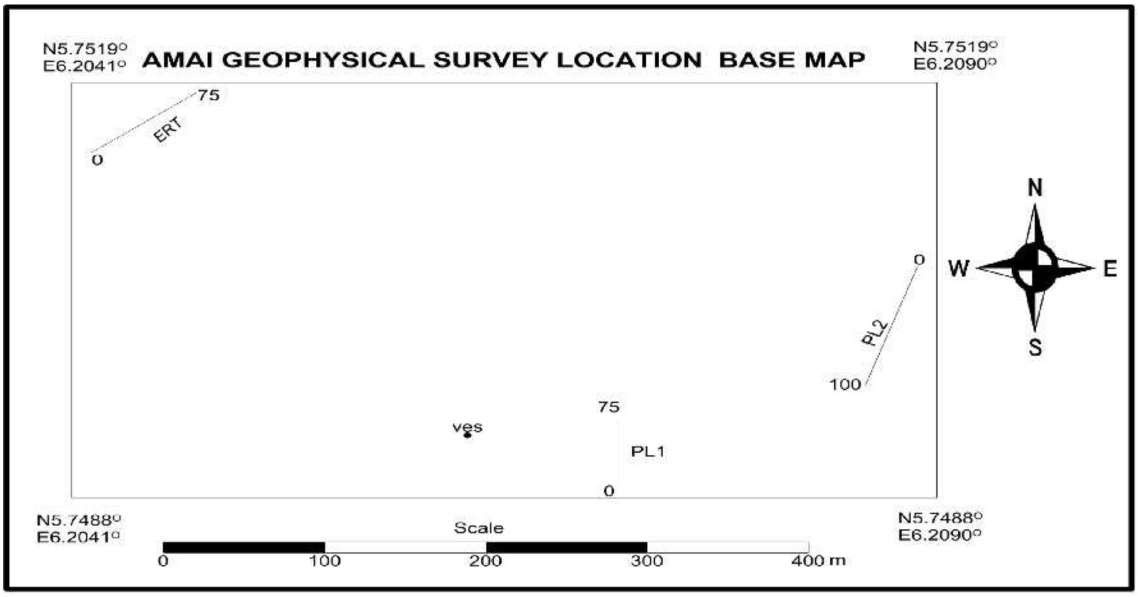

Fig. 1: Constructed base map for the location

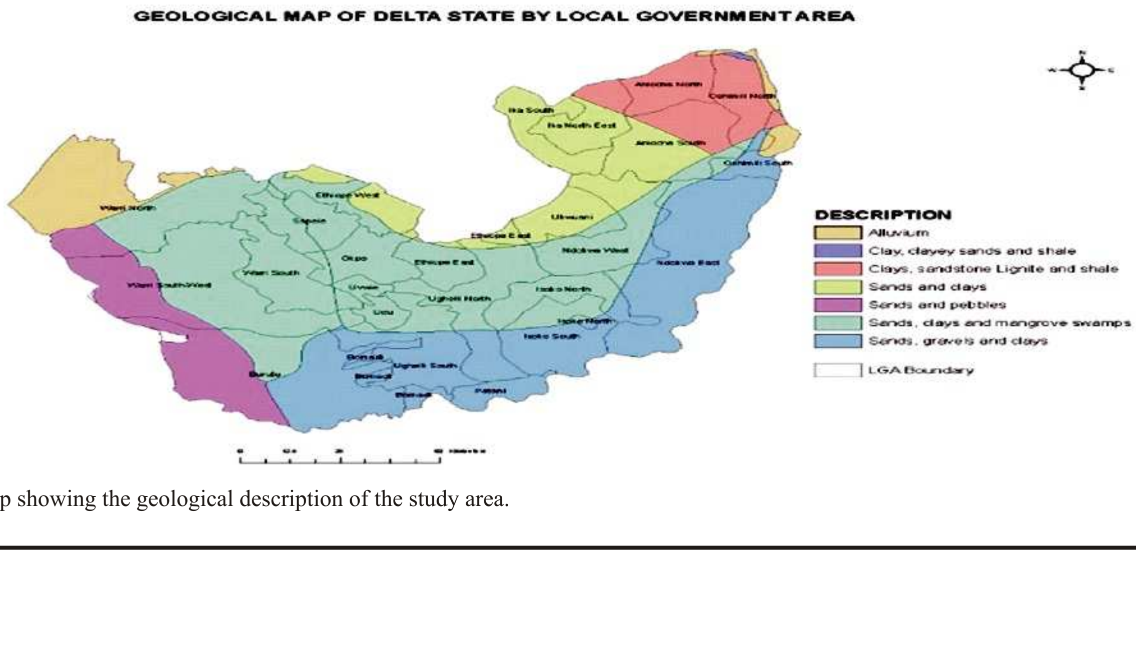

Fig. 2: Map showing the geological description of the study area.

Geology of the Study Area

The lithology of the study area, Amai is composed of; clays, sands, (coarse and fine), sandy-clay and gravels. This is evident from the depiction in figure 2 which shows the geologic map revealing lithology of the study in terms of Local Government Areas. Amai is a typical Niger Delta region underlain by the Benin, Agbada and Akata formations. In Amai, the topmost layer of the soil contains humus content. Below the humus soil is a bed of lateritic soil. It is dark brown and at. Further depth, it becomes reddish brown. This massive bed lateritic soil is a feature of the Benin formation (Ibrahim et al., 2012).

Wenner Array

The simplest of the arrays is the Wenner array. This array was first proposed for geophysical prospecting by Wenner in (1916). Many of the early 2-D surveys were carried out with the Wenner array. The Wenner Array has two receiver electrodes placed between two transmitter electrodes and is used for imaging along a profile (transect) at a constant depth (Figure 3). A constant spacing (a) between all four electrodes is maintained such that AM = MN = NB = a, and AB ≥ 3MN hold for this array.

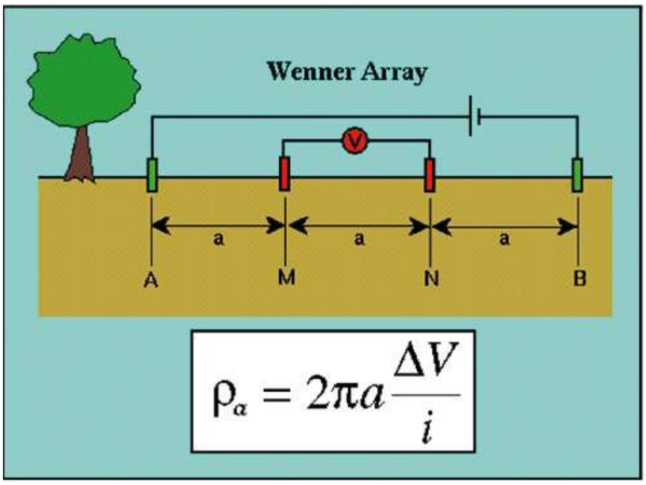

Fig. 3: The Wenner Array for an electrical resistivity survey.

Schlumberger Array

Like the Wenner Array, the Schlumberger Array also uses four electrodes, consisting of two receiver electrodes (M and N) between two transmitter electrodes (A and B) The distance between adjacent electrodes differ by the geometrical factor spread of AB ≥5 MN, where A and B are current electrodes, M and N are potential electrodes (Figure 2). The Schlumberger Array is a depth-sounding method because all four electrodes are moved systematically to increase the depth of investigation at a point. The inner potential electrodes are usually kept at a very small separation, compared to the two outer current electrodes which are expanded continuously to increase the depth of measurements. At large current electrode spacing, the measured voltage decreases and the signal-to-noise ratio increases; thus, the spacing of the potential electrodes must increase (Gibson and George, 2003).

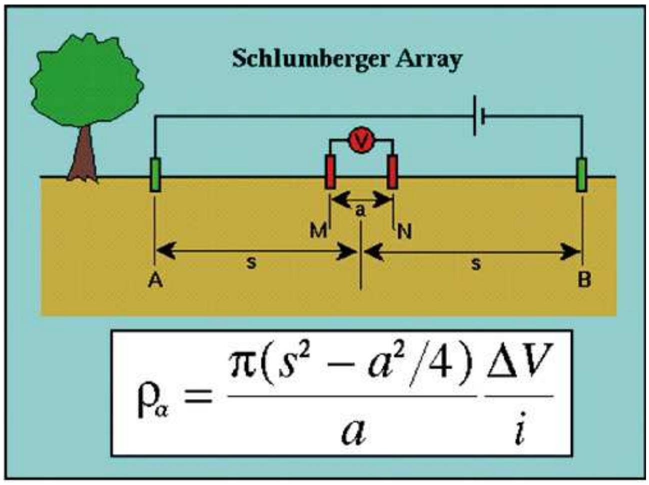

Fig. 4: The Schlumberger Array for an electrical resistivity survey

$$J = \sigma E = \frac{1}{\rho} E = \frac{1}{\rho} \nabla V \quad \text{...(1)}$$

J is the current density vector
E is the electric field vector in units of volts per meter
V is the electric potential measured in volts
σ is the conductivity measured in $(\Omega m)^{-1}$
ρ is the resistivity measured in Ωm
Consider a single point electrode, located on the boundary of a semi-finite, electrically homogeneous medium,which represents a fictious homogeneous earth. If the electrode carries a current "I",measured in amperes "a".

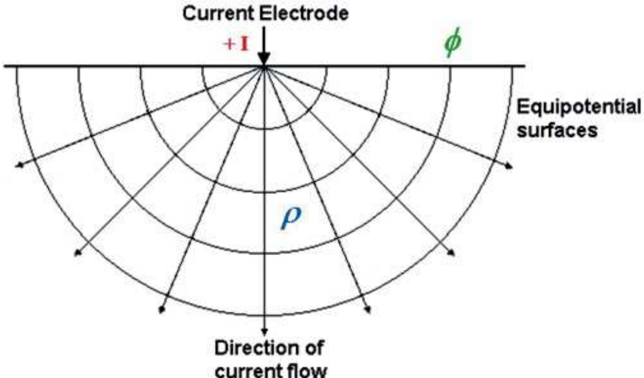

Fig. 5: Electric field at a point source

The potential at any point in the medium or on the boundary in Figure 5 is given by

$$V(r) = \frac{\rho I}{2\pi r} \quad \text{.......(2)}$$

Where;
V(r) is the potential function
P is the bulk resistivity of the material
R is the distance from the elctrode

When we consider the general form of electrode configuration in resistivity surveys as shown in Figure 6.

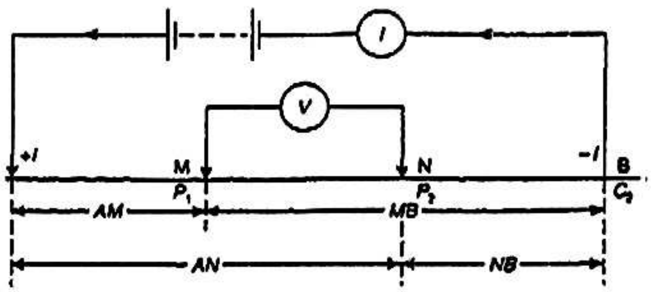

Fig. 6: General configuration of the four surface electrodes in linear resistivity surveys.

Current is delivered through the electrodes A and B, and voltage reading, is made with electrodes M and N. For an electrode pair with current I at electrode A, and -I at electrode B embeded in a similar medium as in the case for a point source in Figure 5, the potential difference at a point is the algebraic sum of the individual contributions.

The electric potential measured at M and N is superposition of the potentials of equation (1) due to each of the two sources of electrodes located at A and B.

The potential at M and N are given by

$$V = \frac{\rho l}{2\pi}\left[\frac{1}{AM} - \frac{1}{MB}\right] \quad \text{.......(3)}$$

$$VN = \frac{\rho l}{2\pi}\left[\frac{1}{AN} - \frac{1}{NB}\right] \quad \text{.......(4)}$$

The total potential difference between the electrodes M and N is thus

$$\mathrm{VMN} = \mathrm{VM} - \mathrm{VN} = \frac{\rho l}{2\pi}\left[\left(\frac{1}{AM} - \frac{1}{MB} - \frac{1}{AN} - \frac{1}{NB}\right)\right] \quad \text{.......(5)}$$

This may be rearranged by making "ρ" the subject to yield

$$\rho = \frac{VMN}{I} K \quad \text{.......(6)}$$

$$Where\ K = 2\pi\left[\left(\frac{1}{AM} - \frac{1}{MB}\right) - \left(\frac{1}{AN} + \frac{1}{NB}\right)\right] - 1 \quad \text{.......(7)}$$

K is the "geometric factor" that will acquire a particular value for a given electrode spacing.

Methodology

The electrical resistivity method was involved in the measurement of the apparent resistivity of soils and rock as a function of depth and position. The resistivity of the soil is a function of porosity, permeability, ionic content of the pore fluids, and clay mine realization. Apparent resistivity is the bulk average resistivity of all soils and rock influencing the flow of current. Before the field measurements, the reading of the prepared imaging survey base map for the survey area was used alongside the compass to locate the traverse on the ground. Next to this, is the planting of electrodes. Electrodes numbering 0-25 were fixed into the ground at selected intervals of 5.00m along selected lines.

The Vertical Electrical Sounding (VES) was acquired using Schlumberger array at Novena University Football Field. The adjacent current electrodes spacing was made small to ensure dense electrical coverage of the subsurface for better visualization. The Petrozenith Earth Resistivity Meter was used for the field measurement. The output resistance values were transformed to apparent resistivity using the Schlumberger equation.

The electrical profiling data acquisition was executed with 5.00m inter electrodes spacing in Wenner configuration. Two profiles were executed at the same location. The resistances, R were recorded at each shifted position of four electrodes in the line and subsequently transformed to apparent resistivity using the Wenner equation.

Data Processing

The apparent resistivity data were entered into IP2WIN software running on personal computer. The data was inverted to obtain the subsurface true resistivity. The subsurface resistivity model was displayed as curve of apparent resistivity against AB/2 as well as the parameters, the geoelectrical layers resistivity, depths and thicknesses.

The apparent resistivity curve was drawn using Grapher

11.0 running on personal computer. The software plots the apparent data against the observation points (mid-way between the potential electrodes), and then remove noise using 3 point numerical filter (moving averaging filter) for better visualization of probable resistivity anomalies along the profiles. The profiling depth was about 2.6m. Figures 6 and 7 depicts plotted graphs for VES curve and geologic sections.

Data Presentation

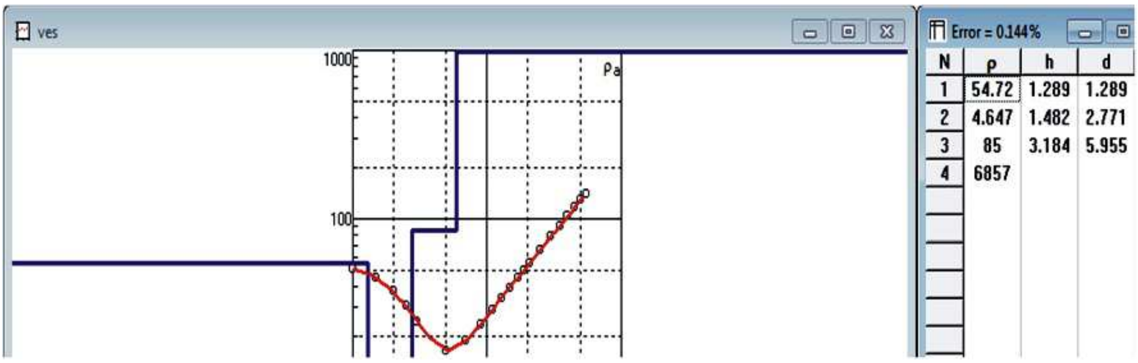

Fig. 6: VES curve

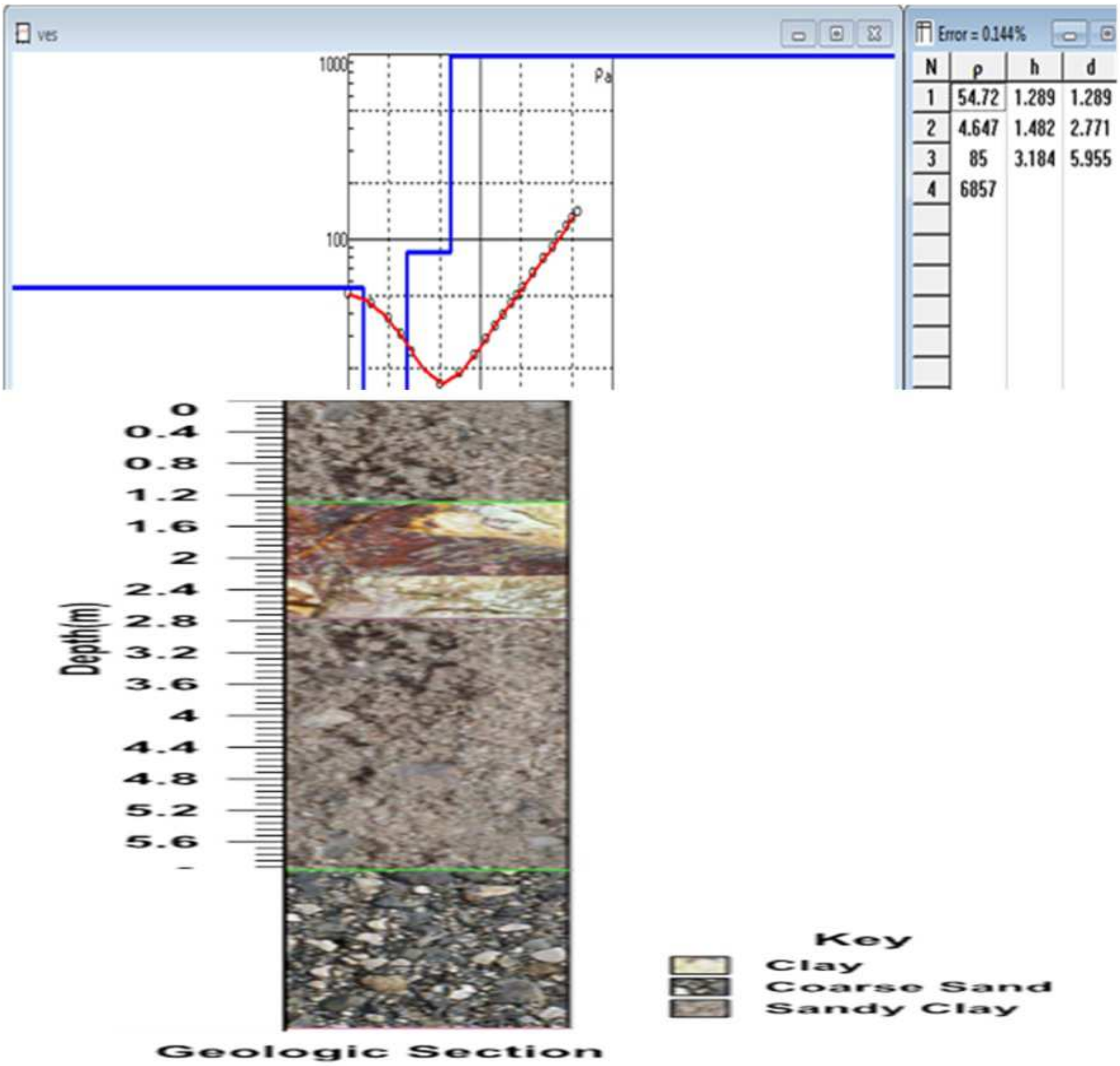

Fig. 7: Geologic section

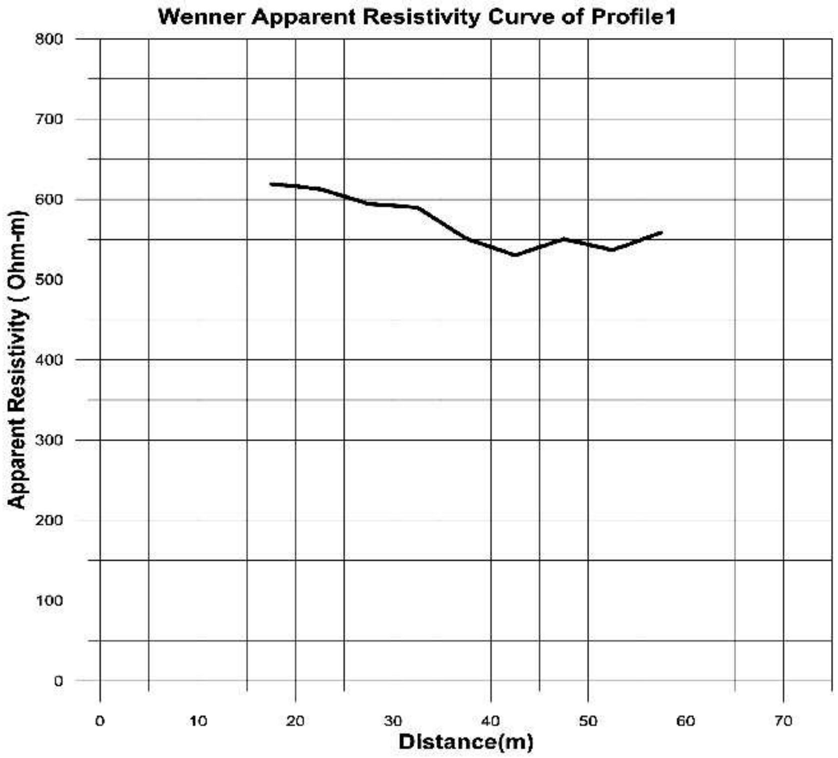

Fig. 8: Wenner apparent resistivity curve for profile1

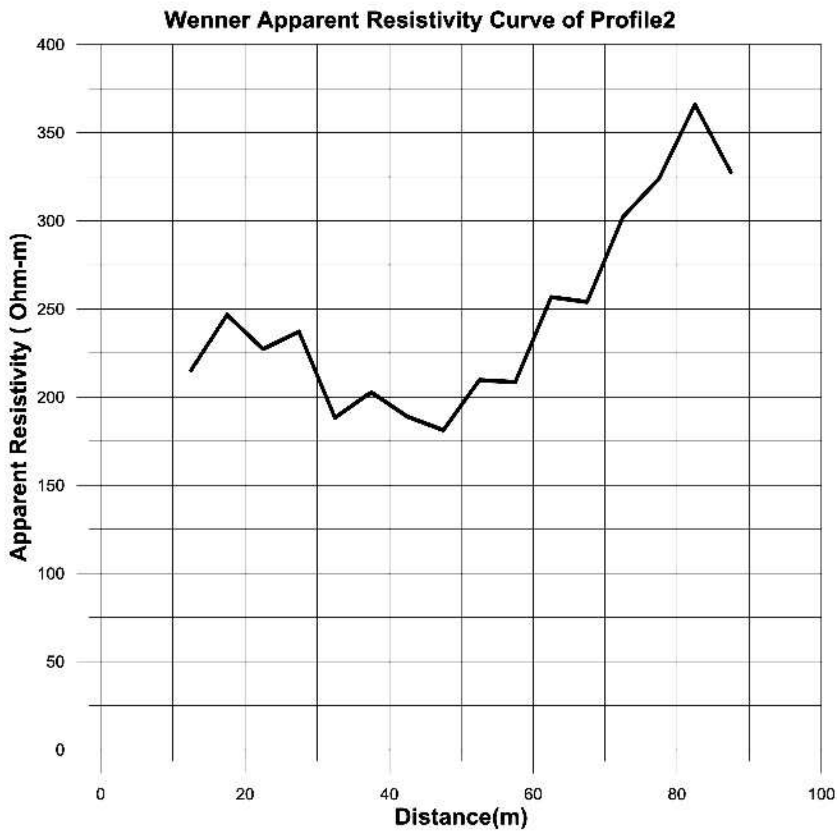

Fig. 9: Wenner apparent resistivity curve for profile 2

Data Interpretation

The VES reveals that at the probing point of about 10.11m, a resistivity less than 100Ωm was encountered originating from the surface. This suggest that the near surface layer is made up of sandy clay / clay just underlain by an unsaturated coarse sand. Beneath it is a high resistivity material of 6857Ωm. The high resistivity is probably due to very low water content since the upper layer, sandy clay and clay has very low permeability for water to reach the coarse sand layer.
The geologic section drawn in strater4 software is shown in figure 7.

The line plot gotten from the profiling using the Wenner array is not parallel to the distance axis but takes irregular shapes. This indicate that the near- surface geologic section investigated is not homogeneous. The curve of profile 2 is more irregular than that of profile1, meaning that the investigated near-surface rapidly change laterally more in profile 2. This is most likely due to changes lateral changes in water content, sand grading, clay content and mineralogical compositions.

Conclusion

The Vertical Electrical Sounding revealed that the near-surface is made up of sandy clay /clay with resistivity below 1ess than 100Ωm and just overlain by coarse sand. The sand most likely may not have its portion or whole saturated with water as impermeable sediment extends from its top to the ground surface. The Electrical Profiling provides physical indication of water content, clay content, mineralogical compositions or texture of near surface sand changes laterally. **10.0**

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