GEOPHYSICAL INVESTIGATION FOR POTENTIAL CLAY DEPOSITS USING 2-DIMENSIONAL ELECTRICAL RESISTIVITY TOMOGRAPHY TECHNIQUE IN OLOGBO COMMUNITY OF EDO STATE NIGERIA

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The occurrence and significance of clay have been acknowledged since the very beginning of civilisation, essentially for making bricks, cooking pots, and construction of mud houses. Hence, geophysical investigation for clay deposits was carried out with the application of 2-D Electrical Resistivity Tomography (ERT) of the electrical resistivity method using Wenner-Schlumberger array in Ologbo Area of Edo State, Nigeria in order to establish and characterize its presence. The field geometry was made up of three traverses each measuring 200.00 m. 2-D ERT data obtained were processed using Res2dinv software. The results of the survey showed the presence of clay deposits occurring at 18 - 26.90 m and 7.75- 13.5 m for Traverse 1. Also, for Traverse 2, clay is meagrely deposited at 2.5 - 6.00 m and 2.5 - 4.00 m. The resistivities of the clay deposit varied from about 50.00 to 116.00 Ωm. However, in traverse 3, there is absence of clay deposits as this area is predominately lateritic (552 to 1804 Ωm) and shale (2286 to 2897 Ωm). Areas of possible clay deposits have been established which would be of economic importance, if exploited.

Key words: Pseudosection, clay deposits, Wenner-Schlumberger array, traverse, resistivity

INTRODUCTION

Clay minerals are characteristically formed over vast spans of time by the steady chemical weathering of rocks, usually silicate-bearing, by low concentrations of carbonic acid and other diluted solvents. Clay deposits are found as either residual in basement complex or transported in sedimentary basins. The formation of clay minerals is dependent on physicochemical conditions of the immediate weathering environment, nature of the starting materials and other related external environmental factors (Wilson, 1999). Clay minerals belong to the phyllosilicate family of minerals, which are characterised by their layered structures composed of polymeric sheets of silica tetrahedral attached with octahedral sheets. In geosciences and soil classification, the term clay includes all particles that are < 2 µm irrespective of their mineralogy (they could even be organic). This is strictly an operational definition, defined by the process of sedimentation as a means to separate particles. The clay fraction is thus the fraction that is smallest, most colloidal, and generally has the largest specific surface area. Clay is found in three forms: surface clay, shale and fire clay. Most bricks are made from surface mined clays that reside near the surface of the earth and are striped-mined. Shales are clays that have been subjected to high pressures causing them to be hardened. Fire clay is found at deeper formations and has more uniform, physical and chemical properties. They can withstand higher temperatures and are used to produce fire bricks for high temperature applications such as refractories (Odom, 1984).

Clay deposits are highly sought-after natural resources in many parts of the world due to their varying uses in domestic, industrial and agricultural applications. Clay deposits are used in brick building in the form of stabilized laterite; in the making of earthen cookware and as raw materials for oil-drilling lubricants. In the form of laterite hardpan, clay deposits acts as a seal to prevent aquifer contamination. Lateritic clay could also be an important source of bauxite (Oluwakunle, 2017).

Clay serves as a major material in the manufacturing of ceramic products (Ikhifa et al., 2008). The study of clay deposits has been reported from different parts of Nigeria, usually area within the tropical region of alternating wet and dry climates - as residual products of tropical weathering of parent rocks (Elueze and Bolarinwa, 2001; Ikhifa et al., 2008; Egbai, 2011; Ezomo, 2012; Okolie, 2012). The high contrast in resistivity values between carbonate rock, clayey and sandy materials favors the use of electrical resistivity method for determining the boundary between these Earth materials (Zhou et al., 2000 and Ozegin, 2019). Since the electrical resistivity of earth materials can be influenced by parameters such as rock matrix, porosity, permeability, temperature, degree of fracturing, grain size, rock type and the extent of weathering, the electrical resistivity method is therefore adopted for this research (Ozegin, 2019). Proceeding to this research work, there has been paucity of information on the existing literature of clay deposit in the area investigated. Therefore, the present effort is aimed at finding a lasting solution in characterising the clay deposit in parts of Ologbo.

Location and geological setting of the study area

Ologbo Community is located in Ikpoba-Okha Local Government Area of Edo State, Nigeria. The Ologbo Community is basically rural and its geographical coordinates are 6°3'0" North and 5°40'0" East (Figure 1). The various formations in the geology of Edo State are Benin, Bende-Ameki, Ogwashi-Asaba, Imo and Nsukka formations. The geology of the area is characterised by deposits laid during tertiary and Cretaceous periods. The area is underlain by sedimentary rock constituting part of the Benin Formation which is made up of over 90% massive, porous, coarse sand with clay/shale interbeds having high groundwater retention capacity (Akpokodje and Etu-Efeotor., 1987). Soil particles vary from coarse grained to fine grained in some areas, and poorly sorted, sub-angular to well-rounded particles with ignite streaks and fragment.

The lithostratigraphic unit is the Benin Formation and a Miocene Age has been suggested for the lower part of the formation. The sedimentary deposit is Tertiary Scalp of Benin. The Benin Formation extends to a depth of about 762.5 m and is located on top of the Agbada Formation which is composed of sandstone and coarse sand. Ologbo Formation is aquiferous in nature due to its very low percentage of shaly layers having a depth of about 2445 m with no overpressure (Aisabokhae and Adagbon, 2016). The study area falls within the well-known rainforest belt of Nigeria, with wet season (March to October) and dry season (November to February) the following year.

Resistivity theory

The electrical resistivity method uses the principle of electric current flow in order to investigate the structure of earth's subsurface. Geoelectrical methods are used extensively in groundwater mapping for investigation of the vulnerability of aquifers and shallow aquifers themselves. The vulnerability of aquifers is closely related to the heterogeneity of the clay cap. The clay content of the formation shows low resistivity, and sandy permeable formation shows high resistivity (Christensen and Sørensen, 1998). A clay or shale particle acts as a separate conducting path in addition to the solution path. It is customary to consider the impedance of clay as being purely resistive. The resistance is usually substantially lower than the mineral grain resistance (Ozegin and Oseghale, 2012).

A geoelectrical measurement is carried out by recording the electrical potential arising from current input into the ground with the purpose of achieving information on the resistivity structure on the ground (Figure 2). In a homogeneous ground (half space), the current flows radially out from the current source and the arising equipotential surfaces run perpendicular to the current flow lines and form half spheres. In a common situation where there are both the current source and current sink, the current flow lines and the equipotential surfaces become more complex. In reality, the current flow lines and the equipotential lines will form an even more complex pattern as the current flow lines will

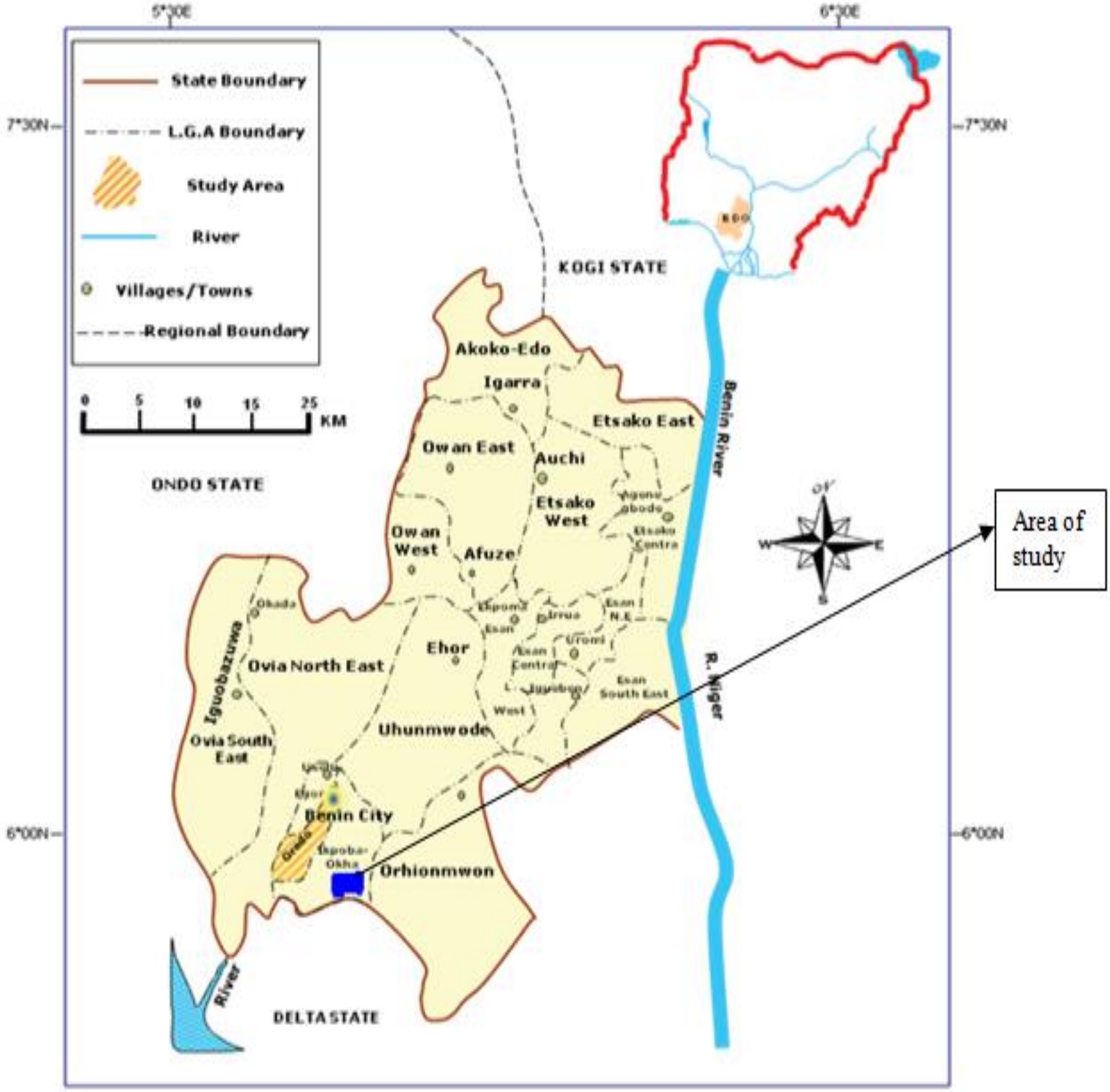

Figure 1. Map of Edo State showing Ologbo.
Source: Ministry of Lands and Survey (2009).

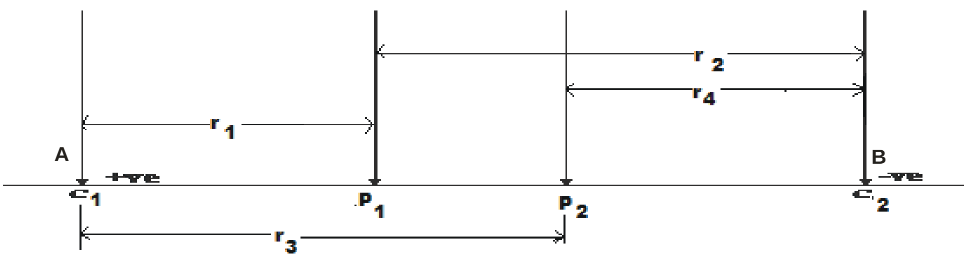

Figure 2. Generalised electrode configuration.
Source: Ozegin and Oseghale (2012).

bend at boundaries, where the resistivity changes. The generalised apparent resistivity equation is expressed as;

$$\rho_a = \frac{2\pi\Delta V}{1}\left(\frac{1}{r_1}-\frac{1}{r_2}-\frac{1}{r_3}+\frac{1}{r_4}\right)^{-1}$$

$$\rho_a = 2\pi R\left(\frac{1}{r_1}-\frac{1}{r_2}-\frac{1}{r_3}+\frac{1}{r_4}\right)^{-1}$$

Since homogenous and isotropic medium cannot be attained in the Earth's media due to a number of geological structures entrenched within the Earth such as faults, lithological contacts, dykes, lumped bodies among others, the measured resistivity is not the true resistivity but the apparent resistivity designated as ρ_a.

MATERIALS AND METHODS

The geophysical method employed was the Electrical Resistivity (ER) method using the Wenner-Schlumberger electrode configuration in Ologbo Community of Edo State. ABEM 300 resistivity meter was used to obtain electrical resistivity field data. The Wenner-Schlumberger array is moderately sensitive to both horizontal and vertical structures. The Wenner-Schlumberger array has a slightly better horizontal data coverage compared with the Wenner array but narrower than that obtainable with the dipole-dipole array. Wenner-Schlumberger configuration has a constant system of spacing rules with a note of factor "n", as this configuration is the comparison of the distance between C1-P1 (or C2-P2) electrodes with spaces between P1-P2 (Figure 3). If the distance between electrodes potentials (P1 and P2)

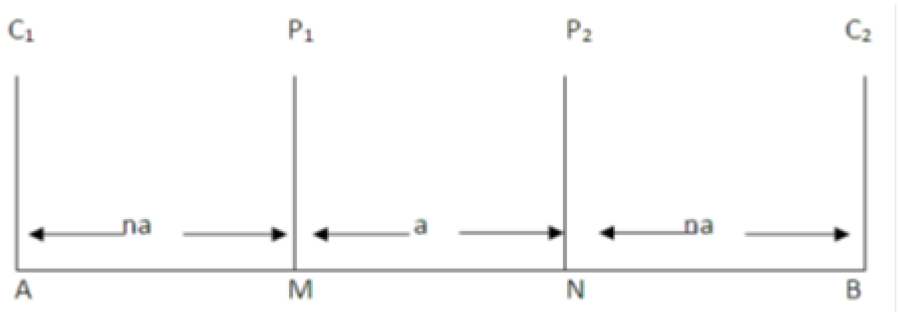

Figure 3. The setting of Wenner-Schlumberger configuration electrode.

is 'a' then the distance between the current electrode, (C1 and C2) is 2na + a. The resistivity determination process uses 4 electrodes placed in a straight line (Jamaluddin and Emi, 2018). This configuration results from the combination of the Wenner configuration and Schlumberger configuration. In the measurement by the spacing factor (n) = 1, the Wenner-Schlumberger configuration is similar to the measurement in the Wenner configuration (distance between electrode = a), but the spacing factor varies for which n = 2, 3, and so on. In principle, the technique involves introducing a current (I) into the ground via a pair of electrodes C_1 and C_2 as shown in Figure 2. This current in turn produces an electrical potential difference between another pair of electrode P_1 and P_2 measured as V by the Terrameter and from Ohm's law; the value of the resistance ***R*** is computed as R=V/I. The Wenner-Schlumberger hybrid configuration was employed, which enabled the build-up of a pseudosection with the geometric factor K for the array used. The resistance value readings were converted to apparent resistivity ρ_a. From the electrode configuration, the geometric factor K is given by:

$$K = \pi n\,(n+1)\,a \qquad (1)$$

The geometric factor (K) is multiplied with the resistance reading (R) from the field to obtain the apparent resistivity ρ_a. So apparent resistivity value can be calculated by:

$$\rho_a = KR \qquad (2)$$

Where 'a' represents the 10 meters of the electrode spacing and n varies from 1, 2, 3, 4, and 5 as observed in the field survey.

RESULTS AND DISCUSSION

Three locations were investigated in Ologbo Community of Edo State, each measuring 200 m. Wenner-Schlumberger arrays were carried out in each of the areas. Res2dinv software was used to process the data obtained from each of the survey lines. Each observed apparent resistivity modelled images consist of three figures (Figure 5a - c). The upper modelled with the raw apparent resistivity. The middle represents a model of the computer generated apparent resistivity data. These two figures are termed pseudosection. The lower figure is produced with the inverted apparent resistivity data, which is the true subsurface resistivity. This lower figure is what is used to deduce the geological make-up of the surveyed depth range. The data provided the model for the different thickness and resistivity values, which were then integrated with a standard table of electrical resistivity values for geologic materials (Table 1) and borehole log around the investigated area (Figure 4). In traverse 1(Figure 5a), clay exists with lateral distance from 103 to 127.00 m and 144 to 156.00 m with corresponding thickness of 8.90 m (18 - 26.90 m) and 5.75 m (7.75 -13.5 m), respectively which is marked in the figure. In traverse 2 (Figure 5b), clay deposits occur at 3.5 m (2.5 - 6.00 m) with lateral spread ranging from 15 - 21.00 m. Also, in this traverse, clay deposits occur at 1.50 m (2.5 - 4.00 m) with lateral spread ranging from 42 to 48.00 m. In traverse 3 (Figure 5c), clay formation is completely absent as this area is predominately lateritic (552 to 1804 Ωm) and shale (2286 to 2897 Ωm).

Table 1. Resistivity and velocity of some common rocks and minerals (Telford and Sheriff, 1984; Ozegin and Okolie, 2018).

Material	Resistivity (Ohm-m)
Igneous / Metamorphic	
Granite	$5 \times 10^3 - 10^8$
Weathered granite	$1 - 10^2$
Basalt	$10^3 - 10^6$
Quartz	$10^3 - 2 \times 10^6$
Marble	$10^2 - 2.5 \times 10^8$
Schist	$20 - 10^4$
Sediments	
Sandstone	$8 - 4 \times 10^3$
Conglomerate	$2 \times 10^3 - 10^4$
Shale	$20 - 2 \times 10^3$
Limestone	$50 - 4 \times 10^2$
Unconsolidated sediment	
Clay	1 - 100
Alluvium	10- 800
Marl	1 - 70
Clay (wet)	20
Groundwater	
Fresh water	10 - 100
Salt water	0.2

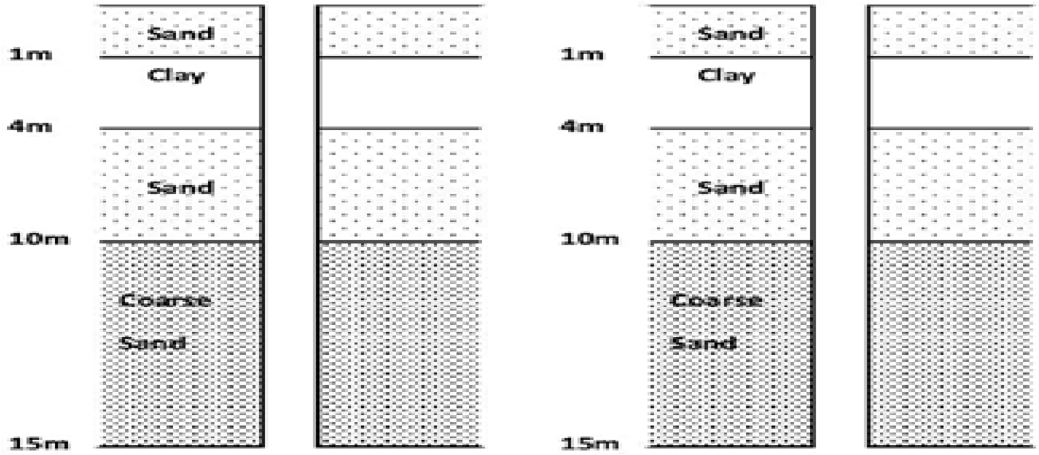

Figure 4. Borehole log around the study area.
Source: Aisabokhae and Adagbon (2016).

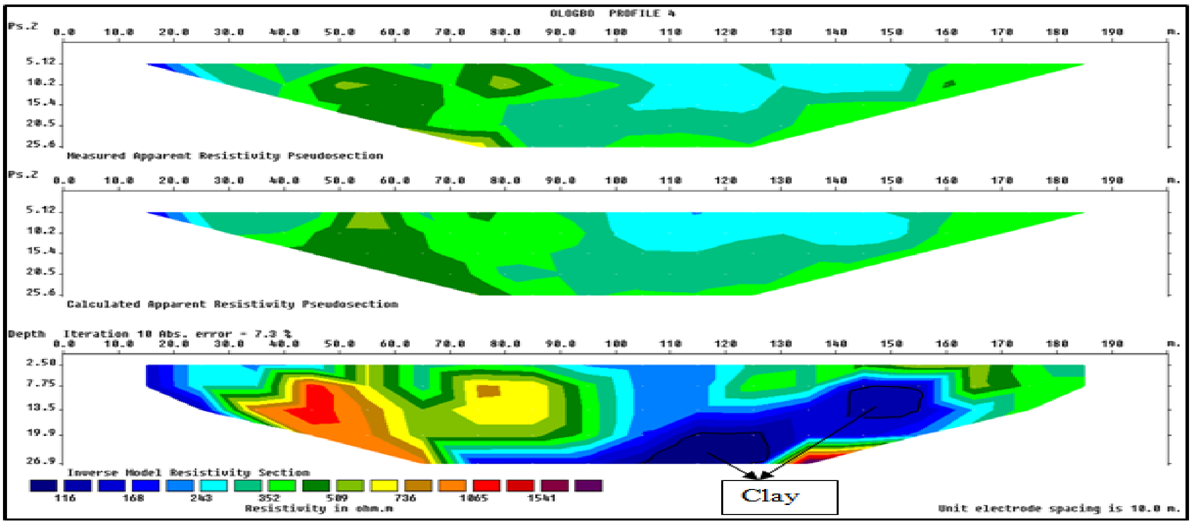

Figure 5a. The observed apparent resistivity pseudosection for *Traverse 1.*

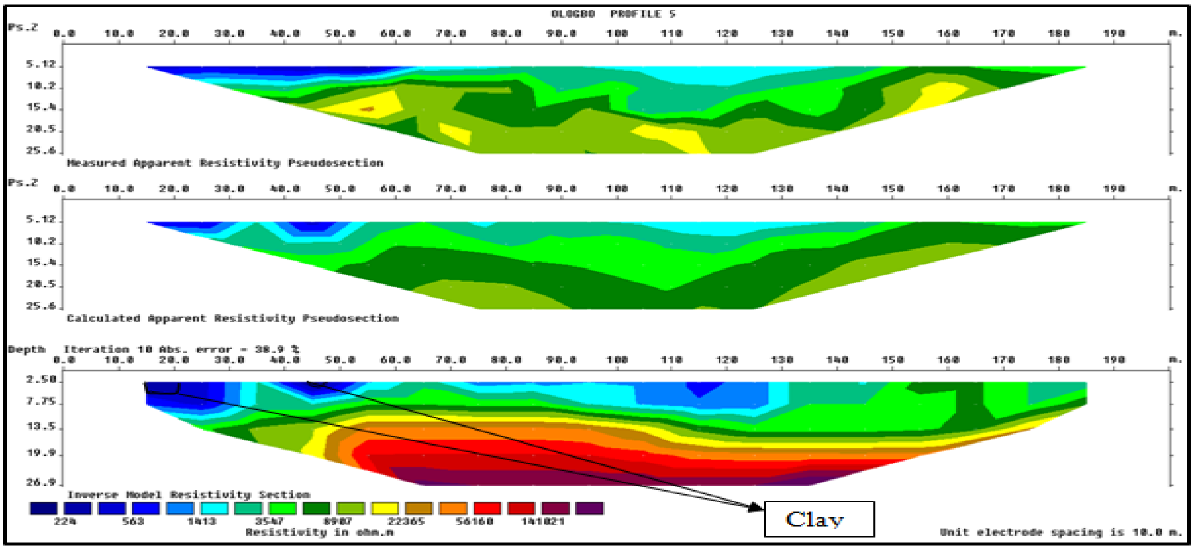

Figure 5b. The observed apparent resistivity pseudosection for *Traverse 2.*

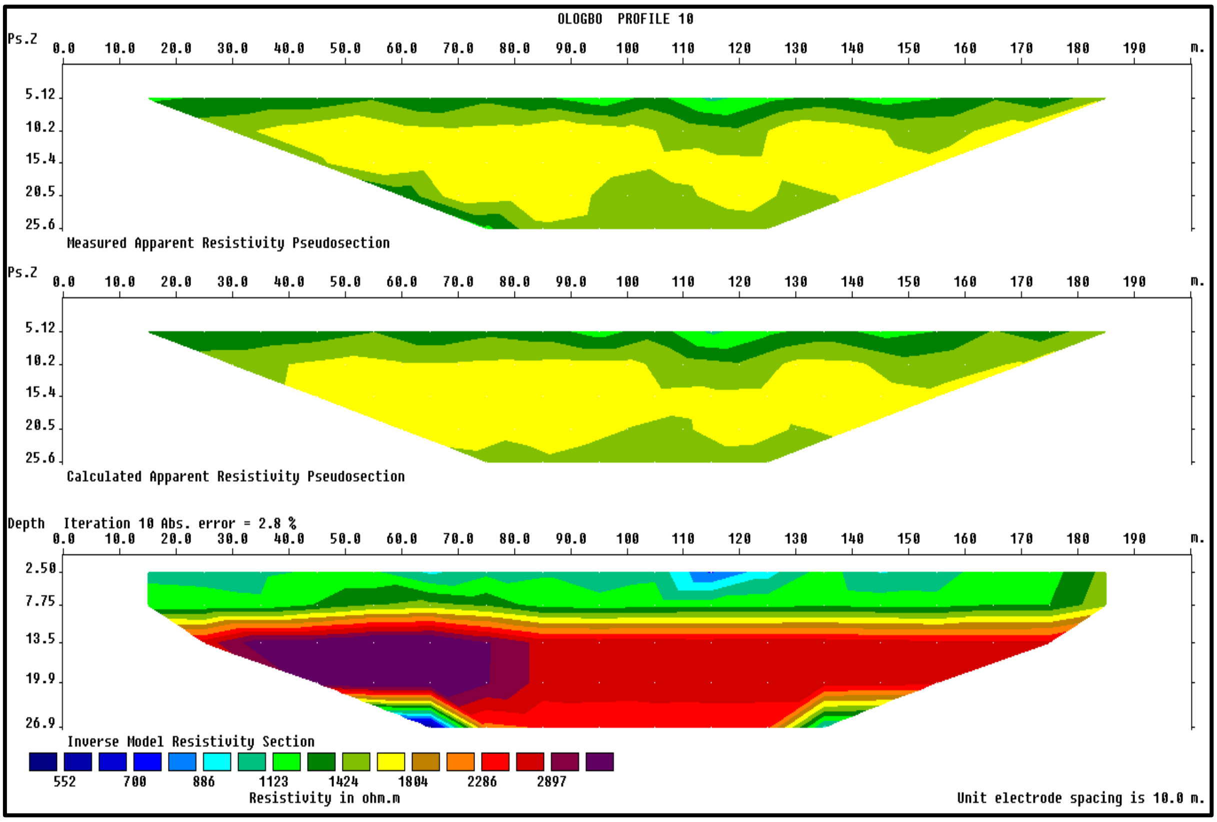

Figure 5c*:* The observed apparent resistivity pseudosection for *Traverse 3.*

Conclusion

Three resistivity images were obtained from the resistivity surveys carried out in Ologbo Community of Edo State using Wenner-Schlumberger array to determine its clay formations, depth and thickness. The images showed the presence of clay deposits occurring at 18 - 26.90 m and 7.75 – 13.5 m for traverse 1, and sparsely deposited at 2.5 - 6.00 m and 2.5 - 4.00 m in traverse 2. The resistivities of the clay deposit varied from about 50.00 to 116.00 Ωm. However, for traverse 3, there is absence of clay deposits. It is therefore recommended that high resolution three-dimensional quantitative electrical resistivity imaging survey be conducted in the study area where clays are inferred and delineated, to further confirm the extent of depths and sizes with greater precision.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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