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Application of Electrical Resistivity Method in Detecting Self-Buried Archaeological Materials

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Abstract

Wenner configuration of electrical resistivity was used to examine self-buried archaeological materials. This configuration was employed because of its sensitivity to vertical changes in the subsurface resistivity below the centre of array. This method was used to check for the accuracy/ resolution ability of Electrical resistivity in detecting archaeological materials. Five (5) pits were filled up with different materials. Measurements were done at different electrode spacing's (a). The electrode spacing varied from 5 m up to 25 m in order to cover the formations embedded beneath the survey line at different depths in a comprehensive way. Three profiles of about 120m were made to cut across the five (5) pits that contained the self-buried archaeological materials. Campus Omega Terrameter was used to acquire the resistance data along each profile. Apparent resistivity was obtained by multiplying the geometric factor with the resistance data acquired. The acquired data was interpreted by using Res2D inversion to obtain the Electrical resistivity tomography (ERT). From the ERT obtained, the buried materials were detected with varying resistivity values in accordance with their points on the profile.

Keywords: - Self-buried, Resistivity, Archaeological, Wenner configuration, ERT

1. Introduction

Archaeology is the study of past cultures through the material remains people left behind (Darvill, 2002). These materials range from small artifacts, such as arrowheads, to large buildings, such as pyramids. Anything that people created or modified is part of the archaeological record. Archaeologists use these remains to understand and re-create all aspects of past culture, from the daily lives of ordinary people to the grand conquests of emperors. Often, these objects are buried and have to be carefully uncovered or excavated before they can be studied. In many cases, they are the only clues archaeologists have to help them reconstruct the lives of ancient people. These objects are like pieces of a giant jigsaw puzzle that the archaeologist must solve.

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Geophysical surveys are one of the essential tools commonly employed in archaeological study in detecting, mapping and studying the characteristics of various types of buried objects and structures in the subsurface. It gives detailed information about the location, depth, size and extent of the archaeological remains. (Weaver, 2006)

Geophysical investigation is a non-invasive tools used in investigating the sub-surface condition of the earth through measuring, analyzing and interpreting physical fields (density, elastic, conductivity, e.tc) of the surface. These methods give the detailed information of the subsurface compared to geotechnical investigation which give point test. In archaeological study, it is ground-based physical sensing techniques used to detect archaeological imaging or mapping. Geophysical survey is used to create maps of subsurface archaeological features by using appropriate instruments in detecting buried features when their physical properties contrast measurably with their surroundings. Readings taken in a systematic pattern become a data set that can be rendered as image maps. Survey results can be used to guide excavation and to give archaeologists insight into the patterning of non-excavated parts of the site. Unlike other archaeological methods, geophysical survey is neither invasive nor destructive. For this reason, it is often used where preservation (rather than excavation) is the goal, and to avoid disturbance of culturally sensitive sites.

The study is aimed at checking the ability of the Wenner configuration in determining the location and depth of the buried archaeological materials. Several authors had used different geophysical tools like magnetic (Dalan *et al*., 2007), ground penetrating radar (Kvamme, 2003; Conyers and Osburn, 2006; Conyers and Connell, 2007), vertical electrical sounding method (Fawale *et. al*., 2011) for archaeological study. Electrical resistivity of geophysics has been widely explored for groundwater exploration due to its simplicity technique and its cheapness by notable authors (Osemeikhan and Asokhia, 1994, Olorunfemi *et al*., 1999, Adeoti et al 2010). Application of electrical resistivity profiling in archaeological investigation has not been fully explored.

However, it has been used by some authors in environmental geophysics in detecting buried faults, hidden cavities underneath voids prior to construction of structure as need may arise (Ayolabi *et al*., 2009; Oyedele and Ekpoette, 2011; Fawale *et al*. 2011; Olatunji and Oladunjoye, 2013). Wenner configuration of geophysical prospecting was first proposed by Wenner in 1916. It is sensitive to the measurement of lateral variation of apparent resistivity.

It is efficient in location of anomalous trend especially in delineation of fault/fractures, vertical contacts, etc.

2. Materials and Methods

The study was carried out in Olabisi Onabanjo University, Main Campus Ago-Iwoye. The study area lies within the crystalline basement complex of Nigeria. The rocks present are mainly Granodiorite- porphyroblastic, Granite, Gneisses and Migmatite Gneisses, Biotite Gneisses and Biotite, Hornblende Gneiss (Rahaman, 1988). The Gneisses constitute the major rocks intended by the other groups of rocks while the minor rock types include pegmatite and quartz veins in the area.

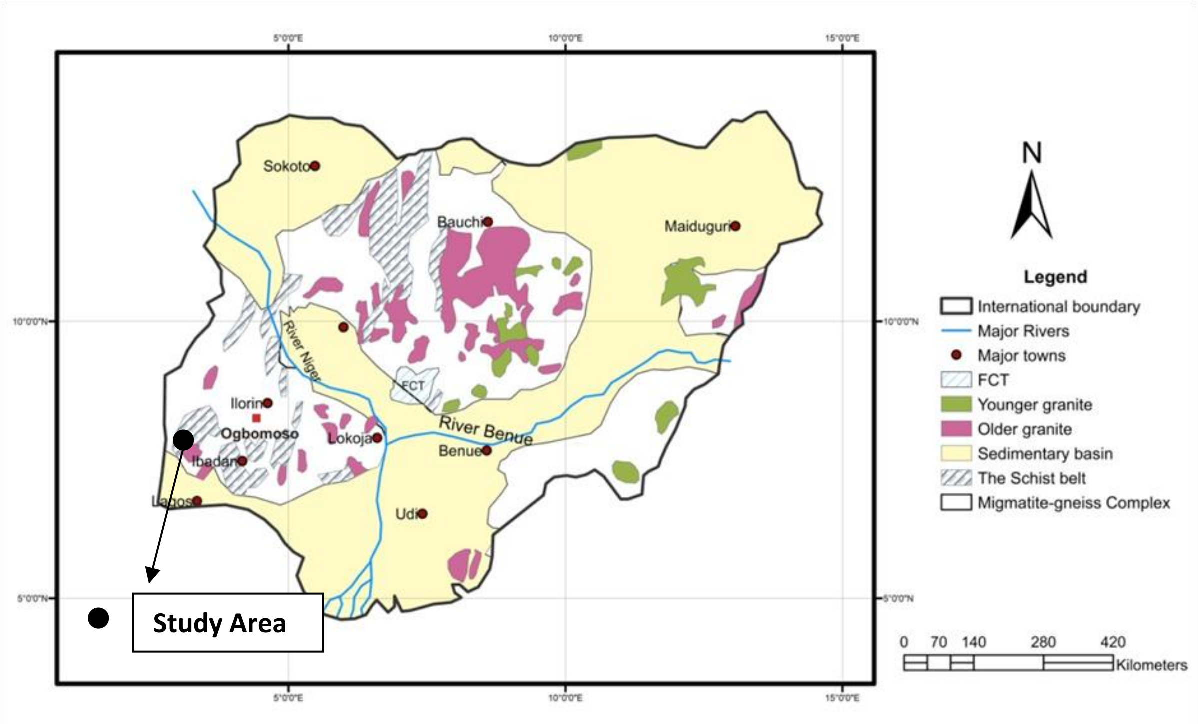

Fig. 1: Geologic Map of Nigeria (After Oyawoye, 1964)

Five different pits were dug to different depths in a remote area within main campus premises of Olabisi Onabanjo University, (OOU) Ago Iwoye. Remote part of the campus was chosen to avoid disruption of the study. The depths of these pits are shown in Table 1. Different materials were buried into these hand-dug pits. The materials include Metals, Blast-rock (rock obtained from controlled use of explosives or other methods to break down or remove rock), Clay pot, Gravel (unconsolidated rock fragments that have a general particle size range) and Aluminum. These covered materials were made to form three profiles whereby the Wenner traverses were obtained from these profiles. The survey was designed to have the sequential consequence of "a" from 5m -25m with maximum profile of 120m. The profiling was designed to cut across more than one pit to so as to represent the inverse model in the same profile and compare their representation on the profile accordingly. The survey was carried out using Campus Omega Tetrameter.

Tab. 1: Showing the Depth and Location of Each Buried Pits.

PIT NO	DEPTH (m)	LOCATION
1	1.8m	40m away from the starting point of profile 1
2	2.2m	70m away from the starting point of profile 1
3	2.6m	45m away from the starting point of profile 2
4	1.2m	75m away from the starting point of profile 2
5	1.2m	30m away from the starting point of profile 3

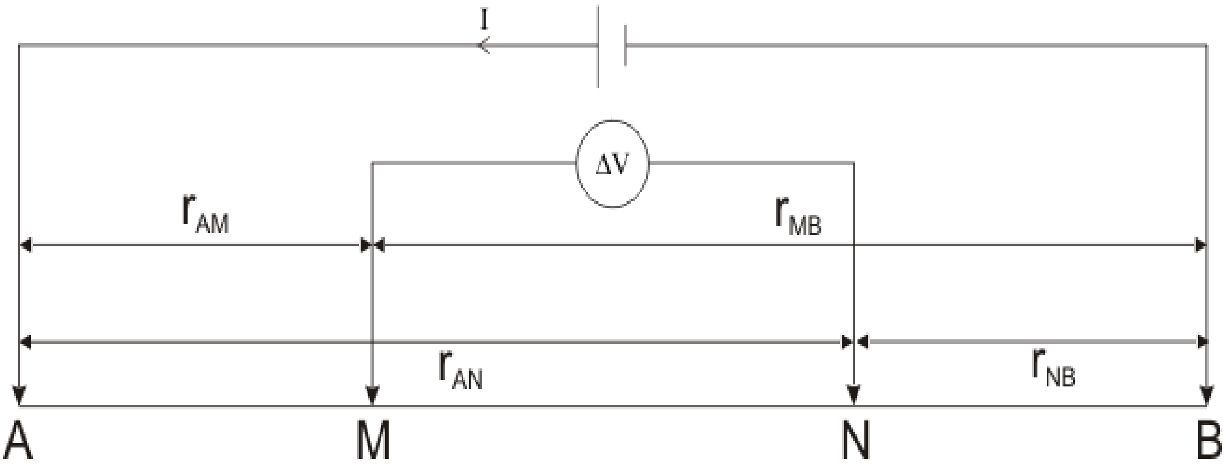

Fig. 2: Electrode Arrangement for Wenner Configuration.

From the figure above, the total potential at M due to A and B can be expressed as

$$V_M^{A,B} = \frac{\rho I}{2\pi}\left\{\frac{1}{r_{AM}} - \frac{1}{r_{MB}}\right\}, \tag{1}$$

similarly, the total potential at N due to A and B can be expressed as

$$V_N^{A,B} = \frac{\rho I}{2\pi}\left\{\frac{1}{r_{AN}} - \frac{1}{r_{NB}}\right\}. \tag{2}$$

The potential difference between potential electrodes M and N is expressed as;

$$\Delta V_{MN}^{A,B} = V_M^{A,B} - V_N^{A,B},$$

$$\Delta V = \frac{\rho I}{2\pi}\left\{\left(\frac{1}{r_{AM}} - \frac{1}{r_{MB}}\right) - \left(\frac{1}{r_{AN}} - \frac{1}{r_{NB}}\right)\right\}, \tag{3}$$

$$\rho = \frac{2\pi\Delta V}{I\left\{\left(\frac{1}{r_{AM}} - \frac{1}{r_{MB}}\right) - \left(\frac{1}{r_{AN}} - \frac{1}{r_{NB}}\right)\right\}} \quad (4)$$

In Wenner Electrode Configuration, all the four electrodes A, M, N and B are planted along a profile such that $AM = MN = BN = \frac{AB}{3}$.

The outer electrodes, A and B are current electrodes while the inner ones, M and N are potential electrodes. Given that;

$r_{AM} = a$, $r_{MB} = 2a$, $r_{AN} = 2a$ and $r_{NB} = a$,

then, equation (4) becomes

$$\rho = \frac{2\pi\Delta V}{I\left\{\left(\frac{1}{a} - \frac{1}{2a}\right) - \left(\frac{1}{2a} - \frac{1}{a}\right)\right\}} \quad (5)$$

The apparent resistivity, ρ_a measured at a particular value of electrode spacing, a is given by the equation:

$$\rho_a = 2\pi a \frac{\Delta V}{I} \quad (6)$$

Since $G_w = 2\pi a$ and $R = \frac{\Delta V}{I}$, then

$$\rho_a = G_w \frac{\Delta V}{I} = G_w R,$$

where R is the resistance value in Ohms measured from Terrameter and G_w is the geometric factor for Wenner array.

3. Results and Discussion

The results of the Constant Separation Traversing (CST) conducted within the premises of main campus of Olabisi Onabanjo University to detect self-buried archaeological materials were presented in 2-D Resistivity Structure along the traverses surveyed. The Electrical Resistivity Tomography obtained shows the lateral resistivity variations along profiles as presented in Fig. 3 - 5. The 2-D resistivity structures along the profile survey were obtained for meaningful conclusions.

The inverse models obtained from 2D inversion of the field data using different starting models mainly showed that the inversion algorithm is stable. After that, comparison of the measured apparent resistivity pseudosection and the calculated apparent resistivity pseudosection resulted in a reasonably good agreement with the inverse model resistivity section. As a result, this demonstrates the stability of the 2D inversion algorithm that can give reliable models. Based on the 2D imaging obtained in the study area, different materials with different resistivity values were observed in the pit that corresponds with the one they were buried.

High and low amplitude reflections with different chemical and physical properties can be used to delineate the buried archaeological materials (Conyers, 2004). Detection of archaeological materials within a geologic context requires the analysis of the stratigraphic sequence of the individual layers which can therefore be used to show environmental changes over time (Kvamme, 2003). Abrupt increase in resistivity value of sounding points can also be attributed to the presence of self-buried materials when such survey is being conducting. For instance, large buried materials were observed from the sounding method employed by Fawale *et al*. (2011).

The data processing was done using Res2D inversion computer software to show the resistivity variations along the profiles. The 2-D pseudosection makes use of color separation to denote high and low resistivity values. In this study, the high and low resistivity areas were identified along the transverse surveyed. The 2-D resistivity structures of the profiles are represented in figures 3 – 5.

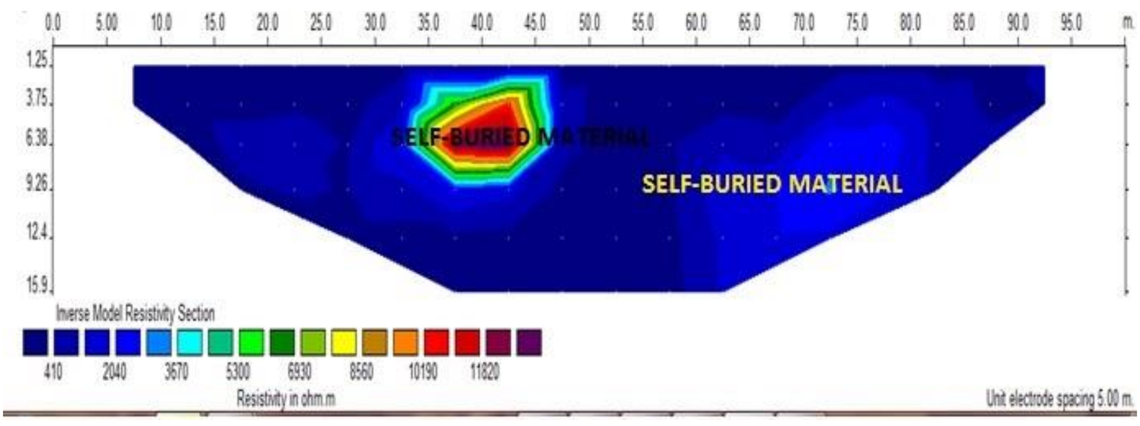

Fig. 3: 2-D Resistivity Structure of Profile 1

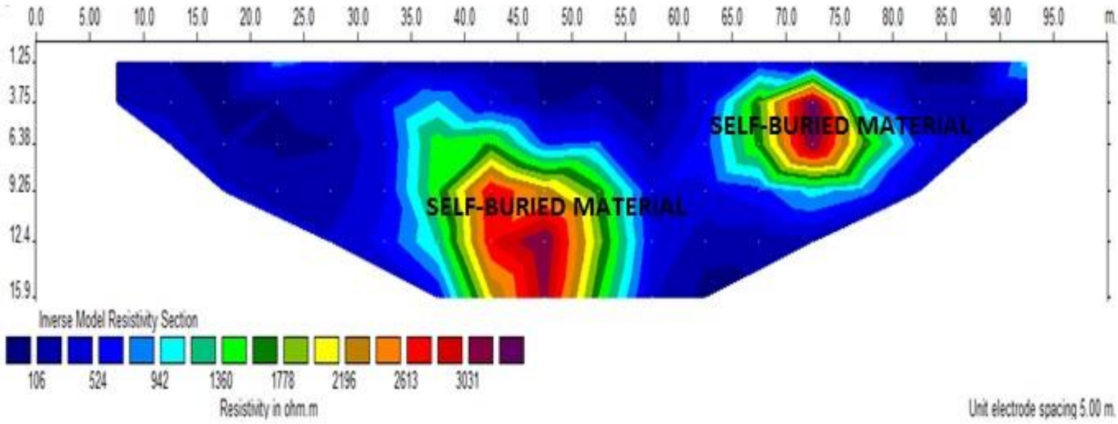

Fig. 4: 2-D Resistivity Structure of Profile 2

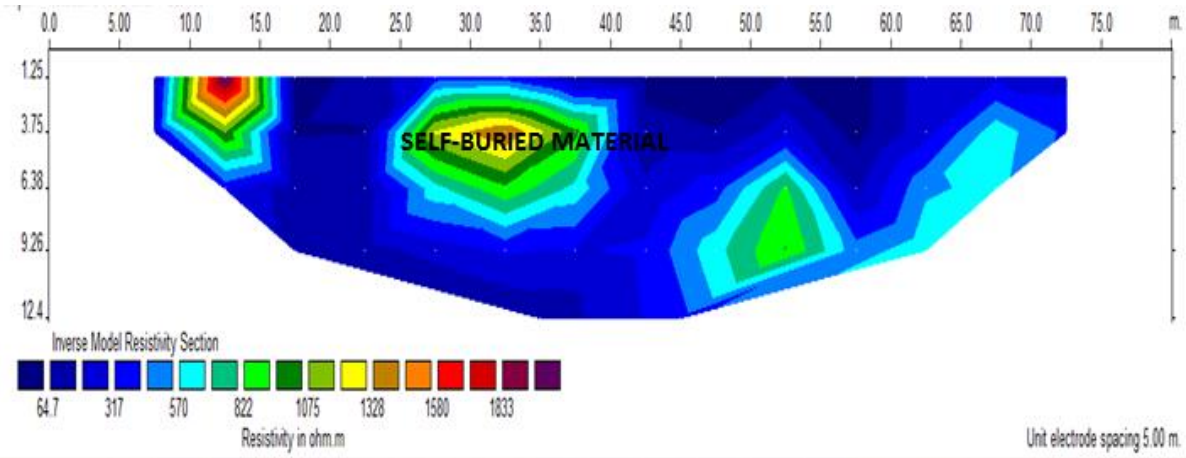

Fig. 5: 2-D Resistivity Structure of Profile 3

The electrical resistivity tomography of profile 1 is presented as in Figure 3. The self-buried material was observed in two different points along the profiled resistivity structure. The first imaging of the self-buried was at point 40.0m from the starting point. The imaging was detected at depth around 1.8m which is the same with the depth of the where materials of the first pit was located. Along profile 1, at point 75.0m from the starting point another imaging of the buried material was also observed. This material is of low resistivity value compare to the other one on the same profile but with depth of about 2.2m. Brief anomaly observed at point 20.0m from the starting is suspected to be termite hive hidden within subsurface which is yet to be outcropped to the surface. This inference is as a result of field inspection observed during the field survey.

The electrical resistivity tomography of profile 2 is presented as in Figure 4. The model shows the resistivity distribution along the second profiles situated parallel to profile 1. The imaging revealed the presence of pits that contains the self-buried materials. The first pits was found at point 40.0m from the starting points with resistivity value ranging from 1778 Ωm - 2613 Ωm. This material was found at a depth of about 2.6 m. The second pit was revealed at point 70.0m from the starting point. This area shows high resistivity of about 2196-3031Ωm at a shallower depth compare to the other pits on the same profile. Materials in this pit show high resistivity value because materials in this pit are fragments of blast gravel from quarry.

The electrical resistivity tomography of profile 3 is presented as in Figure 5.The model shows the presence of self-buried material pit. This pit was found at point 30.0m from the starting point. The resistivity of this material ranges from 1075-1325 **Ω**m, the depth of this pit is found to be at shallow depth of about 2.2m. Though there are some anomalies along the profile but they are suspected to be natural hidden materials which might be termite hive or any other materials.

4. Conclusion

From the study, it was gathered that Wenner Configuration of electrical resistivity with high resolution is capable of detecting archaeological materials. This is as result of detection of self-buried materials by this method. Ground Penetrating Radar (GPR) and Magnetic methods are among the famous geophysical methods using in detecting archaeological materials. The results obtained from this study showed that Electrical method using Wenner Configuration can also fit in for the task effectively

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