Evaluation of Lateritic Soil from Field Resistivity Data at Okada, South-South, Nigeria

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Abstract: ***The electrical properties of laterites was a useful tool for electrical resistivity investigations to evaluate depth and area extent of laterite top soil in Okada South-South, Nigeria. On the field electrical resistivity tomography survey was conducted along four profile using Schlumberger –Wenner configuration. Acquired resistivity data were interpreted based on least square method, the resultant apparent resistivity sections were interpreted with constrain from known lithostratigraphy of the area to infer the true resistivity variation of the different litho units. The litho log from a section of a road cut outcrop on which line 1 electrical survey was done, serves as a reference for correlation between apparent resistive values and actual lithology. A tie of laterite to apparent resistivity for the study area shows a resistivity values of 600 -1000 Ωm are laterites, 300 – 600 Ωm lateritic soil with varying degree of laterization, while 100 Ωm and bellow are clay related, these references agrees with standard references for these lithologies. The electrical resistivity tomography method was effective in delineating clay units from lateritic areas. In terms of exploration, Line 1 and 2 showed extensive concentration of laterite which toward line 2 and 3 decreased with increased patch occurrence of clays.***

Keywords: Laterite, Electrical Resistivity Tomography, Okada

1. Introduction

Rusty-red iron oxides soils commonly called laterites, are soils developed near the earth's surface by intensive weathering of the underlying parent materials. The mechanism of weathering (laterization) involves a prolonged acid dissolving the host mineral, followed by hydrolysis and precipitation of insoluble oxides and sulfates of iron, aluminum and silica. Imprints of these processes were globalized during the mid-Tertiary to mid-Quaternary periods as observed in many parts of Nigeria and Sub-Sahara Africa, aided by tropical conditions which prevent the erosion of top soil while leaching progresses.

Laterites vary significantly according to the parent rock mineralogy and geomorphology of the area (Sudha, 2009). The evaluation of the mineral potential and geological mapping of laterite deposits is imperative due to its verse economic important for ore mineral, construction, water treatment, agriculture etc. which has not been or is under exploited in this region when compared to others. Evaluation of laterites deposits has evolved from pit dug litho-logs and sampling method, were lateral differentiations are based on interpolations between rather distant pits and the three-dimensional (3-D) geometry is poorly understood Robain, H. et. al., 1996. To reduce erroneous interpretation the need for lateral continuity as much as vertical variation with depth is greatly emphasised.

Recent works has shown that the application of relatively low frequencies (i.e. <100 kHz), electrical resistivity measurements is an effective tool characterizing soils with compositional gradient (Robain, H. et. al., 1996; Anicet B. et. al., 2006). Resistivity is a material property and does not depend on the media geometry. In soil systems, bulk resistivity of the soil is measured, which represents the composite resistivities of the pore fluid, degree of saturation, composition of the solids etc (Sebastian, 2005; Thevanayagam, 1993 and Ward, 1990).

For laterite studies, the Electrical Resistivity Tomography (ERT) method is preferred. The ERT method provides a more quantitative and rigorous spatial imaging of the geophysical electrical resistance data which improves on other (DC) electrical resistivity method (Daily et. al., 2005). Also in geological complex terrains most DC methods are inadequate especially where it becomes necessary to have a continuous 2D coverage (Akinlabi and Adeyemi, 2014). I. In general, ERT soundings in such laterite setting show a basic three-layer geoelectrical succession with a low resistive clay-rich saprolite layer sandwiched between much more resistive materials corresponding to the iron crust and basement (Ritz et. al., 1999). The aim of this work is to investigate conduct nature of laterite deposits, delineate the width and depth using Electrical Resistivity Tomography (ERT) in Okada South-south Nigeria.

2. Geology of the Study Area

The study area is located in Okada town, about 28km from Benin City, South-Western Nigeria (fig. 1), within latitude 6^o 40' – 6^o 45' N and longitudes 5^o 20' – 5^o 25' E. The area lies within the rain forest region of Nigeria with rainy season occurring from April to October. The mean annual rainfall values range from 1500mm to 1830mm. Rainfall within the area are usually characterized by high surface runoff due to its generally low infiltration rates and high canopy trees.

The laterite unit in the area is part of the Benin Formation outcrop that is the topmost unit of the Niger Delta Basin consists of about 90% sand and a few shale intercalations. Shale content increases downwards while sand and sandstones are coarse to fine grained, poorly sorted, mostly unconsolidated and commonly subangular to well rounded in texture. The Benin Formation was deposited in continental-fluviatile environment with varying thickness of 0 to 10000 ft, the age ranges from Oligocene to Recent (Whiteman, 1982). The Benin Formation outcrops at Okada as Okada sand.

Laterite formation is favored in Okada due to low topographical reliefs of gentle crests and plateaus which prevent erosion of the surface cover. The reaction zone where rocks are in contact with water from runoff and the water table are progressively depleted of leaches of sodium, potassium, calcium and magnesium.

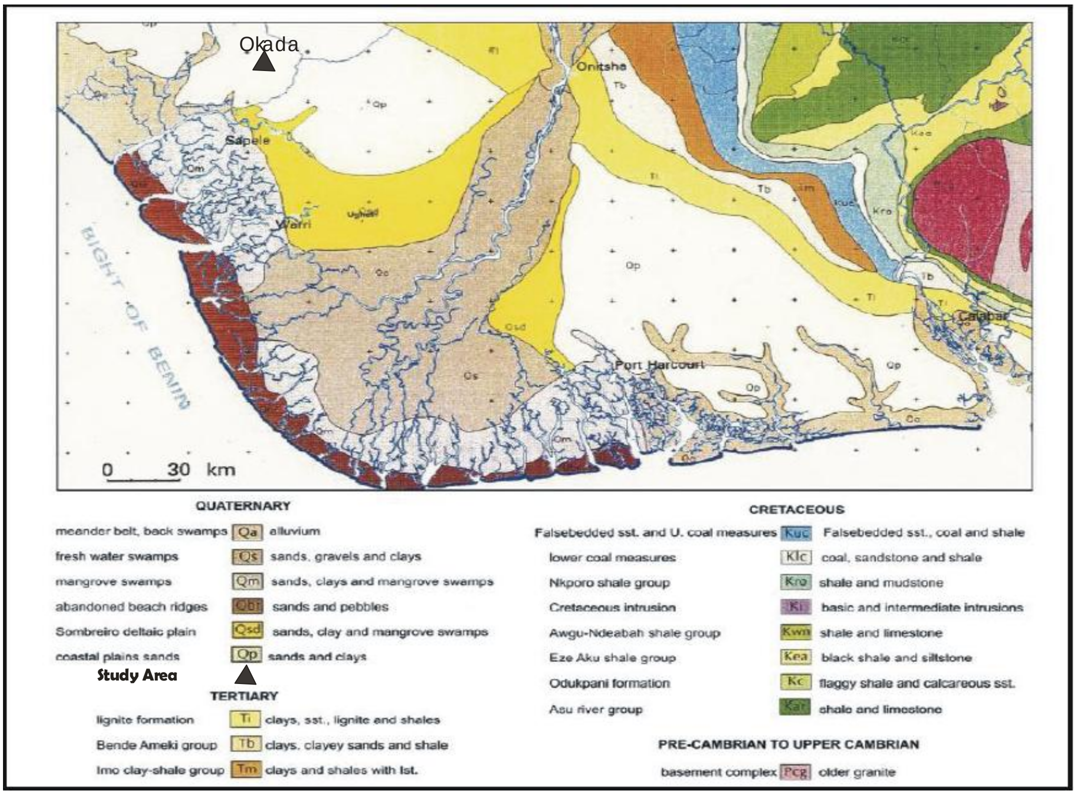

Figure 1: Geologic Map of Okada and its environs

3. Geo-electrical Methodology

Four electric resistivity tomography (ERT) surveys were carried out in Okada (Figure 2) to obtain a comprehensible image of the laterite deposit. The ERT is preferred due to its dense sampling and high resolution appropriate for areas with moderately complex geology (Griffiths and Barker 1993). Different earth materials vary in resistivity based on their material composition and conductivity (Table 1.0).

Table 1.0: Resistivity values of common rocks, soil related materials (After; Loke, 2000).

Material	Resistivity (Ωm)	Material	Resistivity (Ωm)
Sandstone	$8 – 4 \times 10^3$	Sea water	0.2
Shale	$20 – 2 \times 10^3$	Laterite	800 – 1500
Limestone	$50 – 4 \times 10^2$	Lateritic soil	120 – 750
Clay	1 – 100	Dry sandy soil	80 – 1050
Alluvium	10 – 800	Sand clay/clayey sand	30 – 215
Groundwater (fresh)	10 – 100	Sand and gravel	30 – 225

A set of ABEM Terrameter SAS 3000, DC source (battery), multiplexer, connecting cables and electrodes, where used to acquire the field ERT measurements. Twenty (20) equal spaced electrodes were installed in a straight line for each profile in the study. The measurement operation was performed depending on a special mathematical sequence, where the configuration and the interval between the electrodes were automatically moved forward with constant electrode space (2, 5, 10, 15, 20, 25 and 30 m) for the next measurement along the profile, (fig. 2). 2m spacing was taking to give more detailed information on the upper part of the weathering profile, while the larger spacing with 5m increment, have been used to investigate the deeper zones (Rit et. al., 1999) such as the clay unit.

Data Processing

Acquired electrical resistivity data normally assumes a homogenous earth (Koefoed, 1979; Milsom, 2003.) thus, inversion was done using IP2WIN v.2.1, software, which is based on least square method as described by (Milsom, 2003). The resultant pseudo-sections of apparent resistivities were interpreted with constrain from field observed and known lithostratigraphy of the area to infer the true resistivity variation of the different subsurface layers.

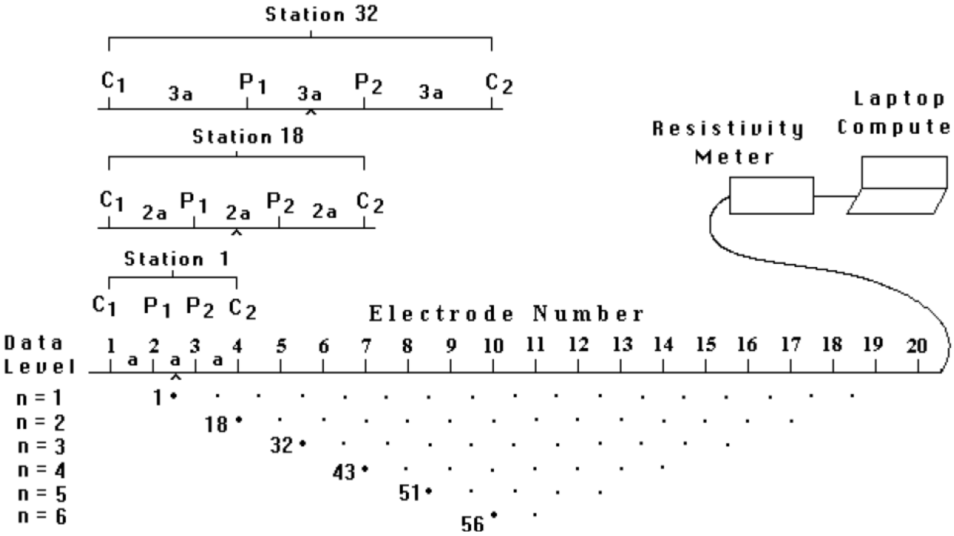

Figure 2: Electrical resistivity tomography configuration with Wenner array for twenty electrodes. (after; Sayed, 2013)

4. Results and Discussion

Lithology – Geoelectrical Correlation

The pseudosection of line 1 along Benin- bypass road and the litho log from a section of the road cut outcrop on which the electrical survey was done, serves as a reference for correlation between apparent resistive values and actual lithology. The road cutting through the outcrop enabled a vertical logged section (fig. 4) which shows two notable clay units; 1) a thin laminar clay unit which occur at depth of 3.2 m from the top, 2cm thick and 2) a cycler clay accumulation of about 1.5 m wide both embedded in the highly lateritic mass. The thin nature of the laminar unit and the relatively large electrode spacing masked it from been resolved in the 2D tomographic image as compared to the lager cycler clay accumulation which is resolved at depth 6- 8m (fig. 3), which agrees with litho log of the outcrop section. A tie of laterite to apparent resistivity for the study area shows a resistivity values of 600 -1000 Ωm are laterites, 300 – 600 Ωm lateritic soil with varying degree of laterization, while 100 Ωm and bellow are clay related, these references agrees with standard references for these lithologies (Table 1.0; Loke, 2000). It would be expected that since there are more metals (mostly aluminum and iron) in laterites, they would be more conductive, and as such possess lesser resistivity than lateritic soils or clays. But this is not the case because the metals are not present in their pure states but as ores and the resistance that results from the presence of impurities in these ores is greater than those resulting from the presence of other soil materials.

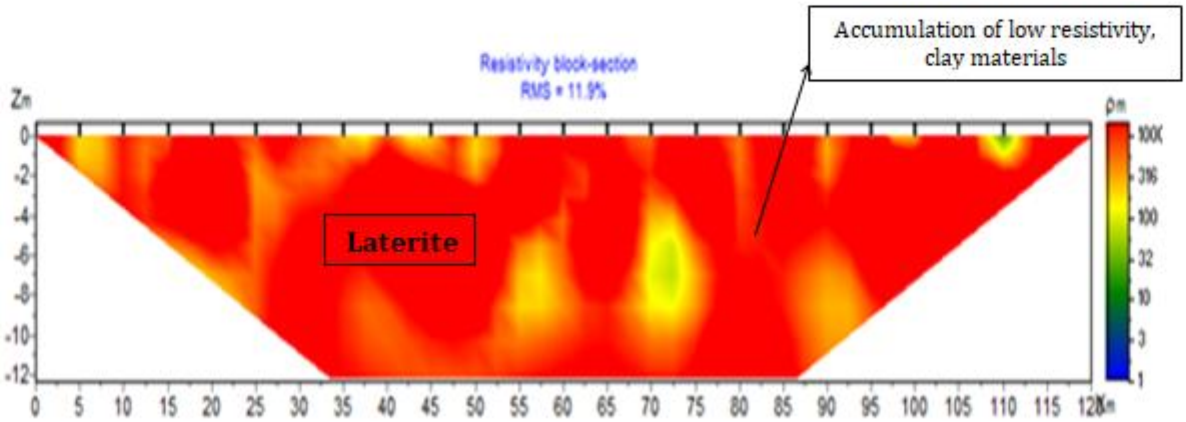

Figure 3: 2D Tomography imaging, of Line 1

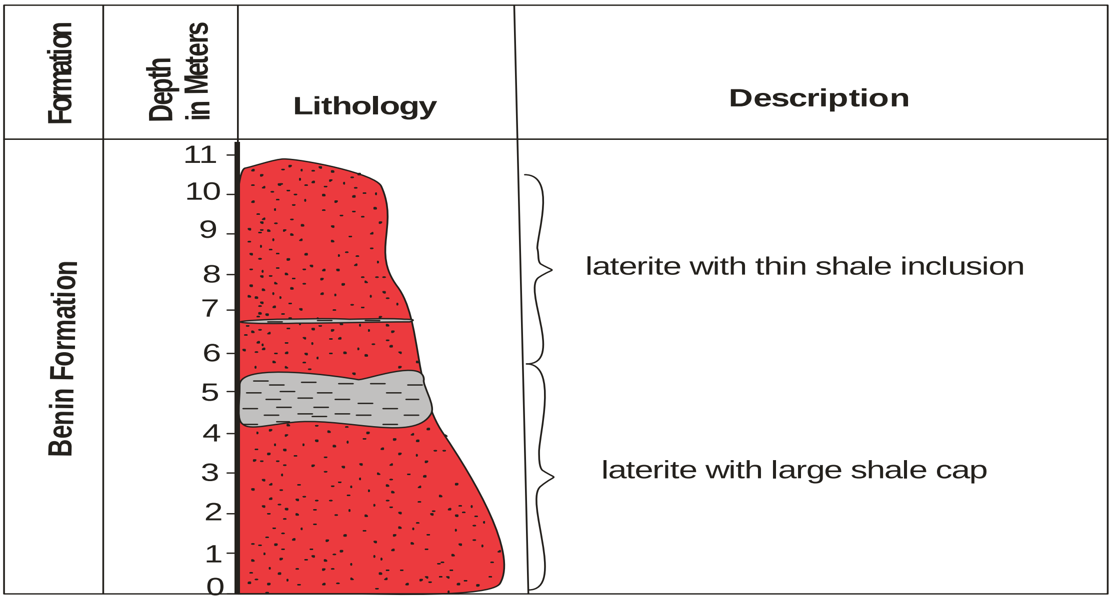

Figure 4: Lithologic description of road cut section of outcrop of Line 1

Ikaladerhan primary school

In the survey area of Line 2, the 2D tomography image shows different accumulations of non-lateritic, low resistivity materials at depth of about 6m from the surface and at positions 21m, 46m, 60m, 72.5m, 84m and 96m respectively (fig. 5). These accumulations have resistivity values ranging from 3 – 10 Ωm. These non-lateritic accumulations are probably clay deposits, which from standard table (table 1.0) have resistivity values ranging from 1 – 100 Ωm. The relatively higher resistivity values observed around these accumulations are the result of the gradual change in resistivity values by the resistivity interpretation software.

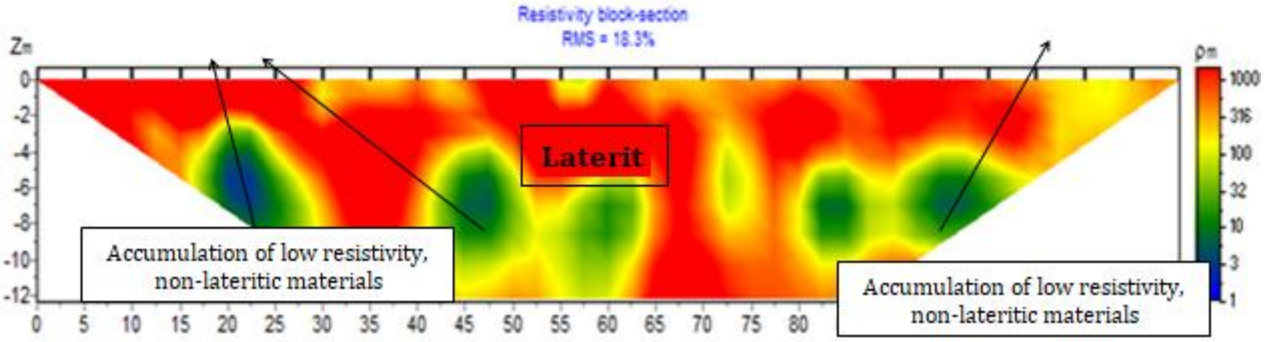

Figure 5: 2D Tomography imaging, Line 2

Okada grammar school

The laterite zone in this area is extensive as shown in the 2D tomography image of line 3 (fig. 6). The most prominent resistivity is about 1000 Ωm, which agrees with the outcrop resistivity values for lateritic section in the study area (fig.3). Some patch accumulations of non-lateritic zones observed at a depth of about 7m and 12m respectively.

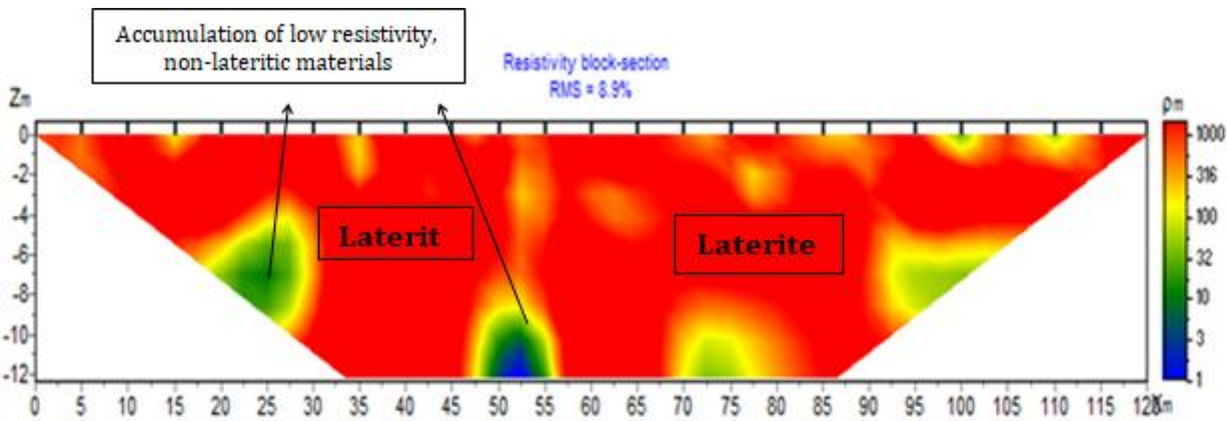

Figure 6: 2D tomography imaging, Line 3.

Mission Road

From the 2D image obtained from Line 4, it can be observed that the area is rich in laterite. In fact, laterites are the major constituents of the soil in the survey area especially near the surface. The dominant resistivity observed is about 1000 Ωm as well as a study of the geology of the area, makes us infer that the major constituent of the soil in the survey area is laterite. As we go deeper, we observe an increase in non-lateritic accumulations. Their resistivity range is from 1 to 100 Ωm which coincides with the resistivity of clay.s

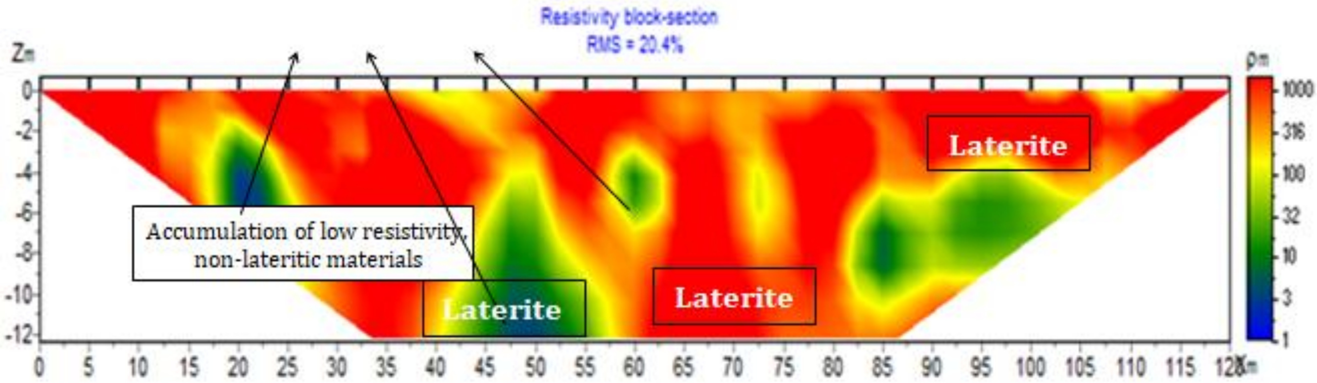

Figure 7: 2D Tomography imaging, Line 4

5. Conclusion

Inferring from outcrop litho-log and the observed resistivity distribution in Line 1, Line 2 Line 3 and Ling 4 and those from standard resistivity values suggest that the low resistivity zones are non-lateritic accumulations most commonly clay deposits. The laterite accumulations in Line 2 and Line 4 are shallow in depth resulting in a thin non-economical volume. In Line 1 and Line 2, the scanty and sparse nature of the clay deposits accumulations increases the laterite percentage composition and lateral extensiveness with depth, which implies that the laterite deposit are of economic quantity and should be considered for exploration and mining. Were the ore element composition and quality are established alongside quantity evaluation that is here established. Then a complete study of the economic viability of this deposit can be established.

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