Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 8(6):233-243
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jeteas.scholarlinkresearch.com

Delineation of Laterite Deposits using Two-Dimensional Geo-Electric Imaging in Agbonmwoba Village Area of Obaretin Town, Edo State, Nigeria.

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Abstract

The study involves delineation of laterite deposits in Agbonmwoba village area of Obaretin town, Edo state using 2D resistivity tomography technique to predict the extent and the economic viability of the deposit, in order to improve wellbeing status. The Petrozenith earth resistivity meter was employed using the Wenner-Schlumberger electrode configuration. Five different locations were investigated within the study area, and a total of ten (10) Wenner-Schlumberger soundings were acquired in the area with a spread length of 200m along each traverse. The field data was inverted using the Zondres 2D software. Four (4) lithologic units were delineated namely; clay deposit with resistivity range of about 1 – 100Ωm, sand deposit with resistivity range of about 200-570Ωm, laterite deposits with resistivity distribution overlapping from about 1000-3162Ωm and gravel deposit whose resistivity distribution ranging from about 8000-10,000Ωm. Laterite deposit were found along traverses 1, 2 and 8 sampled at old sapele road Ekiosa at depths of 13-15m in TR 1, 10-15m in TR2, and 5m in TR8 at horizontal spread of 40-90m, 10-20m, and 20-170m respectively. Laterite deposit were found along traverses 3 and 4 sampled at presco road Obaretin at depths of 10-15m in TR3, and 10-15m in TR4 at horizontal spread of 140-160m, and 160-180m respectively and also laterite deposit were found along traverses 5, 6 and 7 sampled at Agbonmwoba primary school at depths of 5-15m in TR5, 5m in TR6, and 15-25m in TR7 at horizontal spread of 40-50m, 50-70m, and 110-120m respectively. Traverse 9 showed no evidence of laterite deposit from its resistivity pseudo-section. The result shows that laterite deposits along traverses 1, 2, 3, 4, 5, 7, and 10 are located almost at the same depth within the subsurface which implies that the subsurface geology distribution along these traverses are homogenous, and the laterite deposits along these profiles is commercially viable for exploitation, while the laterite deposits delineated along traverses 6, and 8 in the study area are not homogeneously distributed with those delineated along other traverse at the depth imaged and as such is not commercially viable. The results were further compared with borehole lithologic section drilled along TR5 in the area and both sections agreed. Thus 2D resistivity imaging gives a better lateral view of the subsurface layers than geo-electric section computed from 1D models because of its ability to give a continuous record of subsurface formations at greater depth.

Keywords: electrical resistivity tomography (ert), geometrical effect, wenner-schlumberger configuration,

INTRODUCTION

Laterite deposit found at the surface in Agbonmwoba village area of Obaretin town Edo state is of high economic significance to the development of the area, which can serve the purpose of road construction, groundwater establishment, waste water treatment, building blocks, agriculture, ore formation and above all create job opportunity in the area. This has led to further and deeper investigation of its reserve within the subsurface of the area to see whether it can be exploited in commercial quantity for the benefit of the nation. A major geophysical mapping of the area was carried out using 2D resistivity tomography technique. 1D electrical method using vertical electrical sounding (VES) technique has been employed over the years in studying subsurface geologic characteristics of an area, and to map subsurface geological features in sedimentary areas (McDowell, 1979, Ayolabi et al, 2003, Ezomo et al, 2015). However results from 1D resistivity sounding is limited to resistivity change in the vertical direction (1D), without taking into consideration the horizontal changes in subsurface resistivity; this is the greatest limitation of 1D resistivity sounding (Loke and Dahlin, 1997).

Recently, geophysical prospecting has shifted to a more accurate method of imaging the subsurface called Tomography. 2D and 3D resistivity tomography images are created by inverting about hundreds to thousands of individual resistivity measurements (Loke and Barker, 1996a, b) to produce

an accurate model of the subsurface resistivity. Surface geophysical investigation is key in delineating the subsurface geology of an area which enables information about lithology (rock type), density, thickness and depth of subsurface formations to be deduced. The use of 2D electrical resistivity imaging to address a wide variety of environmental, hydrological and geo-technical problems is increasingly becoming very popular (Dahlin 1996).

STUDY AREA

Obaretin is a town located in Ikpoba Okha Local government area of Edo state within the Niger Delta area of Nigeria, with geographical coordinates starting from 6°7.107'N and 5°39.457'E to 6°7.261'N and 5°39.748'E. The geology of the study area is characterized by sediments deposited during the tertiary and cretaceous periods. The sedimentary rock of the study area constitutes the Benin formation which is made up of over 90% massive, coarse sand with clay/shale interbeds having a high groundwater retention capacity (Short and Stauble 1967). The topography of the area is generally flat (Akpokodje et al, 1999)

LIMITATIOS OF STUDY

In the course of data acquisition, the field team were accosted by community dwellers despite prior permission from the constituted authority, although it was eventually resolved.

THEORY

The purpose of electrical surveys is to determine the subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity of the subsurface can be estimated. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock. The fundamental physical law used in resistivity surveys is Ohm's Law that governs the flow of current in the ground. The equation for Ohm's Law in vector form for current flow in a continuous medium is given by

$$J = \sigma E \quad (1)$$

where σ is the conductivity of the medium, J is the current density and E is the electric field intensity. In practice, what is measured is the electric field potential. We note that in geophysical surveys the medium resistivity ρ, which is equals to the reciprocal of the conductivity (ρ = 1/σ), is more commonly used. The relationship between the electric potential and the field intensity is given by

$$E = \nabla \emptyset \quad (2)$$

Combining equations (1) and (2), we get

$$J = -\sigma \nabla \emptyset \quad (3)$$

In almost all surveys, the current sources are in the form of point sources. In this case, over an elemental volume ΔV surrounding the current source I, located at (xs, ys, zs) the relationship between the current density and the current (Dey and Morrison 1979a) is given by

$$\nabla . J = \left(\frac{I}{\Delta V}\right) \delta (x - xs) \delta (y - ys) \delta (z - zs) \quad (4)$$

Where δ is the Dirac delta function.

This is the basic equation that gives the potential distribution in the ground due to a point current source. A large number of techniques have been developed to solve this equation.. For the 1-D case, where the subsurface is restricted to a number of horizontal layers, the linear filter method is commonly used (Koefoed 1979). For 2-D and 3-D cases, the finite-difference and finite-element methods are the most common. For a homogeneous subsurface and a single point current source on the ground surface (Figure 2.1), the current flows radially away from the source, and the potential varies inversely with distance from the current source. The equipotential surfaces have a hemisphere shape, and the current flow is perpendicular to the equipotential surface. The potential in this case is given by

$$V = \frac{\rho I}{2\pi r} \quad (5)$$

where r is the distance of a point in the medium (including the ground surface) from the electrode. In practice, all resistivity surveys use at least two current electrodes, a positive current and a negative current source. The potential value in the medium from such a pair is given by

$$V = \frac{\rho I}{2\pi}\left(\frac{1}{rc1} - \frac{1}{rc2}\right) \quad (6)$$

where rC1 and rC2 are distances of the point from the first and second current electrodes. In practically all surveys, the potential difference between two points (normally on the ground surface) is measured. The potential difference is then given by

$$\Delta V = \frac{\rho I}{2\pi}\left(\frac{1}{rc1p1} - \frac{1}{rc2p1} - \frac{1}{rc1p2} + \frac{1}{rc2p2}\right) \quad (7)$$

The above equation gives the potential that would be measured over a homogenous half space with a 4 electrodes array.

Actual field surveys are invariably conducted over an in-homogenous medium where the subsurface resistivity has a 3-D distribution. The resistivity measurements are still made by injecting current into the ground through the two current electrodes and measuring the resulting voltage difference at two potential electrodes (P1 and P2). From the current (I) and potential (ΔV) values, an apparent resistivity (ℓa) value is calculated.

$$\rho a = k \frac{\Delta V}{I} \quad (8)$$

Where

$$K = \frac{2\pi}{\left(\frac{1}{rc_1p_1} - \frac{1}{rc_2p_1} - \frac{1}{rc_1p_2} + \frac{1}{rc_2p_2}\right)} \quad (9)$$

k is a geometric factor that depends on the arrangement of the four electrodes. Resistivity measuring instruments normally give a resistance value, R = ΔV /I, so in practice the apparent resistivity value is calculated by

$$\rho a = kR \quad (10)$$

The calculated resistivity value is not the true resistivity of the subsurface, but an "apparent" value that is the resistivity of a homogeneous ground that will give the same resistance value for the same electrode arrangement. The relationship between the "apparent" resistivity and the "true" resistivity is a complex relationship. To determine the true subsurface resistivity from the apparent resistivity values is the "inversion" problem.

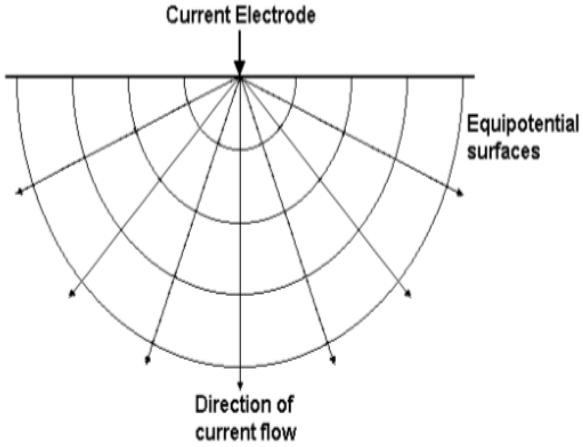


Figure 1: The flow of current from a point current source and the resulting potential distribution.

METHOD

Ten (10) Wenner-Schlumberger soundings were acquired at five (5) different locations widely distributed in the area. The traverses TR1, TR2, and TR8 are located along Old sapele road, TR3 and TR4 are located at presco road, while TR5, TR6, TR7 are located at Agbonmwoba primary school. In each case, ground resistivity data acquisition were made using the Petrozenith earth resistivity meter which enables the generation of a Pseudosection through the use of ZONRES 2d software.

The 2D data was acquired using a new array hybrid which is the Wenner-Schlumberger geometry. This array geometry is a new hybrid between the Wenner and Schlumberger arrays (Pazdirek and Blaha 1996), with n value = (1,…, 8) and a total profile length range of 0m -200m. The "n" value of this array is the ratio of the distance between C1-P1 (or P2-C2) electrodes to the distance between P1-P2 potential electrodes. The median depth of investigation for this array is about 10% greater than that for the Wenner array of same distance between the C1-C2 electrodes and for "n" values above 3, hence it has a better depth coverage and higher resolution.

The schematic diagram of the distribution of the 2D resistivity imaging profiles is shown in figure 2.

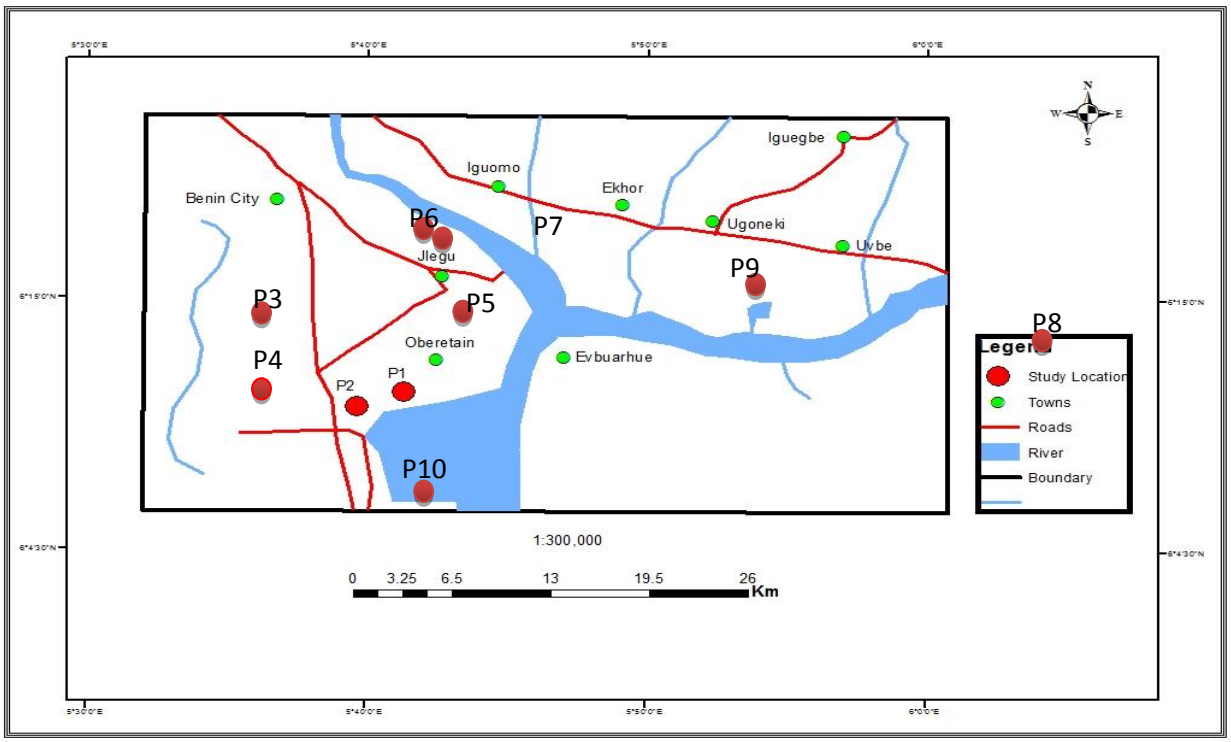


Figure 2: Base map of location showing the ten (10) sampled points.

The knowledge of the geology of the study area was put into consideration in interpreting the geoelectric images formed in correlation with related literatures.

RESULTS AND GEO-ELECTRIC SECTIONS

Ten (10) 2D traverses well distributed in the area were inverted. 2D data was inverted using ZONDRES 2d software. The distribution of resistivity along inverted model resistivity pseudosection gives 4 geo-electric layers identified along various profiles.

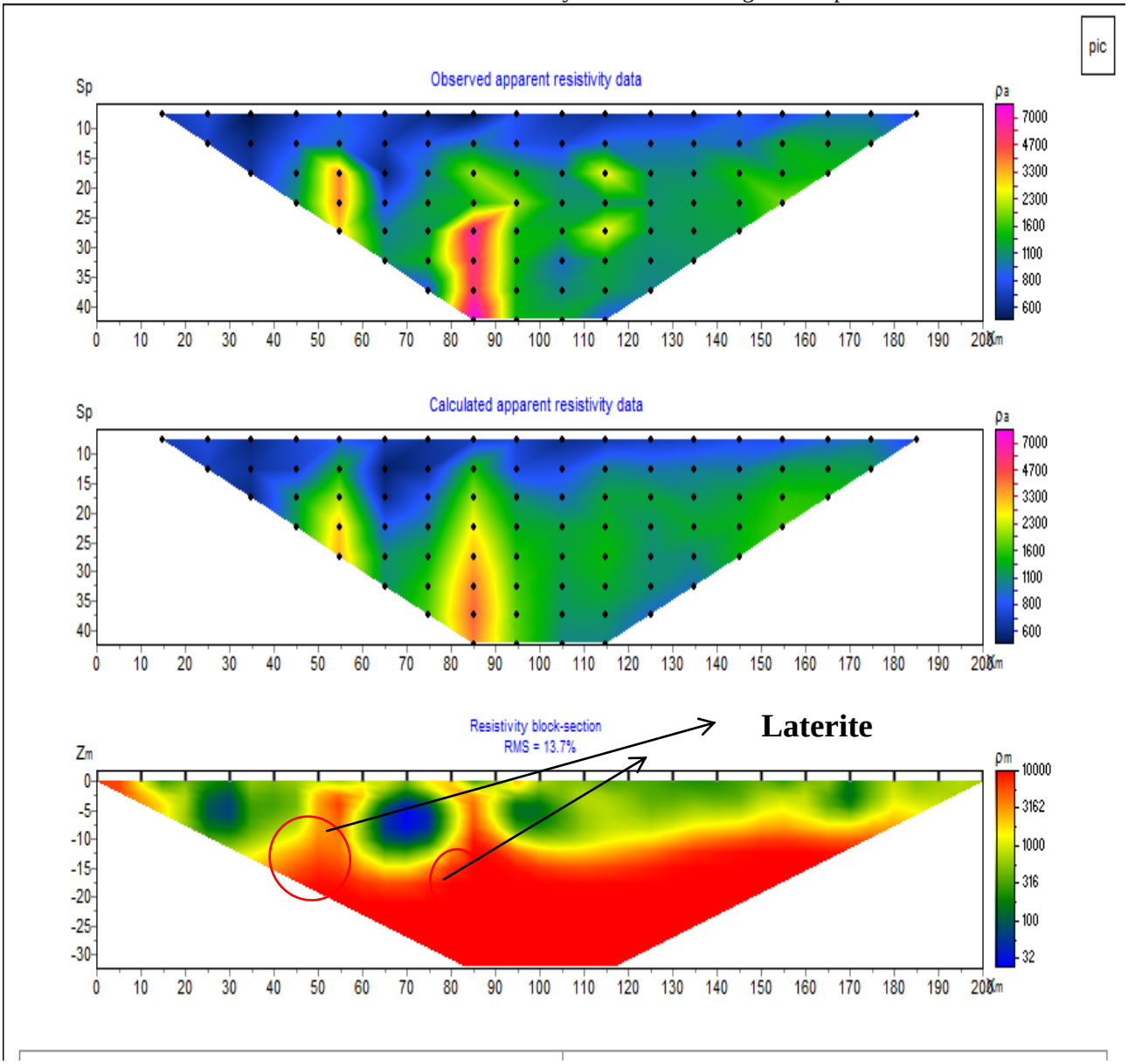


Figure 3: 2d Inverse Model Resistivity Section For Profile 1.

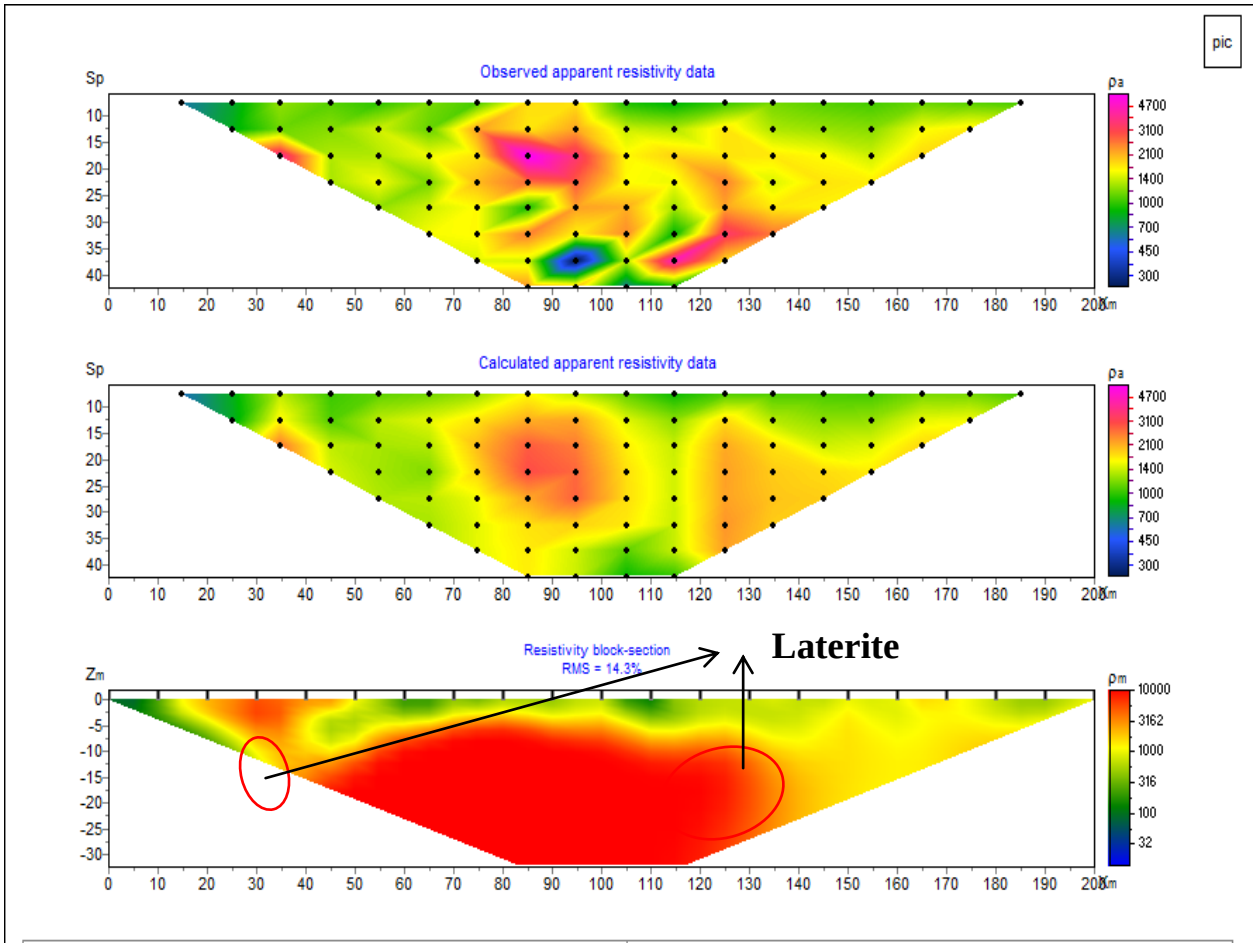


Figure 4: 2d Inverse Model Resistivity Section For Profile 2.

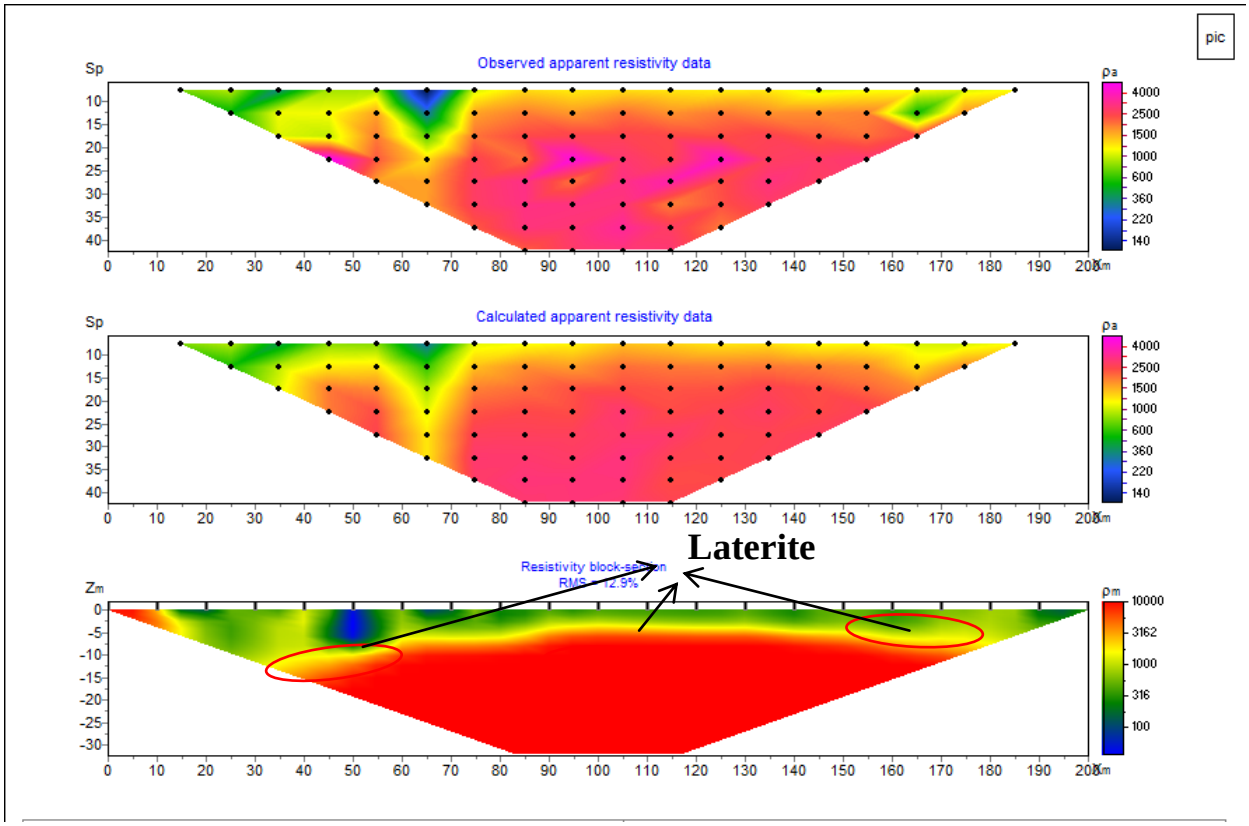


Figure 5: 2d Inverse Model Resistivity Section For Profile 3

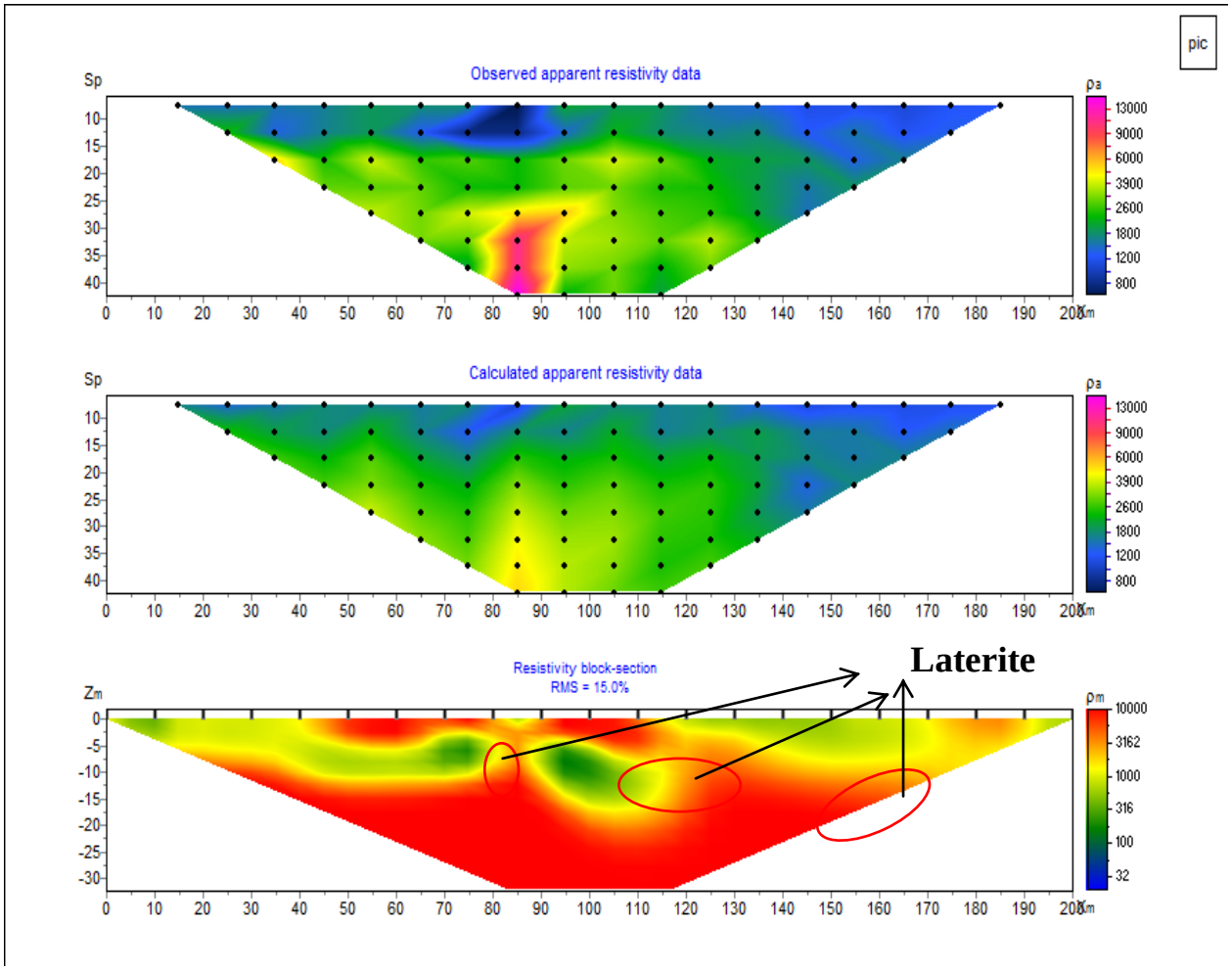


Figure 6: 2d Inverse Model Resistivity Section For Profile 4

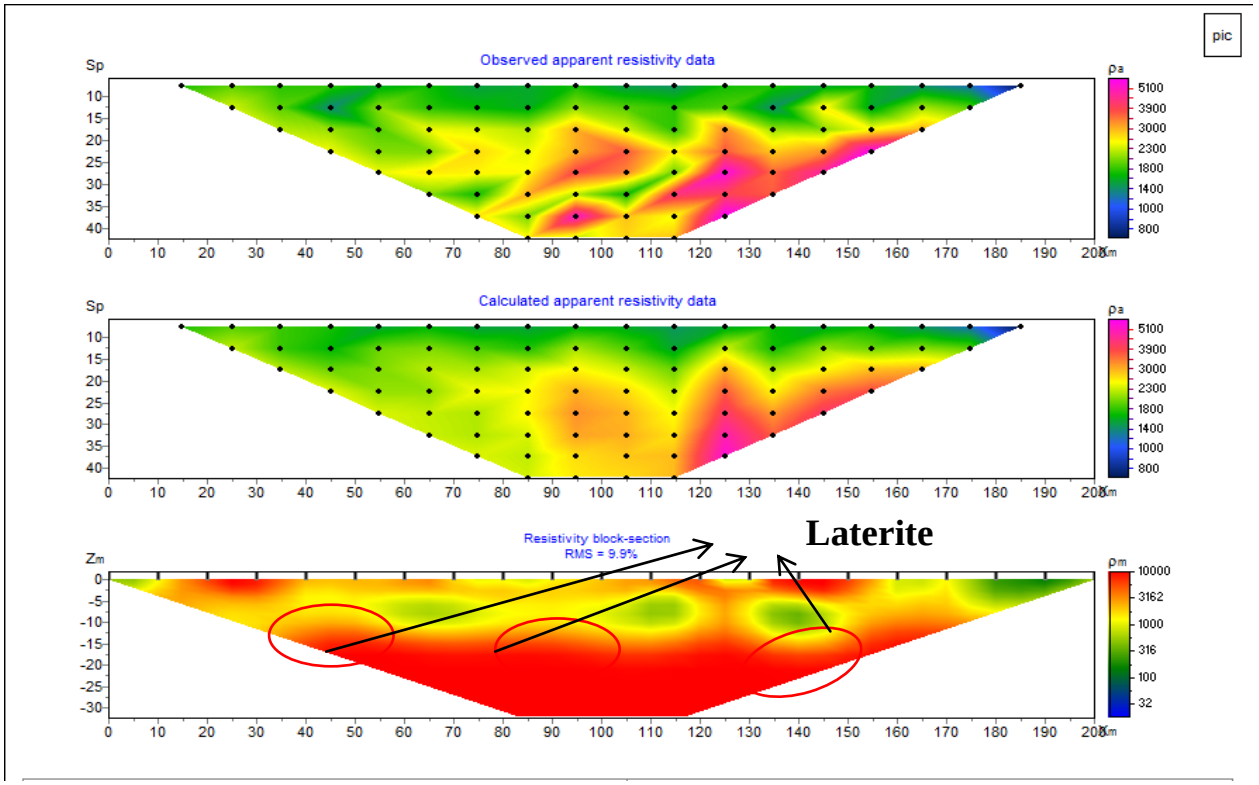


Figure 7: 2d Inverse Model Resistivity Section For Profile 5

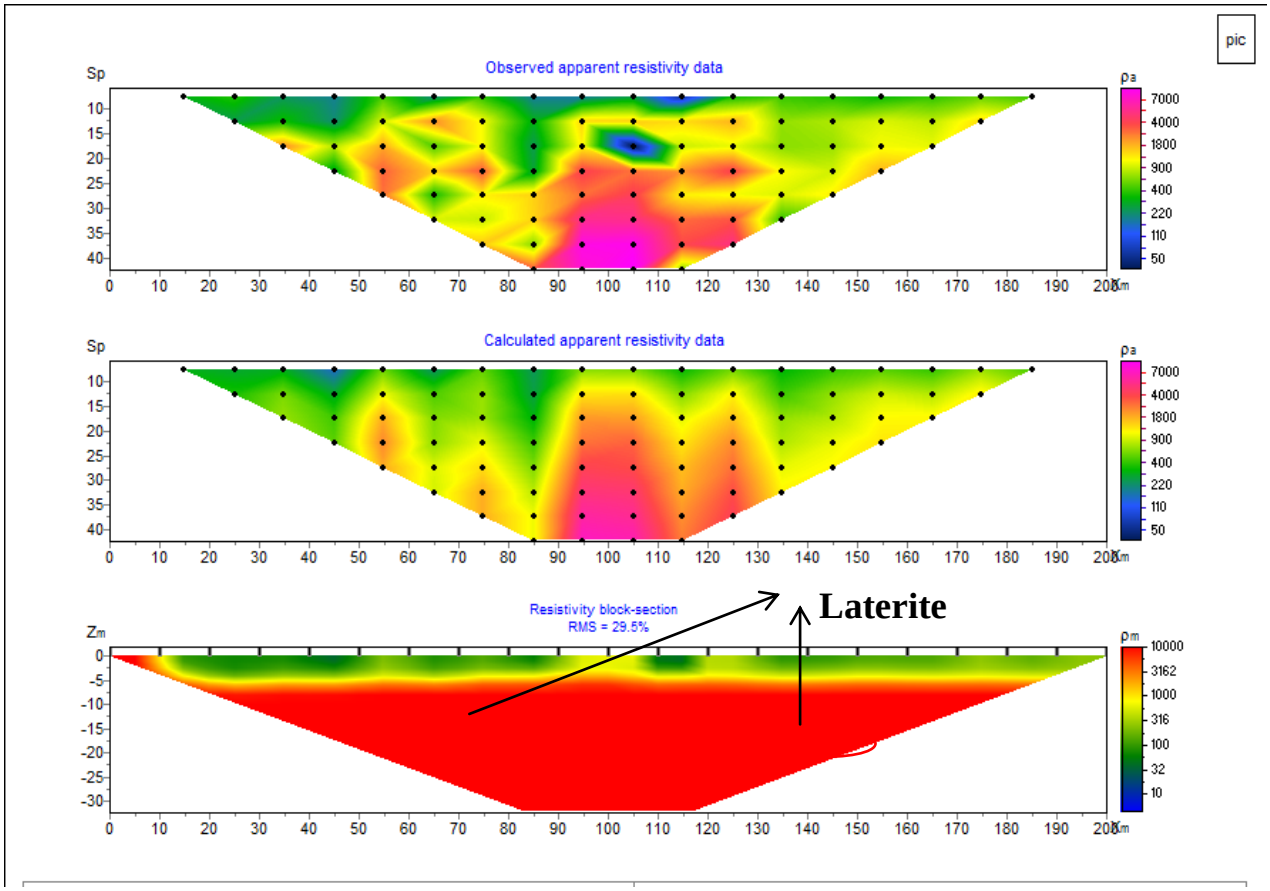


Figure 8: 2d Inverse Model Resistivity Section For Profile 6

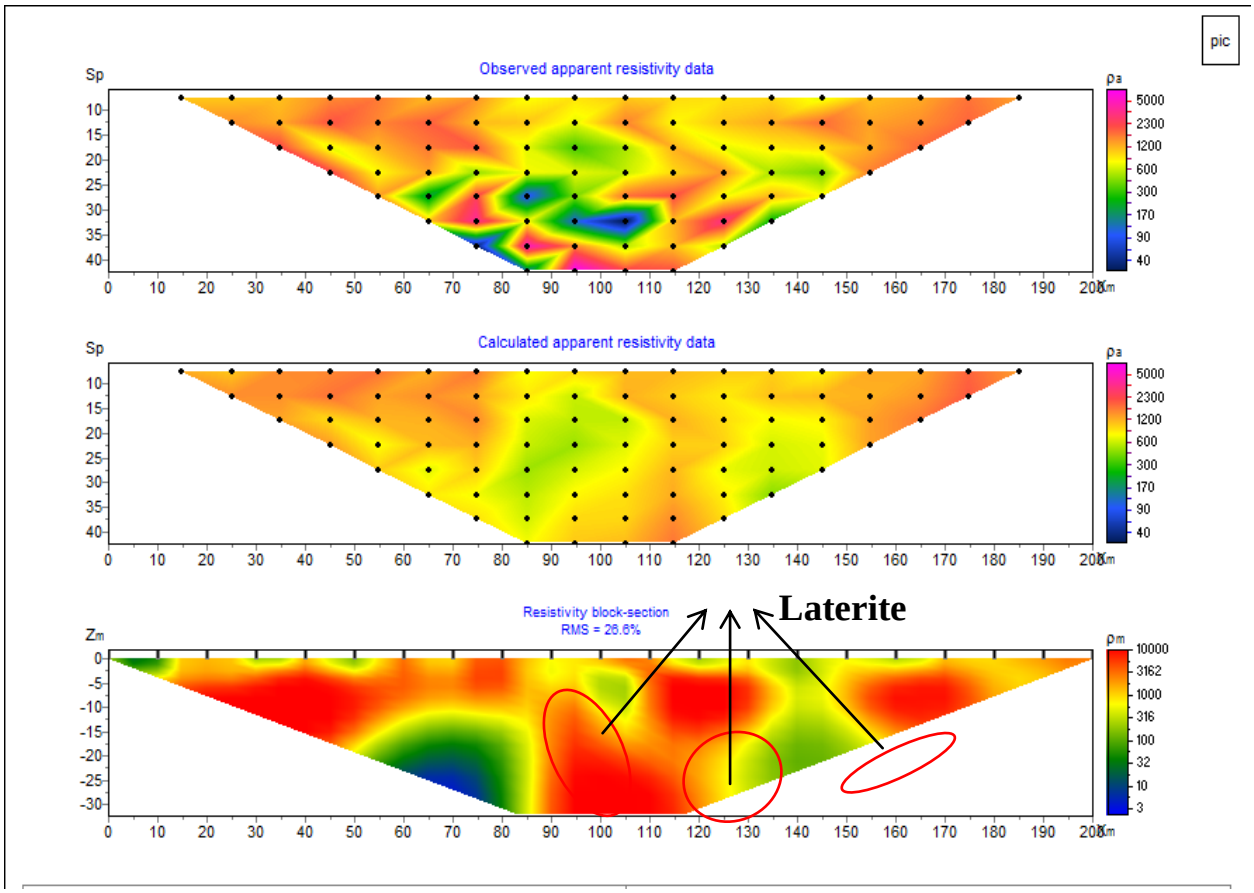


Figure 9: 2d Inverse Model Resistivity Section For Profile 7

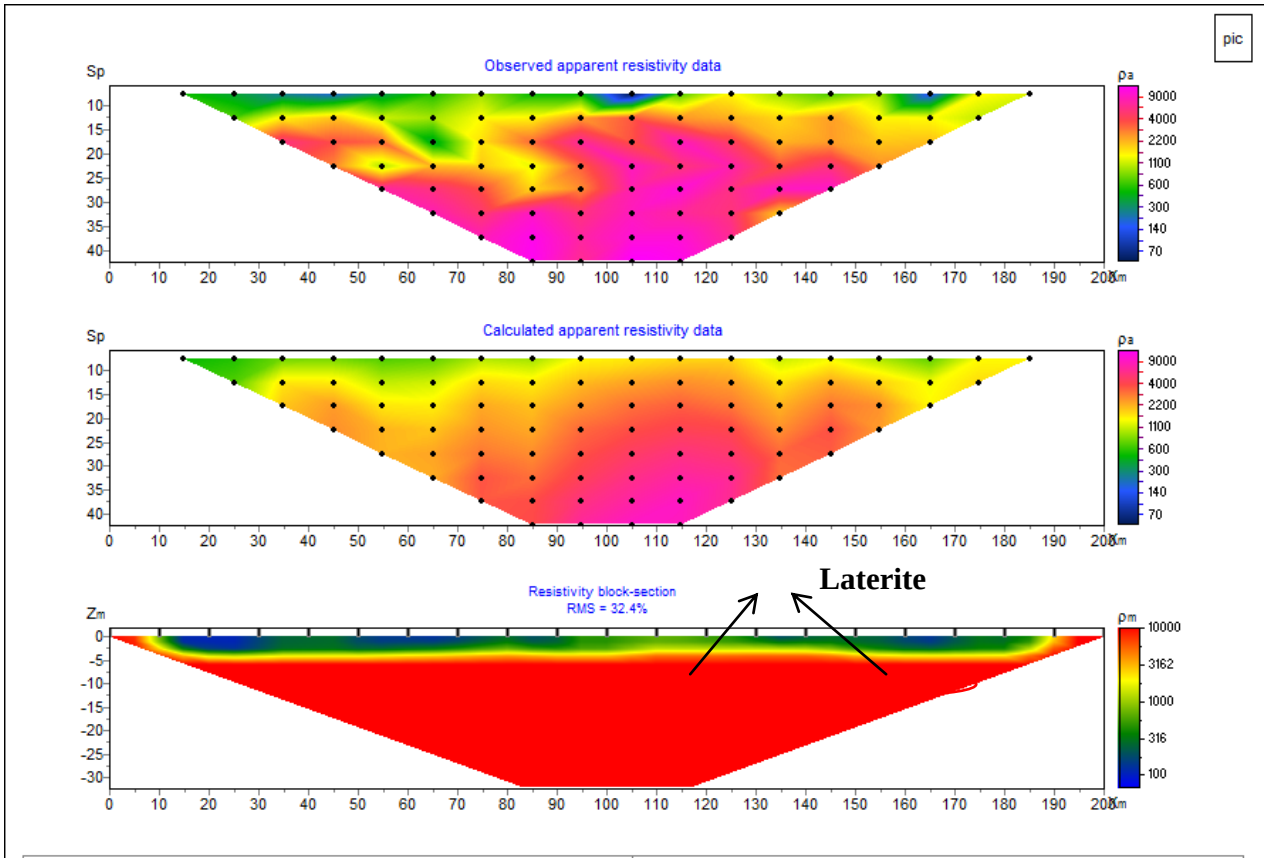


Figure 10: 2d Inverse Model Resistivity Section For Profile 8

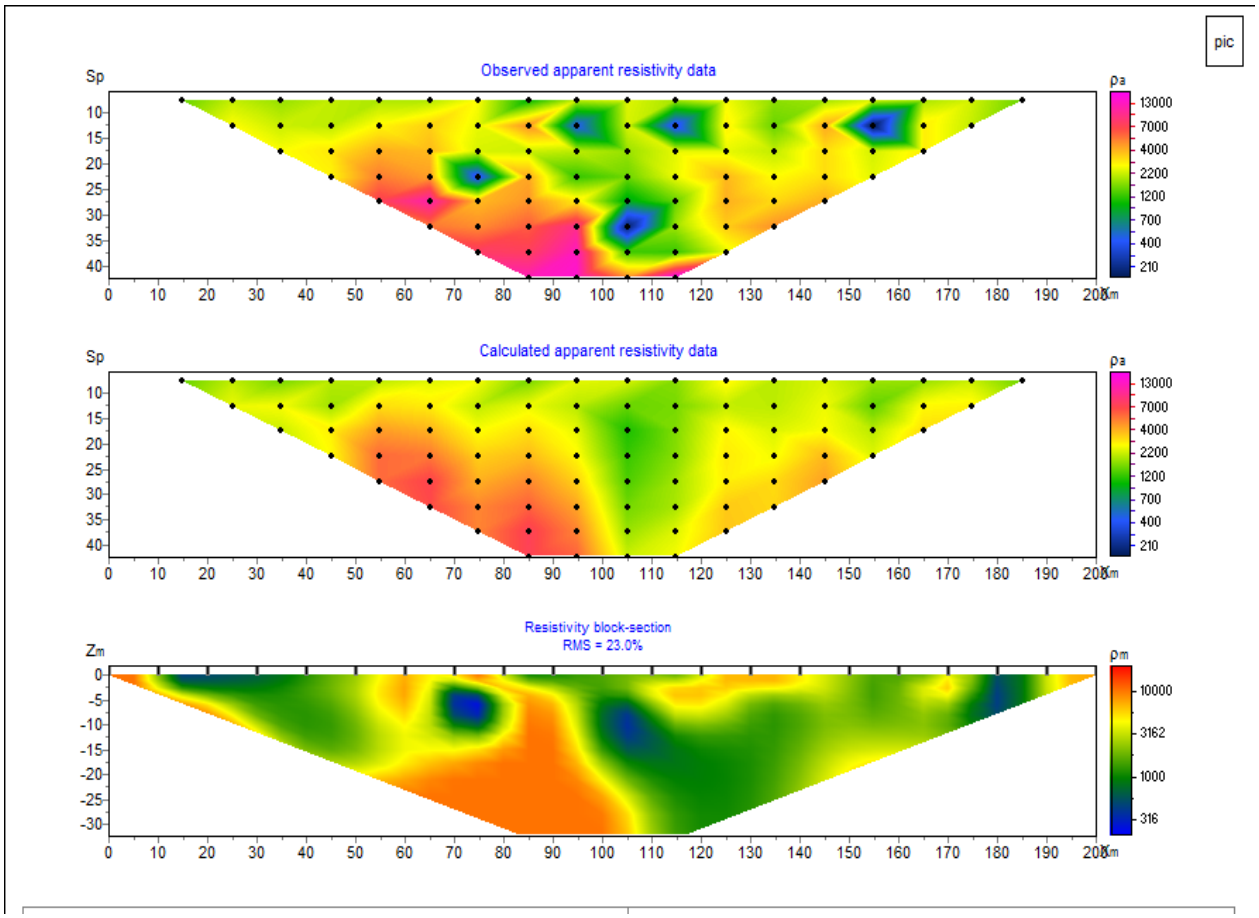


Figure 11: 2d Inverse Model Resistivity Section For Profile 9

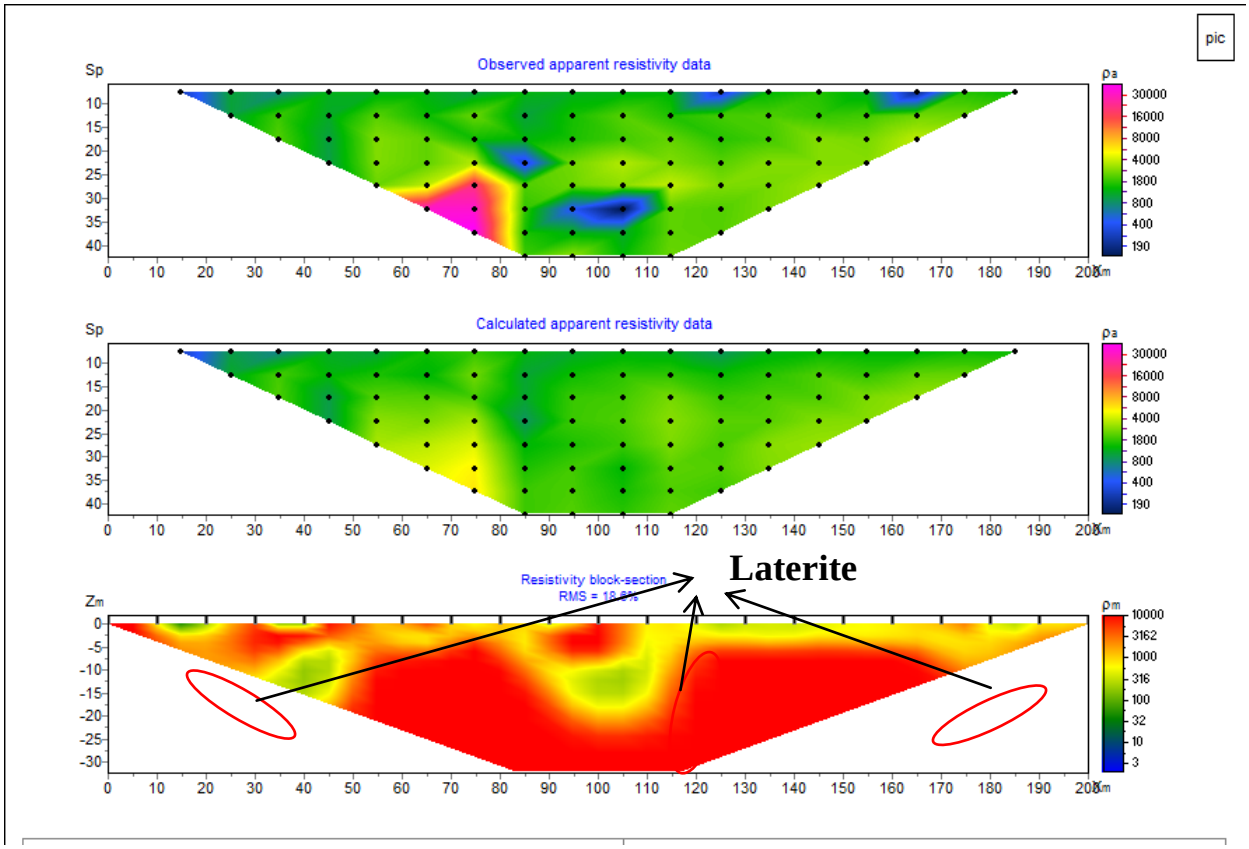


Figure 12: 2D INVERSE MODEL RESISTIVITY SECTION FOR PROFILE 10.

DISCUSSION OF RESULTS

2D inverted resistivity pseudosections for the ten (10) profiles are presented from figure 3 to figure 12 above. For effective delineation of laterite deposit in the study area, resistivity values of subsurface geologic materials from selected literatures were correlated to deduce the zones of laterite deposit, and its vertical and lateral extent. Low resistivity values (1-100Ωm) are indicatives of clay deposits. However, laterite deposit were interpreted as formations with resistivity values of 2081Ωm, which is directly underlain by gravel with resistivity range of 8290-10,000Ωm. These resistivity interpretations were coined from literatures i:e (Alile *et al*., 2012, Ezomo et al. 2015). From the pseudo-section, the blue colour band on the inverted resistivity block sections indicates clay deposit whose resistivity values ranges from 1- 100Ωm, while laterite deposit with resistivity value of 2081Ωm is seen to overlap between 1000 - 3162Ωm (shown by the red circles) seen in the resistivity block sections. Sand deposit with resistivity value of 570Ωm is seen on the green colour band of the resistivity block and gravel deposit (red) with a resistivity range of 8000 – 10,000Ωm, is seen to underlay the various formations from profiles 1-10.

The RMS errors obtained in the inverted models were between a minimum of 9.9% to a maximum of 29.5%. The models show a range of low, medium and relatively high resistivity zones.

Four (4) lithologic units were delineated namely; clay deposit (blue) with resistivity range of about 1 – 100Ωm, sand deposit (green) with resistivity range of about 200-570Ωm, laterite deposits (yellow to yellow red) with resistivity distribution overlapping from about 1000-3162Ωm and gravel deposit (red) whose resistivity distribution ranging from about 8000-10,000Ωm. Laterite deposit were found along

Traverses 1, 2 and 8 sampled at old Sapele road Ekiosa showed laterite deposits at depth 13-15m in TR (fig 3), 10-15m in TR2 (fig 4), and 5m in TR8 (fig 10) at horizontal spread of 40-90m, 10-20m, and 20-170m respectively. Along traverses 3 and 4 sampled at presco road Obaretin laterite deposits were seen at depth 10-15m in TR3 (fig 5), and 10-15m in TR4 (fig 6) at horizontal spread of 140-160m, and 160-180m respectively and also laterite deposit were found along traverses 5, 6 and 7 sampled at Agbonmwoba primary school at depth 5-15m in TR5 (fig 7), 5m in TR6 (fig 8), and 15-25m in TR7 (fig 9) at horizontal spread of 40-50m, 50-70m, and 110-120m respectively. TR9 showed no evidence of laterite deposit from its resistivity pseudo-section in fig 11. Laterite seen along TR10 occurred at same depth to other traverses. This result shows that laterite deposits along traverses 1, 2, 3, 4, 5, 7, and 10 are located almost at the same depth within the subsurface and implies that the subsurface geology distribution along these profiles are homogenous, and the laterite deposits along these

profiles are commercially viable for exploitation, while the laterite deposits delineated along traverses 6, and 8 in the study area are not homogeneously distributed with those delineated along other profiles at the depth imaged and as such are not commercially viable for exploitation.

Comparism Between Borehole Section And 2d Result Along Traverse 5

2D pseudosection along traverse 5 was compared with a borehole section drilled along this traverse around Iyanomon area of Agbonmwoba village. The borehole section is shown in figure 13(b) below. It is observed that the depth of laterite location obtained from borehole drilling data correlates with the depth imaged from the 2D tomography result along traverse 5 and other traverses. From both sections (resistivity and borehole) laterite deposit are seen as the top soil, with intercalation of sand and clay, with gravel deposits underlying the subsurface geologic formations. Thus only ERT with continuous imaging along a traverse is reliable for delineating subsurface geologic materials.

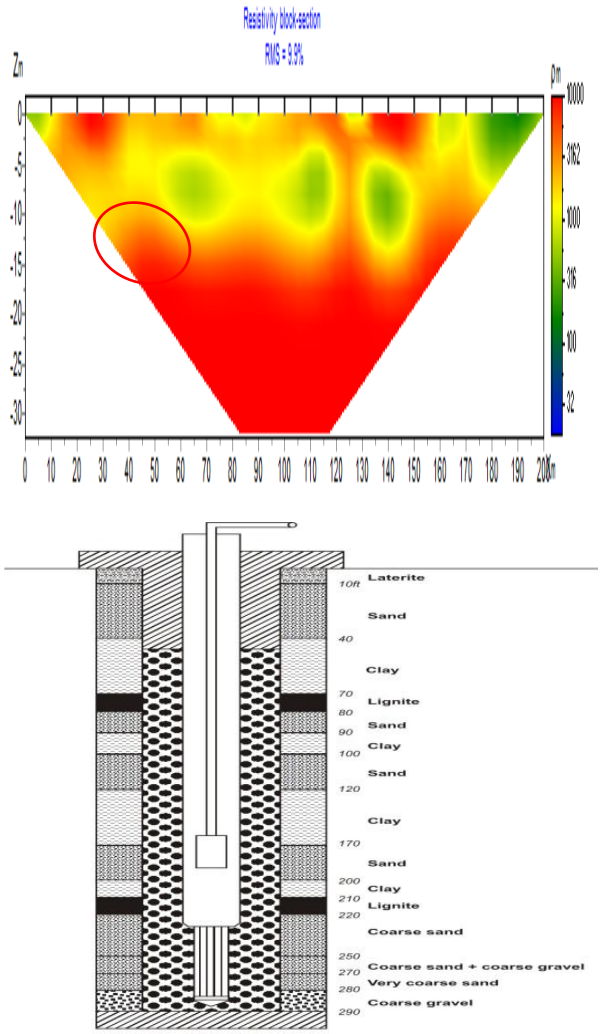


Figure 13(a)Showing the inverted profile and the lithologic section for the borehole drilled (Alile, et al., 2012) near Agbonmwoba primary school along profile 5.

CONCLUSIONS

The study evidently revealed a distinct delineation of the vertical and lateral deposits of laterites in the area, and correlated the results of the 2D resistivity tomography interpretation to borehole lithologic section in the area. This shows the sensitivity of 2D imaging technique to resolving subsurface lithologic units compared to pseudo-sections computed from 1D models. The results of the electrical resistivity imaging technique has helped to successfully delineate the depth and lateral extent of laterite deposits in Agbonmwoba area of Obaretin town, Benin City, Edo state.

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