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INVESTIGATION OF THE ELECTRICAL RESISTIVITY AND INDUCED POLARISATION RESPONSE OVER A SIMULATED MINERAL TARGET USIING POLE-DIPOLE CONFIGURATION

Oke O. P.[1], Alasi T. K.[2*]
[1]Department of Physics, Federal University, Oye- Ekiti, Nigeria.
[2]Department of Physics with Electronics, University of Ilesa, Ilesa, Nigeria.
Corresponding Author: Alasi T. K., Email: taiwo_alasi@unilesa.edu.ng

Abstract: A geophysical investigation was carried out in parts of Oye-Ekiti, to delineate and characterize the response of simulated mineral target in the area. Induced polarization (IP) and electrical resistivity (2D) were employed in this study. This research used a model tank experiment to stimulate, measure, and analyze data acquisition. The interpretation was carried out using Dipro software and statistical techniques to assess the accuracy of the pole configuration in defining mineral zones. The IP data revealed a number of subsurface zones with high real component current density which define the potential subsurface structural features (fractures/ faults zones) with possible kaolinite zone. The results from the geo-electric imaging models reveal a heterogeneous nature of mineralisation within zone of high resistivity (low conductivity) that may represent kaolin bearing quartzite vein. The 2D section of the kaolinated showed regions of both high and low conductivity with values that ranged from -100 to 74.9 Ω-1m^{-1} with structural trends in the NE-SW direction. The results from this research will serve as a future reference for other researchers who may wish to embark on a similar research in the mineralized zone and also help enlighten mining investors on the mineral potentials of the area.

Keywords: Geophysical; Fracture; Mineralisation; Subsurface; Revealed; Potentials; Kaolin

1 INTRODUCTION

The development of the solid minerals sector opens up the state to economic opportunities and consequently result into job creation though the establishment of various industries and provision of social amenities associated with improved standard of life. The commercial value of solid minerals has been estimated to run in to hundreds of trillions of dollars, with 70 per cent of these resources buried in the bowels of Northern Nigeria [1]. Mineral exploration is the initial stage of the mining cycle and the aim is to locate a new source of useful minerals. The search for mineral deposits begins with identifying large areas that may show the occurrence of certain type of ore deposit that could be developed as a resource. The exploration geophysical method, aims to detect and inferred the presence and position of ore minerals, hydrocarbons, geothermal reservoirs, groundwater reservoirs and other geological structures using surface methods to measure the physical properties of the earth along with the anomalies in these properties [2]. A wide range of geophysical surveying methods exists, for which there is an 'operative' physical property to which the method is sensitive. Geophysical methods are often used in combination with other geological information to gives a well detailed and accurate interpretation of the subsurface properties. The application of geophysical method ranged from shallow engineering studies, groundwater and mineral deposits explorations as well as in a variety of geo-environmental studies which includes investigations of contaminated sites or waste disposal areas [3-4].

Resistivity surveying investigates variations of electrical resistance by causing an electrical current to flow through the ground electrode. Resistivity soundings and resistivity profiling are the two major approached used in resistivity surveying. Resistivity soundings are used to determine the depth to bedrock, while resistivity profiling is mostly used to locate the boundaries of ore deposit. This study applies resistivity profiling in which the location of the spread are changed while maintaining a fixed electrode.

2 GEOLOGY OF THE STUDY AREA

The geology of the study area is significant as it contains several mineral deposits that are of economic importance. The basement complex rocks in the area can be divided into three main litho-units based on their mineralogy, texture, and structural features [5]. These units are the Older Granites, Younger Granites, and Metasedimentary rocks. The Older Granites are mainly composed of biotite and muscovite granite and are characterized by their massive and slightly foliated texture. The Younger Granites are mainly composed of biotite and hornblende granite and are characterized by their porphyritic texture. The Metasedimentary rocks are composed of various schists, quartzites, and gneisses and are characterized by their high degree of foliation and metamorphism. In addition to these litho-units, there are also some intrusions of dolerite and basaltic rocks in the area. These rocks are usually found as dykes and sills within the granite and gneiss formations. The area is known to contain deposits of gold, kaolin, tin, and columbite, among others. These deposits are often associated with the Older and Younger Granites and occur as veins and disseminations within the rock formations (Figure 1)[6].

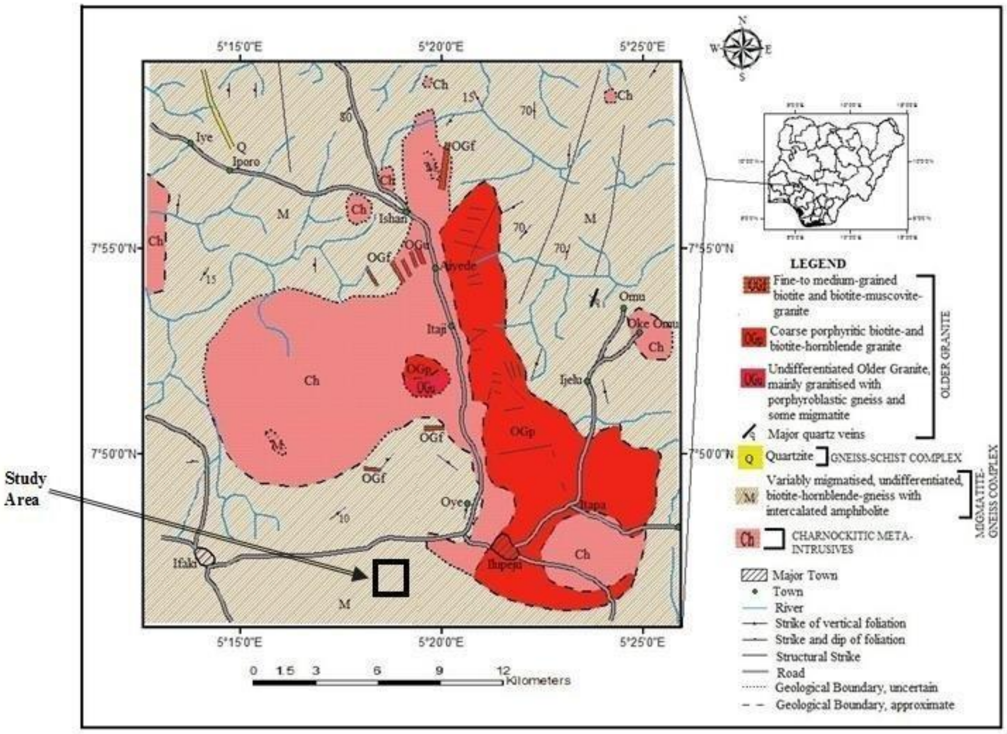


Figure 1 Geological Map Showing Minerals Deposit over Parts of the Study Area. (Adapted from Sheet 56 NGSA Map)

3 MATERIAL AND METHODS

The resistivity measurements are normally made by injecting a controlled electric current into the model tank through two current electrodes (C1 and C2), and measuring the resulting voltage difference at two potential electrodes (P1 and P2). From the current (I) and voltage (V) values, an apparent resistivity (pa) value is calculated [7]. The measurements are recorded using Ultraminires resistivity meter.

$$\mathrm{Pa} = \frac{KV}{I} \tag{1}$$

Where K is the geometric factor that depends on the arrangement of the four electrodes. Resistivity meters normally give a resistance value, $\mathbf{R} = \frac{\boldsymbol{V}}{\boldsymbol{I}}$ so in practice the apparent resistivity value is calculated by the equation below:

$$\mathrm{Pa} = \mathrm{KR} \tag{2}$$

The calculated resistivity value is not the true resistivity of the subsurface, but an “apparent” value which is the resistivity of a homogeneous ground that will give the same resistance value for the same electrode arrangement. To determine the true subsurface resistivity, an inversion of the measured apparent resistivity values was carried out using Dipro software. This transformed the data to a meaningful geophysical parameters.

$$R = \rho \frac{L}{P} \tag{3}$$

Where ρ is the constant of proportionality called resistivity.
But from Ohm’s law:

$$R = \frac{\Delta V}{I} \tag{4}$$

By substituting for ‘R’ in equation (4)

$$\frac{\Delta V}{I} = \rho \frac{L}{A} \tag{5}$$

$$\frac{\nabla V}{I} = \rho L \tag{6}$$

$$\rho = \frac{\Delta VA}{IL} \tag{7}$$

Where:
ΔV = Potential difference between any two points, measured in Volts.
I = Current flowing in the conducting medium between points, measured in amperes

R = Resistance between two points in the medium, measured in ohms.
ρ = Resistivity, measured in (Ωm)
Equation (4) can be used to determine the resistivity of any homogenous medium provided the geometry is simple. But when the medium is semi-infinite, equation (7) needs to be modified before it can be applicable. If we allow parameters A and L to shrink to infinitesimal size.
Then:

$$\rho = \frac{\frac{\Delta V}{L}}{\frac{I}{A}} \tag{8}$$

$$\rho = \frac{E}{J} \tag{9}$$

Where E is the electric field and J is the current density
From equation 9,$E = J\rho$
Imagine that the current source is located at the center of spherical body of radius ‘r’
And the current density is given as

$$J = \frac{I}{A} \tag{10}$$

Where A = area of the sphere given as

$$A = 4\pi r^2$$

$$J = \frac{I}{4\pi r^2} \tag{11}$$

Electric field becomes

$$E = \frac{I\rho}{4\pi r^2} \tag{12}$$

The processed parameters provide valuable insights into the subsurface properties and the presence of the simulated mineral target (Kaolin).

4 INDUCED POLARIZATION

The induced polarization (IP) method is based on a current stimulated electrical phenomenon observed as a delayed voltage response in earth materials. The IP effect is observed as a residual voltage decay after the current flow is interrupted (time domain IP) or as a frequency dependent resistivity (frequency domain). In the time domain, the voltage decay is recorded during a time interval Δt (ms) after the current flow is interrupted.

$$\Delta t = t_2 - t_1 \tag{13}$$

The calculated parameter is the chargeability, given by

$$M = \frac{1}{V}\int_b^a V(t)dt \tag{14}$$

The first step in interpreting data in electrical tomography is to construct a pseudosection. This is obtained by plotting the value of the apparent resistivity measured at the center of the array and at a depth dependent on the spacing between the electrodes [8].

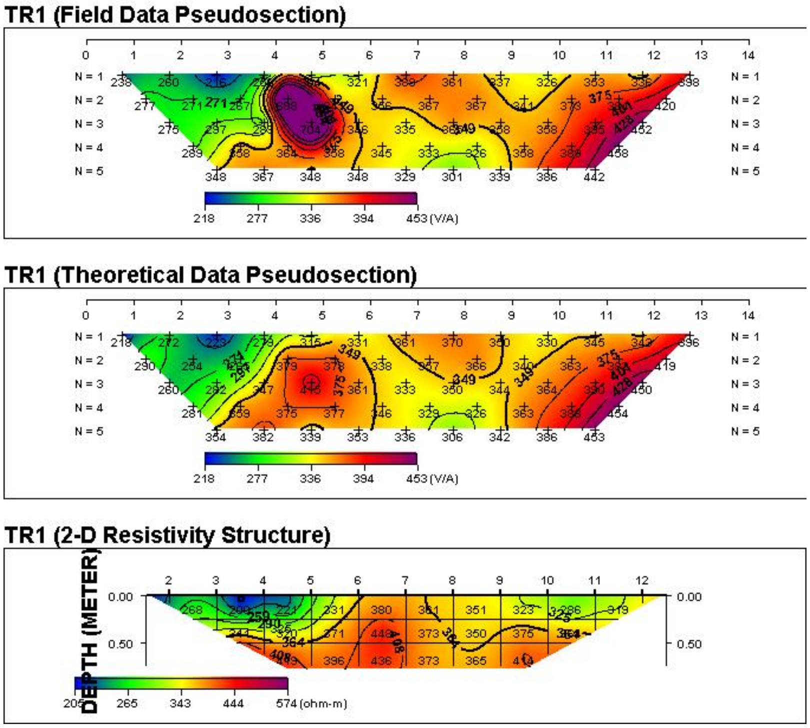
5 RESULTS AND DISCUSSION

The apparent resistivity measurements from the survey were commonly plotted in the form of a pseudo section. The pseudo section is a useful method to present the data in a pictorial form and also as an initial guide for further quantitative interpretation [9]. The pseudo section gives a distorted picture of the subsurface structure. The shapes of the contours depend on the type of array used as well as the true subsurface resistivity. A 2-D model that consists of a large number of cells is used to interpret the data [10]. A non-linear optimization method is then used to automatically change the resistivity of the model cells, to minimize the difference between the measured and calculated apparent resistivity values. The inversion problem is frequently ill-posed due to incomplete, inconsistent and noisy data. Smoothness or other constraints are incorporated to stabilize the inversion procedure such that numerical artifacts are avoided.

The apparent resistivity pseudo sections from the field survey using the pole-dipole array for profile 1, 2, 3 and 4 which trend N-S direction are shown in Figure 2a-d [11]. Positive response result into a probable fracture zones which act as a conduits for kaolin mineralisation. Both the field data and the theoretical data in Figure 2a-d corresponds. The positive corresponds is used to deduce the depth and location of both conductive and resistive zones. The less resistive zone (conductive area) ranged from 6-7, 8.5-11, 6-7, 5-7 at 0.5 m depth of profile 1,2,3,4 respectively which is the lateritic area (host).

Figure 3a-d shows the analysis of the resistivity data for kaolin deposition and the measured apparent resistivity pseudo section from a survey when using the pole-dipole array for profiling which trend N-S direction. Formation of high resistivity anomaly which were confined to the top at few meter with shallow subsurface layer of the top soil exhibit irregular and discontinuous shapes influenced by structural fracture or faults. A gradual transition in resistivity values were observed.

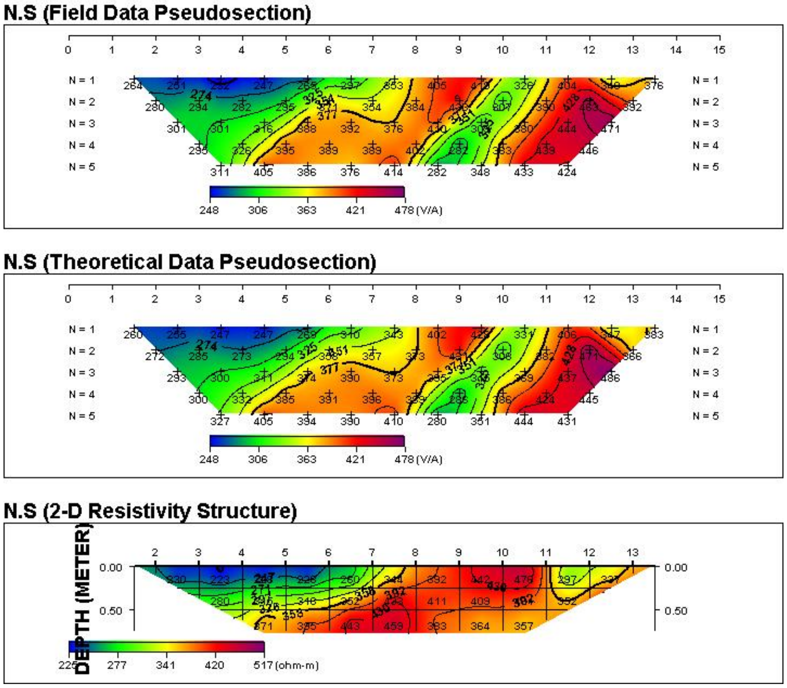
This transition zone represents the gradual change from high resistivity of the kaolin –rich zone to the lower resistivity of the surrounding soil layer


TR1 (Field Data Pseudosection)

TR1 (Theoretical Data Pseudosection)

TR1 (2-D Resistivity Structure)

Figure 2a 2-D Resistivity Image at Tr1


N.S (Field Data Pseudosection)

N.S (Theoretical Data Pseudosection)

N.S (2-D Resistivity Structure)

Figure 2b 2-D Resistivity Image Tr2

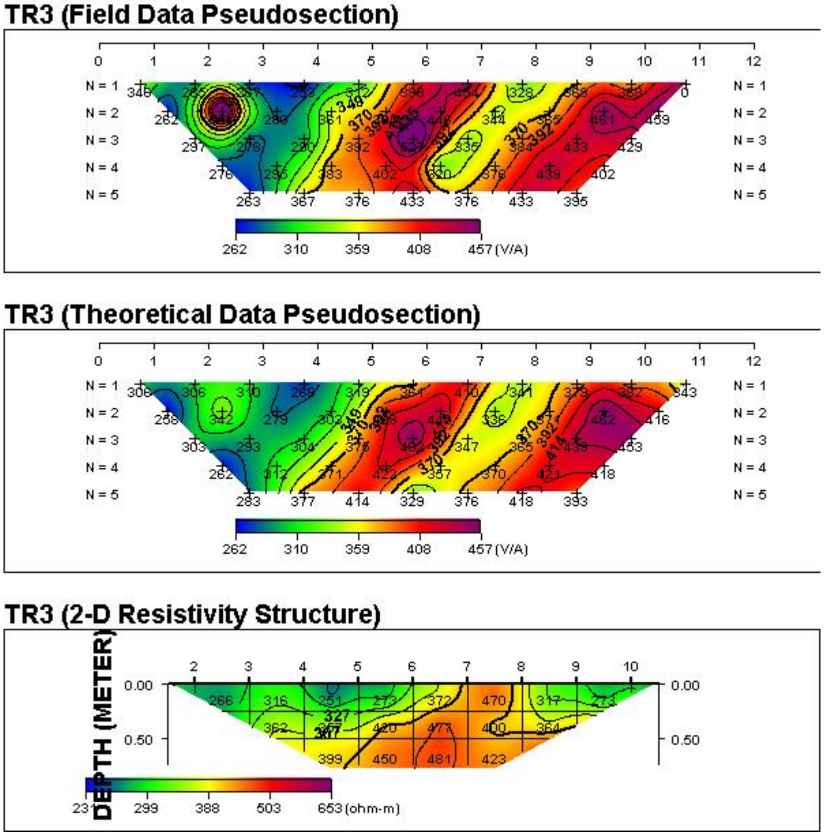


Figure 2c 2-D Resistivity Image Tr3

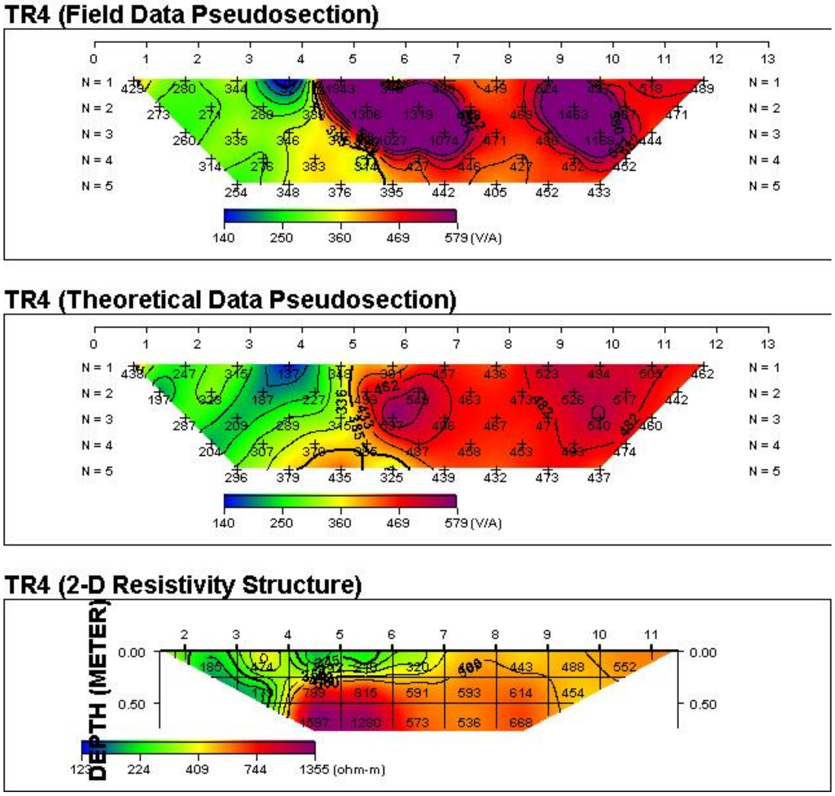
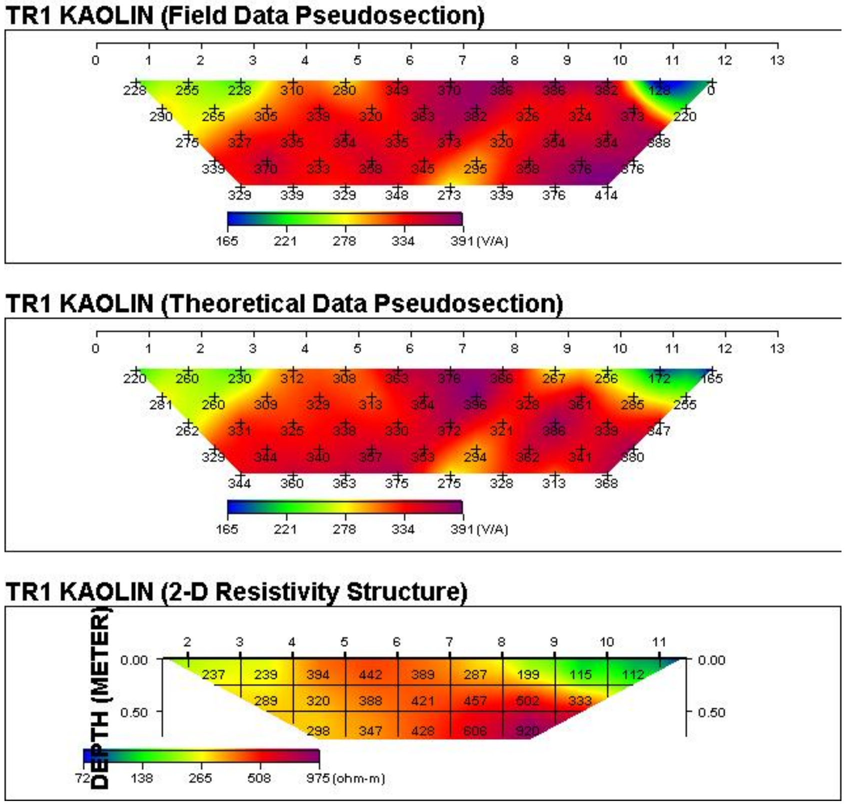


Figure 2d 2-D Resistivity Image Tr4

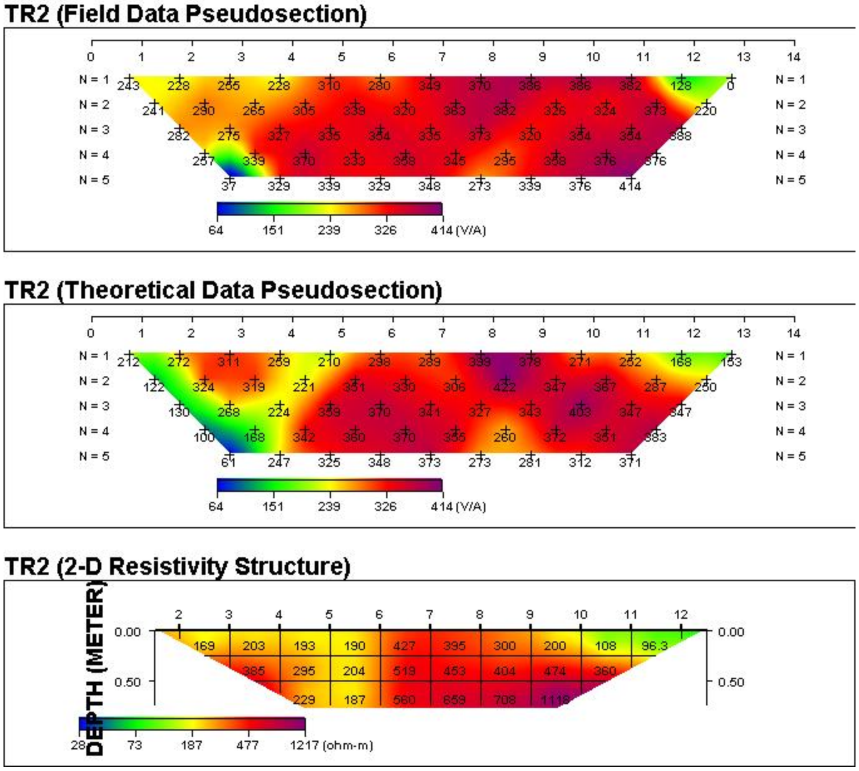


TR1 KAOLIN (Field Data Pseudosection)

TR1 KAOLIN (Theoretical Data Pseudosection)

TR1 KAOLIN (2-D Resistivity Structure)

Figure 3a Kaolinated 2-D Resistivity Image

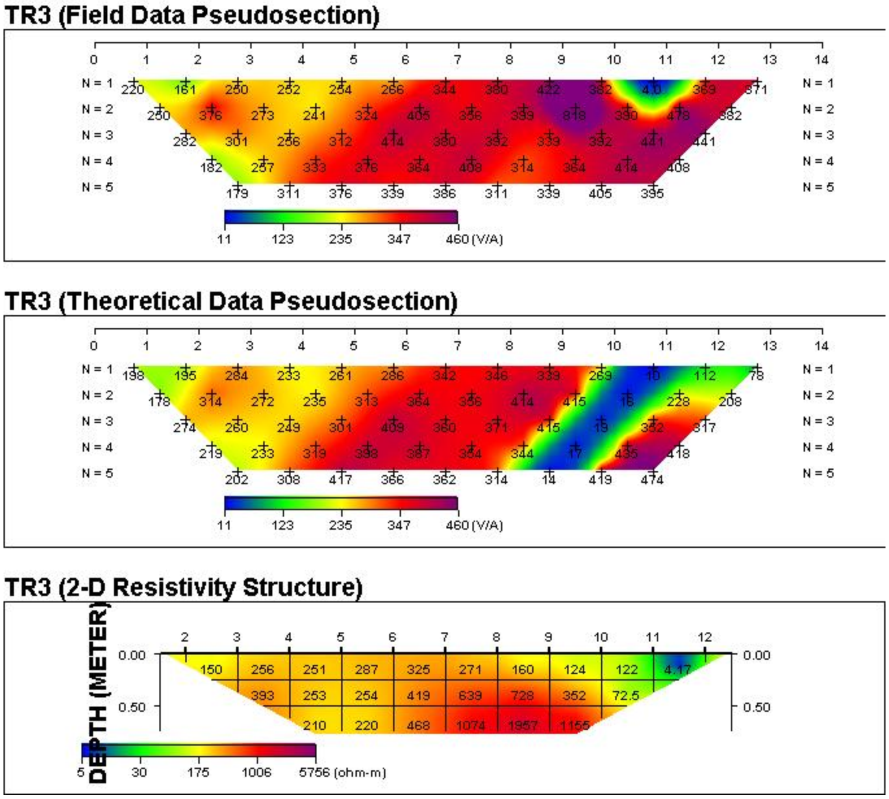


TR2 (Field Data Pseudosection)

TR2 (Theoretical Data Pseudosection)

TR2 (2-D Resistivity Structure)

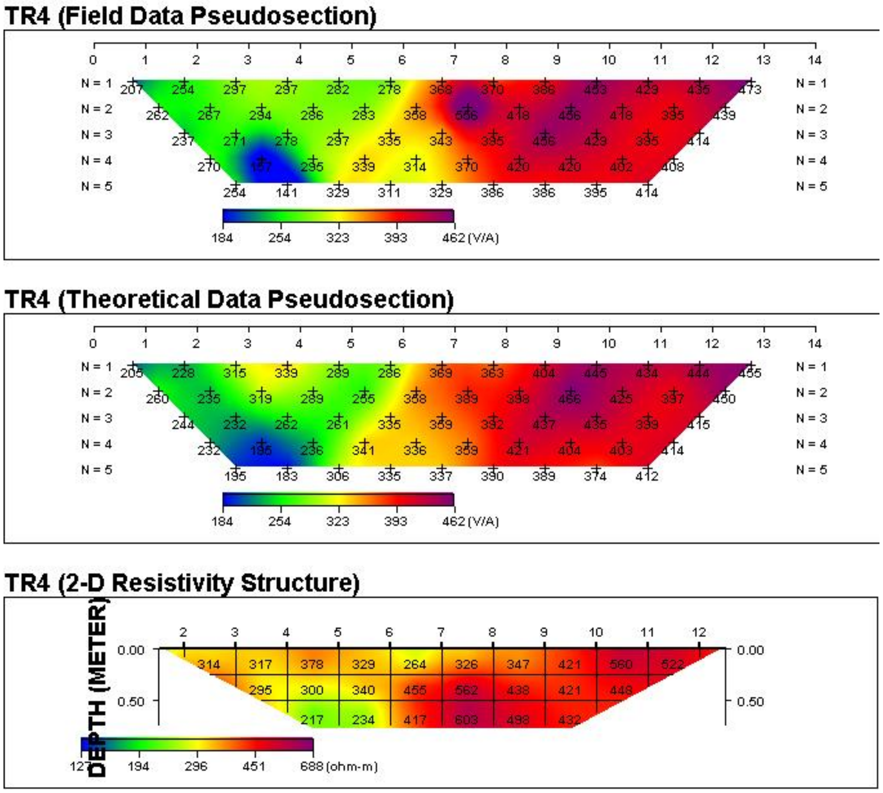
Figure 3b Kaolinated 2-D resistivity Image


TR3 (Field Data Pseudosection)

TR3 (Theoretical Data Pseudosection)

TR3 (2-D Resistivity Structure)

Figure 3c Kaolinated 2-D Resistivity Image


TR4 (Field Data Pseudosection)

TR4 (Theoretical Data Pseudosection)

TR4 (2-D Resistivity Structure)

Figure 3d Kaolinated 2-D Resistivity Image

The high resistivity anomalies associated with kaolin are consistent with its low conducting nature. The shallow depth and irregular shapes of the kaolin deposits suggest the influence of localized geological processes, sedimentation or erosion. Contrast in resistivity value with the surrounding soil layer highlights the potential of 2-D resistivity interpretation in mapping and delineating kaolin-rich zones. The gradual resistivity transition along the deposited boundaries indicates a gradual change in material properties likely influenced by variation in kaolin concentration or mixing with the surrounding soil. The results from the geo-electric imaging models reveal a heterogeneous nature of mineralisation within zone of high resistivity (low conductivity) that may represent kaolin bearing quartzite vein. Quartz veins signatures are identified by high resistivity (>200 ohm-m) anomalies both at shallow and greater depths [12]. These high resistive zones will serve as target zones for further mineral exploration for kaolin.

The high anomalies delineated from the study area yielded a high conductivity contrast. This elevated conductivity contrast is suggested to be as a result of fractures that consequently lead to potential mineralization and the geologic information of the area. Similarly, regions with very low conductivity results from the basement rock (quartzite) are suggested to serve as the potential mineralisation zones. This hold to the fact that a quartz veining structure shows very low conductivity contrast. The 2D sections, identified some regions of low and high current density values. The high values delineating regions of relatively high conductivity that could be attributed to occurrence of fractured zones. Profiles 1- 4 shows a very visible contrast with the relative high current density values. The region with low current density values could indicate resistive zones within the basement rocks having little or no fractures. This resistive zones are visible on Profiles 1, 2 and 4 and they exists between two rocks of varying conductivity. The result is fairly in agreement with that obtained by over parts of the study area [12]. The low conductive (elevated resistivity) zones is suggested to be a quartz veins owing to their high resistivity signature. Quartz veins and other hard rock kaolin deposit occur in zones along faults.

6 CONCLUSION

The study showed a structural trend with principal joint orientation in the NE and SW direction. This shows that the structures in the study area are in line with the principal joint direction in which mineralisation in the area is been structurally controlled. IP data revealed a number of subsurface zones with high real component current density which define the potential subsurface structural features (fractures/ faults zones) with possible kaolinite zone. These zones were interpreted as the potential or inferred structurally controlled fracture zones with possible kaolin zone. The 2D section of the kaolinated shows regions of both high and low conductivity with values that ranged from -100 to 74.9 Ω-1m^{-1} with structural trends in the NE-SW direction. The high conductive zones could be as a result of fracture which served as a potentials for either water or mineral exploration. The results of the study conformed to similar study on geophysical evaluation of laterite continuity of some part of Ikere kaolin deposit, southwestern, Nigeria [9].

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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