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3-DIMENSIONAL (3D) ELECTRICAL RESISTIVITY TOMOGRAPHY (ERT) GEOPHYSICAL INVESTIGATION OF MINERAL OCCURRENCES IN USEN, SOUTHERN NIGERIA

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Abstract

Electrical Resistivity Tomography (ERT) investigation was carried out at two (2) locations at Usen Ovia south west area of Edo State, Southern Nigeria. This was done with a view to target deposited minerals in the survey locations. The survey was done at two different locations
Elawure Grammar School field environment and Old Quarry environment, located within longitudes $6^0\,44'$, $6^0 45'$ ***East and latitude*** $5^0\,20'$, $5^0 22'$ ***North. A series of 2D apparent resistivity data were acquired in parallel and perpendicular directions using Dipole-dipole electrode configuration with resistivity meter SAS 1000 using electrode separations of a = 5m and inter spacing of L=10m making a total of 60m square grid for the lateral extent. The 2D data set were inverted separately using RES2DINV software producing 2D models of each line. Then the 2D data were collated into 3D data using the inversion code RES3DINV. The images were presented as 3D slices and block models. The total depth attained for the two locations were 15.7m (51.81ft). The material and aggregate that fall within the resistivity range (17.8 Ωm to 46938 Ωm) observed from the models are dolomite, maris, clay, alluvium, moraine, soil 40% clay, soil 20% clay, lateritic soil, sand clay/ clay sand, limonite, quartz, rock salt, lignite, syenite, basalt, schists, marble, conglomerates, and sandstone.***
The physical properties of lateritic soil, sand, sandstone, shale, clay and dolomite agree with some of the outcrop minerals found in the study area. This research has acknowledged the fact that the minerals that can be found in Usen are clay, sand, laterite, sand clay, sandstone, and dolomite.

Keywords: Tomography, resistvity, aggregate, minerals, configuration.

1.0 INTRODUCTION

MINERALSAND THEIR PHYSICAL PROPERTIES

According to [1] "although it is difficult to formulate a succinct definition for the word mineral, the following is generally accepted".

A mineral is a naturally occurring homogeneous solid with a definite (but generally not fixed) chemical composition and a highly ordered atomic arrangement. It is usually formed by inorganic process [1].

The physical properties of many minerals make them valuable. For example, graphite and diamond, both polymorphs of carbon have properties that make them useful for industrial purposes. Diamond, because of its great hardness is widely used as an abrasive and in cutting tools and it also can be a prized gemstone because of its clarity and brilliance. Graphite, in contrast, is very soft and is used as a lubricant and in the "lead" in pencils [1].

2.0 MOTIVATION FOR THE RESEARCH

The drastic fall in prices of petroleum products in the international market had made the country to experience hard economic situation leading into recession. This drastic fall has propelled the country to consider other ways of reducing the harsh economic realities by considering the exploration and exploitation of solid minerals. This led to the embarkation of this research.

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In addition, the outcrop of aggregates collected at the study area forms part of the motivation for this research.

3.0 AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to use 3D Electrical Resistivity Tomography (ERT) geophysical method to delineate the presence of mineral deposits at Usen, Ovia South West L.G.A Edo State.

The objectives are to:

1. Acquire 2D resistivity data in parallel and orthogonal directions of the survey locations;
2. Process the 2D data set separately using RES2DINV software.
3. Generate 3D data set from 2D data acquired;
4. Invert the 3D data set using RES3DINV software;
5. Produce block models of the 3D depth slices using VOXLER 2 software;
6. Determine the thickness of lithologic formation from depth to surface using 3D data set.

4.0 LOCATION AND TOPOGRAPHICAL MAP OF STUDY AREA

Usen town is a nuclear settlement in Ovia South-West L.G.A of Edo state. It lies approximately 4km North-West of Okada the administrative headquarter of Ovia North-East Local Government Area. This survey was carried out at two different locations within Usen Community. The areas are located within longitudes $6^0 44'$, $6^0 45'$ East and latitude $5^0 20'$, $5^0 22'$ North. The approximate average elevation is about 130 m above mean sea level. The survey locations at Elawure Grammar School field environment, the Old Quarry environment, Usen. With co-ordinates of latitudes, longitudes and elevations above sea level on a detailed scale are as shown below in Tables 1and 2

Table 1: Location 1 (Elawure Grammar School field environ)

Points	Latitude	Longitude	Elevation (m)	Latitude	Longitude	Elevation (m)
Point 1	$6.74062^0 N$	$5.35323^0 E$	126.6	$6.74015^0 N$	$5.35354^0 E$	130.6
Point 3	$6.74087^0 N$	$5.35373^0 E$	134.3	$6.74017^0 N$	$5.35355^0 E$	132.2

Table 2: Location 2 (The Old Quarry environ, Usen)

Points	Latitude	Longitude	Elevation (m)	Latitude	Longitude	Elevation (m)
Point 1	$6.74787^0 N$	$5.34222^0 E$	96.9	$6.74841^0 N$	$5.34220^0 E$	89.9
Point 3	$6.74787^0 N$	$5.34168^0 E$	94.0	$6.74816^0 N$	$5.34166^0 E$	92.3

The coordinates values of the sites were collected using the Geographical Positioning System (GPS) by Garmin and the base map is shown in Figure 1.

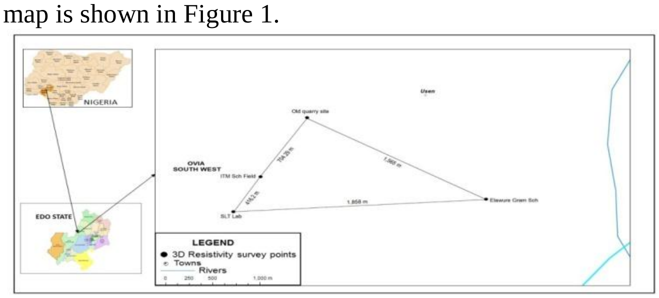

Figure 1: Usen Location and Topographical Map.

5.0 THEORY

BASIC PRINCIPLES

Consider an electrically uniform cube of side length L through which a current (*I*) is passing (Figure 2). The material within the cube resists the conduction of electricity through it, resulting in a potential drop *(V)* between opposite faces [2].

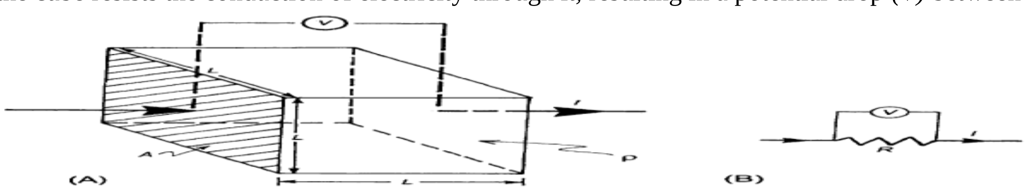

Figure 2: (A) Basic definition of resistivity across a homogeneous block of side length *L* with an applied current *I*and potential drop between opposite faces of *V*. (B) The electrical circuit equivalent, where *R*is a resistor [2].

The resistance (R)is proportional to the length (L) of the resistive material and inversely proportional to the cross-sectional area (A). Resistance (R) is proportional to length (L) divided by area (A) *i.e.* $R \propto L/A$.This can be written as $R = \rho L/A$, where ρ is the true resistivity.
For an electrical circuit, Ohm's Law gives $R = V/I$, where V and I are the potential difference across a resistor and the current passing through it, respectively.
This can be written alternatively in terms of the electric field strength (E; volts/m) and current density (J; amps/m^2) as

$$\rho = E/J \ (\Omega/m) \quad (1)$$

$$\rho = \frac{VA}{IL} \ (\Omega/m) \quad (2)$$

The constant of proportionality is the 'true' resistivity (ρ). According to Ohm's Law the ratio of the potential drop to the applied current (*V/I*)also defines the resistance (R)of the cube and these two expressions can be combined to form the product of a resistance (Ω) and a distance (area/length; metres); hence the units of resistivity are ohm-metres (Ωm). The inverse of resistivity ($1/\rho$) is conductivity (σ) which has units of siemens/metre (S/m) which is equivalent to mhos/metre ($\Omega^{-1}m^{-1}$) [2].

6.0 METHODOLOGY

3D ELECTRICAL RESISTIVITY TOMOGRAPHY (ACQUISITION)

Three-Dimensional Electrical Resistivity Tomography survey was carried out at Elawure Grammar School environment and Quarry Site environment.
Dipole-dipole array was used for this survey because of the low E.M. coupling between the current and potential circuits. The choice of a particular method is governed by the nature of the terrain and cost consideration [3]. The arrangement of Dipole-dipole array is shown in (Figure 3).

(a)

(b)

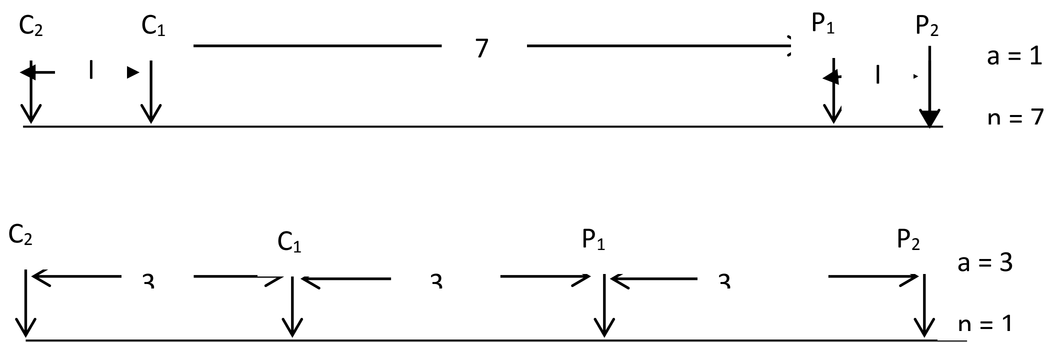

Figure 3: Two different arrangements of a dipole-dipole array measurement with the same array length but with different "a" and "n" factors resulting in very different signal strengths [4].
The series of parallel and orthogonal 2D data acquired was inverted using RES2DINV code [5,6] to produce 2D models for each profile. The 2D data later collated into 3D data set and inverted using RES3DINV code [7,8] and VOXLER- 2 software to give 3D models which were displayed as horizontal depth slices and block models.
The 3D slices and block models were interpreted using standard resistivity table showing that the surveyed area was suspected to contain limestone, dolomite, maris, clay, alluvium, moraine, soil 40% clay, soil 20% clay, lateritic soil, sand clay/ clay sand, limonite, quartz, rock salt, lignite, granite, syenite, gabbro, basalt, schists, marble, consolidated shale, conglomerates, and sandstone. With resistivities ranging from 17.8 Ωm to 46928 Ωm for both units electrode spacing.

7.0 RESULTS AND INTERPRETATION

Elawure Parallel –X and Orthogonal -Y 2D Models.

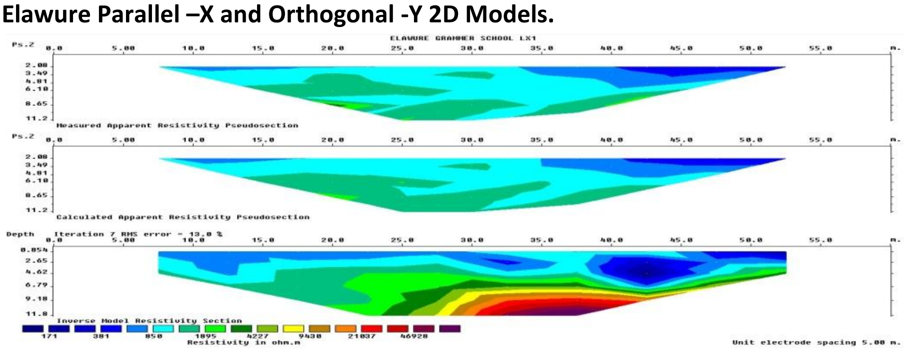

Figure 4: Elawure line Lx_1; 2D smoothness constrained inversion model resistivity section

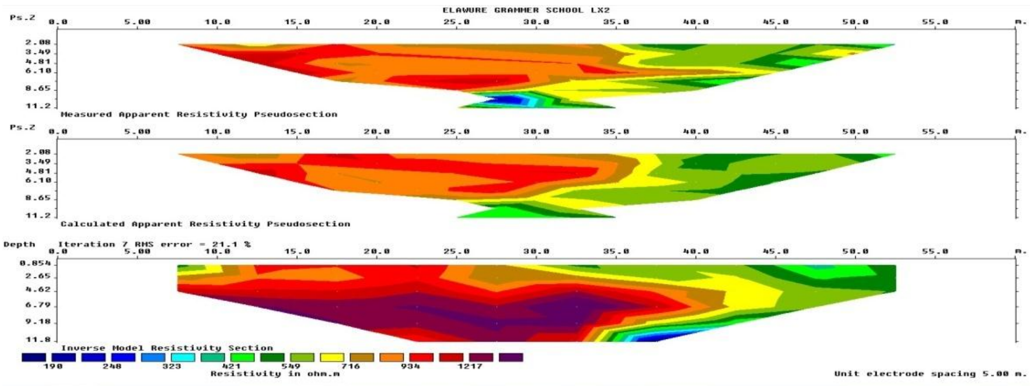

Figure 5: Elawure line Lx_2; 2D smoothness constrained inversion model resistivity section

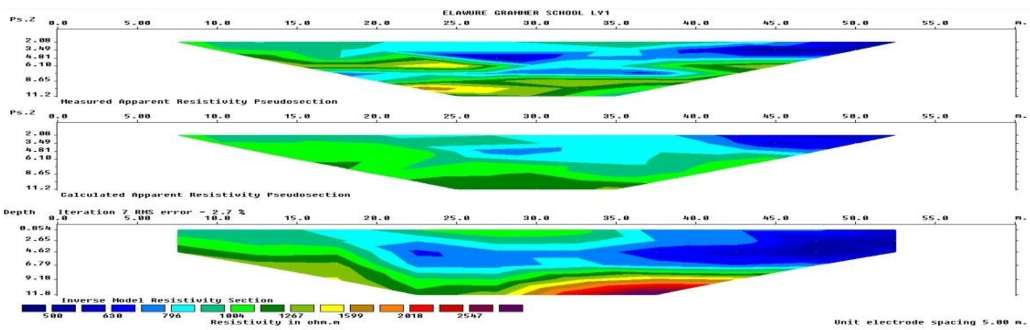

Figure 6: Elawure line Ly_1; 2D smoothness constrained inversion model resistivity section

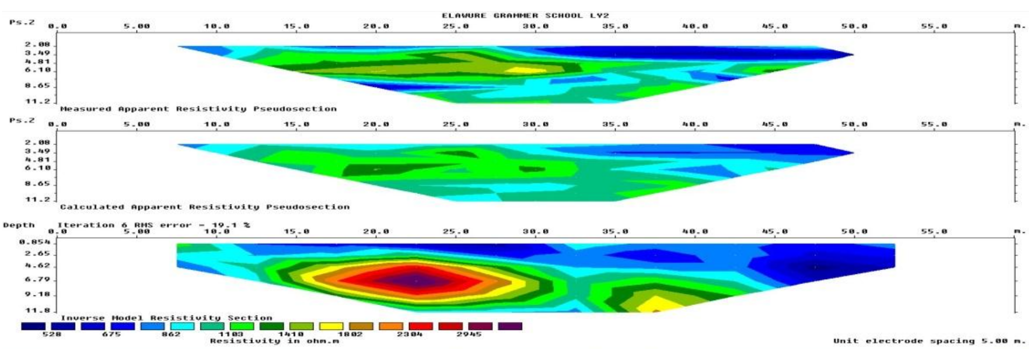

Figure 7: Elawure line Ly_2; 2D smoothness constrained inversion model resistivity section

Quarry Site Parallel –X and Orthogonal -Y 2D Models. Location

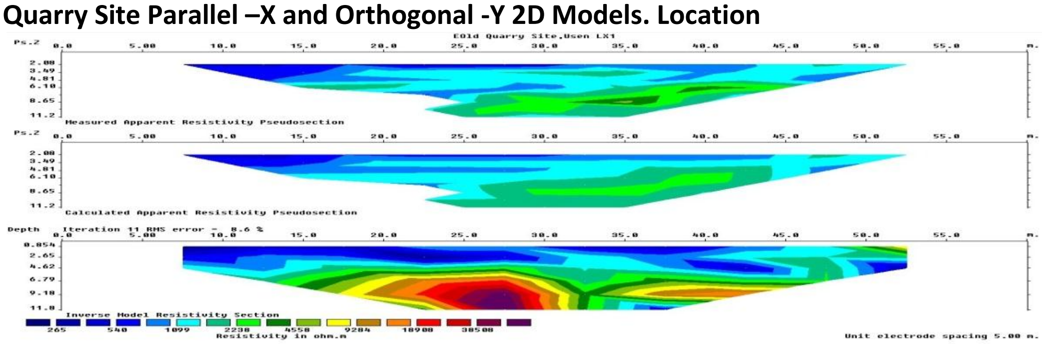

Figure 8: Quarry Site line Lx_1; 2D smoothness constrained inversion model resistivity section

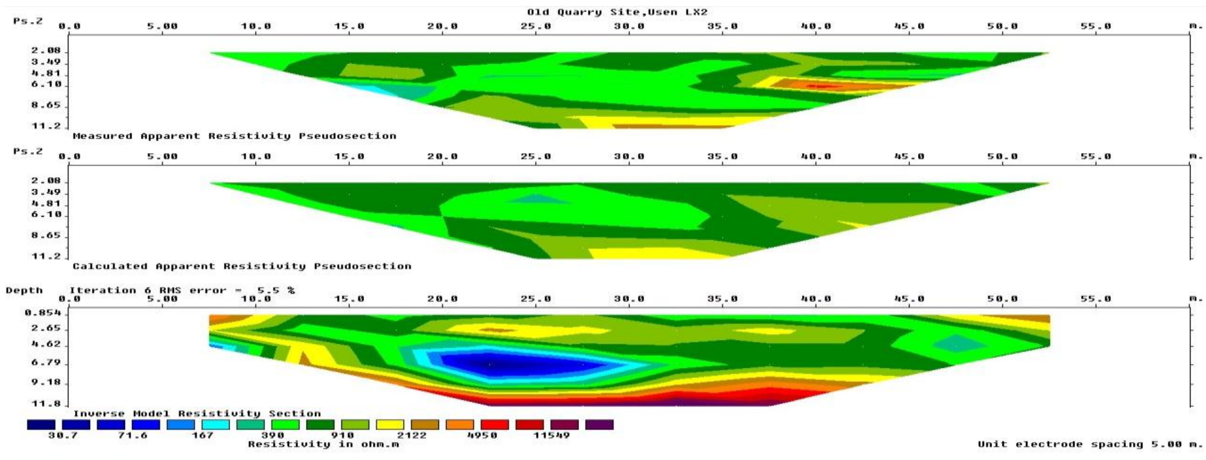

Figure 9: Quarry Site line Lx_2; 2D smoothness constrained inversion model resistivity section

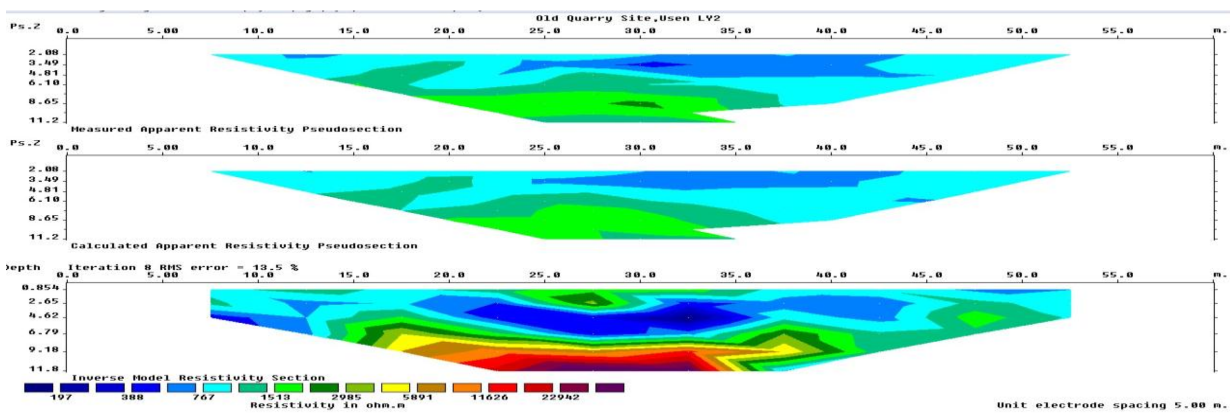

Figure 10: Quarry Site line Ly_1; 2Dsmoothness constrained inversion model resistivity section

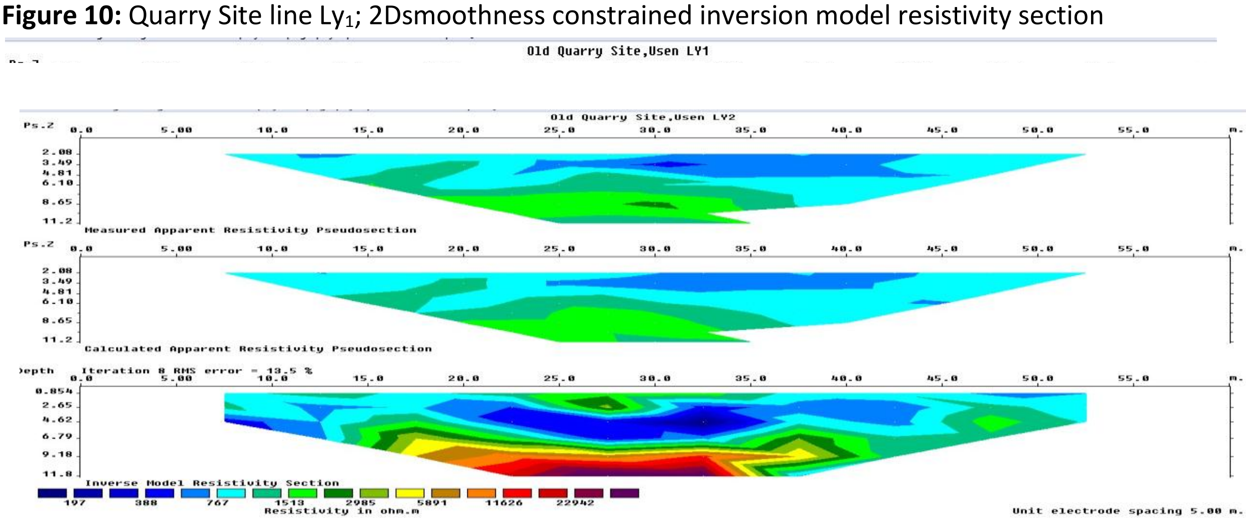

Figure 11: Quarry Site line Ly_2; 2D smoothness constrained inversion model resistivity section

8.0 DISCUSSION

The 3D inverse models obtained from the inversion of 2D data sets collated from the parallel 2D profiles in X and Y directions are presented as horizontal depth slices using RES3DINV. VOXLER 2 software was used to model the slices into block models [8].

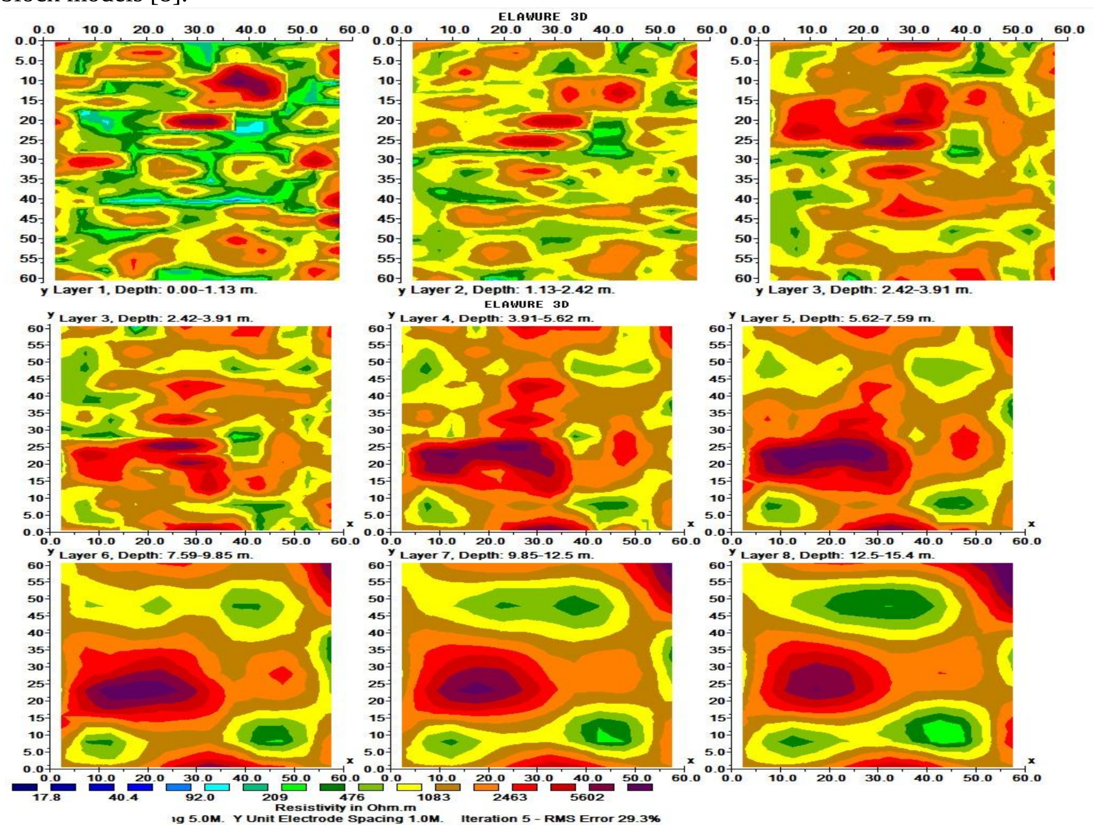

Figure 12: Elawure 3D horizontal depth slices of smoothness constrained inverse model.

Location 1: Elawure Gramma School Field Environment Figure 12 shows the horizontal depth slices displayed after the collation of all 2D data set into 3D, it is revealed that the 3D block is separated into eight (8) geo-electric layers. Having five (5) iterations with a total depth of 15.4 m with the first to the eighth layer having thicknesses of 1.13 m, 1.29 m, 1.49 m, 1.7 1m, 1.97 m, 2.26 m, 2.65 m and 2.90 m respectively. The first to forth layers having resistivity range of between 17.8 Ωm to 5602 Ωm for unit electrode spacing of 5.0 m Also for the last four layers having a high resistivity range of between 209 Ωm to 5602 Ωm for the same unit electrode spacing reveals that the layers are probably compose of limestone, dolomite, maris, clay, alluvium, moraine, soil 40 % clay, soil 20 % clay, lateritic soil, sand clay/ clay sand, limonite, quartz, rock salt, lignite, granite, syenite, gabbro, basalt, schists, marble, consolidated shale, conglomerates, and sandstone.

TABLE 3: Interpretation Location 1

NAME OF SURVEY SITE: ElawureGramma School Environment			
ELECTRODE SPACING: 5.0 m			
TOTAL DEPTH ATTAINED: 15.4 m			
LAYER NO	**THICKNESS (m)**	**RESISTIVITY RANGE Ωm**	**INTERPRETATION**
1	**1.13**	**17.8-5602 Ωm**	limestone, dolomite, maris, clay, alluvium, moraine, soil 40% clay, soil 20% clay, lateritic soil, sand clay/ clay sand, limonite, quartz, rock salt, lignite, granite, syenite, gabbro, basalt, schists, marble, consolidated shale, conglomerates, and sandstone.
2	**1.29**		
3	**1.49**		
4	**1.71**		
5	**1.97**	**209-5602 Ωm**	
6	**2.26**		
7	**2.65**		
8	**2.90**		

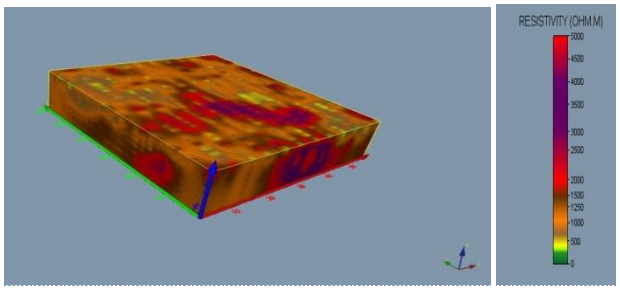

Figure 13: Elawure 3D block model top view

Figures 13represents the top view of 3D block model from collated 2D inverse model of Elawure survey.

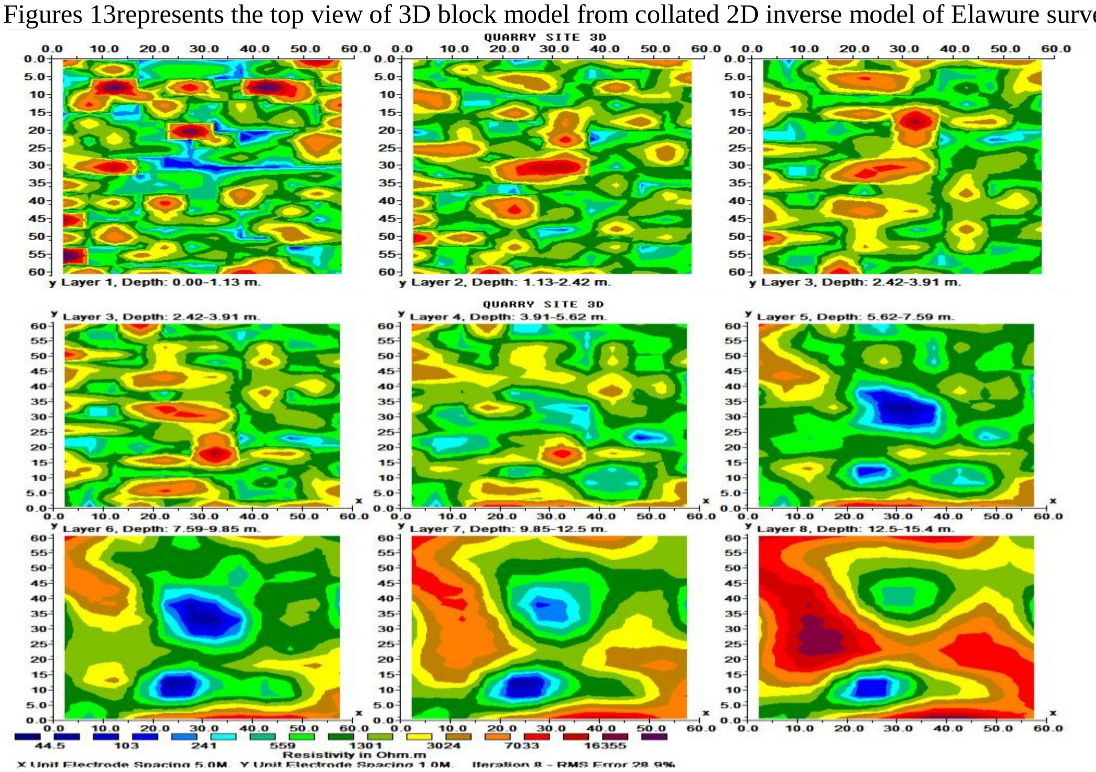

Figure 14: Quarry Site Environment, 3D horizontal depth slices of Smoothness

Location 2: Quarry Site Environ.

Figure 14 shows the horizontal depth slices displayed after the collation of Quarry site 2D data set into 3D data set using RES3DINV software, it is revealed that the geoelectric layers are divided into eight (8). Having eight (8) iterations with total depth of 15.4m. The first to the eighth layer having thicknesses of 1.13 m, 1.29 m, 1.49 m, 1.71 m 1.97 m, 2.26 m, 2.65 m and 2.90 m respectively. The first four layers having relatively lower resistivity of 44.5 Ωm to 7033 Ωm for unit electrode spacing of 5.0 m. Also the last four (4) layers having resistivity range of 44.5 Ωm to 16355 Ωm for the same unit electrode spacing. Using the standard resistivity table reveals that the layers are probably compose of limestone, dolomite, maris, clay, alluvium, moraine, soil 40% clay, soil 20% clay, lateritic soil, sand clay/ clay sand, limonite, quartz, rock salt, lignite, granite, syenite, gabbro, basalt, schists, marble, consolidated shale, conglomerates and sandstone.

TABLE 4: Interpretation Location 2

NAME OF SURVEY SITE: Quarry Site Environ.			
ELECTRODE SPACING: 5.0 m			
TOTAL DEPTH ATTAINED: 15.4 m			
LAYER NO	**THICKNESS(m)**	**RESISTIVITY Ωm**	**INTERPRETATION**
1	**1.13**	**44.5-7033 Ωm**	limestone, dolomite, maris, clay, alluvium, moraine, soil 40% clay, soil 20% clay, lateritic soil, sand clay/ clay sand, limonite, quartz, rock salt, lignite, granite, syenite, gabbro, basalt, schists, marble, consolidated shale, conglomerates, and sandstone.
2	**1.29**		
3	**1.49**		
4	**1.71**		
5	**1.97**	**44.5-16355 Ωm**	
6	**2.26**		
7	**2.65**		
8	**2.90**		

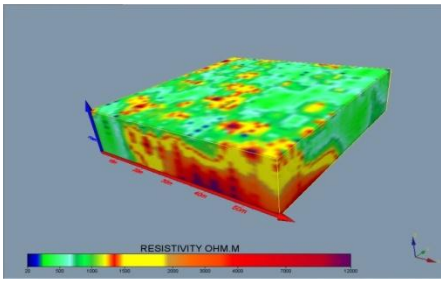

Figure 15: Quarry Site 3D block model top view

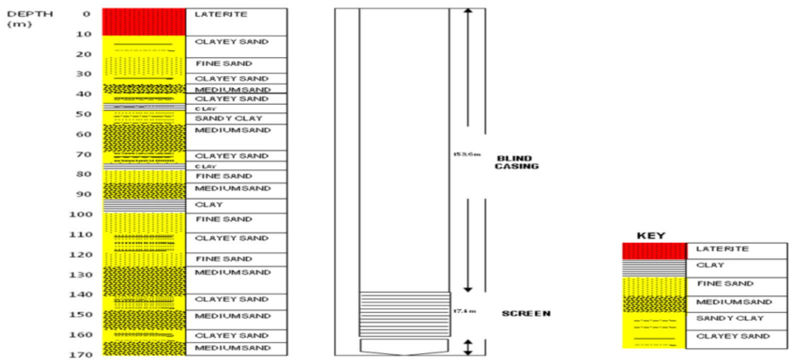

Figure 16: Lithologic Section of Usen Borehole. **Benin Owena River Basin**

Confirming from a drilled borehole log within the quarry site location shown on figure 16 Showed that the layers are composed of lateritic soil, sand, sand clay/ clay sand, granite, consolidated shale, clay, dolomite and sandstone.

9.0 FINDINGS

The findings of the study were as follows:

1. The ERT survey performed delineated the conductors of the survey as mineral deposits as resistivity of minerals identified is greater than 17.8 Ω*m* for all 3D models.
2. The mineral that lies within the resistivity distribution (17.8 Ω*m* to 46928 Ω*m)* observed on the slices and block models of all two (2) survey locations are limestone, dolomite, maris, clay, alluvium, moraine, soil 40% clay, soil 20% clay, lateritic soil, sand clay/ clay sand, limonite, quartz, rock salt, lignite, granite, syenite, gabbro, basalt, schists, marble, consolidated shale, conglomerates and sandstone.
3. The suspected mineral deposits that lies within the resistivity range (17.8 Ω*m* to 46928 Ω*m)* are; lateritic soil, sand, clay, sand clay, sandstone, granite, shale and dolomite.

10.0 CONCLUSION

This study has shown that ERT gives one of the best prospecting method for the investigation of mineral deposits in any survey location. It reveals that the use of Dipole-dipole arrays showed the subsurface features in terms of depth range and good resolution. The methods makes it possible to carry out 3D electrical resistivity tomography using a many-electrode system with single-channel equipment to achieve the same results as if a multi channel equipment were used.

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