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Adopting Electrical Resistivity Formula in Subsurface Imaging of Coal Deposit: Case Study of Lokoro, Nigeria.

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Abstract: *Electrical resistivity imaging was conducted in Lokoro, Northeast Nigeria, using dipole-dipole electrode configuration to image subsurface resistivity for coal identification in the study area (Lokoro). Measurements were carried out successfully across four profiles. Res2DInv software was used in data processing. Interpretations were taken from the measured resistivity variations processed using the Res2DInv software and the results of this research revealed that in profile one, coal resistivity variation is about 90-150 Ωm. In profile two and three, the coal resistivity variation is about 60-100 Ωm and 60-200 Ωm respectively. In the last profile, profile four, the coal resistivity variation is about 100-300 Ωm. By these resistivity variation of coal from this research, which is in agreement with many previous research on coal resistivity variation of about 100-400 Ωm, it is concluded that coal deposit in Lokoro, Northeast Nigeria is potential for mining, though further research on the size of the coal deposit using more sophisticated geophysical materials and methods is recommended.*

Keywords: *Coal; Lokoro; Dipole-dipole;Guyuk; Northeast Nigeria; Resistivity imaging; Resistivity variation.*

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I. Introduction

Coal is an organic-rich combustible sedimentary rock consisting of undecomposed organic matter accumulated in to, or transported from elsewhere to a depositional site. It is formed from unconsolidated accumulation of debris under metamorphic process (cycles). These cycles of accumulation and sediment deposition continued (Ghosh, 2009), followed by diagenetic and tectonic (Li, 2014) activity. The rank or grade of coal is determined by the percentage of carbon present in it. Coal was formed by plants that lived in freshwater environments, commonly grew in the tropics (Samanlangi, 2018). In the context of Nigeria, coal has significant role in electricity generation, steel production, cement manufacturing and paper production. Chemical and pharmaceutical products can be produced from the by-products of coal. Coal deposits, so far discovered in Nigeria, are located mainly in the Lower, Middle and Upper Benue Trough, with different characteristics in each of the geologic formations.

In regard to Geology of Nigeria, Lokoro lies on the Yola Arm of the Upper Benue Trough and the stratigraphic succession is given in Fig. 1.1. in this arm of the basin, the Albian Bima Sandstone lies unconformably on the Precambrian Basement. This formation was deposited under continental conditions (fluvial, deltaic, lacustrine) and is made up of coarse to medium grained sandstones, intercalated with carbonaceous clays, shales, and mudstones (Obaje, 2009).

Electrical Resistivity Imaging (ERI) is one of the near surface geophysical techniques proven to be successful and cost effective for identification of near surface lithology. It is a geophysical technique based on the principle of current flow to study the near surface structure of the earth. Vertical Electrical Sounding (VES) is one of the acquisition techniques associated with the resistivity method. Sounding (VES) measures resistivity variation vertically using Schlumberger configuration and imaging measures resistivity variation vertically and laterally using Wenner, Wenner-Schlumberger, and Dipole-dipole (Dahlin, 2003). For the purpose of this research, dipole-dipole configuration was adopted and Res2DInv was used for data processing

Res2DInv.exe program performs smoothness constrained inversion (automatic model interpretation) using finite difference forward modelling and quasi-Newton technique (Loke H. , 1999). Real resistivity is interpreted using automatic 2D smoothness constrained least-squares inversion. The smoothness constrain prevents unstable and extreme solutions, whereas a quasi-Newton technique reduces the numerical calculations (Loke M. a., 1996). The apparent resistivity value is calculated using potential difference data, electrical current injected, and geometry factor of dipole-dipole configuration and the real resistivity is calculated by using inversion method applied by Res2DInv software (Levieux).

In this research, electrical resistivity imaging is adopted to investigate presence of coal deposit in Lokoro using dipole-dipole electrode configuration.

II. Material and Methods

2.1 Geology of the Study Area

Lokoro, is located in Guyuk Local Government area of Adamawa State, north-east Nigeria. It lies between latitude 9^0 60′00″N and 9^0 85′00″N and longitude 11^0 64′ 00″E and $11^0$91′00″E. Lokoro lies on the Yola Arm of the Benue Trough Basin. The Benue Trough of Nigeria is a rift basin in central West Africa that extends NNE-SSW for about 800 km in length and 150 km in width (Obaje, 2009). The geology of Lokoro approximately described the dark, carbonaceous shales that occurred within the Bima Sandstone. Figure 3 shows the dark, carbonaceous shales describing the Bima Sandstone of the study area, Lokoro. On the Bima Sandstone, the Yolde Formation of Cenomanian age, lies conformably. This represents the beginning of marine incursion which is made up of sandstones, limestones, shales, clays and claystones (Obaje, 2009). The geology of the study area made it even more interesting to investigate the likelihood of coal deposit in Lokoro as preliminary study to serve as reference for future geophysical investigation and possible development of coal in Lokoro.

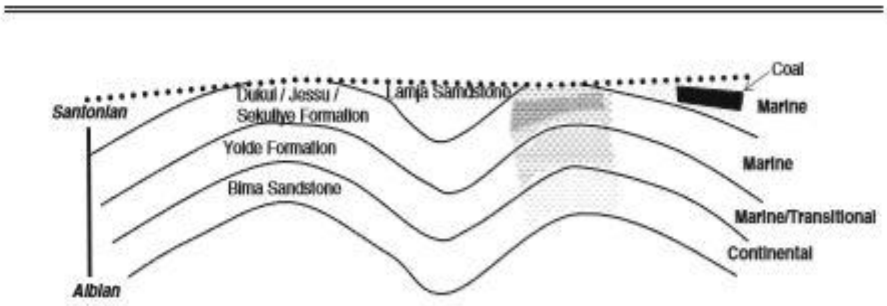

Figure 1: Stratigraphic successions in the Upper Benue Trough (Yola Arm) extracted from Geology of Nigeria

Figure 2: Geology of the study area (extracted from NASA Goddard Space Flight Center)

Figure 3: Dark carbonaceous shale around the study area: 5 km West of Numan-Guyuk Highway

2.2 Data Acquisition and Analysis

A 40-meter-long profile of 41 electrodes, each spaced one meter away from the other, was set up at the field (study area) to carryout resistivity measurements using dipole-dipole configuration. The 41 steel electrodes stakes are then connected to SAS1000 ABEM Terrameter via multi-conductor cables. It was arranged such that electrodes in positions one and two were to inject current into the earth's surface and were labeled A and B as current electrode. Electrodes in positions three and four were labeled Mand N, to measure voltage as potential electrode (Fig: 4). Measurements were taken in apparent resistivity using the ABEM Terrameter. The measured data is then transferred to the Computer PC in a data-format readable by Res2DInv.exe software for onward processing. This process is repeated consecutively with the ABEM Terrameter moving the potential electrodes (M and N) to the electrodes in next position, until the last electrode, at 40th position. In all, four profiles were carried out and the Res2DInv.exe software processed a total of 276 datum points across 8 data level for each profile. Figures 5,6,7 and 8 gives the two dimension images of the processed data.

Figure 4: Schematic Diagram of Dipole-dipole electrode configuration

The data set in each of the four profiles appears to show large resistivity variations near the surface, hence for significantly better results, a model where the cell width is half the unit electrode spacing (0.5m) was adopted.

III. Results and Discussions

Figures 5, 6, 7 and 8 give the results of resistivity distributions processed using the Res2DInv software for profiles one, two, three and four respectively.

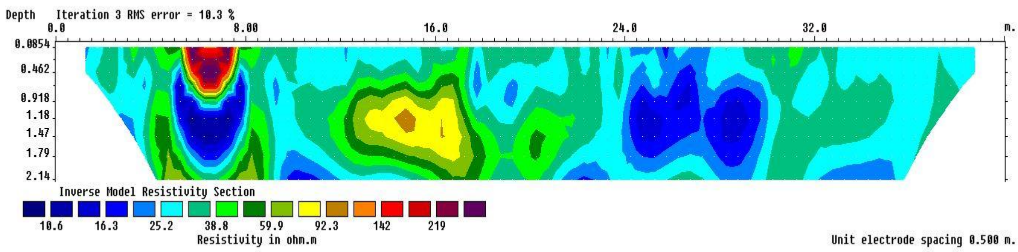

Figure 5: Distribution of Resistivity across Profile One

Resistivity distribution from profile one is shown in Figure 5 above. From this profile, the resistivity variation starts from 10.6 Ωm to about 220 Ωm. The resistivity imaging from this profile is interpreted to have distribution of coal and other lithology resistivity. Resistivity distribution of about 90-150 Ωm suggested the region (layer) of coal deposit. The coal layer is about 4 meters in thickness. Clay and sandy clay are two other lithology interpreted from this resistivity distribution. Resistivity value of about 1.8-20 Ωm suggested clay (wet) whereas the value of resistivity of about 25-60 Ωm suggested sandy clay.

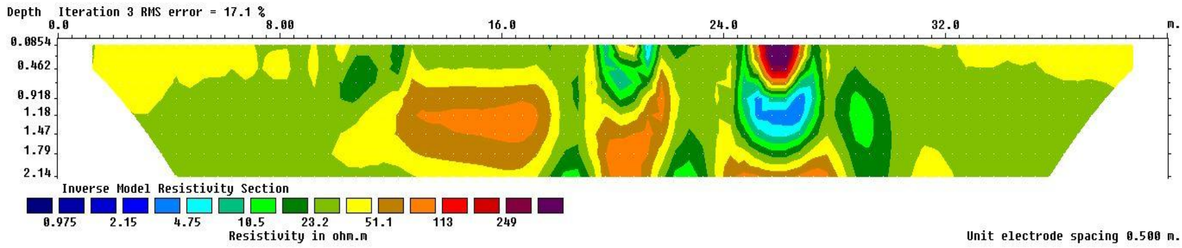

Figure 6: Distribution of Resistivity across Profile Two

Resistivity distribution from profile two is shown in Figure 6 above. From this profile, the resistivity variation starts from 0.075 Ωm to about 250 Ωm. The resistivity imaging from this profile is interpreted to have distribution of coal and other lithology resistivity. Resistivity distribution of about 60-100 Ωm suggested the region (layer) of coal deposit. The coal layer is about 5 meters in thickness. Clay and sandy clay are two other lithology interpreted from this resistivity distribution. Resistivity value of about 0.01-3 Ωm suggested clay (wet) whereas the value of resistivity of about 10-30 Ωm suggested sandy clay.

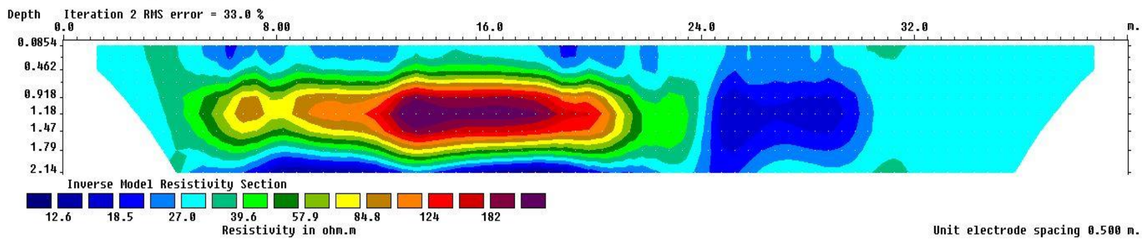

Figure 7: Distribution of Resistivity across Profile Three

Resistivity distribution from profile three is shown in Figure 7 above. From this profile, the resistivity variation starts from 12.6 Ωm to about 200 Ωm. The resistivity imaging from this profile is interpreted to have distribution of coal and other lithology resistivity. Resistivity distribution of about 60-200 Ωm suggested the region (layer) of coal deposit. The coal layer is about 4 meters in thickness. Clay and sandy clay are two other lithology interpreted from this resistivity distribution. Resistivity value of about 10-20 Ωm suggested clay (wet) whereas the value of resistivity of about 30-60 Ωm suggested sandy clay.

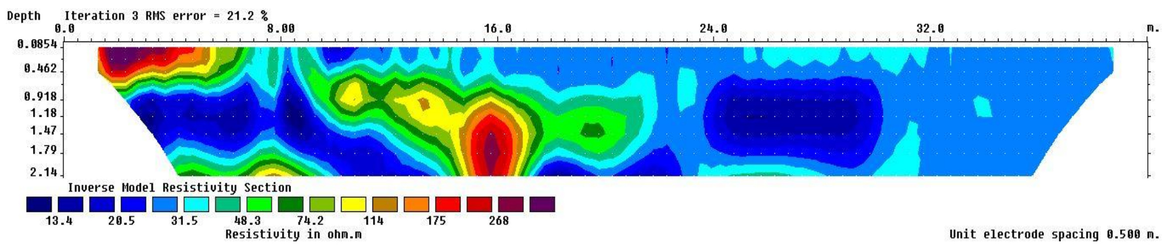

Figure 8: Distribution of Resistivity across Profile Four

Resistivity distribution from profile four is shown in Figure 8 above. From this profile, the resistivity variation starts from 13.4 Ωm to about 300 Ωm. The resistivity imaging from this profile is interpreted to have distribution of coal and other lithology resistivity. Resistivity distribution of about 100-300 Ωm suggested the region (layer) of coal deposit. The coal layer is about 4 meters in thickness. Clay and sandy clay are two other lithology interpreted from this resistivity distribution. Resistivity value of about 12.8-30 Ωm suggested clay (wet) whereas the value of resistivity of about 40-80 Ωm suggested sandy clay.

Coal resistivity variation from this research ranges from 60-300 Ωm. This is basically endorsing the many previous research works that suggested a resistivity variation of about 100-400 Ωm for coal.

IV. Conclusion

Electrical resistivity imaging was conducted in Lokoro, Northeast Nigeria, using dipole-dipole electrode configuration. Measurements were carried out successfully across four profiles. Res2DInv software was used in data processing. Interpretations were taken from the measured resistivity variations processed using the Res2DInv software and the results of this research revealed that in profile one, coal resistivity variation is about 90-150 Ωm. In profile two and three, the coal resistivity variation is about 60-100 Ωm and 60-200 Ωm respectively. In the last profile, profile four, the coal resistivity variation is about 100-300 Ωm. By these resistivity variation of coal from this research, which is in agreement with many previous research on coal resistivity variation of about 100-400 Ωm, the authors of this research concluded that coal deposit in Lokoro, Northeast Nigeria is potential for mining, though further research on the size of the coal deposit using more sophisticated geophysical materials and methods is recommended.

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