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Electrical Resistivity Imaging of a Coal Deposit at Tai Area of Gombe State, North Eastern Nigeria

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Abstract
A 2-D electrical resistivity imaging of some parts of Tai in Akko Local Government area of Gombe State, northeastern Nigeria was carried out. Tai is located 28 km from Pindiga and lies between latitudes 10^0 00′00″ and 10^0 06′00″N and longitudes 10^0 40′ 00″E and $10^0$45′00″E. This study was prompted by a report that in the course of siting a hand-dug well and hand-pump borehole in Tai, coal seam was intercepted. The aim of this geoelectrical investigation is to image the survey area for possible location and future exploitation of coal seam found in the area. The survey was targeted at determining the lateral extent of the coal seam, resistivity values associated with the coal seam and depth to the coal seam. ABEM Terrameter SAS 1000 was used to acquire the data in this survey. The protocol chosen was the Wenner-Schlumberger array because of its sensitivity to both horizontal and vertical structures. Data processing was done using RES2DINV software. The results show that the resistivity values range from 3Ωm to 2033 Ωm. The top layer has resistivity ranges of about 66 Ωm to 2033 Ωm. Below this, is a layer of low resistivity ranging from 3 Ωm to 57 Ωm probably saturated with water. The layer with resistivity range of about 250 Ωm to 900 Ωm is probably the host of the coal seams. It can be concluded that the occurrence of the coal seam is probably more at the Northwest of the survey area and the coal seam is suspected to have resistivity values ranging from about 250 Ωm to 900 Ωm and depth varying from 3 m to 17.2 m.
Keywords: Coal Seam, Lateral Extent, Electrical Resistivity Imaging

Introduction

Coal is an organic sedimentary rock that forms from the accumulation and preservation of plant materials buried millions of years ago, usually in a swamp environment. Coal is the world's most abundant and widely distributed fossil fuel with reserves for all types of coal estimated to be about 990 billion tones, enough for 150 years at current consumption (BGR, 2009). Coal fuels 42% of global electricity production, and is likely to remain a key component of the fuel mix for power generation to meet electricity demand, especially the growing demand in developing countries. Estimates based on preliminary investigation reveals that Nigeria has an estimated coal reserve of over 2.7 billion tones (Sada, 2012). Despite the reported occurrence of these amounts of deposits, Nigerian Government has paid just little attention to coal. And according to World Coal Institute (2009), many countries like Poland, South Africa, China, and Australia rely on coal for over 94%, 92%, 77%, and 76% of its electricity respectively.

The method employed for this research was the 2D Electrical Resistivity imaging, using the ABEM LUND Imaging System. The method was adopted because, from previous work, like the work of Singh *et al.* (2004) reveals that Coal seams have high resistivity with respect to the surrounding formation and its values vary from few hundreds of Ωm to few thousand Ωm. Their results suggest that this method can be applied to detect coal deposit. Also coal itself usually has a high resistivity compared to other sedimentary rock types. This property has formed the basis for detecting coal from borehole logs and DC resistivity surveying was used as a tool for exploring coal as early as 1934 (Ewing *et al.*, 1936).

Geology of the Study Area

The study area (Tai) forms part of the Upper Benue Trough which is made up of two arms, the Gongola Arm and the Yola Arm (although some authors have sub-divided the Upper Benue Trough to include a third central Lau-Gombe sub-basin, Akande *et al.*,1998). In both arms of the basin, the Aptian-Albian Bima Sandstone lies unconformably on the Precambrian Basement.

The Yolde Formation lies conformably on the Bima Sandstone. The Yolde Formation was deposited under a transitional/coastal marine environment and is made up of sandstones, limestones, shales, clays and claystones. In the Gongola Arm, the Pindiga Formation lies conformably on the Yolde Formation. Lithologically, this formation is characterized by the dark/black carbonaceous shales and limestones, intercalating with pale coloured limestones, shales and minor sandstones. The type locality of the Pindiga Formation is at Pindiga village. The Pindiga Formation is subdivided into three members namely: Kanawa, Deba-Fulani and Fika members in the Gombe Sub-basin (Zaborski *et al.*, 1997). The Gombe Sandstone however, contains coal, lignite, and coaly shale intercalations which in places are very thick (Obaje, 2009). Figure 1 shows the geological map of the study area.

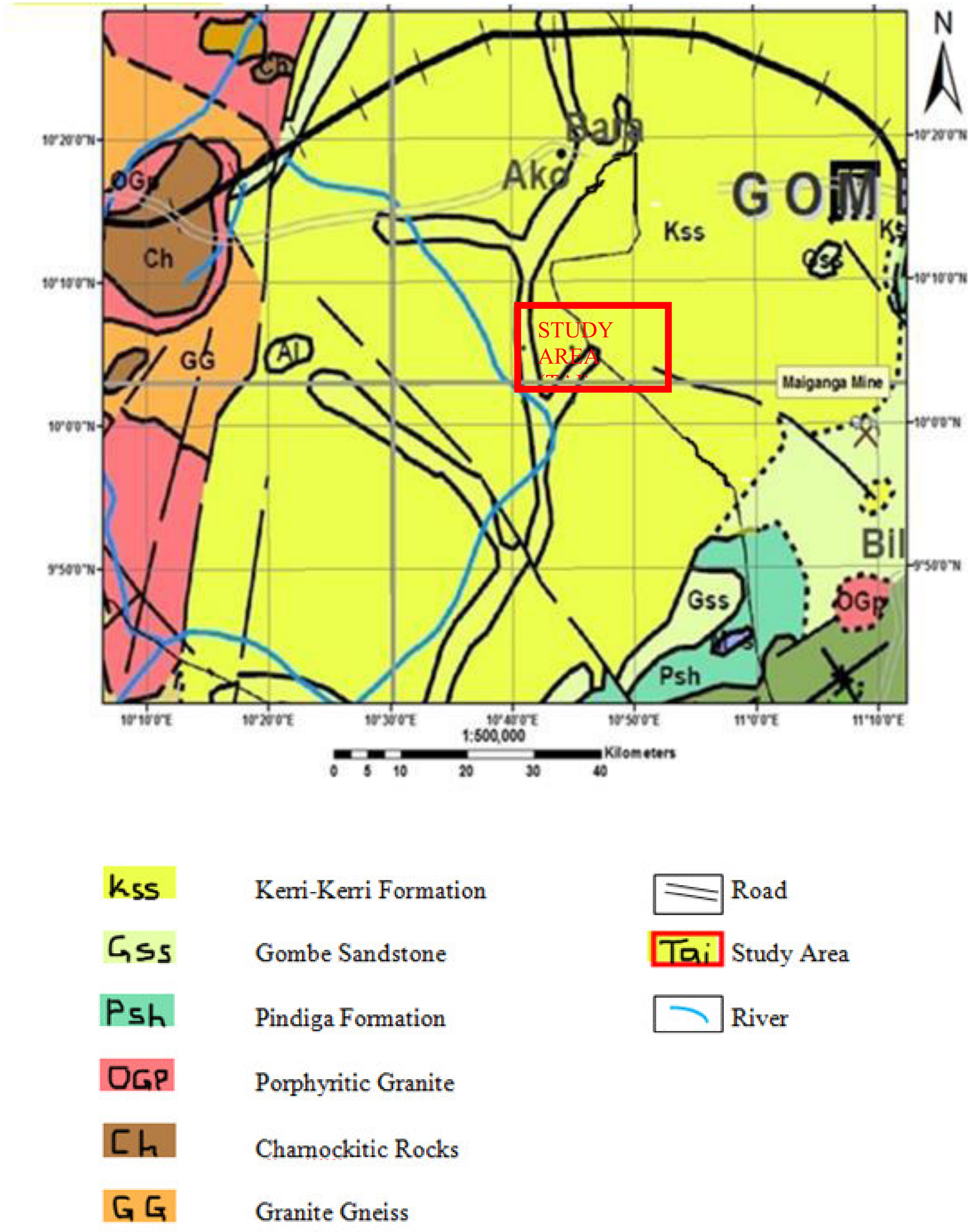


Figure 1 Geological map of study area (Courtesy Nigeria Geological Survey)

Methodology

The Wenner-Schlumberger array was chosen for this survey. The field measurement usually starts with laying out the cables and electrodes along the chosen profile. The cables were connected to electrode selector. The electrodes were connected to all the take-outs cables using jumpers. For a moist or soft ground, electrodes were just pushed into the ground by hand and then connected. However, hammering and wetting were done on dry and hard ground. The Terrameter was then connected to an external 12 volts battery and switched on, which automatically switches on the Electrode Selector and the system set-up which was echoed to the screen. The instrument was set to resistivity mode and LUND Imaging System was selected. Electrode test commenced immediately, and grounding improved for the electrodes with bad ground contact. The connectors were also checked for unsatisfactory electrode positions. Electrodes were tested pair-wise against each other starting from the outermost electrodes going towards the centre. The electrode test checks if it is possible to transmit current through all electrodes. This test takes a couple of minutes but saves time afterwards; because programme may stop depending on poor electrode contact. Measurement may also stop if the batteries for either the Terrameter or the Electrode Selector are low. The programme automatically continues to measure using the two electrode cables when the contact is satisfactory. Nine profiles were taken for the survey (Figure 2).

Figure 2. A map illustrating the profiles layout (1 to 9). P1 and P2 are locations of hand dug well and hand-pump borehole. Arrows are indicating profiles direction.

Results and Discussions

The 2D electrical resistivity images of the earth's subsurface along the profiles obtained in the study area are presented later. A total number of nine profiles were taken for this work, but emphasis will be made on only profiles that reveal the possible occurrence of coal. The inversion result for each profile is also shown depicting the images of the geoelectric sections obtained from the processed data. The results show three images for each profile. The upper image is a plot of the measured apparent resistivity pseudosection which is obtained by plotting the observed apparent resistivity data against the depth with colour infill instead of line contours. The middle image is the calculated apparent resistivity pseudosection obtained by plotting the calculated apparent resistivity data against the depth with colour infill instead of line contours. The lower image is the resistivity model obtained after a definite number of iterations of the inversion programme. The resistivity model shows variation in the geologic properties of the subsurface, in relation to the measured resistivity with scales shown at the lower end of the plot, ranging from 1 Ωm to 2033 Ωm; the side bar shows the depth below the subsurface with a mean depth of about 17.2 m and the lateral distance is shown above the section. The origin of the profiles is centered at the midpoint of each profile that is why the lateral distance of each profile starts from -40 m to 40 m. The negative and positive values represent distances from left and right of the midpoint respectively. The discussion of the individual profiles now follows.

Profile One

Figure 3 shows the measured apparent resistivity pseudosection, the calculated apparent resistivity pseudosection and the resistivity model of profile one. The resistivity model reveals a thin layer of high resistivity ranging from about 140 Ωm to 787 Ωm which may be composed of laterite and sand. Underlying this layer is a moderately high resistive layer to a depth of about 17.2 m with resistivity value varying from about 44 Ωm to 443 Ωm. There is also an occurrence of small section of low resistivity between a distance on the profile of about 4 m to 10 m from a depth of 15 m to 17.2 m. This low resistivity section might be groundwater trapped in the aquifer. Although no borehole data was used to correlate the results because there was no borehole around the study area, reference was made to typical resistivities values of geological materials.

Profile Two

Figure 4 shows the measured apparent resistivity pseudosection, the calculated apparent resistivity pseudosection and the resistivity model of profile two. The resistivity model reveals a layer with resistivity values ranging from about 66 Ωm to 361 Ωm with a thickness of about 5m. This layer may be intercalation of sandy and lateritic clay which constitutes the top soil. Underlying the top soil to a depth of about 11m between the distance of -34 m to -24 m along the profile is a low resistivity section with resistivity values ranging from about 5 Ωm to 28 Ωm. The low value of the resistivity is an indication that the layer may be saturated with water. There is occurrence of high resistivity values of 361 Ωm to 843 Ωm between 16 m to 30 m and 4 m to 8 m on the profile, at a depth of about 4.2 m and 16.5 m respectively. The high resistive section is likely to be a coal seam, because coal is attributed with high resistivity.

NS SW

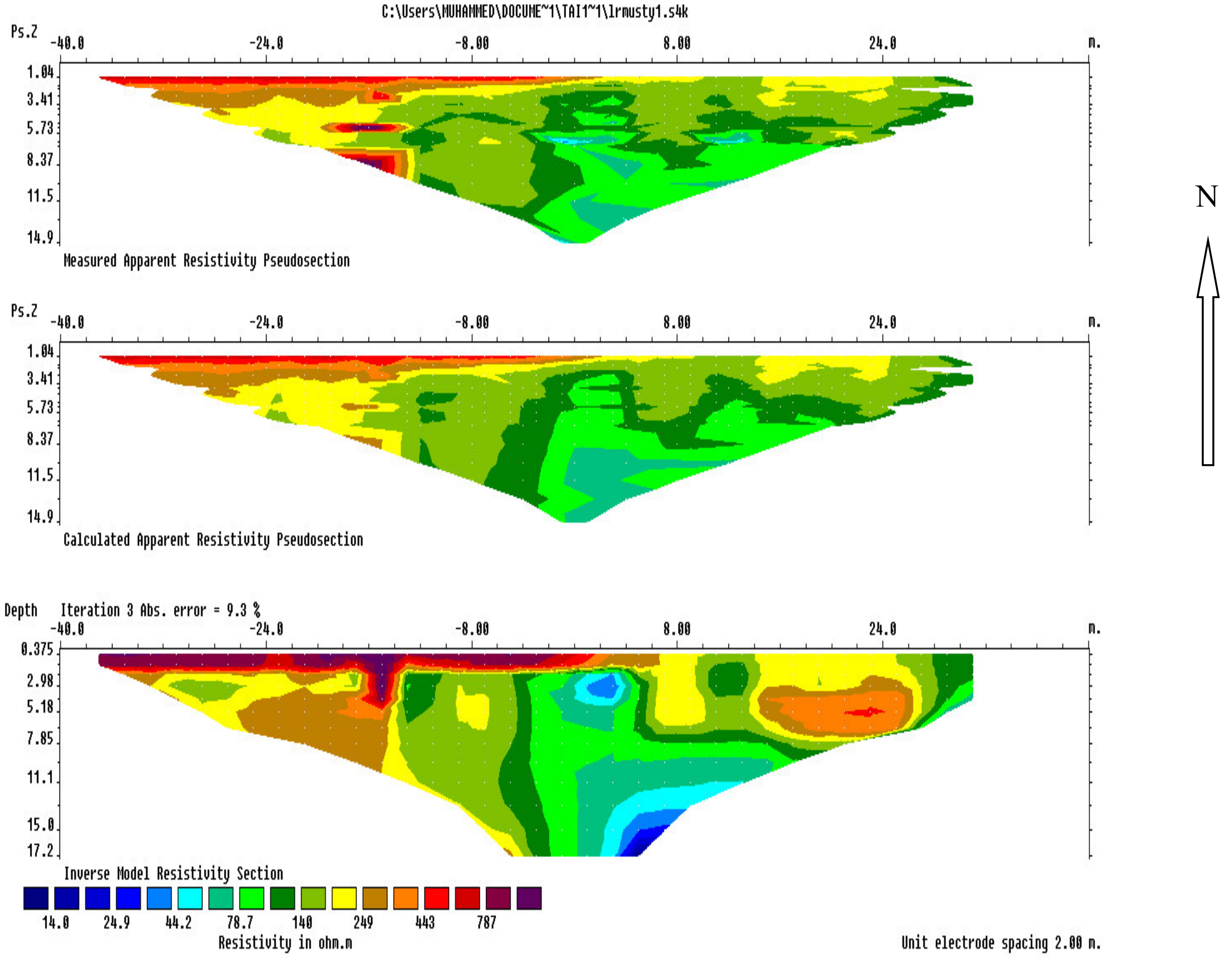


Figure 3: Result of 2D inversion of the Wenner-Schlumberger array data along profile 1

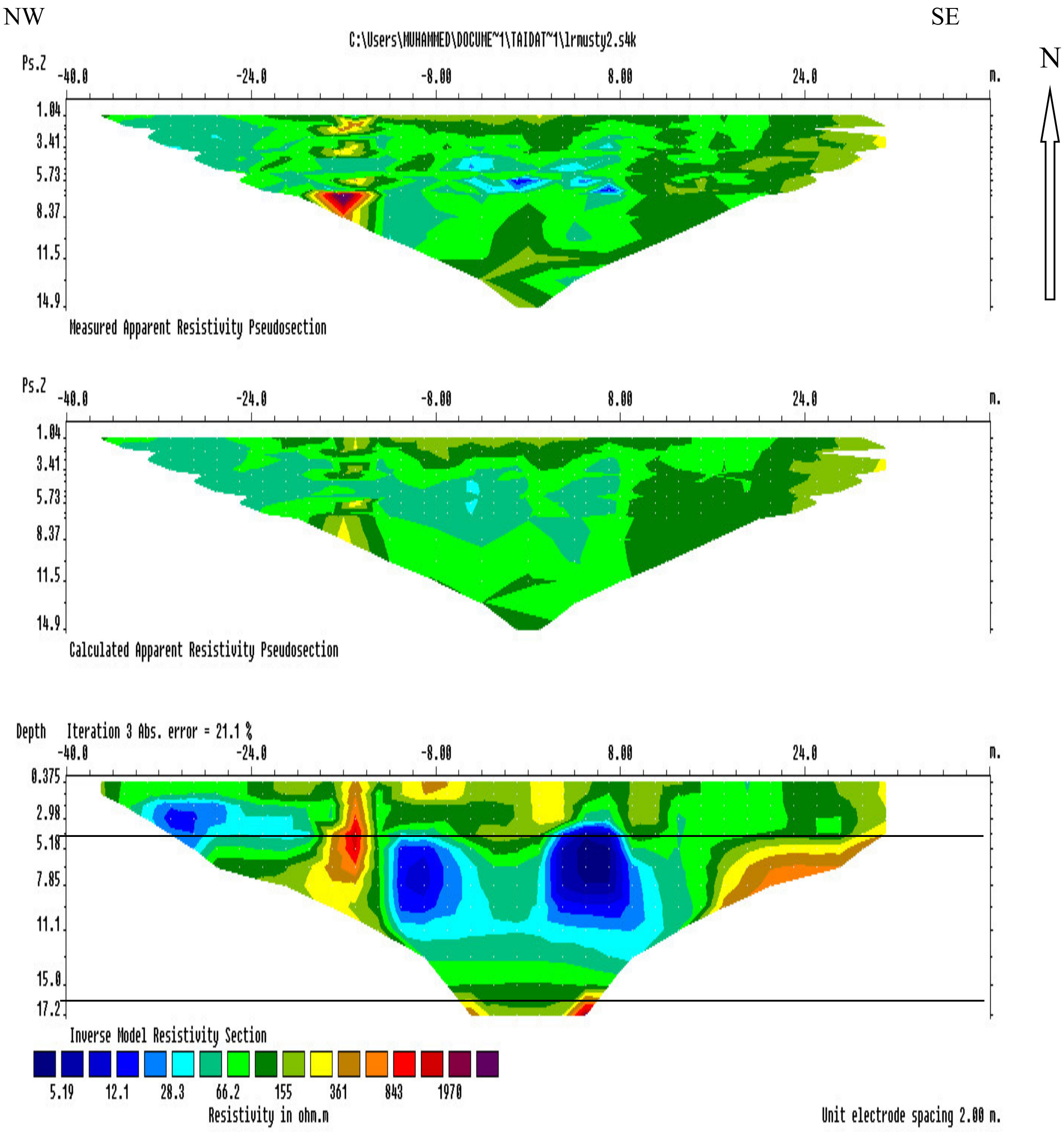


Figure 4: Result of 2D inversion of the Wenner-Schlumberger array data along profile 2

Profile Three

Figure 5 shows the measured apparent resistivity pseudosection, the calculated apparent resistivity pseudosection and the resistivity model of profile three. The resistivity model shows a high resistivity of about 113 Ωm to about 396 Ωm in the image and constitutes the top soil having a thickness of about 1.5m. This layer may be made up of silt, clay and sand. At a depth of about 3 m to 9 m, very low resistivity values of 4 Ωm to 17 Ωm were observed which indicate probably its clay saturated with water. Between -8m to 16m along the profile, emerge a high resistivity section with resistivity value ranging from about 212 Ωm to 396 Ωm at a depth of 5 m to 17.2 m which is suspected to be a coal seam because coal is attributed with high resistivity.

Profile Four

Figure 6 shows the measured apparent resistivity pseudosection, the calculated apparent resistivity pseudosection and the resistivity model of profile four. The resistivity model shows a thin layer of resistivity ranging from about 171 Ωm to 309 Ωm and thickness of 2 m. This layer is the top soil which may be composed of sand, silt and clay. A low resistivity section occurs below the top soil with patches of very low resistivity (8 Ωm to 29 Ωm) between distance on the profile of -36 m to -20 m, -6 m to 0m and 4 m to14 m within a depth of 2.5 m to 5 m and 8 m to 15 m. There is also appearance of high resistivity section (171 Ωm to 558 Ωm) between 16 m to 30 m and 4 m to 8 m along the profile at a depth of about 4 m and 16.5 m respectively. This high resistive section is likely to be a coal seam.

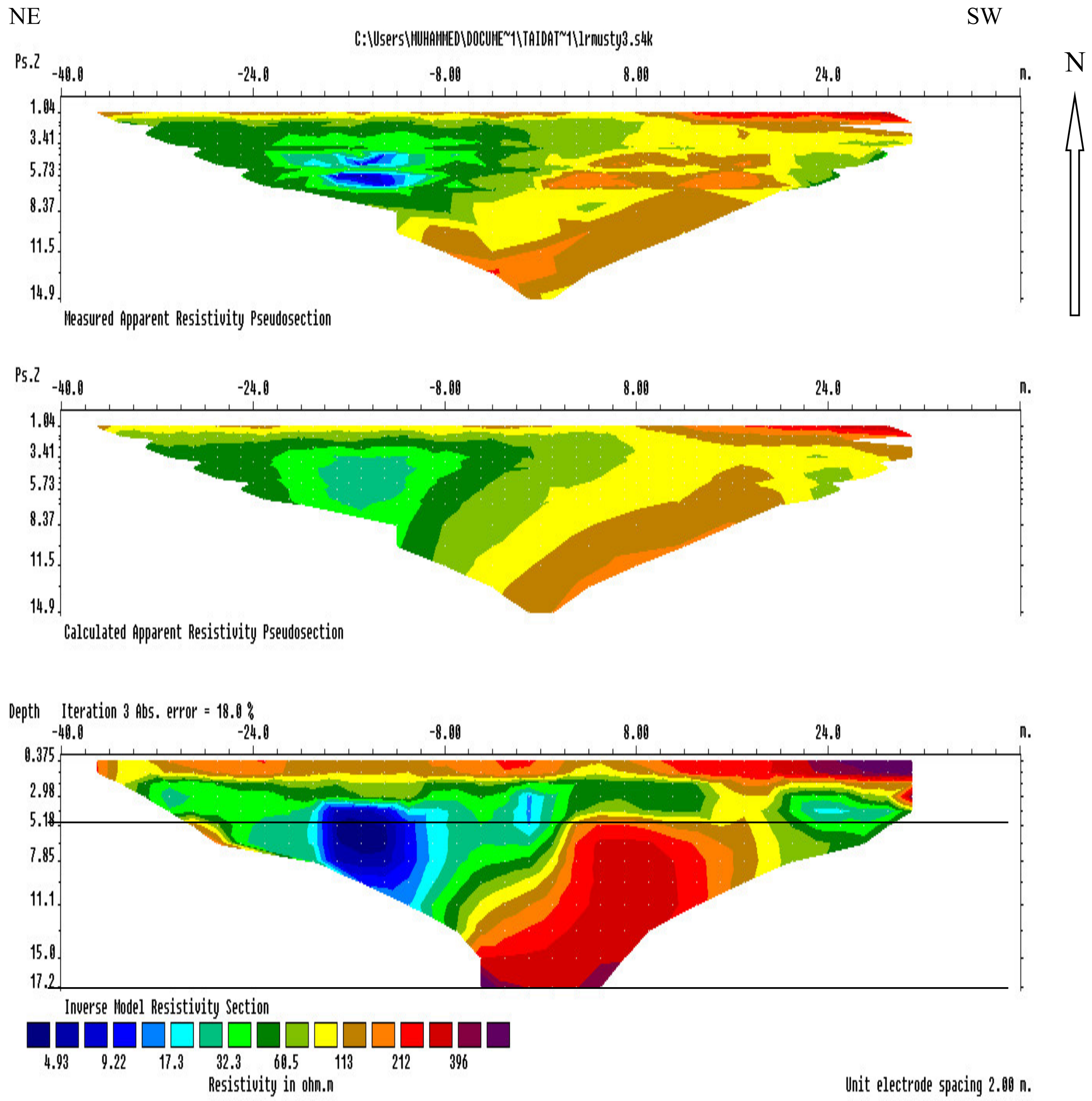


Figure 5: Result of 2D inversion of the Wenner-Schlumberger array data along profile 3

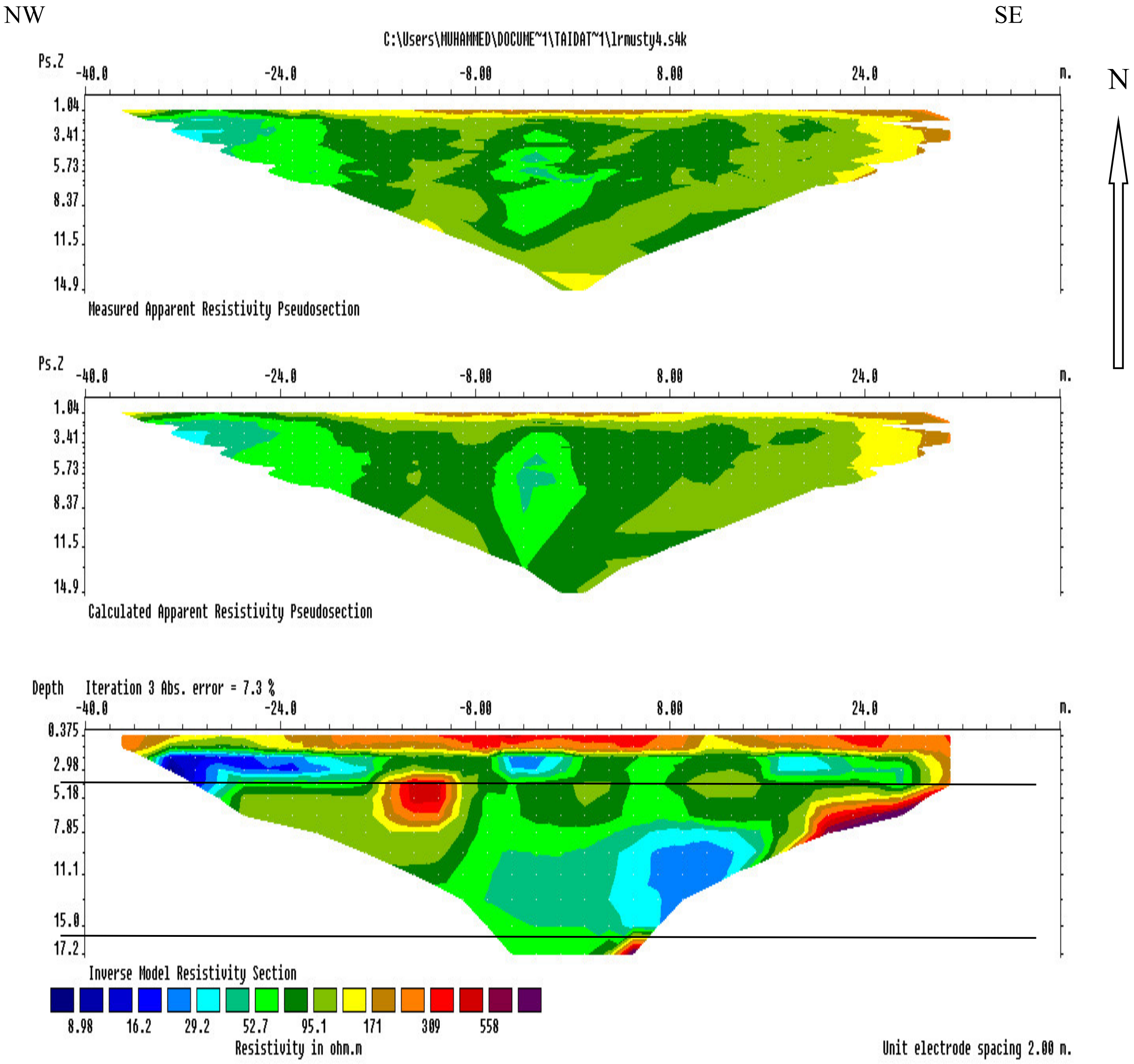


Figure 6: Result of 2D inversion of the Wenner-Schlumberger array data along profile 4

Profile Five

Figure 7 shows the measured apparent resistivity pseudosection, the calculated apparent resistivity pseudosection and the resistivity model of profile five. The resistivity model reveals a thin layer of high resistivity with resistivity value ranging from about 225 Ωm to 457 Ωm on the top soil which indicates the likely presence of consolidated sand, silt and clay. Between distance of -32 m to -16 m along the profile shows very low resistivity values 6 Ωm to 13 Ωm. This might probably be clayey soil saturated with water. Below the top soil is a layer with low resistivity varying from about 3 Ωm to 111 Ωm with a thickness of about 15 m. Other isolated patches of high resistivity section ranging from 225 Ωm to 457 Ωm traversed by the profile are seen at -22 m to -12 m, -2 m, 6 m, and 20 m to 26 m marks at a depth varying from 3 m and 16.5 m. These patches are suspected to be coal seams at a shallow depth, since coal is associated with high resistivity.

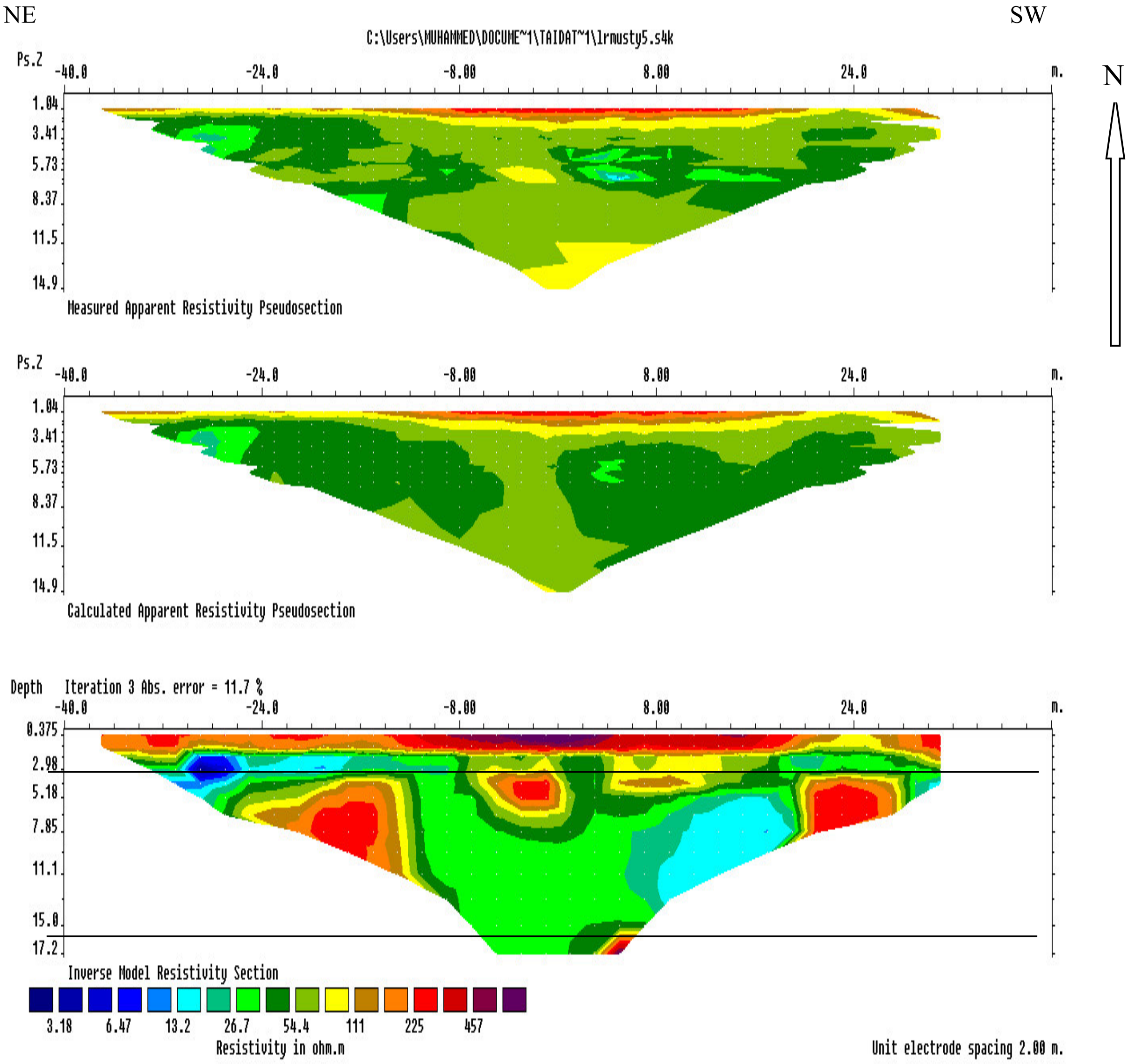
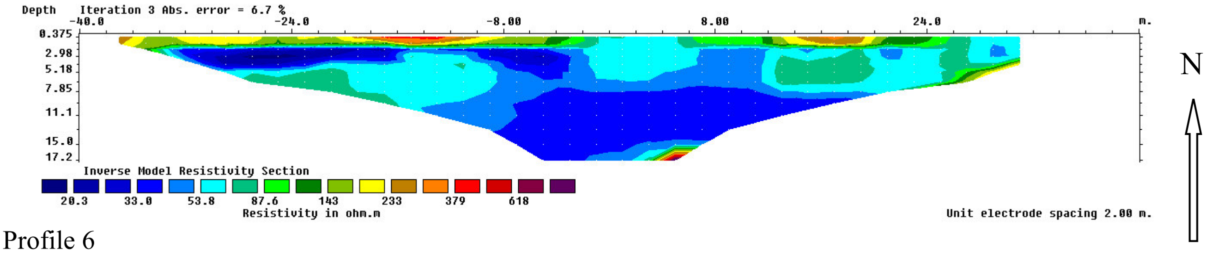


Figure 7: Result of 2D inversion of the Wenner-Schlumberger array data along profile 5

Profile Six, Seven and Eight

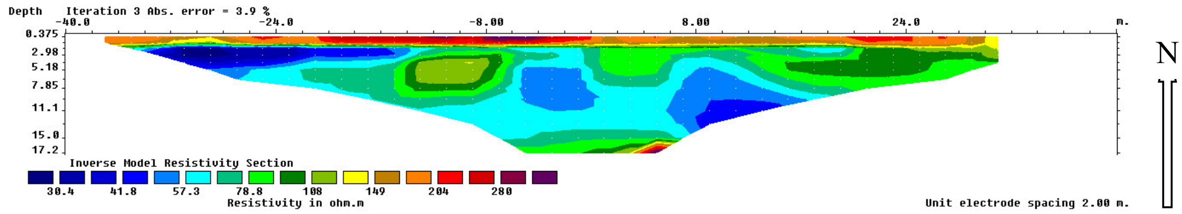
The resistivity model in profiles six, seven and eight respectively (figure 8) shows patches of high resistivity ranging from about 143 Ωm to 907 Ωm on the surface which constitutes the top soil that is composed of mainly dry sand. The top soil has high resistivity because its pore space lacks water. Underlying this layer may be a clay layer with low resistivity values ranging from about 7 Ωm to 37 Ωm. The low resistivity zone indicates that water is probably trapped within the layer. This resistivity model also indicated that the basement is far. The possibility of intercepting a coal seam here might be at greater depth.

NW SE



Profile 6

NE SW



Profile 7

NW SE

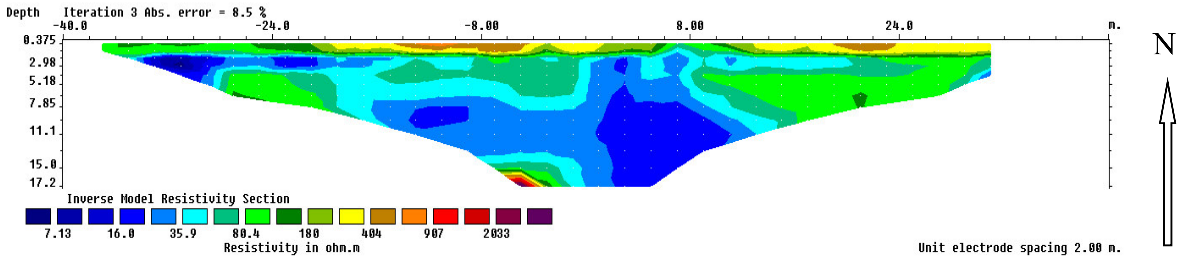


Figure 8: Result of 2D inversion of the Wenner-Schlumberger array data along profile 6, 7 & 8 respectively.

Profile Nine

Figure 9 shows the measured apparent resistivity pseudosection, the calculated apparent resistivity pseudosection and the resistivity model of profile nine. The resistivity model shows the top soil with resistivity values ranging from about 83 Ωm to 365 Ωm and a thickness of about 1.5 m. This is likely due to the observed dry and consolidated lateritic clay top soil. Underlay the top soil is a low resistivity section with resistivity values ranging from about 27 Ωm to 57 Ωm. The section might probably be groundwater trapped in an aquifer. At a depth of about 3.8 m to17.2 m, there is occurrence of very high resistive section ranging from about 174 Ωm to 365 Ωm which might be a coal seam at a shallow depth.

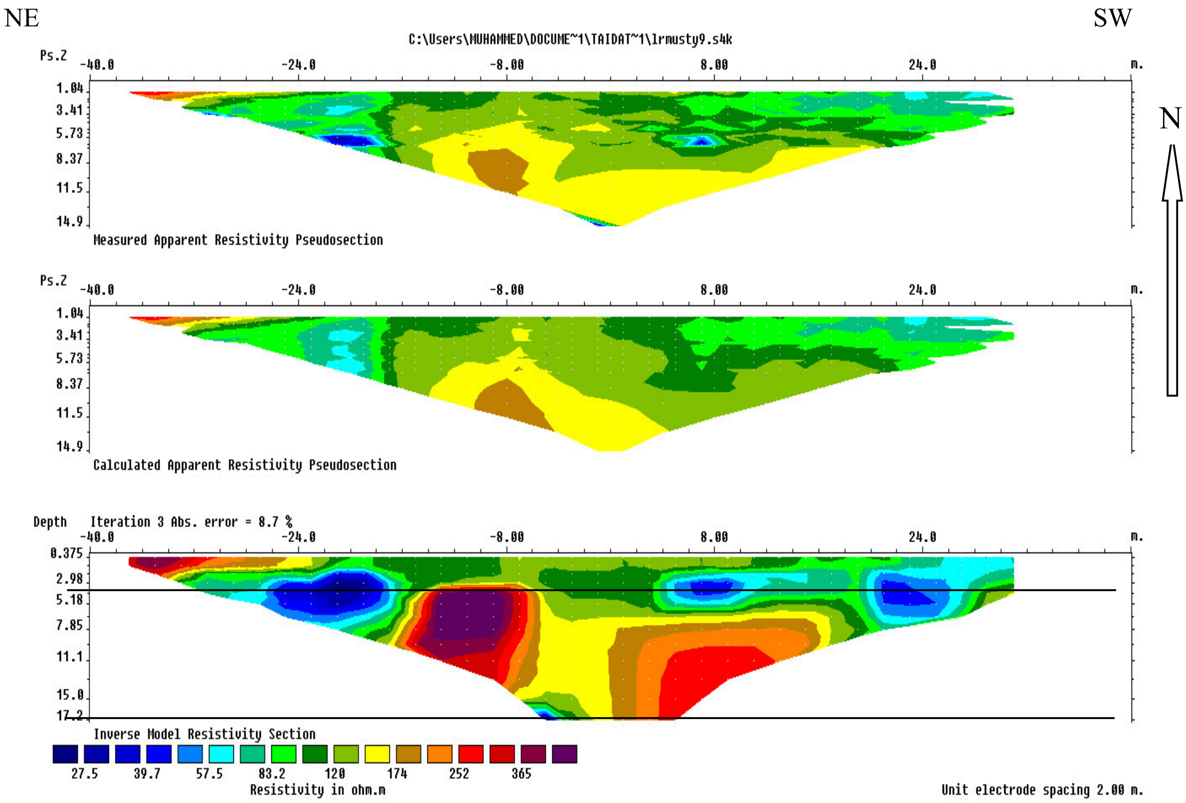


Figure 11: Result of 2D inversion of the Wenner-Schlumberger array data along profile 9

Conclusions

Electrical resistivity imaging was successfully carried out at Tai/Akko area of Gombe State, Northeastern Nigeria with the aim of delineating the lateral extent of the coal deposit, the strike direction and the resistivity values associated with the coal seam. The results of the electrical resistivity imaging showed that the near surface materials may be composed of sand and laterite with resistivity values ranging from about 66 Ωm to 907 Ωm. Below the near surface materials, is a layer likely to be clay saturated with water. It was more pronounced in profiles 6 and 8 which have low resistivity values of about 3 Ωm to 57 Ωm. Underlying the clay layer in profiles 2, 3 and 4, was a high resistive zone with resistivity values ranging from about 250 Ωm to 900 Ωm and depth varying from 3 m to 17.2 m. This high resistivity is too low to be that of the basement rock and is therefore inferred to be a coal seam. There is also likely occurrence of the coal seam at a shallow depth in profiles 9 due to the reappearance of high resistivity which is similar to that of profiles 2, 3 and 4 located near the hand dug well where coal had been intercepted. Based on these results, it can be concluded that the occurrence of the coal seam is probably more at the Northwest of the survey area and the coal seam is suspected to have resistivity values ranging from about 250 Ωm to 900 Ωm within a depth varying from 3 m to 17.2 m. There is likelihood from the study that the coal seam might exceed beyond a depth of 17.2 m. Therefore, it is recommended that further investigation should be carried out on the profiles using equipment with wider electrode spacing so that it will probe deeper into the subsurface.

References

Akande S. O., Ojo O. J., Erdtmann B. D., Hetenyi M. (1998). Paleoenvironments, source rock potential and thermal maturity of the upper Benue rift basins, Nigeria. Implications for hydrocarbon exploration. *Organic Geochemistry* **29**: 531–542.

BGR (Bundesanstalt fur Geowissenschaften und Rohstoffe – Federal Institute for Geosciences and Natural Resources) (2009), *Reserves, Resources and Availability of Energy Resources – Annual Report 2009*, BGR, Hannover, Germany, www.bgr.bund.de.

Ewing, M. A., Crary, A. P. Peoples J. W. and Peoples, J. A. (1936). *Prospecting for Anthracite by the Earth Resistivity Method*, Transactions of the American of Mining and Metallurgical Engineers, Coal Division, Vol**. 119**, pp 43-483.

Obaje, N.G. (2009). *Geology and Mineral Resources of Nigeria, Lecture Notes in Earth Sciences Springer-Verlag Berlin Heidelberg,* pp. 57-68.

Sada M.M. (2012). Investment opportunities in Nigeria minerals and metals sector, 19 pages. Paper presented at

Africa Down Under International Conference, Perth, Western Australia.

Singh K. K. K., Singh K. B., Lokhande R. D. and Prakash A. (2004). Multielectrode resistivity imaging technique for the study of coal seam in northern part of Jharia Coalfield of Dhanbad district. *Journal of Scientific and Industrial Research,* **63**: 927-930.

World Coal Institute (2009). *The coal resources: A comprehensive overview of coal* (Research report). Retrieved from http://www .worldcoal.org

Zaborski, P. M., Ugoduluwa, F., Idornigie, A., Nnabo, P. and Ibe, K. (1997). Stratigraphy and structure of the Cretaceous Gongola Basin, north eastern Nigeria. Bulletin des centres des Recherches Exploration-production Elf- Aquitaine **21**: 153-185.