CHARACTERIZATION OF A COAL DEPOSIT OVER PART OF TAI AREA OF GOMBE, NORTH EASTERN NIGERIA

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Abstract: The purpose of this research work is to delineate the strike direction of a coal deposit at Tai area of Gombe, Northeastern Nigeria using a 2-D electrical resistivity method. ABEM Terrameter SAS 1000 was used for the data acquisition. Wenner-Schlumberger array protocol was employed because of its large median depth of investigation and slightly better horizontal coverage. Data processing was done using RES2DINV software and the result shows that there is continuity of geological structure. The study reveal that the suspected coal seam in profile 3 and 9 taken in Northeast-Southwest (NE-SW) direction showed a clearer picture of the suspected coal seam because the profiles were laid perpendicular to the strike direction while that of profile 2 and 4 taken in Northwest- Southeast (NW-SE) direction was not pronounced because the profile was laid along the strike direction. Hence it can be concluded that the coal seam is striking in the NW-SE direction, and therefore for any future research to ascertain the coal reserve of the area, profiles should be laid in Northwest-Southeast direction in order to obtain an optimum result.

Keywords: Coal seam, resistivity imaging, strike direction, wenner-schlumberger array

Introduction

Coal is a vital component of the world's energy resources, and one that is expected to fill a significant role in meeting our energy needs well into the foreseeable future (Ward, 2003). It's the oldest commercial fuel in Nigeria with production dating from 1916 when 24,500 tones were produced (Olayande et al., 2012). Currently Nigeria's coal deposit is estimated at about 2.8 billon tones (Christine, 2015). The proven coal reserve in the country so far is put at about 639 million tones (Olayande et al., 2012). There are sparsely occurrences of lignites and minor sub-bituminous coals in the Sokoto Basin (Kogbe, 1976) and in the Mid-Niger Basin (Adeleye, 1989). Apart from these, all the coal deposits of Nigeria occur in the Benue Trough. Mineable coal deposits in Nigeria occur at Enugu, Okaba, Ogboyaga, Orukpa, Lafia-Obi, Gombe and Chikila (Obaje, 2009).

Coal has important uses worldwide. The most significant uses are in electricity generation, steel production, cement manufacturing and other industrialprocesses. Report from the study area that coal was intercepted during the course of sinking a hand dug well coupled with the aforementioned uses of coal made it necessary to carry out a preliminary survey. This study is aimed at determining the strike direction of the coal seam using 2-D electrical resistivity imaging. The method was adopted because according to some work such as (Singh et al., 2004; Verman & Bhuin, 1979) reveals that coal seam in parts of the Jharia coal field in India are characterized by high values of electrical resistivity with respect to the surrounding formation and its values vary from few hundreds of Ωm to few thousand Ωm. It is of paramount important to know the strike direction of the coal seam because it will serve as a guide when embarking on an in depth survey to ascertain the coal reserve of the study area. Since, to obtain an optimum result in any geophysical survey, the profiles must be laid perpendicular to the strike direction of the anomalous body.

The area of study, Tai is in Akko Local Government area of Gombe State. Fig. 1 depicts the topographical map of Tai and its environs. It lies between latitude $10^0\ 00'\ 00''$N and $10^0\ 06'\ 00''$N and longitude $10^0\ 40'\ 00''$E and $10^0\ 45'\ 00''$E. It 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, the Aptian-AlbianBima Sandstonelies unconformably on the Precambrian Basement. The Yolde Formationlies conformably on the Bima Sandstone. 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, 1997). In the Gombe area of the Upper Benue Trough the poorly developed coalfields occur within the Gombe Sandstone, also of Maastrichtian age. The Gombe Sandstone however, contains coal, lignite, and coaly shale intercalations which in some places are very thick (Obaje, 2009). Fig. 2 shows the Stratigraphic successions in the Upper Benue Trough (Gongolar arm).
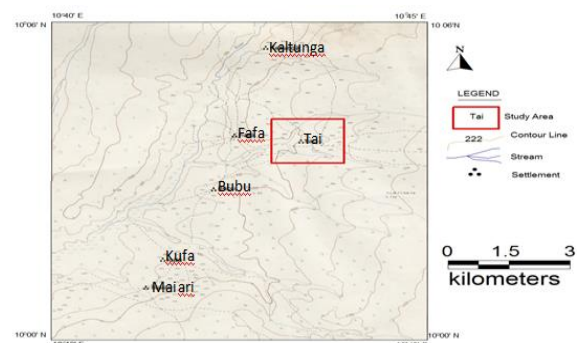

Fig 1: Topographical map of Tai and its environs

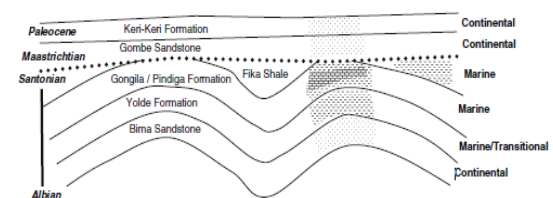
Fig. 2: Stratigraphic successions in the Upper Benue Trough (Gongola arm) (Obaje, 2009)

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Materials and Method

Two-dimensional electrical resistivity imaging method was adopted for this study using forty two (42) electrodes connected to a multi-core cable. ABEM Terrameter SAS 1000 with an internal microprocessor controlled circuitry together with an electronic switching unit was used to automatically select the relevant four electrodes for each measurement. A total of nine profiles were taken for the survey (Fig. 3) using the Wenner-Schlumberger array. Four profiles were taken around and surrounding the point P1 (location of the hand dug well) and point P2 (location of the hand pump borehole) respectively. It was taken in this way so that whichever direction the coal seam is striking, will be identified. The acquired data was processed using RES2DINV software. The program has been designed to automatically subdivide the subsurface structures into number of blocks and then uses a least-squares inversion scheme to determine the appropriate resistivity values for each block so that the apparent resistivity values agrees with the measured apparent resistivity values from the field survey.

The electrical resistivity varies between different geological materials, dependent mainly on variation in water and dissolved ions in the water. Of all the physical properties of earth materials (rocks and minerals), electrical resistivity has the widest range of variation (Fig. 4).

Fig. 3: A Map illustrating the profile layout (1 to 9). P1 and P2 are locations of hand dug well and hand-pump borehole, respectively. Arrows are indicating profiles direction.
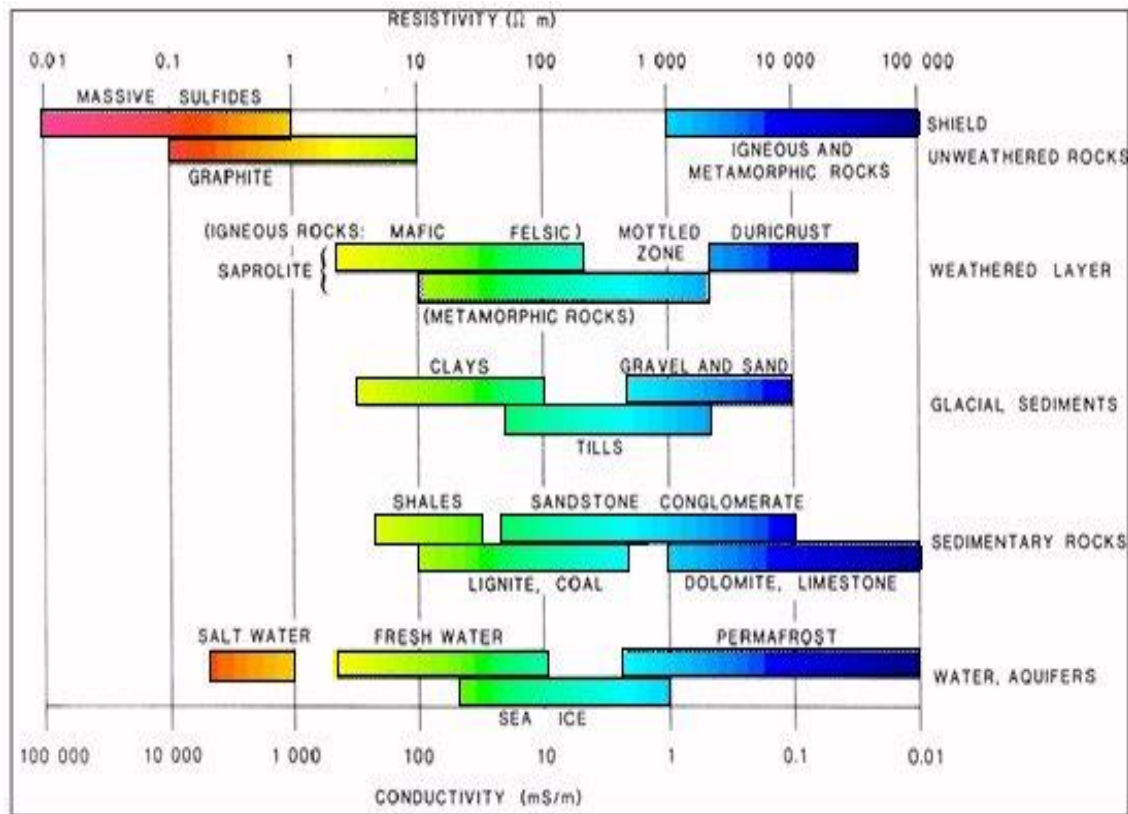
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Fig. 4: A typical range of resistivities of geological materials (Modified from ABEM instruction manual).

Results and Discussion

The obtained 2-D electrical resistivity images of the Earth's subsurface along the profile are presented in Figs. 5-11. The inversion result for each profile show three images (Fig. 5). 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. Therefore only the resistivity model of each profiles were considered for explanation. Since the aim of this study is to delineate the strike direction of the coal seam, emphases were given to profiles that show the possible occurrence of coal seam.

Profile one

Figure 5 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 to 787 Ωm which constitute the top soil and may be composed of dry sand and laterite. The top soil has high resistivity because its pore space is devoid of water. Underlying this layer is a moderately high resistive layer to a depth of about 17.2 m with resistivity value varying from about 44 to 443 Ωm. There is also an occurrence of small section of low resistivity between a distance on the profile of about 4 to 10 m from a depth of 15 to 17.2 m. This low resistivity section might be groundwater trapped within the layer.

Profile two

Figure 6 shows the resistivity model of profile two. The resistivity model reveals a layer with resistivity values ranging from about 66 to 361 Ωm with a thickness of about 5 m. This layer may be intercalation of sandy and lateritic clay which constitutes the top soil. Underlying the top soil to a depth of about 11 m between the distance of -34 to -24 m along the profile is a low resistivity section with resistivity values ranging from about 5 to 28 Ωm. The low resistivity value of the layer is an indication that it may be saturated with water since the resistivity of a rock decreases as the percentage of water saturation increases. There is occurrence of high resistivity values of 361 to 843 Ωm between 16 to 30 m and 4 to 8 m on the profile, at a depth of about 7 and 17, respectively. The high resistive section is likely to be a coal seam. This range of high resistivity values agrees with the resistivity values of coal depicted in Fig. 3 that shows typical range of resistivities of geological materials.

Profile three

Figure 7 shows the resistivity model of profile three. The model shows a high resistivity of about 113 to about 396 Ωm which constitutes the top soil having a thickness of about 1.5 m. This layer may be made up of sand and silt. At a depth of about 3 to 9 m, very low resistivity values of 4 to 17 Ωm were observed which indicate probably the presence of clay saturated with water. Between -8 to 16 m along the profile, emerge a high resistivity section with resistivity value ranging from about 212 to 396 Ωm at a depth of 5 to 17.2 m which is suspected to be a coal seam and it conform to the study carried out by Singh *et al*. (2004) and Verman & Bhuin (1979) in the northern part of Jharia coal field of Dhanbad district, India which reveal that coal is attributed with high resistivity.

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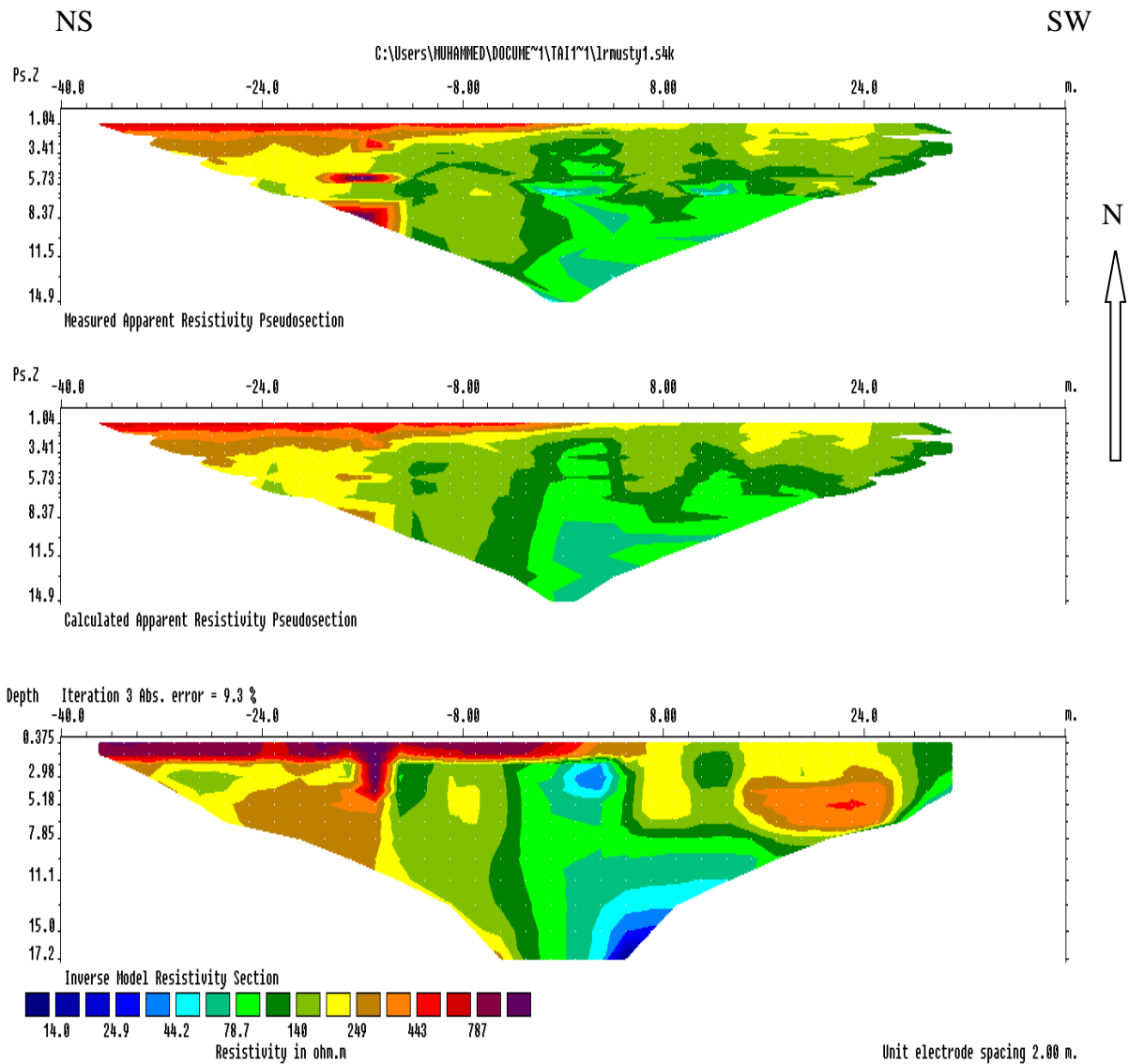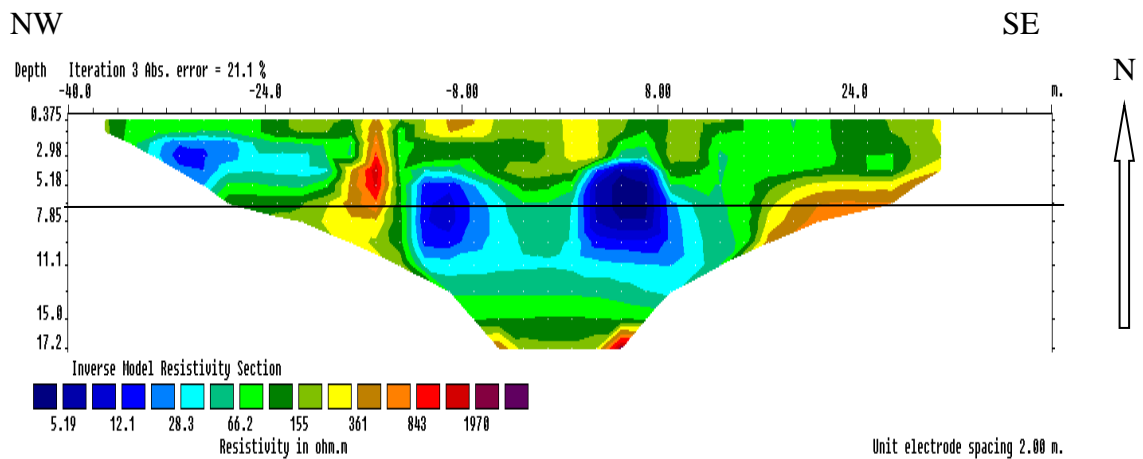e-ISSN: 24085162; p-ISSN: 20485170; April, 2017: Vol. 2 No. 1B pp. 554 – 561

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Fig. 5: Result of 2D inversion of the Wenner-Schlumberger array data along profile 1

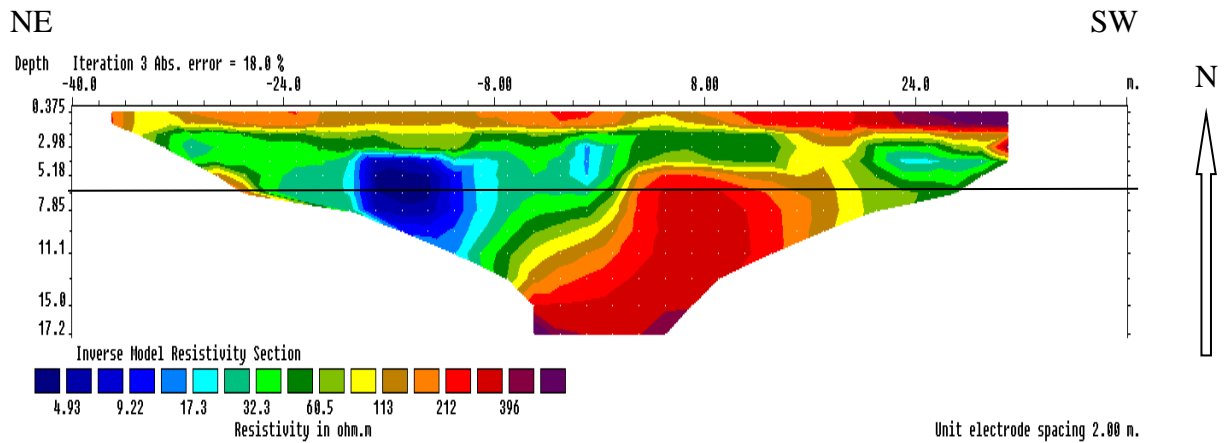**Fig. 6:** Result of 2D inversion of the Wenner-Schlumberger array data along profile 2

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Fig. 7: Result of 2D inversion of the Wenner-Schlumberger array data along profile 3

Profile four
Figure 8 shows the resistivity model of profile four. The resistivity model shows a thin layer of resistivity ranging from about 171 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 to 29 Ωm) between distance on the profile of -36 to -20 m, -6 to 0 m and 4 to 14 m within a depth of 2.5 to 5 m and 8 to 15 m. There is also appearance of high resistivity section (value) between 16 to 30 m and 4 to 8 m along the profile at a depth of about 4 and 17 m, respectively. This high resistive section is likely to be a coal seam with reference to Fig. 3 and (Singh *et al.*, 2004).

Profile five
Figure 9 shows the resistivity model of profile five. The resistivity model reveals a thin layer of high resistivity with resistivity value ranging from about 225 to 457 Ωm on the top soil which indicates the likely presence of consolidated sand, silt and clay. Between distance of -32 to -16 m along the profile shows very low resistivity values 6 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 to 111 Ωm with a thickness of about 15 m. Other isolated patches of high resistivity section ranging from 225 to 457 Ωm traversed by the profile are seen at -22 to -12 m, -2, 6 m,

and 20 to 26 m marks. These patches are suspected to be coal seam, since coal is associated with high resistivity.

Profile six, seven and eight
Figure 10 shows the resistivity model of profile six, seven and eight. The resistivity models revealed that the top soil is composed of mainly dry sand having a resistivity range of 143 to 907 Ωm. The top soil has high resistivity because its pore space lacks water. It is overlain by a layer of low resistivity (about 7 to 53 Ωm) which is suspected to be an aquifer zone. This implies that the basement is far, probably that might be the reason why the hand-pump borehole was sited near the location where profile six, seven and eight were taken.

Profile nine
Figure 11 shows the resistivity model of profile nine. The resistivity model shows the top soil with resistivity values ranging from about 83 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 to 57 Ωm. The section might probably be groundwater trapped in an aquifer. At a depth of about 3.8 to 17.2 m, there is occurrence of very high resistive section ranging from about 174 to 365 Ωm which might be a coal seam at a shallow depth.
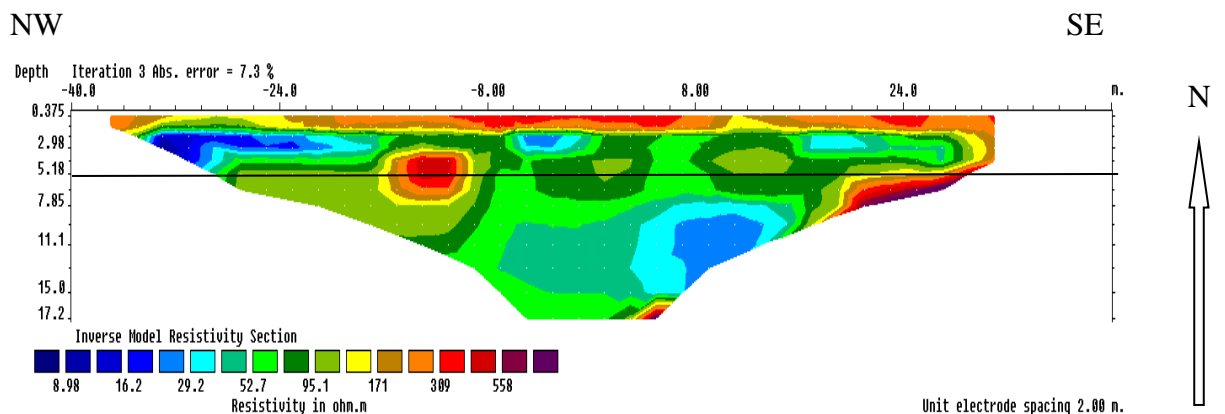

Fig. 8: Result of 2D inversion of the Wenner-Schlumberger array data along profile 4

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NE   SW

Depth   Iteration 3 Abs. error = 11.7 %
-40.0   -24.0   -8.00   8.00   24.0   m.

Inverse Model Resistivity Section

3.18   6.47   13.2   26.7   54.4   111   225   457

Resistivity in ohm.m

Unit electrode spacing 2.00 m.

N

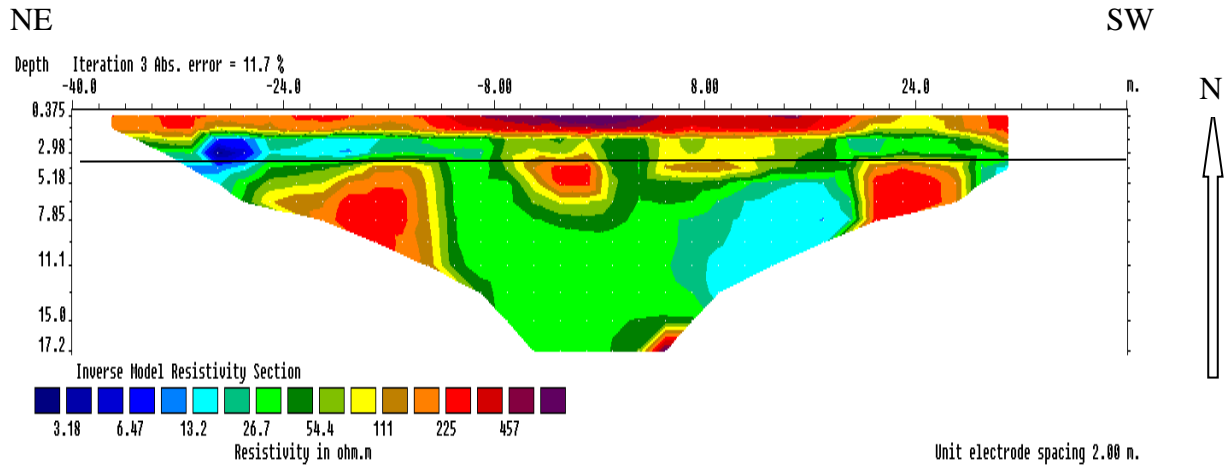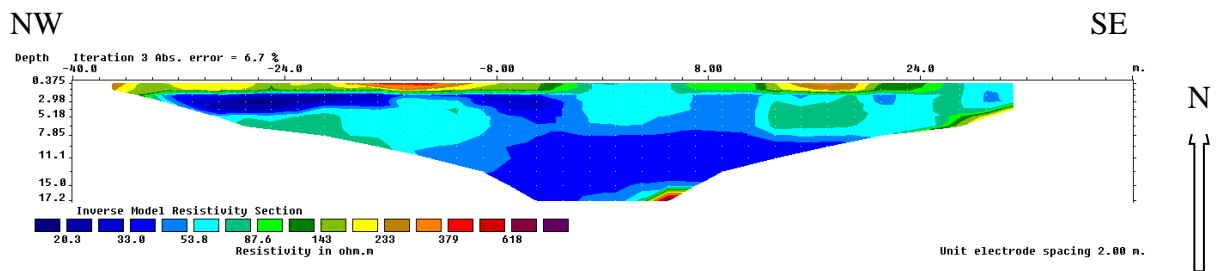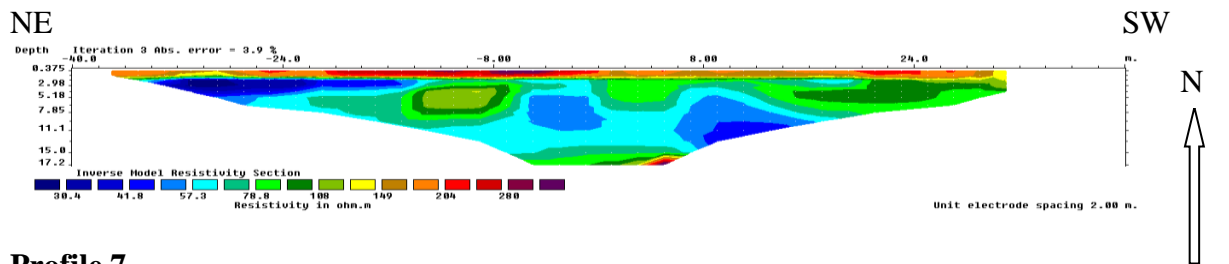**Fig. 9:** Result of 2D inversion of the Wenner-Schlumberger array data along profile 5

NW   SE
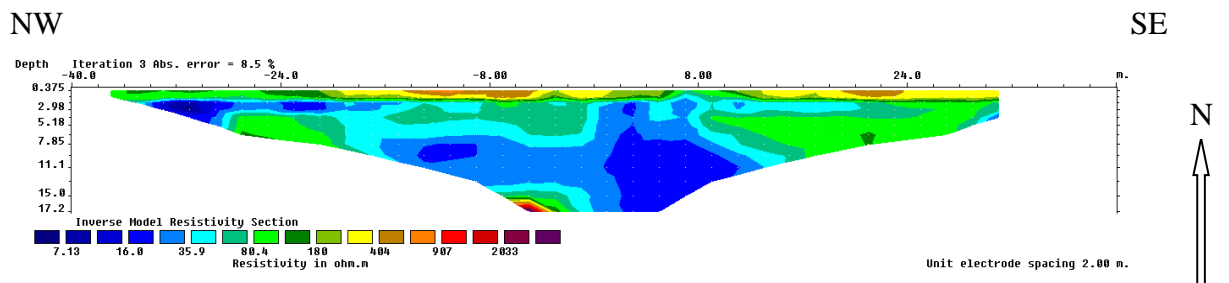
Depth   Iteration 3 Abs. error = 6.7 %
-40.0   -24.0   -8.00   8.00   24.0   m.

Inverse Model Resistivity Section

20.3   33.0   53.8   87.6   143   233   379   618

Resistivity in ohm.m

Unit electrode spacing 2.00 m.

N

Profile 6

NE   SW

Depth   Iteration 3 Abs. error = 3.9 %
-40.0   -24.0   -8.00   8.00   24.0   m.

Inverse Model Resistivity Section

30.4   41.8   57.3   78.8   108   149   204   280

Resistivity in ohm.m

Unit electrode spacing 2.00 m.

N

Profile 7

NW   SE

Depth   Iteration 3 Abs. error = 8.5 %
-40.0   -24.0   -8.00   8.00   24.0   m.

Inverse Model Resistivity Section

7.13   16.0   35.9   80.4   180   404   907   2033

Resistivity in ohm.m

Unit electrode spacing 2.00 m.

N

Fig 10: Resistivity model of profile six, seven and eight, respectively

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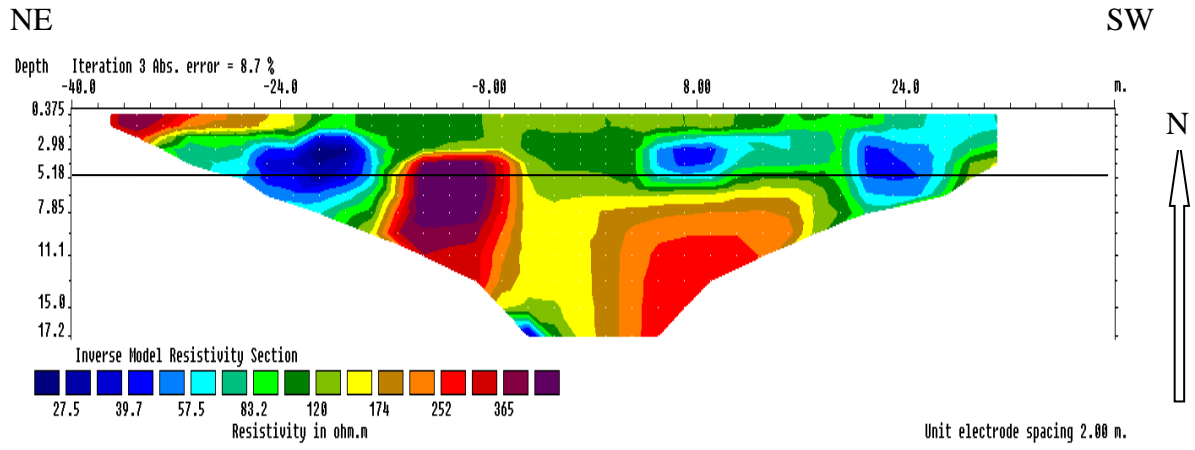
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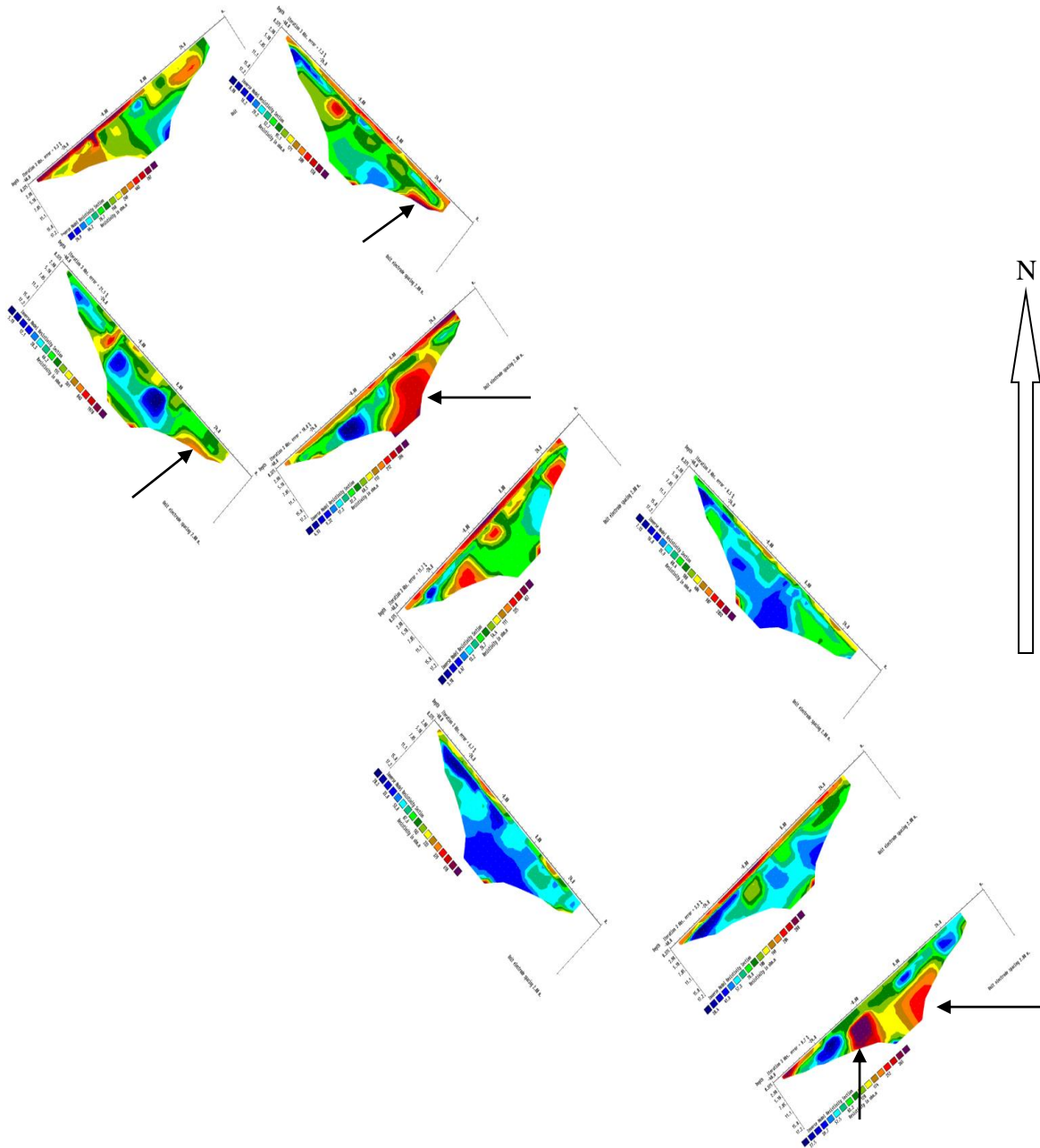**Fig 11:** Result of 2D inversion of the Wenner-Schlumberger array data along profile 9

Fig. 12: Resistivity model sections of all the profiles with the arrows indicating possible location of coal seam

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Merging of the profiles for the detection of continuity of the subsurface structures

The resistivity model of each profile taken was aligned as in the map illustrating the profiles layout (Fig. 12). This was done to enable the check for continuity of the subsurface structures. According to Steno's Principle of lateral continuity "Material forming any stratum was continuous over the surface of the earth unless some other solid bodies stood in the way (Stovall, 1954)". This principle was used to trace coal seams from one mountain to the next in West Virginia (Stovall, 1954).

It can be observed in Fig. 12 from the four profiles taken surrounding point P1 (location of the hand dug well) that there are high resistivity sections in models of profile 2 and 4 between the same distance below the top soil, which indicates the possibility of continuity in the subsurface structure (coal). A close look at profile 3 also revealed a high resistive section which is more pronounced than that of profile 2 and 4. This is probably because profile 3 was laid perpendicular to the suspected strike direction (NE-SW) of the coal seam while profile 2 and 4 are laid parallel to the suspected strike direction (NW-SE). Though, basement rock is also characterized with high resistivity, but its resistivity is higher than that of coal. Based on this, it can be inferred that the coal seam is striking in Northwest-Southeast direction.

Similarly, from the resistivity models of the four profiles taken around and surrounding point P2 (location of the hand-pump borehole), it can be seen that the continuity observed previously still persisted with the top soil having high resistivity indicating most likely the presence of dry sand. Below the top soil is a very low resistivity section with resistivity values ranging from 7 to 90 Ωm, which is an indication that the basement is deeper within this region. This might have coincided with the previous survey that was probably used in locating the position of the hand-pump borehole, since the position is favoured by a large overburden thickness. Therefore the coal seam is suspected to be at a deeper depth here.

Conclusion

It was observed from the results obtained that there is continuity of geological structure. The suspected coal seam in profile 2 appeared to continue to profile 3 and 4. The suspected coal seam in profiles 3 and 9 taken in NE-SW direction showed a clearer picture of the suspected coal seam because the profiles were laid perpendicular to the strike direction while that of profile 2 and 4 taken in NW-SE direction was not pronounced because the profile was laid along the strike direction. Hence it can be concluded that the coal seam within the study area is striking in the NE-SW direction.

It is therefore recommended that for an in depth survey, equipment with wider electrode spacing should be used and the profiles should be laid in Northeast-Southwest direction in order to obtain an optimum result.

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