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Application of Electrical Resistivity Imaging in investigation of Late Maastrichtian coal seam at Amoso Edda/Owutu Edda environs, Anambra Basin, Nigeria

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ABSTRACT

The coal exploration has been carried out using Electrical Resistivity imaging around Afikpo area of Southeastern Nigeria with the aim of delineating possible occurrence, depth to and thickness of coal seam. The results obtained from the interpretation of the VES identified four to seven lithologic units with varying depths and thicknesses, which include top soil, laterite, shale and coal seam. The thickness of the coal seam within the area ranges from 0.9-3.2m with an average of 2.05m, while average overburden thickness is estimated at 27.75m. Thin coal seams were delineated in few locations mostly in the central part and towards the NorthWestern side of the study area. Further drilling programme is recommended to estimate the total reserve of the resource coal available within the area.

Key words*:* mineral resources, geophysics, coal seam.

INTRODUCTION

The world coal production has been on increase until 2015. Then, the consumption reduced and the production again picked up towards the end of 2016 (b.p.com/statistical review). In Nigeria, the preliminary investigation reveals the country's coal reserve is over 2.7 Billion tons (Sada 2012).

Electrical Resistivity Imaging has gained attention among other geophysical methods for subsurface investigation of coal. A number of studies carried out in different parts of the world include: (Logn (1954), Van Nostrand and Cook (1966), Hallof (1966), Zohdy (1969), Zohdy et al., (1973), Singh and Jha (1972), Jain et al., (1973), Stanley et al., (1976), Patella (1978), Maillol et al., (1999), Antonio-Carpio et al., (2004), Singh et al., 2004, Van Schoor (2005), Wilkinson et al., (2005), Krishnamurthy et al., (2003), Krishnamurthy et al., (2009), Omowumi (2014) and Mohammed et al., 2016.

The purpose of the present study is to determine the nature, location, and extent of the resources of coal available in Afikpo area of Southeastern Nigeria to delineate the features that may affect their economic extraction.

Location and site description

The study area is located between Longitudes 7° 45′ 30″E to 7° 49′30″E and Latitudes 5° 50′00 5° to 52′00″N covering a total surface area of about 8km^2 with the North-South traverse being 4km and East-West traverse being 2km. The area is traversed by a major road that trends North-South through Amasiri to Itim. Major villages in this license area include Oso, Ndiuche, Ndi-Ikpo, Ndi-Ugbo, Ndi-Okpo as indicated in Figure 1.

Geology of the study area

The study area is generally underlain mainly by a sequence of outcropping shales, and sandstones Figure 1. The sandstones, which occur as elongated erosional relicts have been identified to belong to both the pre-and post-Santonian sediments of Abakaliki basin,which has shown evidence of being upturned with clear vertical dips up to 60^0 in places underlying a more flat-lying post-tectonic (Santonian) medium- coarse grained loosely consolidated sandstone sequence.

The shales are fine-grained, compacted, very dark and sometimes fissile. They are mostly flat-lying and clearly not affected by the regional Santonian tectonics. Outcrops of the shale are few, and where they occur especially south of Owutu they are visibly weathered and fissile. In the eastern parts of the license area especially around Asaga village, the shale is clearly gypsiferous. This gypsiferous shale can be traced within an area of 500 square meters. This occurs as locally massive, plateau or interposed with shale. The study area, seems to be at the boundary of the Anambra basin Nkporo shale and the older lower Benue trough probably represented by the Coniacian-Turonian

Figure 1. Picture of the pit dug indicating Shale underlying by Sandstone.

sequences.As recognized by Murat (1972) the megatectonic setting in the southern domain of the Benue trough was a longitudinal faulted crust whose eastern half subsided preferentially to become the Abakalikisub basin. The western fragment remained as a stable platform up to the Santonian following the Santonian folding and uplift, the main depocentre in the Benue trough (around Abakaliki area) became flexural inverted, displacing the depocentre to the west and northwest, thus creating the Anambra Basin.

The stratigraphy of the study area consists of Asu River Group and Eze-Aku Formation deposited in alternating transgressive and regressive phases. The Asu River Group, consisting of shale, sandstone, and limestone, is the older lithostratigraphic unit in the area and was deposited during Albian transgressive phase. It is also the oldest dated sedimentary rock unit in southern Benue Trough (Whiteman, 1982). In this project area, it is believed that the sediment filled the depression in the Afikpo area,which is considered as a part of the Anambra Basin and that the shale belongs to the Nkporo shale as proposed by Okoro (1995) and Nwajide (2013). The area was subjected to the tectonic invasion that produced the depocentre to the west of the Abakaliki Anticlinorium.

The sedimentary sequences in this area may have been part of a major Nkporo transgression (Okoro 2006, Nwajide 2013). The Nkporo shale as a formation has several lateral age equivalents. Reyment (1965) had earlier postulated the Nkporo to be lower Maastrichtian overlain by Mamu Formation and even believed that the coal cycle beds are time evaporation of the upper part of the Nkporo shale. However, recent classification generally agreed on stratigraphic correlation data to be of late Campanian.

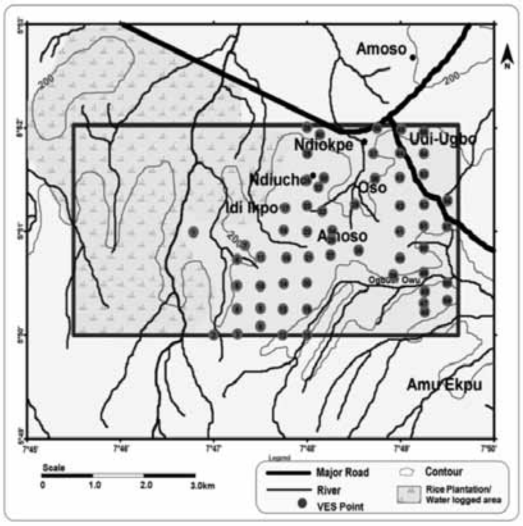

Figure 2. Layout of map of the study area showing the traverse lines and VES points.

Data Acquisition and Processing:

As an alternative to conventional drilling and sampling, a DC resistivity technique was employed to determine the depth and lateral extent of the coal seam. Vertical Electrical Sounding (VES) adapting Schlumberger configuration has been used to generate resistivity data. The mid-point of the array is kept fixed while the distance between the current electrodes is progressively expanded from 1 - 200 m.

The equipment used for the exercise includes one (1) Geopulse Tigre and four (4) Campus Ohmega resistivity meters, respectively. The measurements (VES) were conducted along pre-determined traverse lines running approximately East - West. On the other hand, VES were conducted randomly/spatially at areas where approximate E-W traverse could not be established because of hilly topography, extensive rice plantation, and waterlogged/swampy conditions. Some areas were completely inaccessible especially in the western parts of the study area Figure 6. A total of 6 traverses were laid with 10 VES points on each traverse. A total of 41 VES points could be completed and some points were off the traverse to get free space for the current electrode spread and finally to have a good distribution of the VES points over the study area.

The field curves were manually interpreted using master curves and auxiliary point charts. Geoelectric parameters obtained from manual interpretation were then used as an input model for computer-aided iteration of WINRESIST program for the interpretation until it yielded a final geoelectric model that satisfactorily fits well with the field curve.

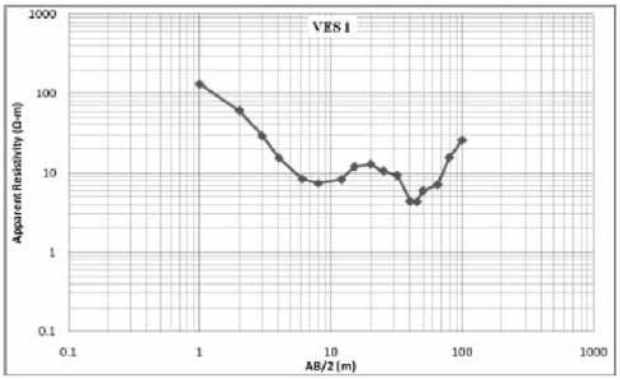

Figure 3. A Typical Resistivity Curve of the Study Area

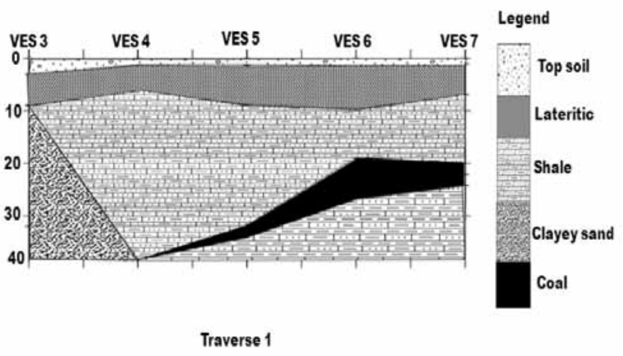

Figure 4. Geoelectric section of Traverse 1

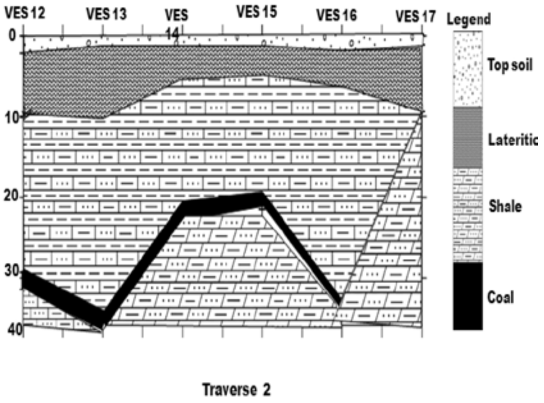

Figure 5. Geoelectric section of Traverse 2.

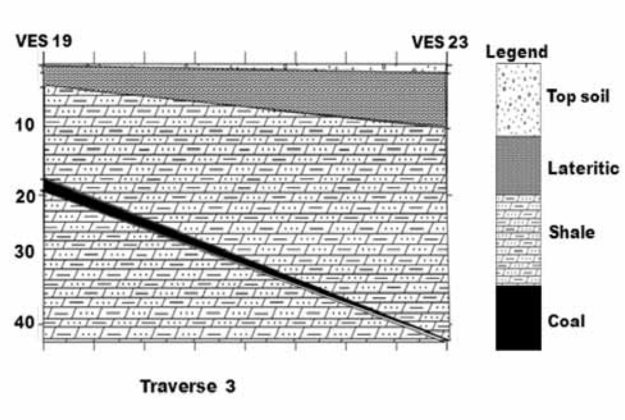

Figure 6. Geoelectric section of Traverse 3

Table 1. Coal-bearing strata and thickness in traverse 1.

VES NO	RESISTIVITY OF LAYER (ΩM)	COAL THICKNESS(M)	DEPTH TO TOP(M)
5	*36*	*2.2*	*31.9*
6	*22*	*3.2*	*26.9*
7	*49*	*1.6*	*22.6*

Table 2. Coal-bearing strata and thickness in traverse 2.

VES NO	RESISTIVITY OF LAYER (ΩM)	COAL THICKNESS(M)	DEPTH TO TOP(M)
12	*36*	*2.1*	*29.3*
13	*27*	*1.6*	*34.3*
14	*38*	*2.1*	*20.4*
15	*22*	*1.6*	*19.9*
16	*16*	*1.1*	*32.8*

RESULTS AND DISCUSSION

The resisitivity of the top soil ranges from 17 Ωm to 680 Ωm, clayey sand ranges from 13 Ωm to 115 Ωm, laterites range from 42 Ωm to 410 Ωm, shale ranges from 8 Ωm to 75 Ωm ,while that of coal ranges from 15 Ωm to 68 Ωm. These values are in agreement with the previous work done in the area (Oladapo et al, 2008). The resistivity of coal varies from that of a good conductor (10 Ωm) to a good insulator (1000 Ωm) depending upon the moisture content and the degree of saturation Figure 7. The coal in the study area is sandwiched between layers of shale that

Table 3. Coal-bearing strata and thickness in traverse 3.

VES NO	RESISTIVITY OF LAYER (ΩM)	COAL THICKNESS(M)	DEPTH TO TOP(M)
19	*52*	*1.7*	*17.6*

Table 4. Coal-bearing strata and thickness in traverse 4.

VES NO	RESISTIVITY OF LAYER (ΩM)	COAL THICKNESS(M)	DEPTH TO TOP(M)
27	*32*	*1.9*	*33.3*
28	*25*	*1.3*	*36.7*

Table 5. Coal-bearing strata and thickness in traverse 5.

VES NO	RESISTIVITY OF LAYER (ΩM)	COAL THICKNESS(M)	DEPTH TO TOP(M)
36	*20*	*1.4*	*30.1*

Table 6. Coal-bearing strata and thickness in traverse 6.

VES NO	RESISTIVITY OF LAYER (ΩM)	COAL THICKNESS(M)	DEPTH TO TOP(M)
39	*68*	*2.1*	*22.3*
42	*68*	*2.1*	*27.5*
45	*38*	*1.2*	*36.7*

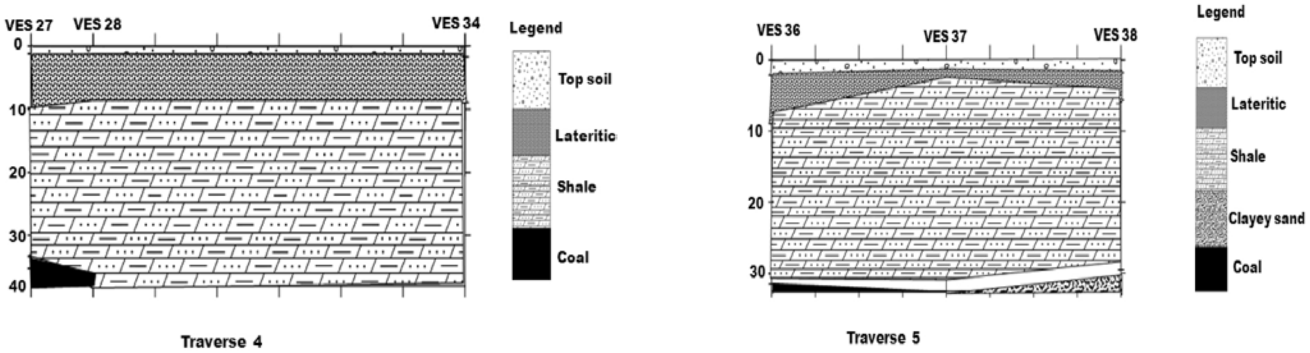

Figure 7. Geoelectric section of Traverse 4 and 5.

is conductive.Because of such a combination of layering, the resistivity of the coal seam, which was expected to be relatively high was considerably reduced (Oladapo et al 2008).

The geoelectric parameters obtained from the interpreted VES were used to construct litho section across some of the traverses to delineate possible areas of coal occurrences. The resistivities of different layers obtained from VES vary between 9 and 680 ohm.m ,while that of the coal bearing formation varies between 16 and 68 ohm m.

Figures 4-10 show the litho sections for VES points. The common probable lithologies comprise topsoil, clayey sand and shale (soft and indurated) and suspected coal seam as indicated in Table 9.

The various lithologic units with their varying thicknesses are shown in Tables 1 to 8. The probable thicknesses and depths of the suspected coal seam bearing horizons are also indicated. It is generally noticed that the abundance of the coal occur at the center of the study area. Some pockets of coal are also observed towards the Eastern part of the area.

Table 7. Coal-bearing strata and thickness in traverse 7.

VES NO	RESISTIVITY OF LAYER (ΩM)	COAL THICKNESS(M)	DEPTH TO TOP(M)
47	*32*	*1.1*	*37.6*
54	*15*	*0.9*	*37.9*
55	*15*	*1.9*	*33.1*

Table 8. Coal-bearing strata and thickness in traverse 8.

VES NO	RESISTIVITY OF LAYER (ΩM)	COAL THICKNESS(M)	DEPTH TO TOP(M)
59	*68*	*2.2*	*30.4*

Table 9. Summary of Geoelectric parameters and lithology.

VES number	Resistivity(Ωm)ρ1/ρ2/…./ρn	Depths (m) d1/d2/…./dn	Remark
1	140/72/10/25/8/32	1.3/4.9/6/9/20	Topsoil/Clayey sand/ Indurated shale / Clayey sand
2	110/60/20/35/18/63	1.2/6.2/7.2/2.1/14.6	Topsoil/Clayey sand/Shale/ Coal / Shale Clayey Sand
3	230/410/15/65	3/6/20	Topsoil(Compacted)/Compacted lateritic Clay/Shale/Clayey Sand
4	90/40/8/19	1.6/4.7/32	Top soil/clayey sand/shale/ Clayey sand
5	300/180/15/36/18	1.3/7.6/23/2.2	Topsoil (Compacted)/Lateritic Clay/Shale/ /Shale
6	270/110/9/15/22/10	1.6/7.9/9.6/7.8/3.2	Topsoil /Lateritic Clay/Shale/Indurated Shale/ Coal / Shale
7	240/75/35/49/25	1.1/5.8/15.7/1.6	Topsoil /Lateritic Clay/Indurated Shale/Coal / Shale
12	760/185/22/36/18	2.2/7.9/19.2/2.1	Topsoil (Reworked)/ Lateritic Clay/Shale/Coal /Shale
13	158/92/65/27/10	1.1/9.6/23.6/1.6	Topsoil /Lateritic Clay/Indurated Shale/Coal /Shale
14	195/140/15/38/13	1.1/4.6/14.7/2.1	Topsoil /Lateritic Clay/ Shale/ Coal /Shale
15	105/68/12/22/39	1.2/3.9/14.8/1.6	Topsoil /Lateritic Clay/ Shale/ Coal / Indurated Shale
16	96/42/8/16/11	1.6/5.2/26/1.1	Topsoil /Lateritic Clay/ Shale/ /Shale
17	210/95/11	1.1/8.3	Topsoil (Reworked)/ Lateritic Clay/Shale
18			
19	610/230/18/52/21	1.1/2.3/14.2/1.7	Topsoil(Reworked)/ Lateritic Clay/Shale/Shale
23	110/92/29/41	1.2/8.6/32.6	Topsoil /Lateritic Clay/ Shale/Clayey Sand
27	160/62/15/32/17	1.2/8.6/23.5/1.9	Topsoil /Lateritic Clay/ Shale/ Coal / Shale
28	225/106/12/25/10	1.3/7.8/27.6/1.3	Topsoil /Lateritic Clay/ Shale/Shale
29	105/82/11/38/17	1.1/8.3/12.8/1.7	Topsoil /Lateritic Clay/ Shale/ Coal /Shale
30	106/82/75/115	3.2/5.6/41.2	Topsoil /Lateritic Clay/Indurated Shale/Clayey Sand
34	120/62/8	1.7/7.2	Topsoil /Lateritic Clay/Shale
35	102/72/9	1.8/7.6	Topsoil /Lateritic Clay/Shale
36	110/68/12/20/10	2.1/6.8/21.2/1.4	Topsoil /Lateritic Clay/ Shale/ Coal or /Shale
37	26/17/6/15	1.2/2.7/28.6	Topsoil/Clay/Shale(Soft)/Clayey Sand
38	20/12/7/13	1.8/3.8/23.9	Topsoil/Clay/Shale(Soft)/Clayey Sand
39	680/210/32/68/42	1.8/7.9/12.6/2.1	Topsoil\(Reworked)/ Lateritic Clay/Shale/Coal/Shale
40	620/175/9/15	1.6/9.2/17.6	Topsoil (Reworked)/ Lateritic clay/Shale Clayey Sand
41	162/75/10/19	1.2/7.6/31.2	Topsoil/Lateritic Clay/Shale/Clayey Sand
42	550/98/20/68/40	1.2/7.6/18.7/2.1	Topsoil /Lateritic Clay/ Shale/ Coal Shale
43	103/78/11/25	1.2/9.2/22.6	Topsoil/Lateritic Clay/Shale/Clayey Sand
44	83/42/5/13	1.0/4.3/20.6	Topsoil/Lateritic Clay/Shale (Soft)/Clayey Sand
45	104/75/15/38/21	2.8/7.2/26.7/1.2	Topsoil /Lateritic Clay/ Shale/Coal/Shale
46	125/83/12/25	1.1/7.6/35.7	Topsoil/Lateritic Clay/Shale/Clayey Sand
47	680/192/15/32/18	1.6/9.7/26.3/1.1	Topsoil (Reworked)/ Lateritic Clay/Shale/Coal /Shale
48	210/63/13/22	1.3/7.3/27.9	Topsoil/Lateritic Clay/Shale/Clayey Sand
50	106/70/11/21	1.5/7.3/28.6	Topsoil/Lateritic Clay/Shale/Clayey Sand
54	106/55/8/15/7	1.7/7.6/28.6/0.9	Topsoil /Lateritic Clay/ Shale/ Coal / Shale
55	17/11/5/15/10	1.2/2.3/29.6/1.9	Topsoil /Clay/ Shale/ Coal / Shale
56			
57	106/78/15/29	1.3/7.8/17.8	Topsoil/Lateritic Clay/Shale/Clayey Sand
58	170/78/8/15	1.6/6.9/23.4	Topsoil/Lateritic Clay/Shale/Clayey Sand
59	120/82/10/68/15	1.6/7.2/21.6/2.2	Topsoil /Lateritic Clay/ Shale/Shale

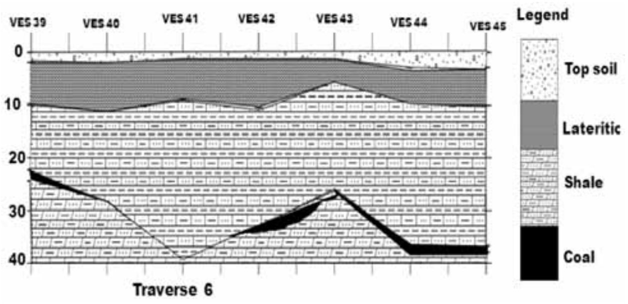

Figure 8. Geoelectric section of Traverse 6.

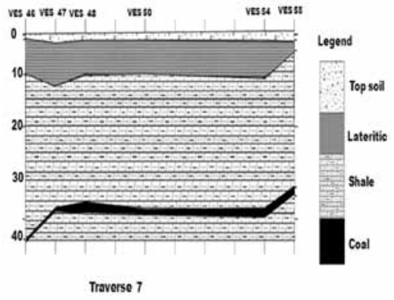

Figure 9. Geoelectric section of Traverse 7..

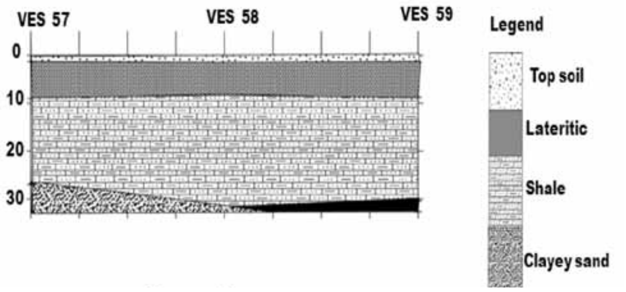

Figure 10. Geoelectric section of Traverse 8.

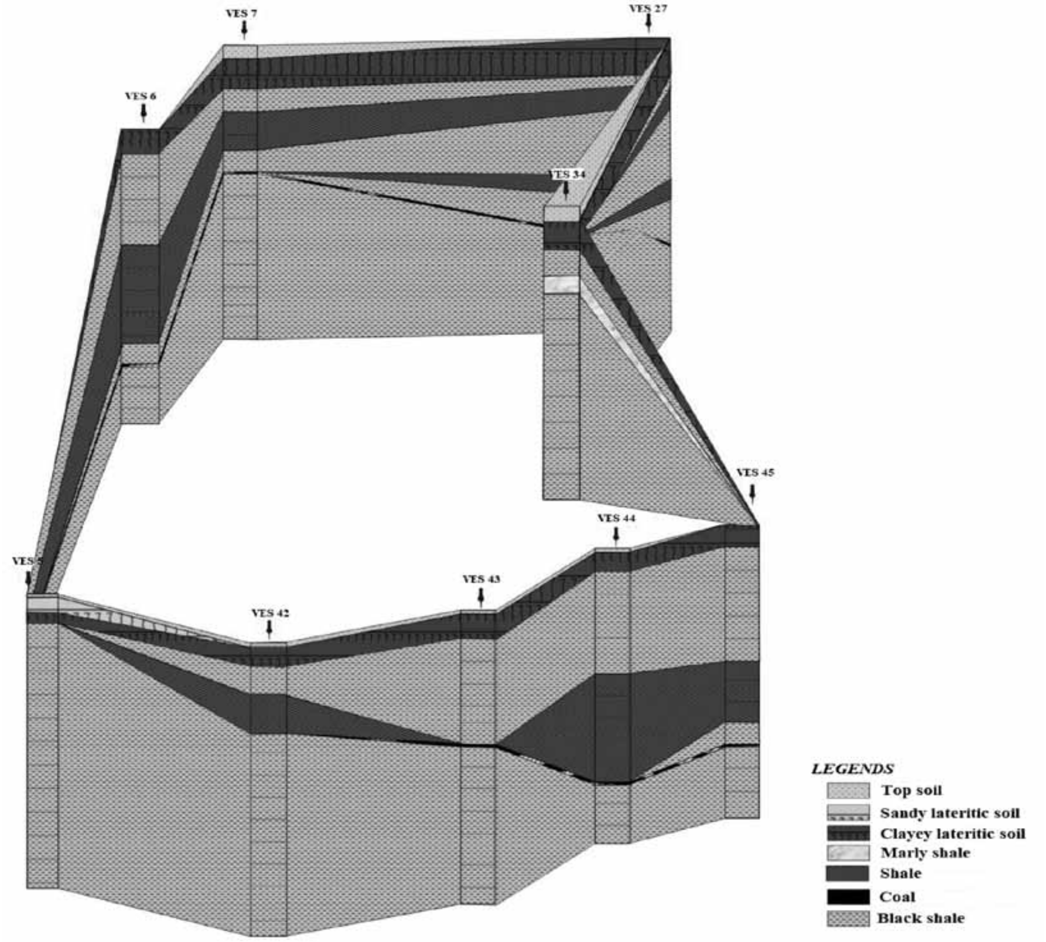

Figure 11. Fence diagram showing the distribution of different layers in the study area.

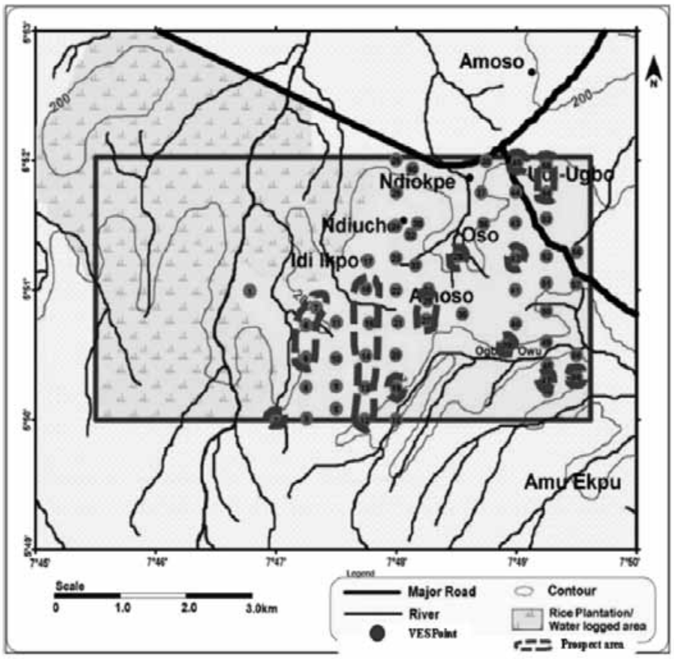

Figure 12. Map of the area indicating the coal bearing section.

CONCLUSION & RECOMMENDATION

The coal within the study area was observed to be sandwiched between layers of shale. In general, the coal bearing horizons vary in thickness from 0.9 - 3.2m, while the thickness of the host shale unit varies from 5 - 40m in most of the cases. These results match well with the previous works (Oladapo et.al., 2008 Singh et al., 2004, Subba Rao et. al., 2015). Possible prospect areas for further confirmation test were delineated. It is important to note that the depth and thickness ranges given above may not be exact due to overlapping values of resistivity for coal bearing zone and shale formation. Hence, test drilling is recommended at 12 locations (shown in Figure 12) which will also help in estimating the total reserve of the resource coal available within the area. Thus, it can be concluded that the resistivity imaging is economical and effective in delineating coal horizons .

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Compliance with Ethical Standards

The authors declare that they have no conflict of interest and adhere to copyright norms.

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