REDEFINITION OF EZIMO COALFIELD, SOUTH - EASTERN NIGERIA

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Abstract

The earlier definition of the Ezimo coalfield was based on a genetic model that restricted coal occurrence to shallow marine environment. Exploration models based on this genetic model proved or inferred only part of the resources. In this study, we propose an exploration model based on the genetic model that recognizes that the coal was formed in a variety of environments, including shallow marine and continental. The study involved geological mapping on a scale of 1:25,000. Three stratigraphic units designated A, B and C were established. Unit A comprises sub-units A_1 and A_2 .The condition of deposition has been reconstructed and varies from continental (sub-unit A_1 and part of unit B) to shallow marine (sub-unit A_2 and part of unit C). The result of the study shows that about 150km² of the area is underlain by coal seams. A tentative reserve of about 80 million tonnes of coal is inferred.

Keywords: *Coalfield, coal seams, genetic model, exploration model, shallow marine, continental.*

Introduction

The coal industry in Nigeria from 1913 to date has been based on the mining of sub-bituminous coal of the Mamu Formation (Reyment, 1965). The coals recorded at Enugu, Ezimo, Owukpa, Okaba and Ogboyoga have been described as containing low sulphur and high ash. The high ash content has adversely affected the use of the coals as thermal fuel. Most of the previous exploration models were based on a shallow marine genetic environment. The genetic model was generally given as coal derived from peat originating from lagoon and swamp. The major contributions were summarized by de-Swardt and Casey (1963).

McCabe (1984) suggested a modification of previous genetic models for coal. This was based on the characteristics of coals worldwide, including lithological associations. The overall picture is that coals occur in diverse sedimentary environments. Water enclosing the material is essential but marine water is not a limiting feature. The economic implication of the foregoing is that there are greater resources of coal, even of higher quality.

The Ezimo coalfield presents a unique opportunity to re-evaluate the existing models of the genesis of coals in the Southeastern Nigeria and evolve new exploration models based on valid empirical and genetic models integrated with the physiography and other features.

Location of Study Area

The Ezimo coalfield is an area totaling about 150km^2. It is bounded by latitude 6° 47'N and 6° 56'N and longitude 7° 25'E and 7° 33'E. The major population centres are Ezimo, Umuabo, Opi, Eha-Alumona, Isienu, Ehandiagu, Umundu, Orba, Obollo - Afor and Umosigide. The coal seams in the area are

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referred to as Ezimo coal (de-Swardt and Casey, 1963).

Figure 1 is a map showing the major towns and link roads in the study area.

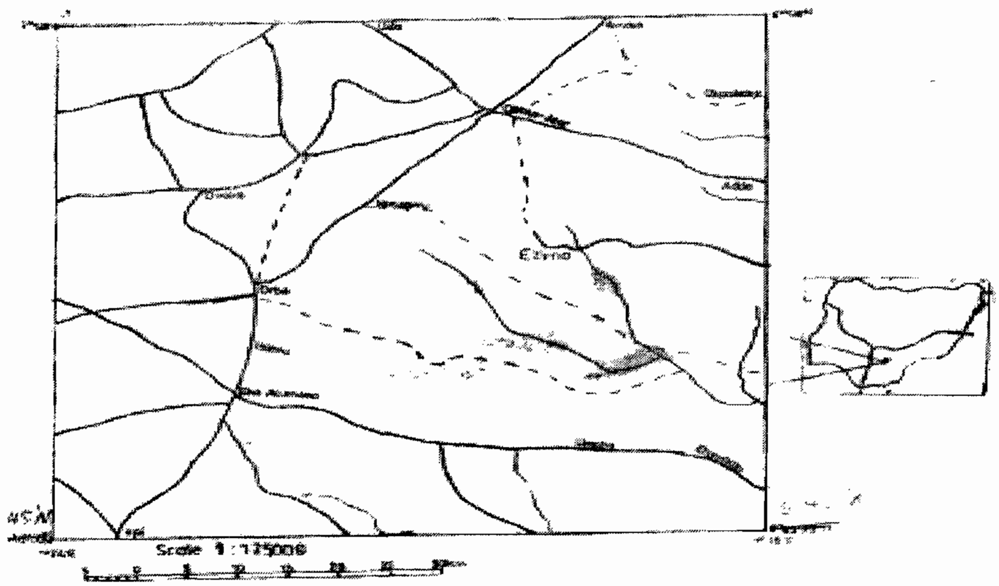

Fig. 1: Map showing the access routes of the study area

Geologic Setting
In this study the first approach adopted was to carry out a detailed geological mapping of the study area, recording coal occurrences, favourable lithologies, structures and other features that may have favoured coal depositions. Subsurface information was obtained from Geological Survey of Nigeria borehole numbers 1213, 1219, 1220 and 1235 (Table1) and a number of pits and vertical sections analysed in the study area (Fig.2).

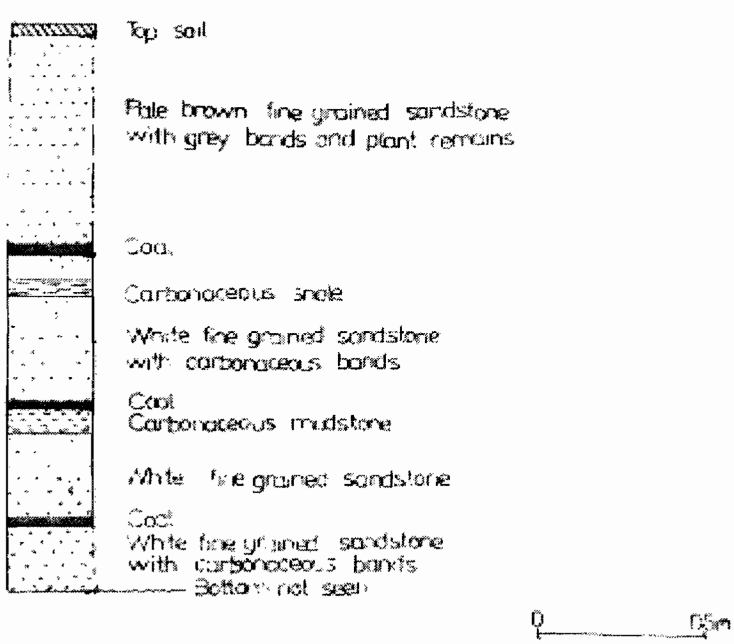

Fig. 2: Pit No. 3 (Lithological succession at the study area)

Three units of formation status were mapped in the coalfield and designated A, B and C. Unit A was divided into sub-units of rank of members and designated sub-units A_1 and A_2.

Table 1: Drilling results of boreholes in Ezimo (de Swardt and Casey, 1963).

GSN. BH NO.	Colony Co-ordinates	Elevation (m)	Depth (m)	Coal seams		
				From (m)	To (m)	Thickness (m)
1213	N. 1.050,490 E. 1.857,386	359.45	139.02	125.70 132.15	125.84 134.15	0.14 2.08
1217	N. 1,044,570 E. 1,855,510	358.23	82.47	-	-	-
1218	N. 1,044,340 E. 1,855,534	353.66	78.66	-	-	-
1219	N. 1,040,577 E. 1,847,576	319.21	88.41	80.86	81.86	1.30
1220	N. 1,049,586 E. 1,852, 881	464.02	247.56	240.85	242.65	1.80
1231	N. 1,045,721 E. 1,850,424	390.55	142.68	138.95	139.42	0.47
1232	N. 1054,517 E. 1,850,392	422.56	218.67	-	-	-
1235	N. 1,045,701 E. 1,850,392	390.24	163.11	140.67 140.90 159.15	140.90 141.43 160.67	0.23 0.53 1.52
1240	N. 1045,882 E. 1,844,907	371.65	79.57	-	- -	-

Paleoenvironment

The lithological characteristics of the study area and the stratigraphic units established indicate that the parameters utilized for the reconstruction of the conditions of deposition must be carefully selected. Previous authors (de Swardt and Casey 1963, Reyment 1965,Nwabufo-Ene 1990, among others) placed the coal measures into two units-Lower Coal Measures and Upper Coal Measures.

Considering the foregoing, fossil content analysis, sieve analysis and pebble morphometric analysis were used to determine the sample size and the frequency distribution of the sandstones in the relevant stratigraphic units. A total of twenty samples were collected from different stratigraphic units and analysed.

Results

The outcrop mapping revealed that throughout the coal sequence, from the base to the top, the lithology is more complex than hitherto appreciated. For example, the sandstone unit at the base is much thicker and laterally extensive than earlier noted. There are thin intercalations of marine shales and mudstones within thick sections of friable sandstones referred to as Ajali Sandstones (Reyment, 1965).

The formational analysis in this study has a very strong genetic basis. Three lithostratigraphic units were established, designated unit A, B and C. Unit A comprises two members designated A_1 and A_2 (Fig. 3).

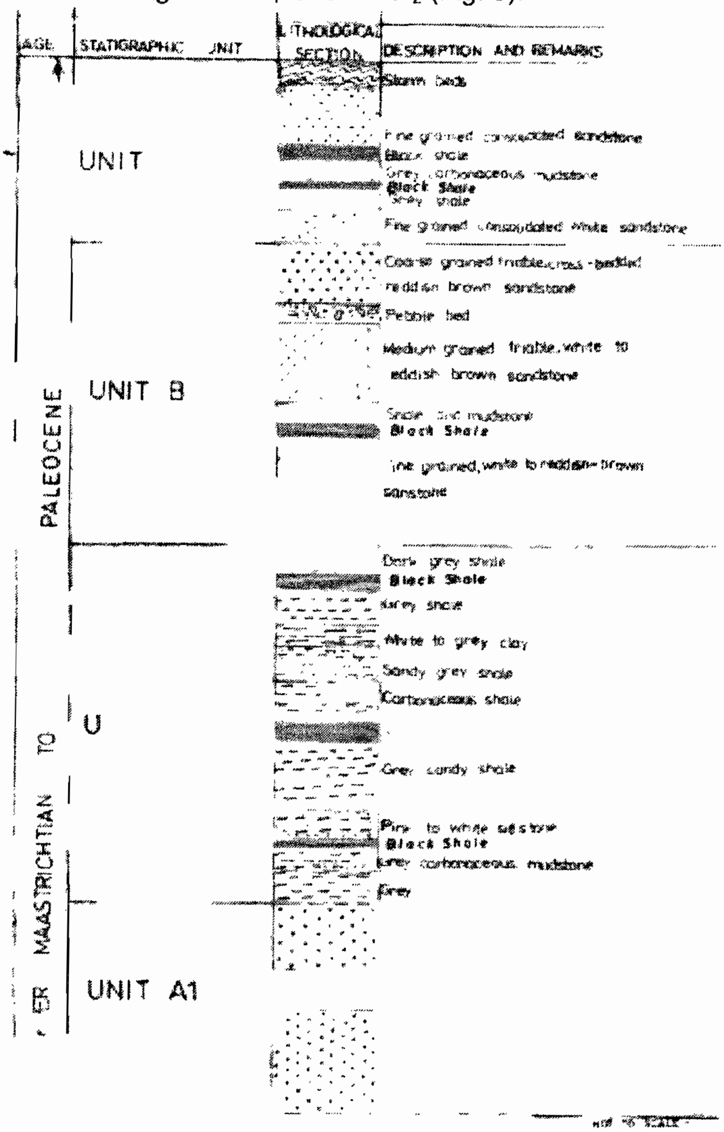

Fig. 3: Generalized stratigraphy of the study area

Member A_1 is predominantly consolidated sandstones that are well bedded. There are also thin beds of friable sandstones that show cross – bedding: subordinate shales and mudstones. Member A_2 is predominantly a shale–mudstone sequence. There are also siltstones and clays. Unit B is a thick sequence of white or reddish brown friable sandstone with a number of intercalations of marine shales and mudstones. Unit C comprises alternating beds of consolidated sandstones, shales and mudstones. Storm beds of tempestite occur towards the top of the unit.

From the fossil content analysis, some horizons in sub-unit A_2 and unit C yielded specimens of foraminifera haplophrigmoides. These are simple walled agglutinating types and indicate shallow marine environment of deposition. Some horizons in all the three units A–C show remains of marine macrofossils.

Table 2 illustrates the sieve analysis of a typical sample in the area. It has a mean of 0.764cm which is within the coarse range. The standard deviation indicates that the said grains are friable and poorly sorted. The grains are positively skewed. The result shows that the sandstones in this group are of continental origin. (Folk and Ward, 1980, Freidman and Sanders, 1978).

Table2: Sieve analysis of sandstone sample collected from a continental environment.

Sieve Opening (mm)	Phi-scale	Sieve weight (gm)	Corrected weight (gm)	Weight %	Cumulative weight (%)
2.80-2.00	-1.5-(-1.0)	1.88	1.8824	3.78	3.78
2.00-1.40	-1.0-(-0.5)	5.20	5.2041	10.46	14.24
1.40-1.00	-0.5-0.0	6.24	6.2342	12.54	26.78
1.00-0.71	0.0-0.5	7.84	7.8438	15.82	42.60
0.71-0.50	0.5-1.0	7.86	7.8604	15.86	58.46
0.50-0.355	1.0-1.5	5.24	5.2421	10.48	68.94
0.355-0.25	1.5-2.0	3.16	3.1645	6.38	75.32
0.25-0.18	2.0-2.5	4.38	4.3827	8.78	84.08
0.18-0.125	2.5-3.0	3.66	3.6619	7.38	91.46
0.125-0.106	3.0-3.2	3.88	3.8837	7.84	99.30
<0.106	>3.2	0.27	0.2714	0.58	99.88
Total Wight		49.61			
Sieve Loss		0.39			

Statistical Parameters

(a) Weight of sample: 50g
(b) Medium (Ma) = 0.525
(c) Mean (Mz) = 0.764
(d) Standard Deviation (Sorting) = 1.704
(e) Skewness (Ski) = 0.33
(f) Kurtosis (KG) = 1.51

Other features that support this conclusion are the unimodal distribution and the Kurtosis which is leptokurtic.

Table 3 illustrates a typical sample of consolidated sandstone type from another location in the study area. The sandstones are fine to medium grained, well sorted and negatively skewed. The kurtosis is platykurtic and the distribution is bimodal. The features indicate a shallow marine environment of deposition.

TABLE 3: Sieve analysis of sample collected from shallow marine environment.

Sieve Opening (mm)	Phi-scale	Sieve weight (gm)	Corrected weight (gm)	Weight %	Cumulative weight (%)
2.80-20	-1.5 – (-1.0)	5.07	5.0710	10.15	10.15
2.00-1.4	-1.0 – (-0.5)	7.76	7.7622	15.52	25.67
1.40-1.0	-0.5 –0.0	1.79	1.7904	3.58	29.25
1.00-0.71	0.0 – 0.5	7.83	7.8323	15.63	44.88
0.71-0.50	0.5 –1.0	5.13	5.1324	10.26	55.14
0.50-0.355	1.0 –1.5	3.49	3.4915	7.06	62.20
0.355-025	1.5 –2.0	5.04	5.0103	10.06	72.26
0.25-0.18	2.0 –2.5	4.38	4.3841	8.76	81.02
0.18-0.125	2.5 –3.0	3.65	3.6520	7.31	88.33
0.125-0106	3.0 –3.2	5.40	5.4046	10.80	99.13
< 0.106	>3.2	0.30	0.3042	0.58	99.71
Total Weight		49.84			
Sieve Loss		0.16			

Statistical Parameters

(a) Weight of sample: 50g
(b) Medium (Ma) = 0.514
(c) Mean (Mz) = 0.656
(d) Standard Deviation (Sorting) = 1.876
(e) Kurtosis (KG) = 0.75
(f) Skewness (Ski) = 0.16

The results of the pebble morphometric analysis show that the average flatness ratio for the pebbles is 0.5cm while the elongation ratio ranges from 0.61cm to 0.84cm with a mean of 0.73cm. The maximum projection sphericity of the pebbles ranges from 0.63cm to 0.81cm with a mean value of 0.73cm. The diagram of Sneed and Folk (1958) was used to determine the form for each pebble. The result shows that: compact – bladed form constitute 58%, the bladed form 20%, the compact – elongate form 16% and the elongate form 8%. Based on the scale of Pettijohn and Potter (1963), most of the pebbles from unit B are sub- rounded.

Discussion

Condition of Deposition

A careful integration of all relevant data has made the following conclusions on the conditions of deposition possible.

Sub unit A_1 was deposited in a continental environment. A fluvial environment is indicated by the roundness, mean, elongation ratio, flatness ratio and maximum projection sphericity. Also the sands being positively skewed as well as the unimodal distribution support the continental environment interpretation.

It is important to note that throughout this sub-unit, horizons occur in which thin beds of friable sandstones alternate with the consolidated sandstones indicating fluctuations in the sea level and return to continental sedimentation at intervals. Also minor marine activity periodically interrupted the major continental deposition that marked the lower part of this stratigraphic unit.

Sub unit A_2 was deposited in a shallow marine environment. This conclusion is supported by the occurrence of agglutinating foraminifera of the simple wall–type. The shale with well-developed parallel laminations indicates deposition in low energy environment. The black shales indicate deposition in oxygen-depleted environments. Some horizons contain consolidated sandstones with carbonate cement, supporting the shallow marine environment interpretation.

The conditions of deposition of Unit B are similar to those of the lower part of Sub – Unit A_1 (friable sandstones). There are however, thin beds of marine shales and mudstones in a number of horizons implying brief periods of marine incursion. The unit is therefore very complex, having been deposited in varying environment conditions- continental, fresh water, fluvial-deltaic, shallow marine (lagoon. swamp or estuarine).

Unit C also represents a number of environment kinds–shallow marine, fresh water, fluvial-deltaic. The shales and mudstones contain agglutinating foraminifera of the simple wall-type indicating deposition in shallow marine environment. The associated consolidated sandstones with carbonate cement support this conclusion. The horizons with friable poorly sorted sandstones represent deposition in a continental environment.

Redefinition

The objective of this study is to redefine the Ezimo coalfield. This is based on the integration of all relevant data of previous work and the results of the present investigations. Figure 4 shows the redefined Ezimo coalfield. The redefinition concentrated on the following features.

(i) Geological Setting

The lithology comprises sandstones, siltstones, mudstones and shales. Repeated cycle of units may be present, which indicate uplift and subsidence of land during deposition. This sediments range in age from Uppermost Maastrichtian to Lower Paleocene. Deposition was in lagoons, swamps, deltaic, fluvial–deltaic and limnic environments

(ii) Stratigraphy

The Lithostratigraphy of the study area has been reviewed. Previous Lithostratigraphic conclusions were very broad concepts. It appears that the generalization was prompted by the conclusion of a lagoon

/swamp environment for the deposition of the coal measures.

Three units of formation status have been mapped in the coalfield and designated units A, B and C. Unit A has been divided into two sub – units of rank of members and designated Sub-Units A_1 and A_2.

Unit A corresponds with the Lower Coal Measures of Simpson (1954) or Mamu Formation of Reyment(1965).Unit B is correlatable with the False Bedded Sandstones (Simpson,1954) or Ajali Sandstones(Rement,1965) while Unit C can be correlated with the Upper Coal Measures of Simpson(1954) or Nsukka Formation of Rement(1965).

(iii) Coal Resources

A major seam outcrops for a distance of 7km along the escarpment. In the southern and central parts of the area the coal is 1.2 to 1.5m thick, but north of the Oshenye stream, a parting develops in the stream. In the Enerve river in the extreme northeast of the area the seam has thinned to 0.3m. Fairly thick outcrops were also recorded in Iyiozuma stream (1.4m), Ogele stream 1.2m, Okpeke stream (1.3m) and Aboine river (1m).

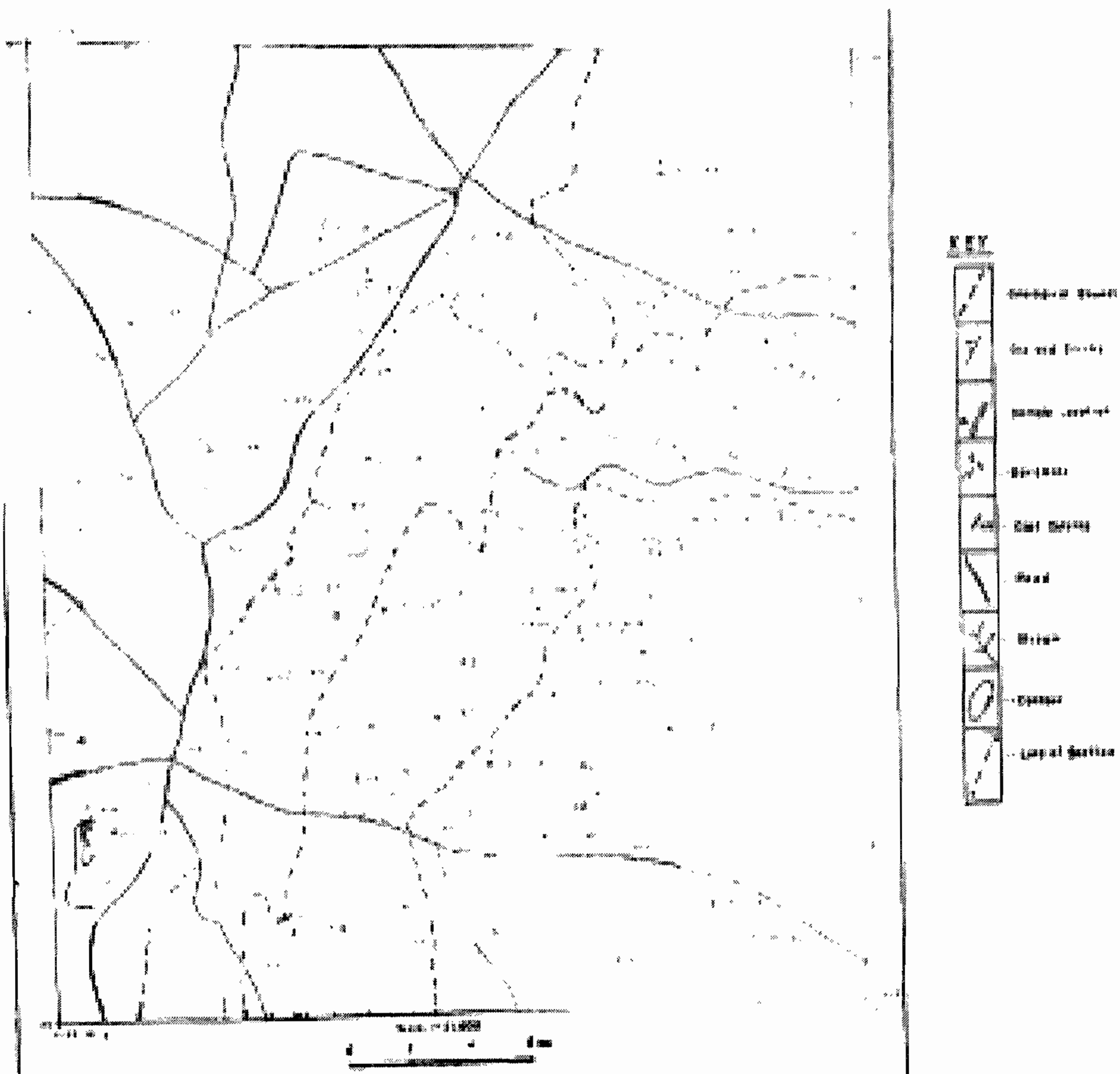

Fig 1 EZIMO COALFIELD SHOWING SAMPLE LOCATIONS AND COAL OUTCROPS

Some of the coal seams exposed are shown in plates1and 2.

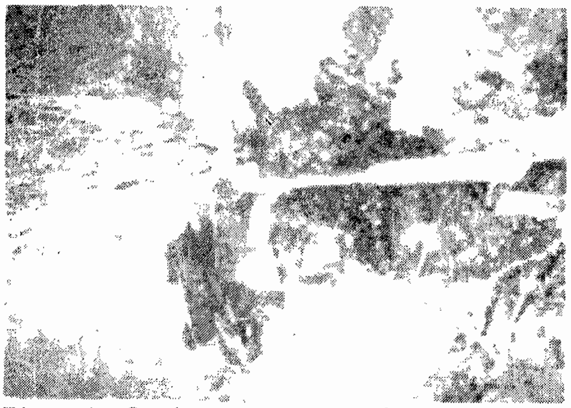

Plate 1: Coal seam exposed at Iyiozuma stream

Plate 2: Coal seam exposed at Ogele stream.

de – Swardt and Casey (1963) gave the following figures as coal reserves in the Ezimo area.

Indicated	Inferred
29 million tonnes	17 million tonnes

Nwabufo – Ene (1993) gave the Ezimo coal reserves as:

Indicated	Inferred
56 million tonnes	60 million tonnes

According to de – Swardt and Casey (1963) "The indicated reserves in the range of 0.6m to 1.06m are not indicated in the total reserves as competent mining engineers have expressed the opinion that seams less than 1.06m thick could not be economically worked in Nigeria under the present conditions". Assuming that there is at the present time improved mining engineering technology to exploit seams less than 1.06m, and since thick seams outcrop in streams other than the Egodo and Iyioku, as well as other sections, an inference of additional coal reserve of at least 20 million tonnes to a depth of 540m is made. Considering the foregoing, the coal reserves are as follow.

Indicated	Inferred
56 million tonnes	80 million tones

(iv) **Genetic and Exploration Models**
Previous genetic models for Ezimo coal include those of Simpson (1954), de Swardt and Casey (1963), Reyment (1965), Nwabufo – Ene (1990, 1993).

The genetic model of de-Swardt and Casey (1963) implies that coal deposition was dependent on the shallow sea. Thus coal exploration model must necessarily aim at discovering periods of marine encroachment during the deposition of the Mamu Formation.

The field observation shows the validity of the conclusions of Nwabufo – Ene (1993). The association of coal seams with fluvial – deltaic deposits in the Ezimo area is comparable to coal deposits described by Styan and Buskin (1984). Thus the genetic models for coals in the study area include coals from shallow marine environments as well as coals from continental environments.

Exploration for these coals should therefore include the use of modern techniques which are able to appraise targets indicated by the foregoing genetic models. Stratigraphic and structural studies are essential. Geophysical and geochemical surveys may also be employed to support detailed geological mapping programmes. Pitting, trenching and drilling are also essential tools.

Conclusion

The result of the geological investigation of the Ezimo area shows that the area is underlain by shales, clays, mudstones, siltstones, friable sandstones and consolidated sandstones. Three stragigraphic untis, designated Unit A, Unit B and Unit C were established. Unit A comprises two sub-units (Sub–Unit A_1 and A_2). Unit A may be correlated with the Mamu Formation while unit B corresponds to the Ajali Sandstones.

Unit C is correlatable with the Nsukka Formation.

Sub–Unit A_1 and Unit B were deposited in fluvial–deltaic environment with periods of shallow marine sedimentation. Sub-unit A_2 was deposited in shallow marine environment, mostly in quiet water (lagoons and swamp). Some friable sandstones in sub-unit A_1 and unit B are cross-bedded which represents fluctuations in flow energy. Unit C was deposited in a variety of environments, from shallow marine, estuarine to fresh water.

The present study has thus shown that marine shales and mudstones occur in lithologies previously placed under the Ajali sandstones (Reyment, 1965).

New genetic models have been defined for coals in the Ezimo area.The genetic models for coals in the Ezimo area include-:

(i) Coals associated with lagoons and swamp
(ii) Fluvial coals
(iii) Fluvial-deltaic coals
(iv) Coals of other continental origin (limnic,estuarine)

Based on the new genetic models, exploration models should be aimed at locating shallow marine coals as well as continental coals.

Integration of all relevant data (from pits, boreholes and outcrops) made possible the evaluation of the coal resources. About $150km^2$ is underlain by coal seams. The average coal thickness is 1.1m. Exploration for continental coals will lead to increased coal resources in the study area other than the value hitherto defined by shallow marine coals. Inferred coal reserve is about 80 million tonnes to a depth of 540m.

The genetic and exploration models developed for Ezimo coalfield could be used in other target areas in Nigeria.

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