

MAJOR OXIDE COMPOSITION OF SELECTED COALS FROM ANAMBRA BASIN, SOUTHEASTERN NIGERIA: IMPLICATIONS FOR ASH DEPOSITION TENDENCY, PALEOENVIRONMENT RECONSTRUCTION AND TECTONIC SETTING

Onwuchekwa, Chidiebere N¹ and Amobi, Johnson O²

¹ Department of Mineral & Petroleum Resources Engineering, School of Engineering Technology, Federal Polytechnic Nekede, Owerri. Imo State, Nigeria.

² Department of Geology, University of Nigeria, Nsukka. Enugu State Nigeria.

Corresponding authors: onwuchekwa.chidi@fpno.edu.ng, johnson.amobi@unn.edu.ng

Abstract

The study on major oxide geochemistry of coal is vital to the determination of ash deposition tendencies, paleoclimatic and paleoredox condition reconstruction, hydrothermal influence and tectonic setting of coal. Geochemical analysis for Eha-Alumona and Ehandiagu coals was performed by X-ray fluorescence (XRF) Spectroscopy techniques with values in the range as follows SiO₂ (47.39-51.64%), Al₂O₃ (29.38-33.32%), Fe₂O₃ (6.50 -10.36%), and TiO₂ (1.22–1.98%), MgO (0.045–0.11%), CaO (0.25– 0.50%), Na₂O (0.020–0.040%), and of K₂O (0.13-0.027). Major oxides such as SiO₂, Al₂O₃ and Fe₂O₃ constitute greater than 86% of the bulk compositions of both coals. The ash deposition indices suggest a low slagging and fouling propensity which means the coals are non-problematic during combustion. Results from the computed values of major oxide geochemical indices and bivariate plots revealed that the coals are sub-bituminous in rank, a semi-arid palaeoclimatic climatic condition prevailed at the time of deposition, an oxic to sub-oxic paleoredox condition. The coal samples are derived mainly from terrestrial sources. The tectonic setting of the source material for forming coal is from an active continental margin related to the subduction of oceanic crust beneath the continental crust.

Keywords: **Anambra Basin, Major oxide, Paleodepositional reconstruction, Ash deposition tendencies**

1. Introduction

Coal, an end product of biological and geologic processes acting on plants remains over time, consisting of a complex combination of organic and inorganic matter [1]. The organic components of coal are fundamental to defining the nature of coal while the inorganic constituents can have profound environmental, economic, technological and human health impacts [2; 3]. The inorganic constituents in coal are all elements (excluding C, H, O, N and S) in mineral form and organically bound inorganic elements. Small quantities of certain minerals and inorganic compounds are known to modify the behaviour of coal during pyrolysis and gasification processes. They can cause technological problems such as fouling and slagging of coal-fired boilers, corrosion and erosion of combustors, abrasion of mining and grinding equipment, affect washability and oxidizability of coal, the heating value of coal, contribute to environmental pollution, but also contain information on defining and explaining palaeo-sedimentary environments of coal formation, diagenesis and source materials [4]. Each coal deposit is unique and has individual plant constituents and regional, deposition and paleoenvironmental factors which cause a specification in predictable end products of a definite set of biological, chemical and physical conditions. Hence, a given coal's final chemical and mineral composition is a very important unique genetic code, indicating the changes at different stages during material deposition and coalification [5]. This diversity presents a challenge to constructing a coherent picture of coal geochemistry and the processes that influence the chemical composition of coal. The sound and effective use of coal requires a better understanding of the geochemistry of coal, i.e., the chemical and mineralogical characteristics of the coal that control its technological behaviour, by-product characteristics, and environmental and human health impacts. The

complex nature of coal is due to the presence of organic and inorganic constituents. Inorganic constituents and minerals, which are present in smaller quantities, are defined as “mineral matter” [6]. Mineral matter in coal can either be sourced from coal-forming plants (inherent minerals), or derived from the weathering of source rocks carried by the wind or water (extraneous minerals) [7; 8]. These minerals can be formed both in the final syngenetic phase and in the epigenetic phase [9]. Inherent impurities in the combustion process leave ash in the form of oxides from SiO₂, Al₂O₃, TiO₂, Mn₃O₄, CaO, Fe₂O₃, MgO, K₂O, Na₂O, P₂O₅. Knowledge of the behaviour of inorganic matter during the heating of different coals can be useful in anticipating their technological impacts during combustion, gasification, carbonization and liquefaction. Most studies in the coals of Anambra Basin have concentrated on the geology and geochemistry, petrology and petrography, thermal and kinetic properties of some coals [10-16]. Therefore, in the present investigation, an attempt has been made to infer the paleodepositional conditions that controlled the formation of studied coal and predict the propensity to slag and fouling during combustion using geochemical indicators from major element oxides.

2. Geological Setting

The study area is a part of the Anambra basin whose rocks are upper cretaceous in Age (Reyment, 1965). It lies between longitudes 6° 51' 22.71" E and 6° 45' 34.26" E and latitudes 7° 32' 51.72" N and 7° 26' 42.29" N. These areas are within Eha-Alumona in Nsukka LGA and Ehandiagu in Ezeagu LGA, all situated in Enugu State, Nigeria (Figure 1).

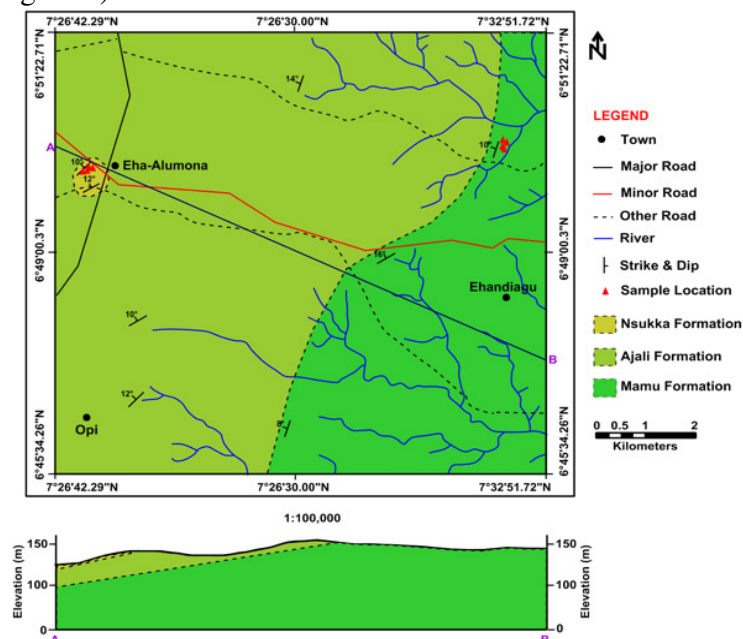


Figure 1. Location Map of the study area.

The Cretaceous Anambra basin (Figure 2) is one of the inland sedimentary basins in Nigeria and a sub-basin of the Benue rift structure covering about 2200 km². The Anambra Basin is believed to be an integral unit of the Lower Benue Trough with its morphology roughly triangular. It is located in the south-central part of Nigeria and is embodied by vast lithological heterogeneity in both horizontal and vertical extensions derived from a variety of paleo-environmental milieus [17]. It is a NE-SW trending syncline that is part of the Central African Rift System which developed in response to the stretching and subsidence of major crustal blocks during a Lower Cretaceous break-up phase of the Gondwana super-continent. The movements were re-activated by further plate activity in the Lower Tertiary soon after the intermittent Upper Cretaceous rifting. The Anambra Basin contains about 6km thick Cretaceous / Tertiary sediments

and is the structural link between the Cretaceous Benue Trough and the Tertiary Niger Delta [17]. Sedimentation in the Anambra Basin commenced with the Campano–Mastrichtian marine and paralic shales of the Enugu and Nkporo Formations, overlain by the coal measures of the Mamu Formation. The fluviodeltaic sandstones of the Ajali and Owelli Formations lie on the Mamu Formation and constitute its equivalents in most places (Figure 3).

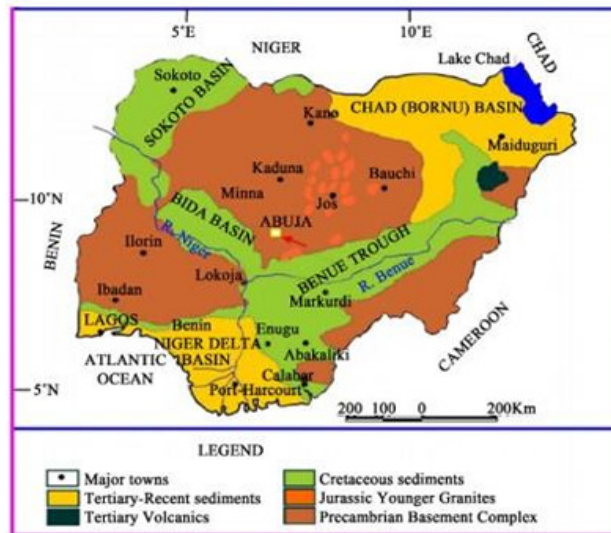


Figure 2. Nigerian geological map [adapted from 18] showing the NE-SW trending the Anambra Basin.

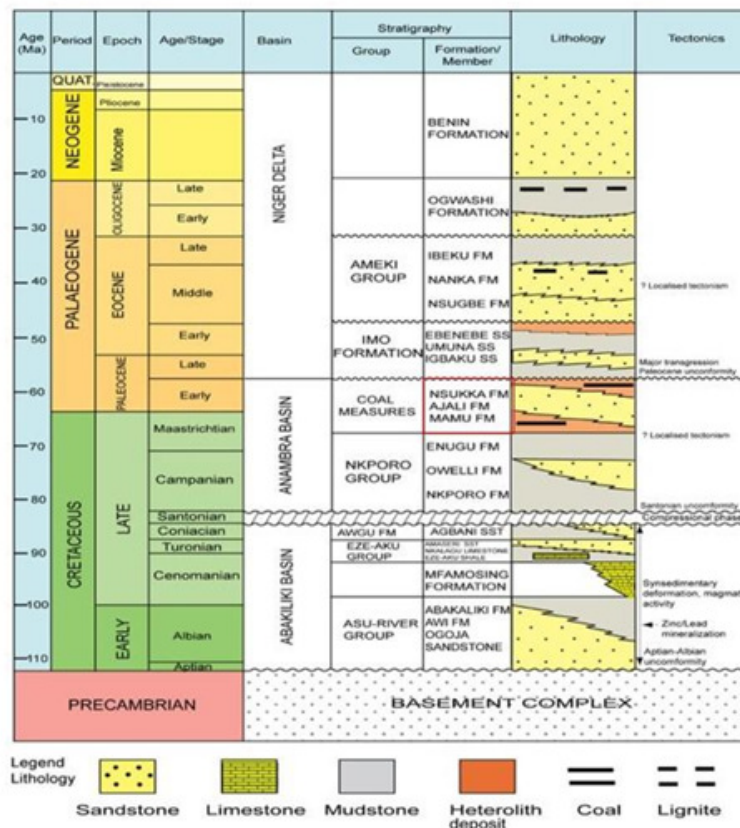


Figure 3. Anambra Basin Stratigraphic Succession [modified after 19].

3. Materials and Methods

3.1 Sample Collection and Preparation

Eight samples from Eha-Alumona and Ehandiagu coal deposits in the Anambra Basin of Nigeria were collected. Four samples per location at several regular meters intervals apart were taken with consideration of possibilities of variations in sample constituents. About 2kg each of the representative samples were collected in an air-tight aluminium pack and were labelled EHA 01, EHA 02, EHA 03, EHA 04 (for Eha-Alumona coal), EHN 01, EHN 02, EHN 03, EHN 04 (for Ehandiagu coal) respectively. About 1kg weight of each sample was ground to fine powder, using an auger grinding machine and passed through 150 micro mesh sieves to ensure homogeneity of the samples and the powdery coal used for various analyses. All analytical determinations were done according to the ASTM-1992 standard methods. All sample analyses were carried out at the Nigerian Geological Survey Agency Laboratory, Kaduna, Nigeria.

3.2 Determination of Major element Oxides in Coal

X-ray Fluorescence (XRF) was used to determine the various major element oxides, including SiO₂, Al₂O₃, CaO, K₂O, Na₂O, Fe₂O₃, MnO, MgO, TiO₂, and P₂O₅, in the coal and coal ash samples. Samples were oven-dried at 100°C for 12 hours to remove the absorbed water and then crushed with a mortar and pestle to fine powder. Nine grams of the dried powdered samples were mixed with 2g of binder (a mixture of wax C and EMU powder). Binders were used to glue the individual grains of the samples together before making the mixture into pellets at a pressure of 15 kbar for a minute. The fused ash was placed in the XRF-minimal 4 and the percentage composition of each oxide was displayed on the monitor.

3.3 Prediction of Ash Deposition Tendency.

The use of standardized ashing processes, ash fusion experiments, and some empirically based slagging and fouling indices has been the traditional method of predicting coal ash behaviour [20;21]. The prediction indices are widely developed and preferred due to their convenience, practicality, and time-saving. To determine the propensity of slagging and fouling of the coal sample under investigation, several indices have been employed to evaluate the slagging and fouling potential of coals. These include the Base-to-acid oxides ratio (B/A), Slagging Viscosity Index (S_R), Bed Agglomeration index (BAI), and Fouling index (F_u) [22-25].

Base-to-Acid Ratio: The base-to-acid ratio (*B/A*) is defined as the ratio of basic oxides to acidic oxides as follows:

Basic to acidic ratio (*B/A*) = $\%(\text{Fe}_2\text{O}_3 + \text{CaO} + \text{MgO} + \text{Na}_2\text{O} + \text{K}_2\text{O}) / [\%(\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{TiO}_2)]$ **Slagging**

Viscosity Index: Slagging Viscosity Index (S_R) = $(\text{SiO}_2 / (\text{SiO}_2 + \text{CaO} + \text{MgO} + \text{Fe}_2\text{O}_3)) \times 100$

Iron Percentage Index (% Fe): (%Fe) = %Fe₂O₃ Index

Fouling Index (F_u): Fouling index (F_u) = $(\text{B/A}) \times (\text{Na}_2\text{O} + \text{K}_2\text{O})$

Where SiO₂, Al₂O₃, TiO₃, Fe₂O₃, CaO, MgO, Na₂O, and K₂O represent the percentages of individual oxides in the ashes.

4. Result and Discussion

4.1 Major Elements of the coal samples

The major element oxide composition of the eight coal samples is presented in Table 1. The result of the analysis revealed that SiO₂ (47.39-51.64%), Al₂O₃ (29.38-33.32%), Fe₂O₃ (6.50 -10.36%), and TiO₂ (1.22–1.98%) were the dominant oxides while MgO (0.045–0.11%), CaO (0.25– 0.50%), Na₂O (0.020–0.040%), and of K₂O (0.13-0.027) are all less than 1. In comparison to the average values for the values of Post Archean Australian Shale (PAAS) [26] to find out whether there is an enrichment or depletion in the oxide

compound composition. The concentrations for SiO₂, CaO, MgO, Na₂O and K₂O are generally lower while values for Al₂O₃, Fe₂O₃ and TiO₂ were higher than the average values of PAAS. The concentration coefficient of a major element is the ratio of the thickness-weighted average of the content in the coal to the corresponding elemental content can reflect the depletion and enrichment status of major elemental constituents in coal. According to the classification method proposed by [27], the concentration coefficients are divided into six categories: depletion (<0.5), normal (0.5~2), slight concentration (2~5), concentration (5~10), high concentration (10~100), and abnormal concentration (>100). In the studied coal, MgO, CaO, Na₂O and K₂O while TiO₂ are classified as normal with concentration coefficients of (1.22-1.98%) and Fe₂O₃ showing low concentration to high concentration for Eha-Alumona and Ehandiagu respectively (Table 1). Compared with other major oxides, the relatively high amount of Si and Al indicates the presence of clay minerals in large proportion in these coal samples. High silica contents in the coal are characteristics of high-rank coal while their low concentrations are typical of lignites [28; 30] The majority of the silica contents in the studied coal samples, when compared with the datasets given by [29], reveal that Eha-Alumona and Ehandiagu coals are sub-bituminous in rank. The rank of the coal increases with the increase of SiO₂, Al₂O₃, and TiO₂ contents while the rank decreases with the increase of Fe₂O₃, CaO, SO₃, MgO, K₂O, and Na₂O [30]. The rank of the studied coals based on the concentrations of the major oxides present in the coal ashes (Table 1) can be categorized as sub-bituminous.

Table 1: Major oxide composition of the coal.

Coal Sample	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	TiO ₂	CaO	MgO	Na ₂ O	K ₂ O
EHA-01	47.42	29.40	8.48	1.93	0.497	0.047	0.040	0.027
EHA-02	47.41	29.42	8.48	1.98	0.495	0.046	0.036	0.026
EHA-03	47.39	29.38	8.54	1.95	0.50	0.045	0.037	0.027
EHA-04	47.38	29.40	8.52	1.95	0.496	0.046	0.035	0.024
AVERAGE	47.40	29.40	8.52	1.95	0.497	0.046	0.035	0.024
EHAN-01	51.64	33.32	6.50	1.24	0.26	0.10	0.020	0.014
EHAN-02	52.38	33.17	10.34	1.30	0.28	0.09	0.021	0.013
EHAN-03	53.31	33.31	10.35	1.28	0.29	0.11	0.023	0.015
EHAN-04	52.87	33.28	10.36	1.22	0.25	0.10	0.020	0.014
AVERAGE	52.33	33.27	10.35	1.26	0.27	0.10	0.021	0.014
PAAS	62.8	19.00	6.50	1.00	1.30	2.20	1.20	1.70

4.2 Ash Deposition Characteristics

The prediction of slagging fouling of samples from Eha-Alumona and Ehandiagu coal can be seen in Table 2. One of the most commonly utilized indicators is the (B/A) ratio. The base-to-acid ratio should not be a single criterion for measuring ash deposition propensity. However, corroboration with additional indices or factors is required, especially if the value is less than 0.1 or greater than 1.0. The ratio has been linked to viscosities and ash fusion temperatures. It represents an ash’s melting potential. The low, medium and high slagging represents the prediction of coal behaviour concerning slagging in the Boiler during the combustion. Low slagging means there is non-problematic combustion, the deposition does not affect the heat transfer, and cleaning up is unnecessary. High slagging refers to the formation of a thick layer of ash deposit on the boiler heat transfer section which will retard the heat transfer in boiler tubes [31]. The slagging tendency of the ash increases with increasing B/A ratio. The ash is said to have a low slagging inclination when B/A < 0.5, medium for 0.5 < B/A < 1, high for 1 < B/A < 1.75 and severe for B/A above 1.75 [32]. From the analysis, the base acid ratio for both coal samples shows a low-level potential for slagging (Table 2). The grate and furnace wall deposits are almost identical to the original ash composition

and retain most silica present in the ash. The slag viscosity index (S_R) is hence used to evaluate the slagging tendency inside the furnace. High values correspond to high viscosity and therefore low slagging. Low slagging occurs when S_r is above 72, medium for $65 < S_r < 72$ and high for values below 65 [32]. The computed values for the slag viscosity index for the eight coal samples are in the range of 109.02 to 110.76 (Table 4.1). Good coals have a high slag viscosity index. All the computed values for the studied coal samples show high values above 65 indicating all the coals have high viscosity with low potential to slagging.

Table 2. Slagging fouling performance prediction based on conventional indices of coal samples.

Index	EHA 01	EHA 02	EHA 03	EHA 04	EHAN 01	EHAN 02	EHAN 03	EHAN 04
(B/A)	0.12	0.12	0.12	0.12	0.13	0.12	0.12	0.12
Criteria	Low	Low	Low	Low	Low	Low	Low	Low
S_R	109.02	109.08	109.07	109.04	110.70	110.72	110.76	110.70
Criteria	Low	Low	Low	Low	Low	Low	Low	Low
% Fe_2O_3	8.48	8.48	8.54	8.52	6.50	10.34	10.35	10.36
Criteria	High	High	High	High	Medium	High	High	High
Fu	0.01	0.01	0.01	0.01	0.004	0.004	0.004	0.004
Criteria	Low	Low	Low	Low	Low	Low	Low	Low

Another important parameter in determining the ash-slagging potential is the content of iron. High iron content usually lowers the melting point of slag [33], which results in a high slagging potential. Iron content lower than 6% in coal ash translates to a low slagging tendency while 6-7 per cent and greater than 7 per cent are medium and high slagging potentials respectively [34]. The percentage of iron oxides for studied coal samples has been computed and the results obtained are also presented in Table 1. The results indicate that coal both Eha-Alumoa and Ehandiagu coals have % Fe_2O_3 higher than 6 per cent on average, therefore, we expect their deposition potential to be high. Iron oxide is a low melting phase compound and acts as a strong fluxing agent [33-34]. Where the iron index is high slagging of the heating surface is controlled by pyrite behaviour which may react with clay and quartz to form alumino-silicate slags. The dissolution of iron into alumina-silicate reduces the melting point of fly ash in the combustion system. The computed values for the fouling index for the eight coal samples are in the range of 0.01 to 0.04 (Table 1). Fouling potential predictions have been categorised as < 0.6, 0.7 - 40 and above 40 to be low, high and severe fouling propensity [25; 35]. The fouling index (Fu) is based on the base-to-acid ratio (B/A) but also considers the sum of Na and K oxides. Potassium and Sodium vaporize and decompose to form eutectic compounds during combustion exhibit very low melting temperatures and cause slagging and fouling. When chlorine is not present or its presence is low, alkali also plays an important role in the formation of deposits [35]. This is the reason for completing the base-to-acid ratio index with the sum of Na_2O and K_2O . However, the results obtained for this index which is less than 0.6 show that all six coal samples present low tendencies to foul [36]. The value of the fouling index of the coal ash samples is less than 0.6. Thus, there is only a low propensity to fouling. For all the computed values, low slagging and fouling mean that Eha-Alumoa and Ehandiagu coals are non-problematic during combustion. The deposition does not affect the heat transfer and cleaning up may not be necessary.

4.3 Geochemistry of the Major oxides ratios.

Major element oxides in coal play an important role in reconstructing geological evolution such as palaeoclimatic, clastic input, and hydrothermal influence on coal formation and tectonic setting.

Table 3. Geochemical indices applied to estimate the paleodepositional condition of the coal sample.

Coal Sample	TiO ₂ /Al ₂ O ₃	Fe ₂ O ₃ /Al ₂ O ₃	Al/(Al+Fe)	Fe/Ti
EHA-01	0.066	0.29	0.78	4.39
EHA-02	0.065	0.29	0.77	4.28
EHA-03	0.066	0.29	0.78	4.38
EHA-04	0.066	0.07	0.78	4.37
AVERAGE	0.066	0.29	0.78	4.38
EHAN-01	0.037	0.19	0.84	5.24
EHAN-02	0.039	0.31	0.76	7.95
EHAN-03	0.038	0.31	0.76	8.09
EHAN-04	0.037	0.31	0.76	8.49
AVERAGE	0.030	0.31	0.76	8.21

Palaeoclimate condition reconstruction: Climate plays a crucial role in coal formation, and the content and ratio of elements in coal represent the climatic conditions during coal formation to a certain extent [37]. During sedimentation of rocks, paleoclimatic conditions can be evaluated from chemical analyses [38]. However, paleoclimatic conditions can be inferred from major elements-based discrimination diagrams proposed by several investigators [38-39]. In this study, the paleoclimatic conditions were evaluated using the proposed binary SiO₂ versus (Al₂O₃ + K₂O + Na₂O) diagram to restrict paleoclimatic conditions during sedimentation [38]. Based on the plot of SiO₂ versus (Al₂O₃ + K₂O + Na₂O), the clustering of data points in the plot suggests semi-arid palaeoclimatic climatic conditions that prevailed at the time of the deposition of the studied coals, characterized by low chemical weathering. This inferred palaeo-climatic condition is in agreement with the result of [40].

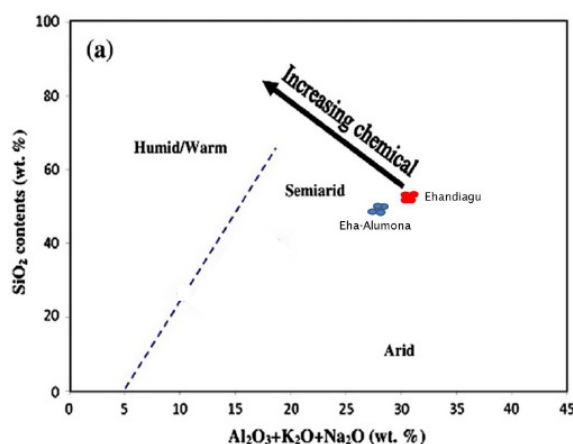


Figure 4. Bivariate plot of SiO₂ vs. (Al₂O₃ + K₂O + Na₂O) to discriminate palaeoclimatic conditions during the deposition of the coal (after [38]).

[41] argued that Ti and Al are chemically more resistant minerals than other common rock-forming oxides, as both are insoluble in water. In humid climates (intense chemical weathering), other minerals chemically decompose and wash out easily, whereas chemically resistant minerals like TiO₂ and Al₂O₃ enrich the sediments. However, in humid conditions, aluminosilicate shows a preferential loss in more mature sediments than more resistant TiO₂. The TiO₂/Al₂O₃ ratio is higher for the sediments deposited in humid conditions compared to those deposited in arid conditions. The ratio for continental lagoon clays deposited under humid conditions is 0.051 [41]. However, the climate is not the only factor controlling the mineralogical composition of coal. However, the composition of the source rock, maturation of the

sediment, energy condition in the basin, grain size, and quartz content also play an important role. Quartz content increases with an increase in grain size [41] The $\text{TiO}_2/\text{Al}_2\text{O}_3$ ratio increases with an increase in quartz content and thus with grain size [41] $\text{TiO}_2/\text{Al}_2\text{O}_3$ ratio ranges from 0.03 to 0.06, with an average of 0.07 and 0.03 for Eha-Alumona and Ehandiagu respectively (Table 3). It may be suggested that a semi-humid to semi-arid climate prevailed during the deposition of these coals.

Paleoredox conditions: The environment of some minerals and elements and their relative concentration in coal may represent the redox condition under which the coal has been deposited. However, the enrichment of a particular mineral or elements and their ratios does not show affinity to a particular syngenetic depositional environment rather several processes may be involved in the enrichment [27]. Many ratios have been used to predict paleoredox conditions V, Ni, U, TH, Cr, Co, Fe, Cu, Zn, Mo, Ba, Pb and Cd [42-43]. During the present study, the $\text{Fe}_2\text{O}_3/\text{Al}_2\text{O}_3$ ratio has been analyzed to determine paleoredox conditions for the studied coals. The ratios of $\text{Fe}_2\text{O}_3/\text{Al}_2\text{O}_3$ are good indicators of palaeoredox conditions [41-42]. The $\text{Fe}_2\text{O}_3/\text{Al}_2\text{O}_3$ value in the studied sample ranges from 0.19 to 0.31. The average value of $\text{Fe}_2\text{O}_3/\text{Al}_2\text{O}_3$ for the Eha-Alumona and Ehandiagu coal deposits is 0.29 and 0.31, respectively (Table 3). Lyons and Severmann (2006) suggested that a $\text{Fe}_2\text{O}_3/\text{Al}_2\text{O}_3$ ratio < 0.5 is indicative of oxic to suboxic conditions while $\text{Fe}_2\text{O}_3/\text{Al}_2\text{O}_3$ ratios > 0.5 suggest euxinic conditions. These computed values of $\text{Fe}_2\text{O}_3/\text{Al}_2\text{O}_3$ ratios of the coal samples are less than 0.5 suggesting an oxic to suboxic palaeoredox conditions. This is supported by (50) Ogala, 2018 which Mamu coal deposits also showed the $\text{Fe}_2\text{O}_3/\text{Al}_2\text{O}_3$ ratios between 0.4 and 0.5 revealing an oxic to sub-oxic redox condition.

Hydrothermal depositional condition on the coal formation: three sources (detrital, biogenic and hydrothermal) are responsible for the presence of silica in marine and sedimentary rocks (61)(Hamade et al., 2003). The ratios of Fe/Ti and $\text{Al}/(\text{Al} + \text{Fe})$ can be used to determine whether or not sediments have been exposed to hydrothermal activity. High enrichment of iron and manganese in cherts is linked to a hydrothermal source while the enrichment of aluminium and titanium is associated with detrital source (62)(Liu et al., 2015). $\text{Al}/(\text{Al}+\text{Fe})$ ratio less than 0.4 and Fe/Ti ratio greater than 20 suggest a hydrothermal source while $\text{Al}/(\text{Al}+\text{Fe})$ ratio greater than 0.4 and Fe/Ti ratio less than 20 points to a terrestrial source (63)(Bostrom et al., 1973). The studied coal samples from the Eha-Alumona and Ehandiagu coal deposits had an $\text{Al}/(\text{Al}+\text{Fe})$ ratio ranging from 0.76 to 0.84 while the Fe/Ti ratio ranged from 4.28 to 8.49 (Table 3). The studied coal samples had $\text{Al}/(\text{Al}+\text{Fe})$ ratios greater than 0.4 in all coals samples while Fe/Ti ratios were less than 20. These values suggest that the coal samples are derived mainly from terrestrial sources (Bostrom *et al.*, 1973). This is in agreement with the studied coal samples from the Mamu Formation which had an $\text{Al}/(\text{Al}+\text{Fe})$ ratio greater than 0.4 and a Fe/Ti ratio less than 20 which suggests that the coals are derived mainly from continental sources [40]

Tectonic Setting: Tectonic settings of sedimentary rocks can be determined from the relative concentrations of major, trace and rare earth elements as well as bivariate plots of the major oxides as suggested by earlier researchers The influence of plate tectonic settings on the chemical compositions of rocks within sedimentary basins is significant [49] Consequently, bulk geochemical analyses have proposed three or four sedimentary origins and tectonic settings, including oceanic island arc, continental island arc, active continental margin, and passive margin [50-52]. In this study, the graph of TiO_2 versus $(\text{Fe}_2\text{O}_3 + \text{MgO})$ is shown in Figure 5. It can be stated that the tectonic setting of the source material for forming coal is the active continental margin which was related to subduction of oceanic crust beneath the continental crust [53]. This tectonic setting inferred for the provenance hosting for the studied Eha-Alumona and

Ehandiagu coal deposits is in agreement with the tectonic events witnessed in West and Central Africa during the Cretaceous period [54-55]

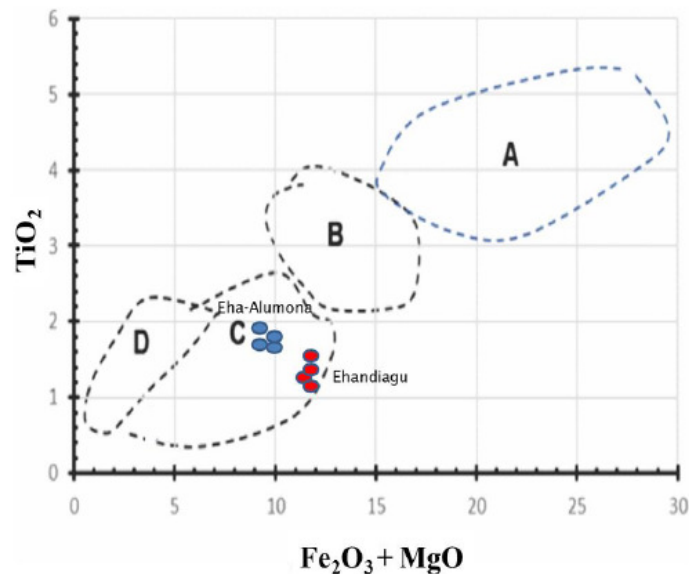


Figure 5. Plot of $(\text{Fe}_2\text{O}_3 + \text{MgO})$ vs TiO_2 for tectonic setting discrimination [56]. (A-oceanic island arc; B-continental island arc; C-active continental margin and D – active continental margin).

5. Conclusion

The assessment of Eha-Alumona and Ehandiagu coal deposits in the Anambra Basin, Southeastern Nigeria has predominantly focused on the major oxide geochemistry of these coal deposits, exploring the ash deposition tendencies, reconstruction of paleoclimatic and paleoredox condition, hydrothermal influx and tectonic setting. Coal samples from two coal deposits across nine locations in the Anambra Basin underwent X-ray fluorescence spectrometry. According to the geochemistry of major elements in the studied coals, the following preliminary conclusions can be drawn. (1) The coals under study exhibit a significant presence relatively high amount of Si and Al indicating the presence of clay minerals in large proportion in these coal samples. (2) The coals show for all the computed values of basic to acidic ratios, slag viscosity index, iron percentage and fouling index, a low slagging and fouling propensity which means that Eha-Alumona and Ehandiagu coals are non-problematic during combustion. The deposition does not affect the heat transfer and cleaning up may not be necessary. (3) From the computed major oxide geochemical ratios and plots the results revealed that coals are sub-bituminous in rank due to their high silica content, a semi-arid palaeoclimatic climatic conditions prevailed at the time of the deposition, coal samples are derived mainly from terrestrial sources and the tectonic setting of the source material for forming coal is the active continental margin which was related to subduction of oceanic crust beneath the continental crust.

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