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Hydrocarbon Generation Potential of the ETA Zuma Coal Mines, Anambra Basin, Nigeria: Insight from OrganicPetrography

Habeeb Ayoola Ayinla*, Musa Azeez Ololade, Ola-Buraimo Abdulrazaq Olatunji, Sule Peter Isaac, David Emmanuel, Baba Aminu Mu'awiya, Francis, Joseph Amobi

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Abstract: *The ongoing exploration at the ETA Zuma coal mine uncovers a large coal reserve with unassessed details concerning its hydrocarbon potential. Thus, organic petrography characterization of sedimentary facies in the mine was carried out to determine the organic matter quantity, quality, and thermal maturity of the potential source rock in the area. The organic petrography method employed involves kerogen preparation for investigation of hydrocarbon potential following the routine palynological slide preparation for biostratigraphic study with slight modification. This involves the non-inclusion of the oxidation stage in the kerogen slide preparation. The results indicate that the kerogens (palynomorphs) show fair abundance and diversity with depth, especially for the claystone and coal. A quantitative-rich occurrence of pollens and spores was retrieved in some samples (depths 12.5-19.7 m, and 23.8 m) with a similar trend in the dinoflagellates recovery. This interval (12.5-23.8 m) which is composed of coal and claystones recorded a reasonable quantity of organic matter (from 20-27) that could generate hydrocarbon. Based on the palynomorph recovery, the study area has mainly Kerogen Type II and III characterized by terrestrial and marine source input. The intervals 12.5-18.8 m, 19.3 m, 19.7 m, 21.3-23.8 m which show yellow-brown and brown-coloured forms represent stages 2 and 3 on the Thermal Alteration Index (TAI) scale. This is an indication that the organic matter within the claystone and coal is thermally matured with source potential capable of generating both oil and gas.*

Keywords: Sedimentary facies, hydrocarbon potential, kerogen type source rock, thermal maturity.

Habeeb Ayoola Ayinla*
Department of Geology, Federal University Lokoja, P.M.B 1154, Nigeria
Email: geohabeb@yahoo.com
Orcid id: 0000-0003-1625-1798

Musa Azeez Ololade,
Department of Geology, Federal University Lokoja, P.M.B 1154, Nigeria
Email: musaazeez2018@gmail.com
Orcid id: 0009-0009-7553-7906

Ola-Buraimo Abdulrazaq Olatunji,
Department of Geology, Federal University Birnin Kebbi, Birnin Kebbi, Nigeria
Email: rolaburaimo@yahoo.com
Orcid id: 0000-0001-9601-1545

Sule Peter Isaac,
Department of Geology, Federal University Lokoja, P.M.B 1154, Nigeria
Email: sulepeterisaac@gmail.com
Orcid id: 0009000903293914

David, Emmanuel,
Department of Geology, Federal University Lokoja, P.M.B 1154, Nigeria
Email: Emmykaydavies@gmail.com
Orcid id: 0009-0006-5224-3532

Baba Aminu Mu'awiya,
Department of Geology, Federal University Lokoja, P.M.B 1154, Nigeria
Email: muawiya.babaaminu@fulokoja.edu.ng
Orcid id: 0000-0001-5278-153X

Francis, Joseph Amobi
Department of Geology, Federal University Lokoja, P.M.B 1154, Nigeria
Email: joseph.francis@fulokoja.edu.ng
Orcid id: 0000-0002-8536-5337

1.0 Introduction

Evaluation of the hydrocarbon potential of a potential source rock involves the determination of organic matter quantity, quality and thermal maturity (Ayinla *et al*., 2017a). Aside from the pyrolysis method (Rock-Eval and Source Rock Analyzer), efforts are being intensified in using palynology/organic petrography to resolve these geological problems and this has proved useful in recent times (Peters and Cassa, 1994; Ogala, 2011; Obaje, 2009; Ola-Buraimo *et al*., 2015; Ayinla *et al*., 2017b). It is known that palynomorphs content in sedimentary rock can be used in age determination, biozonation, biostratigraphic correlation, paleodepositional environment and paleoclimatic studies among others (Ayinla *et al*., 2013; Ayok *et al*., 2020). Careful modification of the procedure can be used in evaluating the hydrocarbon generation potential of the source in terms of kerogen Type (palynomorphs), abundance and diversity for organic matter quantity and variation in colour for thermal maturity determination (Ola-Buraimo *et al*., 2015). Although, coal (as obtainable at ETA Zuma coal mine) which is very rich in organic matter content has its peculiarity while determining its hydrocarbon generation potential when extra caution is taken the result can be interpreted correctly (Peters and Cassa, 1994; Ayinla *et al*., 2017a).

The current study area is located in the ETA Zuma coal mine, Anambra Basin, kogi sector, Nigeria where the ongoing exploration has uncovered a large coal reserve of which its detailed hydrocarbon potential has not been adequately assessed. Therefore, there is a need to conduct a comprehensive Organic Geochemical and Petrographical analysis of the sedimentary facies exposed at Zuma Mine to determine the type, quality, quantity, and depositional environment of the organic matter. This analysis will provide critical information to identify potential source rocks, reconstruct paleoenvironmental conditions, determine hydrocarbon potential, and assess environmental implications associated with hydrocarbon exploration and production in the Anambra Basin. In this case, organic petrography characterization of sedimentary facies in the mine was carried out to determine the organic matter quantity, quality, and thermal maturity of the potential source rock in the area. The organic petrography method employed involves kerogen preparation for investigation of hydrocarbon potential following the routine palynological slide preparation for biostratigraphic study with slight modification. This involves the non-inclusion of the oxidation stage in the kerogen slide preparation as described by Ola-Buraimo *et al*. (2015).

1.1 Geologic Setting

The Anambra Basin is a Cretaceous sedimentary basin in Nigeria with a total sediment thickness of about 9km which can present an ideal geo-reactor for all manner of complex chemical reactions that can lead to the formation and occurrence of economically viable hydrocarbon deposits (Whiteman, 1982). The roughly triangular-shaped Basin covers an area of about 40,000 sq.km, located in the south-central part of Nigeria and extending northwards in the Benue River (Olubayo, 2010). The basin is bounded to the south by the Niger Delta hinge line. It extends north-westward into the Niger Valley, northward to the Jos Massif and northeastward as far as Lafia. The eastern and western limits of the basin are defined by the Abakaliki Anticlinorium and Ibadan Massif respectively.

The structural evolution of the Anambra Basin has been described by Ojoh (1992) and Obi *et al*. (2001). The origin of the basin is generally believed to be linked to the Santonian tectonics of the Abakaliki-Benue Basin, during which an N–S compression between the African and Eurasia plates folded the Abakaliki Anticlinorium (Obi *et al*., 1995). Prior to the tectonic event the Anambra Basin was a platform that was only thinly covered by sediments. The folding of the Anticlinorium laterally shifted the depositional axis into the Anambra Platform which then began to accumulate sediments shed largely from the Abakaliki Anticlinorium (Murat, 1972). The Anambra Basin fill comprises over 2500 m of sediments that accumulated during the Campanian–Maastrichtian Period.

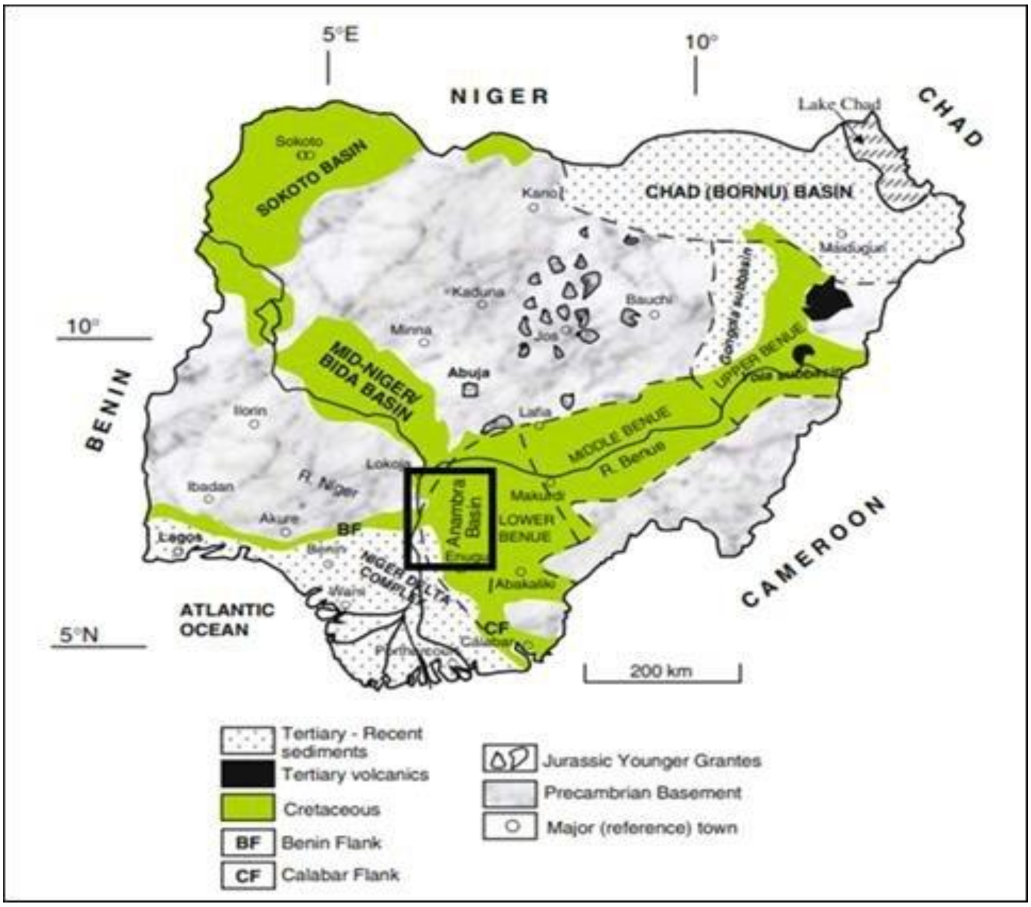

Fig. 1: Generalized-geological-map-of-Nigeria-showing-the-Anambra-Basin-in-the-thick-rectangular (Obaje. 2009)

The Anambra Basin developed as a result of the Santonian tectonic event which greatly affected the Benue Trough terminating sedimentation in the Abakaliki Basin. Before then, sedimentation in southern Nigeria which began in the Early Cretaceous was facilitated by the breakup of the African and South American continents leading to the formation of the Benue Trough (Burke *et al.*, 1970; Benkhelil, 1989). Sedimentation in the trough was controlled by three major tectonic phases, giving rise to three successive depocentres (Short and Stauble, 1967; Murat, 1972; Obi *et al.*, 2001; Oboh-Ikuenobe *et al.*, 2005). Although, Ola-Buraimo and Ehinola (2022), suggested that there are about 8 transgressive cycles with 5 major unconformities, the three phases are as follows,

a. The Abakaliki Benue phase (Albian-Santonian)
b. The Anambra Basin phase (Campanian-Mid Eocene) and
c. The Niger Delta phase (Late Eocene-Pliocene)

The first phase (Albian–Santonian) featured the deposition of the Asu River Group, Eze-Aku and Awgu Formations within the Abakaliki-Benue Trough which was flanked to the east by the Anambra Platform and to the southwest by the Ikpe Platform (Short and Stauble, 1967; Murat, 1972; Obi *et al.*, 2001; Oboh-Ikuenobe *et al.*, 2005). Based on palynological evidence, it has to be noted that Ola-Buraimo and Akaegbobi (2013b) believed that the Asu River Group is better described as Albian-Early Cenomanian. The second phase (Campanian-Eocene) was characterized by compressive movements along the NE-SW axis which resulted in the folding and uplift of the Trough into an anticlinorium. This forced the Anambra Platform to subside and formed the Anambra Basin and the Afikpo Syncline. The deposition of the Nkporo Group, Mamu Formation, Ajali Sandstone, Nsukka Formation, Imo Formation and the Ameki Group then followed. The third sedimentary phase credited for the formation of the petroliferous Niger Delta commenced in the late Eocene as a result of a major earth movement that structurally inverted the Abakaliki region and displaced the Depositional axis further to the Anambra Basin (Obi *et al.*, 2001). Reyment (1965) undertook the first detailed study of the southern Nigeria sedimentary basin and he proposed many of the lithostratigraphic units in the region.

The oldest succession in the Anambra Basin is the Nkporo Group (Nwajide, 1990). It was deposited in Late Campanian, Comprising Nkporo Shale, Owelli Sandstone and Enugu Shale (Reyment, 1965; Obi, 2000). Nkporo Group is overlain by the Mamu Formation (Fig 2). It was deposited in early Maastrichtian (Kogbe, 1989; Obi, 2000). It comprises a succession of siltstone, shale coal seam and sandstone (Kogbe, 1989). The Ajali Sandstone (Maastrichtian) overlies the Mamu Formation (Reyment, 1965; Nwajide 1990), which consists mainly of unconsolidated coarse-fine grained poorly cemented sandstone and siltstone (Kogbe, 1989). The Ajali Sandstone is overlain by the diachronous Nsukka Formation (Maastrichtian -Danian) which is also known as the upper coal measure (Obi, 2000). A conformable facies was reported to exist between the Nsukka and Imo formations. The marine transgression of the Middle Eocene led to the deposition of the Ameki Formation which was followed by an unconformity before the younger Ogwashi/Asaba Formation (Ola-Buraimo and Ehinola, 2022). In the Ogwashi-Asaba Formation, Ola-Buraimo and Akaegbobi (2012) used diagnostic pollen and dinoflagellate forms to assign it a Late Miocene to Pliocene age.

2.0 Materials and Methods

Twenty samples of coal and claystone from the ETA Zuma Coal Mine were prepared in the laboratory for recovery of kerogen. The study involved the digestion of twenty coal mine samples of 20gm each in weight in hydrofluoric acid. The macerals were obtained by sieving the samples with 10 µ mesh. The concentrated organic matter was taken through the process of floatation in Zinc bromide (ZnBr2) with the aid of a centrifuge. It is noteworthy to mention that the digested rock was not oxidized or bleached in Nitric acid. The oxidation process would alter the original or natural color of the kerogen that has passed through the processes that led to coalification which included an increase in temperature with progressive burial and time. This will yield sufficient kerogen for the required analyses. The recovered kerogen was later mounted on glass slides for observation under the binocular microscope (Ola-Buraimo *et al*., 2015). There were point counts of the pollen, spores, dinoflagellates and algae present, characterized by different kerogen colours were noted for statistical purposes following the work of Ola-Buraimo *et al*. (2015). The other methods employed for the determination of the hydrocarbon potential of the coal, underlying and overlying claystone beds are described below.

2.1 Kerogen slide analysis

The prepared palynological slides were analysed petrographically using an OPTIKA G-150 microscope for identification and point counts of pollen, spores, dinoflagellates, algae, fungal and micro-foraminiferal wall linings. Another form of analysis was carried out to determine the different colours of the organomacerals which vary from yellow, through yellow-brown, brown and black.

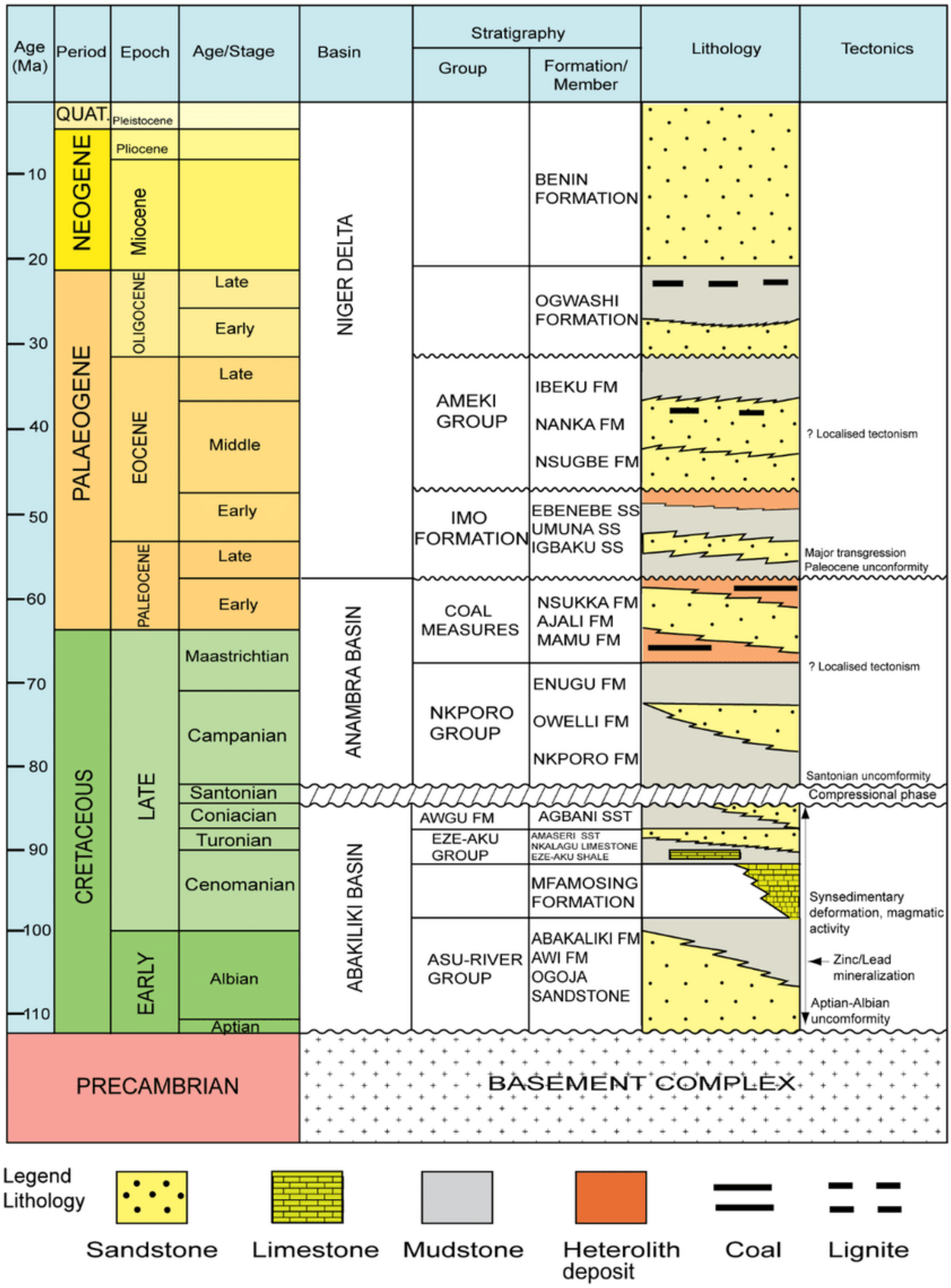

Fig. 2: Stratigraphic Succession in the Anambra Basin and Outcropping Niger Delta (Ekwenye and Nichols, 2016)

2.2 *Data gathering*

Data was collected from the analyzed kerogen slides. The various data used were generated for the following:

2.3 *Organic richness*

This was based on the count of palynomacerals recovered from the samples in terms of their total abundance and diversity.

2.4 Kerogen type

This was based on the counts of differentiated palynomacerals present in various categories such as pollen, spores, dinoflagellates and algae, and their associated derivative paleoenvironments such as terrestrial, marine or lacustrine.

2.5 Kerogen colour

The kerogen colour was determined by noting various colours of the kerogen when subjected to thermal alteration. Therefore, a statistical count of the several colours varying from yellow through yellow-brown, brown and black was noted.

3.0 Result and Interpretation

3.1 Hydrocarbon Potential: Organic richness

The generation of hydrocarbon from source rock is dependent on the organic richness, which is favoured by the rate of supply of organic materials, a reducing (anoxic) environment of deposition and the relatively high rate of burial of the sedimentary particles. The work of Ola-Buraimo *et al*. (2015) categorized organic richness based on palynomorphs abundance to vary from:

0-20 Lean kerogen
20-40 Fair kerogen
40-80 Good kerogen
> 80 Organically richkerogen (or very rich)

The Ola-Buraimo *et al*. (2015) organic classification shall be adopted for the categorization of kerogen abundance of the analysed samples. The kerogen was denoted by the amount of palynomorph abundance recovered as recorded in Table 1. The upper section of the ETA Zuma Coal Mine investigated for this study depicts an interval with depths 0.5-11.0 m composed of distinctive lean kerogen with values varying from 3-6. The substantial part of this interval is claystone facies, except the lowermost part of the stratigraphic section which is a claystone that is organically rich.

However, the interval of 12.5-23.8 m is composed of coal and clay intervals, they are composed of kerogen that was classified as fair; kerogen richness varies from 20-27. There are lean kerogen intervals which are intercalated within the fair kerogen beds. The lean kerogen beds include intervals 0.5-11.0 m; depths 19.1 m, 19.5 m, 20.3 m, and 20.8 m. Their kerogen values vary from 3-12 (Tab. 1).

The fair kerogen values within the ETA Zuma Coal Measure and the underlying claystone are capable of generating oil or gas or a combination of oil and gas if other hydrocarbon-generating factors were fulfilled (Tisot and Welt, 1978). The minimum threshold for organic generation was put at 20 in terms of palynomorph abundance (Ola-Buraimo *et al*., 2015).

The organic richness with depth is presented in Table 1. Table 1 also indicates the correlation of the palynomorph abundance with depth and the corresponding lithofacies. Fig. 3 is a bar chart that illustrates the palynomorph abundance, diversity and depth points. Fig. 4 depicts the relative abundance and diversity of the organomacerals against their serial number and depth of recovery. Fig. 5 depicts the absolute count of macerals and their diversity with high abundance recorded in sample numbers 8-11, 13, 15, 18,19, and 20. They all belong to the fair kerogen richness. Fig. 6 shows a similar trend in parallel relationship rather than vertical. However, Fig. 7 shows the peaks of the palynomorph abundance and diversity against the depth and their respective serial number with depth.

Here samples 8-11, 13, 15, and 18-20 are source beds that are capable of generating hydrocarbon provided they satisfy the adequate temperature and pressure necessary for the generation of hydrocarbon. The stratigraphic relationship with kerogen abundance indicates that the lower claystone, coal beds and lowest part of the upper claystone interval contain adequate kerogen richness that could generate hydrocarbon.

3.2 Type of Kerogen

The type and amount of petroleum that could be produced from a particular kerogen depends on the kerogen richness, the organic source materials and the diagenetic history of the conserved kerogen (Ola-Buraimo *et al*., 2015). Kerogen classification had been into 3 or 4 divisions as proposed by Tissot and Welt (1978), Dow (1977), Harwood (1977) and as used by Ola-Buraimo *et al*. (2015). The detailed composition of the kerogen type was described in the work of Ola-Buraimo *et al*. (2015).

Table 1: Kerogen abundance in the analysed samples

S/N	Sample No.	Depth Point (m)	Palynomorph Abundance	Palynomorph Diversity	Lithofacies
1	1A	0.5	4	4	Claystone
2	1B	2.0	5	4	Claystone
3	2A	3.5	6	5	Claystone
4	2B	5.0	5	3	Claystone
5	2C	6.5	5	4	Claystone
6	3A	9.5	4	4	Claystone
7	3B	11.0	3	4	Claystone
8	3C	12.5	22	11	Claystone
9	3D	17.0	20	13	Claystone
10	4A	18.7	20	11	Coal
11	4B	18.9	23	12	Coal
12	4C	19.1	8	6	Coal
13	4D	19.3	20	11	Coal
14	4E	19.5	12	7	Coal
15	4F	19.7	24	13	Coal
16	4G	20.3	5	5	Coal
17	5A	20.8	3	2	Claystone
18	5B	21.3	22	14	Claystone
19	5C	22.3	20	14	Claystone
20	5D	23.8	27	11	Claystone

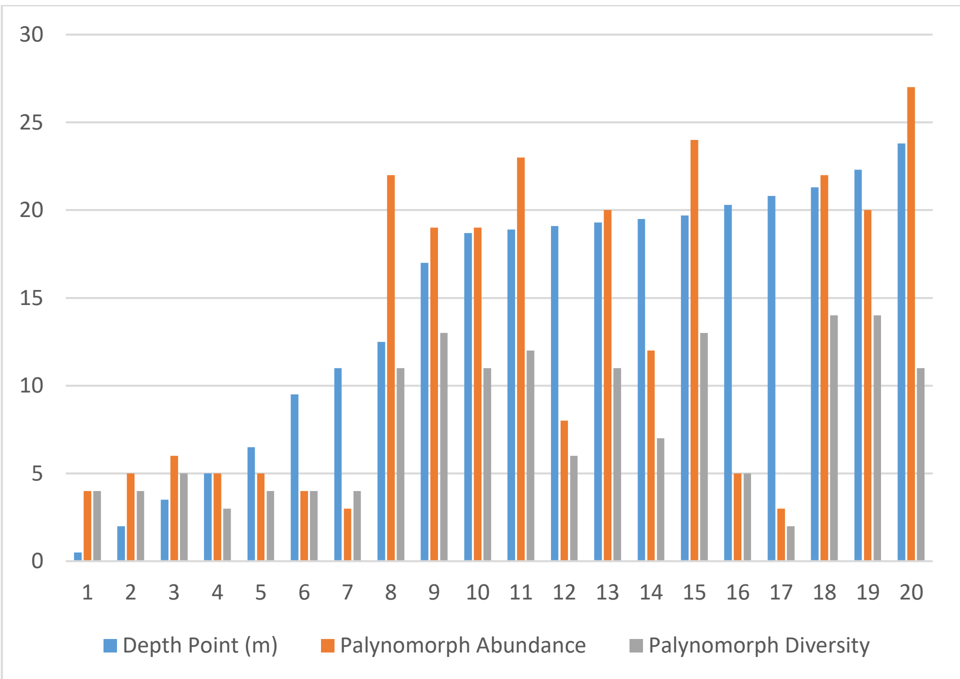

Fig. 3: Histogram plot of palynomorph abundance and diversity against depth.

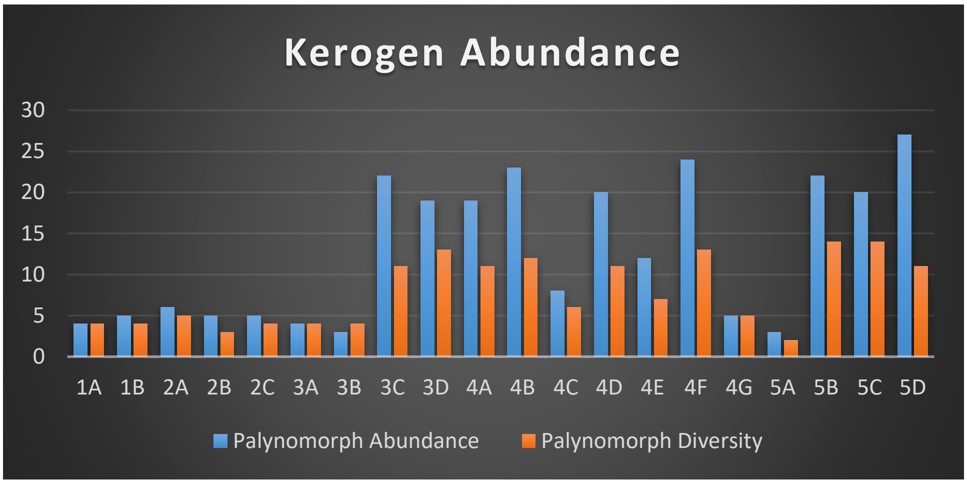

Fig. 4: Palynomorph abundance and diversity plot against sample names and depth

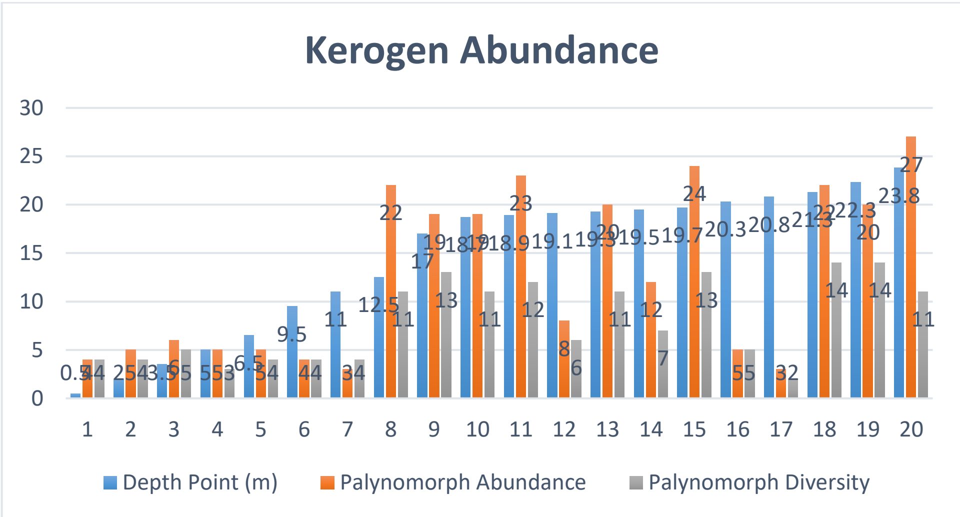

Fig. 5: Quantitative representation of abundance and diversity against depth

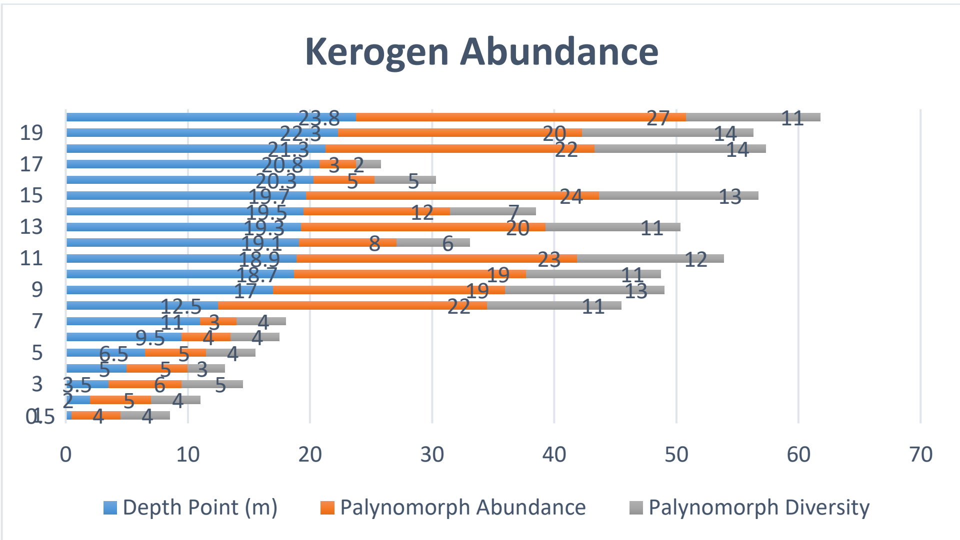

Fig. 6: Absolute Horizontal peak values of palynomorph abundance and diversity

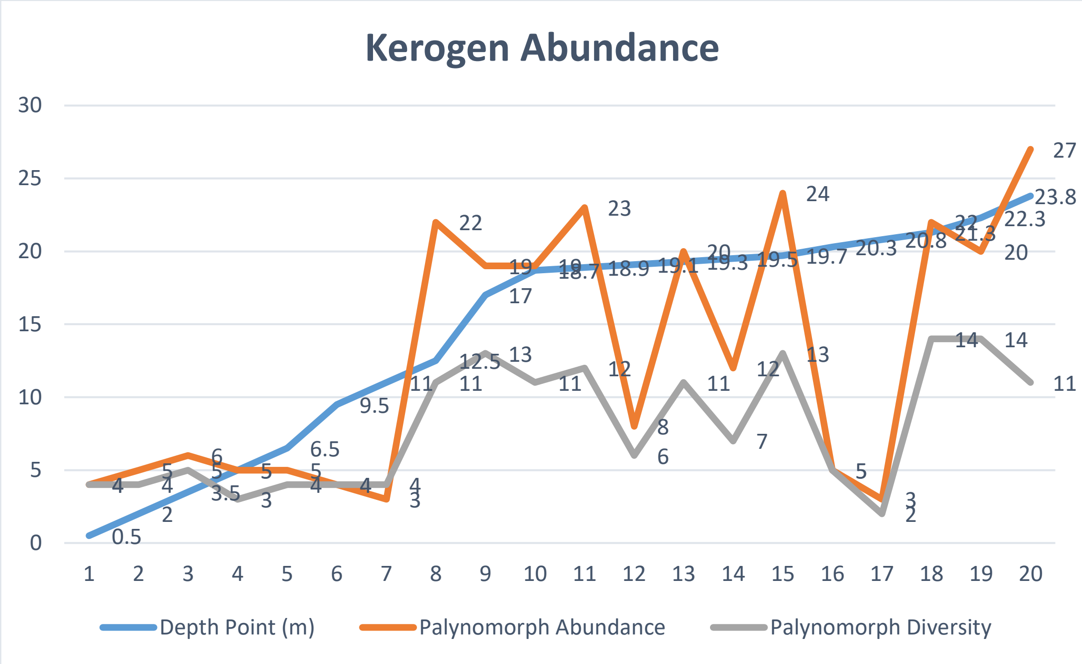

Fig. 7: Palynomorph abundance and diversity peaks with depth

A division of the kerogen sources are land-derived plants, referred to as humic (Tissot and Welt, 1978) and the marine sourced kerogen, called kerogenous (Meyer and Nederlof, 1984). The relative quantitative values of pollen and spores, dinoflagellates and algae against depth with their lithofacies were presented in Table 2. The result shows a few amounts of pollen and spores, dinoflagellates and algae; prevalent in depths 0.5-11.0 m. A quantitative rich occurrence was retrieved in sample interval and sample depths 12.5-19.7 m, and 23.8 m respectively. A similar trend was observed in the dinoflagellates recovery.

A relatively moderate organic matter was recovered in depths 12.5 m, 18.7 m, 18.9 m, 19.3 m, 19.7 m, and 21.3 m. The algae are generally poor, but few quantitative recoveries is present in depths 12.5 m, 17.0 m, 18.7 m, 18.9 m, and 20.8 m. Therefore, the relative moderate richness of the pollen, dinoflagellates and algae are predominant in the coal source beds and few claystone beds in the lower and upper claystone facies intervals.

Fig. 8 shows the distribution of the pollen and spores, dinoflagellates, and algae against depth, while Fig. 9 shows the absolute values of the recovered pollen, dinoflagellates and algae against depth. Fig. 10 shows the horizontal view and relationship of the absolute values of the macerals against depth, while Fig. 11 indicates the peak values of the maceral types against depth. The intervals dominated by pollen are the land-derived source, while the intervals characterized by fair abundance of both pollen and dinoflagellates are regarded as admixture of land and marine (Ola-Buraimo, 2020; Ola-Buraimo and Ehinola, 2022); intervals defined by the recovery of pollen, dinoflagellates and algae were regarded as admixture of land, lacustrine and marine sourced kerogen (Figs. 8-11).

3.3 Kerogen Type

The kerogen precursors and kerogen type in the investigated interval are presented in Table 3. The kerogen precursors are mainly land-sourced kerogen and marine-sourced, while the kerogen type is mainly Kerogen Type II and Kerogen Type III. The Type II kerogen is defined as kerogen that has both land and marine-sourced organic materials while the Type III kerogen is described as one that is dominated by terrestrially (land) derived organic matter. Here, the main concern is the type of kerogen derivable from the source beds. The analysed samples are dominated by the Type II kerogen belonging to depths 0.5 m, 2.0 m, 12.5 m, 19.3 m, 19.7 m, 20.8 m, and 21.3 m. The Type III kerogen are present in sample depth 3.5-11.0 m, 19.5 m and 20.3 m (Table 3).

Table 2: Pollen, Spores, dinoflagellates and algae abundance

S/N	Sample No	Depth Point (m)	Pollen and Spores	Dinoflagellates	Algae	Facies
1	1A	0.5	3	1	0	Claystone
2	1B	2.0	2	0	3	Claystone
3	2A	3.5	6	0	0	Claystone
4	2B	5.0	4	1	0	Claystone
5	2C	6.5	4	1	0	Claystone
6	3A	9.5	4	0	0	Claystone
7	3B	11.0	3	0	1	Claystone
8	3C	12.5	16	4	2	Claystone
9	3D	17.0	13	2	4	Claystone
10	4A	18.7	10	5	5	Coal
11	4B	18.9	13	6	4	Coal
12	4C	19.1	5	2	1	Coal
13	4D	19.3	10	9	1	Coal
14	4E	19.5	11	1	0	Coal
15	4F	19.7	16	7	1	Coal
16	4G	20.3	4	1	0	Coal
17	5A	20.8	1	0	2	Claystone
18	5B	21.3	12	10	0	Claystone
19	5C	22.3	9	7	4	Claystone
20	5D	23.8	20	6	1	Claystone

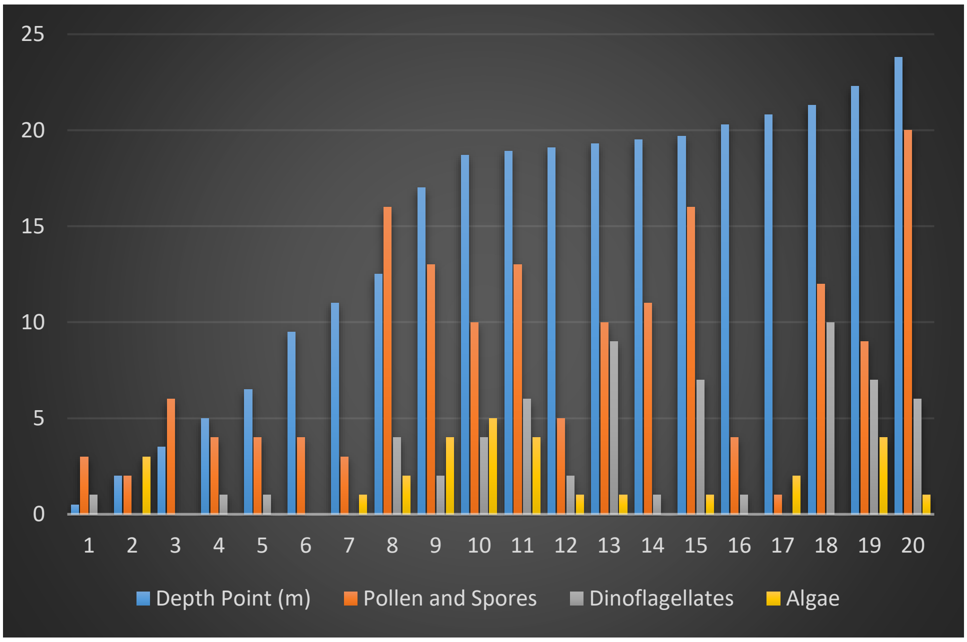

Fig. 8: Distribution of pollen and spores, dinoflagellates and algae against depth.

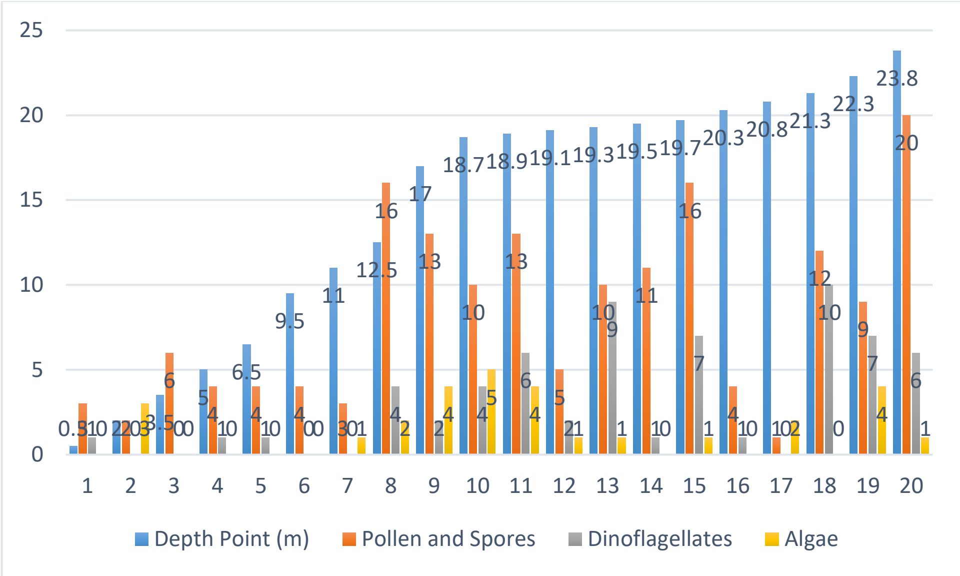

Fig. 9: Absolute distribution values of pollen, dinoflagellates and algae

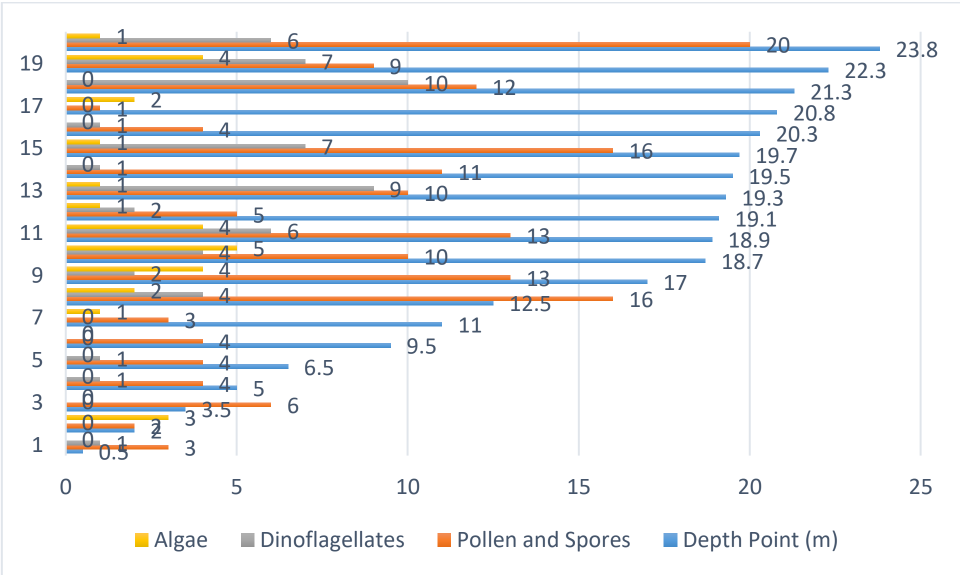

Fig. 8: Horizontal relationship of absolute values of pollen, dinoflagellate and algae with depth

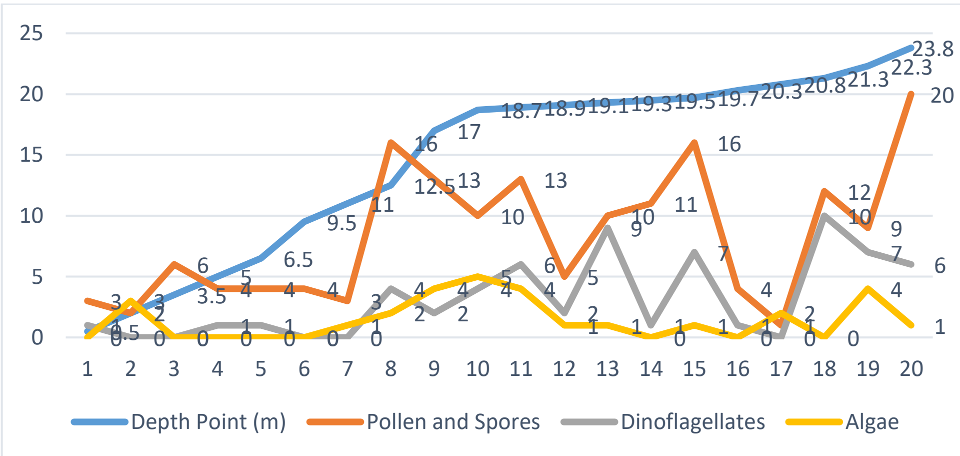

Fig. 11: Peaks values of Pollen and spores, dinoflagellates and algae recovered against depth

A diagrammatic description of the land and marine source kerogen and their respective kerogen types is indicated in Fig. 12. The ability to produce and the amount of petroleum produced are dependent on adequate temperature, pressure, and organic richness of the source beds. Therefore, the intervals 12.5-18.8 m, 19.3 m, 19.7 m, 21.3-23.8 m belong to Type II kerogen, capable of generating both oil and gas provided the kerogen contained is matured. Intervals that show the tendency to produce gas of Type III kerogens are organically lean (Tabs. 1 and 3).

Table 3: Kerogen Precursors and Kerogen Type in the analysed intervals

S/N	Sample No.	Depth Point (m)	Land Sourced Kerogen	Marine Sourced Kerogen	Kerogen Type 2	Kerogen Type 3
1	1A	0.5	3	1	2	
2	1B	2.0	2	3	2	
3	2A	3.5	6	0		3
4	2B	5.0	4	1		3
5	2C	6.5	4	1		3
6	3A	9.5	4	0		3
7	3B	11.0	3	1		3
8	3C	12.5	16	6	2	
9	3D	17.0	13	6	2	
10	4A	18.7	10	9	2	
11	4B	18.9	13	10	2	
12	4C	19.1	5	3	2	
13	4D	19.3	10	10	2	
14	4E	19.5	11	1		3
15	4F	19.7	16	8	2	
16	4G	20.3	4	1		3
17	5A	20.8	1	2	2	
18	5B	21.3	12	10	2	
19	5C	22.3	9	11	2	
20	5D	23.8	20	7	2	

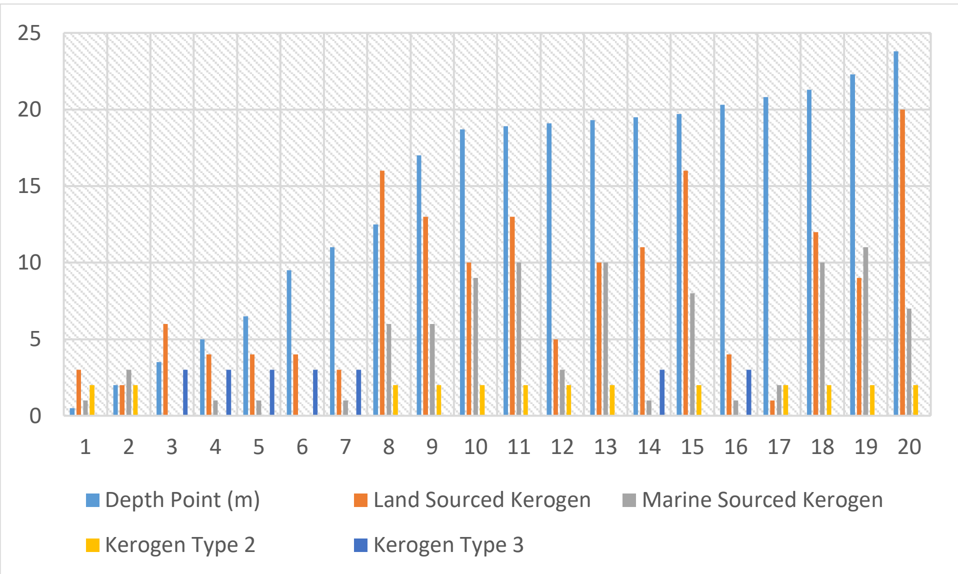

Fig. 12: Discrimination of the sourced kerogen and kerogen Types against depth

3.4 Kerogen thermal maturity

The kerogen thermal maturity deduction was generally explained in the work of Ola-Buraimo *et al*. (2015). Other workers also noted that the colours of organic materials alter with increasing temperature during progressive burial. Therefore, there is a Thermal Alteration Index (TAI) scale proposed by Staplin (1969). Stage 1 is colour Yellow; equivalent to an immature stage of kerogen evolution, stages 2 and 3 are Yellow-Brown and Brown respectively, they are the oil generation windows. Therefore, the coloured macerals are substantial but not limited to the analysed depth intervals 12.5 m, 17.0 m, 18.7 m, 19.3 m, 19.5 m, and 22.3 m.

The dominant light yellow kerogen such as sample 20.3 m is at an immature stage of kerogen evolution, low in organic richness and is incapable of generating hydrocarbon. The generating window occurs only in stages 2 and 3 (Yellow-Brown and Brown, Table 4). The samples within stages 2 and 3 and with minimum organic richness necessary for hydrocarbon generation are samples 12.5 m, 18.7 m, 18.9 m, 19.3 m, 19.7 m, 21.3 m and 23.8 m (Table 4; Figs. 13 and 14).

Therefore, claystone facies with depths 12.5 m, 21.3 m and 23.8 m and coal facies with depths 18.7 m, 19.9 m, 19.3 m, and 19.7 m are capable of producing hydrocarbon.

Therefore, the ETA Zuma Coal Mine, containing the claystone and coal facies Type II kerogen and may have generated oil and gas, though with the capability of producing more gas than oil. The absence of an adequate reservoir rock with a seal and the proximity of the source rocks to the surface may be responsible for the dissipation and perhaps seepage of such generated hydrocarbon.

Table 4: Kerogen colour distribution in the analysed intervals

S/N	**Sample No**	**Depth Point (m)**	**Kerogen**			
			Yellow	Yellow-Brown	Brown	Black
1	1A	0.5	0	0	4	0
2	1B	2.0	2	0	0	3
3	2A	3.5	1	0	3	2
4	2B	5.0	0	3	0	2
5	2C	6.5	0	0	2	3
6	3A	9.5	1	0	3	0
7	3B	11.0	3	0	1	0
8	3C	12.5	5	0	12	4
9	3D	17.0	12	0	6	0
10	4A	18.7	9	0	11	0
11	4B	18.9	8	0	14	1
12	4C	19.1	1	1	4	2
13	4D	19.3	10	0	9	1
14	4E	19.5	6	0	5	1
15	4F	19.7	3	0	20	1
16	4G	20.3	4	0	1	0
17	5A	20.8	0	0	1	2
18	5B	21.3	7	0	15	0
19	5C	22.3	12	0	7	1
20	5D	23.8	7	15	5	0

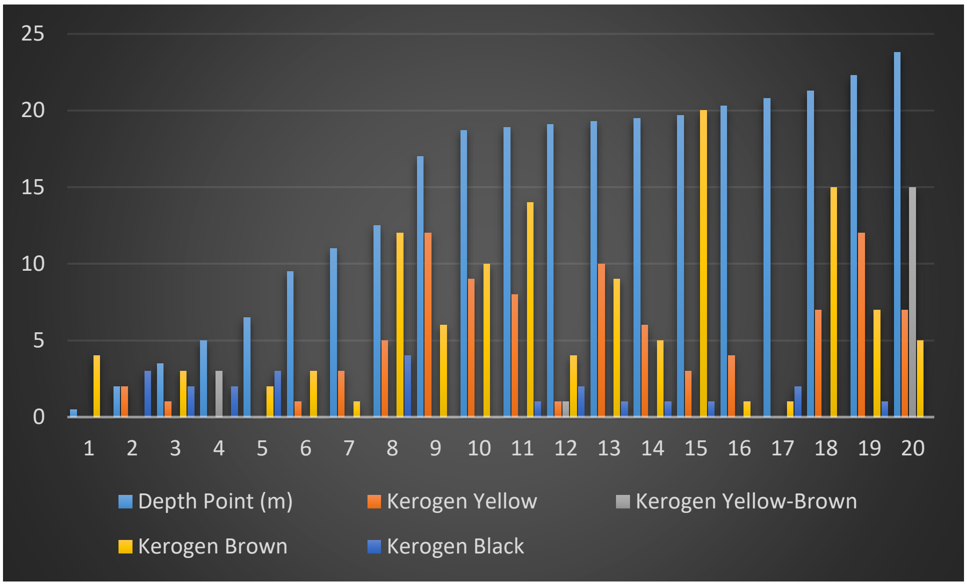

Fig. 13: Kerogen classification

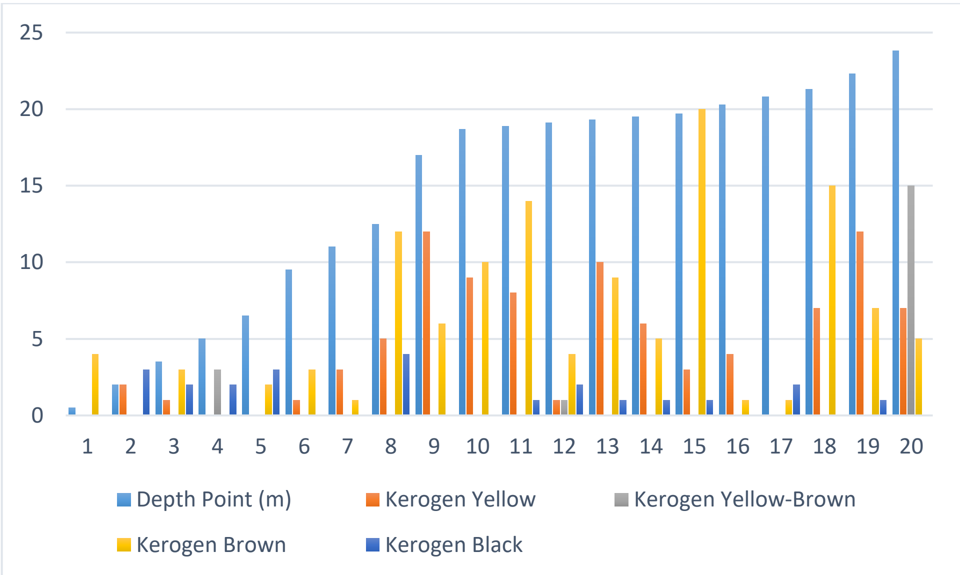

Fig. 14: Kerogen classification with depth

4.0 Conclusion

The hydrocarbon generation potential of the potential source rock at ETA Zuma Coal Mines, Anambra Basin, Nigeria was evaluated using the organic petrography method and the following were inferred from the results of the studies:

(i) Petrographic analysis indicates that, quantitatively, the interval (12.5-23.8 m) which is composed of coal and claystones recorded a reasonable quantity of organic matter ranging from 20-27 suggesting good hydrocarbon generation potential for the studies samples from the Anambra Basin.

(ii) Categorization of the kerogen types based on the palynomorph recovery shows that the study area has mainly Kerogen Type II and III which is a clear indication of terrestrial and marine source input.

(iii) Thermal maturity assessment using TAI scale shows that the intervals 12.5-18.8 m, 19.3 m, 19.7 m, 21.3-23.8 m characterized by yellow-brown and -brown-coloured forms represent stages 2 and 3. Meaning that the organic matter within the claystone and coal are thermally matured and could be a potential source rock for hydrocarbon generation in the study area.

(iv) This information can be used for further hydrocarbon exploration campaigns within the Kogi sector of the Anambra basin.

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Compliance with Ethical Standards Declarations

The authors declare that they have no conflict of interest.

Data availability

All data used in this study will be readily available to the public.

Consent for publication

Not Applicable

Availability of data and materials

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