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Research Article

KEROGEN EVALUATION OF CORE SAMPLES FROM GREATER UGHELLI, CENTRAL SWAMP AND OFFSHORE DEPOBELTS OF NIGER DELTA BASIN

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ABSTRACT

The palynofacies analysis of selected core samples from the OML 61, Obagi, and Abo fields identified two units: PF1 (Heterolithic-oxic shelf of type III or IV gas prone kerogen) and PF (dysoxic-suboxic deltaic environment), kerogen type III, which is prone to gas or oil. The terrigenous origin of the source organic matter, as well as the fact that maturity varies from depobelt to depobelt, were revealed by palynomorphs recovered from analysed cores. The source organic matter for the entire sequence studied is thought to be in the gas stage, with a spore coloration index of 6-8 and a thermal alteration index of 3 and above. The pollen association indicates a mangrove swamp habitat. The consistency of crude oil content suggested a single large reservoir split by fault lines rather than multiple independent reservoirs developed over time.

Keywords: Kerogen, Palynofacies, maturity, Niger Delta.

INTRODUCTION

Kerogen (Palynofacies):

Combaz (1964) was the first to introduce the idea of palynofacies to explain the overall assemblage of particulate organic-matter recovered from sedimentary rocks by palynological strategies. This practice over time had end up useful and have been efficaciously applied to paleoenvironmental depositional evaluations and sequence stratigraphic interpretations in several fields, especially within the quest for hydrocarbon efficient basins (Al- Ameri et al.,1999; Ibrahim, 2002; Oboh-Ikuenobe and de Villiers, 2003; and Martinez et al., 2005: all in Rodriguez et al., 2007).Powell et al. (1990: in Tyson 1995) defined palynofacies as a distinctive assemblage of HCl and HF insoluble particulate organic substance (palynoclast) in which their composition displays a particular sedimentary setting. Also, in lots of geological studies in which the environment isn't understood (in particular in fine-grained sediment) and it's identification has been inferred from the palynofacies analysis. Staplin (1969) and Jones (1986: in Tyson 1995) verified a dating among palynofacies (kerogen) and genesis of hydrocarbons.

Tyson (1995) and Batten (1996b) considered that palynofacies can help both to establish the depositional settings and also to determinate the hydrocarbon source potential and thermal maturity evaluation of the host sediments.

Palynofacies applications:

Batten (1996a) used palynofacies as indicators of variations in the distance to the shoreline. This ultimately can be related to changes in relative sea level. However, stochastic events such as retransporting of organic matter by oceanic currents and storms, pollen and spores transported by the wind, as well as changes in run-off and climate, canal so have an influence on the organic matter content of sediments. Tyson (1993) applied the palynofacies technique for:-

Determination of the magnitude and location of terrigenous inputs (provenance and proximal-distal relationships with respect to clastic sediment source).

Determining depositional polarity (onshore-offshore direction):

Identification of regressive transgressive trends in stratigraphic sequences and thus depositional boundaries.

Characterization of the depositional environment in terms of: Salinity (normal or saline lake waters, brackish "estuarine" or marine); Oxygenation and redox conditions (strongly or moderately oxidizing oxic conditions, and strongly or moderately reducing dysoxic to anoxic conditions); Productivity (normal or upwelling), and Water column stability (permanently stratified, seasonally stratified, or continuously mixed); Characterization and empirical subdivision of sedimentologically "uniform" facies, especially shales and other fine grained sediments.

Deriving correlations at levels below biostratigraphic resolution:

Preliminary qualitative or semi-quantitative determination of hydrocarbon source rock potential,

and qualification of bulk rock geochemical parameters. Producing sophisticated and detailed organic facies models.

Aim of Study:

The aim of this study is to evaluate the kerogen content of Obiafu field (central swamp depobelt), Obagi field (Greater Ughelli depobelt), OML-61 unidentified field (central swamp depobelt) and Abo field (Offshore depobelt). In this study, by using transmitted light microscope, the main organic matter components, namely, Amorphous Organic Matter (AOM), Palynomorphs, Phytoclasts and Opaque materials were recognized and classified. Figure 1below is a topographic map of the study area

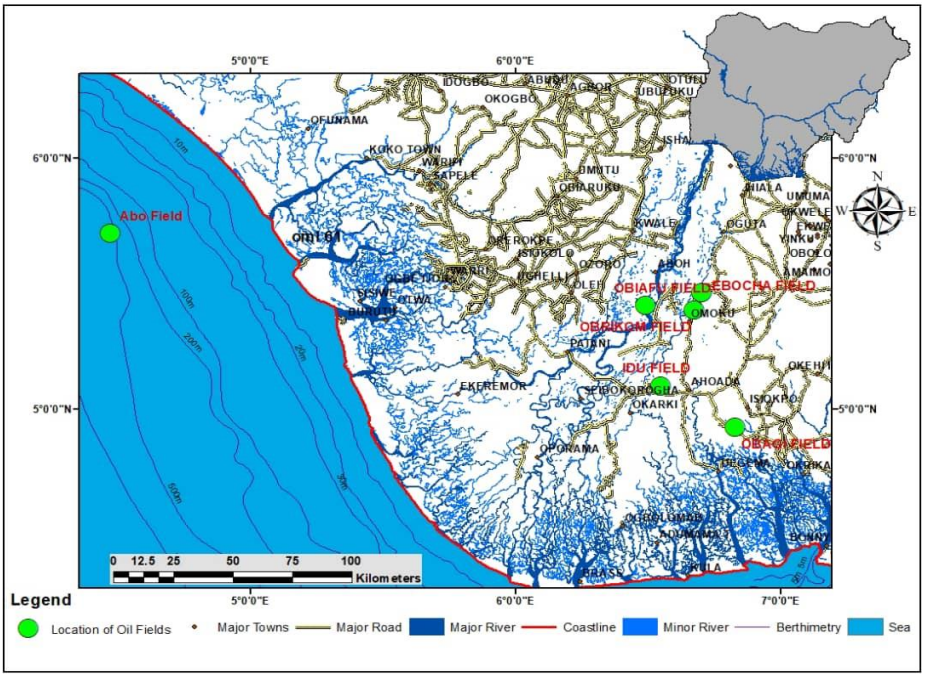


Figure 1: A topographic map showing the fields under the study area

MATERIALS AND METHODS

The suite of oils and core samples were subjected to lithologic, biomarker, and kerogen examination. A total of twenty one crude oil and six core samples were collected from seven wells each, spanning three fields: Obagi, Obiafu, OML 61, and Abo. The fields also cut across three depobelts namely Greater Ughelli depobelt, Coastal swamp and offshore depobelts. These samples were taken from well heads and placed in a sample vial with Teflon caps before delivery to the laboratory for analysis.

Methods:

Kerogen analyses were performed on a portion of the remaining core samples collected after palynological preparations. The following are the steps that were taken:

Dissolution of carbonates: The samples are subjected to treatment with Hydrochloric acid (HCl_{aq}) to dissolve any carbonate. The samples are at that point completely washed with condensed water after

emptying the HCl_{aq}.

Dissolution of silicates: The addition of Hydrofluoric acid (HF_{aq}) to the treated samples used to break down the silicates. The samples are mixed at standard ratios with a plastic or nickel bar and then cleared out overnight. Samples are completely washed with condensed water after tapping the HF_{aq}.

Removal of fluoride gels: The samples are at that point treated with warm 36% HCl_{aq}, and after that cold HCl_{aq} to dissolve fluoride gels and washed with condensed water.

Residue Separation: The following strategy is to wash with 0.5% HCl_{aq} and after that exchange the tests into little 15cc. Centrifuge tubes. The 0.5% HCl_{aq} is tapped after centrifuging and the Zinc bromide (s. G.2.2) is included and mixed with glass bar. After centrifuging, the drifting portion comprising of is tenderly emptied into another tube. That residue will be tapped into another tube and then washed with distilled water.

Neutralisation of acids: Warm Potassium hydroxide (KOH_{aq}) is included to the residues and kept for around 5 minutes. It is centrifuged and the KOH_{aq} tapped. The residue is washed approximately 2 or 3 times with distilled and deionized (D&D) water in orange to guarantee that all KOH_{aq} is washed out. The residue is at last washed twice with alcohol.

Preservation of residues: The residues are protected by including a drop of glycerol/glycerin to each of the well-labeled phials. They are then stored in water.

Preparation of microscopic slides: In the center of a clean slide, a small amount of mounting medium is placed, and a small amount of organic residue is added and warmed. The mixture is equally spread out on the slide, which is then covered with a cover slip and labeled with sample location names.

RESULTS AND DISCUSSION

The results of the lithologic, and kerogen analysis carried out on the suite of oils and core samples are discussed as follows.

Lithologic Description:

The description and identification of Samples was carried out using observable physical, cores were however, not sampled for Obiafu wells.

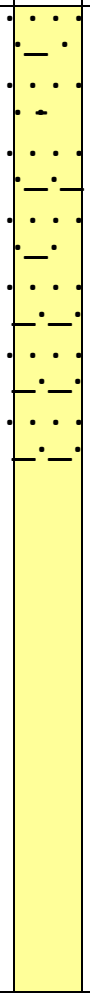
Wells	Depth	Lithology	Mud	Sand						Gravel				Texture	Lithofacies	Shale/Sand	Formation
			Shale	Silt	Very fine	Fine	Medium	Coarse	Very coarse	Granule	pebble	Cobble	boulder				
Oml 61-2	3060													Light brown colour, veryfine to medium grain, subangular to subrounded, moderately to wellsorted, sediments with fossil content	Silty Sandstone	40% 60%	Agbada

Figure 2: Lithofacies analysis of samples from OML 61 well 2, Central Swamp Depo belt.

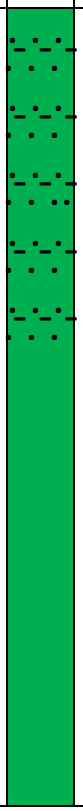
Wells	Depth	Lithology	Mud	Sand						Gravel				Texture	Lithofacies	Shale/Sand	Formation
			Shale	Silt	Very fine	Fine	Medium	Coarse	Very coarse	Granule	pebble	Cobble	boulder				
Oml61-7	3335													Grey colour, very fine to clay subrounded to moderately rounded indurated sample with fossil content	Sandy Clay	80% 20%	Agbada

Figure 3: Lithofacies analysis of samples from OML 61 well 7, Central Swamp Depo belt.

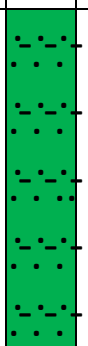
Wells	Depth	Lithology	Mud	Sand						Gravel				Texture	Lithofacies	Shale/Sand	Formation
			Shale	Silt	Very fine	Fine	Medium	Coarse	Very coarse	Granule	pebble	Cobble	boulder				
Obagi 2	3335													Dark grey colour, friable, very fine to clay subrounded to moderately rounded sample withfossil content	Sandy Clay	80% 20%	Agbada

Figure 4: Lithofacies analysis of samples from Obagi well 2, Coastal Swamp Depo belt.

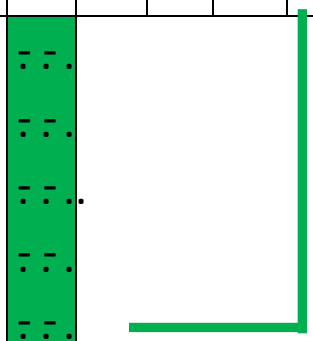
Wells	Depth	Lithology	Mud	Sand						Gravel				Texture	Lithofacies	Shale/Sand	Formation
			Shale	Silt	Very fine	Fine	Medium	Coarse	Very coarse	Granule	pebble	Cobble	boulder				
Obagi 7	3415													Lightgrey colour, friable, fine to clay grain, subrounded to moderately rounded, sample without fossil content	Sandy Clay	85% 15%	Agbada

Figure 5: Lithofacies analysis of samples from Obagi well 7, Greater Ughelli Depo belt.

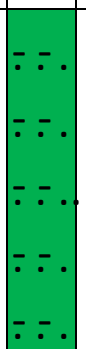
Wells	Depth	Lithology	Mud	Sand					Gravel				Texture	Lithofacies	Shale/Sand	Formation
			Shale	Silt	Very fine	Fine	Medium	Coarse	Very coarse	Granule	pebble	Cobble	boulder				
Abo 2	3115													Dark browncolour, indurated, very fine to clay, subrounded to moderately rounded, sample with fossil content	Sandy Claystone	85% 15%	Agbada

Figure 6: Lithofacies analysis of samples from Abo well 2, Offshore Depo belt.

Wells	Depth	Lithology	Mud	Sand						Gravel				Texture	Lithofacies	Shale/Sand	Formation
			Shale	Silt	Very fine	Fine	Medium	Coarse	Very coarse	Granule	pebble	Cobble	boulder				
Abo 4	3115													Dark greycolour, indurated, very fine to clay, subrounded to moderately rounded, sample	Sandy Claystone	93% 7%	Agbada

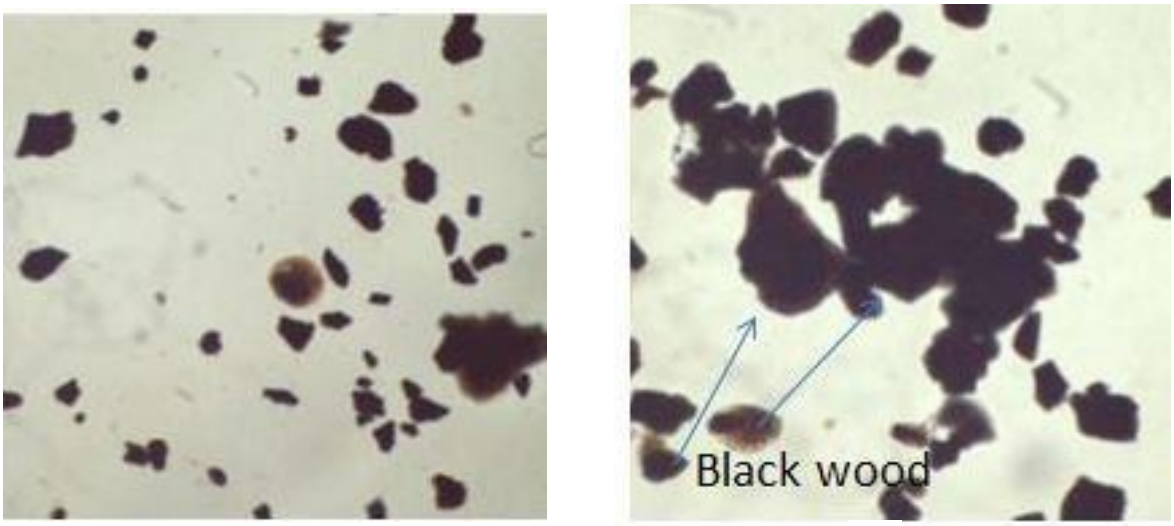
Figure 7: Lithofacies analysis of samples from Abo well 4 , Offshore Depo belt.

DISCUSSION

The lithologic analysis of the samples indicated that OML 61 samples are indurated and with much less shale/sand. Shaliness expanded downwards. Obagi samples had been friable with an expanded shaliness. The extra shale /sand indicate deposition underneath high energy figure 2-7.

The dispersed organic matter in the sediments (figures 8-10) is useful in deciphering the sources and depositional conditions of the study area. Palynofacies encompasses the total complement of acid-resistant organic matter recovered from a sediment or sedimentary rock by palynological processing techniques as earlier described. Several factors control the amount and types of dispersed organic matter in sedimentary rocks, and they include the sources of organic matter, depositional environment, lithology, tectonic setting, sea-level fluctuations, paleoclimate, paleoproductivity, sedimentation rate, diagenesis, and paleoceanography. In a marine setting, the narrow width of the continental shelf, such as the present shelf, will exert an important control on the relative positions of proximal and distal facies of the different environments. The palynofacies analysis presented in this study represent a subset of the Cretaceous to Pleistocene data

discussed by Oboh-Ikuenobe et al.(1997). The dominant palynodebris in most samples is phy toclast which is an increase in terrestrially derived components such as plant tissues, roots, wood and cuticles. Samples were analysized to identify palynofacies assemblages in the entire suite of sediments. The results are summarized in (table1). Photomicrograph of selected locations was used to illustrate the different assemblages of Miocene Sediments within the study area. Three main groups are used in this study and they include Vitrinite (brown wood), Exinite mostly palynomorphs (plant cuticles, spores, pollen, dinocysts, acritarch, resins and Amorphous Organic Matter (AOM) of aquatic, algal and bacterial origin and Inertinite (black wood). Vitrinite and inertinite, collectively referred to phytoclasts, are remains of land plants and most times accumulates within fluvial-lacustrine systems in estuaries, near-shore to proximal offshore. The percentage occurrences of these groups were recorded relative to each other to define the different depositional environments. The results are stated below;



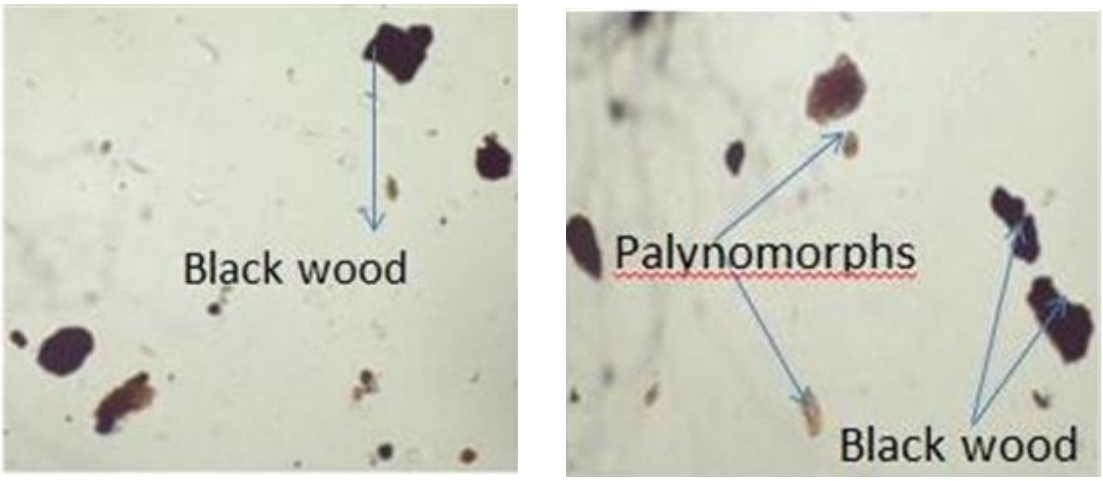
a b

Figure 8a & 8b: Palynofacies recovered from OML 61 well 7, and 2, respectively

OML 61 wells 7 yielded the palynofacies shown in figure 8 a. They are made up of equidimensional opaque biostructures that extend all the way to the boundary of the photomicrograph's western region, which could be pits caused by plant debris. The eastern corner is littered with a big brown debris encircled with lath-shaped brown detritus. Biostructures in the palynofacies imply that woody tissues have been oxidised or carbonated. The central and eastern regions of the photomicrograph, however, are lined up with cuticles and cortical tissue, suggesting that they are plant roots. As a result, the palynofacies represents a pristine continental deposition environment for the source organic matter. The presence of dark brown and black pytoclast implies a significant amount of fluvio-deltaic sources of continental source organic matter, as well as near proximity to or re-deposition from them.

Figure 8 (b) shows palynofacies found in OML 61 well 2. It also has a lot of big black debris, which

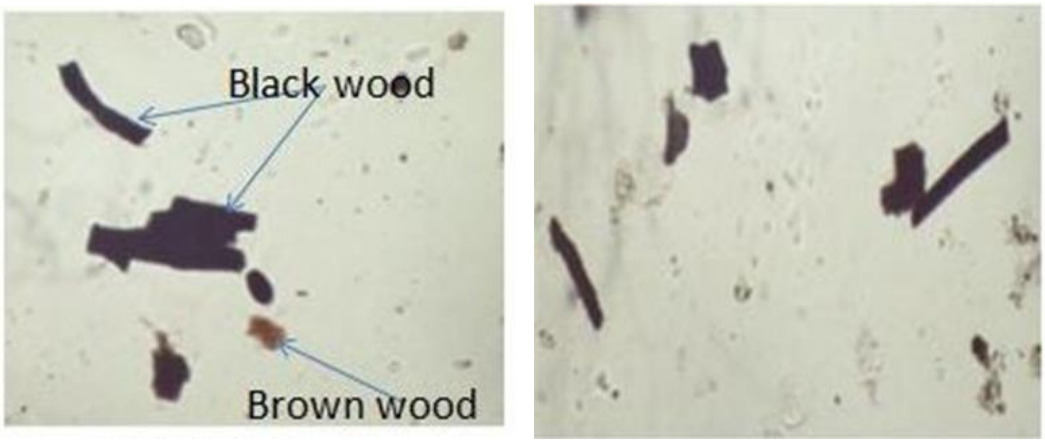
indicates that it was deposited in an oxidising environment and was close to fluvio-deltaic sources. The palynofacies also point to a continental origin for the organic matter source.



a b

Figure 9a & 9b: Palynofacies recovered from Obagı well 2

Figure 9(a) and 9(b) show the palynofacies recovered from Obagi well 2. Both photomicrographs show that the source organic matter is largely few pytoclasts of big debris and a higher number of cuticles from the plant. Given the higher quantity of cuticles in comparison to the equant and lath palynomacreals, the palynofacies suggest a proximal fluvio-deltaic or mangrove-estuarine sub-environment.



a b

Figure 10a & 10b: Palynofacies recovered from Abo well 2 and 4 respectively

Figure 10(a) and 10(b) depict palynofacies retrieved from Abo wells 2 and 4 respectively. The extraction from both wells was minimal, however it was largely made up of lath black woods and cuticles. The palynofacies suggests distal deposition, in which delicate constituents have been removed, leaving the more resilient components well preserved. However, Abo well 4 had more lath than Abo well 2, indicating that Abo well 2's shelf environment was more distant.

S/N	SAMPLE	PALYNOFACIES CONTENT			
		Exinite (%)		Vitrinite (%)	Inertinite (%)
		Palynomorphs	AOM	Phytoclasts	
1	OML-61 W-2	15	5	80	0
2	OML-61 W-7	20	5	5	70
3	OBAGI-W-2	30	0	10	60
4	OBAGI-W-7	BARREN			
5	ABO W-2	40	0	15	45
6	ABO W-4	10	0	30	60

Table 1: Palynofacies percentage distribution

The APP ternary of Tyson (1995) was used to estimate the paleo-depositional environment of the palynofacies identified in this investigation. Following the charting of the organic matter components (AOM, Palynomorphs, and Phytoclasts + Opeque materials) from Table (1) to Tyson's ternary (as illustrated in the figures 11-13). The following outcomes were achieved

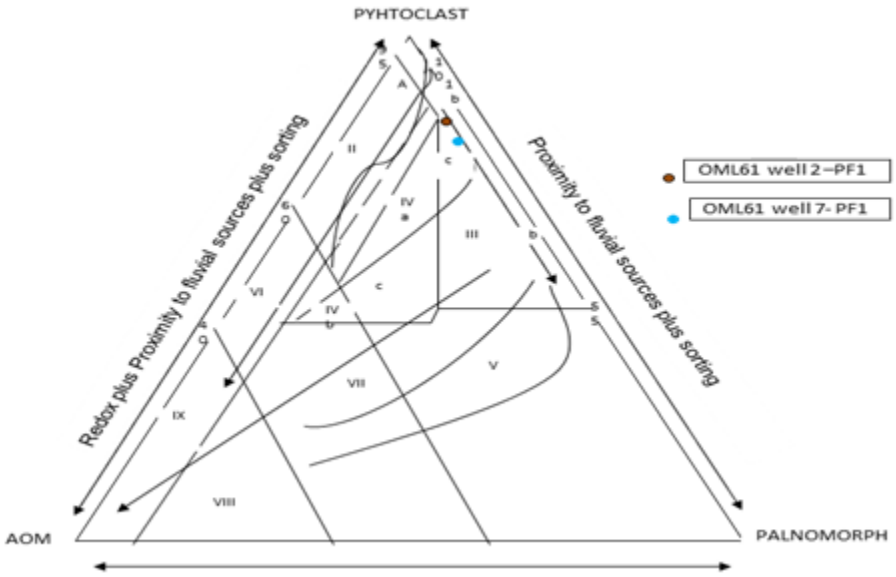


Figure 11: APP ternary diagram of Tyson (1993) environment of deposition determination of OML well 2 and well 7

OML 61 wells 2 and 7 ternery plots suggests a Heterolithic oxic shelf (proximal shelf) deposition environment, with low AOM and absolute phytoclast abundance dependant on real closeness to fluivo deltaic source, with oxidation and reworking prevalent. Palynofacies research also indicates that both wells include type III or IV kerogen, which is gas-prone.

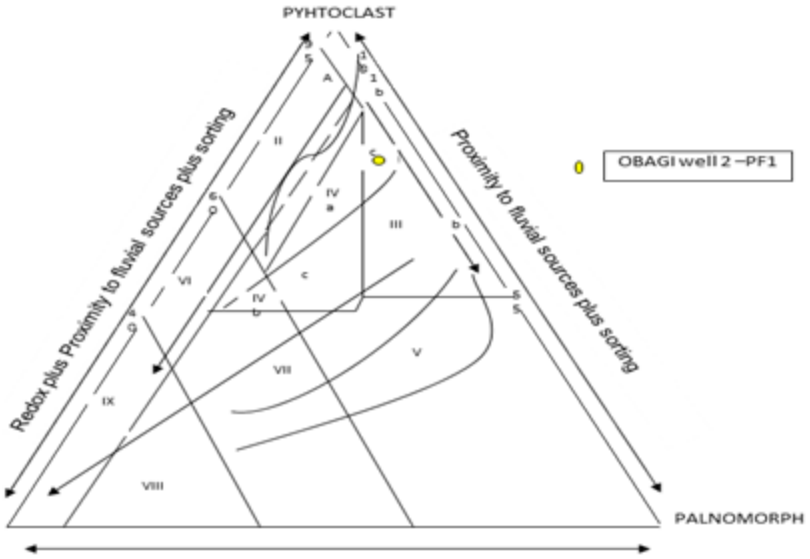


Figure 12: APP ternary diagram of Tyson (1993) for determination of depositional environment of Obagi well 2 and well 7

The ternery plot of palynofacies from Obagi 61 well 2 indicates a Heterolithic oxic shelf (proximal shelf) environment of deposition, the low AOM and absolute phytoclast abundance is dependent on actual proximity to fluivo deltaic source, oxidation and reworking are common. Palynofacies study also suggests that both wells have type III or IV kerogens, which are primarily gas prone.

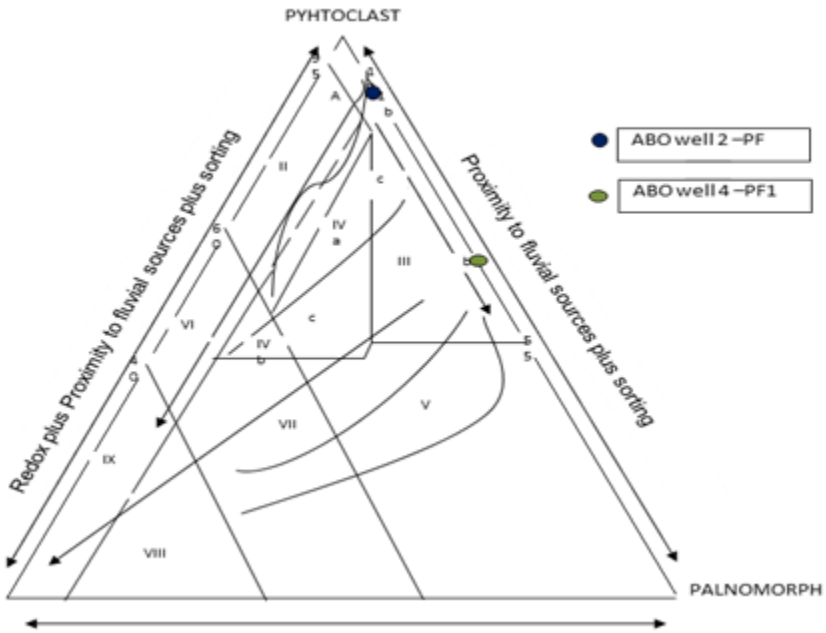


Figure 13: APP ternary diagram of Tyson (1993) for determination of depositional environment of Abo well 2 and well 4

The abundance of phytoclasts from figure above shows proximity to source and degree of re-deposition in the ternery plot of palynofacies from Abo well 2, indicating an high proximal shelf environment of deposition, where the high phytoclast supply dilutes other componets. Palynofacies analysis also infers a Type III kerogen which is mainly gas prone for the well. However, Abo well 4 plot indicates a heterolithic oxic shelf environment. There were no AOM and had high phytoclast supply which is dependent on actual nearness to fluivo-deltaic source. A gas prone type III kerogen is inferred for this well.

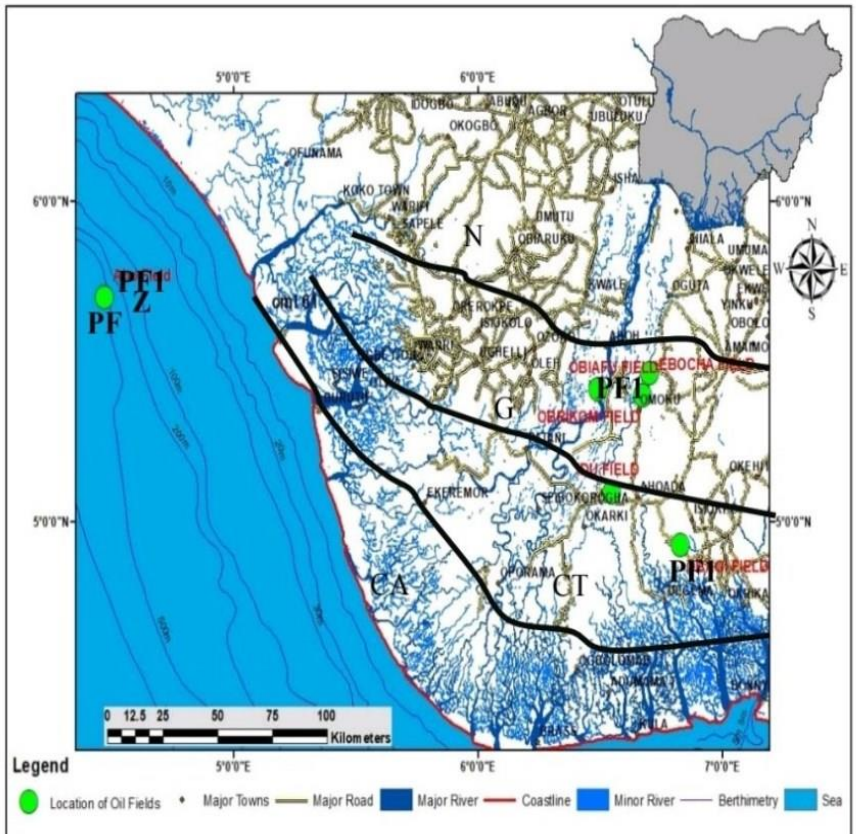


Figure 14: Palynofacies of the studied depobelts.

Pollen, spore, and phytoclasts were well preserved in the samples examined. Standard palynological processes was used on these materials, as described,, and the results of the analyses are listed from Tables 2-6. The preservation of palynomorphs was relatively good. Except for one sample from Obagi well (W-7) that was devoid of palynomorphs, the samples provided reasonably diversified assemblages of miospores. However, none of the maritime indicator palynomorphs were found in any of the areas studied. The following are the findings of the investigation:

According to the findings, samples from OML 61 and Obagi were most likely deposited during the 'earliest' period of the Early Miocene, while samples from Abo were most likely deposited during the Late Miocene. The microfloral assemblages found in these samples are largely from the Eocene to the Recent epochs. With the exception of Steriosporites sp., no index markers were found in these samples. Abo samples

with a Late Miocene last downhole occurrence (LDO) (P780). As a result, the Abo samples have been assigned a Late Miocene age.

OML 61 (W-2) and (W-7) samples were most likely assigned earliest. The early Miocene age was determined using Evamy et al(1978) .'s zonation scheme, which included the presence of Racemonocolpites hians, abundant Zonocostites ramonae, Psilatricolporites crassus, Psilastephano colporites laevigatus & Ctenolophonidites costatus, and a rich occurrence of Pachydermites diederix

The absence of crucial marker species such as Nympheapollis clarus, Peregrinipollis nigericus, Cyperceapollis sp., and Steriosporites sp., which are younger than the ascribed age, also supports this age assignment.

W-2 samples were most likely deposited during the Miocene epoch, while OBAGI (W-7) yielded almost little palynomorph. Early Miocene is the 'earliest' of the Miocene epochs. This age determination is based on the presence of Polypodiaceoisporites sp., Gemmamonoporites sp., moderate occurrences of Monoporites annulatus, Retitricolporites irregularis, singular occurrence of Racemonocolpites hians, super abundant occurrence of Zonocostites ramonae, fair presence of Psilatricolporites crassus, presence of Psilaste The Late Miocene age of ABO (W-2) and (W-4) samples was determined using the zonation scheme of Evamy et al., 1978, based on the moderate occurrence of Steriosporites sp., which has its base within the P780 subzone, super abundant occurrence of Zonocostitesramonae, presence of Psilatricolporites crassus, presence of Psilastephanocolporiteslae

The absence of crucial marker species such as Nympheapollis clarus, Peregrinipollis nigericus, and Cyperceapollis sp. further supports this age assignment.

OML 61 (W-2)

Psilatriporitessp	1 Paleocene- Pliestocene
Smooth monolete spore	1
Zonocostitesramonae	1 Early Miocene- Pleistocene
Smooth trilete spore	*2 late Miocene*
Psilatricolporitescrassus	*9 Eocene-Pleistocene*
Fungal spore	*1*
Racemonocolpiteshians	*1 Eocene-Early Oligocene*
Psilamonocolpitessp	*2 Ealy Miocene*
Psilastephanocolporiteslaevigatus	*1 Late Oligocene-Early Miocene*
Verrucatosporitesalienus	1

Pollen	Spore	Fungi	Age
Zonocostites ramonae	*Verrucatosporitesalienus*	Fungal spore	Late Oligocene- Early miocene
Psilatriporites sp	*Smooth trilete spore*		
Psilatricolporites crassus			
Racemonocolpiteshians			
Psilamonocolpitessp			
Psilastephanocolporiteslaevigatus			

Table 2: Palynomorp occurance in OML 61 well 2

OML 61 (W-7)		
Zonocostitesramonae	*37*	
Pachydermitesdiederixi	*6*	
Polypodiaceoisporitessp	*1*	
Smooth monolete spore	*2*	
Smooth trilete spore		*2*
Verrucatosporitesalienus	*8*	
Fungal spore		*2*
Psilastephanocolporiteslaevigatus	*1*	
Cyatheadites sp.	*1*	
Psilatricolporites crassus	*3*	
Retimonocolpites sp.		*1*
Psilatricolporites sp.		*1*
***Ctenol**ophonidites costatus*		1

Pollen	Spore	Fungal spore	Age
Zonocostites ramonae	Verrucatosporites alienus	Fungal spore	Oligocene- Early Miocene
Psilatriporites sp	Smooth trilete spore		
Psilatricolporites crassus	Smooth monolete spore		
Racemonocolpites hians	Cyathadites sp.		
Psilamonocolpites sp			
Psilastephanocolporites laevigatus			
Pachydermites diederixi			
Psilatricolporites crassus			
***Ctenol**ophonidites costatus*			

Table 3: Palynomorp occurance in OML 61 well 7

OBAGI (W-7)

Practically No Palynomorphs

OBAGI (W-2)

Polypodiaceoisporitessp	*5*	
Zonocostitesramonae		*294*
Verrucatosporitesalienus	*36*	
Fungal spore		*1*
Fungal hyphae	*1*	
Psilatricolporitescrassus	*3*	
Smooth trilete spore		*15*
Ctenolophoniditescostatus		*1*
Smooth monolete spore	*12*	
Pachydermitesdiederixi	*6*	
Gemmamonoporitessp	*2*	
Retitricolporitesirregularis		*7*
Monoporitesannulatus	*1*	
Monoporisporiteskoenigii	*1*	
Psilatricolporites sp.		*2*
Retitriporites sp	*4*	
Psilastephanocolporites laevigatus		*1*
Praedopollis sp	*1*	
Pluricellaesporites sp.		*1*
Retitricolpites sp	*2*	
Retitricolporites sp		*7*
Striatricolporites sp.		*1*
Retitricolporites amazoensis		*2*
Retistephanoporitessp		*1*
Retibrevitricolporitesobodoensis	*3*	
Retimonocolpites sp.		*1*
Retibrevitricolporites sp.	*1*	
Verrucatosporites farvus	*1*	
Racemonocolpiteshians	*1*	
Echiperiporitesestelae		
Alchorneacordifolia		*1*
Polyporisporites sp		*1*

Verrutricolporites sp.	1

Pollen	Spore	Fungal spore	Age	
Zonocostites ramonae	*Verrucatosporites alienus*	Fungal spore	Oligocene-	Early
Psilatriporites sp	*Smooth trilete spore*	Fungal hyphae	Miocene	
Psilatricolporites crassus	*Smooth monolete spore*			
Racemonocolpites hians	*Cyatheadites sp.*			
Psilamonocolpites sp	*Polypodiaceoisporitessp*			
Psilastephanocolporites laevigatus	*Monoporisporiteskoenigii*			
Pachydermites diederixi	*Pluricellaesporites sp.*			
Psilatricolporites crassus	*Verrucatosporites farvus*			
***Ctenol**ophonidites costatus*	*Polyporisporites sp.*			
Gemmamonoporitessp				
Retitricolporitesirregularis				
Monoporitesannulatus				
Psilatricolporites sp.				
Retitriporites sp				
Psilastephanocolporites laevigatus				
Praedopollis sp				
Retitricolpites sp				
Retitricolporites sp				
Striatricolporites sp.				
Retitricolporites amazoensis				
Retistephanoporitessp				
Retimonocolpites sp.				
Retibrevitricolporites sp.				
Echiperiporitesstelae				
Verrutricolporites sp.				

Table 4: Palynomorp occurance in Obagi well 2

ABO (W-2)		
Verrucatosporitesalienus	*2*	
Zonocostitesramonae		*144*
Fungal spore		*1*
Ctenolophoniditescostatus		*1*
Retitricolpites sp.		*1*
Steriosporites sp.	*1*	

Plant cuticle		*1*
Magnastriatiteshowardi	*2*	
Multicellitessp		*1*
Callimothalluspertusus		1

Pollen	Spore	Fungal spore	Age
Zonocostites ramonae	*Verrucatosporites alienus*	Fungal spore	Early Miocene-Late Miocene
Psilatriporites sp	*Smooth trilete spore*	Multicellites sp	
Retitricolpites sp.	*Smooth monolete spore*	Callimothalluspertusus	
Psilastephanocolporites laevigatus	*Magnastriatites howardi*		
Ctenolophonidites costatus			

Table 5: Palynomorp occurance in Abo well 2

ABO (W-4)		
Zonocostitesramonae		*165*
Periporisporitessp		*2*
Magnastriatiteshowardi	*1*	
Smooth monolete spore	*8*	
Verrucatosporitesalienus	*32*	
Striatricolporitescatatumbus		*1*
Multicellitessp		*2*
Psilatricolporites sp.		*1*
Monoporisporiteskoenigii	*1*	
Polyporisporites sp.		*2*
Psilastephanocolporiteslaevigatus	*3*	
Pachydermitesdiederix	*4*	
Fungal spore		*4*
Smooth trilete spore		*2*
Fungal hyphae	*4*	
Retitricolporitesirregularis		*1*
Verrucatosporites sp.		*1*
Steriosporites sp.	*4*	
Polypodiaceoisporitessp	*7*	
Retibrevitricolporitesobodoensis	*3*	
Psilatricolporitescrassus	*1*	

Fusiformisporites sp.	*2*	
Retitricolporites sp.	*1*	
Lycopodiumsporites sp.	1	

Pollen	Spore	Fungal spore	Age
Zonocostites ramonae	*Verrucatosporites alienus*	Fungal spore	Late
Psilatricolporites crassus	*Smooth monolete spore*	*Lycopodiumsporites sp*	Miocene
Psilastephanocolporites laevigatus	*Polypodiaceoisporitessp*	*Fusiformisporites sp.*	
Psilatricolporites crassus	*Monoporisporiteskoenigii*	*Multicellites sp*	
Striatricolporitescatatumbus	*Steriosporites sp*		
Retitricolporitesirregularis	*Verrucatosporites sp*		
Psilatricolporites sp.	*Polyporisporites sp.*		
Psilastephanocolporites laevigatus	*Periporisporitessp*		
Pachydermitesdiederix	*Magnastriatites howardi*		
Retitricolporites sp	*Smooth trilete spore*		
Retibrevitricolporitesobodoensis			
Retitricolporites sp			
Retibrevitricolporitesobodoensis			

Table 6: Palynomorph occurance in Abo well 4

Evaluating Maturity by TAI:

The optical evaluation of the researched samples was done by detecting the colour shift of the palynomorphs due to temperature effects, as well as determining the maturity stage of the OML 61, Obagi, and Abo fields in the studied wells. To determine the true TAI of the tested samples, a spore with the widest variety of appearance was chosen to demonstrate the effect of temperature on colour changes. Some spores were picked because it has the longest appearance and is found in all six areas tested (Figures 16-20). The TAI values for the analysed slides were calculated in this work using transmitted light microscopy and according to Waples' TAI scale (1985) as shown in Table 2 below.. The colour variation of the studied palynomorphs ranged from orange (2 TAI) to dark yellow (2+ TAI) to light yellowish brown (3- TAI) to dark brown (>3TAI) as seen in (Figure16-20), indicating that the kerogen within the studied samples had not been exposed to pale temperatures above 100^{o}C. (in line with Waples,1985 pale temperature scale) The mature region has been reached in the OML 61, OBAGI, and ABO fields (from depths of 3060m to 3335m), as evidenced by dark yellow palynomorphs (3 TAI) from depths of 3109 to 3415m and light yellowish brown palynomorphs (more than three TAI) in the deeper parts. In addition, the TAI values were linked to the Spore Colouration Index SCI in order to provide an accurate maturity assessment for sediments.

Vitrinite reflectance (%R_o)	Spore coloration index (SCI)	Thermal alteration index (TAI)	Pyrolysis Tmax (°C)	Generalized hydrocarbon zone
0.40	4.0	2.0	420	Immature
0.50	5.0	2.3	430	Immature
0.60	6.0	2.6	440	Oil
0.80	7.4	2.8	450	Oil
1.00	8.1	3.0	460	Oil
1.20	8.3	3.2	465	Oil & wet gas
1.35	8.5	3.4	470	Wet gas
1.50	8.7	3.5	480	Wet gas
2.00	9.2	3.8	500	Methane
3.00	10	4.0	500+	Methane
4.00	10+	4.0	500+	Overmature

Table 2: Thermal Alteration Index after Waples 1985

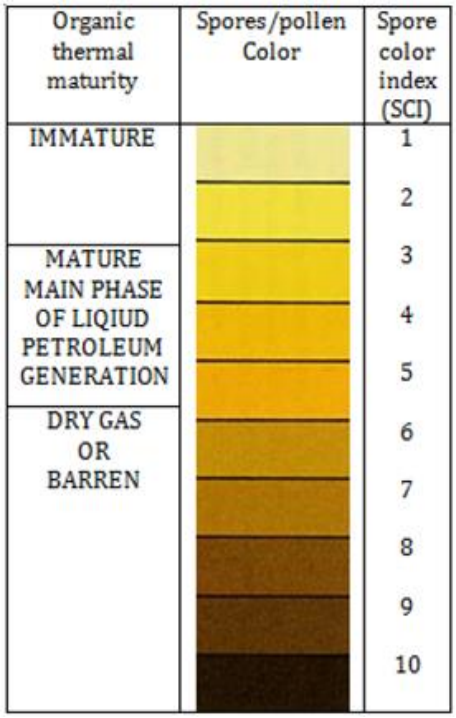


Figure 15: After Fisher , M.J, (1980)in Lucas et al 2018. Palynofacies Analysis, Organic Thermal Maturation and Source Rock Evaluation of Sedimentary Succession

Figure 16: *Magnastriatites howardii* recovered from Abo well 2

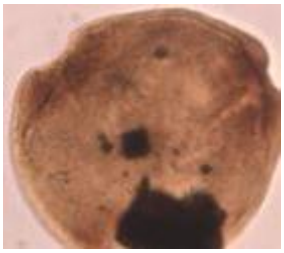


Figure 17: *Psilatricolporites crassus* recovered from Oml well *2*

Figure 18: *Cythiadite*s recoverd from Oml well 2 and Obagi 7

Figure 19: Fungal spore recovered from Oml well 7, Obagi 2 and Abo

Figure 20: Fungal spore recovered from Oml well 2,

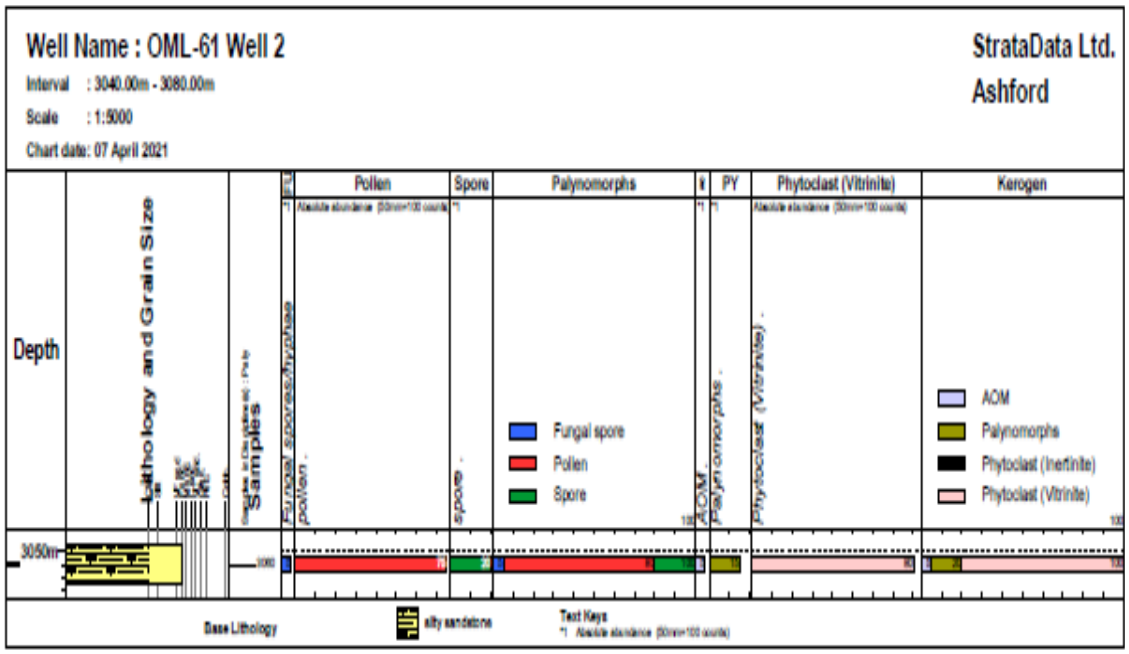


Figure 21: Percentage distribution of palynofacies in OML 61 well 2

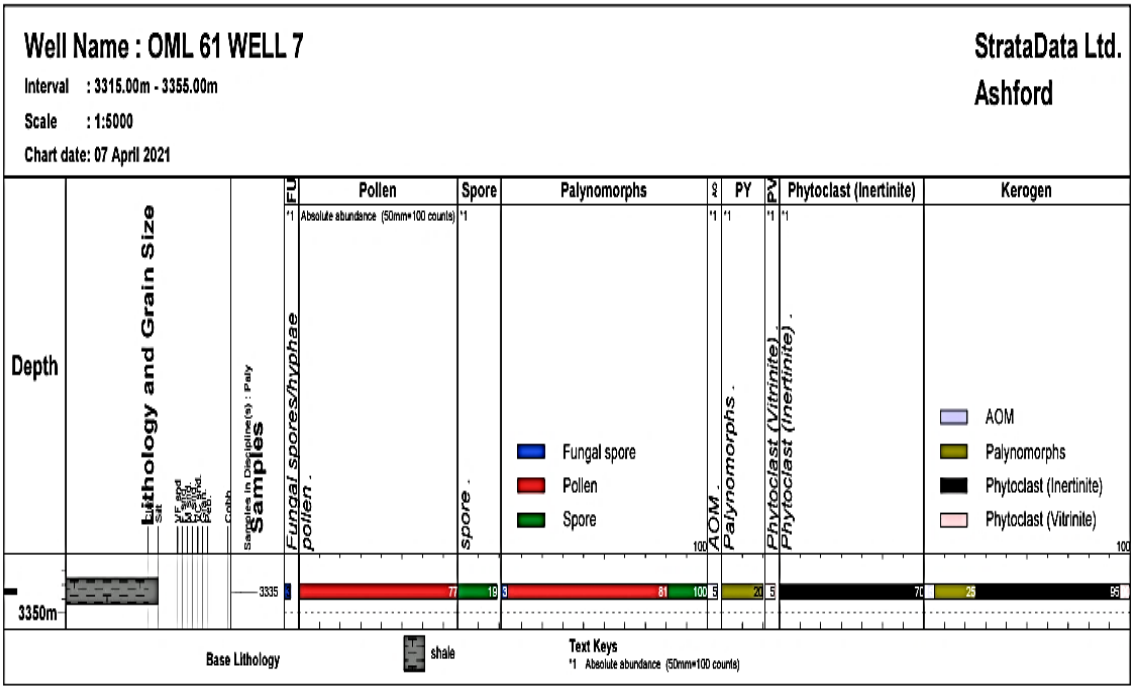


Figure 22: Percentage distribution of palynofacies in OML 61 well 7

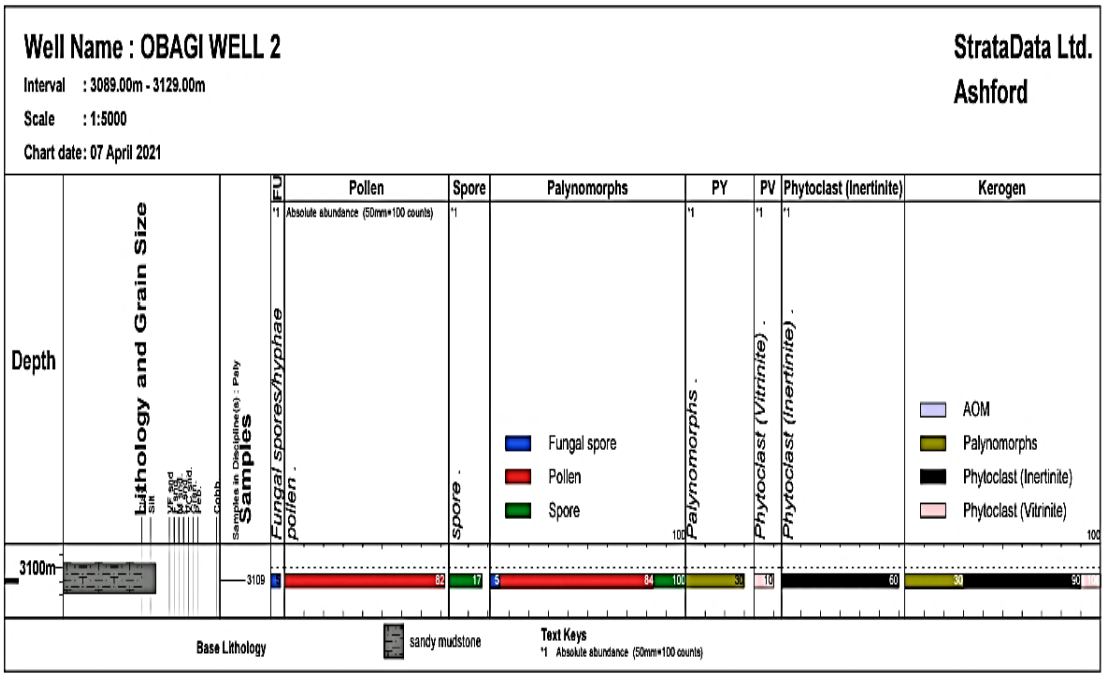


Figure 23: Percentage distribution of palynofacies in Obagi Well 2

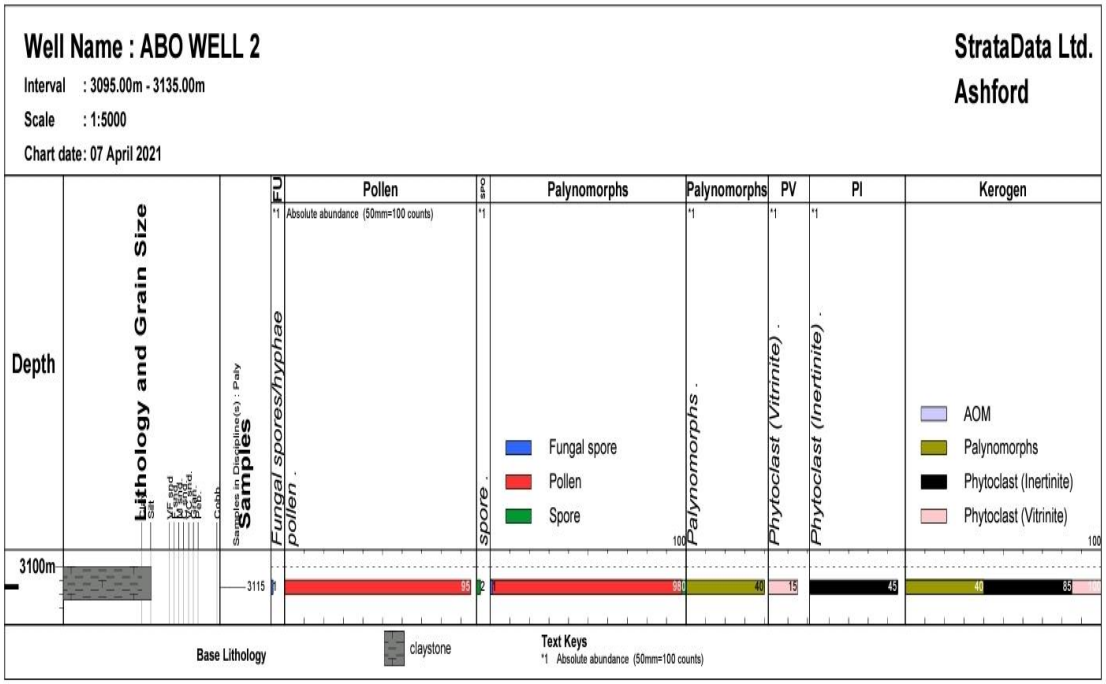


Figure 24: Percentage distribution of palynofacies in Abo Well 2

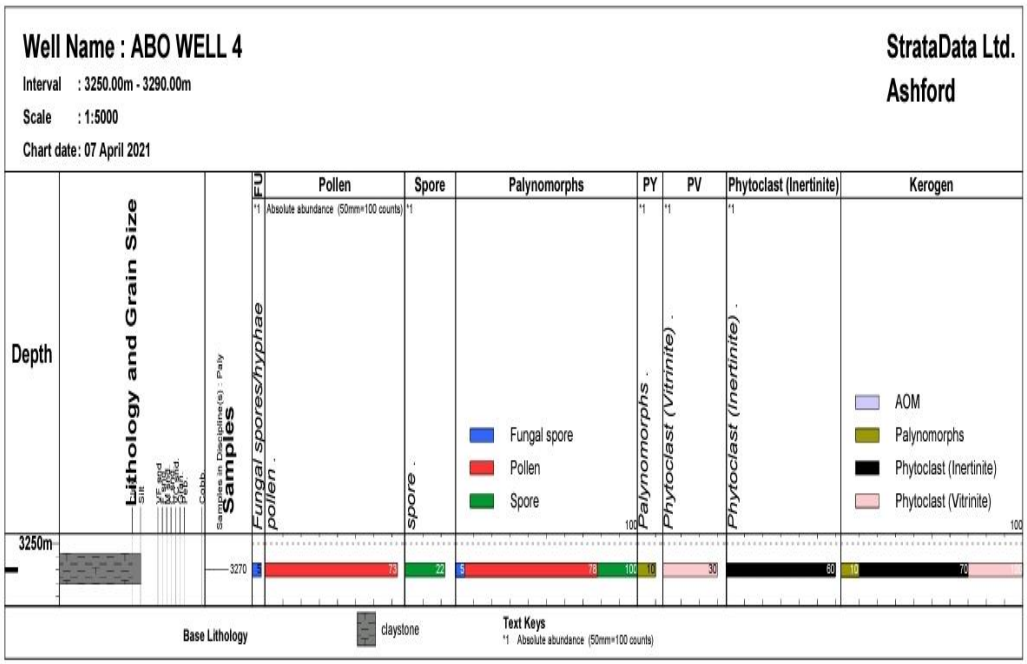


Figure 25: Percentage distribution of palynofacies in Abo Well 4

CONCLUSION

Kerogen evaluation suggested two palynofacies namely; PF and PF1 (figure 14). The OML 61, wells 2 and 7, Obagi represented by Well 2 and Abo well 4 from the three fields indicates heterolithic oxic shelf environment of deposition which is represented by PF1. The Low AOM and dominance of phytoclast is dependent on real proximity to fluvio deltaic placing which is associated with a low oxidation. From the palynofacies PF, each field plotted as gas prone Kerogen type III. The Palynofacies PF1 of well 2 Abo field indicated a dysoxic-suboxic transitional environment of deposition for the supply organic matter.

Also, the presence of phytoclasts indicates proximity to the source of deposition; yet, there was more lath (distal shore) than equants (nearshore or coastal or shallow marine). The PF plotted as a gas-prone type III kerogen. In addition, all fields with a thermal alteration value of 3 or higher revealed a mature sequence.

Palynological study of the fields revealed a high production of pollen, spore, and fungal spore; however, no dinoflagellates or other marine palynomorphs were discovered. Based on pollen and spore relationships, the OML61 and Obagi fields were assigned Late Oligocene-Early Miocene and Early Miocene ages, respectively. The Abo fields have been assigned a late Miocene date based on palynomorph assemblages found. The spore colouring index revealed that all of the sequences tested were mature.

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