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Research Article

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Paleoenvironmental Analysis of Sediments in Well Z, Offshore Niger delta, Southern Nigeria

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Abstract This research was carried out on ditch cutting rock samples from an EXXONMOBIL exploratory well Z, located in offshore Niger delta and was aimed at the integration of lithostratigraphic and palynostratigraphic results for the purpose of interpretation of the depositional environment of the sediments. Palynological analysis revealed well preserved ecological groups of palynomorphs (dinoflagellate cysts, pollen and spores, archritarchs and foraminiferal test linings). Abundance and diversity plots of these ecological groups of palynomorphs were used as paleoenvironmental models supplemented with the lithological and textural characteristics of the rock samples. Three environmental zones were recognised. The coastal plain, the neritic and deep marine setting (open ocean). The coastal environment was interpreted for the very thin shale intercalation on thickly bedded, rounded to sub- rounded coarse grained, poorly sorted pebbly sandstones that are conglomeritic at the top with scattered mica flakes, shells and shell fragments; rare to non occurrence of marine Microplankton representing the Benin formation. While the shallow marine (neritic) setting was interpreted for the coarse to medium grained sand, silty shale and fine grained sand intercalations with shells and shell fragments and scattered mica flakes of the main paralic Agbada formation. the open ocean setting was interpreted for the thick, dark(organic rich) marine shales with inter beds of medium to coarse grained,rounded to sub rounded, moderately to well sorted sandstone and siltstones at the base with grey shales and sandy shales alternating with medium to coarse grained sand more paralic at the top representing the lower Agbada formation. The paleo shelf edge was recognised at 4800 ft depth.

Keywords environment, palynomorphs, dinoflagellate cysts, ecology, marine

Introduction

Palynology provides useful information in paleoenvironmental reconstruction. Analysis revealed well preserved ecological groups of palynomorphs (dinoflagellate cysts, pollen and spores, archritarchs and foraminiferal test linings) utilised for the purpose of environmental interpretation. This research was carried out on ditch cutting rock samples from an EXXONMOBIL exploratory well Z, located in offshore Niger delta (figure 1). The study was aimed at the integration of lithostratigraphic and palynostratigraphic results for the interpretation of the depositional environments of the sediments. The abundance and diversity plots of ecological groups of palynomorphs which include Rhizophora pollen *Zonocostites ramona*, angiosperm and fungal spores, total. Microplankton abundance, dinocyst abundance and gonyaulacacean ratio were used as paleoenvironmental models. The textural analysis of rock samples was also made by viewing these samples under the microscope with a grain size comparator in order to identify the different rock types penetrated by the wells and its variability within succession. The ratio of the marine to terrestrial palynomorphs (Microplankton ratio) gives clue to the paleowater depth. These marine palynomorphs include dinocyst, Architarch and foraminiferal test lining and varies from 100% in total marine setting to zero in non -

marine (Terrestrial) environment. The percentage microplankton per total palynomorph count also permits the recognition of transgressive and regressive phases of sea level cycle useful in identification of sedimentation cycles. During transgression, there is a relative increase in the population of the microplankton but decrease to a minimum during regressive phase.

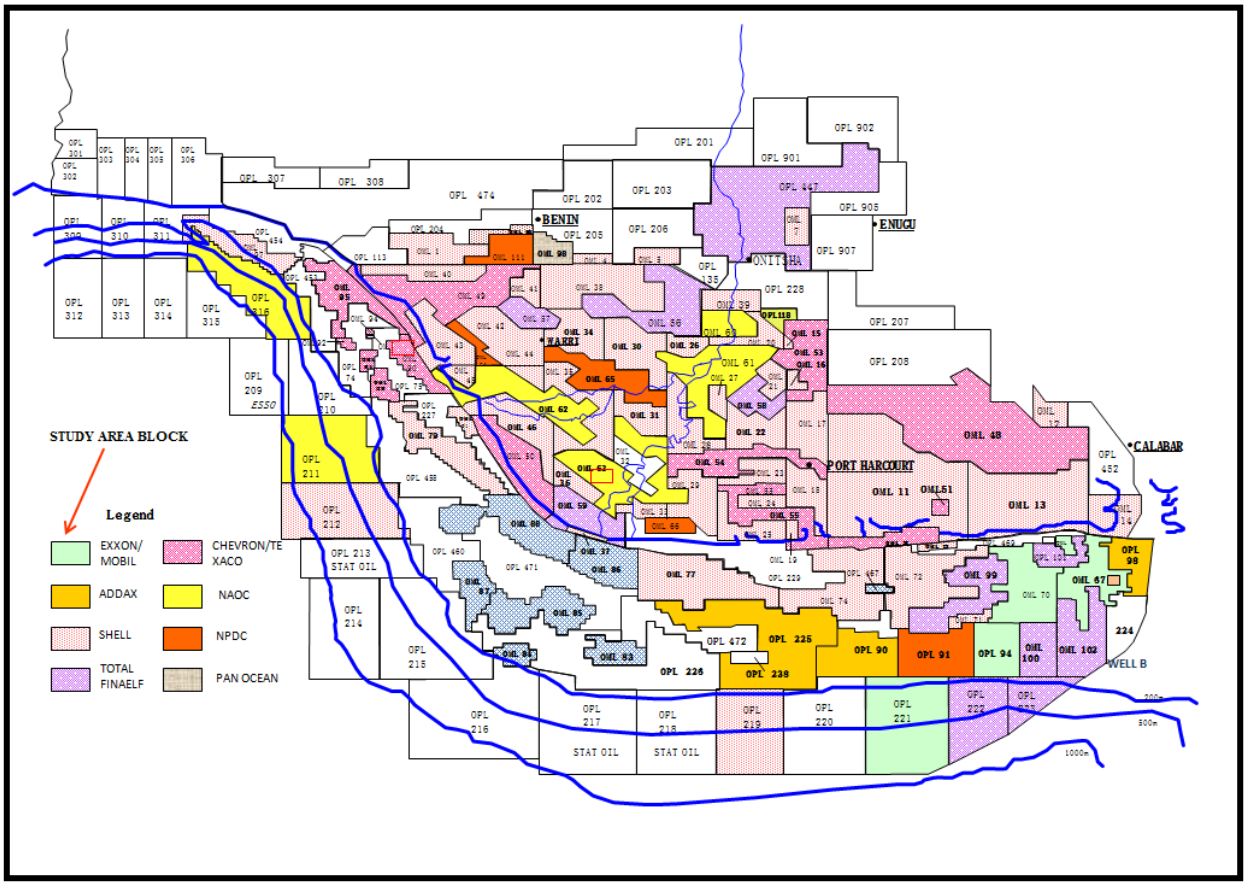


Figure 1: Niger Delta oil mining lease (OML) map showing location of the study area block

Gonyaulacoid dinoflagellate cysts are known to inhabit deeper water environment while the peridinoids are found to concentrate in shallow water. A parameter known as gonyaulacacean ratio which is the ratio of gonyaulacacean cysts to peridinacean cysts [1-2] was also used as a measure of openness of the marine environment. The higher the ratio, the more open the marine environment. Other groups of palynomorphs such as *Impagidinium species* known to concentrate in specific environments [1] were also employed in the paleoenvironmental analysis. The mega fossil and associated accessory mineral content of the sediments were also considered within the limit of the available data. Selley (1985) [3] has shown that although Shell fragments which are common constituent of many sands are derived from fresh water organisms, the preservation potential of these calcareous particles in many continental sedments is, however, probably limited, due to leaching by acidic meteoric waters. The presence of shell material, therefore, most likely indicates a marine depositional setting. He also used detrital mica flakes to diagnose depositional environments. Flakes of mica tend to be winnowed out of high energy environments by turbulence and strong currents and carried away to be deposited in lower energy environments. Micaceous sands therefore tend to be absent from well-winnowed environments like barrier islands, shallow shelf bars, and aeolian dunes. Settings in which micaceous sands characteristically occur include outer delta slopes, outer shelf, and submarine channels and fans.

Niger delta Stratigraphy

The Tertiary Niger delta complex is divided into three formations, representing prograding depositional facies that are distinguished mostly on the basis of sand-shale ratios. They are the Akata, Agbada and Benin Formations. The type sections of these formations have been reviewed as described in Short and Stäuble (1967)

[4] and summarized in a variety of papers [5-7]. The Akata Formation which underlies the entire delta is composed of thick shale sequences (potential source rock), turbidite sand (potential reservoirs in deep water), and minor amounts of clay and silt. It is of marine origin and formed during Lowstand when terrestrial organic matter and clays were transported to deep water areas characterized by low energy conditions and oxygen deficiency. Turbidity currents likely deposited deep sea fan sands within the upper Akata Formation during development of the delta. This formation is characteristically over pressured and range in age from the Paleocene to Recent.

The overlying Agbada Formation consists of paralic siliciclastic sequences over 3700 meters thick and represents the actual deltaic portion of the sequence. The clastics accumulated in delta-front, delta-topsets, and fluvial-deltaic environments. In the lower Agbada Formation, shale and sandstone beds were deposited in equal proportions, however, the upper portion is mostly sand with only minor shale interbeds. This formation is the major petroleum bearing unit and deposition started in the Eocene and continues into the recent. The Agbada Formation is overlain by the third formation, the Benin Formation, a continental latest Eocene to Recent deposit of alluvial and upper coastal plain sands that are up to 2000 m thick. This is the freshwater bearing formation in the Niger delta (figure 2).

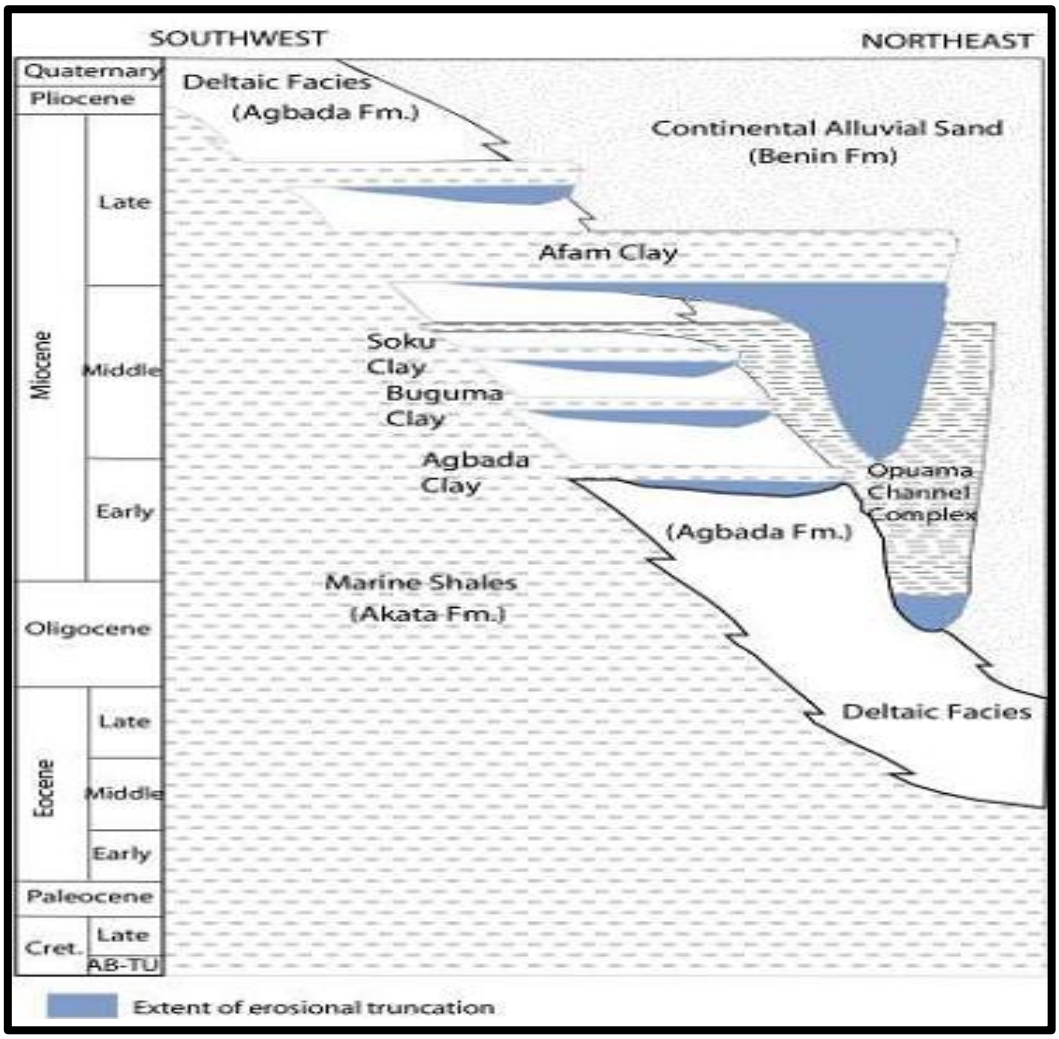
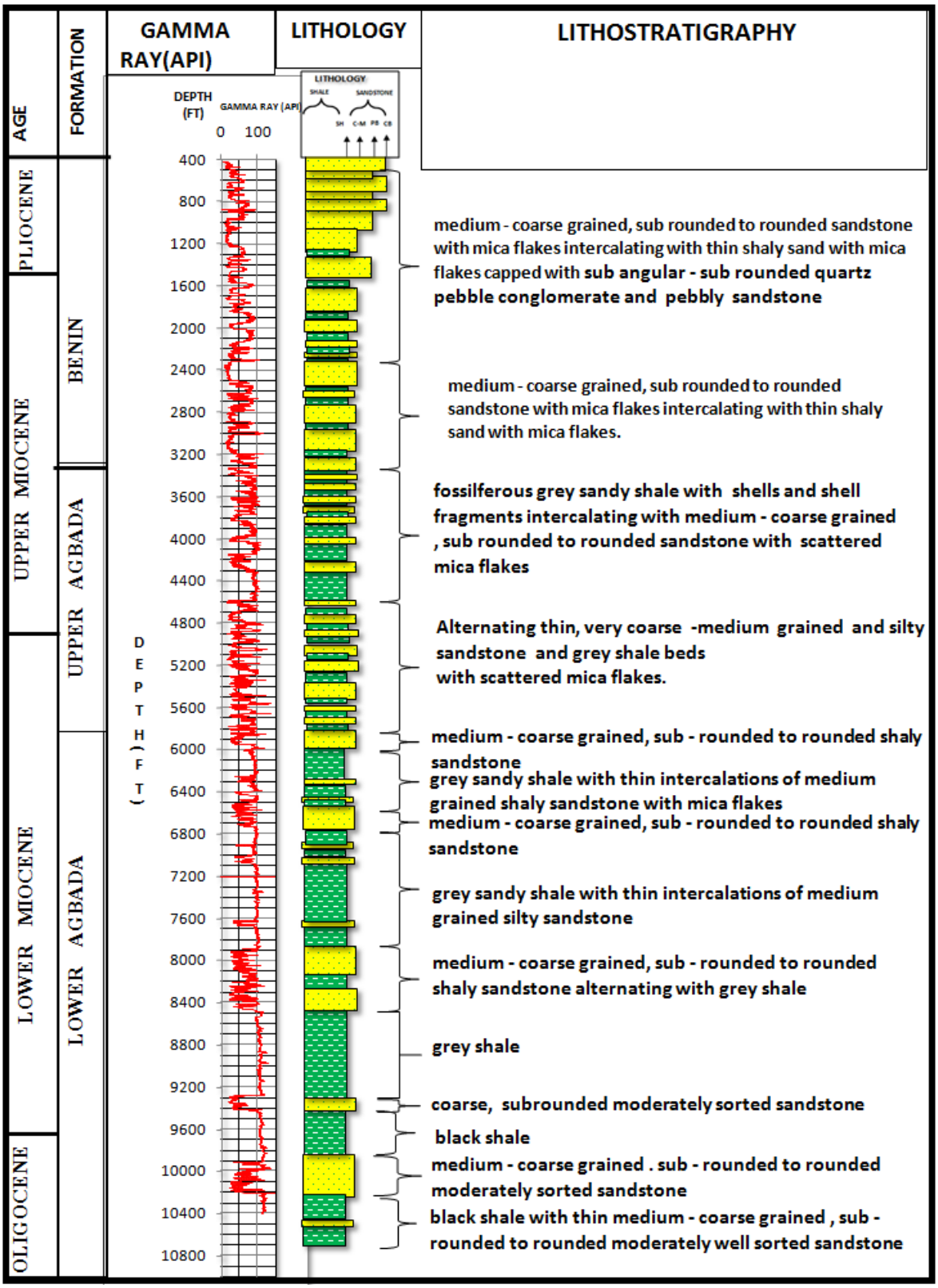


Figure 2: Stratigraphic column showing formations of the Niger delta (modified from Doust and Omatsola, 1990 [6] and Tuttle et al., 1999 [8]).


AGE
FORMATION
GAMMA RAY(API)
LITHOLOGY
LITHOSTRATIGRAPHY
PLIOCENE
UPPER MIOCENE
LOWER MIOCENE
OLIGOCENE
BENIN
UPPER AGBADA
LOWER AGBADA
DEPTH (FT)
GAMMA RAY (API)
0 100
400
800
1200
1600
2000
2400
2800
3200
3600
4000
4400
4800
5200
5600
6000
6400
6800
7200
7600
8000
8400
8800
9200
9600
10000
10400
10800
DEPTH (FT)
SHALE
SANDSTONE
SH
C-M
PB
CB
medium - coarse grained, sub rounded to rounded sandstone with mica flakes intercalating with thin shaly sand with mica flakes capped with sub angular - sub rounded quartz pebble conglomerate and pebbly sandstone
medium - coarse grained, sub rounded to rounded sandstone with mica flakes intercalating with thin shaly sand with mica flakes.
fossilferous grey sandy shale with shells and shell fragments intercalating with medium - coarse grained , sub rounded to rounded sandstone with scattered mica flakes
Alternating thin, very coarse -medium grained and silty sandstone and grey shale beds with scattered mica flakes.
medium - coarse grained, sub - rounded to rounded shaly sandstone
grey sandy shale with thin intercalations of medium grained shaly sandstone with mica flakes
medium - coarse grained, sub - rounded to rounded shaly sandstone
grey sandy shale with thin intercalations of medium grained silty sandstone
medium - coarse grained, sub - rounded to rounded shaly sandstone alternating with grey shale
grey shale
coarse, subrounded moderately sorted sandstone
black shale
medium - coarse grained . sub - rounded to rounded moderately sorted sandstone
black shale with thin medium - coarse grained , sub - rounded to rounded moderately well sorted sandstone

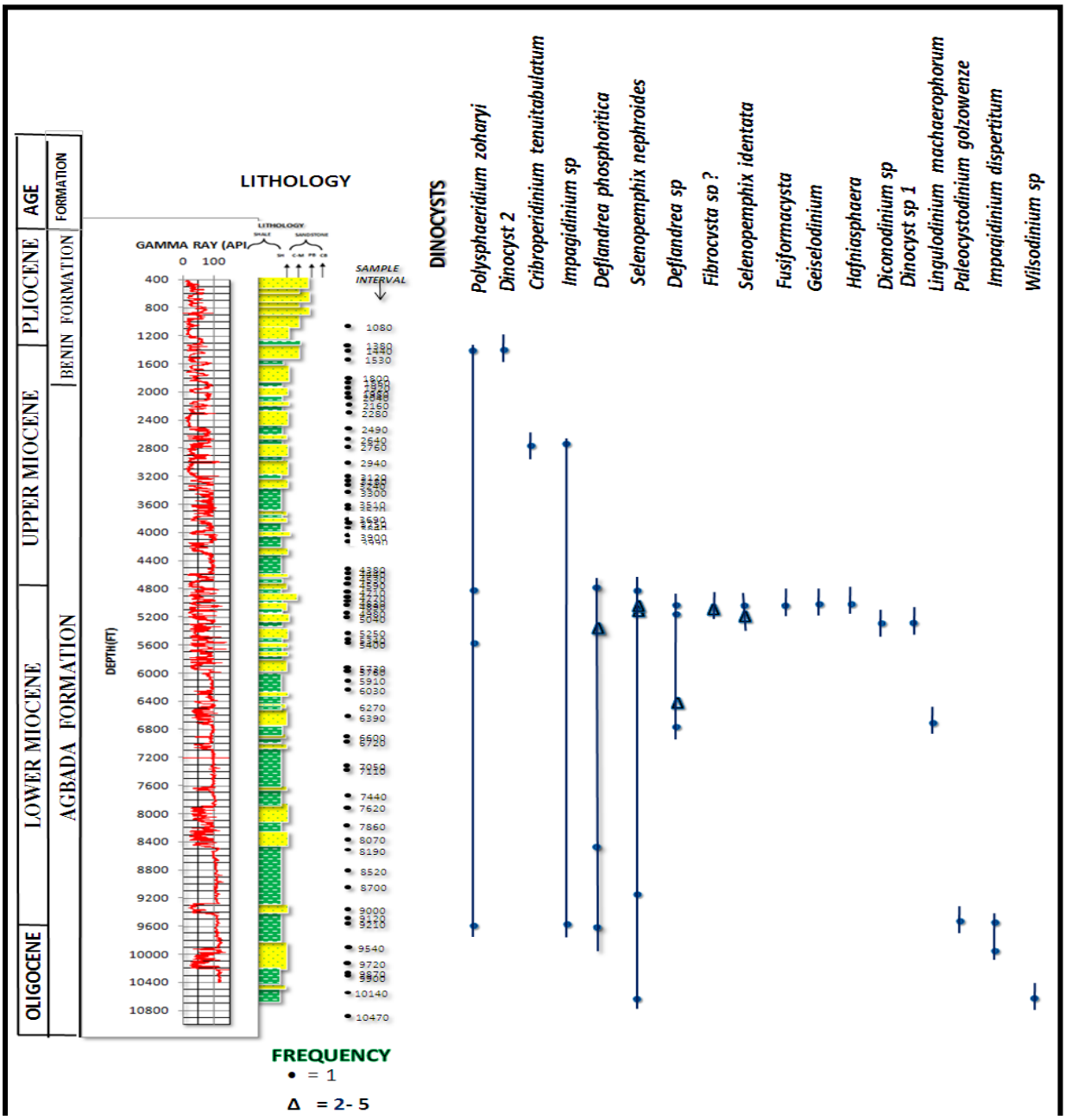


Figure 4: dinoflagellate cyst range chart of well Z

Results and Discussions

The paleobathymetric profile consist of environments ranging from fluvial (coastal plain) facies through neritic to open marine environments.The result of the paleoenvironmental analysis is shown in Figure 5 while the lithostratigraphy is shown in figure 3. The paleoenvironmental interpretation is based on the abundance and diversity of certain ecological groups of palynomorphs and lithological characteristics of the sediments.

Coastal Plain Setting

This environment is interpreted for paleoenvironmental zone which covers from 10470 to 4800ft of well Z. The lithological characteristics of the this zone include shale intercalation on thickly bedded, rounded to sub-rounded coarse grained, poorly sorted pebbly sandstones that are conglomeritic at the top with scattered mica flakes, shells and shell fragments; rare to non occurrence of marine Microplankton represented by few acritachs,

foraminiferal test lining, and dinoflagellate cysts such as *Polyspaeridium zoharyi*, *Lingulodinium machaerophorum* and *Spiniferites* species; high relative abundance of mangrove pollen, *Zonocostites ramonae*, *Verrutricolporites rotundiporis, and Pachydermites diederixi* with abundant fungal spore, fresh water algae Botryococcus brunni and minimal record of *Monoporites annulatus* indicating wet climate (Plate 1). The mangrove pollen, *Zonocostites ramonae* constitutes 95 to 98% of the total miospores in the samples indicating a coastal plain environment for the sediments. *Z. ramonae* is a distinctive pollen type found in extant genera of mangroves notably Rhizophora [9]. Rhizophora shows its optimal development in an unconsolidated clayey to sandy soils in coastal and shallow marine environment. Its quantitative distribution therefore, makes it a useful species for environmental interpretation.Also fungal spore are known to concentrate on coarse, oxidizingand highly stressed environment so the high abundance of fungal spore at this interval is also diagnostic to this paleoenvironment.

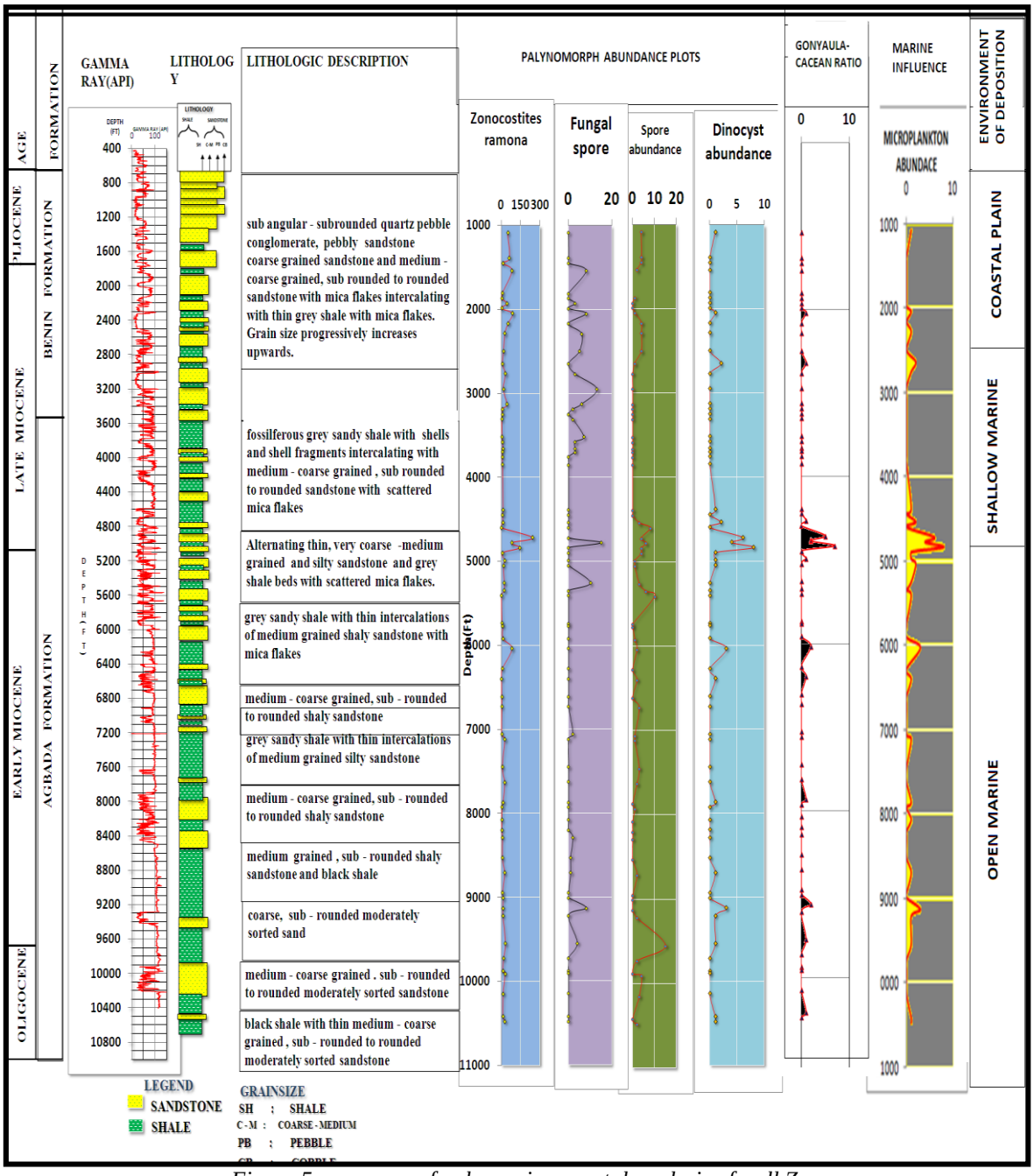


Figure 5: summary of paleoenvironmental analysis of well Z

Neritic (shallow marine) Environment

This setting covers from 4800 to 2800 ft. The neritic setting is a subdivision of shallow marine environment. The characterstics of this interval diagnostic of this environments include: coarse to medium grained sand, silty shale and fine grained sand intercalations with shells and shell fragments and scattered mica flakes. The presence of shell material and detrital mica indicates a shallow marine depositional setting for the sediments [3]. The dinoflagellate cyst assemblage is dominated by peridinacean cysts which has less floatation mechanism and consequently inhabit shallow waters. They include *Deflandrea phosphoritica, Cribroperidinium tennuitabulatum* and *species of selenopemphix* which dominate the assemblage with few gonyaulacoids as *Cordosphseridium fibrospinosum* and *Homotryblium tennuispinosum.* The range chart is shown in figure 4. The peaks of the ecological groups of palynomorphs (*Zonocostites ramonae, Monoporites annulatus*, fungal spore, and miospore abundance) also correspond with the times of marine transgression. There is a remarkable record of Cretaceous and older palynomorphs. This is an evidence of reworking of older sediments into this depositional environment. Examples of the reworked dinoflagellate cysts *Tubiosphaera filosa, Geiselodinium geisetalense, Fusiformacysta salasii* and *Dinogymnium euclaensis,*while the reworked miospores are represented by *Longapertites vaneendenburg i*and *Retidiporites magdalenensis.*

Open (deep marine) Setting

This is interpreted for the environmental zone which range from 10470 to 4800ft of well Z. This interpretation follows the recognition of the paleo shelf edge at 4800 ft. The deduction was made from the high gonyaulacacean ratio recorded at this interval. Althogh there was general paucity of dinoflagellate cyst, the assemlage at 4800 ft is dominated by gonyaulacacean cyst giving rise to high gonyaulacacean ratio (figure 5). Harland 1983, used the high relative abundance of gonyaulacacean ratio to recognise the shelf edge in the wood hole, The Lithological characteristics of the sediments include, thick, dark(organic rich) marine shales with inter beds of medium to coarse grained,rounded to sub rounded, moderately to well sorted sandstone and siltstones at the base with grey shales and sandy shales alternating with medium to coarse grained sand more paralic at the top. It is generally observed throughout the rock sequence that the palynomorph abundance peaks (*Zonocostites ramonae, Monoporites annulatus*, spore abundance, total miospores etc) not only responded to ecological changes but also followed the deposition of the shales therefore, proxies to transgression. The abundace and diversity of palynomorphs responds to transgression and regression of sealevel. This interval witnessed a major fall in relative sea level as evidenced in the rare distribution of dinoflagellate cysts species, the occurrence of reworked pre - Cretaceous to Paleocene palynomorphs such as *Canningia recticularis, Gotchtodinium simplex, Triorites africaensis, longapertites marginatus,* etc. indicating reworking of these older materials into the basin and the co- occurrence of shallow marine dinoflagellate cysts with species of *selenopemphix* dominating the assemblage. However, the occurence of *Impagidinium dispertitium* at this interval in both wells indicate open ocean for the sediments (Harland, 1983). Species of *Impagidinium* dominates the insitu dinoflagellate cyst assemblage. The rare occurrence of *Zonocostites ramonae* also suggests environment far from the shore.

Summary/conclusion: The integration of palynological results and sedimentological information revealed paleoenvironment ranging from coastal plain from 2800 ft to the top of the studied well characterised by very thin shale intercalation on thickly bedded, rounded to sub- rounded coarse grained, poorly sorted pebbly sandstones that are conglomeritic at the top with scattered mica flakes, shells and shell fragments with rare to non occurrence of marine Microplankton; Shallow marine from 2800 ft to 4800 ft characterised by coarse to medium grained sand, silty shale and fine grained sand intercalations with shells and shell fragments and scattered mica flakes while the thick, dark(organic rich) marine shales with inter beds of medium to coarse grained, rounded to sub rounded, moderately to well sorted sandstone and siltstones ranging from 4800 ft to 10470 ft was interpreted as open (deep marine) setting. The first downhole high relative abundance of dinoflagellate cyst was used to recognise the paleo shelf edge (200 meters depth of water) at 4800 ft.

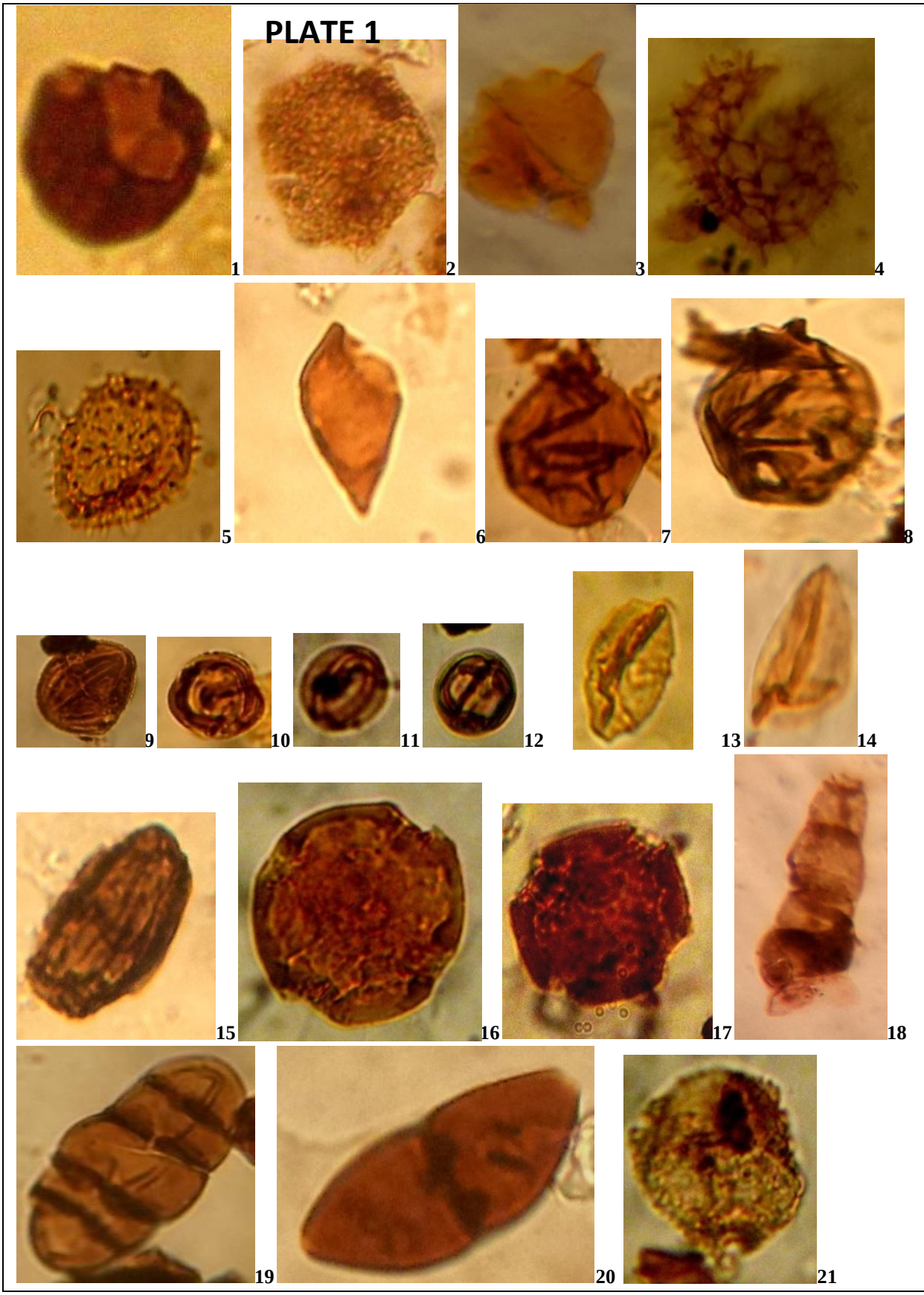


PLATE 1
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

PLATE 1	
N0	NAMES
1	*Batiacasphaera compta*
2	*Canningia reticulata*
3	*Geiselodinium geiseltanense*
4	*Polysphaeridium zoharyi*
5	*lingulodinium machaerophorum*
6	*Fusiformacysta salasii*
7	*Cribroperidinium tenuitabulatum*
8	*Cribroperidinium tenuitabulatum*
9	*Zonocostites ramonae*
10	*Zonocostites ramonae*
11	*Zonocostites ramonae*
12	*Zonocostites ramonae*
13	*Verrutriculporites rotundiporis*
14	*Verrutriculporites rotundiporis*
15	*Beskipolis elegans*
16	*Pachydermites diederixi*
17	*Pachydermites diederixi*
18	Foraminiferal test lining
19	Fungal spore
20	Fungal spore
21	*Retibrevitriculpites protrudens*

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