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Biozonation and Sequence Stratigraphic Characterization of Sediments in X-well, JV-field Greater Ughelli Depo-belt Niger Delta Basin

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Abstract Biozonation and sequence stratigraphic characterization of sediments in X-well, JV-Field Greater Ugheli Depo belt Niger Delta Basin were carried out using a total of One hundred and ninety (190) Ditch cutting samples, with the aim of identifying palynological and foraminiferal bio-events such as abundance, zones, paleoenvironment, age and also identify sequence stratigraphic key surfaces such as Maximum Flooding Surfaces (MFS) and Sequence Boundaries (SB) of sediments penetrated by the drill. Diagnostic Palynomorphs such as *Praedapollis africanus, Peregrinipollis nigericus, Retibrevitricolporites obodoensis* aided in the establishment of three P-zones which are *P620, P580, P560* Zones in the well. *P620* and *P580* Zones were lumped together and occur at depth 4680ft-7620ft while *P560* occur at depth 7620-11580ft, species of foraminifera recorded are calcareous and arenaceous benthic Foraminifera species. Planktic Foraminifera specie are generally absent. Species recorded include *Sproplectammina wrightii, Florilus atlanticus, Florilus costiferum, Eponides cf eshira, Quinqueloculina rhodiensis, Nonion centrosulcatum, and Alveolophragmium crassum.* Foraminiferal zones established are *Nonion centrosulcatum* (N9), *Fursenkoina punctata* (N5) planktic and N8-N5 zone. the well records the occurrence of Two maximum flooding surfaces (Mfs) and two sequence boundary(SB) which was establish in *P620/P580* zones and one maximum flooding surface which was established in the *P560* Zone. The Sequence boundaries, Maximum flooding surfaces and their respective ages in these palynological zones occurred at various depths, P620 and P580 occurred at 26.2Ma Alabamina 1 Mfs at (6397ft) and 28.1Ma *BOLIVINA* 27Mfs at (7401ft) and the Sequence boundaries occurred at 6750ft at 27.3Ma SB,7553ft at 29.3Ma SB, P560 occurred at depth 31.3Ma *UVIGERINELLA 5*Mfs at (11200ft).

Keywords: *palynological zones, foraminiferal zones, palynomorphs, maximum flooding surface*

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1. Introduction

Petroleum has been a key source of energy and a major contributor to the economic growth in most industrialized and developing countries. The Niger Delta Basin is economically important because of its petroliferous nature and the economy of Nigeria depends largely on the oil and gas derived from it. Geologically it is found in the Tertiary period in the geologic column, It lies mainly in the Gulf of Guinea to the southwest of the Benue – Trough and constitutes the most important Cenozoic deltaic construction in the south Atlantic. The combination of source rock, lithologic types, structures and thermal history of the basin are favorable for the generation, accumulation and retention of hydrocarbons [1,2]. The tertiary Niger delta has prograded south west ward from Eocene to present forming depo belt that represent the most active portion of the delta at each stage of its development [3]. The 12km thick Niger delta clastic wedge spans a 75,000 km^2 area in southern Nigeria and the Gulf of Guinea offshore Nigeria. This clastic wedge contains the 12th largest known accumulation of recoverable Hydrocarbon with reserves exceeding 34billion barrels of oil and 93 trillion cubic feet of gas. The Niger delta province contains only one identified petroleum system [1], this system is referred to as the tertiary Niger delta (Akata -Agbada) petroleum system.

The use of lithofacie, palynology and foraminifera as tools and components in evaluating sedimentary pile and basin analysis has become increasingly important in recent times as seen in works by [4-14].

Presently, there is awareness amongst explorationists that the chrono-and litho-stratigraphic correlation of sequences and the environments in which they were deposited is better understood by the incorporation of seismic data, electric well logs and biofacies information.

This combined exploratory tool known as sequence stratigraphy was pioneered by researchers at the EXXON Production and Research Company in Houston is an outgrowth of seismic stratigraphy [15]. The approach is based on the recognition of unconformities and reflection patterns on seismic data and uses familiar concepts of relative sea-level changes and the balance between rates of accommodation, creation and sediment supply. These ideas have been codified into a methodology and terminology, which are largely familiar in the oil companies. The "new" element is the interpretation step that erosional unconformities are related explicitly to drops in relative sea-level and by extension, that the unit between sequence bounding unconformities represent a relative sea-level rise. The application of this new tool in the study of depositional sequences has furnished more information on the seemingly familiar formations of the Niger Delta Basin especially the prospective Agbada Formation.

The area of study is located in Greater Ughelli depo belt of Niger Delta basin with the aim of establishing a Sequence stratigraphic framework of sedimentary succession penetrated by the drill. The objectives of this research are

- To establish a litholog/lithofacie model for the wells succession.
- To identify palynological and foraminifera events such as abundance, zones. paleoenvironment and age of sediments in the sucession penetrated by the drills
- To identify sequence stratigraphic key surfaces such as Maximum Flooding Surfaces (MFS) and Sequence Boundaries (SB)
- To establish the sequence stratigraphic frame work.

2. Lithostratigraphy of Niger Delta

The Stratigraphic succession is an overall coarsening upward sequence of over 12,000m thick at the position of the ocean/continent transition. The Lithofacies are diachronouns and represent a classical regressive deltaic off lap sequence (Figure 1).

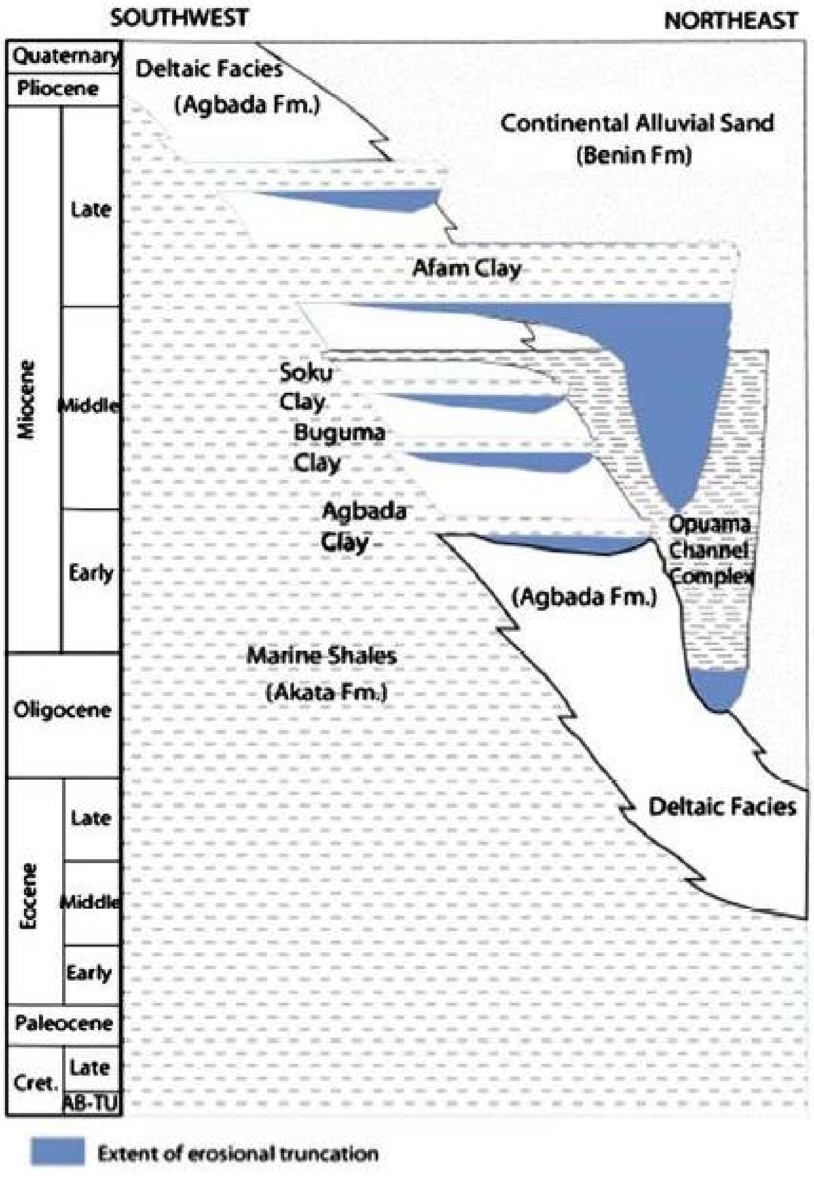


Figure 1. Stratigraphic column displaying formations of the Niger Delta Basin [16]

The Tertiary section of the Niger Delta is divided into three formations, representing prograding depositional facies that are distinguished mostly on the basis of sand-shale ratios. The type sections of these formations are described in [17] and summarized in a variety of papers [18,19]. However, the three (3) Stratigraphic units are: Akata Formation, Agbada Formation and Benin Formation [17]. The three major lithostratigraphic units defined in the subsurface of the Niger Delta (Akata, Agbada and Benin Formations) becomes progressively younger farther into the basin, reflecting the overall regression of depositional environments within the Niger Delta clastic wedge. Stratigraphic equivalent units to these three formations are exposed insouthern Nigeria. The formations reflect a grosscoarsening-upward progradational clastic wedge [17], deposited in marine, deltaic, and fluvial environments [20,21].

3. Akata Formation

This is the major time transgressive lithological unit of the Niger Delta, it is mainly a marine mud facies with turbidity sand and continental slope channel fills. The type section of the Akata Formation was defined in Akata 1 Well, 80 km east of Port Harcourt [17]. A total depth of 11,121 feet (3, 680 m) was reached in the Akata 1 well without encountering the base of this formation. The top of the formation is defined by the deepest occurrence of deltaic sandstone beds (7,180 feet in Akata well).the formation underlies the whole of the Niger delta complex [2]. The Akata formation consist of dark grey shales andsilts, with rare streaks of sand of probable turbidite flow origin [16]. in the upper part, in some localities it tend to be sandy were it grades in to the Agbada formation. The formation is taught to range from 2000ft(610m) to 20,000ft (6,100m) in thickness. The Akata formation is Paleocene to Recent in Age [16], rich in Planktic foraminifera which indicate deposition on a shallow marine shelf. Marine planktonic foraminifera make up to 50% of the microfauna assemblage and suggest shallow marine shelf deposition [16].

4. Agbada Formation

[17] Named the middle part of the tripartite Niger delta stratigraphic succession as the Agbada formation. The Agbada formation is defined in the Agbada 2 well drilled about 11km north-northwest of Port Harcourt [17]. The mangrove swamp to coastal barrier and fluviomarine zone of the present day delta constitute the surface exposure of the Agbada formation of recent age. The well reached a total depth of 9500 feet without penetrating the base of the formation (the base was defined as the top of the Akata Formation in Akata 1 well).the top of the formation is usually taken as the shallowest occurrence of shale bearing a brackish or marine fauna. The Agbada formation is often seen in seismic as an erosional surface demarcating it from the overlying unfaulted benin sand. The lithologies consist of alternating sands, silts and shales arranged within ten to hundred feet successions defined by progressive upward changes in grain size and bed thickness. The strata are generally interpreted to have formed in fluvial-deltaic environments. The formation ranges in age from Eocene to Pleistocene. The thickness of the Agbada formation varies greatly across the delta. [22] gave a range from 9,600ft to 14000ft (2,927m -4,268m). The Agbada formation is thickest on the central swamp and coastal swamp depobelt which is were the Benin formation is also thickest and regarded as the zone of maximum subsidence. The sequence is associated withsedimentary growth faulting and contains the bulk of the hydrocarbon reservoirs. The top of the Agbada Formation is often defined as the base of fresh water sand.

5. Benin Formation

The name benin sand series was first used by Parkinson in (1907) which was later change by the Geologic survey of Nigeria to Coastal plain sand, all referring to the continental fluvial sand underlying an extensive area of southern Nigeria. The Benin Formation comprises the top part of the Niger Delta clastic wedge,from the Benin-Onitsha area in the north to beyond the present coastline [17]. Its type section in Elele 1 Well, drilled about 38 km north-northwest of Port Harcourt [17]. The top of the formation is the recent subaerially-exposed delta top surface and its base extends to a depth of 4600 feet. The base is defined by the youngest marine shale.

Shallow parts of the formation are composed entirely of non-marine sand deposited in alluvial or upper coastal plain environments during progradation of the delta [16]. The formation thins basinward and ends near the shelf edge.Although lack of preserved fauna inhibits accurate age dating, the age of the formation is estimated to range from Oligocene to Recent [17]. It is a continental latest Oligocene to Recent deposit of alluvial and upper coastal plain that are up to 2000m thick [18]. It is deposited in the upper coastal plain environments following a southward shift of deltaic deposition into a new depobelt. Benin Formation is the youngest formation in the Niger Delta; the formation consists of massive, highly porous, freshwater bearing sandstones with local thin shale interbed which is considered to be of braided stream origin. the formation is identifiable in the subsurface on account of its high sand percentage (70-80%),few shale breaks which increase in frequency towards the base and the general absence of brackish water and marine faunas. The sand and sandstone of the Benin Formation are coarse to fine grain in general and are poorly sorted. The formation thins basinward and ends near the shelf edge.

This study is aimed at using chemical finger print to classify the sedimentary succession penetrated by the drill.

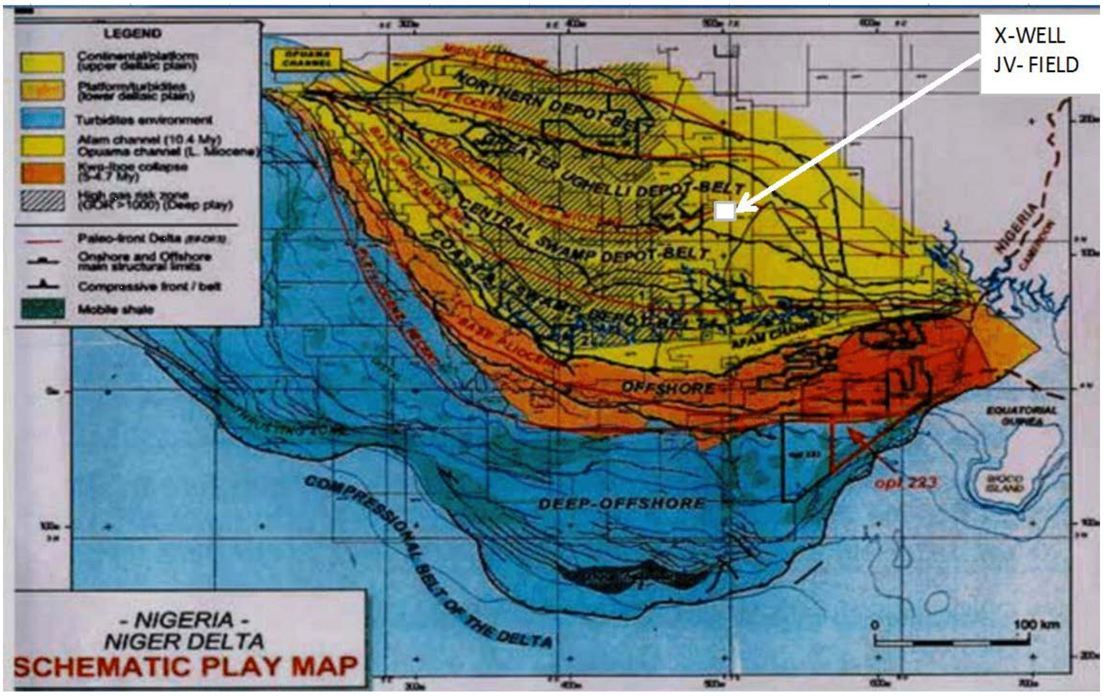


Figure 2. Location map of X-Well (Source: Nigerian Petroleum Development Company)

6. Materials and Method

Fifty (50) selected ditch cutting samples were collected from the well ranging from 20ft. (6.09m) to 11,820ft. (3603.7m) were utilized for palynological slide preparation and foraminifera analysis. The slides were analyzed under the microscope for palynological and foraminifera content.

Palynological Sample Preparation: The sample preparation was carried out following the international standards given below: 10g of sample was crushed between aluminum pie dishes, collected and tested for limestone ($CaC0_3$) using HCl, while effervescence occurred, the limestone was eliminated by further addition treatment with concentrated HCl. After two or three hours, the sample was decanted and the waste solution transferred to one special waste container bottle. The broken down mineral material and fossils were removed and centrifuged for about 1-2 minutes and decanted repeatedly until a neutral reaction was reached. Concentrated HNO_3 was used for oxidization and heated over bunsen burner. KOH of 10% solution was added to the sample and transferred to styrofoam cups and HF added and let to stand overnight. The sample was then washed with water until a neutral reaction was reached and decanted. Sodium hypochlorite (Purex) as well as some drops of HCl was added, agitated and let for about 15 minutes. Two drops of Ammonium Hydroxide concentrate was added and diluted with water. At this stage, separation of the organic matter from the inorganic material (silica) was done by floatation using diluted zinc bromide (ZnBr). The samples were transferred to a flexible plastic tubes, already prepared (cut and mount immersed into warm water); such plastic tubes are set into centrifuge tubes with water around them. Zinc bromide has a specific gravity of 2.2 thus, everything with a specific gravity of more than 2.2 will settle down. The process of centrifugation using zinc bromide took about 15 minutes. A small portion of the supernatant liquid was observed under the microscope. Then, a clip across the flexible plastic tube was inserted so that the supernatant liquid would be easy to take out by pipette decantation or eye dropper.

Palynomorphs Distribution Chart: A palynomorph distribution chart was established based on the first appearance datum (last downhole occurrence) and last appearance datum (first downhole occurrence) of each palynomorph identified in the well section.

Microscopic view of the supernatant liquid decided how to clean, run acetolysis or stain. Add acetic anhydride and three of four drops of H_2SO_4 to take out the water, then immerse test tube in boiling water for about ten minutes. The sample was properly washed at each stage. Here, it was ready for cleaning and mounting; during this stage several views under the microscope accomplished with some attempt to get mainly fossil material was done. The palynomorph counting and logging were done by straight transects across each slide and coordinates. The recovered palynomorphs species were identified with the aid of Shell palynological photo album, other relevant publications and manuals such as web-based albums. Morphological characters of the pollens and spores such as the size, exine, structure, shape, sculpture and aperture type provided the basis for the identification of the forms. Species name and their abundance were recorded in the analysis data sheets.

7. Foraminifera Sample Preparation

7.1. Materials and Procedure

Sieves, distilled water, water jet.

Having observed all safety requirements:

20gm of each sample is weighed (using a Mettler PC 440 digital balance) into each sample bowl.

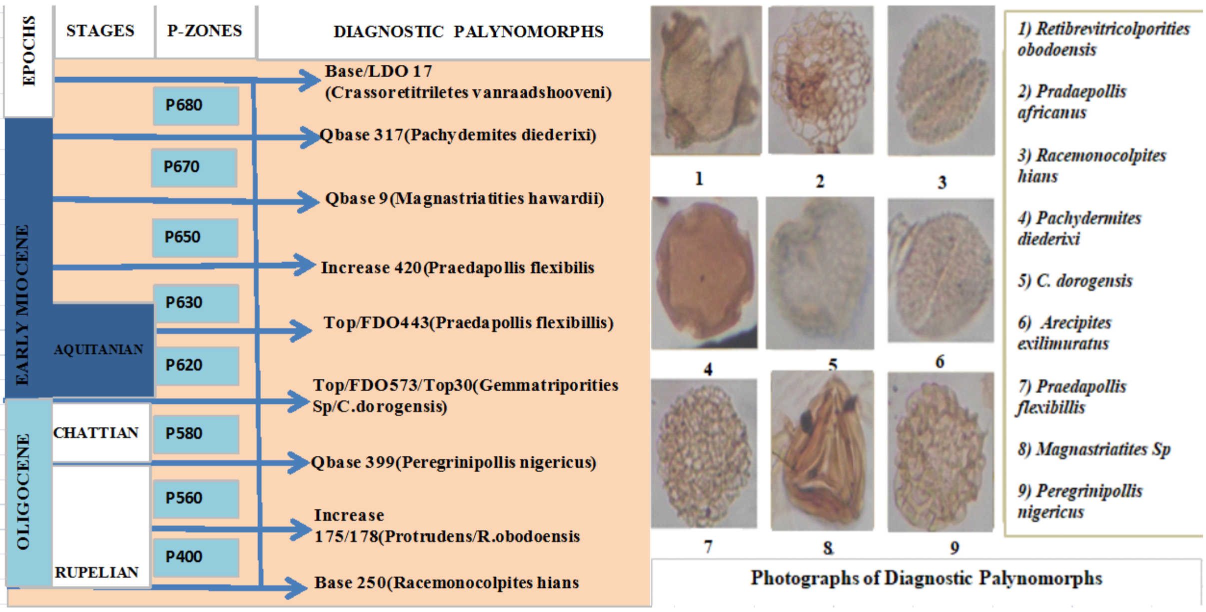


Figure 3. GUIDELINES FOR CHARACTERIZING P-ZONES IN GREATER UGHELLI DEPO BELT (Fregene T.J and Luca F.A in present study)

Depths on samples are correctly transferred to clean aluminium sample bowls. 30 ml of kerosene is poured into sample while still hot to soak for two hours. Drain out kerosene and soak sample in water.20% Hydrogen peroxide is then poured into the sample for about 10minutes. Each sample is then washed over a 63 microns sieve with water from a hand directed water jet. The residue collected from the sieve is replaced in the sample bowl and dried on the hot plate. The residue then sieved over 20 and 80 mesh sieves for the coarse and medium fractions while the finest residue in the receiver is treated as fine fraction. The coarse, medium and fine fractions are then stored in properly labeled sample phials for onward transfer to the pickers and analyzers.

8. Result and Discussion

Palynomorphs that were stratigraphically significant and environmentally necessary were recovered in the analyzed samples and were plotted in order to interpret the Palynostratigraphy/P-zones and age of the well section. The pollen and spores recovered are relatively moderate in abundance. Palynological Count. From the analyzed palynological slides, Nine hundred and sixty four (964) palynomorphs species were identified.Nine hundred and fiftyfour (954) were Miospore (pollen and spore) and ten (10) were Dinocysts.

Table 1. Palynomorph distribution with depths

S/N	DEPTH (ft.)	DEPTH (m)	POLLEN	SPORES	MIOSPORES	DINOCYSTS	TOTAL PALYNOMORPHS
1.	1640	500	0	8	8	2	10
2.	1760	536	2	0	2	0	2
3.	1940	591	0	5	5	3	8
4.	4500	1372	7	5	12	3	15
5.	4560	1390	10	1	11	0	11
6.	4620	1408	8	3	11	0	11
7.	4680	1426	6	1	7	0	7
8.	4820	1469	14	5	19	0	19
9.	5040	1536	3	7	10	0	10
10.	5100	1554	12	9	21	0	21
11.	5340	1628	6	20	26	0	26
12.	5400	1646	32	20	52	0	52
13.	5460	1664	18	7	25	0	25
14.	5580	1701	6	13	19	0	19
15.	5700	1737	8	19	27	0	27
16.	5820	1774	4	8	13	0	13
17.	5980	1823	10	8	18	0	18
18.	6100	1859	7	11	18	0	18
19.	6220	1896	8	10	18	0	18
20.	6340	1932	4	7	11	0	11
21.	6400	1951	11	14	25	1	26
22.	6520	1987	8	15	23	0	23
23.	6580	2006	9	8	17	0	17
24.	6700	2042	14	16	30	0	30

S/N	DEPTH (ft.)	DEPTH (m)	POLLEN	SPORES	MIOSPORES	DINOCYSTS	TOTAL PALYNOMORPHS
25.	6940	2115	12	18	30	0	30
26.	7060	2152	10	13	23	0	23
27.	7180	2188	2	6	8	0	8
28.	7300	2225	4	7	11	0	11
29.	7440	2268	44	38	82	0	82
30.	7620	2323	32	19	51	0	51
31.	7800	2377	35	16	51	0	51
32.	7860	2396	28	18	46	0	46
33.	8060	2457	6	8	14	0	14
34.	8180	2493	7	13	20	0	20
35.	11040	3365	17	14	31	0	31
36.	11100	3383	20	14	34	0	34
37.	11160	3402	17	11	28	0	28
38.	11280	3438	21	14	35	1	36
39.	11400	3475	6	2	8	0	8
40.	11580	3530	15	9	24	0	24
41.	11640	3548	7	7	14	0	14
42.	11760	3584	6	10	16	0	16
		TOTAL			954	10	964

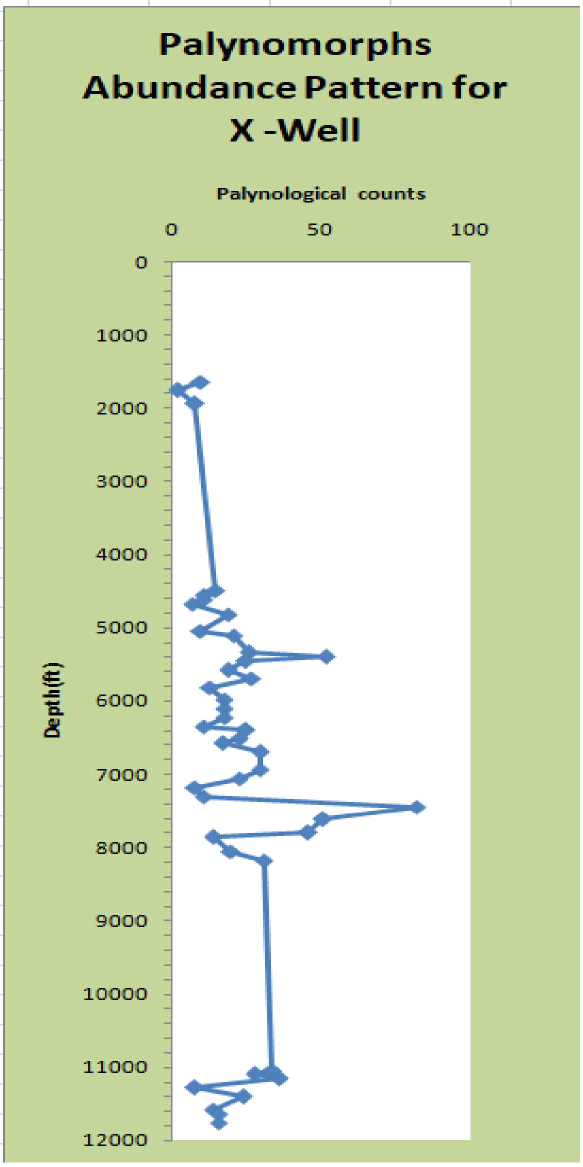


Figure 4. Palynomorphs abundance in X well

The recovered Miospores are as follows: *Miospores recovered are: Polypediaceisporites, Verrucatosporites usmensis, Dichtyphidiles harassi, Crototricolpites crotonoisculptus, Echiperiporites estelae, Smooth trilate spore cf. Acrostichun aureum, Pradapollis africanus, Retibrevitricolporites obodoensis, Laevigatosporites smooth monolete spore, Classopollis, Retitricolporites irregularis, Proxapertites operculatus, Praedapollis flexibilis, Psilatricolporites crassus, Sapotaceae pollenites, Pachydemites diederixi, Psilamonocolpites marginatus, Arecipites exilimuratus, Striatmonocolpites rectostriatus, Striatricolpites catatumbus, Monoporites annulatus, Numulipollis neogenicus, Verrucatosporites usmensis, Stereisporites, Zonocostites ramonae, Spirosincoporites brunnii, Polygalaceae, Cinctiperiporites mulleri, Racemonocolpites hians, Grimsdalea baculatus, Magnastriatites, Cyperoceapollis sp, Retimonocolpites obaensis, Magnastriatites hawardi, Racemonocolpites rarispinosus, Psilaheterecolpites, Pediastrum,Belskipollis elegans, Polyadopollenites vancampori, Bombacacidites, Echitricolpolrites spinosus, Ericipites.*

Recovered Palynomorphs that were stratigraphically significant and environmentally necessary were plotted in order to interpret the P-zones and zonal age dating of the well. They were subdivided based on the first appearance datum (last down hole occurrence) and last appearance datum (first down hole occurrence) of each palynomorph identified in the well section from top to bottom and also aided in establishing P-zones in the well. (See Table 2)

8.1. Palynological Zones

P620 and P580 Zones: This zones were lumped together and was established based on the occurrence of Top *Pradapollis africanus* at 4500ft and quantitative base of *Peregrinipollis nigericus* at 7620ft.This zone was lumped together because the Top/FDO *Cicatricosisporites dorogenesis* (30)/*Gemmatriporites sp* (573) which represents the base of P620 zone and top of P580 zone were undefined.

P560 Zone: Top of this zone was defined by the appearance of quantitative base *Peregrinipollis nigericus* at 7620ft and and increase *Retibrevitricolporites obodoensis* at 11580ft.

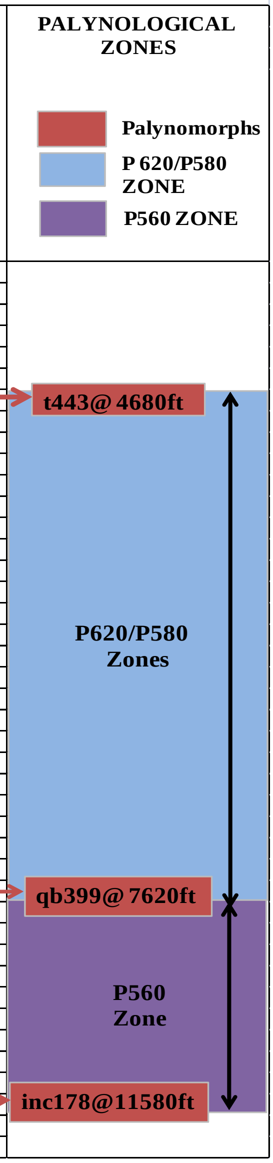
Table 2. Range Chat of Recovered Diagnostic Palynomorphs

DEPTH (FEET)	Polypediaceisporites	Verrucatosporites usmensis	Dichtyphidiles harassi	Echiperiporites estelae	Pradapollis africanus	Retibrevitricolporites obodoensis	Retitricolporites irregularis	Praedapollis flexibilis	Psilatricolporites crassus	Pachydemites diederixi	Arecipites exilimuratus	Striatmonocolpites rectostriatus	Striatricolpites catatumbus	Monoporites annulatus	Spirosincoporites brunnii	Cinctiperiporites mulleri	Racemonocolpites hians	. Peregrinipollis nigericus
1640	1	3	4															
1760				1														
1940			3	1														
4500	1		3		2	1	2											
4560						1	3	3	1									
4620			2				2											
4680			1				2			1								
4820		2	1			1	2				1	2	1	1				
5040		3	1										1					
5100	1						1				1			1	1			
5340		3					3							1				
5400		4	3				4		2	1	3					1	2	
5460	1	2	1		2		5		2			1			1			
5580	1					1				1								
5700	3	2	2						1		2							
5820	2										3							
5980	2									1	3							
6100	1	1					2				3		1					
6220		2	3		1		3	1										
6340		4									1				1			
6400	1	1			1		4				1							
6520	3	4	2				4		1		1							
6580	1		1				1		1		1							
6700	2	1									5						3	
6940	3	6	2				2	2				1					1	
7060	3	6					3	2			3						1	
7180	1		2															
7300			1					1						1			1	
7440	1	28	3				1				11	4					9	
7620	6		3		3	1	4			1	4			1	1		2	1
7800	1	7	3		2			2					2	1	2	2	6	
7860	2	8		1	2		2				3	1		2			1	
8060	2	3			1										2		1	
8180	2	1	2				6			1								
11040		5	2		1		3	2		2	2	1	1			1	2	
11100	1	3	2			2				3	3	1			1		2	
11160											4						3	
11280	2	4	2		2			1			5	2						
11400										2					1			
11580	2	6			2	2	1			2	4	1		2		1		
11640	1		4		2						1						1	
11760	1	2	1					2			2	1						

Table 3. Palynomorphs distribution chart embracing P-Zones

PALYNOMORPHS DISTRIBUTION CHART EMBRACING P-ZONES FOR X- WELL

DEPTH (FEET)	Polypediaceisporites (38) cf (33)	Dichtyphidiles harassi (11)	Echiperiporites estelae (200)	Pradapollis africanus(443)	Retibrevitricolporites obodoensis(178	Retitricolporites irregularis (511)	Proxapertites operculatus (272)	Praedapollis flexibilis (420)	Psilatricolporites crassus (535) cf (53	Pachydemites diederixi(317)	Arecipites exilimuratus(280)	Striatmonocolpites rectostriatus (252)	Striatricolpites catatumbus (445)	Monoporites annulatus (125)	Numulipollis neogenicus(139)	Zonocostites ramonae (531)	Spirosincoporites brunnii(412)	Cinctiperiporites mulleri(190)	Racemonocolpites hians (250)	Magnastriatites (14)	Peregrinipollis nigericus(399)	Magnastriatites hawardi (9) cf (14)	Bombacacidites (400)
1640	1	4																					
1760			1																				
1940		3	1																				
4500	1	3			1	2	1																
4560					1	3		3	1														
4620		2				2																	
4680		1		1		2				1													
4820		1			1	2					1	2	1	1	1								
5040		1											1										
5100	1					1					1			1		1	1						
5340						3								1									
5400		3				4	3		2	1	3							1	2				
5460	1	1		2		5			2			1					1			1			
5580	1				1					1													
5700	3	2							1		2										1		
5820	2										3					2							
5980	2						1			1	3					2							
6100	1					2	1				3		1										
6220		3		1		3		1															
6340											1						1						
6400	1			1		4					1											1	
6520	3	2				4			1		1											1	
6580	1	1				1			1		1					2							
6700	2										5								3				
6940	3	2				2		2				1							1				
7060	3					3		2			3								1				
7180	1	2																					
7300		1						1						1					1			1	
7440	1	3				1					11	4				6			9				
7620	6	3		3	1	4				1	4			1		3	1		2		3	1	
7800	1	3		2				2					2	1		2	2	2	6			1	
7860	2		1	2		2					3	1		2					1				
8060	2			1													2		1				
8180	2	2				6				1													
11040		2		1		3		2		2	2	1	1					1	2				
11100	1	2			2					3	3	1				4	1		2				
11160											4					4			3				1
11280	2	2		2				1			5	2				3							
11400										2							1						1
11580	2			2	2	1				2	4	1		2				1					
11640	1	4		2							1								1				
11760	1	1						2			2	1											



Age Determination: The presence of diagnostic palynomorphs such as *Praedapollis africanus*, *Peregrinipollis ni obodoensis* aided in the establishment of *P620, P580 and P560* Zones which concurs with the Oligocene to Early Miocene Age of paralic sequence [16].

8.2. Foraminifera Interpretation of the Well

The results of the Foraminifera analysis gotten from the sampled intervals between 1,640ft and 11,760ft of the Well are presented in the table 4 below.

Table 4. Foraminiferal specie count

S/N	DEPTH(FT)	SPECIE NAME	SPECIE COUNT
1	1640-4560	-	Barren
2	4620	Eponides cf. eshira	1
3	4680-4820	-	Barren
4	5040	Florilus costiferum	1
5	5100-6340	-	Barren
6	6400	Arenaceous indeterminate, Trochammina sp.	2
7	6520-7300	-	Barren
8	7440	Arenaceous indeterminate	1
9	7620	Foraminifera indeterminate	1
10	7800	Planktic indeterminate Arenaceous indeterminate	2
11	7860-9560	-	Barren
12	9620	Planktic indeterminate	1
13	9680	Florilus atlanticus	1
14	9740	-	Barren
15	9800	Nonionella tugidus	1
16	9920-10760	-	Barren
17	10900	Poritextularia panamensis	1

S/N	DEPTH(FT)	SPECIE NAME	SPECIE COUNT
18	11040-11100	-	Barren
19	11160	Quinqueloculina rhodiensis,	1
		Spiroplecatammina wrightii	2
		Cyclammina minima	1
		Florilus costiferum	1
		Florilus atlanticus,	1
		Nonionella turgidus	2
		Caneris oblongus,	1
		Nonion centrosulcatum	1
20	11,640ft	Arenaceous indeterminate	2
21	11,760ft	Spir plectammina wrightii	1
		Alveolophragmium crassum	1
	TOTAL COUNT		26

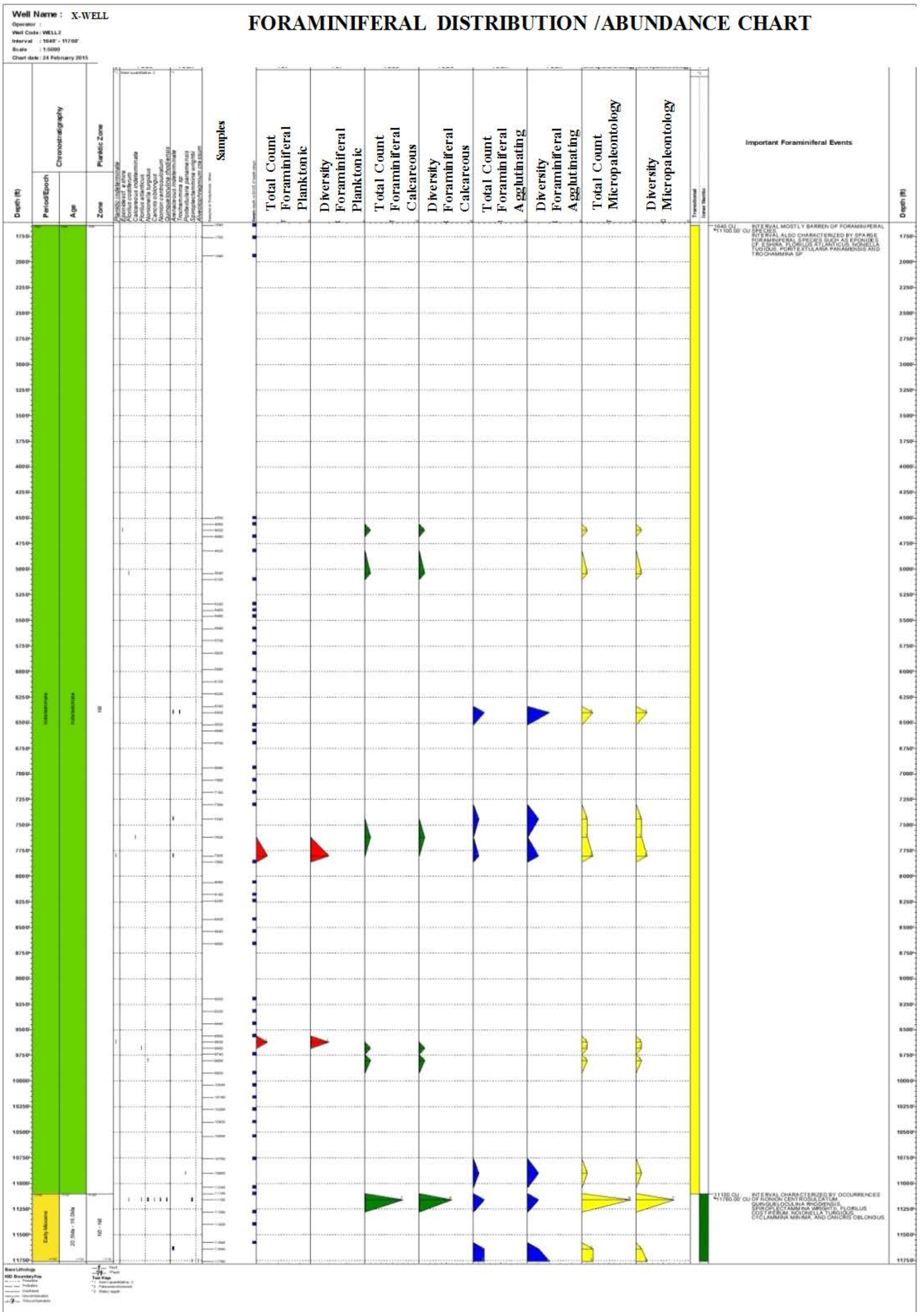


Figure 5. Foraminiferal Distribution/ Aboundance Chart

8.3. Foraminifera Zonation of JVX Well

The Foraminifera zonation of the well was guided by the works of Blow [4,5].

Table 5. Foraminifera Biostratigraphic summary

Foraminifera Biostratigraphic summary of JVX well (First Downhole Occurrence of stratigraphically important Foraminifera species)				
Depth (m)	**Epoch/Period**	**Age (Ma)**	**Zones [4,5]**	**Significant Foraminifera datums**
1640	*First sample analysed*			
1,640 – 11,100	Indeterminate	-	*N9*	Interval mostly barren of Foraminifera species. Interval also characterized by sparse Foraminifera species such as *Eponides cf. eshira, Florilus atlanticus, Nonionella tugidus, Poritextularia panamensis and Trochammina sp*
11,160-11,760	Early Miocene	16.0 – 20.5	N8 – N5	Interval characterized by occurrences of *Nonion centrosulcatum, Quinqueloculina rhodiensis, Spiroplectammina wrightii, Florilus costiferum, Nonionella turgidus Cyclammina minima, and Cancris oblongus*
11,760	*Last sample analysed*			

The results of the analysis indicate that the studied interval (1,640-11,760ft) was deposited during the early Miocene epoch, of estimated numerical age of 16.0Ma to 20.5Ma and straddling the *Nonion centrosulcatum* (N9)and*Fursenkoina punctata* (N5)planktic zone of [7] and [4,5].

Index species among the recovered Foraminifera assemblages have been used in dating and zoning the intervals. Details are given below :

Interval: **1,640 – 11,100ft**
Planktic zone: **N9**

Definition:

The top of this zonal interval is placed at 1640ft (Top of analyzed interval).

The base is marked at 11,100ft by the FDO of *Nonion centrosulcatum*.

The age of this zonal interval is indeterminate and might be based on its stratigraphic position

Features:

Interval generally barren of Foraminifera species. The lone occurrence of *Eponides cf eshira* at depth 4620ft suggests that this well is not younger that N9 zone at this depth.

Early Miocene
Interval: **11,160 – 11,760ft**
Planktic zone: **N8 – N5**
Estimated numerical age: **16.0 - 20.5Ma**

Definition:

The top of this zonal interval is marked by the FDO *Nonion centrosulcatum* at 11,160ft.

The base is placed at the terminal depth (11,760ft).

Features:

11,160 – 11,760ft:

- Interval is characterized by sparse benthic Foraminifera species.
- Interval characterized by the co-occurrence of *Nonion centrosulcatum, Spiroplecatammina wrightii, Quinqueloculina rhodiensis, Florilus costiferum, Nonionella tugidus, Cyclammina minima and Cancris oblongus* suggesting N8-N5 zone in the early Miocene age

8.4. Sequence Stratigraphic Interpretations

The sequence stratigraphic interpretation of the well was based on the recovered Foraminifera and Palynomorphs which were present in the well. A Foraminifera abundance plot was established based on the total count and diversity of Foraminifera present and was used to locate the maximum flooding surfaces and sequence boundaries. The presence of diagnostic palynomorphs such as *Praedapollis africanus, Peregrinipollis nigericus, Retibrevitricolporites obodoensis* aided in the establishment of palynological zone *P620, P580, P560* of which three maximum flooding surfaces(MFS) and two sequence boundary(SB) was establish with in the *P620* and *P580* and one maximum flooding surface was established in the *P560* Zone. The sequence boundaries and maximum flooding surfaces and their respective ages with in the palynological zones are as follows

Table 6. Showing maximum flooding surfaces (MFS) and sequence boundary (SB)

	JVX WELL	
P-ZONES	**MFS**	**SB**
P620-P580	26.2MA ALABAMINA 1 MFS at 7285FT	27.3MA SB at 6750FT
	28.1MA BOLIVINA 27MFS at 7675FT	29.3MA SB at 7553FT
P560	31.3MA UVIGIRINELLA 5MFS at 11200FT	

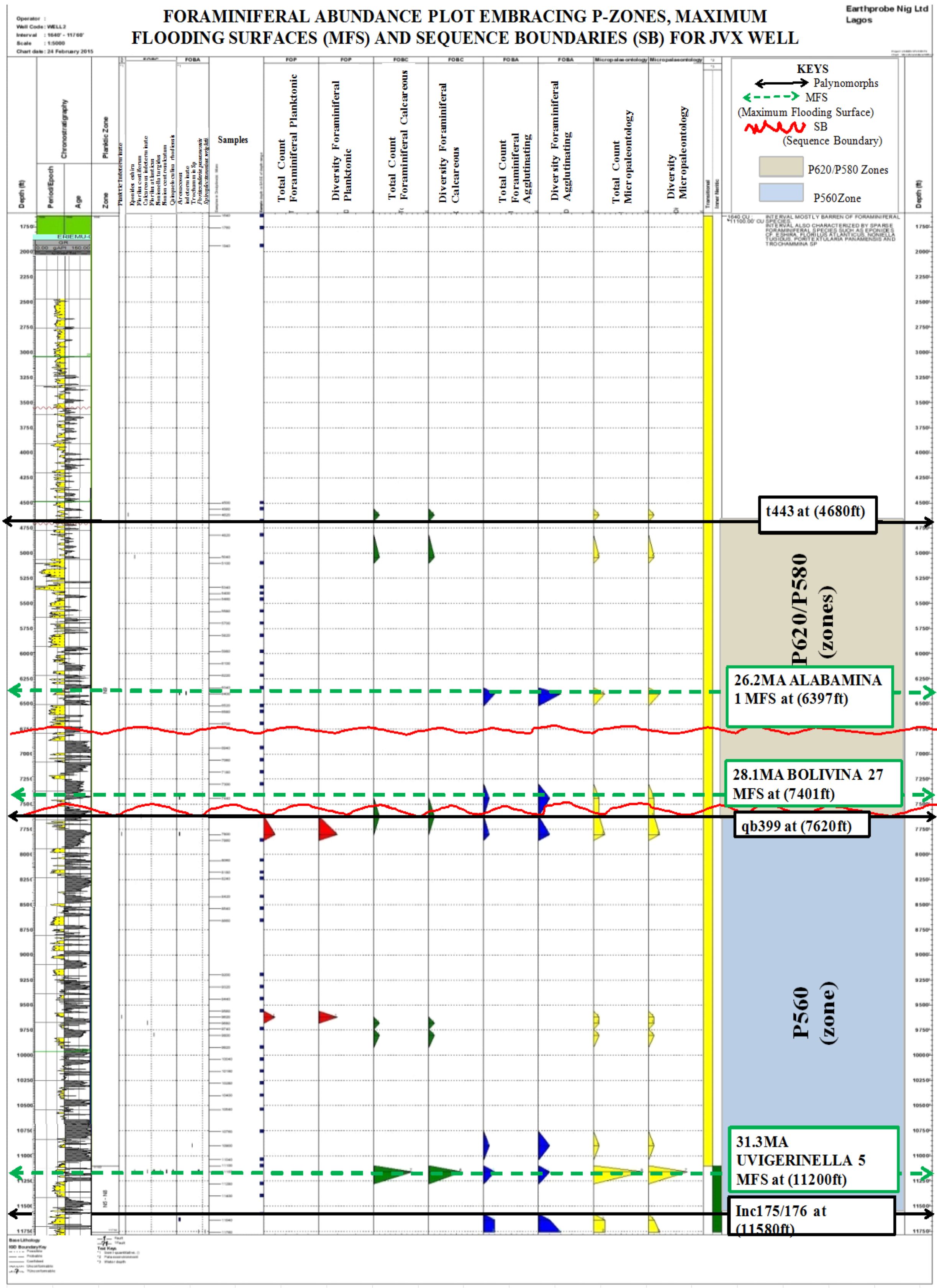


Figure 6. Foraminiferal Distribution/ Aboundance Pattern Calibrated with Interpreted P-zones, MFS and SB for JVX well

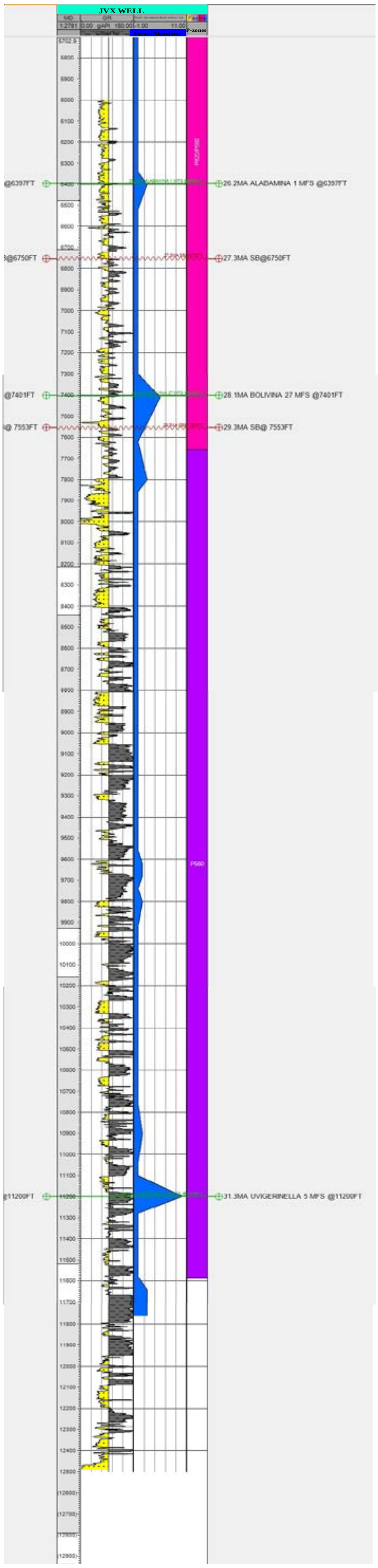


Figure 7. SEQUENCE STRATIGRAPHIC MODEL OF JVX WELL

9. Conclusion

The Palynological analysis of the studied samples was used to determine the Palynological zonation and age of the sediments penetrated by the drill. The presence of diagnostic palynomorphs such as *Praedapollis africanus, Peregrinipollis nigericus, Retibrevitricolporites obodoensis* aided in the establishment of the age and P-zones in the well. Three P-zones which are *P620, P580, P560* Zones were identified. *P620* and *P580* Zones were lumped together and occur at depth 4680ft -7620ft while *P560* occur at depth 7620-11580ft, Species of foraminifera recorded are calcareous and arenaceous benthic Foraminifera species. Planktic Foraminifera specie are generally absent. Species recorded include *Sproplectammina wrightii, Florilus atlanticus, Florilus costiferum, Eponides cf eshira, Quinqueloculina rhodiensis, Nonion centrosulcatum, and Alveolophragmium crassum.* Three MFS and two SB were established in the well with 26.2Ma Alabamina 1 Mfs established at (6397ft), 28.1Ma *BOLIVINA* 27Mfs at (7401ft) and 31.3Ma *UVIGERINELLA 5*Mfs at (11200ft).Sequence boundaries occurred at 6750ft at 27.3Ma SB and 7553ft at 29.3Ma SB.

Acknowledgements

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Plates

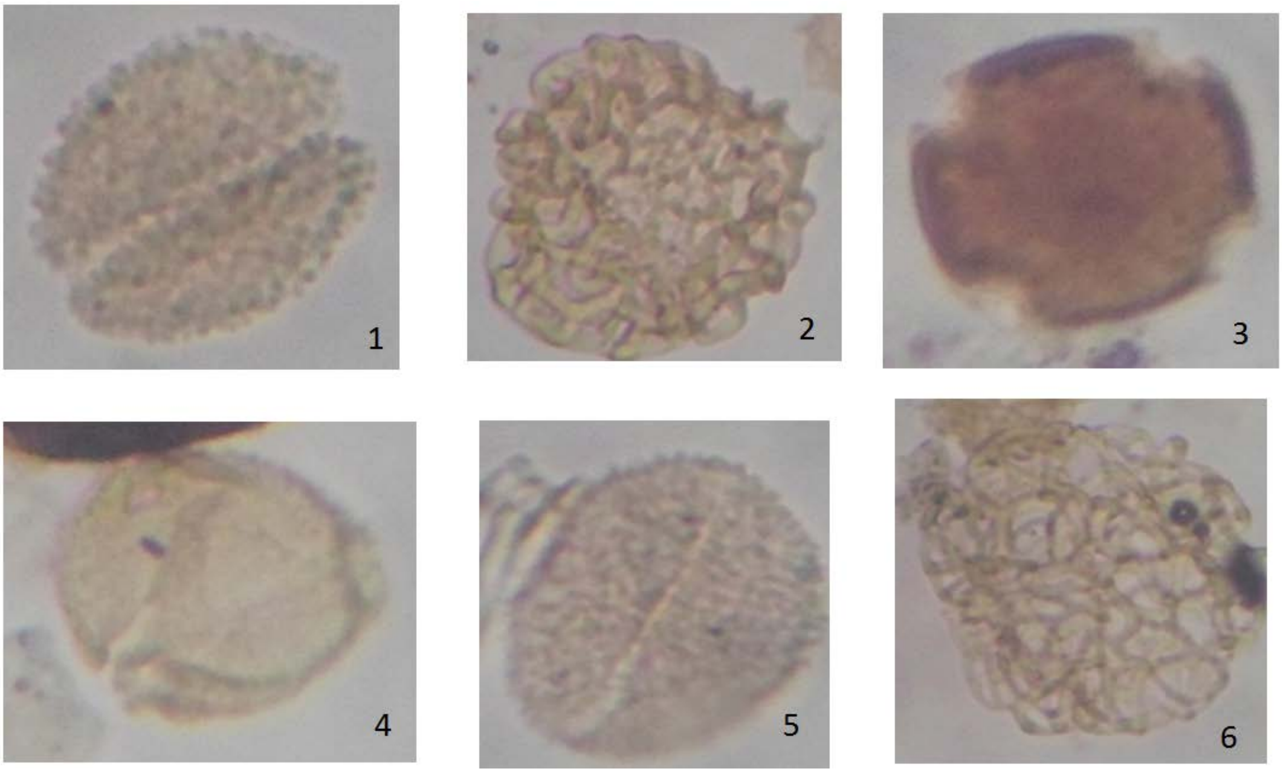

Plate 1. 1. Racemonocolpites hians (250), 2. Peregrinipollis nigericus (399), 3. Pachydemites diederixi (317), 4. Retibrevitricolporites obodoensis (178), 5. Arecipites exilimuratus (280), 6. Praedapollis africanus (443)

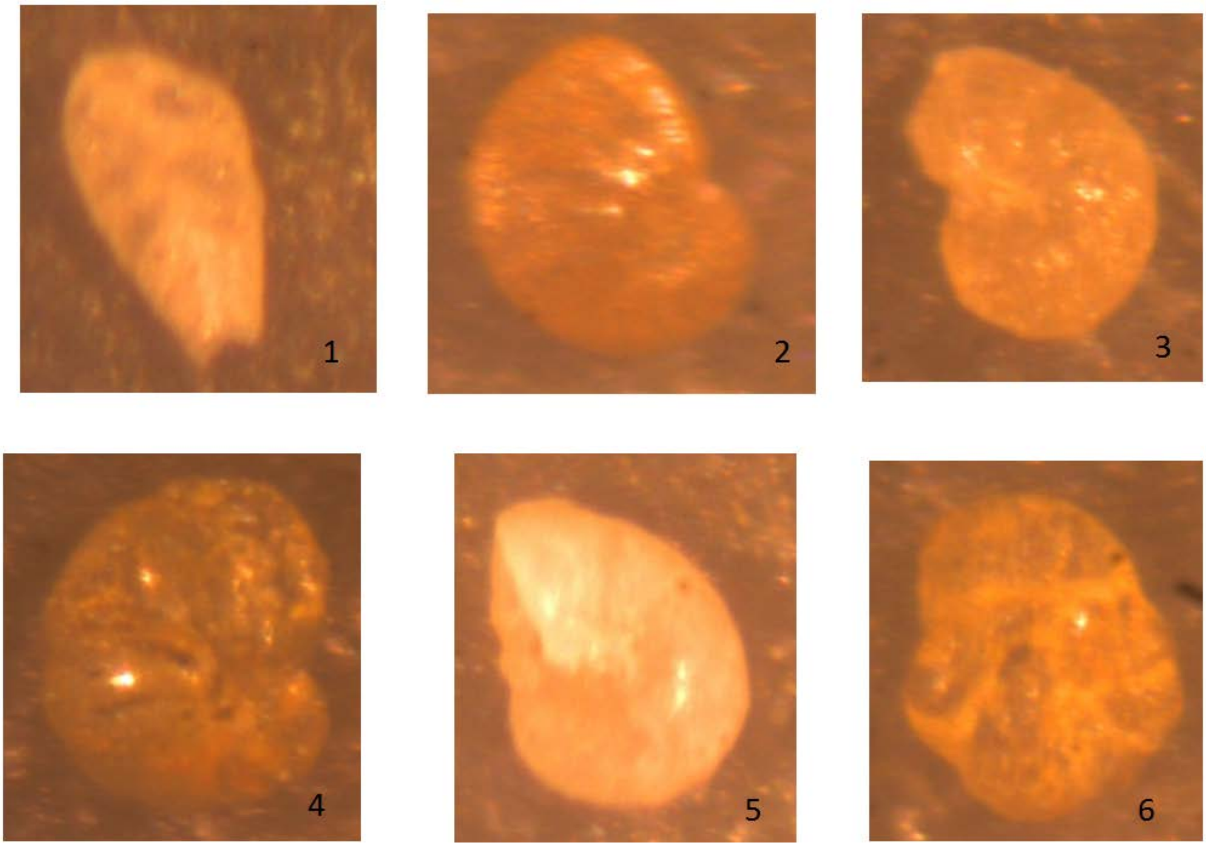

Plate 2. 1. Bolivina dertonensis, 2. Bolivina sp, 3. Nonion centrosulcatum,4. Florilus atlanticus, 5. Nonion sp, 6. Cyclammina minima