International Journal of Current Research and Applied Studies, (IJCRAS)

ISSN: 2583-6781

available at https://ijcras.com/

Volume 1 Issue 2 May-June 2022

Page 17-34

SEDIMENTOLOGICAL, BIOSTRATIGRAPHIC AND WIRELINE LOG ANALYSIS OF AF-1 WELL, NIGER DELTA BASIN, NIGERIA.

E.J. IGHODARO[1] and T.J. FREGENE[2]

[1]Department of Geology and Petroleum Studies, Western Delta University, Oghara, Delta State. Nigeria.
[2]Department of Geology, University of Benin, Benin City. Edo State, Nigeria.

ABSTRACT

Sedimentological, Biostratigraphic, and Wireline techniques were applied to AF-1 Well for well based characterisation. Hundred (100) ditch cutting samples were analysed and a lithologic section was produced based on the sedimentological analysis. AF-1 Well has a total thickness of 6335 ft ranging from depths of 5525ft – 11860ft. From 5525ft – 7175ft, continental sands were encountered. From 7235ft – 11860ft, there was intercalation of sand and shale lithologies.

Three Maximum Flooding Surfaces (MFSs) were picked and dated as P784 (10.4Ma), P770 (11.5Ma) and P750 (12.8Ma). Two Sequence Boundaries (SBs) were picked, which were at P784 (10.6Ma) and P750 (12.1Ma).

Keywords: Sedimentological, Biostratigraphic, Wireline Log, Characterisation

INTRODUCTION

The Niger Delta Basin, geographically located in the eastern Gulf of Guinea, is one of the most prolific petroleum basins in the world (Fig 1). The delta consists of Tertiary marine and fluvial deposits that overlie oceanic crust and fragments of the extended African continental crust (Bilotti & Shaw, 2005).

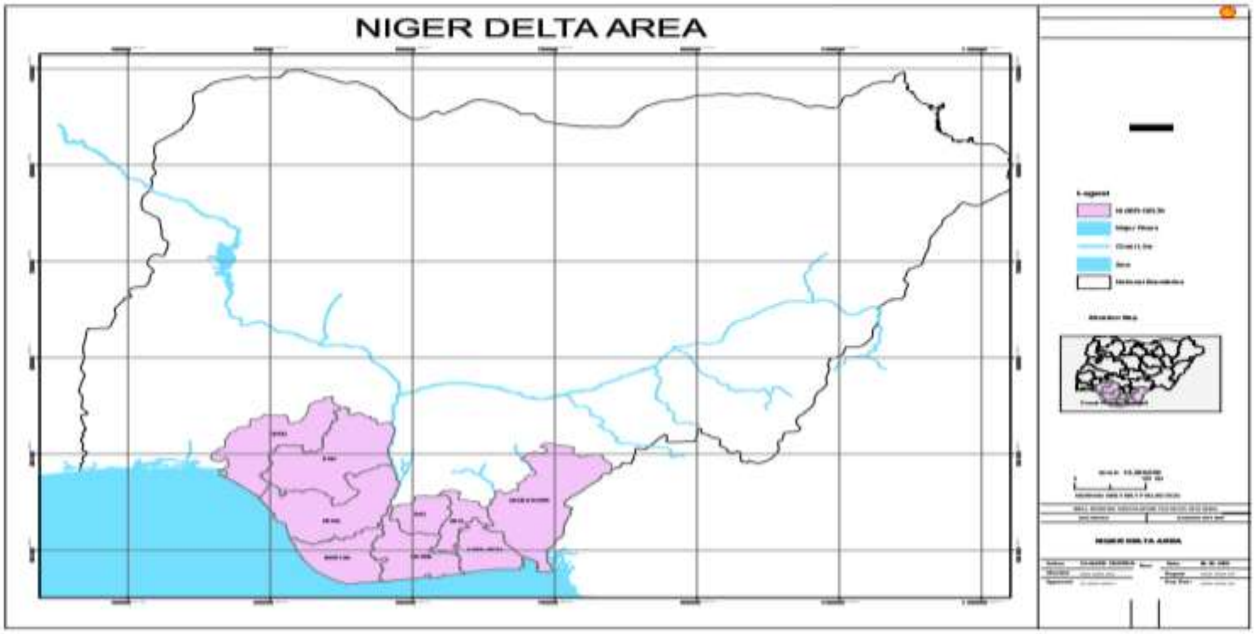

Fig. 1: A grid of the Niger Delta Area in Nigeria. (SPDC Cartography department Warri, 2009)

In the course of exploring for crude oil, a multi-disciplinary approach is needed to be able to get all the desired information that are necessary for a successful well investigation, and to put this information together to achieve a unified goal of successfully exploring, finding and exploiting recoverable crude oil. In finally bringing all the available information together for interpretation, biostratigraphic data is key information that will enable the defining of different stratigraphic sequences of the well, which will greatly aid in reservoir characterization and correlation.

Where the required biostratigraphic data is indeterminate (barren), reservoir characterization can still be carried out based on the sedimentological and sequence stratigraphic subdivisions.

GEOLOGICAL SETTING

Study Area

The study well "AF-1 Well" is located in the Central Swamp depobelts of the Niger Delta Basin (Fig 2 below)

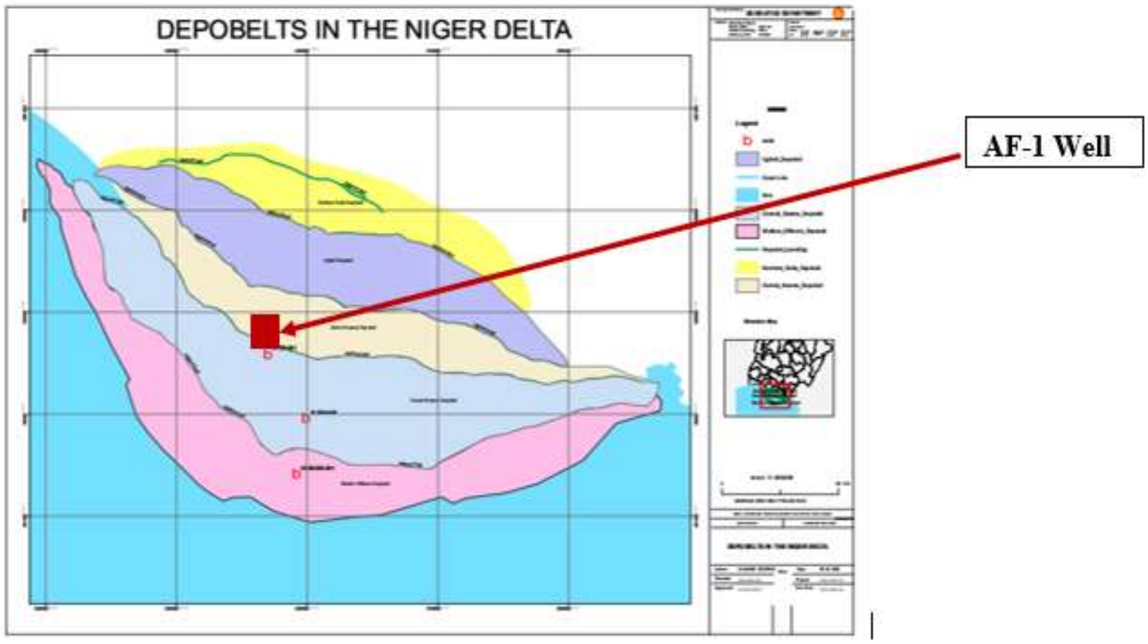

Fig 2: Location of Study Area (in red) insert in the Regional Niger Depobelts. (Modified from SPDC Creations 2008)

Regional Niger Delta Development.

The Niger Delta clastic wedge formed along the failed arm of a triple-junction system (aulacogen) that originally developed during break-up of the South American and African plates in the late Jurassic. Two rift arms that followed the Southwestern and Southeastern Coasts of Nigeria and Cameroon developed into the passive continental margin of West Africa, whereas the third failed arm defined the Benue trough, located under the Gulf of Guinea, offshore (Owoyemi et al, 2006). Therefore, the Niger Delta is situated, building out into the Gulf of Guinea and extends throughout the Niger Delta Province as defined by Klett, et al (Tuttle et al, 1999).

Following an early history of rift filling in the late Mesozoic, this clastic wedge steadily prograde into the Gulf of Guinea during the Tertiary as drainage networks developed across the African Craton and this passive margin subsided (Owoyemi et al, 2006).

Initially, the subsequent instability and subsidence along the rift zones led to a marine transgression which terminated in late middle Cretaceous times. In the late Cretaceous, a proto-Niger Delta first developed, but this ended with a major transgression during the Paleocene. From the Eocene onward, a continued progradation occurred with the deposition of a wedge of fluvio-deltaic sediments which built out into the South Atlantic as the proto-modern Niger Delta (Lambert-Aikhionbare and Shaw, 1982). The overall area of the Niger Delta is an issue of minor controversy in that different authors have given different areal extents for it. Magbagbeola and Willis, 2007, in their work stated that the Niger Delta covers an area of 70,000km^2 within the Gulf of Guinea. Pochat et al, 2004, asserts that the Niger Delta covers an area of about 140,000 km^2 and has an average sediment thickness of about 12 km, and that this siliciclastic system began to prograde across the pre-existing continental slope into the deep sea during the late Eocene and is still active today. Finally, Lambert-Aikhionbare and Shaw, 1982, suggested that the Niger Delta today occupies 64,000 km^2 of the sedimentary basin of Southern Nigeria. As discussed, the coastal sedimentary basin of Nigeria has been the scene of three depositional cycles. The first began with a marine incursion in the middle Cretaceous and was terminated by a mild folding phase during the Santonian. The second included the growth of a proto-Niger Delta during the Late Cretaceous and ended as a result of a major Paleocene marine transgression. The third cycle, from Eocene to Recent, reflects the continuous growth of the main Niger Delta (Short and Stauble, 1967), as we know it know in its modern sense.

The onshore portion of the Niger Delta Province is delineated by the geology of southern Nigeria and southwestern Cameroon. The northern boundary is the Benin flank – an east-northeast trending hingeline south of the West African basement massif (Fig. 3). The northeastern boundary is demarked by outcrops of the Cretaceous on the Abakaliki High, and further east-south-east by the Calabar flank – a hingeline bordering the adjacent Precambrian. The Offshore boundary of the province is defined by the Cameroon volcanic line to the east, the eastern boundary of the Dahomey basin (the eastern-most West African transform fault passive margin) to the west.

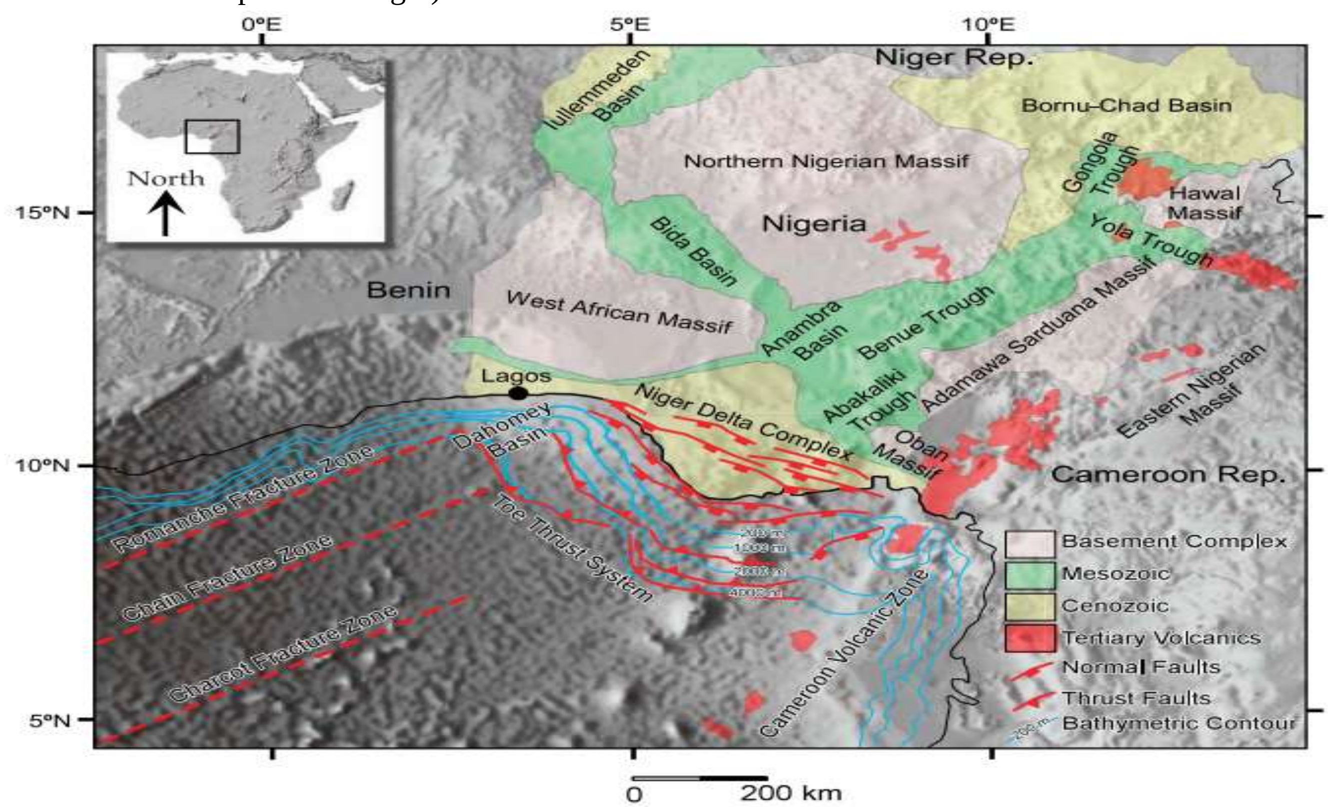

Fig. 3: Location of the Niger Delta region showing the main sedimentary basins and tectonic features. The delta is bounded by the Cameroon volcanic zone, the Dahomey Basin, and the 4,000-m (13,100-ft) bathymetric contour (Modified from Onuoha,1999).

Regional Stratigraphy of the Tertiary Niger Delta

The Niger Delta basin consists of Cretaceous to Holocene marine clastic strata that overlie oceanic, and fragments of continental crust. The Cretaceous section has not been penetrated beneath the Niger Delta basin, and thus, Cretaceous lithologies can only be extrapolated from the exposed sections in the next basin to the northeast, the Anambra basin. In the latter basin, Cretaceous marine clastics consist mainly of Albian-Maastrichtian shallow-marine clastic deposits. The precise distribution and nature of correlative Cretaceous deposits beneath the offshore Niger Delta is unknown. From the Campanian to the Paleocene, both tide-dominated and river dominated deltaic sediments were deposited during transgressive and regressive cycles respectively. In the Paleocene, a major transgression, referred to as the "Sokoto transgression" initiated deposition of the Imo Shale across the Anambra basin and the Akata Shale in the Niger Delta basin. During the Eocene, the sedimentation changed to being wave dominated. At this time, deposition of sediments began in the Niger Delta basin, and as the sediments prograded south, the coastline became progressively more wave dominated (Corredor et al, 2005). Thus, the Tertiary section of the Niger Delta is divided into three formations representing fairly continuous prograding depositional environments namely the Akata, Agbada and Benin Formations (Fig. 4).

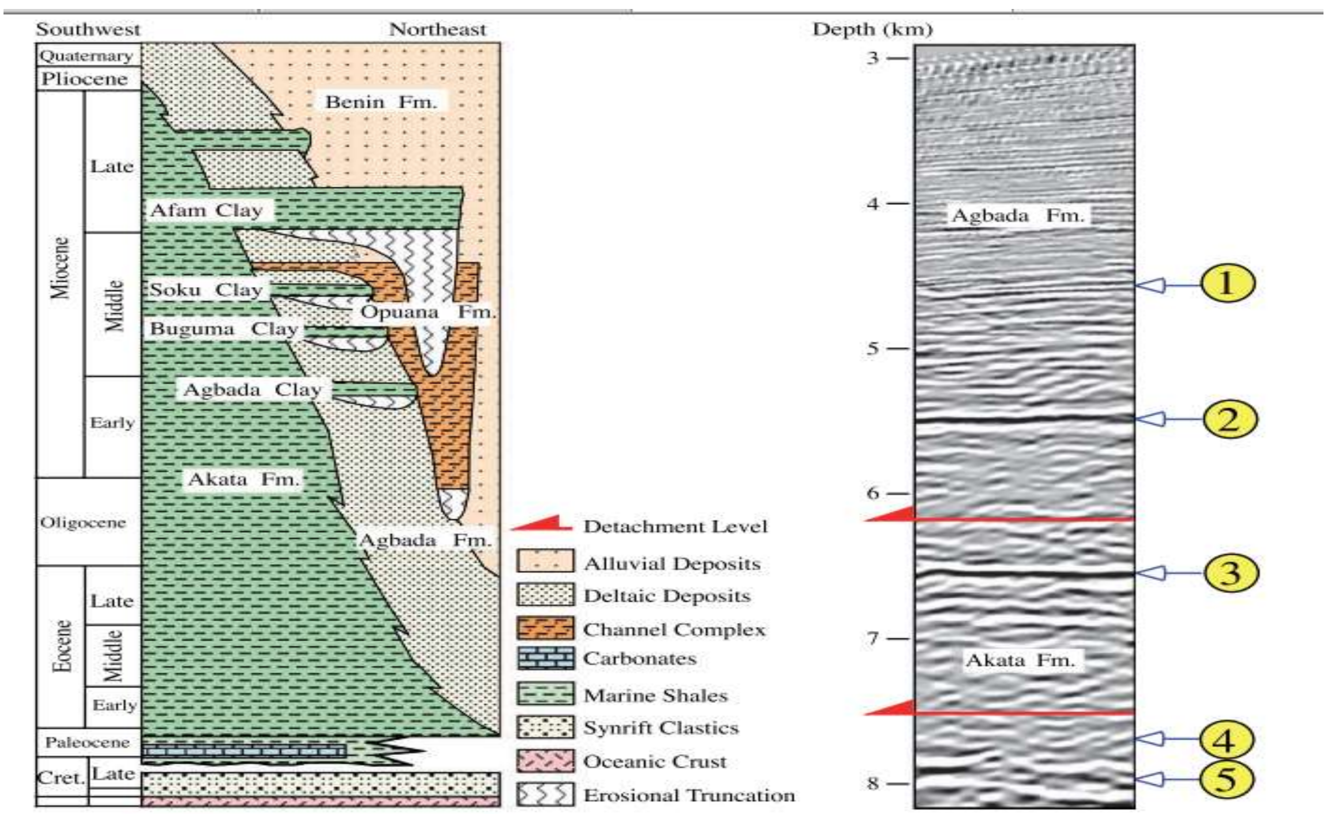

Fig. 4: Schematic diagram of the regional stratigraphy of the Niger Delta and variable density seismic display of the main stratigraphic units in the outer fold and thrust belt and main reflectors, including: (1) top of the Agbada Formation, (2) top of the Akata Formation, (3) mid – Akata reflection, (4) speculated top of the synrift clastic deposits, and (5) top of the oceanic crust. Main detachment levels are highlighted with red arrows (Modified from Lawrence *et al*, 2002).

MATERIALS AND METHODS

This research involves different disciplines will be integrated to better highlight the final result. The study involves three phases of analysis viz: sedimentological analysis, biostratigraphic data interpretation and Wireline Log analysis

Materials used are:

- Well Ditch Cutting samples

AF-1 Sample Inventory

S/N	DEPTH	S/N	DEPTH	S/N	DEPTH	S/N	DEPTH	S/N	DEPTH
1	5525	**21**	6815	**41**	8090	**61**	9370	**81**	10645
2	5600	**22**	6875	**42**	8150	**62**	9430	**82**	10705
3	5660	**23**	6935	**43**	8210	**63**	9490	**83**	10765
4	5720	**24**	6995	**44**	8270	**64**	9550	**84**	10825
5	5780	**25**	7055	**45**	8330	**65**	9610	**85**	10885
6	5840	**26**	7115	**46**	8390	**66**	9670	**86**	10945
7	5900	**27**	7175	**47**	8450	**67**	9730	**87**	11005
8	5960	**28**	7235	**48**	8510	**68**	9790	**88**	11065
9	6020	**29**	7295	**49**	8575	**69**	9850	**89**	11125
10	6080	**30**	7355	**50**	8635	**70**	9910	**90**	11185
11	6140	**31**	7415	**51**	8695	**71**	9970	**91**	11245
12	6200	**32**	7475	**52**	8755	**72**	10030	**92**	11305
13	6260	**33**	7535	**53**	8815	**73**	10090	**93**	11365
14	6320	**34**	7595	**54**	8875	**74**	10150	**94**	11425
15	6380	**35**	7655	**55**	8935	**75**	10210	**95**	11485
16	6455	**36**	7730	**56**	9010	**76**	10285	**96**	11560

17	6530	**37**	7805	**57**	9085	**77**	10360	**97**	11635
18	6605	**38**	7880	**58**	9160	**78**	10440	**98**	11710
19	6680	**39**	7955	**59**	9235	**79**	10510	**99**	11785
20	6755	**40**	8030	**60**	9310	**80**	10590	**100**	11860

- Well Wireline Log
- Biostratigraphic data (F-zones, P-zones and abundance array of both forams and palynological data)
- Niger Delta Cenozoic Chart

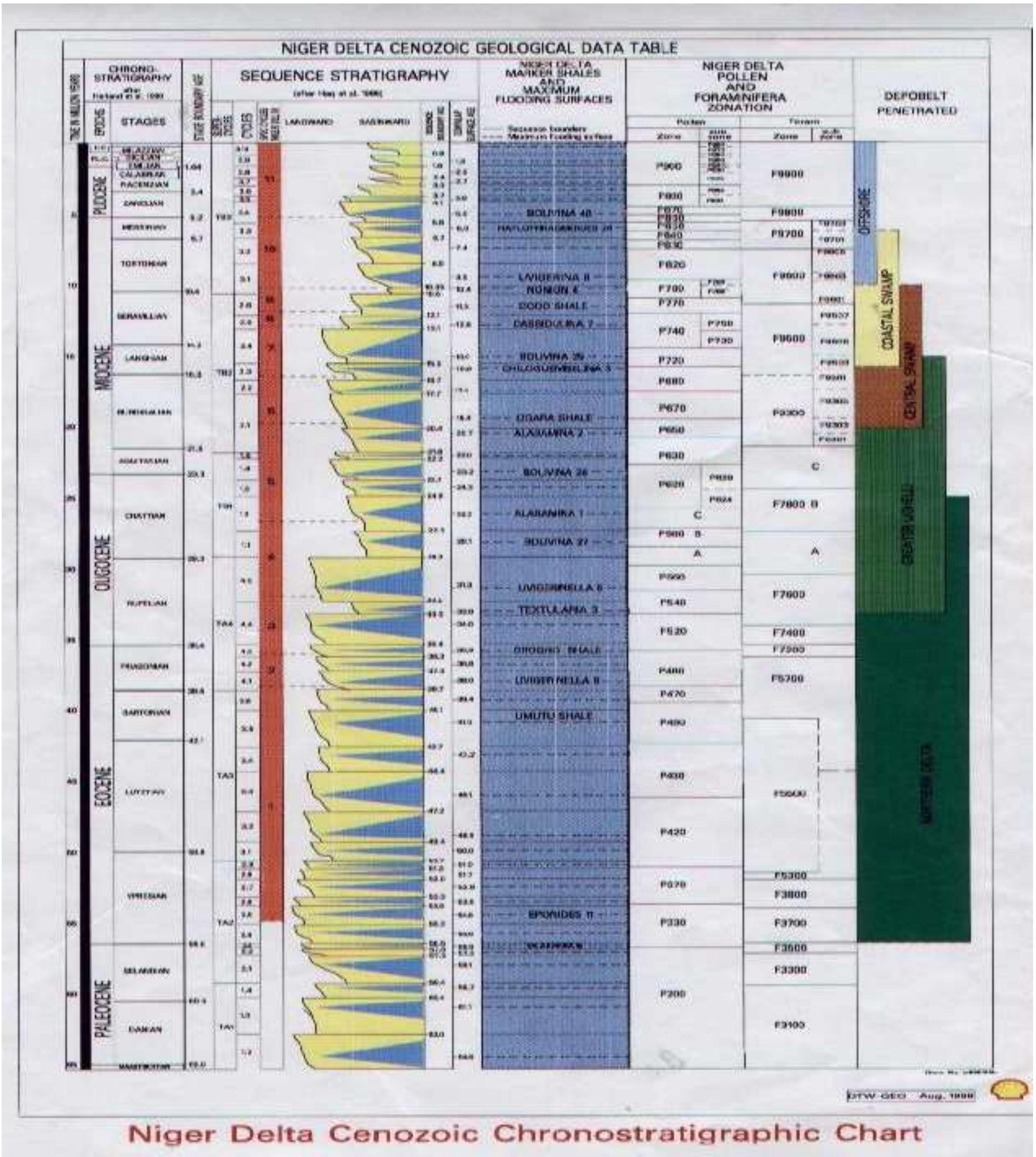

Fig. 5: The SPDC Niger Delta Cenozoic Chronostratigraphic Chart (Haq et al. 1988)

Methods used are:

a. Sedimentological Analysis

The sedimentological analysis of my well samples involved washing the samples initially with water to remove the contamination of the drilling mud, since the drilling mud used is water based mud. After that, the washed samples were dried in pans placed on hot plates. After the drying, the samples were viewed and analyzed with the aid of a microscope for sedimentological description of the samples with particular focus on sediment texture, sorting and lithologic type

b. Wireline Log Analysis

The Wireline logs used were the Caliper Log, Gamma Ray Log and the Spontaneous Potential (SP) Log. These logs are sensitive to sediment variance and therefore can delineate between sand and shale lithologies

c. Biostratigraphic Interpretation

Biostratigraphy is a powerful tool for constraining the ages of stratigraphic sequences. When integrated with wireline logs, it becomes very useful to locate sequence boundaries (SB) and condensed sections Maximum Flooding Surface (MFS).

RESULT AND INTERPRETATION

Sedimentological Analysis

The sedimentological analysis of AF–1 Well was carried out and samples description was done with the production of a resultant lithologic section. The following table showcases the result of the analysis.

Table 1: Sedimentary Description of Af-1 (Central Swamp Depobelt) Well Samples

SEDIMENTARY DESCRIPTION OF AF-1 (CENTRAL SWAMP DEPOBELT) WELL SAMPLES

LEGEND

1		Coarse sand stone	**DTH**	DEPTH
2		Medium/fine sand stone	**SST**	SAND STONE
3		Very fine sand stone	**SHL**	SHALE
4		Shaly sand stone	**SLTS**	SILT STONE
5		Heterolithic lithology	**LITH**	LITHOLOGY
6		Sandy Shale		
7		Shale		

S/N	**DTH**	**% SST**	**% SHL**	**%SLTS**	**LITHOLOGIC DESCRIPTION**	**ACCESSORY MINERALS**	**LITH**
1	5525	99	0	<1	Sandstone, colourless, coarse, well sorted, angular	Fossil casts	
2	5600	98	2	0	Sandstone, colourless, very fine, very well sorted, sub-angular		
3	5660	99	0	<1	Sandstone, colourless, fine, very well sorted, sub-angular		
4	5720	100	0	0	Sandstone, whitish, very fine, very well sorted, sub-angular		
5	5780	100	0	0	Sandstone, whitish, very fine, very well sorted, sub-angular		
6	5840	97	2	1	Sandstone, whitish, fine, well sorted, angular		
7	5900	99	<1	0	Sandstone, whitish, very fine, very well sorted, sub-angular		
8	5960	100	0	0	Sandstone, whitish, fine, very well sorted, angular		
9	6020	100	0	0	Sandstone, whitish, very fine, very well sorted, angular		
10	6080	100	0	0	Sandstone, whitish, very fine, very well sorted, angular		
11	6140	99	<1	0	Sandstone, gray, fine, very well sorted, sub-rounded		
12	6200	99	0	<1	Sandstone, colourless, very fine, very well sorted, sub-rounded		
1	6260	100	0	0	Sandstone, colourless, very fine, very well		

3					sorted, sub-rounded		
14	6320	100	0	0	Sandstone, colourless, very fine, very well sorted, sub-rounded		
15	6380	100	0	0	Sandstone, colourless, very fine, very well sorted, sub-rounded		
16	6455	99	0	<1	Sandstone, colourless, very fine, very well sorted, sub-rounded		
17	6530	100	0	0	Sandstone, whitish, very fine, very well sorted, sub-rounded		
18	6605	100	0	0	Sandstone, colourless, medium, very well sorted, sub-rounded		
19	6680	99	<1	0	Sandstone, colourless, very fine, very well sorted, sub-rounded		
20	6755	99	<1	0	Sandstone, whitish, very fine, very well sorted, sub-rounded		
21	6815	99	<1	<1	Sandstone, colourless, fine, very well sorted, sub-rounded		
22	6875	99	<1	<1	Sandstone, colourless, medium, well sorted, sub-angular		
23	6935	99	<1	<1	Sandstone, colourless, fine, well sorted, sub-angular		
24	6995	99	0	1	Sandstone, colourless, medium-coarse, well sorted, angular		
25	7055	70	20	10	Shaly sandstone, whitish, fine-coarse, poorly sorted, angular		
26	7115	99	<1	0	Sandstone, whitish, very fine, very well sorted, sub-rounded		
27	7175	99	<1	0	Sandstone, gray, fine, well sorted, sub-rounded		
28	7235	2	98	0	Shale, dark gray		
29	7295	60	40	0	Shaly sandstone, whitish, very fine, very well sorted, sub-rounded		
30	7355	80	20	0	Shaly sandstone, colourless, very fine, well sorted, angular		
31	7415	<1	99	0	Shale, dark gray		
32	7475	99	<1	0	Sandstone, colourless, very fine, very well sorted, sub-rounded		

3 3	7535	89	10	<1	Shaly sandstone, colourless, fine, well sorted, sub-angular		
3 4	7595	85	15	0	Shaly sandstone, colourless, fine-coarse, poorly sorted, angular		
3 5	7655	99	<1	0	Sandstone, colourless, very fine, very well sorted, sub-rounded		
3 6	7730	99	1	0	Sandstone, whitish, medium, very well sorted, sub-rounded		
3 7	7805	50	50	0	Heterolic, brownish, very fine-coarse, poorly sorted, angular	Minute carbonaceous particles	
3 8	7880	90	10	0	Sandstone, very fine, very well sorted, angular		
3 9	7955	95	5	0	Sandstone, whitish, very fine, very well sorted, sub-angular	Likeness of coachroach abdominal cast, and much woody input	
4 0	8030	99	<1	0	Sandstone, whitish, very fine, very well sorted, angular		
4 1	8090	99	1	0	Sandstone, whitish, very fine, very well sorted, sun-angular		
4 2	8150	98	2	0	Sandstone, colourless, fine-coarse, moderately sorted		
4 3	8210	98	2	0	Sandstone, colourless, fine-coarse, poorly sorted, angular		
4 4	8270	90	10	0	Shaly sandstone, colourless, fine-coarse, moderately sorted, angular		
4 5	8330	40	60	0	Sandy shale, dark gray		
4 6	8390	2	98	0	Shale, dark gray		
4 7	8450	50	50	0	Heterolic, brownish, very fine, very well sorted, sub-rounded		
4 8	8510	90	10	0	Shaly sandstone, whitish, fine, well sorted, sub-angular		
4 9	8575	<1	99	<1	Shale, dark gray		
5	8635	99	1	0	Sandstone, colourless, very fine, very well		

0					sorted, sub-rounded		
51	8695	99	1	0	Sandstone, colourless, very fine, very well sorted, sub-rounded	Coal particles	
52	8755	95	3	2	Sandstone, colourless-gray, coarse, well sorted, angular		
53	8815	1	99	0	Shale, dark gray		
54	8875	50	50	0	Heterolic, gray, very fine, very well sorted, sub-rounded		
55	8935	98	1	1	Sandstone, gray, very fine, very well sorted, sub-rounded		
56	9010	20	80	0	Sandy shale, dark gray		
57	9085	1	98	1	Shale, dark gray		
58	9160	99	1	0	Sandstone, whitish, very fine, very well sorted, sub-angular	Much woody input	
59	9235	98	2	0	Sandstone, gray, very fine, well sorted, sub-rounded		
60	9310	99	1	0	Sandstone, whitish, very fine, well sorted, sub-rounded		
61	9370	99	<1	0	Sandstone, whitish, very fine, very well sorted, sub-rounded	woody particles	
62	9430	90	10	0	Shaly sandstone, whitish, very fine, very well sorted, sub-rounded		
63	9490	30	70	0	Sandy shale, dark gray, very fine		
64	9550	98	2	0	Sandstone, colourless, moderate, well sorted, angular		
65	9610	95	5	0	Sandstone, whitish, fine, well sorted, sub-rounded		
66	9670	99	1	0	Sandstone, whitish, very fine, very well sorted, angular	Much woody impute	
67	9730	95	5	0	Sandstone, colourless, fine, well sorted, sub-rounded	Micaceous flakes, woody inputs	
68	9790	93	5	2	Sandstone, colourless, fine, moderately sorted, angular		
69	9850	2	98	0	Shale, dark gray		

70	9910	80	20	0	Shaly sandstone, brownish, medium, moderately sorted, angular	Much Ferrugineous input	
71	9970	<1	99	0	Shale, dark gray		
72	10030	<1	99	0	Shale, dark gray		
73	10090	98	2	0	Sandstone, whitish, fine, well sorted, angular	Much Ferrugineous input	
74	10150	95	4	1	Sandstone, whitish, medium, moderately sorted, angular		
75	10210	92	8	0	Shaly sandstone, whitish, medium, well sorted, angular	Much Ferrugineous input	
76	10285	20	80	0	Sandy shale, dark gray		
77	10360	99	<1	0	Sandstone, whitish, medium, well sorted, angular		
78	10440	95	3	2	Sandstone, whitish, medium, very well sorted, sub-angular		
79	10510	95	3	2	Sandstone, whitish, medium, well sorted, sub-angular	Ferrugineous sst	
80	10590	95	5	0	Sandstone, whitish, very fine, well sorted, sub-angular		
81	10645	1	99	0	Shale, dark gray		
82	10705	1	99	0	Shale, dark gray		
83	10765	90	10	0	Shaly sandstone, brownish, very fine, very well sorted, sub-rounded		
84	10825	60	40	0	Heterolic, colourless, fine, well sorted, sub-angular		
85	10885	98	2	0	Sandstone, colourless, fine, well sorted, sub-angular	Ferrugineous Particles	
86	10945	95	5	0	Sandstone, colourless, fine, well sorted, sub-angular		
87	11005	96	2	2	Sandstone, colourless, medium, moderately sorted, angular		

88	11065	40	60	0	Sandy shale,		
89	11125	2	98	0	Shale, dark gray		
90	11185	95	4	1	Sandstone, whitish, medium, well sorted, angular		
91	11245	80	20	0	Shaly sandstone, gray, medium, moderately sorted, sub-angular		
92	11305	40	60	0	Heterolic, gray, very fine, well sorted, sub-angular		
93	11365	80	20	<1	Shaly sandstone, colourless, very fine, well sorted, sub-rounded		
94	11425	90	10	0	Shaly sandstone, colourless, fine-coarse, poorly sorted, angular		
95	11485	98	1	<1	Sandstone, colourless, very fine-coarse, moderately sorted, angular	Coal particles, ferrugineous sst	
96	11560	20	80	0	Sandy shale, dark gray		
97	11635	30	60	10	Sandy shale, light gray, very fine sst		
98	11710	<1	99	<1	Shale, dark gray		
99	11785	<1	99	<1	Shale, dark gray		
100	11860	70	5	25	Sandstone, colourless, very fine, moderately sorted, sub-angular		

AF-1 Well samples displayed a lithologic section that is generally sandy at the top, with the mid-section and the basal parts having intercalations of sand and shale lithologies. The sands range from very fine to coarse grained. The overall lithologic section suggests a lateral shifts of depositional environment from shallow to deep water environment.

Biostratigraphic and Wireline Interpretations

A broad biostratigraphic framework was developed for the well with the MFSs determined based on biofacies abundance data with the associated sequences boundaries mapped. Wireline logs were used in conjunction with the biofacies data. Using an already established data of MFSs and SBs in the Niger Delta Basin as Portrayed in the Niger Delta Cenozoic Geological Data Chart, the relative F and P zones and biofacies data of AF-1 Well enabled the delineation of the MFSs and SBs in the well.

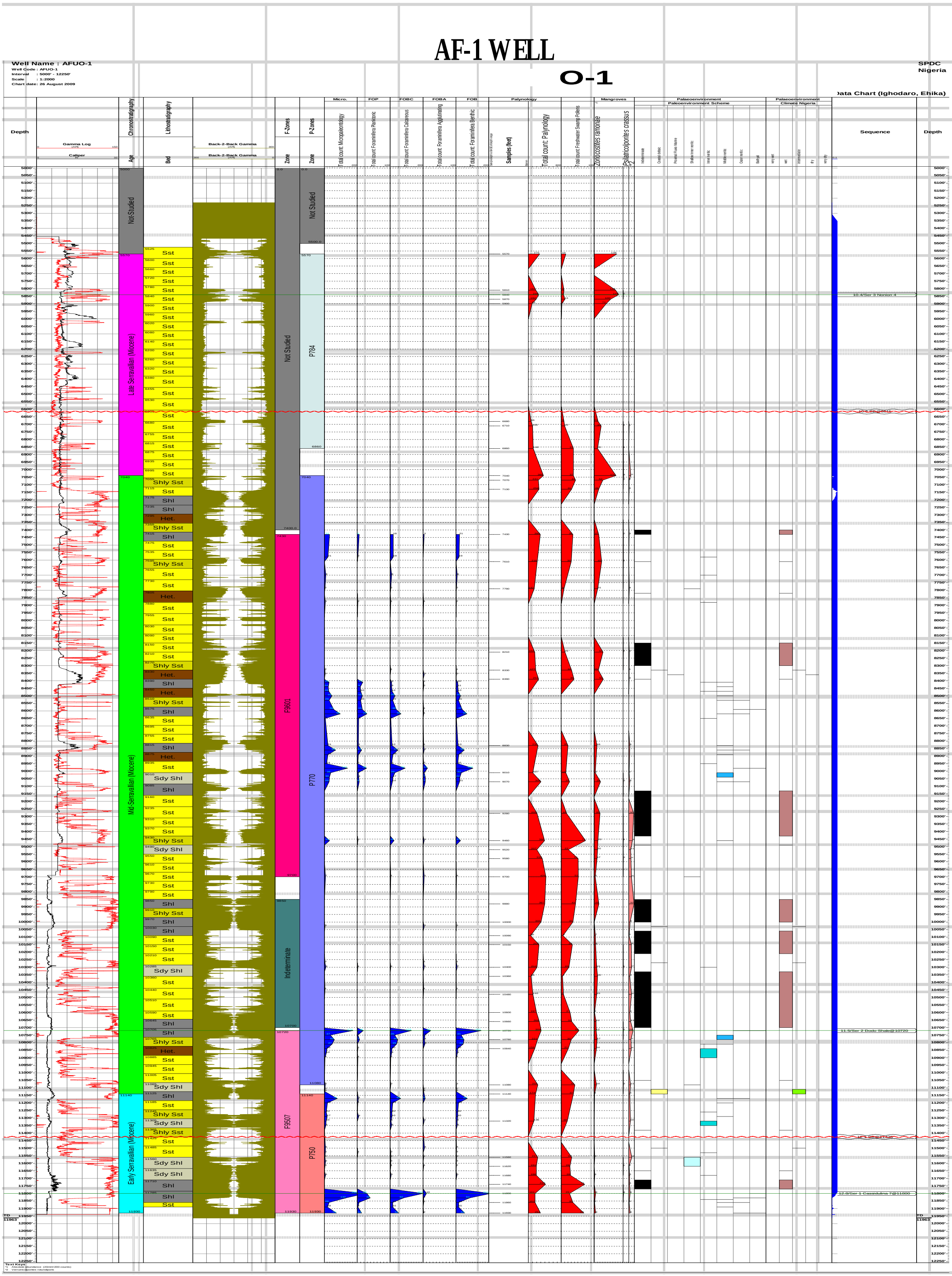

Fig. 6: Stratabugs plot of AF-1 Well composite interpretations. Showing the depth scale, wireline

logs, interpreted lithologic section, F & P zones, biofacies abundance data and the stratigraphic surfaces (MFS & SB)

The first MFS is suggested at 5840ft and it was identified by the abundance peaks of the biofacies data and attributed to the fossil “Nonion 4” associated with 10.4Ma. It occurred within the P784 palynology biozone and matched against the Niger Delta Cenozoic Chart. The Gamma Ray (GR) log showed an increase in shale content in the system over that interval.

At depth 6615ft, the first SB was established based on the very low count/barrenness of microfossils. It was established within the P784 biozone and tied to the 10.6Ma Sequence Boundary of the Niger Delta Cenozoic Chart.

The second MFS was defined at the depth of 10720ft and tied to the microfossil abundance peaks of both foram and paly data sets. The GR log confirmed that it fell within a condensed section and fell within the P770 biozone. Its occurrence is associated with the 11.5Ma Dodo Shale event.

The second SB was picked at depth of 11425ft within the P750 biozone, and confirmed by GR log decreased deflection, and tied to the 12.1Ma SB shown on the Niger Delta Cenozoic Chart.

At the depth of 11800ft, the third MFS is postulated and is attributed to foram abundance peak of “Cassidulina 7”. It fell within the P750 biozone and the GR log showed a condensed section. It is aged 12.8Ma as matched against the Niger Delta Cenozoic Chart.

Based on the biostratigraphic subdivisions, the well has been characterised into five (5) major lines of subdivision.

CONCLUSION

This work has employed sedimentological analysis to produce lithologic section of AF-1 Well; biostratigraphic interpretation was used to define the chronostratigraphic surfaces (Maximum Flooding Surfaces and Sequence Boundaries) which define the Third Order sequence. The litholgic sections give visual aspects of the well from shallow to deep water environments as the sediment type grades from sand to shaly lithologies. The biostratigraphic interpretation defined Maximum Flooding Surfaces and Sequence Boundaries based on microfossils abundance peaks and the signatures of the wireline logs, producing a characterization on chronostratigraphic lines of subdivision, which spells out the Third Order sequence. From the result, it is evident the tools used in this research for well based characterization and correlation are indispensable in detailed reservoir prediction in petroleum exploration.

REFERENCES

Bilotti, F. and Shaw, J. H. (2005): Deep-water Niger Delta Fold and Thrust Belt Modeled as a Critical-taper Wedge: The Influence of Elevated Basal Fluid Pressure on Structural Styles. The American

Association of Petroleum Geologists. Vol. 89 (11). Pp 1475 – 1491.

Corridor, F., Shaw, J. H. and Bilotti, F. (2004): Structural Styles in the Deep-water Fold and Thrust Belts of the Niger Delta. The American Association of Petroleum Geologists. Vol. 89 (6), Pp 753 – 780.

Lambert-Akhionbare, D. O. and Shaw, H. F. (1982): Significance of Clays in the Petroleum Geology of the Niger Delta. The Mineralogical Society, 1982, Vol. 17. Pp 91 – 103

Magbagbeola, O. A and Willis, B. J. (2007): Sequence Stratigraphy and Syndepositional Deformation of the Agbada Formation, Robertkiri Field, Niger Delta, Nigeria. The American Association of Petroleum Geologists. Bulletin. Vol. 91. Pp 945 – 958.

Owoyemi, A. O. and Willis, B. J. (2006): Depositional Patterns Across Syndepositional Normal Faults, Niger Delta, Nigeria. Journal of Sedimentary Research. Vol.76 (2). Pp 346 – 363

Pochat, S., Castelltort , S., Van Den Driessche, J., Besnard, K. and Gumiaux, C. (2004): A Simple Method of Determining Sand/Shale Ratios from Seismic Analysis of Growth Faults: An Example from Upper Oligocene to Lower Miocene Niger Delta Deposits. The American Association of Petroleum Geologists. Bulletin Vol. 88 (10). Pp 1357 – 1367.

Short, K. C. and Stauble, A. J. (1967): Outline of Geology of Niger Delta. The American Association of Petroleum Geologists. Bulletin Vol. 51 (5). Pp 761 – 779

Tuttle, M. L. W., Charpentier, R. R., and Brownfield, M. E. I. (1999): The Niger Delta Petroleum System: Niger Delta Province, Nigeia, Cameroon and Equatorial Guinea, Africa. US Geological Survey Open-File Report 99-50-H, Denver, Colorado, 70-73.