International Journal of Advance Studies in Engineering and Scientific Inventions
Volume 3 Number 1, JULY 2015. ISSN (Print): 1741-8763 ISSN (Online):1741-8771

SEQUENCE STRATIGRAPHIC ANALYSIS OF ?MR" -WELL IN SOUTHEASTERN SECTOR OF NIGER DELTA, NIGERIA

[1]Itam, Asukwo Essien & [2]Nyong, Eyo Etim
[1&2]Department of Geology
University of Calabar, P.M.B. 1115,Calabar

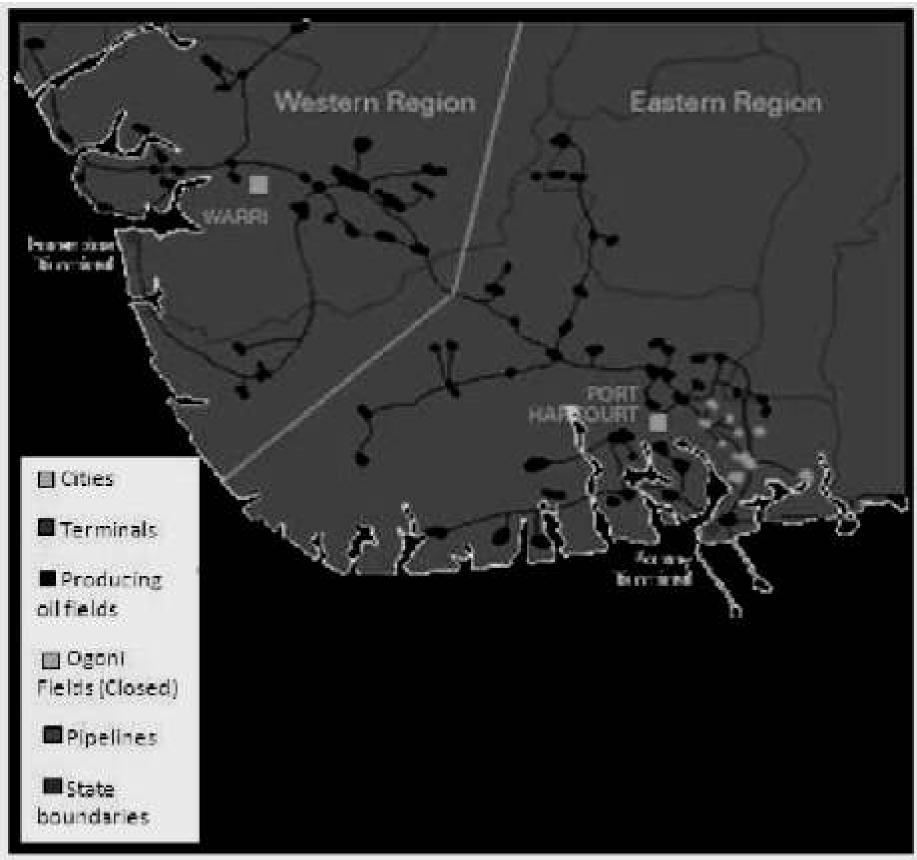
Abstract
Well logs and biostratigrahic data from ?MR"-Well in the Coastal Swamp Depobelt of the Niger Delta were integrated to construct high resolution sequence stratigraphic framework. based on the approach of Galloway.The analysis showed two third order depositional sequences with three Maximum Flooding Surfaces (MFS) dated 17.4, 15.9 and 15.0 Ma, with three intervening Sequence Boundaries (SB) within the Maximum Flooding Surfaces aged 16.7,15.5 and 13.8Ma respectively.The onset of marine flooding , which marks the setting of retrogradational facies sequence, called Transgressive Surface (TS) were delineated. The depositional sequence identified from sediments penetrated by this well consists of the Basin Floor Fans (BFF) and Slope Fan Complex (SFC) of the Lowstand System Tract (LST), Transgressive System Tract (TST) and Highstand System Tract (HST), with their distinct log signatures. The sediments of? MR"-Well shows upward coarsening facies with decreasing shale contents. The age of these sedimentary units is from Early- Miocene to Middle-Miocene interval. The delineation of paleoenvironment based on biofacies , wireline log and lithofacies show deposits range from deltaic plain to pro- deltaic setting while the paleo water depth is inferred from inner neritic to upper bathyal paleo-water depth.This integrated interpretations show that sequences may have potential source, reservoir and seal rocks for hydrocarbon exploration.

Keywords: *Sequence stratigraphic, Flooding, Niger Delta*

Website: http://internationalpolicybrief.org/journals/international-scientific-research-consortium-journals/intl-journal-of-engineering-vol3-no1-july-2015

Background to the Study

The last decades in Nigeria has witnessed arapid increase inpopulation which equate with the demand for oil and gas. There is therefore needs to curb up with this huge demand.Geoscientists have devised ways other than conventional geophysical techniques, in searching for hydrocarbon resources deposits in some of the by-pass producing zones and at a lesser cost of exploration and production. This alternatives method combines other geosciences communities as a single entity. This new and proven method is known as sequence stratigraphy andit involves a combination of sedimentology, stratigraphy, wireline logs and seismic data.Sequence stratigraphy has been widely appliedglobally in the last two decades in petroleum industries to search for hydrocarbon source, reservoir, and sealed rocks in sedimentary basins. This research work will attempt to apply this technique in ?MR"--Well located in the southeastern Nigeria (Figure, 1) to delineate chronstratigraphic surfaces, systemtracts, depositional environments and possible predictions on hydrocarbonpotentials.



Location of the study well

Figure 1: Location map of the Niger Delta showing "MR"-Well (Modified from Imasuen etal., 2011).

Geological Setting

The Niger Delta is located on the continent margin of the Gulf of Guinea in Equitorial West Africa. It located at the southern margin of the Nigeria between latitude 03° and 06°N and longitude 005°E and 008°E.The Niger Delta province is delineated by the geology of southern Cameroun stable megatectonic frames and West African shield, these include; Benin and Calabar hinge lines at the northwestern and eastern boundaries of the delta respectively, while the Gulf of Guinea borders the Niger Delta basin in the south and the base of the Benue Trough, Anambra Basin and Abakaliki High mark the northern boundary (Figure, 2). This configuration of the basin reflects decrease in age basinward to reveal the overall regression of depositional environment within the Niger Delta clastic wedge (Oyedele et al; 2012 and 2013)

Three main lithostratigraphic units recognized and delineated (Figure, 3) are: Akata, Agbada and Benin Formations (Short and Stauble, 1967). These reflect a complex mixture of marine, fluvio-marine, littoral and deltaic plain environment (Weber and Daukoru, 1975). The Akata Formation is the basal sequenced and characterized by uniform shale development and the shale is generally dark gray, with some sandy or silty in the upper part and plant remains and mica. The marine planktonic for aminifera is about 50% of the micro fauna assemblage and suggest shallow marine shelf deposition (Doust and Omatsola, 1989). The age spanned from Palaeocene- Recent (Doust and Omatsola, 1989) and the shale is about 600m thick and is the major source of hydrocarbon generation.Overlying the basal marine unit is the paralic Agbada Formation, which is made up of alternating sandstone, siltstone and shale. The percentage sand increased upward while that of shale increases downward. These indicate a cyclic sequence of fluvial and marine deposits. This Formation extends throughout the Niger Delta subsurface and is the most explored unit. The age of Agbada Formation decrease from north to south in Eocene to possibly Pleistocene (Short and Stauble, 1967).The Formation is about 4500m thick and contains hydrocarbon prospective sequences in the Niger Delta.

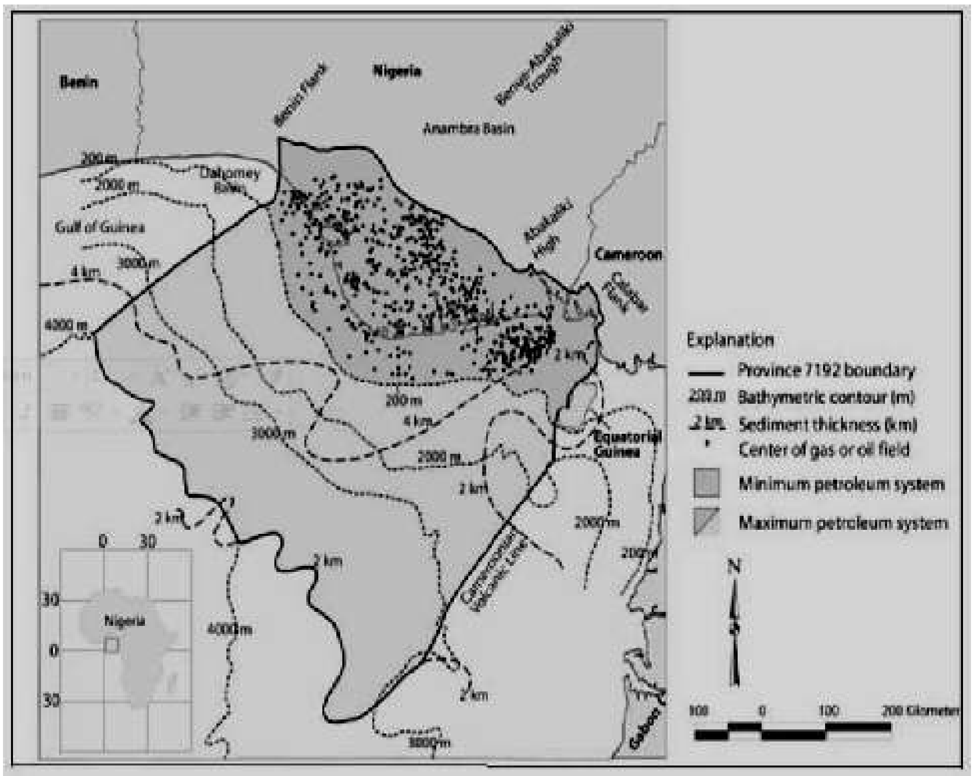


Figure2: Map of the Niger Delta showing province outline (maximum petroleum system) bounding structural features; minimum petroleum system as defined by oil and gas field center points (Tuttle et al., 1999)

Benin Formation is the topmost and most shallow part of the deltaic clastic wedge. According to Ojo and Gbadamosi (2013), the Formation can be easily recognized based on its high sand percentage (70% -100%). This Formation has a few shaley intercalations (Esan, 2002). This continental deposit has a thickness of about 200m (Beka and Oti, 1995), with age of Oligocene in the north and becomes progressively younger southward.

From the inception of the Niger Delta to the present the delta has been prograding into the adjoining oceanic crust southward, forming the most active portion of the delta at each stage of its development called the depobelt (Doust and Omatsola, 1990). These depoblets are 5/6 types (Northern, Greater Ughelli, Central Swamp, Coastal Swamp and Offshore Shallow/Deep Offshore) depobelts). The Niger Delta has a major fault, which is a synsedimentary structures called the growth fault, which are the major building faults in the delta and is restricted to the paralic Agbada Formation and some bound the depobelts.

The Niger delta province has been identified to contain one well known petroleum system known as the Tertiary Niger Delta (Akata- Agbada) Petroleum System (Ekweozor and Daukoru, 1984 and Kulke, 1995), where hydrocarbon is produced from rocks (sandstone and unconsolidated sands) of Eocene to Pliocene age in the onshore areas and from Pliocene to Pleistocene age in the offshore sections, with expected production from the flanks of Cretaceous rocks (Ozumba, 1999). The hydrocarbon production are controlled by the dominant growth fault system.

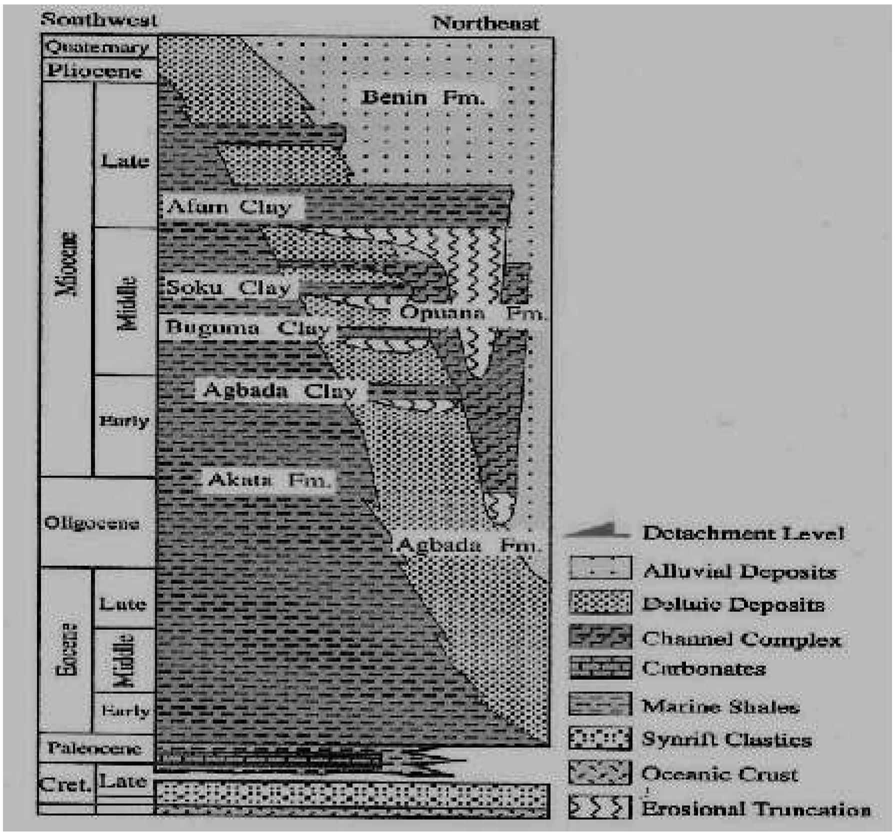


Figure 3: Stratigraphic column of the Niger Delta (After Adeigbe et al; 2013)

Methodology

The various data sets involve in the present studies are wireline- log (consisting of gamma-ray and resistive logs), high resolution data chart consisting of showing foraminifera distribution interms of abundance and diversity, ditch cuttings from “ MR”- Well (4370m-3370m) and Niger Delta Chronostratigraphic chart.

The methods employed in the present studied include lithologic descriptions and their correlation with the different wire log motifs at different intervals inorder to infer the likely depositional environment. The various for aminifera biostratigraphic markers with assign ages were correlate to Niger Delta Chronostratigraphic chart in order to determine their actual ages of the key bounding surface. The integrated result is shown in figure 4

Lithofacies

The lithology is dominated by alternating shale and sand. The shale-sand ratio is approximate 70% : 30% and overall sequence is coarsening upward trend. The shale is characterized by light gray brownish subfissile to fissile, blocky, moderately hard with , micaceous materials Dominating the accessories are carbonaceous matters, shell fragments and glauconitic gypsum. The sand / sandstone is characterized, by fine to coarse, clean, and colourless to smoky, moderate to well sorted, rounded to subrounded grained Ferruginous matters, minor silt / siltstone and calcareous matters ,occur in the sand / sandstone as minor components

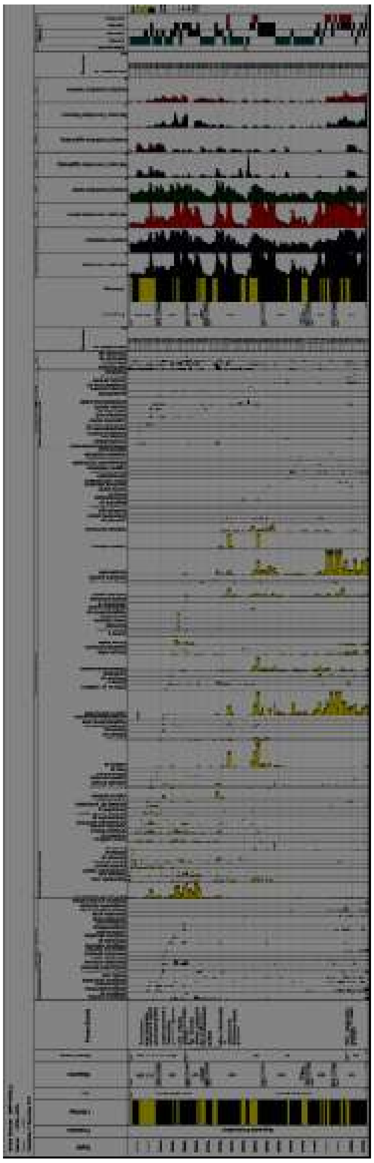
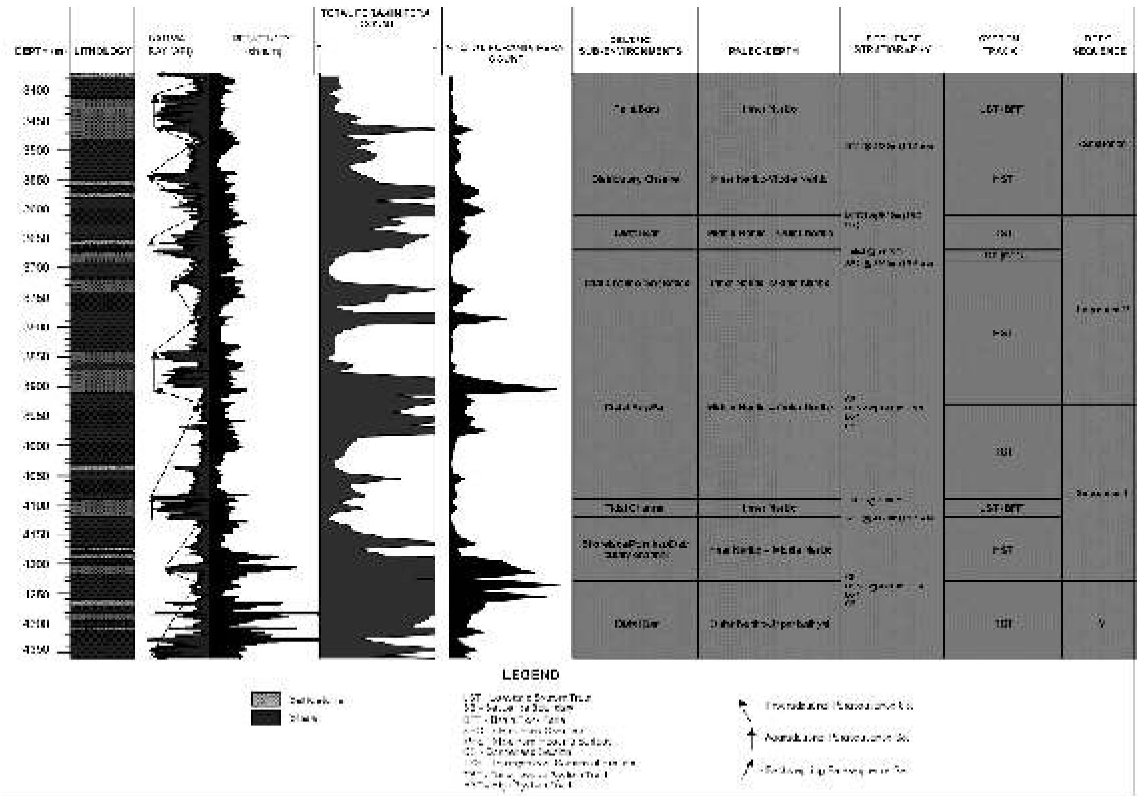


Figure 4: Foraminifera Biostratigraphic, lithologic and sequence Stratigraphic chart of" MR"- Well

Lithologic description shows different log shape motifs (Gamma-ray / Resistivty logs). Five different logs trend were unreavealed in the studied well (Table ,1). A bell shaped of the gamma ray log, with sharp base and top indicating fining upward sequence of decreasing sand size and increasing shaley contents. This log motif may infer a trangressive shelf deposits. A blocky (boxcar or cylindrical) intervals of approximately low gamma- ray log values, with abrupt increase in gamma -ray values at bottom and top. This log shaped is typical channel deposits / barrier island (Weber, 1972) in the Niger Delta. There is also serrated logshaped of roughly steady high gamma ray values. The shale in this serrated log is characterized by intercalated sand and this interval may infer a much more marine activities with some tidal processes. Intervals that start with an abrupt decrease of gamma ray log values; hence lithological interpreted to indicate a sudden coarsening (sandy) upward trend (progradational delta). This is funnel shaped log pattern which may infer shoreface / distal bar deposition. A symmetrical gamma-ray log pattern that showed a progradational pattern at initial stage and then suddenly retrograde at the terminal infer coarsening upward and fining upward sequence. This symmetrical log shaped signified a regressive and and trangressive phases of the delta.

Table 1: Integration of delineated sub-environments, biofacies and system tracts of " MR"- Well



Biostratigraphy of "MR"- Well

The forminiferal biostratigraphy reveals that the sediments of "MR"- Well falls between F9501 to top of F9503 of Foraminiferal Zonation in Niger Delta chronostratigraphic chart (Haq et al ;1988). The well showed three forminiferal zonations (Blow, 1969, Bolli and Sanuders, 1985 and Berggren, 1995) and these are: Catapsydrax stainforthi (N6, older than 17.4Ma), Globigerinatella insueta / Praeorbulina glomerosa (N7 N8 of 17.30Ma-15.60Ma) and Globorotalia foshi peripheronda / Globorotalia foshifoshi / Globorotalia foshi lobata (N9-N10 and younger of age 15.6Ma-12.6Ma) as shown in figure 4. These biostratigraphic zonations were related to the benthonic formainifera biozonation of Ozumba and Amajor (1999), Obaje et al (2010) , Okosun and Chukwu (2012),Fajemila (2012) and some localized foraminifera benthic markers in the Niger Delta Basin as Buliminella subfusiformis (N6 older than N6 , older than 17.4Ma), Lenticulina inornata (Upper N6 and Lower N7 of 17.4Ma-16.7Ma), Brizalina interjuncta (Upper N7 to Lower N8 of 16.7Ma -15.9Ma) , Eponides eshira / Lenticulina grandis (Upper N 8 to Middle N9 of 15.9Ma-15.0Ma) , Brizalina mandoroveensis (top N9 Middle N10 of 15.0Ma-13.8Ma), Sigmolina oligoceanica(Upper N10 and younger of 13.8Ma and younger). These foraminifera biozonatiions showed the age of sediments penetrated by "MR"- Well as Early- Middle

Sequence Straigraphy

Sequence stratigraphy which is the study of rocks that are genetically related within the framework of chronostratigraphical bounded surface was employed in this study. Sequence stratigraphy is an integrated approach that involves biostratigraphy, wireline logs, sedimentology and seismic reflection profiles. For this research work sequence stratigraphy was carried out using biostratigraphy, sedimentology and wireline logs. Seismic profiles were unavailable. The fundamental units of sequence stratigraphy are the sequence. Sequence can be divided into a system tracts and these systems tract has further subdivided into Lowstand System Tract (LST), Transgressive System Tract (TST) and High System Tract (HST), each having a predictable stratigrahic order and shapes and contents. (Neal et al;1993). Each system tract exhibit characteristic log signature, biofacies assemblages and lithofacies. The procedure of identification of the various system tracts and their bounding surfaces was done in-lined, with Wagoner et al (1988): Neal et al (1993) ; Armentrout (1995) and Embry (2009).

Key Bounding Surface

According to Armentrout (1995), the primary horizons used in sequence stratragrphic analysis are Maximum Flooding Surface (MFS), Sequence Boundaries (SB) and Transgressive Surface of Erosion (TSE). These surfaces were encountered in this well of study and the details of the various key bounding surfaces are shown in (table 3).

Maximum Flooding Surface (MFS)

The MFS was defined as the surface of sequence stratigraphy that marks the change from retrogradational sedimentation below to progradationalabove. Thefollowing criteria were used in the investigated well to infer MFS:

i. MFS marks the change in trend from a fining upward trend below to a coarsening upward trend above (Embry, 2001)

ii. The MFS were recognized as intervals of high abundance and diversity of foraminifera.

iii. The lithologies were mainly shaley and the gamma ray logs kicks with high value and the resistivity log was low. at the inflection point from increasing gamma ray (gradual shift to the right indicating fining-upward and increasing shale) to decreasing gamma ray (a shift to the left indicating coarsening upward and decreasing shale).

iv. MFS is interpreted to be generated by a change from decreasing sediment supply to increasing sediment supply at that interval. Such a change in supply rate is most often associated with the change from transgression to regression (Embry, 2009). Thus, the MFS is interpreted to be generated very near the time of start of regression.

v. It separates the underlying TST from overlying HST.

Iv. MFS is represented by a chemical deposit such as gypsum or concentration of glauconite.

Table 2: System tracts and key surfaces with corresponding depths and ages

System Tract	Depth Interval (M)	Key surfaces/ Depth (M)	Age (Ma)	Epoch	Foraminiferal zone
LST (BFF)	3490 – 3370 3490	SB-3@3490	13.8	EARLY– MIDDLE MIOCENE	F9501– F9503
HST	3610 – 3490 3490	MFS-3@3610	15.0		
TST	3670 – 3610 3670	TSE-2@3670			
LST (LSF)	3690 – 3670 3690	SB-2@3690	15.5		
HST	3930 – 3690 3930	?MFS-2@3930	15.9		
TST	4090 – 3930 4090	TSE-1@4090			
LST (BFF)	4120 – 4090 4120	SB 1@4120	16.7		
HST	4230 – 4120 4230	?MFS-1@4230	17.4		
TST	4370 – 4230				

From the analyzed well, the intervals that depict this zone are at 42320m, 3930m and 3610m respectively. These MFS were correlated with Niger Delta Chronostratigraphic cycle chart dated 17.4Ma, 115.9Ma and 15.0ma respectively. However Uvigerina sparsicostataconfirmed MFS of 15.0Ma at 3610m while Chiloguembelina 3 (15.9Ma,a shale marker) was unidentified at 3930m. MFS of 17.4Ma that occurred at 4230m is unnamed in the Niger Delta Cenozoic cycle chart.

Sequence Boundaries (SB)

Sequence boundaries was recognized using the following criteria

i. Interval separating the overlying shallow microfacies from underlying deep water facies.
ii. Minimal biofacies abundance and diversity
iii. It was also recognized as the zone of most basin ward shift in marine bofacies which correspond with coarsening upward sequence.
iv. These intervals depict the top of progradational parasequence set or base of a blocky gamma ray long signature that contain coarse sediments.
v. The interval also characterized by lowest gamma ray log values and high resistivity kicks.
vi. This boundary was depicting at interface between the underlying HST from the overlying LST.
vii. From our analyses three sequence boundaries (SB) which is interval between two successive MFS were recognized when compare with (figure 4). These boundaries occurred at 412om, 3690m and 3490m dated as 16.7Ma, 15.5Ma and 13.8Ma respectively:

Transgressive Surface of Erosion (TSE)

Transgressive surface separates the overlain deepening biofaces from the underlying shallow biofacies (Vail et al;1990), and from the work of Onyekuru et al (2012), TSE lies close to a sequence boundary marking the abrupt changes from progradational facies below to retrogradational facies above and this enhance diminution of sand thickness deposited during sea level fall. The surface marks the initiation of marine influence.The transgressive surface,(TSE) separates the underlying LST from the overlain TST. From the analyses of “MR" -Well. Two distinct TSE were mapped out at 4090m and 3670m.System Tracts Nine different system tracts were marked out from “MR" -Well (table). Each of the system tracts has a distinctive lithologic, biofacies and wireline log characteristics.

Transgressive system tracks (TST)

The TST has a retrogradational sequence that shows overall deepening upgrades in the fossil biofacies (Armstrong and Braiser, 2004). TheTST was bound by the transgressive surface below and the maximum flooding surface(MFS) above.TST was mapped and marked out as interval that depict:

i. Upward increase in marine microfossil (foraminifera) abundance and paleowater depth.
ii. An upward increase in planktonic/benthonic ratio(P/B ratio) of formaminifera assemblage
iii. Landward migration of the shoreline
iv. Upward increase in fine grained sediment (retrogradational parasequence pattern)
v. This zone may have increase in glauconites contents.
vi. The interval of this sequence is capped at the top by MFS.

vii. There is upward increase in gamma ray values and corresponding decrease in resistivities log value.
viii. From the analyses result, three different episodes of TST, were recognized at intervals of 4370m-4230m, 4090m -3930m and 3670m-3610m respectively.

Highstand system tract (HST)

The HST has both aggradational and progradational parasequence sets. This system tract has a gradual shallowing upward biofaces (benthic foraminifera and declining planktonic forminifera biofaces. The criteria adopted in recognizing HST in this work includes:

i. Decrease in P / B ratio
ii. Upward shallowing of paleowater depth
iii. Upward increase in coarse grained size
iv. The bottom of this sequence is capped by MFS and top by top SB.

From the analyzed well, the intervals that marked HST, ranges between 4230m-4120m, 3930m-3690m and 3610m-3490m.

Lowstand system tract (LTS)

The LST is regarded as the oldest system tract. This interval has lowest abundance and diversity of foraminifera. It is dominated by mostly coarse grained sediments.The base and top of this sequence were marked by SB and TSE.Two types of sediments characteristic within the lowstand system tract were encountered in the well of study. These are Basin Floor Fans (BFF) and Slope Fans Complex (SFC) lowstands.The BFF consists of colourless medium subrounded, to round well sorted, sand grained and characterized by block log motifs with sharp top and bottom shale enclosing the sand. Two sets of BFS were encountered at 4120-409m and 73490m-3370m.Slope fans complex (SFC) which has a crescent log motif was encountered at interval dominated by fined-coarse grained sand intercalated with brownish fissile shale. This sequence has low biofacies count. The interval is put at 3690m to 3970m.

Depositional Sequence

This study relied on the approach of Haq et al (1988), to delineate third (3rd) order cycles whereas depositional sequences were obtained using the concept of Galloway (1989);Sequence boundary is the interval between two consecutive maximum flooding surfaces (MFS) is used to demarcate different depositional. This study reveals two depositional sequences (SQ1-2). The sequences are shown in table 2.

Sequence 1 (SQ-1, 4230m-3930m)

This is the oldest sequence and starts at depth of 4230m and ends at 3930m. The transgressive system occurs at the base of this sequence (4370m). The interval of the TST (4370m-4230m) shows a retrogrational sequence consisting dominantly of pelagic shale with some trangressive sand sediments and terminate at maximum abundance and diversity of foraminiferal assemblages called the MFS at 4230m dated 17.4Ma. The overlying HST consist of sand and shale intercalations with sand increasing upwards to terminate at base of cylindrical log shape marking the oldest SB at 4120m (16.7ma). The overlying LST (BFF) is composed dominantly of well sorted sand bounded at top and base by fine grained sediments

This demonstrate a blocky log motif with sudden terminations at top and base. The sudden change in lithology and biofacies at the top of this BFF is an unconformity surface (TSE at 4090m) into retrogradatinal parasequence and to the second episode of TST in this sequence. This TST (4090m 3930m) is divided into two lithofacies: top and bottom shale units and a thin sand body at (4040m-4030m).This TST shows retrogradational parasequence pattern. The top of this TST marked the end of sequence one (SQ-1) which is at MFS (15.9Ma) at 3930m. The shale marker of this interval is Chiloguembelina, was unidentified in the studied well.

Sequence -2 (SQ-2 ,3930m-3610m)

The sequence 2 (SQ-2) episode of deposition commenced with the 2nd higherstand system (3930m-3690m). This HST consists of shale/s and intercalation units with aggredational, retrogradational and progradational parasequence sets. The abrupt change in the gammaray logs response is related to sharp break from fining upward to coarsening sequence at 3690m which marked unconfomity called sequence boundary (SB) that demarcates HST from the overlain SFC lowstand system tracts. The SFC (3690-m 3670m) has a cresentric log shape of aggradational parasequence consisting of dominantly sandy sediments. SFC deposits marks the beginningof retrogradational pattern of TST. This TST consists dominantly of shale and thin layer of reworked sand units. This TST (3670m 3610m) is the youngest TST of this sequence is truncated on its top by a blanket of shale that represent maximum flooding surface at 3610m which is dated using a Uvigerina sparsicostata marker shale as 15.0Ma.

Sequence -3 (SQ-3, 3610m-3370m)

This sequence is not well obtainable. It begins with equal shale and sand intercalation at the base, the amalgamented fining upward shall units at the middle and ending with progradational coarsening units at the top. This is the youngest HST (3610m 3490m).The top of this HST is the base of a blocky log motif of(aggradational parasquence pattern) and consist ofmedium fned grained , subangular to subrounded sandy unit at 3490m and marked the youngest SB dated 13.8Ma. The BFFoverlying thE HST starts with amalgamated aggredational sand unit of a thin top layer of lightgray-brownish subfissile shale. This sequence (SQ-3) is incomplete as only HST and LST were encountered without intervening TST. The top of this sequence marks the end of the analysed well (3370m).

Hydrocarbon Implication

Sequence stratigraphy is one of the extraordinary helpful techniques in generating exploration prospects and producing reservoir and seal quality in both stratigraphic and structural prospect (Adegoke 2012) .The marine sand of TST and the thick massive sand of BFF (LST) could form excellent hydrocarbon reservoir given the right conditions from the studied well. These sands are well sorted with high restivities and low gamma ray logs values. Shales of transgressive and highestand system tracts could serve as both hydrocarbon source and seal rocks; together with the maximum flooding surface shales which may form a regional seal rocks (Onyekuru et al; 2012).

References

Adegoke, A. K. (2012). “Sequence Stratigraphy of some Middle to Late Miocene Sediments, Coastal Swamp Depobelts, Western offshore Niger Delta.” International Journal of Science and Technology, 2 (1): 18-27.

Adeigbe, O.C., Oduneye ,O.C., Yussuph, I.A & Okpoli, C.C., (2012), “Late Miocene-Pleistocene Foraminiferal Biostratigraphy of Well Eb-1 and Eb-2 2 Offshore Depobelt, Western Niger Delta, Nigeria.” Int. Journal of Applied Sciences and Engineering Research, Vol. 2, No. 3,pp. 382-397

Armentrout, J. M. (1995). “High Resolution Sequence Biostratigraphy: Examples from the Gulf of Mexico, Pliocene-Pleisstocene.” Geological Society Special Publication. 104, 65-86.

.Beka, F.T., A. A. Balkem, Postma G. & M. N. Oti, (1995). “The Distal Offshore Niger Delta: Frontier Prospects of a Mature Petroleum Prov-ince.” Geology of Del-tas, Eds. Rotterdamc, pp. 237-241.

Berggren, W.A, Kent, D.V, Swisher, C.C & Aubry, M. (1995), “A revised Cenozoic Geochronology and Chronostratigraphy.”

Blow, W. H. (1969), “The Late Middle Eocene to Recent Planktonic Foraminiferal Biostratigraphy.” Geneva, First Planktonic International Conference Proceedings., 119-422.

Bolli, H. M. & Saunders J. B. (1985), “Oligocene to Holocene Low Latitude Planktic Foraminifera, Plankton Stratigraphy”. Bolli, H. M., Saunders, J. B. and Perch Nielsen, eds. Cambridge Earth Science Series. Cambridge University Press, 165-262.

Doust, H., Omatsola.E., Edwards, J. D. & Santogrossi, P. A. (1990), “Divergent / Passive Margin Basins. American Association of Petroleum Geologists.” Eds. Memoir, 48, 201-238.

Ekweozor, C. M. & Daukoru, E. M. (1984), “Petroleum source bed evaluation of Tertiary Niger Delta reply.” American Association of Petroleum Geologists Bulletin, 68, 390-394.

Evanmy D. D. Harembaure, J., Kamerling, P., Knapp, W. A., Molly, F. A., & Rowlands, P. H., (1978). “Hydrocarbon Habitat of Tertiary Niger Delta.” American Association of Petroleum Geologist Bulletin, 62, 1-39.

Embry, A. F., (2009), “Practical Sequence Stratigraphy, Canadian Society of Petroleum Geologist.” Online at www.cspg.org, 79 p.

Esan, A.O., (2002). "High resolution sequence stratigraphic and reservoir characterization studies of D-07, D-08 and E-01 sands, Block 2 Meren Field, Offshore." Niger Delta: Publ. M.S. Geology Thesis, Texas A & M University, Texas, USA, 115 pp.

Galloway, W.E.(1989), "Genetic stratigraphic sequences in basin analysis 1: Architecture and genesis of flooding-surface bounded depositional units". American Association of Petroleum Geologists Bulletin 73, 125142.

Haq, B. U. Hardenbol, J. & Vail, P. R. (1988),"Meozoic and Cenozoic Chronostratigraphy and Cycles of Sea Level Change". Sea Level Changes: An Integrated Approach, 42, SEPM Special Publication, 42, 72-108

Imasuen, I.O. Okiotor, M.E; & Etobro, A.A.I., (2011), "Reservoir Evaluation of Well A, Field Y, North- Eastern Niger Delta: A Case of Problematic sandstone." Advances in Applied Science Research, 2 (3):pp.114-126.

Kulke, H. (1995), "Nigeria", Regional Petroleum Anarctica, Gebruder Borntraegar, Belin, (pp. 143-172).

Neal, J., Risch, D & Vail, P. (1993), "Sequence Stratigraphy - A Global Theory for local success". USA: Rice University, Huston, Texas,

Ojo, A.O & Gbadamosi, A. O. (2013), "Sequence Palyno - stratigraphical study of DEL-2 Well, Southwest of Niger Delta basin." Nigeria: Research Journal in Enginerering and Applied Science. 2 (2) :86-94

Okosun, E. A. & Liebau A. (1999), "Foraminifera / Biostrategraphy of Eastern Niger Delta, Nigeria." Nigerian Association of Petroleum Explorationists, 14 (2): 136- 156.

Oyedele K. F., Oladele S., Ogagarue, D.O. & Bakare K. (2012), "Sequence stratigraphic approach to hydrocarbon exploration." Journal of Petroleum and Gas Exploration Research, 2(6): pp.106-14. (

Oyedele, K. F., Ogagarue, D. O. & Mohammed, D. U. (2013), "Integration of 3D Seismic and Well log Data in the Optimal Reservoir Characterisation of EMI Field, Offshore Niger Delta Oil Province." Nigeria: American Journal of Scientific and Industrial Research,4 (1):11-21

Onyekuru, S. O., Ibelegbu, E. C., Iwuagwu, J. C., Essien, A. G., & Akaolisa C. (2012), "Sequence Stratigraphic Analysis of XB Field, Central Swamp Depobelt, Niger Delta Basin, Southern Nigeria." International Journal of Geoscience, 3:237-257.

Ozumba, M.B & Amajor ,L.C (1999), "Middle to Late- Miocene Biozonation of Western Niger Delta." Nigerian Association of Petroleum Explorationist NAPE,14 (2) :165-175

Short, K. C & Stauble, A. J. (1967). "Outline of Geology of Niger Delta." American Association of Petroleum Geology. 51, 761-779.

Tuttle, M. L., Charpentier, R. R. & Brownfield, M. F. (1999), "The Niger Delta Petroleum System: Niger Delta Province, Nigeria, Cameron and Equatorial Guinea, Africa." United State Geological Survey Open file report 99 50H

Van Wagoner, J. C., Posamentier, H. W., Mitchum, R. M, Vail, P. R., Sarg, J. F, Loutit, T. S. & Hardenbol, J. (1988), "An Overview of the Fundamentals of Sequence stratigraphy and key Definitions". Sea Level Changes: An Integrated Approach, Vol. 42, SEPM Special publication, (pp. 39-46).

Weber, K. J. & Daukoru (1975), "Petroleum Geology of the Niger Delta." 9th World Petroleum Congress Proceedings, Tokoyo, (2), pp. 209-221.