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# SEQUENCE STRATIGRAPHY ANALYSIS AND RESERVOIR CHARACTERIZATION OF THREE WELLS IN UH OIL FIELD NIGER DELTA BASIN Nigeria

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## Abstract
Three wells in UH field of Niger Delta were studied to erect sequence stratigraphy framework and hydrocarbon reservoir potential within the Niger Delta Basin. Biostratigraphy data (foraminifera and palynology), wireline logs and paleobathymetry data were used in this study. Thirteen major stratigraphic bounding surfaces (seven depositional sequence bounded by eight sequence boundaries (SB) 13.1 Ma to 3.7Ma which mark the onset of marine flooding and turnarounds from progradational facies to retrogradational facies during sequence buildup were delineated. Seven maximum flooding Surfaces (MFS) 12.8Ma to 3.9 Ma which characterized by marker shales, high faunal abundance and diversity were identified and correlated along the strike line of three wells base on their stratigraphic surfaces and relative age which showed sequence thickening from landward to basinward region. The delineated sequences comprise of lowstand system tract (Progradational packages), Transgressive system tract (Retrogradational packages) and High stand system tract (Aggradational packages) which reflect depositional systems deposited during different phases of sea level rise and fall. The delineation of paleoenvironment using biofacies and wireline logs showed delta plain to open shelf. Paleobathymetry panel indicated that the sediment were deposited within inner neritic to Bathyal environment dated Mid-miocene to late Miocene (12.8Ma-3.9Ma) in age. These integrated interpretations suggest that the sequences may hold potential source, reservoir and seal rocks for hydrocarbon exploration.

**Keywords:** Sequence Stratigraphy, Depositional Sequence, Biostratigraphy, Maximum Flooding Surface, Sequence Boundary and System Tract.

## 1 Introduction
Sequence stratigraphy technique applied in several sedimentary basins in the world has led to the discovery and recovery of more hydrocarbon reserves. In the north Central Gulf of Mexico this technique has improved reservoir development and management strategies, provided insights into basin fill history, and contributing to the ongoing exploration successes in the basins (Uwajingba 2021). (Embry 2009), defined it as the recognition and correlation of stratigraphic surfaces which represent changes in depositional trends in sedimentary rocks. Such changes were generated by the interplay of sedimentation, erosion and oscillating base level and are now determined by sedimentological analysis and geometric relationships.

Previous sedimentological, biostratigraphical and sequence-stratigraphic studies (Chiaghanam 2011) revealed the combined influence of eustatic cyclicity and local tectonics. Depositional sequences consist of strata bounded by unconformities and their lateral equivalents are only recognized in specific sectors of the delta, and in contrast, delta - wide genetic sequences as defined by Galloway (1989) are more readily identifiable in the Niger Delta (Reijers, 2011).



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At the turn of the century, the rate of oil production far outweighs the rate of discovery of new oil fields (Uwajingba 2021). Recently, low oil price in the international market has forced most of the oil fields generating below optimum production capacity to be abandoned presently. Nevertheless, new technologies and emerging techniques are encouraging oil and gas companies and institutions to re-appraise most of these abandoned fields with in the central to coastal swamp depobelt. It is hoped that this new technique such as Sequence stratigraphy plays a big role in increasing the hydrocarbon reserve base in Niger Delta Basin Nigeria.

This study focuses on utilizing biofacie data with wireline logs to erect a sequence stratigraphic framework to delineate the sequence stratigraphic surfaces, depositional sequence, system tracts and their genetic correlation for lateral reservoir continuity within the three wells of the early Miocene to late Pliocene sediment of the UH-field (Niger Delta Basin). It is important to adopt this approach in evaluating reservoir characteristic of hydrocarbon fields in the Niger Delta Basin, targeted at drastically reducing uncertainties associated with hydrocarbon low production rate.

## 2. Study Area

The study area of these three wells (X, Y, Z) in UH field occupies the offshore of Niger Delta. The field location and the respective well distances are within Latitude: $5^0$E, $4^0$ N, Longitude $5^0$E ,$2^0$E see fig. 1. A total number of three wells were used in this research work.

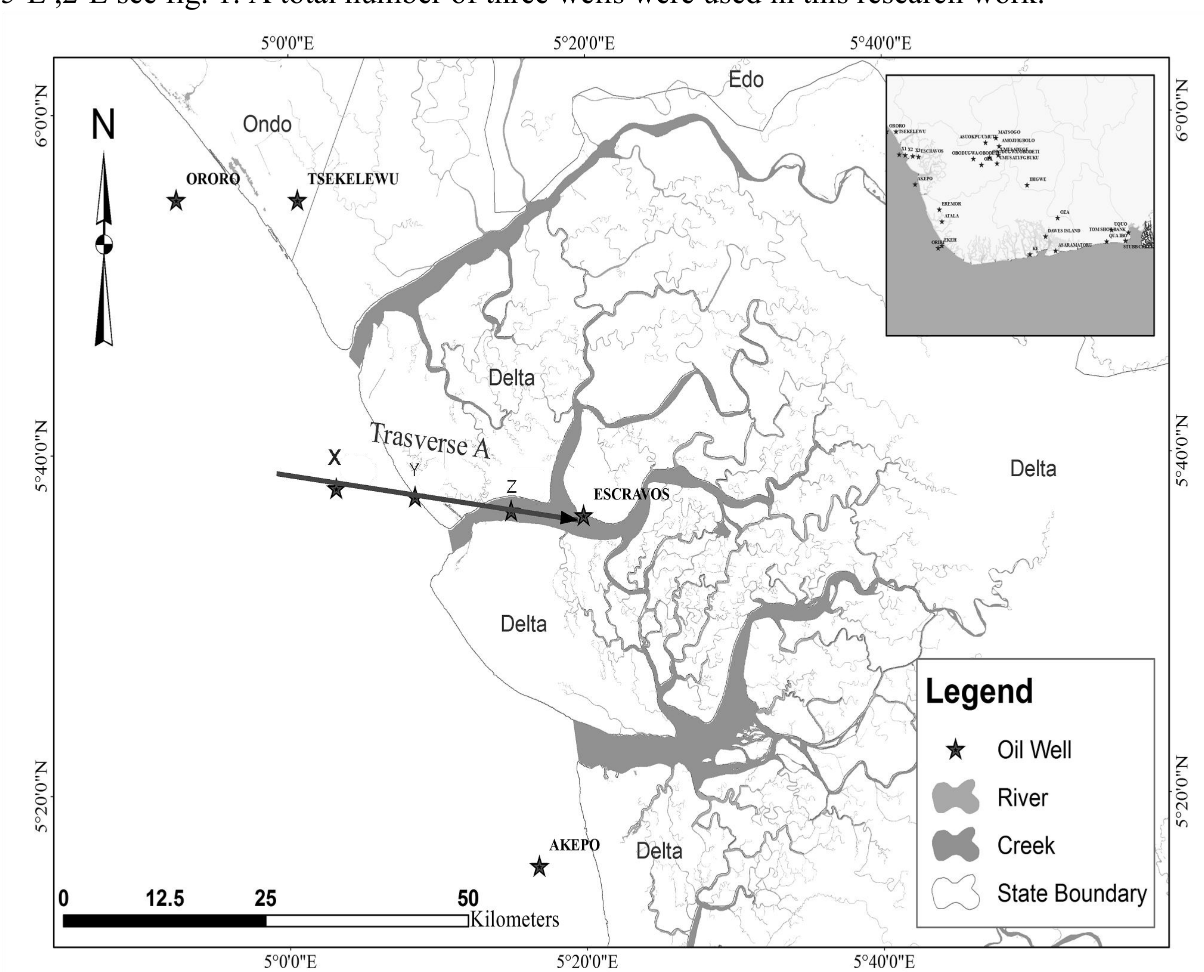


Fig.1: Map of the Study Area



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## 3. Geology and Stratigraphy

Geographically, Niger Delta is located between longitude 5degrees and $8^0$ North and latitude $3^0$ and $6^0$ respectively (see fig.1). It occupies the Gulf of Guinea continental margin in equatorial West Africa. This basin however, occupies a total of about 7,500km$^2$ in the Gulf of Guinea with a sediment thickness up to 12,000 meters. (Slat 2006). Uwajingba (2021) documented that the sedimentary basin of the Niger Delta encompasses a much larger extent region than the modern delta constructed by the Niger -Benue drainage system. This includes the Cross River delta and further extends eastwards into the continental margins of neighboring Cameroun and Equatorial Guinea sub - environments. The sedimentary wedge of the Niger Delta contains a major submarine part (Reijers, 2011) which forms part of the complex continental margin intruding into the Gulf of Guinea. The recent sedimentary environments of the Niger Delta serve as a classic model for high energy, Wave-dominated, constructional arcuate-lobate tropical deltas (Reijers et al., 2011). The Niger Delta is built in a series of depocenters extending over the continental edge and onto the oceanic basement. It consists of predominantly regressive sequence ranging in age from Eocene to Recent (Khani and Back, 2012). Sediments of cretaceous age have been noted to underlie the Niger Delta complex. However, the sediments stepwise out-building of the delta has been explained by the Escalator-Regression Model.

## 4. Methodology.

Wireline logs consisting of Gamma ray (G-R) and Deep Induction logs were analysed for this research to interpret the lithology and containing fluid in the well. Biofacies analysis were also carried out which provide detailed information on fossil abundance/diversity, Foraminifera and biozonations, plantics and benthics with few shale marker species present which were used to establish the genetic age of the stratigraphic surfaces. Stratigraphic bounding surfaces, which includes the maximum flooding surfaces (MFSs) dated with marker shales and sequence boundaries (SBs) were tied to well-defined foraminiferal (F) biozones, palynology (P) zones. The Niger Delta chronostratigraphic chart was used to calibrate and delineate systems tracts, stacking patterns which was supported by log–motifs/signatures in the three wells were utilized for the interpretation and correlation of the component system tracts across the field.

## 5. Interpretation

Sequence Stratigraphic analysis of the three wells (X, Y and Z) within the coastal swamp depobelt of the Niger Delta Basin enabled subdivision into depositional sequences, system tracts and depositional cycles. This has shown that the three selected wells within the western offshore Niger Delta fall between Middle –Late Miocene age. The integration of the data sets has facilitated the understanding of the process that generated the vertical stratigraphic succession of sediments and lateral facie changes which are the characteristics feature of the system tracts. Seven major depositional sequences were identified in well X and Y (see table 1 and 2), then three depositional sequences in well Z (see table 3) which consist transgressive system tract, high stand systems tracts. Six sequence boundaries and seven maximum flooding surfaces in well X and Y (see table 1 and 2), then three sequence boundaries and maximum flooding surfaces were also delineated in well Z (see table 3). Using the marker shales which shows high faunal content with the gamma ray log motif and low faunal abundance and log signature for sequence boundary which is supported with Paly event. Applying (SPDC CYCLES, of Niger Delta 1998) the key bounding surfaces were found to be within eight, nine to eleven cycles. The structural setting of the field indicates a fault line depositional model and also displacement of sediments,


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which clearly suggest that as one moves from coastal to offshore region (X to Y) the key surfaces identified is thinning basinward and thickening landwards as a result of Overburden pressure of sediment deposition.

**Table 1. Stratigraphic Summary Table in well X**

| Interval (ft) | Lithology | Stacking pattern/ log motif | System Tract | Depositional Sequence | Depth/ type of chrono - surface. | Date of chrono – surface (Ma, Haq et al, 1988)/ Remarks. |
|---|---|---|---|---|---|---|
| 5500 – 5320 | Shale/sand | Retrogradation (FU)Finning upward Bell shape | TST | 7 | 5320 - MFS | 5.0 (High GR and Low Resistivity log values). |
| 6220 – 5500 | Stacks of sand/shale + silt intercalations | Aggradation (CU) Blocky Gamma ray log motif. | LST | | - | Sudden deflection of GR log to the left (High GR) = renewed transgression. |
| 6940 – 6220 | Sand/shale | Progradation (CU) | HST | 6 | 6220 - SB | 5.6 (High resistivity and low GR Log motif values). |
| 7480 – 6940 | Shale/sand | Retrogadation (FU) Finning upward Bell shape | TST | | 6940 - MFS | 6.0 (High GR and Low Resistivity log values). |
| 8020 – 7480 | Sand/shale | Progradation (CU) coarsening upward Funnel shape | HST | 5 | 7480 - SB | 6.7 (High resistivity and low GR Log motif values). |
| 8500 – 8020 | Shale/sand | Retrogadation (FU) Finning upward Bell shape | TST | | 8020 - MFS | 7.4 (High GR and Low Resistivity log values). |
| 8920 – 8500 | Sand/shale | Progradation (CU) coarsening upward Funnel shape | HST | 4 | 8500 - SB | 8.5 (High resistivity and low GR Log motif values). |


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|---|---|---|---|---|---|---|
| 9460 – 8920 | Shale/sand | Retrogadation (FU) Finning upward Bell shape | TST | | 8920 - MFS | 9.5 (High GR and Low Resistivity log values). |
| 10060 – 9460 | Sand/shale | Progradation (CU) coarsening upward Funnel shape | HST | 3 | 9460 - SB | 10.35 (High resistivity and low GR Log motif values). |
| 11500 – 10060 | Shale/sand | Retrogadation (FU) Finning upward Bell shape | TST | | 10060 - MFS | 10.4 (High GR and Low Resistivity log values). |
| 11980 – 11500 | Sand/shale | Progradation (CU) coarsening upward Funnel shape | HST | | 11500 - SB | 10.6 (High resistivity and low GR Log motif values). |
| 12370 – 11980 | Shale/sand | Retrogadation (FU) Finning upward Bell shape | TST | 2 | 11980 - MFS | 11.5 (High GR and Low Resistivity log values). |
| 13330 – 12370 | Sand/shale | Progradation (CU) coarsening upward Funnel shape. | HST | 1 | 12370 - SB | 12.1 (High resistivity and low GR Log motif values). |
| 13570 – 13330 | Shale/sand | Retrogadation (FU) Finning upward Bell shape. | TST | | 13330 - MFS | 12.8 (High GR and Low Resistivity log values). |


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**Table 2: Sequence Stratigraphic Summary table in Well Y**

| Interval (ft) | Lithology | Stacking pattern/ log motif | System Tract | Depositional Sequence | Depth/ type of chrono - surface. | Date of chrono – surface (, Haq et al, 1988)/ Remarks. |
|---|---|---|---|---|---|---|
| 4440 – 3990 | | | HST | 7 | | - |
| 5300 – 4440 | Shale/sand | Retrogradation (FU) Finning upward Bell shape | TST | | 4440 - MFS | 3.9(High GR and Low Resistivity log values). |
| 5760 – 5300 | Sand/shale | Progradation (CU) coarsening upward Funnel shape | HST | 6 | 5300 - SB | 4.1 (High resistivity and low GR Log motif values). |
| 6660 – 5760 | Shale/sand | Retrogradation (FU) | TST | | 5760 - MFS | 5.0(High GR and Low Resistivity log values). |
| 7020 – 6660 | Sand/shale | Progradation (CU) | HST | 5 | 6660 - SB | 5.6(High resistivity and low GR Log motif values). |
| 7680 – 7020 | Shale/sand | Retrogradation (FU) | TST | | 7020 - MFS | 6.0(High GR and Low Resistivity log values). |
| 8040 – 7680 | Sand/shale | Progradation (CU) | HST | 4 | 7680 - SB | 6.7(High resistivity and low GR Log motif values). |
| 8160 – 8040 | Shale/sand | Retrogradation (FU) | TST | | 8040 - MFS | 7.4(High GR and Low Resistivity log values). |


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| | | | | | | |
|---|---|---|---|---|---|---|
| 8340 – 8160 | Sand/shale | Progradation (CU) | HST | 3 | 8160 - SB | 8.5(High resistivity and low GR Log motif values). |
| 8940 – 8340 | Shale/sand | Retrogradation (FU) | TST | | 8340 - MFS | 9.5(High GR and Low Resistivity log values). |
| 9300 – 8940 | Sand/shale | Progradation (CU) | HST | 2 | 8940 - SB | 10.35(High resistivity and low GR Log motif values). |
| 9900 – 9300 | Shale/sand | Retrogradation (FU) | TST | | 9300 - MFS | 10.4(High GR and Low Resistivity log values). |
| 10550 – 9900 | Sand/shale | Progradation (CU) coarsening upward Funnel shape | HST | 1 | 9900 - SB | 10.6(High resistivity and low GR Log motif values). |
| 11250-10660 | Shale/sand | Retrogradation (FU) Finning upward Bell shape | TST | | 10660 –MFS | 11.5(High GR and Low Resistivity log values). |


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**Table 3: Sequence Stratigraphic Summary table in Well Z**

| Interval (ft) | Lithology | Stacking pattern/ log motif | System Tract | Depositional Sequence | Depth/ type of chrono - surface. | Date of chrono – surface (Ma, Haq et al, 1988)/ Remarks. |
|---|---|---|---|---|---|---|
| 3640 – 2710 | | | LST | | | - |
| 5650 – 3640 | Sand/shale | Progradation (CU) coarsening upward Funnel shape | HST | 3 | 3640 – SB | 6.7(High resistivity and low GR Log motif values). |
| 6630 – 5650 | Shale/sand | Retrogradation (FU) Finning upward Bell shape | TST | | 5650 – MFS | 7.4(High GR and Low Resistivity log values). |
| 7050 – 6630 | Sand/shale | Progradation (CU) | HST | 2 | 6630 – SB | 8.5(High resistivity and low GR Log motif values). |
| 8060 – 7050 | Shale/sand | Retrogradation (FU) | TST | | 7050 – MFS | 9.5(High GR and Low Resistivity log values). |
| 8420 – 8060 | Sand/shale | Progradation (CU) coarsening upward Funnel shape | HST | 1 | 8060 – SB | 10.3(High resistivity and low GR Log motif values). |
| 9750 – 8420 | Shale/sand | Retrogradation (FU) Finning upward Bell shape | TST | | 8420 – MFS | 10.4(High GR and Low Resistivity log values). |

There is uplift of sediment from the offshore towards the coastal swamp along the strike line within the three wells. This displacement is attributed to rollover fault systems, which are characteristics of the Niger Delta Basin.

**Depositional Cycle.**

A sedimentary cycle represents a direct link between geological concept, sedimentary process and the formation of stratigraphic sequences. The study of cyclic depositional patterns in the geologic record produced by climatic and tectonic process called Cyclostratigraphy consists of series of stacked coarsening upward or fining upward sequences representing regressive or transgressive events within a basin. The causes of this can be attributed to eustatic sea level, orbital climatic or tectonic effects, time span, volume of supplied sediments and accommodation space, which affect sedimentary sequences and sedimentary cycle. Therefore, a relationship exists between sedimentary cycle concept and sequence stratigraphy.

**Cycle 8 (Middle Miocene F9500 – P740)** is marked by MFS (12.8Ma) Marker shale and is recognized only in well Z at depth 13330ft. **Cycle 9 (Middle Miocene F9500/F9600 – P770)** This cycle is marked by MFS (11.5Ma) marker shale which was observed in well X at depth 11980ft and at depth 10560ft at well Y respectively. **Cycle 10 (Middle Miocene –Late Miocene, F9600/F9700-P780-P870)** The cycle is marked by MFS 10.4Ma, 9.5Ma, 7.4Ma, and 6.0Ma marker shale in well X and Y, in well Z it occurred at MFS 7.4Ma and 5.0 Ma. **Cycle 11 (Late Miocene, F9800/F9900- P860-P880).** This cycle is marked by MFS (5.0Ma) marker shale in well X and MFS 5.0Ma, 3.9Ma respectively.

## 5 Conclusion

Biostratigraphy approach in this sequence stratigraphic study has help in elucidating the chronostratigraphic ages and zones in the analysed wells, X, Y and Z. The delineations of zones (F9500/P780 – F9900/P880) and ages (Mid Miocene – Late Miocene) have been achieved by the use of the recovered benthic and planthic taxa from the analysed wells. The log signatures (Gamma ray and Deep Induction on Resistivity) couples with the lithology description of the ditch cuttings has unveiled the respective formations penetrated by the X, Y and Z wells. The depositional sequences experienced major flooding episodes characterized by high faunal population and diversity. In each sequence, the lowermost sections were marked by deposits arising from relatively low sea level, forming channels and slope complexes. The middle sections were deposited during a generally high relative sea level, while the uppermost sections were deposited during gradual drops in relative sea level lowering (Highstand). These inferred variations in relative sea level defined third order depositional systems that comprised Lowstand Systems Tract (LST) at the base of the section, Transgressive Systems Tract (TST) in the middle of the section and the Highstand Systems Tract (HST) at the top of each section. Correlation across the X, Y and Z wells indicates that the stratigraphic column appears to be dipping in a North-South / Northeast direction and striking in the East-West direction.

Deposition tends to be thicker in well Z which was located updip. The occurrence of the identified chronostratigraphic surfaces at different depths along dip and strike lines in the studied wells shows evidence of faulting within the wells. This is attributed to rollover fault systems, which typical characteristics of Niger Delta Basin. In terms of hydrocarbon exploration, the sand units of the LST and HST formed the basin floor fans, channel and shore face sands of the delta. The high resistivity log values revealed that they are potential hydrocarbon reservoirs. The shales of the transgressive system tract (TST) in which most of the Maximum flooding surfaces (MFS) were delineated could form seals to the reservoir units. A combination of the reservoir sands of the low stand system tract (LST) and high stand system tract (HST) and the shale units of the TST form good stratigraphic traps for hydrocarbon and hence should also be targeted during hydrocarbon exploration and production. Paleobathymetry maps suggest generally, that sediments were deposited within Neritic to Bathyal environments at different times, aligning with the progradational pattern of deposition of the Niger Delta. Gross Depositional

Environment spans through incised Canyons, Channels, Inner Mid Shelf, Shelf Margin and Slope Margin.

**References**

Chiaghanam, O.I. Ozumba, B.M., Ladipo, K, Orajaka, I.P Ofoma, A.E. and Chiadikobi, K.C., (2011). The role of accommodation/Sediment supply regime/basin morphology in Predicting coastal depositional style: A sequence stratigraphic framework approach for selected deep wells of Oligocene /Miocene sediments of coastal swamps in Niger Delta. *Archives of applied science research 3(5):*

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

Galloway, W.E., (1989). Genetic Stratigraphic sequences in basin analysis: architecture and genesis of flooding surface bounded depositional units. American Association of Petroleum Geologists Bulletin. 73: 125-142.

Haq, B.U., Hardenbol, J. & Vail, P.R., (1988). Mesozoic and Cenozoic Chronostratigraphy and eustatic cycles. In: C.A. Wilgus, B.S. hastings, C.G. St. kendail, H.W. Posamentier, C.A. Ross and J.C. Van Wagoner (eds) Sea-level changes: An integrated Approach. *Gulf Coast Section Society of Economic Paleontologists and Mineralogists. 42(18), 40-45.*

Khani, H.F. and Back, S., (2012). Temporal and lateral variation in the development of growth faults and growth strata in western Niger Delta. *American Association of Petroleum Geologists Bulletin. 96(4): 595 – 614.*

Reijers, T.J.A. (2011). *Stratigraphy and Sedimentology of the Niger Delta. Geologos*. The Netherlands, 17(3), 133-162.

Slatt, R.M. (2006). Stratigraphic Reservoir Characterization, Handbook of Petroleum Exploration and Production, Elsevier. The Netherlands. P.379-422.

Uwajingba H.C. (2021). Sequence Stratigraphy of Early Miocene to Late Pliocene Sediment Of The Niger Delta Basin unpublished Ph.D. Thesis Chukwuemeka Odumegwu Ojukwu University Uli.

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