International Journal of Multidisciplinary Comprehensive Research

Sequence Stratigraphy and Facies Description of Depositional Environments in a Niger Delta Basin “X” Field from the Analysis of Well Log Data

Adizua OF [1*], Agoha CJ [2], Eyo AJ [3]
[1, 2] Geophysics Research Group GRG, Department of Physics (Applied Geophysics Option), Faculty of Science, University of Port Harcourt, River State, Nigeria
[3] ExxonMobil Nigeria Unlimited, Qua Iboe Terminal, Ibeno, Akwa Ibom State, Nigeria

* Corresponding Author: **Adizua OF**

Article Info

ISSN (online): 2583-5289
Volume: 02
Issue: 02
March-April 2023
Received: 15-03-2023;
Accepted: 16-04-2023
Page No: 40-47

Abstract
Sequence stratigraphy is a technique used in dividing, analyzing and mapping sedimentary rocks. It is a process that involves the interpretation of sedimentary packages and entails an understanding of depositional processes and the factors that directly influence them such as sea level changes, subsidence rates sediment supply, climatic conditions and basin geometry, thus allowing one to describe and predict their occurrence, extent, geometry and economic importance to sedimentary facies. The sequence stratigraphy and facies analysis of an “X” field located in the Niger Delta Basin was carried out to enable the description of the depositional environments, which could be of great importance while generating a regional facies model, which in turn enables one to study properly the general summary of a specific sedimentary environment to guide exploration and field development objectives. The aim of the study entailed using well log data in establishing the sedimentary facies, their successions and environments of deposition as well as to determine the sequence stratigraphy of the prospect “X” field. The method of analysis involved identification and correlation of facies by log signatures. A total of four log facies were recognized in the study area; funnel-shaped facies representing a deposition of cleaning upward sediment or an increase in the sand content of the turbidite bodies; a cylindrical-shaped facies representing slope channel-fills and turbidite fans; a bell-shaped facies which is indicative of a transgressive marine shelf and the serrated/irregular shaped facies which has no character, representing aggradation of shales or silts. Each of the types of facies identified had its own sediment supply and characteristic which provided a stratigraphical framework for environment of deposition description and interpretation. The results from the four wells (Well 010, Well 005, Well 007, Well 011), showed that the two main identified lithologies across the Niger Delta Basin “X” field were sandstones and shale. The sequence stratigraphic analysis revealed also a lithology of alternating sandstones and shale. Sequence boundaries and maximum flooding surfaces were equally identified in the field. The results achieved would enhance the exploration and field development planning objectives in the prospect “X” field.

Keywords: Well Logs, Maximum Flooding Surface, Sequence Boundary, Facies Description, Environment of deposition, Depositional Sequence, Sequence Stratigraphy s

1. Introduction

Sequence stratigraphy is the study of sedimentary rocks within a chronostratigraphic framework of repetitive, genetically related strata bounded by surfaces of erosion or non-deposition and their correlative conformities. Facies analysis provides useful information in paleoenvironmental reconstruction. The criteria commonly used to identify facies on the logs are based upon characteristic shapes and changes in the log curves. A sharp shift in the curve is indicative of an abrupt bed boundary and highly contrasting depositional energies. Geophysical logs provide a complete vertical profile of the borehole and also yield to the interpreter curve shapes and features representative of depositional facies. Some of these features include fining upward sequences, which is an indication of a decreasing depositional energy towards the top of the units, coarsening upward sequences, which is an indication of an increasing energy of deposition up section and uniform sequences, which is an indication of more uniform massive bedding and consistent depositional energy within the bed (Iwuoma and Ogidi 2016) [7].

Facies is the aspect, appearance and characteristics of a rock unit, usually reflecting the conditions of its origin; especially as differentiating it from adjacent or associated units (Bates and Jackson, 1984) [2]. Facies classification is primarily used for integrating datasets of differing scales, for example, rock sample data with well log data. Various techniques are available to define facies including using neural networks or cluster analysis, computer-based classification, and manual interpretation. Core and well log facies are routinely employed at a field scale for static reservoir modeling during development evaluation. However, in petroleum exploration, we rarely conduct facies classification at a regional scale because of incomplete, inconsistent datasets and variable rock properties. Studies that have applied facies classification to exploration wells are typically calibrated with extensive conventional core. Also, interpreting depositional facies considering the shape of well-log curve has been shown to directly relate to the grain size of rock successions (Yemets *et al*., 2021) [13]. A lot of information about the sediments and sedimentary processes is embedded in well log data. Sediments in different paleoenvironments display characteristic log motifs. As a result, borehole logs are widely used to interpret sedimentary facies (Weber, 1971) [11]. Such log facies may be used to describe the reservoir section in a well that has been logged but has not been cored (Gluyas and Swarbrick, 2004) [6]. Our study will be based on interpretation of well logs in order to establish correlation units within the prospect. This is adopted to divide the rock units into various environment of deposition and their chronostratigraphic surfaces (Maximum Flooding Surfaces and Sequence Boundaries) using well logs as time lines to these surfaces penetrated by the wells.

Sequence stratigraphy is based on the recognition of hierarchy of strata units including beds, bedsets, parasequences and sequences bounded by chronostratigraphically significant surfaces of erosion, or correlative surfaces (Embry, 2009) [4]. The best stratigraphic model of a sedimentary fill of a basin is provided by well logs and outcrops studies which provide access to a detailed vertical resolution of sedimentary sections. Depositional environments are critical factors in analyzing reservoir geology of a field. They have a strong impact on hydrocarbon accumulations and their constituents. Depositional facies impact both hydrocarbon storage and flow because they often directly govern porosity and permeability of the formation. The Niger Delta Basin has spectacularly maintained a thick sedimentary apron and salient petroleum geological features favorable for petroleum accumulation from the onshore through the continental shelf and to the deep water offshore terrains. Depositional history of the Niger Delta Basin is an indication of the basement response to sea-level variation, tectonics activities, sediment supply and climate change (Oyedele *et al*., 2013) [8]. The depositional and environmental factors are responsible for the cycles of sediment and depobelt formed in different parts of the basin. The accumulated sediment during each cycle is known as depositional sequence (Embry *et al*., 2007) [5]. Facies recognition using well logs is a useful means for interpreting the depositional settings of any given area. The types of depositional facies determine the volume and type of hydrocarbon resource and evaluate reservoir production performance. There is need to properly and adequately evaluate reservoirs and their depositional facies in order to determine the producibility of a field.

The objective of this paper therefore, is to perform sequence stratigraphy and facies description of the depositional environment for a prospect Niger Delta Basin "X" field, from the analysis of well log data acquired from the prospect. The significance of this study is to use sequence stratigraphy and facies description to delineate lithology, map potential reservoir units within the prospect field, infer the environment of deposition based on log responses and facies descriptions as well as determine sequence boundaries and maximum flooding surfaces which would optimize the process of building the regional sequence stratigraphic and facies models of the prospect "X" field.

2. Geologic Settings of the Niger Delta Basin

The Niger Delta sedimentary Basin is a product of triple junction phenomenon comprising the Gulf of Guinea, South Atlantic Ocean and Benue depression. The formations in the tertiary Niger Delta Basin include the Agbada and Benin Formations to the North with a transition to the Akata Formation in the deep water portion of the Basin where the Agbada and Benin Formations thin out and disappear seaward. The Akata Formation at the base of the Delta is of marine origin and is composed of thick shale sequences (potential source rock), turbidite sand (potential reservoirs in deep waters), and minor amounts of clay and silt. The Agbada Formation which overlies the Akata Formation, consists of unconsolidated to slightly consolidated paralic siliciclastic sequence of sandy unit with minor shale intercalations of about 4500m thickness (Weber and Daukoru, 1975) [12]. The Benin Formation marks the upper most unit of the Deltaic complex and consists mainly of 2000m thick fresh water-bearing massive continental sands and gravels which are deposited in the upper deltaic plain environment. The sands are yellowish brown or white in colour due to the presence of limonite, haematite and feldspars. Brackish water and marine faunas are absent in this formation. Reyment (1965) [9] considered the formation to be partly marine, partly deltaic, partly estuarine, partly lagoonal and partly fluvio-lacustrine in origin but in a continental and upper deltaic environment.

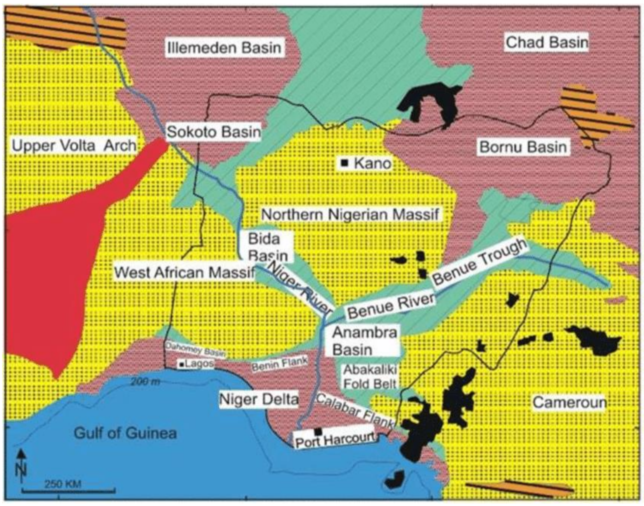


Fig 1: Map of Nigeria showing the location of the Niger Delta Basin in relation to other basins within and around the country.

3. Overview of the gamma ray log operation and its interpretational guide

The Gamma ray logging tool detects naturally occurring gamma rays along logged intervals or paths. The gamma rays are detected as pulses that are transmitted to the surface where they are converted to electrical voltages and are recorded continuously as the downhole logging tool known as the sonde is pulled up the hole. The gamma ray emissions are produced by three radioactive series which are located in the earth's crust (Adizua, 2019) [1]. Gamma-ray logging is highly useful in distinguishing impermeable rocks such as shale from other permeable rock types such as sandstones. Gamma ray logs are the predominant log type used for this study, hence the need to provide an interpretational guide to how measurements taken from the log where used to achieve the focal objectives for the study. A deflection towards the right on a gamma ray log usually signifies an increase in radiation and vice versa, while deflection to the extreme right indicates shaly formation. The parts of the curve with less deflection indicate non-shale lithologies such as limestone and sandstone. The gamma-ray log is used principally for bed definition, correlation, and determination of lithofacies because of its shale-distinguishing feature or characteristic. The high penetrating power of gamma rays permits logging in cased or uncased holes, regardless of the nature of the fluid, if any, in the hole. The log is usually calibrated from 0 to 150 API on a linear scale. Gamma rays passing through rocks are slowed down and absorbed at a rate which depends on how dense the formation is. A less dense formation usually exhibits more radioactivity than a dense formation.

4. Dataset, data processing tool and research workflow

The data sets for this study comprised mainly of well log (gamma ray log) data acquired from the prospect "X" field. The gamma ray log data was procured from four wells within the prospect and named for purposes of identification and reference in this research paper as Well 010, Well 005, Well 007 and Well 011. The log data was edited, corrected after which it was imported and loaded to ensure quality control. Interpretation of well logs and well log correlation were achieved using Schlumberger's (Petrel E&P 2014) software. The gamma ray logs of the four wells were first placed at an equal depth in order to facilitate correlation. The depth measurement was considered in Mean Depth (MD) value. Matching of similar lithologies was then carried out from well to well using the top and bottom horizons as controls. Similar features in terms of gamma ray signatures were marked. Well logs for Wells 010, 005, 007 and 011 were placed side by side and correlated to determine their depositional environment. The research workflow was implemented with the following steps and as listed in the flow chart of Figure 2.

1. Uploading the well log data to the tool (Petrel E&P 2014).
2. Filtering the well log data for possible errors and performing routine quality control (QC) checks.
3. Well log analysis and interpretation to delineate the different lithologies.
4. Correlation of sand units.
5. Performing a detailed sequence stratigraphic analysis across the wells.
6. Identification of reservoirs and identification of lithofacies from well log signatures.

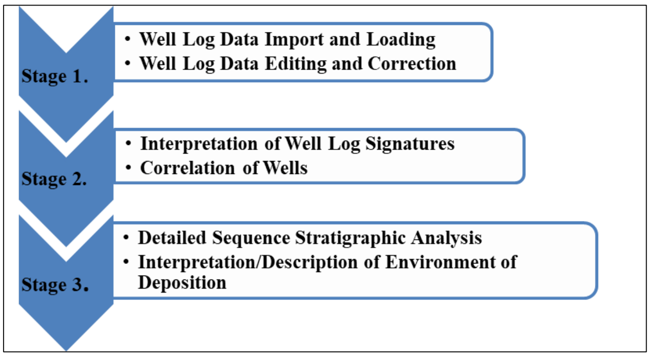


Fig 2: Flow chart showing the research workflow.

5. Results and Discussion

The results from the analysis of the gamma ray log data of the four wells (Wells 010, 005, 007 and 011) showed that the two main lithologies across the Niger Delta Basin 'X' field were sandstones and shale. This result is in conformity/agreement with the Niger Delta geology. The gamma ray log shapes and depositional settings adapted from Cant (1992) [3] in Figure 3, aided in the interpretational aspects of the work.

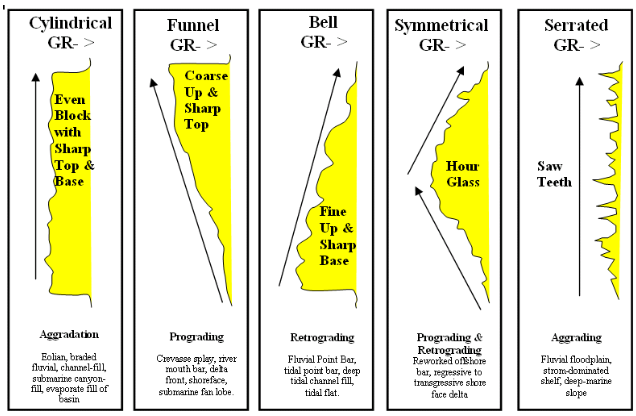


Fig 3: Gamma ray log shapes and their associated sediment logical facies/depositional settings (Adapted from Cant (1992) [3].

Determination of Key Bounding Surfaces from Well Logs

At the onset of an interpretation of sequence stratigraphy using well logs, it is important to first and foremost identify and determine the predominant significant surfaces (sequence stratigraphic or bounding surfaces). The surfaces include Sequence Boundaries (SBs) and Maximum Flooding Surfaces (MFSs).

Determination of Sequence Boundaries from Well Logs

Sequence Boundaries (SBs) were identified on the gamma ray log by the coarsening upward stacking pattern ending a particular depositional sequence and beginning a subsequent one.

Determination of Maximum Flooding Surfaces from Well Logs

Maximum Flooding Surfaces (MFSs) were identified on the gamma ray log as the shaliest part of the section with a high gamma ray value.

Determination of depositional sequence from Well Logs

Depositional sequences were determined by the record of cycle or relative sea level. In vertical succession, depositional sequences were identified by the following elements in this order: Sequence Boundary (SB I), Lowstand Systems Tract (LST), Transgressive Systems Tract (TST), Maximum Flooding Surface (MFS), Highstand Systems Tract (HST), and the following Sequence Boundary (SB II) as shown in Figure 4.

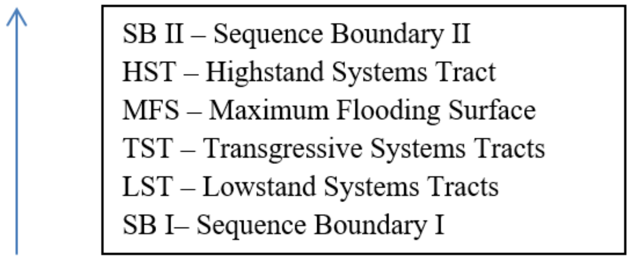


Fig 4: Hierarchy of Bounding Surfaces.

Prediction of depositional environment was achieved based on sandstone composition and gamma ray log shapes. In our study, the prediction of depositional environment was made from the comparison of gamma ray log responses from the four different wells in relation with established responses/description adapted from Cant (1992) [3] as shown previously in Figure 3. A funnel log response (progradational) represents a change from mainly shale into high sandstone lithology. It also indicates a gradual change from clastic to carbonate deposition. A bell log response is an indication of lithology change from sand to shale (waning of submarine fans-reducing sand contents). It is predominant within meandering or tidal channel deposits in a non-marine setting. A cylindrical response indicates fluvial channel sands, turbidites and aeolian sands.

The gamma ray log trend of Well 010 (Figure 5), which ranged between depths of 3700m and 3760m, was serrated and funnel-shaped with a thickness of about 60m. This trend is usually interpreted to indicate deposition of cleaning upward sediment or an increase in the sand content of the turbidite bodies, as applied to a deep marine setting. Same was obtained at the depth between 3845m and 3870m. A cylindrical and serrated trend was dominant at the depth between 3770m and 3845m in the dense carbonaceous units and some of the sands bodies of this type have a high reservoir quality. According to Cant (1992) [3] log shape classification scheme, cylindrical-shaped gamma ray logs could indicate a slope channel and inner fan channel environments.

The well log trend from Well 005 (3845 - 3850m) appears to be thin-funnel shape and serrated with a thickness of 5m. All thin funnel-shaped successions are less than 8m, and are interpreted as crevasse splay of a deltaic channel; they are too thin to interpret prograding delta. This trend indicates when a sediment deposition is cleaning upward or an increase in the sand content of the turbidite bodies, as applied to a deep marine setting. Selley (1998) [10] considered regressive barrier bars, prograding submarine fans and prograding deltas or crevasse splay as a favorable sedimentary environment for funnel shaped environment. While Crevasse splay, river mouth bar, delta front, shore face and submarine fan lobe may also indicate depositional environment of funnel shapes. If trend of coarsening upward is not clean and trend of funnel shape is serrated, lithology is interpreted as varying lithology. Change in irregular trend of GR in shoreface sand of Figure 5 is due to inter-bedding of fine grain beds.

For Well 007, the gamma ray motif was made up of a bell (3800m – 3860m; 3925m forward), cylindrical (3860m – 3885m), funnel (3885m – 3900m) and serrated-shaped successions. The bell-shaped successions are usually indicative of a transgressive sand, tidal channel or deep tidal channel and fluvial or deltaic channel. The cylinder-shaped gamma ray log which was dominant in Well 011 is serrated. Again, these are usually indicative of silts and shale with the periodical appearance of sands.

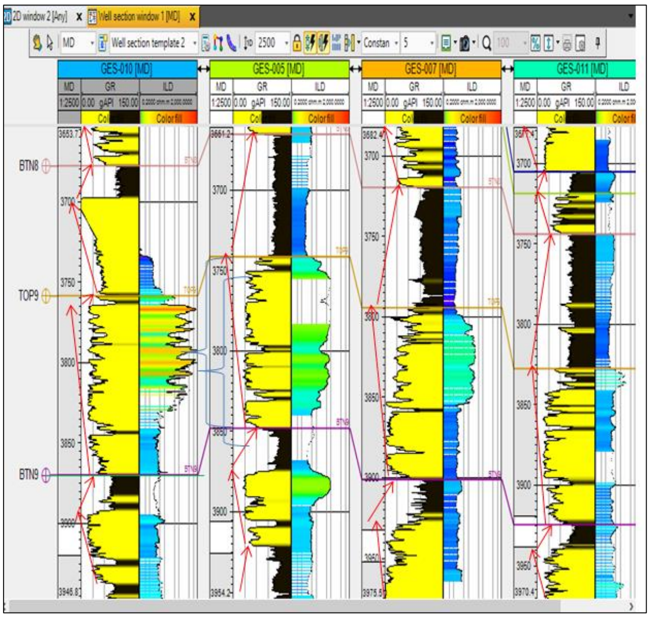


Fig 5: Correlation of sandstone units across the four wells from the log trends.

The log trend from top to bottom (TOP1-BTN1) across all four wells (Well 010, Well 005, Well 007, Well 011) are serrated and cylindrical-shaped successions (Figure 5). The cylindrical-shaped gamma ray log signature indicates consistent lithology. The possible environments of deposition of a cylindrical succession as documented by Selley (1998) [10] include tidal sand wave, grain flow fill and delta distributary channel; a cylindrical-shaped succession is mostly associated with glauconite and mica in a submarine channel. Cant (1992) [3] defined cylindrical trend as clean trend and considered aeolian (sand dunes), fluvial channels, carbonate shelf (thick carbonate), reef, submarine canyon fill as suitable environment of cylindrical/boxcar shape. Selley (1998) [10] considered tidal sands, grain flow fill and prograding delta distributaries channels as favorable sedimentary environment for funnel shape environment in clastics.

One – Dimensional Sequence Stratigraphic Analysis on Well Logs

Figures 6.1 to 6.4 show one-dimensional (1-D) sequence stratigraphic analysis performed on the logs from the prospect field using vertical stacking patterns of progradation and retrogradation for Wells 010, 005, 007 and 011.

Well 010

Four sequences have been recognized in this well (Figure 6.1).

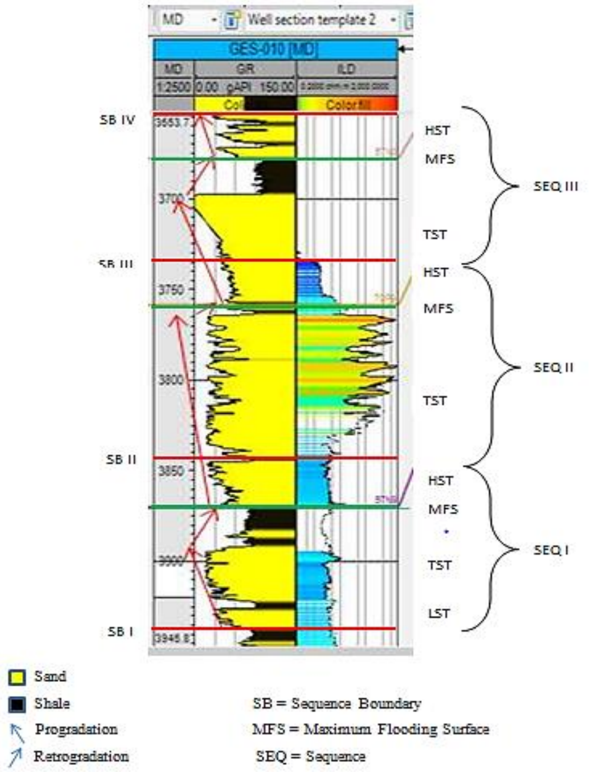


Fig 6.1: One Dimensional stacking pattern showing delineated candidate bounding surfaces in Well 010

Sequence I (3987 – 3845m)
In this sequence, the LST was made up of the progradational stacking pattern of sand. The TST thinned into a major condensed section – the MFS was mainly made up of interbedded clay and shale. The HST lies directly above the MFS and is made up of mostly sand. The HST is terminated at the top by the SB at 3845m, which is defined as the point of inflection in the stacking pattern from net coarsening upwards to net fining upwards. The noticed abrupt change in the gamma ray log signature indicated an erosional truncation that defined the aforementioned SB.

Sequence II (3845 – 3735m)
In this sequence, the LST was not penetrated. The TST was made up of progradational stacking pattern of interbedded sand. The TST thinned into the MFS which is made up of small portion of shale. The HST was made up of mainly intercalated sandstone prograding to argillaceous siltstone that changed to aggradational unit of medium grained sandstone of about 25m thickness.

Sequence III (3735 – 3845m)
The LST was not penetrated in this sequence as well. The TST was made up of argillaceous sandstone. The stacking pattern was progradational with upward coarsening units. The abrupt change in the log signature coupled with major condensed section was indicative of a MFS. The HST was made up of two sandy units interbedded by thinly bedded shale intercalations.

Well 005
Two sequences have been identified in this well as shown in Figure 6.2. They are Sequences I and II respectively.

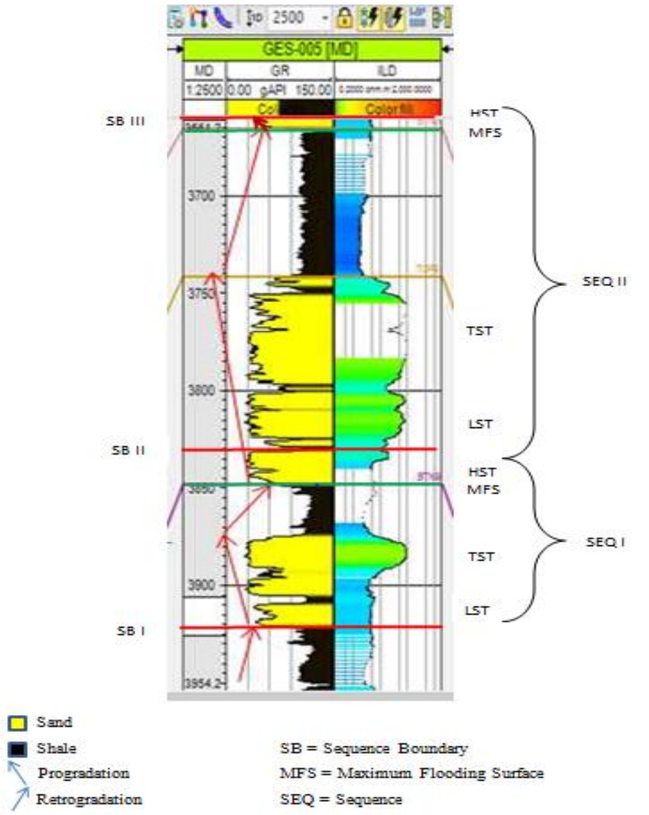


Fig 6.2: One Dimensional stacking pattern showing delineated candidate bounding surfaces in Well 005

Sequence I (3920 – 3830m)
This sequence is made up of LST, TST MFS and HST. The sequence starts at the depth of 3920m and ends at 3830m. The LST begins this sequence bounded below by SB 1. The sand package above the boundary is described as a prograding complex showing coarsening upward pattern. The LST is overlain by the TST that covers the depth of 3905 – 3875m and consists of an overall retrograding parasequence stacking pattern capped by a MFS at the depth of 3875 – 3850m. The HST rests on the MFS and covers the depth range of 3850 – 3830m. It has a prograding stacking pattern that coarsens upward and truncates at the top by SB II.

Sequence II (3830 – 3658m)
Resting upon SB II is sequence II. It is made up of LST, TST, MFS and HST. The LST (3830 – 3800m) is made up of about 85% sand indicating that it is a potential reservoir rock. It has an overall prograding which coarsens upward from the base of SB II. The TST (3800 – 3740m) is made up of fining upward retrogradational stacking pattern of sandstone units interbedded by thin bedded shales. The MFS is defined at the top of the TST at the depth of (3740 – 3664m) with high shaly condensed section. The HST marks the end of this sequence with a thin prograded sandy unit within the logged intervals.

Well 007

Three sequences have been recognized in this well (Figure 6.3).

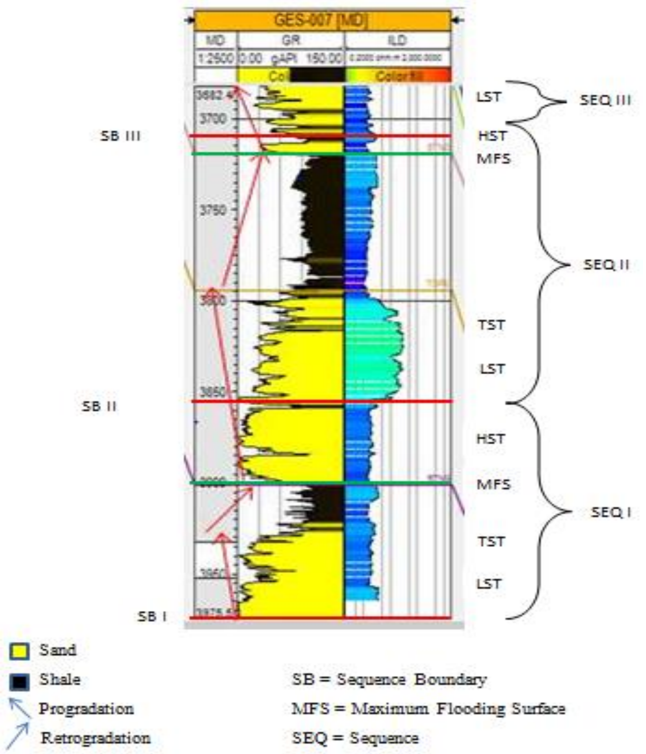


Fig 6.3: One Dimensional stacking pattern showing delineated candidate bounding surfaces in Well 007

Sequence I (3975 – 3855m)

This sequence is made up of LST, TST, MFS and HST. The LST (3975 – 3950m) has progradational stacking pattern and is made up of mostly sandy units. The Lowstand prograding complex has coarsening upward stacking pattern. The TST (3950 – 3915m) is made up of coarsening upward progradational stacking pattern of sandy units. The MFS is defined at the top of the transgressive systems tract at depth of 3915 – 3900m with shaly condensed section. The HST (3900 – 3855m) is dominantly made up of progradational stacking pattern of sandy units. The net coarsening upward pattern noticed and the wireline signature signifies an erosional truncation that defines the sequence boundary.

Sequence II (3855 – 3720m)

This sequence is made up of LST, TST, MFS and HST. The LST (3855 – 3815m) has a prograding stacking pattern and is made up of mostly sandy units which coarsen upward. The TST (3815 – 3795m) has an overall retrogradational stacking pattern. The lower sandy unit fines upward into a condensed section of shale forming the Maximum Flooding Surface (MFS) at the depth of (3795 – 3720m). The HST is made up of a single unit of argillaceous sandstone.

Sequence III (3720 – 3685m)

This sequence is made up of only the lowstand prograding complex. It is dominantly made up of continental sandstone interbedded by sequences of mixed sandstones (80% coarse grained). The lithofacies is referred to as the Benin Formation. The well log signature pattern is serrated shaped with coarsening upward stacking pattern.

Well 011

Three sequences have been observed in well 011 (Figure 6.4). They include Sequences I, II and III respectively.

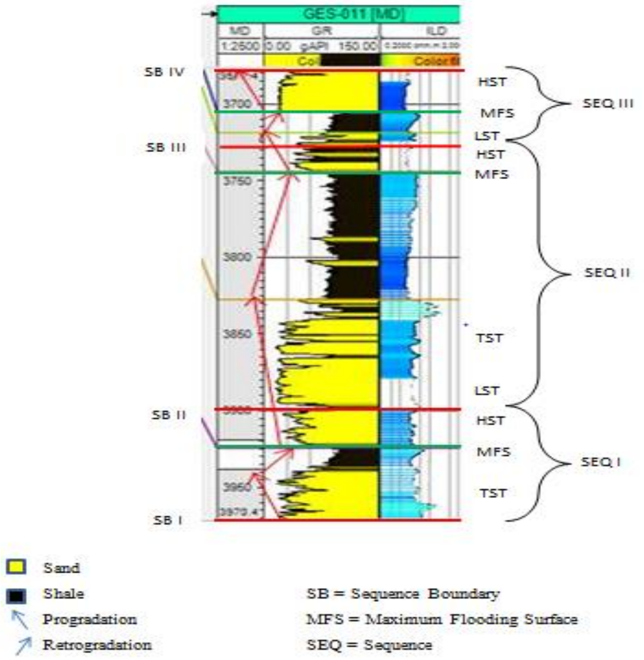


Fig 6.4: One Dimensional stacking pattern showing delineated candidate bounding surfaces in Well 011

Sequence I (3970 – 3900m)

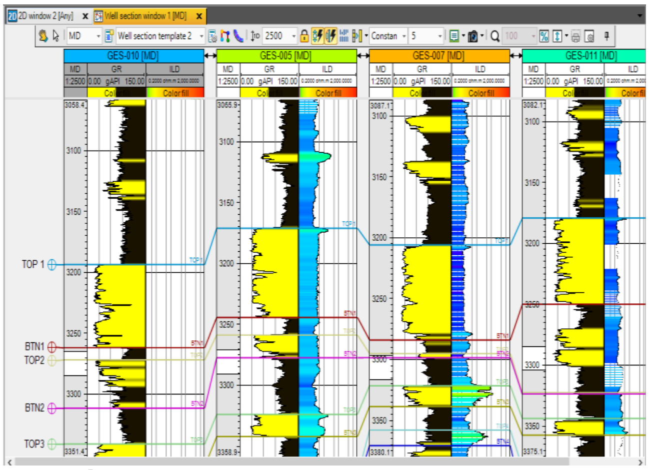
Sequence I consists of TST, MFS and HST. The TST extends from the depth of 3970 – 3940m and is made up of progradational stacking pattern of interbedded sand. The sandy unit in the TST fines upward and changes into shaly condensed section defining the MFS at the depth of 3940 – 3925m. The HST (3925 – 3900m) is made up of progradational stacking pattern that coarsens upward to the SB (3900m).

Sequence II (3900 – 3730m)

This sequence consists of LST, TST, MFS and HST. The LST (3900 – 3865m) has a progradational stacking pattern which coarsens upward and is made up of mainly sandy unit. The TST (3865 – 3830m) has retrogradational stacking pattern and thinned into the MFS which is made up of mainly shale at a depth of 3830 – 3745m. The HST (3745 – 3730m) is made up of mudstone prograding to argillaceous siltstone that changed to sandy units.

Sequence III (3730 – 3680m)

Sequence III lies on sequence II, the base of sequence III coincides with the top of sequence II. The lower part of this stratigraphic interval (3730 – 3720m) is characterized by LST prograding complex. The Lowstand prograding complex is capped by the condensed section defining the MFS at depth of 3720 – 3705m. The HST (3705 – 3680 m) is made up of prograding stacking pattern of mainly sandy units.



Sand
Shale

Figure 7: The correlated wells across the prospect showing log trends

From the gamma ray logs, two predominant lithologies were identified namely sand and shale (Figure 7). The interval with yellow colour was identified as sand because of the low value in gamma ray, while the black colour was identified as shale as a result of high gamma ray readings. The gamma log signatures are lithology indicators and therefore can successfully identify areas of sandstones and shale. From this study, three lithological reservoirs were identified from the results of the correlation as the reservoirs of interest. They include Reservoirs 1, 2 and 3 for Well-010, Well-005, Well-007, and Well-011 respectively based on gross thickness and presence of significant pay thickness with reservoir tops ranging from 3194.85m to 3342.65m for Well-010, 3271.45m to 3324.85m for Well-005, 3201.75m to 3322.65m for Well-007 and 3174.85m to 3344.80m for Well-011 while the reservoir base depths were taken at 3262.75m to 3365.45m for Well-010, 3245m to 3345.50m for Well-005, 3285m to 3339.90m for Well-007 and 3250m to 3357.75m for Well-011 as shown in Figure 7.

The thicknesses of the reservoir intervals, that is, from the top of the reservoir to the base of the reservoir (gross thickness of the reservoir) were equally estimated. The thickness varied from one well to the other across the field. The thickness of reservoir 1 was 67.90m in Well-010, 26.45m in Well-005, 83.25m in Well-007 and 75.15m in Well-011. Reservoir 2 had a thickness of 41.05m in Well-010, 19.50m in Well-005, 4.0m in Well-007 and 1.50m in Well-011. The thickness of reservoir 3 was 23.95m in Well-010, 19.0m in Well-005, 16.50m in Well-007 and 13.0m in Well-011. Averagely, the gross thicknesses of the reservoirs are: Reservoir 1 is 63.19m; Reservoir 2 is 16.50m, Reservoir 3 is 18.10m respectively. From the results obtained, Reservoir 1 had the highest average thickness while Reservoir 2 had the least average thickness. The results show that the various reservoir sands have sufficient thickness to accumulate an appreciably high volume of hydrocarbons. A detailed petrophysical parameters assessment of these three identified reservoirs (using additional log information) would be the emphasis of a further (complementary) study.

6. Conclusion

The sequence stratigraphic analysis and facies description of depositional environment of the prospect "X" field in the Niger Delta Basin was established and the results obtained were used to evaluate the hydrocarbon potential of the area. This was achieved based on the analysis of well logs motifs (responses) which were utilized within a chronostratigraphic framework for the study area. Interpretation of gamma ray logs of the wells showed that the lithology is dominated by alternating sand and shale, occurring approximately in a ratio of 80:20 in well 005, 70:30 in wells 005 and 007 and 60:40 in well 011 (within the logged intervals). Two bounding surfaces namely; Sequence Boundaries (SB) and Maximum Flooding Surfaces (MFS) have been identified in the prospect field. These include four sequence boundaries and three maximum flooding surfaces in wells 010 and 011 respectively. Similarly, three sequence boundaries and two maximum flooding surfaces in wells 005 and 007. Three depositional sequences namely SEQ I, SEQ II and SEQ III have been identified in wells 010, 007 and 011 while one depositional sequence has been identified in well 005. Also from the analysis of the well log data, a total of four facies have been identified. The facies present are funnel-shaped successions, bell-shaped successions and the cylindrical-shaped successions. These facies successions were all serrated across the sand bodies. Majority of the sand bodies were presented by slope channel and mixed tidal flats environment. The environments identified are potential reservoirs for hydrocarbon accumulation. The alternation of Highstand Systems Tract sands and shales provides a union of reservoir and seal rocks that are essential for hydrocarbon accumulation and stratigraphic trapping. The application of the gamma ray logs in facies description/depositional environment analysis and sequence stratigraphic studies has been emphasized and demonstrated in this study. After our next focus, which is to carry out a detailed petrophysical assessment of the prospect field, we would also in the future, explore the integration of seismic and biostratigraphic data, seismic attribute analysis and seismic inversion to confirm the lithology, characterize the reservoirs and type the hydrocarbon locked in these reservoirs.

Acknowledgements

We are grateful to the Geophysics Research Group within the Department for availing my team well log datasets procured from Shell Petroleum Development Company (SPDC) and their other allied companies, whom they work together with in partnerships. We equally acknowledge Schlumberger for granting access to Petrel E&P 2014 for Academic/Research purposes. We thank our primary affiliate institution, the University of Port Harcourt, Rivers State – Nigeria for providing the teaching and research platforms.

References

1. Adizua OF. Degree class lecture note on Well Logging and Well Log Interpretation I (Unpublished), 2019.
2. Bates RL, Jackson JA. Dictionary of Geological terms: American Geological Institute, 1984.
3. Cant DJ. Subsurface Facies Analysis. In: Walker, R.G., James, N.P editors. Facies Models, Response to Sea Level Changes; (1992) p.2745. Geological Association, Canada, 1992.
4. Embry A. Practical Sequence Stratigraphy, Canadian Society of Petroleum Geologists, 2009, p.81.
5. Embry A, Johannessen E, Owen D, Beauchamp B, Gianolla P. Sequence Stratigraphy as a "concrete" Stratigraphic Discipline. Report of the ISSC Task Group

on Sequence Stratigraphy, Calgary, 2007.
6. Gluyas J, Swarbick R. Petroleum Geoscience. Oxford: Blackwell Publishing Co, 2004, p. 40-52.
7. Iwuoma JO, Odigi MI. Facies Analysis and Depositional Environment Of Obua Field, Niger Delta, Nigeria. International Journal of Science Inventions Today. 2016; 5(2):p.203-214.
8. Oyedele KF, Ogagarue DO, Mohammed DU. Integration of 3D Seismic and Well Log data in the Optimal Reservoir Characterization of EMI Field, Offshore Niger Delta Oil Province, Nigeria. American Journal of Scientific Industrial Research. 2013; 4:p.11-21.DOI: 10.5251/ajsir.2013.4.1.11.21.
9. Reyment RA. Aspect of Geology of Nigeria. University of Ibadan Press, 1965.
10. Selley RC. Elements of Petroleum Geology. Department of Geology, Imperial College, London, 1998, p.37-145.
11. Weber KJ. Sedimentological aspects of Oil Fields in the Niger Delta, Environmental Geology, Minbouw. 1971; 50(3):p.559-576.
12. Weber KJ, Daukoru, EM. Petroleum Geological Aspects of the Niger Delta. 9th World Petroleum Congress Proceedings, 1975, p.209-221.
13. Yemets V, Antoniuk V, Bezrodna I. Facies Interpretation from Gamma Ray Log as Basic Well Logs Applied to Volodymyrska Field (Dnipro-Donetsk depression). EAGE online event, 2021.