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SEQUENCE STRATIGRAPHIC STUDY OF BIWA FIELD IN GREATER UGHELLI DEPOBELT, NIGER DELTA, NIGERIA

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ABSTRACT

High resolution biostratigraphic study of Biwa Field has enhanced the recognition of sequences (SB), Maximum Flooding Surfaces (MFS) and associated Systems Tracts. Three (3) sequences were identified from the base to the top of the study field with varying average thicknesses of sediments. The three (3) sequences, respectively and the candidate maximum flooding surfaces delineated were interpreted from the gamma ray log and biostratigraphic data. Sequence stratigraphic interpretations of the wells were performed and the chart produced is useful in further deepening the knowledge of the subsurface geology of the study field, Niger Delta area of Nigeria. The higher gamma ray and lowest resistivity readings were used to identify maximum flooding surfaces, which were further established with biostratigraphic data. The sequence stratigraphy of the well was attempted based on the presence of some selected marker fossils. The studied interval was dated Oligocene to Early Miocene base on the geologic ages of Sequence Boundaries (SB) and positions of Maximum Flooding Surfaces (MFS) interpreted which range between sequence I (F7800, P630) – 23.7Ma, sequence II (F7600, P580) – 29.3Ma and sequence III (F7600, P560) – 32.4Ma. The MFS were between 23.3Ma, and 31.3Ma. The sediment in the study area correspond to the sedimentary facies deposited in the Greater Ughelli depobelt

KEYWORDS : Systems tracts, Sequence Boundary, Maximum Flooding Surfaces, Oligocene, Miocene. Depobelt.

INTRODUCTION

The study area, “Biwa Field” is located within the Greater Ughelli Depobelt of the Niger Delta region. It lies between longitudes 5.05°E and 7.35°E and latitudes 4.15°N and 6.01°N (figures 1) on the onshore part of the Niger Delta. The Cenozoic Niger Delta is situated at the intersection of the Benue Trough and the South Atlantic Ocean where a triple junction developed during the separation of South America and Africa in the Late Jurassic (Whiteman, 1982). Sequence stratigraphy evolves as an aspect of stratigraphy that subdivides rock record using a succession of depositional sequences composed of genetically related strata as regional and inter-regional correlative units (Haq *et al*., 1988). It is concerned with the relative rates of change in sea level and sedimentation. Thus, genetically related facies are studied within a frame work of chronostratigraphically significant surfaces (Van Wagoner *et al.*, 1990), and rock units that are genetically related and constrained by time lines (Reijers, 1996). Sequence stratigraphy is most successfully achieved using data base that integrates biostratigraphic, core, and seismic data of the study area. This approach offers a predictive model in which a series of systems tracts within a depositional sequence is interpreted to be deposited in response to a cycle of fall and rise of sea level. This is related

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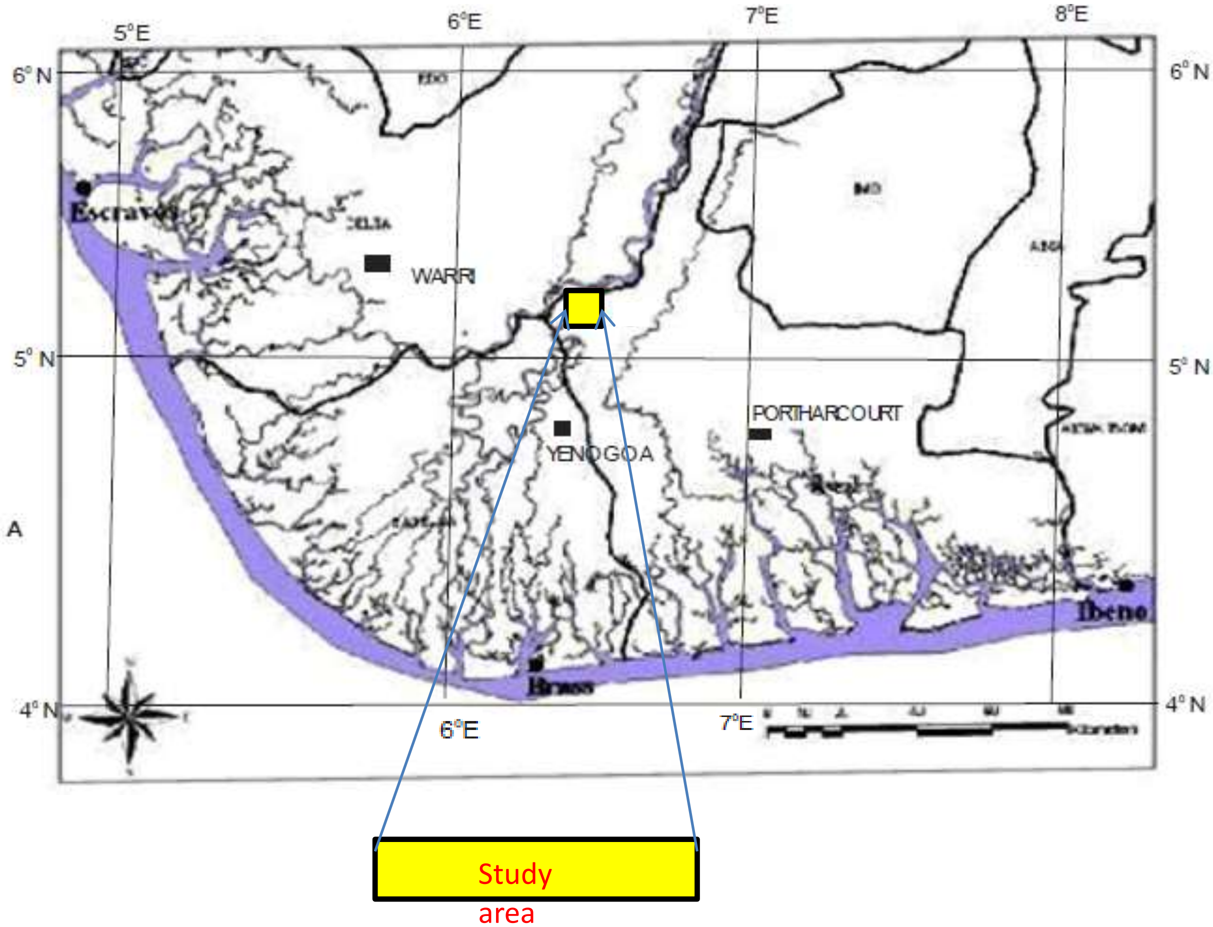

Figure 1: Location map of study area.

to a eustatic cycle. It also emphasizes the basic framework for the analysis of the relationship of tectonic subsidence and stratigraphy to eustatic cycles (Sangree et al, 1990); thus enhancing the understanding of the evolution of sedimentary strata.
Depositional sequence is the basic stratigraphic unit of sequence stratigraphy. A sequence is defined as a relatively conformable succession of genetically related strata bounded by unconformities or their correlative conformities (Vail *et al.*, 1977 and Van Wagoner *et al*., 1990, etc.). Sequences can be subdivided into systems tracts, which are linkages of contemporaneous depositional systems (Van Wagoner *et al.*, 1990; and Hart, 2005, etc.). These include Lowstand System Tracts (LST), Transgressive System Tracts (TST), Highstand System Tracts (HST) and shelf margin systems tracts, respectively. Each systems tract is deposited at a predictable position in an interpreted eustatic cycle, and has recognizable signatures in well logs and seismic data (Vail *et al.*, 1977 and Van Wagoner *et al.*, 1990, etc.). Sequences and systems tracts can be defined on the basis of strata geometry and physical relationships. Fundamental recognition criteria for sequences include definition of sequence boundaries (unconformities or their correlative conformities) and vertical relationships and facies of systems tracts within the sequences.

Objective of study

The objectives of the study involved the following:

1. Identification of foraminifera and calcareous nannofossils and their abundance in the strata penetrated in the wells.
2. Utilization of biostatigraphic data to delineate candidate chronostratigraphical surfaces.
3. Determination of the ages of the studied wells intervals.
4. Interpretation of well log signatures and stacking pattern.

Geological Setting

The geology of the Niger delta is well studied through the numerous subsurface data acquired during oil prospecting. Prominent among the authors are Short &

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Stauble, 1967; Murat, 1972; Weber and Daukoru, 1975 and Whiteman, 1982). Short and Stauble, 1967, and Weber and Daukoru, 1975, recognized three main formations in the subsurface of the Niger Delta. Many workers and multinational companies that carried out work in the delta have recorded that the major lithostratigraphic sequences or units within the Niger Delta formation include, the Benin, Agbada and Akata Formations respectively. These formations showed intercalating of sand, shale, silt and/or sandstone facies equivalents which represent the delta plain, delta front and the prodelta environments respectively. Growth faults are the dominant structural features within this part in the Niger Delta .These formations were deposited in the continental, transitional and marine environments, respectively; together they form a thick, overall progradational passive-margin wedge.
The Akata Formation is the basal unit composed mainly of marine shales believed to be the main source rock (Ekweozor, and Okoye, 1980) within the basin.

The Agbada Formation is made up of alternating sandstone, siltstone and shale sequences that constitute the petroleum reservoirs of the basin. Lambert-Aikhionbare and Ibe (1980) in their work concluded that the shale from Agbada formation is the major source rock.

On the other hand, the Benin Formation largely consists of non-marine sands with a few shaly intercalations. Amajor, 1986, in his study of the Coastal Plain Sands of Niger Delta, described the sands as deposits of alluvial fan facies.

METHOD OF STUDY

The method of study includes interpretation of wireline logs and high resolution biostratigraphic data. The procedures adopted are outlined below.

Wireline Log Data

Gamma ray and resistivity logs of study well were used to interpret the stacking pattern and the lithology and thus identify the various systems tracts, sequences, sequence boundaries and maximum flooding surfaces. The criteria for recognizing these features from gamma ray and resistivity logs as discussed by Mitchum *et al*., (1993) were employed. Log patterns were therefore determined and utilized in defining the different systems tracts, sequences, sequence boundaries and maximum flooding surfaces. The well log suites provided for the study area were displayed at consistent scales to enhance log trends and also to aid recognition of facies stacking patterns and parasequences. This procedure involves recognition of patterns that reflect changing water depths and distribution of accumulated sediments within depositional cycles (Escalona and Mann, 2006). Gamma Ray Log values and signatures (fining and coarsening upward signatures) helped in determining lithofacies and depositional environments of the different rock units in the study well. Bell shaped log patterns on Gamma Ray Logs indicating increasing clay contents up section or fining upward trends or an upward increase in gamma ray value is a typical feature of fluvial channel deposits. Figure 2, summarizes the log response a variety of different clastic depositional systems (Rider, 1996) Funnel-shaped log patterns indicating decreasing clay contents up section or a coarsening upward trend, clearly showed deltaic progradation. Cylindrical (blocky) log motif was delineated as thick uniformly graded coarse grained sandstone unit, probably deposits of braided channel, tidal channel or subaqueous slump deposits. Serrated log motif suggested intercalation of thin shale's in a sandstone body, typically of fluvial, marine and tidal processes.

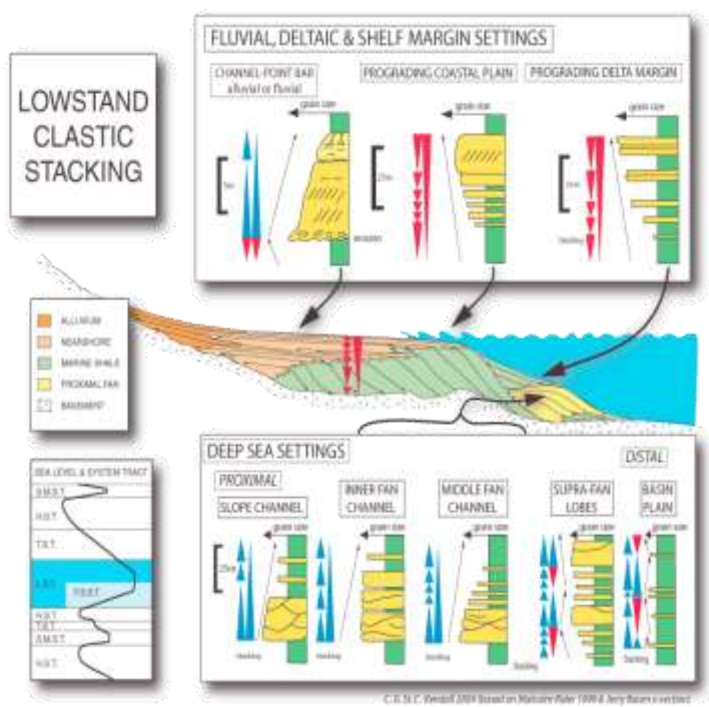

Figure 2: Log response of different clastic depositional systems (Rider, 1996)

Biostratigraphic Data

High resolution biostratigraphic data was provided for Biwa well comprising of foraminiferal population, foraminiferal diversity, planktonic population,

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planktonic diversity and environments. Based on relative maximum faunal abundance and diversity peaks Maximum Flooding Surfaces were picked while relative faunal abundance and diversity minima were used to identify Sequence Boundaries from the biostratigraphic data plots. Also, the microfaunal and micro floral zonation checklists (Niger Delta Cenozoic chronostratigraphic chart of Reijers, 1996) were used to date and correlate Maximum Flooding Surfaces (MFS) and Sequence Boundaries (SB) identified (figure 3)

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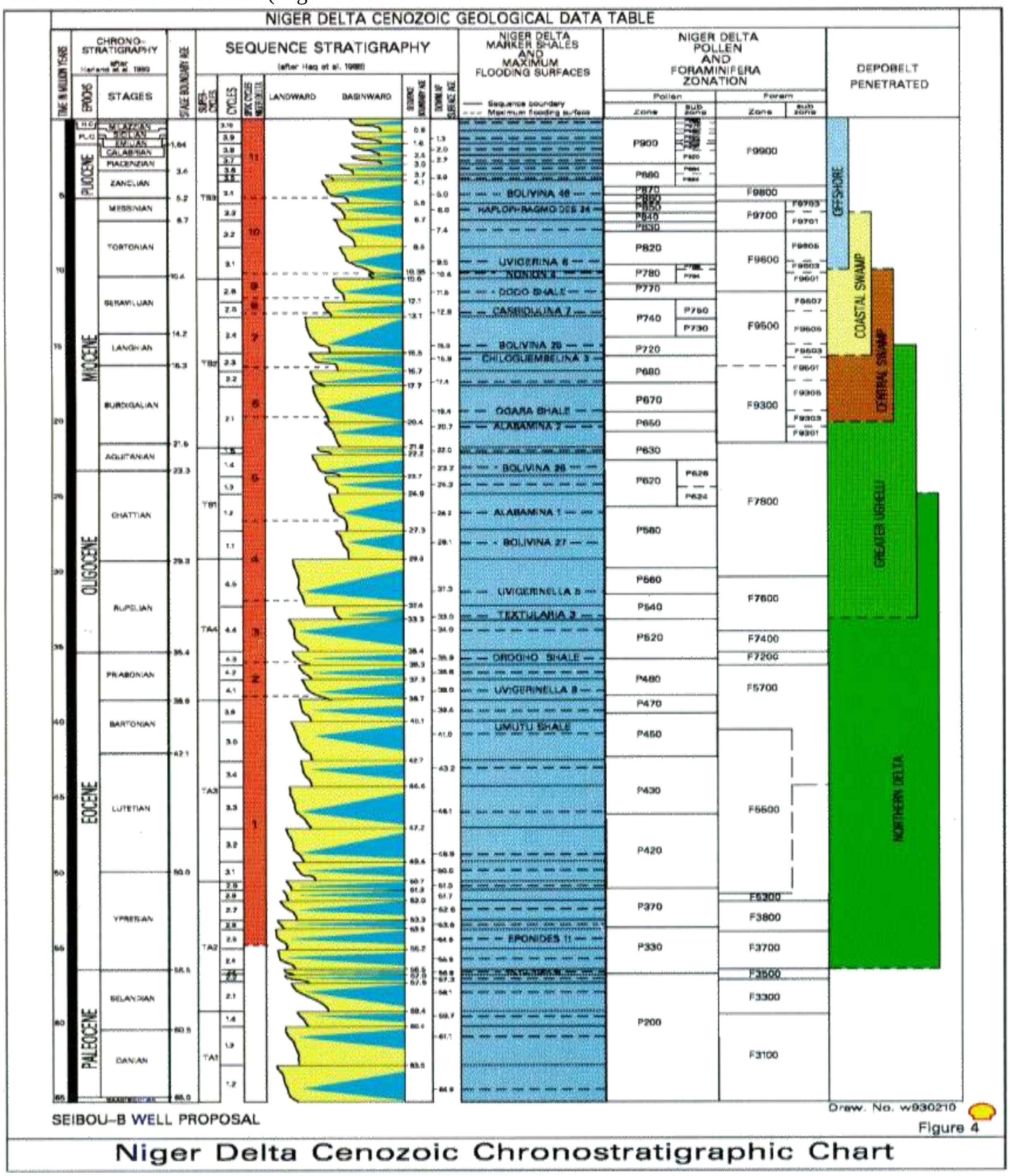

Figure 3: NIGER DELTA CENOZOIC CHRONOSTRATIGRAPHIC CHART (Courtesy SPDC)

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RESULT, INTERPRETATION AND DISCUSSION

Biostratigraphic result

The result of biostratigraphy data are summarized as tabulated in (Table 1). The table shows the result of F-Zone, P-Zone and age of the paralic sequence in the study area. Based on the faunal assemblages in the well data; it indicates Bolivina 27 and Uvigerinella5 as marker species representing a Maximum Flooding Surface (MFS). Faunal diversity minima were used to pick Sequence Boundaries (SB).

Table 1: Summary of Representative Biofacies Data of Wabi-10 Well.

Top Depth (m)	Base Depth (m	Zone Type	Zone Code	Markar fauna	Zone Type	Zone Type	Age
2070	2355	F	F9600	Nonion	P	P780	Middle Miocene
2355	2510	F	F9600	Uvigerina	P	P820	Middle Miocene
2510	2670	F	F7800	Bolivia 26	P	P630	Lower Miocene
2670	3060	F	F7800	Bolivina27	P	P580	Oligocene
3060	4122	F	F7600	Uvigerinella5	P	P560	Oligocene

Biostratigraphic results from Biwa-01 Well, Niger Delta placed a broad constraint on the age of the Agbada Formation (Table 1) in the study area. The first occurrence of *Nonion* at 2070-2355m and *Uvigerina* at 2355-2510m corresponds to F9600 Planktonic foraminifer zone indicating Middle Miocene age. The first occurrence of Bolivia 26 at 2510---2670m and Bolivia 27 at 2670-3060 indicating Lower Miocene age and Oligocene age respectively. The first occurrence of Uvigerinella5 at 3060-4122m also indicating Oligocene age. These result suggest that the Formation in the study were deposited over 23 million years during the Oligocene to Middle Miocene.

Based on the pollen and foraminifera zones, three sequence boundaries are identified within the Agbada Formation in the study area, also, the geologic age of the interpreted horizons, as well as the hierarchy of the stratigraphic sequences between interpreted horizons, were ascertained base on the biostratigraphic data from the Biwa-01 field. The geologic ages of Sequence Boundaries (SB) and positions of Maximum Flooding Surfaces (MFS) interpreted range between sequence I (F7800, P630) – 23.7Ma, sequence II (F7600, P580) – 29.3Ma and sequence III (F7600, P560) – 32.4Ma. The MFS were between 23.2Ma, and 31.3Ma. They correspond to the sedimentary facies deposited in the Greater Ughelli depobelt (Knox and Omotsola, 1989).

Well Log Sequence Stratigraphy of Biwa Fields

An integration of the two data sets led to a refinement of the interpretation. Biostratigraphic information was annotated on the well logs; initial interpretation of the systems tracts, maximum flooding surfaces and sequence boundaries were refined so that maximum flooding surfaces corresponded to shaly zones while sequence boundaries corresponded to sandy zones on well logs. Iterative interaction of the data sets led to continuous refining of interpreted packages as more information was deduced until interpretation from one data set was verified from the other.

The first Maximum Flooding Surface (MFS1) recognized in the Biwa-01 Well (Figure 4) was dated 31.3Ma using the Niger Delta Chronostratigraphic Chart,(figure 3), a regional marker, *Uvigerinella 5* and the occurrence of the event was within P560 and F7600 biozones. The second Maximum Flooding Surface (MFS2) recognized in Biwa-01 Well, was dated 28.7Ma using the Niger Delta Chronostratigraphic Chart, (figure 3), a regional marker, *Bolivia* 27 and the occurrence of the event within P580 and F7800 biozones. The third Maximum Flooding Surface (MFS3) recognized in Biwa-01 Well, was dated 23.2Ma using the Niger Delta Chronostratigraphic Chart, (figure 3), a regional marker, *Bolivia* 26 and the occurrence of the event within P630 and F7800 biozones, they occur in the wells are shown in (Figure 4).

The oldest Sequence Boundary (SB1) identified in the study field was dated 37.4 Ma while the oldest Maximum Flooding Surface (MFS) in the area is dated 13.3Ma (Fig. 4) and the surface represent a substantial erosional surface.

Five (5) Vail sequences and four (4) Galloway sequences (figure 4) were identified for the Biwa fields.

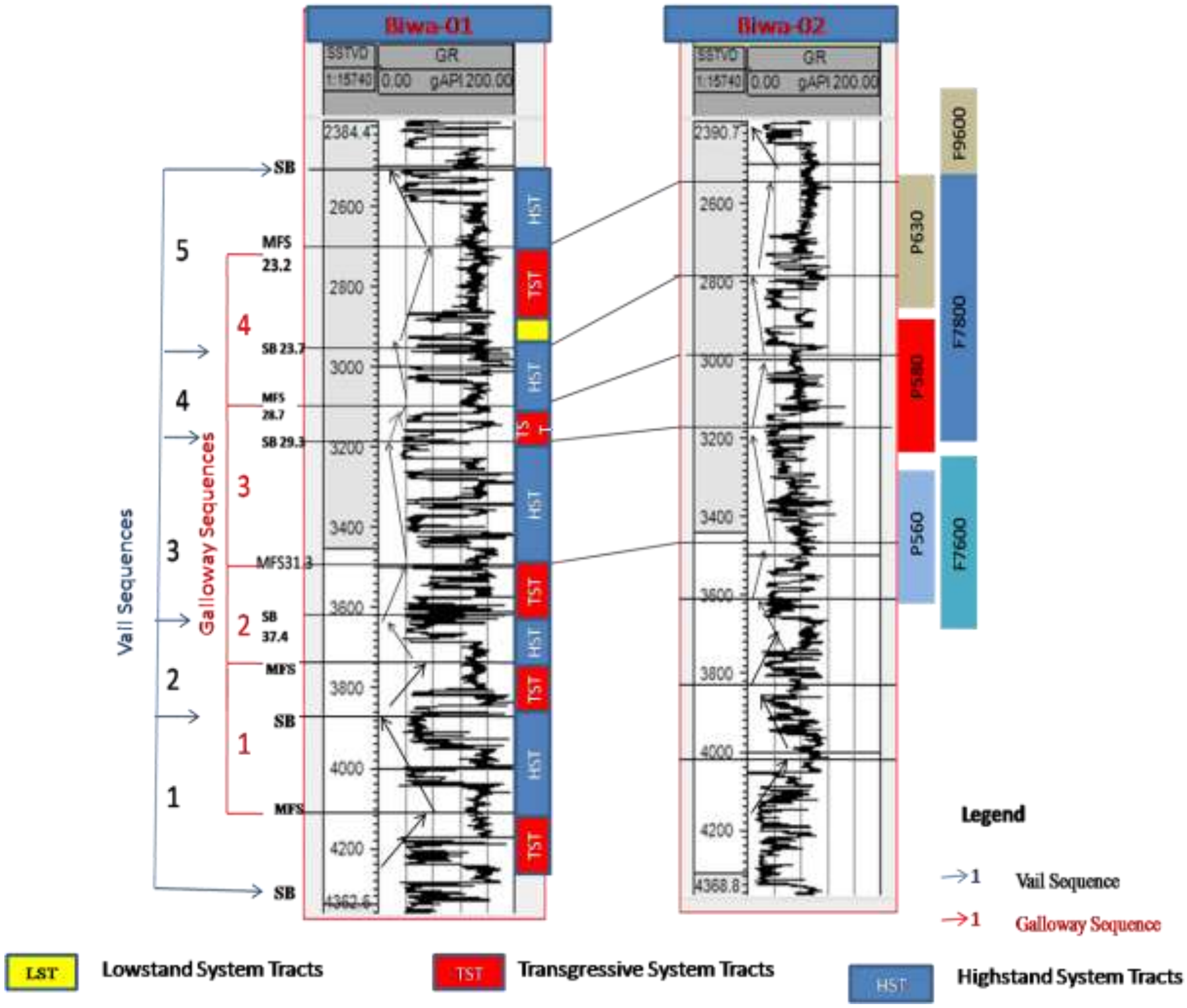

Figure 4: A representative plot of wireline logs, stacking pattern and biostratigraphic data of Biwa Fields.

Sequence I (2549.5 – 2950m)

In this sequence, the Lowstand Systems Tract (LST) was penetrated between (2900-2950m). The Transgressive Systems Tract (TST: 2700 - 2950 m) is made up of retrogradational stacking pattern of interbedded clay, shale, mudstone, and silty mudstone of single unit of 250 m thick. The Transgressive Systems Tract thinned into a major condensed section (MFS: 23.2 Ma) indicated by the abundance peaks of FDO: of *Nonion* and *Uvigerina* at 2355-2510m. The Highstand Systems Tract (HST: 2549.5 - 2700m) is made up of shale/mudstone prograding to siltstone that changed to aggradational unit of sandy mudstone interbedded by thinly cross bedded fine - medium grained sandstone of about 50 m thickness. The Highstand Systems Tract is terminated at the top by Sequence Boundary (SB) at 2549.5 m depth, which is defined at the point of inflection in the stacking pattern from net coarsening upwards to net fining upwards. The sequence boundary is indicated by the abrupt change in the gamma ray log signature showing an erosional truncation.

Sequence II (2950 - 3,200 m)

This sequence is made up of transgressive systems tract and highstand systems tract. The Transgressive Systems Tract (TST: 3200 - 3100 m) is made up sandstone units, underlying sandy mudstone and finally mudstone units, showing a retrogradational stacking pattern with upward fining units well log patterns. It thin into the fine grained mudstone with major faunal/floral abundance peaks that are indicative of maximum flooding surface (MFS: 28.7 Ma) at 3100 m. The MFS is dated by the FDO: The first occurrence of Bolivia 26 at 2510---2670m and Bolivia 27 at 2670-3060 marker fossils. The Highstand Systems Tract (HST: 3100 – 3200 m) is

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made up of aggradational stacking pattern of sandy unit. The Highstand Systems Tract is terminated at the top by Sequence Boundary (SB) at 2950 m depth, which is defined at the point of inflection in the stacking pattern from net coarsening upwards to net fining upwards and is marked by the sequence boundary (SB: 23.2 Ma).

Sequence III (3200-3650.5 m)

This sequence is made up of transgressive systems tract and highstand systems tract. The Transgressive Systems Tract (TST: 3650.5 - 3500 m) is made up sandstone units, underlying sandy mudstone and finally mudstone units, showing a retrogradational stacking pattern with upward fining units well log patterns. It thin into the fine grained mudstone with major faunal/floral abundance peaks that are indicative of maximum flooding surface (MFS: 31.3 Ma) at 3100 m. The MFS is dated by the FDO: The first occurrence of Uvigerinella5 at 3060-4122m *marker* fossils. The Highstand Systems Tract (HST: 3500 – 3200 m), and is made up of aggradational stacking pattern of four sandy units. The Highstand Systems Tract is terminated at the top by Sequence Boundary (SB) at 3200m depth, which is defined at the point of inflection in the stacking pattern from net coarsening upwards to net fining upwards and is marked by the sequence boundary (SB: 29.3 Ma).

SUMMARY AND CONCLUSION

The interpretation of well log responses (gamma-ray and resistivity logs) was integrated with biostratigraphic data to characterize the sequence stratigrtaphic of the Biwa Field, Niger Delta. The well log stacking patterns were used to delineate the sequences and the systems tracts. The identified sequence boundaries were found at the inflection of progradation to retrogradation of parasequences in a shallowing upward sand unit, and also at the inflection of the lowstand prograding complexes (lowstand systems tract). The higher gamma ray and lowest resistivity readings were used to identify maximum flooding surfaces, which were further established with biostratigraphic data. The sequence stratigraphy of the well was attempted based on the presence of some selected marker fossils. The studied interval was dated Oligocene to Early Miocene The geologic ages of Sequence Boundaries (SB) and positions of Maximum Flooding Surfaces (MFS) interpreted range between sequence I (F7800, P630) – 23.7Ma, sequence II (F7600, P580) – 29.3Ma and sequence III (F7600, P560) – 32.4Ma. The MFS were between 23.3Ma, and 31.3Ma. The sediments in the study area correspond to the sedimentary facies deposited in the Greater Ughelli depobelt (Knox and Omotsola, 1989).

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