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SEQUENCE STRATIGRAPHY OF NEOGENE COASTAL SWAMP I, WESTERN NIGER DELTA BASIN, NIGERIA

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Abstract

Sedimentary sequences are often misinterpreted especially in many-sided depositional settings such as Niger Delta. However, the chances of interpretational error diminish by keeping in mind more than one depositional settings /model during analysis. This work was done to determine the lithostratigraphy, chronostratigraphy, possible reservoir sands, age and depositional environment of the study area for opportunities that will support exploration program. Different Formations, lithologies, lithofacies, sediment types, depositional sequences and their environments of deposition were identified from log signatures of the six wells. High resolution biostratigraphic data consisting of microfauna abundance and diversity chart aided in the delineation of the Maximum Flooding surfaces (MFSs), paleobathymetric interpretation and in age determination.

Depositional sequences, system tracts, system boundaries and candidate MFSs were identified based on their diagnostic characteristic log patterns in the studied wells and age-dated with marker species. Sequence Boundaries (SBs) were recognized from logs, age-dated where possible, and constrained by age control sensu. Interpretation showed that the lithology is dominated by alternating sand and shale, vertical profiles and lateral accretion revealed channel sands, bar sands and tidal sands. Five reservoir sand units were identified and these units were penetrated by five wells. Three sequence boundaries dated, 12.1Ma, 13.1Ma and 15.5Ma and three maximum flooding surfaces, dated 11.5Ma, 12.8Ma, and 15.0Ma were revealed. The systems tracts delineated were LST, TST and HST. The result indicated that the HST and LST coarse-grained sediment supply decreases and has high hydrocarbon potential while the inter-bedded mudstone facies of TST increases thus providing good top seal to the reservoirs and often potential source rock to the underlying sands. The depositional settings of the Middle Miocene strata were influenced by fluvial, tidal and marine systems. The integrated interpretation of these datasets in the study area has enabled the sub-division of the stratigraphic column of the wells into sequences, systems tracts and sedimentary cycles. These sequences have potential to serve as excellent source rock and reservoirs while the systems tracts also depict excellent seals and stratigraphic traps.

Keywords: Sequences, Wireline logs, Depositional settings, Reservoir, Hydrocarbon potential

1.0 INTRODUCTION

The Tertiary Niger Delta is composed of an overall clastic succession that reaches a maximum thickness of 9 - 12,000 meters [1] (Figure 1). The Middle Miocene play is one of the Niger delta's most prolific, and is developed in the North and Central belts of the Coastal Swamp depobelt and in the eastern part of the Shallow Offshore depobelt. The Middle Miocene is primarily restricted to the Coastal Swamp depobelt, with many reservoirs where most of the traps are structural (growth fault related rollover anticlines), and the deep water, where the traps almost always have a stratigraphic component in association with compressive structures. The history of petroleum exploration has shown that there will always be enough possibility of finding more oil and gas, if more accurate exploration technique is employed in the right place. Detailed sedimentology and sequence stratigraphy has turned out to be one of the best useful techniques in generating exploration prospects and predicting reservoir and seal quality in both stratigraphic and structural prospects.

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2.0 MATERIALS AND METHODS

Well log data suites, and biofacies data, provided for this work were prepared in Petrel. The well log suites were digitized, plotted at standard scale to enhance log trend of which they can easily be used and also to aid recognition of facies stacking patterns andparasequences.

The stacking pattern (vertical occurences of repeated cycles of coarsening of fining upwards sequences), gave rise to progradational, retrogradational, or aggradational parasequence sets. (Figure 2). The plot of faunal abundance and diversity (biofacies) of well Polo-5 curves alongside well logs and enhanced the

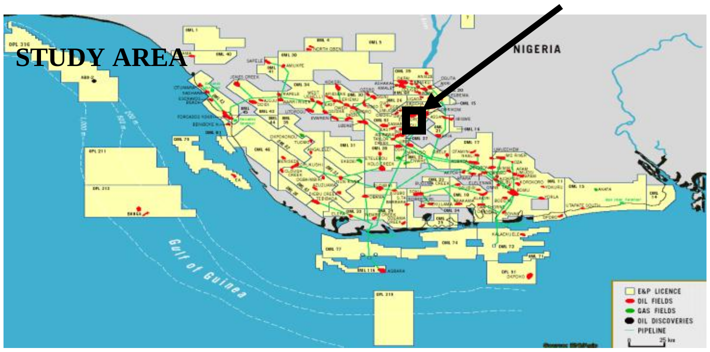

Figure 1: Map of Niger Delta basin showing the location of study area.

recognition of maximum flooding surface (MFS), transgressive surface of erosion (TSE), sequence boundary (SB). The Niger Delta Chronostratigraphic chart was used in the identification and assigning dates to the key surfaces.

3.0 RESULTS AND DISCUSSION

Sedimentology and Lithofacies Interpretations

An interval of middle Miocene paralic sandstone of the Agbada Formation was examined during this study. Sand percentage is one of the most reliable ways of expressing lithofacies and this can be calculated from well logs (Gamma ray) per hundred feet (100ft) interval. [2] suggested the various sand percentages that can indicate the different lithofacies. Lithofacies interpreted from sand percentages and well logs can be used for reservoir characterization, burial history and lithofacies zonation. The stratigraphic column in" Polo field" was divided into four lithofacies namely: Coarse Grained Basal Sandstones Facies, Shaly Sandstone Facies, Mudrock Facies and Heterolithic Facies (Figure 3). Channel (blocky or cylindrical log), shoreface (funnel-shaped log pattern), and tidal (bell – shaped log pattern) were the sub-depositional environments revealed in the field [3].

Biofacies Interpretation

The biofacies interpretation was focused on the identification of major faunal abundance and diversity peaks, which coincide with MFS within condensed sections, while faunal abundance and diversity minima correspond to SB. The biozone records obtained from the well Polo-5 were the palynological and foraminifera zones popularly referred to as the P- and F-Zones. Five (5) different pollen zones (P-Zones) and two fauna zones (F-Zones) recognized were P770, P740, P720, P680, P670 and F9500, F9300 respectively [4] (Table 1& 2).

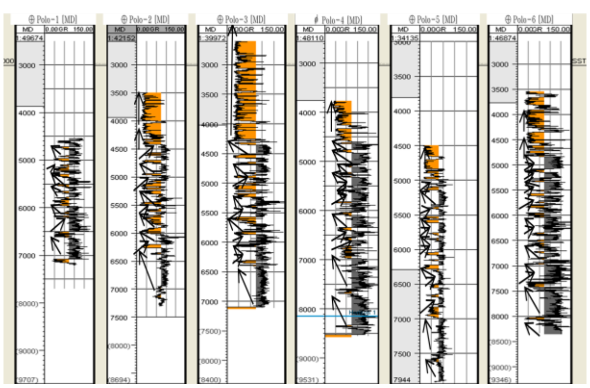

Figure 2: Parasequence Stacking Pattern (Progradational, Retrogradational and Aggradational) [5]

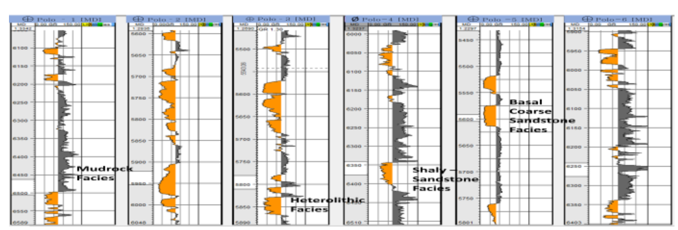

Figure 3: Four lithofacies were identified in the six wells

Table 1: GENETIC SEQUENCE

CHRONO SURFACE	AGE(Ma)	MARKER FAUNA	BIOZONES		DEPTH (Ft)					
			P-ZONE	F-ZONE	Polo-1	Polo-2	Polo-3	Polo-4	Polo-5	Polo-6
MFS1	15.0	Bolivina 25	P720	F9500	6866	6775	6722	7301	7431	7075
MFS2	12.8	Cassididulina 7	P740	F9500	4866	4829	4740	5099	5486	5206
MFS3	11.5	Dodo Shale	P770	F9500	3935	3653	3972	4302	4680	4323

Table 2: DEPOSITIONAL SEQUENCE

KEY SURFACE	AGE(Ma)	DEPOSITIONAL SEQUENCE	DEPTH (Ft)					
			Polo-1	Polo-2	Polo-3	Polo-4	Polo-5	Polo-6
SB1	15.5	2	NP	NP	NP	6970	7695	7400
SB2	13.1	3	6195	5875	5879	5845	6335	6390
SB3	12.1	4	4510	4430	4350	4260	5140	4820

Recognition of systems tracts and Depositional Sequences

The three types of systems tracts i.e. lowstand (LST), transgressive (TST) and highstand (HST) were recognized in the study area. Each systems tract was deposited at a predictable position in an interpreted base level cycle caused by eustasy and has recognizable signature on well logs [6, 7, 8]. (Figure 4)

Four (4) depositional sequences (DSQ1, DSQ2, DSQ3 and DSQ4) and the accompanying systems tracts were identified and mapped, based on log–motifs of the location wells and the spatial distribution of the recognized constrained surfaces (MFSs and SBs).

Depositional Sequences DSQ1 and DSQ4 formed the deepest (oldest) and top- most (youngest) depositional sequences respectively. The DSQ1 is an incomplete sequence. It is enclosed on top by the 15.5 Ma SB, which was revealed only in wells Polo-4, Polo-5 and Polo-6 that probed deeper stratigraphic sections of the well field. Accompanying transgressive systems tract (TST) contained marine shales rich in fauna with minor sand unit enveloped by the 15.0 Ma MFS. The transgressive sand units have been interpreted as shoreface sands deposited in the shelf region during rising sea levels.

The DSQ2 is approximately 1135 ft thick and is bounded top and bottom by 13.1 Ma and 15.5 Ma sequence boundaries, respectively. The Lowstand Systems Tract (LST)/ transgressive systems tract of this sequence formed thick sand deposits interpreted as lowstand prograding wedge, deposited in the shallow inner neritic(SHIN) to middle neritic(MN) depositional settings. The DSQ3 overlies the 13.1 Ma SB and is capped by the 12.1 Ma SB. It is 1585ft thick in the down dip of wells Polo -4, Polo -3, and Polo -1and Polo -6. The sequence displayed predominantly fluvial and tidal processes (progradational to aggradational stacking pattern) as shown in Figure 5. The LST of this sequence contains reworked channel sand deposits which were more pronounced in the down dip wells. The 12.8Ma MFS was identified in this sequence.

The DSQ4 is the topmost (youngest) sequence in the study area. It rests unconformably on the 12.1 Ma SB. The sequence consists of thick sand units at its base, deposited during relative sea level lows. The environment of deposition in this sequence was not determined because of insufficient data. The 11.5 Ma MFS was identified in this sequence.

Reservoir Potentials

Reservoir tops and bases were defined based on sand packages as revealed on log signatures. Five (5) potential reservoirs (RS1, RS2, RS3, RS4 and RS5) delineated in the "Polo Field" were mainly channel sands and shoreface sands of LSTs and HSTs, respectively, that displayed low gamma ray(GR) and high resistivity(RES_D and RES_S) values. The reservoirs are stacked with thickness of about 30 – 175ft of continuity across the field. (Figure 5 and 6)

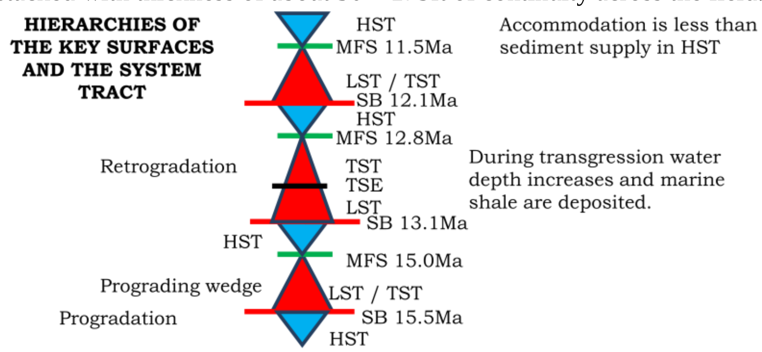

Figure 4: Recognition of system tracts in the wells [9].

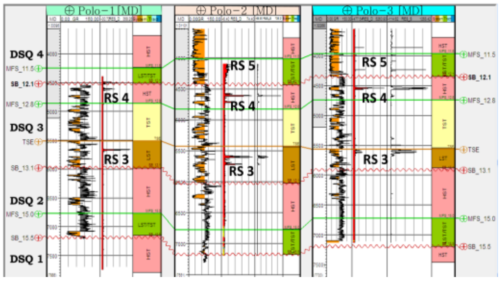

Figure 5: Stacked potential reservoirs in Polo-1, Polo-2 and Polo-3.

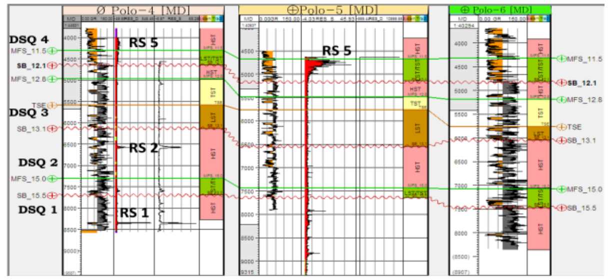

Figure 6: Stacked potential reservoirs in Polo-4 and Polo-5.

4.0 CONCLUSION

Sequence stratigraphy interpreted from well logs tied to biostratigraphy is used to correlate and analyze sedimentary rocks from the perspective of geologic time [10]. The lithology is dominated by alternating sand and shale strata that were influenced by fluvial, tidal and marine systems which are characterized by continental-marine facies of the Agbada Formation i.e. (Shallow Inner Neritic, Inner Neritic and Middle Neritic). Paleoenvironment interpretations were based on paleobathymetric sedimentary facies derived from biofacies data. This has confirmed that the six wells within the western offshore Niger Delta fall in Middle Miocene age, bounded chronologically by third order 15.5 Ma SB, 13.1 Ma SB and 12.1 Ma [5]. Marker Shales identified were 15.0Ma (*Bolivina 25*), 12.8Ma MFS (*Cassidulina 7*) and 11.5Ma (*Dodo shale*). The systems tracts are the prograding wedge complexes of the lowstand systems tracts, transgressive systems tracts and highstand systems tracts with three sequence boundaries and maximum flooding surfaces. The shales of the TST in which most of the MFS were delineated could form seals to the reservoir units. A combination of the reservoir sands of the LST and HST can form good stratigraphic traps for hydrocarbon and hence should also be targeted during hydrocarbon exploration.

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