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Research Article

SEQUENCE STRATIGRAPHICAL STUDIES OF FIELD X, NIGER DELTA BASIN. NIGERIA

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ABSTRACT

The hydrocarbon bearing sand units were analyzed based on systems tracts. The LST had more hydrocarbon bearing sand units, followed by HST, while none was observed for the TST. The average porosity and permeability values for the systems tracts are; for the first HST, 0 = 38%, K = l2O2mD, Second HST, 0 = 36%, K = l52mD, LST 0 = 35%, K = 37n0 and the last HST 0 = 33%, K = 34mD. The reservoirs are more of gas bearing than oil. This is attributed to the source rock type, temperature effect and low permeability values (reduced pore throat).

INTRODUCTION

The Cenozoic Niger Delta complex is a prolific oil province within the West African sub-continent. It has been described as an arcuat- lobate shaped sediment wedge of the destructive, wave dominated type. It built across the Anambra Basin and the Cross River margins and eventually extended onto the Late Cretaceous continental margin. Its sediments are transported from adjoining older rocks of the West African miogeocline and deposited onto the cooling and subsiding oceanic crust by the help of the rivers Niger and Benue which were generated as the South American and African continents spread apart.

The application of Sequence stratigraphy which is the basis of this research work in the Niger Delta has contributed to a better knowledge and understanding of the Delta. Exploration activities concentrated in the onshore part (Eocene-Pliocene are gradually being shifted to both the offshore (Pliocene-Pkistocene sections) and the flanks of the delta

AIM OF THE RESEARCH WORK

To establish the sequence stratigraphic model of the area and to determine the various reservoir characterisatics, (porosity, permeability and hydrocarbon saturation) and evaluate their hydrocarbon potentials.

LOCATION OF STUDY AREA:

The area of study lies within the coastal swamp depobelt in OML 13 of the eastern part of the Niger delta petroleum province.

Well Xl is a vertical hole type spudded on 22m1 february, 1955, with a true vertical depth subsea (TVDSS) of 8915.5ft (2700m) and derrick floor elevation (DFE) of 69.89ft (2 im). It is an exploration well.

Well X2 is a deviated hole type spudded on 26th October, 1986, with a true vertical depth subsea (TVDSS) of 9690.2ft (2935m) and derrick floor elevation (DFE) of 67.33 ft (20m). It is an exploration well.

Well X3 is a vertical hole type spudded on 27” December, 1986, with a true vertical depth subsea of (TVDSS) of 6759.4ft (2O47m and derrick floor elevation (DFE) of 66.75ft (20m). It is an appraisal well. Well X4 is a vertical hole type spudded on 23’ january, 1987, with a true vertical depth subsea (TVDSS) of 7227.9ft (2189m) and derrick floor elevation (DFE) of 44.22ft (13m). It is an appraisal well.

JUSTIFICATION OF PROJECT WORK:

The wells in the area have not yet been developed. The sequence stratigraphy and petrophysical characteristics of the study area needed to be established. This research work was, thus, necessary to establish the Sequence stratigraphic setting of the field and also to determine its influence on the porosity, permeability distribution, and reservoir geometry and hydrocarbon systems of the study area.

LITERATURE REVIEW:

The depositional sequence is the fundamental unit of sequence stratigraphy (Catuneanu, 2006). The depositional sequence is a conformable succession (uninterrupted by significant disconformities) of genetically related strata (temporally and spatially related by geologic processes), bounded at top and base by sequence boundary. Sequence boundaries are formed by an abrupt fall in relative sea level i.e., type 1 sequence boundary (Van Wagoner et al, 1990) and sequences are thus deposited between two episodes of relative sea level fall, which coincide, for instance, with falling inflection points on a hypothetical relative sea level curve. If a relative sea level eventually falls below the shelf edge, valley incision pronounced erosion of the shelf, and extensive deep-water turbidite deposition will occur (Posamentier and Allen, 1999). A type 2 sequence boundary occurs when the fall in relative sea kvel is of a small enough magnitude to restrict it to the landward side of [áe offlap break and no lowstand fans are deposited, differentiating it from the type I where the offlap break is exposed and lowstand fans deposited downslope. Sequences are composed of parasequences, which are genetically related deposits bounded by marine flooding surfaces (Van Wagoner et al., 1990). Parasequences are grouped into parasequence sets according to their stacking pattern which is, in turn, controlled by the ratio of depositional rate and accommodation rate (Van Wagoner et al., 1990).

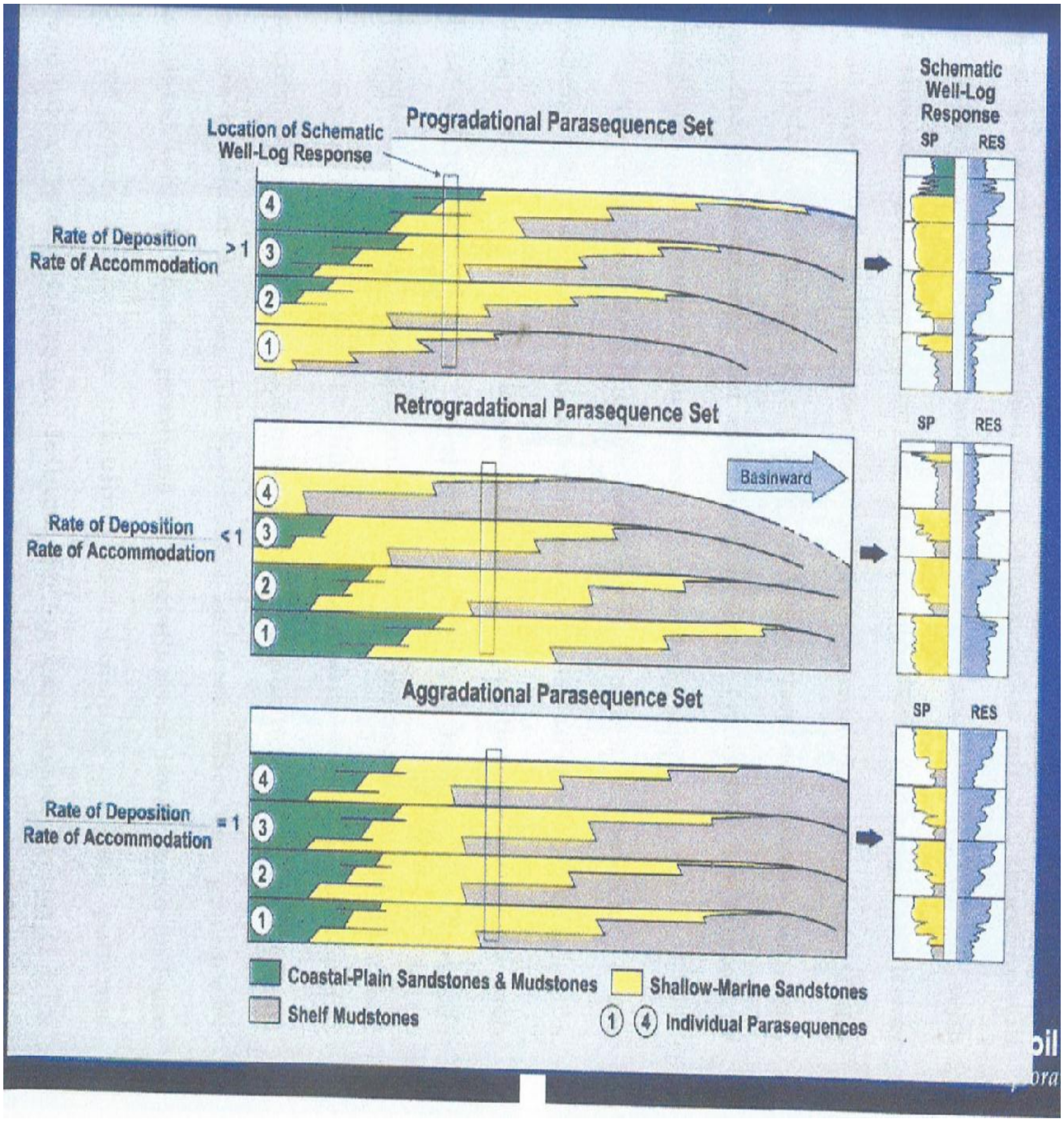

Figure 1: Parasequence Stacking Pattern (Van Waenger et al, 1990)

A stacking pattern refers here to the architecture of a vertical succession of parasequence. Progradational, retrogradational and aggradational stacking patterns can be recognized. If the over all depositional rate is higher than the accommodation rate, the shoreline will have a regressive tendency, and a parasequence set is progradational, with the succeeding parasequence being deposited in an average shallower water environments than the previous one within the same set. If the overall depositional rate is equal to or lower than accommodation rate, then the parasequence set is aggradational (stilistand shoreline) or retrogradational (overall transgressive shore line), respectively.

As accommodation space creation is controlled by relative sea level changes, parasequence sets can be associated to specific periods of a relative sea level curve. The contemporary depositional systems to each period of the relative sea level curve will thus have a characteristic parasequence set stacking pattern and define a systems tract.

Systems tracts are 3D linkages of contemporaneous depositional systems, found in specific positions within a depositional sequence and are bounded by specific, significant surfaces. They are genetically associated with particular positions of a relative sea level curve and are built of parasequence sets exhibiting distinguishing stacking patterns. Three main systems tracts are defined, the lowstand systems tract (LST), e transsive tract (TST). and. the high stand systems tract HST

DATA AND METHOD OF STUDY

DATA USED FOR STUDY:

The following data were used for this study:

- Seismic base map of the field showing all the five wells at their exact positioned locations.
- Raw numerical data of wire-line logs made up of Gamma Ray log (OR), Spontaneous Potential log (SP), Compensated Bulk Density Log (CDL), Compensated Neutron Log (CNL), Borehole Compensated Sonic Log (BCSL) and Resistivity log.
- Available biofacies data of well Xl, was used as a control to interprete the other wells, which provided information on fossil abundance and diversity. The indicated sample type used here are side wall cores and ditch cuttings.

Sand top/bases Report:

- Side wall core sample description data for three of the wells were available.
- The chronostratigraphic chart of the Niger Delta was used for the dating of the surfaces

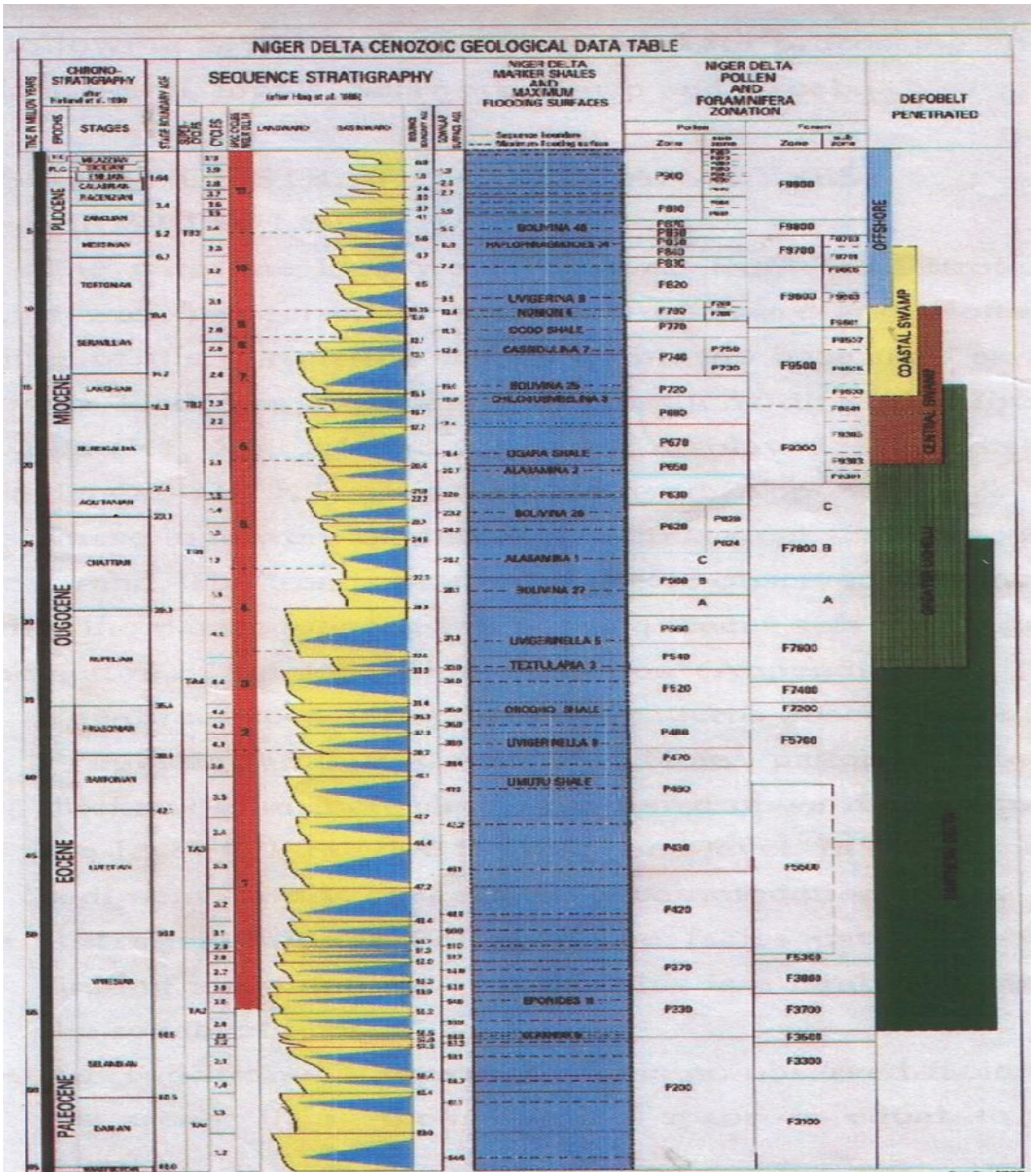

Figure 2: Niger Delta Cenozoic Chronostratigraphic Chart

RESULTS PRESENTATION AND INTERPRETATION:

The key stratigraphic surfaces aided in marking out the systems tracts. The transgressive systems tract had a characteristic finning and thinning of facies upwards, for the Lowstand systems tract, the facies thickened and coarsened upward while within the Highstand system tract, the facies coarsened upward and subsequently maintained a uniform trend. The system tracts within the study area were in the order of Highstand system tract (HST), Transgressive system tract (TST), another HST/Lowstand system tract (LST), and then finally HST and TST. We observed a situation of an HST seating directly on an LST, and two sequence boundaries l0.35ma and l0.6ma succeeding each other. This is the effect of the missing Nonion 4, lO.4ma MFS.

Wells	Xl	X5	X4	X3	X2
Key Stratigraphic Surfaces					
Uvigerina9.5ma Ift)	3886	3730	3780	3650	3752
Sequence Boundary l0.35ma (ft)	3946	3875	3886	3770	3805
Sequence Boundary 1O.6ma(ft)	5488	5380	5565	5230	5200
Dodo—Shale l1.5ma (ft)	6889	6779	7080	6780	6580

Table 1: Key Stratigraphic Interpreted Log Depths of the Study Area

Wells	Xl	X5	X4	X3	X2
Key Stratigraphic Surfaces					
Uvigerina9.5ma Ift)	3880	3734	3776	3653	3757
Sequence Boundary l0.35ma (ft)	3940	3871	3880	3703	3807
Sequence Boundary 1O.6ma(ft)	5490	5372	5562	5232	5205
Dodo—Shale l1.5ma (ft)	6890	6780	7072	6764	6566

Table 2: Key Stratigraphic Interpreted Seismic Depths of the Study Area

RESERVOIR CHARACTERISATION AND INTERPRETATION:

The studied area has more of gas reservoirs. The LST has 12 hydrocarbon bearing sand bodies, while HST has 7, and none in the TST. Well Xl has no density nor sonic logs, and so was not analysed for petrophysical parameters. The Well X4 is barren of Hydrocarbon. The key stratigraphic surfaces structural time-depth converted values summarized in tables 2 and 3 proved that well X4 was drilled on a synclinal structure, and this likely explains its lack of hydrocarbon. The purpose of this well was to establish some research on appraisal uncertainties (Eriavbe, personal communication, 2006).

The average porosity (0) and permeability (K) values for the systems tracts calculated are: for the first HST, 0 = 38%, K = 1202mD, Second HST, 0 = 36%, K = l52mD, LST 0 = 35%, K = 37mD and the last HST 0 = 33%, K = 34mD. The TST within the studied area are dominated by shale, without any real sand body.

The appreciable high values of average porosity and permeability within the first and second Highstand systems tracts, could be associated with the shallow depth and relatively less compaction effects. The lack of any substantial sand body within the TST is probably associated with the rise in sea-level during transgression which favored dominance.

Depth	Sand Name	System tracts	Hydrocarbon Pore fill	Average Porosity (%)	Average Permeability (mD)
1956-3650	X100	HST(Depositional Sequence 2)	-	38	1200
3650-3780	X200	HST (Depositional Sequence 2)	-	37	1000
3924-4125	X300	HST (Depositional Sequence 2)	-	36	80
5695-5740	X1200	LST (Depositional Sequence 1)	-	29	34
5860-5970	X1300	LST (Depositional Sequence 1)	-	28	35
6178-6298	X1400	LST(Depositional Sequence 1)	-	30	34
6560-6650	X1500	HST(Depositional Sequence 1)	-	27	34
6840-7030	X1600	HST(Depositional Sequence 1)	-	26	33

Table 3: Petrophysical summary sheet of Well X4

DISCUSSION OF RESULT

MISSING NONION 4, MFS (10.4ma):

Biostratigraphic analysis of the study area showed that no index fossil was seen within the Nonion 4, 1 0.ma. This was established by the missing of P780 from the biofacies zonation data. Erosional interval accompanied by missing sections has been reported in some parts of South-Western Niger Delta (Olabode, 2000). The missing of transgressive surface and maximum flooding surfaces have equally been reported in some parts of the South-Eastern and South-Western Niger delta (Ozumba and Obilaja, personal communication, 2006).

The Application of Biostragraphy has confirmed that, there is no region in the world with a complete lithology/stratigraphy geologic column. This is as a result of faulting, erosion, weathering and nondepositional periods. (Oloto, 2004). The miocence deltaic Agbada formation was deposited on a succession of cuspate faults displaced basin ward under the weight of accumulating sediments. This succession contains five erosionally bounded sequences (Owoyemi, 2006).

It has been argued that the missing of transgressive surface and maximum flooding surface are not equivalent to the erosion surfaces produced by a sea level fall since the missing sediments means that it cannot be established how the erosion surface was modified on the following transgression (Loucks, et. al., 2006).

However, there appears to be a relationship between the periods of eustatic sea level fall and sequence development. The sea level fall is likely to be associated with increase rates of sediment progradation and loading onto shales of the underlying Akata formation, which accelerated structural collapse of the clastic wedge into the basin. It would therefore be said that the depositional patterns within sequences reflect a diversion of sediment transport pathways along irregular basin floor topography produced by faulting. Thus faulting initiated the eroding of the transgressive system tract and maximum flooding surface (Nonion 4, 1 0.4ma), within the study area.

PICKING THE EROSIONAL INTERVAL OF THE MISSING SECTION:

The erosional interval of the missing section was a problematic task to pick on the log, following the depositional processes of the vertical grain size trends.

Standard sequence stratigraphic models for prograding deltaic deposits suggest that a sequence bounding erosion surface should cap a coarsening and shoaling upward succession (forward-stepping parasequences). Thus deposits directly above the sequence boundary are expected to record falling stage and lowstand incision of fluvial channels, and the filling of these valleys with sandy fluvial sediments during subsequent sea level rise (Van Wagoner et. al., 1990).

Thus, the erosional interval was determined on the log as represented by an abrupt coarsening of facies which separated the Highstand system tract from the Lowstand system tract.

On the seismic, it had a characteristic chaotic pattern. This agrees with Owoyemi, (2006) erosional Interval Interpretations.

SEQUENCE BOUNDARY TYPES:

The sequence boundaries; 10.35ma and l0.6ma, within the study area were studied and confirmed to be of the type 1.

This deductions were based on the facts that; for the sequence boundary 10.6ma, it has Lowstand deposits above it, which cannot be seen in a type 2 sequence boundary. And for sequence boundary 10.3 5ma, the Afam clay canyon and other canyons of the Niger delta are interpreted to have formed during sea level

Lowstand. (Owoyemi, 2006).

HYDROCARBON SYSTEM ANALYSIS:

The source rock type, temperature effect of source rock maturation and low permeability were considered as contributing factors to the gas saturated reservoirs within the study area.

However, recent research shows that the 9.5ma MFS controls black oil systems. The 10.5ma MFS controls volatile oil with up to about 70% of the oil in place found in reservoirs below this regional seal. The Hydrocarbon system within and below the 11 .5ma MFS and 12.8ma MFS has not been tested yet, but from regional trends, it is conducted to range from volatile oil to gas, up to a hard over pressure zone. (Ganz, et. al., 2006).

Since hydrocarbon migrates vertically upwards using major faults as migration conduits, it is a probalistic deduction that the major source rock within the study area is likely the Dodo-Shale (1 l.5ma) MFS, and so relating it to the more gas reservoirs.

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