Sequence Development and Palaeogeography Evolution of Ewan and Oloye Fields (Middle Miocene), Northwestern Niger Delta

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Abstract

Sequences developed within the middle Miocene in the study area are interpreted to be controlled locally by episodic shelf instability, basin physiography (shelf edge), fault growth and linkage. Relative sea level changes provide the major control on sequence development and deep valley incisions. The latter have a strong geomorphological impact on the area and a strong control on sequence variability. Interpretation of GDE maps shows that sands were originally deposited in river- and mouth bars with longshore drift currents redistributing the sand parallel to the shoreline. During lowstand periods, canyons developed which served as conduits for sand to the basin (deep water sand), recognized as high amplitude seismic facies on the slope and on the basin floor. This mechanism has led to the deposition of considerable amount of sandstones in the slope and offshore environments.

Idealized schematic sequence stratigraphic development models have been generated for the study area, while schematic palaeogeography and general conceptual depositional models of the study area during middle Miocene time are also presented.

Keywords: Oloye fields; Miocene; Niger delta

Introduction

The depositional setting of the study area (Figure 1) has been interpreted to range from continental to offshore environments within a shelf edge depositional setting [1]. Important depositional facies interpreted include undifferentiated continental deposits, fluvial/tidal channel sandstones, mouth bars and upper shoreface sandstones, lower shoreface heterolithics, and offshore mudstones (with discrete slope channel and basinal sand).

Seismic stratigraphic analysis of this study area consists of six depositional sequences [1] figures with base map of seismic survey showing position of seismic cross sections and wells in Figure 2. Sequences are made up aggradational to progradational HST. Important depositional facies to be described and changes observed between main units within a sequence as well as between sequences. Because TST in this study area are thin but widespread, Highstand GDE maps are constructed to be made up the period of transgression (TST) and progradation (HST). The position of the shoreline for each sequence (both LST and HST) are highlighted and annotated, as well position of the control wells, depocentres and faults.

Generally, shoreline geometries are lobate, and prograde basinward (south) during lowstand period, retrograde (TST) and subsequently prograde during highstand period. It is observed in all the sequences that the distal part of the study area is more tectonically active and faulted. In this area where we have syn depositional faults a more complex facies distribution/a depositional pattern is observed thereby creating some local depocentres (Figures 3-6).

Depositional sequence 1

There are few data to constrain the palaeogeography of this sequence, this due to the lack of well control/penetration and poor seismic definition at the base of Agbada Formation reflectors. Two GDE maps are constructed for this depositional sequence, for the lowstand and highstand period respectively (Figures 3a and 3b). Depositional Sequences 1 developed due to a relative sea level fall that led to the exposure of the shelf edge area. This has led to incisions within the shelf creating 3 palaeovalleys originally described (Depositional Sequence maps were constructed for four of the depositional sequences. This has allowed the depositional fills, spatial relationships and geometry of facies to be described and changes observed between main units within a sequence as well as between sequences. Because TST in this study area are thin but widespread, Highstand GDE maps are constructed to be made up the period of transgression (TST) and progradation (HST). The position of the shoreline for each sequence (both LST and HST) are highlighted and annotated, as well position of the control wells, depocentres and faults.

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Figure 1: Location of the study area.

Figure 2: Base map of seismic survey showing position of seismic cross sections and wells. Area under study is enclosed within the white shaded portion [1].
a) Sequence 1: LST.

i) Rms Amplitude

ii) Palaeogeography

Figure 3: Schematic Synthesis of Sequence Development and Palaeogeographic Evolution of Sequence 1, also showing faults geometry.

b) Sequence 1: HST.

i) Rms Amplitude

ii) Palaeogeography

“RMS amplitude and interpreted GDE map including contraints from seismic stratigraphic and borehole observations.”
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a) Sequence 3: LST

b) Sequence 3: HST.

Figure 4: Schematic Synthesis of Sequence Development and Palaeogeographic Evolution of Sequence 2, also showing faults geometry.
i) Rms Amplitude

“RMS amplitude and interpreted GDE map including contraints from seismic stratigraphic and borehole observations”.

a) Sequence 3: LST

Figure 5: Schematic Synthesis of Sequence Development and Palaeogeographic Evolution of Sequence 3, also showing faults geometry.

b) Sequence 3: HST.
“RMS amplitude and interpreted GDE map including contraints from seismic stratigraphic and borehole observations”.

a) Sequence 4: LST

b) Sequence 4: HST

Figure 6: Schematic Synthesis of Sequence Development and Palaeogeographic Evolution of Sequence 4 also showing faults geometry.
Depositional sequence 2

This lowstand period, characterised by relative sea level fall, resulted in incisions cutting into the underlying continental deposits of Sequence 2 (Figure 4a). This sea level fall is observed to have fallen below the shelf break and deposition of mouth bar deposit and upper shoreface sandstones are interpreted in front of the shoreline. During this lowstand period, shorelines and facies belts prograde basinward, and canyons transport potentially considerable amount of sand basinward (Figure 4a).

The following hightstand system tract is characterised by rising relative sea level (flooding) and most of the incisions on the shelf that have been filled by continental deposits were also transgressed and overlain by upper shoreface sandstones, lower shoreface and eventually prodelta/basinal deposits (Figure 4b).

Depositional sequence 3

A major regression occurred across much of the area during this lowstand period. This period is characterised by several deep incisions across the shelf. This suggest there is a pronounced relative sea level fall resulting in erosion of the shelf edge. These incisions/canyons acted as sand conduits and transportation of sand into deep water with sandstones deposited on the slope and within the basin floor (Figure 5a).

The highstand period follows an initial marine transgression that causes the shelf to be flooded. Subsequently, the HST deposits prograde back into the basin (Figure 5b).

Depositional sequence 4

Depositional sequence 4 evolution is similar to the sequence 3 described above. Major regression characterised the period of lowstand with several incisions cutting across shelf area (Figure 6a). This suggests there is a pronounced relative sea level fall resulting to incision into the shelf edge.

As observed from sequence 3, highstand relative sea level period is defined by marine transgressions that cause the shelf to be flooded and most of the incisions formed during lowstand period that have been filled by continental deposits, were transgressed and overlain by upper shoreface sandstones, lower shoreface and eventually prodelta/basinal deposits. Subsequently, the HST deposits prograde back into the basin (Figure 6b).

Summary of facies model of the study area is presented in Figure 7. Widespread of incisions indicate a rapid and strong progradation during the lowstand period which suggest that during LST times most of the area was periodically subaerially exposed. This has led to the development of incisions/canyons within the shelf and slope. These canyons acted as a sand feeder that led to the deposition of deep water sands on the slope and within the basin floor.

Discussion

Interpretations and descriptions of depositional sequences suggest that most sequence boundaries are eroded by sea level lowstand incision of the shelf, coupled with increased shelf instability and slope collapse structures. Patterns of sequence erosion occur both on the footwalls and hanging walls (but deeper mostly in the hanging wall) and deposits thickens across downthrown fault blocks, suggesting that most of these faults were active during the middle Miocene time of Agbada Formation deposition. The restriction of lowstands system tract deposits to within the valley fills across the entire study area, and the occurrence of deep incisions, suggests that the entire shelf region became periodically subaerially exposed during the successive relative sea level falls.

Observations from the sequence analysis show that throughout sequence development within the study area, the shelf margin has been controlled also by growth faults which have migrated basinward through time (Figures 3-7). In a case where the shelf margin is being controlled by growth faults, one of the processes of transporting sand into the basin is shelf collapse, with resultant slumping. However, there is an observed reduction in the upward propagation of faults. This may be due to changes in sediment deposition rates and fluvial discharge locations causing minor faults to become buried and truncated; fault segmentation and differential displacement on adjacent segments. Sedimentation patterns suggest that faulting, local incision and HST cliniform geometry dominate the formation of depocentres across the shelf.

Previous work showed that each depobelt is parallel to the modern coastal belt in which has been distinguished by their ages and are defined by sedimentary faults (Figure 8). Modern faults are observed to be parallel to these regional depobelts and the present day facies belts (Figures 8 and 9). Structural analysis of the study area shows a different local facies belt orientation versus the growth faults and the depobelts, which is very different from the present day orientation and relationship. Evidence from this study presented in the GDE structural maps shows that local facies belts are oblique to the regional depobelt (Figures 8-10) and often oblique to the interpreted growth faults. This
Figure 7: Block schematic diagram of the Lithofacies Relations within the Study area [2,5].

Figure 8: Age of deltaic sequences in depobelt and relationship to the broad changes in tectonic style [2,5].
observation suggests that the ancient coastal belt of the delta is more lobate/arcuate than the modern Niger delta. The delta became broadly convex to the sea during the late Miocene [2].

The overall strong progradational character of the study area as evidenced from the overall seismic geometry, prograding of shoreline break as observed from GDE maps, and dip line section at the

Figure 9: Growth faults and known hydrocarbon accumulation [6].

Figure 10: Schematic paleogeography and general conceptual depositional model of the study area during middle Miocene time [1].
proximal part. They are interpreted to reflect a long time decrease in accommodation triggered by a combination of tectonic uplift of the north-western Niger delta and the middle Miocene eustatic fall [2-6]. Increase in the proportion of sandstone relative to mudstone up section within the study area clearly also shows long-term progradation and graduation from the paralic Agbada formation into continental sand Benin Formation.

Conclusion

Detailed sequence stratigraphic analyses showed that the middle Miocene-early Pliocene strata in the Ewan and Oloye fields of the northwestern Niger delta consist of six depositional sequences (Figures 11-16) [1]. During lowstand period, shorelines and facies belts prograde basinward (south) and there are a development of canyons which serve as a conduit for high amplitude deposit (deep water sand) on the slope and within the basin floor. This mechanism is interpreted to have led to the deposition of considerable amount of sandstones basinward.

Sequences developed within the middle Miocene in the study area are interpreted to be controlled locally by episodic shelf instability, basin physiography (shelf edge), fault growth and linkage. Relative sea level changes provide the major control on sequence development and deep valley incisions. The latter have a strong geomorphological impact on the area and a strong control on sequence variability. Interpretation of GDE maps shows that sands were originally deposited in river- and mouth bars with longshore drift currents redistributing the sand parallel to the shoreline. During lowstand periods, canyons developed which served as conduits for sand to the basin (deep water sand).
Appendix E: Random line showing the geometry, reflection patterns and position of slope and basinal fans within LST Depositional Sequence 1-(Upper Patches). See position in inset above.

Figure 15: Random line showing the geometry, reflection patterns and position of slope and basinal fans within LST Depositional Sequence 1-(Upper Patches). See position in inset above.

Appendix F: Random line showing the geometry, reflection patterns and position of slope and basinal fans within LST Depositional Sequence 1-(Lower Patches). See position in inset above.

Figure 16: Random line showing the geometry, reflection patterns and position of slope and basinal fans within LST Depositional Sequence 1-(Lower Patches). See position inset above.
recognized as high amplitude seismic facies on the slope and on the basin floor.

Idealized schematic palaeogeography and general conceptual depositional models of the study area during middle Miocene time are presented in Figures 7 and 10.

References