Sequence Stratigraphic Analysis Within The Zambezi Depression, Offshore Northern Mozambique Basin

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Abstract

The post-rift sequence stratigraphy within the Zambezi Depression is significantly controlled by relative sea level, sediment supply and subsidence rate. The Knowledge of basinal stratigraphic architecture and basin evolution is very useful for the exploration of oil and natural gas resources. Ten regional stratigraphic surfaces and associated depositional sequences were interpreted in the study area. Depositional pattern, were analyzed to evaluate the variable influences of relative sea level and sediment supply rate on depositional processes. The depositional sequences were categorized into three main magasequences based on sea level changes and sediment supply. Sediment supply changed through geological time, initially sediments were supplied from the SW and SE, in the later stage sediment supply was from the west. Considering the factors affecting different depositional processes, basin evolution can be divided into three phases. Phase 1: consists of non-marine deposits probably controlled by slope gradients. Phase 2: deposits were mainly controlled by systematic transgressive and regressive cycles and this stage is comprised of shallow to deep marine sediments suggesting a basin floor fan. Phase 3 is the youngest and consists of progradational clinoforms indicating that sediment supply outpaces the accommodation space. The prospectivity for hydrocarbon is high in sequences which and dominated by turbidities and are associated with canyon infill and basin floor fans.

1. Introduction

The current study is located within the Zambezi Depression in the northern part of the Mozambique passive margin Basin (Figure 1), the study comprises sequence stratigraphic analysis to determine stratigraphic architecture and evolution of depositional environments, within the post-rift sequences of the Zambezi Depression. In this study, the regional seismic observations were integrated with well data to improve understanding of the depositional processes and the controlling factors on these processes. A better understanding of depositional process and the basin evaluation is useful for hydrocarbon exploration. This study, was driven to satisfy the following objectives:

- To analyze the seismic stratigraphic architecture of the post-rift deposits within Zambezi Depression;
- To recognize and characterize the regional stratigraphic surfaces that represent changes in depositional trends of sedimentary packages through geological time and
- Understand the post-rift basin evolution

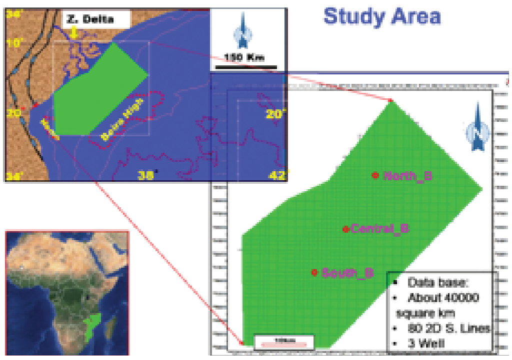


Figure 1: Location map of the Zambezi Depression

2. Results

Sequence analysis involved ten stratigraphic surfaces and nine sequences that were grouped into three magasequences (Figure 2). Observation such as external seismic geometry and internal seismic character were the key for horizon picking and sequence analysis as follow:

Sequence S1

Is the lowest post-rift stratigraphic unit, delimited at the base by SB-1, seismic facies show tilting trend, and internally, heterogeneous (parallel and sub-parallel discontinuous facies and chaotic), probably related to several depositional processes and variations of depositional energy environment that might have contributed on facies distribution. Facies onlap against the highs to the west and to the east and sub-parallel and discontinuous reflectors could be related with rapid changes in depositional energy level and the chaotic character could be associated with high energy deposits.

Sequence S2

Delimited by SB-2 at the base and conformable with the underlying S1. At the top is truncated on SB-3 surface to the west, conformable in the central and eastern part of the area. Facies are variable from the bottom to the top and the sequence comprises three seismic units. The lower unit was interpreted as LST, through the middle portion facies onlap landward, most likely related to an initial stage of sea level rise (TST) and to the upper most unit facies are parallel, continuous and down lap (HST). Sediments were supplied from SW to NE, and the thickness increase from west to the Central Basin and thinning to the east.

Sequence S3

Is bounded by surfaces SB-3 at the base and SB-4 at the top (Figure 4). Overlain on subaereal unconformity to the west, conformable in the central and east part. The top is marked by SB-4, which is truncated across the slope and conformable basinward. Two units were identified, the lower unit extends from the basin floor to slope (Figure 4), characterized by low to moderate amplitude, sub-parallel, chaotic and transparent facies, interpreted LST. The second from the middle to the top this sequence to the West, it consists of moderate to high amplitudes, conformable along topset, grading to gently dipping strata. At the slope, facies are more chaotic and transparent basin wards.

Sequence S4

Is bounded at the base by SB-4, which comprises an erosional surface on the shelf then is conformable basinwards. At the top is delimited by regional erosional surface SB-5 (truncated along shelf and slope). From the base to the middle is characterized by high frequency and amplitude, facies are parallel, sub-parallel and continuous reflectors, then change to chaotic trend towards the top. SB-5 was interpreted as sequence boundary Type-I and this period is marked by changes related to the depositional processes. At the lower section facies are not homogenous and comprises chaotic, parallel and sub-parallel, channel and truncations are also present on SB-5. The isopach map of the Sequence-4 shows that the thickness is greatest along the slope zone and thin towards the basin.

Sequence S5

Is bounded by SB-5 surface at the base, which is truncated from the shelf to the slope break and is correlative with canyon SW-NE, Figure 5. Comprise three units, the lower unit is conformable with SB-5 in the eastern part, characterized by high amplitude and frequency, with variable facies such as chaotic, parallel waved and mounded features, is assumed to as LST and contemporaneous with canyon. Then facies onlap landward, associated with sea level rise (TST), at this time canyon was filled with transparent facies probably related to homogeneous lithofacies. To the west is characterized by high frequency, low to high amplitude, and downlapping clinoforms against SB-5(HST), probably deposited during sea level fall stage. Isopach map reveals thin sediments associated with canyon development due to erosion, the maximum thickness is towards the basin.

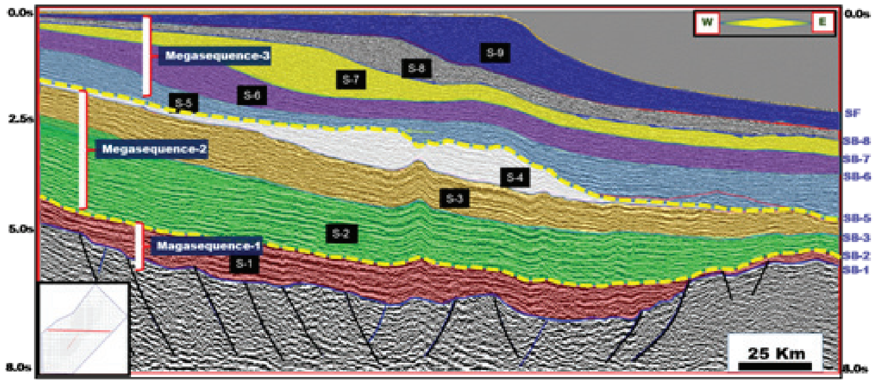


Figure 2. Seismic profile show stratigraphic surfaces and sequences within Zambezi Depression

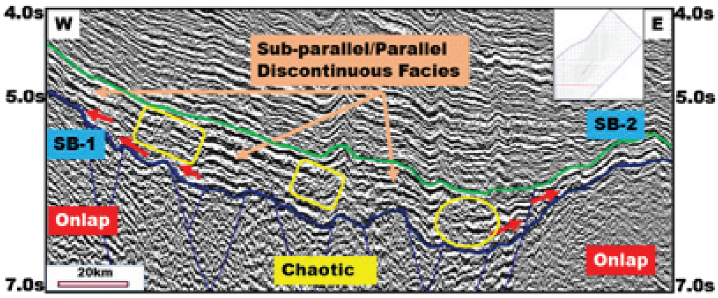


Figure 3. Sequence-1, show seismic facies distribution within the stratigraphic surfaces SB-1 at base and SB-2 at the top and seismic contrast is prominent below SB-1 from the highlighted sequence

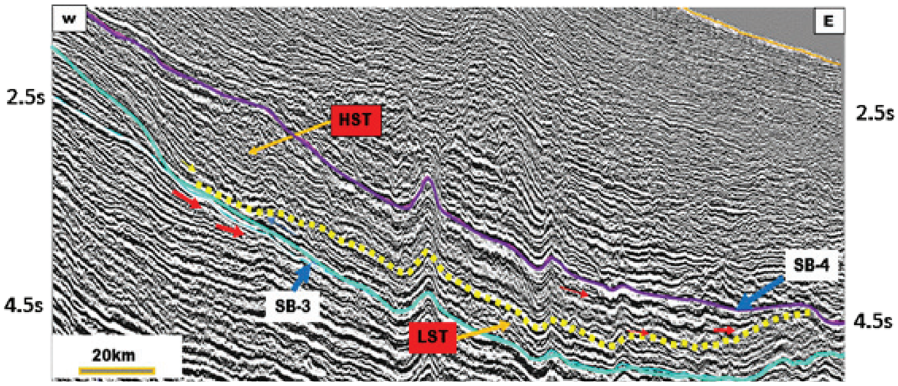


Figure 4. Seismic units distributions within the sequence S3

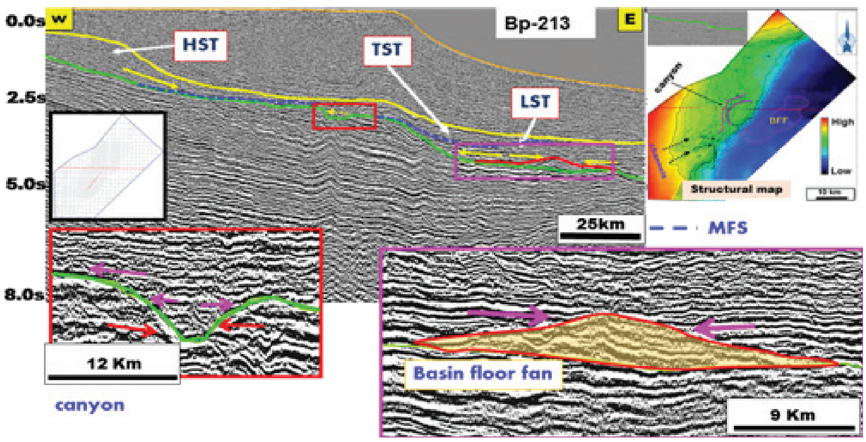


Figure 5. Sequence S5 show seismic unit distributions and relevant geological features

Sequence S6

Is bounded at the base by SB-6, characterized truncation on slope and conformable at the basin floor. Seismic character changes across the shelf, slope and basin floor (facies are parallel at the shelf then gently dipping clinoforms). Sediments is high and outpaced the accommodation space, with transparent facies on slope, also parallel and sub-parallel. The sequence is thicker on slope and thickness maps reveal changes on sedimentation pattern from lobate to elongate, parallel to the coastline, related with sediments redistributions due to open marine conditions (tides), Figure 6.

Sequences- S7, S8 and S9

Understand WNW – ESE shelf progradation, marked by coastline shifting through time, definitely related to Zambezi Delta as major source of sediment supply. S7 is gently dipping then grades to steep dipping for S8 and S9, sedimentary packages are thicker on slope and stratigraphic surfaces are coincident with regional strong amplitude reflector and with prominent backstepping on slope. These sequences have diversified facies and almost similar to sequence S6, topset is conformable, gently to steep dipping foreset quite conformable bottomset but localized chaotic facies are also present. Isochore maps, show alignment of sediments SW-NE and WNW – ESE shelf evolution (Figure 7).

3. Discussion Relative to Sediment Supply and Subsidence Rate

The stratigraphic framework was established by regional 2D seismic interpretation, then constrained on sediment supply and subsidence, which are major factors that directly influence stratigraphic patterns and architecture of the sedimentary fill within the basin, so:

Sequence S1

Is thickening from west to the central basin and thin at the eastern part, it suggests that the western highlands have contributed with high rate of sediment supply basinward compared than Beira High (Figure 3). Sediment distribution was controlled by the basal relief, is thicker on depocenter and thinning against the high lands, it suggests thermal subsidence and loading in minor scale.

Sequences S2 and S3

Comprise parallel to wavy reflectors which indicates uniform sedimentation conditions, there are thicker at the western part and gradually thin basinward. Sediment supply looks to be in equilibrium with accommodation space in quite basin or low subsidence rate, Figure 7.

Sequence S4

Comprise parallel and sub-parallel facies then change to chaotic towards the top. It suggests

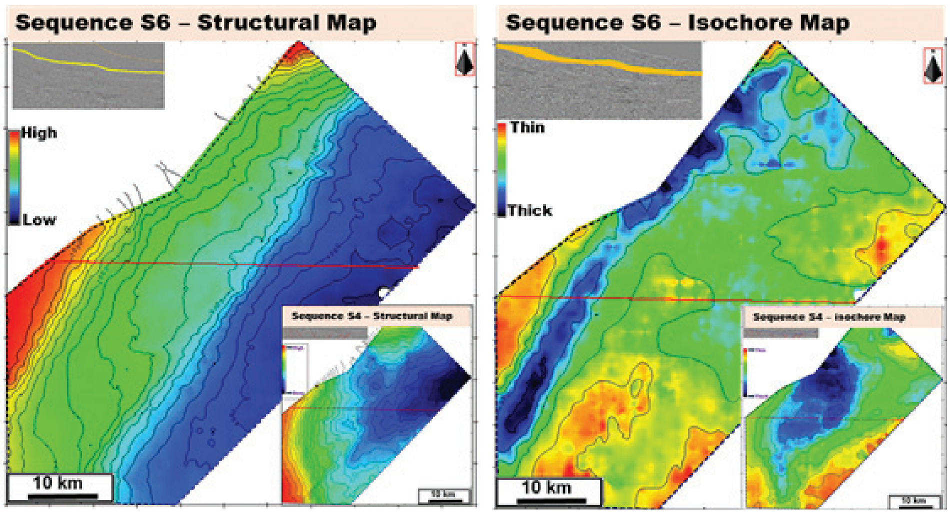


Figure 6. Sequence S6 show evidences of depositional pattern changes (lobate to elongate)

dramatic increase of the rate of sediment supply for this sequence, as compared to the lower sequences. Chaotic facies could be related with high rate of sediment supply by mass sediment slides as a result of gravity driven sediments flow. Channel cut and well developed canyon could be indication of low subsidence rate related to intensive erosion.

Sequence S5, S6, S7, S8 and S9

At this stage, Zambezi Delta is the major source of sediment supply, with thicker sedimentary packages on slope (Figure-7). Is a set of progradational packages, seen as evidence of high rate of sediments supply that overcame the accommodation space. The clinoforms show progressive thickening and steepening on slope. A canyon is oriented NW-SE, observed on seismic profile, which is correlative with SB-5, it could not have played a major roll on sediment supply but gives orientation path of the sediments from source to accommodation space.

Progradation of well-developed clinoforms is indicative of low subsidence rate, so sediment supply was high and exceeded the accommodation space, as a result, the clinoforms thicken and steepen basin wards.

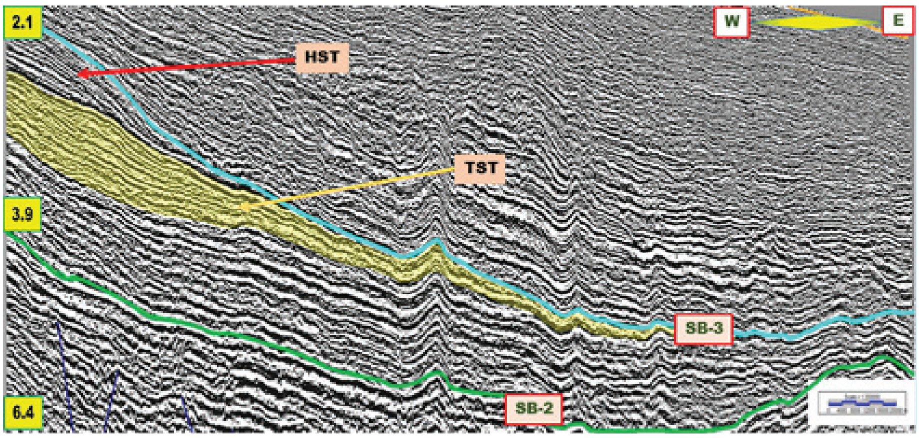


Figure 7. Seismic profile show parallel or sub-parallel reflectors within sequence S2. Quite similar with S3

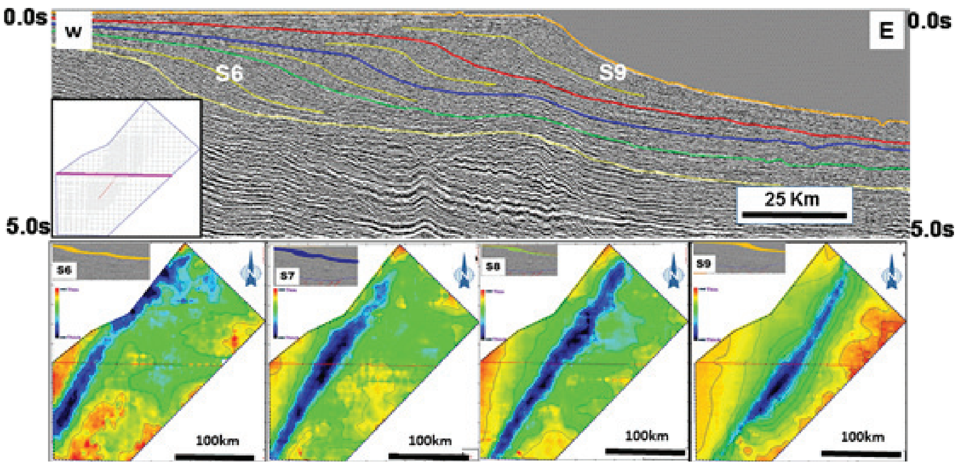
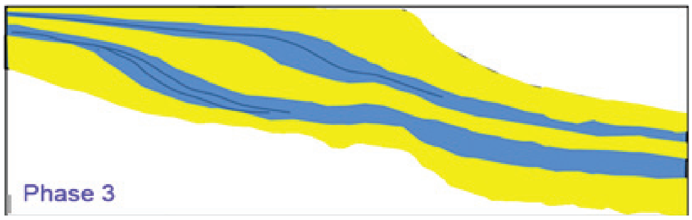


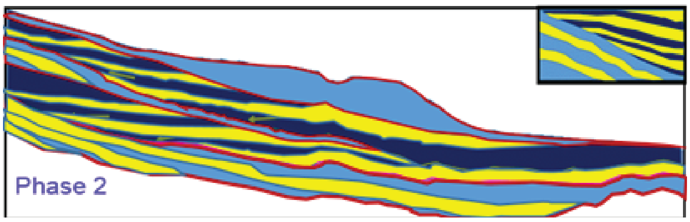
Figure 8. Seismic profile and thickness maps of sequences S6, S7, S8 and S9

3. STRATIGRAPHIC EVOLUTION OF POST-RIFT DEPOSITS

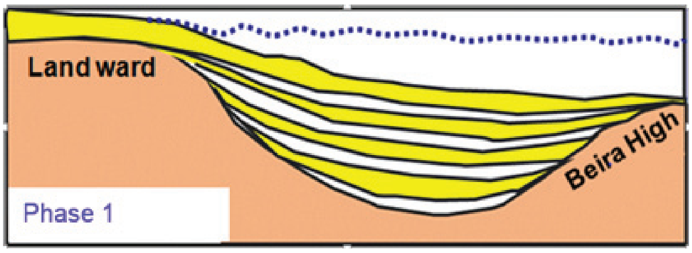
The sedimentary evolution of Zambezi Post-rift deposits suggests three phases separated by two major sequence boundaries SB-2 and SB-5,detailed as follow:



Phase 3: Comprise the upper most megasequence (S5, S6, S7, S8 and S9. All sequences show shallow to deep marine deposits. Is assumed to have been deposited during a period of high rate of sediment supply evidenced by progradation of the clinoforms and occurrence of turbidites in basin floor.



Phase 2: Comprises sequences S2, S3 and S4, S2 and S3 are shallow to deep marine deposits. Sediments were gradually supplied and controlled by the cyclicity of the sea level across the slope. Sequence S4, correspond to low relative sea levels, associated with deep marine deposits, which could have been developed during lowstand system tracts.



Phase 1: involve the lower most sequence characterized by highly variable depositional energy environment, evidenced by the presence of onlapping and chaotic facies. It is assumed to represent litoral, paralic, or non-marine deposits.

4. CONCLUSIONS

The post-rift stratigraphic architecture on Zambezi Depression comprises nine sequences and ten stratigraphic surfaces. These sequences can be grouped into three magasequences. Megasequence 1 overlay top-syn-rift deposits, which is interpreted as deposits accumulated during relative low base. Internal facies varies from sub-parallel, chaotic and fluvial deposits at the lower level, with gradual change to marine on top. Magasequence 2, characterized by parallel planar and regionally continuous facies on lower and mid-levels within the sequence, grading to chaotic at the upper levels. Could be related with transgressive and regressive marine cycles and the upper most part is related with progradational clinoforms, which are evidence of high rates of sedimentation. The top of Megasequence 2 is marked by regional unconformities interpreted as type 1, correlative with canyon and conformable with basin floor fan. Magasequence 3 consist of progradational sequences.

Through time sediment supply direction changed. During the deposition of Megasequence 1, sediments were supplied from high lands in the SW and SE. Magasequence 2 received sediments from the SW then the source of sediment supply changed to west in stage of delta. Also, the depocenter center moved from NE to W trough time and isopach maps show changes of deposition pattern from lobate to elongate, related to redistribution of sediments by open marine conditions (tides).

The sequence stratigraphic model for Zambezi Depression reflects interplay of controlling factors such as sea level fluctuations, sediment supply and basinal geomorphology. Based on observation, its evolution suggests three phases;

Phase 1: involves the lower most sequence characterized by highly variable depositional energy, evidenced by the presence of onlapping and chaotic facies.

Phase 2: is comprised of shallow to deep marine deposits. Sediments were gradually supplied and controlled by the cyclicity of the sea level across the slope. In the final stage, this phase corresponds to low relative sea levels, associated with deep marine deposits, which could have been develop during lowstand system tracts.

Phase 3: comprised the upper most megasequence. All sequences show shallow to deep marine deposits. It is assumed to have been deposited during a period of high rate of sediment supply evidenced by progradation of the clinoforms and occurrence of turbidites on the basin floor. Sequence S4 contains turbidite facies and is overlain by basin floor fan and may have good reservoir potential.

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