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# SEQUENCE STRATIGRAPHIC FRAMEWORK OF 'AKOS' FIELD, NIGER DELTA

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## ABSTRACT

*The aim of this study is to investigate the sequence-stratigraphic framework of a hydrocarbon prospect of 'AKOS' Field, Niger Delta, using well logs, and 3-D seismic data. To achieve this, the researchers identify the various sand/shale and seismic facies, build a sequence-stratigraphic framework of the oilfield, and assess the petroleum play of identified system tracts. A fault analysis reveal twelve (12) fault sets (Fault 1-12) mapped across the seismic volume. These faults are picked on an increment of 50 and examined for consistency using time slice and variance attributes. Faults-1 and 2 are major faults. The other ten (10) are minor faults. The mapped faults are normal growth faults common in the Niger Delta, as most trend approximately E-W direction. Sequence-stratigraphic analysis of the prospect based on chronostratigraphic correlation reveal two (2) sequences. Sequence-1 is between Sequence Boundary (SB) 0 to SB-1. Sequence-2 is between SB-1 to SB-2. Results from interpreted and analyzed system tracts reveal all three (3) present in Sequence-1. However, the Lowstand System Tract (LST) is absent in Sequence-2. The Lowstand Systems Tracts (LST) identified by shallowing and coarsening-upward succession, and progradational and aggradational parasequence sets are major hydrocarbon-producing intervals within the oilfield. The Transgressive Systems Tract (TST) typified by dirtying-upward seal the Lowstand Reservoirs. The upper section of the Highstand Systems Tracts (HST) has reservoir potential.*

**Keywords:**Facies, Faults, Sequence, Sequence Boundary (SB), System tracts.

## INTRODUCTION

Seismic stratigraphy involves establishing stratigraphic surfaces via identifying various reflection terminations, thus understanding the seismic facies relationship. Sequence stratigraphy applies both time and relative base-level changes to understand and identify facies migration. It is necessary to predict the vertical and horizontal distribution of depositional sequences, their system tracts, and facies during exploration and development of sandstone reservoirs. Sequence stratigraphy is an indispensable tool in basin-wide geologic analysis with widespread applications, especially aiding an understanding of the relationship between sea-level changes and sediment supply (Catuneanu, 2002). It also assists in correlating locally recognized depositional sequences.

The Niger Delta consists of a regressive sequence of clasts of deltaic and marine origin. It consists of three primary lithofacies- marine shale within the Akata Formation at the bottom, followed by a stacked sequence of Agbada Formation, and non-marine alluvial (continental) sands within the Benin Formation at the top. Weber and Daukoru (1975) report the cyclic nature of sedimentation of paralic deposits. Their study results suggest a complete cycle consisting of thin fossiliferous transgressive marine sands followed by an offlap sequence commencing with marine sediments, and another transgression possibly terminating the cycle.

Doust and Omatsola (1990) recognize six depobelts: Offshore megastructures (Late Miocene), Coastal Swamp (Middle-Late Miocene), Central Swamp II (Middle Miocene), Central Swamp I (Early Miocene-Middle Miocene), Greater Ughelli (Oligocene - Early Miocene), and the Northern delta (Late Eocene - Early Miocene). These are distinguished by Ozumba (1999) while developing a stratigraphic framework of the Western Niger Delta using wireline log data and foraminifera acquired from four wells drilled within the Central-Swamp and Coastal depobelts. The results conclude that sequences formed during the Late Miocene are thicker than those of the Middle Miocene period.

Going by the seismic stratigraphy concept alongside a chart of the global sea-level cycle, one may assume eustasy as the primary driving influence behind the formation of sequences at every stratigraphic cyclicity level. The new stratigraphic methodology highlights seismic stratigraphy and the global sea-level cycle chart as an inseparable package (Catuneanu, 2002). As seismic stratigraphy evolved to sequence stratigraphy over time, there was a better understanding of the latter while combining outcrop and well-log data.

The study objective is to delineate sequence boundaries from their system tracts, correlate the reservoir sand bodies within the oilfield, predict sand body characteristics that form potential reservoirs, and infer the depositional environment of sand bodies within the oilfield through the combination of two stratigraphic tools; wireline well-logs, and seismic dataset.

## MATERIALS AND METHODS

The dataset for this study include well-log, seismic covering about 110 sq. km, deviation, and check shot for six wells. Schlumberger's PETREL™ software is used in this study to aid well-log interpretation and well-to-well correlation.

Two approaches of structural and stratigraphic principles are applied to carry out the seismic interpretation. Firstly, the observation of reflection terminations against a planar or curvilinear trend to guide seismic structural interpretation. Then, analyzing seismic data attributes such as lithofacies, erosion, paleotopography, bedding patterns, thicknesses, spacing, paleobathymetry, and gross depositional environments to guide stratigraphic interpretation.

## RESULTS AND DISCUSSION

### Structural Interpretation

Schlumberger's Petrel™ software is used for seismic interpretation. The study investigators generated time structure maps from the horizons and the time domain maps were depth converted using the time-depth relationship derived from the check-shot data

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**Fault Interpretation**

The study investigators mapped twelve (12) fault sets (Fault 1-12) across the seismic volume. These faults were picked on an increment of 50 and examined for consistency using time slice and variance attribute. The mapped faults are normal growth faults common with the Niger delta. Almost all the faults trend approximately E-W. Two (2) sets: Fault 1 and 2 are major while the other ten (10) are minor (Figures 1 and 2).

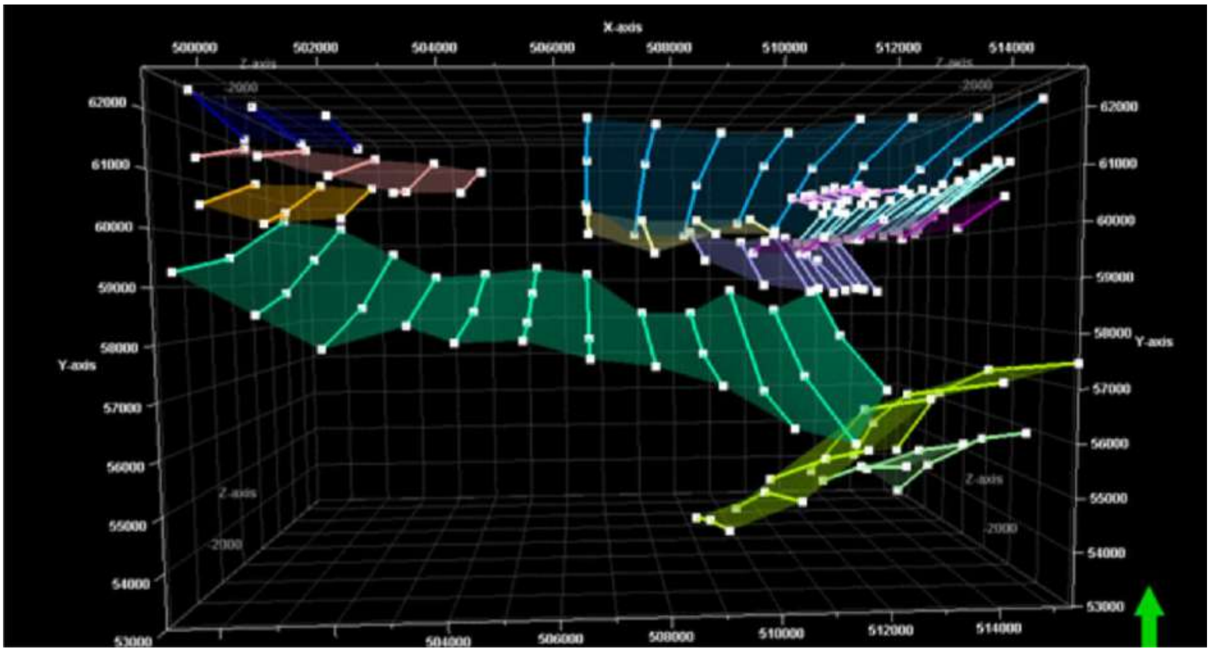


Figure 1: Fault interpretation as displayed on a 3D window

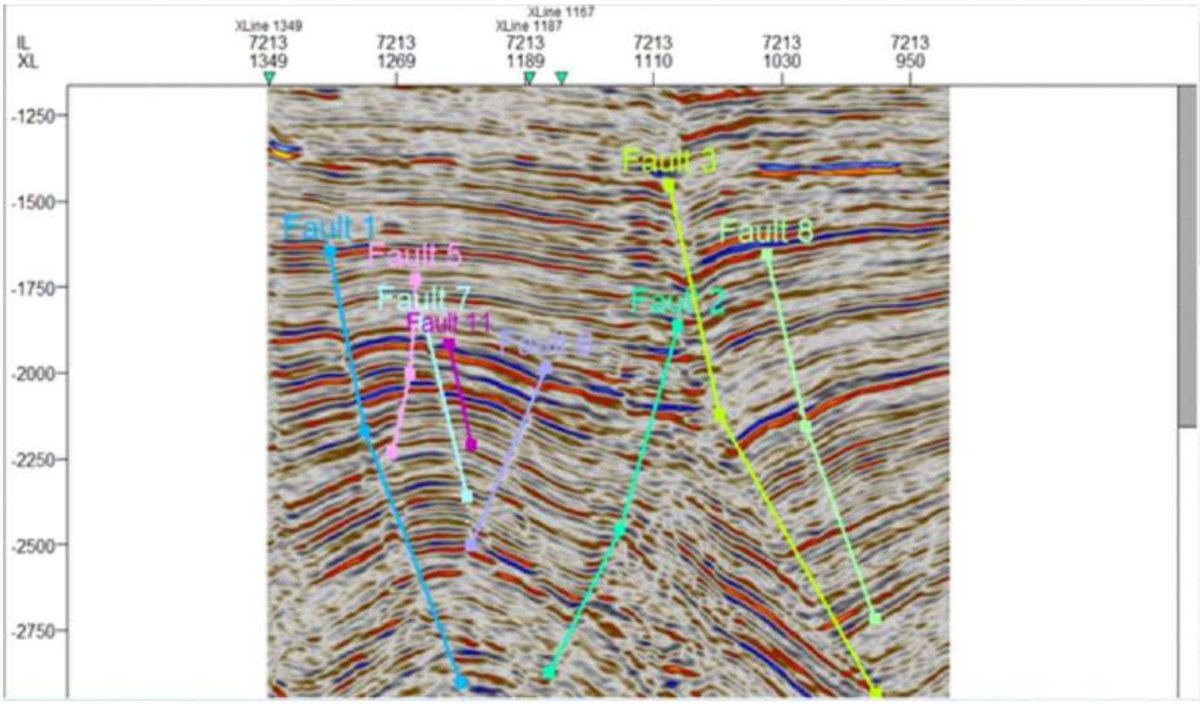


Figure 2: Seismic section Inline 7213 showing some of the interpreted faults

## Well Correlation

A well-to-well correlation was done to establish the continuity and lateral extent of important stratigraphic surfaces. This was achieved using a lithology sensitive log (GR) and Resistivity log in six wells (Figure 3). By using four wells through the NW-SE strike line, it was possible to carry out another correlation for intervals that are potentially hydrocarbon-bearing. To achieve this, a shale baseline was established and areas to the left of the baseline were taken to be sand, and zones where the sand corresponded to a high resistivity log reading were assumed potentially hydrocarbon-bearing (Figure 4).

## Well-to-seismic Calibration

The researchers generated a synthetic seismogram from the AKOS-1 well, helping to tie well-to-seismic data. Differences in the domains of well and seismic datasets were less pronounced. A combination of sonic and density logs and then matching them to the seismic information produced acoustic impedance attributes within the well.

The researchers obtained a sufficiently good match in calibrating the well to seismic trace (Figure 5).

## Horizon Interpretation

The study investigators identified the stratigraphic surfaces on the oil well logs, mapped them on the seismic volume, and interpreted these surfaces on both in-lines and cross-lines on an increment of 5 (Figure 6). Next, they converted horizons to time structure maps (Figures 7 - 12) using the convergent interpolation method. Time structure maps were then converted to depth structure maps using the mathematical relationship obtained by plotting the time-depth relationship derived from the check shot data (Figure. 13). Figures 14 - 19 show the resulting depth structure maps.

The isopach maps of the resulting system tracts showed changes in the thickening and thinning directions (Figures 20 – 24).

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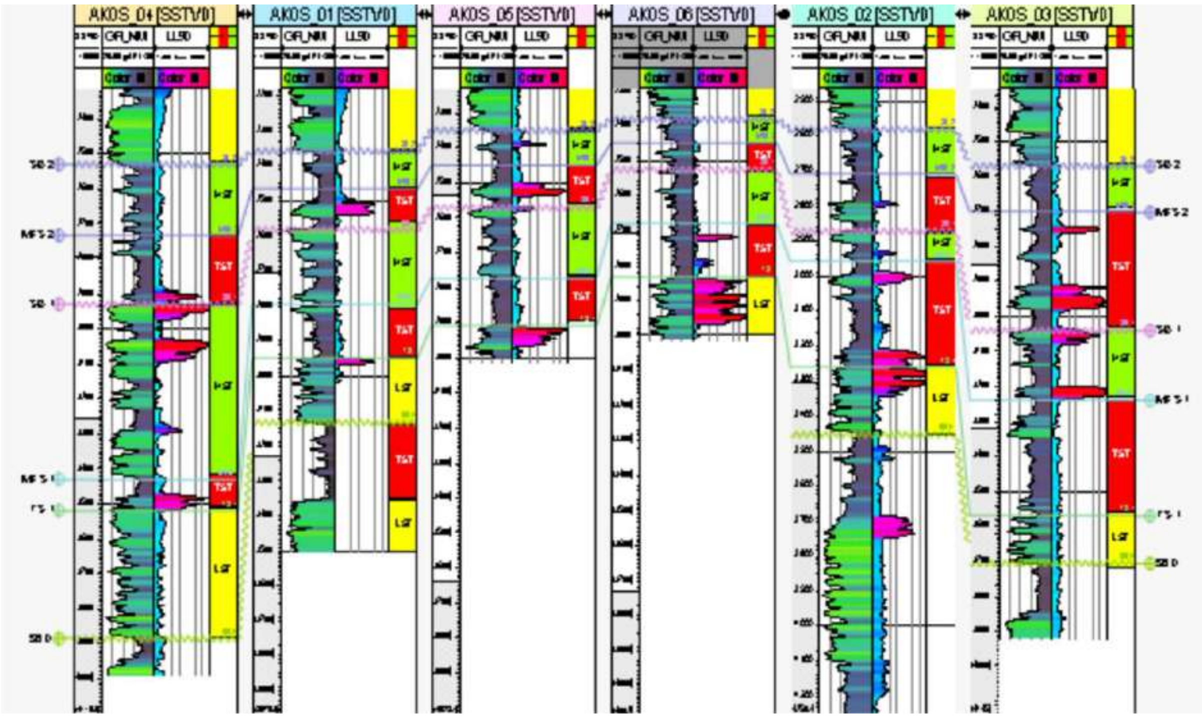


Figure 3: Correlation of Wells across 'AKOS' Field showing important surfaces and systems tracts

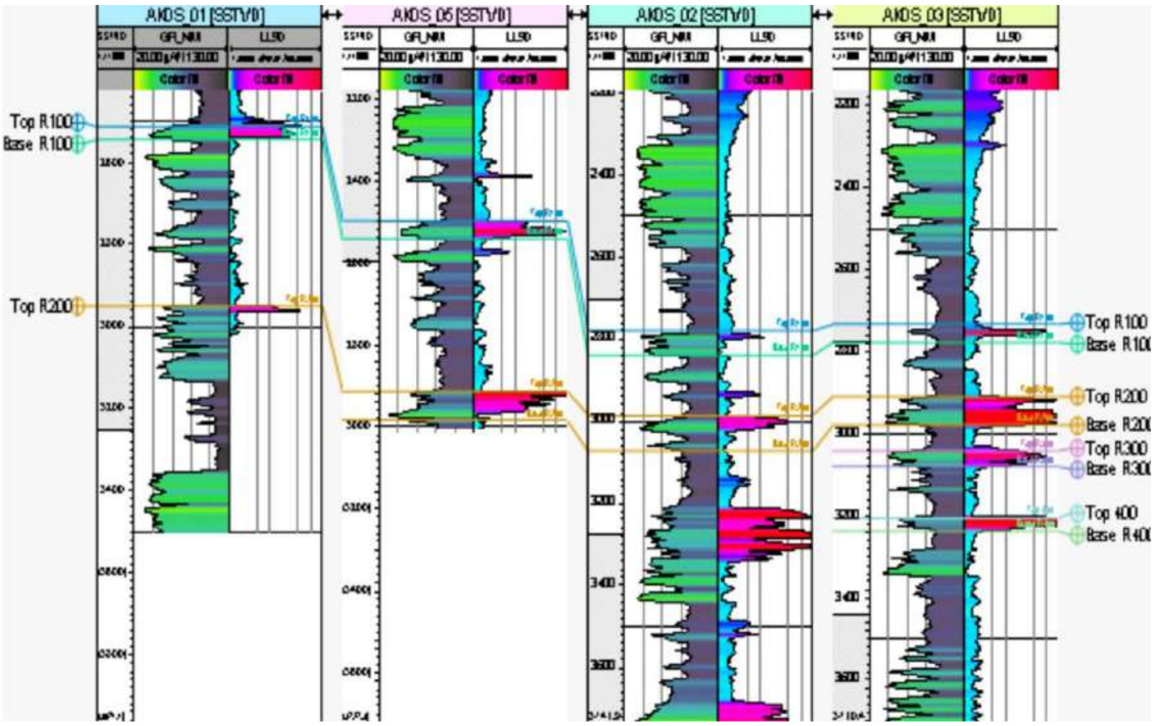


Figure 4: Well correlation panel showing the potential hydrocarbon-bearing intervals across the four wells

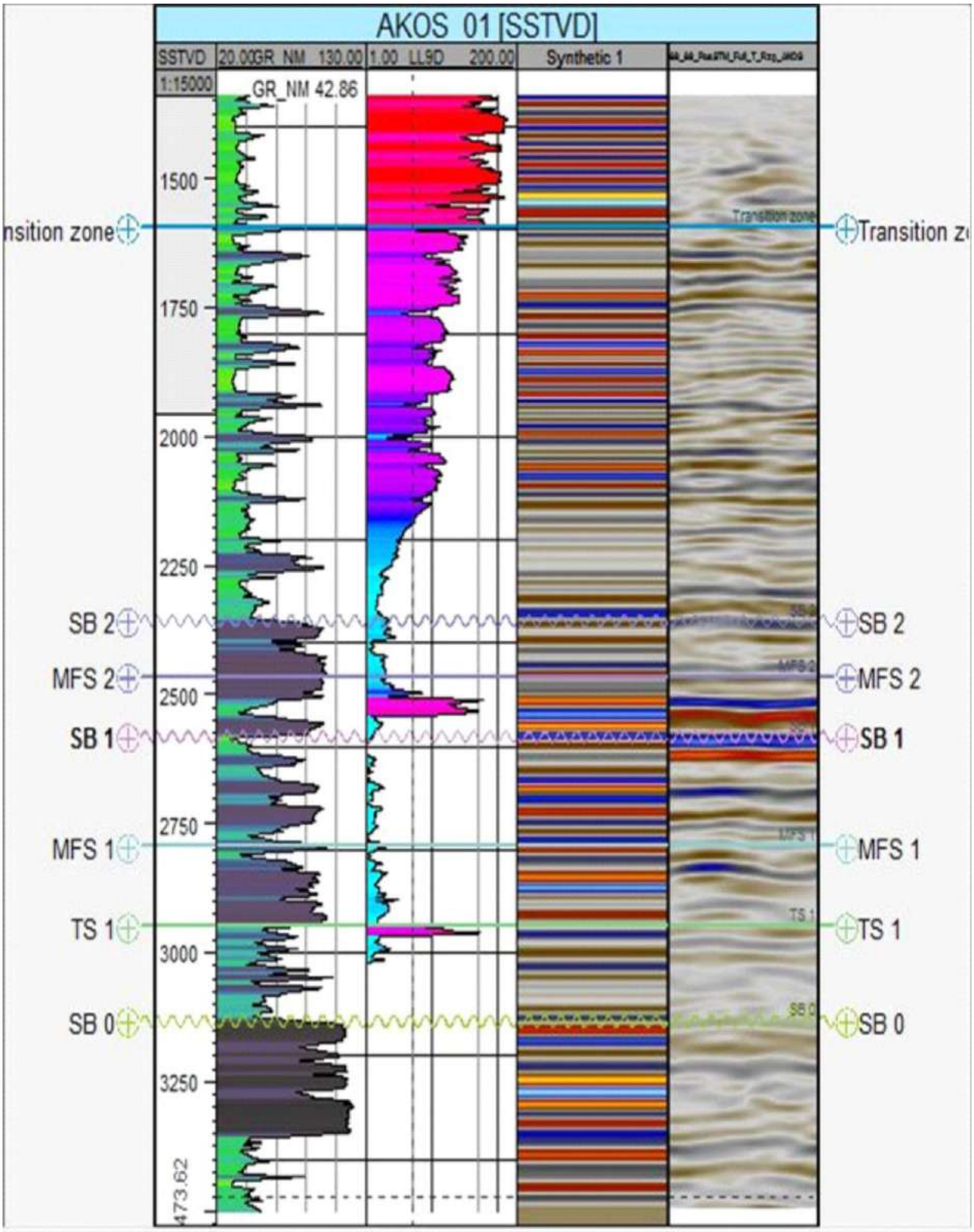


Figure 5: Synthetic seismogram for well AKOS 01

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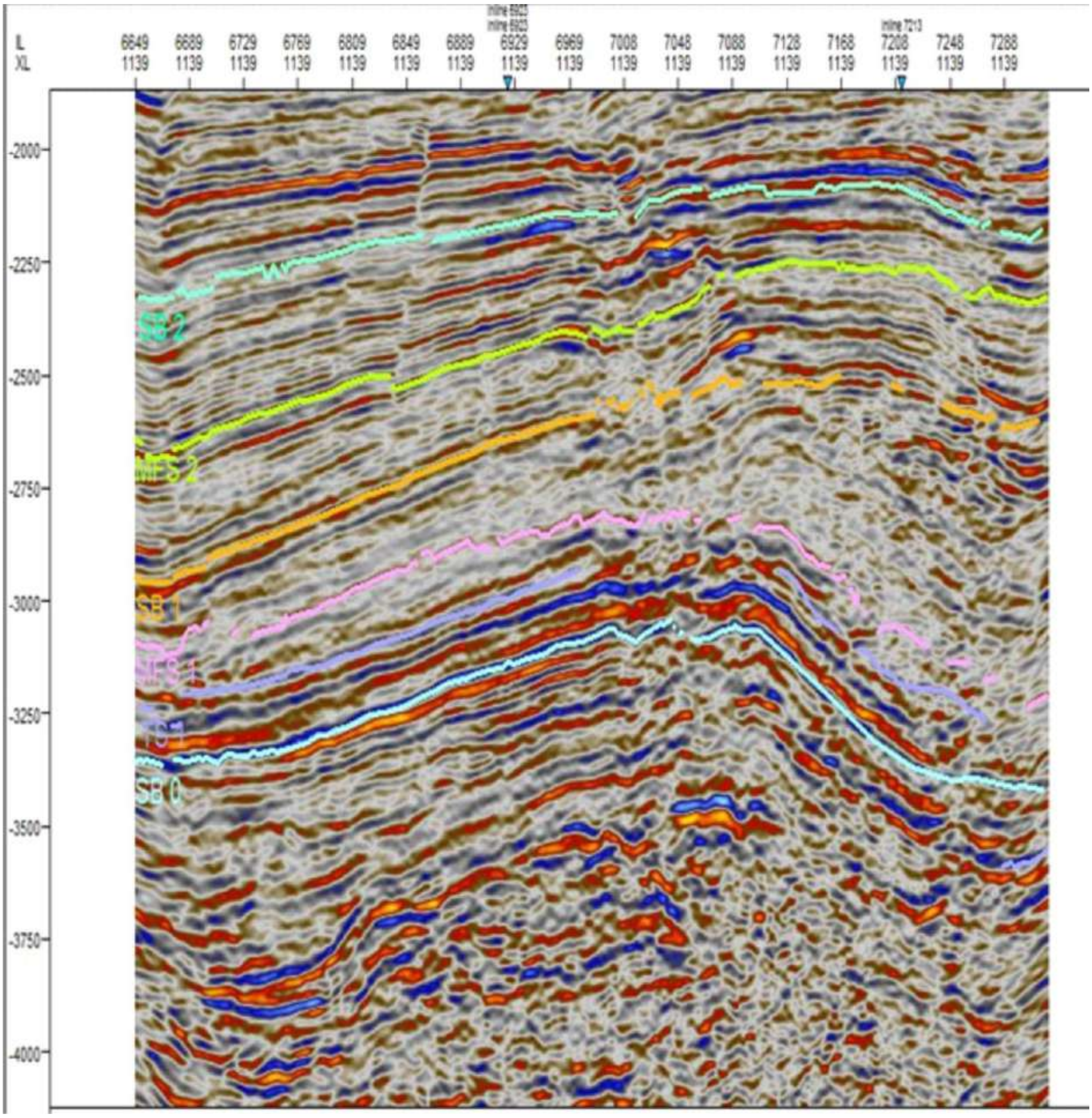


Figure 6: Seismic section along cross-line 1139 showing the interpreted surfaces

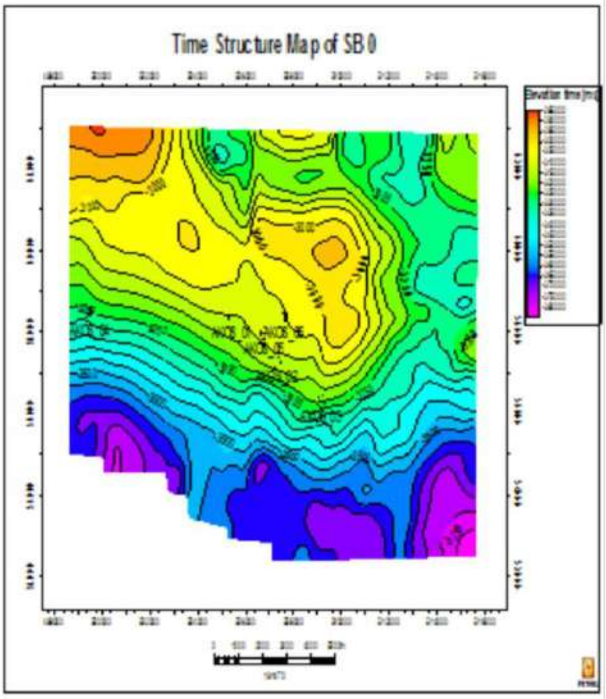


Figure 7: Time structure Map of SB 0

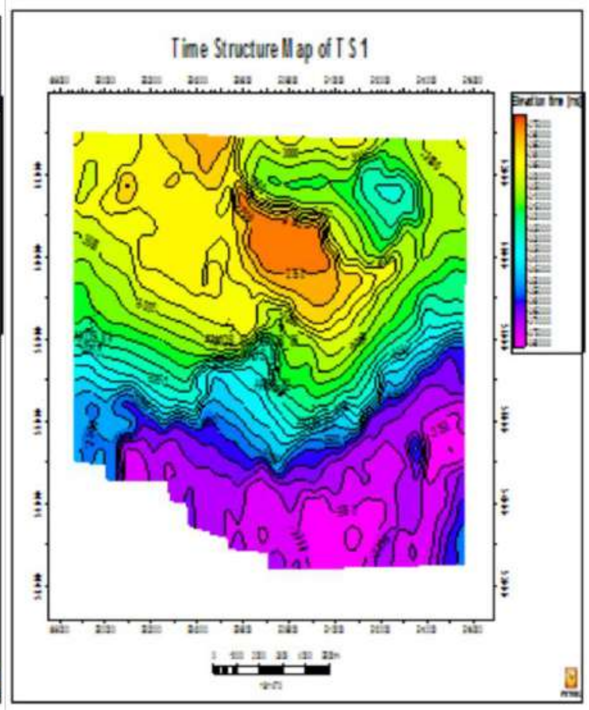


Figure 8: Time structure Map of TS 1

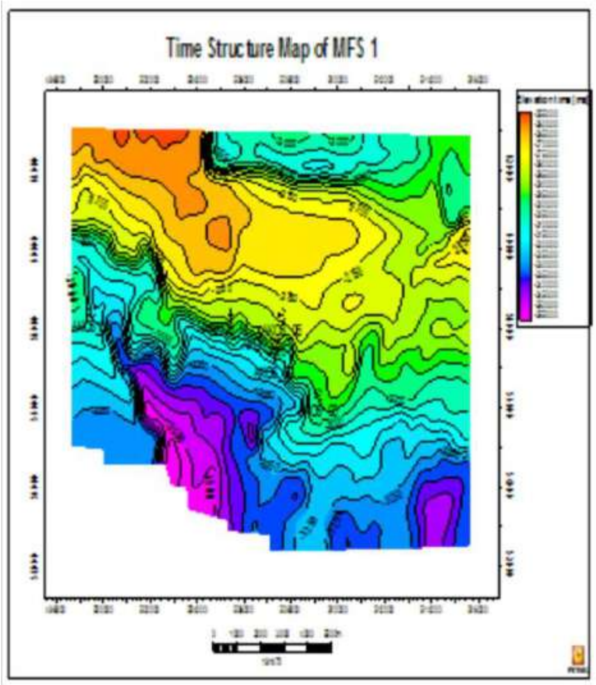


Figure 9: Time structure Map of MFS 1

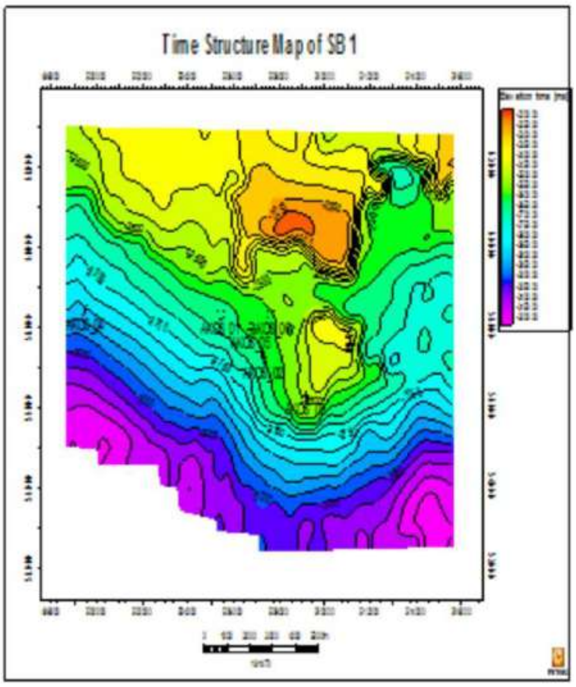


Figure 10: Time structure Map of SB 1

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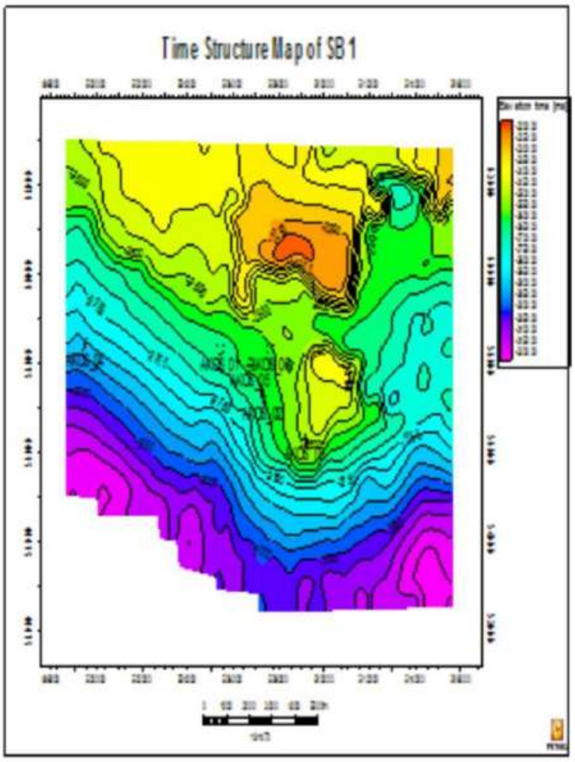


Figure 11: Time structure Map of MFS 2

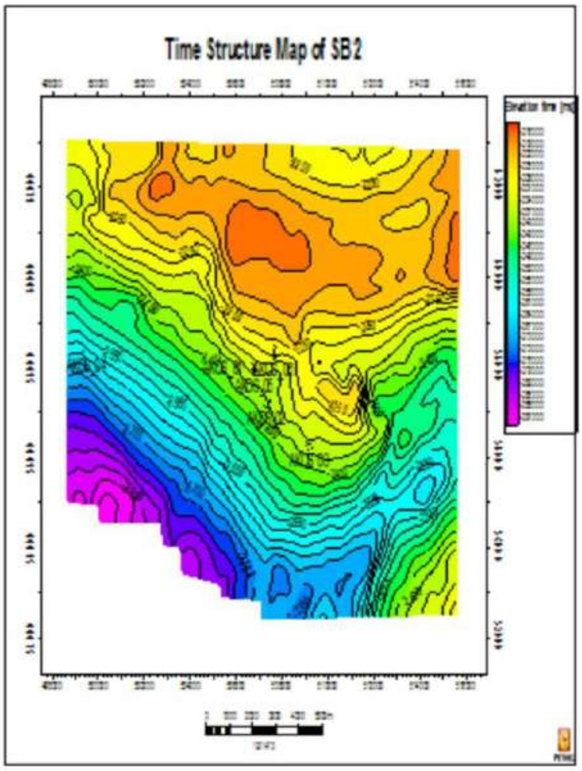


Figure 12: Time structure Map of SB 2

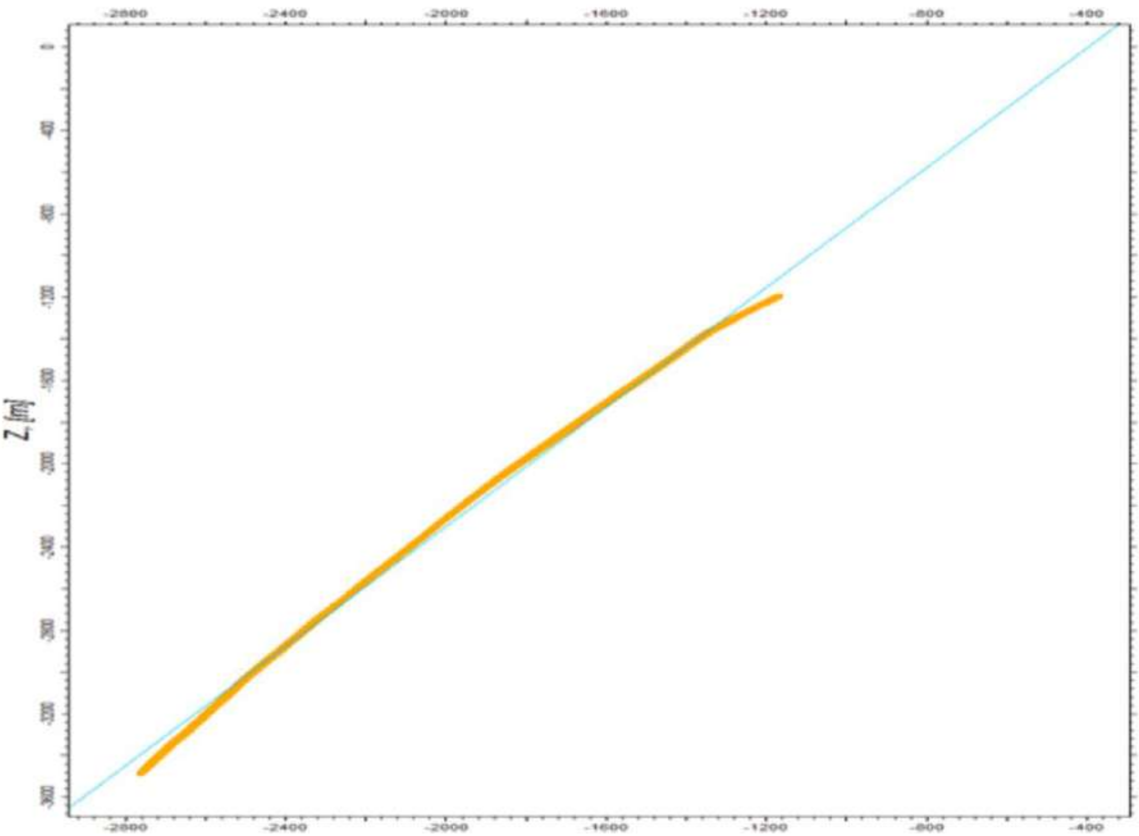


Figure 13: TWT Vs. Depth Linear Function Plot for Time-Depth Conversion (The resulting equation is: Y = 1.43464 * X + 568.571)

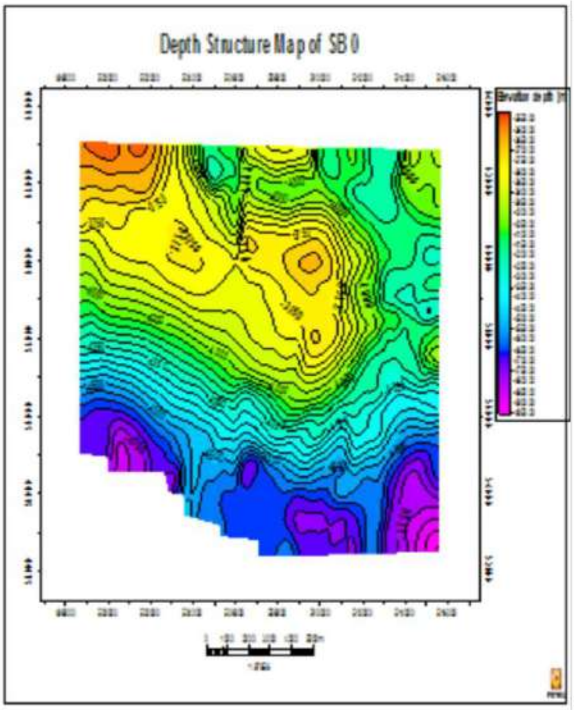


Figure 14: Depth structure Map of SB 0

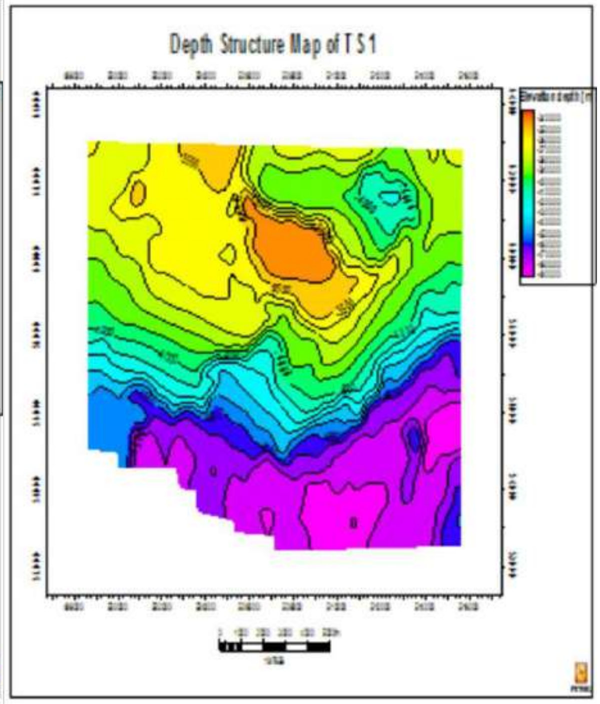


Figure 15: Depth structure Map of TS 1

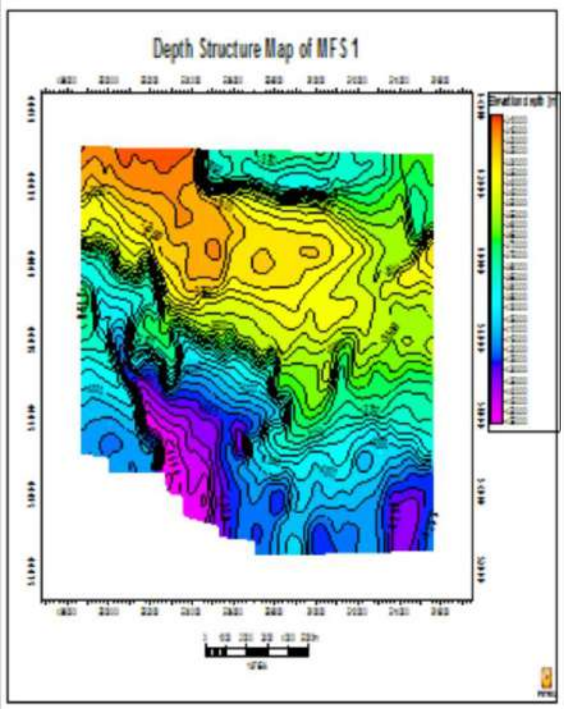


Figure 16: Depth structure Map of MFS1

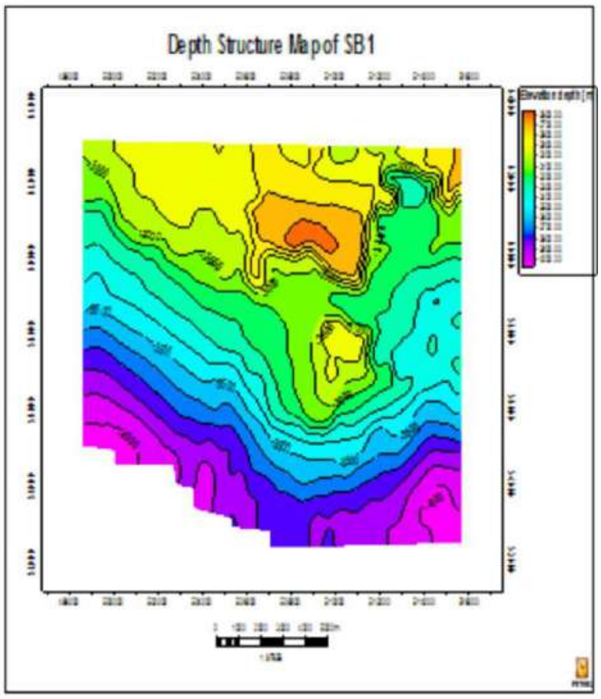


Figure 17: Depth structure Map of SB1

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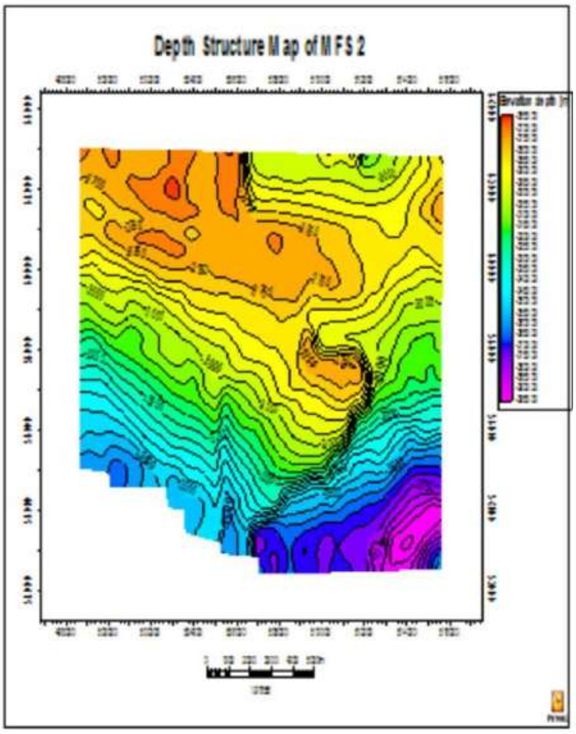


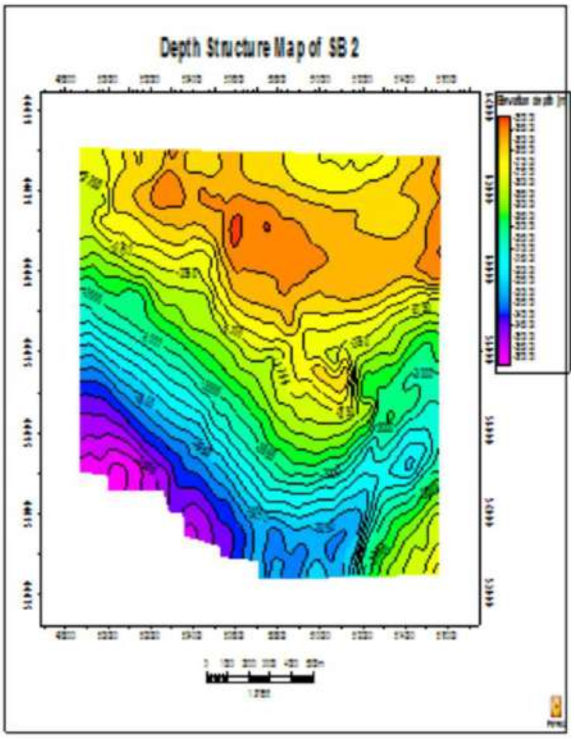
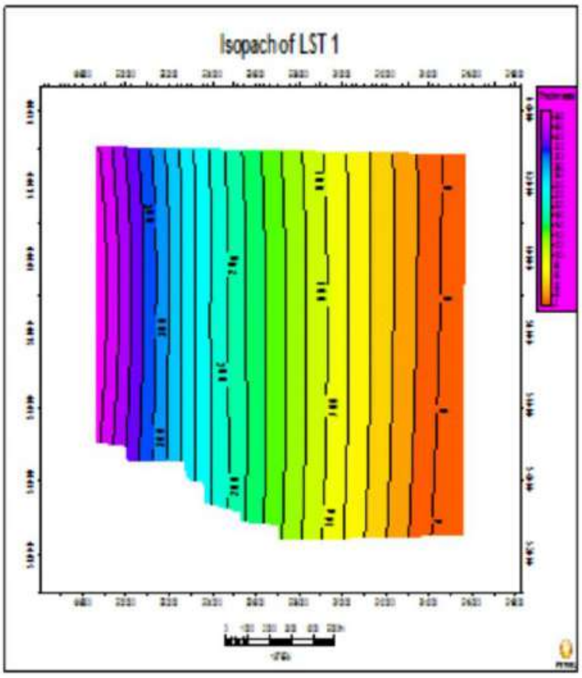




Figure 18: Depth structure Map of MFS 2

Figure 19: Depth Structure Map of SB 2



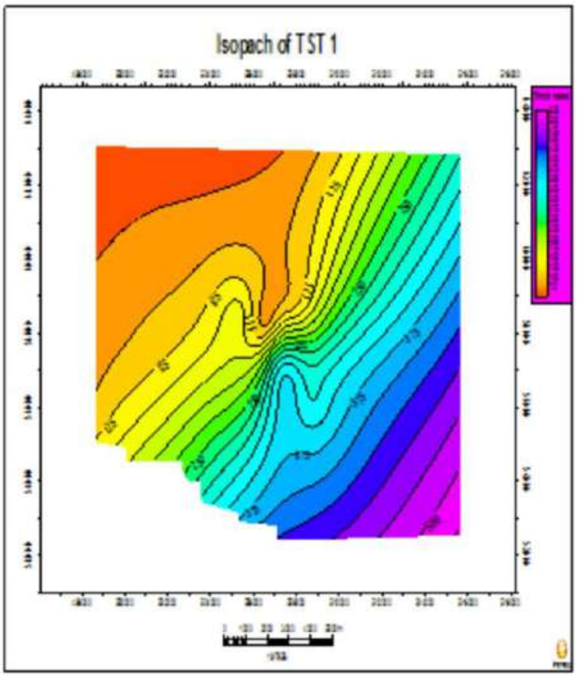




Figure 20: Map showing variation in thickness across LST1

Figure 21: Map showing variation in thickness across TST 1

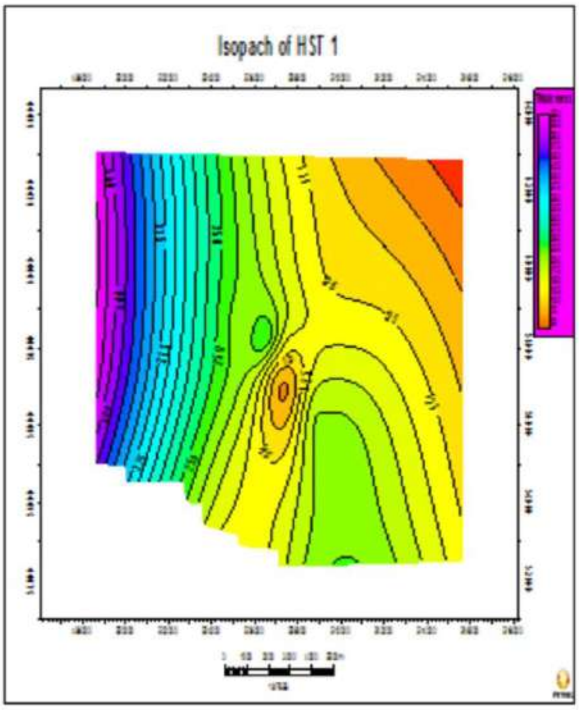



Figure 22: Map showing variation in thickness across HST 1

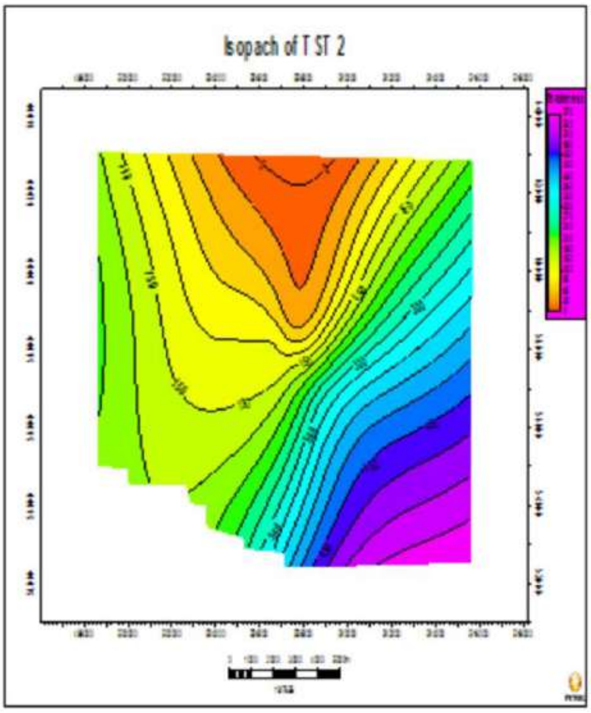



Figure 23: Map showing variation in thickness across TST 2

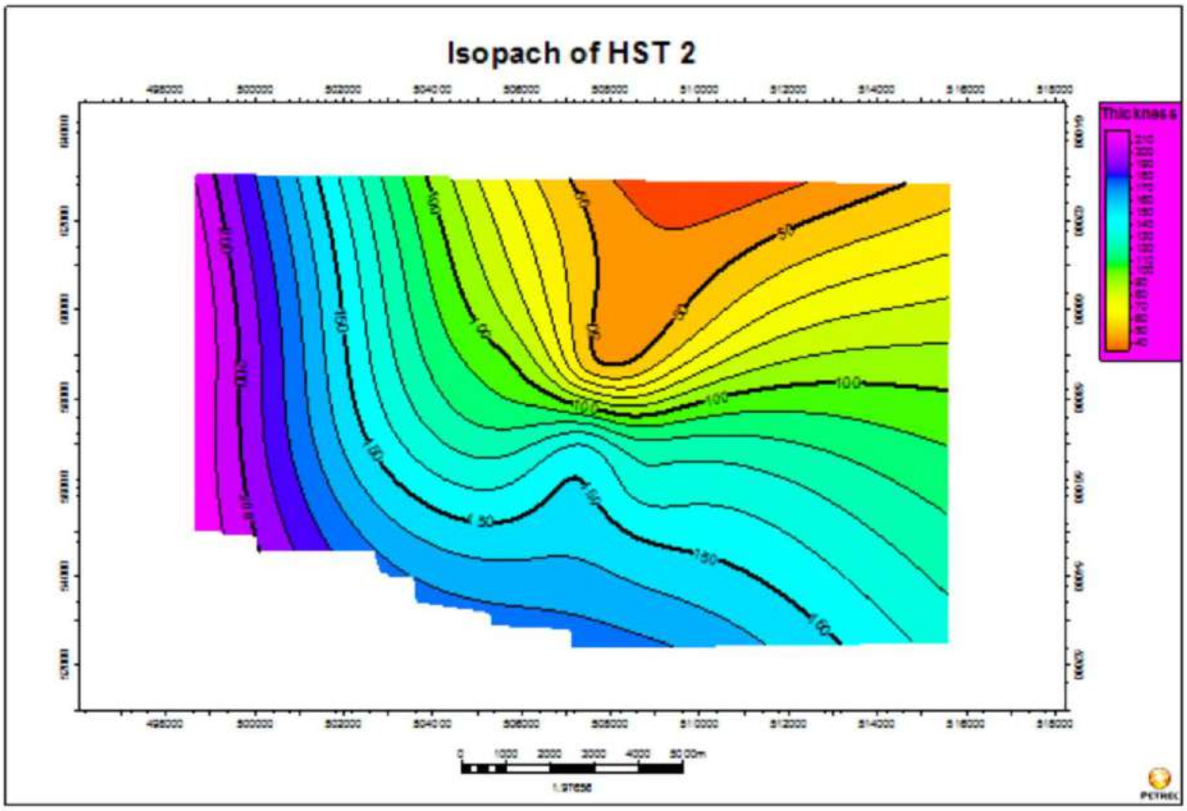



Figure 24: Map showing variation in thickness across HST 2

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**Sequence Stratigraphic Evaluation of 'AKOS' Field**

Two (2) crucial sequences are identified based on the chronostratigraphic correlation. Sequence 1 covers the interval between SB 0 to SB 1. Sequence 2 covers SB 1 to SB 2 interval. All three (3) crucial systems tracts are present in sequence 1. The Lowstand system tract (LST) is absent in Sequence 2.

The Lowstand systems tract (LST) identified by a shallowing-upward, coarsening-upward succession and progradational and aggradational parasequence sets is the major interval producing hydrocarbon within the Field. The transgressive systems tract (TST), typified with a dirtying-upward succession seals the lowstand reservoirs. The upper section of the Highstand Systems Tracts (HST) has reservoir potentials. Based on the studied Systems Tracts and their positioning, the crucial reservoir-seal pair elements required for accumulation are present. Hence, 'AKOS' Field could be a viable hydrocarbon Field.

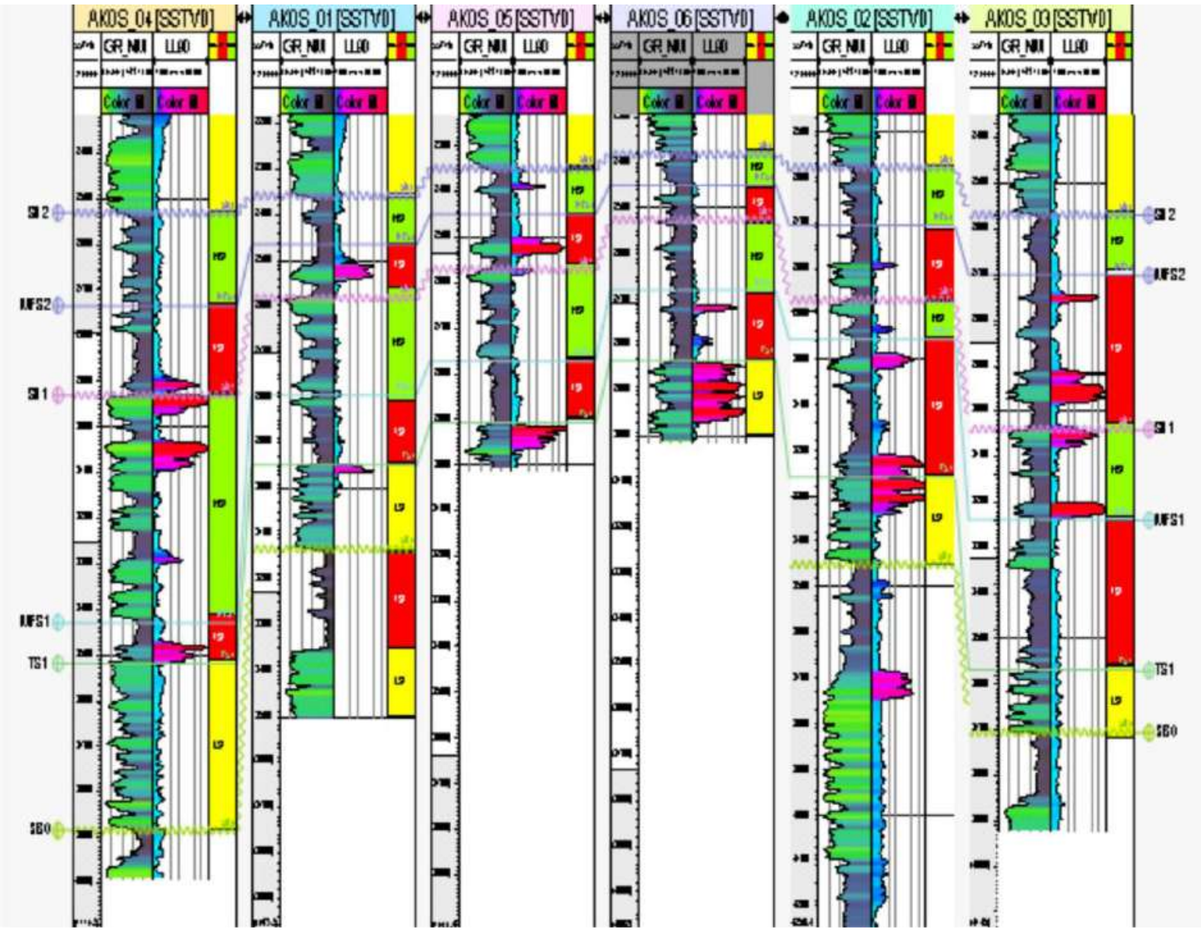


Figure 25: Sequence stratigraphic framework of 'AKOS' Field showing the identified systems tracts on Well correlation panel

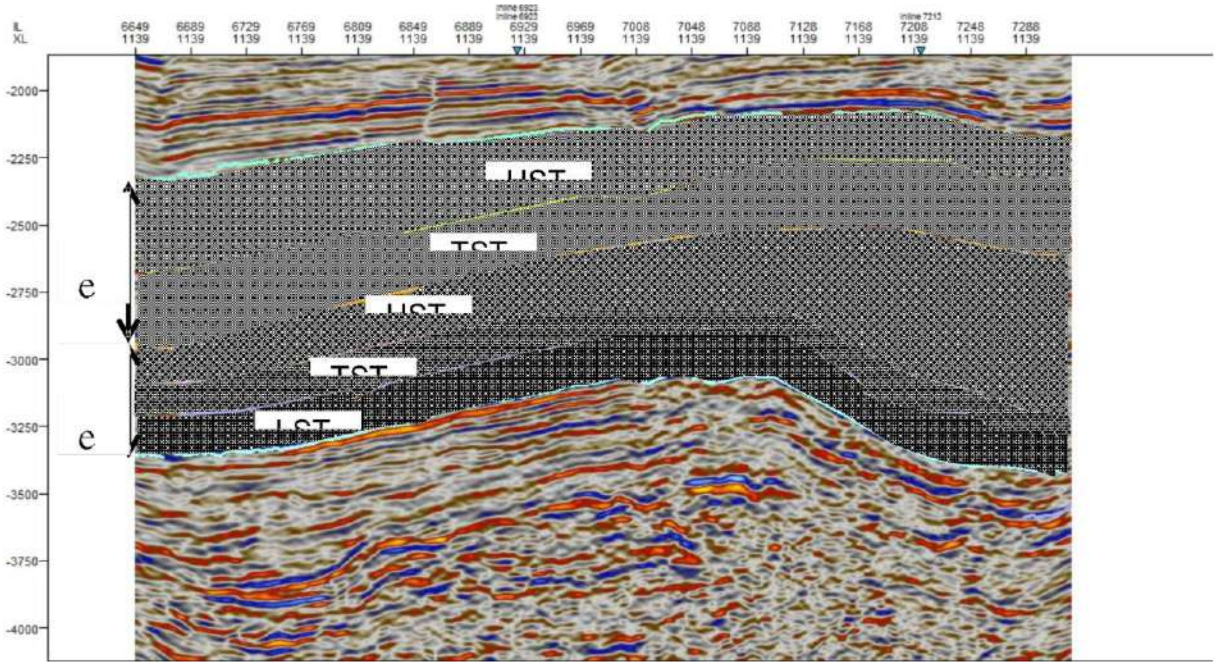


Figure 26: Sequence Stratigraphic framework of AKOS Field showing the identified system tracts in the two (2) sequences

## CONCLUSION

From the analysis and interpretation of the available dataset, "AKOS" Field possesses good hydrocarbon potential with good reservoir-seal pairs. The research investigators identify leads. The identified potential reservoirs are laterally continuous. The reservoir units are considerably thick and can host commercially quantifiable hydrocarbon provided the petrophysical attributes of the reservoir rocks are effective for hydrocarbon accumulation.

The fault network serves a decisive role in the trapping style of the field due to its nature and connectivity. All the faults display a dominant E-W trend.

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**Conflict of Interest**: On behalf of all the co-authors, the corresponding author states that there is no conflict of interest.

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