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Research Paper

Seismic-Well Integration for Reservoir Extent and Depth Evaluation in the WABI Oil Field, Niger Delta Nigeria

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ABSTRACT: *Accurate reservoir delineation in geologically complex settings such as the Niger Delta requires integrated interpretation of seismic and well log data. This study focuses on the WABI Oil Field, where five well logs and a 3D seismic dataset were analyzed to characterize reservoir extent and depth. Well log correlation identified a primary reservoir interval between 9270 ft and 9980 ft, consistent with regional subsurface trends. A seismic-to-well tie was performed using a synthetic seismogram generated from a calibrated sonic log and density log. A non-linear third-degree polynomial velocity function was derived to enhance time–depth conversion accuracy. The interpreted reservoir horizon was mapped across the seismic section, and time and depth structure maps were constructed. The resulting depth map revealed a structurally continuous, fault-free reservoir ranging from 9000 ft to 13,500 ft. These results highlight the effectiveness of seismic-well integration for improving structural interpretation, reducing exploration uncertainty, and supporting reservoir development strategies in deltaic petroleum systems.*

KEYWORDS: *Seismic, Well Log, Reservoir, Extent, Depth.*

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I. INTRODUCTION

Reservoir characterization is a critical step in hydrocarbon exploration and development, as it provides insight into the spatial distribution, geometry, and physical properties of subsurface reservoirs [1, 2]. In complex sedimentary environments such as the Niger Delta, an integrated approach that combines 3D seismic data and well log information offers a powerful means of delineating reservoir extent and estimating depth with improved accuracy. While seismic data provide broad areal coverage and capture subsurface structural and stratigraphic variations, well logs contribute high-resolution vertical measurements of lithological and petrophysical properties [3, 4]. Integrating these complementary datasets enhances the reliability of subsurface models and supports informed decision-making in field development and management.

The Niger Delta Basin is one of the world's most prolific petroleum provinces, with a complex stratigraphy dominated by deltaic depositional systems, growth faulting, rollover anticlines, and stacked hydrocarbon-bearing sands [5, 6]. In this region, accurate mapping of reservoir boundaries and depth structures is often challenged by lateral facies changes, variable compaction trends, and seismic resolution limits [7, 8]. Therefore, a robust seismic-well integration framework is essential for de-risking drilling targets and optimizing production strategies.

This study focuses on the WABI Oil Field, located in the onshore Niger Delta, where significant exploration and production activities have been undertaken over the past decades. However, uncertainties still persist regarding the lateral continuity and depth configuration of key reservoir units. The main objective of this work is to integrate 3D seismic reflection data with available well log information to delineate the spatial extent and depth of the target reservoirs in the field. Specific goals include the correlation of well log markers to seismic horizons, generation of time and depth structure maps, and interpretation of subsurface geometries that control reservoir distribution.

By providing a more detailed and integrated subsurface model of the WABI Field, this study contributes to the broader goal of improving reservoir prediction and field development planning in the Niger

Delta. The results have implications not only for local field optimization but also for analog studies in similar fluvio-deltaic depositional settings.

II. MATERIALS AND METHOD

2.1MATERIALS

The study utilized suite of well logs (AKOS-002, AKOS-003, AKOS-005, AKOS-006, AKOS-009, AKOS-013), whose locations are depicted in Figure 2, and pre-processed 3D seismic data that had undergone noise attenuation, deconvolution, velocity analysis, and post-stack time migration, rendering it suitable for structural and stratigraphic interpretation. Petrel software was used to analyze the dataset for this research work.

The seismic section, depicted in Figure 1, contains traces of seismic amplitudes measured over 6002ms. The study area measures roughly 16,825×10625m. It is a high-resolution 3D data set derived from 673 inline sand 425 cross lines spaced 25map art. Furthermore, Figure 3.8 shows information of an inline, a crossline, and a temporal section, together with the features of the seismic section

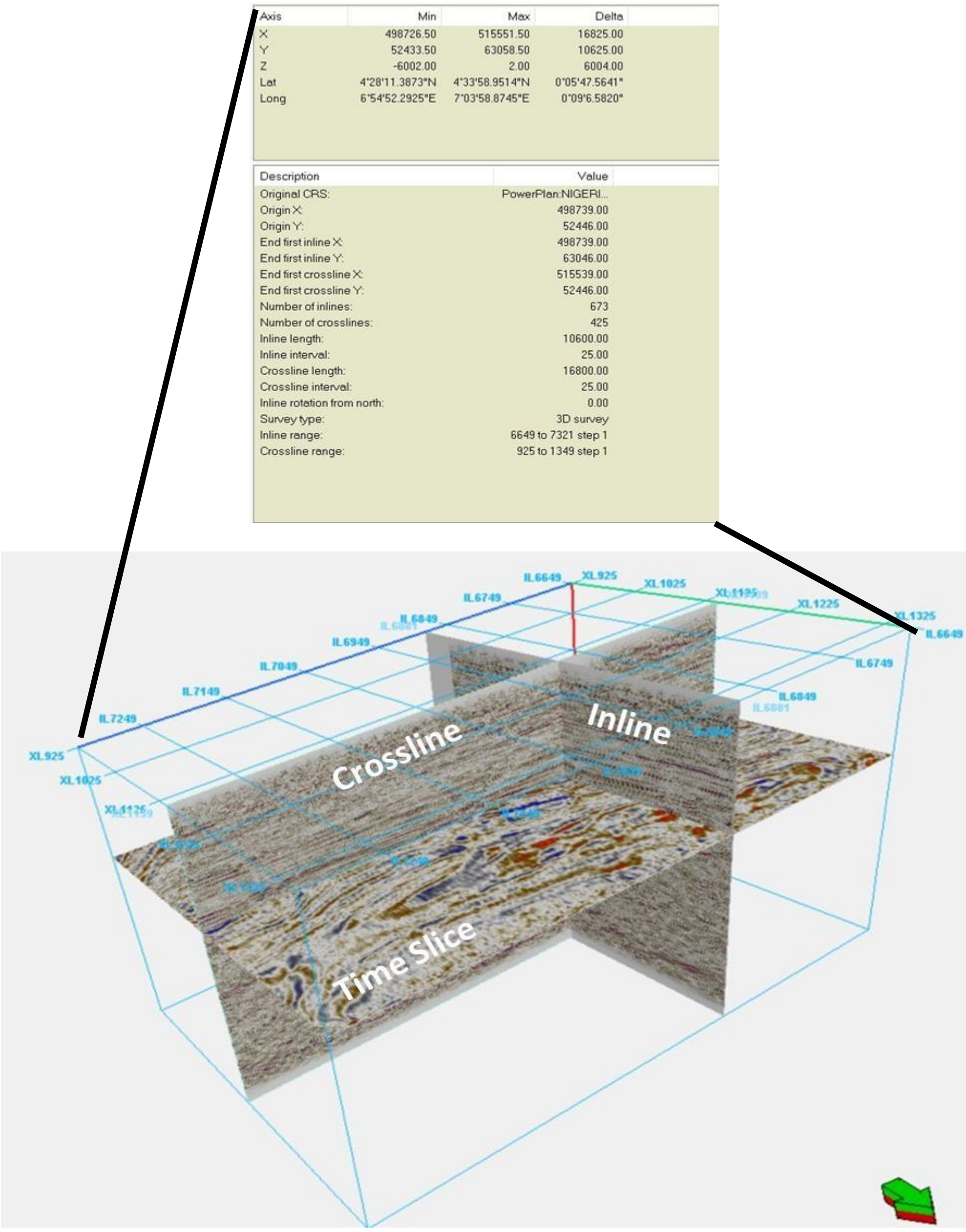


Figure 1: Seismic dataset showing an inline, a crossline and a time slice

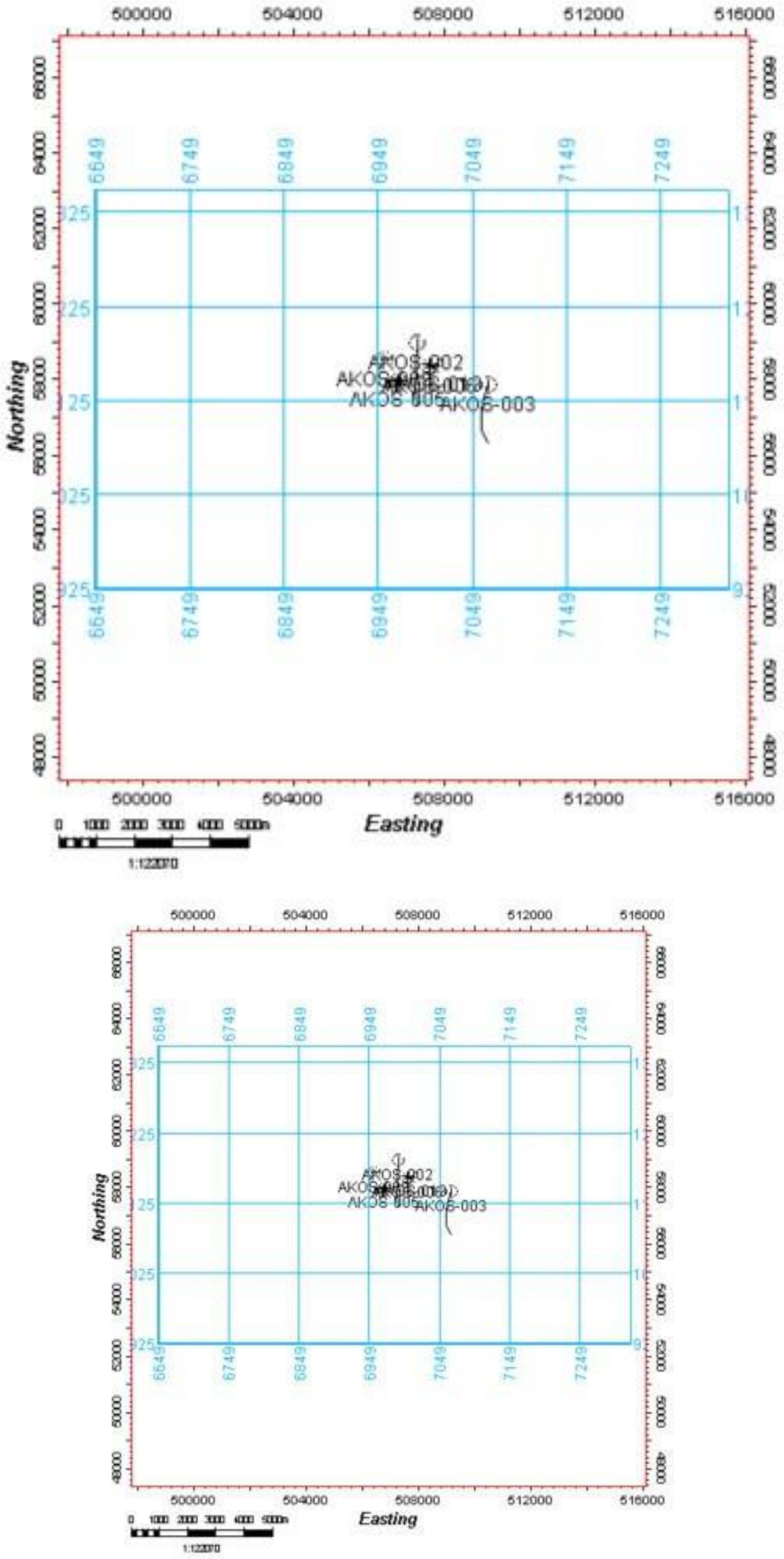


Figure 2: Position of the wells relative to the coverage of the seismic data in the field

2.2 METHOD

The analysis commenced with the importation of the 5 well logs into Petrel™ software. Given that the primary objective was to estimate lateral extent and depth to the reservoir unit within the study area, a well log correlation will be performed. This involved identifying reservoir and seal units based on gamma ray log responses (to distinguish between sandy and shaley formations) and resistivity log responses (to detect potential hydrocarbon-bearing zones). This process is critical for constructing a consistent subsurface framework, supporting accurate structural and stratigraphic mapping, and reducing uncertainty in reservoir delineation, especially when integrating with seismic data for 3D reservoir modeling [9, 10].

Among the five wells, only Well 1 contained a sonic log. To ensure accuracy, this sonic log was calibrated against an available checkshot survey to correct for any anomalies or time-depth mismatches. This calibration was critical for subsequent time-depth conversion and synthetic seismogram generation.

To characterize the structural framework, fault system, and lateral continuity of the correlated reservoir-seal units, a 3D seismic volume was loaded into Petrel. A seismic-to-well tie was then carried out to establish a time–depth relationship. This was achieved by generating a synthetic seismogram through convolution of an extracted wavelet (from the seismic volume) with an acoustic impedance log, which was computed using the density log and the calibrated sonic log from Well 1. The input parameters and wavelet characteristics used in the synthetic generation are illustrated in Figure 2.

Following the seismic-to-well tie, tops and bottoms of the correlated reservoir units, originally identified from the well logs, were mapped onto the seismic section by aligning synthetic traces with actual seismic reflectors. Structural interpretation was performed at 10-inline and crossline intervals to delineate the spatial distribution of the mapped horizons. This interpretation facilitated the generation of a time-structure map, which was subsequently converted to a depth map using the established time–depth function. The resulting depth map provided a detailed description of the structural configuration, lateral extent, and depth range of the reservoir–seal pairs within the WABI Field.

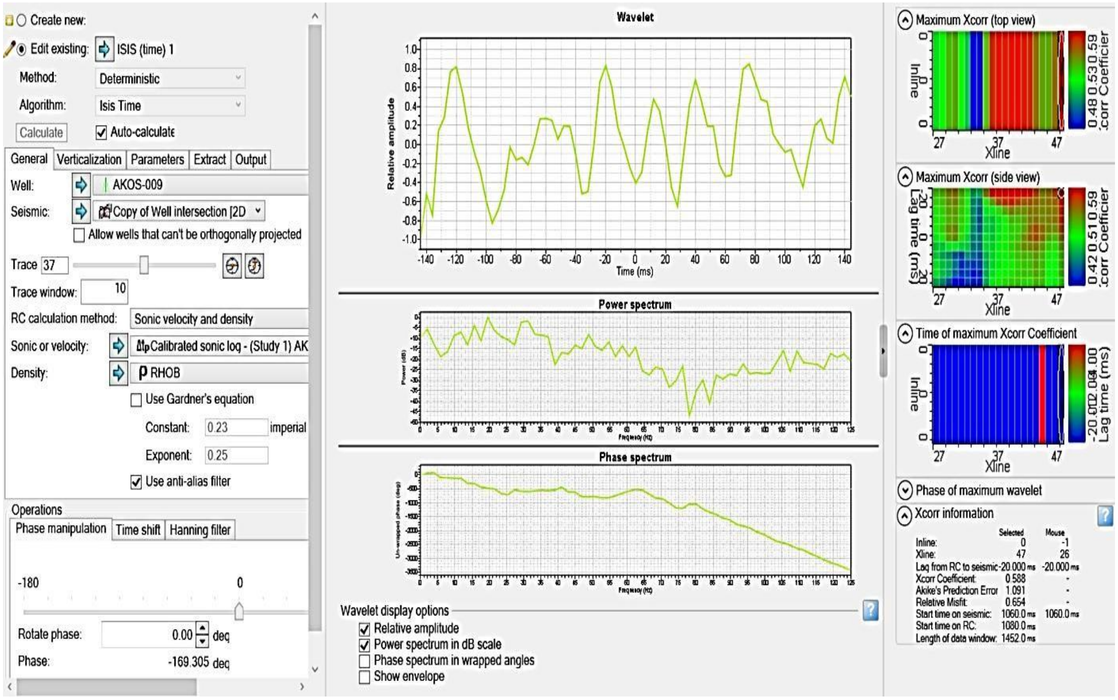


Figure 3: Wavelet extraction for generation of synthetic seismogram

III. RESULTS

The results obtained in from the analysis of the seismic data are shown in Figures 4 to 10 below.

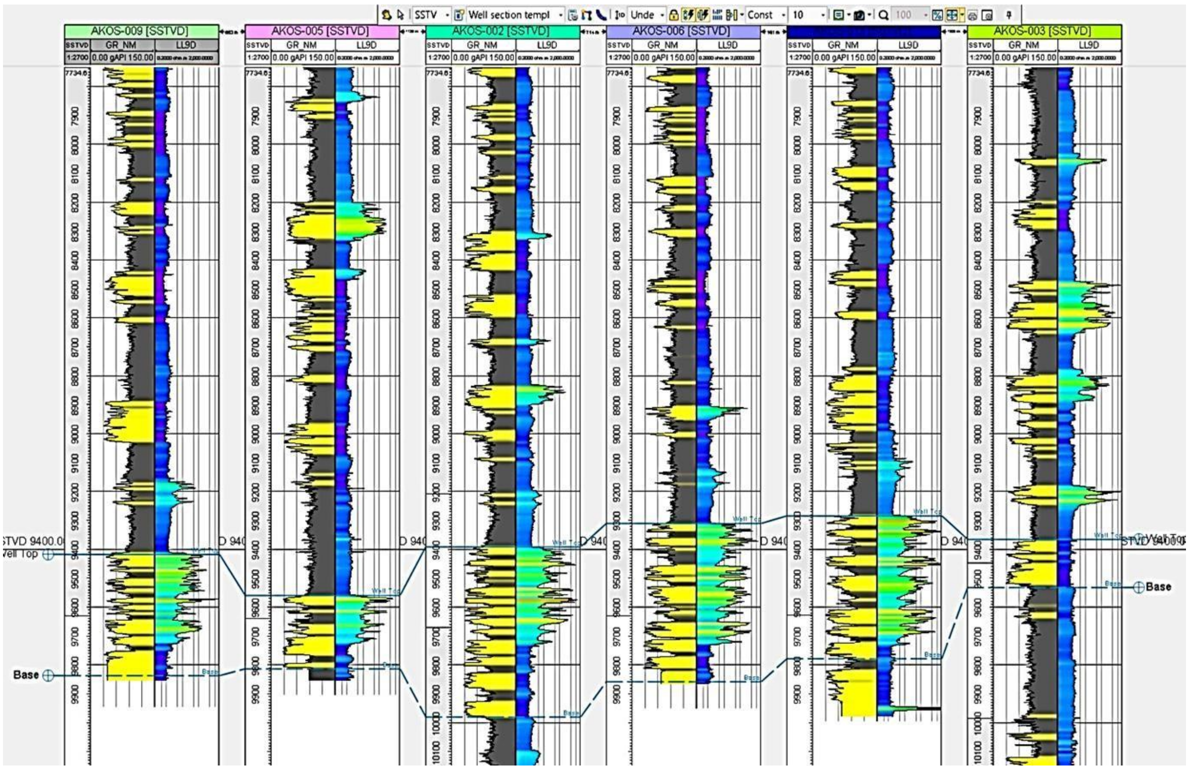
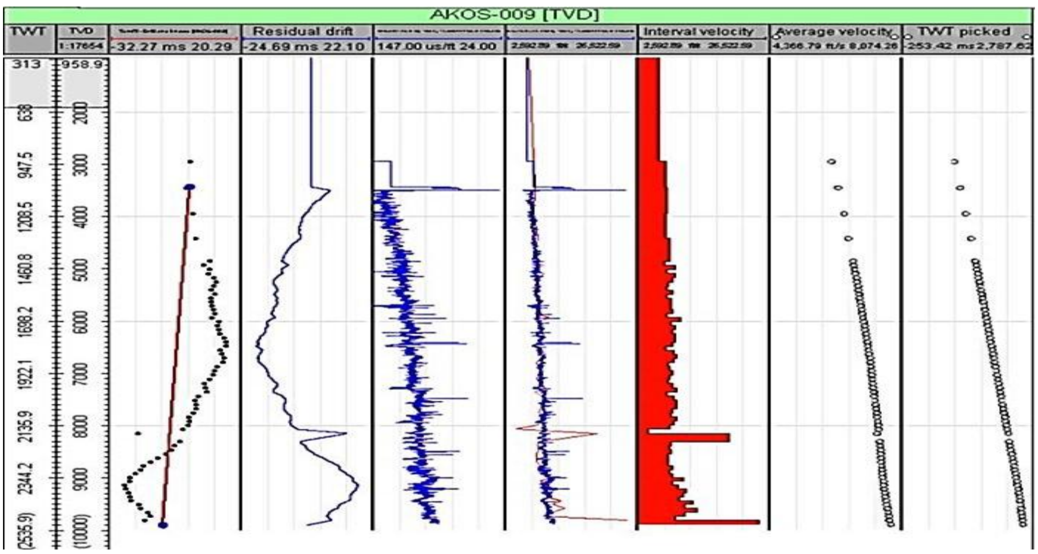


Figure 4: Well log correlation for the reservoir of interest

Table 1: Reservoir intervals from the correlated well logs

WELL NAME	RESERVOIR DEPTH RANGE (ft)
AKOS-009	9406-9854
AKOS-005	9560-9820
AKOS002	9385-9980
AKOS-006	9310-9860
AKOS-013	9290-9970
AKOS-003	9370-9530

(a)



(b)

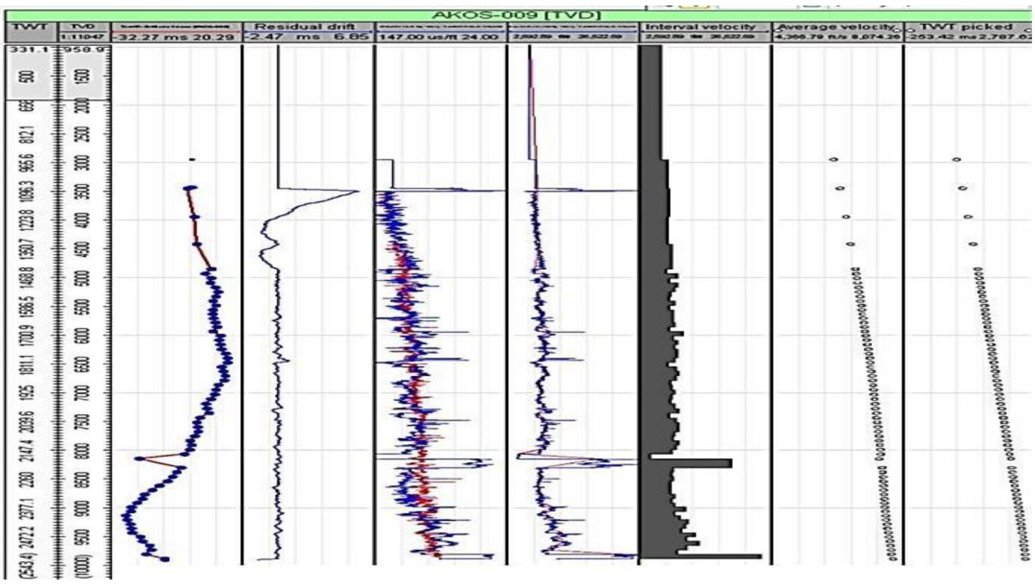


Figure 5: Calibration of sonic logs using check shots (a) before and (b)after calibration

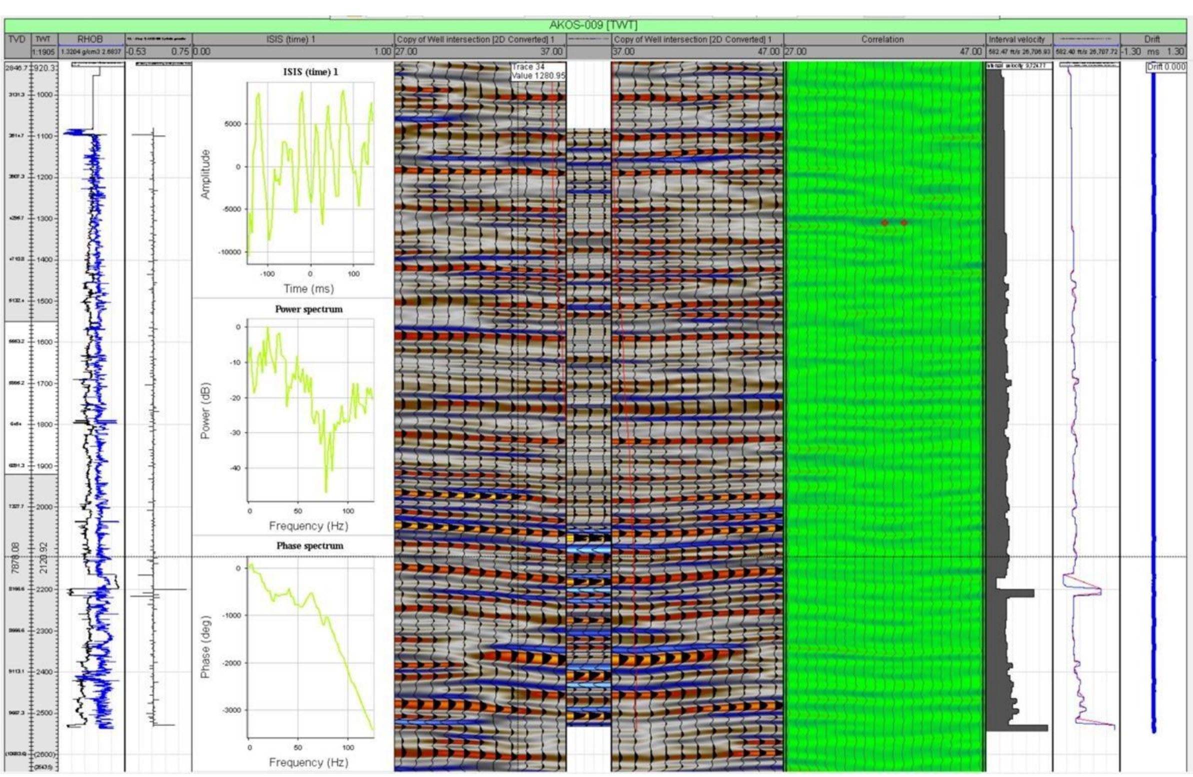


Figure 6: Generated Synthetic Seismogram

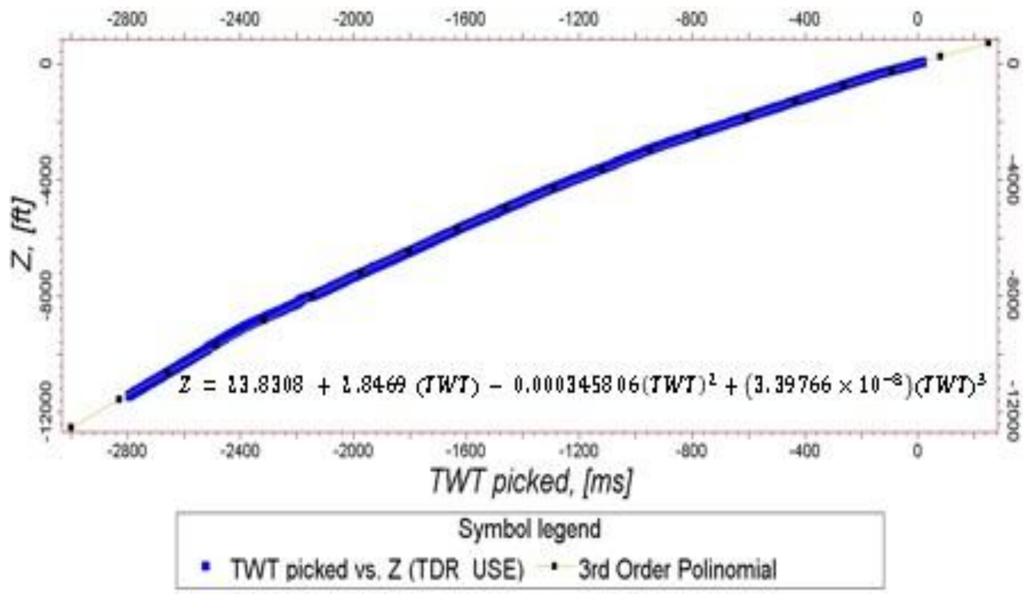
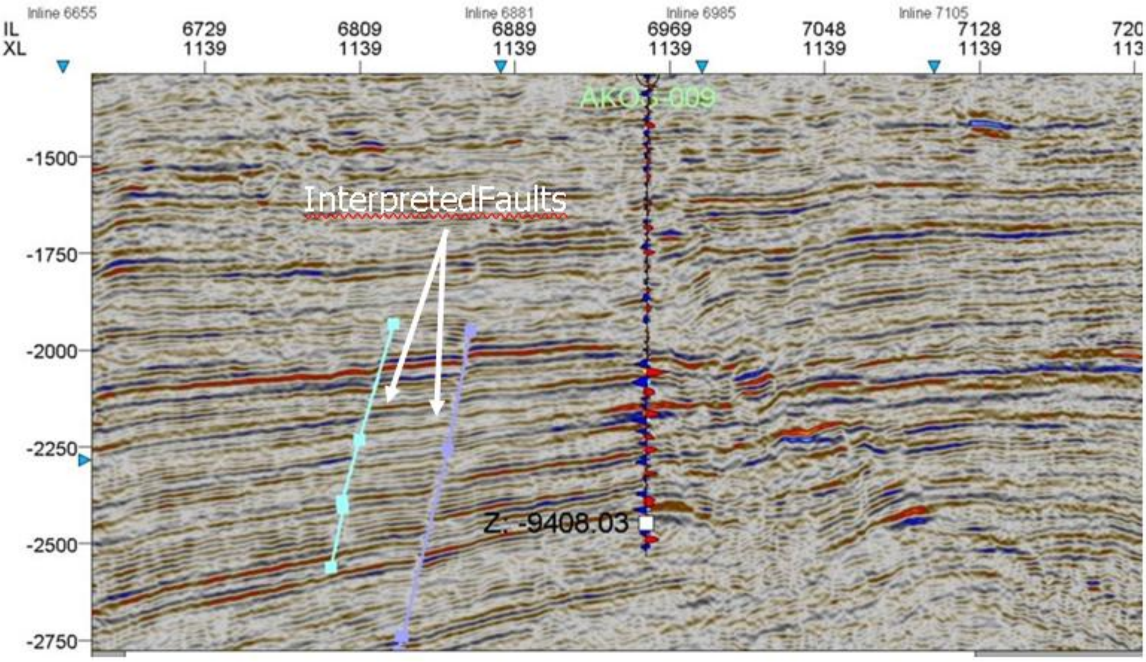


Figure 7: Time-depth relationship curve and 3rd order polynomial equation for domain conversion

(a)



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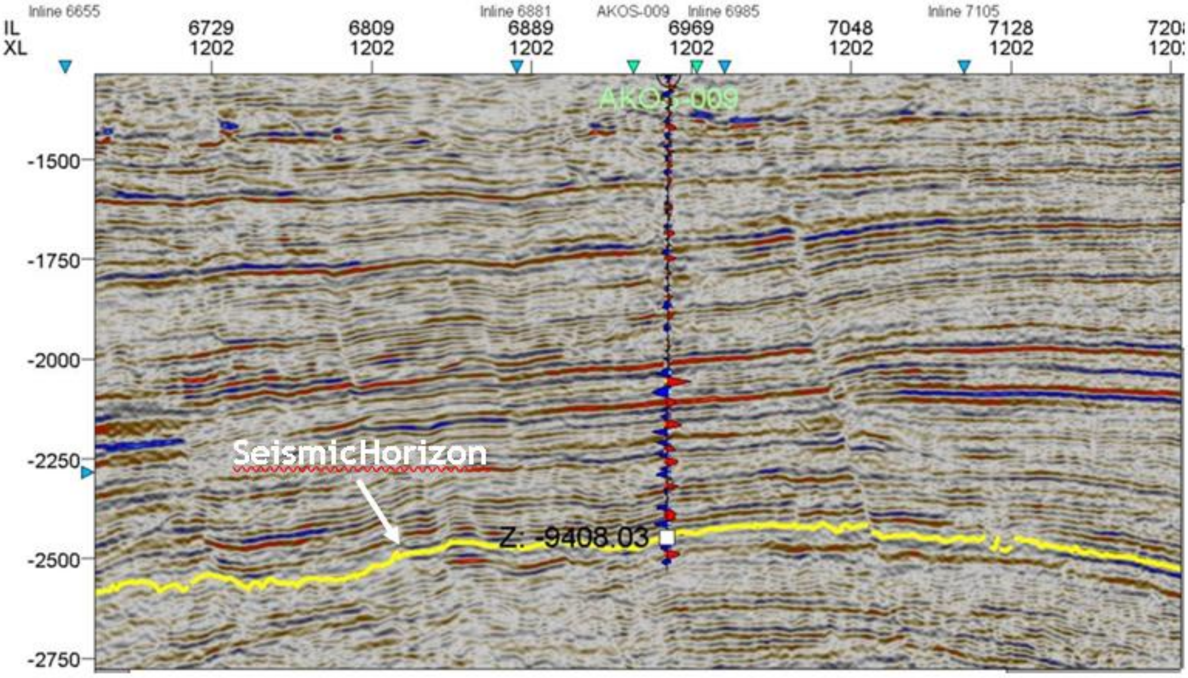
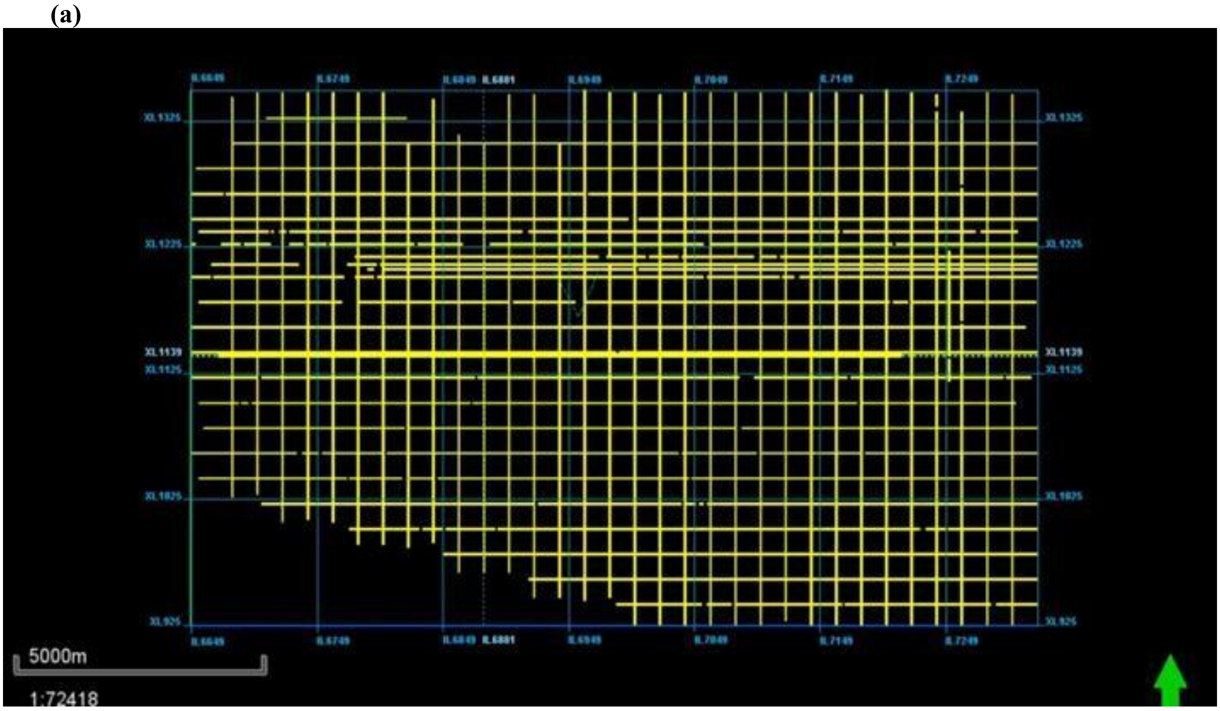


Figure 8: The intersecting well and the picked reservoir top alongside (a)interpreted fault and (b) the mapped reservoir horizon of interest

(a)



(b)

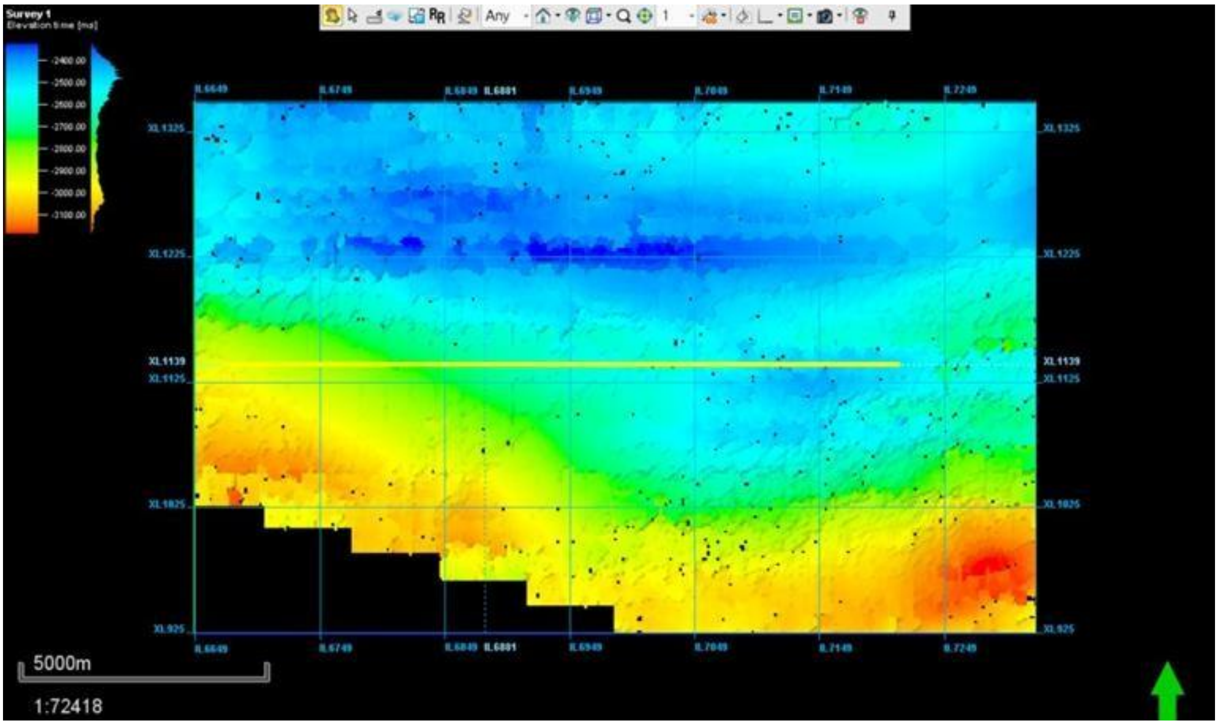
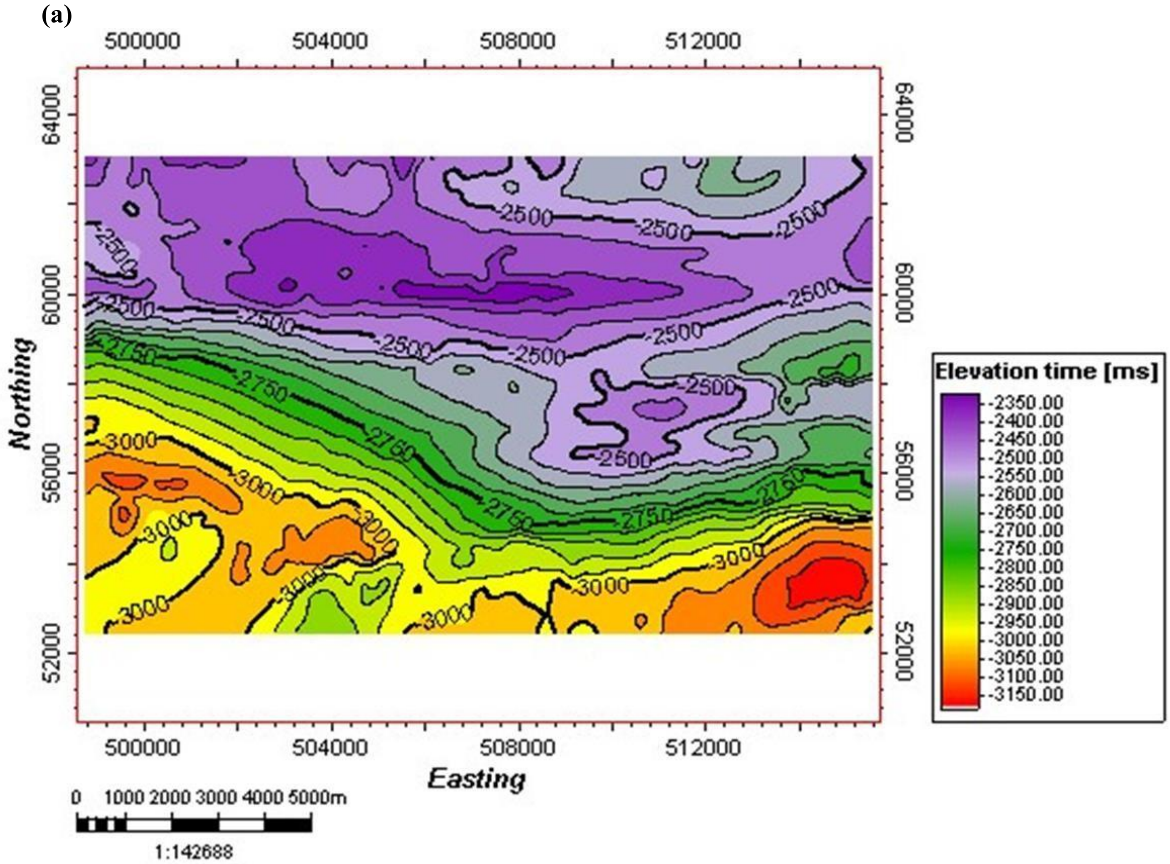


Figure 9: Time grid produced for the horizon of interest (a)Manually picked grids (b)Auto-generated grids from the manual grids

(a)



(b)

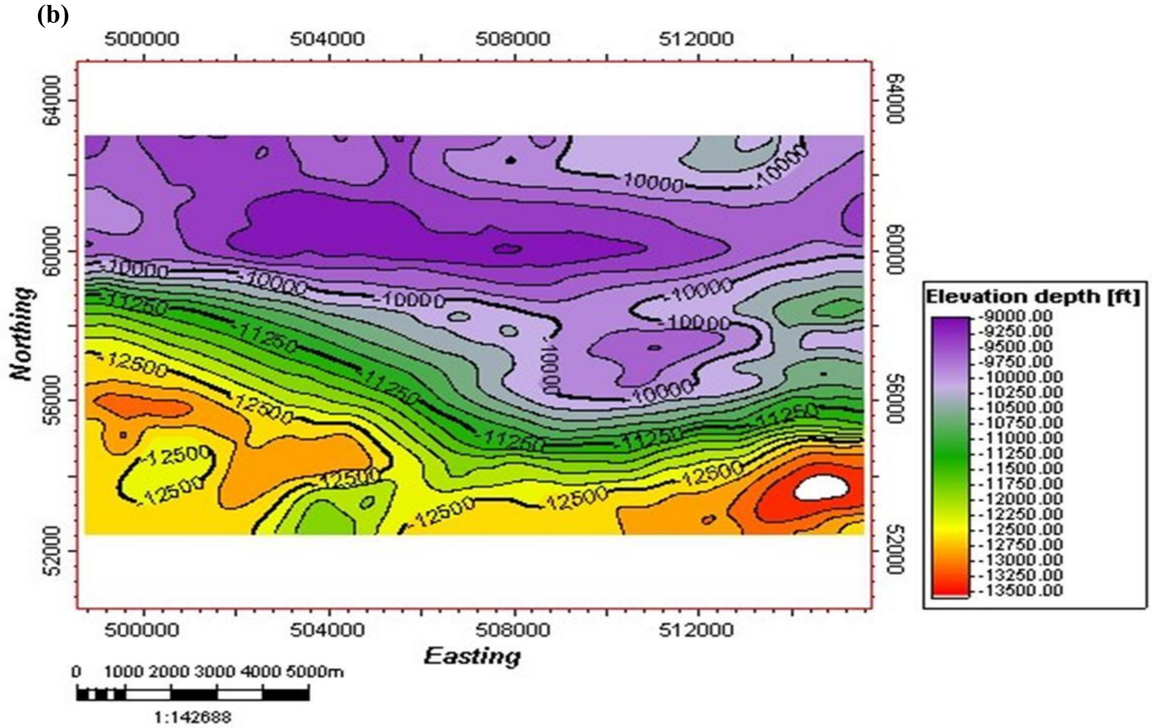


Figure 10: (a) Time map of the reservoir of interest (b) Depth map of the reservoir of interest

IV. DISCUSSIONS

The interpretation of the seismic dataset began with well log correlation (Figure 4), which was essential for calibrating the seismic data and enhancing the accuracy of the resulting subsurface model. As highlighted by Nanda [11], this process improves depth conversion and strengthens the reliability of seismic interpretation by tying seismic reflectors to geological markers identified in the well logs. Such integration facilitates more robust stratigraphic correlation, structural delineation, and ultimately reduces uncertainty in reservoir characterization and hydrocarbon exploitation.

In the current study, the well log correlation revealed a prominent reservoir interval between depths of 9270 ft and 9980 ft (Table 1), consistent with reservoir depths previously reported for the Niger Delta [12-14]. To further verify this interval and evaluate its lateral continuity, a seismic-to-well tie was performed using a synthetic seismogram (Figure 6), enabling transformation between time and depth domains. Since only Well AKOS-009 had a sonic log, this log was calibrated against the checkshot data (Figure 5) to mitigate anomalies and ensure a more accurate time–depth relationship. This calibration step is essential in addressing velocity inconsistencies and aligning seismic events with geologic horizons [15].

Following the calibration, a third-degree polynomial velocity function (Figure 7) was derived from the tie. The use of a non-linear function allowed for a more realistic representation of velocity variations within the subsurface, which is especially beneficial in geologically complex settings like the Niger Delta [16]. This higher-order polynomial function improved the accuracy of the time-to-depth conversion, providing a reliable basis for subsequent structural interpretation.

Using the seismic-to-well tie as a guide, the correlated reservoir horizon was mapped across the seismic section. The seismic response of this horizon, along with associated fault structures, was clearly identifiable on both crosslines and inlines (Figure 9a). From the interpreted seismic horizons, time grids were generated using both manual and automated approaches (Figure 9b), leading to the construction of a time structure map (Figure 10a). This map, combined with the velocity function, enabled the creation of a depth structure map (Figure 10b), which indicated that the reservoir occurs between 9000 ft and 13,500 ft, again aligning well with regional trends in the Niger Delta [12, 14, 17].

Importantly, the depth structure map revealed that the mapped reservoir is largely free of faulting, a feature with significant implications. Fault-free reservoirs typically exhibit enhanced structural integrity, improved lateral continuity, and reduced risks of fluid leakage or compartmentalization [18, 19]. These attributes support more efficient hydrocarbon recovery, simplified reservoir management, and improved predictability in both static and dynamic models. The absence of major faulting in the mapped interval enhances the economic and operational viability of the reservoir, indicating promising prospects for safe and productive exploitation.:

V. CONCLUSION

This study demonstrates the value of integrating 3D seismic data with well log analysis for accurate reservoir characterization in the WABI Oil Field, located in the Niger Delta Basin. The initial well log correlation helped identify a key reservoir interval between 9270 ft and 9980 ft, in alignment with established regional trends. Seismic-to-well tie, calibrated with checkshot data, enabled the creation of a reliable synthetic seismogram and an accurate time–depth relationship through a third-degree polynomial velocity function. This integration facilitated the mapping of the reservoir horizon across the seismic section, the generation of time and depth structure maps, and the confirmation of lateral continuity. Notably, the interpreted reservoir appeared largely fault-free, a feature that enhances reservoir integrity, improves recovery potential, and reduces operational risks. These findings underscore the importance of seismic-well integration for de-risking subsurface interpretations and improving hydrocarbon exploration strategies in complex deltaic systems like the Niger Delta.

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