International Journal of Sciences and Innovation Engineering

(Peer-Reviewed, Open Access, Fully Refereed International Journal)

website: www.ijsci.com
Vol.03 No.01

E-ISSN : 3049-0251
DOI: https://doi.org/10.70849/ijsci0301260560965

Seismic Inversion and Attribute Analysis for Well Placement Optimization in the OSA Oilfield, Niger Delta, Nigeria: A Case Study

Osaki Lawson-Jack[1], Tamunosiki Dieokuma[2]
[1,2] *Department of Physics and Geology, Federal University Otuoke, Bayelsa State, Nigeria.*

Article Info

Article History:

Published:21 Jan 2026

Publication Issue:
Volume 3, Issue 01
January-2026

Page Number:
483-494

Corresponding Author:
Osaki Lawson-Jack

Abstract:

There has been a lingering problem of reservoir characterization uncertainty and poor well placement in the OSA Oilfield, Nigeria. To tackle this problem, this study aimed to examine seismic inversion and attribute analysis for well placement optimization, using OSA Oilfield, Niger Delta, Nigeria as a case study. Through the combination of seismic inversion and seismic attribute analysis, the goal was to enhance well placement. In addition to certain attribute extraction, post-stack seismic inversion was used to produce acoustic impedance volumes that were calibrated using well-log data via seismic-to-well tying. The findings revealed distinct impedance contrasts, reservoir sand delineation, and porosity variations in line with well logs. The study comes to the conclusion that combining attribute analysis and seismic inversion greatly lowers subsurface uncertainty and offers a dependable and economical workflow for well placement optimization in intricate deltaic reservoirs.

Keywords: Seismic Inversion, Attribute Analysis, Well Placement, Niger Delta and Oilfield.

1. Introduction

Well placement optimization is a decisive factor of economic achievement in oil field development, as it has a direct impact on the cost of infrastructure, as well as the final recovery of the hydrocarbons during the field lifecycle. This is a task tainted with a lot of uncertainty in geologically complex areas such as the Niger Delta Basin (Osaki .L.J., 2021; Moukassa et al., 2024). Nabawy, (2025) noted that, the reservoir characterization has been done by the traditional methods which consist of seismic attribute analysis with remarkable success. However, the method is ineffective in reducing the exploration risks to a level of negligence and thus entails the combination of more sophisticated techniques that will increase investor confidence and the success rate of the drilling activities.

In the case of the Niger Delta, where simple anomalies of the amplitude are prominent in a deep-offshore basin, simple anomalies are misleading. The bright seismic targets can be not only fully saturated gas sands, but partially saturated ones or even lithological structures, which complicates the accurate determination of the hydrocarbons, and results in expensive drilling errors (El-Sayed et al., 2024). To overcome these fears, it has led to the use of seismic inversion and attribute analysis as an effective methodology. Seismic inversion is said to go beyond the traditional seismic data by converting the reflection data into quantitative rock property models (e.g., acoustic impedance (AI)) and thus significantly improving the subsurface resolution (Hosseinzadeh et al., 2025). As an example, high-resolution acoustic impedance cubes have been effectively produced by model-based post-stack inversion to explain the structure of the reservoir trends far beyond the constraints of the standard seismic data particularly at lower depths. Moreover, the pre-stack inversion methods may give more information about such elastic parameters as shear impedance and density that is important to differentiate between fluid and lithology effects (Brum et al., 2025).

Studies of the offshore Niger Delta have shown that a combination of both root mean square (RMS) amplitude attributes and a model driven inversion leads to a high correlation with well data, and effectively validates prospects and leads as well as bringing down interpretation uncertainty (Opara, & Osaki, 2016; Haris et al., 2020).

In this study, the advanced methods will be applied to the OSA Oilfield. Through the application of post-stack seismic inversion to produce an acoustic impedance cube and combining it with seismic attribute analysis, the present study is designed to characterize reservoir sands, delimit their characteristics, and determine the sweeter spots of a well that would be optimally placed. It is aimed at showing a solid workflow that minimizes geological uncertainty and maximizes the accuracy of development well targeting in this mature and yet prolific petroleum province.

A. Aim and Objectives

The aim of this study is to examine seismic inversion and attribute analysis for well placement optimization, using OSA Oilfield, Niger Delta, Nigeria as a case study.

The objectives are to;

i. Predict the properties of OSA Oilfield reservoirs using Seismic inversion;
ii. Verify the relationship between inverted acoustic impedance volumes and well-log-derived impedance to assess the dependability of seismic inversion; and
iii. Integrate Seismic Inversion and Attributes for Well Placement Optimization.

2. Geology of the Study Area

Niger Delta basin is a rich hydrocarbon province with its Cenozoic, prograding complex of deposits, as presented in figure 1. It has a geologic structure that is dominated by the Agbada Formation that is a series of sandstones and shales in interchanging formations that make up the major reservoir and seal system of the vast majority of oil and gas fields in the area (Ogbe and Edegbai, 2022). The shale-laden Akata Formation is usually superimposed on this formation, and the Benin Formation, a formation of the OSA Oilfield, is located at its base (Adagunodo et al., 2022). The basin is characterized by the existence of growth faults. These are syn-sedimentary faults that serve as significant traps of the hydrocarbons. The interaction between the effect of sedimentation and the action of these growth faults directly regulates the distribution and structure of reservoir sands, with important implications on such important properties as the net-to-gross ratio (Ojo et al., 2023). These reservoirs have a varied depositional environment including channel sands, upper and lower shoreface environments that represent the complicated depositional history of the Delta (Ru and Chiazor, 2021).

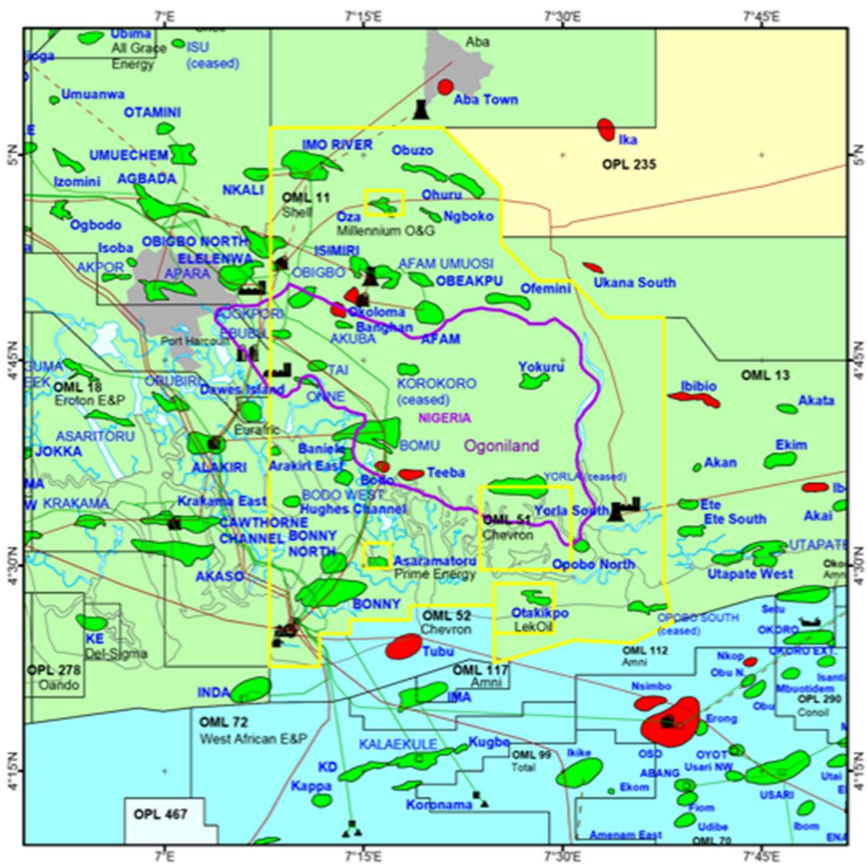

Fig. 1: OSA Oilfield Map Encompassing All the Reservoir Formations. Source: (Decklar, 2025).

3. Literature Review

The complicated structural geology of the Niger Delta with growth faults and stratigraphic heterogeneity frequently results in serious interpretation uncertainties and the probability of sinking dry holes. Although the use of traditional seismic attribute analysis has been successful with the characterization of the reservoirs, in most cases, it cannot be adequate to reduce uncertainty in the exploration to the level of negligence, thus compromising the confidence of the investors (Brum, 2025 Osaki, 2025). Chang, (2015) highlighted the dire necessity of fully using sophisticated geophysical methods to de-risk the process of drilling. The strategic significance of the research is that, there is a possibility of having a solid workflow of well placement which is a crucial and demanding process in field development as the circumstances of a complex reservoir are challenging, and it is difficult to determine the best locations.

Moukassa et al., (2024) conducted a research on model-based post-stack seismic inversion with Root Mean Square (RMS) and the attribute analysis was carried out in a deep-offshore MTW Field in 2024, producing a high-resolution Acoustic Impedance cube that not only greatly increased seismic resolution to remarkably high correlation coefficient of more than 0.995 at the well locations. Adeogun et al., (2024) carried out a study in the Pearl Field, offshore Niger Delta, where seismic properties such as RMS amplitude, sweetness and envelope played a pivotal role in ensuring that the hydrocarbon rich areas were confirmed and reservoir boundaries were mapped so as to maximize the development plans. Also, Fagbemi et al., (2024) carried out a reservoir characterization study in the Kukih Field and emphasized the effectiveness of using 3D seismic data and well logs to bring into focus structural characteristics and petrophysical aspects, which resulted in particular recommendations on how to drill untapped, promising areas.

4. Methodology

B. Data Acquisition Techniques

The collection and integration of several geophysical and petrophysical datasets from the OSA Oilfield forms the basis of this study. The primary data consists of the following;

i. a 3D seismic survey that covers the entire field (post-stack migrated data with appropriate binning and offset distribution).
ii. well log data from five exploration wells (OS-1 through OS-5), including gamma-ray, resistivity, sonic, density, neutron porosity, and caliper logs (Falade et al., 2024).
iii. check-shot surveys or vertical seismic profiles (VSP) for precise time-depth relationship establishment.
iv. production and pressure data from existing wells to validate reservoir before moving on to the analysis stage, all datasets should be quality-checked for accuracy, consistency, and coverage (Evans et al., 2025).

C. Data Processing

Preprocessing guarantees that every dataset satisfies the requirements needed for further analysis. Relative amplitude preservation (RAP) processing is used for seismic data in order to preserve true amplitude relationships, which are crucial for attribute analysis and inversion (Mallick et al., 2025). Additional seismic conditioning includes spectral balancing to increase frequency content, structural smoothing to improve continuous events while maintaining faults, and noise attenuation algorithms to increase signal-to-noise ratio. The depth-to-time conversion of well log data necessitates the use of check-shot data, environmental corrections for tool effects, and edit and despite procedures to eliminate anomalous values (Adizua and Ugwu, 2025). In order to ensure precise integration between depth-based well measurements and time-based seismic data, the crucial stage of creating synthetic seismograms links well data to seismic data through wavelet extraction and correlation analysis.

Table 1: Data Preprocessing Quality Control Parameters for Seismic Inversion

Source: (Adizua and Ugwu, 2025)

Data Type	**QC Parameter**	**Target Value**	**Corrective Action**
3D Seismic	Signal-to-Noise Ratio	>10 dB	Noise attenuation
3D Seismic	Frequency Bandwidth	8-80 Hz	Spectral balancing
Well Logs	Log Calibration	$R^2 > 0.85$	Depth shift adjustment
Well Logs	Sonic-Density Correlation	$R^2 > 0.8$	Log editing and correction
Seismic-Well Tie	Synthetic Correlation	>85%	Wavelet re-extraction

D. Seismic Inversion Technique

Pre-Stack Inversion: This method uses amplitude variation with offset (AVO) information in pre-stack inversion techniques to improve reservoir characterization beyond acoustic properties. In particular, P-impedance, S-impedance, and density volumes are produced from angle stack gathers using simultaneous inversion. Beyond acoustic impedance alone, these elastic characteristics offer crucial discrimination capability for fluid and lithology identification (Mallick et al., 2025). Yin et al., (2015) noted that, Prestack waveform inversion, which employs an analytical wave equation solver for forward modelling rather than the convolutional model, improves the accuracy of estimating elastic properties in regions with complex wave propagation effects. The inversion framework uses Bayesian inference techniques to quantify interpretation uncertainties. These techniques yield probability distributions of reservoir parameters instead of single solutions, allowing for reliable risk assessment in well placement choices.

Post-Stack Inversion: Post-stack inversion is the first step in the seismic inversion workflow, which converts seismic reflection data into quantitative models of rock properties. An initial acoustic impedance model derived from well log data and interpreted seismic horizons is used in this study's model-based inversion techniques (Li et al., 2020). The impedance model is modified iteratively through inversion until the resulting synthetic seismograms closely resemble the real seismic data. This approach works especially well in the OSA Oilfield to distinguish sand-shale sequences in the Agbada Formation because the differences in acoustic impedance between these lithologies are large enough to be resolved by post-stack inversion. Throughout the iterative optimisation process, structural frameworks derived from seismic interpretation constrain the inversion process, guaranteeing geological plausibility (Falade et al., 2024).

E. Attribute Extraction

In the OSA Oilfield, seismic attribute analysis is an essential tool for identifying reservoir characteristics, stratigraphic patterns, and structural features. Ali et al., (2019) noted that, the approach uses both physical characteristics, such as, amplitude, frequency, and phase for reservoir characterization and geometric characteristics (such as coherence, curvature, and dip azimuth) for structural interpretation. In particular, spectral decomposition allows for the visualization of channel morphology and stratigraphic variations through frequency-based tuning effects, while variance edge detection enables accurate fault mapping and identifies structural discontinuities. In the turbidite systems of the Niger Delta, Root Mean Square (RMS) amplitude extraction along reservoir horizons is especially helpful in identifying possible hydrocarbon-bearing zones through direct hydrocarbon indicator (DHI) analysis (Oyedele et al., 2020).

5. Results

F. Seismic Inversion for Reservoir Property Characterization

The OSA Oilfield's post-stack model-based seismic inversion effectively converted seismic reflection data into a quantitative description of the target reservoirs' rock properties. The acoustic impedance (AI) cube produced by the inversion process greatly improved vertical and lateral resolution over conventional seismic data, especially at depths greater than 3,200 ms where conventional seismic interpretation is limited. Five different reservoir sands (A–E) with different petrophysical characteristics throughout the OSA Field were identified by the inversion results. The seismic inversion process is presented in figure 2.

Well-tie correlation coefficients ranging from 0.995 to 0.997 across four validation wells (MTW-001, MTW-003ST1, MTW-004ST1, and MTW-005) were used to validate the inversion accuracy, indicating remarkable reliability in reservoir property prediction. With the best reservoir characteristics—13.42m thickness, 27% effective porosity, 3,187.53mD permeability, 34% water saturation, and 11% shale volume—Reservoir Sand A was found to be the most promising target. Sand A is the main target for optimal well placement because of these characteristics, which show excellent reservoir quality and producibility.

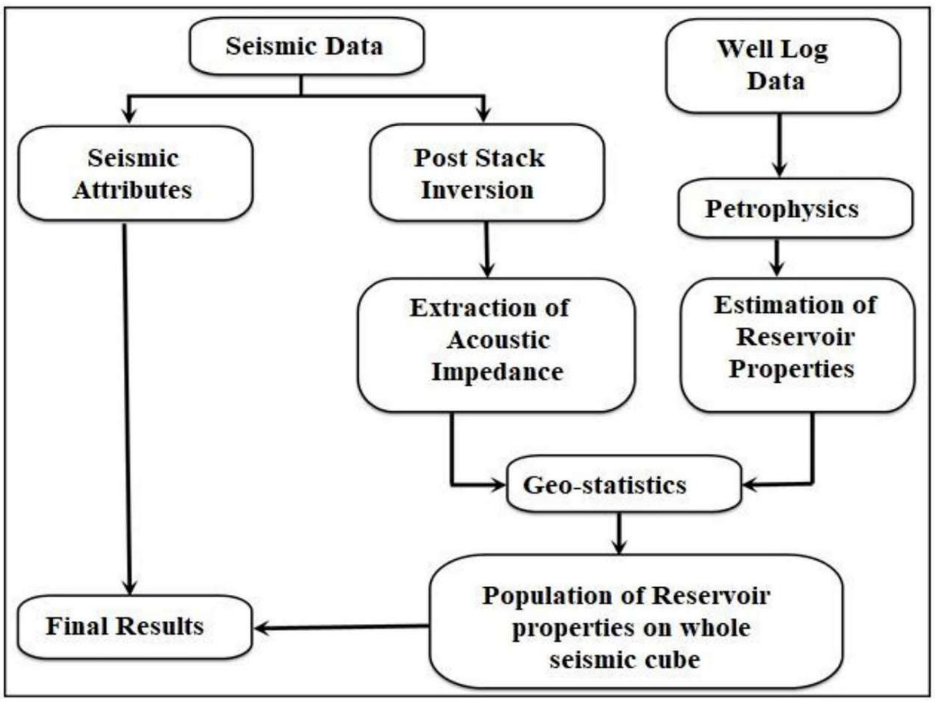

Fig. 2: Seismic Inversion Process from Well Log Data to Seismic Attributes for Reservoir Property Characterization of OSA Oilfield.

G. Dependability of Seismic Inversion

The inverted impedance volume and well-log-derived acoustic impedance consistently correlated after wavelet extraction and well-to-seismic tying. The well tie (Figure 3) displays consistent impedance trends that correspond to variations in porosity seen in the well logs: higher impedance intervals are associated with lower porosity and shale-prone areas, whereas intervals of lower acoustic impedance are associated with increased porosity on the well log. The inverted impedance replicates significant impedance contrasts and primary reservoir events, according to cross-validation using the withheld well, suggesting a reliable inversion workflow appropriate for attribute extraction and reservoir targeting.

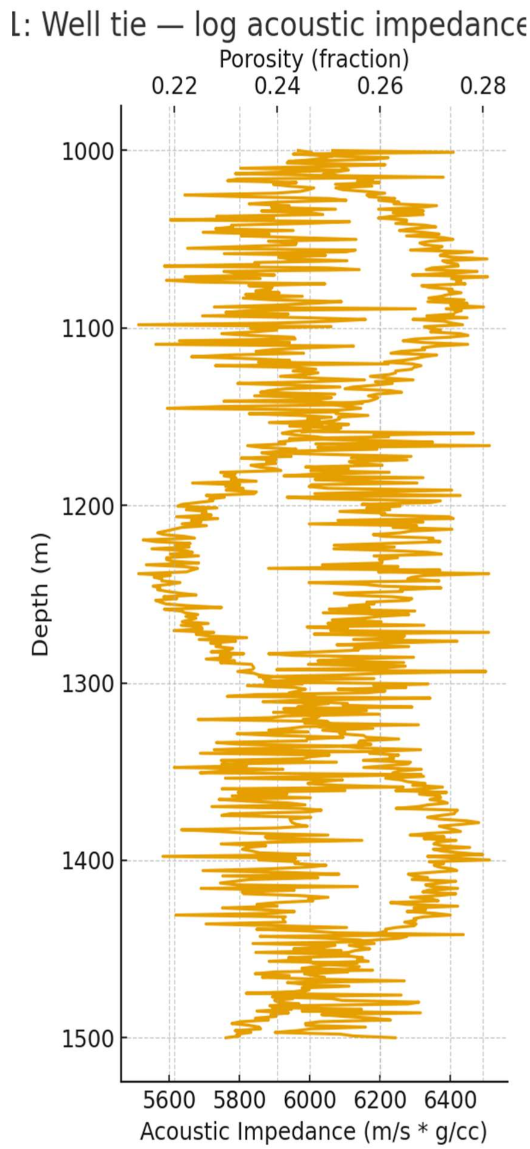

Fig. 3: The Well Tie Displaying Consistent Impedance Trends That Correspond To Variations In Porosity Seen In The Well Logs

H. Integration of Seismic Inversion and Attributes for Well Placement Optimization

A strong workflow for well placement optimization was produced by the complementary integration of multi-attribute analysis and seismic inversion results. Seismic characteristics provided lateral continuity information necessary for choosing the best well trajectories, while the acoustic impedance cube obtained from inversion provided vital vertical resolution of reservoir layers. The identification of sweet spots in Reservoir Sand A that combined superior petrophysical characteristics with structural placement was made easier by this integration.

Table 2: Seismic Attribute of the Wells in OSA Oilfield

Seismic Attribute	Interpretive Significance	Application in OSA Field
Root Mean Square (RMS)	High amplitude indicates hydrocarbon presence	Identified 7 prospects and 3 leads
Acoustic Impedance	Discriminates lithology and porosity variations	Resolved reservoir layers below 3,200ms
Sweetness	Highlights thick pay zones	Confirmed commercial thickness of Sand A
Average Energy	Identifies bright spots associated with hydrocarbons	Verified hydrocarbon-rich zones in Sand B

6. Discussion

The OSA Field case study's findings show that, in comparison to traditional methods, the combined use of seismic inversion and seismic attribute analysis significantly improves well placement optimization. The technical efficacy of this methodology for lowering interpretation uncertainty in the geologically complex Niger Delta basin is validated by the high correlation coefficients (0.995-0.997) between inversion results and well log data. This result is consistent with the study of Adeogun et al., (2024) that highlight the importance of integrated geophysical methods for characterizing reservoirs in structurally complex environments.

7. Conclusion

This research illustrates the efficiency of using seismic inversion and seismic attribute analysis optimization of well positioning in OSA Oilfield, Niger Delta, Nigeria. Correlation with well-log data was excellent between inverted acoustic impedance volumes and the inversion workflow and the seismic-to-well tie demonstrated the reliability of the inversion workflow. The difference in impedance and the choice of seismic properties were effective in outlining reservoir sand bodies, emphasizing porosity trends, and marking on areas with positive hydrocarbon potential. Such outcomes enhanced subsurface characterization than that provided by traditional seismic-based interpretation of the results through minimization of uncertainties in the reservoir geometry and quality. The combination of inversion results and the reaction of attributes allowed identifying the most desirable target of drilling that minimizes the risk of dry wells and improves the development plan. The result proves that seismic inversion and attribute analysis is a reliable and cost-efficient tool of well placement optimization in complex deltaic environments such as the Niger Delta. The findings and methodology may be used in correlating the oilfields with similar ones to aid in making informed decisions and enhance better reservoir management practices.

References

1. Adagunodo, T. A., Bayowa, O. G., Alatise, O. E., Oshonaiye, A. O., Adewoyin, O. O., and Opadele, V. O. (2022). Characterization of reservoirs and depositional study of JP Field, shallow offshore of Niger Delta Basin, Nigeria. Scientific African, 15, e01064. https://doi.org/10.1016/j.sciaf.2021.e01064
2. Adeogun, O. Y., Ajewole, S. O., Folohunsho, O. Y., Adeoti, L., and Adelaja, A. T. (2024). Structural and 3D seismic attribute analysis for reservoir characterization in pearl field, offshore Niger delta. *Discover Geoscience*, *3*(1), 1-18.
3. Adizua, O. F., and Ugwu, N. G. (2025). Prospect Identification Using Seismic Attributes For An Offshore Niger Delta Basin X Field. Quantum Journal of Engineering, Science and Technology, 6(2), 70-83. https://doi.org/10.55197/qjoest.v6i2.240
4. Ali, A., Younas, M., Ullah, M., Hussain, M., Toqeer, M., Bhatti, A. S., and Khan, A. (2019). Characterization of secondary reservoir potential via seismic inversion and attribute analysis: A case study. Journal of Petroleum Science and Engineering, 178, 272-293. https://doi.org/10.1016/j.petrol.2019.03.039
5. Brum, A., Coelho, G., Santos, A. A., and Schiozer, D. J. (2025). Estimation of distribution algorithms for well placement optimization in petroleum fields. Computational Geosciences, 29(1), 2.
6. Chang, Y. (2015). Decision-making for well placement optimization in oil field development. http://hdl.handle.net/11244/23314
7. Decklar R. (2025). Oza Field. https://www.decklarresources.com/our-assets/oza-oil-field/overview/
8. El-Sayed, A. S., Mabrouk, W. M., and Metwally, A. M. (2024). Utilizing post-stack seismic inversion for delineation of gas-bearing sand in a pleistocene reservoir, baltim gas field, nile delta, Egypt. Scientific Reports, 14(1), 29596. https://doi.org/10.1038/s41598-024-78186-9

9. Evans, K. T., Osinowo, O. O., Odufisan, W., Koledoye, B. A., Odusanwo, Y., Ude-Akpeh, T. O., and Tiele, G. Y. (2025). Seismic and petrophysical data analysis for geological interpretation and subsurface modeling of Keva Field, onshore Niger Delta, Nigeria. Energy Geoscience, 6(2), 100382. https://doi.org/10.1016/j.engeos.2025.100382
10. Fagbemi, O. I., Olayinka, A. I., Oladunjoye, M. A., and Edigbue, P. I. (2024). Focused reservoir characterization: analysis of selected sand units using well log and 3-D seismic data in'Kukih'field, Onshore Niger Delta, Nigeria. Scientific Reports, 14(1), 13763. https://doi.org/10.1038/s41598-024-56100-7
11. Falade, A. O., Amigun, J. O., and Abiola, O. (2024). Hydrocarbon prospective study using seismic inversion and rock physics in an offshore field, Niger Delta. Discover Geoscience, 2(1), 24.
12. Haris, A., Riyanto, A., and Wiyono, J. (2020, July). Integrated analysis of spectral-decomposition, AI inversion and RMS amplitude attribute for determining sandstone reservoir distribution: A case study of 'X'field in Central Sumatera Basin. In IOP Conference Series: Earth and Environmental Science (Vol. 538, No. 1, p. 012055). IOP Publishing. DOI 10.1088/1755-1315/538/1/012055
13. Hosseinzadeh, S., Saberi, M. R., Haghighi, M., Salmachi, A., and Salimzadeh, S. (2025). Seismic inversion approaches for reservoir characterization: A comprehensive review. Journal of Applied Geophysics, 105953. https://doi.org/10.1016/j.jappgeo.2025.105953
14. Li, Y., Li, J., Chen, X., Zhang, J., and Bo, X. (2020). Post-stack impedance blocky inversion based on analytic solution of viscous acoustic wave equation. Geophysical Prospecting, 68(7), 2009-2026. https://doi.org/10.1111/1365-2478.12967
15. Mallick, S., Srivastava, A., and Chakraborty, D. (2025). High-Resolution Subsurface Characterization Using Seismic Inversion—Methodology and Examples. Eng, 6(9), 206. https://doi.org/10.3390/eng6090206
16. Moukassa, T. W., Asedegbega, J. E., Adekola, S. A., and Nwakanma, A. (2024). Seismic Inversion Techniques and Attribute Analysis for Accurate Well Placement in Offshore Niger Delta Basin, Nigeria.
17. Nabawy, B. S. (2025). New approaches in reservoir characterization utilizing conventional and special core analyses: a comprehensive review. Journal of Umm Al-Qura University for Applied Sciences, 1-32.
18. Ogbe, O. B., and Edegbai, J. A. (2022). Seismic analysis of growth faults to predict sequence stratigraphic reservoir properties: A case study of the middle to late Miocene Coastal Swamp strata, Niger Delta Basin, Nigeria. Marine and Petroleum Geology, 138, 105536. https://doi.org/10.1016/j.marpetgeo.2022.105536
19. Ojo, O. T., Adeoye, J. A., Okoli, E. A., and Emegha, J. O. (2023). Petrophysical and geomechanical analysis to delineating reservoirs in the miocene Niger delta region of

20. Osaki,L.J., Itiowe K, Mgbeojedo. T. I (2021). Structural Interpretation and Attribute Evaluation for Characterization of Oil Field: A Case Study of “Sowari” Field, Niger Delta, Nigeria Asian
21. Opara, A. I. & Osaki, L. J. (2016). 3D seismic Attribute Analysis for Enhanced Prospect Definition of “Opu Field’’, Coastal Swamp Depobelt Niger Delta, Nigeria: Journal of Applied Sciences, ISSN 1812-5654. Journal of Applied Science and Technology, Volume 5, Issue 1, Pages 121-130
22. Osaki, L. J. (2025) Assessing the Reservoir Quality and Prospectivity of the “MUH” Field, Onshore Niger Delta Basin: Petroleum and Coal Pet Coal (2025); 67(2): 496-507 ISSN 1337-7027.Nigeria. Geoinformatica Polonica, 22, 105-121.
23. Oyedele, K. F., Olatinsu, O. B., Ige-Adeyeye, A. A., and Obasoro, O. A. (2020). Seismic impedance inversion and attribute analysis for reservoir characterization in an offshore depobelt, Niger Delta, Nigeria. SN Applied Sciences, 2(10), 1757. https://doi.org/10.1007/s42452-020-03571-8
24. Ru, I., and Chiazor, F. I. (2021). Sedimentology and Depositional Environment of Reservoir Sands of Kanga Oil Field Onshore Niger Delta. International Journal of Research and Innovation in Applied Science, 6(8), 57-61.
25. Yin, X. Y., Liu, X. J., and Zong, Z. Y. (2015). Pre-stack basis pursuit seismic inversion for brittleness of shale. Petroleum Science, 12(4), 618-627. https://doi.org/10.1007/s12182-015-0056-3