International Journal of Engineering Research and Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 22, Issue 4 (April 2026), PP 110-117

Geological Interpretation of Depositional Sequence and Environment of Deposition in OBJ Field, Niger Delta, Using Well Logs

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ABSTRACT: *This paper characterizes the depositional sequence and paleoenvironmental evolution of the OBJ Field in the Niger Delta, utilizing a total of three well logs (OBJ 1, 2, and 3) obtained from the Nigerian Agip Oil Company (NAOC). Integration of gamma ray log motifs reveals a vertical succession typically the Agbada Formation, transitioning from basal progradational delta front shales into a 25m thick, blocky reservoir sand in OBJ-2. This interval is significant tohigh energy distributary channel or shoreface depocenter within a highstand or regressive systems tract. Lateral correlation shows a distinct shale unit having a finning upward sequence toward the distal margins in OBJ-1 and OBL-3, indicating a localized deltaic lobe geometry. The sequence is capped by a fining upward bell motif, signifying a regional transgressive system tract (TST) and the establishment of a maximum flooding surface (MFS). These results define a high resolution stratigraphic framework of regressive to transgressive cycles, offering critical insights into reservoir architecture and sealing potential in the OBJ Field.*

Keywords: *Agbada Formation, Niger Delta, Sequence Stratigraphy, Log Facies, Parasequence, Depositional Environment, Reservoir Architecture*

Date of Submission: 20-03-2026 Date of acceptance: 03-04-2026

I. INTRODUCTION

A depositional system is the product of sedimentation in a particular depositional environment which includes the assemblage of strata whose geometry and facies lead to the interpretation of a specific paleo-depositional environment (Galloway, 1989). The environment of deposition of sediments is the sum of the physical, chemical, and biological condition under which it was deposited. These conditions are recorded in the form of sedimentary facies from which a judgement can be made of the paleodepositional conditions. Electrofacies analysis is a systematic approach to sequence interpretation for the prediction of depositional sequence and environments of deposition from well logs (Osaki and Oghonyon, 2025; serra and Sulpice, 1975). The analysis of depositional sequences and environments of rock units can be accomplished with geophysical well log interpretation (Oghonyon et al., 2025;Reijers, 2011; Serra and Abbott, 1982; Van Wagoner et al., 1990).

The Niger Delta stands as one of the most prolific hydrocarbon provinces in the world, characterized by a complex Cenozoic sedimentary wedge that has prograded into the Atlantic Ocean. The primary reservoir units are located within the Agbada Formation, a paralic sequence of alternating sands and shales (Short and Stäeuble, 1967). Understanding the spatial distribution of these reservoirs requires a robust geological interpretation of the depositional sequences and environments (Erhire *et al*., 2025; Osaki and Oghonyon, 2025). By utilizing well log data, geoscientists can reconstruct the ancient landscapes of the Niger Delta, identifying where sand-rich channels or wave-dominated shorefaces were deposited millions of years ago (Emery and Myers, 1996; Oghonyon *et al*., 2025; Osaki and Oghonyon, 2025; Umukoro and Okengwu, 2022).

Primarily, standard lithostratigraphic correlation often fails to capture the subtle stratigraphic traps or the connectivity of reservoir sands, leading to uncertainties in field development (Reijers, 2011). Without a detailed sequence stratigraphic framework, it is difficult to predict how sand bodies pinch out or how shale seals behave across the field (Nnurum *et al*., 2026). This study addresses these uncertainties by moving beyond simple rock type identification to a genetic understanding of how the strata were bundled during shifts in base level.

This research evaluates the depositional sequences and paleo-environments of the OBJ Field to enhance reservoir characterization by: Identifying lithology and depositional environments using gamma ray (GR) and resistivity log motifs, delineating key stratigraphic surfaces, such as sequence boundaries (SB) and maximum flooding surfaces (MFS), determining the progradational, retrogradational, and aggradational stacking patterns within the interpreted sequences.

GEOLOGY OF THE STUDY AREA

The OBJ Field is located within the depobelt of the Cenozoic Niger Delta, Nigeria. Geologically, the area is situated within the Agbada Formation, which is characterized by an alternation of sandstone and shale units (Oghonyon *et al*., 2025; Short and Stäeuble, 1967; Erhire *et al*., 2025). The structural framework of the OBJ Field is dominated by syn-sedimentary growth faults and associated roll-over anticlines, which are typical of the Niger Delta's extensional regime (Doust and Omatsola, 1989; Chiazor and Ugwueze, 2020).The climate of the region is tropical, with high rainfall and humidity, which has historically influenced the delta's progradation and sediment discharge. The stratigraphic succession in the area involves the basal Akata Formation, the hydrocarbon-bearing Agbada Formation, and the overlying continental Benin Formation (Doust and Omatsola, 1989).The Niger Delta Basin is situated on the continental margin of the Gulf of Guinea in Equatorial West Africa, covering about 75,000kmwith average thickness of about 12km (Oghonyon et al., 2025; omatsola,1988). It is one of the world’s most petroliferous Tertiary Delta that together account for about 5% of the world’s oil and gas reserves. The onshore portion of the Niger Delta province is delineated by the geology of southern Nigeria and southwestern Cameroon, the northern boundary of Niger Delta is the Benin flank and east northwest trending hinge line south of the West Africa basement massif. The northeastern boundary is defined by outcrop of the cetaceans on the Abakaliki High and further east south east by the Calabar flank, a hinge line bordering the adjacent Precambrian. The offshore boundary of the province is defined by the Cameroon Volcanic line to the east, the eastern boundary of the Dahomey basin (The easternmost West African transform-fault passive margin) to the west The Niger Delta Basin has built out into the central Atlantic at the north of the Niger-Benue and Cross River drainage systems (Aikulola et al., 2010). The Delta stretches for about 300km from apex to mouth and covers an area of at least 75,000km (Doust and Omatsola, 1989, Umukoro and Okengwu, 2022). It is considered to have been built out covering a crustal tract on the trailing edge of the Africa continent, and has been classified as a marginal sag basin (Dishroon, 1983). Various articles have been published on the origin, geology, hydrocarbon generation, plays and potentials of this important prolific Delta. Data acquired during exploration and exploitation and researches by oil developing companies and the academia (Department of geology and related disciplines in Nigerian universities) have contributed whole lots of information to the understanding of the petroleum geology of Niger Delta basin. Paleogeography and tectonics: The tectonic framework of the continental margin along the West coast of Equatorial Africa is controlled by Cretaceous fracture zones expressed as trenches and ridges in the deep Atlantic developed during the continental rifting and separation of Africa from South America. The fracture zone ridges subdivide the margin into individual basins, and in Nigeria, from the boundary fault of the Cretaceous Benin-Abakaliki Trough, which cuts far into the West African Shield.

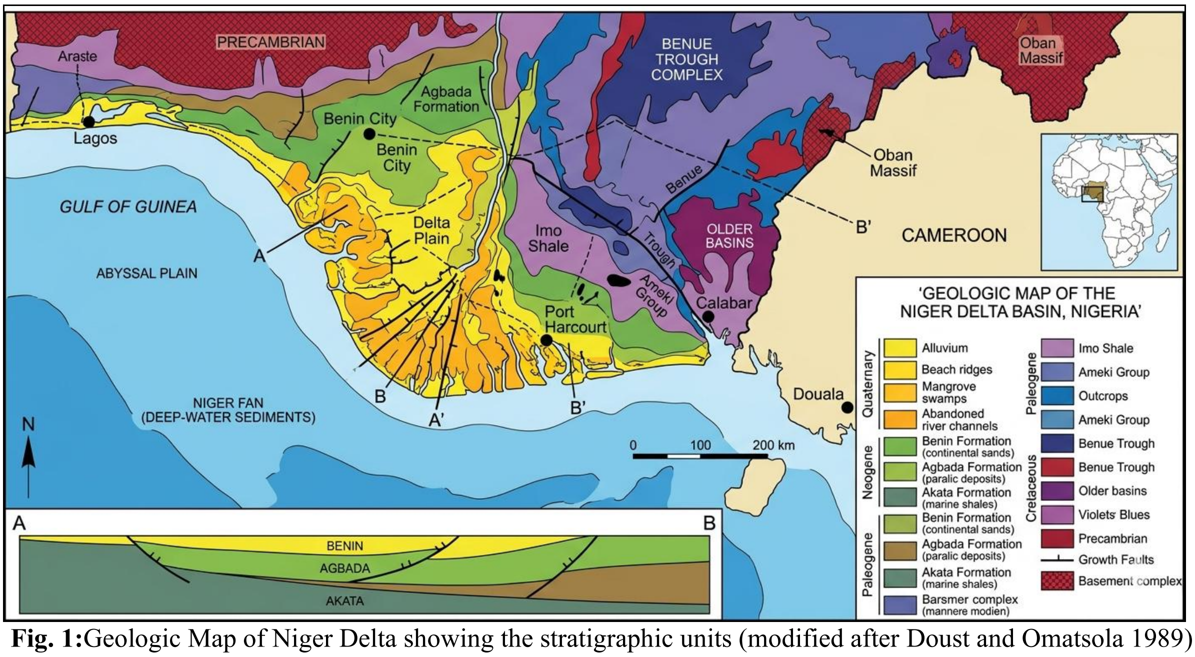

Fig. 1: Geologic Map of Niger Delta showing the stratigraphic units (modified after Doust and Omatsola 1989).

II. MATERIALS AND METHODS

*Acquired Data Set:*The data for this paper was provided by the Nigerian Agip Oil Company (NAOC). The dataset consists of a suite of wireline logs from multiple wells within the OBJ Field. The specific logs utilized include: gamma ray (GR) Logs, and resistivity logs (LLD/LLS); (used for lithology identification, facies analysis, depositional sequences, and depositional environments.

Lithofacies Identification: The GR log was the primary tool for distinguishing between sand and shale units. A shale baseline was established to calculate the Volume of Shale (Vs), which helped in identifying clean sand reservoirs.

Depositional Environment Analysis: This involved the qualitative interpretation of log motifs or shapes (Selley, 1985; Serra, 1984), which includes; Bell shapes (fining upward describing fluvial or tidal channels), Funnel shapes (coarsening upward describing prograding delta fronts or crevasse splays), Cylindrical shapes indicating aggradational thick channel sands or shorefaces.

Sequence Stratigraphic Framework: The logs were scrutinized for significant stratigraphic surfaces such as maximum flooding surfaces (MFS) observed by high GR peaks and low resistivity values (indicating condensed sections), while sequence boundaries (SB) identified at the base of the thickest progradational sand units, often representing a depositional shift in facies (Vail et al., 1977).

Correlation and Stacking Patterns: By aligning the wells along interpreted MFS markers, the paper analyzed systems tracts (highstand, lowstand, and transgressive). This allowed for the mapping of how depositional environments shifted across the OBJ Field over geologic time (Erhire et al., 2025).

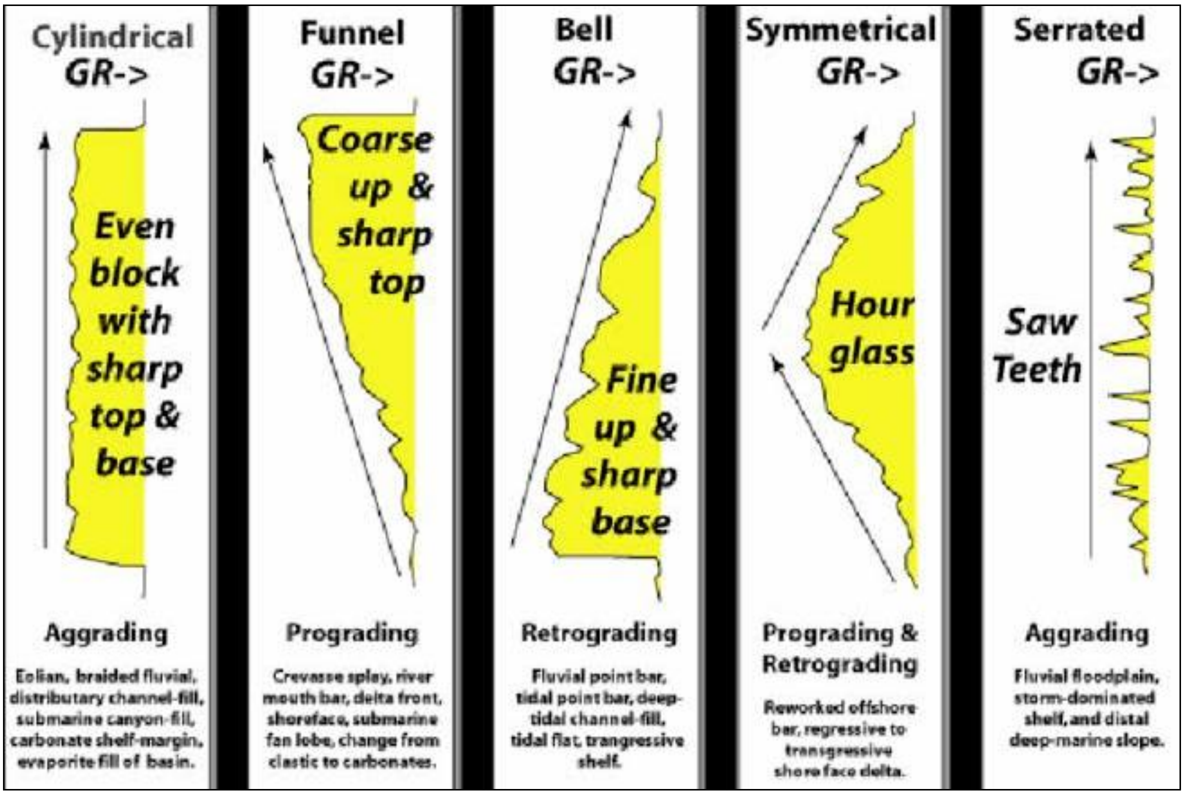

Fig. 2: Log motiffs for interpretation of depositional sequences and environments of deposition (modified after Selley, 1985; and Serra, 1984)

III. RESULTS AND DISCUSION

The provided well logs (as shown in Figure 3, 4, and 5 above) from the OBJ Field Niger Deltashow classic gamma ray signatures with color-coded lithology overlays (yellow for clean/low GR sands, brown for shaly/high GR intervals, indicating lithological transitions). These signatures are interpreted using standard GR log motifs for depositional sequences.

The sequence in OBJ-1 (see figure 3 below) begins at the base (approx. 3054SSTVD) with a high-gamma ray reading, low-resistivity shale baseline representing a quiet, offshore shelf environment. The serrated to funnel shaped motif between 3042SSTVD and 3040SSTVD, indicates a progradational delta front or lower shoreface where sand pulses are beginning to interline with silt. Above this, the log returns to a high gamma bell shape. At 3030SSTVD to 3020SSTVD, the log exhibits a cylindrical shape indicating an aggradational stacking pattern where there is high and steady energy flow, and then a steady shale baseline toward the top

(2985SSTVD), suggesting a transgressive marine flooding event that drowned the sandy system and restored deep water hemiplegic sedimentation.

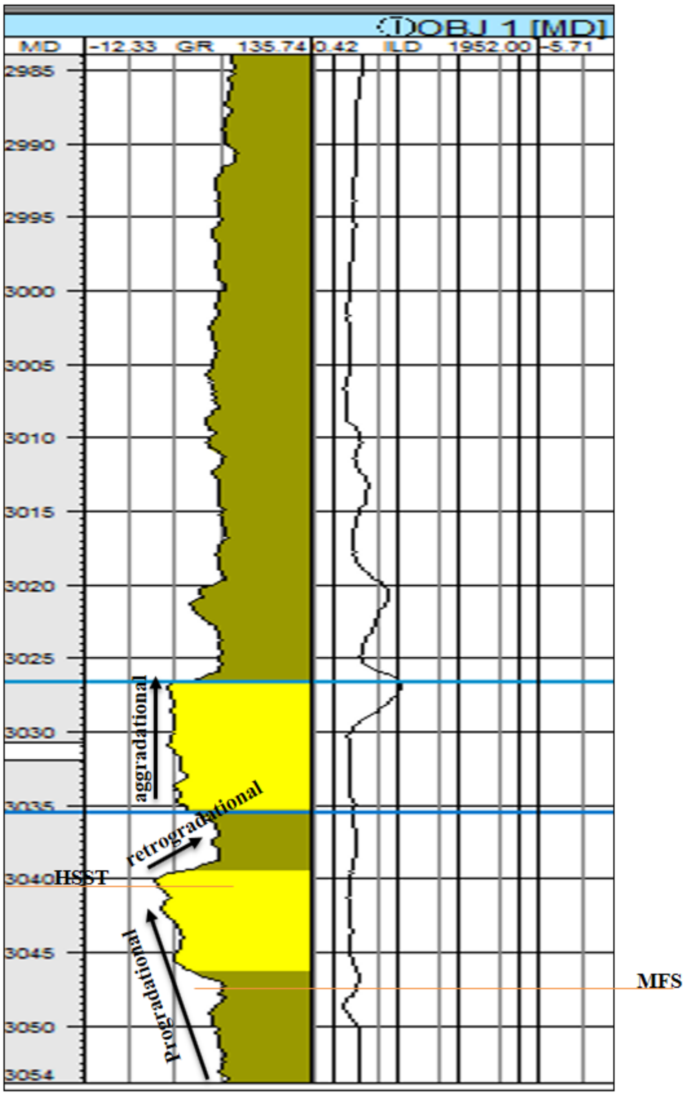

Fig. 3: OBJ field composite well log-1

The OBJ 2 (see figure 4 below) displays the most robust reservoir development, suggesting it is located in the axial (central) portion of the depositional system. From the bottom (3068SSTVD) to 3042SSTVD, it shows a coarsening upward trend (highstand systems tract). This is abruptly truncated by a thick, blocky (cylindrical) sand motif from 3042SSTVD to 3015SSTVD, which likely represents a distributary channel or a high energy stacked shoreface unit. The sharp basal contact suggests a sequence boundary (SB) or an incised valley fill (lowstand systems tract). The top of this sand (3015SSTVD) shows a rapid fining upward signature as it transitions into a thick marine shale, marking the onset of a transgressive systems tract (TST).

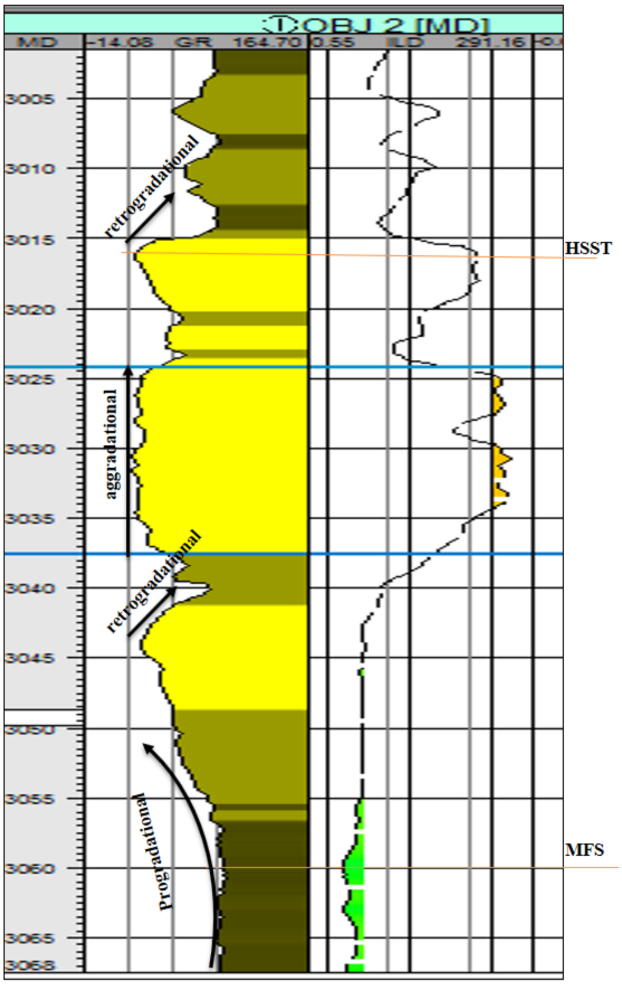

Fig. 4: OBJ field composite well log-2

In OBJ 3 (see figure 5 above), the depositional sequence shows a thick shale deposit or more distal compared to OBJ-2 well. The base of the log (3042STTVD) is dominated by shale until approximately 3005SSTVD, where a distinct blocky to funnel sand appears between 3005SSTVD and 2988SSTVD. Interestingly, this sand sits much higher in the stratigraphic column than the main sands in OBJ-1 and OBJ-2. This suggests a lateral facies shift or a younger progradational pulse. The interval above 2988SSTVD quickly returns to high gamma shale, containing a probable maximum flooding Surface (MFS) near 2995SSTVD, characterized by the highest gamma ray peak in the section.

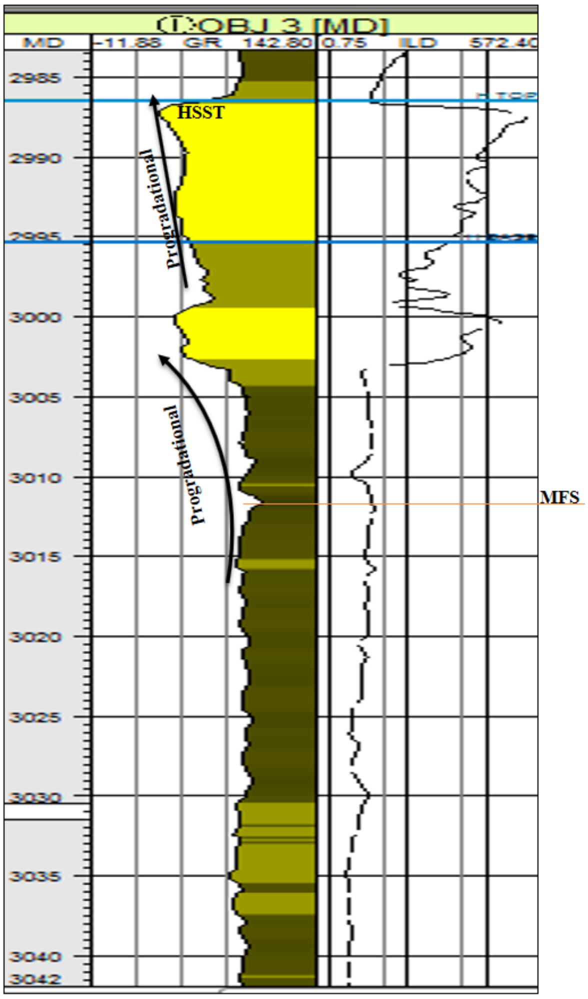

Fig. 5: OBJ field composite well log-3

The correlation lines (see Figure 5 above) reveal a dynamic sequence stratigraphic framework: The lower correlation lines connect the base of the sands across the wells. There is a noticeable dip or down stepping from OBJ-3 toward OBJ-1 (Figure 3, 5, and 6). This represents clinoform progradation, where the delta or shoreline was building out into the basin from right to left (or vice versa depending on regional dip). The main sand body is most continuous between OBJ-1 and OBJ-2 (Figure 6). However, the sand in OBJ-2 (Figure 4 and 6) is significantly thicker and cleaner than in OBJ-1 (Figure 3 and 5). This indicates that the environment in OBJ-2 (Figure 4 and 6) was the high energy depocenter, while OBJ-1 (Figure 3 and 6) was on the lower energy margins of the lobe. The upper correlation lines show a uniform transition into shale across all three wells. This is a regional marine flooding surface. The entire system was eventually submerged by rising sea levels, capping the reservoir sands with a thick shale seal.

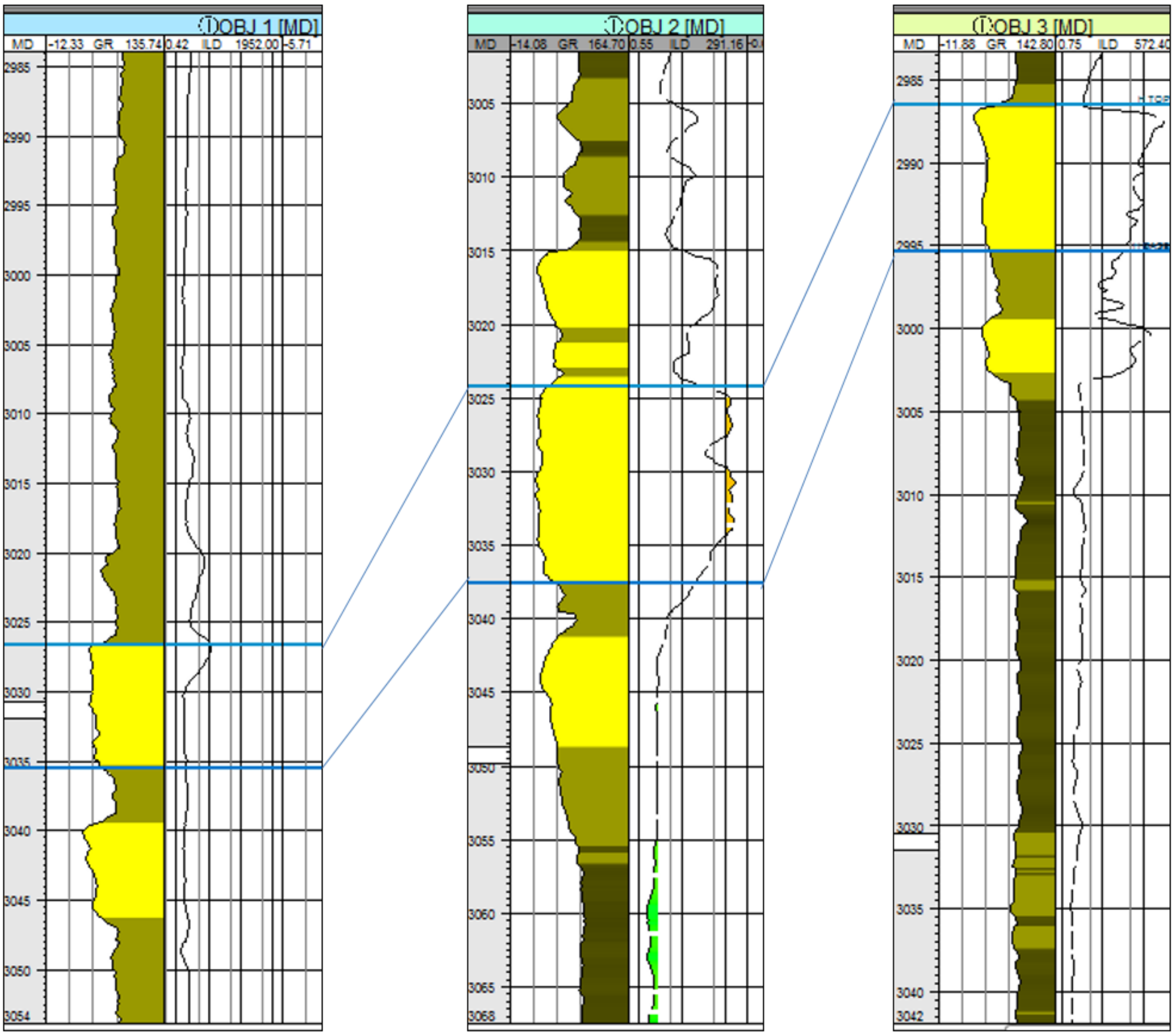

Fig. 6: Structural correlation panel between wells OBJ-1, OBJ-2 and OBJ-3, showing the lateral continuity and structural position of clean sand.

IV. CONCLUSION

The well log suitesreveal a classic progradational to transgressive deltaic sequence, characterized by a transition from basal offshore shales into high energy distributary channel or shoreface sands (reaching maximum development in the blocky motifs of OBJ-2), and ultimately capped by a regional marine flooding event. The vertical succession from coarsening upward funnel shapes to cylindrical reservoir units, followed by fining upward transgressive shales, defines a clear stratigraphic evolution from a highstand/regressive systems tract to a transgressive systems tract. This interpretation is reinforced by the lateral correlation of the sand bodies, which shows a thickening toward the central depocenter (OBJ-2) and a distal shale thinning toward the flanking wells, providing a robust framework for understanding both the reservoir geometry and the shifting paleodepositional energy across the field. These findings refine reservoir architecture models for similar paralic successions, highlighting predictable sand body geometries controlled by delta lobe progradation. To build on this, it is important to incorporate resistivity and density logs for net pay and hydrocarbon saturation evaluation, perform seismic interpretation to map fault seals, channel trends, and potential stratigraphic traps, and plan additional infill/appraisal wells to test lateral extensions and reservoir heterogeneity. Implementing these steps will enhance field development strategy, reduce exploration risk, and improve recovery efficiency in the OBJ Field.

DECLARATIONS

Ethical Approval: This study did not involve human participants or animal experimentation. All procedures involving data handling and analysis were conducted responsibly and in accordance with standard academic and institutional guidelines.

Disclaimer (Artificial Intelligence): Author(s) hereby declare that Artificial Intelligence (AI) technologies such as Large Language Models (ChatGPT, COPILOT) and text-to-image generators have been used during writing or editing this manuscript.

Conflict of Interest: The authors declare that no known conflict of interest or personal relationships that have influence the work reported in this paper.

Data Availability: Data are available upon request from the corresponding, first, or fourth Author.

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