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# Sequence Stratigraphic Framework of the Albian Clastic in Luhais Oilfield, Southern Iraq

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**Abstract**
The establishing of a high-resolution sequence stratigraphic framework for the Albian Clastic represented by Nahr Umr Formation within the Luhais Oilfield, southern Iraq was conducted in this research. The study integrates 214.54 meters of continuous core descriptions across six selected wells (X1, X2, X3, X4, X5, and X6) with calibrated wireline log behaviours, mainly Spontaneous Potential and Gamma Ray logs. The depositional history demonstrates that the represented lithofacies were deposited within complex, transitional depositional environments ranging from fluvial to tidal and coastal settings. The sequence stratigraphic study delineated systems tracts; Lowstand Systems Tracts, Transgressive Systems Tracts, and Highstand Systems Tracts (LST, TST, and HST) through stacking patterns and lithofacies distribution. Chronostratigraphically, the Nahr Umr Formation is divided into two 3rd-order depositional sequences. First Sequence initiates at the onset of formation deposition, bounded at the base by a Type-1 Sequence Boundary (SB1) and at the top by a Type-2 Sequence Boundary (SB2), with the Maximum Flooding Surface (MFS) situated in the middle portion of the formation. Second Sequence overlies First Sequence and extends upward to the Mauddud Formation, where a regional Transgressive Surface (TS) is recognized as the contact separating the Nahr Umr and Mauddud formations. Hydrocarbon reservoirs within the formation are predominantly concentrated within fluvial channel deposits at the top of the Lowstand Systems Tract (LST) at the base of the formation, as well as within tide-influenced channel deposits of the Transgressive Systems Tract (TST).

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**Keywords:** Sequence Stratigraphy, Luhais Oilfield, Nahr Umr Formation

## 1. Introduction

The Albian Nahr Umr Formation constitutes one of the premier siliciclastic hydrocarbon reservoirs in central and southern Iraq, exhibiting exceptionally high porosity and permeability properties (Talib & Al-Jawad 2026) [23]. This formation has undergone extensive research and surveying by Iraqi and numerous foreign oil corporations and researchers. Among them are Chatton and Hart (1960) [11], Al-Naqib (1967) [2], Ditmar (1972) [14], Al-Siddiki (1978) [10], Al-Badry *et al*. (1983) [3], Ibrahim (1983) [15], Al-Jawadi (1990) [6], Al-Khirsan (1992) [8], Al-Hadithy (1994) [5], Abid et. al. (2015), Khudhair and Al-Zidy (2018) [17] and Mohammed and Alsultan (2022 and 2023). Regionally, Nahr Umr Formation is equivalent to the Khafji and Safaniya Formations of Saudi Arabia, the Burgan Formation of Kuwait, and the Lower Kazhdumi Formation in Iran. Tectonically, the Luhais Oilfield lies within the Zubair Subzone in the Mesopotamian Basin of the Unstable Shelf (Jassim and Goff, 2006) [16]. Structurally, it forms an elongated, amoebic-shaped anticlinal structure measuring approximately twenty kilometers in length and ranging from five to ten kilometers in width, western flank characterized by a slightly steeper relative to eastern flank. This study concentrates on establishing a sequence stratigraphic model, with key stratigraphic surfaces, explaining systems tracts, and determining

the sequence-controlled distribution of reservoir intervals without delving into fine-scale sedimentological or petrographic facies descriptions.

## 2. Study Area

The Luhais Oilfield is located in the southern desert of Iraq, approximately 90 km southwest of Basra city and 50 km southwest of the North Rumaila Oilfield (Figure 1).

Nahr Umr Formation that overlies the Shua`aiba Formation with unconformable contact, the upper contact surface is conformable and gradational with the Mauddud Formation (Jassim and Goff, 2006) [16]. The Nahr Umr Formation increases in thickness toward south and south-eastern part of the oilfield to reach maximum thickness of 250.9m in LU-4 well.

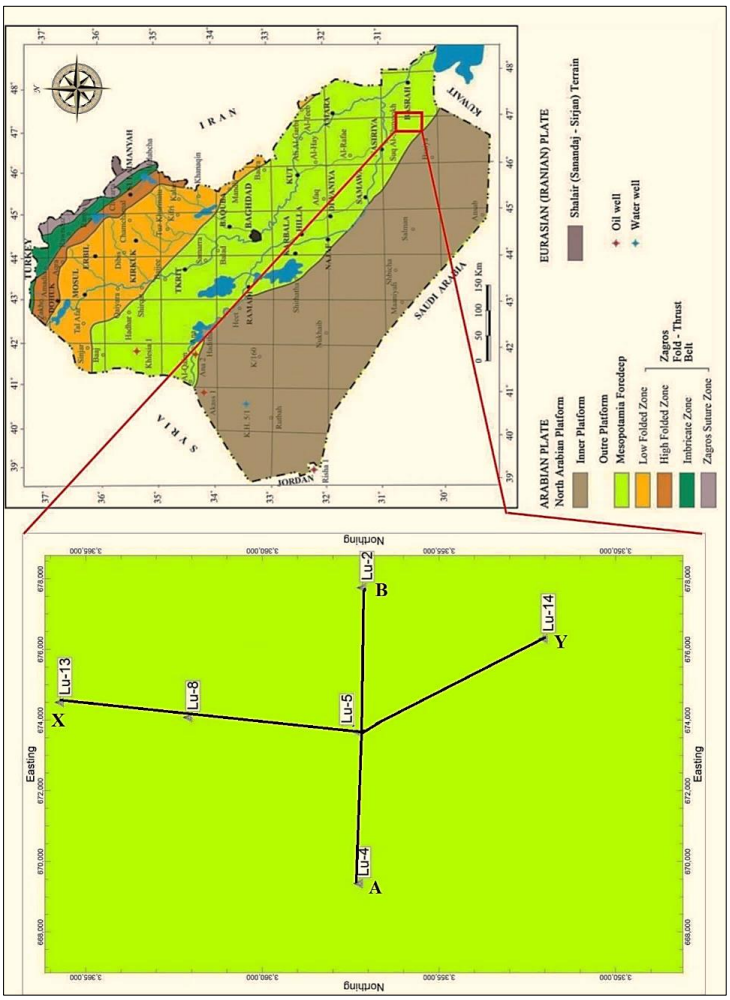



**Fig 1:** location and tectonic map of studied area, modified after Abid Husseinet al. (2015).

## 3. Study Objective

The study aims to identify the sedimentary facies and environment, as well as to attempt to subdivide the formation based on the principle of sequence stratigraphy using the available information from well logs and Core data analysis. Then, the stratigraphic framework and the geological model of the Nahr Umr Formation in the Luhais Oilfield were determined.

## 4. Materials and Methods

This research synthesizes wireline log interpretations with subsurface core data from six selected wells to reconstruct the stratigraphic framework of the Nahr Umr Formation in Luhais Oilfield. A 214.54-meter sequence of core intervals (Data from the final core analysis report was incorporated into the evaluation) was depth-shifted to calibrate log profiles with physical rock evidence (Al-Banna & Al-Khafaji 2021) [4]. Electrofacies signatures characterized by blocky, bell, funnel, and serrated motifs from Spontaneous Potential and Gamma Ray logs were then leveraged to trace sequence boundaries across uncored sections (Al-Nafie. *et al*, 2022) [9] Guided by Exxon's sequence stratigraphy models, the analysis delineated third-order depositional sequences and key horizons, such as transgressive and maximum flooding surfaces. Finally, analysing progradational, retrogradational, and aggradational stacking patterns allowed for the detailed mapping of Lowstand, Transgressive, and Highstand Systems Tracts.

## 5. Results and Discussion

### 5.1. Lithofacies and Depositional Environment

Through describing and studying the available core in terms of Lithofacies precisely based on lithological and textural analysis, and the sedimentary structures of the available well cores and their relationship with electrofacies from the response of different logs, seven (7) different lithofacies were identified as follows:

- **F1 Lithofacies:** Cross-Bedded Sandstone Lithofacies
  Cross-Bedded Sandstone Lithofacies: The rocks of this lithofacies consist mainly of sandstone with a few clay drapes extending along the bedding planes. The sandstone rocks are characterized by a medium to very fine grain size variation indicating a fining upward trend. The characteristic sedimentary structures for these facies are trough cross-bedding, and occasionally current-ripple cross-lamination, with common occurrences of plant remains, coal, and distinctive oil shows.
- **F2 Lithofacies:** Wave-Rippled Cross-Laminated Sandstone Lithofacies
  Wave-Rippled Cross-Laminated Sandstone Lithofacies: This lithofacies consists mainly of fine to very fine sandstone. The apparent sedimentary structures are parallel and wavy lamination with wave-ripple cross-laminations, along with the presence of clay drapes between sets of ripple laminae and laminae sets. Biogenic structures (Bioturbation) appear scattered and include trace fossils, with the presence of plant remains and the appearance of iron oxides (Iron oxide), in addition to good oil shows in other instances.
- **F3 Lithofacies:** Interlaminated Sandstone, Silt and Shale Lithofacies
  Interlaminated Sandstone, Silt and Shale Lithofacies: This lithofacies consists of alternating laminations of very fine sandstone with siltstones and shale rocks. Sedimentary Structures: Include horizontal lamination, with low to absent cross-lamination, and occasionally showing some ripple marks. Most of these laminations appear in a scale of a few centimetres as paired alternations between silt and organic-rich shale. The deposited beds range from clay-dominated to sand-dominated ranges.
- **F4 Lithofacies**: Bioturbated Mudstone Lithofacies
  Bioturbated Mudstone Lithofacies: Consists mainly of shale, and may grade into silty rocks in vertical section. Biogenic structures (Bioturbation) are common and mostly characterized by indistinct trace fossils.
- **F5 Lithofacies:** Bioturbated Silty Sandstone Lithofacies
  Bioturbated Silty Sandstone Lithofacies: Consists of very fine-grained to silty and clayey sand, colored red due to iron minerals. This lithofacies reflects a fining upward trend (Fining upward). Biogenic structures (Bioturbation) are common and diverse.
- **F6 Lithofacies:** Laminated dark gray Shale Lithofacies
  Laminated Dark Gray Shale Lithofacies: Characterized by very fine-grained sediments consisting mainly of dark black shale with parallel bedding and high to moderate fissility. It is rich in organic drapes (Organic drapes). The characteristic sedimentary structure is parallel lamination. Biogenic structures are uncommon and difficult to identify due to the high fissility of the shale, with an abundance of amber and plant remains. Iron oxide nodules (Iron oxide nodules) may occasionally be present.
- **F7 Lithofacies:** Interlaminated Shale and Silty Sandstone Lithofacies
  Interlaminated Shale and Silty Sandstone Lithofacies: Consists of dark gray shale alternating with silty-sandy sandstone. Composed of very fine to silty sandstone alternating with shale rocks. This lithofacies forms under depositional conditions where mud deposition is greater than sand (more than 60% shale rocks), where the sand supply is weak, forming incomplete ripple marks. The most prominent sedimentary structures are lenticular lamination (isolated lenticular lamination with flat lenses). It occasionally appears as lenses, balls, and pods of light-coloured, very fine sandstone interbedded with shale (and pods of light colour very fine Sandstone interbedded with Shale lenses). Biogenic Structures: Biogenic structures (Bioturbation) are rare and characterized by trace fossils.

### 5.2. Facies Analysis

The different depositional facies were identified based on the cut core intervals of the formation and on the response of logs in sections lacking core. Lithofacies can be classified into three environments represented by groups of lithofacies, according to the nature and depositional environment influential in the area, as follows:

**1. First: Fluvial Environment:** Consists of the following facies:

**A. Fluvial Channels & Incised Valley Fill (IVF) Facies**:
Represented by Sandstone Lithofacies (F1: Cross-Bedded Sandstone Lithofacies). The sands of this group are characterized by a fining-upward trend. Their overall shape is reflected on spontaneous potential curve and gamma ray curve logs as pointing to a bell shape. The sandstone body may show uniform grain size, displayed on well-log curves as a boxy or cylindrical shape (as per Conybeare, 1976; Pirson, 1977; Schlumberger, 1985) [13, 22]. Characterized by grain size variation ranging from medium to very fine, with good to moderate sorting. The deposits of this group clearly appear as thick sandstone sequences, representing fluvial channel facies filling valleys in low-gradient fluvial floodplain deposits (updip braid-plain), as shown in the lower part deposits of the formation.

**B. Fluvial Overbank and Levee Facies:**
Represented by lithofacies F3, these consist of floodplain deposits reflected by high Gamma Ray log values within the sandstones. They exhibit a serrate log shape, which reflects the alternating stratification of shale and siltstone beds within very fine-grained sandstones showing a finning-upward trend.
These deposits can be considered interdistributary channel deposits, where the sediment supply for these facies is driven by overbank flooding. This occurs when sediment-laden waters spread across a wide area via crevassing through the natural levees, forming what is known as a crevasse-splay. Under these conditions, the deposition of fine-grained materials transported as suspension load deposits predominates. Conversely, coarser sediments settle closer to the channel banks during flood periods, building up the levees. Repeated flooding events result in successions of well-sorted, fine-grained sands. interbedded between finer shale layers containing iron nodules and amber grains, as well as silty shale layers in which bioturbations are common.

**C. Swamp and Marshes Facies:**
Characterized by very fine-grained sediments of black shale with highly fissile horizontal lamination, as in lithofacies (F6). This is accompanied by the presence of high percentages of black organic matter with an abundance of plant remains and coal, providing evidence that deposition

occurred under stagnant water conditions (Coleman, 1980) [12].

**2. Secondly: Tidal Environment:** It consists of the following facies:

**A. Tidal-Dominated Bars and Channels Facies**
consisting of shaly sandstone deposits represented by lithofacies (F2 & F7). These are reflected by Gamma Ray (GR) values slightly higher than those of fluvial deposits. Its units exhibit greater variability, predominantly featuring fining-upward or coarsening-upward trends. Generally, they feature a sharp base and a heterogeneous upper part.

**B. Bay, mudstone-dominated facies**
Bay and estuarine facies, represented by lithofacies (F4 & F7), are usually dominated by interbedded mud deposits with shale/siltstone deposits exhibiting parallel lamination, along with some very fine-grained to silty sandstone deposits. Sedimentary structures show parallel and occasionally lenticular laminations, with an abundance of biogenic structures (trace fossils), reflected by high Gamma Ray log values.

**3. Thirdly: Shoreface and Offshore Environment:** It consists of the following facies:

**A. Transgressive shoreface and shoreline sandstone facies**
Represented by lithofacies (F2), these consist of alternating rock deposition with some shale lenses. Its sediments are characterized by a grain size grading from fine at the bottom to coarse at the top, reflecting a coarsening-upward trend. This pattern is exhibited by SP and GR log curves with a serrate funnel shape (Conybear, 1976) [13]. The vertical succession of this facies begins with lenses and pods of very fine-grained to silty sand at the base of the facies, accompanied by common biogenic structures (bioturbation). These represent coastal and offshore sandstone deposits, which are continuously exposed to the action of tidal currents or ocean wave currents.

**B. Offshore facies**
Represented by lithofacies (F5 and F6), these reflect transgressive facies or marine offshore deposits. They consist of very fine-grained dark grey shale deposits that reflect a zone situated below the effective storm wave base. Biogenic structures are weak and uncommon in this facies, which is further characterized by high Gamma Ray (GR) log values.

**5.2. Key Stratigraphic Surfaces**

1. **Sequence Boundary Surface (SB):** Type 1 sequence boundary (SB1) was identified to mark the lower boundary of the formation. This boundary is characterized by a sharp, abrupt decrease in Gamma Ray (GR) and/or Spontaneous Potential (SP) log responses within a cleaning-upward trend of the lithological units. This trend reflects sudden upward shallowing resulting from rapid shoreline regression, caused by a rate of eustatic fall exceeding the rate of tectonic subsidence. This type of boundary is distinguished by subarial exposure and the occurrence of erosion via fluvial rejuvenation. Furthermore, Type 2 sequence boundary (SB2) was identified, resulting from the exposure of the red shale beds that separate the Highstand Systems Tract (HST) from the Lowstand Systems Tract (LST) in the upper part of the formation.
2. **Transgressive Surface (TS):** The transgressive surface represents an abrupt increase in clay/shale content, reflected by a sudden increase in Gamma Ray and Spontaneous Potential log readings across retrogradational parasequence and parasequence set units toward the basin. Two transgressive surfaces were delineated: the first in the lower part of the formation, separating the Lowstand Systems Tract (LST) from the Transgressive Systems Tract (TST), and the second at the top of the formation, acting as a regional flooding surface that marks the boundary between the Mauddud and Nahr Umr formations.
3. **Maximum Flooding Surface (MFS):** This surface was approximately identified near the middle of the formation, representing the boundary between underlying retrogradational patterns within the Transgressive Systems Tract (TST) and overlying progradational units toward the basin within the Highstand Systems Tract (HST). This transition is reflected by SP and Gamma Ray logs, shifting from non-clean to clean lithological units (dirtying upward to cleaning upward, respectively), with the Gamma Ray log reaching its peak value at the Maximum Flooding Surface (MFS).

**5.2. Formation Correlation**
To establish a concrete comprehension of the stratigraphic relationships and depositional stages of the Nahr Umr Formation within the Luhais Oilfield, a comparative evaluation of the formation was conducted across various depositional systems. Efforts were made to correlate its sedimentary components and define chronostratigraphic relationships across the analysed wells along different orientations.

**5.3. Depositional Cycles**
Sequence stratigraphic analysis of the studied wells in the Luhais Oilfield indicates that the Nahr Umr Formation comprises two depositional cycles. Each cycle is characterized by retrogradational to basinward progradational and upward-aggradational parasequence sets followed by a landward-retrogradational parasequence set, and terminating in a basinward-progradational parasequence set (Van Wagoner *et al*., 1990) [26].

**5.4. Systems Tracts**
Systems tracts and stacking patterns within the stratigraphic sequences delineated the Lowstand Systems Tract (LST). This tract exhibits the dominance of thick braided river deposits with minor shale intercalations at the base of the formation, along with tide-influenced estuarine deposits at the top (Figure 2).
Figures (3, 4) indicate the representation of four systems tracts within the formation according to sequence stratigraphy principles. The first cycle begins at the lowermost part of the formation, characterized by thick incised-valley fill (IVF) fluvial deposits that dominate the lower section. These rest on a basally erosional Type-1 sequence boundary (Posamentier and Vail, 1988; Van Wagoner *et al*., 1988) [21, 25], which marks a relative sea-level fall. In general, valley incision reflects the interplay between sedimentation rates and relative sea-level fluctuations.

Incised valleys are typically backfilled by fluvial activity during the late Lowstand Systems Tract (LST) and the early Transgressive Systems Tract (TST) as relative sea level begins to rise. This transition is marked by a shift from progradational stacking to vertical aggradation, ultimately culminating in landward retrogradation.

Subsequently, the sea gradually transgresses landward, indicating an accelerated sea-level rise where sedimentation rates fall behind accommodation creation. This is evidenced by an increased deposition rate of shale at the expense of sandstone across the Transgressive Surface (TS). This transgression leads to maximum flooding, marked by barrier, tidally influenced channel, and mudflat deposits within estuarine/tide-dominated deltaic environments. This part comprises a retrogradational cycle within the Transgressive Systems Tract (TST) (Posamentier and Vail, 1988) [21].

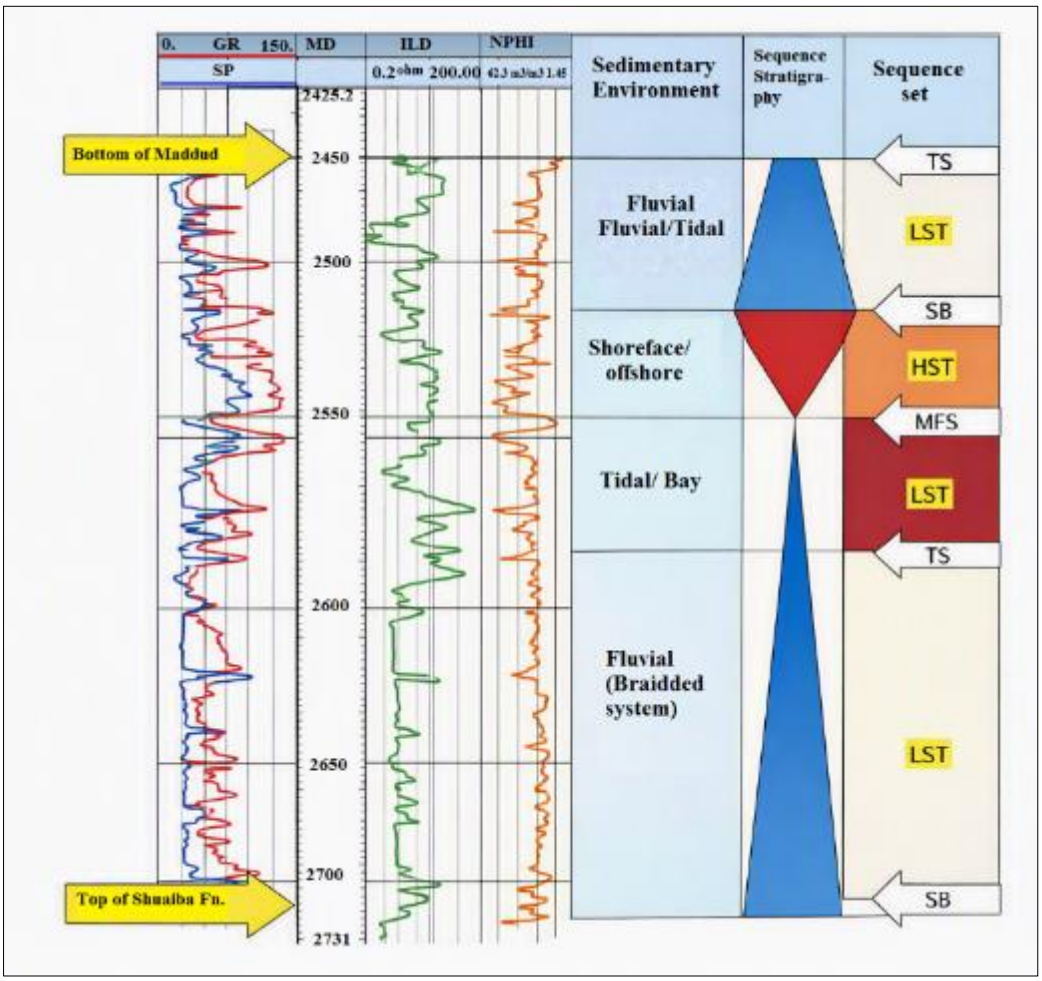



**Fig 2:** Sedimentary succession and stratigraphic distribution of the Nahr Umr Formation – Well X2.

The transition and observed shift toward a landward-retrogradational stacking pattern indicates the onset of the transgressive surface (TS) or marine transgression. This reflects an increase in accommodation space resulting from relative sea-level rise outpacing sediment supply. This phenomenon is reflected in Gamma Ray log responses, which shift from a cleaning-upward to a dirtying-upward lithological pattern, accompanied by an increase in clay and shale content coaly laminae belonging to secondary environments, including bays, marshes, and estuarine channels, along with channel and tidally influenced barrier deposits, terminating in a Maximum Flooding Surface (MFS) that caps the tidally influenced deltaic deposits.

Subsequently, shoreface sandstone and marine sand deposits associated with shallow-shelf facies begin to deposit within the Highstand Systems Tract (HST), terminating at a wave-cut erosion surface (SB2) or its correlative conformity, thereby concluding the first depositional sequence cycle of the formation.

Following this, another marine transgression occurs, indicating the initiation of the second sedimentary sequence. Its deposits display upward-stacking patterns comprising tidally influenced fluvial channels alternating with marshes and tidal mudflats in a rapid, cyclic, and complex succession of sandstone, shale, and siltstone bodies, depending on the well location within the basin. This sequence terminates in a regional marine transgression that initiates the deposition of the Mauddud Limestone Formation, separated by a regional Transgressive Surface / Flooding Surface (TS) at the top of the Nahr Umr Formation, which is consistent with (Timothy M. Demko *et al*., 2003) [24].

## 6. Stratigraphic Framework of Reservoir Zones

The spatial distribution and quality of hydrocarbon reservoir zones within the Luhais Oilfield are vehemently dictated by the sequence stratigraphic architecture. Core oil-saturation records indicate that the thickest and most permeable reservoir bodies occur within the lowstand channel fills

located directly above the basal Sequence Boundary SB1. These lowstand sand bodies possess high lateral continuity and optimal effective porosity due to minimal fine-grained clastic contamination. Secondary reservoir zones of high quality are localized within the Transgressive Systems Tracts of both Sequence 1 and Sequence 2, where tide-influenced channel sands form porous intervals separated vertically by transgressive mudstone barriers.

## 7. Conclusions

1. Two 3rd-order depositional cycles were identified in the Nahr Umr Formation. The first cycle begins with the onset of formation deposition, bounded at the base by a Type-1 sequence boundary (SB1) and at the top by a Type-2 sequence boundary (SB2), with the Maximum Flooding Surface (MFS) located in the middle section of the formation. Subsequently, the second cycle occurs, extending to the Mauddud Formation, where the regional transgressive flooding surface forms the regional boundary separating the Nahr Umr and Mauddud formations.
2. Four distinct sequence sets were recognized based on stacking geometries and systems tract pathways. Each sequence exhibits distinct characteristics in terms of orientation, thickness, and distribution, as well as reservoir quality. From base to top of the formation, these include:

- **Aggradational geometries:** Represent the Lowstand Systems Tract (LST), characterized by a braided fluvial system and incised-valley fill (IVF).

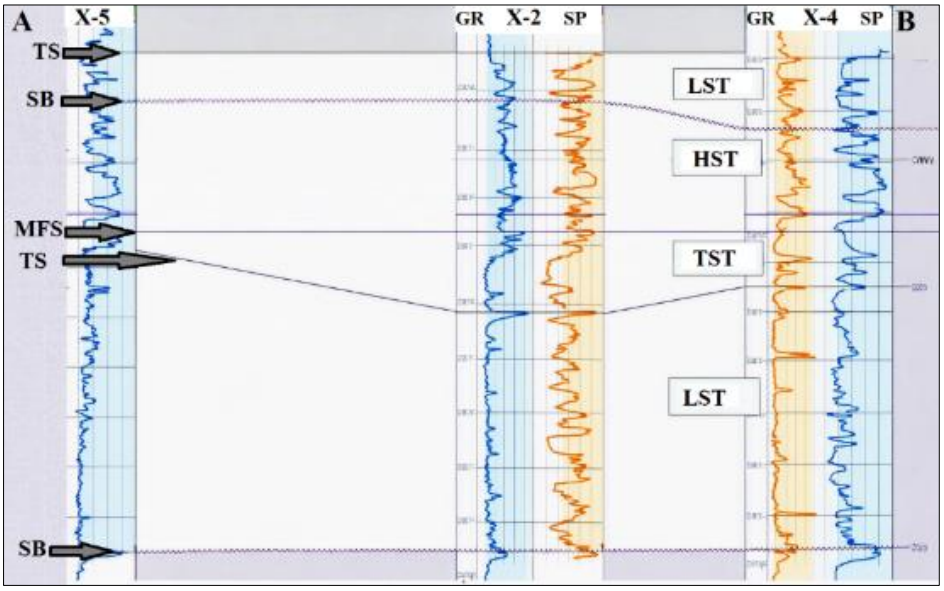



**Fig 3:** Stratigraphic correlation along A-B section.

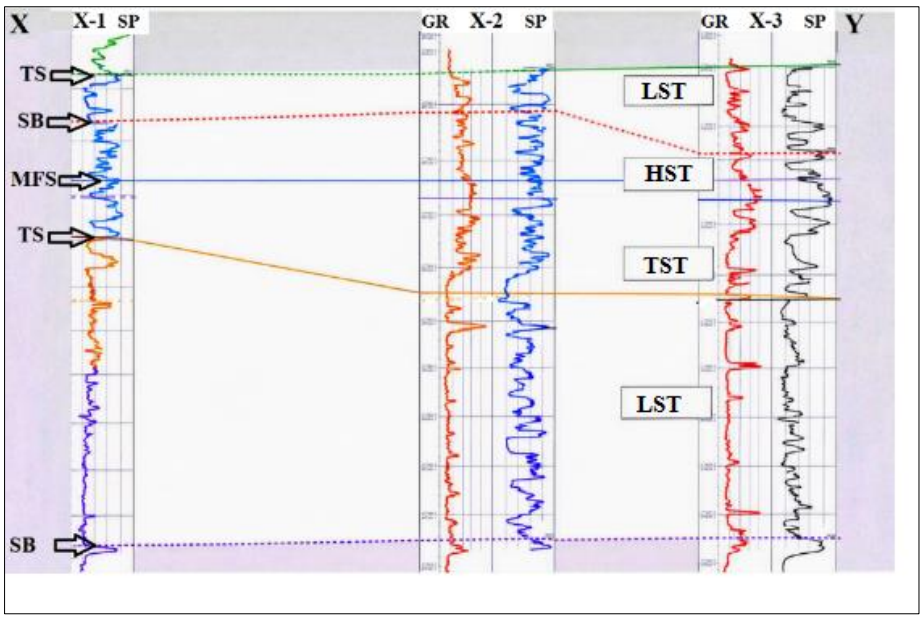



**Fig 4:** Stratigraphic correlation along X-Y section.

- **Landward-retrogradational geometries:** Represent the Transgressive Systems Tract (TST), reflecting deposition within tidal and bay environments.
- **Basinward-progradational geometries:** Represent the Highstand Systems Tract (HST), displaying coastal system deposits and shallow-marine environments.

- **Aggradational geometries (re-established):** Represent a subsequent Lowstand Systems Tract (LST), characterized by tidally influenced fluvial channels and tidal mudflats.

3. Oil shows derived from available core samples demonstrated a direct correlation with the depositional environment of the formation. These shows are primarily concentrated within fluvial deposits at the top of the Lowstand Systems Tract (LST) in the lower part of the formation, as well as within tidally influenced fluvial channel deposits of the Transgressive Systems Tract (TST), which represent the dominant host lithology.

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