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Seismic and sequence stratigraphy of Late Jurassic in Nasiriyah oil-field

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ABSTRACT

The study scope has focused on the Late Jurassic Group: the three genetically related Najmah, Gotnia, and Sulaiy formations beneath an area of more than 40000 Km2 capitalizing on huge integrated 3-D, 2-D seismic and well data compiled with competent previous regional studies and foreign literatures related, to get the utmost understanding, where, each of which, is related to each other, genetically and depositional. The study has summarized the story of the development and deterioration of the three that made up the Late Jurassic succession. Accordingly, this study, based on sequence and seismic sequence stratigraphy, has proceeded and achieved some substantial successes, the most notable ones being the identification of the optimum-Najmah reservoir quality facies throughout the Oil Province. The study has determined some proposed optimum well locations to hit the predicted optimum Najmah facies. On the Basrah basin sub-basin-western margin, it has been interpreted that the shallow water dolomitic limestones of Najmah Formation are predominant and are unconformable overlain by Very Early Cretaceous Sulaiy due to Pre-cretaceous erosion where Sulaiy overlie the last Najmah-SB above the Najmah MFS-J70 (the unconformity part of the SB=the cropped out part of the SB)and due to Gotnia Formation wedges out towards the same margin, while the Najmah Formation time-correlated, deep water limestones-Naokalekan Formation is conformably overlain by the same evaporates where Gotnia Formation directly overlie the submerged SB-part (i.e., conformable conformity =CC). Furthermore, the study has proved that the former stratigraphic relation aspects are true for the rest of the Iraqi areas in addition to the Basrah basin-western margin.

Keywords: *Jurassic, Nasiriyah oil-field, Seismic , Sequence stratigraphy*

1 INTRODUCTION

The interpretations and conclusions from 3D and 2D seismic data beneath an area of approximately 40000 Km² (Embayed Block-10, including the Eridu-Oil Field, as well as more than five oil fields: Nasiriyah, Gharaf, Abu Amood, Abu Amood-East, and Dujailah-Oil Fields, located in the southern part of Iraq). These are integrated into the current study through the analysis of tens of wells and related logs, cores, geologic depositional knowledge, DST tests, and other information from exploration and appraisal wells, as well as seismic inverted attributes [1]. The Late Jurassic succession in the Nasiriyah Oil Field represents one of the most significant intervals for hydrocarbon exploration in southern Iraq, reflecting a complex interplay of tectonic activity, sea-level fluctuations, and sedimentary dynamics within the Arabian Plate margin. Seismic and sequence stratigraphic analysis of this interval provides critical insights into the depositional environments, reservoir heterogeneity, and stratigraphic architecture that control hydrocarbon distribution [2]. By integrating seismic reflection data with well logs and core information, it is possible to delineate key stratigraphic sequences, identify system tracts, and reconstruct the paleogeographic evolution of the basin during the Late Jurassic. Understanding these relationships not only refines the regional geological model of the Mesopotamian Basin but also enhances predictive capabilities for future exploration and reservoir development in the Nasiriyah field and its surrounding areas [3].

Variance and Maximum Amplitude -Attributes by Petrel SW. and Acoustic Impedance by HRS.SW) have contributed to building a 3D-facies model that, in return, helps to formulate an initial development plan (IDP) on the Najmah Formation scale (by proposing to drill some appraisal wells needed shortly to fulfill the late Iraqi OEC ambitions related to Late Jurassic Prospective, Figure 1.

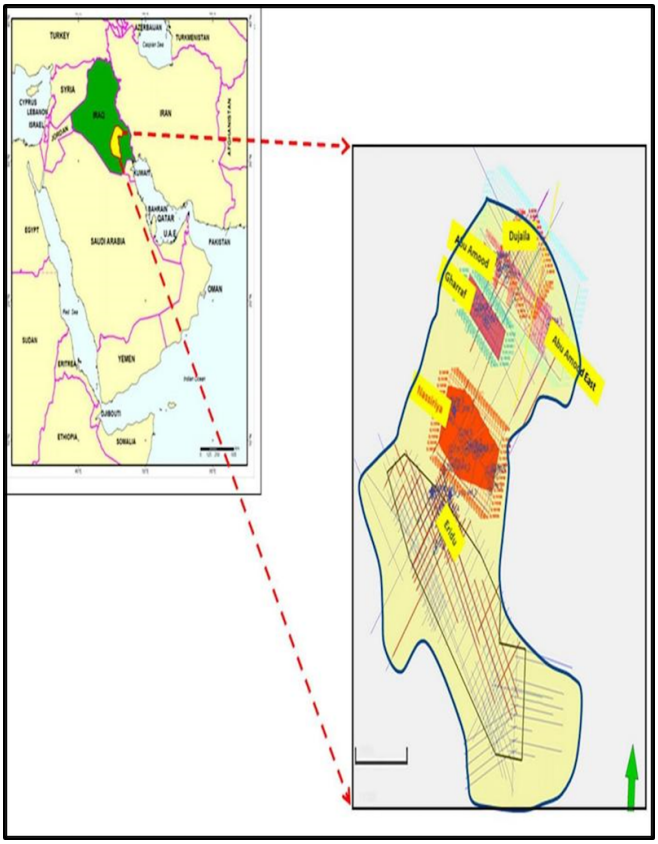

Fig. 1 Location map of the study area

This study represents a significant advancement in the Oil Exploration Company's efforts to enhance regional understanding of Jurassic petroleum systems. It builds on previous exploration programs by presenting a detailed and thoughtful reservoir characterization that combines seismic interpretation with available well data. Although the number of wells that have fully penetrated the Jurassic formations, particularly the Late Jurassic, remains limited, the integration of these data sets has allowed for a reliable interpretation of the subsurface architecture and depositional patterns. The results provide a clearer picture of the stratigraphic framework and the potential distribution of reservoir facies, offering valuable guidance for ongoing and future exploration projects in the Nasiriyah area and other parts of southern Iraq [4].

The Jurassic full succession has not been encountered in southern Iraq except in wells of R-172, K-1, Dn-1, and WK-1, and in well Minagish-27 in Kuwait, where technical and drilling problems in other wells, such as WQ-1, Ur-1, and Sa-1, have hampered Iraqi OEC efforts to explore the entire succession. The current study has realized that there is no way to track the delicate aerial distribution of Najmah Formation high HC-potentials (that have a closed Petroleum system) only by comprehending the paleo architecture of Najmah-depositional surface by discriminating the distribution of the Grabens induced-deep parts of Najmah Sub-basin (fruited deep marine carbonate Naokelekan facies) from the horsts induced-paleo high-topographies of the same basin(Oolitic Carbonate Najmah FM-Shoal) [5].

1.1 Data capitalized on

Data used by the study were five 3-D seismic cubes with more than 350 (2-D seismic lines), tens of wells, and data related (including DST-tests, well logs), previous Iraqi and foreign studies, geological literature, pretty rare data of the oil fields belonging to the neighboring countries such as Kuwait and Saudi Arabia, and personal consultation [6].

1.2 Objectives and study strategy

The primary aim of this study is to predict and delineate the spatial and stratigraphic extent of the oil-bearing Najmah Shoal facies within the Late Jurassic succession of the Nasiriyah Oil Field. By integrating seismic interpretation, sequence stratigraphy, and well-log data, the research seeks to identify the depositional trends and structural controls that influence the development and distribution of these productive carbonate shoals. The ultimate objective is to apply these insights to enhance the field development strategy, enabling more accurate well placement, optimized reservoir management, and improved hydrocarbon recovery efficiency across the Najmah Formation [7].

2 TECTONO-STRATIGRAPHIC FRAMEWORK ANALYSIS

Sequence Stratigraphy based-understanding study [8] conducted on Nasiriyah Oil Province resulted in a good understanding of the play concept behind the predicted developments and deterioration of U-Jurassic targets

in the south of Iraq (Jurassic-Basrah sub-basin) [6], particularly in Nasiriyah Oil Province, and the same study has inferred, after giving a great deal of concern to the tectonic framework analysis. The most substantial tectonic framework elements have contributed as a main constrainer in the play concept of Najmah-HC accumulations development in Nasiriyah-Oil Province, where Najd NW-SE strike-oriented Longitudinal faults with E-NE general dipping (Figure 2).

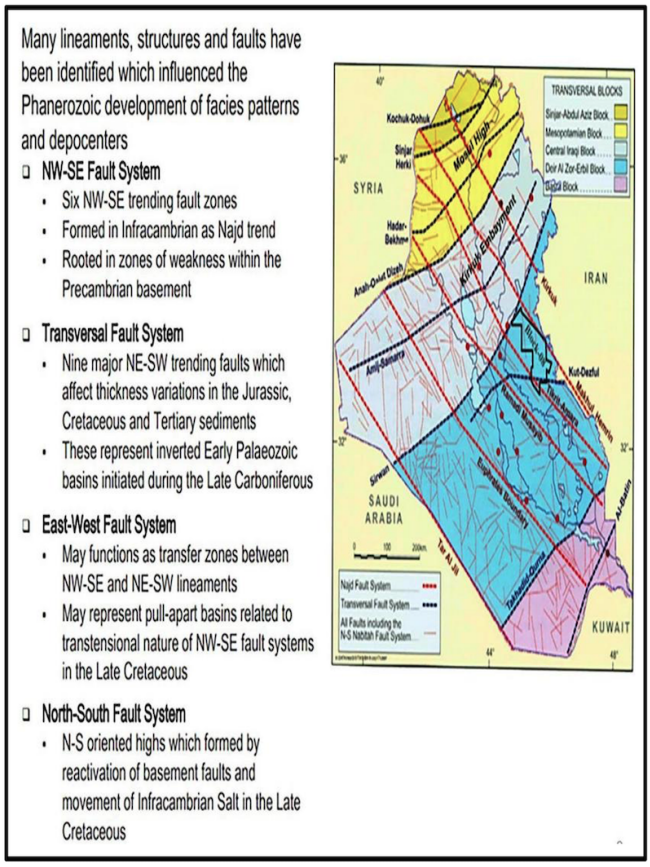

Fig. 2 Tectonic Zones of Iraq (after Aqrawi et. al., 2010) [9]

3 SEQUENCE AND SEISMIC SEQUENCE STRATIGRAPHY ANALYSIS

11 Jurassic-Js starting with J10 to end with J110. J70=Top of Naokelekan = Intra- Top Najmah, that means some of Najmah is cropped out. Najmah comprises three "Js": J50, J60, J70, J80 is an intra-Gotnia MFS. The study focused on Najmah, which is engaged with the AP7 Mega sequence. Uppermost Najmah-SB overlies MFS-J70, where the study has interpreted the later surface as interpreted E-W trending Arbitrary Line_4.

3.1 Seismic sequence stratigraphy patterns

The sub-surface seismic sequence stratigraphy patterns have been witnessed beneath an area of more than 40000 Km2, which is called Nasiriyah Oil Province were:

1. Najmah has witnessed forestepping seismic patterns where the Najmah Formation has revealed what is called forced regression-down lapping induced-seismic stratigraphic patterns (**Shallowing upward Hummocky Pattern**), Figures 3 and 4

2. Gotnia has witnessed (**fill in = Onlapping in every direction**)-Seismic Patterns.

3. Sulaiy has revealed that such a consistent plate-wide seismic character implied the deep marine environment-seismic character due to relative activation-cessation in basin rifting activity while Sulaiy was depositing. Sulaiy has witnessed (**backstepping seismic Patterns**) to develop eventually at the far west and northwestern parts of the five-oil field. The study has diagnosed some key stratigraphic surfaces, such as Mid-Sulaiy mfs (Downlapping surface and Onlapping surface), Figures 5 and 6. The geological model developed by the study was supported by certain seismic attributes utilized in this study, including the Cosine of Phase and Maximum Amplitude Attributes. By using Maximum Amplitude Attributes, the study has interpreted the Gotnia Top in the Nasiriyah Oil Province and revealed a manner in which the U-Jurassic Gotnia Sub Basin-Extent has been characterized. Two Najmah margins are identified below, where Proper Gotnia seismic characters exist, and above which they have diminished to the west and east. This manner has repeatedly been seen in each one of the five Oli-Fields [10–12].

3.1.1 Gotnia formation (kimmeridgian)

Gotnia Formation is 230m thick east of Kuwait, near the axis of this district arch, to 457m or thicker in the southwest of the management structure. This sequence unit reaches maximum thickness in the south and western sides of Kuwait, whereas it shows thinning when it reaches the southwest of the Iraqi border. The Gotnia Formation is composed of four alternations of salt and anhydrite-limestone units.

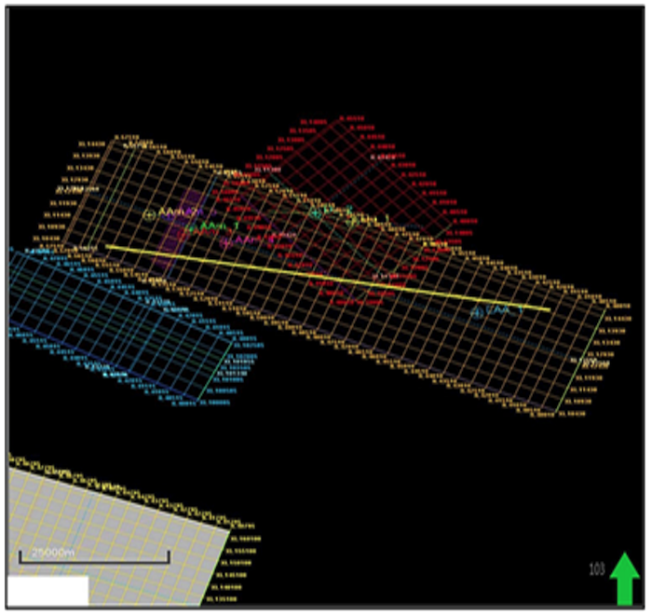

Fig. 3 Nearly E-W trending Arbitrary Line_4/Abu Amood Oil Field

The salt is white to clear and crystalline, whereas the anhydrite is light- to dark-grey or white, and argillaceous, mostly inter-bedded with fossiliferous, argillaceous limestone, shale, and some bitumen. The evaporites of the

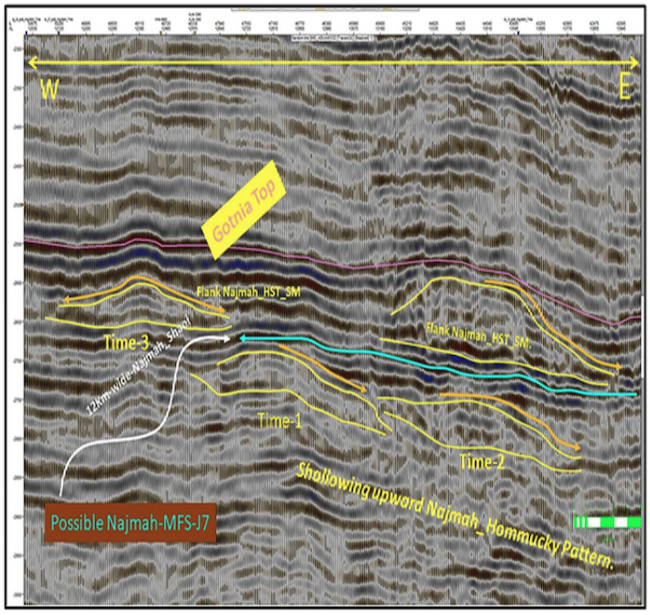

Fig. 4 Exaggerated nearly E-W trending Arbitrary Line_4 reveals the mounded-shaped developed Najmah-body (Shelf Margin)

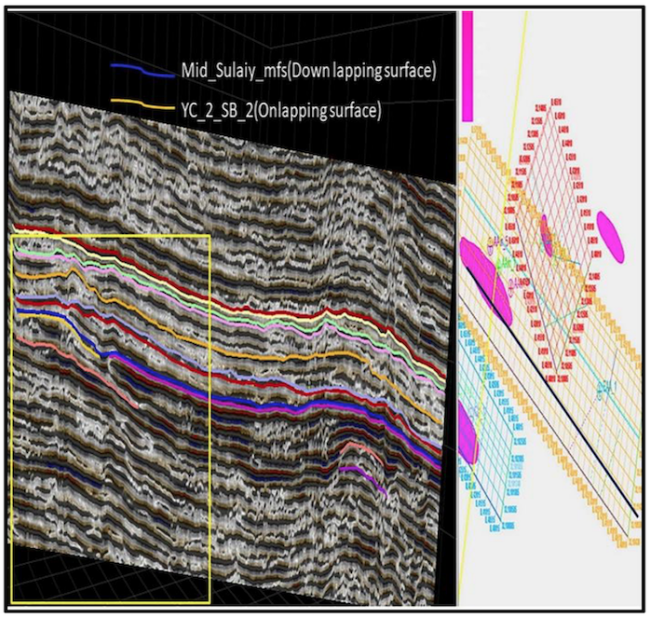

Fig. 5 Seismic Interpretation for X line_13265 Abu Amood/reveals the developed bodies within Yamama Fm. (2) SB & mfs-surfaces and systems tracts related

Kuwait deep well Burgan No.113, which lies between drilled depths of nearly 457m thick, are pure homotextural with the Gotnia anhydrite formation [13–15].

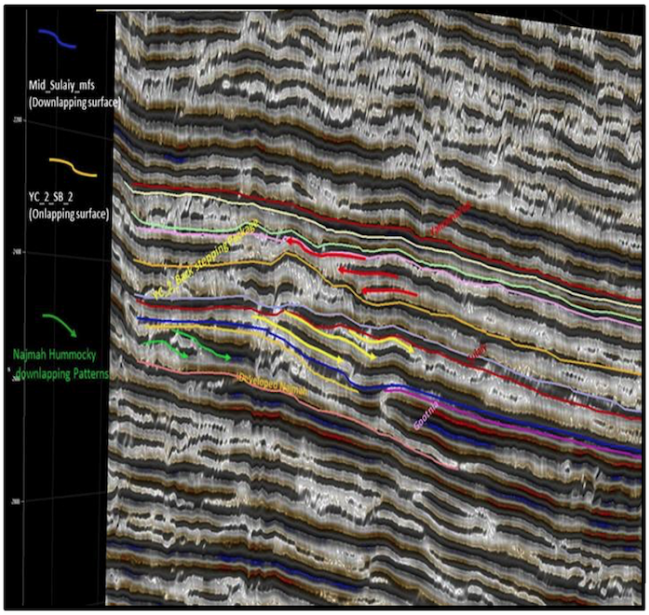

Fig. 6 Seismic Interpretation for X line_13265 Abu Amood reveals the developed bodies within Yamama FM and the SB & mfs_ surfaces and systems tracts

3.1.2 Najmah formation (callovian-oxfordian)

The formation consists of argillaceous limestone and locally contains from 24 to 104 m of interbedded, bituminous, and calcareous black shale (Figure 7). There is an abrupt change in thickness at Ahmadi, and a more gradual thickening occurs in western Kuwait, where the limestone tends more towards lime mudstone, with a few bioclastic Wackstone and Packstone intercalations. Locally, some of the limestone is impregnated with a kerogen-like material. These sediments represent deposition in an outer-neritic environment. Deep-water, euxinic conditions are inferred from the presence of black, ammonitic, radiolarian limestone. As reducing conditions are favorable for the accumulation of organic materials, the formation is currently considered the best source rock for oil generation in the entire Jurassic section. Additionally, there is some oil production from the fractured limestone of the Najmah Formation in certain areas within Kuwait [16]. Ultimately, this study has found that the formation has a thickness ranging from 229 m (750 ft) in eastern Kuwait close to the axis of the Kuwait Arch to more than 457 m (1,500 ft) on the western side of the arch in the Minagish Structure.

3.1.3 Middle tithonian-berriasian sulaiy formation

Sulaiy formation consists of an alternating limestone succession with shale beds deposited in a neritic environment. The succession lying below the Ratawi formation and above the Gotnia anhydrite is treated as a combined unit, the Yamama/Sulaiy formation (Figure 8). The Sulaiy formation is likely correlative with the Makhul formation in wells of central Iraq, and it is probably of the same age as the Makhul formation. Thus, in terms of sequence stratigraphy-based understanding, and chronowise, the two represent two depositional settings in one chrono-stratigraphic package [17–19].

3.2 Developed najmah-distribution in contrast to gotnia-one. in nasiriyah oil-province's fields

It is revealed that Najmah generally develops more northwestwards than these five Oil fields and far southeastwards in some of these five.

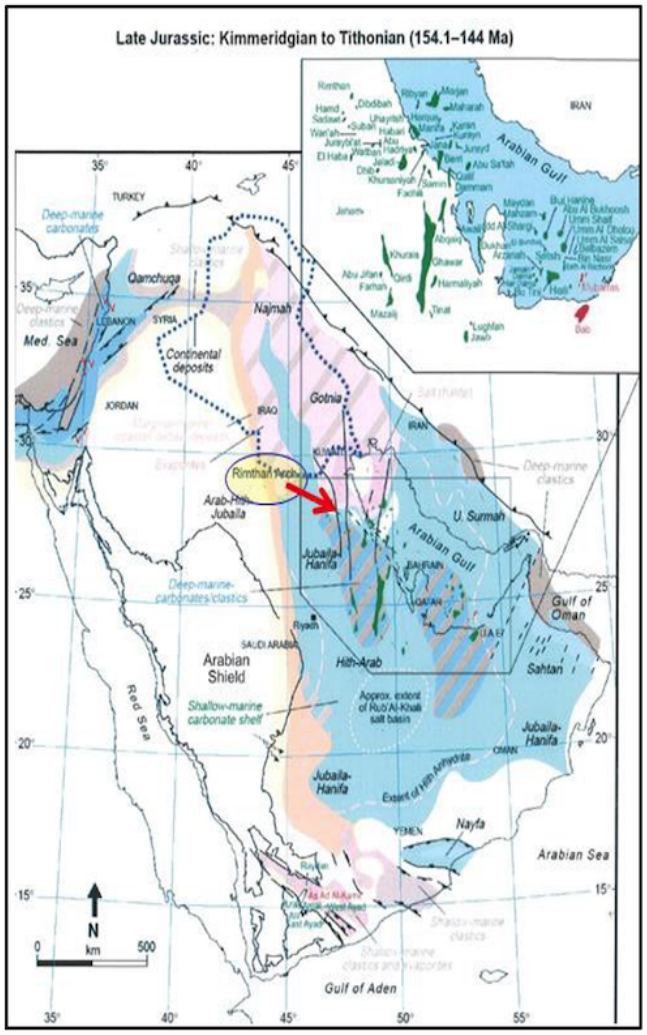

Fig. 7 Late Jurassic: Kimmeridgian-Tithonian paleo-facies (154.1-144 Material distribution by Zeigler, 2001.) [20]

Accordingly, the study has interpreted the two main shoal trends of Najmah along the province and further southwards, the province, and the study can go further in tracking the shoal, but the rarity of seismic data in the area between the oil fields has hampered efforts to accomplish and realize the regional Najmah shoal [21,22]. The study interprets the Nearly East-West Najmah Shoal Trend, which is Parallel to the northwestern border of the province, as continuous and joining its counterpart in the Eridu Oilfield and Block 10 area to form a single, continuous trend (Figure 9).

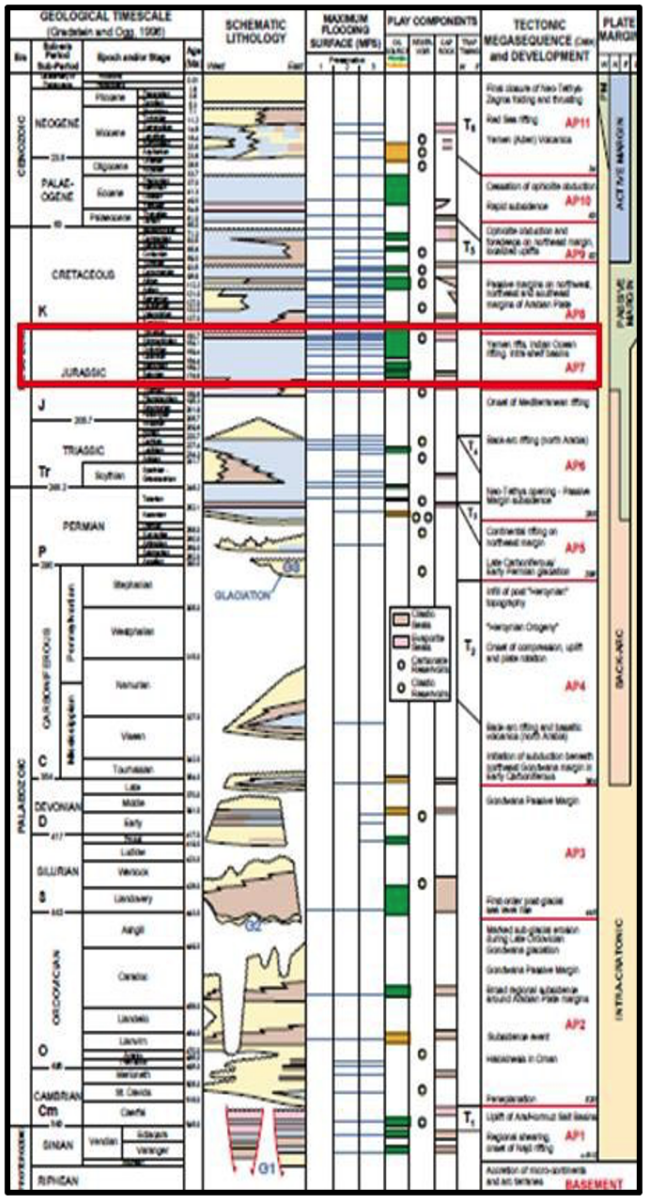

Fig. 8 Sequence Stratigraphy summary by Sharland et. al.,2001. [23]

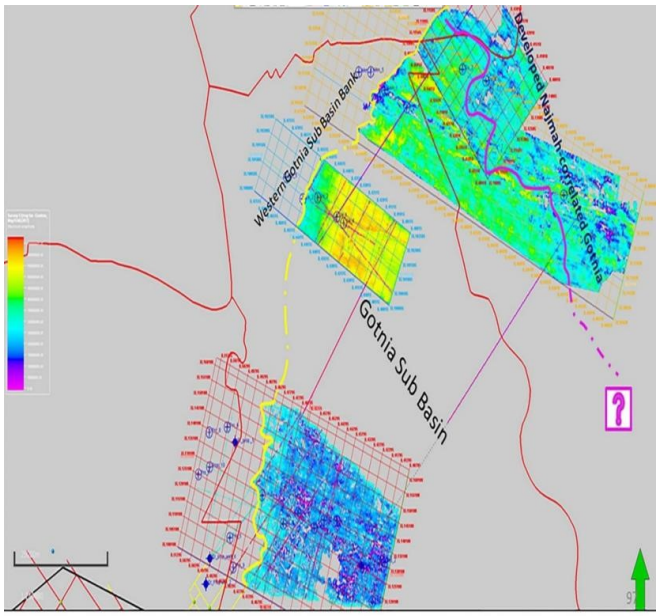

Fig. 9 By using Maximum Amplitude Att. The study has interpreted Gthe otnia Top.in the Nasiriyah Oil-Province and revealed the extent of the Late Jurassic Gotnia Sub Basin, suggesting two platform margins below which Proper Gotnia seismic characters exist.

4 CONCLUSION

The results of this study indicate that the Gotnia Evaporites were deposited as a Lowstand System Tract (LST) in a basin-center anhydrite setting rather than a sabkha environment.

This LST phase succeeded the carbonate deposition of the Naokelekan/Najmah Highstand System Tract (HST) and was terminated by a high-stand sea-level rise that introduced water-refreshing conditions, recorded by the carbonate Sulaiy Formation of the very Late Jurassic to earliest Cretaceous transgression. The tectonic evolution led to the fragmentation of the platform into multiple sub-basins and half-grabens, while delicate oolitic shoals developed along the horst-bounded margins. The study also establishes a clear genetic relationship between the Gotnia Evaporite and Najmah formations, where the thick evaporitic facies of the Gotnia begin to accumulate precisely as the Najmah carbonates wedge out. These findings highlight the strong interplay between sea-level fluctuations, tectonic subsidence, and sedimentary dynamics during the Late Jurassic. Future work should focus on integrating 3D seismic stratigraphic modeling, isotopic geochemistry, and basin evolution simulation to refine the spatial and temporal interpretation of the Gotnia–Najmah system and enhance reservoir prediction across the Mesopotamian Basin.

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DATA AVAILABILITY

N/A

DECLARATIONS

Conflict of interest

There are no conflict of interests.

Consent to publish

N/A

Ethical approval

No eithical approval is required for this study

Abbreviations: SB = Sequence Boundary, OEC = Oil Exploration Company, WQ-1 = West Qurnah -1, Sa-1 = Samawa-1, Ur-1 = Ur well -1

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