Iraqi National Journal of Earth Science

www.earth.mosuljournals.com

Stratigraphic Traps Evaluation of Yamama Formation in Selected Area, Southern Iraq with Low Data Availability

Rami M. Idan[1*], Amani L. M. Salih[2], Marwah H. Khudhair[3]

[1,2,3] Geophysics Department, College of Remote Sensing and Geophysics, Al-Karkh University of Science, Baghdad, Iraq.

Article information

Received: 21- Feb -2024

Revised: 29- Apr -2024

Accepted: 30- May -2024

Available online: 01- Apr – 2025

Keywords:
Stratigraphic Traps
Southern Iraq
Sequence Stratigraphy
Yamama Formation

Correspondence:
Name: Rami M. Idan

Email: ramisc3@gmail.com

ABSTRACT

The selected area is located in the southern part of Iraq near the Kuwait and Saudi Arabia borders, specifically within Muthanna Governorate. One oil well had been drilled to 3393 m depth within the Najmah Formation. The current study aims to study the sequence stratigraphy of the Late Tithonian-Valanginian succession, which consists mainly of Yamama Formation, and determines the reservoir properties and their lateral extensions representing generally stratigraphic traps in the study area. This study tried to prove the results with low available data, like there is only one well to study, as well as the lack of core analysis and thin sections. Based on the available data, especially for the neighboring area close to the field, the area has an economic importance in petroleum reserves, especially the sequences of the Cretaceous period. The depositional processes that took place on the Yamama platform are described as a periodic transition regression multistory of the sedimentary units. These units are represented by granular economic units, which progress towards the relatively deeper parts of the basin during the high-stand conditions separated by shale rocks that acted as a cap rock between the reservoir units. Depending on the stratigraphic point of view, the Yamama Formation platform is a ramp setting as the depth of the Yamama Formation increases towards the northeast of well (X-1); and therefore, the reservoir units (YS1 and YS2) consisting of oolite are probably located completely in the aforementioned direction.

DOI: 10.33899/earth.2024.147106.1236,

تقييم المصائد الطباقية لتكوين اليمامة في منطقة مختارة، جنوبي العراق مع قلة توفر البيانات

رامي محمود عيدان[1*]، اماني لؤي محمد صالح[2]، مروة حاتم خضير[3]

[1،2،3] *قسم الجيوفيزياء، كلية التحسس النائي والجيوفيزياء، جامعة الكرخ للعلوم، بغداد، العراق.*

معلومات الارشفة

تاريخ الاستلام: 21- فبراير -2024

تاريخ المراجعة: 29- ابريل -2024

تاريخ القبـول: 30- مايو -2024

تاريخ النشر الالكتروني: 01- ابريل -2025

الكلمات المفتاحية:

المصائد الطباقية

جنوبي العراق

طباقية التتابع

تكوين اليمامة

المراسلة:

الاسم: رامي محمود عيدان

Email: ramisc3@gmail.com

الملخص

يقع الحقل النفطي المختار في الجزء الجنوبي من العراق بالقرب من الحدود المشتركة مع الكويت والمملكة العربية السعودية وتحديداً ضمن محافظة المثنى. تم حفر البئر النفطي (X-1) بعمق 3393 م منتهيا ضمن تكوين نجمة. تهدف الدراسة الحالية إلى دراسة طباقية التتابع لتتابعات التيثوني المتأخر–الفالانجيني والتي تتمثل بشكل أساسي بتكوين يمامة، وتحديد الخصائص المكمنية وامتداداتها الجانبية، والتي تمثل بشكل عام المصائد الطباقية في منطقة الدراسة. حاولت هذه الدراسة إثبات النتائج من خلال البيانات القليلة المتوفرة مثل وجود بئر واحد فقط للدراسة، فضلاً عن الافتقار إلى تحاليل اللباب الصخري والشرائح الصخرية .وبناء على المعطيات المتوفرة، وخاصة بالنسبة للمناطق المجاورة القريبة من الحقل، فإن المنطقة لها أهمية اقتصادية من حيث الاحتياطي النفطي، وخاصة تتابعات العصر الطباشيري. توصف عمليات الترسيب التي تمت على منصة تكوين يمامة بأنها بيئة منحدر انتقالي يتكرر فيه الطور التقدمي مرة والتراجعي مرة اخرى بشكل دوري مكونة الوحدات الرسوبية. وتتمثل هذه الوحدات بوحدات حبيبية مهمة اقتصاديا، تتقدم نحو أجزاء الحوض العميقة نسبياً من الحوض أثناء نظام الرقع العالي، وتفصل بينها صخور من الحجر الجيري–السجيلي كصخور غطاء بين الوحدات المكمنية. طباقيا، فإن منصة تكوين يمامة عبارة عن وضع منحدر، حيث يزداد عمق ترسيب تكوين يمامة باتجاه الشمال الشرقي من البئر (X-1)، وبالتالي فإن الوحدات المكمنية (YS1وYS2) المكونة من الدمالق ربما تكون معظم اجزاء التكوين في الاتجاه المذكور اعلاه.

DOI: 10.33899/earth.2024.147106.1236, ©Authors, 2025, College of Science, University of Mosul.

Introduction

The studied oilfield area is located in the southern part of Iraq, near the Kuwait and Saudi Arabia borders, specifically within the Muthanna Governorate. Structurally, the area is located in the stable shelf within the Salman Zone, which extends from Kuwait in the west to the center of the Saudi Arabia (Jassim and Goff, 2006) as illustrated in Figure (1). The Yamama Formation mainly comprises of grain-supported limestone, underlain by argillaceous limestone interbedded with the thin lamina of shale. Some of the dolomitic intervals located in the upper parts and the non-deposition surfaces of the formation. Yamama Formation conformably overlies Sulaiy Formation, while it gradually changes upward into heterogeneous limestone Ratawi Formation. The formation relates to the L. Tithonian-Hauterivian Thamama Group. In Iraq, the formation is placed within the late Berriasian-Aptian cycle. The later cycle consists of Zubair, Ratawi, Yamama, Shuiaba, and Lower Balambo formations (Jassim and Goff, 2006), where these formations represent the shore to deep basin environments respectively (Idan *et al.*, 2020).

The only one drilled well in the area is the (X-1) well. As well as, the drilling did not reach its final goal due to many technical problems and stopped at a depth of 3393 m within the Najmah Formation (Assi, 2023). The region received a few geological and seismic studies, as seismic reflections of some formations that have reservoir importance such as the Yamama Formation, which is considered an important reservoir target (Al-Ameri *et al.*, 2015). Based on the studies and scientific publications, especially from neighboring countries close to the field, the region is of reservoir and economic importance, especially the sequences of the Cretaceous period (Sharland *et al.*, 2001) and (Nairn and Alsharhan, 1997). The results of the studied well are adopted to determine the stratigraphic sequence and identify the penetrated geological formations and their depths in the region (Figure 2).

Aim of study

This study is an attempt to evaluate the stratigraphic traps assessment and distribution with sequence and seismic stratigraphy approaches of the Late Tithonian-Valanginian successions, namely the Yamama Formation as well as the subsurface geological modelling in the studied area. The resulted stratigraphic model may give an idea of the next exploration targets as well as the seismic investigation survey.

Materials and Methods

A systematic strategy is required for studying the sequence stratigraphy of the Yamama Formation that is often utilized for such studies. Well log data are gathered from borehole and compared with the adjacent area. These include gamma ray, sonic, and porosity logs, which can give vital lithological and stratigraphic information. The logs are corrected and interpreted with Petrel software (2018). The final figures are treated and introduced with Excel and Coral programs. On the other hand, the obtained seismic data of 2D or 3D seismic sections for the area assist in the visualization of subsurface structures and the identification of sequence boundaries. A seismic section is a suitable tool to assess and evaluate the sequences' continuity, thickness, and shape, in addition to stratigraphic relationships.

PetroMode 1D is an essential program to determine petroleum system, basin analysis, burial history, and geological interpretations with a one-dimensional model that enables single-point data (well) to be constructed from scratch or to be extracted from other PetroMode software of 2D and 3D models. This tool can calibrate results such as heat flow histories, which enables calibration work in all packages to be performed much faster (Gardi *et al.*, 2024). In addition, the PetroMode can produce the thermal and migration histories in the probable basin (Abeed *et al.*, 2013). PetroMode combines the depositional setting, pressure estimation (Habeeb, 2023), compaction rate, heat flow and temperature within the time and depth, and calibration parameters such as vitrinite reflectance (Ro) or source rock analysis. As the data mentioned above, sedimentary rocks compile lithology within the formation for reference and comparison. As well as, this data can also be compared with the adjacent countries' information and results.

Geographic Location of the Study Area

The studied oil field is located in the southern part of Iraq near the common borders with Kuwait and Saudi Arabia, within Al-Muthanna Governorate. The geographic coordinates according to UTM are explained in Table (1), where the points are illustrated in Figure (1).

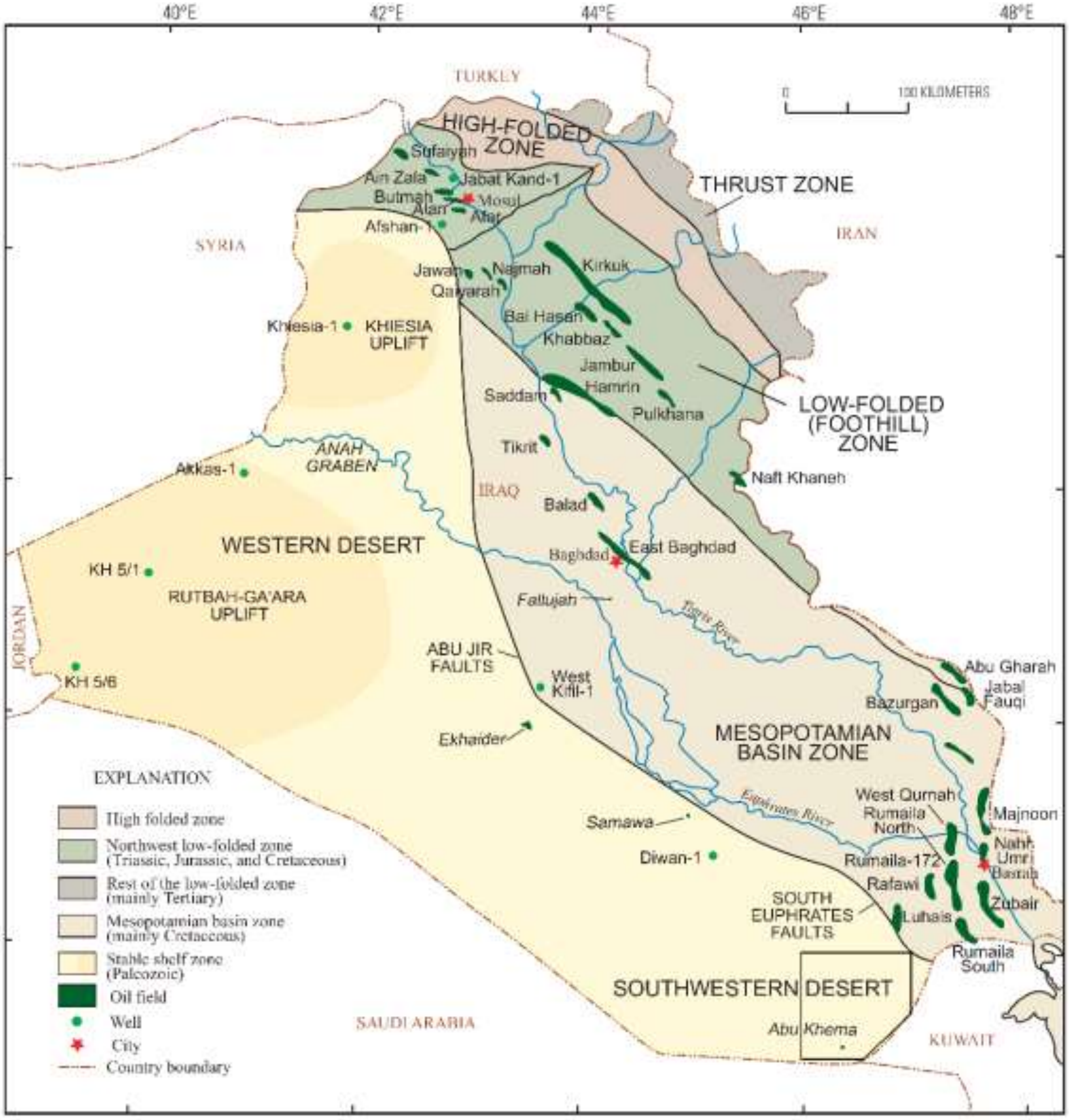


Fig. 1. The tectonic map of Iraq shows the study area (Fox and Ahlbrandt, 2002).

Table 1: The geographic coordinates of the study area.

No.	Point	Easting	Northing
1.	A	600000	3300000
2.	B	600000	3225000
3.	C	655000	3225000
4.	D	675000	3250000
5.	E	675000	3300000

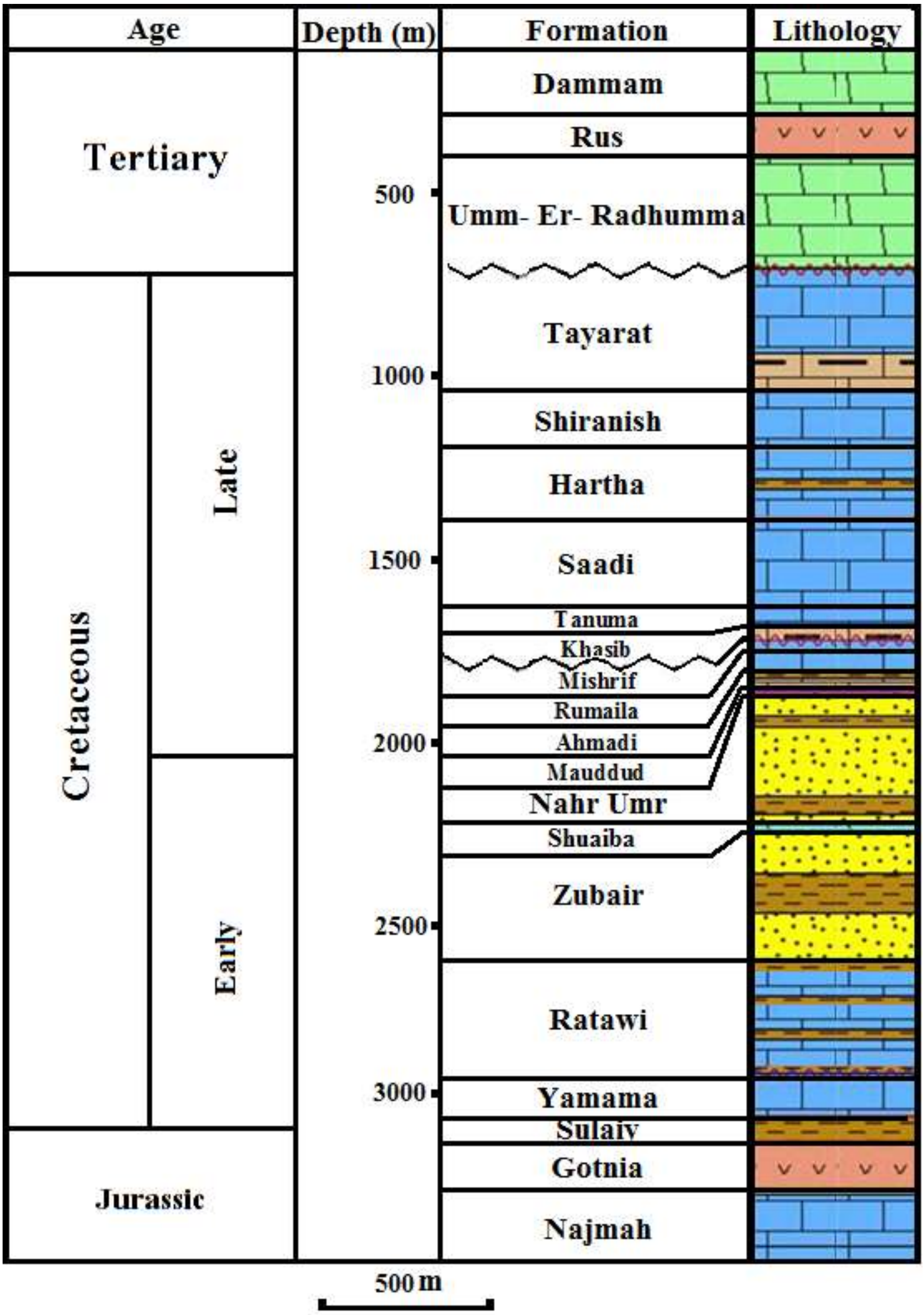


Fig. 2. Stratigraphic column of (X-1) oil well illustrating the succession from upper Jurassic to Tertiary formations.

Tectonic Setting

Tectonic Setting of Arabian Plate

According to the divisions of Jassim and Goff (2006), the studied oilfield is located in the stable shelf within the Salman zone. Structurally, it witnessed the period that represents the end of the Jurassic and the beginning of the Early Cretaceous period that separated the Arabian plate from the Indian plate, specifically from the side of Oman at the southwestern edge. This separation led to the emergence of a passive margin along the Neo-Tethys Sea, and this edge later developed towards the northeast and southeast of the Arabian plate, while the western edge exposed to an uplift at the beginning of the Early Cretaceous period because of the opening in the south and central Atlantic Ocean. These structural events caused a change in the direction of the movement of the Arabian plate from the northeast to bend towards the east, which caused the creation of clastic continental sedimentary basins towards the eastern borders along the Arabian plate (Sharland *et al.,* 2001) as shown in Figure (3).

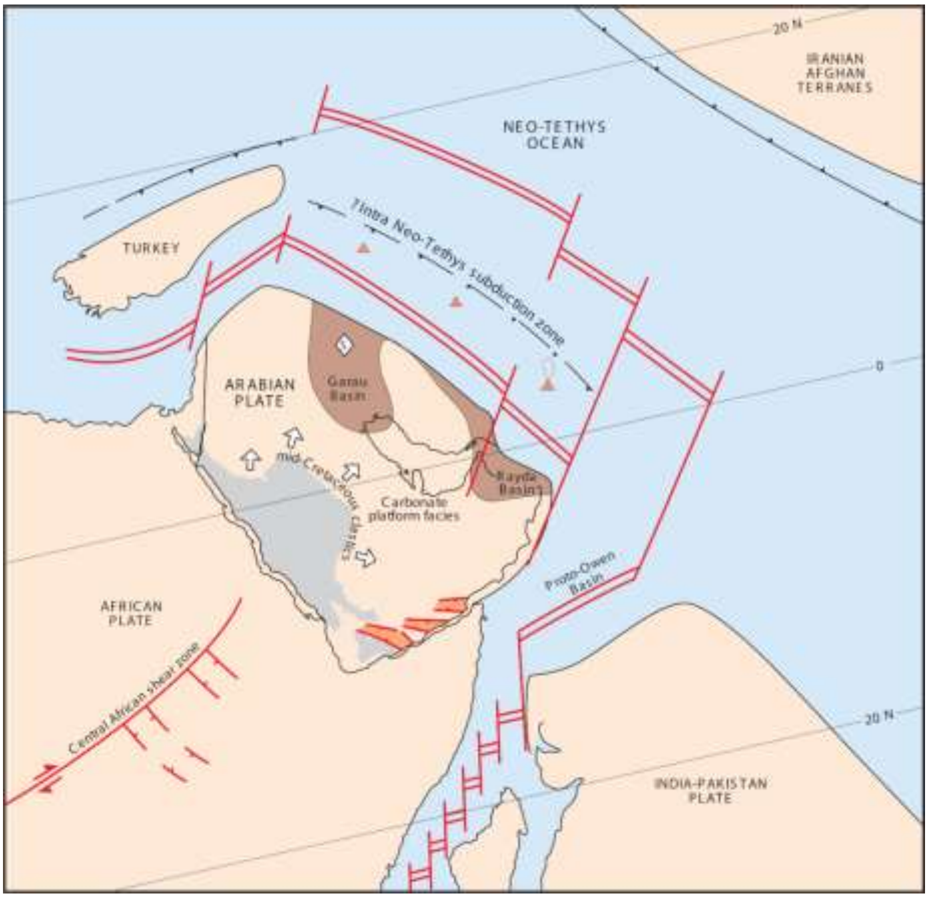


Fig. 3. Location map of the Arabian plate at the beginning of the early Cretaceous period (Sharland *et al.,* 2001).

Structural Evolution of Sedimentary Basins

The structural events, that the Arabian plate suffered from during the geological ages, have greatly affected the development, growth and emergence of different types of sedimentary basins. In addition to the **very** important secondary tectonic movements that affected the growth and shape of internal sedimentary basins leading to the sedimentary units and belong to the interval from the Late-Tithonian to the Early Turonian. This importance is related to the interested stratigraphic sequences of good petroleum potential including the Yamama Formation. The formation had been deposited in large basins within the sedimentary platform contemporaneously with the opening of the Neo-Tethys Sea (Idan *et al.*, 2020). The difference in the subsidence rates results from the variation in the thickness of the sediment packages, especially at the edges of the reverse faults (Al-Musawi *et al.,* 2022). The spreading of the Neo-Tethys Sea led to the creation of passive margins along the north-eastern border of the Arabian plate, and that the Rutba uplift formed the western margin of the Mesopotamian basin. While a huge carbonate barrier determined the continental parts along the Neo-Tethys, which had formed the north-eastern edge. This barrier also prevented the mixing of crustal material from either side resulting in the formation of the Zagros Mountains. This barrier also created a unique environment for the development of the Mesopotamian basin (Faisal *et al.,* 2016) as elaborated in Figure (4).

The most important event in the Late Jurassic was the retreat of the Gotnia basin, which led to a decrease in evaporate sediment production. This interval is separated by a regional boundary to the preceding period, which indicates a regional unconformity of 149 Ma (Aqrawi *et al.*, 2010). The decrease of evaporate sediments production was replaced by deep basin calcareous sediments rich in shale and organic matter (OM), in addition to marly limestone intervals. During the early Cretaceous period, the subsidence rate varied and affected the sediment deposition leading to thick sedimentation rates that formed the Balambo basin (Le Nindre *et al.*, 2008). In addition, the uplifting in the Arabian shield at the western edge of the Arabian plate led to the flow of clastic continental sediments (Ibrahim, 1983).

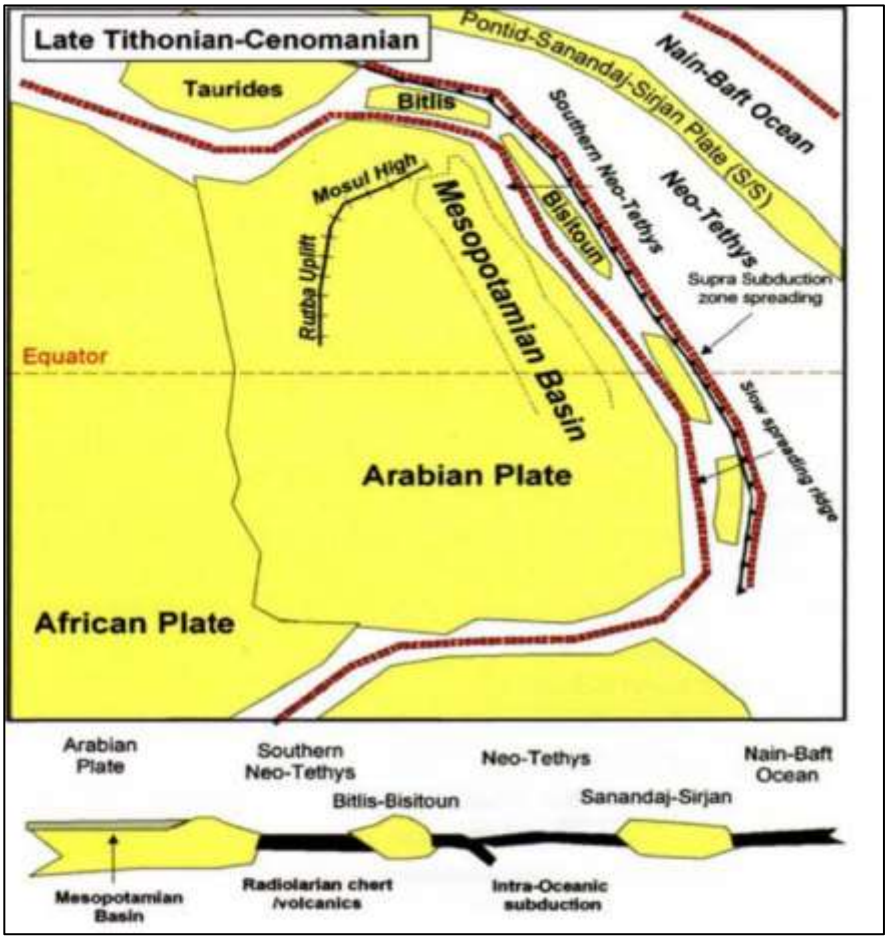


Fig. 4. Paleo-geographic map showing the evolution of the Arabian plate during the Late Tithonian–Cenomanian (Jassim and Goff, 2006).

Petroleum System Analysis

The Hydrocarbon Potential

The petroleum system of the Cretaceous period is of great importance because it contains many stratigraphic sequences that have the ability to store and preserve hydrocarbons within oil and gas reservoirs and in large economic quantities (Al-Musawi *et al.,* 2020). In addition, the presence of limestone intervals that have the ability to generate hydrocarbons because they contain high quantities and percentages of organic matter, while the others have depositional properties that create cap rocks that lack fluid conduits (Idan *et al.,* 2015a).

The hydrocarbon potential map in Figure (5) shows that the study area is within the good hydrocarbon potential range of the Cretaceous rock packages (Verma *et al.,* 2004). These rocks are characterized by relatively good reservoir properties, especially the formation of interest. The Yamama Formation consists of oolitic, clean, and mature limestone intervals of different environments. These facies contain many types of marine organisms and their bioclasts, which indicate good reservoir units. In addition, the layers of shale units may also represent that they play as a multi-story source and/or impermeable cap rock (Al-Ghuribawi and Faisal, 2021).

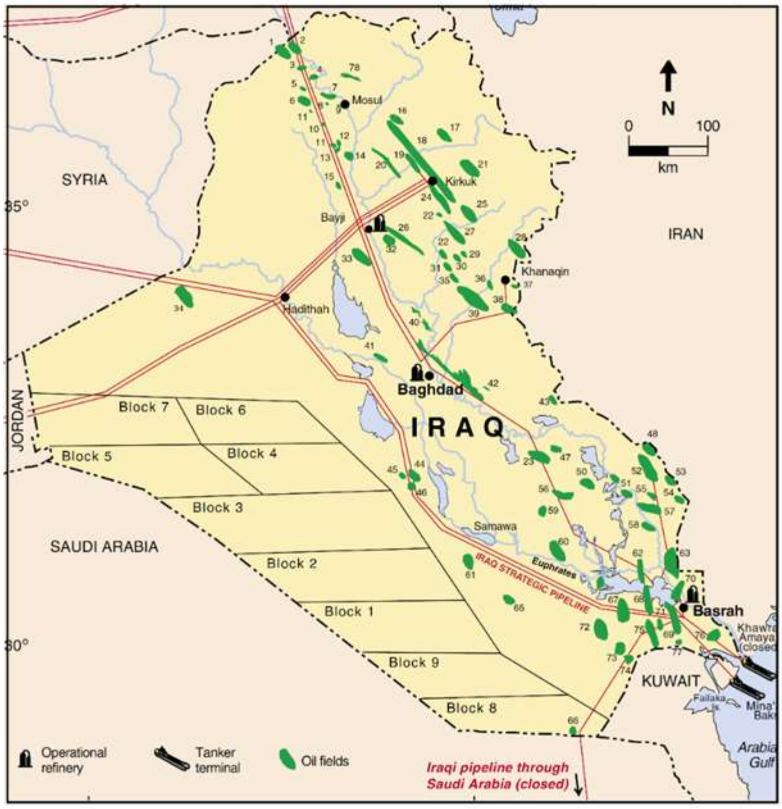


Fig. 5. The hydrocarbon potential map of Iraq (Communication, 2003)

Source Rock

The importance of the source rocks, which belong to the Late Jurassic-early Cretaceous period, comes from being responsible for generating the oils found in the reservoirs of the Triassic and Cretaceous periods. This period rocks are characterized by high quality and ability to generate crude oil, especially the lower parts of this sequence (Murris, 1980) as illustrated in Figure (6).

The Sulaiy Formation is considered one of the important source rocks in Iraq because it contains high levels of total organic carbon (TOC). The thickness of the formation in southern Iraq ranges between 150-200 meters and this is due to the presence of layers of argillaceous limestone, which have a good role in the generation of hydrocarbons (Al-Ameri *et al.*, 1999), in addition to the shale intervals of Zubair Formation the area of interest (Idan, 2017). The other main source rocks are the Sargelu and Naokelekan formations of the Upper Jurassic interval. These formations may act as source rock in most of the Iraqi petroleum systems due to their suitable thickness, source rock properties, and location from the columnar stratigraphic section (Khudhair and Idan, 2024).

In addition, the thermal history analysis of the studied area indicates that the maturity of the OM within the formation or specific interval starting from Zubair Formation and downward, it reached the required transformation ratio (TR) that allow to crude oil generation. The TR as achieved by Peters et al. (2009) ranged from 50 to 90 % to consider the interval is mature, while in Zubair Formation, the TR reached to 50% at approximately 33 Ma. So, the underneath formations have more than 50% TR depending on the thermal gradient and the depth increasing, in addition to overburden pressure as illustrated in Figure (7). Whereas the OM-rich intervals of Ratawi, Yamama, Gotnia, Najmah formations are within the end of oil expulsion stage.

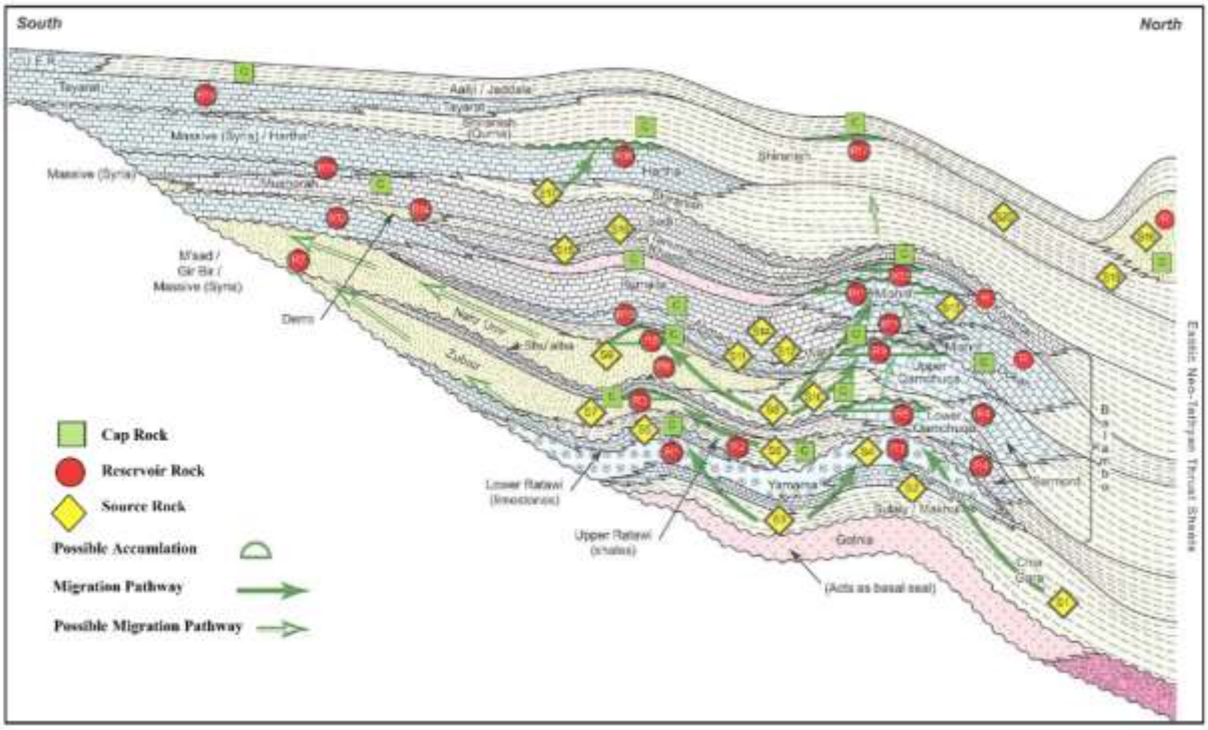


Fig. 6. The Petroleum system of the Cretaceous age in Iraq (Aqrawi *et al.*, 2010).

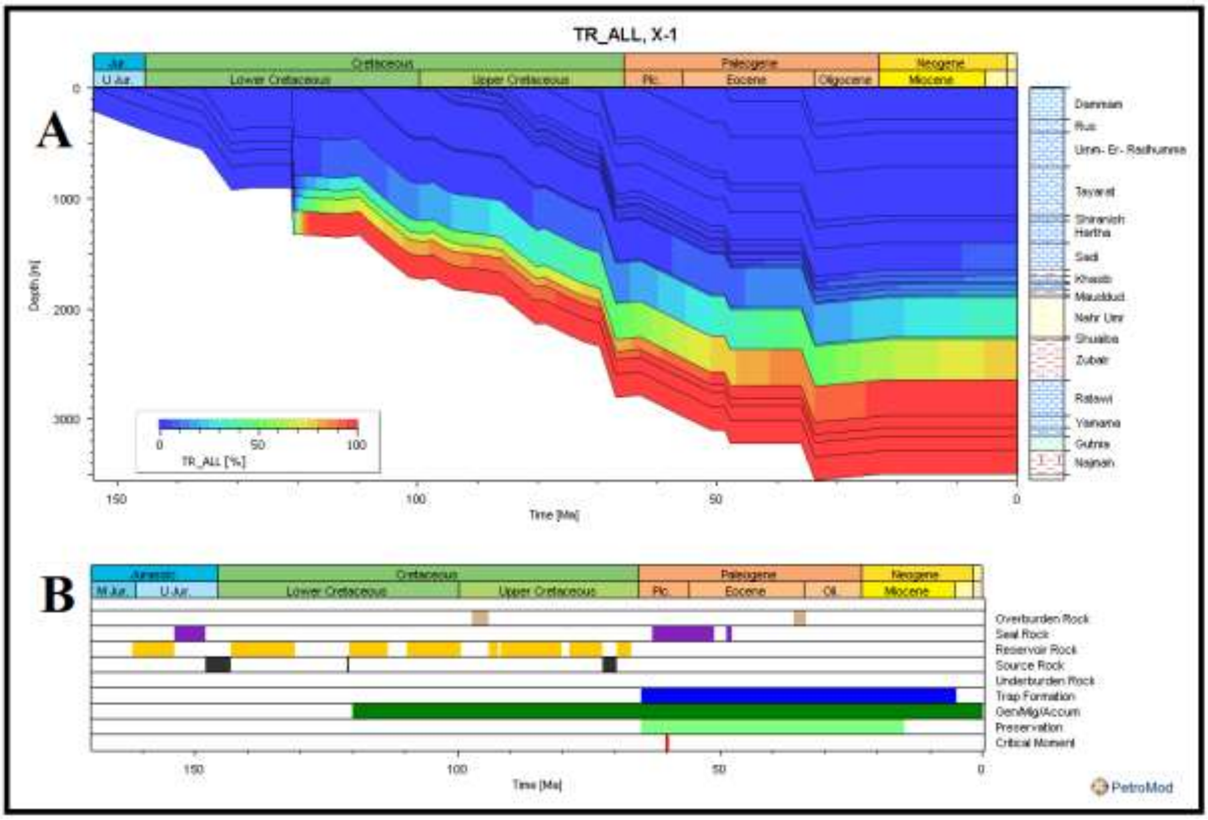


Fig. 7. The hydrocarbon potential and basin analysis section, A- Burial history preview overlapped by the Transformation ratio, B- Petroleum System Event chart of the studied area.

Reservoir Rock

The Cretaceous period sequences are important reservoir rocks because they contain very high hydrocarbon reserves, especially Early and Middle Cretaceous sequences, specifically in the southern and southeastern parts of Iraq (Khudhair, 2021 and Murris, 1980). The biggest evidence of this is the giant oil fields, which are concentrated in the south and southeastern Iraq.

It is known that the Yamama, Zubair, Nahr Omr, Mishrif and Khasib sequences are the most important deposits of the Cretaceous period, which are considered major hydrocarbon reservoirs in most of the oil fields (Ibrahim, 1983). In addition, there are other reservoirs, but they are considered secondary compared to the previous formations including the Hartha, Saadi, Tanuma, Nahr Omr, and Mauddud formations (Abbas *et al.,* 2022 and Al-Gailani, 1996). The more important reservoirs are as follows:

Yamama reservoir is considered one of the most important reservoirs of the early Cretaceous period because it contains large oil reservoir, especially in the northern Rumaila, Majnoon, West Qurna, and Tuba oilfields (Sattam *et al.,* 2018). Its importance comes due to its sediments with granular limestone, which enhances the porosity and permeability of the reservoir. Accordingly, the hydrocarbons within the Yamama reservoir will be trapped within anticline as a structural trap. In addition, the granular facies have a wide extension, which reinforce and confirm the presence of stratigraphic traps (Idan *et al.,* 2020).

Zubair reservoir is the most important clastic reservoir in Iraq especially in southern oil fields. It is characterized by gradual change from delta front facies to shelf mudstone and to limestone of Shuaiba Formation in the deep marine environments. The highest thickness of the Zubair reservoir is in the Zubair field with a thickness of more than 200 meters (Idan *et al.,* 2015b).

Mishrif reservoir is composed of high porous and permeable rudist facies. The abundant production of this reservoir is concentrated in the southern Iraqi oilfields (Idan and Salih, 2023). Because the formation contains skeletal grain dominant facies that represent the platform margin environments and the rudist reef, the porosity is of vuggy type in addition to the moldic type that arises from digenesis processes such as dissolution (Al-Mimar *et al.,* 2018 and Idan and Al-Khazraji, 2024).

Khasib reservoir is composed of shaly limestone sediments. The formation is considered a major reservoir within the East Baghdad and Balad oilfields and contains important oil accumulation within the Nahr Omr, West Qurna, and Mesan oilfields (Sattam *et al.,* 2018). It consists of chalky limestone rocks, which represent shallow-water sediments, and its good porosity is caused by fractures and cracks (Gayara and Al khaykanee, 2015).

Cap Rock

The petroleum system of the Cretaceous period in Iraq is based on balance and equilibrium in the presence of two components of the petroleum system, namely the reservoir and the cap rocks. The efficiency of the cap rocks and their ability to capture the hydrocarbon, both are crucial parameters. The evaporitic deposits of the Gotnia Formation are very thick in southern and southeastern Iraq. They represent the highly efficient cap rock separating between the late Jurassic and early Cretaceous petroleum system (Aqrawi *et al.,* 2010).

It is likely that the marl and shale layers, in addition to the clay limestone rocks that are present within the Ratawi Formation, represent the cap rocks of the oil found within Yamama Formation, especially in southeastern Iraq (Idan *et al.,* 2020). As well as, the argillaceous limestone rocks within Yamama Formation play a role in capturing the existing oil, as it represents local cap rock (Al-Mafraji and Al-Zaidy, 2019). The shale layers within the Zubair Formation represent an efficient cap rock (Al-Marsoumi *et al.,* 2005).

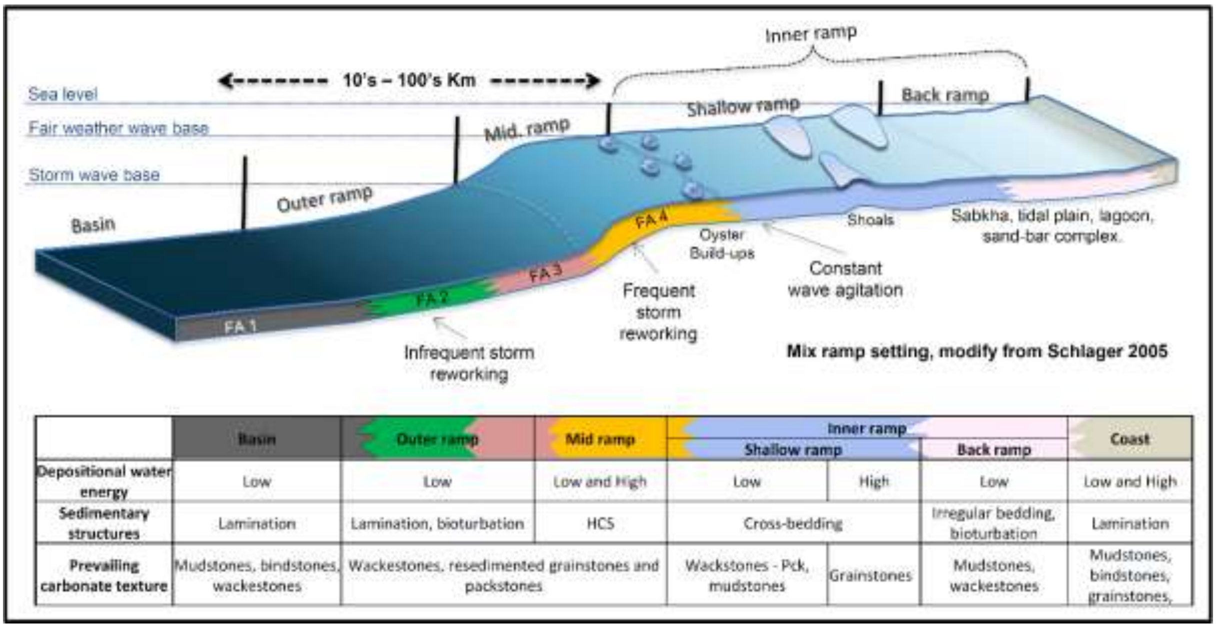
Facies Association of Yamama Formation

Due to the importance of Yamama Formation from the reservoir point of view, this study provides some details, especially in terms of stratigraphy and facies association, as well as the determination of sedimentary environments. The horizontal distribution tracking of those facies is a good tool to indicate the sequence pattern, in addition to the data from the seismic sections, which show a horizontal distribution of the granular-oolitic units, which in total represent very good stratigraphic traps. This study also depends on other previous studies that paid attention to this formation (Sharland *et al.,* 2001; Le Nindre *et al.*, 2008; Sadooni, 1993; Sadooni and Aqrawi, 2000).

The Yamama Formation was identified for the first time through survey discoveries in Saudi Arabia, where the name was given to the upper part of the clean limestone sequences below the Ratawi Formation in the well (Rt-1) (Sadooni, 1993). This description is considered the ideal section of the Yamama Formation, where the wide distribution of these limestone units is observed in most of the subsurface sections, especially in the eastern parts of Saudi Arabia and northern Kuwait (Sharland *et al.,* 2001). The age of the formation was determined in Barriasian-Valanginian depending on the presence of fossils within the grain-dominated limestone facies. These facies have a wide distribution and are present in some wells, making the Yamama Formation a good oil reservoir because of its high porosity and permeability.

The Yamama Formation was deposited within a ramp limestone platform that has a very gentle slope ranging from 1 to 3°, and a very wide horizontal distribution as shown in Figure (8). This type of sedimentary platform is difficult to distinguish and identify its sedimentary facies and environments compared to other types of rimmed platforms with high slopes, which are easy to distinguish and identify their sedimentary environments (Wright and Burchette, 1998 and Abd and Abd, 2024).

The underneath Sulaiy Formation gradually turns up into the Yamama Formation, which represents a conformable contact. While the upper contact that separates the formation from the Ratawi Formation represents an unconformity surface, this explains the great variation between the relatively clean intervals of Yamama and the argillaceous and dirty intervals of the Ratawi Formation (Abd and Abd, 2024).



	Basin	Outer ramp	Mid ramp	Inner ramp: Shallow ramp		Inner ramp: Back ramp	Coast
Depositional water energy	Low	Low	Low and High	Low	High	Low	Low and High
Sedimentary structures	Lamination	Lamination, bioturbation	HCS	Cross-bedding		Irregular bedding, bioturbation	Lamination
Prevailing carbonate texture	Mudstones, bindstones, wackestones	Wackestones, resedimented grainstones and packstones		Wackstones - Pck, mudstones	Grainstones	Mudstones, wackestones	Mudstones, bindstones, grainstones,

Fig. 8. Sedimentary environments of Ramp type platform (Tomassini *et al.,* 2016).

Discussion

The L. Tithonian-Valanginian sedimentary cycle, represented by the Sulaiy and Yamama formations, begins with a marine transgression phase (TST). This TST rises on a regional sequence boundary (SB) surface separating the sediments of the late Jurassic period (the uppermost of the Sulaiy Formation) and the sedimentary intervals of the early Cretaceous period. The SB led to the accumulation of marly limestone sediments with facies of mud-supported argillaceous carbonate, in addition to the shale sediments represented by the Sulaiy Formation. These sediments ranged from the inner to outer ramp environment, which represents the starting point of the high-stand system tract (HST). The HST phase is a retrogradation depositional phase represented by the Yamama Formation. The formation consists of two retrogradation sedimentary phases (as illustrated in figures 9, 12, and 13) developed from the cumulative organic activity from the shallow lagoon and oolitic facies, where limestone production increases due to shallowing upward, which means an increase in the biological activity. The HST genetically produces the shedding cases that clearly appear in the Yamama Formation thickness within the studied area and adjacent locations. In addition to the oceanic currents that have high energy to give mature grain-dominated intervals, which tend to be packstone and grainstone facies.

The Yamama Formation in the study region consists of oolitic granular intervals, with the base section of each secondary sedimentary cycle consisting of limestone with muddy support and the sedimentary cycle ending in granular facies due to shallowing upward (Figure 9). Shallowing upward occurs when sedimentary deposits become increasingly shallow from the base of the sedimentary cycle to the top. This is due to the decreasing water depth or sea level regression, which results in lower-energy sedimentary particles being deposited lower in the cycle and higher-energy particles being deposited higher in the cycle.

The granular oolitic limestone is a very important part of the Yamama Formation, whose intervals made up the potential and economic importance of the formation, which was considered an important exploratory target in all the fields of the southern region of Iraq (Chafeet, 2016). The vertical succession of the Yamama Formation represents a retrogradation sedimentary phase, while the horizontal distribution facies of the Yamama Formation show gradual facies change from different sedimentary environments. Through the study and examination of the thin sections of Yamama Formation that many researchers achieved as mentioned above, four sedimentary environments were identified over the Yamama basin in southern Iraq (Altala and Mahdi, 2018). These sedimentary environments are mainly compared with Sadooni (1993) as follows:

- Supratidal deposits facies: Sand and shale are the main indicators of this environment as seen in the western parts of the studied oilfield (Figure 10), which is represented by the shoreline and evaporites.

- Tidal Flat facies: The indication of this environment is the muddy limestone facies as a coastal plain deposit. The main microfacies were the peloidal wackestone, which indicates the low-energy environments.

- Inner shelf- Mud facies: The facies of this environment are muddy to granular bioclasts, in addition to the presence of wackestone facies that contain shell fragments and algae. These facies are located in the wells of Siba, Zubair, and South Rumaila oilfields. This environment may also contain protected lagoon facies such as mudstone and wackestone.

-Shoal facies: this facies is an indictor to high-energy environment within the inner ramp. The shoal represented the packstone to grainstone mainly with bioclasts and/or oolites as dominant grains.

- Back Reef facies: The facies of this environment are peloid biogenic wackestone to compacted packstone. This environment includes the shoal facies that comprise of oolitic packstone to grainstone as in the northern wells of Zubair, north Rumaila Ratawi, and Abu-Kima oilfields as illustrated in figures (9 and 10).

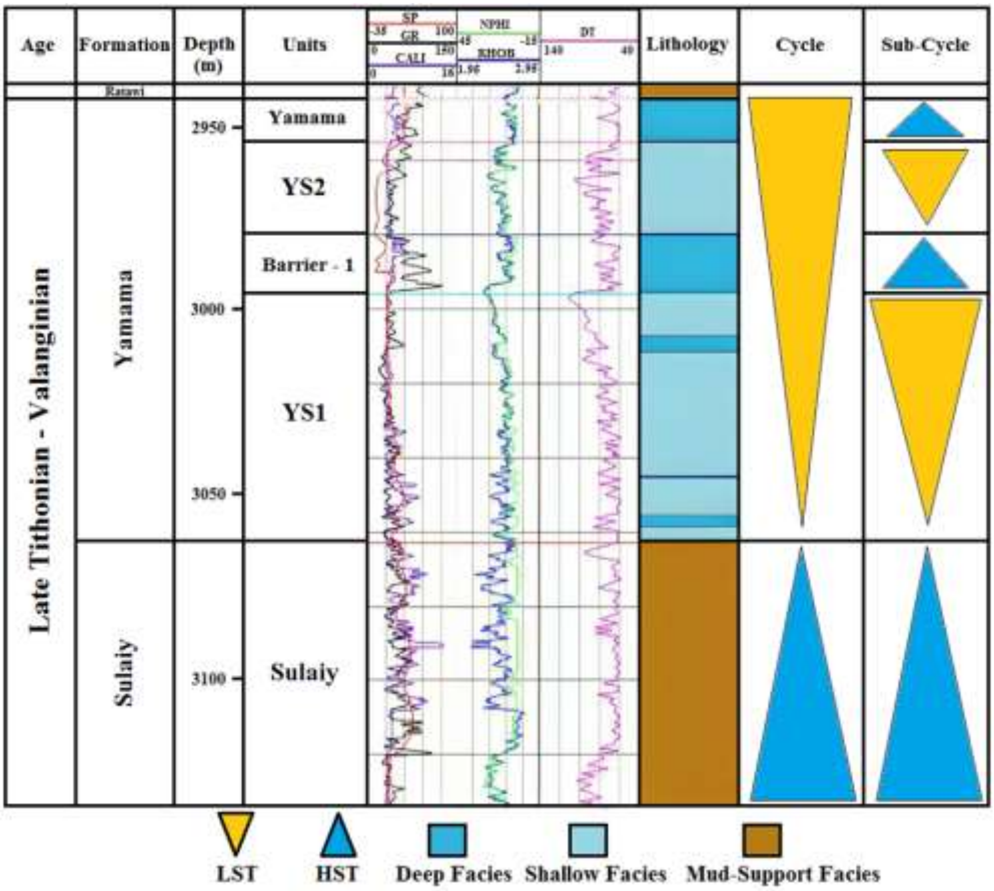


Fig. 9. The L. Tithonian-Valanginian sedimentary cycle of Yamama Formation in the study area, well (X-1), modified from South Oil Company, 1975.

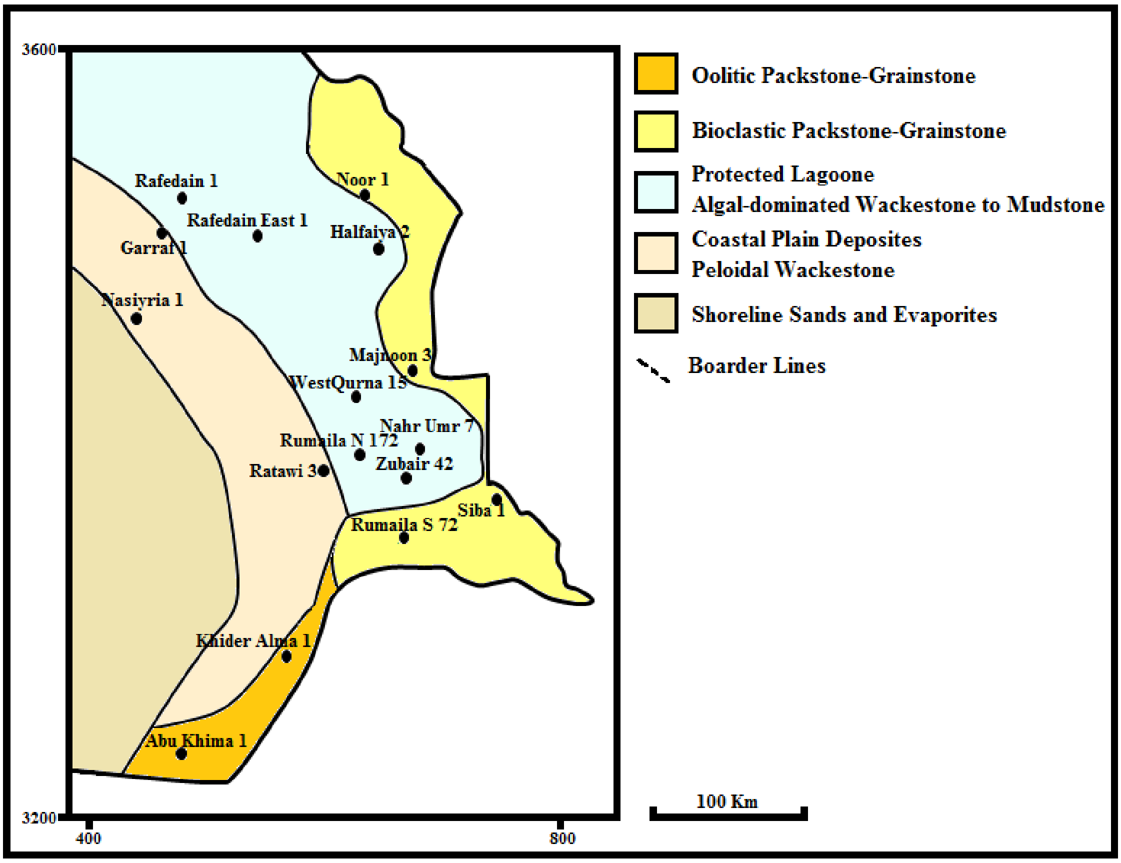


Fig. 10. Facies distribution of Yamama Formation in the study area and surroundings, modified from Sadooni (1993).

As mentioned above, the platform of the Yamama Formation is a ramp type extending towards the northeast of the studied area structure (Figure 10). The isopach map of the Yamama Formation in the region as in Sadooni (1993), confirms this indication. The gradual slope towards the northeast as well as the thickness increasing in the NE direction are also good proof of the ramp-setting phenomenon as indicated by Sadooni (1993). The thickness decreases towards the SW, as well as the increase of the granular reservoir units toward the NE directions as illustrated in Figure (11) representing the relatively high depth of the sedimentary basin that represents the vertical and horizontal distribution of the sedimentary environments. The Yamama basin gets back to being shallower again at the extremely NE parts The thickness of the Ratawi, Zubair, Yamama and Sulaiy formations in the region are presumptive to illustrate the hypothetical relationships between the succession, and showing the location of the well (X-1). The Yamama Formation in well (X-1) is divided into lithofacies units, which are identical to the reservoir divisions depending on the well logs as Figure (12) indicates. These units are within the stratigraphic sequence of the studied well, and they are as follows:

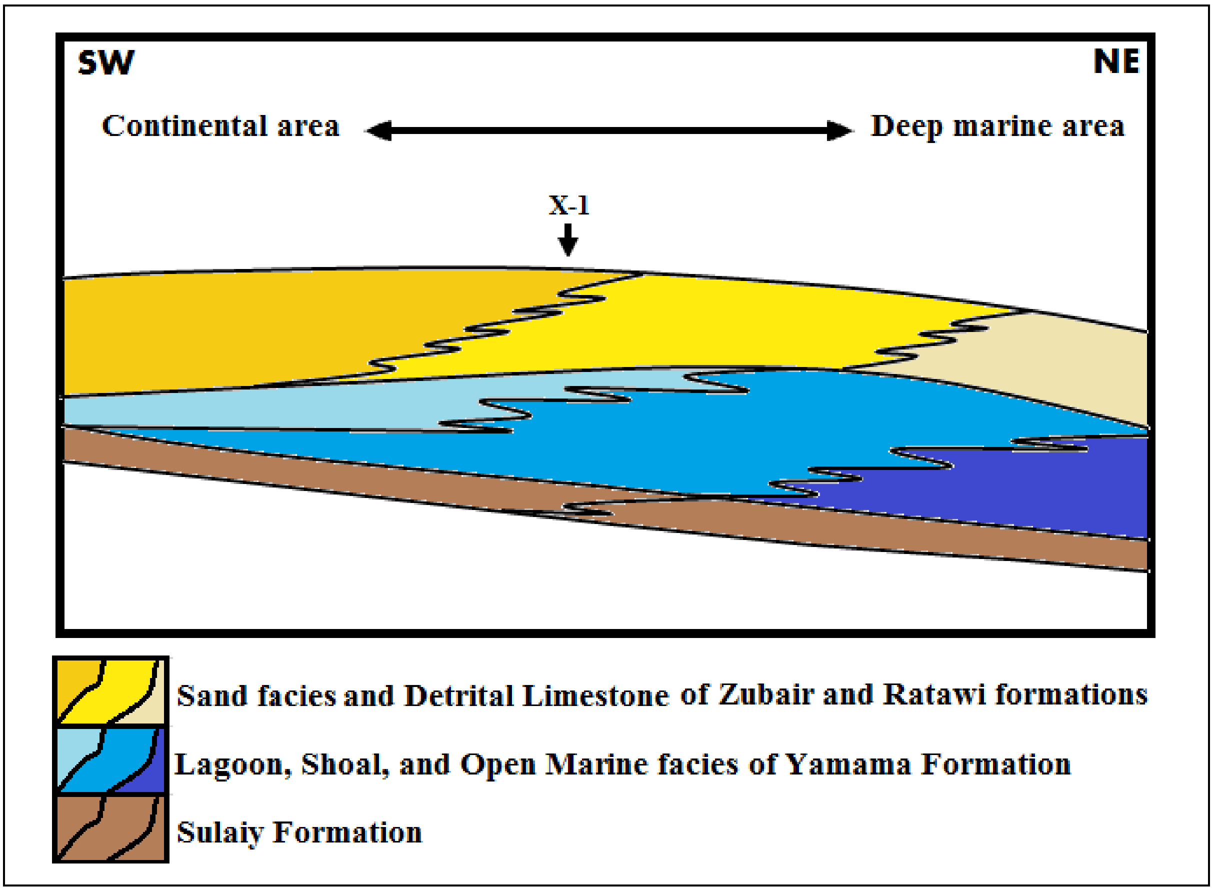


Fig. 11. A schematic attempt to produce local, vertical and horizontal facies distributions of the Yamama Formation in the study area.

- The top of Yamama Formation (Barrier-1), which consists of deep sedimentary facies with layers of shale.

- The upper sequence and reservoir unit (YS2) also consists of oolitic granular calcareous rocks, where the log examinations show that it is a very good reservoir.

- The insulating unit (Barrier bed within Yamama Formation), which consists of limestone rocks with deep facies interbedded with thin layers of shale.

- The lower reservoir unit (YS1) consists of limestone rocks with shallow facies, which could be packstone to grainstone with good reservoir properties. In addition to the presence of an overlap of thin shale units that have bad reservoir properties.

As mentioned above, the Yamama Formation consists of lateral stratigraphic traps appear in the seismic section as onlap and lateral termination. These traps may be confirmed by the 3D seismic survey and the near future exploration and/or exploitation. Hydrocarbon lateral migration and accumulation in the Yamama Formation assessed as the secondary migration that may be within Yamama Formation. This secondary migration may be along main conduits such as the porosity, fractures and faults within the carrier beds of the Yamama Formation. As well as the vertical migration that may be the primary migration from Sulaiy Formation and the underneath to Yamama Formation. On the other hand, the fuzzy places in Figure (13) indicate permeable zones, which are considered as probable hydrocarbon carrier beds.

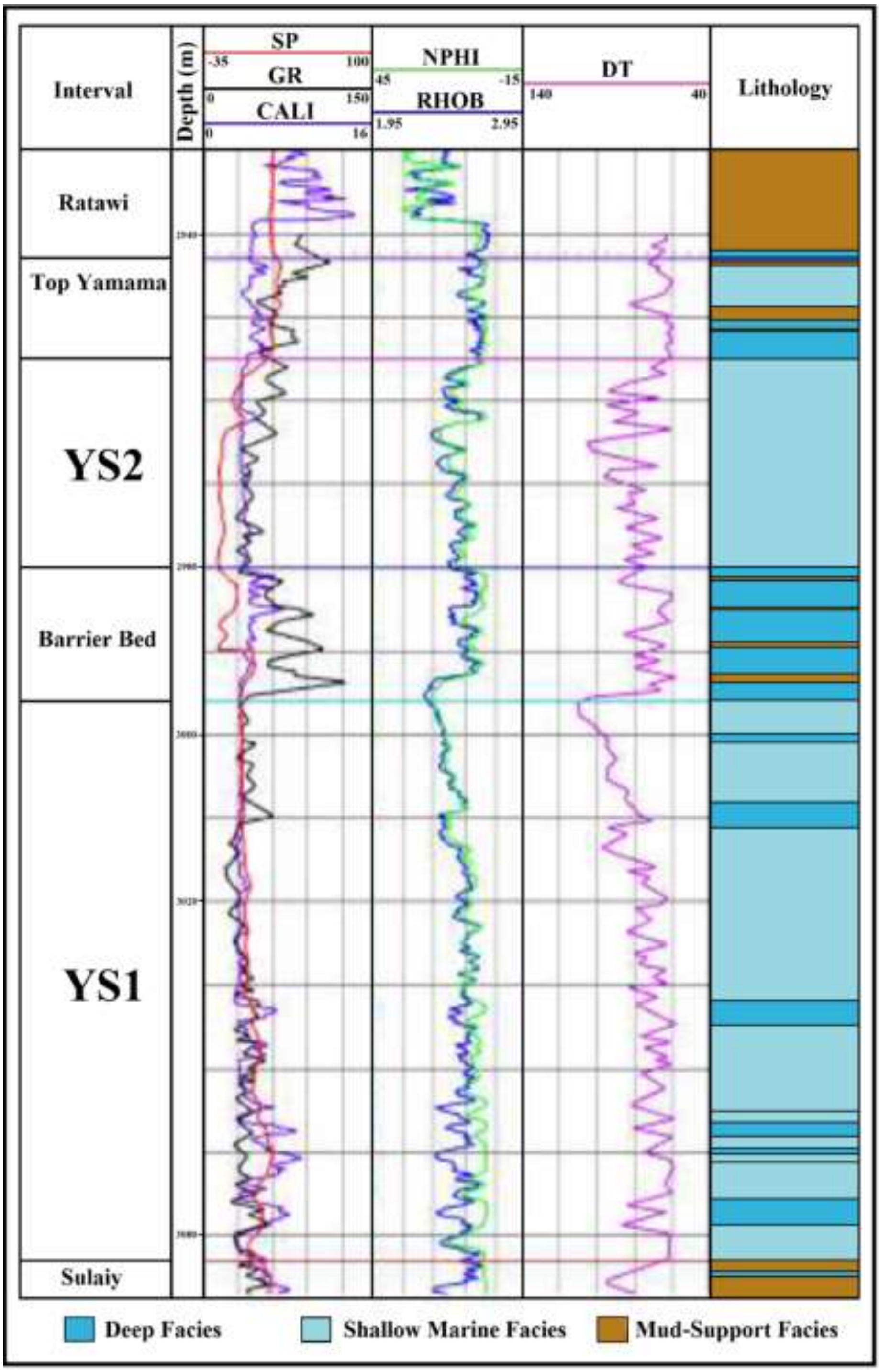


Fig. 12. The Yamama Formation divisions and sequence analysis from the logs point of view that resulted from the utility of Petrel software.

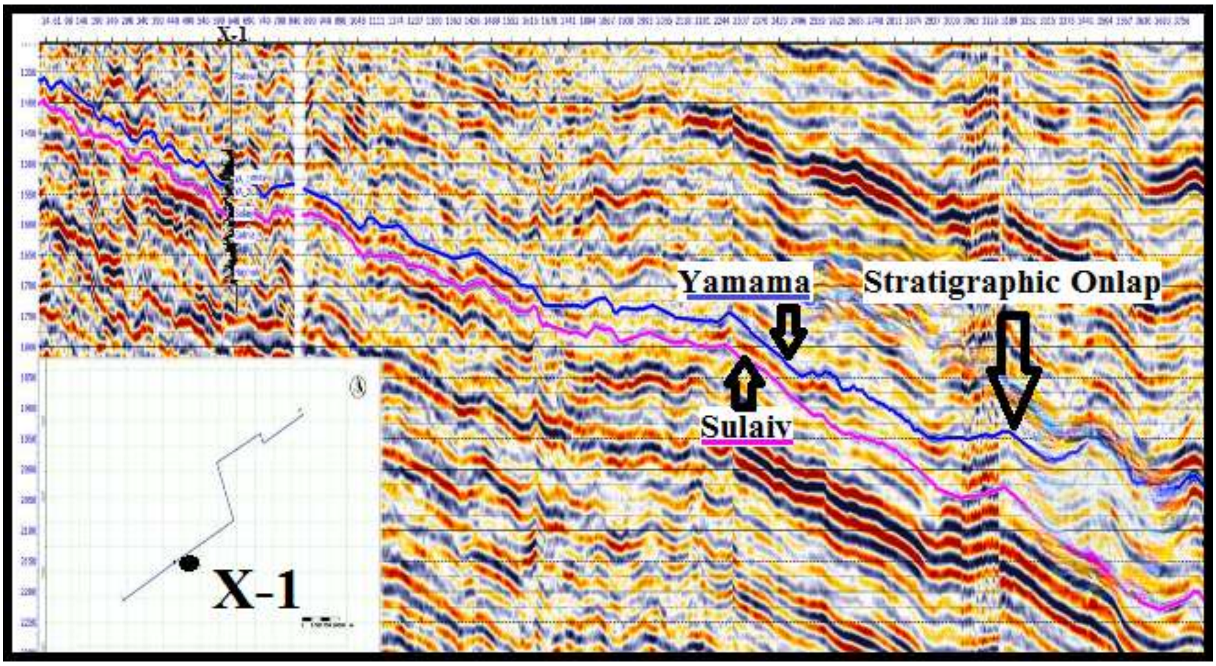


Fig. 13. A seismic section passed by the well of interest illustrating the onlap and the end of the intra-shelf basin of the Yamama Formation in the study area.

Conclusions

The Yamama Formation comprises two main regression phases separated by a barrier bed produced after shallowing and sequence boundary relief. The general dip of the layers is towards the northeast, as the region is structurally higher than the southeast side as indicated in the seismic section. The upper part of the Yamama Formation shows an angular relationship surface with Ratawi Formation. This relation may reflect an unconformity surface between the Yamama and the above formation due to the shallowing upward or relative sea-level fall. Depending on the results of the logs response and seismic section in well (X-1), the Yamama Formation in the field of interest consists of two reservoir units separated by a barrier unit, and those units are YS1 and YS2. The Yamama basin is as deeper toward the NE area than the studied oilfield that made the high thicknesses. The maximum thicknesses in this area are not only due to the higher depth of the basin, but also the shedding of the high-stand system tracts of the regression phase. While the SW area was the basin margins that produced the lower thicknesses of the formation.

Acknowledgements

The authors express their profound gratitude to the Basra Oil Company for providing the requisite data and their generous support. The authors extend their heartfelt appreciation to the reviewers, Editor in Chief Prof. Dr. Rayan Ghazi Thannoun, the Secretary of the Journal and the Technical Editors for their valuable efforts and insightful comments.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

References

Abbas, M.S., Khudhair, M.H. and Al-Saadi, O.S., 2022. Electro-Facies and Petrophysical Properties of the Hartha Formation in Selected Wells of East Baghdad Oil Field. Iraqi Journal of Science, 63(3), pp. 1129-1145. https://doi.org/10.24996/ijs.2022.63.3.20

Al-Mafraji, T.G.Z. and Al-Zaidy, A.A.H., 2019. Microfacies Architecture and Stratigraphic Development of the Yamama Formation, Southern Iraq. Iraqi Journal of Science, 60(5), pp. 1115-1128. https://doi.org/10.24996/ijs.2019.60.5.20

Al-Ameri, T.K., Al-Mimar, H.S. and Zumberge, J., 2015. Petroleum System Modeling and Risk Assessments of Ad'daimah Oil Field: A Case Study from Mesan Governorate, South Iraq. Arabian Journal of Geosciences, 8, 5739-5766. https://doi.org/10.1007/s12517-014-1599-0

Al-Ameri, T.K., Al-Musawi, F.S. and Batten, D.J., 1999. Palynofacies Indications of Depositional Environments and Source Potential for Hydrocarbons: Uppermost Jurassic-Basal Cretaceous Sulaiy Formation, Southern Iraq. Cretaceous Research, 20(3), pp. 359-363. https://doi.org/10.1006/cres.1999.0157

Khudhair, M.H. and Idan, R.M., 2024. Geochemistry and Reservoir Properties of the Upper Jurassic Formations, in Selected Oilfield Central Iraq. IOP Conf. Ser.: Earth Environ. Sci. 1300 012031. https://doi.10.1088/1755-1315/1300/1/012031

AL-Gailani, M., 1996. Iraq`s Significant Hydrocarbon Potential Remains Relatively Undeveloped. Oil and Gas Journal, 94(31).

Al-Ghuribawi, M.M. and Faisal, R.F., 2021. An Integrated Microfacies and Well Logs-Based Reservoir Characterization of Yamama Formation, Southern Iraq. Iraqi Journal of Science, 62(10), 3570-3586. https://doi.org/10.24996/ijs.2021.62.10.16

Al-Marsoumi, A.H., Salman, A.D., Al-Mohamed, R.A., 2005. Evaluation of Organic Matter in the Yamama Formation at West Qurna Oil Field, Southern Iraq. Iraqi Jour. Earth Sci., 5(1), 9-17.

Al-Mimar, H.S., Awadh, S.M., Al-Yaseri, A.A. and Yaseen, Z.M., 2018. Sedimentary Units-Layering System and Depositional Model of the Carbonate Mishrif Reservoir in Rumaila Oilfield, Southern Iraq. Modeling Earth Systems and Environment, 4, pp. 1449-1465. https://doi.org/10.1007/s40808-018-0510-5

Al-Musawi FA, Idan RM, Salih AL., 2020. Reservoir Characterization, Facies Distribution, and Sequence Stratigraphy of Mishrif Formation in a Selected Oilfield, South of Iraq. InJournal of Physics: Conference Series 2020 Nov 1. 1660, p. 012073. IOP Publishing. DOI: 10.1088/1742-6596/1660/1/012073

Al-Musawi, Furat, Abed. Ali M., Idan, R. M., 2022. Acquisition and Preparation of 3D Seismic Data for Pre-Stack Inversion at Siba Oilfield, Southeastern Iraq. Iraqi Journal of Science, 63(8), 3555-3569. https://doi.org/10.24996/ijs.2022.63.8.28

Altala S.J., Mahdi T.A., 2018. Reservoir Units of Yamama Formation in Gharafoilfiled, Southern Iraq. Iraqi Journal of Science, 59(2A), pp. 697-710.

Aqrawi, A.A.M., Goff, J.C., Horbury, A.D. and Sadooni, F.M., 2010. The Petroleum Geology of Iraq. Scientific Press Ltd.

Assi, A.H., 2023. Investigation of Drilling Problems in Iraqi Oil Fields. Iraqi Journal of Oil and Gas Research, 3(2). https://doi:10.55699/ijogr.2023.0302.1041

Chafeet, H., 2016. Yamama Reservoir Characterization in the West Qurna Oil Field, Southern Iraq. Iraqi Journal of Science, 57(2A), pp. 938-947.

Communication, G., 2003. Iraq's Reserve Estimates by Year From 1906 Through 2002.

Faisal, R.F., Idan, R.M., Salih, A.L.M., 2016. Assessment of the Lower Cretaceous Source Rock Using PetroMod Approach in West Qurna Oilfield- Southern Iraq. Iraqi Journal of Sciences, 57(3c), pp. 2258-2269.

Fox, J.E. and Ahlbrandt, T.S., 2002. Petroleum Geology and Total Petroleum Systems of the Widyan Basin and Interior Platform of Saudi Arabia and Iraq (Vol. 2202). US Department of the Interior, US Geological Survey. http://geology.cr.usgs.gov/pub/bulletins/b2202-e

Gardi, K.I., 2024. Seismic, Petrophysics and Attribute Analysis to Evaluate the Tertiary Reservoir in the High Folded Zone, Kurdistan Region-Iraq. Iraqi National Journal of Earth Science, Articles in Press. http://doi:10.33899/earth.2023.142239.1121

Gayara, A.D. and Al khaykanee, M.H., 2015. Paleoenvironments and Sequence Stratigraphy of the Turonian-Lower Campanian Succession at Majnoon Oil Field, Southern Iraq. Iraqi Journal of Science, 56(4A), pp. 2880-2886.

Habeeb, A., 2023. The Geological Approach to Predict the Abnormal Pore Pressures in Abu Amoud Oil Field, Southern Iraq. Iraqi National Journal of Earth Science, 23(2), pp. 250-265. http://doi:10.33899/earth.2023.139641.1072

Ibrahim, M.W., 1983. Petroleum Geology of Southern Iraq. AAPG Bulletin, 67. http://doi:10.1306/03b5accd-16d1-11d7-8645000102c1865d

Idan, R.M., 2017, Total Organic Carbon (TOC) Prediction from Resistivity and Porosity Logs: A Case Study from Iraq, Bull. Iraq Nat. Hist. Mus. 14 (3): pp. 185-195. DOI: https://doi.org/10.26842/binhm.7.2017.14.3.0185

Idan, Rami M. and Al-Khazraji, O.N., 2024. Characterization and Interpretation of Dedicated Reservoir Interval: A 2D Seismic Structural Approach", Iraqi Journal of Science, vol. 65, No. 3, pp. 1402–1411, Mar. https://doi: 10.24996/ijs.2024.65.3.19

Idan, R.M., Salih, A.L.M., Al-Khazraji, O.N.A. and Khudhair, M.H., 2020. Depositional Environments, Facies Distribution, and Porosity Analysis of Yamama Formation in Majnoon Oilfield. Sequence Stratigraphic Approach. Iraqi Geological Journal, 53(1), pp. 38–52. https://doi.org/10.46717/igj.53.1D.4Rw-2020-05-03

Idan, R.M., Al-Rawi, D., Nasser, M.E., AlMashaekhy, D., 2015a. Reservoir Properties and Seal Efficiency in the Zubair Formation in Euphrates Subzone, Southern Iraq. Arabian Journal of Geosciences, 8(2), 773-780. https://doi.org/10.1007/s12517-013-1221-x

Idan, R.M., Faisal, R.F., Nasser, M.E., Al-Ameri, T.K. and Al-Rawi, D., 2015b. Hydrocarbon Potential of Zubair Formation in the South of Iraq. Arabian Journal of Geosciences, 8(7), pp. 4805–4817. https://doi.org/10.1007/s12517-014-1569-6

Idan, R.M. and Salih, A.L.M., 2023. Reservoir Quality Related to Diagenetic Development in the Carbonate Mishrif Formation: A Case Study from the X Oilfield, Southern Iraq. Iraqi Geological Journal, 57(1A), 1000114. https://doi.org/10.46717/igj.56.2C.8ms-2023-9-14

Jassim, S.Z. and Goff, J.C., 2006. Geology of Iraq. Brno: Dolin, Prague and Muravian Museum.

Khudhair, M.H., 2021. Petrophysical Properties and Digenetic Evolution of Shuaiba Formation in Nasiriyah Oil Field, Southern Iraq. Iraqi Journal of Science, 62(12), pp. 4810-4818. https://doi.org/10.24996/ijs.2021.62.12.19

Le Nindre, Y.M., Vaslet, D., Maddah, S.S., and Al-Husseini, M.I. 2008. Stratigraphy of the Valanginian? to Early Paleocene Succession in Central Saudi Arabia Outcrops: Implications for Regional Arabian Sequence Stratigraphy. GeoArabia, 13(2), pp. 51-86. https://doi:10.2113/geoarabia130251

Murris, R.J., 1980. Middle East: Stratigraphic Evolution and Oil Habitat. AAPG Bulletin, 64. https://doi:10.1306/2f918a8b-16ce-11d7-8645000102c1865d

Nairn, A.E.M. and Alsharhan, A.S., 1997. Sedimentary Basins and Petroleum Geology of the Middle East. Elsevier. https://doi.org/10.1016/B978-0-444-82465-3.X5000-1

Abd, O.K. and Abd, N., 2024. Seismic Sequence Stratigraphic Model and Hydrocarbon Potential of Yamama Formation in Al-Fao Area, Southeastern Iraq. The Iraqi Geological Journal, pp. 56-69. https://doi.org/10.46717/igj.57.1A.6ms-2024-1-17

Peters, K., Schenk, O. and Wygrala, B., 2009. Exploration Paradigm Shift: The Dynamic Petroleum System Concept. Swiss Bull. angew. Geol., 14(1), pp. 65-71.

Sadooni, F., 1993. Stratigraphie Sequence, Microfacies, and Petroleum Prospects of the Yamama Formation, Lower Cretaceous, Southern Iraq. AAPG Bulletin, 77(11), pp. 1971-1988. https://doi.org/10.1306/BDFF8F92-1718-11D7-8645000102C1865D

Sadooni, F.N., Aqrawi, A.A., 2000. Cretaceous Sequence Stratigraphy and Petroleum Potential of the Mesopotamian Basin, Iraq. (R. W. Abdulrahman S. Alsharhan, Ed.) SEPM Special Publication (69), pp. 315-334. https://doi.org/10.2110/pec.00.69.0315

Sharland, P.R, Archer, R., Casey, D.M., Davies, R.B. Hall S.H., Heward A.P. Horbury A.D. and Simmons, M.D., 2001. Arabian Plate Sequence Stratigraphy, an Integrated Approach. In Geo-Arabia special publication, 340P.

Sattam, M., A-Sharaa, G.H. and Hindi, M.H.A., 2018. Micro Facies Analysis and Development of Diagenetic Processes in Khasib Formation in Selected Oil Wells, South East of Iraq. Journal of University of Babylon for Pure and Applied Sciences, 26(4), pp. 187-197. https://doi:10.24237/ASJ.01.04.656C

South Oil Company, 1975. Final Geological Report. Basrah.

Tomassini, F.G., Hryb, D.E., Sagasti, G., Massaferro, J.L. and Smith, L., 2016. Why Do We Have to Care About Detailed Reservoir Characterization? We will Break it All. Do We? SPE/AAPG/SEG Unconventional Resources Technology Conference, URTEC-2460837, pp. 1-10. https://doi:10.15530-urtec-2016-2460837

Verma, M.K., Ahlbrandt, T.S. and Al-Gailani, M., 2004. Petroleum Reserves and Undiscovered Resources in the Total Petroleum Systems of Iraq: Reserve Growth and Production Implications. GeoArabia, 9(3), pp. 51-74. https://doi:10.2113/geoarabia090351

Wright, V.P. and Burchette, T.P., 1998. Carbonate Ramps: An Introduction. Geological Society, London, Special Publications, 149(1), pp. 1-5. https://doi.org/10.1144/GSL.SP.1999.149.01.01