ISSN: 0067-2904

Microfacies analysis and sequence stratigraphy of Oligocene formations within Bai Hassan oil field, Northern Iraq

Dalya Kameran*[1], Mazin Y. Tamar-Agha[2] , Fawzi M. Al-Beyati[3]
[1]*Department of Petroleum Engineering, College of Engineering, Al-Kitab University*
[2]*Department of Geology, College of Sciences, University of Baghdad*
[3]*Engeneering Technical College of Kirkuk, Northern Technical University, Iraq*

Received: 9/9/2022 Accepted: 25/1/2023 Published: 30/12/2023

Abstract

Bai Hassan Oil field is considered one of the important north Iraq oil fields. The giant oil field of Bai-Hassan is located near Kirkuk City in North Iraq. The field consists of two domes (in SE – NW direction) Kithka Dome and Dauod Dome separated by a narrow saddle called Shashal saddle.

The current study is focused on microfacies analysis to interpret the stratigraphic sequence of the Palani Formation (early – lower Oligocene age), Baba, Bajawan and Tarjil Formations (middle Oligocene age).

The Bajawan Formation consists basically of five microfacies easily recognizable throughout the thin section. These microfacies are Lime Mudstone Microfacies, Miliolid Packestone Microfacies, Miliolid Grainstone Microfacies and Dolostone Microfacies. The Baba Formation comprises four microfacies: Rutalia - Nummulites Packstone Microfacies, Coral Boundstone Microfacies and Dolostone Microfacies. Two microfacies have been recognized in Tarjil Formation, these are Lime Mudstone Microfacies and Planktic foraminiferal packstone microfacies. In addition to two microfacies within Palani Formation are Lime Mudstone and Planktonic foraminifera Wackstone Microfacies.

The depositional environment of the studied formations and the analysis of their facies components showed that they were deposited within the three parts of the ramp environment, where the Palani Formation was deposited in the deeper part from the outer ramp during TST and HST stages, while the Tarjil Formation was deposited at the distal part of upper slope area from middle ramp environment during HST stage. The Baba Formation was deposited on the swelling parts of the approximal part for the middle ramp at the lower part (TST), and it was reached separately by MFS from the distal part of inner ramp sediments which were deposited during HST as two cycles. The Bajawan Formation with its two parts was deposited at the approximal part from the inner ramp environment during the early and late HST stage.

Keywords:- Macrofacies Analysis, Sequence Stratigraphy, Oligocene formations, Bai Hassan oil field

التحليل السحني و طباقية التتابع لتكوينات الاوليغوسين في حقل باي حسن النفطي، شمال العراق

داليا كاميران*[1] و فوزي مردان البياتي[2] و مازن يوسف تمر اغا[3]
[1]قسم هندسة البترول ، كلية الهندسة ، جامعة الكتاب
[2]الكلية التقنية الهندسية في كركوك ، الجامعة التقنية الشمالية ، العراق
[3]قسم الجيولوجيا . كلية العلوم . جامعة بغداد

*Email: dalia.kamran9@gmail.com

الخلاصة

يعد حقل باي حسن النفطي أحد حقول النفط المهمة في شمال العراق ، ويقع حقل باي حسن النفطي الصغير العملاق بالقرب من كركوك في شمال العراق. يتكون الحقل من قبتين باتجاه شمال غرب – جنوب شرق هما قبة داوود و كاثيكا المفصولتين بهبوط ضيق يسمى سرج شاشال. ركزت الدراسة الحالية على تحليل السحنات الدقيقة لتفسير التتابع الطبقي لتكوينات البالاني (عمر الأوليغوسيني المبكر – السفلي) و بابا و باجوان وتارجيل (عصر الأوليغوسين الأوسط).

يتكون تكوين باجوان أساسًا من خمس سحنات دقيقة يمكن التعرف عليها بسهولة في جميع الشرائح الصخرية المدروسة. وهي

Lime Mudstone Microfacies, Miliolid Packestone Microfacies, Miliolid Grainston Microfacies, and Dolostone Microfacies.

يتكون تكوين بابا من أربعة سحنات دقيقة تم تشخيصها ، وهي:-

Rutalia – Nummulites Packstone Microfacies, Coral Boundstone Microfacies, Dolostone Microfacies.

تم التعرف على اثنين من السحنات الدقيقة في تكوين تارجيل هما:-

Lim Mudstone Microfacies, Planktic foraminiferal Packstone microfacies.

بالاضافة الى سحنتين دقيقتين ضمن تكوين بالاني هما:-

Lime Mudstone and Planktonic foraminifera Wackstone Microfacies.

أظهرت البيئة الترسيبية للتكوينات المدروسة وتحليل مكونات سحناتها أنها ترسبت داخل الأجزاء الثلاثة من بيئة المنحدر ، حيث ترسب تكوين بالاني في الجزء الأعمق من المنحدر الخارجي خلال مرحلتي TST و HST ، بينما كان تكوين تارجيل ترسب في الجزء البعيد من منطقة المنحدر العلوي من بيئة المنحدر الأوسط خلال مرحلة HST . في حين تم ترسيب تكوين بابا على الأجزاء المرتفعة للجزء البعيد للمنحدر الأوسط في الجزء السفلي من التتابع (TST) ، و الذي تم فصله بسطح MFS عن الجزء البعيد من رواسب المنحدرات الداخلية التي ترسبت خلال HST على شكل دورتين. ترسب تكوين باجوان بأجزائه المختلفة في الجزء التقريبي من بيئة المنحدر الداخلي خلال مرحلة HST المبكرة والمتأخرة.

1. Introduction

Iraq is considered one of the greatest countries - rich with hydrocarbon in the world most of the Oil reservoir is located in Cretaceous and Tertiary rock units. Tertiary rocks are divided into many sedimentary cycles. The Oligocene sediments are distributed relatively in Iraq a restricted area, and also reduced in thickness [1].

The Oligocene is less represented than the Eocene. It occupied a limited area, located mainly within the Mesopotamian [2]. The formations of the Oligocene are separated by break and unconformity from both the underlying Eocene and Paleocene and the overlying Miocene.

The sequence of Oligocene carbonate is called the Kirkuk group comprises nine formations (Anah, Azkand, Ibrahim, Bajawan, Baba, Tarjil, Shurau, Sheikh Alas and Palani) distributed within upper, middle and lower Oligocene [3].

Bai Hassan Oil Field is considered one of the important northern Iraq oil fields, the giant oil field of Bai-Hassan is located near Kirkuk in North Iraq (Fig.1.1). The field has been discovered in 1953 by the Iraqi Oil Company (IPC) and having come on production in 1960 [4]. The structure of the field is about 40 km long and about 3.5 km wide and consists of a longitudinal,

sinusoidal, asymmetrical anticline. The southern limb of the structure is steeper and its slope is about 37°-65° while the eastern limb slope is about 22°-35° [5].
The Oligocene rocks in Iraq were divided into the early Oligocene age which includes Shura, Sheikh Alas, and Palani successions, while the middle Oligocene succession includes Bajawan, Baba, and Tarjil successions, and the late Oligocene sequence includes Anah, Azkand, and Ibrahim successions [6].

The Bai-Hassan small giant oil field is located geographically northwest of Kirkuk- northern Iraq in the low folded zone according to [7] or zone of Hamren – Makhool according to Buday and Jassim [8], which is an Unstable Shelf Zone (Figure1). Structurally, the oil field is asymmetrical elongated anticline extended for 40km in length and 13.5km in width in-between Kirkuk and Qara Chauq anticlines.

The field consists of two domes (in SE – NW direction) Kithka Dome and Dauod Dome previously separated by a narrow saddle called Shahal saddle, Kithka dome is bigger in size and higher structurally by (335m) than the Dauod dome.

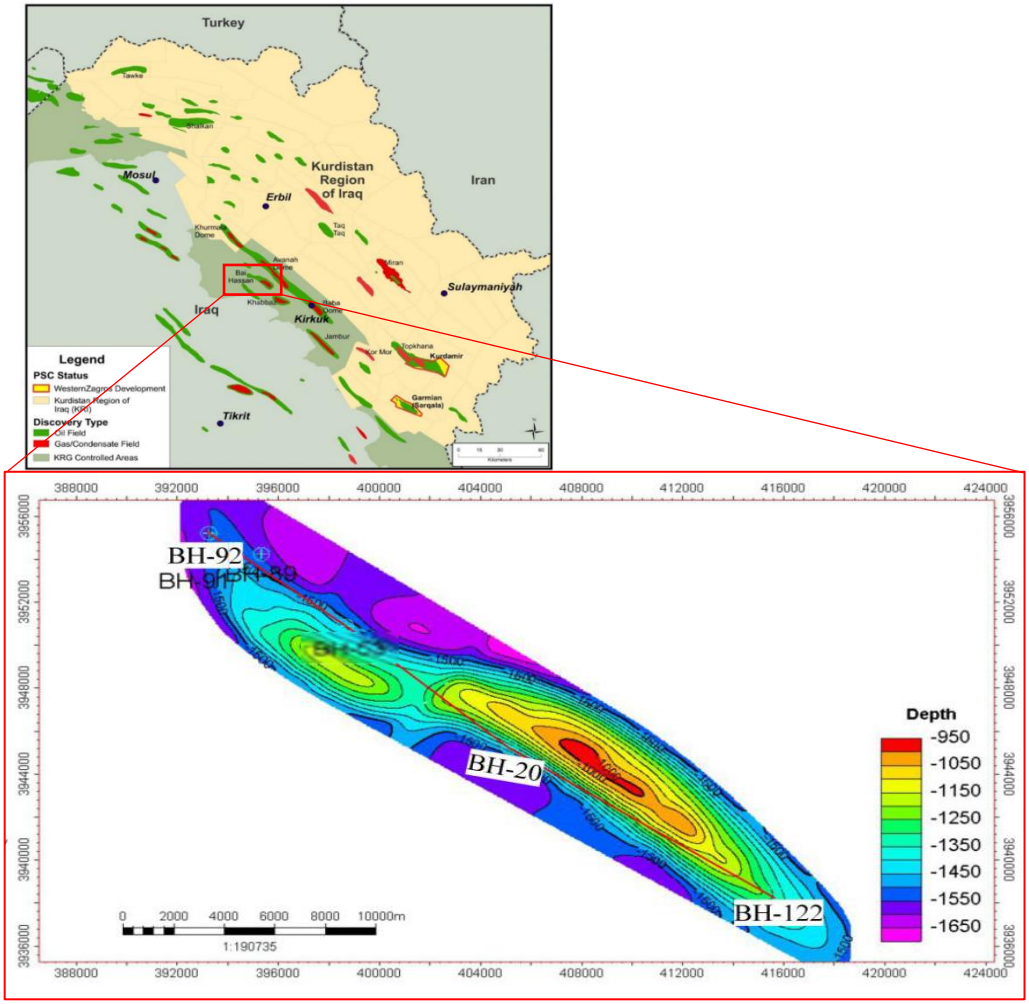


Figure 1: Location and structural map of the Bi Hassan oil field

2. Methods of work

2.1 Preparation works:

In the current study, it has been viewed on the final reports of the oil wells that penetrated the Oligocene rocks in Bi Hassan Oil Field to choose the best wells which have considerable thickness, lithology, stratigraphy, structure and logs available of these wells.
Three oil wells have been chosen and (250) thin sections of samples cover all formations at the Bai Hassan structure in the Kirkuk area (North Oil Company).

2.2 Practical work

The selected thin sections of Oligocene succession have been studied in North Oil Company laboratories by using the polarized microscope. It has been described petrographically for facies interpretation and classification and also to indicate the important digenetic processes which lead to the determination of the depositional environments and construction of the model of sedimentation, where the number of slides for wells Bh-20, Bh-92, and Bh-122 about 350 slides are chosen.

3. Geological Settings

3.1 Tectonic Setting

This Megasequence is associated with the collision of Neo-Tethyan terrains along the north and east sides of the Arabian Plate, resulting in the folding and thrusting of the Neo-Tethyan terrains. Co-incident was the opening of the Gulf of Aden and the Red Sea, accompanied by thermal uplift, flood basalts, and rifting on the south and west sides of the plate. The Gulf of Aden opened first during the Oligocene time, followed by the Red Sea in the early Miocene [9, 10].

There is more than one classification of tectonics in Iraq: according to Sharland et al., [11] Iraq is divided tectonically into three different areas: Stable Shelf, Unstable Shelf and the Zagros Suture (Figure 2). The Zagros Central Faulting Zone is characterized by a thick sedimentary cover (as much as 13 km thick) and well-developed folding formed by long, narrow, NW-SE trending anticlines separated by broad, flat synclines. Several major commercial oil fields are situated in this area, including Kirkuk, Bai Hassan, and Jambur [12].

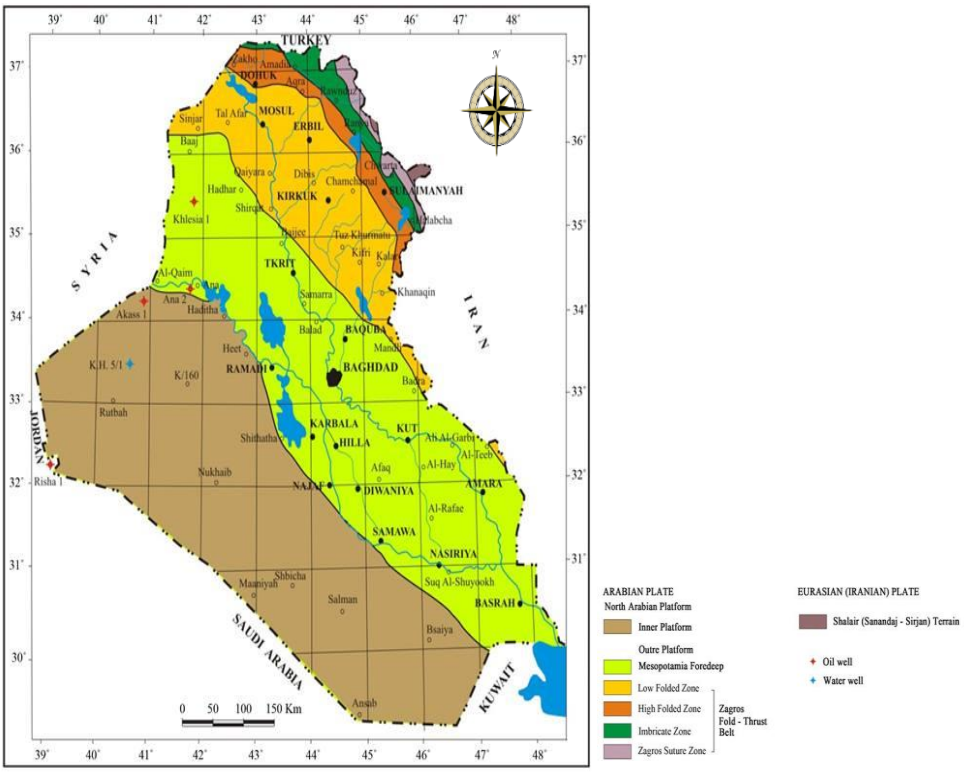


Figure 2: Tectonic subdivision map of Iraq [13].

Bai Hassan Oil Field has extended previous mapping to include associated fault frameworks consisting of an imbricate front thrust and back thrust fault set within each of the two structures; in addition, northeast-southwest trending tear faults are present within the Bai Hassan structure to accommodate differential fault movement on the separate and loosely coupled lateral thrust sheet segments comprising the front and back thrusts age [14].

Bai Hassan Oil Field is one of several elongated, asymmetrical, doubly plunging anticlines that characterize the Foothills Region of the Unstable Shelf Zone in eastern Iraq. The northwest-southeast trending structure measures 34 km long and 3.8 km wide. Bed dips on the flanks are approximately 40 degrees while the noses plunge at approximately 5 degrees. The dipmeter data acquired on early wells show local dips of more than 50 degrees that are most likely associated with faults [8].

The top of the structure is relatively flat with dips less than 10 degrees noted. Two individual domes separated by a shallow saddle make up the Bai Hassan structure. Kithka Dome is the larger and more prolific of the two domes. It has a significant surface expression that is easy to see on remote-sensing images. The Dauod Dome does not have a surface expression, is smaller, and is less prolific. Consequently, it was not discovered and produced until several years after production was established on Kithka Dome [8].

The two domes are physically separated by the Shahal Saddle. The Shahal Saddle is likely associated with a deep-seated, axis perpendicular, extension fault that was reactivated and influential in the general structural development of the Bai Hassan oil field during Miocene compression and folding. It is also likely that the structure is still in compression today [8].

Two distinctly different periods of tectonism are responsible for the creation of the present-day structure and resulting stratigraphy. Early pre29 Tertiary rifting caused by extension of the

Arabian and Eurasian plates created a graben system of normal faults and basement fault blocks that were covered with a thick succession of platform carbonates. The onset of compression in the early Tertiary resulted in the closing and shallowing of the ancestral Cretaceous seaway [8].

3.2 Stratigraphic setting

The Kirkuk Group represents a major part of the "Main Limestone" (Middle-Upper Eocene and Oligocene). The term "Main Limestone" is an informal term introduced to indicate the first main oil pay zone of the Kirkuk structure. nine Oligocene formations of the Kirkuk Group that occur in the Kirkuk structure [1, 14, 15] are the Shurau, Sheikh Alas, Palani, Bajawan, Baba, Tarjil, Anah, Azkand and Ibrahim formations in one stratigraphic package (Figure 3). The absence of certain formations of the Kirkuk group may reflect the palaeo-configuration of the basin [16]. However, because Kirkuk Group formations existed in Folded Zone "HFZ" will be missing usually.

The Middle-Late Eocene basin is represented by a transgression stage with high subsidence, where the sea level had been raised and covered the northeastern and eastern parts of the Mesopotamian basin by deep-sea deposits (Jaddala Formation) [17]. This succession was underlying the Oligocene which was described by [18] as marly limestone with planktonic foraminifera in the southeastern part of the Mesopotamian basin center during the transgressive and highstand conditions.

Tertiary formations are the most widespread deposit on the surface and in the subsurface section throughout almost all the structural units of Iraq. However, the Tertiary sediments have a small areal extent in the high folded, Imbricated and northern thrust zone unit. The studied formations, therefore, have various facies and include typical eugeosyniclinal sediments, molasses and sediments of the platform cover. The Tertiary group can be divided into individual sedimentary cycles. Ditmar et al., [19] situate the boundary between the two main development stages of Iraq on the lower and middle Eocene boundary, considering the middle Eocene-Quaternary periods as on a bigger sedimentary cycle, corresponding to the late and post geosynclinals development stage. The following cycles were established:

a. Paleocene – lower Eocene.
b. late Lower Eocene – upper Eocene.
c. Oligocene.
d. lower and middle Miocene.
e. upper Miocene – Pliocene.
f. Quaternary.

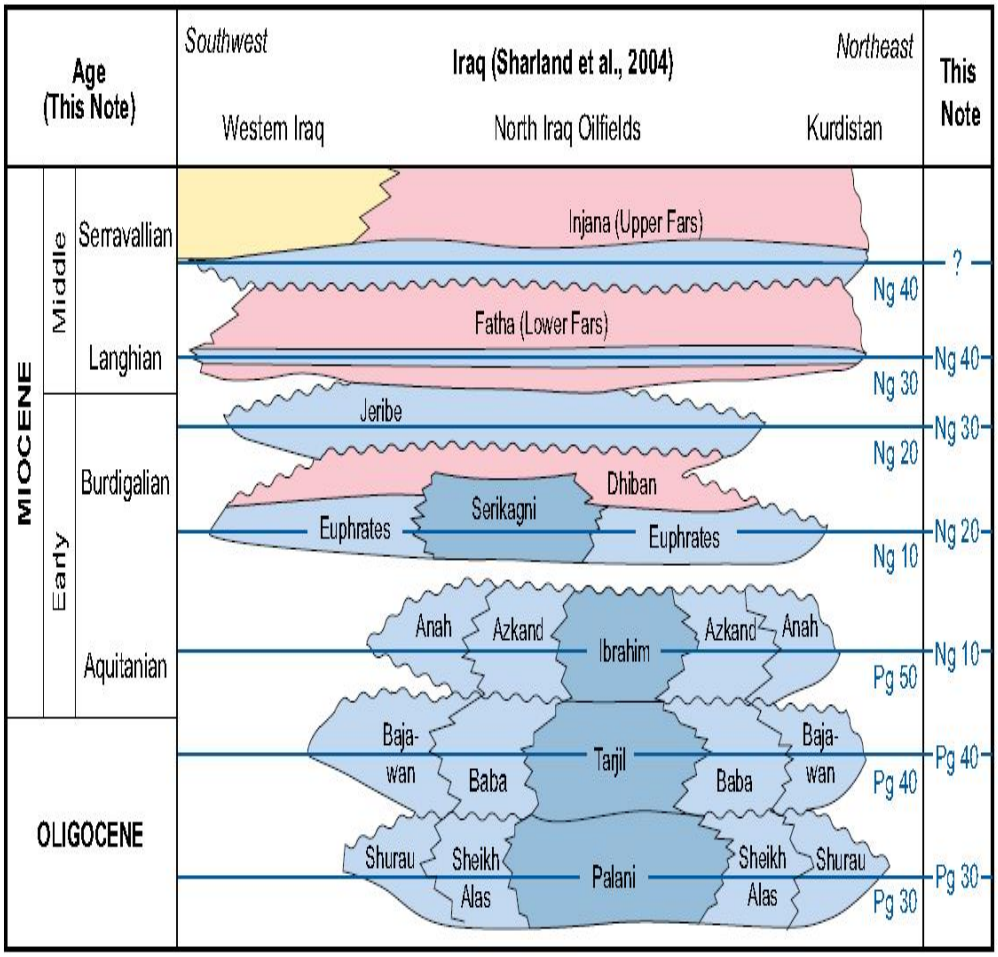


Figure 3: Stratigraphic section shows the Tertiary sequence of Iraq appeared as a natural boundary (modified by [20])

The Oligocene period is marked by the uplift and first folding of the Tertiary eugeosyncline and by a well-expressed regressive phase on the shelf.

There are now some problems concerning the stratigraphy of the Oligocene and consequently the boundaries of the cycle too. Bellen [1] introduced a tripartite vertical and horizontal division, claiming the precent of lower, middle and upper Oligocene, each of them is in three facies i.e., backreef/reef, forereef and basinal facies. backreef/reef (Bajawan Formation) and forereef (Baba Formation) Originally the succession was introduced by [14, 1], the Shurau, Sheik Alas, and Palani formations are of Early – Lower Oligocene age Baba, Bajawan and Tarjile Formations of the middle Oligocene age and Anah, Azkand and Ibrahim Formations of late – upper Oligocene (Figure 3).

The Baba Formation, on the other hand, consists of soft fossiliferous, dolomitic limestones. The Formation is characterized by the dominance of large Foraminifera Lipidocyclina, Large Mollusks, and Echinoid [6], The Bajawan Formation was defined by [1] it comprises tight backreef miliolid limestone alternating with porous, partly dolomite, The upper boundary is unconformable with overlaying Basalt Fars Conglomerate (Lower Fares) formation in all wells.

The lower boundary is conformable with the underlying Shurau Formation in all studied wells, except well K-152 where unconformable with Tarjil Formation.

Henson [21] established the original stratigraphy and the reef concept (backreef, reef, forereef and basin) for this group in the Kirkuk Oil Field. It has been argued by [5] that the Oligocene succession is bounded by breaks and unconformities at both its lower and upper contacts. It would be located in the first sequence of Megasequence AP11 and Ng10 [2].

The sequences show lateral facies variations from basinal to the reef and back reef facies (Table 3). Ditmar et al., [19] modified Bellen's divisions into only two sequences rather than three based on lithological and well-log correlation; they arranged the formations into two sequences: a lower sequence comprising the Palani, Sheikh Alas, Shurau and Tarjil formations and the upper sequence comprising the Ibrahim, Anah, Azkand, Bajawan and Baba Formations.

4. Microfacies Analysis

The description of carbonate rocks of Kirkuk Group formations is according to the carbonate rocks classification by Dunham [22] and modified by Embry and Klovan [23], (Figure 4). Microfacies determination from Bajawan, Baba, Tarjil and Palani Formations based on sedimentological features and skeletal and non-skeletal components. Four carbonate microfacies are distinguished from Bajawan Formation and two microfacies are described from Baba Formation and four in both Tarjil and Palani Formations. These Facies associations are compared with the models of standard microfacies and depositional environment belts of carbonates proposed by [24, 25].

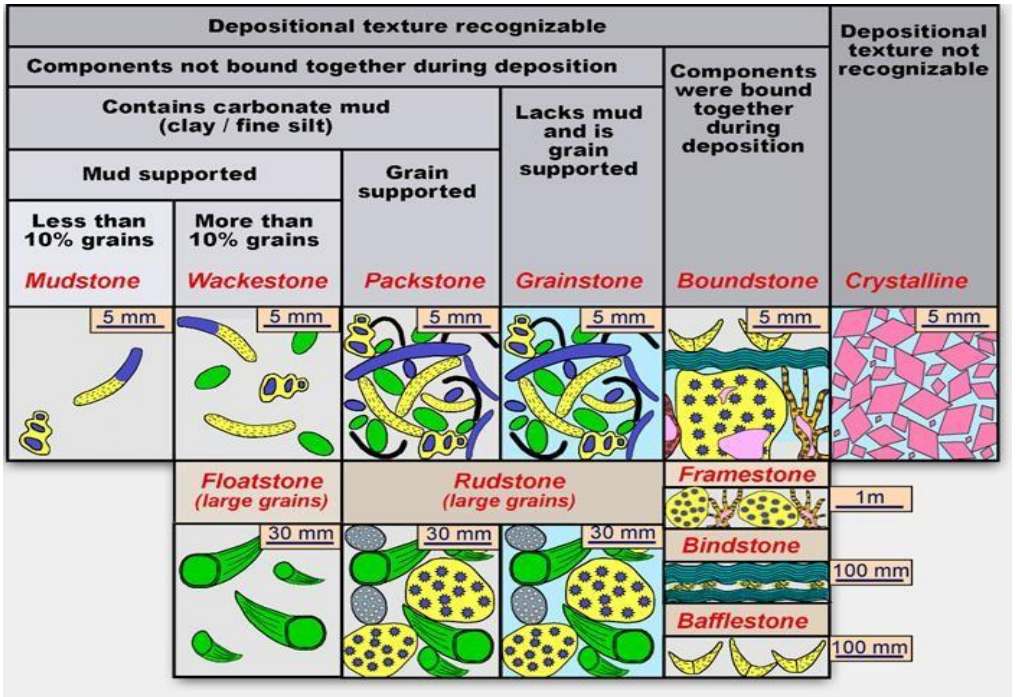


Figure 4 : Classification of carbonate rocks [22], and modified by [23].

4.1 Microfacies of Bajawan Formation

Bajawan Formation consists basically of five microfacies easily recognizable throughout the thin section, these microfacies are:

4.1.1 Lime Mudstone Microfacies

This facies is composed mainly of micrite and shells of fossils<10% according to Dunham [22]. The thickness of this facies ranges between 5 and 10 m. It is found in the upper and lower

part of the Bajawan Formation in well BH-20, and BH-92. This microfacies is similar to standard microfacies (SMF19) that are deposited in the facies zone (FZ-8) according to [24, 25].

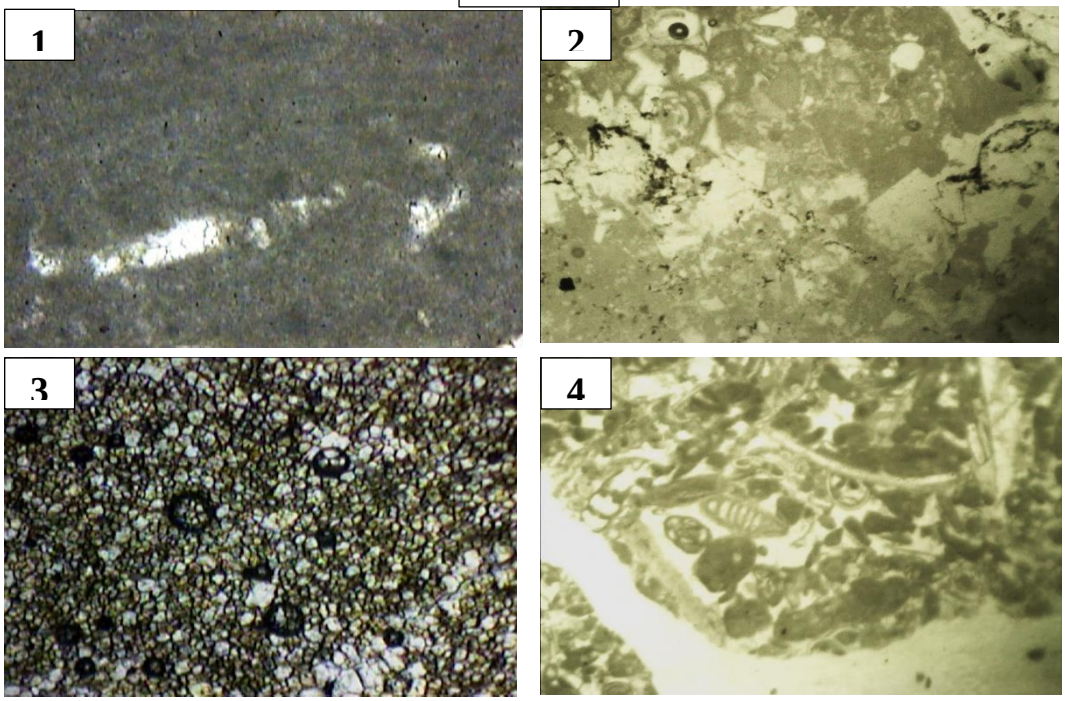
4.1.2 Miliolid Packestone microfacies

This facies is composed of imperforate foraminifera (miliolids, peneroplids) and other benthic foraminiferas. In addition, Rotalia is composed of dense lime wackestone This facies occurs at the upper and lower parts of the Bajawan Formation in all studied wells at a thickness of about 5 – 15 m. The main facies in the Bajwan Formation is miliolidae wackestone to packstone. They are associated with benthic foraminifera and echinoid fragment(pl,1/E&F). This facies appears in all the studied wells (BH-92, BH-122 and BH-20). It was deposited in a semi-restricted marine environment (back-reef facies). The presence of a large number of imperforate benthic foraminifer tests suggests that this microfacies is similar to standard microfacies SMF-12 of [25], that deposited in the facies zone FZ-5.

4.1.3 Dolostone microfacies

This microfacies is characterized by dolomitized limestone which appeared in two wells (BH-122, BH-20 and BH-92) with a thickness of about 5-15m.

Plate-1



1. **Lime mudstone - BH-20, depth 1380m, X10**
2. **Miliolid Packstone - BH-20, depth 1375m, X10**
3. **Dolostone - BH-20, depth 1385m, X10**
4. **Miliolid grainstone - BH-20, depth 1405m, X4**

4.1.4 Miliolid Grainstone microfacies

This facies is composed of imperforate foraminifera (miliolids). Other common constituents include benthic foraminifera such as *Spirolina Ousteriaca* and *plisipoda paches*. This facies appeared in the upper part of wells BH-122 and BH-92, Where the thickness of this facies is about 8-10m respectively.

4.2 Microfacies of Baba Formation

Baba Formation comprises four microfacies diagnosed by the study of the thin section, these microfacies are:

4.2.1 Rutalia - Nummulites Packstone Microfacies (RNP)

This microfacies is predominantly composed of lime packstone, which represents the upper, middle and lower part of the Baba Formation. The predominant grain types are large perforate foraminifera consisting of, Nummulites, *Mesophylum* sp., Rotalia , and Archuphylum (pl,2/E).

This facies appeared in all wells, which they consider are the main facies for Baba Formations and occur in the middle and lower part in different thicknesses of about 10- 40m. in all studied wells.

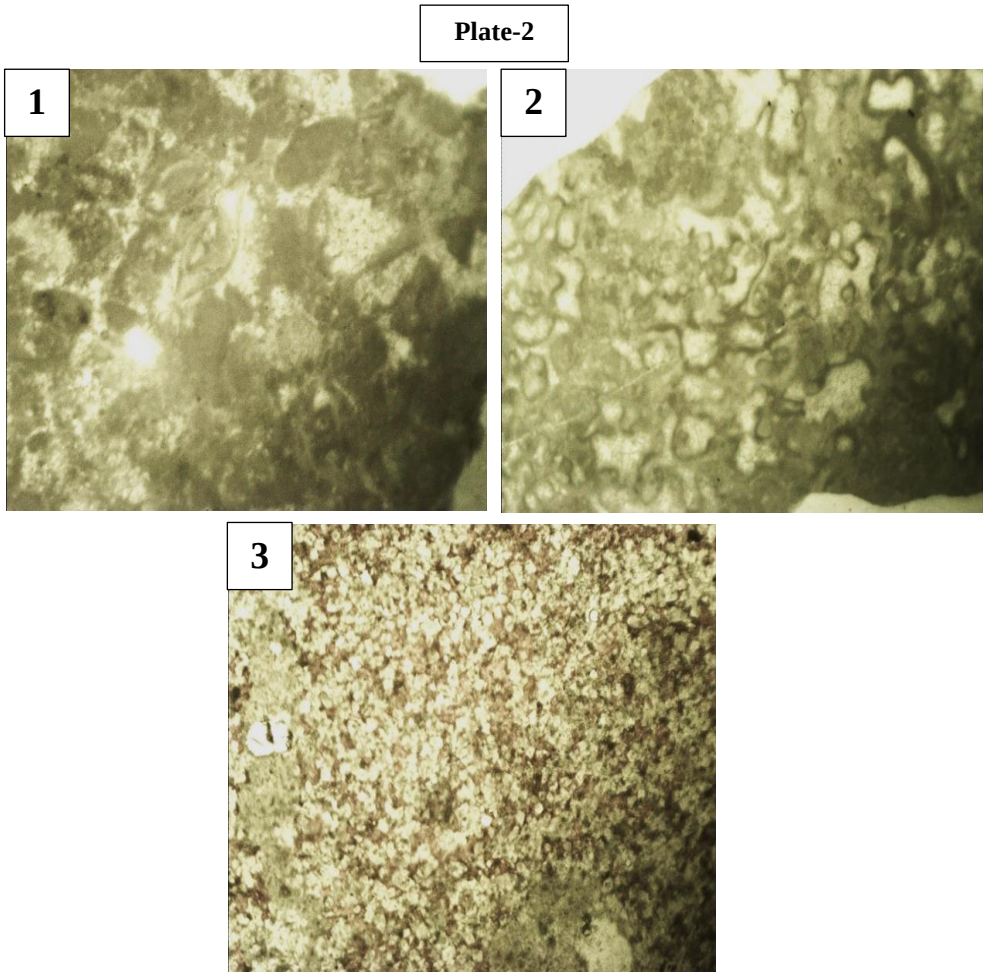
Larger foraminifera is typically associated with tropical and subtropical shallow-water carbonate sediments [26]. They can form a considerable portion of the skeletal debris of reef and platform environments, It was deposited in the reef to an open marine environment The limited diversity of plentiful hyaline, large and flat foraminifera such as Nummulite and Rotalia and the presence of typical open marine, normal salinity and Oligophotic Zone in a shallow open marine setting [27]. This flattened test shapes suggest that this microfacies was deposited in the lower photic zone in the distal middle ramp [28, 26, 29, 30, 31, 32, 33]. This microfacies is similar to standard microfacies [25] that was deposited in the facies zone FZ-7.

4.2.2 Coral Boundstone Microfacies (CB)

It is present as a patch reef which are common in open (non-restricted) lagoons and/or barrier reef which separated the open marine from a restricted lagoon [34]. This microfacies is predominantly composed of coral and echinoid fragments, coral is abundant (pl,2/D). This has appeared in BH-20, BH-92 and BH-122 wells with thicknesses of about 5m and 10m respectively. Coral, boundstone microfacies is the most abundant microfacies in reef environment (coral build-up reef facies) as coralline boundstone. The presence of coral refers to the upper part of a carbonate slope environment in an oligotrophic situation [24, 25]. This microfacies is similar to standard microfacies SMF-7 of Flugel [25] that was deposited in the facies zone FZ-5.

4.2.4 Dolostone Microfacies (D)

This microfacies has appeared in two wells (BH92, BH122) with thicknesses of about 50m - 5m respectively.



1. **Rutalia - Nummulites Packstone -BH-20, depth 1672m, X10**
2. **Coral Boundstone -BH-122, depth 1370m, X10**
3. **Dolostone – BH-92, 1605.30**

4.3 Microfacies of Tarjil Formation

This formation is composed of 25m of marly limestone in BH-92 and BH-122. The lower boundary of the Tarjil Formation is unconformable with the underlying Palani Formation (Early Oligocene) according to [14]. Two microfacies have been recognized in Tarjil Formation.

4.3.1 Lime Mudstone Microfacies (LM)

This microfacies appears in wells BH-92 and BH-122 with a thickness of about 5m.

4.3.2 Planktonic foraminiferal Packstone microfacies (PP)

This microfacies is predominantly composed of lime packstone, which represents the upper, middle and lower part of the Baba Formation. The predominant grain types are large perforate foraminifera consisting of *Mesophylum* sp., (pl,2/E). This microfacies was appeared in two wells (BH122 and BH92) about thickness(2-5m).

4.4 Microfacies of Palani Formation

This formation appears only in BH-92 with a thickness of about 20m of marly limestone. The upper boundary of the Palani Formation is unconformable with the overlying Tarjil Formation (Middle Oligocene) according to [14]. Two microfacies have been recognized in Tarjil Formation.

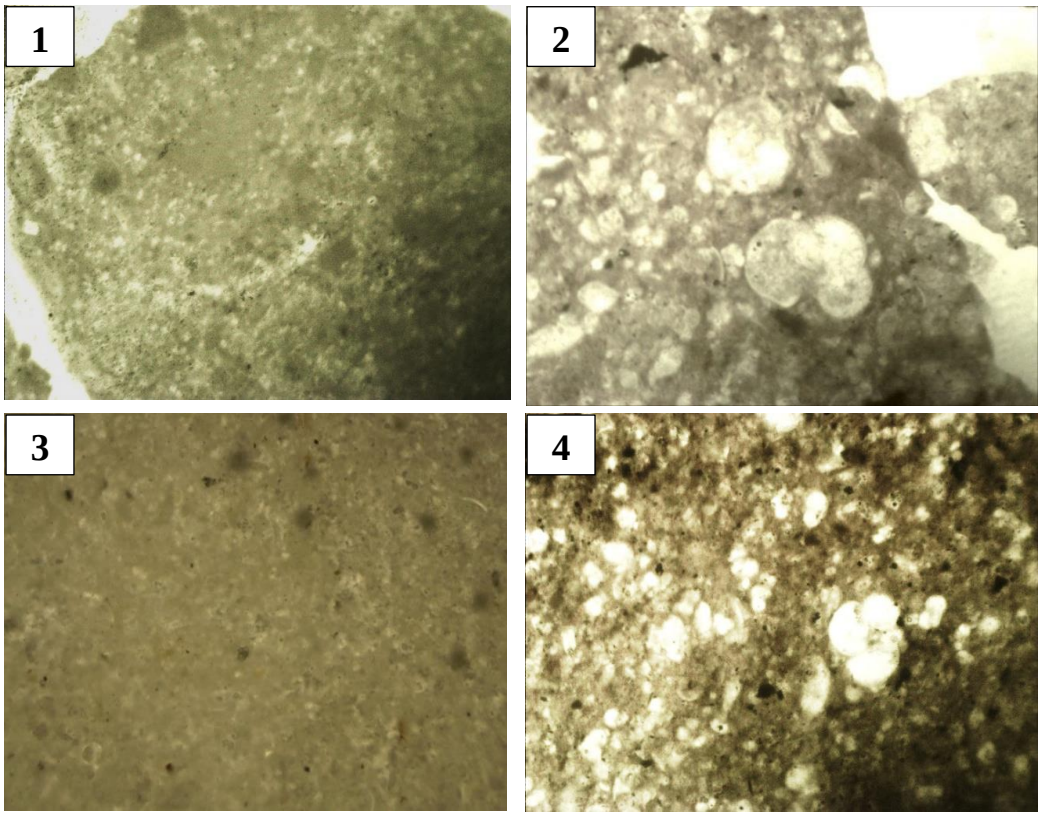
4.4.1 Lime Mudstone Microfacies

This microfacies appears in the middle part of wells BH-92 with a thickness of about 6m.

4.4.2 Planktonic foraminifera Wackstone Microfacies (PWP)

This microfacies appears only in well BH- 92 with a thickness of about 10 m, and it's characterized by crowds of planktonic foraminifera.

Plate-3



1. **Lime mudstone - BH-92, depth 1661m, X10**
2. **Planktonic Packestone - BH-122, depth 1111m, X4**
3. **Lime mudstone - BH-92, depth 1695m, X4**
4. **planktonic foraminifera wackstone - BH-92, depth 1690m, X10**

5. Sequence Stratigraphy and Depositional Environment Modeling

First of all, we must mention the existence of several facts that characterize the Bai Hassan Oil Field, which is the overlap among three basic elements in sequence stratigraphy architecture, these elements are climate, Eustacy (sea level change), as well as accommodation space which were responsible for the production of the sequence stratigraphy that appeared in the studied reservoir, this interference was identified through the appearance of four formations from total nine formations representing the Kirkuk group in the study area. The Oligocene is a period of coldness. The globe, and what was known as Ice houses appeared, this case was referred to by many references such as [35, 36, 37], which were inferred by the disappearance of plankton foraminifera in contrast to the increases in the number of benthonic foraminifera.

The depositional environment of the studied formations and the analysis of their facies components showed that they were deposited within the three parts of the ramp environment, where the Palani formation was deposited in the deeper part from the outer ramp, while the Tarjil Formation was deposited at the distal part of upper slope area from middle ramp environment. The Baba Formation was deposited on the swelling parts of the approximal part

of the middle ramp, and it reached a distal part of the inner ramp. The Bajawan Formation with its two parts was deposited at the approximal part from the inner ramp environment (Figure 5). The ramp depositional environment of studied formations from nearby Kirkuk Oilfield was suggested by [38], and also from the Zagros basin of Iran by [39].

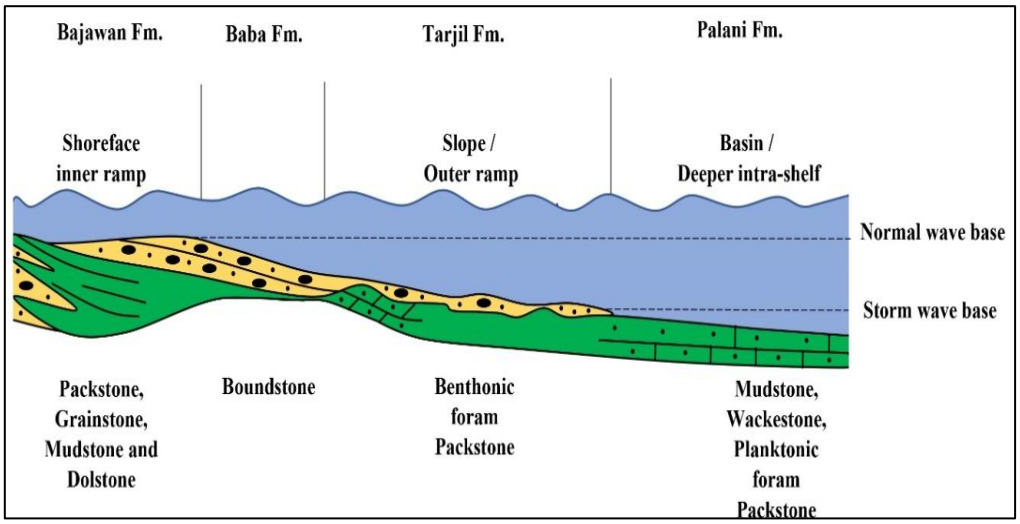


Figure 5 : Depositional environments models for studied succession.

The influence on the climate in the study area was not rapid and not sudden changes, the evidence for this is the presence of Palani formation at the Daoud area, in the lower part of which an MFS (Figure 6) as a sequence boundary type three was distinguished at the end of TST stacking pattern, this boundary characterized by the accumulation of planktonic foraminifera, while this boundary did not appear at either Shashal or Kithka area respectively because Palani Formation is an absence at the two areas, also it should be noted that the basinal character formation from Kirkuk group appears at Kirkuk oilfield adjacent to the studied oilfield, as well as some of these formations disappear at Khabaz oilfield, which is an oil field adjacent to the Kirkuk Oil Field [38, 40]. This evidence shows that the influence of the climate (Icehouse) was not significant at the early Oligocene in the study area, at least, but its effect on the sea level was very clear. Therefore, it was found a mix of an accumulation from a very small number (at Daoud area) of planktonic foraminifera with an increased number of benthonic foraminifera in the Tarjil Formation, and the planktonic foraminifera disappeared.

The Tarjil Formation at Daoud and Shashal areas is characterized by large benthonic foraminifera and represents the HST pattern (Figures 7 & 8), this disappearance of planktonic foraminifera from the sediment of the Tarjil Formation refers to the fact that the effect of Icehouse was at its pears and the disappear Tarjil Formation at Kithka area refer to no available positive accommodation. The Baba formation revealed a different pattern from system tracts (Figure 5-28) in the three parts of the study areas the response to the interaction between the change in sea level to the two facies of accommodation either positive and negative face, both factors affected by the tectonic subsidence or uplift, the tectonic subsidence helped. in the presence of the TST Pattern with two types of sequence boundary.

The growth of Patches of coral in the higher parts of the basin at the late HST due to the instability of basin topography as a response to the tectonic effect at the Daoud area, which represents the deeper part of the studied area. The Shashal and Kithka areas which represented the shallow parts compared to the Daond area revealed an HST pattern, and the growth of Coral Patches and accumulation of large benthonic foraminifera, with the complete disappearance of

planktonic foraminifera, this disappearance was not due to Icehouse, but due to the instability of the sedimentary basin. With the development of the sedimentary basin at fate Oligocene under tectonic instability influence and its different topography produces as well as the influence on the sea level, also with the end of Icehouse effect on the study area the sediments of the Bajawan Formation were deposited at the three parts of the study area. The Daoud and Kithk areas characterized at the early LST pattern by packstone microfacies as well as dolostone, those two facies were improved the reservoir quality at the lower part of the Bajawan Formation, while the late HST Pattern was responsible for Shashal and Kithka areas from the improve the reservoir quality through the packstone microfacies as well as dolostone, with the late LST pattern the Shashal area characterized through the grainstone, while, the Kithka area characterized by mudstone in addition to grainstone microfacies, also Daoud area revealed the same two microfacies.

The similarity between the distribution of the same microfacies at the Kithka and Daoud areas refers to the fact that the Shashal area was higher than these two areas which means that the Shashal area was uplifted at the end of the Oligocene. These differences among the three parts of the study area toward the tectonic and its responsibility from accommodation availability as well as the sea level change were continued to the end of the Oligocene due to compressional tectonics influence on the study area along the Oligocene [41, 42, 35].

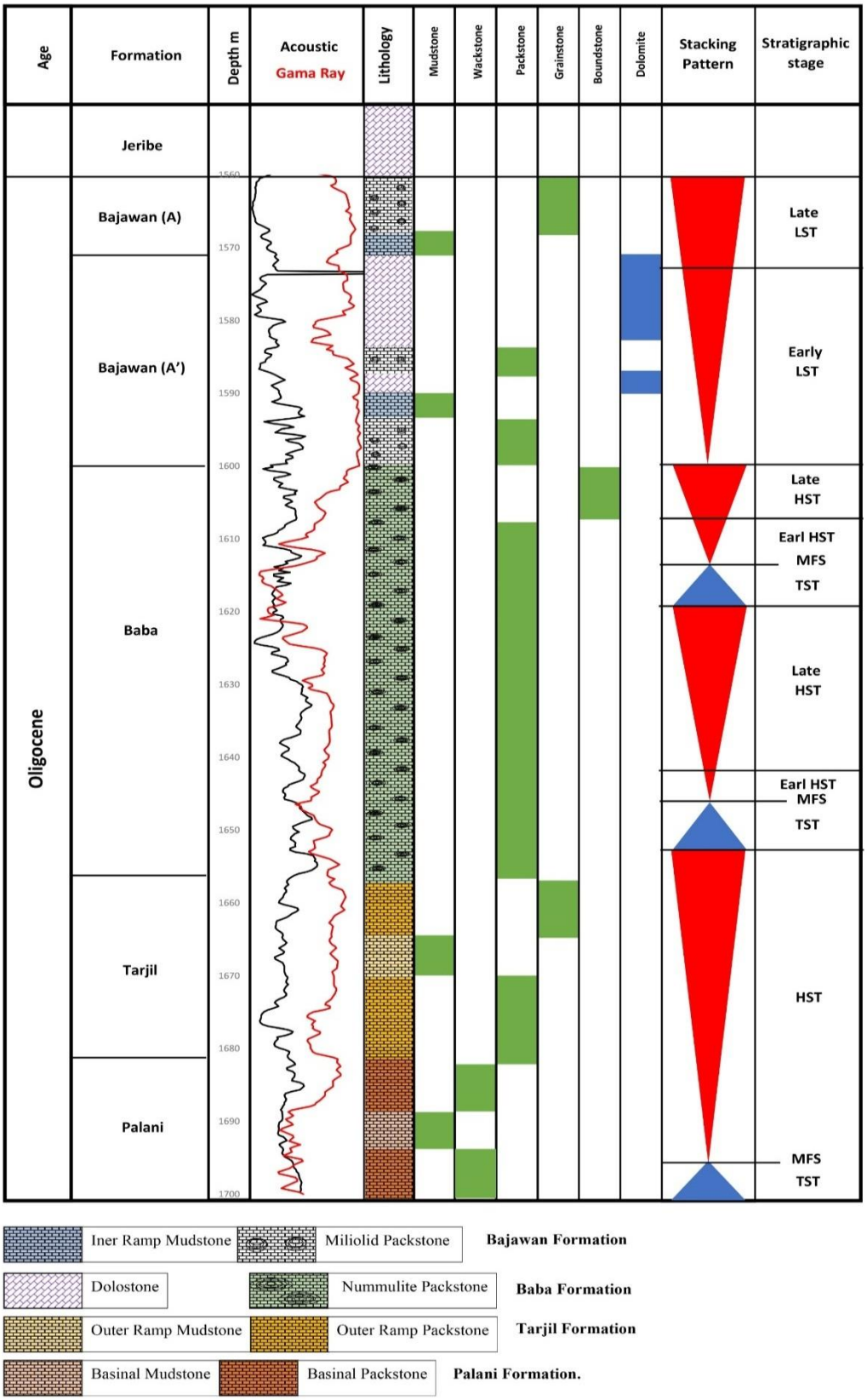


Figure 6 : Reveal the microfacies distribution and stacking pattern at Daoud area within Bai Hassan oil field (BH-92)

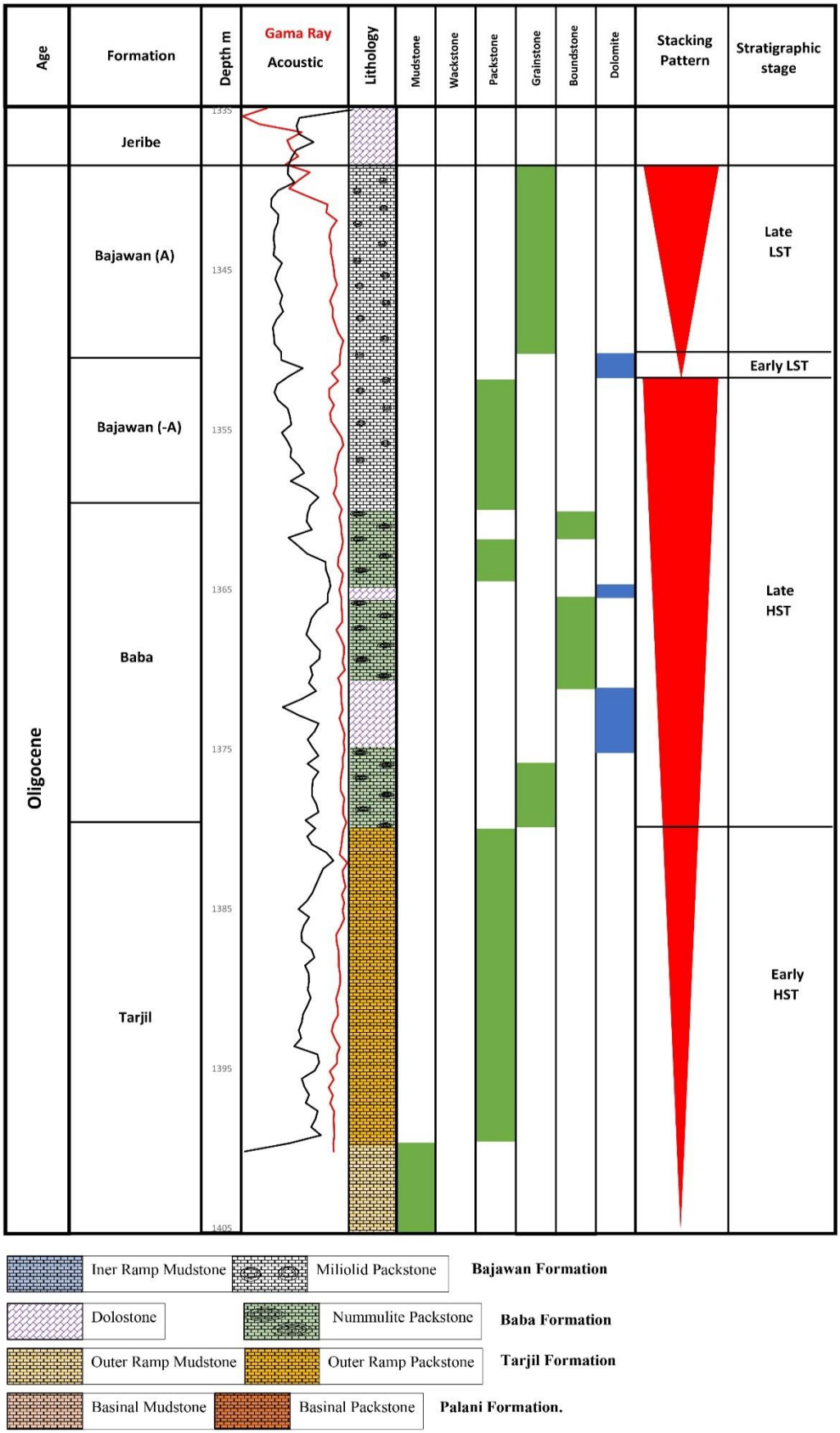


Figure 7: Reveal the microfacies distribution and stacking pattern at Shashal area within Bai Hassan oil field (BH-122)

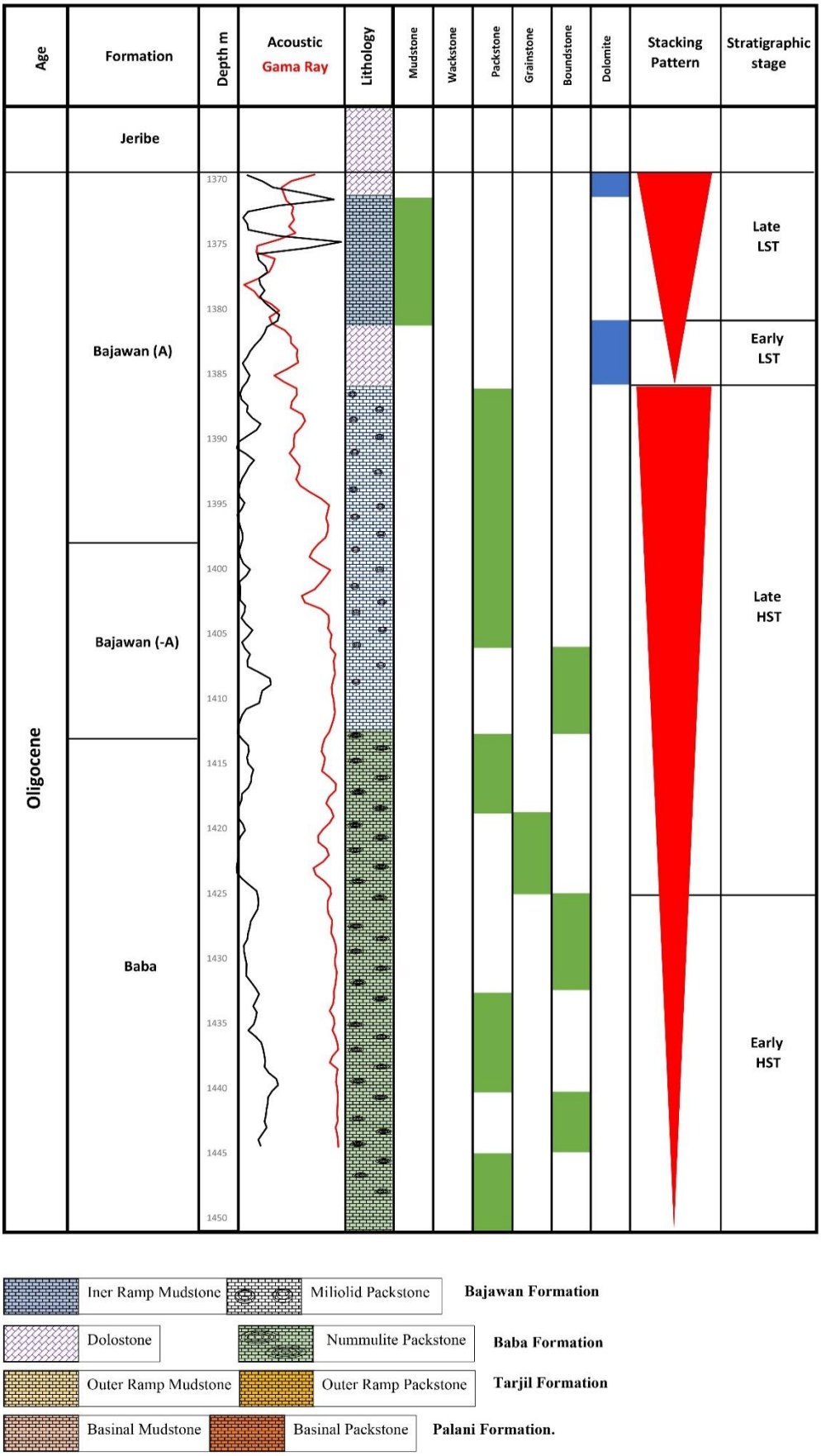


Figure 8: R Microfacies distribution and stacking pattern at the Kithka area within the Bai Hassan oil field (BH-20)

6. Conclusions

The current study focused on microfacies analysis to interpret the stratigraphic sequence of the Palani Formation (early – lower Oligocene age), Baba, Bajawan and Tarjil Formations (middle Oligocene age).

Bajawan Formation consists basically of five microfacies easily recognizable throughout the thin section. These microfacies are Lime Mudstone Microfacies, Miliolid Packestone Microfacies, Miliolid Grainston Microfacies, and dolostone Microfacies. The Baba Formation comprises four microfacies that are diagnosed by the study of the thin section, these microfacies are Rutalia - Nummulites Packstone Microfacies, Coral Boundstone Microfacies, and Dolostone Microfacies. Two microfacies have been recognized in Tarjil Formation, there are Lim Mudstone Microfacies and Planktic foraminiferal packstone microfacies. Two microfacies that have been recognized in Tarjil Formation are Lime Mudstone Microfacies and Planktonic foraminifera Wackstone-Packston Microfacies.

The depositional environment of the studied formations and the analysis of their facies components showed that they were deposited within the three parts of the ramp environment, where the Palani formation was deposited in the deeper part from the outer ramp during TST and HST stages, while the Tarjil Formation was deposited at the distal part of upper slope area from middle ramp environment during HST stage. The Baba Formation was deposited on the swelling parts of the approximal part for the middle ramp at the lower part (TST), and it reached separately by MFS from the distal part of inner ramp sediments which was deposited during HST as two cycles. The Bajawan Formation with its two parts was deposited at the proximal part from the inner ramp environment during the early and late HST stage.

References

[1] R. C. Van Bellen, "The Stratigraphy of the 'Main Limestone'of the Kirkuk, Bai Hassan and Qarah Chauq Dagh structure in the north Iraq," *Journal Institute of Petroleum*, vol. 42, no. 393, pp. 233-263,1956.

[2] S. Z. Jassim and J. C. Goff, "Geology of Iraq". Dolin. 341p., 2006.

[3] V. Ditmar, and Iraqi-Soviet Team, "Geological conditions and hydrocarbon prospects of the Republic of Iraq". Vol. II, South Iraq. Manuscript report, INOC, 1972.

[4] M. A. Ismail, "Reservoir Characterization of the Tertiary Reservoir in Small Giant Bai Hassan Oil Field, Northern Iraq ". Engineering and Applied Sciences Department of Petroleum Engineering, Unpublished thesis, 194p., 2011.

[5] T. Buday, "Regional Geology of Iraq: Vol. 1, Stratigraphy and paleogeography". IIM Kassab and SZ Jassim (Eds). DG of Geological Survey and Mineral Investigation. 445p., 1980.

[6] H.A.J. Al-Hashimi and R.M. Amer, "Tertiary Microfacies of Iraq". GEOSURV, Baghdad, Iraq, 56pp., 1985.

[7] H. V. Dunnington," Generation, accumulation, and dissipation of oil in Northern Iraq". In Weeks, L. G. (ed.) Habitat of Oil, AAPG, Tulsa, Oklahoma, USA, p. 1194-1251, 1958.

[8] T. Buday, and S. Z. Jassim, "The Regional Geology of Iraq". Vol.2: Tectonism, Magmatism and Metamorphism. Publication of GEOSURV, Baghdad, 352p., 1987.

[9] J. Makris; C. H. Henke, "Pull-apart evolution of the Red Sea". *Journal of Paetroleum Geology*, vol. 15, pp.127-134, 1992.

[10] G. W. Hughes and Z. R. Beydoun, "The Red Sea-Gulf of Adan: Biostratigraphy, lithostratigraphy and palaeoenvironments". *Journal of Petroleum Geology*, vol. 15, pp.135-156, 1992.

[11] P. R. Sharland; R. Archer; D. M. Casey; R.B. Davies; S.H. Hall; A.P. Heward; A.D. Horbury and M. D. Simmons, "Arabian Plate Sequence Stratigraphy". GeoArabia, special publication, Gulf Petrol. Ink, Bahrain, 321p., 2001.

[12] M. K. Verma, T. S. Ahlbrandt and M. Al-Gailani, "Petroleum reserves and undiscovered resources in the total petroleum systems of Iraq: reserve growth and production implications". GeoArabia, vol. 9, no. 3, 2004. Gulf Petrolink, Bahrain, 2004.

[13] S.F. Fouad, "Tectonic Map of Iraq, Scale 11000,000". 3rd Edition, Iraq Geological Survey Publications, Baghdad, 2012.
[14] R.C.V. Bellen; H. Dunnington; R. Wetzel and D. Morton, "Lexique Stratigraphique, Interntional". Asie, Iraq. 333p., 1959.
[15] A. H. Majid, J. A. N. Veizer, "Deposition and Chemical Diagenesis of Tertiary Carbonates, Kirkuk Oil Field, Iraq". AAPG Bulletin, 70, pp.898-913, 1986.
[16] K. M. Al-Naqib, "*Geology of the southern area of Kirkuk Liwa, Iraq". 2nd Arab Petroleum Congress, Beirut*, 2, pp. 45-81, 1960.
[17] M. A. Menshed, & A. A. H. Al-Zaidy, "Sedimentary Basin Reconstruction and Tectonic Development of Paleocene-Eocene Succession, Southern Iraq, by Geohistory Analysis". *Iraqi Journal of Science*, vol. 62, no. 4, pp. 1213–1225, 2021.
[18] H. Sh. Aoudah; A. A. H. Al-Zaidy and H. A. F. Al-Tarim, "Stratigraphy and Basin Development of the Oligocene-Early Miocene Succession, Southeastern Iraq". *Iraqi Journal of Science*, vol. 63, no. 7, pp. 2987-3001, 2022.
[19] V. Ditmar and Iraqi-Soviet Team, "Geological conditions and hydrocarbon prospects of the Republic of Iraq (Northern and Central parts)". Manuscript report, INOC Library, Baghdad, 1971.
[20] N.Y. Al-Banna, "Oligocene / Miocene boundary in northern Iraq". *GeoArabia, Gulf PetroLink, Bahrain*, vol. 13, no. 2, 2008.
[21] F. R. S. Henson, "Cretaceous and Tertiary reef formations and associated sediments in Middle East". *American Association of Petroleum Geology Bulletin*, vol. 34, pp.215–238, 1950.
[22] R.J. Dunham, "Classification of carbonate rocks according to depositional texture. Classification of carbonate rocks". *American Association of Petroleum Geologists Memoir*, vol. 1, pp.108-121, 1962.
[23] A. F. Embry and J. E. Klovan, "A Late Devonian reef tract on northeastern Banks Island, NWT". *Bulletin of Canadian Petroleum Geology*, 19, 730p., 1971.
[24] J. L. Wilson, "Carbonate Facies in Geologic History". Springer Verlag. 471p., 1975.
[25] E. Flugel, "*Microfacies of carbonate rocks-analysis, interpretation and application" (second edition). Springer, Berlin*, 1006 p., 2010.
[26] L. Hottinger, "Recherches sur les Alv´eolines du Pal´eoc`ene et del' ´ Eoc`ene". Schweiz Pal¨aontol Abh. 75, pp.1–243, 1960.
[27] J. Romero; E. Caus and J. Rossel, "A model for the paleoenvironmental distribution of larger foraminifera based on late Middle Eocene deposits of the margin of the south Pyrenean basin (NE Spain)". *Palaeogeography, Palaeoclimate and palaeoecology*, vol. 179, pp. 43-56, 2002.
[28] L. Hottinger "Répartition comparée des grands foraminifères de la mer Rouge et de l'Océan Indien". Annali dell'Università di Ferrara, 6: pp. 35–51, 1980.
[29] J. Hohenegger, "Remarks on the distribution of larger foraminifera (Protozoa) from Palau (western Carolines), in Aoyama T., (ed.), The progress report of the 1995 survey of the research project, Man and the environment in Micronesia". Kagoshima University Research Center for the Pacific Islands, Occasional Papers, 32: pp.19–45, 1996.
[30] Hallock, P., 1999. Symbiont bearing foraminifera, in Sen Gupta B.K., (ed.) Modern Foraminifera: Dordrecht. Kluwer, pp. 123–139.
[31] Z. Reiss and L. Hottinger, "The Gulf of Aqaba". Ecol. Micropaleontol. pp. 501-354, 1984.
[32] S. Leutenegger, "Symbiosis in benthic foraminifera, specificity and host adaptations". *J. Foram. Res*., vol. 14, pp. 16–35, 1984.
[33] S.J. Beavington-Penney and A. Racey, "Ecology of extant nummulitids and other larger benthic foraminifera: applications in paleoenvironmental analysis". *Earth Sci. Rev*., vol. 67, pp. 219–265, 2004.
[34] M.E. Tucker; V. P. Wright and J. Dickson, "Carbonate sedimentology". Wiley-Blackwell, 1990.
[35] F.N. Sadooni and A. S. Alsharhan, "Regional stratigraphy, facies distribution, and hydrocarbons potential of the Oligocene strata across the Arabian Plate and Western Iran". Carbonates and Evaporites volume 34, pp. 1757–1770, 2019.
[36] O. Brien; L. Charlotte; M. Huber; E. Thomas; M. Pagani; R. Super, James; E.E. Leanne and M. H. Pincelli, "Oligocene Biomarker Temperature Estimates from ODP Hole 154-929A and DSDP Hole 75-516F. PANGAEA, https://doi.org/10.1594/PANGAEA.922997, 2020.

[37] Andrew T.Lin, Chih-Cheng Yang, Ming-Huei Wang, Jong-Chang Wu, "Oligocene-Miocene sequence stratigraphy in the northern margin of the South China Sea: An example from Taiwan". *Journal of Asian Earth Sciences*, vol. 213, 15, 2021.

[38] H.N. Farhan; L.S. Kadem and Q.A. Mohammed, "Microfacies and depositional environment of Bajawan and Baba Formations in Kirkuk Oil fields north Iraq". *Tikrit Journal of Pure Science*, vol. 21, no. 6, pp. 112-125, 2018.

[39] F. N. Karimvand; R. Moussavi-Harami and A. Mahboubi, "Depositional Environment and Sequence Stratigraphy of the Oligocene-Miocene Deposits North and East of Dehdasht, Izeh Zone, Zagros Basin, Iran". *Journal of Sciences, Islamic Republic of Iran* (JSCIENCES), vol. 30, no. 2, pp.143 -166, 2019.

[40] H. A. Mahdi, M. Sh. Al-Kubaisi and S. N. Al-Jawad, "Structural Study of the Late Oligocene-Early Miocene Sequence in Khabaz Oil Field, NE of Iraq". *Iraqi Geological Journal*, vol. 55, (1F), pp.70-80, 2022.

[41] S. S.J. AL-Sheikhly, M. Tamar-Agha M. M. Mahdi, "The facies analysis of the Cenomanian – Turonian succession of Surdash –Shaqlawa area, NE. Iraq". *Iraqi Journal of Science*, vol. 56, no.(1C), pp. 767-773, 2015.

[42] Y. S. Al-Jwaini, A. D. Gayara, "Upper Palaeogene-Lower Neogene Reservoir Characterization in Kirkuk, Bai Hassan and Khabaz Oil Fields, Northern Iraq". *Tikrit Journal of Pure Science*, vol. 21, Issue 3, pp. 86-101, 2016.