Iraqi National Journal of Earth Science
www.earth.mosuljournals.com

Microfacies Analysis and Depositional Environment of Baba Formation in Selected Wells from Kirkuk Oil Field, Northeastern Iraq

Rania T. Simo[1] , Zaid A. Malak[2*] ,`Qahtan M. Hussain[3] , Saad A. Mahmood [4]
[1,2] *Department of Geology, College of Science, University of Mosul, Mosul, Iraq.*
[3,4] *Department of Geology, North Oil Company, Kirkuk, Iraq.*

Article information

Received: 16- Mar -2023

Revised: 28- May -2023

Accepted: 12- June -2023

Available online: 31- Dec – 2023

Keywords:
Facies Analysis
Baba Formation
Kirkuk
Carbonate ramp
Iraq

Correspondence:

Name: Zaid A. Malak

Email:
zaidmalak@unmosul.edu.iq

ABSTRACT

Abstract: The Baba Formation succession (Middle-Late Oligocene) is studied within the wells (K-1) and (K-2) in Kirkuk oil field, northeastern Iraq. The formation thickness in the first well is about (45) meters and in the second well is about (65) meters respectively. The formation consists of hard limestone, brown in color and dolomitic limestone. The formation consists of many benthic foraminifera as (Miliolid) and planktonic foraminifera as (*Globigerina aselli*, *Globigerina ampliapertura*, *Globigerina praebulloides*, *Catapsydrax dissimilis*, *Chilogumbelina* sp., *Globigerina ciperoensis*, *Paragloborota liaopima)*, In addition to *Nummulites fichteli*, *Nummulites vascus* and a few of *Lepidocyclina* sp., echinoderms, bryozoa, and algae, and their fragments. The Microfacies appear to be highly affected by many diagenesis processes such as dolomitization, compaction, cementation, dissolution and recrystallization. The formation is composed of three main microfacies, which in turn are divided into (11) secondary microfacies whose general characteristics are similar to the characteristics of the microfacies proposed by Flugel, namely (RMF-2, RMF-3, RMF-5, RMF-7, RMF-13, RMF-16). Based on the results of the microfacies analysis, it is found that the sedimentary environment of the Baba Formation is the carbonate ramp environment, as the facies of the Baba Formation spread within the restricted environment of the inner ramp, which was characterized by the spread of the millolid fossils to the middle ramp environment with the distribution of *Nummulites* shells, and towards the outer ramp with the presence of planktonic foraminifera.

DOI: 10.33899/earth.2023.139055.1057, ©Authors, 2023, College of Science, University of Mosul.

التحليل السحني الدقيق والبيئة الترسيبية لتكوين بابا في ابار مختارة من حقل كركوك النفطي، شمال شرقي العراق

رانيا تحسين سمو [1] ، زيد عبدالوهاب ملك [2]* ، قحطان محمد حسين [3] ، سعد أحمد محمود [4]

[1, 2] قسم علوم الارض، كلية العلوم، جامعة الموصل، الموصل، العراق.

[3, 4] قسم علوم الارض, شركة نفط الشمال, كركوك, العراق.

معلومات الارشفة

تاريخ الاستلام: 16– مارس –2023

تاريخ المراجعة: 28– مايو –2023

تاريخ القبول: 12– يونيو –2023

تاريخ النشر الالكتروني: 31– ديسمبر –2023

الكلمات المفتاحية:

التحليل السحني

تكوين بابا

كركوك

المنحدر الكاربوناتي

العراق

المراسلة:

الاسم: زيد عبدالوهاب ملك

Email: zaidmalak@unmosul.edu.iq

الملخص

تمت دراسة تتابعات تكوين بابا(Middle -Late Oligocene) من الناحية الرسوبية ضمن البئرين (K-1) و(K-2) في حقل كركوك النفطي، شمال شرقي العراق. اذ يبلغ سمك التكوين في البئر الأول حوالي (45) متراً وفي البئر الثاني حوالي (65) متراً على التوالي. يتالف التكوين من الحجر الجيري الصلب، بني اللون والحجر الجيري المتدلمت. بتروغرافيا، تتالف صخور التكوين الجيرية من العديد من اصداف الفورامنيفرا القاعية (Miliolid) واصداف الفورامنيفرا الطافية (Globigerina aselli, Globigerina ampliapertura, Globigerina praebulloides, Catapsydrax dissimilis, Chilogumbelina sp., Globigerina ciperoensis, Paragloborota liaopima) واصداف متحجرات النيوميولايت (Nummulites fichteli, Nummulites vascus) والليبيدوسايكلينا وشوكيات الجلد والبرايوزوا والطحالب إضافة الى فتاتاتها. تظهر سحنات التكوين تاثرها الشديد بالعديد من العمليات التحويرية مثل عملية الدلمتة والتضاغط والسمنتة والاذابة وإعادة التشكل.

سحنيا يتالف التكوين من ثلاث سحنات رئيسة، والتي قسمت بدورها الى (11) سحنة ثانوية تشابهت صفاتها العامة مع صفات السحنات الدقيقة المقترحة من قبل فلوكل وهي (RMF-2 , RMF-3 , RMF-5, RMF-7 , RMF-13 , RMF-16) . اعتماداً على نتائج التحليل السحني لصخور التكوين، تبين ان البيئة الترسيبية لتكوين بابا هي بيئة المنحدر الكاربوناتي، اذ انتشرت سحنات تكوين بابا ضمن البيئة المقيدة والبحر المفتوح للمنحدر الداخلي والذي تميز بانتشار اصداف متحجرات المليولد الى بيئة وسط المنحدر بأنتشار اصداف النيوميولايت وباتجاه المنحدر الخارجي بوجود اصداف الفورامنيفرا الطافية.

DOI: 10.33899/earth.2023.139055.1057,

Introduction

The first oil well was drilled in Iraq in 1927 specifically in the Baba dome, where oil was discovered in large commercial quantities in the giant Kirkuk field, and this was considered the first huge discovery of oil in the Middle East and the most important event in the modern history of Iraq. The Kirkuk oil field is considered one of the oldest oil fields in Iraq. The main limestone reservoir sequences in its fields contain large reserves of hydrocarbons in Iraq, especially the formations deposited in the environments of reefs in the Kirkuk area. The typical section of the Baba Formation is located in the Kirkuk well K-109 (Bellen, 1956). The name of the formation is derived from the dome of Baba with which this well was drilled in the city of Kirkuk in northeastern Iraq. The formation generally consists of dolomitic limestone, as the thickness of the formation in its typical section is about 20 meters, and it may reach 90 meters in other wells. Henson (1950) has described the limestone rocks in Kirkuk oil field and indicated that it is a complex of coral reefs, and he showed that these deposits are important for oil generation, accumulation and storage because they contain primary and secondary porosity.

Bellen et al. (1959) has divided the Oligocene section based on their relative stratigraphic position rather than age diagnostic fossils to three sequences of assumed Early, Middle and Late Oligocene age. Depending on the difference in type of lithology, Ditmar et. al. (1971) has divided the Oligocene sedimentary cycle into two sub-cycles. The lower cycle consists of Sheikh Alas, Shura, Palani, and Tarjil Formations, and the upper cycle consists of Anah, Bajwan, Azkend, Baba, and Ibrahim Formations. They indicated that the Baba Formation represents the northeastern edge of the Oligocene Basin.

Al-Qayim and Khaiwka (1980) divided the Oligocene sequence in Kirkuk oil field into two reef cycles, each cycles consists of three facies. The back reef/reef facies represented by the Bajwan and Shurau Formations; the forereef facies represented by Baba and Sheikh Alas Formations; and the basinal facies represented by Tarjil and Palani Formations.

Abid (1983) conducted a subsurface study of the Oligocene group in the western desert of Iraq and changed the upper Oligocene cycle and stated that it extends to the early Miocene (Aquitanian) and considered that the formations Anah, Azqand and Ibrahim were deposited within (Upper Oligocene - Lower Miocene).

Majid and Veizer (1986) studied the nature of sedimentation and the chemical processes of limestone rocks in the Tertiary period of the Kirkuk group, and determined the age of the Kirkuk group as early and middle Oligocene, as the early Oligocene layers include the coral reefs of Shurau, Sheikh Allas and Palani Formation, which represent an environment in front of the reef, while the middle Oligocene beds include on the Bajwan Formation (back reef), the Baba Formation (reef), and the Tarjil Formation (fore reef). El Eissa 1(992) studied the formations of the Kirkuk Group in the Kirkuk oil field and divided them into the Early Oligocene, which includes (Palani, Sheikh Allas, and Shurau formations), and the Late Oligocene, which includes (Tarjil, Baba, and Bajwan formations). Kharajiany (2008) and Al-Banna (2008) described the sedimentary facies of the Oligocene sequences in Ashdag Mountain in Sinjar, northern Iraq, and indicated that the age of the Baba Formation is the Middle Oligocene. Ghafur (2012) studied the succession of the exposed and subsurface beds of the fossiliferous limestone (Baba Formation) in the Kirkuk area, and showed that these beds were deposited in a shallow open marine environment during the period from Chattian to Aquitanian. Also he studied the microfossils and stratigraphy of the Baba Formation in the Bai Hassan 25 oil well in the Kirkuk area, northern Iraq, as he showed that these rocks were deposited in shallow and open marine environment during the late Oligocene. Then Ghafor *et.al*. (2014) conducted a biostratigraphic study of the Oligocene successions in the High Folds region of Sulaymani in the Kurdistan region, northeastern Iraq, and identified many species of benthic and planktonic foraminifera fossils.

Karim *et. al*. (2014) studied the stratigraphy of (Oligocene - early Miocene) formations in the Sinjar area, northwest of Iraq, and showed that the Baba Formation is exposed in the Qara Jogh anticline, especially in deep valleys. Al-jwaini (2015) studied the hydrocarbon reservoir units of wells in the Kirkuk oilfield, and showed that they consist of four reservoir units that covered the formations of the Oligocene, including the Baba Formation, and diagnosed several types of porosity such as the intergranular, intercrystalline, fractures, channels, moldic and vuggy porosity. Farhan *et. al.* (2016) have diagnosed two main microfacies, and based on these microfacies, sedimentary environments were identified, which were represented by the fore reef environment. Karim and Ahmad (2019) studied the Oligocene sequences in Dohuk Governorate, Kurdistan Region, northern Iraq, by drawing geological maps, and indicated the presence of about (20-30) meters of Oligocene rocks from the Kirkuk group. Ghafor and Ahmad (2021) studied the stratigraphy of the Oligocene and Early Miocene in the Darzilla section in the Sangaw area of Kurdistan in northeastern Iraq, and recorded the occurrence of the Baba Formations in this area.

The aims of the study are to deduce the sedimentary environment through the results of the microfacies analysis up to drawing the sedimentary model.

Geological Setting

The study area is located within Kirkuk Governorate, in the northeastern part of Iraq, where the giant Kirkuk oil field is located about 147 km southeast of Mosul. The Kirkuk field extends along a northwest-southeast direction, with a length of 97 km and a width of 4 km. The structure of the Kirkuk field consists of three domes, which are (from northwest to southeast) Khurmala dome - Avana dome - Baba dome (Al-Hayali, 2019). Baba dome is about 16 km away from the Arafa area near the center of the city of Kirkuk. The current study relied on the selection of two oil wells from the Kirkuk oil field from Baba dome, which include well (K-1) and well (K-2) (Figure 1):

1- Well (K-1) is one of the important oil wells in northeastern Iraq in Kirkuk Governorate, which is located at the intersection of longitude (E 44° 18' 21.32") with latitude (N 35° 32' 42.21"). The succession of the Baba Formation in this well is limited to depths of (421-466) meters, and thus the thickness of the Baba Formation in this well is (45) meters.

2- Well (K-2) is the second well that chosen within the Kirkuk field in northeastern Iraq. This well is located at the intersection of longitude (E 44° 26' 51.97") and latitude. (N 35° 25' 24.60"), and the formation of Baba is limited to this well, between depths (917-982) meters and a thickness of (65) meters.

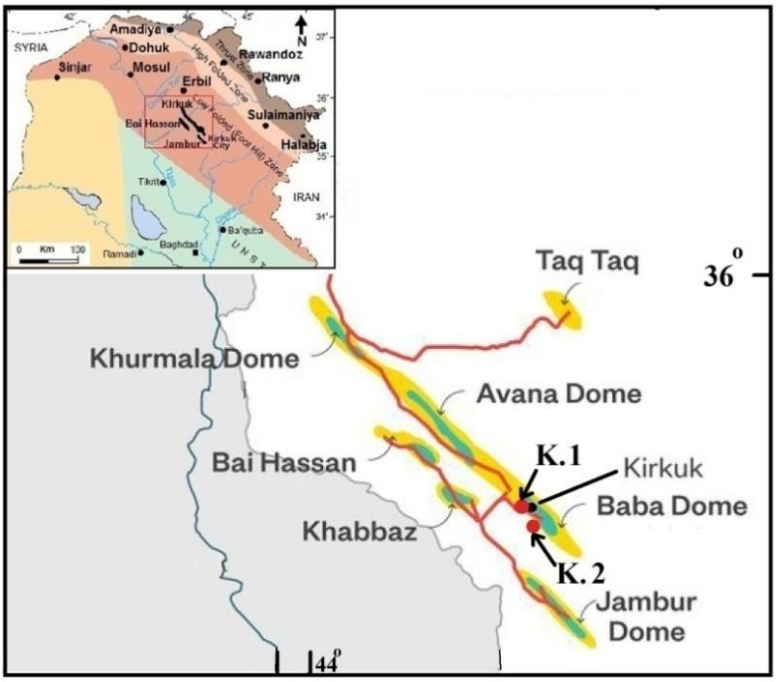

Fig. 1. Location map of the study area (http // Kurdistan oil and gas activity)

Materials and Methods

Several geological methods are used to complete the requirements of the current study, the most prominent carrying out multiple visits to the North Oil Company, Kirkuk, to view the final complete reports on the selected wells for this study. Conducting a detailed description of the Baba Formation sequences of the study wells, including measuring the thickness of the formation as a whole, as well as determining its rock characteristics such as hardness and color.

Moreover, taking a rock sampling from the formation from different depths that are not covered by slides, and making thin sections for them, where (26) thin sections are chosen from the formation in the well (K-1) in addition to (130) thin sections from the well (K-2). These slides are examined under a polarizing microscope and described accurately to determine their exact components in order to give names to their microfacies and to compare them with the standard microfacies of Flügel (2010) to infer the sedimentary environment of the formation.

Results

Lithological description of Baba Formation

The present study is based on two wells, the first is (K.1) with total thickness of about 45m of the Baba Formation. The formation extends between depths (421-466 m.). The formation generally consists of brown, medium-sized crystals hard limestone and dolomitic limestone. Subsequent studies have shown that it is subjected to many diagenetic processes (recrystallization in some parts and dolomitization) and has clear vuggy porosity. The formation is also characterized by containing many fossils (in thin sections) such as miliolids, echinoids, bryozoan, as well as *Lepidocyclina* and *Nummulites*. The second well (K.2), where the thickness of the formation is (65) meters, and it lies between depths (917-982 m.). The formation generally consists of limestone and dolomitic limestone. According to reports seen in the North Oil Company, the formation is generally porous and contains oil. The formation rocks were are characterized by their impact on many diagenetic processes that will be mentioned later. The formation is also characterized by the prevalence of fossils (in thin sections) as (*Lepidocyclina*), planktonic foraminifera, and echinoid detritus, as well as *Rotalia* and *Nummulites* (Figs. 2 and 3).

Microfacies Analysis

The complete petrographic analysis of carbonate rocks of the Baba Formation revealed that these rocks could be categorized into 3 microfacies subdivided to 11 submicrofacies (Figures 2, 3).

1. Lime Mudstone Microfacies M

This facies consists of carbonate grains with a small percentage that does not exceed 10% of the components of the rock as a whole. These grains consist of pieces of Milliolid tests, Echinoderms, Bryozoa debris, and shells of *Nummulite* fossils, all of the above components are embedded in a micritic matrix. This microfacies is affected by many diagenetic processes such as compaction, dissolution, dolomitization, recrystallization and cementation. This main microfacies has been divided into four submicrofacies depending on their granule components described as follows:

• Bioclastic Lime Mudstone Submicrofacies M1

The thickness of this microfacies is (2) meters, which are spread in the middle parts of the Baba Formation in the well (K-1) only (Figure 4 a). This microfacies consists of bioclasts belonging to the benthic foraminifera. The fossils are indistinct due to the effect of the diagenetic processes. It is of low percentage that does not exceed (5%) of the proportion of the components as a whole, embedded in a matrix made of micrite. This microfacies is affected by many diagenetic processes, especially dolomitization, in which the texture of floating rhomb dolomite is common, as well as the dissolution process, in which porous channels and intergranular spaces are formed. The process of recrystallization is evident in this facies by the alteration of micrite to microspar. The general characteristics of this microfacies are compared with the characteristics of standard microfacies given by Flügel (2010), and it is found that this microfacies is similar in characteristics to the (RMF-3) facies within the range of facies (Mid Ramp).

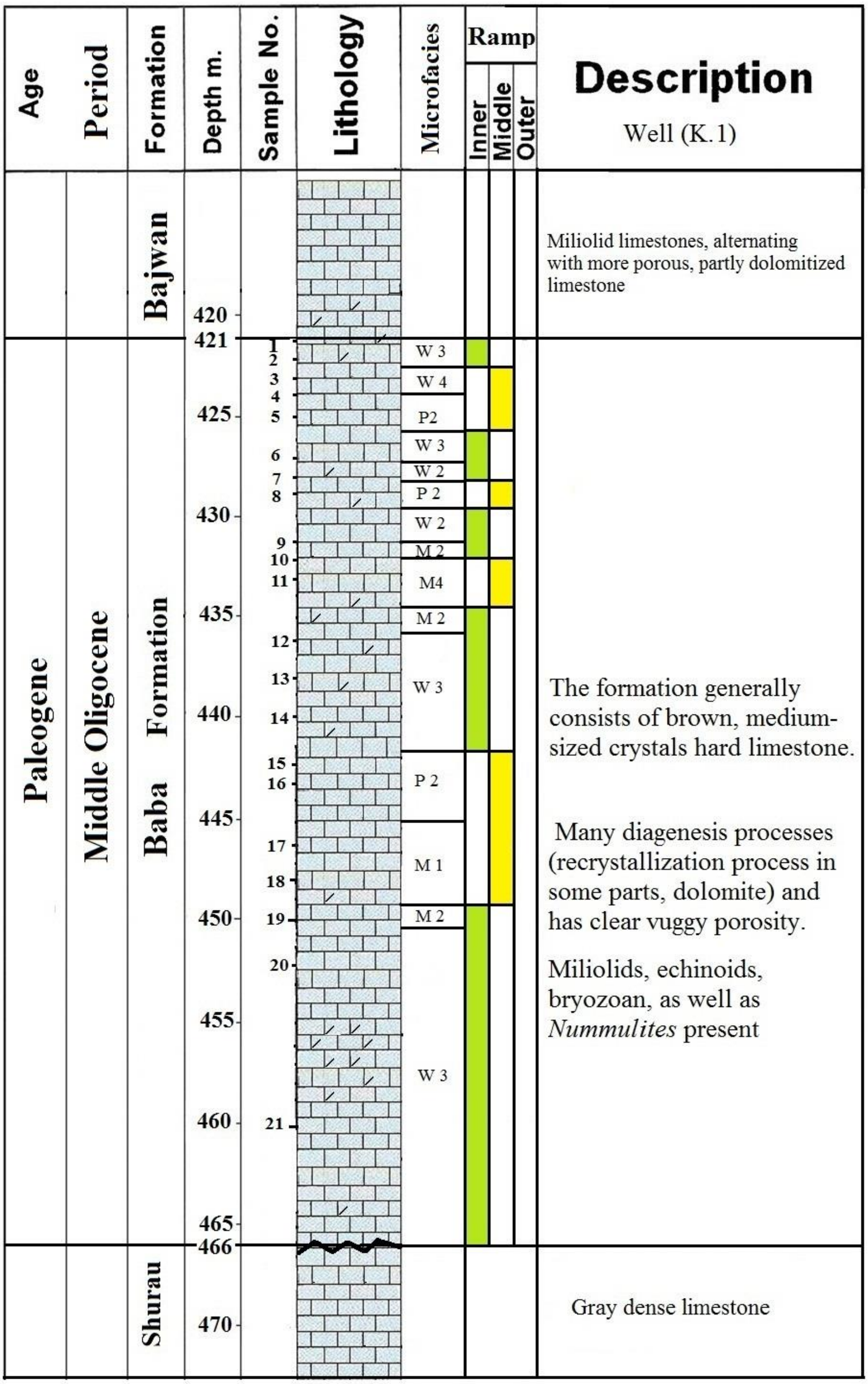

Fig. 2. Stratigraphic columnar section of the Baba Formation in well (K.1).

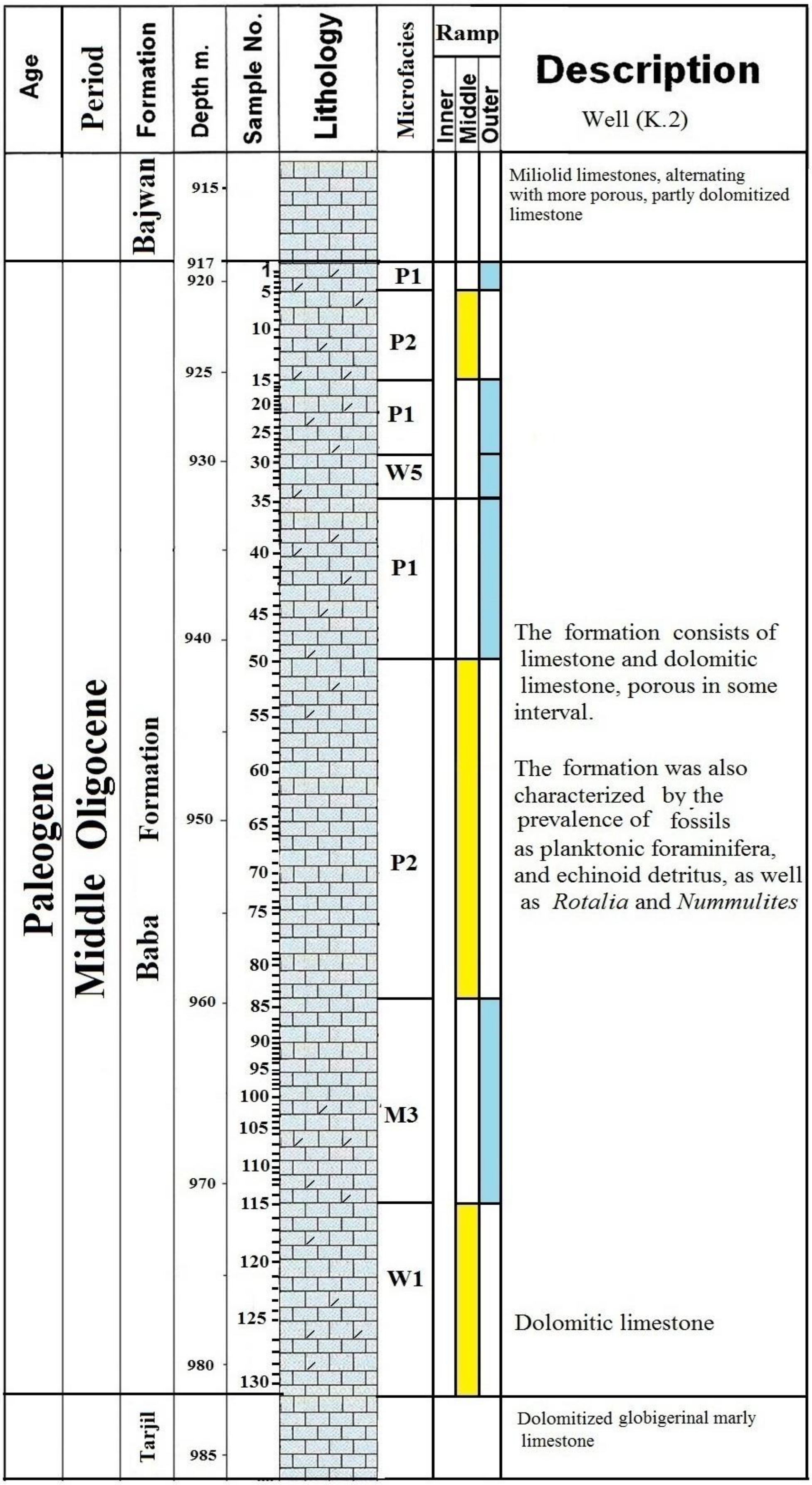

Fig. 3. Stratigraphic columnar section of the Baba Formation in well (K.2).

• Miliolid Lime Mudstone Submicrofacies M2

This microfacies spreads out with a thickness of about three meters distributed in the middle and lower parts of the sequences of the Baba Formation at the well (K-1). This microfacies is characterized by the prevalence of benthic foraminifera (Miliolid) shells, especially *Quinquiloculina* sp., echinoderms and bryozoans, with less than (10%) of the components as a whole embedded in a micritic matrix. This microfacies appears to be highly affected by many diagenetic processes such as dolomitization (fogged, suture mosaic textures), compression, cementation, and dissolution of an intergranular type, also characterized by the presence of stylolite. This microfacies is similar in its characteristics to the (RMF 16) within the facies zone (Inner Ramp), which is represented by the isolated restricted environment, due to the prevalence of (Miliolid) species (Flügel, 2010).

• Non-fossiliferous Lime Mudstone Submicrofacies M3

This microfacies is found in the lower parts of the well (K-2) only with a thickness of about (10) meters. This microfacies mainly consists of the micrite which is devoid of fossil shells. The microfacies is affected by compaction process, where stylolite is found. The presence of stylolite associated with micrite indicates a deep marine environment (Malak et al., 2021; Al-Mansoor, et. al., 2023). This microfacies is similar in its characteristics to the microfacies (RMF 5) within the outer ramp (Flügel, 2010).

• Nummulitic Lime Mudstone Submicrofacies M4

This microfacies is found in the upper parts of the Baba Formation in the well (K-1), with a very small thickness of one meter. This facies consists mainly of skeletal grains represented by the shells of the (*Nummulites Fichteli*), whose shells are well preserved, as well as the presence of a very small percentage of lithoclastic pieces, all of which are embedded within a micritic matrix. This microfacies is similar in characteristics to the microfacies (RMF 2) within the range of facies (Mid-Ramp) (Flügel, 2010).

2. Lime Wackestone Microfacies W

This microfacies generally consists of skeletal particles ranging from (10%-50%) of the contents of the facies as a whole embedded in a micritic matrix. The skeletal grains are the shells of benthic foraminifera fossils such as the (Miliolid) represented by the genera (*pyrgo* sp.) and (*Peniroplis* sp.) and the (*Nummulites*) that are well preserved, and the shells of mollusks, echinoderms and bryozoans, as well as the presence of pieces of coral (Coral) and a few of planktonic foraminifera and red algae, all of them are buried in a micrite which is subjected to a process of recrystallization into microspar. This microfacies was subjected to many diagenetic processes such as cementation, dissolution, and micritization, in addition to the severe dolomitization. This main facies is divided into five submicrofacies as follows:

• Bioclastic Lime Wackestone Submicrofacies W1

The thickness of this microfacies is about (10) meters within the lower parts of well (K-2). This microfacies mainly consists of the bioclasts of the benthic foraminifera represented by the *Nummulites fichteli*, fragments of echinoderms with a percentage of less than (15%) and lithoclasts, in addition to the presence of planktonic foraminifera less than (1%), all of which are buried in the micrite (Figure 4 b). This facies was subjected to dissolution (vuggy and channels). This microfacies is similar in their characteristics to the standard microfacies (RMF 7) within the zone (Mid-Ramp) (Flügel, 2010).

• Miliolid Lime Wackestone Submicrofacies W2

This microfacies consists of the benthic foraminifera represented by the milliolid such as *Quinquiloculina* sp., *pyrgo* sp. *Triloculina* sp., *Austrotrillina* sp.), all of these components constitute less than (40%), in addition to the diagnosis of (*Volvunlina* sp., *Risonaneiza* sp.)

whose percentage did not exceed (3%), with the presence of a few rotalid, green algae and red algae, all embedded in a micritic matrix and microspar (Figure 4 c). The thickness of this microfacies is about one meter in the upper and middle parts of the formation for the well (K-1) only. This microfacies was subjected to many diagenetic processes such as dolomitization, recrystallization, cementation, dissolution and micritization on the outer surfaces of the benthic foraminifer's shells.

This microfacies is similar in their characteristics to the microfacies (RMF 16) within the facies zone (Inner Ramp) (Flügel, 2010).

• Fossiliferous Lime Wackestone Submicrofacies W3

This microfacies occurs in separate parts of the Baba Formation only in well (K-1). This microfacies consists of the skeletal granules represented by the shells of the benthic foraminifera such as Quinquiloculina sp., *pyrgo* sp. *Triloculina* sp., *Austratrillina asmariensis*, *Austratrillina straita*, *Dentritina rangi*, *Lentoculara* sp., *praerchapydionina delicata*), *Peniroplis* sp., *Reuuesella* sp., mollusk shells, bryozoans, and echinoderms, with a percentage of less than (40%). The bioclasts of the benthic foraminifera such as rotalidis, Textularia and red algae with a percentage not exceeding (5%), all of them are buried in matrix of micrite (Figure 4 d). This microfacies was affected by cementation, dissolution and dolomitization (spotted, fogged), and recrystallization. This microfacies is similar in their characteristics to the microfacies (RMF 13), which is represented by the restricted marine environment isolated from the miliolid and the open sea within the facies (Inner Ramp).

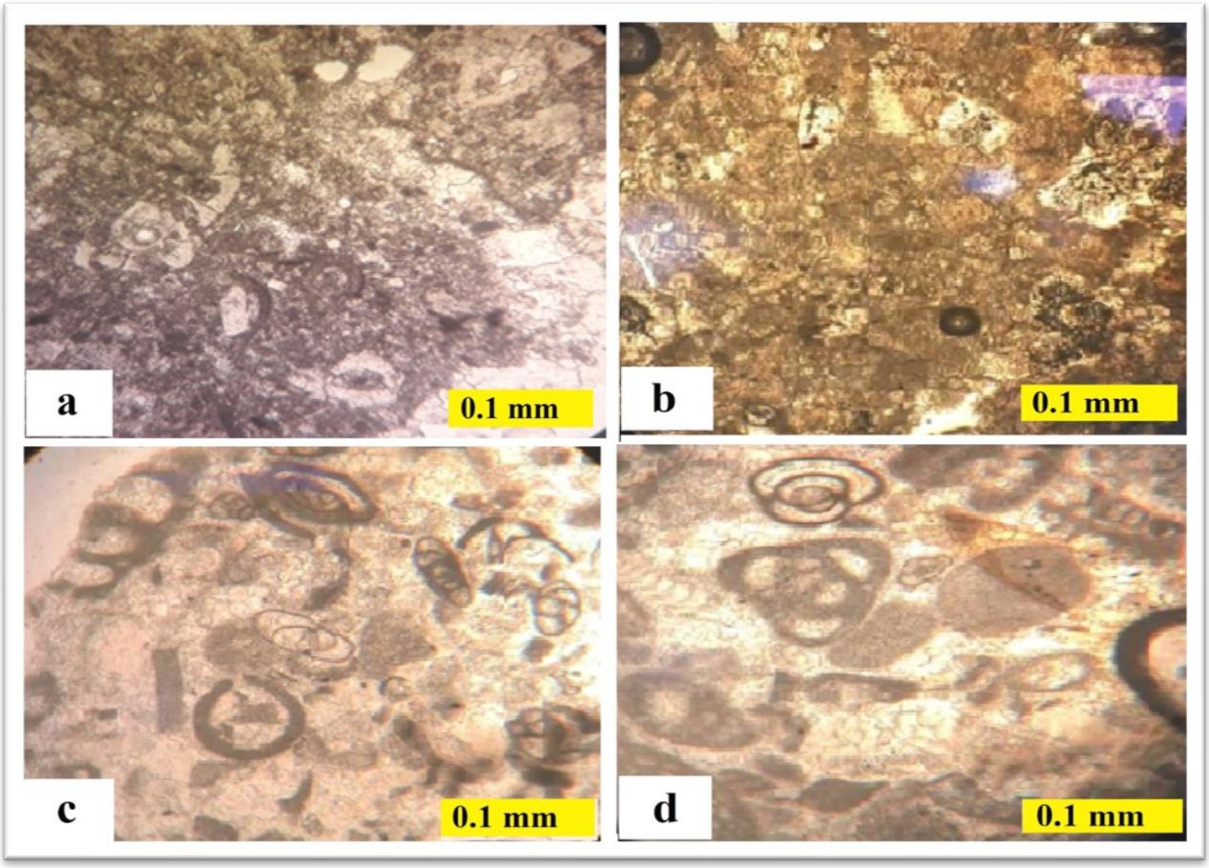

Fig. 4. Photomicrographs of Baba Formation showing microfacies types a, Bioclastic Lime Mudstone Submicrofacies M1; B, Bioclastic Lime Wackestone Submicrofacies W1; C, Miliolid Lime Wackestone Submicrofacies W2; D, Fossiliferous Lime Wackestone Submicrofacies W3.

• Nummulitic Lime Wackestone Submicrofacies W4

The thickness of this microfacies is about one meter in the upper part of the Baba Formation sequences at well (K-1) only. This microfacies consists of the skeletal grains of the shells of the (*Nummulites fichteli*), which are well-preserved at a rate of less than (50%) (Figure 5 a). The micritic matrix affected by recrystallization, cementation, especially the type of granular cementation. This microfacies is similar in their characteristics to the microfacies (RMF 2), within the facies zone (Mid- Ramp) (Flügel, 2010).

• Planktonic Foraminiferal Lime Wackestone Submicrofacies W5

The presence of this microfacies is confined to the middle and upper parts of well (K-2), with a thickness of about (7) meters. This microfacies mainly consists of skeletal grains of the well-preserved planktonic foraminifera characterized by their large size and spherical chambers with spiral wrapping and clear ornamentations, represented by genera: *Globigerina aselli*, *Globigerina ampliapertura*, *Globigerina praebulloides*, *Catapsydrax dissimilis*, *Chilogumbelina* sp. , *Globigerina ciperoensis* , *Paragloborota liaopima* , *Dentoglobigerina globularis* , *Glopigerina ouachitaensis* , *Globorotalid* sp. , *Globoquadrina sellii* , *Globogerina tella*), less than (40%) (Figure 5 b), and a small percentage of echinoderm and mollusks bioclasts, in addition to lithoclasts. This microfacies was affected by cementation, especially the type of blocky cement, and the dissolution (small channels and fractures). This microfacies is similar in its characteristics to the microfacies (RMF 5), which extends from the facies zone of the outer ramp to the deep basin.

3. Lime Packstone Microfacies P

This microfacies is characterized by an abundance of the carbonate grains that are well compacted and with a rate ranging between (50%-85%) in a ground of micrite. The skeletal grains identified in this facies are the well-preserved shells of the (*Nummulites*), in addition to the planktonic foraminifera represented by (*Globanomalina* sp., *Globigerina selli*, *G. Ciperoensis*, *G. Ciperoe*, *G. opima*, *Catapsydrax* sp. *Globigerinoides* sp., *Globigerina venzueluna*, *Globigerina ampliapertura*, *Globigerina praebulloides*) and echinoderms, mollusks, shells of (Rotalia) and bryozoans and *Lepidocyclina* sp., *Reuuesella* sp. and pieces of green algae and red algae. The facies was affected to many diagenetic processes, especially dolomitzation and recrystallization. This microfacies is divided into two submicrofacies as follows:

• Bioclastic Lime Packstone Submicrofacies P1

This microfacies is represented in the upper and middle parts of well (K-1), with a thickness of about (7) meters. This microfacies consists mainly of bioclasts at a rate ranging between (50%-70%) for most of the benthic and planktonic foraminifera, in addition to the shells of echinoderms, mollusks, and pieces of red and green algae. Also, lithoclasts are found in a very small percentage (1-5%). Great percentage (15%) of the planktonic foraminifera represented by the genera (*Globanomalina* sp., *Globigerina selli, G. Ciperoensis, G. Ciperoe, G. opima, Catapsydrax sp., Globigerinoides sp., Globigerina venzueluna, Globigerina ampliapertura, Globigerina praebulloides),* all of them are embedded in a mictitic matrix (Figure 5 c). This facies was subjected to many diagenetic processes such as cementation (granular and druzy cement), dissolution (vuggs and channels), and recrystallization. This microfacies is similar in characteristics to the microfacies (RMF 3) within the facies zone (Middle - Outer Ramp).

• Nummulitic Lime Packstone Submicrofacies P2

This microfacies is identified in the upper parts of the formation in well (K-1) and the upper and middle parts of the formation in well (K-2) with a thickness ranging between (1-25) meters. This microfacies mainly consists of benthic Foraminifera shells (*Nummulites vascus*)

(Figure 5 d), well-preserved with a high percentage in addition to small amount of *lepidocyclina* sp. Also, the Rotalia, *veinnoti* sp., *Neorotalia* sp., *miogypsinoides deharti*, *dendritina rangi*, in addition to bryozoans, rotalids, echinoderms, and red algae (*Lithophylum* sp.). This microfacies is affected by the processes of dolomitization, recrystallization, cementation and dissolution in the form of vugs. This microfacies is similar in characteristics to the microfacies (RMF 2), that it is deposited in the environment of the middle ramp.

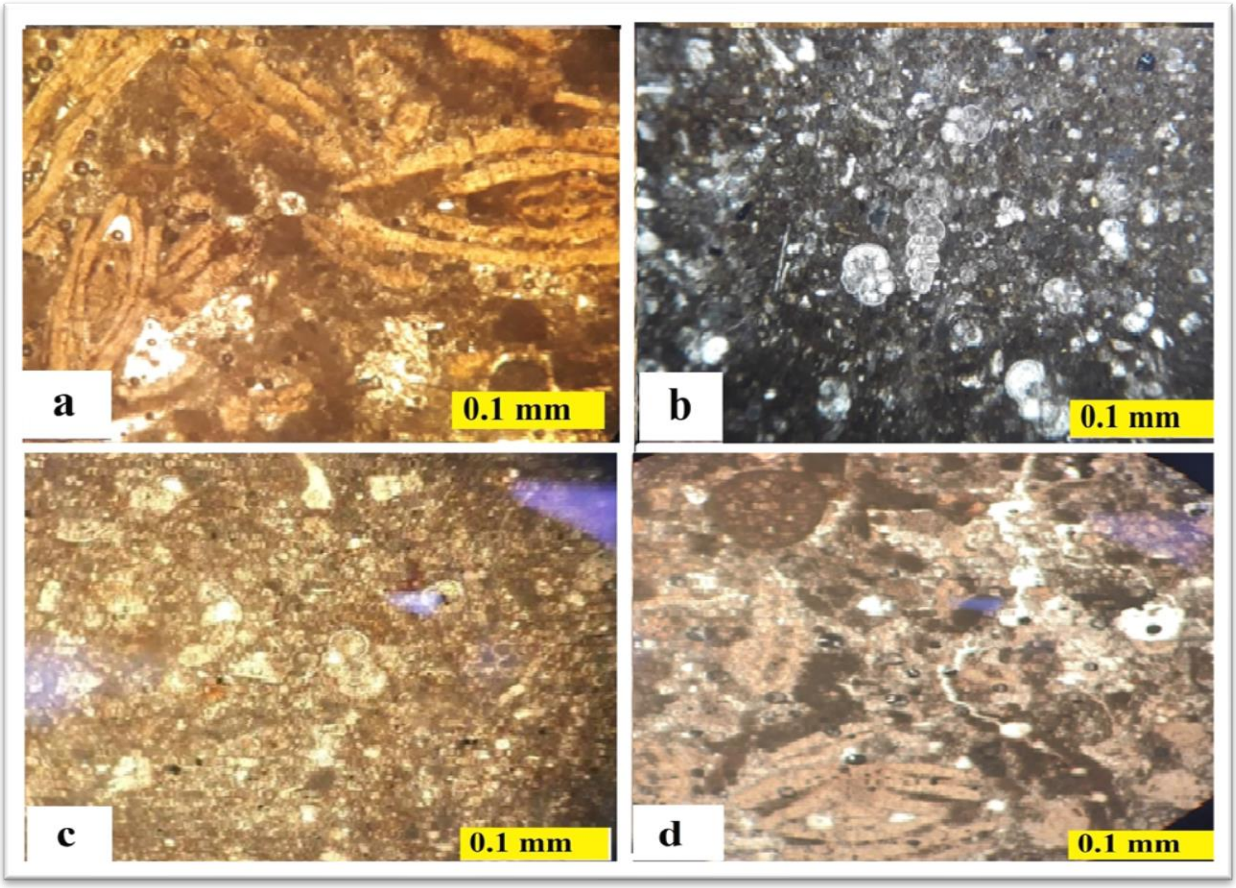

Fig. 5. Photomicrographs of Baba Formation showing microfacies types a, *Nummulitic* Lime Wackestone Submicrofacies W4; b, Planktonic Foraminiferal Lime Wackestone Submicrofacies W5; c, Bioclastic Lime Packstone Submicrofacies P1; d, *Nummulitic* Lime Packstone Submicrofacies P2.

Depositional environment

The facies analysis in the current study shows that the sedimentary environment of the Baba Formation is a carbonate depositional ramp environment, and this is consistent with many previous studies (El-Eisa, 1992; Al-Banna et al., 2002; Kharajiany, 2008; Ghafur, 2012; Ameen and Gafur, 2015; Al Jwaini, 2015; Qader, 2020 and Ghfor and Najaflo, 2022). The diagnosed microfacies represented by the M, W and P and their sub subdivisions show their compatibility with many microfacies suggested by Flügel (2010) such as RMF-2, RMF-3, RMF-5, RMF-7, RMF-13 and RMF-16, which indicate that the formation was deposited within the (Inner Ramp, Mid-Ramp, and Outer Ramp). In general, the formation of Baba in the wells chosen for the study (K-1, K-2) consist of limestone, dolomitic limestone, as the sediment is divided into three main microfacies represented by the mudstone, wackestone and packstone (M, W, P) which in turn is divided into submicrofacies. The variation in the appearance of the microfacies, as well as the difference in the grains ratio reflect the instability in the sea level or unstable tectonics, which greatly affected the variation in the energy of the water currents and the depth of the water (Qader, 2020).

The following is a detailed explanation of the environments in which the Baba Formation microfacies were deposited:

• Inner Ramp environment

The microfacies deposited within the inner ramp environment in Baba Formation are (W2), (W3) and (M2). This environment extends between the top of (Shore face) and the base of the (Fair-Weather Wave) (Flügel, 2010). These microfacies are characterized by abundance of *Quinquiloculina* sp., *pyrgo* sp., *Triloculina* sp., *Austratrillina* sp., *Reuuesella* sp., Bryozoans, pelecypoda, peniroplis sp., *Textularia* sp., *Praerchapydionina delicata*, *Dendritina* sp), and Ostracoda.

The abundance of the miliolid indicates shallow marine environment with high salinity and low energy at a depth of not more than 50 meters (Brasier, 1980). Also, the abundance of *Austrotrillina* sp. indicates a marine environment with calm energy (Vaziri-Moghaddam et al., 2006). The abundance and diversity of benthic foraminifer's miliolids, *Austrotrillina* sp., and *Dendritina* sp. together indicates a shallow marine environment (Hallook & Glenn, 1986). The presence of *Austratrillina* sp., *Peniroplis* sp. association with milioids indicates normal to high salinity marine waters within the Inner Ramp environment (Barattolo and Romano, 2007; Flügel, 2010; Dill et al., 2012; Al-Shammary, et al., 2023).

On the other hand, the presence of the following groups of fossils *Reuuesella* sp., *Peniroplis* sp., *Textularia* sp., *Praerchapydionina delicata*, with brayozoa, ostracoda and pelecypoda are found indicating a shallow, low-energy marine environment (Wilson and Evans 2002; Vaziri-Moghaddam et al. 2006; Flügel 2010).

Several studies have identified the presence of microfacies similar to the above-mentioned microfacies, which are characterized by the prevalence of these groups of fossils, whose presence indicates the environment of the inner ramp (Corda & Brandano, 2003; Farhan, 2016; Joudaki and Baghbani, 2018; Ameen et al., 2020; Gafor and Najaflo, 2022).

• Mid Ramp environment

The Mid Ramp environment extends between the base of the fair- weather wave and the base of the storm wave, with a water depth extending from tens to hundreds of meters (Flügel, 2010). The microfacies of this environment are spread within the well (K-1) represented by (W4, M1and M4), as well as within the well (K.2) represented by (W1 P1 and P2).

The previous microfacies are characterized by the abundance of *Nummulites* found in shallow open marine waters of normal salinity (Leutenegger, 1984; Romero et al., 2002). These organisms are also commonly present below the photic zone at the end of the mid-ramp (Hottinger, 1983; Hoheneger 1996, Hallock and Glenn 1999; Reiss and Hottinger 1984; Leutenegger, 1984, Beavington-Penney and Racy, 2004, Asaad, et al., 2022). The presence of *Nummulites vascus* indicates mostly quiet, normal-saline, warm tropical waters located on the Mid-Ramp, also the presence of rotalid in the microfacies above indicates a shallow marine environment with a depth not exceeding 50 meters, with normal salinity, as it often indicates the environment of the Mid-Ramp (Buxton and Pedley, 1989; Murray, 2006; Brandano et al., 2009). On the other hand, the association of echinoderms, corals, and rotalid together indicates a shallow marine environment (Murray, 2006).

Association of bryozoans with a good percentage of red algae (*Lithophylum*) and the presence of *Nummulites* with red algae indicate marine waters with depths ranging between (40-80) meters, often located within the Middle- Ramp as shoal or shallow ramp buildup (Bosence, 1983; Buxton and Pedley, 1989; Hottinger, 1997; Beavington-Penney and Racey, 2004). The coexistence of *Miogypsina*, *Peniroplis* and *Nummulites* indicates their sedimentation within the shallow part of mid-ramp (Pomar, 2001a, 2001b; Brandano and Corda, 2002; Corda and Brandano, 2003; Cosovic et al., 2004, Lawa & Ameen, 2008).
Amirshahkarami et al. (2007) identified microfacies similar in characteristics to the microfacies of the Baba Formation mentioned above during his study of the Asmari Formation in

southwestern Iran, and indicated that this microfacies are deposited in the environment of the middle ramp (Ghafur, 2012, who also identified the microfacies “Coralline red algae-*Nummulites* wackestone”) which contain *Nummulites* and that it falls within the mid-ramp environment.

• Outer Ramp environment

This outer ramp extends below the base of the normal storm wave and below (photic zone) with a depth extending between (10) meters to hundreds of meters. This zone is characterized by low water energy (Flügel, 2010). The microfacies within this zone are diagnosed in well (K-2) only, and they are represented by the microfacies of the (W5, P1 and M3). These microfacies are characterized by the abundance of planktonic foraminifera, as their presence indicates the deep marine environment, whose water depth exceeds (200) meters (Geel, 2000; Al-Lhaebi, et. al., 2020). The association of planktonic foraminifera with a micritic matrix indicates an open marine environment towards the deep sea with normal salinity and low water energy (Buxton and Pedley, 1989; Cosovic et al., 2004; Flügel, 2004; Al-Mutwali, & Al-Banna, 2004, 2005; Al-Miamary et al., 2022).

Also, the shells of echinoderms and pelecypoda are associated with a very small percentage of rotalid, red algae and *Reuueslla* sp. in addition to a small percentage of lithoclasts about (5%) buried within a micritic matrix indicating the absence of the influence of currents and sea waves that exist in a low-energy environment below the base of a storm wave (Burchette and Wright, 1992).

Amirshahkarami et al. (2007) described a similar microfacies in Asmari Formation in southwestern Iran and defined its environment as the outer ramp environment. Al Jwaini (2015) also identified the microfacies (*Globigerinoides* Wackestone – Packstone microfacies) from the formation of Abraham, which is similar in their characteristics to the microfacies of the Baba Formation in this zone, as they are characterized by the prevalence of planktonic foraminifera, which refers to outer ramp. Ghafor (2012) also identified similar microfacies deposited within the outer ramp.

Baba Formation Model

Through the data of the microfacies analysis of the Baba Formation and its environmental evidences, the sedimentary model of the formation is derived. It is found that the Baba Formation had microfacies deposited in a spectrum that covered most parts of the Ramp environment (Figure 6), where the lateral differences in the distribution of the microfacies and fossils indicate the presence of a gradual shallowing in the depth of marine waters towards the top of the formation, with no evidence indicating the presence of a steep slope, a barrier, a break in the slope or a coral barrier. The differences in the shapes and sizes of the fossils that have been studied in the formation also indicate their presence in different environments ranging from the shallow environment to the deep marine environment (Burchette and Wright, 1992; Bou Dagher-Fadel, 2008). The Sedimentological and paleontological studies show that a ramp type carbonate platform sedimentary model can be fully applied to the Baba Formation. According to Burchette and Wright (1992) the carbonate ramp environments are separated into inner ramp, middle ramp and outer ramp.

In general, the Baba Formation microfacies were deposited in an inner ramp, represented by W2, W3 and M2 microfacies within the well (K-1) only, which are characterized by the presence of miliolids, whose presence indicates shallow marine environment. According to Farhan et al. (2016), such microfacies were deposited in shallow subtidal environments with relatively low energy giving that they are rich in a large number of benthic foraminifera (Miliolids) and particularly in an inner ramp platform (Brandano et al., 2009; Flugel, 2010).

While other microfacies are represented by W4, M1, and M4 microfacies within the well (K-1), and three microfacies W1, P1 and P2 within the well (K-2), which are characterized by the prevalence of *Nummulites* shells (may be *Nummulites* shoal or shallow ramp buildup). Such high-energy deposits are typically associated with carbonate shoals on carbonate platforms (Moghaddam et al., 2010). The presence of *Nummulites* and *lepidocyclina* indicates that sedimentation took place in a relatively deep water (Geel, 2000; Beavington and Racey, 2004; Nebelsick et al., 2005; Bassi et al., 2007; Barattolo et al., 2007) compared to the inner ramp environment. Thus, the wackestone, packstone submicrofacies with *Nummulites* and *lepidocyclina* were deposited under low energy conditions, below fair weather wave base (FWWB) and above storm wave base (SWB) in the middle ramp setting, at tropical/subtropical environments (Hohenegger et al., 2000; Langer and Hottinger, 2000).

As the microfacies that were deposited in the deep marine environment (outer ramp), they are represented by the following microfacies (P1, W5 and M3) within the well (K-2) only, which is characterized by the prevalence of planktonic foraminifera.

The depositional environment of Baba Formation is represented by (Inner - Middle - Outer Ramp) environments, where most of the facies diagnosed in the well (K.2) represent the environment of the deep outer slope that tends to shallowing upward to an environment below the middle ramp, while the facies diagnosed in the well (K.1) represent the environment of the middle slope to the shallow inner ramp, and this is consistent with many other previous studies about formation in different regions of Iraq, such as the studies of (Ghafur, 2012; Qader, 2020; Ghafor et.al., 2022).

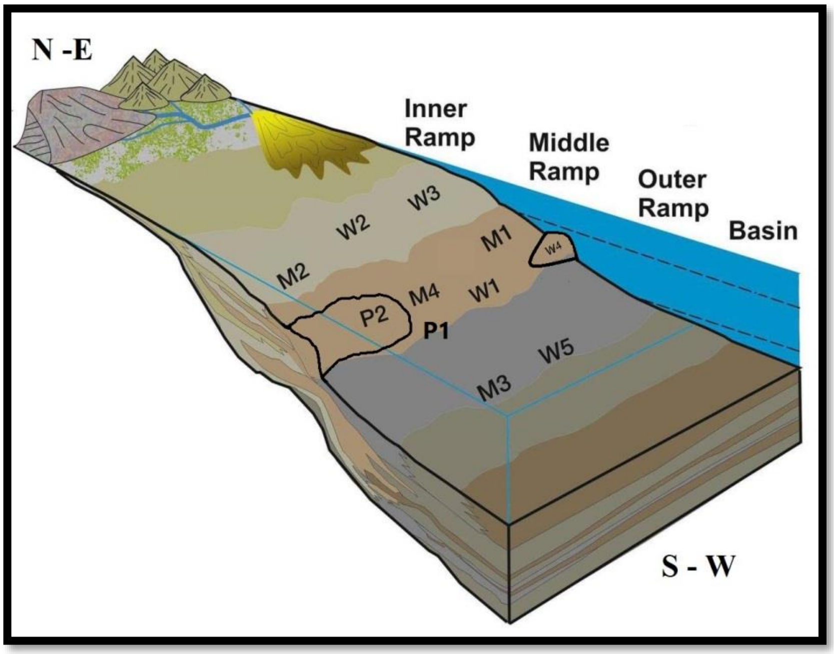

Fig. 6. Depositional model of the Baba Formation (Modified from Bayet-Goll et. al., 2018)

Conclusions

• The Baba Formation has about 45m thickness in the well (K-1), and about 65 m. in the well (K-2). The formation consists of brown, medium-sized crystals hard limestone and dolomitic limestone. It is characterized by many fossils such as miliolids, echinoids, bryozoan, as well as *Lepidocyclina* sp. and *Nummulites* sp. and some planktonic foraminifera.

• Based on the classifications of Dunham, three main microfacies are recorded in carbonate rocks of Baba Formation, these are: lime mudstone, lime wackestone, lime packstone microfacies which are later divided to 11 submicrofacies.

• The three main microfacies reflect the precipitation of the Baba Formation in a ramp carbonate platform.

Acknowledgements

The authors are very grateful to the College of Science, University of Mosul for providing facilities. The authors are very grateful to the Editor-in-Chief Prof. Dr. Rayan Ghazi of INJES and the editorial board members and the technical editors for their great efforts and valuable comments.

References

Abid, A.A., 1983. Microfacies of Anah limestone formation, Dissertation, University of Baghdad, Iraq, 120 P.

Ameen, F.A., Fattah, A.I. and Qader, B.O., 2020. Microfacies and depositional environment of the Upper Oligocene and Lower Miocene successions from Iraqi Kurdistan Region. Kuwait Journal of Science, 47 (4), pp. 127-136. https://doi.org/10.48129/kjs

Amirshahkarami, M., Vaziri-Moghaddam, H. and Taheri, A., 2007. Sedimentary facies and sequence stratigraphy of the Asmari Formation at Chaman-bolbol, Zagros Basin, Iran. Journal of Asian Earth Sciences, 29 (5-6), pp. 947-959. https://doi.org/10.1016/j.jseaes.2006.06.008

Al-Banna, N.Y., Amin, M.A. and Al-Hashimi, W.S., 2002. Oligocene- Miocene boundary in Sheikh Ibrahim and Sasan areas, northwest Iraq. Iraqi Journal of Earth Science, 2, pp. 37-47.

Al-Banna, N.Y., 2008. Oligocene/Miocene boundary in northern Iraq. GeoArabia 13 (2), pp. 187–190. https://doi.org/10.2113/geoarabia1302187

Al-Hayali, R.S., 2019. Biostratigraphy of Calcareous Nannofossils of Aliji Formation in Well (K-116) in Northern Iraq, Unpublished Master Thesis University of Mosul, College of Science 124 P. https://doi.org/10.33899/EARTH.2019.170265

Al-jawani, Y.S.K., 2015. Sequence stratigraphy and reservoir characterization of the late Palaeogene-early Neogene succession in Kirkuk area. Unpublished Master Thesis Baghdad University, Iraq, 130 P.

Al-Lhaebi, S.F., Al-Juboury, A.I. and Al-Miamary F.A. 2020. Sedimentological, Paleontological and Mineralogical Evidences for Oceanic Anoxic Event-2 (OAE -2) in the Gulneri Formation (Early Turonian), Northeastern Iraq. Iraqi National Journal of Earth Science, 20 (2), pp. 105-125. https://doi.org/10.33899/earth.2020.170372

Al-Miamary F.A, Al-Lhaebi, S.F.; Al-Juboury, A.I. and Swennen, R. 2022. Depositional Conditions and Nature of Source Rocks of the Upper Part of the Balambo Formation in Northeastern Iraq Based on Rare Earth Elements Data. Iraqi Journal of Science,63 (9), pp. 3804-3816. https://doi.org/10.24996/ijs.2022.63.9.13

Al-MutwaIi, M. M. and Al-Banna, N. Y., 2005. Sedimentary Cycles and Microfacies Analysis of Lower Miocene Formations in Sinjar and Sharafaddin Areas, NW Iraq. Rafidain journal of science, 16 (5), pp. 57-68.

Al-MutwaIi, M.M., Al-Banna, N.Y. and Al-Ghrea, J.S., 2008. Microfacies and sequence stratigraphy of the Late Campanian Bekhme Formation in the Dohuk area, north Iraq, GeoArabia, 13 (1), pp. 39-54

Al-Qayim, B.A.J. and Khaiwka, M. H., 1980. Depositional environments and diagenesis of the Oligocene reef cycles, Kirkuk oil field, Northern Iraq. Modern Geology, 7, pp. 177-190.

Al-Mansoor, A., Al-Hamidi, R.I and Al-Badrani, O.A. 2023. Sedimentary Environments and Age Determination of the Chia Gara Formation, Northern Iraq. Iraqi Geological Journal, 56 (1B), pp. 64-79. https://doi.org/10.46717/igj.56.1B.6ms-2023-2-14.

Al-Shamary, M. A., Malak, Z. A. and Al-Badrani, O. A., 2023. The Use of Calcareous Nannofossils in Determining the Age of the Sargelu Formation in the Hanjera section, Sulimani Governorate, Kurdistan Region, Northern Iraq. Iraqi National Journal of Earth Science, 23, (1), pp.1-12. https://doi.org/10.33899/earth.2022.133948.1016

Asaad I.Sh., Al-Haj, M.A. and Malak, Z.A., 2022. Depositional Setting of Khurmala Formation (Paleocene-Early Eocene) in Nerwa section, Berat Anticline, Kurdistan Region, Northern Iraq. Iraqi Geological Journal, 55 (1F), pp. 20-39. https://doi.org/10.46717/igj.55.1F.2Ms-2022-06-17

Bassi, D., Hottinger, L. Nebelsick, H., 2007. Larger Foraminifera from the Upper Oligocene of the Venetian area, northeast Italy: Palaeontology, 5(4), 845-868.

Barattolo, F., Bassi, D. and Romano. R., 2007. Upper Eocene larger foraminiferal-coralline algal facies from the Knokova mountain (southern continental Greece). Facies, 53, pp. 361–375.

Bayet-Goll, A., Esfahani F.Sh., Daraei M., Monaco P., Sharafi M. and Mohammadi A.A., 2018. Cyclostratigraphy across a Mississippian carbonate ramp in the Esfahan–Sirjan Basin, Iran: implications for the amplitudes and frequencies of sea-level fluctuations along the southern margin of the Paleotethys. International Journal of Earth Sciences. 107, pp. 2233–2263. https://doi.org/10.1007/s00531-018-1597-7

Bellen, R.C. Van., 1956. The stratigraphy of the main limestone of Kirkuk, Bai-Hassan and Qarah Chauq Dagh structures in northern Iraq. Inst. Petroleum found. Vol. 42, London

Bellen, R.C.V., Dunnington, H., Wetzel, R., Morton, D. 1959. Lexique Stratigraphique, Interntional. Asie, Iraq. 333 P.

Beavington-Penney, S.J. and Racey, A., 2004. Ecology of extant Nummulitids and other larger benthic foraminifera: applications in paleoenvironmental analysis. Earth Sci. Rev. 67, pp. 219–265.

Bosence, D.W. J., 1983. Coralline algal reef frameworks. Journal of the Geological Society, 140(3), pp. 365-376.

Bou-Dagher-Fadel, M.K., 2008. Evolution and geological significance of larger benthic foraminifera, Elsevier.

Brandano, M. and Corda, L., 2002. Nutrients, sea level and tectonics: constrains for the facies architecture of a Miocene carbonate ramp in central Italy. Terra Nova, 14 (4), pp. 257-262.

Brandano, M., Frezza, V., Tomassetti, L. and Cuffaro, M., 2009. Heterozoan carbonates in oligotrophic tropical waters: the Attardmember of the lower coralline limestone formation (Upper Oligocene, Malta). Palaeogeography, Palaeoclimatology, Palaeoecology, 274 (1-2), pp. 54-63.

Brasier, M.D., 1980. Microfossils. George Allen and Unwind Ltd., London, 193 P.

Burchette, T.P. and Wright, V.P., 1992. Carbonate ramp depositional systems. Sedimentary geology, 79(1-4), pp. 3-57.

Buxton, M.W.N. and Pedley H.M., 1989. Short paper: a standardised model for Tethyan Tertiary carbonates ramps. Journal Geological Society London. 146, pp. 746–748.

Corda, L. and Brandano, M., 2003. Aphotic zone carbonate production on a Miocene ramp, Central Apennines, Italy. Sedimentary Geology, 161(1-2), pp. 55-70.

Ćosović, V., Drobne, K. and Moro, A., 2004. Paleoenvironmental model for Eocene foraminiferal limestone of the Adriatic carbonate platform (Istrian Peninsula). Facies, 50 (1), pp. 61-75.

Ditmar, V., and Iraqi-Soviet team, 1971. Geological Conditions and Hydrocarbon Prospects of the Republic of Iraq-Northern and Central Parts. Iraq National Oil Company Library, Baghdad (Unpublished report).

Dill, M.A., Seyrafian, A. and Vaziri-Moghaddam, H., 2012. Palaeoecology of the Oligocene-Miocene Asmari Formation in the Dill Anticline (Zagros Basin, Iran). Neues Jahrbuchfür Geologie und Paläontologie - Abhandlungen, pp. 167-184.

Dunham R.J., 1962. Classification of carbonates rocks according to the depositional texture. In: Ham, W.E. (Eds.) Classification of carbonate rock. American Association of Petroleum Geologists, Memoir, No. 1, pp. 108–121

El-Eissa, M.E., 1992. The two subdepositional cycle of the Early Miocene in Kirkuk oil field area, north Iraq. Journal Geological Society, Iraq 25, pp. 41–58.

Farhan, H.N., Kadem, L.S. and Mohammed, Q.A., 2016. Microfacies and depositional environment of Bajawan and Baba Formations in Kirkuk Oil fields north Iraq. Tikrit Journal of Pure Science, 21(6), pp. 112-125.

Flügel, E., 2004, Microfacies of Carbonate Rock, Analysis, Interpretation and Application. Springer-Verlag, Berlin, 976 P.

Flügel, E., 2010. Microfacies of carbonate rocks: analysis, interpretation and application. Berlin: springer. 2004 P

Ghafor, I.M., Karim, K.H. and Sissakian, V., 2014. Biostratigraphy of Oligocene succession in the High Folded Zone, Sulaimani, Kurdistan Region, Northeastern Iraq. Arabian Journal of Geosciences, 7 (9), pp. 3599-3610.

Ghafor, I.M. and Ahmad, P.M., 2021. Stratigraphy of the Oligocene-Early Miocene successions, Sangaw area, Kurdistan Region, NE-Iraq. Arabian Journal of Geosciences, 14 (6), pp. 1-17.

Ghafor, I.M. and Najaflo, S., 2022. Biostratigraphy, microfacies, paleoenvironment, and paleoecological study of the Oligocene (Late Rupelian–Early Chattian) Baba Formation, Kirkuk area, Northeastern Iraq. Carbonates and Evaporites, 37(1), pp.1-15.

Ghafur, A., 2012. Sedimentology and reservoir characteristics of the Oligocene-Early Miocene carbonates (Kirkuk Group) of southern Kurdistan (Doctoral dissertation, Cardiff University) 304 P.

Geel, T., 2000. Recognition of stratigraphic sequences in carbonate platform and slope deposits: empirical models based on microfacies analysis of Palaeogene deposits in southeastern Spain: Palaeogeography, Palaeoclimatology, Palaeoecology, 155, pp. 211–238.

Hallock, P. and Glenn, E.C., 1999. Larger foraminifera: A Tool for Paleoenvironmental Analysis of Cenozoic carbonates depositional facies: Palaios, No.1, pp. 55-64.

Henson, F.R.S., 1950. Cretaceous and Tertiary reef formations and associated sediments in Middle East. AAPG Bulletin, 34 (2), pp. 215-238.

Hohenegger, J., 1996. 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 search project, Man and the environment in Micronesia. Kagoshima University Research Center for the Pacific Islands, Occasional Papers, 32: pp.19–45.

Hohenegger, J., Yordanova, E., Hatta, A., 2000, Remarks on West Pacific Nummulitidae (Foraminifera): Journal of Foraminiferal Research, 30(1), pp. 3-28.

Hottinger, L., 1983. Processes determining the distribution of larger foraminifera in space and time: Utrecht Micropaleont. Bull. 30, pp. 239-253.

Hottinger, L., 1997. Shallow benthonic foraminiferal assemblages as signals for depth of their deposition and their limitations. Bull Geol. Soc. Den. Fr. 168: pp.491–505.

Joudaki, M. and Baghbani, D., 2018. Biostratigraphy of Oligocene and Lower Miocene deposits, Anneh anticline, folded Zagros, SW of Iran. Carbonates Evaporites 33(3): pp. 509–515. https://doi.org/10.1007/s13146-017-0362-5

Karim, S. A., Sissakian, V. K. and Al-Kubays, K. N., 2014. Stratigraphy of the Oligocene-Early Miocene exposed formations in Sinjar area, NW Iraq. Iraqi Bull Geolgical Mining 10(3): pp.1–28

Karim, K. H. and Ahmad, H. B., 2019. Chronicle of the Oligocene succession (Kirkuk Group) in Duhok Governorate, Kurdistan Region, North Iraq. Journal Zankoy Sulaimani Part A 21(1): pp. 75–90.

Kharajiany, S. O. A., 2008. Sedimentary facies of Oligocene rock units in Ashdagh mountain-Sangaw district-Kurdistan region-NE Iraq. Unpublished M.Sc. thesis, College of Science, University of Sulaimani, 132p.

Langer, M., Hottinger, L., 2000, Biogeography of selected 'larger' foraminifera: Micropaleontology, 46(1), pp. 105–126.

Lawa, F. A. and Ghafur, A. A., 2015. Sequence stratigraphy and biostratigraphy of the prolific late Eocene, Oligocene and early Miocene carbonates from Zagros fold-thrust belt in Kurdistan region. Arabian Journal of Geosciences, 8 (10), pp.8143-8174.

Lawa, F. A., 2008. Sequence Stratigraphy and Basin Modeling of the Eocene Succession from Kurdistan Region, Northeastern Iraq. In AAPG Search and Discovery Article# 90077, GEO 2008 Middle East Conference and Exhibition.

Leutenegger, S., 1984. Symbiosis in benthic foraminifera; specificity and host adaptations. The Journal of Foraminiferal Research, 14(1), pp. 16-35.

Majid, A. H. and Veizer, J., 1986, Deposition and chemical diagenesis of Tertiary carbonates, Kirkuk oil field, Iraq. AAPG bulletin, 70 (7), pp. 898-913.

Malak, Z. A., Al-Badrani O. A. and Al-Fandi, E. I., 2021. Stratigraphic and microfacies study of Upper Campanian - Lower Maastrichtian succession (Shiranish Formation) in Bade village, Bekhere anticline, Kurdistan region, northern Iraq. Bulletin of the Geological Society of Malaysia, 71, pp. 47 – 55. https://doi.org/10.7186/bgsm71202104

Moghaddam, H. V., Seyrafian, A., Azizolah Taheri, A. and Motiei, H., 2010. Oligocene-Miocene ramp system (Asmari Formation) in the NW of the Zagros basin, Iran: Microfacies, paleoenvironment and depositional sequence. Revista Mexicana de Ciencias Geológicas, v. 27, (1), pp. 56-71

Murray, J. W., 2006. Ecology and applications of Benthic foraminifera. Cambridge University Press, Cambridge, p 426.

Nebelsick J.H., Rasser, M. Bassi, D., 2005, Facies dynamic in Eocene to Oligocene Circumalpine carbonates: Facies, 51(4), pp.197-216.

Pomar, L., 2001a. Ecological control of sedimentary accommodation: evolution from carbonate ramp to rimmed shelf, Upper Miocene, Balearic Islands. Palaeogeography, Palaeoclimatology, Palaeoecology 175, pp. 249–272.

Pomar, L., 2001b. Types of carbonate platforms: a genetic approach. Basin Research 13, pp. 313–334.

Qader P. O., 2020. Stratigraphy microfacies and depositional environment of Oligocene Early Miocene successions at Sagrma and Aj-Dagh structures, Kurdistan Region, Northeastern Iraq. In: Dissertation, Sulaimani University, Iraq, 135p.

Reiss, Z. and L., Hottinger, 1984. The Gulf of Aqaba: Ecological Micropaleontology: Berlin – Springer. 354p.

Romero, J., Caus, E. and Rosell, J., 2002. A model for the palaeoenvironmental distribution of larger foraminifera based on late Middle Eocene deposits on the margin of the South Pyrenean basin (NE Spain). Palaeogeography, Palaeoclimatology, Palaeoecology, 179 (1-2), pp.43-56.

Vaziri-Moghaddam, H., Kimiagari, M. and Taheri, A., 2006. Depositional environment and sequence stratigraphy of the Oligocene-Miocene Asmari Formation in SW Iran. Facies, 52, pp. 41-51.

Wilson, M. E. J. and Evan, M. J., 2002. "Sedimentology and diagenesis of Tertiary carbonates on the Mangkalihat Peninsula, Borneo: Implications for the subsurface reservoir quality", Marine and Petrology Geology 19: pp. 873- 900.http://www.iraqoilforum.com/wp-content/uploads/2011/11/Kurdistan-Oil-Gas-Activity-Map-Nov-2011.