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Benthic Foraminifera as A Tool for Indication of Microfacies, Biostratigraphy, and Depositional Environment of the Baba Formation [Late Oligocene], Kirkuk Oil Field, Northeastern Iraq

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Abstract

A moderately diverse larger foraminiferal is described from the NE Iraq, Baba Formation with important stratigraphy, paleontology, microfacies, and palaeoenvironment implications. The fauna is dominated by hyaline perforated and porcellaneous forms including Nummulites, Austrotrillina, Amphistegina, Archaias, Lepidocyclina, Spiroclypeus, Operculina, and Neorotalia. The presence of those fossils allows the age of the formation to be determined as Late Rupelian [Shallow Benthic Zone SBZ 22A] - Early Chattian [Shallow Benthic Zone SBZ 22B], based on the two recognized biozones from older to younger: - Nummulites fichteli -Nummulites intermedius biozone and Lepidocyclina [Eulephidina] dilatata- Nummulites intermedius- Nummulites fichteli biozone. The identified benthic foraminifera were used to recognize three microfacies types: Nummulitic wackestone facies of inner-shelf environment, Nummulitic wackestone-packstone facies of middle-shelf environment, and Epicyclical packstone facies of outer-shelf environment. The palaeoenvironmental setting of the Baba Formation is interpreted as a shallow ramp lagoon environment rich in nutrients, slightly hyper-saline with the shallowest part of the photic zone characterized by the genera Archaias and Austrotrillina, the deeper part of the inner ramp with Nummulites, to the shallow part of the middle ramp with Spiroclypeus and Operculina, to deeper middle ramp setting dominated by coralline rhodoliths along with Lepidocylinids. Microfossils from Baranan and Kurdamir sections have been used for the regional correlations from Eocene-Early Miocene.

Keywords: Benthic Foraminifera, Microfacies, Biostratigraphy, Paleoenvironment, Oligocene, Ne Iraq.

1. Introduction

Larger foraminifera were prolific carbonate producers in the worldwide tropical to sub-tropical platform belts during the Paleogene [1, 3]. Such carbonate-producing benthic biota is sensitive to changing environmental conditions and thus have had a rich and complex evolutionary diversity since the Cambrian time [4]. Due to the high diversification and extinction rates of the larger foraminiferal genera and species throughout the Eocene and Oligocene, these organisms are key biostratigraphic markers for this period [1, 5-7]. In addition, a major extinction and turnover of larger foraminifera, and other organisms such as scleractinian corals, occurred at the Oligocene–Miocene boundary [1]. The Oligocene strata extend toward neighboring countries [equivalents] as in Turkey and are represented by red mudstone and claystone with nodular and massive gypsum, known as Selimiye Formation while in SE.

Turkey is not recorded. In Iran, the Oligocene units were determined from North and Northwest as reefal carbonate facies, represented by Asmari and Khamir Formations which are correlated to Early Middle Oligocene Formations in Iraq [8]. In Syria [Chilou Formation] from West and Northwest. The absence of Oligocene deposits over most of Kuwait, due to the sea regressive at the end of Eocene, and a widespread unconformity occurred finally in Saudi Arabia, the Oligocene strata are missed. According to, the Oligocene/Miocene boundary is located between the Tarjil and Ibrahim sequences and two sedimentary cycles represented in Oligocene, the first cycle embraces Palani, Sheikh Alas, and Shurau Formations [Rupelian] deposited in upper bathyal to intertidal environments, the second cycle includes Tarjil, Baba and Bajwan Formations [Chattian], and the third cycle represents Anah, Azkand, and Ibrahim Formations [Aquitanian] [9] [Fig.1].

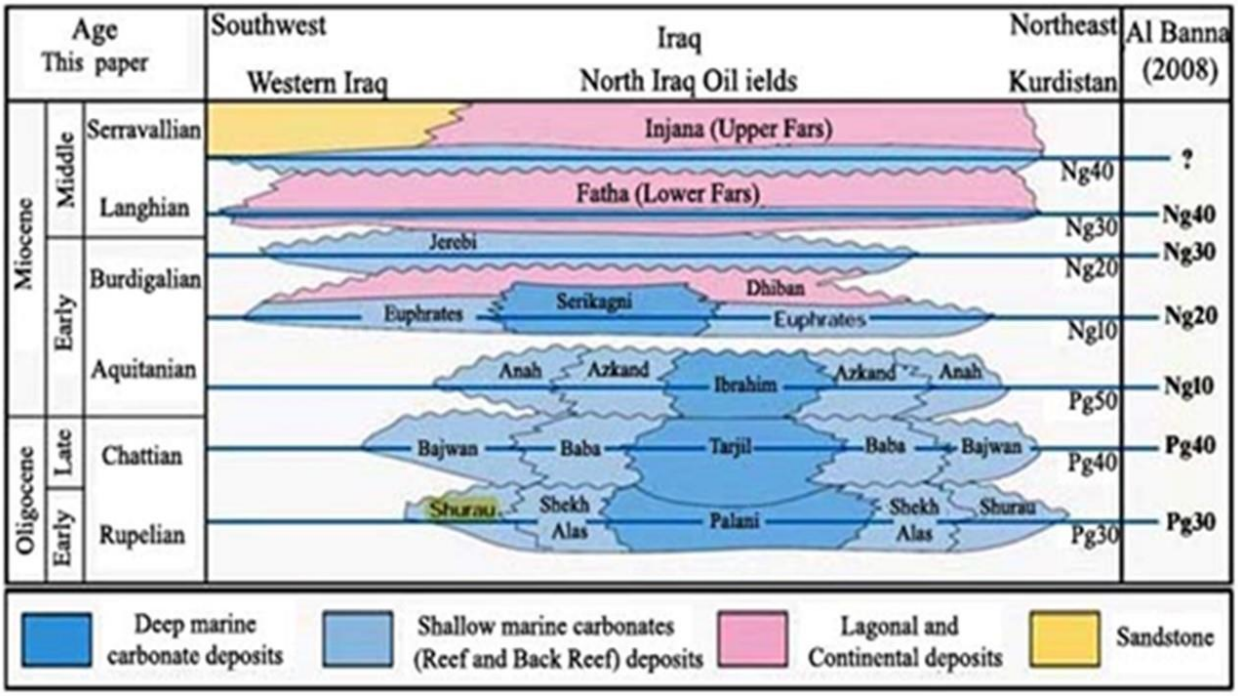

Figure 1: Tertiary sequence stratigraphy of Iraq. The Oligocene-Miocene boundary was tentatively interpreted as occurring between the Tarjil and Ibrahim sequences. Revised boundary the positions of, and maximum flooding surfaces [MFS] of are after [10-12].

The study includes sedimentological and sequence-stratigraphic analyses and a larger foraminiferal biostratigraphic framework for this sedimentary succession. The results fill a gap in the geological and paleontological knowledge of the Asmari Fm. in this western marginal part of the Fars sub-basin and thus are of significance for Oligocene–Miocene paleobiogeographic reconstructions of the Tethyan Seaway, which connected the Indo-Pacific and Mediterranean– Atlantic sides of Tethys through the Iranian Plate [13, 14].

The carbonate of Kirkuk Group succession hosts major hydrocarbon reserves and comprises nine formations and represent three separate cycles of carbonate sedimentation [8, 15, 16] [Table 1].

A					B					
Age	Sed. Cycle	Facies			Age		Sed. Cycle	Facies		
		Reef-Back Reef	Fore Reef	OffShore				Reef-Back Reef	Fore Reef	OffShore
Oligocene	Upper	Bajwan formation	Baba formation	Ibrahim and Tarjil formations	Oligocene	Late	Upper	Anah formation	Azkand Formation	Ibrahim formation
						Middle	Middle	Bajwan Formation	Baba Formation	Tarjil Formation
	Lower	Shurau Formation	Alas Shekh Formation	Palani Formation		Early	Lower	Shurau Formation	Shekh-Alas Formation	Palani Formation

Table 1: (A) Oligocene lithostratigraphic units and facies, (B) Lithostratigraphic units of Kirkuk Group subdivisions, based on age, facies, and relationships between reef/back reef-fore reef and offshore facies [8, 15].

Several studies have been conducted in Iraq, for Oligocene - Miocene strata in Kirkuk Oil fields and High folded zones: - Buday, Ghafor, Ghafor & Muhammad, Muhammed and Ghafor, Ghafor and Ahmad, Ghafor and Najaflo, Ghafor et al., [17-33]. Baba Formation was described for the first time, from the Kirkuk well -10, on the Baba Dome of the Kirkuk structure, which is about 20 m thick and composed of porous dolomitized limestone, as the fore-reef equivalent of lagoonal Bajwan Formation and changes seawards into Tarjil Formation, that is from the second reef cycle of the Middle Oligocene age, this formation is covered conformably by the Bajwan Formation and underlies unconformably by the Shurau Formation. Baba Formation is identified in the studied well, which is generally composed 35 m thick of light grey milky white crystalline and massive fossiliferous limestone, the formation overlies the Sheikh Alas Formation conformably and is underlain by the Bajwan Formation [15] [Fig. 2].

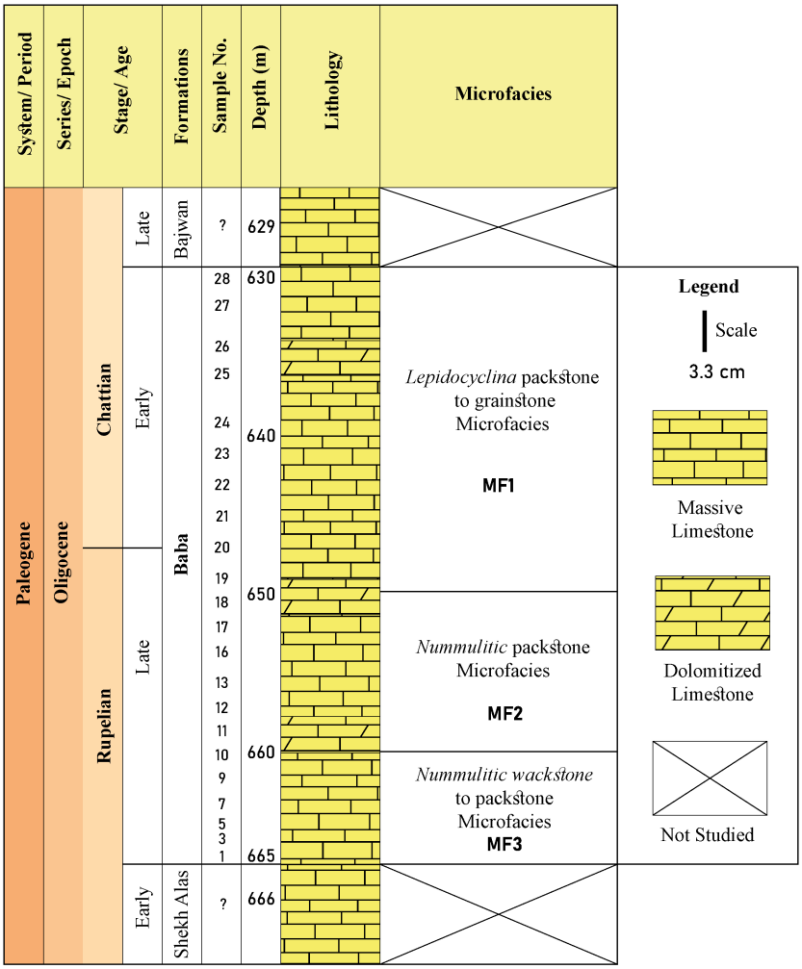

Figure 2: Lithostratigraphic column and microfacies of the Baba Formation at the Kirkuk Well-19 section.

The main aim of this research is to recognize larger benthic foraminifera and document the different microfacies, biostratigraphy of the Kirkuk Group, facies relationships, and them environmental interpretations to produce an integrated depositional model and compare it with regional and global data., to correlate the results of the Kirkuk oil field with the neighboring Baranan well (B) and Kurdamir wells [K1, k2, and K3].

1.1. Geological Setting

According to, the Oligocene succession of Iraq is restricted to the Mesopotamian region with a relatively smaller thickness than the Eocene succession [15]. Both upper and lower contacts of the succession are confirmable. Oligocene and Lower Miocene sediments from the High Folded Zone of Iraqi Zagros have been studied paleontologically in the south of Sulaimaniyah, Kurdistan Region, NE Iraq [20]. The studied oil fields of the Kirkuk well-19 are located at the Himmerin-Makhul Subzone-Foot Hill Zone of the unstable shelf area, within Kirkuk Governorate, about 20-50 km. Northwest of Kirkuk City, Northeast Iraq [34] [Fig. 3].

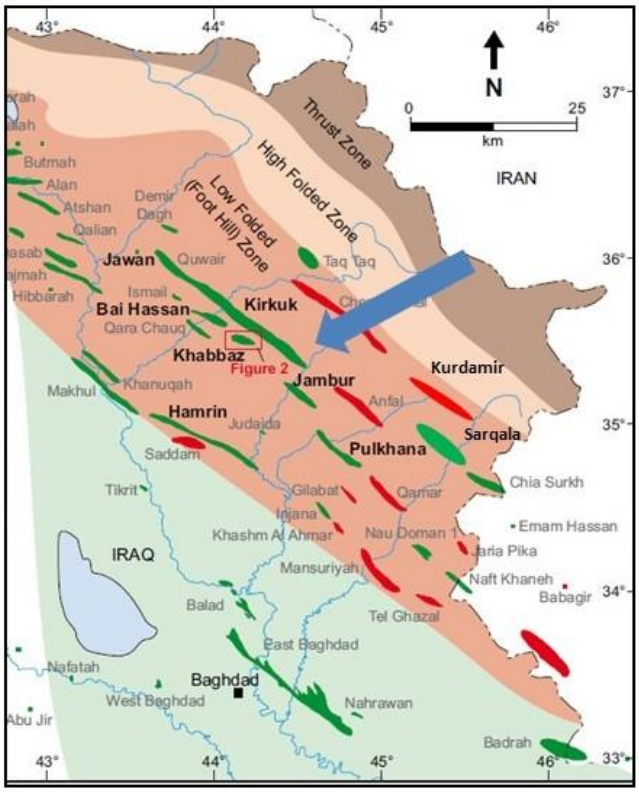

Figure 3: Location map of the studied area. A Tectonic map of Iraq after [35]. B Satellite map of the study area taken from Google Earth.

Clarified that the northern areas of Iraq are considered geologically one of the most important areas since they have different rock structures and are very complicated in morphology [34]. Therefore, these areas are very active tectonically and according to, Iraq can be divided into three tectonically different areas; Stable Shelf, Unstable Shelf, and Zagros Suture Zones. Baba Formation on Kirkuk structure, oil well K-109 as the type locality, is defined by the coordinates: 44° 18′ 55″ E, 35° 33′ 08″ N. It is exposed in eastern Iraq and occurs widely in all wells southeast of the Lesser Zab, on the Kirkuk structure, it also occurs on the northeast flank of the Bai Hassan structure, and at the surface of the northern dome of the Qarah Chauq Dagh. Northwards, the Baba limestone formation is found in several M.P.C. wells, including Qalian No. 1, Gullar No. 1, Gusair No. 1, and wells on the Ain Zalah structure. To the west of its type locality, the formation changes its facies into the Tarjil Formation which disappears further west.

2. Materials and methods

From 35m thick of the studied well, 28 F34 samples are borrowed from the Iraqi Oil Ministry and 40 petrographic thin sections from the calcareous units were examined. All the random and oriented thin sections of the foraminiferal species described and figured in this paper are deposited in the collection of Sulaimani University, Iraq. A standard petrographic microscope equipped with a digital camera was used to qualitatively identify the microfossils in the thin sections. Microfacies analysis was carried out using the standard models of [36-39]. The identification of the recognized benthic foraminifera and the biostratigraphic analysis are assisted by using, the studies of, were used for the of paleoenvironmental interpretation [40-43].

2.2. Microfacies analysis

Three carbonate sedimentary facies were recognized for the Baba Formation in the study well to interpret the depositional history, these facies are related to three depositional settings [tidal flat, lagoon, and open marine] of inner, outer and middle portions of a carbonate platform. The identified carbonate microfacies are [Fig. 4].

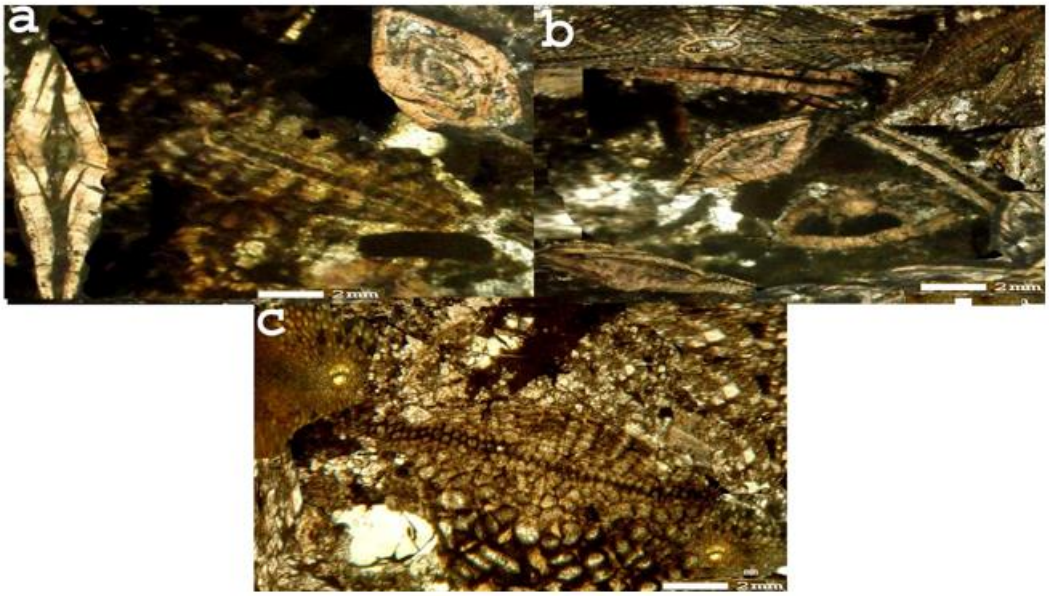

Figure 4: Photomicrographs of Microfacies: a- Nummulitic Wackstone Packstone microfacies [MF1], b- Nummulitic Packstone microfacies [MF2], c- Lepidocyclina Packstone Grainstone [MF3].

Nummulitic wackestone packstone microfacies [MF1]: The thickness of these microfacies is about 5m and underlies the Nummulitic Packstone Microfacies [MF1], with thickness ranges between 5m and it is recorded at the lower part of the studied well, it mainly consists of skeletal allochems including benthic perforate foraminifera species. Dissolution and partial recrystallization processes are well defined in this microfacies type and correlated with SMF4 of FZ4 of [Fig. 4a] [38, 39]. Due to the predominance of mud-rich texture with miliolids and the presence of high diversity foraminiferal arrangement, a restricted platform, very shallow lagoon is suggested for deposition of this microfacies in the inner ramp environment [2, 44-47]. This microfacies is correlated with SMF4 of FZ4 of [38, 39].

Nummulitic packstone microfacies [MF2]: These microfacies underlie the Lepidocyclina - packstone grainstone microfacies [MF3], with thickness, ranges between 10m and is recorded at the middle part of the studied well, including benthic foraminifera species [Fig. 4b]. The presence of a large number of imperforate benthic foraminifer tests suggests that these facies was deposited in a middle ramp setting and points to nutrient-rich with the slightly hypersaline and warm euphotic condition. This microfacies type can be correlated with SMF8 of FZ7 [2, 3, 38, 39, 48-50].

Leptocyclina packstone grainstone microfacies [MF3]: These microfacies overlie the Nummulitic packstone Microfacies [MF2]. including benthic foraminifera species, it has thickness ranges between 20m and it is recorded at the upper part of the studied well, it is characterized by predominating the skeletal grains of larger perforate foraminifera [Fig. 4c]. Recrystallization and diagenesis processes affected these microfacies. This microfacies type is compared with [FZ4 or FZ5] and SMF5 [38, 39].

2.3. Biostratigraphy

About 35 m thick of Oligocene succession has been studied biostratigraphically with recognition of thirty species from twenty genera of benthic foraminifera, in addition to gastropods, bivalves, coral, and calcareous algae [Fig 5, Plate I; Fig.6, Plate 2; Fig 7. Plate 3]. Based on the identified fossils two biozones are recognized, the biozones are arranged from older to younger [Fig. 8].

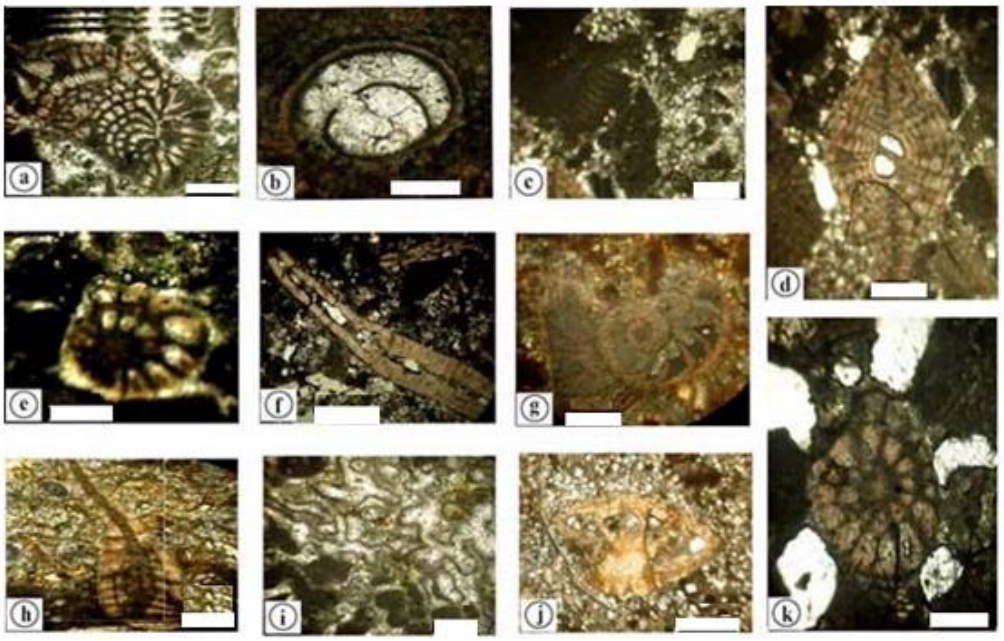

Figure 5: Plate I, a- Peneroplis evolutus, oriented section, sample no.22; b- Lepidocyclina [Eulepidina] dilatatata, oriented section, sample no. 22; c- Algae, sample no.23; d; Nephrolepidina marginata, axial section, sample no. 25; e- Neorotalia sp., sample no.25; f- Lepidocyclina [Eulepidina] sp., axial section, sample no. 26; g- Operculina complanata, equatorial section, sample no. 12; 12; h- Peneroplis thomasi, axial section, sample no.20; i- Coral, sample no.23; j- Neorotalia viennoti, [Greig], sample no. 18; k- Neorotalia sp. , sample no.8.

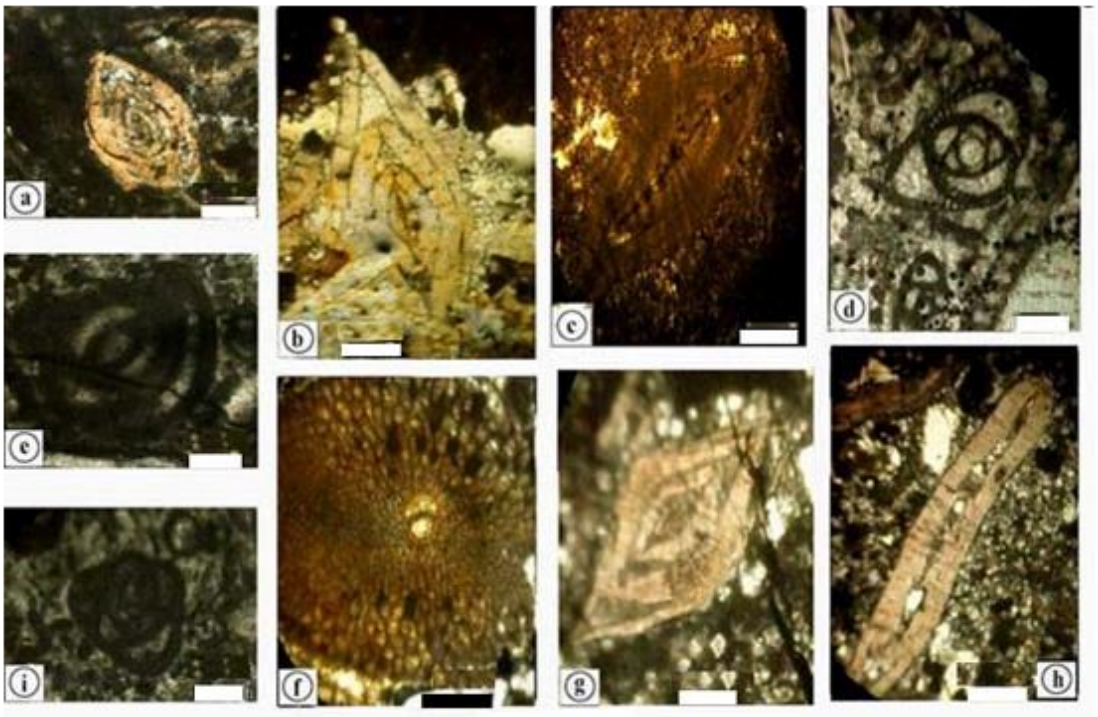

Figure 6: Plate II, a. Amphistegina sp. sample no. 10; b. Nummulites intermedius sample no. 11; c. Nummulites fichteli, equatorial section, sample no.15; d. Austrotrillina paucialveolina, oriented section, sample no. 13; e. Pyrgo sp., sample no. 32; f. Nephrolepidina marginata, oriented section, sample no.27; g. Amphestegina sp. sample no. 12; h. Operculina sp., axial section, sample no. 14; i. Quinqueloculina sp., equatorial section, sample no. 20.

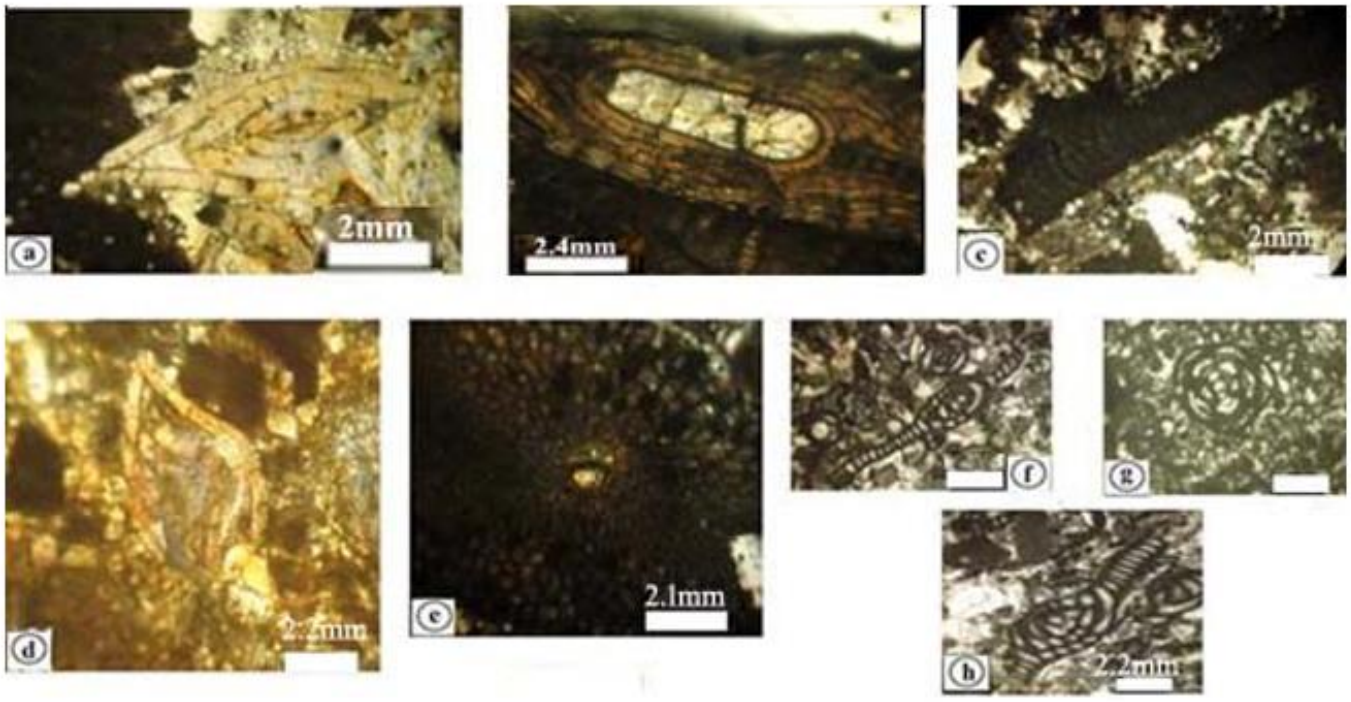

Figure 7: a. Nummulites sp., sample no. 10; b. Eulepidina, axial section, sample no.26; c. Algae, sample no.23; d. Amphistegina sp., sample no. 13; e. Nephrolepidina marginata, oriented section, sample no.27; f. Peneroplis sp., axial section, sample no. 23; g. Quinqueloculina sp., equatorial section, sample no. 18; h. Archaias sp., sample no. 24.

2.4. Nummulites Ficteli- Nummulites Intermedius Assemblage Zone –Sbz22a- [Late Rupelian]

Definition: Biostratigraphic interval of this zone is characterized by the association of the taxa Nummulites fichteli and Nummulites intermedius.

Remarks: This zone is about 15 m thick from samples 1-18, which starts with the First Appearance Datum (FAD) of Nummulites fichteli -Nummulites intermedius., and ended with the Last Appearance Datum (LAD) of Lepidocyclina (Eulepidina) dilatata. The most diagnostic species include Nummulites fichteli -Nummulites intermedius; Nummulites vascus; Nummulites sp., Austrotrillina asmaricus; Austrotrillina paucialveolina, Austrotrillina sp., Archaias kirkuknesis, Archaias sp., Peneroplis hensoni; Peneroplis evolutus; Peneroplis sp; Operculina compalnata; Operculina sp., Spiroclypeus blankhorni : Spiroclypeus sp., Heterostegina assilinoides , Neorotalia viennoti, Neorotalia sp., Quinqueloculina sp., Textularia sp., Pyrgo sp., Ditrupa sp., Amphistegina sp., Miliolids, calcareous algae, coral, and mollusks.

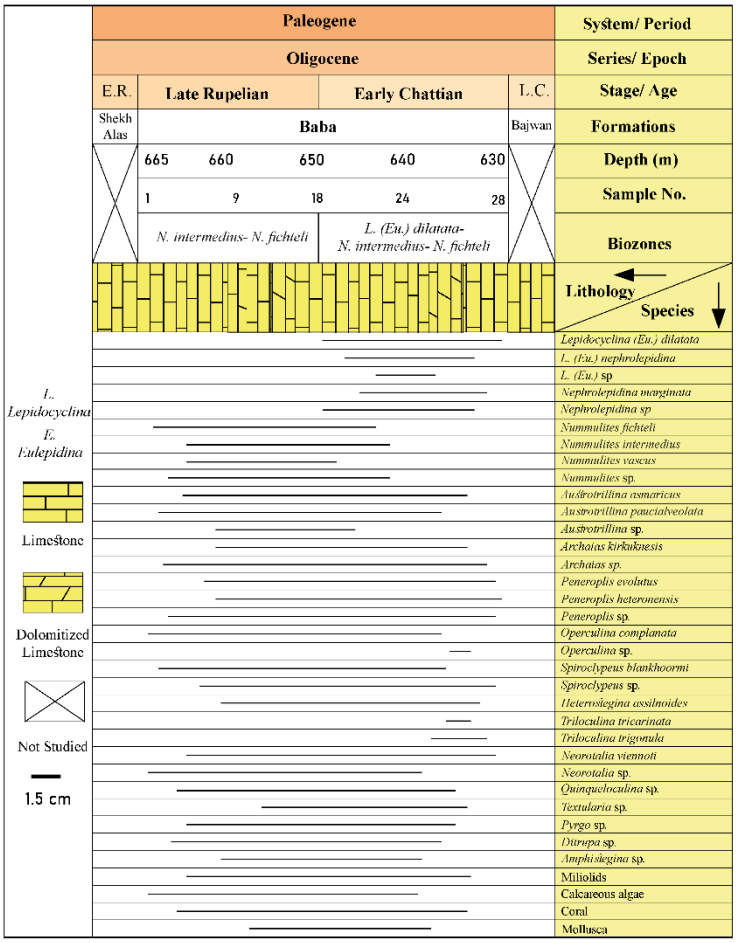

Figure 8: Biostratigraphic column of the Baba Formation in the Kirkuk Well-19 Section.

Correlation: The biozone is correlated with comparatively well-known biozones from other parts of the Tethys region which showed a good comparison between these biostratigraphic zones established in this study with other studies. e.g. it is equivalent to the Nummulites vascus-Nummulites fichteli-Eulepidina zone, established by, with the zone Nummulites fichteli - Nummulites – vascus of correlated with the lower part of the zone Nummulites fichteli - Nummulites – vascus- Spiroclypeus corphycus –Eulepidina-formosides- Austrotrillina brummi- Austrotrillina paucialveolina, that recorded by, to the zone Globigerina- Turborotalia cerrazulensis- Hantkenina of two Nummulites vascus-Nummulites fichteli zone of, it is equivalent to the Eulepidina dilatata - Nephrolepidina marginata zone recorded by, and finally to the zone Nummulites vascus-Nummulites fichteli, [Table 2]. Age: Oligocene [Late Rupelian] [1, 23, 29, 51-53]

2.5. Leptidocyclina [Eulephidina] Dilatate-Nummulites Intermedius Fichteli Assemblage Zone- Sbz22b – [Early Chattian]

Definition: Biostratigraphic interval of this zone is characterized by the association of the taxa Lepidocyclina [Eulephidina dilatata; Nummulites intermedius and Nummulites fichteli.

Remarks: This zone is about 20 m thick from samples 19-28, which starts with the First Appearance Datum [FAD] of Lepidocyclina [Eulephidina] dilatata- Lepidocyclina [Eulephidina] elephantina and ended with the Last Appearance Datum [LAD] of Nephrolepidina marginata. The most diagnostic species include Lepidocyclina [Eulephidina] dilatata, Lepidocyclina (Eulephidina) elephantina, Lepidocyclina [Eulephidina] sp., Nephrolepidina marginata, Nephrolepidina sp., Nummulites fichteli -Nummulites intermedius; Austrotrillina asmaricus; Austrotrillina paucialveolina, Austrotrillina sp., Archaias kirkuknesis, Archaias sp., Peneroplis hensoni; Peneroplis evolutus; Peneroplis sp; Operculina complanata; Operculina sp., Spiroclypeus blankhorni : Spiroclypeus sp., Heterostegina assilinoides, Neorotalia viennoti, Neorotalia sp., Quinqueloculina sp., Textularia sp., Pyrgo sp., Ditrupa sp., Amphestegina sp., Miliolids, calcareous algae, coral, and mollusca.

Correlation: The biozone is correlated with these biostratigraphic zones that are recorded outside of Iraq. e.g. Miogypsinoides complanatus zone [SBZ22B] of [1]. Archaias asmaricus- Archaias hensoni- Miogypsinoides complanatus Zone of Lauresen the upper part of Nummulites fichteli - Nummulites – vascus- Spiroclypeus corphycus –Eulepidina-formosides- Austrotrillina brummi- Austrotrillina paucialveolina zone, established by Lepidcyclina-Operculina- Ditrupa zone of Joudaki and Baghbani and Mughaddam [43, 51]. The biozone is correlated with these biostratigraphic zones that recorded inside of Iraq e.g. Lepidocyclina (Eulepidina) dilatata- Nummulites vascus-Nummulites fichteli zone of Qader; to the Praehapydionina delicata-Peneroplis evolutus zone of Ghafor & Ahmad, it is corresponds to the lower part of Assemblage Zone II by Ghafor(a), and finally this zone is equivalent to the Lepidocyclina [Eulepidina] dila-

tata- Nummulites vascus-Nummulites fichteli zone recorded by Ghafor(b), [Table 2]. Age: Oligocene [Early Chattian] [22, 23, 29, 53].

System / Period		Paleogene	
Series / Epoch		Oligocene	
Stage / Age		Late Rupelian	Early Chattian
Studies			
Outside Iraq	Cauhaz & Poigmant, 1997	SBZ22A	SBZ22B
		Nummulites vascus- Nummulites fichteli - Eulepidina Zone	*Miogypsinoides complanatus* Zone
	Lauresen et al., 2009	*Nummulites fichteli - Nummulites - vascus* Zone	*Archaias asmaricus- Archaias hensoni- Miogypsinoides complanatus Zone*
	Serra Kiel et al. 2016	*Nummulites fichteli – Nummulites formosides, Eulepidina vascus , Spiroclypeus corphycus Austrotrillina brummi Austrotrillina paucialveolina Zone*	
	Joudaki & Baghbanni, 2018	*Globigerina- Turborotalia cerrazulensis- Hantkenina* Zone	*Lepidocyclina- Operculina- Ditrupa* Zone
	Mugahddam et al. 2019	*Nummulites vascus- Nummulites fichteli* Zone	*Lepidcyclina- Operculina- Ditrupa* Zone
Inside Iraq	Qader, 2020	*Nummulites vascus- Nummulites fichteli* Zone	*Lepidocyclina(Eulepidina) dilatata- Nummulites vascus- Nummulites fichteli* Zone
	Ghafor & Ahmad, 2021	*Eulepidina dilatata - Nephrolepidina marginata* Zone	*Praehapydionina delicata- Peneroplis evolutus Zone*
	Ghafor & Najaflo, 2021	*Nummulites vascus- Nummulites fichteli* Zone	*Lepidocyclina (Eulepidina) dilatata - Nummulites vascus- Nummulites fichteli* Zone
	Ghafor, 2022a		Assemblage Zone II
Biozonation of this Study, 2023		*Nummulites fichteli Nummulites intermedius* Zone	*Lepidocyclina (Eulepidina) dilatata - Nummulites fichteli - Nummulites intermedius* Zone

Table 2: Comparisons of zonal schemes of the studied section with those proposed by some authors.

2.6. Depositional Environment

Three microfacies were recognized from the Baba Formation in the study area, these facies are related to three depositional settings [inner ramp, middle ramp, and outer ramp] of a carbonate platform. The profile for the deposition of the Baba Formation at the studied well shows a northwest-to-southeast transition from the inner to outer ramp environment as follows [Fig. 9].

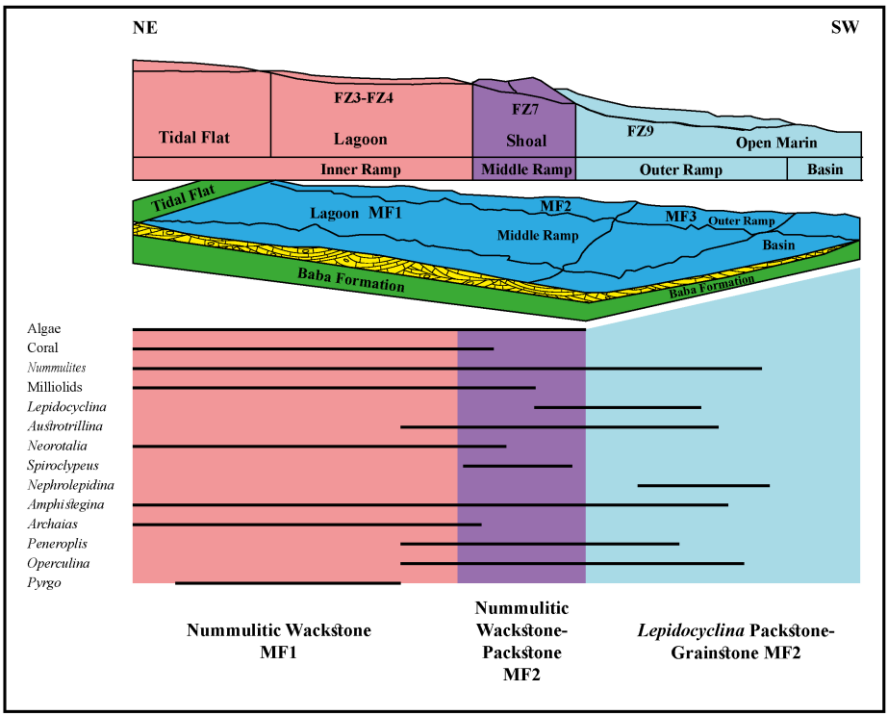

Figure 9: Depositional model of the distribution of main components in the Baba Formation of the studied well. The interpretation is based on Flügel [39].

2.7. Inner-Ramp Environment

MF1 facies is distinguished in this area that occurs in a proximal shore-face environment at the lower part of the formation and it is characterized by microfacies mainly consisting of skeletal allochems and including different genera, [Archaias, Austrotrillina, Nummulites, Neorotalia, Pyrgo, coral and algae] these components are of hypersaline stressful, low-energy shallow water environment in near-shore settings [39]. [MF1] microfacies of the studied wells were deposited within the FZ3 and FZ4 of Wilson and Flügel [38, 39].

2.8. Mid-Ramp Environment

MF2 microfacies are distinguished in this area at the middle part of the formation, the limestones are composed of bioclastic coral, and include different genera [Spiroclypeus, Amphistegina, Peneroplis, Operculina, and algae], indicating tropical and subtropical shallow- water environmental conditions of the lagoonal type, with a water depth less than 20 meters [4, 54]. These facies were deposited within the FZ7 of, with a high-energy area that corresponds to the shoal or middle ramp environment [28 ,38, 39].

2.9. Outer-Ramp Environment

MF3 microfacies are distinguished in this area at the upper part of the formation and are mainly composed of different genera [Lepidocyclina, Nephrolepidina, Austrotrillina, Neorotalia, Amphistegina, Operculina, Peneroplis, and algae]. The combination of larger foraminifera and micritic matrix [Nummulite and Lepidocyclina], association with echinoids fragments that took place in the lower photic zone in a distal-open marine environment [44, 55, 56]. According to the presence of Lepidocyclina and Nummulites shows that these microfacies occurred in deep water and the lower photic/oligophotic zone [3, 6, 57]. These facies were deposited within the FZ9 of [38, 39]. According to the recognized microfacies, the Baba Formation was deposited from inner to outer ramp environments.

3. Discussions and Interpretation

Generally, within the Kirkuk embayment, Oligocene-Early Miocene shows progressive shallowing upwards with a major depression mainly. Show that the Oligocene cycle consists of the Palani, Sheikh Alas, and Shurau Formations extending through a variety of depositional environments [10]. Considered the Palani and part of the Tarjil and Sheikh Alas formations as forming one cycle in the Late Eocene [8]. The present interpretation of the Kirkuk Well-19 of the studied section shows that the age of the Baba Formation is shown to be close to Late Rupelian-Early Chattian, as follows:

3.1. Nummulites fichteli -Nummulites intermedius Zone [Late Rupelian]

Recognized this benthic foraminifer [Nummulites fichteli -Nummulites intermedius; Nummulites vascus; Austrotrillina paucialveolina, Archaias sp, Peneroplis sp. Spiroclypeus sp] from the

Early Oligocene (Rupelian) age [58].

3.2. Lepidocyclina [Eulephidina] Dilatata-Nummulites Intermedius-Nummulites Fichteli Zone [Early Chattian].

According to these benthic foraminifera [Lepidocyclina [Eulephidina] dilatata, Lepidocyclina [Eulephidina] elephantina, Lepidocyclina [Eulephidina] sp., Nephrolepidina marginata, Nephrolepidina sp., Eulepidina-Nephrolepidina], are the min important index fossils of the Chattian age, the palaeoenvironmental of the Baba Formation is interpreted as:- Shallow ramp lagoon, rich nutrient, hyper-saline characterized by the genera Archaias and Austrotrillina, the inner ramp with Nummulites, middle ramp with Spiroclypeus and Operculina, the Paleogene-Neogene corals thrived mainly in the mesophotic to oligophotic conditions and can be applied to the present one that seen in the upper part of the section Lepidocyclina [Eulephidina] dilatata - Nummulites intermedius-Nummulites fichteli Assemblage Zone], which is the important and first documentation of the whole ramp profile. The gathered evidence about the Oligocene environment is strong and unique during Late Oligocene when the inner shelf of the carbonate platform was uplifted and transformed to terrestrial land temporarily [13, 30, 54, 57].

The interpretation of the depositional model of the Baba Formation from the studied well is based on the study of Flügel [39]. The studied well of the Baba Formation, about 35 m thick shows that the paleoenvironment of the Baba Formation characterized by the carbonate ramp model includes three microfacies the distal part of the formation penetrated only outer ramp deposits [MF3], the frontal part penetrated only inner ramp deposits [MF1] and the middle part consists mainly of [MF2], the increase in sprite and the size of foraminifera from MF1 to MF3 indicates the increase in wave energy, these microfacies found in Oligocene Tethyan inner-outer ramp of the shallow euphotic zone [60].

Occurrence of these marine faunas [Nummulites spp., Lepidocyclina spp., Nephrolepidina spp. Austrotrillina paucialveolina, Archaias sp., Peneroplis sp. Spiroclypeus sp. Eulepidina-Nephrolepidina] in the Oligocene sediment of the study area suggests that communication between the Northeastern and Southwestern provinces of the western Tethys Region still existed. The closure of the Tethys during the Oligocene had a major impact on ocean circulation and climate [61]. The Lower Oligocene deposits recorded in the study area are equivalent to the Jordan and part of marine Siliciclastics and marly limestones of the Dabba/Tinha Formations found in the subsurface of northern Egypt, whereas on the southern African/Arabian plate a phase of southward retreat occurred leading to a deposition of continental to fluviatile or deltaic siliciclastics [14, 62].

Oligocene rocks from Baranan and Kurdamir sections, rich in microfossils related to the genera of benthic foraminifera, Lepidocyclina; Nephrolepidina, Neorotalia; Heterostegina Schlumbergerina; Borelis melo; Spiroloculina; Pyrgo; Austrotrillina; Nummulites; miliolids. [Fig 10, Plate 4]. Three boreholes from Baranan and Kurdamir sections were logged. Investigations of the Eocene Cycle and five Oligocene-Miocene cycles were undertaken, where the first cycle of the Eocene rocks includes Jadala, Avana, and Pilaspi formations, while the first cycle of the Oligocene includes, Palani, Shekh Ala, and Shurau formations. Tarjil, Baba, and Bajwan formations show as the third cycle, and the four-cycle includes Ibrahim, Azkand, and Anah formations, and the Lower Miocene cycles include Dhiban and Jerebi formations [63-88].

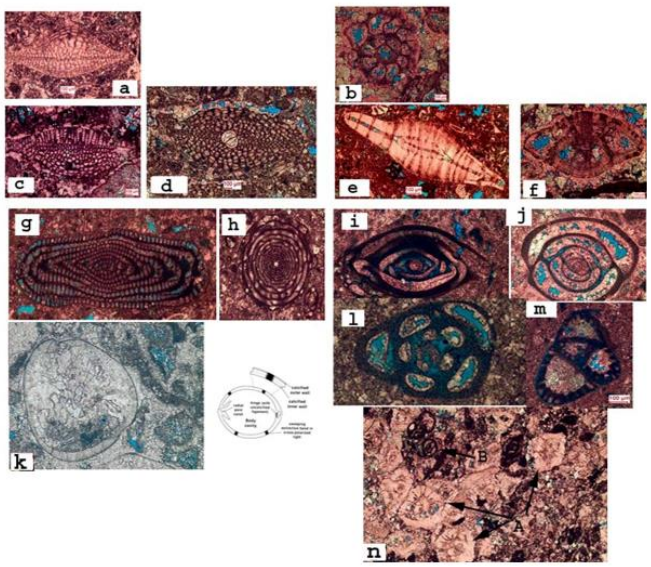

Figure 10: Plate 4. a. Lepidocyclina [Nephrolepidina] sp. [2601.71 m, 100 μ□]; b- Neorotalia viennoti [2514.46 m], c. Nephrolepidina praemarginata. [Douvillé], [2574.42 m, 100 μ□]; d. Nephrolepidina marginata [Michelotti, 1841] [576.80 m, 100 μ□]; e. Heterostegina sp., [2571.11m, 100 μ□]; f. Neorotalia viennoti [Greig], [2613.93 m; 100 μ□]; g. Schlumbergerina sp. [2570.32 m; 100 μ□]; h. Borelis melo curdica (2562.82 m; 100 μ□); i. Spiroloculina sp., (2665.95; 100 μ□); j. Pyrgo sp. [2586.86 m; 100 μ□]; k. Ostracoda, small bivalved crustaceans, are found as articulated or disarticulated valves. Carapace structure is a stable micro-prismatic calcite that gives a sweeping extinction in XN. [2667.33 m; 100 μ□]; l. Austrotrillina paucialveolina Grimsdale, 1952, [2570.32 m; 100 μ□] m. Austrotrillina howchini [Schlumberger], [2565.95 m; 100 μ□]; n- A. Nummulites vascus Joly and Leymerie, [2639.58 m; 250 μ□]; B. Miliolids [2639.58 m; 250 μ□].

3.3. Regional Correlation

Eocene cycle: Eocene showed carbonate lagoonal facies - carbonate margin facies, and carbonate basinal facies. This cycle consists of the Pilaspi, Avanah, and Jaddala formations [Fig. 11].

The distribution of the Oligocene succession [basinal and reef–back-reef deposits] in Iraq closely follows the pattern set in Middle to Late Eocene times. Reef–back-reef limestone has a linear outcrop across northern Iraq from the northwest [the eastern part of the studied area] to the southeast [9]. In the Baraan well, the Palani Formation of the Lower Oligocene and Baba Formation as the tongue has been shown [Figs. 12].

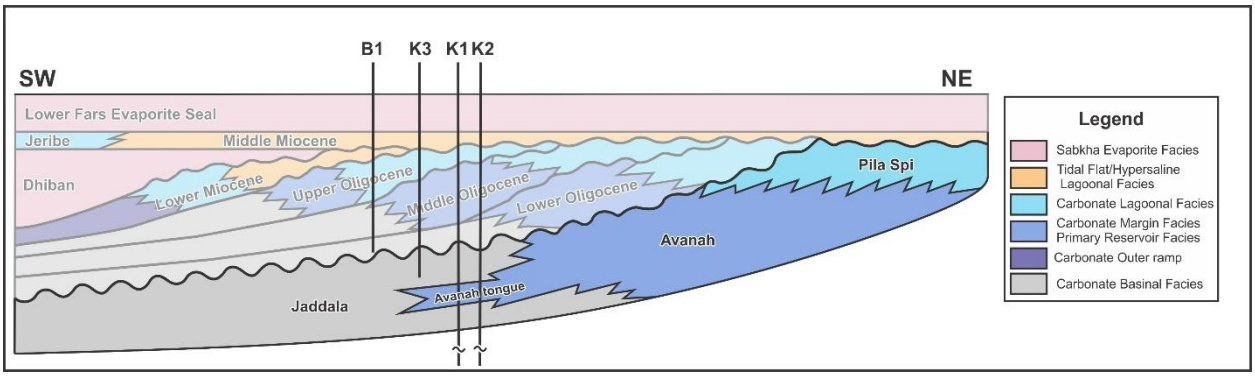

Figure 11: Baranan well B1; Kurdamir wells K3, K1, and K2 indicating Eocene cycle [Pilaspi, Avanah, and Jaddala formations].

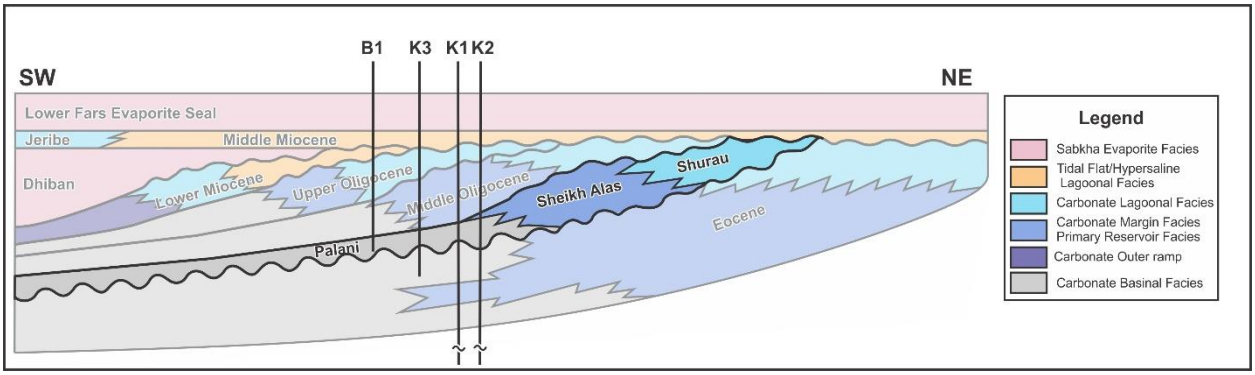

Figure 12: Location of Baranan well B1; Kurdamir wells K3, K1, and K2 indicating the Palani Formation of the Lower Oligocene and Sheikh Alas Formation.

Based on the lithologic and biostratigraphy data, the study area shows a variety of sedimentary facies within each formation. The grouping of facies within each formation and their distribution within the Baba Basin has been interpreted as carbonate margin facies and primary reservoir facies, Accordingly, the Oligocene deposits were subdivided into the following sedimentary cycles:

3.4. Oligocene First Cycle – Rupelian

This cycle consists of the Palani, Sheikh Alas, and Shurau formations, extending from the carbonate lagoonal facies-carbonate margin facies to the carbonate basinal faces [Fig. 12], through a variety of depositional environments [18]. Considered the Palani and parts of the Tarjil and Sheikh Alas formations as forming one cycle in the Early Oligoene [8].

3.5. Oligocene Second Cycle-Chattian

The Late Rupelian transgression continued into the Early Chattian. It showed fluctuations but was generally more extensive than the earlier transgressive cycle [9]. This cycle consists of the Tarjil, Baba, and Bajwan formations, which extend through a variety of carbonate lagoonal facies-carbonate margin facies to the carbonate basinal faces [Fig.13], depositional environments [10]. Considered the Palani and part of the Tarjil and Sheikh Alas formations as forming one cycle in the Late Eocene [8].

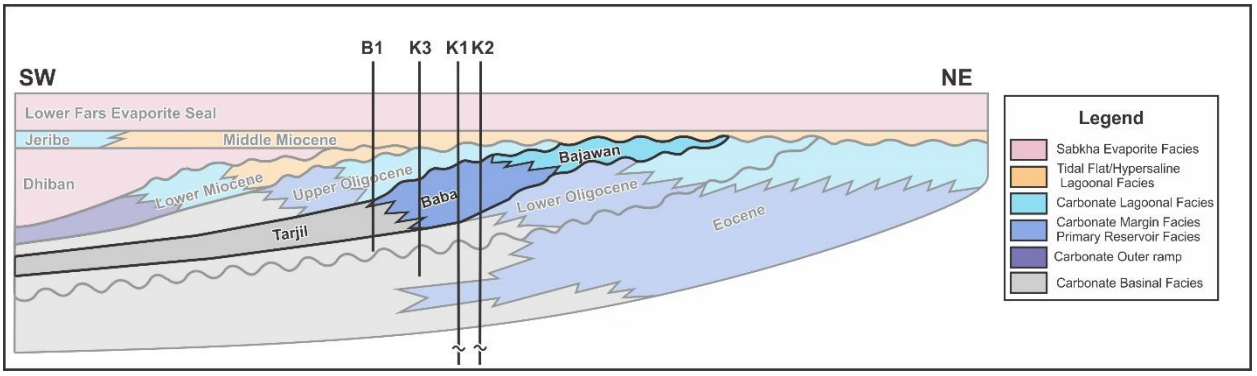

Figure 13: Baranan well B1; Kurdamir wells K3, K1, and K2 indicating Tarjil, Baba, and Bajawan formation

3.6. Oligocene Third Cycle-Chattian-Aquitanian

The Late Chattian transgression continued into the Early Aquitanian. It showed fluctuations but was generally more extensive than the earlier transgressive cycle [9]. This cycle consists of the Ibrahim, Azkand, and Anah formations, which extend through a variety of carbonate lagoonal facies-carbonate margin facies to the carbonate basinal faces [Fig. 14], depositional environments [10].

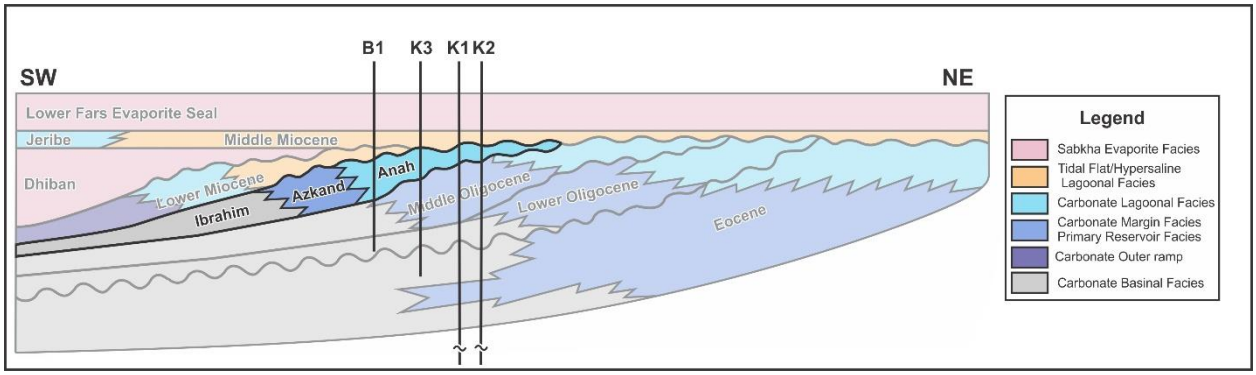

Figure 14: B1 Baranan well -1; K3; K1 and K2 are Kurdamir wells indicating Azkand and Anah formations

3.7. Lower Miocene Cycle

Early Miocene showed tidal flat hypersaline lagoonal facies to carbonate outer ramp. This cycle consists of the Euphrates and Serikagni formations [Fig. 15], depositional environments [10].

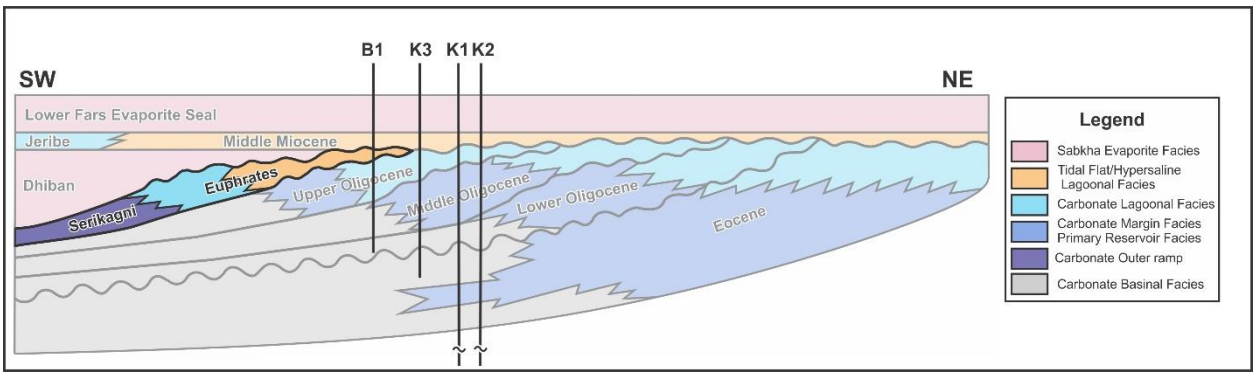

Figure 15: Baranan well B1; Kurdamir wells K3, K1, and K2 indicating Euphrates and Serikagni formations.

4. Conclusions

This study revealed the following conclusions:

- The Late Oligocene rock units of the Baba Formation in the Kirkuk well-19 section, were studied for the first time in detail from a point view of bio stratigraphically, microfacies, and paleoenvironment.
- Nummulites fichteli -Nummulites intermedius Assemblage zone and Lepidocyclina [Eulepidina] dilatata- Nummulites intermedius- Nummulites fichteli Assemblage zone were recognized in the Late Rupelian-Early Chattian of the studied well.
- Biostratigraphic correlation of the Baba Formation with other parts of the Tethys region showed a good comparison between the biostratigraphic zones established in this study with other studies.
- Baba Formation, its environment determined from the inner shelf - middle-shelf to outer-shelf environment, these rock units display cyclic sedimentation and relatively rapid lateral facies changes that may be related to deposition on the shelf.
- It was deposited in a very shallow lagoon, nutrient-rich with a slightly hypersaline and warm euphotic condition.
- The relative correlations of sedimentary cycles of the Oligocene deposits suggest that
- the north Arabian platform was flooded twice during the Rupelian and Chattian transgressions.

Conflict of Interests: The authors declare no conflict of interest.

References

1. Cahuzac, B., & Poignant, A. (1997). Essai de biozonation de l'Oligo-Miocène dans les bassins européens à l'aide des grands foraminifères néritiques. Bulletin de la Société géologique de France, 168(2), 155-169.
2. 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(3-4), 211-238.
3. Romero, J., Caus, E., & 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), 43-56.
4. Holzmann, M., Hohenegger, J., Hallock, P., Piller, W. E., & Pawlowski, J. (2001). Molecular phylogeny of large miliolid foraminifera (Soritacea Ehrenberg 1839). Marine Micropaleontology, 43(1-2), 57-74.
5. Serra- Kiel J. K. Drobne Less G. Ferràndez-Cañadell, C. Jauhri A. A, (1998) Larger Benthic Foraminifera (Paleogene), Bull Soc Geol, France, 169(2): 281- 299
6. Barattolo, F., Bassi, D., & Romano, R. (2007). Upper Eocene larger foraminiferal–coralline algal facies from the Klokova Mountain (southern continental Greece). Facies, 53, 361-375.
7. Habibi, T. (2016). Biostratigraphy, paleoenvironment and foraminiferal associations of the Rupelian-Chattian sediments in Zagros Basin, SW Iran. Journal of African Earth Sciences, 123, 370-380.
8. Ditmar, V. (1971). GEOLOGICAL CONDITIONS&HYDROCARBON PROSPECTS OF THE REPUBLIC OF IRAQ (NORTHERN & CENTRAL PARTS).
9. Al-Banna, N. Y., Al-Mutwali, M. M., & Ismail, N. R. (2010). Oligocene stratigraphy in the Sinjar Basin, northwestern Iraq. GeoArabia, 15(4), 17-44.
10. Van Bellen, R. C. (1956). The Stratigraphy of the" Main Limestone" of the Kirkuk, Bai Hassan, and Qarah Chauq Dagh Structures in North Iraq. Institute of Petroleum.
11. Sharland, P. R., Casey, D. M., Davies, R. B., Simmons, M. D., & Sutcliffe, O. E. (2004). Arabian plate sequence stratigraphy–revisions to SP2. GeoArabia, 9(1), 199-214.
12. Al-Banna, N. Y. (2008). Oligocene/Miocene boundary in northern Iraq. GeoArabia, 13(2), 187-190.
13. Boukhary, M., Kuss, J., & Abdelraouf, M. (2008). Chattian larger foraminifera from Risan Aneiza, northern Sinai, Egypt, and implications for Tethyan paleogeography. Stratigraphy, 5(2), 179-192.
14. Kuss, J., & Boukhary, M. A. (2008). A new upper Oligocene marine record from northern Sinai (Egypt) and its paleogeographic context. GeoArabia, 13(1), 59-84.
15. Van Bellen, R. C., & Dunnington, H. V. (1959). Lexique stratigraphique international: Asie. Iraq. Centre national de la recherche scientifique.
16. Al-Eisa, M. E. (1992). The two subdepositional cycle of the Early Miocene in Kirkuk oil field area, north Iraq. Journal of Geological Society of Iraq, 25(1), 41-58.
17. Ghafor, I. M. (2004). Biometric analysis of Lepidocyclina (Nephrolepidina) and Miogypsinoids from Baba and Azkand formations (Oligocene–Miocene) in Kirkuk area, Iraq. Unpub. Unpublished Ph. D. Thesis., College of Science. University of Sulaimani, Iraq, 170.
18. Ghafor, I. M. (2010, March). Systematic Description of Larger Foraminifera from Oligocene-Miocene in Different Oil Field, Kirkuk Area, North Iraq. In GEO 2010 (pp. cp-248). European Association of Geoscientists & Engineers.
19. Ghafor, I. M. (2011). Microfacies and biostratigraphy of Baba Formation (Late Oligocene) in Bai Hassan, oil well-25, Kirkuk Area, Central North Iraq. Iraqi Bulletin of Geology and Mining, 7(3), 25-32.
20. Ghafor, I. M. Biometric analysis of Lepidocyclina (Nephrolepidina) from Baba Formation (Late Oligocene) in Bai-Hassan Well-25, Kirkuk area, Northeast Iraq.
21. Ghafor, I. M. (2015). Evolutionary aspects of Lepidocyclina (Nephrolepidina) from Baba Formation (late Oligocene) in Bai-Hassan well-25, Kirkuk area, Northeast Iraq. Arabian Journal of Geosciences, 8(11), 9423-9431.
22. Ghafor, I. M. (2022). Biostratigraphy and microfacies of Azkand Formation in Qarah Chaugh-Dagh Section, Kirkuk Area (Northeastern Iraq). In Recent Research on Geomorphology, Sedimentology, Marine Geosciences and Geochemistry: Proceedings of the 2nd Springer Conference of the Arabian Journal of Geosciences (CAJG-2), Tunisia 2019 (pp. 251-256). Springer International Publishing.
23. Ghafor, I. M. (2022). Systematic, microbiostratigraphy and paleoecology of the Bajwan Formation (Late Oligocene) in the Kirkuk Well-160, northeastern Iraq. Carbonates and Evaporites, 37(3), 45.
24. Muhammed, I. M. G. Q. A. Evolutionary Aspects of Lepidocyclina (Nephrolepidina) from Baba and Azkand Formations (Oligocene-Miocene) in Kirkuk area, Iraq.
25. Ghafor, I. M., & Muhammed, Q. A. (2007). Evolutionary Aspects of the Miogypsinidae from Azkand Formation (Oligocene-Miocene) in Kirkuk Area, Iraq. Iraqi Journal of Earth Sciences, 7(1), 21-36.
26. Ghafor, I. M., & Mohammad, Q. A. (2011). Lepidocyclina (Nephrolepidina) kirkukensis n. sp., a new Larger Foraminifera from the Late Oligocene of Kirkuk Area, Northern Iraq. Iraqi National Journal of Earth Science, 11(2), 37-50.
27. Muhammed, Q. A., & Ghafor, I. M. (2008). Biometric analysis of Miogypsinidae and their taxonomic significance from Azkand Formation (Oligocene-Miocene) in Kirkuk area, Iraq. Tikrit Journal of Pure Science, 13(1), 198-213.
28. Ghafor, I. M., & Ahmad, P. M. (2019). Biostratigraphy and paleoecology of Anah Formation in the Pungalla village, Sangaw area, Sulaimaniya, Northeastern Iraq. Iraqi Bulletin of Geology and Mining, 15(2), 1-15.
29. Ghafor, I. M., & Ahmad, P. M. (2021). Stratigraphy of the Oligocene-Early Miocene successions, Sangaw area, Kurdistan Region, NE-Iraq. Arabian Journal of Geosciences, 14(6), 454.
30. Ghafor, I. M., & 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), 7.
31. Ghafor, I. M., Lawa, F. A., & Karim, K. H. (2003). New discovery of Carnivores Mammalian Skeleton Fossils of Late Miocene-Early Pliocene age from Chamchamal area/Kurdistan Region/NE-Iraq. Journal of Zankoy Sulaimani-Part A, 6(1), 61-73.
32. Ghafor, I. M., Karim, K. H., & Sissakian, V. (2014). Biostratigraphy of Oligocene succession in the High Folded Zone, Sulaimani, Kurdistan Region, Northeastern Iraq. Arabian Journal of Geosciences, 7, 3599-3610.
33. Ghafor, I., Ahmad, P., & Khafaf, A. A. (2023). Biostratigraphy and Paleoecology of the Anah Formation in Kurdistan Region, Iraq. IRAQI BULLETIN OF GEOLOGY AND MINING, 19(1), 17-28.

34. Buday, T. (1980). The regional geology of Iraq: stratigraphy and paleogeography (Vol. 1). State Organization for Minerals, Directorate General for Geological Survey and Mineral Investigations.
35. Al-Kadhimi J. A, M, Sissakian V.K, Fattah, A. S. Deikran D. B, (1996) Tectonic Map of Iraq, scale 1: 1000 000, 2nd edit‖, Geosurvv, Baghdad, Iraq, pp.1-38
36. Dunham, R. J. (1962). Classification of carbonate rocks according to depositional textures.
37. Embry, A. F., & Klovan, J. E. (1971). A Late Devonian reef tract on northeastern Banks Island, NWT. Bulletin of Canadian petroleum geology, 19(4), 730-781.
38. Wilson, J. L., & Wilson, J. L. (1975). The lower carboniferous Waulsortian facies. Carbonate facies in geologic history, 148-168.
39. Flügel, E., & Munnecke, A. (2010). Microfacies of carbonate rocks: analysis, interpretation and application (Vol. 976, p. 2004). Berlin: springer.
40. Bakhtiar, H. A., & Taheri, M. R. (2010). Microfossils pictorial atlas of Zagros formations in Iran. Iran: Technical manager (geology).
41. Serra-Kiel J. K., Gallardo-Garcia, A., Razin, P. Robinet, J., Roger J. Grelaud C. Robin C, (2016) Middle Eocene-Early Miocene larger foraminifera from Dhofar (Oman) and Socotra Island (Yemen)‖, Arabian Journal of Geosciences 9(5).
42. Boudaugher-Fadel, M. K. (2018). Evolution and geological significance of larger benthic foraminifera. UCL press.
43. Moghaddam, I. M., Roozpeykar, A., & Shirmohamadi, G. (2019). Biostratigraphy of early Oligocene-early Miocene benthic foraminifera in Lorestan Zone, south-west Iran.
44. Amirshahkarami, M., Ghabishavi, A., & Rahmani, A. (2010). Biostratigraphy and paleoenvironment of the larger benthic foraminifera in wells sections of the Asmari Formation from the Rag-e-Safid oil field, Zagros Basin, southwest Iran. Stratigraphy and Sedimentology Researches, 26, 63-84.
45. Sooltanian, N., Seyrafian, A., & Vaziri-Moghaddam, H. (2011). Biostratigraphy and paleo-ecological implications in microfacies of the Asmari Formation (Oligocene), Naura anticline (Interior Fars of the Zagros Basin), Iran. Carbonates and evaporites, 26, 167-180.
46. Rahmani, A., Vaziri-Moghaddam, H., Taheri, A., & Ghabeishavi, A. (2009). A model for the paleoenvironmental distribution of larger foraminifera of Oligocene–Miocene carbonate rocks at Khaviz Anticline, Zagros Basin, SW Iran. Historical Biology, 21(3-4), 215-227.
47. Sahraeyan, M., Bahrami, M., & Arzaghi, S. (2014). Retracted: facies analysis and depositional environments of the oligocene–miocene asmari formation, zagros basin, iran.
48. Corda, L., & Brandano, M. (2003). Aphotic zone carbonate production on a Miocene ramp, Central Apennines, Italy. Sedimentary Geology, 161(1-2), 55-70.
49. Bassi, D., Hottinger, L., & Nebelsick, J. H. (2007). Larger foraminifera from the Upper Oligocene of the Venetian area, north-east Italy. Palaeontology, 50(4), 845-868.
50. Vaziri-Moghaddam, H., Kalanat, B., & Taheri, A. (2011). Sequence stratigraphy and depositional environment of the Oligocene deposits at Firozabad section, southwest of Iran based on microfacies analysis. Geopersia, 1(1), 71-152.
51. Laursen, G. V., Monibi, S., Allan, T. L., Pickard, N. A. H., Hosseiney, A., et al. (2009, May). The Asmari Formation revisited: changed stratigraphic allocation and new biozonation. In Shiraz 2009-1st EAGE International Petroleum Conference and Exhibition (pp. cp-125). European Association of Geoscientists & Engineers.
52. Joudaki, M., & Baghbani, D. (2018). Biostratigraphy of oligocene and lower miocene deposits, Anneh Anticline, Folded Zagros, SW of Iran. Carbonates and Evaporites, 33, 509-515.
53. Qader, P. O. (2020). Stratigraphy microfacies and depositional environment of Oligocene Early Miocene successions at Sagrma and Aj-Dagh structures, Kurdistan Region, Northeastern Iraq (Doctoral dissertation, Dissertation, Sulaimani University, Iraq).
54. Hatefi, S. M., Seyrafian, A., Vaziri-Moghaddam, H., Rahmani, A., & Perrin, C. (2018). Biostratigraphy, microfacies and paleoecology of the Asmari formation, interior fars province, Zagros Basin, Iran. N Jb Geol Palaont Abh, 288(1), 87-105.
55. Amirshahkarami, M., Vaziri-Moghaddam, H., & 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), 947-959.
56. Farhan, H. N., Kadem, L. S., & 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), 112-125.
57. Sadeghi, R., Vaziri-Moghaddam, H., & Taheri, A. (2011). Microfacies and sedimentary environment of the Oligocene sequence (Asmari Formation) in Fars sub-basin, Zagros Mountains, southwest Iran. Facies, 57, 431-446.
58. Sajadi, S. H., Baghbani, D., Daneshian, J., & Moezabad, M. K. (2016). Stratigraphy of Oligocene–Miocene salt deposits in the SE Persian Gulf. Carbonates and Evaporites, 31, 277-288.
59. Gedik, F., & Karadenizli, L. (2021). Oligocene larger benthic foraminifera and sedimentation of the Burdur Basin, SW Anatolia, Turkey. Geodiversitas, 43(13), 377-389.
60. Bagherpour, B., & Vaziri, M. R. (2012). Facies, paleoenvironment, carbonate platform and facies changes across Paleocene Eocene of the Taleh Zang Formation in the Zagros Basin, SW-Iran. Historical Biology, 24(2), 121-142.
61. Hewaidy, A. G. A., Farouk, S., & Ayyad, H. M. (2014). Integrated biostratigraphy of the upper Oligocene–middle Miocene successions in west central Sinai, Egypt. Journal of African Earth Sciences, 100, 379-400.
62. Farouk, S., Ahmad, F., & Smadi, A. A. (2013). Stratigraphy of the Middle Eocene–Lower Oligocene successions in northwestern and eastern Jordan. Journal of Asian Earth Sciences, 73, 396-408.
63. Abid, A. A. (1997). Biostratigraphy and Microfacies of the Late Oligocene–Middle Miocene formations Center and North Iraq (Doctoral dissertation, ph. D., Coll. of Sci., Univ. Baghdad. 285p).
64. Ahmad, P. M. (2020). Biostratigraphy of Oligocene-Miocene successions, Sangaw area, Kurdistan Region, North-

east Iraq (Doctoral dissertation, M. Sc. Thesis, University Sulaimani. Iraq).
65. Alavi, M. (2007). Structures of the Zagros fold-thrust belt in Iran. American Journal of science, 307(9), 1064-1095.
66. ALJWAINI, Y. S. K. (2015). SEQUENCE STRATIGRAPHY AND RESERVOIR CHARACTERIZATION OF THE LATE PALAEOGENE-EARLY NEOGENE SUCCESSION IN KIRKUK AREA (Doctoral dissertation, University of Baghdad).
67. Al-Naqib, K. M. (1955). Geology of the Kirkuk oil fields: Ankara. In Colloque Geologique Applique de Procheorient (pp. 198-212).
68. Al-Naqib, K. M. (1959). GEOLOGY OF SOUTHERN AREA OF KIRKUK LIWA, IRAQ.
69. Amirshahkarami, M. (2013). Microfacies correlation analysis of the Oligocene-Miocene Asmari Formation, in the central part of the Rag-e-Safid anticlinal oil field, Zagros Basin, south-west Iran. Turkish Journal of Earth Sciences, 22(2), 204-219.
70. Benedetti, A., & GIRMM, Informal Group of Micropalaeontological and Malacological Research http://www.girmm. com. (2018). Eocene carbonate clasts in Oligocene siliciclastic sediments of the Trapani Basin (NW Sicily): depositional and stratigraphic significance. Facies, 64(3), 14.
71. Buday, T., & Jassim, S. Z. (1987). The regional geology of Iraq, vol. 2: tectonism, magmatism and metamorphism. GEOSURV, Baghdad, 352pp.
72. Daniel, E. J. (1954). Fractured reservoirs of middle east. AAPG Bulletin, 38(5), 774-815.
73. Dunnington, H. V. (1958). Generation, migration, accumulation, and dissipation of oil in northern Iraq: Middle East.
74. Ghafur, A. (2012). Sedimentology and reservoir characteristics of the Oligocene-Early Miocene carbonates (Kirkuk Group) of southern Kurdistan (Doctoral dissertation, Cardiff University).
75. Henson, F. R. S. (1950). Cretaceous and Tertiary reef formations and associated sediments in Middle East. AAPG Bulletin, 34(2), 215-238.
76. Karim, K. H., & Hama, B. A. (2019). Chronicle of the Oligocene succession (Kirkuk Group) in Duhok Governorate, Kurdistan Region, North Iraq. Journal of Zankoy Sulaimani, 21(1), 75-90.
77. Khanaqa, P. A., Karim, S. A., Sissakian, V. K., & Kareem, K. (2009). Lithostratigraphic study of a late Oligocene–Early Miocene succession, south of Sulaimaniyah, NE Iraq. Iraqi Bull. Geol. Min, 5(2), 41-57.
78. Kharajiany, S. O. A. (2008). Sedimentary facies of Oligocene rock units in Ashdagh mountain-Sangaw District-Kurdistan Region (Doctoral dissertation, University of Sulaimani).
79. Majid, A. H., & Veizer, J. (1986). Deposition and chemical diagenesis of Tertiary carbonates, Kirkuk oil field, Iraq. AAPG bulletin, 70(7), 898-913.
80. Mossadegh, Z. K., Haig, D. W., Allan, T., Adabi, M. H., & Sadeghi, A. (2009). Salinity changes during late Oligocene to early Miocene Asmari formation deposition, Zagros mountains, Iran. Palaeogeography, Palaeoclimatology, Palaeoecology, 272(1-2), 17-36.
81. Pomar, L., Baceta, J. I., Hallock, P., Mateu-Vicens, G., & Basso, D. (2017). Reef building and carbonate production modes in the west-central Tethys during the Cenozoic. Marine and Petroleum Geology, 83, 261-304.
82. Rahmani, A., Taheri, A., Vaziri-Moghaddam, H., & Ghabeishavi, A. (2012). Biostratigraphy of the Asmari formation at khaviz and bangestan anticlines, Zagros Basin, SW Iran. Neues Jahrbuch für Geologie und Paläontologie-Abhandlungen, 1-16.
83. Seyrafian, A., & Mojikhalifeh, A. (2005). Biostratigraphy of the late paleogene-early neogene succession, north-central border of Persian Gulf, Iran. Carbonates and Evaporites, 20, 91-97.
84. Sharland, P. R., Casey, D. M., Davies, R. B., Simmons, M. D., & Sutcliffe, O. E. (2004). Arabian plate sequence stratigraphy–revisions to SP2. GeoArabia, 9(1), 199-214.
85. Sirel, E., Ozgen Erdem, N., & Kangal, O. (2013). Systematics and biostratigraphy of Oligocene (Rupelian-Early Chattian) foraminifera from lagoonal-very shallow water limestone in the eastern Sivas Basin (central Turkey). Geologia Croatica, 66(2), 83-110.
86. Vescogni, A., Bosellini, F. R., Papazzoni, C. A., Giusberti, L., Roghi, G., et al. (2016). Coralgal buildups associated with the Bolca Fossil-Lagerstätten: new evidence from the Ypresian of Monte Postale (NE Italy). Facies, 62, 1-20.
87. Youkhanna, R. Y., & Hradecky, P. (1978). REPORT ON REGIONAL GEOLOGICAL MAPPING OF KHANQIN-MAIDAN AREA, PART I.
88. Zamagni, J., Mutti, M., & Košir, A. (2008). Evolution of shallow benthic communities during the Late Paleocene–earliest Eocene transition in the Northern Tethys (SW Slovenia). Facies, 54, 25-43.