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THE CARBONATE SEDIMENTS AND PALEOENVIRONMENTAL CONSIDERATION FROM THE BABA FORMATION (OLIGOCENE) KIRKUK AREA, ZAGROS BASIN, NORTHEASTERN IRAQ

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Summary. This study investigates the carbonate sediments and paleoenvironment of the Baba Formation using samples from the Bai Hassan Oil Well-4 and Kirkuk Oil Well-19 in the Zagros Basin, northeastern Iraq. A total of fifty samples were collected from Bai Hassan Oil Well-4 and twenty from Kirkuk Oil Well-19.

The larger foraminiferal assemblages within the Baba Formation at these sections were classified into seven main genera: *Lepidocyclina, Miogypsina, Miogypsinoides, Amphistegina, Austrotrillina, Pararotalia*, and *Nummulitidae*, along with *Alveolinids*, coralline algae, and encrusting foraminifera. A quantitative analysis of thin sections revealed variations in the abundance and distribution of these taxa across different stratigraphic units.

In Kirkuk Well-19 *Lepidocyclina* and encrusting foraminifera were notably abundant in the lower units, while *Nummulitidae* was more prevalent in the upper units. In contrast, Bai Hassan Well-4 showed a more uniform distribution of *Lepidocyclina* and *Amphistegina*, with localized peaks in encrusting foraminifera abundance in the upper unit.

The findings indicate that carbonate sedimentation in the Baba Formation consists of four distinct microfacies: 1) Fine to very coarse bioclastic larger foraminiferal packstone grading to grainstone; 2) Fine to very coarse bioclastic larger foraminiferal packstone; 3)Fine bioclastic smaller foraminiferal packstone;4) Fine bioclastic smaller foraminiferal wackestone transitioning to dolostone.

The depositional environment of the Baba Formation is interpreted as an isolated slope or platform setting, with open marine conditions prevailing throughout the period of deposition.

Keywords: *Baba Formation, benthic foraminifera, microfacies, paleoenvironment, Oligocene, Iraq*

Introduction

The study area is located within the Kirkuk Governorate in the central northern part of Iraq bounded by latitudes 36º19'12" and 36º18'30" and longitudes 45º10'15" and 45º09'44" (Fig. 1) (Buday, 1980).

The region is part of the Zagros Basin, which is of significant geological and economic importance due to its hydrocarbon reservoirs. Major hydrocarbon reserves of Iraq are primarily accumulated in Oligocene carbonate successions, notably within the Kirkuk Group. The Kirkuk oil field, a prominent feature of this group, contains oil trapped in a long, narrow, and steeply dipping anticline (95 km x 4 km) divided into three culminations: Khurmala, Avanah, and Baba (Fig. 2).

Different kinds of noises arising in potential geophysical field applications for salt body delineation

Modern gravity and magnetic equipment enable the detection of even tiny gravity of 1 microGal (1microGal = 0.001 milliGal (mGal)) and magnetic of 1 picoTesla (1 picoTesla = 0.001 nanoTesla (nT)) and fewer anomalies. However, different kinds of noise (artificial and natural origins) complicate the qualitative and quantitative analyses of the abovementioned fields over salt bodies. These main kinds of noise are presented in Fig. 1 (modified after Eppelbaum (2011a, 2011b)). Let us briefly consider the different kinds of noise.

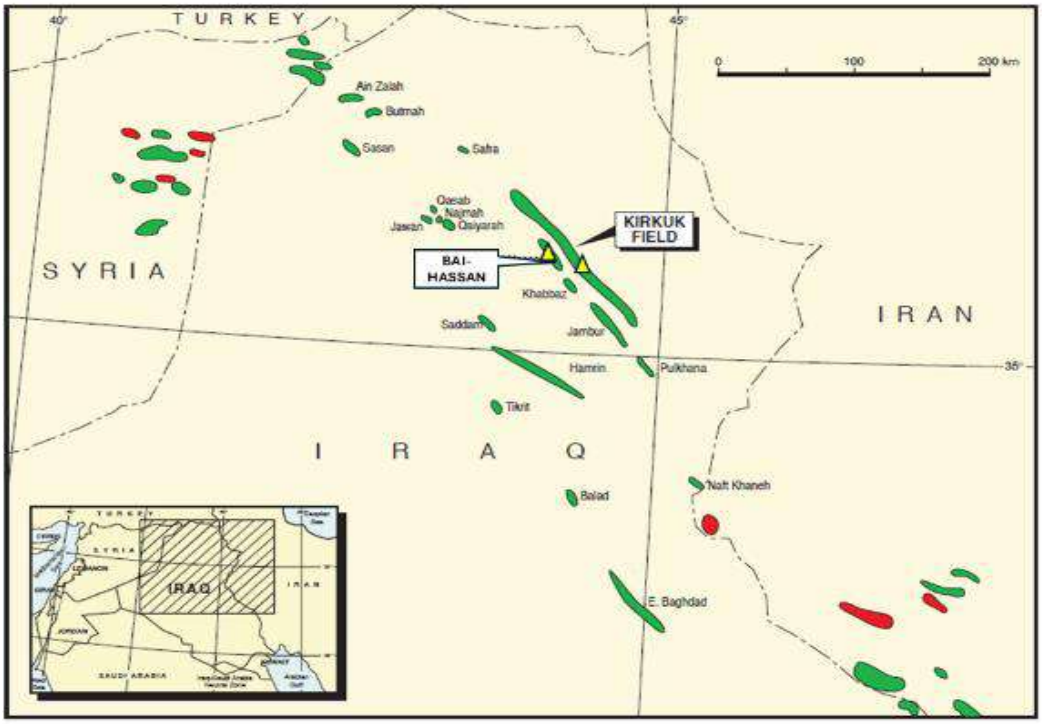

Fig. 1. Location map of the studied wells

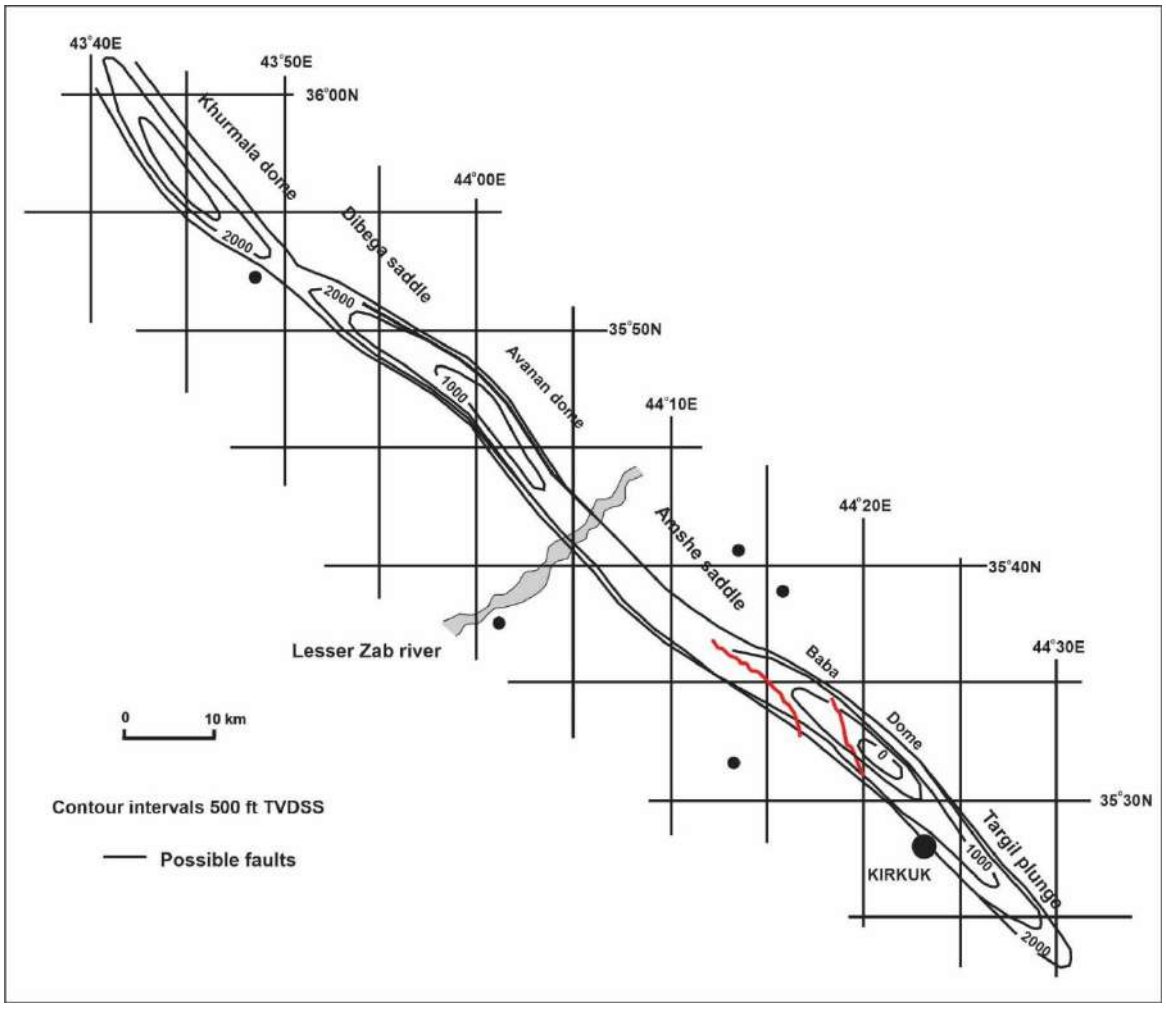

Fig. 2. Depth structure map on the near Top Main Limestone reservoir (modified after Sims and Shafiq, 1960)

The Main Limestone reservoir, the principal oil-bearing unit, comprises three carbonate cycles, including shelf-edge banks and bioherms that fringe an intra-shelf basin. Structural complexity due to thrust faulting and dislocated younger Tertiary strata has led to speculative interpretations of the subsurface structure, though development drilling has confirmed the geometry of anticline. This field began production in 1934, with additional hydrocarbon accumulations found in the Upper Cretaceous Shiranish and Early Cretaceous Qamchuqa limestones. The Oligocene sediments in Iraq characterized by relatively limited distribution and reduced thickness are predominantly represented by the Baba Formation. First defined by Bellen in 1956 using samples from Kirkuk oil well-109, the Baba Formation comprises porous dolomitized limestones with a chalky appearance in outcrops. Deposited in a fore-reef environment along the northeastern and southeastern margins of the Oligocene basin, it contains diverse fossil assemblages, including *Lepidocyclina, Nummulites fichteli, Operculina* sp., and *Heterostegina* cf. *assilinoides*. The age of formation is identified as Middle Oligocene conformably overlying the Shurau Formation and overlain by the Bajwan Formation in the type area (Bellen et al., 1959). In central Iraq, the Baba Formation is widespread in oil wells south of the Lesser Zab River and the Kirkuk structure extending to the northeastern flank of the Bai Hassan structure and the Qarah-Chough-Dagh dome. It also occurs in the Gusiar oil well and wells within the Ain Zala structure. On the surface, it crops out in the Qarah-Chough-Dagh area and along the Euphrates Valley west of Anah. Subsurface occurrences extend between Ain-Zala and Bai Hassan in the northeast to Hit and Dujaila in the southwest. The Baba Formation exhibits depositional environments consistent with shallow-water carbonates rich in larger foraminifera reflecting continuous facies changes in response to dynamic depositional settings. While numerous studies have examined the Baba Formation across Iraq, this research focuses on its carbonate sedimentology, microfacies and paleoenvironmental implications in the Bai Hassan oil well-4 and Kirkuk oil well-19. The findings provide insights into microfacies and depositional environments, contributing to the understanding of Oligocene carbonate systems in the Zagros Basin.

Geological Framework

The Oligocene sediments in Iraq are characterized by a restricted distribution and reduced thickness compared to other geological periods (Bellen et al., 1959). This limited distribution is largely confined to the Mesopotamian Basin with many areas completely lacking Oligocene deposits. The absence of molasse sediments in the foredeep and narrow strip of distribution for Oligocene formations further distinguish this period from earlier epochs. The Oligocene marks the formation of a new basin that occupied the previously emergent Khleisia uplift and areas of the Stable Shelf north of the Euphrates River (Buday, 1980). This basin reflects a significant tectono-sedimentary shift from the Eocene, where the continuous deposition of pelagic facies across the upper Eocene to lower Oligocene is not uniformly confirmed. Regional correlations with surrounding countries reveal those formations such as the Jahrum Formation (Lower Oligocene) and the Asmari Formation (Upper Oligocene) share lithostratigraphic and faunal similarities with Oligocene deposits of Iraq (Bolli and Krasheninnkov, 1977; Rashidi et al., 2023, 2024) (Table 1).

The formations of the Oligocene are bounded by unconformities or breaks in sedimentation. For example, the Baba Formation, a significant unit of this period, predominantly consists of porous dolomitized limestones and chalky outcrops. Its deposition occurred along the fore-reef areas of both the northeastern and southeastern margins of the Oligocene Basin. The unit contains abundant larger foraminifera, including Lepidocyclina, Nummulites, and Operculina, indicative of a shallow marine depositional environment (Bellen et al., 1959). In the central parts of Iraq, the Baba Formation is found in all oil wells southwest of the Lesser Zab River, particularly within the Kirkuk structure. It also occurs in subsurface sections between Ain Zala and Dujaila and along the Euphrates Valley near Anah. The facies within the Baba Formation exhibit continuous lateral and vertical variations reflecting depositional environments ranging from fore-reef zones to shallow lagoonal settings. This study focuses on the Baba Formation in two critical subsurface sections: Bai Hassan oil well-4 and Kirkuk oil well-19. These sections are located within the Himmerin-Makhul Subzone of

the Foothill Zone, part of the unstable shelf area (Buday and Jassim, 1987). This tectonic setting significantly influenced the sedimentation and distribution of Oligocene carbonate deposits. The identified microfacies and fossil content provide insights into the paleoenvironments and depositional processes that characterized the formation during the Oligocene. Oligocene sedimentary cycle in Iraq, which comprises the Kirkuk includes nine formations that represent three separate cycles of carbonate sedimentation, back reef/reef, fore reef, and basin facies (Bellen et al., 1959; Ditmar et al., 1971; Mohammed, 1983; Jassim and Karim, 1984; El-Eisa, 1992) (Fig. 3).

Table 1

Stratigraphic correlation between Oligocene sediments of Iraq and surrounding countries (modified after Buday, 1980)

LOWER PART OF THE OLIGOCENE/PRIABONIAN?	UPPER PART OF THE OLIGOCENE/RUPELIAN STAMPION	AGE / AREA	
A B S E N T		SAUDIA ARABIA, KUWAIT, W AND SE SYRIA, IRAQ	STABLE SHELF
Dhahkiye Chalk Formation / Taiybia Beds	?Usdom Group	JORDAN	STABLE SHELF
Alternating calcareous marly and clastic / Bishir sand and Allied Formation		CENTRAL SYRIA,-PALMYRIDS	STABLE SHELF
Shekh Alas Formation, Bajwan Formation, Anah Formation Limestones: Shurau Fn. / Baba Fn.	Organic detrital and Reef Azkand Fn.	SYRIA-IRAQ-EUPHRATES VALLEY-W OF RAMADI	STABLE SHELF
Tarjil Formation	Ibrahim Formation	SYRIA - IRAQ - JEZIR	STABLE SHELF
A B S E N T		MESOPOTAMIAN ZONE, SW OF THE AWASEL- UZAIR ZONE	STABLE SHELF
Shekh Alas Formation. / Shrau Formation	Bajwan Fn / Baba Fn. / Azkand Fn. / Anah Fn.	MESOPOTAMIAN ZONE ALONG THE FAULT-AFAQ-DUJAILA LINE	STABLE SHELF
Tarjil Formation	Ibrahim Formation	MESOPOTAMIAN AND FOOT HILL ZONES SW OF THE GULLARCHIA SURKH LINE	MOBILE SHELF
Shekh Alas Formation / Shrau Formation		FOOT HILL ZONES BETWEEN THE GULLAR CHIA SURKHI AND MOS-UL- BASKI ZANUR LINE	MOBILE SHELF
A B S E N T /Only Anah Limestone Formation in the NW Corner/		HIGH FOLDED AND NOERHERN THRUST ZONE	MOBILE SHELF
Upper Swais Group /IV/ Partly		IMBRICATED ZONE	MOBILE SHELF
Flysh Facies saddi Kashgah Ammari-Sadi- Kashgan Fn. / Jahrum Formation	Lower Asmari Formation		MOBILE SHELF

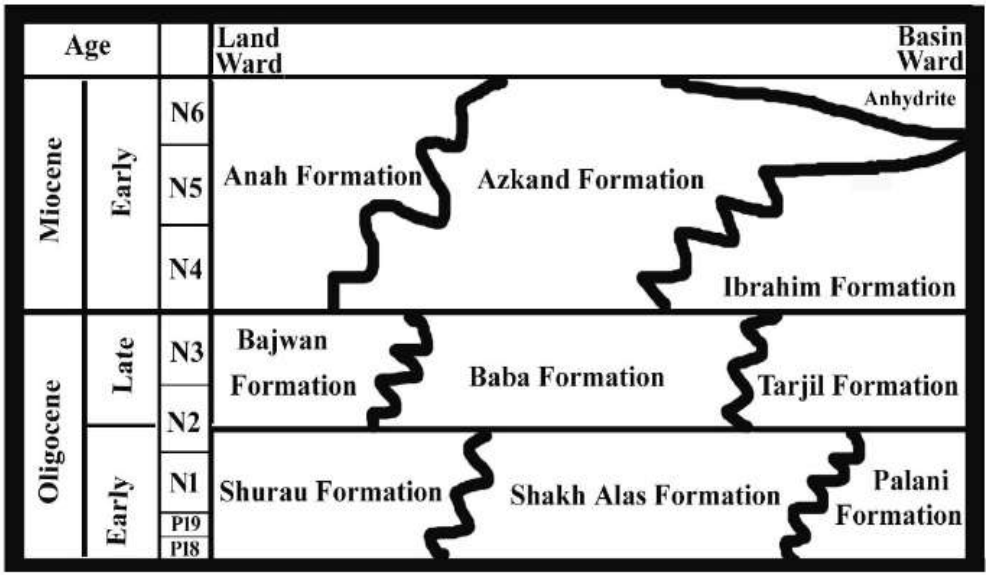

Fig. 3. Age relationships of Oligocene–early Miocene Formations in northern Iraq (after EI-Eissa, 1992)

Structure of the studied area

The Kirkuk Field is hosted by one of the many NW trending anticlines of the folded belt of northern Iraq. Two basement blocks, the Kirkuk and Mosul blocks have been defined below the folded belt using changes in sediment thickness and fault/fold orientations (Figs. 4 and 5).

Faults internal to these blocks controlled differential subsidence during the Mesozoic, and reversal of the fault movement during Zagros compression has probably inverted earlier graben to create many of the fold structures such as Kirkuk (Ameen, 1992). The Kirkuk structure is a long narrow anticline 95 km long by up to 4 km wide with an area of 300 km^2 (Fig. 2).

Two prominent saddles divide the structure into three main culminations: Khurmala, Avanah, and Baba (Fig. 6).

The Baba dome plunges gradually to the SE and the Khurmala dome gently to the NW, to form a four-way dip-closed structure. The fold is relatively flat-topped and concentric with steep flanks dipping at up to 50^o (Fig. 7). No recent structure maps of the field are available but the 1960s versions show just a few NW- to N-trending faults cutting the Main Limestone in the south, which are reported to have maximum throws of 650 ft. The reservoirs are heavily fractured perpendicular to the fold plane in the crestal parts but dying out onto the flanks. The origin of the fracture system relates to folding and not to faulting, although faults also have associated fracture zones. Fracture density is greatest where the fold is tightest, i.e., at the crest, and at lateral bends in the fold plane (Daniel, 1954). The Upper Fars and Bakhtiari sections are detached at the Fat'ha Formation evaporites and discordantly folded and thrust faulted to the surface over the crestal area. The Baba dome has the shallowest crest at the Main Limestone level of 75 ft ASL, the Avanah crest is at 650 ft TVDSS. (Al-Naqib et al., 1971), and the Khurmala crest lies deepest at ~1250 ft TVDSS (Fig. 6).

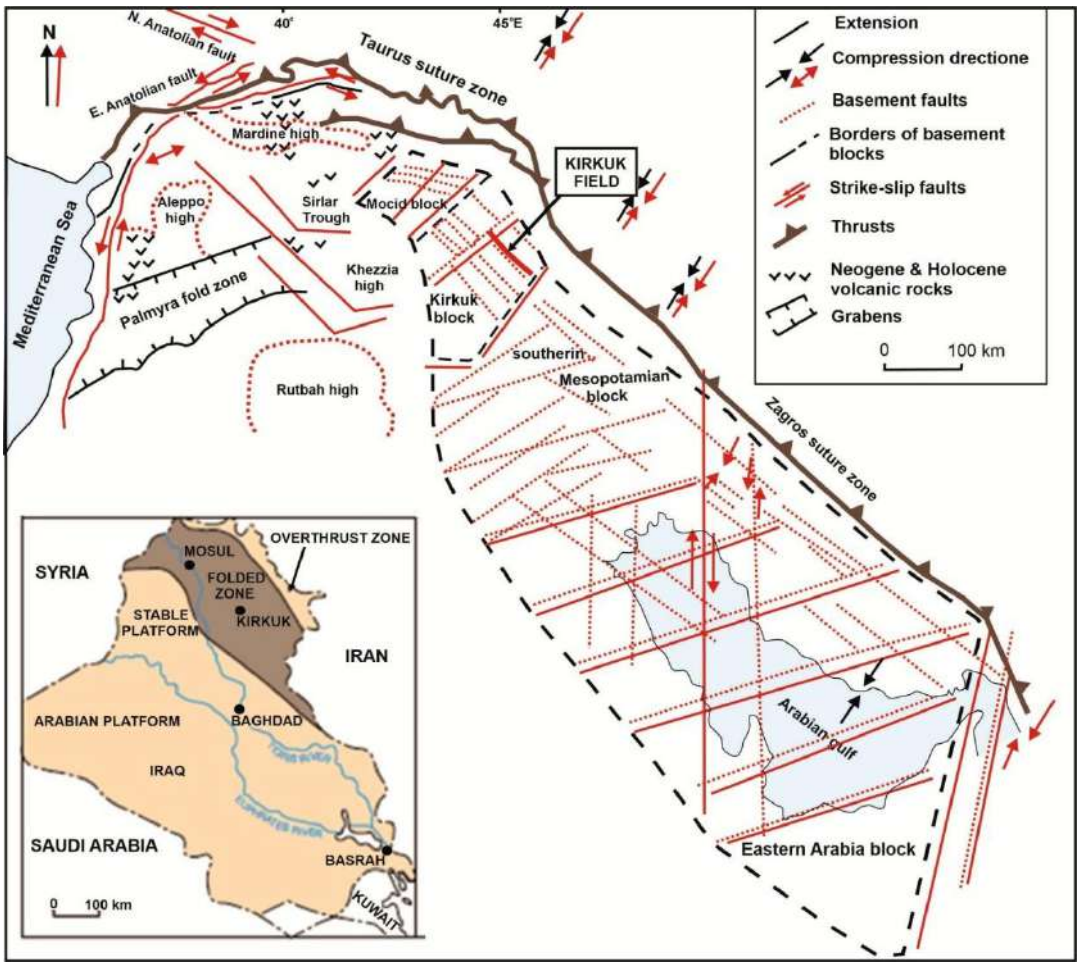

Fig. 4. Tectonic elements and tentative basement fault trends for the NE Arabian Plate (Ameen, 1992). Inset map shows the main tectonic zones of Iraq

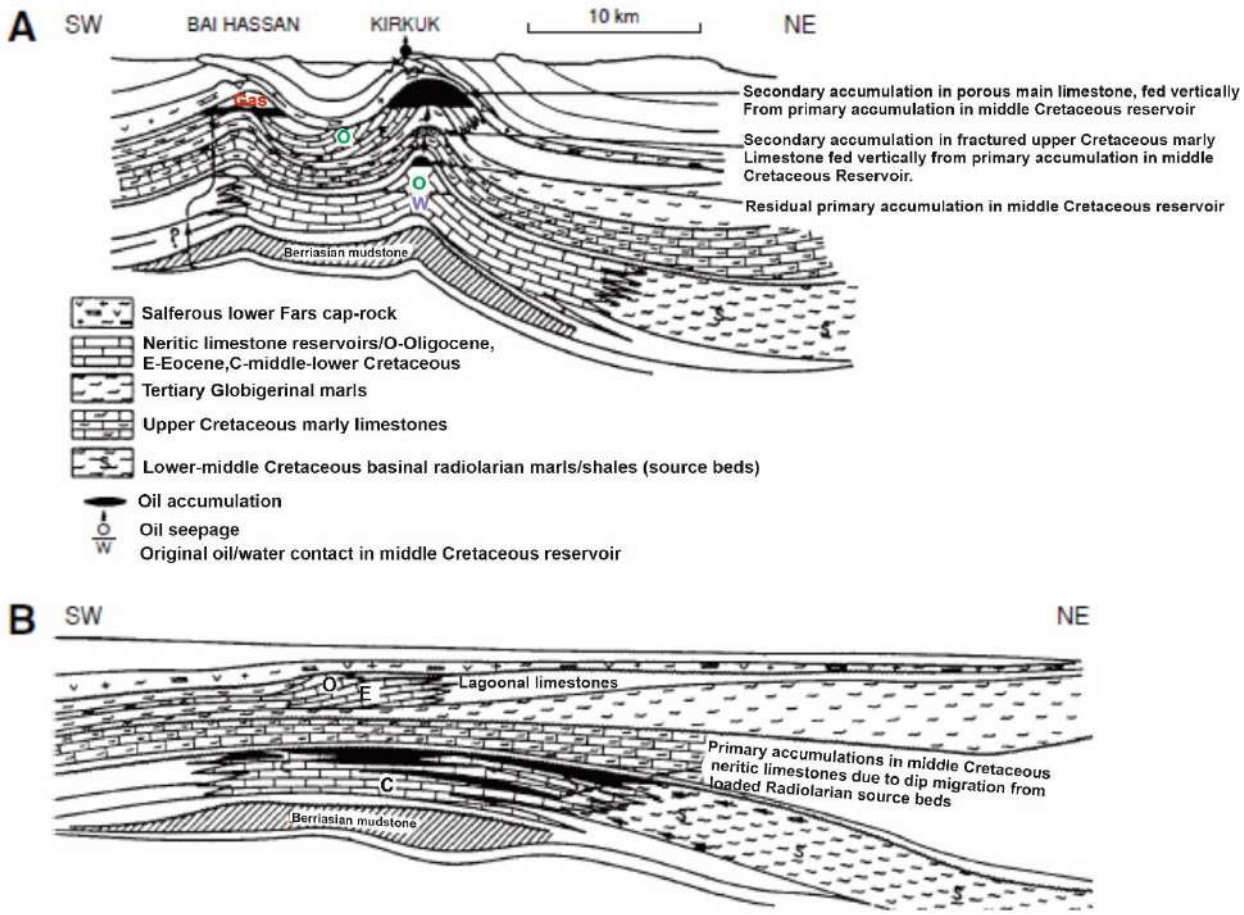

Fig. 5. SW-NE schematic regional sections across the Bai Hassan and Kirkuk structures illustrating hydrocarbon migration paths for (**A**) the current structures produced by the Late Miocene folding when fracturing provided conduits for vertical migration from Cretaceous accumulations up into the Tertiary traps; and (**B**) the situation in the Middle Miocene immediately prior to the folding event when Cretaceous reservoirs acted as lateral migration pathways for hydrocarbons generated in depocenters to the east (Dunnington, 1958)

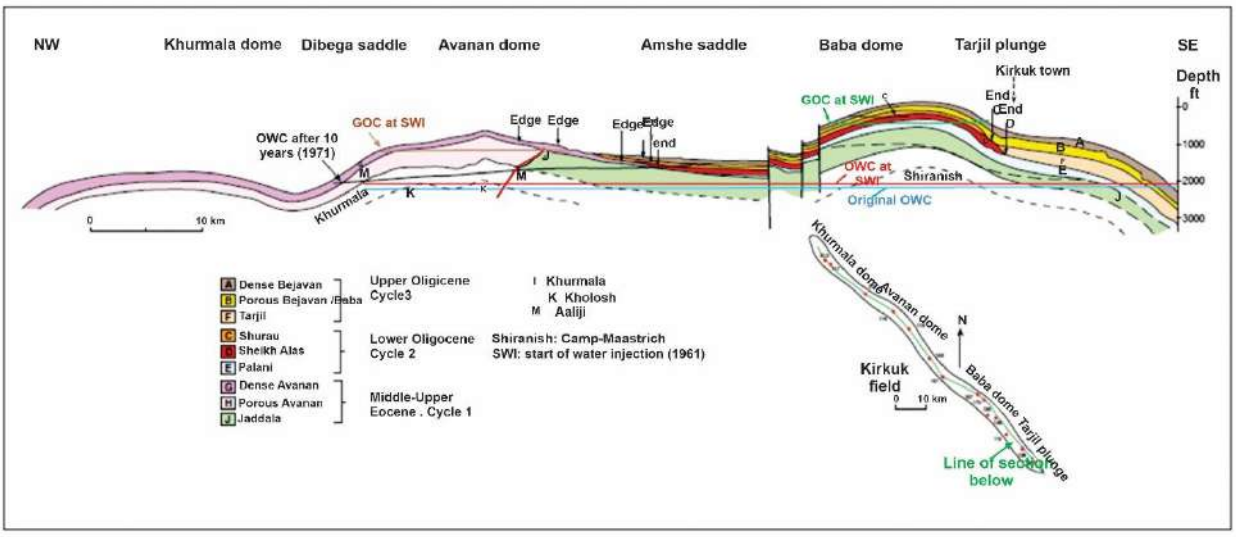

Fig. 6. NW-SE structural cross-section through the Kirkuk Field showing reservoir geometry and fluid contacts (Alamir, 1972). The main reservoir unit over the Khurmala and Avanah domes does not reach the Baba dome, while reservoir units of the Baba dome and Amshe saddle are younger and thin rapidly onto the Avanah dome (See Fig. 10 for explanation of lithostratigraphic units and depositional facies)

The Main Limestone is ultimately sealed by Middle Miocene Fat'ha Formation evaporites. Intervening Lower Fars conglomerates, shales and limestones are largely non-reservoir but where fractures connect through to the thin limestones of the Fat'ha Formation, they are oil-bearing and become part of the Main Limestone reservoir system below (Daniel, 1954). Seeps of gas and oil at surface show that the seal is not perfect but it is remarkably effective considering the long oil column and thin overburden (as thin as 900 ft in places). The trap began to form in the Late Miocene (Bakkal and Al-Ghreri, 1993; Ghafor et al., 2003). Smaller accumulations than the Main Limestone both in area and oil column height are found in the Middle and Late Cretaceous fractured carbonates sealed by shale units (Figs. 5 and 7).

Stratigraphy of the studied wells

The Main Limestone reservoir ('First Pay Zone') is a 1200 ft interval of fractured bioherm and shoal carbonates of the Middle Eocene-Oligocene age (Fig. 8), which is the subject of this research. Shiranish Formation marly limestones ('Second Pay Zone') are Campanian-Maastrichtian basinal deposits (Fig. 8), (Ghafor, 1988; Bakkal and Al-Ghreri, 1993, Al-Shaibani et al., 1993), unconformably overlain and sealed by the Paleocene Aaliji shales (Al-Fattah et al., 2017, 2018, 2020a,b). The Hauterivian-Albian Qamchuqa Formation ('Third Pay Zone') comprises a thick (1000-2000 ft) interval of platform carbonate reservoir rocks interfingering with basinal marls of the Sarmord Formation that also form the top-seal (Ghafor and Mohialdeen, 2016, 2018). It conformably overlies Upper Paleocene-Lower Eocene basinal shales and siltstones of the Aaliji and Kolosh formations with a transition to shallow marine sediments of the Khurmala and Sinjar formations in NW Kirkuk (Fig. 6) (Al-Taee et.al, 2024a, b, c).

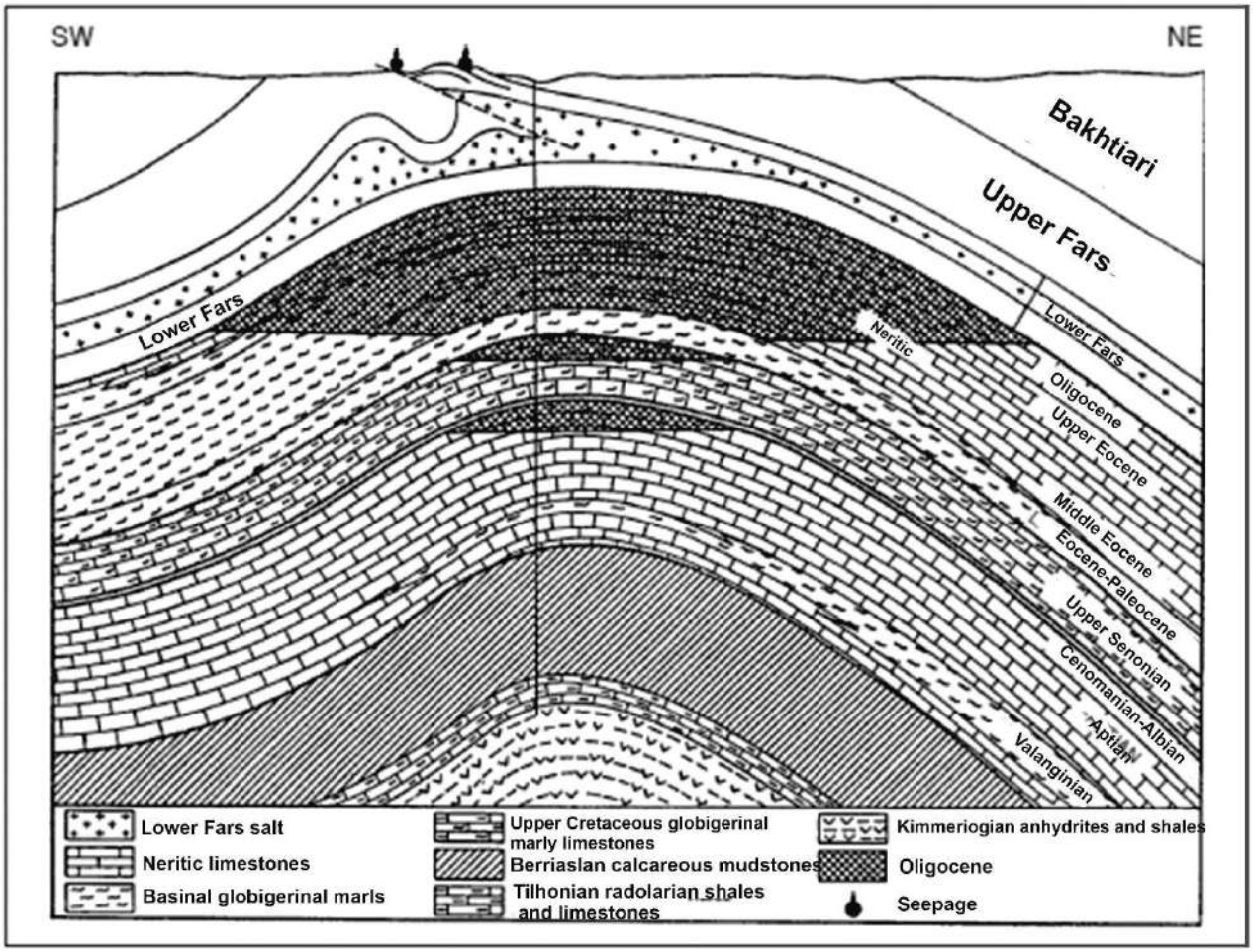

Fig. 7. SW-NE schematic structural cross-section of the Kirkuk structure showing three main oil accumulations (Dunnington, 1958)

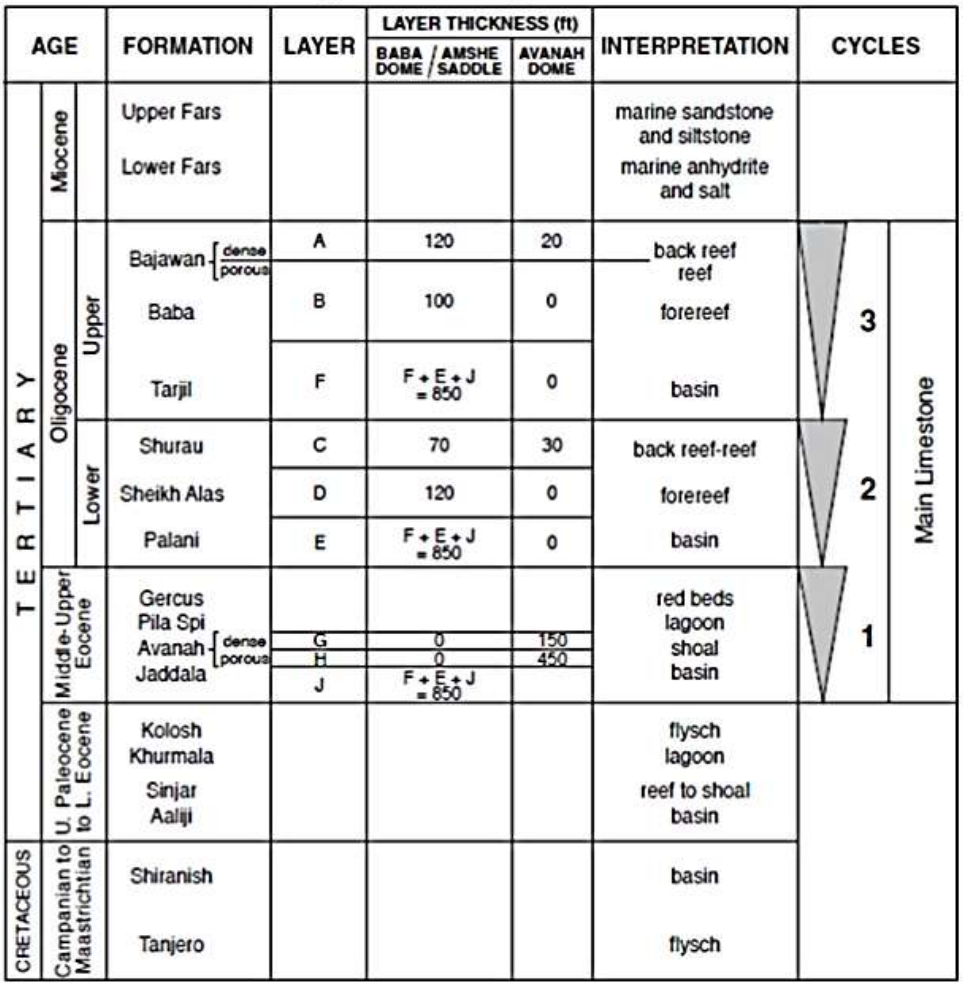

Fig. 8. Stratigraphy and depositional environments of Tertiary strata in the Kirkuk Field (Majid and Veizer, 1986)

The Middle Miocene Fat'ha Formation unconformably overlies the Main Limestone. The youngest Main Limestone units below the unconformity in the SE are Oligocene, whilst those in NW Kirkuk are as old as Eocene (Fig. 9) (Dunnington, 1958). The Oligocene reservoir units therefore thicken to the SE from a zero line around the middle of the Avanah dome (Fig. 6). The Lower Miocene limestones and evaporites of the Euphrates, Dhiban and Jeribe formations pinch out SW of Kirkuk and are over-stepped onto Kirkuk by the Fat'ha Formation (Fig. 9).

The Main Limestone reservoir in the Kirkuk Field was deposited in three upward-shoaling cycles (Fig. 8). Each one begins with basinal carbonate facies (Jaddala, Palani, and Tarjil formations) followed by carbonate bank-margin and fore-reef deposits (Avanah, Sheikh Alas, and Baba formations) passing upward into reef and back-reef facies (Pilaspi, Shurau and Bajwan formations) (Figs. 10 and 11). Bank-margin facies of the Eocene Avanah Formation form a reservoir unit that extends over the Khurmala and Avanah areas with an average thickness of 450 ft and maximum 650 ft (Fig. 8) (Al-Qayim et al., 2014; Al-Qayim and Ghafor, 2022, Ghafor and Al-Qayim, 2021, Ghafor and Muhammad, 2022, 2023a, b). Oligocene bioherm and fore-reef facies provide reservoir units averaging 290 ft total thickness over the Baba dome (Sheikh Alas, Shurau, Baba and lower Bajwan). Lime mud deposits of back-reef lagoonal and tidal mud-flat origin dominate the Khurmala area. Depositional facies belts that occur in all three cycles comprise: (**1**) near-shore mudstones, wackestone, and packstone with bioclasts of miliolids, *Peneroplis*, rotaliids, red algae and corals; (**2**) platform-margin build-ups of packstone, grainstone, and mudstones with bioclasts of red algae, corals, rotaliids, echinoderms, *Nummulites*, *Lepidocyclina*, *Discocyclina*, but lack frame-building organisms in growth position; (**3**) fore-slope packstone

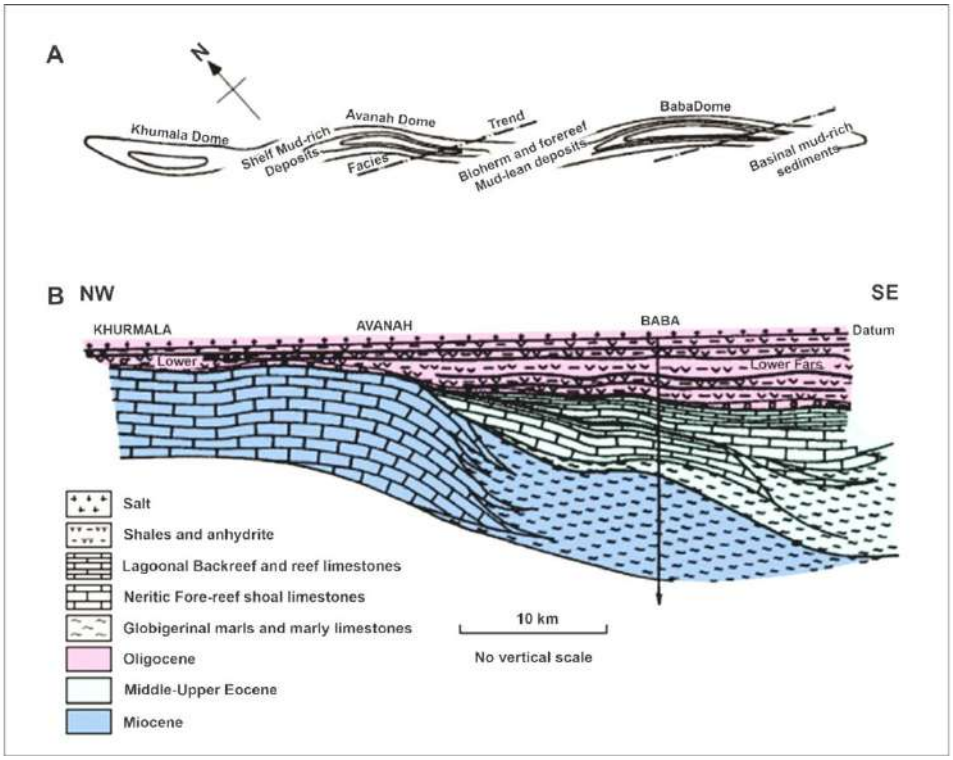

Fig. 9. Stratigraphy and depositional environments of Tertiary strata in the Kirkuk Field (Majid and Veizer, 1986). Main Limestone reservoir layers (which are shown in the cross-section in Fig. 8) and thickness are also given (Al-Naqib et al., 1971)

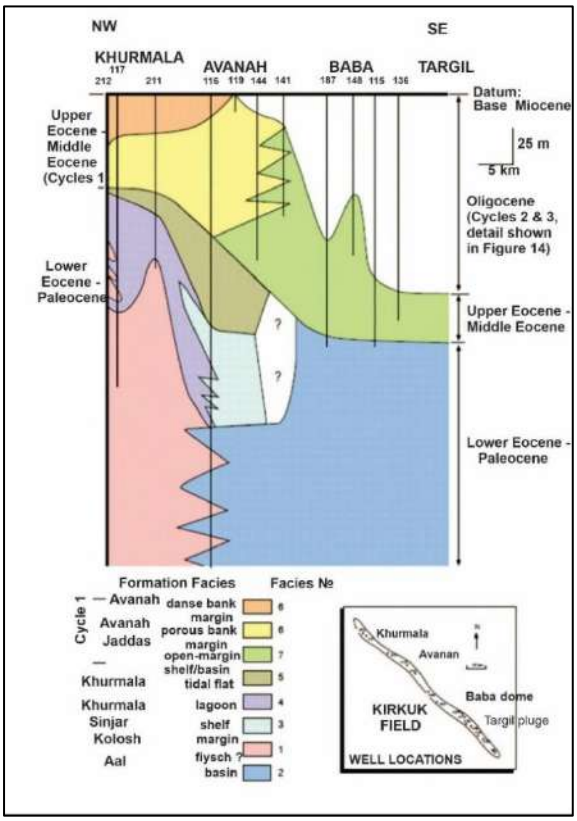

Fig. 10. NW-SE schematic stratigraphic cross-section through the Kirkuk Field showing lateral variation in relative thickness and facies of the Upper Paleocene-Upper Eocene interval (Majid and Veizer, 1986)

and grainstone with a mixture of *Nummulites*, *Lepidocyclina*, *Discocyclina*, and traces of red algae, corals, and rotaliids; and (**4**) basinal mudstones and wackestone with *Globigerina*, radiolarians, and tintinids (Van Bellen, 1956; Majid and Veizer, 1986). The first cycle of the Main Limestone is interpreted as signaling a mid-Eocene change in basin architecture from a homoclinal siliciclastic ramp to a carbonate platform that rimmed an intrashelf basin (Fig. 12).

The facies belts are WNW-trending and transected at a low angle by the Kirkuk structure (Fig. 9). An end-Eocene major drop in base-level exposed the Cycle 1 bioherms and shelf margin, and the carbonate platform reestablished itself in the fore-slope and basinal area, but probably had not onlapped the Eocene platform before another drop in base-level occurred. The Cycle 3 carbonate platform was initiated downslope from Cycle 2, but rapidly infilled relief, onlapping the Cycle 2 platform (Figs. 9 and 13).

It may have transgressed the Cycle 1 platform as well, but there is no remaining evidence of this as a further drop in relative sea-level at end-Cycle 3 eroded unknown amounts of section

and the succeeding Fars Formation rests directly on Cycle 1 reefal facies in the NW of Kirkuk (Fig. 6).

Materials and methods

This study investigates the Oligocene subsurface succession in the Low Folded Zone, focusing on two subsurface sections: Kirkuk well-19 and Bai Hassan well-4. A total of 70 samples were collected from fossiliferous limestone intervals with 20 samples obtained from Kirkuk well-19 and 50 samples from Bai Hassan well-4. The lithological characteristics of two sections are similar providing a robust basis for comparative analysis. The identification and taxonomic classification of the microfossils were conducted using thin-section petrography. These microfossils were categorized based on systematic framework established by previous studies (Ghafor, 2022a; Ghafor and Najaflou, 2022; Ghafor, 2022b; Rajabi, Ghafor, 2024; Serra-Kiel et al., 2016). Observations under a polarizing microscope facilitated the identification of microfacies, bioclast composition, and sedimentary structures, which were further interpreted to deduce depositional environments and paleoenvironmental conditions. Field and laboratory work involved detailed lithological logging and sampling with a focus on identifying the depositional characteristics and faunal assemblages of the Baba Formation. The observed microfacies were analyzed to determine sedimentological features such as grain size, sorting, and bioclast type and abundance. Additionally, the spatial distribution of larger foraminifera was quantified to reveal variations in palaeoecological conditions across the studied sections. The methodology employed allows a comprehensive analysis of the depositional environments, paleogeography, and faunal diversity within the Baba Formation contributing deep understanding of Oligocene carbonate systems in the Zagros Basin.

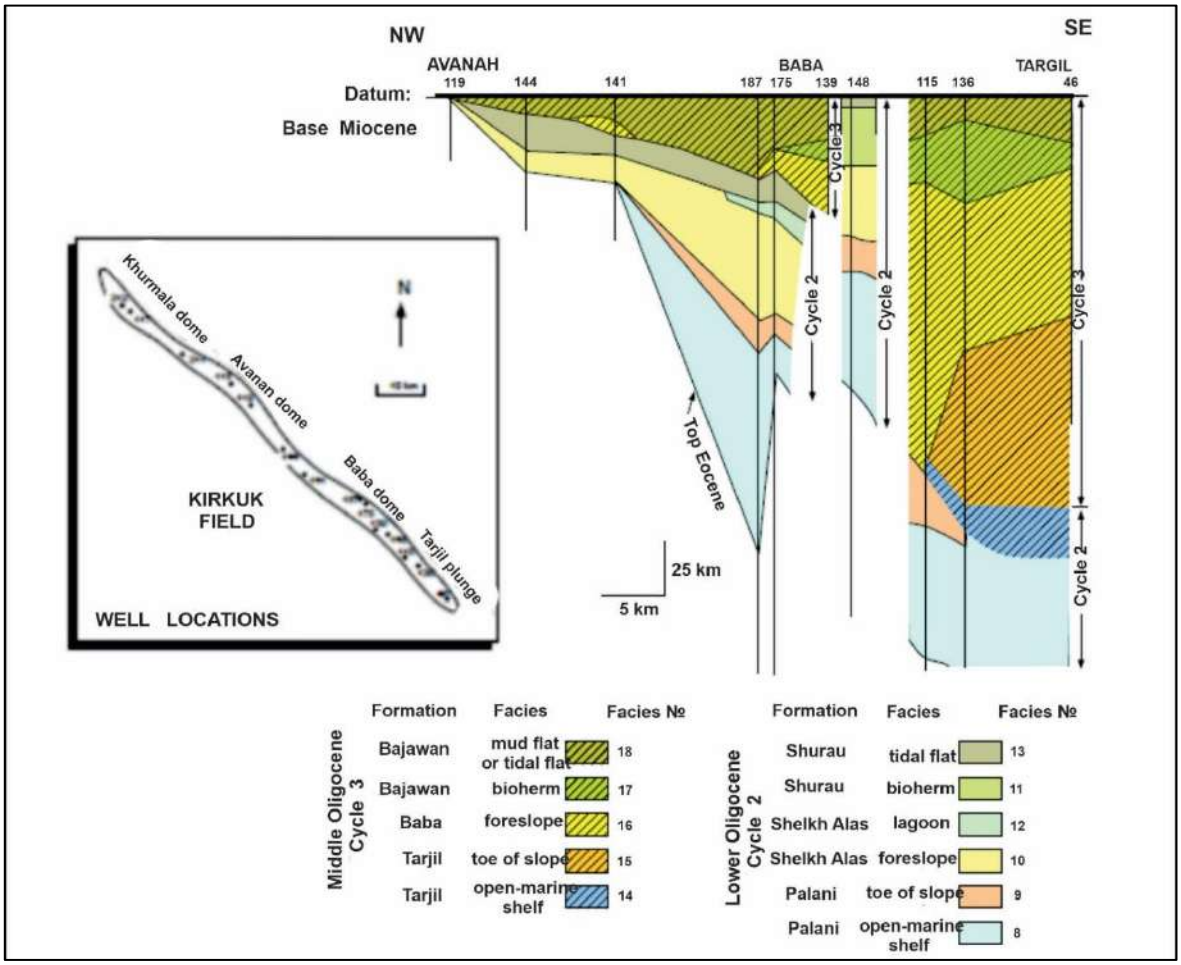

Fig. 11. NW-SE schematic stratigraphic cross-section through the Kirkuk Field showing lateral variation in relative thickness and facies of the Oligocene interval (Majid and Veizer, 1986). Inset map gives well locations

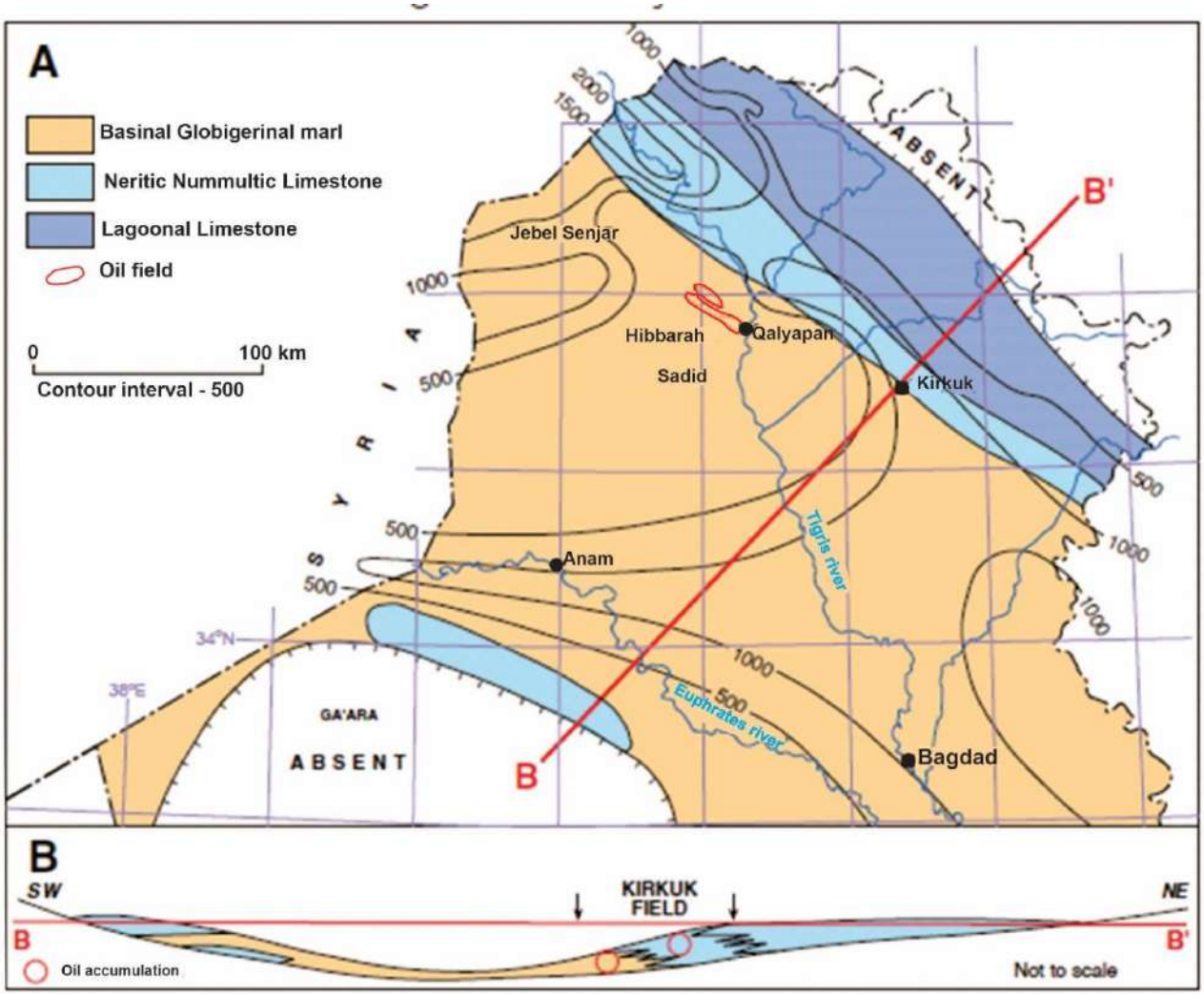

Fig. 12. (**A**) Isopach and paleogeography map of the Middle-Upper Eocene section of northern Iraq. This interval constitutes the lower Main Limestone reservoir at the Kirkuk Field. (**B**) Schematic cross-section across the basin in Eocene times showing the carbonate platform that fringed the NW-trending interior seaway or intra-shelf basin with the relative location of Kirkuk marked (Dunnington, 1958). Line of section is shown in (**A**)

Review of the Baba Formation

The Baba and Azkand formations are two significant geological formations located in the region. These formations have been extensively studied by geologists due to their unique characteristics and importance in understanding the geological history of the area. The Baba Formation is composed of limestone and sandstone layers, indicating a marine depositional environment. Fossils of marine organisms have been found in this formation, providing valuable data on the past marine life in the area.

Overall, the Baba Formation offers a glimpse into the geological past of the area and provides valuable insights for researchers studying the region history. The formation was first defined (Van Bellen, 1956) from Kirkuk well-109. It lithologically consists of porous dolomitized limestones. The limestone has a chalky appearance and is mostly massive with some bedded parts in surface outcrops (Buday, 1980). The Baba Formation has been studied by (Abid, 1997; Ghafor, 2004: Ghafor, 2011; Ghafor, 2015; Ghafor and Muhammed, 2005; Ghafor and Muhammed, 2007; Ghafor and Muhammed, 2011; Muhammed and Ghafor, 2008; Ghafor, Ahmad, 2019; Ghafor, Ahmad, 2021; Roozpeykar and Moghaddam, 2016; Ghafor, Ahmad and Khafaf, 2023; Ghafor et al., 2023a,; Ghafor et al., 2023b; Ghafor et al., 2014; Ghafor et al., 2023c).

Results and discussion

Subdivision of Larger Foraminifera

The larger foraminiferal assemblages within the Baba Formation were classified into seven

main generic groups: *Lepidocyclina, Miogypsina, Miogypsinoides, Amphistegina, Austrotrillina, Pararotalia,* Nummulitidae, Alveolinids, coralline algae and encrusting foraminifera. Quantitative analysis of thin sections revealed variations in the abundance and distribution of these taxa across different stratigraphic units (Figs. 14, 15 and 16).

In Kirkuk well-19, the frequency of *Lepidocyclina* and encrusting foraminifera was notably high in lower units, while Nummulitidae were more prevalent in the upper units. In contrast, the Bai Hassan well-4 section exhibited a more uniform distribution of *Lepidocyclina* and *Amphistegina* with localized peaks in encrusting foraminifera abundance in Unit IV.

Microfacies Subdivision of the Baba Formation

The Baba Formation was divided into four distinct microfacies based on lithological and faunal characteristics observed in the thin sections (Figs. 17, 18).

These microfacies are described as follows:

Unit I: Fine to Very Coarse Bioclastic Larger Foraminiferal Packstone to Grainstone.

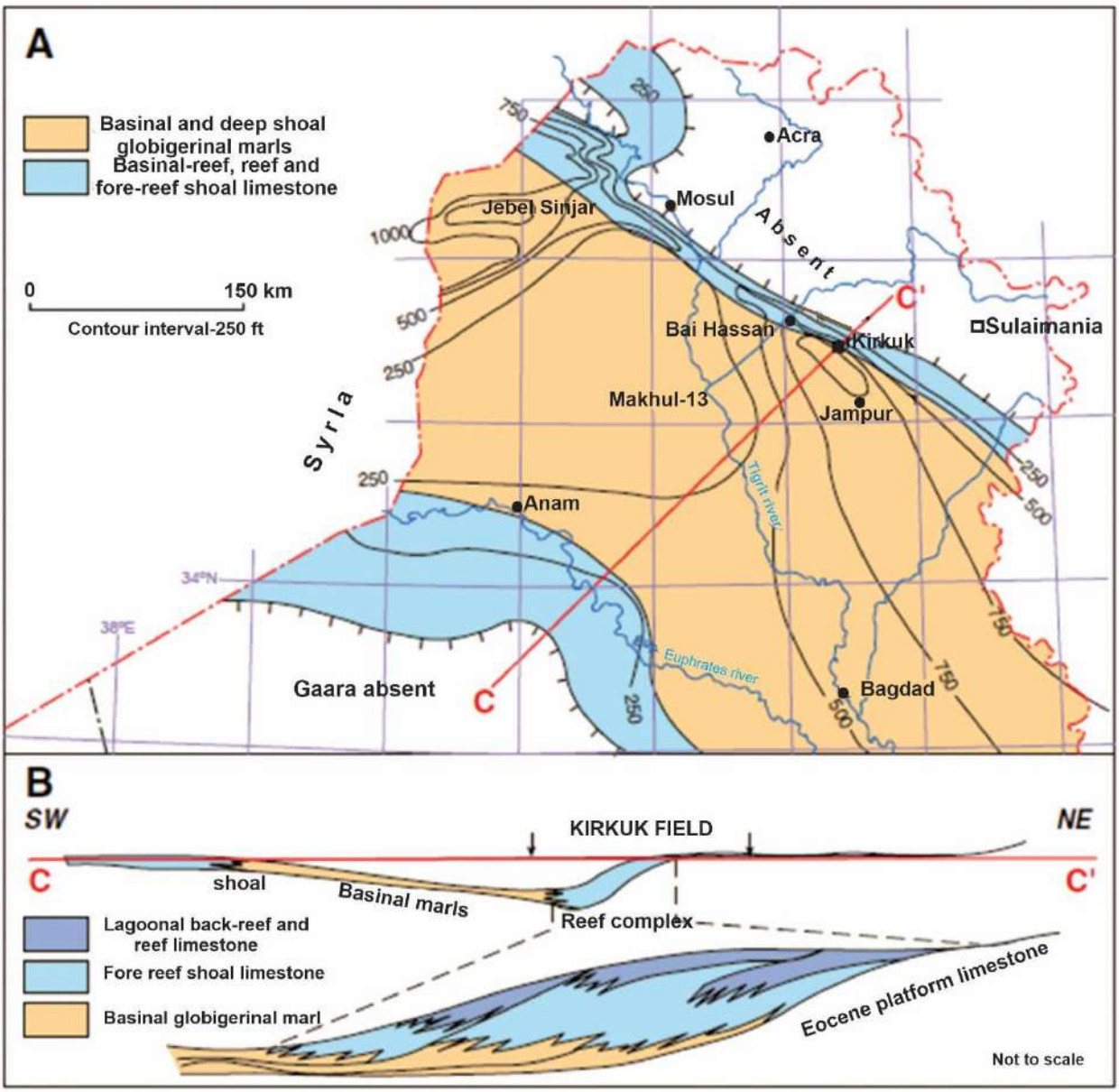

Fig. 13. (**A**) Isopach and paleogeography map for the Oligocene section of northern Iraq. This interval constitutes the Upper Main Limestone reservoir at the Kirkuk Field. (**B**) Schematic cross-section across the basin in Oligocene times. The detailed inset shows how several cycles of reef development prograde basin wards from below the level of the Eocene platform edge (Dunnington, 1958). The relative location of Kirkuk is marked. Line of section is shown in (**A**)

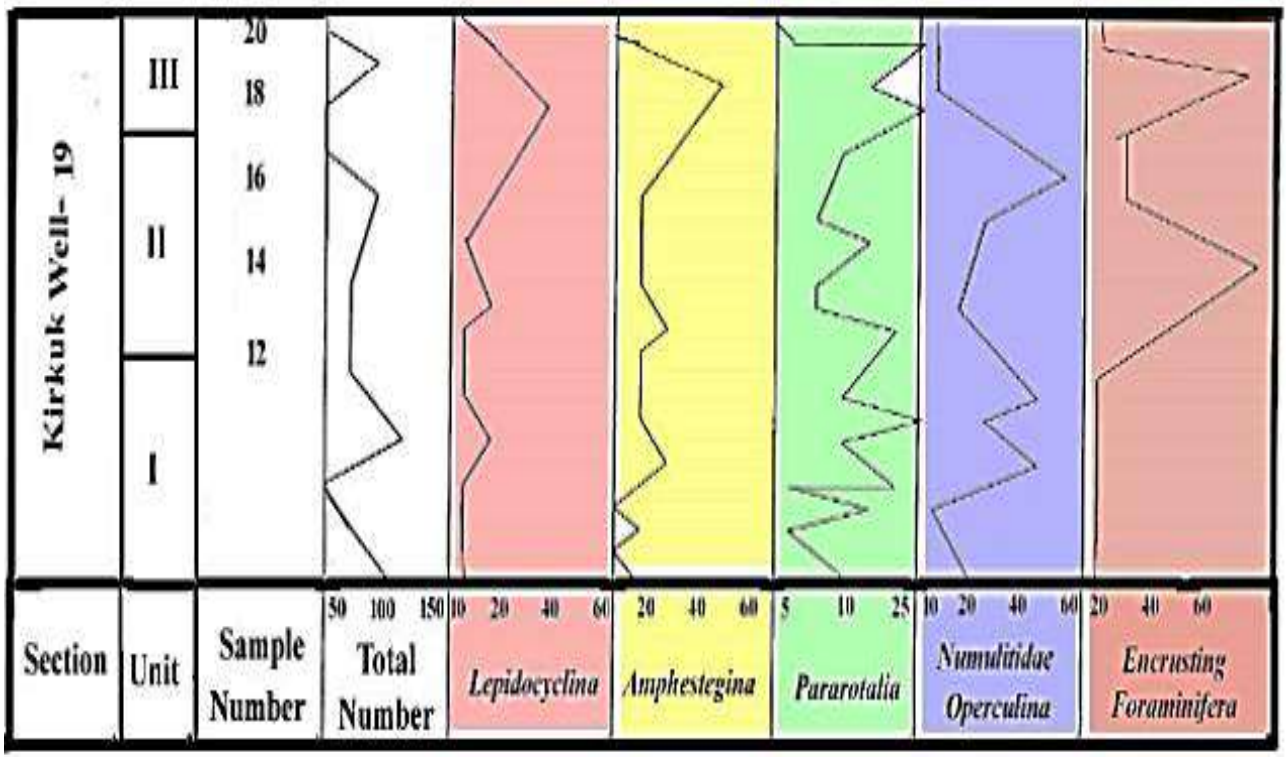

Fig. 14. The total numbers and relative frequency of larger foraminifera in thin sections of units (I, II, and III) in the Baba Formation at the Kirkuk well 19 section

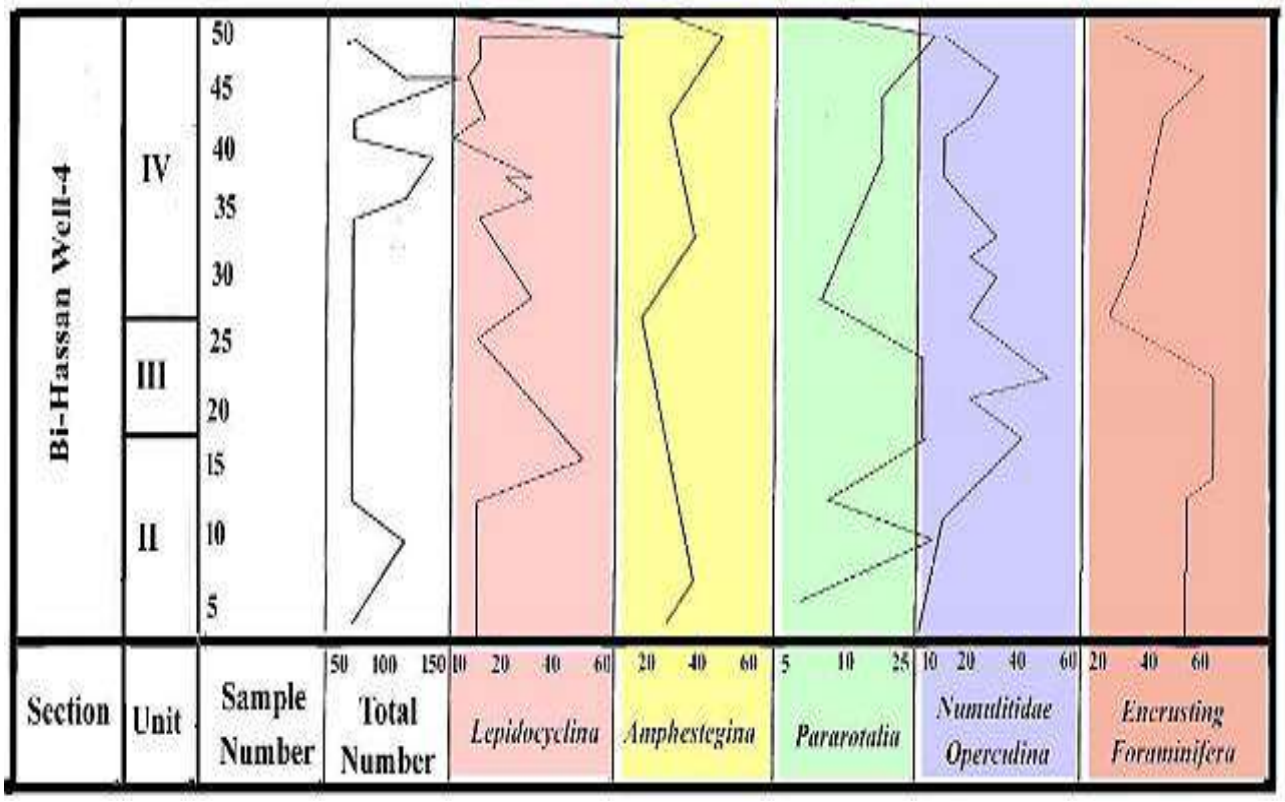

Fig. 15. The total numbers and relative frequency of the larger foraminifera in thin sections of units (II, III, and IV) in the Baba Formation at the Bai-Hassan well-4 section

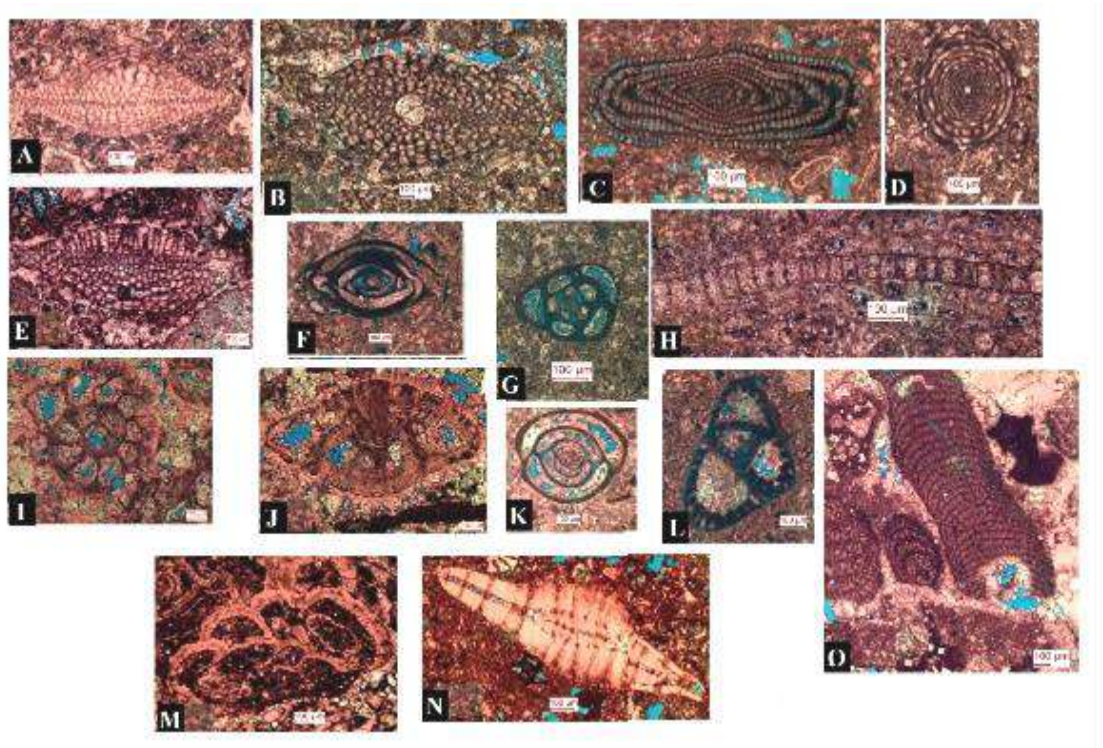

Fig. 16. Fossils in the studied wells. **A, B, E –** Hyaline (clear calcite), symmetrical, annular constructed (concentric chamberlets), symmetrical or asymmetrical, discoidal, sometimes fan-shaped tests, **C, D, H** – coiled tests with abundant chamberlets, either ovoid (Alveolinids, **E** – *Lepidocyclina* , **F, G, K, L –** coiled tests, commonly with lengthwise parallel additions to the coiling (streptorspiral, **I, J, N** – Robust coiled tests, ovoid or flat with thick radial fibrous hyaline walls, **M** – Encrusting hyaline test composed of layered chambers (domal or globular) with perforate walls, **O** – Coralline red algae

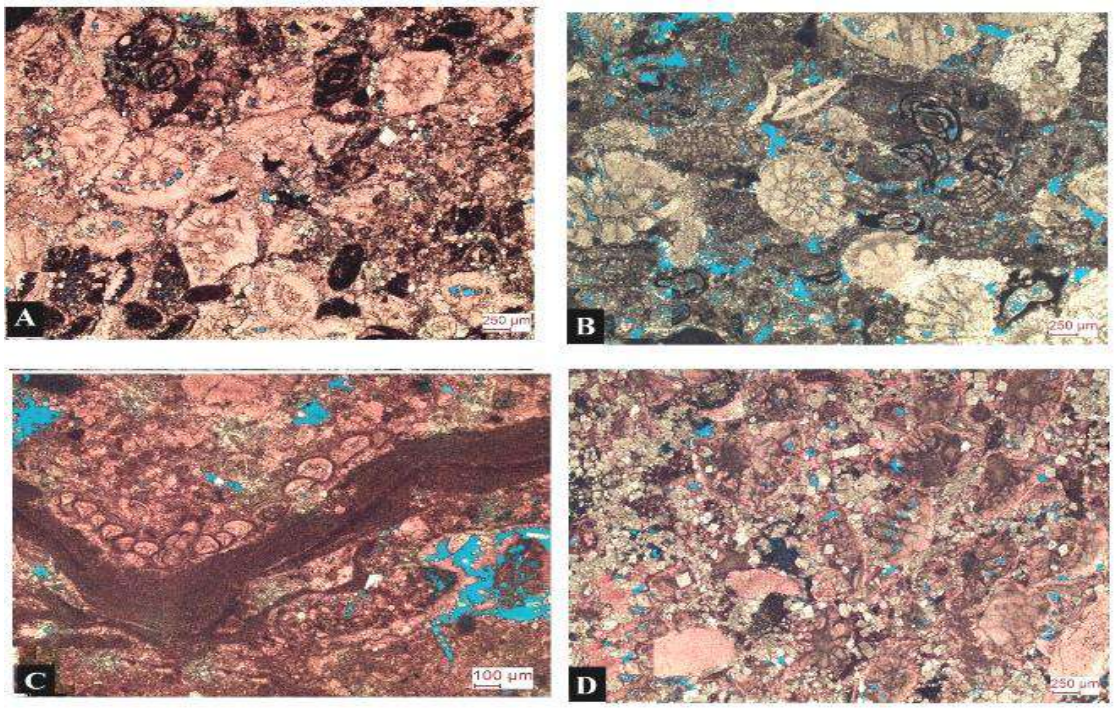

Fig. 17. Facies description: **A** – Fine to very coarse bioclastic larger foraminiferal packstone unit **II**, sample 14, Kirkuk well; 19 section, Baba Formation. **B –** Fine bioclastic smaller foraminiferal packstone unit **III**, sample 20, Bai Hassan well-4 section, Baba Formation. **C** – Fine bioclastic smaller foraminiferal wackestone to packstone unit (**IV**), sample 23, Bai-Hassan well-4 section, Baba Formation. **D** – Fine to very coarse bioclastic larger foraminiferal packstone grading to grainstone, unit (**I**), sample 3, Kirkuk well-19 section, the Baba Formation

This basal unit comprises fine to very coarse packstone that grades into grainstone. The thickness is approximately 18 meters, with coarse grains often exceeding 5 mm in size and exhibiting poor sorting. Bioclasts include *Lepidocyclina, Operculina*, and algal fragments, indicative of a high-energy shallow marine environment.

Interpretation: The coarse bioclasts suggest deposition in a high-energy slope or platform environment with episodic shallowing.

Unit II: Fine to Very Coarse Bioclastic Larger Foraminiferal Packstone.

This unit is characterized by fine to very coarse packstone, showing a fining-upward trend. The relative abundance of planktic foraminifera and smaller benthic foraminifera indicates a transitional environment.

Interpretation: The fining-upward sequence reflects a gradual deepening, possibly transitioning to a more protected environment.

Unit III: Fine Bioclastic Smaller Foraminiferal Packstone.

This unit consists of fine and medium-fine packstone, with occasional larger bioclasts and bioturbation structures. The thickness varies between 9 and 11 meters across two sections. The lower part contains algal fragments and encrusting foraminifera, while the upper part shows an increased abundance of *Lepidocyclina. Lepidocyclina* is a very characteristics element by its large relative frequencies between 25-75 percent and its diameter about 5 mm, and Nummulitidae remain present in the lower part of the unit III. (Fig. 18).

Interpretation: This unit represents deposition in a shallow marine environment, with evidence of progressive shallowing in the upper layers.

Unit IV: Fine Bioclastic Smaller Foraminiferal Wackestone to Dolostone.

The uppermost unit, approximately 35 meters thick, is characterized by dolomitization in the lower part and poorly preserved *Lepidocyclina* in the upper part. The dolomitized layers lack fossils, suggesting a sabkha-like environment.

Interpretation: The dolomitization and reduction in fossil preservation point to deposition in a restricted shallow marine to supratidal environment.

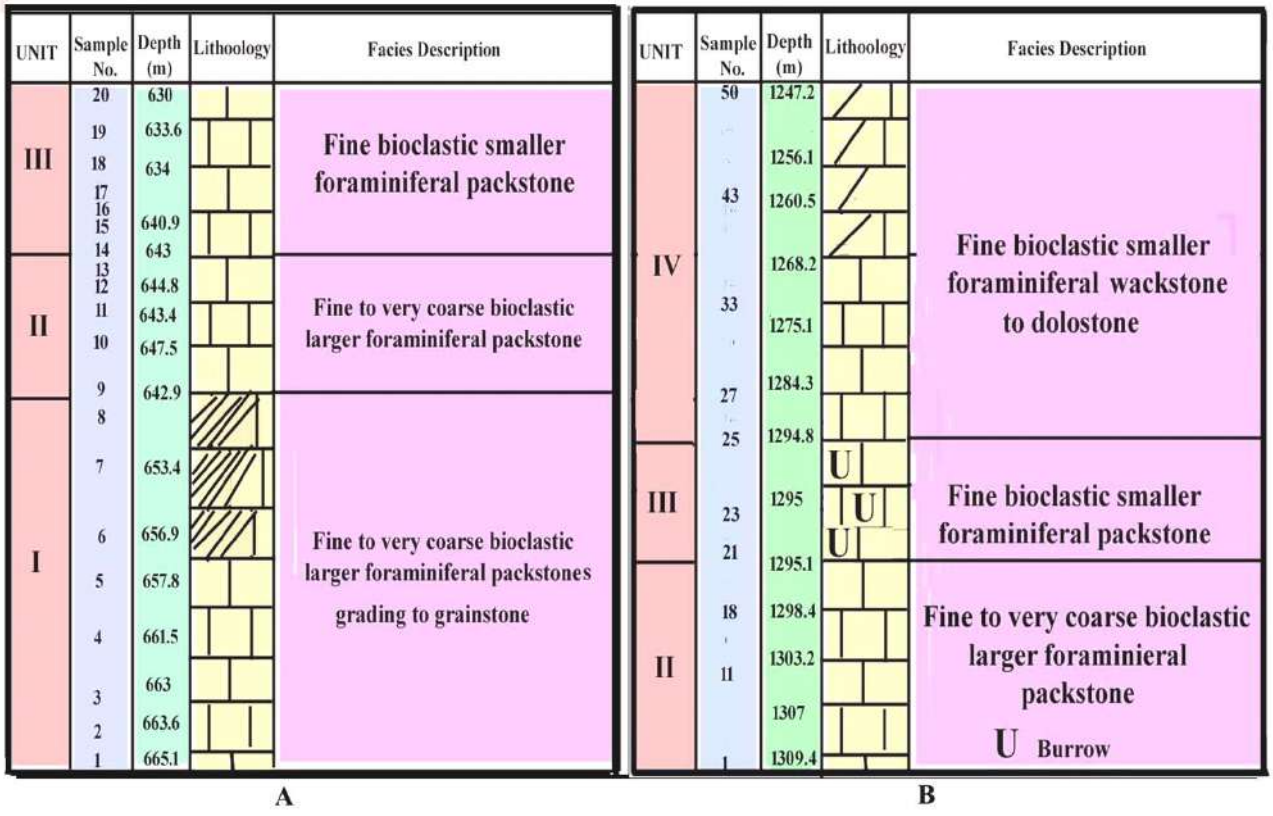

Fig. 18. A – Lithostratigraphic section of the Baba Formation in the Kirkuk well-19, **B** – Lithostratigraphic section of the Baba Formation in the Bai-Hassan well-4

Paleoenvironmental Considerations

The observed microfacies and faunal assemblages suggest that the Baba Formation represents a depositional environment transitioning from high-energy slope settings to more protected, shallow marine, and eventually restricted supratidal conditions. The overall fining-upward trends and fluctuations in bioclast abundance indicate variations in hydrodynamic energy and relative sea levels during deposition. In Kirkuk well-19, the predominance of coarse packstone in the upper layers suggests higher hydrodynamic energy compared to Bai Hassan well-4, where fine packstone dominates. The dolomitization in Unit IV, particularly in Bai Hassan well-4 supports the interpretation of a sabkha environment with episodic exposure and limited biogenic activity.

Conclusions

The Baba Formation in Bai Hassan oil well-4 and Kirkuk oil well-19 is characterized by abundant larger foraminifera, including *Lepidocyclina, Amphistegina, Pararotalia,* Nummulitidae, *Operculina*, and encrusting foraminifera. The fossil assemblages identified in the Baba Formation indicate Late Oligocene age. Four microfacies were identified within the Baba Formation at both studied sections: a. Fine to very coarse bioclastic larger foraminiferal packstone grading to grainstone. b. Fine to very coarse bioclastic larger foraminiferal packstone. c. Fine bioclastic smaller foraminiferal packstone. d. Fine bioclastic smaller foraminiferal wackestone transitioning to dolostone. The depositional environment of the Baba Formation reflects a progression from high-energy shallow marine conditions to more protected, shallow marine environments, and ultimately to restricted supratidal settings. These interpretations align with observations of grain size variations, bioclast distribution, and dolomitization within the studied sections. The facies analysis and paleoenvironmental interpretation suggest that the Baba Formation represents deposition in an isolated slope or platform setting under predominantly open marine conditions with evidence of episodic shallowing and restricted environments during later stages.

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КАРБОНАТНЫЕ ОСАДКИ И ПАЛЕОЭКОЛОГИЧЕСКИЕ ОСОБЕННОСТИ ФОРМАЦИИ БАБА (ОЛИГОЦЕН) В РАЙОНЕ КИРКУКА, ЗАГРОССКИЙ БАССЕЙН, СЕВЕРО-ВОСТОЧНЫЙ ИРАК

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Резюме. Это исследование посвящено карбонатным отложениям и палеосреде формации Баба с использованием образцов из нефтяных скважин Бай-Хассан-4 и Киркук-19 в Загросском бассейне, северо-восточный Ирак. В общей сложности было собрано пятьдесят образцов из скважины Бай-Хассан-4 и двадцать — из скважины Киркук-19.

Крупные фораминиферовые сообщества в пределах формации Баба в этих разрезах были подразделены на семь основных родов: *Lepidocyclina, Miogypsina, Miogypsinoides, Amphistegina, Austrotrillina, Pararotalia* и *Nummulitidae*, а также *Alveolinids*, кораллиновые водоросли и инкрустирующие фораминиферы. Используя количественный анализ шлифов, были определены различия в численности и распространении этих таксонов в разных стратиграфических единицах.

В скважине Киркук-19 *Lepidocyclina* и инкрустирующие фораминиферы были особенно многочисленны в нижних слоях, тогда как *Nummulitidae* преобладали в верхних слоях. В отличие от этого, в скважине Бай-Хассан-4 наблюдалось более равномерное распределение *Lepidocyclina* и *Amphistegina*, с локальными пиками численности инкрустирующих фораминифер в верхних слоях.

В результате исследований было установлено, что карбонатные отложения формации Баба включают четыре различные микрофации: 1) мелкий до очень крупного биокластический крупнофораминиферовый пакстон, переходящий в грейнстон; 2) мелкий до очень крупного биокластический крупнофораминиферовый пакстон; 3) мелкий биокластический мелкофораминиферовый пакстон; 4) мелкий биокластический мелкофораминиферовый вакстон, переходящий в доломит. Осадочная среда формации Баба интерпретируется как изолированный склон или платформенная обстановка, с преобладанием открыто-морских условий в течение всего периода осадконакопления.

Ключевые слова: *формация Баба, бентические фораминиферы, микрофации, палеосреда, олигоцен, Ирак*

BABA FORMASİYASININ (OLİQOSEN) KARBONAT ÇÖKÜNTÜLƏRİ VƏ PALEOEKOLOJİ MÜHİTİN XÜSUSİYYƏTLƏRİ, KƏRKÜK RAYONU, ZAQROS HÖVZƏSİ, ŞİMAL-ŞƏRQİ İRAQ

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Xülasə. Bu tədqiqat Baba Formasiyasının karbonat çöküntülərini və paleomühitini araşdırır və bunun üçün Zagros hövzəsinin şimal-şərqində, İraqda yerləşən Bai-Həsən neft quyusu-4 və Kərkük neft quyusu-19-dan götürülmüş nümunələrdən istifadə edilir. Ümumilikdə, Bai-Həsən neft quyusu-4-dən əlli, Kərkük neft quyusu-19-dan isə iyirmi nümunə toplanmışdır.

Baba Formasiyasının bu kəsimlərindəki iri foraminifer topluluqları yeddi əsas cinsə bölünmüşdür: *Lepidocyclina, Miogypsina, Miogypsinoides, Amphistegina, Austrotrillina, Pararotalia* və *Nummulitidae*, həmçinin *Alveolinids*, korallin yosunları və qabıq əmələ gətirən foraminiferlər. Nazik dilimlərin kəmiyyət analizi bu taksonların müxtəlif stratigrafik vahidlərdəki miqdarı və yayılması baxımından fərqləndiyini göstərmişdir.

Kərkük quyusu-19-da *Lepidocyclina* və qabıq əmələ gətirən foraminiferlər əsasən alt qatlarda çoxluq təşkil edirdi, halbuki *Nummulitidae* üst qatlarda daha çox yayılmışdır. Bunun əksinə olaraq, Bai-Həsən quyusu-4-də *Lepidocyclina* və *Amphistegina* daha bərabər paylanmış və yuxarı qatlarda qabıq əmələ gətirən foraminiferlərin lokal miqdar artımı müşahidə edilmişdir.

Tədqiqatın nəticələri göstərir ki, Baba Formasiyasının karbonat çökmə süxurları dörd fərqli mikrofasiya ilə təmsil olunur: 1) xırdadan çox iri ölçüyə qədər bioklastik iri foraminiferli pakston, greynstona keçid; 2) xırdadan çox iri ölçüyə qədər bioklastik iri foraminiferli pakston; 3) xırda bioklastik xırda foraminiferli pakston; 4) xırda bioklastik xırda foraminiferli vakston, dolomita keçid.

Baba Formasiyasının çökmə mühiti təcrid olunmuş yamac və ya platforma şəraitində formalaşmış, çökmə prosesi boyunca açıq dəniz şəraiti üstünlük təşkil etmişdir.

Açar sözlər: *Baba Formasiyası, bentik foraminiferlər, mikrofasiyalar, paleoekologiya, Oliqosen, İrak*