

## Eureka Journal of Geoscience, Materials & Resource Engineering (EJGMRE)

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### ARTICLE REVIEW ON THE OLIGOCENE SUCCESION IN IRAQ

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#### Abstract

This paper reviews the stratigraphic distribution, paleogeographic setting, tectonic setting, and evolutionary history of the Oligocene succession in Iraq, as interpreted from studies conducted since the early twentieth century. Iraq's Oligocene succession is both a relatively recent succession that is forming within the Eocene-Recent Mega sequence and a depositional unit that resulted from the collision of the Neo-Tethyan terranes present near the East and North margins of the Arabian plate. The formation called Oligocene found in most of the tectonostratigraphic zones, involving, Mesopotamian Zone, Jezira Subzone, and Makhul–Hemrin Subzone of the Foothill Zone. Eastern marginal reef sediment maximum ranges and thickness have been given in 12 words.

The Oligocene series is characterized by two principal depositional cycles. The lower cycle, corresponding to the Rupelian, includes the Tarjil, Shurau, Sheikh Alas, and Palani formations, whereas the upper cycle, assigned to the Chattian, is represented by formations such as Baba and Bajawan. The succession also displays distinct lithofacies variations, reflecting changes in depositional

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environments and geological conditions through time. Based on decades of bio stratigraphic, lithostratigraphic, and sequence-stratigraphic investigations, the study highlights the significant hydrocarbon potential of Oligocene carbonate reservoirs in the Kirkuk Oil Field, emphasizing their considerable economic importance.

The paper mentioned ongoing discussions on stratigraphy largely tied to the Oligocene–Miocene border and the need for fresh investigations into the diagnostic and dating of important unidades which remain in doubt.

**Keywords:** Oligocene succession, Iraq, Kirkuk Group, Arabian Plate, stratigraphy, carbonate facies, hydrocarbon reservoir, Neo-Tethys.

### Introduction

The megasequence record in the region from the late Eocene to present is closely related to the following main events: 1. The opening of the Red Sea and Gulf of Aden on the western side of the Arabian Plate; 2. collision of Neo-Tethyan terranes on the northern and eastern sides of the Arabian Plate. The Neo-Tethyan terranes have been emplaced along the north eastern margin of the Arabian Plate due to the northeastward motion of the Arabian Plate and progressive closure of Neo-Tethys. According to Palaeogeographic reconstructions based on 2D, quite recently, Makris and Henke (1992) and Hughes and Beydoun (1992) noted that the opening of Red Sea was late than that of Gulf of Aden.

The maximum thickness of the Miocene -Pliocene megasequence is about 3000 m in the south-east part of the Iraqi Foothill Zone. The thickness apparently exceeds 6000 m locally within the Dezful Embayment (Jassim and Goff, 2006) in the south-western part of the country. The megasequence is less evident in the region that stretches southeast from Mosul through the Tharthar Valley to the Euphrates. Its thickness here is no more than 500 m, between Kirkuk Basin on the southeast and Sinjar Basin on the northwest. The Nukhaib and Ghadaf grabens feature smaller isolated basins that are connected to them. Mio-Pliocene molasse deposits are found southwest of the Zagros Suture in northern Iraq in



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the foredeep basin in the Foothill and High Folded zones. The thickness in this region reaches 3.

The Kirkuk Oil Field, located in Iraq, has the largest reserve of hydrocarbon. The Oligocene strata of the Iraqi geological system have attracted worldwide attention from geologists and petroleum workers.

Oligocene Deposition occupies a lesser area and is less developed than Eocene Deposition. This sequence shows clear differences in rock facies and fauna from block to block, both horizontally and vertically. The manuscript is a full-covering and well-organised synthesis of earlier works on Oligocene successions in Iraq dealing with surface and sub-surface intervals. . The analyzed stratigraphic interval which has geological value, hydrocarbon potential and economical importance in other industries is the Kirkuk Oil Field.

Overall, the manuscript gives a clear picture of the regional stratigraphy, tectonic setting and paleontology of the Oligocene, Iraq.

### 2. Tectonic setting

A large portion of Iraq is situated on the Arabian Plate which comprises almost the whole northern and central part of Iraq (about 95 per cent of Iraq). The Zagros Main Thrust to the northeast of the Arabian Plate separates the platformal domain of Iraq from Shalair Terrane. According to the Eurasian Plate, the Sanandaj–Sirjan Zone is made of volcanic and metasediments. The region delineated as the Sanandaj–Sirjan Zone is an intra-continental orogenic belt within the Iranian segment of the Eurasian.

The tectonic evolution of the Arabian Plate shows a striking north-south contrast in the tectonics of Iraq (23) The Arabian Plates' inner body is strong enough to respond against the tectonic process of plate convergence and deformation. The outer section of the Arabian Plate, however, was able to maintain its platform character over an extended period of time. In terms of tectonic structure, the Arabian plate of Iraq is mainly divided into two main parts tectonically, namely The Inner Platform and The Outer Platform. The Arabian platform has two sub-platforms of which the Outer and Inner platform.

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According to Fouad (2015), the area in northern Iraq is made up of four small tectonic domains.

The Outer Platform of Northern Iraq adopts two essential tectonic domain, which are Mesopotamian Foredeep and Zagros Fold–Thrust Belt.

The Oligocene rocks were found under a large part of the Inner Platform and part of the Outer Platform, which includes the Low Folded Zone. This is a zone between the Mesopotamian Foredeep Western Zagros Fold–Thrust Belt (Fig. 1). At

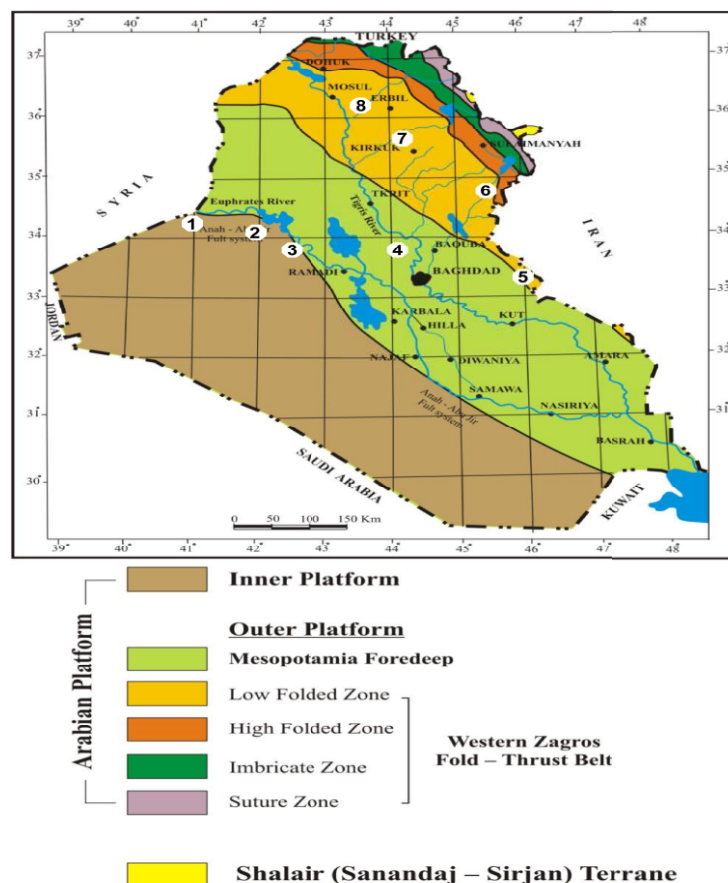


Fig. 1: Iraq's tectonic classification according to (Fouad, 2015) showing the position of the Oligocene successions in Iraq (Modified by Yaser., *et al*)

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### 3. Paleogeography

The Eocene was characterized by the link in the tectono-sedimentary evolution of the termination of the Neo-Tethys seaway, the one we see at present. This seaway had been connected with the present one since the Mesozoic period associated with the folding at the globe. During the late Eocene period, the main intraplate basin got restricted due to the uplift of the High Folded Zone and the tilting of the western Arabian Block. The western shoreline was lost in the easterly direction towards the present day line of the Euphrates river; the eastern shoreline was withdrawn towards the south-western margin of the Butmah–Chemchemal Subzone of the Foothill Zone.

Evidence of a small intermontane molasse basin which was progressively filled by sedimentation is quite clear in the remnant Cretaceous thrust belt. The High Folded Zone in the southwest lifted this sediment and the northeastern Cretaceous thrust zone also contributed to the sediment. During the Oligocene, the basin enveloped the Mesopotamian Zone, Jezira, Makhul–Hemrin Subzone of the Foothill Zone and northern margin Rutba Subzone. The uplift of these zones occurred from 34 to 23 million years ago.

At the Oligocene epoch the extent of the basin was small, with major reef complexes forming, probably for the first time, on the eastern and western margins. Due to the low influx of clastic and shallow marine carbonates, these marls formed at the centre.

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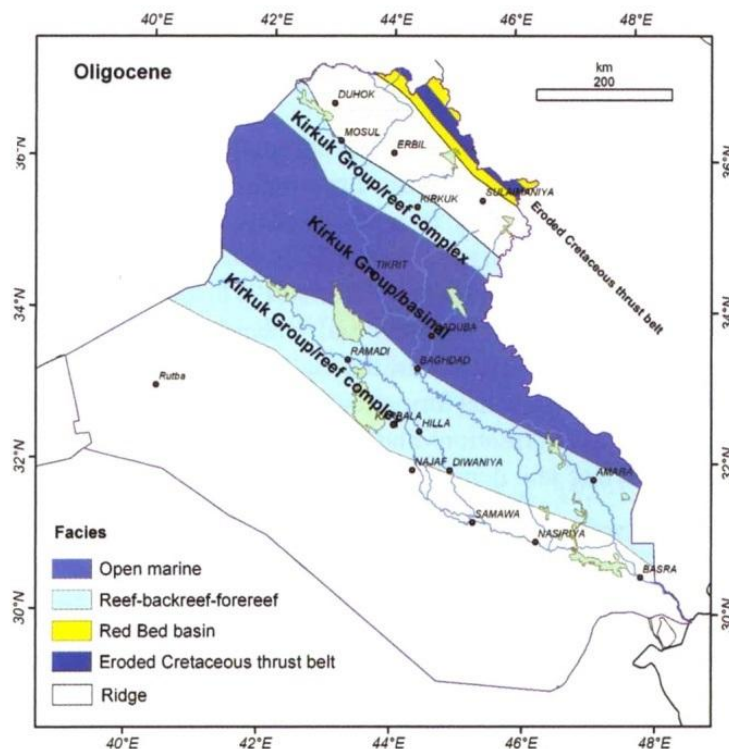


Fig.2: Oligocene Palaeogeography

### 4. Thickness and Distribution

The Late Eocene-Oligocene sequence has some distinct characteristics. Due to these features, there is a difference in the upper and lower contact. Bellen and others in 1959 subdivided the Oligocene successions. As per them there were nine formations and nine rock units. They assigned the whole group to Early, Middle and Late Oligocene. Three depositional sequences are mainly formed. The three are basically one each from the three “Oligocene” divisions.

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Conversely, Ditman and the Iraqi-Soviet crew created a stratigraphy based on below-surface proof and elaborate log correlation. As per Bellen et al. (1959), the stratigraphy is cyclic and not three, but 2 newly formed major depositional cycles and 2 subdivisions. For instance, lower cycle is made up of Tarjil, Shurau, Sheikh Alas and Palani formations. Which the Anah, Azkand, Iraqi outcrops of Oligocene age occur along the Euphrates Valley between Haditha and Anah and the Foothill Zone to the Qara Chauq structure. The Lower Oligocene Sheikh Alas and Shurau formations are found in Wadi Hauran which Al-Hashimi (1974) cited in Jassim et al. (1984) states are situated near Rutba about 200 km to the east and northwest of the Ga'ara Valley near Iraqi-Syrian border. The Qara Chauq structure and Jabal Sin have occasional rocks that are Oligocene in age.

The Ghar Formation is found all along the Euphrates Valley from southern Iraq to Syria. Jassim et al. (1984) assigned it an Early Miocene age all over. They said these clastics are disconformably overlain by Oligocene carbonates. In the past, Ditmar and the Iraqi-Soviet Team (1971) have linked the clastics of the Matean group from the wells situated to the south-east of Iraq belonging to overlying Oligocene carbonate with that.

The lower limit of the Oligocene succession higher in the basin megasequence is generally unconformable with the preceding megasequence, especially at the basin margins, while this boundary is conformable towards the central part of the basin. In the same manner, it is generally unconformable at the top of the succession. The thickness distribution reveals the existence of two principal NW-SE belts where sediment accumulates to a more or less high degree. One trace extends from Al Qaim south west towards Amara near the Iraqi-syrian border. A second belt stretches from the Iraqi-Iranian border in the southeast toward the northwest, passing through the Baba Dome complex in Kirkuk. The pairs of thicker belts are perhaps the marginal or barrier reef re complexes of the basin margins while the deposits in the basin proper between the belts are less thick.

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From Northern Iraq, Butmah – Chemchemical Subzone’s Oligocene deposits are either absent or poorly known. It might not be well-represented or completely absent from the High Folded Zone. The southwestern section of the Balambo – Tanjero Zone rarely studied as that of the Northern Thrust Zone.

The large area of uplifted ground long separated the Red Beds Basin of the northeast from the western basin. Though most Oligocene sediments are present in Iraq, they are absent from the Rutba Subzone, the Salman Zone, the Zubair Subzone and the Euphrates Subzone.

Thickness is one of the geographical controls of the Oligocene succession. A good example of this control study is the reef zone close to Anah on the left bank of the Euphrates River. The thickness of the Oligocene succession in this area is approximately 160 m (Fig. 2). The other geographical limit of the Oligocene succession represents the eastern marginal reef zone of Northeastern Iraq (Fig. 1).

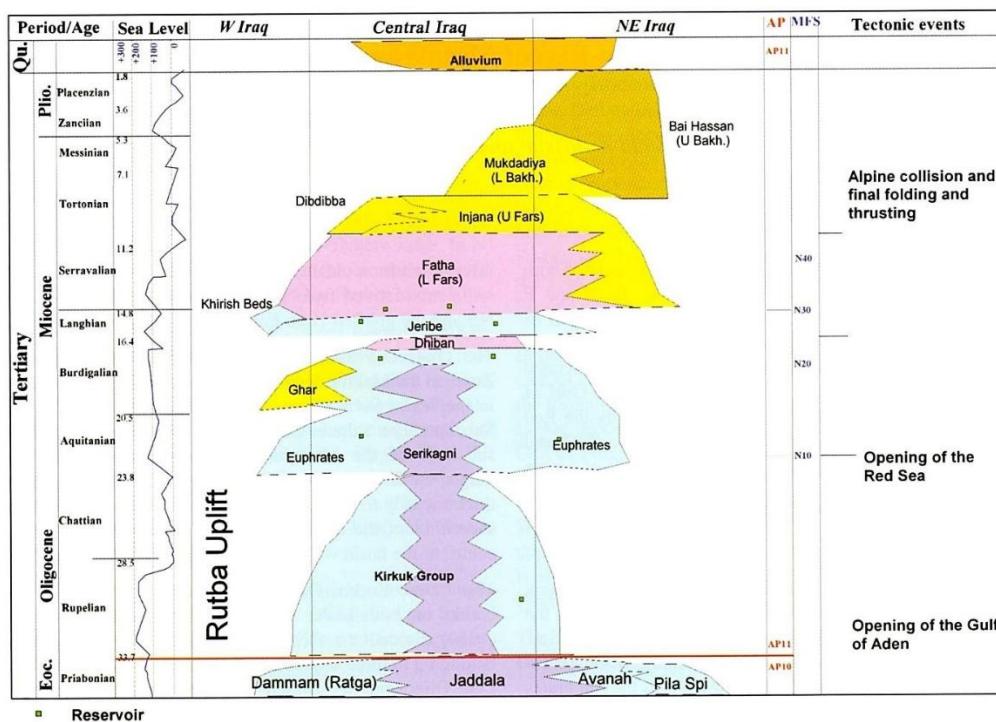


Fig.3: Stratigraphic correlation of Oligocene Formations

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### 5. Review of Previous Studies

Bellen (1956) and Bellen et al. (1959) originally adopted the name "Main Limestone" to describe the geological sequence included in the northern Iraqi buildings of Kirkuk, Bai Hassan, and Qara Chauq. Rocks from the Paleocene, Lower, Middle, and Upper Eocene, as well as the Lower and Upper Oligocene, make up this unit, according to Bellen. He attributed open-shoal reef habitats to Paleocene and Eocene deposits and primarily explained the Oligocene succession in terms of marginal and surrounding reef complexes. The Kirkuk Group included one of the eight distinct formations that comprised this unit. The Bajawan, Baba, Azkand, and Anah formations were part of the upper cycle of the Oligocene reef-driven sequence, whilst the Palani, Sheikh Alas, Shurau, and Tarjil formations were part of the lower cycle.

In 1968, Adams looked into the geographic and stratigraphic distribution of the foraminiferal genus *Austrorillina*. He noted that evolutionary modifications in the wall architecture of this species restricted its range to the Oligocene–Early Miocene era, which had significant stratigraphic implications. During his research, he identified *Austrorillina paucialveolata*\* for the first time using limestone samples from well K.14 in the Kirkuk region. This species was found inside a 30-foot-thick era that is possibly the upper part of the Lower Oligocene or the Middle Oligocene Shurau Formation. In 1986, Majid and Veizer investigated the geochemical properties and sedimentary diagenesis of Tertiary carbonates in the Kirkuk oilfield. The Oligocene strata were divided into two substages: the Early and Middle Oligocene. The Early Oligocene epoch included the back-reef to reefal Shurau Formation, the fore-reef Sheikh Alas Formation, and the basinal Palani Formation. The Middle Oligocene epoch was made up of the basinal Tarjil Formation, fore-reef Baba Formation, and back-reef to reefal Bajawan Formation. Their research revealed important lateral and vertical stratigraphic linkages and offered a comprehensive knowledge of the depositional settings of the Kirkuk Group.

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Abid and Al-Sayyab (1989) used foraminiferal assemblages to establish the Late Oligocene–Early Miocene boundary in order to address taxonomic and chronological discrepancies in the Anah Formation. In a related interpretation, Al-Eisa (1992a) noted that the Late Oligocene succession—that is, the Ibrahim, Azkand, and Anah formations—should instead be attributed to the Aquitanian and thus to the earliest Miocene sub-cycle due to the presence of Globigerinoides in the Ibrahim Formation and its intercalation with the Azkand Formation in the Khabaz oilfield. According to this theory, the Palani, Sheikh Alas, and Shurau formations are Early Oligocene in age, whereas the Tarjil, Baba, and Bajawan formations are Late Oligocene. The Oligocene succession was thus believed to consist of two depositional sequences.

Abid (1997) investigated depositional environments in central and northern Iraq using lithostratigraphy and chronostratigraphy. In addition to the Sinjar and Khanaqin basins, which trended northeast to southeast throughout the Early Miocene to early Middle Miocene, he discovered three deeper Oligocene sedimentary basins in the Mosul, Kirkuk, and Amara regions. Al-Banna (1997) examined the paleontology of the Oligocene–Miocene succession in western Mosul and concluded that the Anah, Azkand, and Ibrahim layers are of Early Miocene age rather than Late Oligocene.

Al-Twajjri (2000) states that beginning in the Late Eocene, the Oligocene succession in western Iraq displays continuous basin development on a moderately inclined carbonate ramp. In their analysis of the planktonic foraminiferal biostratigraphy of the Tarjil and Palani formations in the Sinjar region of northwest Iraq, Al-Mutwali and Al-Banna (2002) placed the Palani Formation in the late Early Oligocene and linked it to the *Cassigerinella chipolensis*/*Pseudohastigerina micra* Zone. After further categorizing the Tarjil Formation into three biozones—*Globigerina ciperoensis angulisuturalis*, *Globigerina ampliapertura*, and *Globorotalia opima opima*—they concluded that it covers the Middle to the Late Oligocene.



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According to Al-Banna's 2004 analysis of the microfacies of Oligocene strata in the Butmah and Rafan regions of northwest Iraq, this region constitutes the eastern edge of the Sinjar Oligocene Basin based on the distribution of microfacies and associated data. Al-Qayim (2006) determined that the Kirkuk Group was a second-order depositional sequence with an uneven Type 1 sequence boundary above and below after studying the Oligocene basin in north-central Iraq. Additionally, he demonstrated how the Oligocene succession was deposited in a very small, sinking interior sag basin that developed during a time of significant uplift and regression.

Based on microfacies analysis and fossil assemblages, Ghafor (2011) concluded that the Baba Formation in the Kirkuk area is Late Oligocene in age. In a subsequent sedimentological study, Ghafur (2012) concluded that the Kirkuk Group's deposition south of Sulaimaniyah occurred on a homoclinal carbonate ramp. However, he also noted that the whole Kirkuk Group was not deposited there because of its proximity to the basin's edge and the influence of regional tectonics on the basin's structure.

The Anah or Ibrahim formations of Early Miocene age, with contacts ranging from nearly conformable to unconformable, cover the Oligocene succession, which rests unconformably on the Middle Eocene Jaddala Formation, according to Al-Banna et al. (2013) in their study of Oligocene strata in the Sinjar region of northern Iraq. Their sequence stratigraphic framework was calibrated using both sedimentary facies and biostratigraphy. In their 2014 biostratigraphic study of the Oligocene succession in the High Folded Zone of Sulaimaniyah, northeastern Iraq, Ghafur et al. identified two biozones based on benthic and planktonic foraminifera together with red algae: Nummulites–Rotalia and Globoquadrina dehiscens.

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According to Lawa and Ghafur (2015), who combined sequence stratigraphy with biostratigraphy of Late Eocene, Oligocene, and Early Miocene carbonates from the Zagros Fold–Thrust Belt in the Kurdistan Region, the Kirkuk Group spans the interval from the Rupelian to the Early Aquitanian and consists of two fourth-order sequences within a single third-order sequence. The Sheikh Alas and Shurau formations belong to the Rupelian sequence, whereas the Bajawan, Baba, Tarjil, Anah, Azkand, and Ibrahim formations belong to the Chattian–Early Aquitanian series. Al-Qayim et al. (2015) examined the Oligocene–Miocene succession at Golan Mountain in Kurdistan that same year using microfacies and sequence stratigraphic research. Four third-order sequences were found, and they were linked to changes in the local and global eustatic sea level. This led them to categorize the Anah Formation as part of the Chattian and the Bajawan Formation as part of the Late Rupelian, both of which they considered to be distinct third-order depositional sequences.

In 2015, Aljwaini also investigated the reservoir characteristics and sequence stratigraphy of the Late Paleogene–Early Neogene succession in the Kirkuk area. He found a single second-order cycle that had a transgression surface (TS) below and a Type 1 sequence boundary (SB1) above. This primary cycle included five third-order cycles. Two of these were identified as A and B in the Kirkuk oilfield, with sequence A confined by TS at both its base and top and sequence B capped by SB1. In the Khabaz oilfield, three further third-order cycles were discovered: sequence C, which is limited below by SB1, sequence D, which is confined below by TS, and the uppermost cycle, represented by the Jeribe Formation, which is bounded above and below by SB1. It was also discovered that the top cycle of the Bai Hassan oilfield was similar.

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According to Farhan et al. (2016), who examined the microfacies and depositional environments of the Bajawan and Baba formations in the Kirkuk oilfields, the abundance of miliolids indicates deposition in very shallow waters with hyposaline to hypersaline conditions, restricted circulation, low oxygen content, and possibly euryhaline environments. Karim and Hama (2019) documented the succession for the first time in the Kirkuk Group's chronology in the Duhok Governorate and showed that it extends about 20 km into the High Folded Zone. This finding implies that the original northern boundary of the Oligocene basin was situated around 50 kilometers farther north than previously believed. Most of the succession in that area is composed of northern polymictic conglomerate layers and lagoonal limestones with patch reef interbeds.

Al-Bayati *et al.* in 2023 studied the Oligocene sequence in selected areas of Iraq. This sequence includes nine geological formations: Balani, Sheikh Allas, Shawraw, Targil, Baba, Bajwan, Ibrahim, Azqand, and Ana.

His study provided a detailed description and classification of the Oligocene sequence in central Iraq, based on physical properties, fossil content, thickness measurements, sedimentary structures, and unconformity surfaces (upper and lower boundaries). These Oligocene formations contain various types of limestone, including travertine, chalk, argillaceous, marly, dolomitic, dolomite, shale, and marl. The Oligocene sequence exhibits several distinct lateral and vertical variations in rock type and thickness.

The Depositional Environment of Palani Formation is middle ramp – (basinal) outer ramp environment, Sheikh Alas Formation is middle ramp environment, Shurau Formation is inner ramp environment, Tarjil Formation is Toe of slope - basinal environment, Baba Formation is lagoon - reef environment, Bajawan Formation is lagoon - back reef, Ibrahim Formation is basinal (outer ramp) environment, Azkand Formation is back reef-reef-for reef environment and Anah Formation is back reef-reef- for reef depositional environment.



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### 6. Conclusions

The Iraqi Oligocene is a significant geological period for both science and the economy. The examination of the corpus of existing literature leads to the following conclusions:

The Oligocene sequence in Iraq The evolutionary process in Iraq took place in a relatively small tectonically confined basin that is located inside the Mesopotamian Zone and Foothill Zone, after a period of uplift and regression at the end of the Eocene. Another characteristic of the basin was the development of barrier and bordering reefs on its east and west boundaries, with the thin sediments being deposited in its central areas.

The two main cycles of this succession are the low Rupelian cycle (Palani, Sheikh Alas, Shurau, and Tarjil formations) and the upper Chattian cycle (Baba, Bajawan, Ibrahim, Azkand, and Anah formations). The bipartite division, which has been shown to provide a more stable framework than the three earlier three-cycle frameworks, is supported by lithological, paleontological, and sequence stratigraphic evidence.

Large foraminifera, benthic or planktonic foraminifera, red algae, and other faunal assemblages have all been employed in biostratigraphic studies that have been essential in establishing the age of the various formations and in solving chronostratigraphic issues, particularly concerning the Oligocene-Miocene boundary. Certain formations that were previously believed to belong to the Late Oligocene have recently been reevaluated as belonging to the Early Miocene (Aquitania), and even the boundary of this boundary is still debatable.

The Oligocene carbonates, particularly the reef-related formations of the Kirkuk Group, which include the largest hydrocarbon reserves, including the Kirkuk Oil Field, demonstrate the petroleum geological significance of the Oligocene period. The dynamic character of the basin's changing paleogeographical structure over the Oligocene has been shown by the emergence of open marine and basinal settings, as well as reef, back-reef, lagoonal, and tidal settings.

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Despite decades of investigation, many aspects of Iraq's Oligocene succession remain unclear. These aspects include the nature of the Oligocene-Miocene transition in different structural contexts, the lateral boundaries of some of the formations, and the characterisation of the carbonate units across the basin. To identify these uncertainties and further delineate the exploration potentials of this important stratigraphic interval, future integrated studies that require a synthesis of complex biostratigraphic analysis, sequence stratigraphic modeling, and detailed field mapping are advised.

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