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Biostratigraphy and depositional setting of the carbonate unit within the upper part of the Maastrichtian Tanjero Formation in the Khanaqa Village, Imbrication Zone, NE Iraq-Kurdistan region

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Abstract. This study investigates the biostratigraphy and depositional environment of a carbonate unit located in the upper part of the Tanjero Formation, exposed in Khanaqa Village within the Imbrication Zone of northeastern Iraq. The unit comprises approximately three meters of massive and thick-bedded, sandy, yellowish-grey, fossiliferous limestone, with thin intercalations of marly bioclastic limestone in its lower section. Petrographic analysis, based on 18 thin sections, reveals a diverse assemblage of shallow-marine macrofossils and microfossils, including corals, rudists, various benthic foraminifera, and algae. Microfacies analysis identified three dominant microfacies, further subdivided into eight types, all characteristic of reefal environments. The benthic foraminiferal assemblages indicate a Maastrichtian age for the studied deposits. Based on lithological, petrographic, and paleontological evidence, the overall characteristics of the carbonate unit are more consistent with those of the Maastrichtian Aqra Formation. The occurrence of the Aqra Formation within the upper part of the Tanjero Formation in the studied area reflects a significant sea-level change, concurrent with tectonic activity in the Tanjero Basin during the latest Cretaceous period in the Kurdistan Region of northern Iraq.

Key words: *Tanjero Formation, Carbonate unit, Aqra Formation, Biostratigraphy, Reef setting, microfacies analysis. porphyry environment.*

Апстракт. Овај рад се бави биостратиграфијом и депозиционим срединама карбонатне јединице откривене у горњем делу формације Танџеро, у селу Канака унутар зоне Имбрикације североисточног Ирака. Ова јединица је састављена од три метра масивног и дебело услојеног, песковитог, жућкасто-сивог, фосилоносног кречњака са танким прослојцима лапоровитих биокластичних кречњака у доњем делу. Петрографски опис заснован на 18 петрографских препарата указао је на присуство разноврсних плитководних макро- и микрофосила као што су корали, рудисти и разне бентонске фораминифере и алге. Анализа микрофација указала је на присуство три доминантне микрофације, подељене у осам типова који карактеришу окружења гребена. Бентоске фораминиферске заједнице подржавају мастрихтску старост проучаваних наслага. У зависности од литолошких, петрографских и палеонтолошких доказа, опште карактеристике проучаване карбонатне јединице су сличне мастрихтској Акра формацији. Присуство Акра формације унутар горњег дела Танџеро формације у проучаваном подручју показује очигледну промену нивоа мора синхрону са тектонским променама басена Танџеро током касног кредног периода у региону Северног Ирака и Курдистана.

Кључне речи: *Формација Танџеро, карбонатна јединица, Формација Акра, биостратиграфија, депозициона средина гребена, микрофацијална анализа.*

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Introduction

The Kurdistan foreland basin, which was formed during the Turonian as a result of the subduction between the Arabian and Eurasian plates (Lawa & Khafaf, 2022; Al-Haj et al., 2024), has undergone numerous geometric changes, primarily due to the ongoing collision of these plates. Successive tectonic movements have led to the development of complex folds and thrust faults, as well as variations in depositional environments (Jassim & Goff, 2006). Different sedimentary basins lead to the formation of different environments, each characterized by its own distinct lithological and sedimentological features (Abid et al., 2022).

Previous studies (Buday, 1980; Sharazwri, 2023) have debated the interpretation of the carbonate unit occurrence within the upper part of the siliciclastic Maastrichtian Tanjero Formation in the northeastern Iraq (Kurdistan region). However, the presence of characteristic Maastrichtian fossils (e.g., Orbitoides medius) in various parts of the studied unit suggests that it may represent a part of the Aqra Formation.

The studied carbonate unit was observed in Khanaqa Village, where it emerges from the upper part of the Tanjero Formation and underlies the Red Bed Series (Suwais Group).

In Smilan and Mergasor areas, in the Imbrication Zone of northeastern Iraq, Karim et al. (2022) and Sharazuri (2023) respectively, described a carbonate succession in the upper part of Tanjero Formation and assigned it as a part of the Aqra Formation. Similarly, Lawa & Qadir (2023) studied the upper part of the Tanjero Formation in several locations within the Sulaimani area and reported a carbonate succession comparable to that described in the present study.

The Tanjero Formation, regarded as a thick clastic flysch facies, extends across large areas of the Folded Zone in northeastern Iraq. It is highly heterogeneous and exhibits significant lateral facies variations. At its type section in the Sirwan Valley near Halabja in the Kurdistan Region of northeastern Iraq, the Tanjero Formation is divided into two units. The lower unit, approximately 484 meters thick, consists of marls containing globigerinids, along with thin limestone and siltstone beds. The upper unit, up to 1500 meters thick and dated to the late Campanian–late Maastrichtian (Aqrawi et al., 2010), comprises silty marls, siltstones, conglomerates, and sandy to silty bioclastic and reefal limestones. The Aqra Formation was first defined by Bennet (1945), as cited in Bellen et al. (1959), as its type section in Gali Sheikh Abdul-Aziz, located on the Aqra Anticline in the High Folded Zone of northern Iraq. This formation crops out in several locations across the Kurdistan Region of Iraq, either as a distinct unit or interfingering with the upper part of the Tanjero Formation. These localities include Zanta Gorge, Gara Mountain, Bekhme Gorge, Diza, Dare Tesu, Gundi-Shikavt, Zibar, Chalki, Ser Amadia, Hadiena, Rawanduz, and the Chwarta–Mawat areas (Buday, 1980).

The formation was deposited during the late Campanian–Maastrichtian as part of a reefal carbo-nate system that developed throughout much of the mountainous zone of Iraq (Buday, 1980). It was originally described as a reef limestone complex consisting of massive rudist- and shoal-type reefs, detrital fore-reef limestones, and locally dolomitized beds, sometimes impregnated with bitumen (Bellen et al., 1959). The thickness of the Aqra Formation ranges from several hundred meters in the type area to a maximum of approximately 1050 meters in other locations. However, the formation thins rapidly toward the southeast of the type area, where it forms relatively thin tongues or interfingers with the Shiranish and Tanjero formations only (Buday, 1980).

The primary objective of this study is to integrate field observations, petrographic analysis, and microfacies data in order to reconstruct the depositional environment and assess the relative age of the upper unit of the Tanjero Formation.

Geological setting

The studied section in Khanaqa Village is located approximately 5 km north of Warte Town and 30 km southeast of Rawanduz District, adjacent to the main road connecting Soran and Ranya cities in northeastern Iraq. The geographic coordinates of the site are 44°46’38” E longitude and 36°32’13” N latitude (Fig. 1).

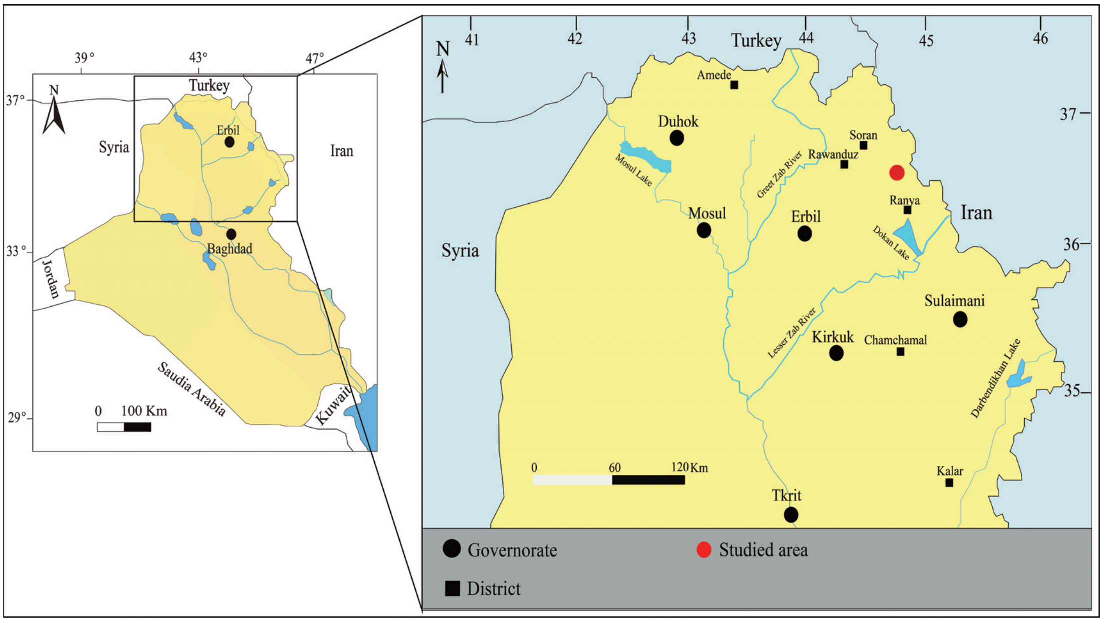
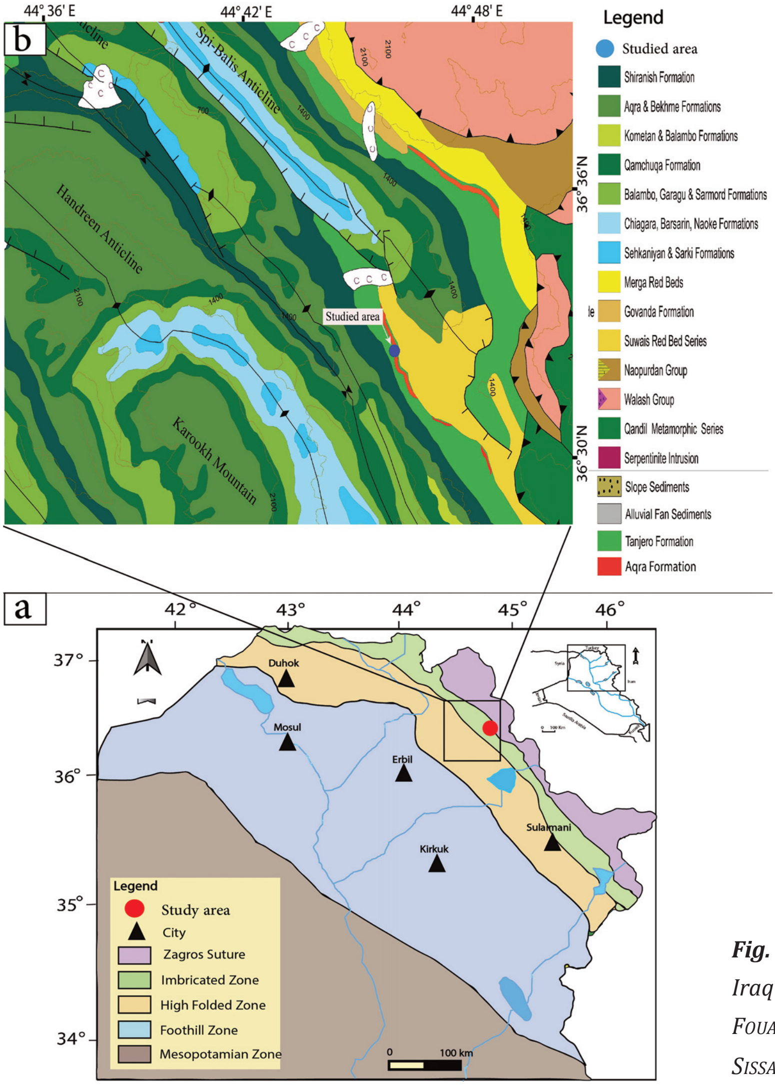


Fig. 1. Location map of the study area.



Tectonically, the section lies within the Imbricate Zone of northeastern Iraq (Fig. 2a) and is situated on the northeastern limb of the Spi Balies–Mama Ruta Anticline (Fig. 2b). To the northwest of the study area lies a thrust belt and imbricate structures, characterized by multiple thrust-fold systems that have significantly deformed the stratigraphic succession. BALAKI (2004) identified two major structural belts surrounding the study area: the Zozik–Rola Anticline to the southwest and the Spi Balies–Mama Ruta Anticline to the northeast. The southwestern limb of the Spi Balies Anticline is steeper, thinner-skinned, and shorter than the northeastern limb, and is generally overturned. The core of the Spi Balies–Mama Ruta Anticline is composed of Lower Jurassic rocks (Sarki Formation), while the Upper

*Fig. 2. Tectonic and geological maps. **a)** Tectonic divisions of Iraq showing the location of the study area (modified after FOUAD, 2015); **b)** Geological map of the studied area (after SISSAKINAN, 2000 and DELIZY et al., 2024).*

Cretaceous Tanjero Formation constitutes the limbs, representing the youngest exposed unit (Delizy et al., 2024) (Fig. 2b).

The geometric pattern of the studied carbonate unit represents a typical small and patchy reef body, characterized by a lensoidal shape. Its discontinuous exposure within the uppermost part of the Tanjero Formation extends periodically–laterally southeastward toward the Mawat–Chwarta areas and northwestward toward the Guezan, Smilan, and Mergasor areas, where it exhibits significant increases in thickness and fossil diversity (Fig. 3a). Lithologically, the unit consists of approximately 3 meters of massive to thick-bedded, hard, sandy-detrital, yellowish-grey, lensoidal, fossiliferous limestone, with intercalated thin (10 cm) marly limestone beds rich in loftusiid foraminifera and rudists (Figs. 3b, c). The lithological characteristics of this unit are similar to those previously described in the upper part of the Tanjero Formation by Bellen et al. (1959), Lawa (1983), Al-Ameri & Lawa (1986), Sharbazheri (2007), Görmüş et al. (2018) in other areas of the Kurdistan Region of Iraq.

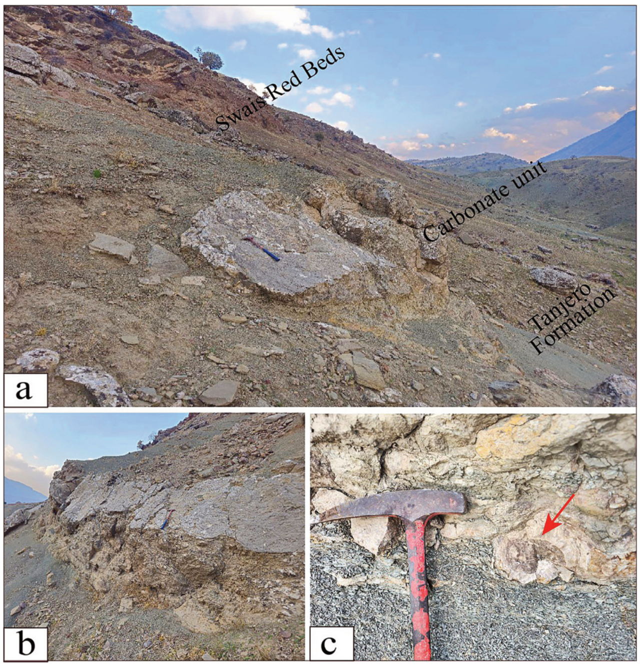


Fig. 3. *Field photographs of the studied carbonate unit.* ***a)*** *Exposure of the carbonate unit within the upper part of the Tanjero Formation, underlying the Red Beds (Suwais Group);* ***b)*** *Massive, thick-bedded, hard, sandy-detrital, lensoidal limestone with calcite veins and interbedded marly limestone;* ***c)*** *Fossiliferous limestone from the lower part of the unit showing a rudist fossil (red arrow).*

Methodology

This research involved a combination of fieldwork and laboratory analysis, encompassing several key tasks. These included examining the overall geology and structural relationships within the Upper Cretaceous succession in the designated study area, as well as identifying the most appropriate location for the present investigation. A comprehensive assessment of field relationships was conducted, including a detailed description of the exposed carbonate unit. Closely spaced sampling was performed, accompanied by the construction of a columnar section through sketching and appropriate field photography. A total of 20 samples were collected from selected outcrops. Eighteen thin sections were prepared from limestone samples at the research center workshop of Soran University. The thin sections were stained with alizarin red solution following the procedure of Friedman (1959), in order to differentiate calcite from dolomite. Petrographic descriptions, microfossil identification, and microfacies analyses were carried out using a Carl Zeiss Jena JENALAB POL polarizing microscope. Microfacies types were determined according to Dunham's (1962) classification, and further correlated with the facies zones of Wilson (1975) and the standard microfacies types defined by Flügel (2010) (Table 1).

Results

Stratigraphic succession of the studied carbonate unit

The upper part of the Tanjero Formation in Khanaqa Village, northeastern Iraq, is characterized by the presence of an exposed carbonate unit that sporadically occurs in other areas within the mountainous belts of the northern Iraqi Kurdistan region. This unit is approximately 3 meters thick and consists of massive, thick-bedded, hard, sandy-detrital, yellowish-grey, fossiliferous limestone, with an intercalation of a 10 cm-thick thin marly limestone rich in loftusiid foraminifera and rudists. The unit crops out and interfingers with the upper part of the Tanjero Formation, underlying the Swiss Red Bed Series (Fig. 4), and extends laterally for several hundred meters before pinching out. Field observations, along with sedimentological and paleontological characteristics, indicate that the studied unit was deposited in a shallow marine, typically reefal environment.

Biostratigraphy

The biostratigraphy of the studied carbonate unit is primarily based on the analysis of benthonic and planktonic foraminifera. The limestones of this formation were analyzed for their fossil content, which is crucial for dating the unit and understanding the paleoenvironmental settings of the region. Some biostratigraphically important taxa have been altered by diagenetic processes, which affected the re-

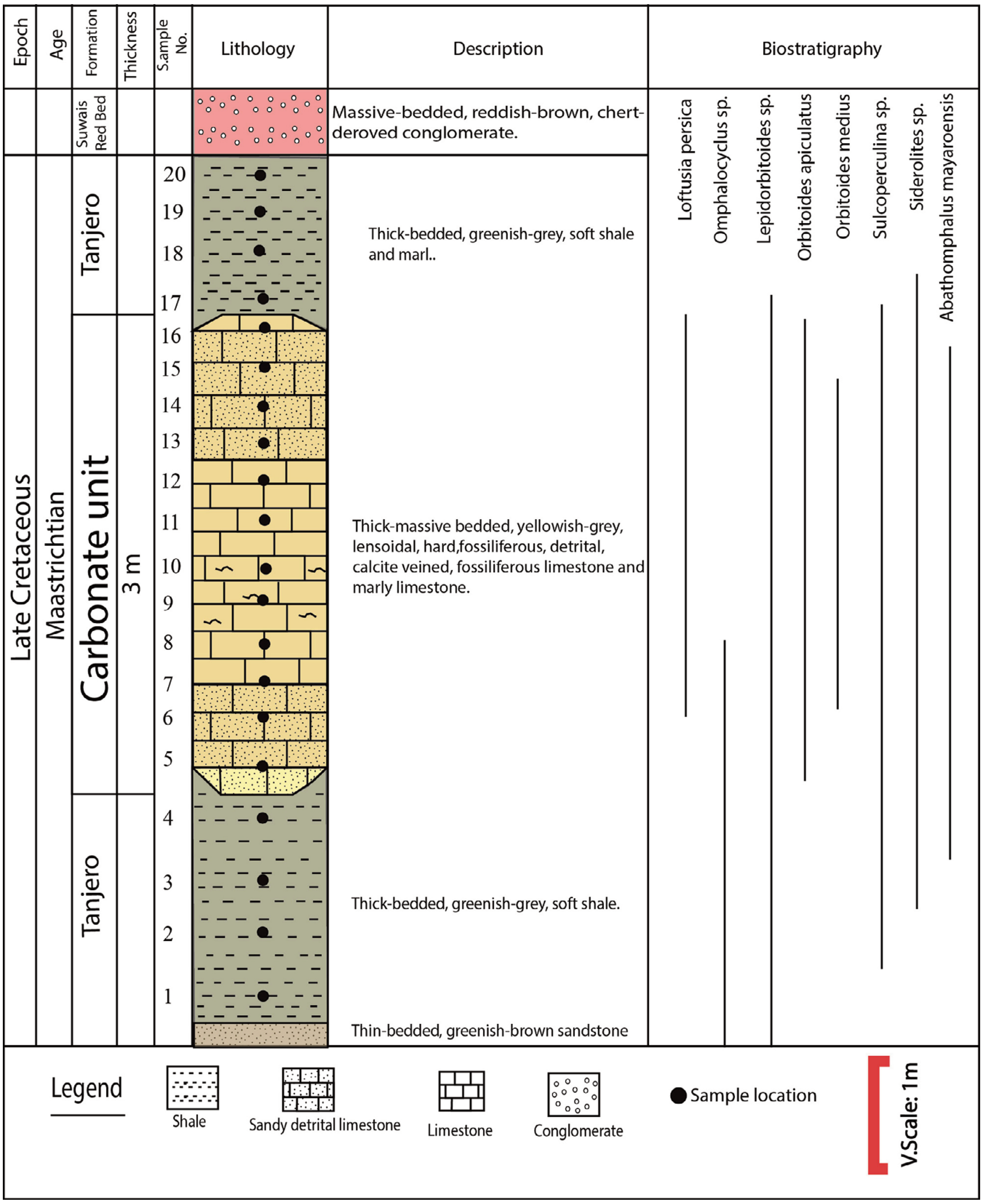


Fig. 4. *Stratigraphic column of the Khanaqa section showing the fossil ranges within the carbonate unit.*

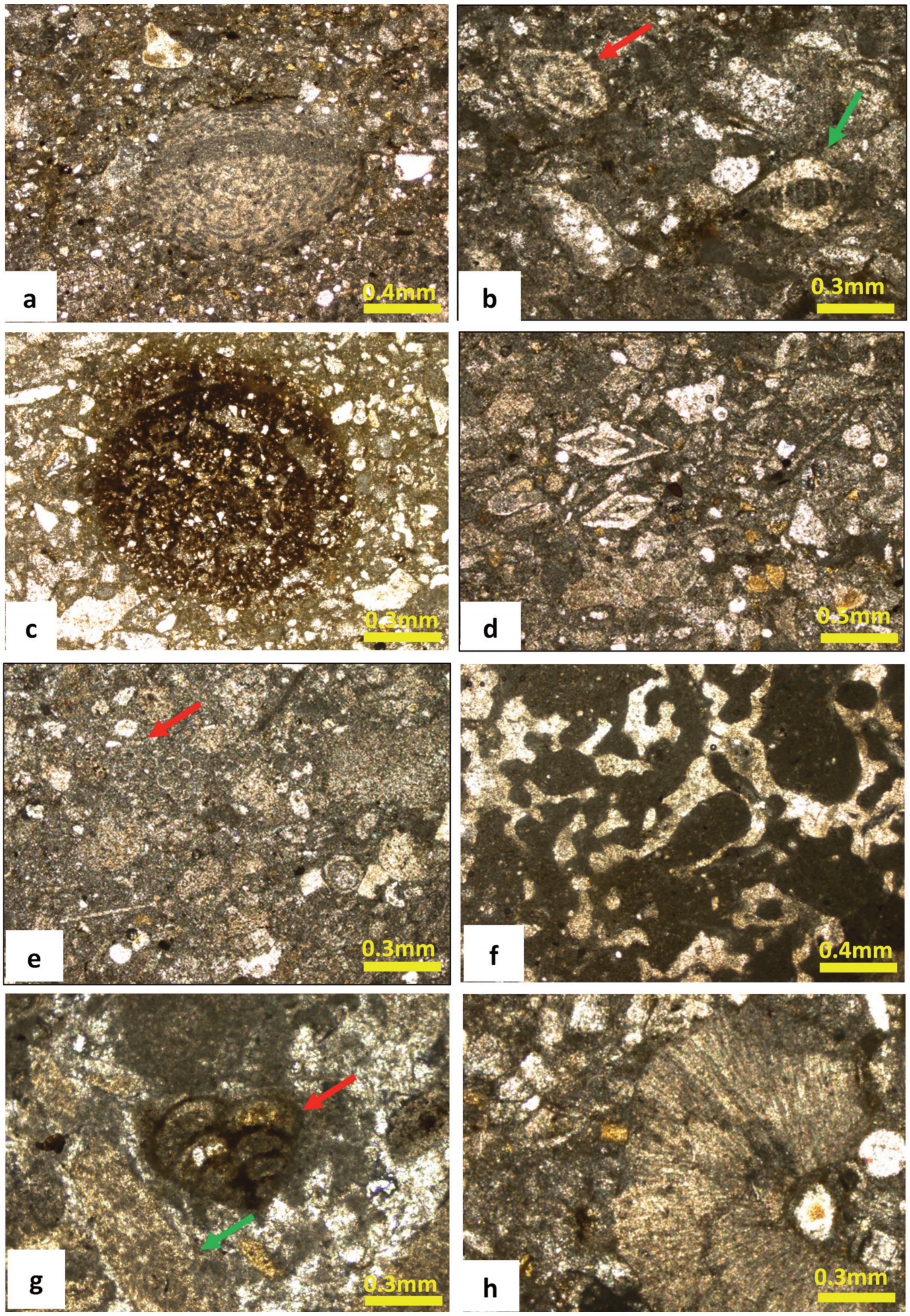


Fig. 5. *Photomicrographs of the carbonate unit.* ***a)*** *Orbitoides apiculatus in a micritic matrix from the upper part of the unit;* ***b)*** *Orbitoides medius (green arrow) and Siderolites* sp. *(red arrow) from the middle part;* ***c)*** *Loftusia packstone submicrofacies with Loftusia persica in micritic matrix;* ***d)*** *Benthic foraminiferal packstone submicrofacies with Sulcoperculina* sp.*;* ***e)*** *Abathomphalus mayaroensis (red arrow) from the middle part of the unit;* ***f)*** *Boundstone facies showing coral and algae (stromatoporoids) framework with cement-filled spaces;* ***g)*** *Algae (green arrow) and miliolid benthic foraminifera (red arrow) in micritic matrix;* ***h)*** *Rudist fragment in a micritic background.*

solution of biostratigraphic data by modifying and obscuring many fossils. The paleontological assemblage of the unit comprises numerous macro- and microfossils, including bivalves, corals, algae, echinoderms, gastropods, and benthonic foraminifera. As previously mentioned, the Aqra Formation is typically regarded as being of Campanian–Maastrichtian age. The biostratigraphy of the carbonate unit in the selected section is illustrated in Fig. 4. The middle to late Maastrichtian is thought to be the source of Orbitoides species such as *Orbitoides apiculatus* (Douville, 1902) (Fig. 5a) and *Orbitoides medius* (Papp & Kupper, 1968) (Fig. 5b). These are key index species for the Maastrichtian, especially Orbitoides medius, which was very abundant in the shallow-marine carbonate platforms of the Tethyan realm during the late Maastrichtian.

According to Brady (1869), *Loftusia persica* (Fig. 5c) is indicative of the late Maastrichtian. *Omphalocyclus* sp. (Bronn, 1853) was long considered a monospecific genus, but recent studies have described several new species (Gunter et al., 2002; Özcan, 2007). In his stratigraphic review, Özcan (2007) reported *Omphalocyclus* sp. (Fig. 5d) from strata as old as the late Campanian to late Maastrichtian. The species *Lepidorbitoides* sp. (Silvestri, 1907), recorded in the Aqra Formation, is restricted to the middle Maastrichtian. *Sulcoperculina* sp. (Thalmann, 1939) (Fig. 5d) dominated during the late Campanian to early Maastrichtian. The planktonic foraminifer *Abathomphalus mayaroensis* (Bolli, 1951) (Fig. 5e) is a very useful index fossil for the late Maastrichtian. *Siderolites* sp. (Lamarck, 1801) (Fig. 5b) represents an age range from the late Campanian to late Maastrichtian. Consequently, the biostratigraphic range of the recorded fossils in the studied carbonate unit mainly corresponds to the Maastrichtian age.

Petrography and microfacies analysis

The examined carbonate unit is characterized by an abundant assemblage of shallow-water macrofossils, microfossils, and bioclastic components. The diversity of petrographic constituents allowed for the recognition of various microfacies, which are crucial for determining and describing the depositional environment. In this study, the most common fossils include corals (Fig. 5f), algae (Fig. 5g), rudists (Fig. 5h), and common benthonic foraminifera such as loftusiids (Fig. 5c), miliolids (Fig. 5g), and orbitoids (Fig. 5a). Microfacies types were identified according to Dunham's (1962) classification andcorrelated with the standard microfacies (SMF) types of Flügel (2010) and facies zones (FZ) of Wilson (1975) to reconstruct the depositional environment. Three main microfacies were recognized: packstone, grainstone, and boundstone, with seve-ral subdivisions within the packstone category (Table 1).

Packstone microfacies

This microfacies is the most common among all identified types within the studied unit and is characterized by the presence of up to 60% skeletal grains. The dominant skeletal components include abundant benthic foraminifera (miliolids, orbitoids, loftusiids), along with rudists, algae, and corals. The packstone microfacies is the dominant facies and is observed throughout the entire carbonate unit. The main diagenetic processes affecting this microfacies are cementation and micritization. Six submicrofacies types have been identified: Loftusia packstone (Fig. 5c), Orbitoides packstone (Fig. 6a), Benthic foraminiferal packstone (Fig. 5d), Rudistid packstone (Fig. 6b), Algal packstone (Fig. 6c), and Miliolids packstone (Figs. 6d and 6e). These submicro-facies types correspond to SMF 6, 10, and 18 of Flügel (2010), indicating deposition in back-reef (SMF 10) and fore-reef (SMF 6 and 18) environments (Table 1).

Bioclastic grainstone microfacies

The grainstone microfacies is characterized by well-sorted and densely packed grains. Although less common than other microfacies types, it is observed in the upper part of the studied carbonate unit. The dominant bioclasts include benthic foraminifera, algae, and corals (Fig. 6f). The primary diagenetic processes affecting this microfacies are cementation, micritization, and compaction. This facies corresponds to SMF 11 of FLÜGEL (2010), which is indicative of deposition within a back-reef environment (Table 1).

between skeletal components are filled with micrite (Fig. 5f). This facies corresponds to SMF 7 of FLÜGEL (2010), which is characteristic of reef core or reef framework environments (Table. 1).

Table 1. *Main microfacies and subdivisions of the carbonate unit in the studied section.*

Main microfacies DUNHAM (1962)	**Subdivision of DUNHAM (1962)**	**Diagenesis features + Type of grains**	**SMF (FLÜGEL, 2010)**	**Depositional environments**
Packstone	**(MF1):** *Loftusia* packstone	The main components are *Loftusia persica* and other benthic foraminifera within micritic matrix. The main diagenetic feature is cementation.	SMF 10	Back reef
	(MF2): Benthic foraminiferal packstone	The major components are benthic foraminifera (*Sulcoperculina* sp.) and corals.	SMF 10	Back reef
	(MF3): *Orbitoides* packstone	The main skeletal grains in this sub-microfacies are *Orbitoides* (*Lepidorbitoides)* and miliolids. Micritization is the main diagenetic process.	SMF 18	Lagoon (Back reef)
	(MF4): Rudistid packstone	The main skeletal grains in this submicrofacies are the rudist fragments. Diagenetic features are cementation and neomorphism.	SMF 6	Fore reef
	(MF5): Algal –benthic foraminiferal packstone	The algae and benthic foraminifera (*Peneroplis evolutus*) are the main skeletal grains.	SMF 18	Back reef
	(MF6): Miliolids packstone	The major components are benthic foraminifera (*Pyrgo, Quinqueloculina*) and algae fragments.	SMF 18	Back reef
Grainstone	**(MF7):** Bioclastic grainstone	The main skeletal grains in this submicrofacies are benthic foraminifera (*Textularia*), corals, algae.	SMF 11	Fore reef (Shoal) to Back reef
Boundstone	(**MF8)**: Boundstone	The main components are corals and algae, cementation is major diagenetic process in this facies.	SMF 7	Core reef

Boundstone microfacies

The dominant components of this facies are red algae and rudists, accompanied by other bioclasts that appear as sheet-like and lamellar skeletal structures. This facies is observed in the lower part of the studied carbonate unit. It forms a reef framework, where most corals are encrusted or coated by other bioclastic material. In the boundstone facies, corals are the dominant framework builders and show evidence of slight neomorphism. Cavities and spaces

Depositional environment

The petrographic and microfacies analyses of the studied carbonate unit from the upper part of the Tanjero Formation indicate that the main skeletal components are rudists and larger benthic foraminifera (*Loftusia*, *Orbitoides*), along with algae, co-

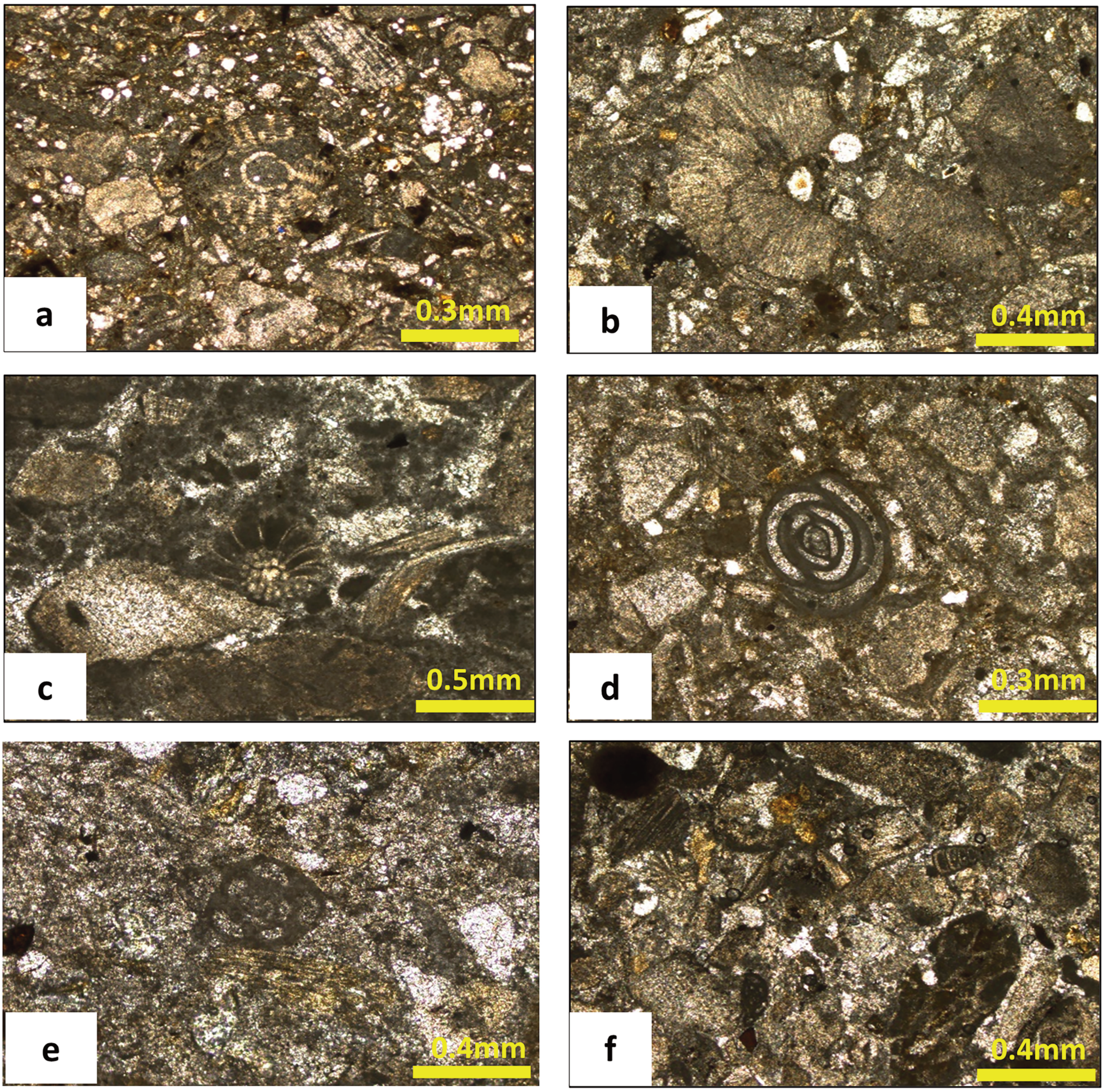


Fig. 6. *Photomicrographs of submicrofacies in the carbonate unit.* ***a)*** *Orbitoides (Lepidorbitoides* sp.*) packstone submicrofacies;* ***b)*** *Rudist packstone submicrofacies;* ***c)*** *Algal benthic foraminiferal packstone submicrofacies;* ***d)*** *Miliolids (Pyrgo* sp.*) packstone submicrofacies;* ***e)*** *Miliolids (Quinqueloculina* sp.*) packstone submicrofacies;* ***f)*** *Bioclastic grainstone submicrofacies composed of benthic foraminifera, corals, and algal fragments.*

rals, and smaller benthic foraminifera (miliolids). The presence of rudist debris and Omphalocyclus suggests deposition in reef and fore-reef environments (Flügel, 2010). The occurrence of bioclastic grainstone rich in benthic foraminifera, coral fragments, and algae points to transport from high-energy to lower-energy environments (e.g., from shoals or reef flanks to back-reef settings) (BouDagher-Fadel, 2008; Flügel, 2010; Delizy & Shingaly, 2022). Moreover, the dominance of *Loftusia* sp., miliolids, pelecypods, and algae supports deposition in back-reef and shallow-water environments (Assad et al., 2024; Balaky et al., 2025). The association of *Loftusia* sp. and solitary corals further supports a shallow, semi-protected marine setting, typical of reef and back-reef environments (Henson, 1950; Al-Omeri et al., 1989). Additional indicators of back-reef settings include the presence of common benthic foraminifera and rudist bivalve debris (Alsharhan 1995; Flügel, 2010). According to the Murray (1960) and Flügel, (2010), miliolids are typically found in restricted to semi-restricted marine lagoons (back-reef) in shallow waters less than 50 meters deep. Algae, on the other hand, are predominant in tropical to subtropical shallow waters near reef cores or back-reef areas (Bucur & Săsăran, 2005). Based on the above evidence, it can be concluded that the microfacies types of the studied carbonate unit correspond to SMFs 6, 7, 10, 11, and 18 of Flügel (2010), which are indicative of shallow-marine environments within a typical reefal system (including fore-reef, reef, and back-reef settings). A proposed depositional model for the studied carbonate unit in the Khanaqa section is presented in Fig. 7.

Discussion

In the studied section, the upper part of the Tanjero Formation is characterized by the presence of a 3-meter-thick, massive, and bedded fossiliferous carbonate unit. Detailed field observations and microscopic analysis of 18 thin sections reveal that the general characteristics of this unit closely resemble those of the Maastrichtian Aqra Formation. Petrographic analysis identified a diverse assemblage of shallow-marine macro- and microfossils, including *Loftusia* sp., *Orbitoides*, *Miliolids*, algae, corals, rudist debris, *Omphalocyclus macroporus*, *Lepidorbitoides* sp., *Orbitoides medius*, *Sulcoperculina* sp., and *Abathomphalus mayaroensis*–similar to fossils previously described from the Aqra Formation by Bellen et al., (1959), Malak & Al-Banna (2014) and Al-Banna & Alrashdi (2023) in northern Iraq. These fossil assemblages are distributed across different microfacies types, Packstone, Grainstone, and Boundstone, which correspond to the standard microfacies (SMF) of Flügel (2010) and represent fore-reef, reef, and back-reef depositional settings.

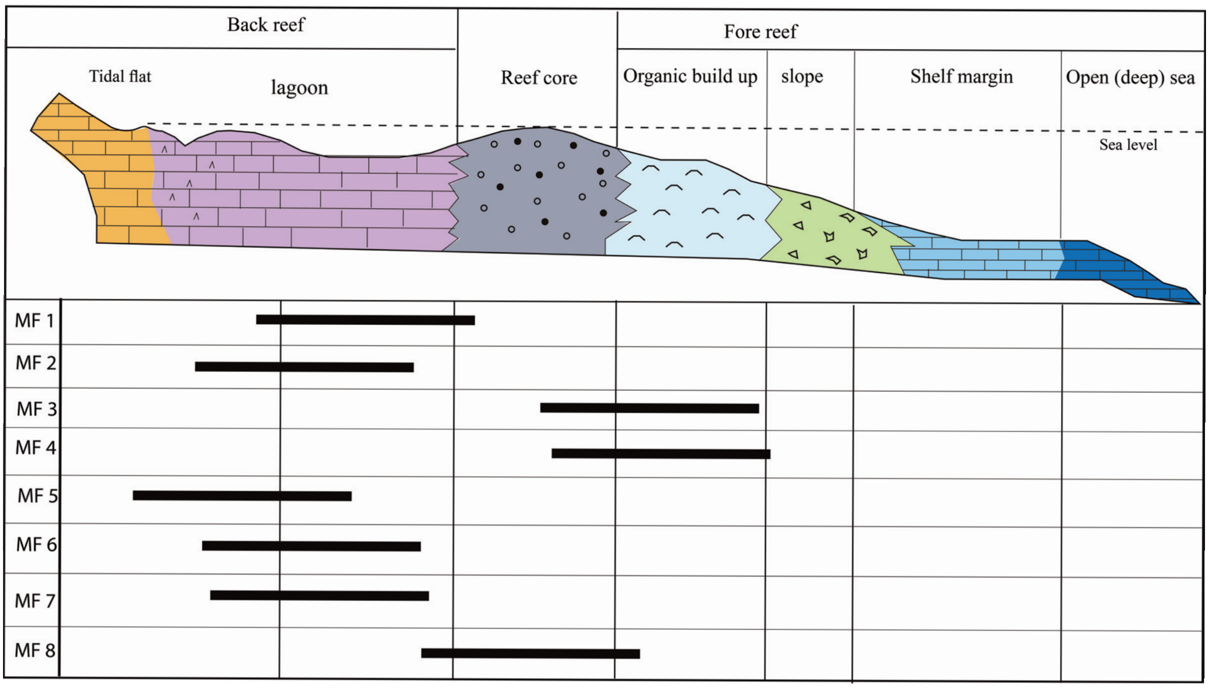


Fig. 7. *Proposed depositional model of the studied carbonate unit in the Khanaqa section, Kurdistan Region, NE Iraq.*

The relative age of the studied unit is determined based on several benthic foraminiferal species that are key indicators of the latest Cretaceous, a time when rudists were particularly prolific. Previous studies have referred the Aqra Formation to the Campanian–Maastrichtian interval. In this study, the presence of *Sulcoperculina* sp. (Thalmann, 1939) indicates a late Campanian to early Maastrichtian age, while *Orbitoides* species (e.g., *Orbitoides apiculatus* and *Orbitoides medius*) and *Lepidorbitoides* sp. suggest a middle to late Maastrichtian age. Additionally, *Loftusia persica* (Brady, 1869) and *Abathomphalus mayaroensis* (Bolli, 1951) and *Siderolites* sp. (Lamarck, 1801) are indicative of a late Campanian to late Maastrichtian age.

As a result, the biostratigraphic data from the studied carbonate unit primarily support a Maastrichtian age, correlating laterally with the Aqra Formation within the upper part of the Tanjero Formation across various parts of the Iraqi Kurdistan region. These findings suggest that during the latest Cretaceous, due to sea-level fluctuations and tectonic activity, intertonguing occurred between the Aqra Formation and the siliciclastic turbidites of the upper Tanjero Formation (Lawa & Qadir, 2023). These conditions extended sporadically toward the southeast of the studied area.

Conclusions

The main conclusions of the current study are:

1. The upper part of the Tanjero Formation in the Khanaqa Village is characterized by the presence of a massive, thick-bedded, fossiliferous carbonate unit, which sporadically crops out in several areas across the northern Iraqi Kurdistan region.

2. Based on Dunham's (1962) classification, three main microfacies and eight sub-microfacies have been identified. These correspond to SMF types 6, 7, 10, 11, and 18 of Flügel (2010), indicating deposition within a fully developed reefal environment.

3. Several biostratigraphically important taxa (*Loftusia persica, Orbitoides apiculatus, Orbitoides medius, Sulcoperculina* sp., *Siderolites* sp., and *Abathomphalus mayaroensis*) confirm a Maastrichtian age for the studied carbonate unit.

4. The general sedimentological features and fossil assemblages of the studied unit closely correspond to those of the Maastrichtian Aqra Formation.

5. During the latest Cretaceous (Maastrichtian), the Aqra Formation inter-fingered with the siliciclastic turbidites of the upper Tanjero Formation in the Khanaqa area. This depositional setting also occurred sporadically toward the southeast of the study area.

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References

Abid, A.A., Asaad, I.S. & Pasha, S.M. 2022. Foraminiferal assemblage, microfacies analysis, and depositional environment of Tanjero Formation (Late Cretaceous) in Hujran section, Northeast Erbil City, Kurdistan Region, Iraq. *Arabian Journal of Geosciences,* 15 (3): 259. https://doi.org/10.1007/s12517-022-09563-9

Al-Ameri, T.K. & Lawa, F.A. 1986. Paleoecological and faunal interaction within Aqra limestone formation (N-Iraq). *Journal of the Geological Society of Iraq,* 19: 7–27.

Al-Banna, N.Y. & Al-Rashedi, M.A. 2023. Facies analysis and sequence stratigraphy of Late Cretaceous Aqra Formation, Northern Iraq. *Iraqi Bulletin of Geology and Mining,* 19 (2): 19–35. https://doi.org/10.59150/ibgm1902a02

Al-Haj, M.A., Asaad, I.S., Al-Taee, N.T. & Balaky, S.M. 2024. Depositional Model of Early–Middle Turonian deep water Gulneri Formation, in selected outcrop and subsurface sections in Northern Iraq. *Iraqi Geological Journal,* 57 (1B): 26–39. https://doi.org/10.46717/igj.57.1B.3ms-2024-2-12

Al-Omari, F., Al-Radoani, M. & Lawa, F.A. 1989. Biostratigraphy of Aqra Limestone Formation (Upper Cretaceous); Northern Iraq. *Journal of the Geological Society of Iraq,* 22 (2): 44–55.

Al-Sharhan, A. 1995. Facies variation, diagenesis and exploration potential of the Cretaceous rudist-bearing carbonate of the Arabian Gulf. *AAPG Bulletin,* 79 (4): 531–550. https://doi.org/10.1306/8D2B1584-171E-11D7-8645000102C1865D

Asaad, I.Sh., Ahmad, A.M. & Balaky, S.M. 2024. Lithostratigraphy and microfacies analysis of Middle–Late Eocene Pila Spi Formation in Sheikh Turab section, Safin anticline, Kurdistan region of Iraq. *Boletín de la Sociedad Geológica Mexicana*, 76 (3):1-18.

Balaki, H.G. 2004. *Geometry and structural history of Zozik-Rola and Spi Balies-Mama Ruta structures of the Zagros fold thrust belt in NE Iraqi Kurdistan.* Unpubl. MSc. Thesis, University of Salahadin, Iraq, 103pp.

Balaky, S.M., Tamar-Agha, M.Y., Asaad, I.Sh. & Radwan A.E. 2025. Sedimentology of Lower Triassic (Induan stage) mixed carbonate-siliciclastic succession of an epeiric carbonate ramp at the northeastern passive margin of Arabian Plate, Northern Iraq – Kurdistan region. *Geological Journal,* 60 (6): 1304–1328. https://doi.org/10.1002/gj.5124

Bellen, R.C., Van Dunnington, H.V., Wetzel, R. & Morton, D. 1959. *Lexique Stratigraphique International Asia,* Iraq. Centre national de la recherche scientifique, 333 pp.

Bolli, H.M. 1951. The genus Globotruncana in Trinidad, B.W.I.: Notes on Occurrence, Nomenclature and Relationships between Species. *Journal of Paleontology,* 25 (2): 187–199.

BouDagher-Fadel, M.K. 2008. *Evolution and Geological Significance of Larger Benthic Foraminifera.* Elsevier, Amsterdam, 540pp.

Brady, G.S. 1869. A Monograph of the Recent British Ostracoda. *Transactions of the Zoological Society of London,* 4: 353–393.

Bronn, H.G. & Roemer, E. 1853. *Lethaea Geognostica; vierte Periode; Kreide-Gebirge,* Aufl. 3, Bd. 2, Theil 5 (1851-1852). Stuttgart: E. Schweizerbart, 95pp.

Bucur, I.I & Săsăran, E. 2005. Relationship between algae and environment: an Early Cretaceous case study, Trascau Mountains, Romania. *Facies,* 51: 274–286. https://doi.org/10.1007/s10347-005-0001-9

Buday, T. 1980. *The Regional Geology of Iraq. Stratigraphy and Paleogeography,* Vol. 1, Dar Al- Kutub Publication, Mosul, Iraq, 445pp.

Delizy, B.A. & Shingaly, W.S. 2022. Microfacies analysis and depositional environment of Sarki Formation (Early Jurassic), Rawanduz area, Kurdistan Region, Northern Iraq. *Tikrit Journal of Pure Science,* 27 (1): 24–35. https://doi.org/10.25130/tjps.v27i1.79

Delizy, B.A, Shingaly, W.S & Balaky, S.M. 2024. Dolomitization model of the Lower Jurassic Sarki Formation depending on petrography and Carbon/Oxygen isotopes, Northeastern Iraq-Kurdistan region. *Jordan Journal of Earth & Environmental Sciences,* 15 (3): 174–182.

Delizy, B.A., Nourmohammadi, M.S., Asaad, I.S. & Omar, S.A. 2024. Sedimentology of Late Jurassic–Early Cretaceous Chia Gara Formation in Rawanduz area, Kurdistan region-Iraq. *Journal of Sedimentary Environments,* 9: 859–873.

Douville, H. 1902. Sur les *Orbitoides et Lepidocyclines. Bulletin de la Société Géologique de France,* 4(2): 1–20.

Dunham, R.H. 1962. Classification of carbonate rocks according to de positional texture. *In*: Ham, W.E. (Ed.). *Classification of carbonate rocks.* AAPG. Memoir., 1: 108–121

Flügel, E. 2010. *Microfacies of Carbonate Rocks, Analysis, Interpretation and Application.* Springer-Verlag, Berlin, 976 pp.

Fouad, S.F. 2015. Tectonic map of Iraq, scale 1: 1000 000, 2012. *Iraqi Bulletin of Geology and Mining,* 11 (1): 1–7.

Friedman, G.M. 1959. Identification of carbonate minerals by staining methods. *Journal of Sedimentary Petrology*, 29 (2): 87–97.

Görmüş, M., Nuaimy, Q.A.M. & Lawa, F.A. 2018. Quantitative data on the genus Loftusia from the Zagros Mts., northern Iraq. *Acta Geologica Polonica,* 68 (2): 207–218. https://doi.org/10.1515/agp-2017-0025

Gunter, M.E., Bandy, O.L. & Langer, M.R. 2002. A new species of *Omphalocyclus* (Foraminiferida) from the Upper Cretaceous of Jamaica and its stratigraphical significance. *Journal of Foraminiferal Research,* 32 (1): 3–30.

Henson, F.R.S. 1950. Cretaceous and Tertiary Reef Formations and associated sediments in Middle East. *AAPG Bulletin,* 34 (2): 215–138.

Jassim, S.Z. & Goff, J.C. 2006*. Geology of Iraq.* Dolin, Prague and Moravian Museum, Brno, 341pp.

Karim, K.H., Daoud, H., Abdula, R.A. & Sharezwri, A.O. 2022. Occurrence and relationship of the Aqra, Bekhme and Govanda formations in the Soran (Rawanduz) area, Kurdistan Region, northeastern Iraq. *Bulletin of the Geological Society of Malaysia*, 73 (1): 67–77. DOI: 10.7186/bgsm73202206

Lamarck, J.B. 1801. Système des animaux sans vertèbres; ou, Tableau général des classes, des ordres et des genres de ces animaux. L'Auteur, Paris, 432pp.

Lawa, F. 1983. *Microfacies of the Aqra Formation in its type section.* Unpubl. MSc. Thesis, University of Mosul, 145pp.

Lawa, F. & Al-Khafaf, A. 2022. Biostratigraphy of Dokan and Gulneri formations from Kosrat Anticline, Sulaimani Area, Kurdistan Region-Iraq. *Iraqi Bulletin of Geology and Mining,* 18 (2): 25–42.

Lawa, F.A. & Qadir, H. 2023. New Biostratigraphic ideas about the Cretaceous/Paleogene boundary from selected sections in Kurdistan–Mesopotamian Foreland Basin, Northern Iraq. *Iraqi National Journal of Earth Sciences,* 23 (2): 124–156. https://doi.org/10.33899/earth.2023.139689.1069

Malak, Z.A. & Al-Banaa, N.Y. 2014. Sequence stratigraphy of Aqra Formation (Late Upper Campanian–Maastrichtian) in Geli Zanta Gorge, Northern Iraq. *Arabian Journal of Geosciences,* 7: 971–985.

Murray, R.C. 1960. Origin of porosity in carbonate rocks. *Journal of Sedimentary Research,* 30 (1): 59–84.

Özcan, E. 2007. Morphometric analysis of the genus *Omphalocyclus* from the Late Cretaceous of Turkey: new data on its stratigraphic distribution in Mediterranean Tethys and description of two new taxa. *Cretaceous Research,* 28: 621–641. https://doi.org/10.1016/j.cretres.2006.09.002

Papp, A. & Küpper, H. 1968. Die Foraminiferenfauna der Gosau (Oberkreide) von Gams (Steiermark). *Mitteilungen der Geologischen Gesellschaft in Wien,* 61: 1–114.

Sharazwri, A.O. 2023. *Paleontology and Stratigraphy of the Govanda Formation and the Underlying Unit in Kurdistan Region, Iraq.* Unpubl. MSc. Thesis, Soran University, Erbil, Iraq, 125pp.

Sherwani, G.H., Naqishbandi, S.F. & Balaky, S.M. 2006. Microfacies and environmental analysis of Harur Formation (Early Carboniferous) – Northern Iraqi Kurdistan. *Iraqi Bulletin of Geology and Mining,* 2 (2): 39–55.

Silvestri, A. 1907. Probabile origine d'alcune Orbitoidine. *Rivista Italiana di Paleontologia,* 13: 79–81.

Sissakian, V.K. 2000. *Geological Map of Iraq, 1:1000000,* GEOSURVE, Baghdad, Iraq.

Thalmann, H. 1939. Zur Stratigraphie und Mikropaläontologie der Kreide in den Ostalpen (Stratigraphy and Micropaleontology of the Cretaceous in the Eastern Alps). *Eclogae Geologicae Helvetiae,* **3**2: 299–374.

Wilson, J.L. 1975. *Carbonate Facies in Geologic History.* Springer–Verlag, Berlin, 471pp.

Резиме

Биостратиграфија и седиментационе средине карбонатне јединице у горњем делу маастрихтске Формације Танџеро у селу Канака, Имбрикациона зона, североисточни Ирак – регион Курдистана

Горњи део формације Танџеро у селу Канака карактерише присуство масивне, дебело услојене, фосилне карбонатне јединице, која се повремено јавља на неколико подручја широм северног дела Ирачког Курдистана. Петрографска анализа је показала присуство разноврсних плитководних макро- и микробентоских организама, укључујући *Loftusia* sp., *Orbitoides*, алге, корале, остатке рудиста, *Omphalocyclus macroporus, Lepidorbitoides* sp., *Orbitoides medius, Sulcoperculina* sp. и *Abathomphalus mayaroensis*. На основу Данхамове класификације (1962), идентификоване су три главне микрофације и осам подмикрофација. Они одговарају типовима СМФ 6, 7, 10, 11 и 18 према Flügel (2010), што указује на депоновање у потпуно развијеном окружењу гребена. Неколико биостратиграфски важних таксона (*Loftusia persica, Orbitoides apiculatus, Orbitoides medius, Sulcoperculina* sp., *Siderolites* sp. и *Abathomphalus mayaroensis*) потврђују мастрихтску старост истраживане карбонатне јединице. Опште седиментолошке карактеристике и фосилне заједнице испитиване јединице блиско одговарају онима из мастрихтске формације Акре. Током касне креде (мастрихт), формација Акре са силицикластичним турбидитима је имала утицај у горњу формацију Танџеро у области Канака. Ово депозиционо окружење се повремено јављало и ка југоистоку испитиваног подручја.

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