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## Biostratigraphy and Paleoenvironments of Benthic Foraminifera From Lower Part of the Damlouk Member, Western Desert, Iraq

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### Abstract

Age and paleoenvironment of part of the Damlouk Member, Ratga Formation from a surface section in the Iraqi Western Desert are investigated. Twenty-nine species of Larger Benthic Foraminifera (LBF) belonging to 13 genera are recognized from the studied section. The LBF assemblage is dominated by the following groups, *Nummulites*, *Alveolina*, *Rotalia*, and *Lockhartia*. Two species of corals with fragments of bryozoan, red algae and mollusca had also been identified.

The palaeontological investigation aimed at identification of LBF assemblages to evaluate their abundance and distribution with respect to sedimentary environment and to determine its age. Based on the recognized Larger Benthic Foraminifera of the studied part of the Damlouk Member, it is subdivided into two biozones: *Nummulites gizhensis* - *Nummulites moculatus* Assemblage Zone and *Assilina spirala* - *Lokharatia hunti* Concurrent Range Zone. Both biozones suggest a Middle - Late Lutetian to Early Bartonian age.

The LBF are concentrated around shallow marine carbonate bank-controlled limestone unit and the associated ramp facies. Two basic environmentally significant assemblages were recognized based on the vertical distribution and the relative abundance of the LBF. The *Nummulites* bank assemblage is characterized by lensoidal and robust *Nummulites* of different species. The other group is the fore-bank assemblage which shows relatively higher diversity, including flat LBF such as: *Nummulites*, *Assilina*, *Lockhartia*, *Heterostigina* and *Operculina*. The third back-bank assemblage is not well presented in the studied section, shows the limited distribution, and is considered part of the back-bank lagoon facies. This group is characterized by the occurrence of *Alveolina* and other imperforated forams. The recognized assemblages represent the transition from inner to middle ramp facies with a water depth not exceeding 50m in relatively low energy conditions.

**Keywords:** Larger Benthic Foraminifera (LBF), Biostratigraphy, Eocene, Palaeoenvironment, Ratga Formation, Damlouk Member, Iraq.

الطباقية الحياتية والبيئية القديمة للفورامينيفيرا القاعية للجزء السفلي لعضو الدملوق، في الصحراء الغربية، العراق

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### الخلاصة

يتناول البحث دراسة العمر والبيئه القديمه لجزء من مكاشف عضو الدملاق, تكوين رطكه في الصحراء الغربيه للعراق. تم تمييز 29 نوع تعود ل 13 جنس من الفورامنيفيرا القاعيه الكبيره . اهم هذه المجاميع البرايوزوا. هذه الدراسه تهدف الى تحديد مجاميع الفورامنيفيرا القاعيه الكبيره لغرض دراسة علاقة غزارتها وانتشارها في السحنات الرسوبيه وتحديد العمر .

بناء على انتشار مجاميع الفورامنيفيرا هذه في الطبقات المدروسه تم تحديد نطاقين احيايين هما :

1- نطاق *Nummulites gizhensis* – *Nummulites moculatus* Assemblage Zone

2- نطاق *Assilina spira*– *Lokharatia hunti* Concurrent Range Zone

كلا النطاقين يمثلان عمر اللوتيتيان المتأخر – الباروتونيان المبكر للطبقات المدروسه.

مجاميع الفورامنيفيرا المميزه تمثل بيئه المصطبه الجبريه البحريه الضحله المتصله بالمنحدر البحري المتدرج. ومن خلال انتشار مجاميع الفورامنيفيرا القاعيه في السحنات المدروسه تم تقسيم مجاميع الفورامنيفيرا بيئيا الى مجموعتين رئيسيه:

1- مجموعة منصه النيوميولايت الكلسيه والتي تمتاز بالفورامنيفيرا العديسيه المننقحه مثل النيوميولايت المننقحه

2- مجموعة مقدمه المنصه الكلسيه والتي تمتاز بوفرة الانواع المقلطحه من الفورامنيفيرا مثل:

*Nummulites, Assilina, Lockhartia, Heterostigina* and *Operculina*.

اما المجموعه الثالثه هي مجاميع الفورامنيفيرا اللاكونيه خلف المنصه والتي تتميز بوجود الالفبولينا والفورامنيفيرا غير المثقبه. المجموعه الاخيره غير واضحه بشكل جلي في المقطع المدروس. اما المجموعه الاولى والثانيه فتمثل البيئه الانتقاليه من المنصه الى المنحدر وبعمق مائي لايزيد على 50 متر وتحت ظروف بيئيه معتدلة الطاقه.

### Introduction

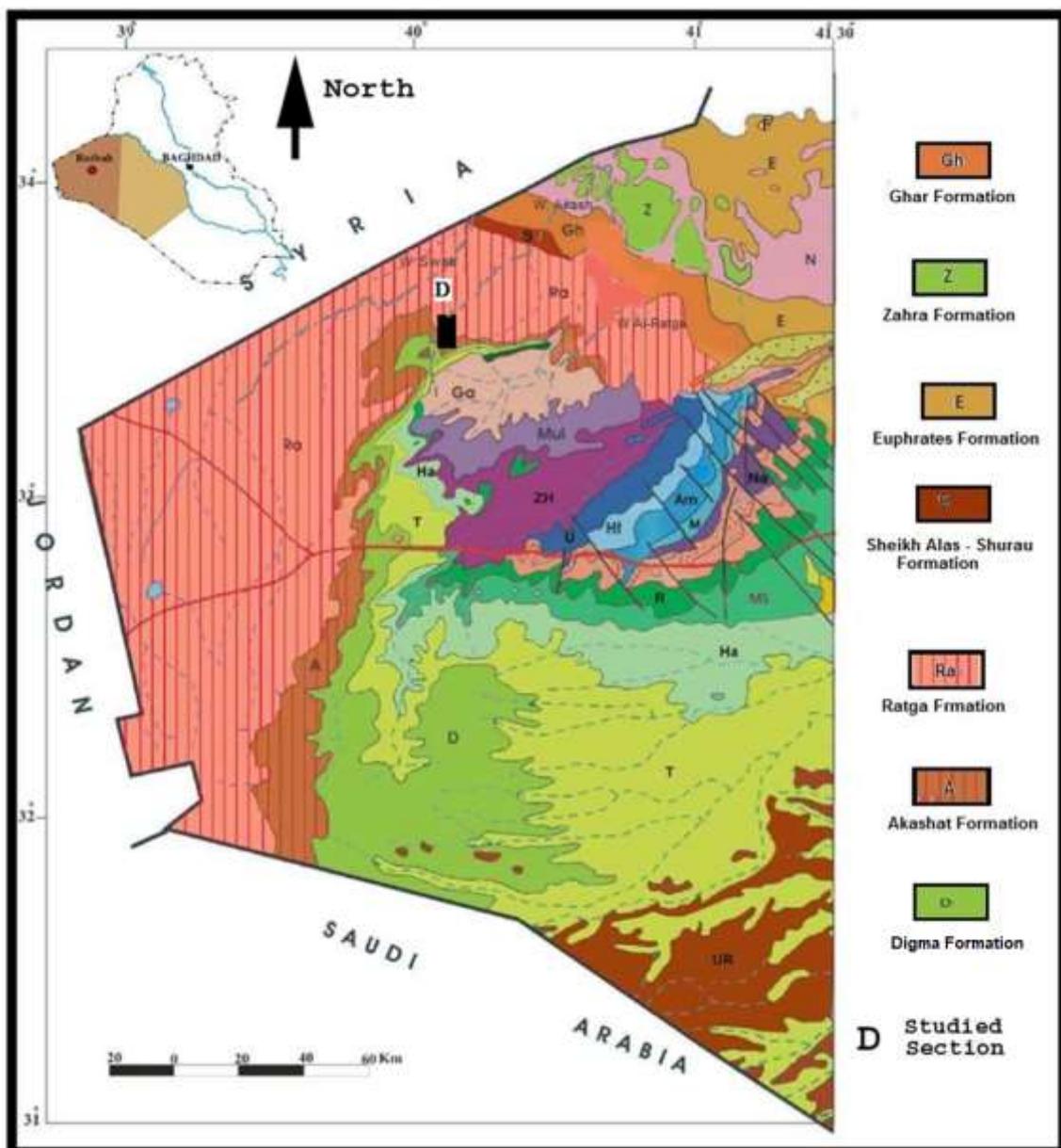
The Cretaceous- Paleogene stratigraphic succession of the Western Desert of Iraq is interesting for two reasons; the first because it includes the economically attractive phosphate horizons of Iraq, and the second reason is the stable tectonic setting of the area as a part of the Arabian plate interior [1]. This conceivably displayed the eustatic controls on stratigraphy in a better resolution than the plate margin sequences. Thus, special attention is growing and given to this sequence, and this work represents part of continuous interest in the stratigraphic development of the area. (see [2] ).

Studies on the western desert were reactivated during the seventies by the geologists of the Geological Survey of Iraq to map the area and evaluate its potential mineral resources, including phosphates and uranium [3]. This attempt is followed by extensive works of teams from the geological survey to revise the stratigraphic status and relations of the Cretaceous- Paleogene phosphatic-rich strata [3, 4]. [5] finish the first report of that revision attempt by revising the stratigraphic status by introducing new units. The Eocene strata of the study area are now considered the Ratga Formation [3]. The argillaceous lime mud of the Damlouk Member in the Ratga Formation rich in planktic foraminifera [6]. [5] gave the stratigraphic formal and detailed description of the Ratga Formation type section, subdivided into three lithologic members from bottom to top: Swab, Damlouk, and Mugur Members. The Formation represents the phosphatic carbonate equivalent unit to part of the platform carbonates of the Dammam Formation of the Southern Desert. Outcrops of these members are distributed along valleys such as Swab, Akashat and Ratga, which drained down towards the Ga'ara Depression to the southeast.

The study area is located in the northwestern part of the Iraqi Western Desert about 80 km from Al-Rutba town in an area called Akashat, between  $40^{\circ} 00'$  and  $40^{\circ} 15'$  Long and  $34^{\circ} 00'$  and  $33^{\circ} 45'$  (Figure 1).

### Geologic Setting

The area is part of the stable platform of the Arabian Plate, which is controlled by subdued tectonic features, including the Hail-Rutba uplift [7]. This uplift and the succeeding erosion expose Paleozoic strata in a sub-circular depression called Gara Depression. Strata at the shoulders of this depression belong to the Mesozoic Era, followed by the Cenozoic strata. To the north and northwestern part of this depression, strata are dipping gently in that direction with dry valleys such as Al-Mana, Al-Ratga, and Akash cutting into the Paleogene strata and draining into the Euphrates valley (Figure 1). The examined section of the Damlouk Member is exposed along these valleys and their tributaries.



**Figure 1:** General geologic map of the Western Desert showing the location of the studied section of the Damlouk Member. (Map from [2]).

To the East and central Iraq, the Ratga Formation is replaced by the equivalent basinal marly limestone sediments of the upper part of the Aaliji Formation (Paleocene – Early Eocene) and the Jaddala Formation (Middle-Late Eocene) Formation. Further northeastwards, towards the northeastern margin of the sedimentary basin, these basinal facies are replaced by the Kolosh\ Sinjar, Gercus formations and the platform carbonates of the Pilaspi \ Avanah formations (Figure 2).

Chronostratigraphy		Saudia Arabia (Hag & Qahani, 2005)	Southern Desert (Hagopian, 1979)	Western Desert (Karim & Al-Bassam, 1997)	Central Iraq (Jassim & Golf, 2006)	NE. Iraq (Kurdistan) (Al-Qayim et al., 2016)	W. Iran (James & Wynd, 1965)
Series	Stage						
Oligocene	Rupelian			Sheikh Alas	Palani	Bajwan	Asmari
	Priabonian	E	E	Mugur	Jaddala	Avanah / Pila Spi	U. Pabdeh
Bartonian	E	E	Damluk	Gercus			
Lutetian	E	E					
	E	E					
	E	E					
Ypresian	Rus	Rus	Swab		Sinjar / Kolosh		
Paleocene	Thanetian	Umm Er Radhuma	Umm Er Radhuma	Akashat	Aaliji	Kolosh	L. Pabdeh
	Selandian						

**Figure 2:** Stratigraphic chart of the Eocene stratigraphic units of the Western Desert and its equivalents. (After [1] ).

The age of the Ratga Formation is Lower- Upper Eocene [3]. It is widely distributed in the Western Desert, with a thickness of 200-220m. The Formation consists mainly of cyclic alternation of Nummulitic limestone, phosphatic limestone, crystalline chalky limestone with irregular chert horizons and nodules, and basinal marly limestones. The lower and upper boundaries conform to the Paleocene Akashat Formation and the Oligocene Sheikh Alas/ Shurau formations [3]. They subdivided the formation into three lithologic members from bottom to top: Swab, Damlouk, and Mugur Members. These members display similar cyclic alternations of similar lithologic associations in each member. The Damlouk Member includes two cycles of similar facies sequence and is often called Damlouk (A) for the lower cycle and Damlouk (B) for the upper one (Figure 3). The type locality of the Damlouk Member is selected from Wadi Akash for Damlouk (A) (28m), and wadi Halgum for Damlouk (B) (52m) [3, 5].

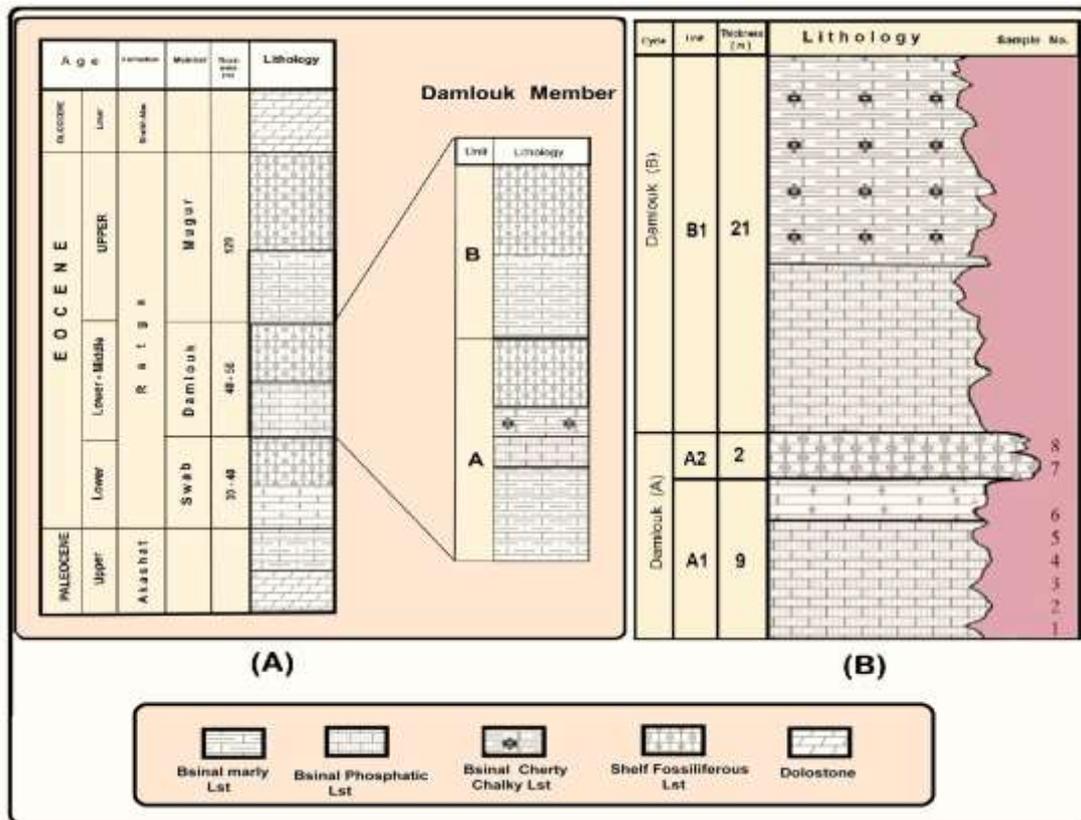
Each cycle consists of two distinctive lithologic units. The lower unit represents the shelf-deep marine facies, and the upper part represents the shallow marine facies and commonly consists of Nummulitic limestone and/or shelly bioclastic limestone making the basic components of a carbonate bank.

The examined section is 32 meters thick and includes the complete lower cycle (Damlouk A) and part of the upper cycle (Damlouk B). Therefore, the examination focuses on the lower cycle where most samples were collected. The cycle is 11 m. thick, and includes both shallow marine and deep marine units. The lower deep marine unit (A1) is about 9 m. thick, and usually consist of chalky limestone and phosphatic limestone (occasionally phosphorite), which is infrequently silicified (Figure 4- A, B, and D). The phosphatic limestone becomes marly limestone towards the bottom of the sequence, forming the overall deep marine part of the cycle (Figures 4- A- C).

The shallow marine unit (A2) consists of a 2 m thick horizon of Nummulitic–shelly limestone of the carbonate bank. This limestone is often hard, protrudes out and is rich in varieties of *Nummulites*.

**Material and Methods**

Eight samples (with 1 – 1.5 m spacing ) were collected from the lower sequence (Damlouk A) of the Damlouk Member in the studied section, which reaches 32 meters in thickness. Sampling cover both units of the sequence: unit (A1), which represents the shallow marine Nummulitic bioclastic limestone facies, and the deep marine chalky, phosphatic, and marly limestone unit (A2) (Figure 3). Thin section for each sample was prepared and stained to differentiate between variable carbonate minerals following [8]. Identification of taxa followed by quantitative analyses of fossils based on percentage and distribution of different species of larger foraminifera. Representative taxa and other recognized microfossils are studied using polarizing microscope photograph images. The identification of the recognized LBF and the biostratigraphic analysis of benthic foraminifera is assisted by using [9 and 10].



**Figure 3:** (A) Stratigraphic column of Ratga Formation, showing general lithologies of its Members. (Compiled from [1, 3, 5, .). (B) Stratigraphic column of the studied section, showing lithologies and sample locations. (V. scale is 1cm = 2m.).

### Microfacies

A detailed microfacies analysis and facies interpretation of the Damlouk Member from the Western Desert of Iraq is well presented by [1]. This presentation is good enough and needs to be reviewed here to shed some additional details on facies type. Each complete sedimentary cycle of the Damlouk Member includes the following basic microfacies:

**a) Nummulitic Grainstone – Packstone microfacie:** It is characterized by the dense occurrence of generally robust Nummulites of different genera amongst *Nummulites fabiani*, *Nummulites striatus*, *Nummulites bahyanesis*, *Nummulites Sabatacicus* and *Nummulites* sp., in addition to the occurrence of *N. gizehensis gizehenses*, *N. discorbinus*, *N.beaumont*. Other LBF includes *Alveolina*, *Lokhartia*, and *Elphidium*. These large benthic foraminifera are often embedded in a partly recrystallized micritic matrix. According to [11], this microfacies is commonly associated with the Nummulitic limestone bank (Figure 4).

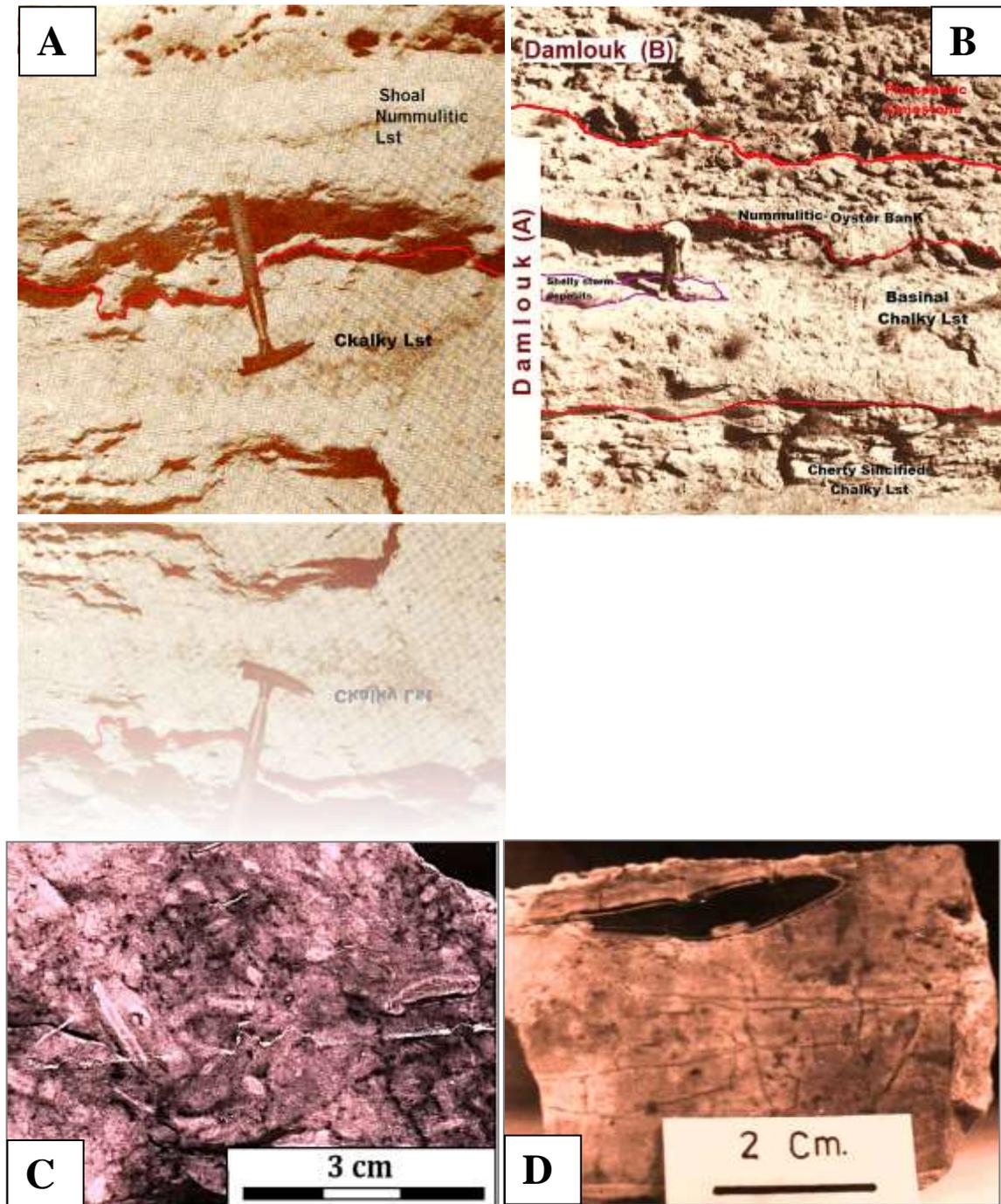
**b) Nummulitic Shelly Bioclastoic Packstone microfacies:** Mixed bank *Nummulites*, pelecypods shells and their fragments are the common components of this microfacies (Figure 4B). Other bioclastic elements include red algae and gastropods. All are embedded in a bioclastic micritic matrix. This microfacies is commonly associated with both the carbonate bank's shelly - Nummulitic limestone horizons [1].

**c) Shelly Packstone to Wackestone microfacies:** This microfacies is characterized by whole shells of pelecypods and gastropods often embedded in a lime mud matrix. Shells sometimes are fragmented, forming bioclastic shelly microfacies. Pelecypods are commonly dominated by the dense occurrence of large *Oysters* or dwarf *Nuculana* shells. These microfacies characterize the shelly or Oyster beds, which are an occasional part of the carbonate bank horizon [12]. These three microfacies are the most common at the carbonate bank and make the back-bank lagoon the basic parts of the inner ramp facies (Figure 5).

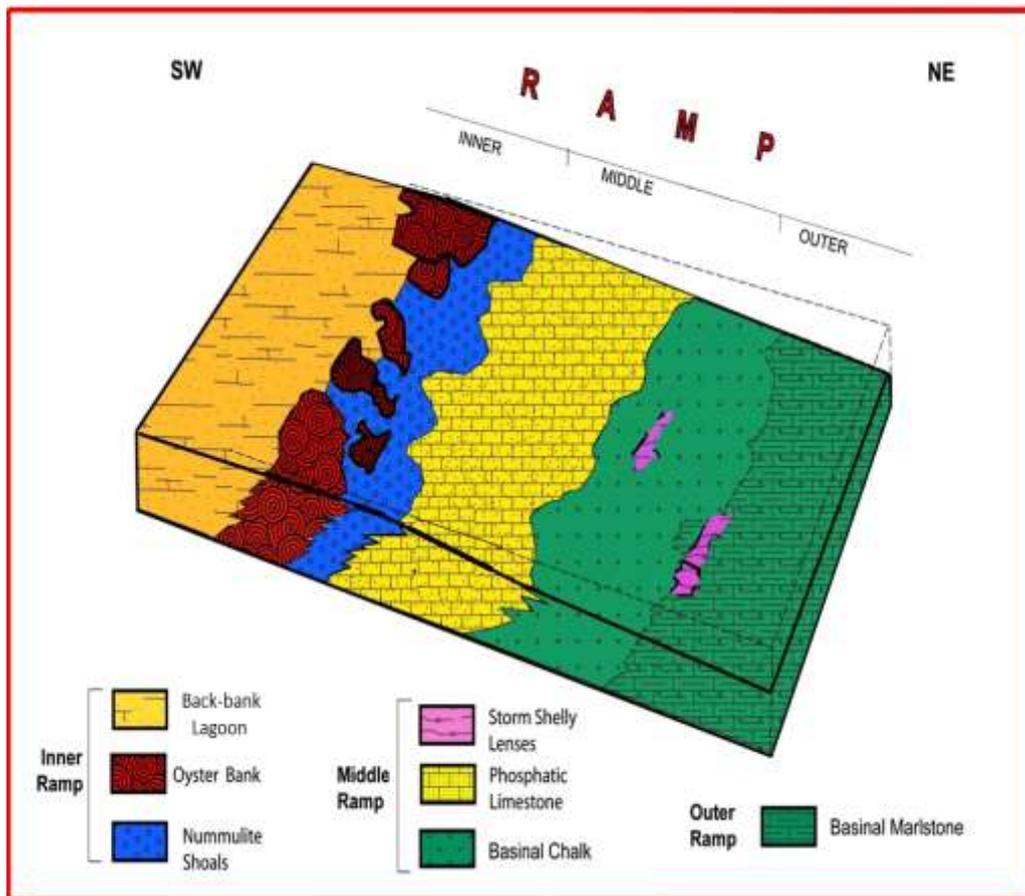
**d) Phosphatic Packstone to Wackestone microfacies:** This microfacies is associated with samples that have phosphatic grains of different kinds and origin. The common type of phosphatic grains is oolites, in addition to peloides, bone fragments, and phosphatic intraclasts. Matrix either lime mud or phosphatic mud, occasionally replaced by calcite cement. It is occasionally associated with bioclasts of different molluscs, indicating active agitation. This microfacies is associated with the phosphatic limestone horizons of the middle ramp [1] (Figure5).

**e) Crystalline Chalky Limestone facies:** It represents the white, porous, crystalline chalky limestone. Coarse calcite crystals and fenestral porosity are the common features. This facies is seemingly influenced by a strong diagenetic effect reflected on the variability of calcite crystal size, different colorations (commonly red), and the association with silicification. This facies is recognized within basinal chalky limestone of the middle ramp facies (Figure 5).

**f) Foraminiferal Lime Wackestone microfacies:** Planktic foraminifera, including species of *Globigerina*, and *Globorotalia* in a bioclastic argillaceous lime mud [6], are the characteristic elements of this microfacies. Other components include silt-size bioclasts and small benthic foraminifera such as *Bolivina*, *Bulimina*, and *Nodosaria*. This microfacies represents the basinal marly limestone horizons of the outer ramp facies [1] (Figure 5).



**Figure 4:** Field photo of the studied section. A) Nummulitic shoal limestone overlaying the basinal chalky limestone. B) Complete succession of Damlouk (A), showing the different lithologies. (C) Hand specimen showing dense *Nummulites* and *Assilina* LBF of the middle ramp facies of Damlouk (A). D) Hand specimen of silicified chalky limestone with brown chert nodule.



**Figure 5:** Facies model for the cyclic deposits of the Eocene, Damlouk Member, Western Desert, Iraq. (From [1] ).

### Biostratigraphy

Ranges and relative abundances of the identified LBF from the studied section is shown in (Figure 6). The larger benthic foraminiferal assemblages has low diversity. A total of twenty-nine species of LBF belonging to thirteen genera have been identified in addition to bioclasts of Mollusca, corals, red algae, and bryozoan (Figures 7 - 9). Based on the identified LBF, the studied section is subdivided into two biozones, from the lower part to the upper part of the section:

#### **a-*Nummulites gizhensis* -*Nummulites moculatus* Assemblage Zone**

**Definition:** Biostratigraphic interval of this zone is characterized by the association of taxa (*Nummulites gizhensis* -*Nummulites moculatus*).

**Zone boundary:** This zone is represented by the First Appearance Datum (FAD), and dominance of the large benthic foraminifera is represented by (*Nummulites gizhensis* – *Nummulites moculatus*).

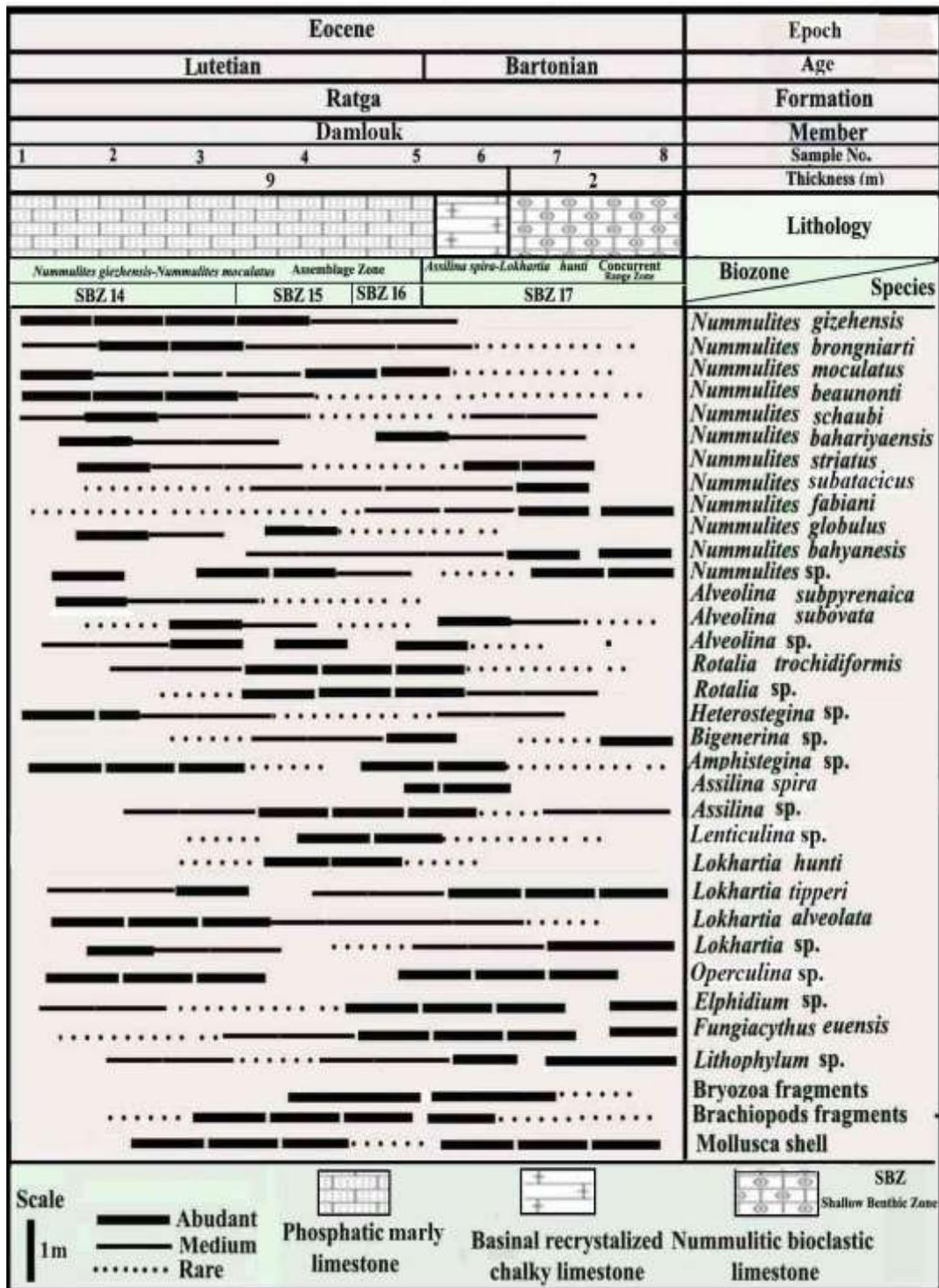
**Thickness:** 8 meters (representing the middle – outer ramp facies association of basinal marly chalky and phosphatic limestone).

**Association:** It is characterized by the appearance and dominance of *Nummulites brongniarti* d'Archiac & Haime, 1853, *Nummulites beaumonti* d'Archiac & Haime, 1853, *Nummulites schaubi* Kacharava, 1969, *Nummulites brongniarti* d'Archiac & Haime, 1853, *Nummulites bahariyaensis* Boukhary, 2014, *Nummulites striatus* (Bruguiere, 1972), *Nummulites fabiani*

(Prever, 1905), *Nummulites subatacicus* Douvillé, 1919, *Nummulites globulus* Leymerie, 1846. *Amphistegina* sp., *Assilina spira* ( De Roissy,1805), *Assilina* sp., *Alvelina subovata* d'Orbigny (1826), *Alveolina subpyrenaica* Leymerie, 1846. *Alveolina* sp., *Lenticulina* sp., *Rotalia trochidiformis* Lamarck, 1804, *Rotalia* sp., *Bignerina* sp., *Heterostegina* sp., *Lockhartia hunti* Ovey, 1947, *Lockhartia tipper* (Davies, 1926), *Lokhartia alveolata* Silvestri,1942, *Lockartia* sp. *Operculina* sp., *Elphidium* sp., In addition to these species fragments of Brachiopods, Bryozoans and Mollusca are also recognized. Other microfossils show relatively less abundance in this part of the section such as bioclasts of algae, *Lithophylum* sp., coral, *Fungiacyathus euensis*, Wells, 1976 and Mollusca.

**Correlation:** This zone is equivalent to NP15c and NP16 of [13], to P11 and P12 of [14], to the SBZ14 and SBZ15 –SBZ16 according to [10], and to SBZ14-SBZ16 and SBZ16 of [15] (Figure 10).

**Age:** This biozone corresponds to the Middle-Late Lutetian age



**Figure 6:** Distribution and relative abundance of the larger benthic foraminifera and other microfossils in the studied section.

**b-Assilina spira- Lokhartia hunti Concurrent Range Zone**

**Definition:** Biostratigraphic interval of this zone is characterized by the association of taxa *Assilina spira* and *Lokhartia hunti*.

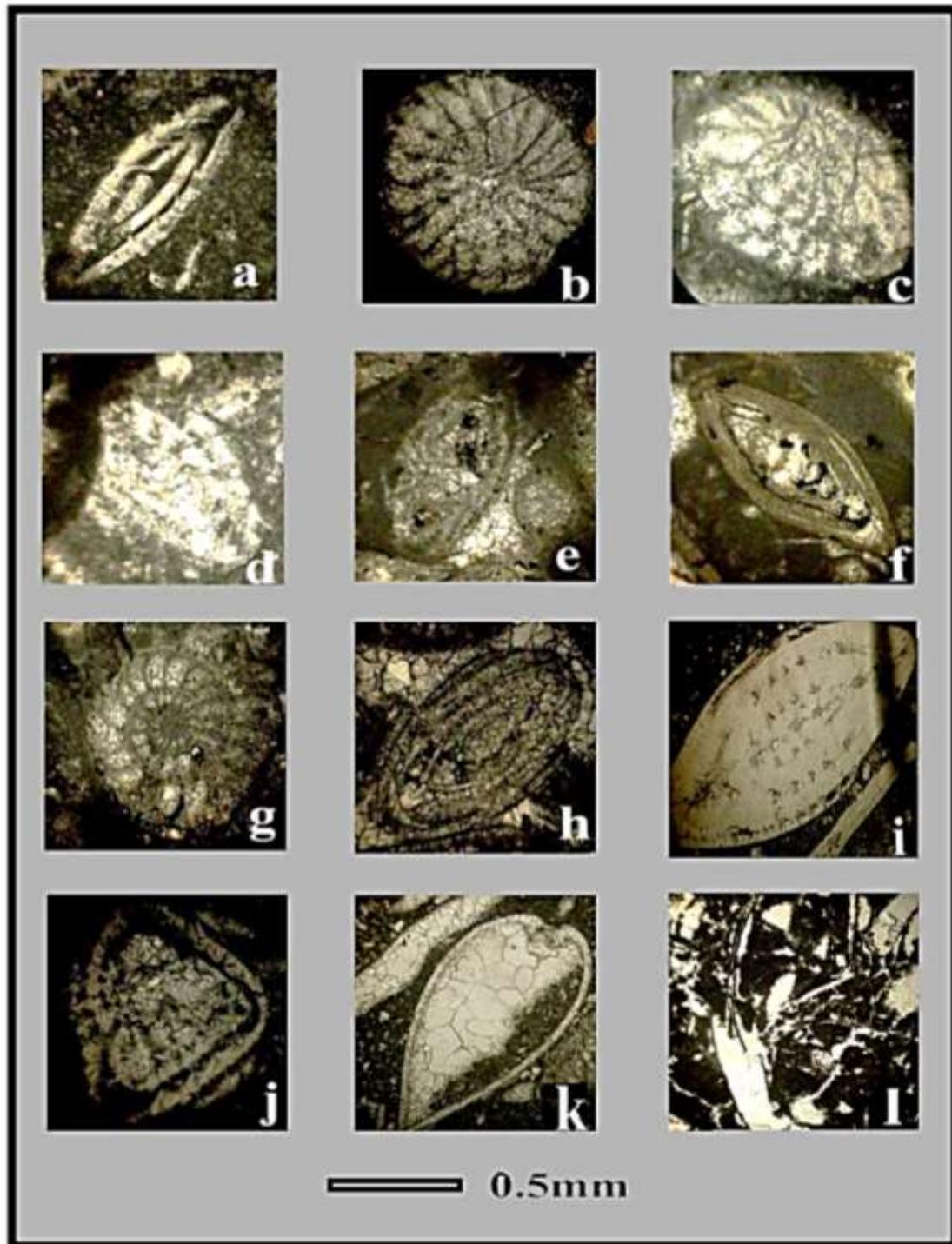
**Zone boundary:** This zone is represented by the First Appearance Datum (FAD) association of taxa at lower boundary and Last Appearance Datum (LAD) at the the upper boundary of *Lokhartia hunti*.

**Thickness:** 3 meters ( representing the upper shallow marine nummulitic – shelly limestone of the inner ramp facies).

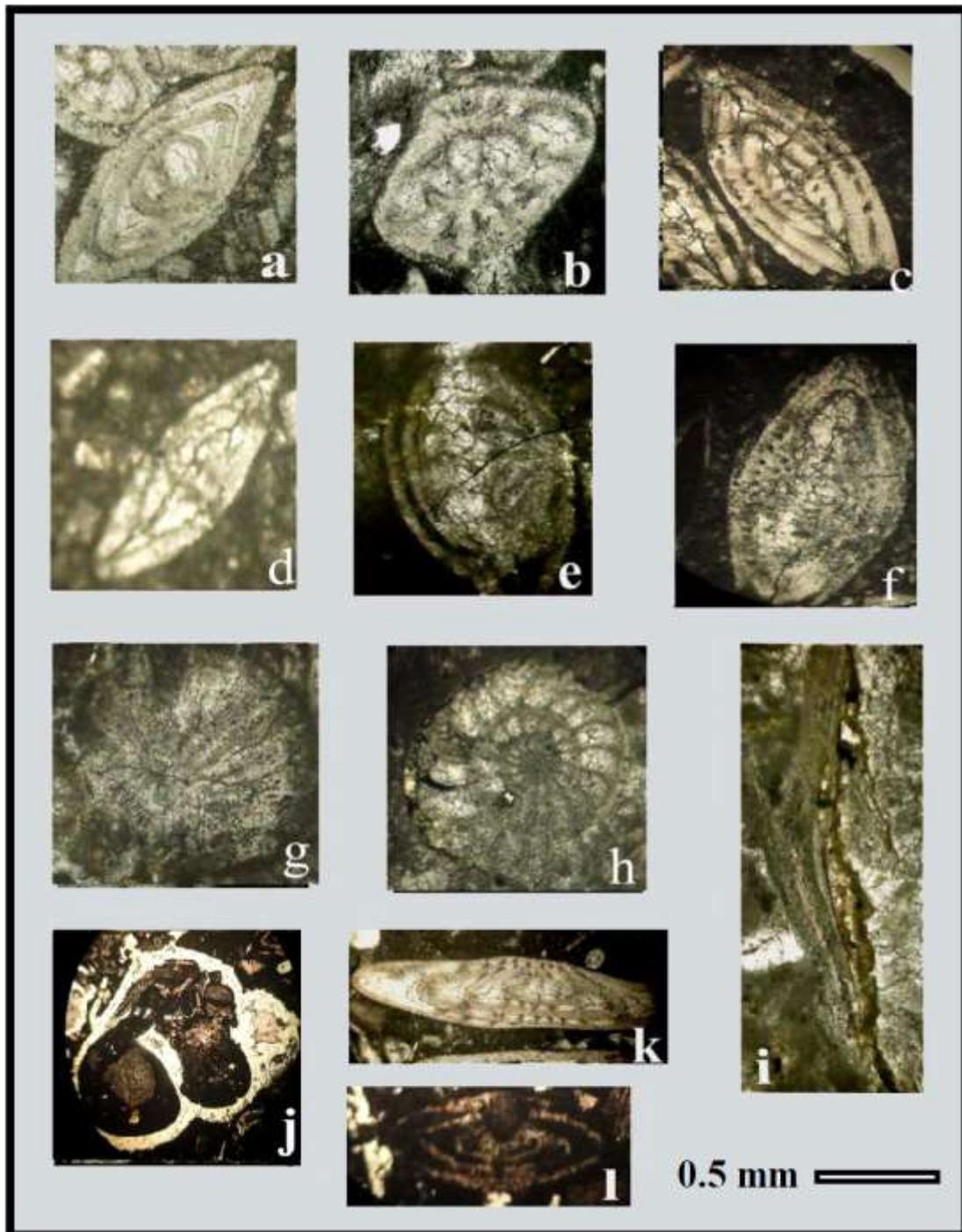
**Association:** It is characterized by the appearance and dominance of *Nummulites brongniarti* d'Archiac & Haime, 1853, *Nummulites beaumonti* d'Archiac & Haime, 1853, *Nummulites schaubi* Kacharava, 1969, *Nummulites brongniarti* d'Archiac & Haime, 1853, *Nummulites bahariyaensis* Boukhary, 2014, *Nummulites fabiani* (Prever, 1905), *Nummulites striatus* (Bruguiere, 1972), *Nummulites subatacicus* Douvillé, 1919, *Nummulites globulus* Leymerie, 1846. *Amphistegina* sp., *Assilina spira* (De Roissy, 1805), *Assilina* sp. *Alvelina subovata* d'Orbigny (1826), *Alveolina subpyrenaica* Leymerie, 1846. *Alveolina* sp., *Lenticulina* sp., *Rotalia trochidiformis* Lamarck, 1804 , *Rotalia* sp., *Bignerina* sp., *Heterostegina* sp., *Lokhartia hunti* Ovey, 1947, *Lokhartia tipper* (Davies, 1926), *Lokhartia alveolata* Silvestri, 1942, *Lokhartia* sp. *Operculina* sp., *Elphidium* sp., In addition to these species fragments of Brachiopods, Bryozoans and Mollusca are also recognized. Other microfossils show relatively less abundance in this part of the section such as bioclasts of algae, *Lithophylum* sp., coral, *Fungiacyathus euensis*, Wells, 1976 and Mollusca.

**Correlation:** This zone is equivalent to NP17 [13], to P13 of [14], to the Lower part of SBZ17, according to [10], and to part of SBZ17-SBZ18 of [15] (Figure 10).

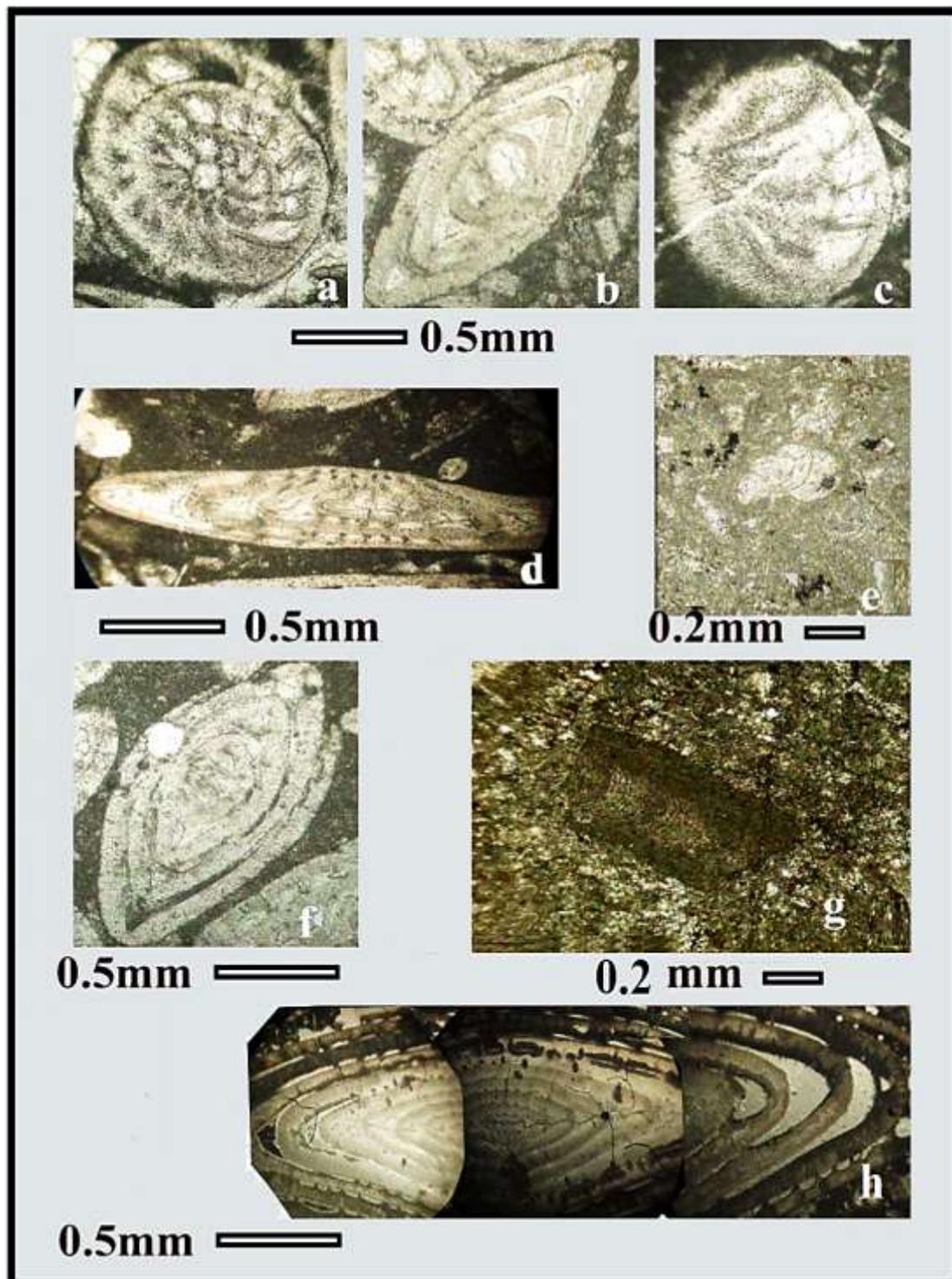
**Age:** This biozone corresponds to Early Bartonian in age.



**Figure 7:** a- *Amphistegina* sp. sample No. 2; b - coral, sample No. 3; c- *Rotalia trochidiformis* (Lamarck, 1804), sample No. 5; d- *Nummulites globulus* Leymerie, 1846, sample No.2; e- *Alveolina subpyrenaica* Leymerie, 1846, sample No. 5; f- *Nummulites striatus* (Bruguiere, 1972), sample No.7; g- *Operculina* sp. ,sample No.7; h- *Alveolina subovata* d'Orbigny (1826), sample No. 3; i- *Assilina* sp., sample No 5; j- *Lockhartia huntii* Ovey, 1947, sample No.4; K. Pelecypods shell, sample No.7; l- Most of the long spines present on brachiopods , sample No.5.



**Figure 8:** a- *Nummulites moculatus* Nuttal, 1926, sample No. 2; b- *Rotalia trochidiformis* (Lamarck, 1804), sample No.3; c- *Nummulites striatus* (Bruguiere, 1972), sample No. 8; d - *Nummulites fabiani* (Prever, 1905), sample No. 6; e- *Nummulites subatacicus* Douvillé, 1919, sample No.7; f- *Nummulites* sp., sample No.6; g- *Fungiacyathus euensis*, Wells, 1976 , sample 8; h- *Nummulites bahyanesis* Checchia-Rispol 1911, sample No.3; i- Brachiopods, sample No. 6; j- Pelecypods shell, sample No.6; k- *Nummulites brongiarti* d'Archiac & Haime, 1853, sample No.1; l- *Nummulites* sp., sample No.7.



**Figure 9:** a- *Operculina* sp., sample No. 2; b- *Nummulites beaumonti* d'Archiac & Haime, 1853, sample No.2; c- *Lockhartia alveolata* Silvestri,1942, sample No. 3; d- *Nummulites brongniarti* d'Archiac & Haime, 1853, sample No. 3; e- *Bignerina* sp., sample No. 5; f- *Nummulites beaumonti* d'Archiac & Haime, 1853, sample No. 3; g- Algae *Lithophylum* sp., sample No.4, h- *Nummulites gizhensis* Förskal, (Forskål in Niebuhr, 1775) , sample No.2.

System	Series	Stage	Martini, 1971	Bergreen et al., 1995	Serra Kiel., 1998	Serra Kiel., et al. 2016	This Study
C e n o z o i c	Eocene	Early Bartonian	NP17	P13	SBZ17	SBZ17-SBZ18 Partim	<i>Assilina spira-</i> <i>Lokhartia hunti</i> Zone
			NP16	P12	SBZ16		
					SBZ15		
		NP15c	P11	SBZ14	<i>Nummulites gizehensis-</i> <i>Nummulites mocolatus</i> Zone		

**Figure 10:** Correlation chart showing the biostratigraphic zones of this study with the other studies.

### Paleoenvironmental Implications

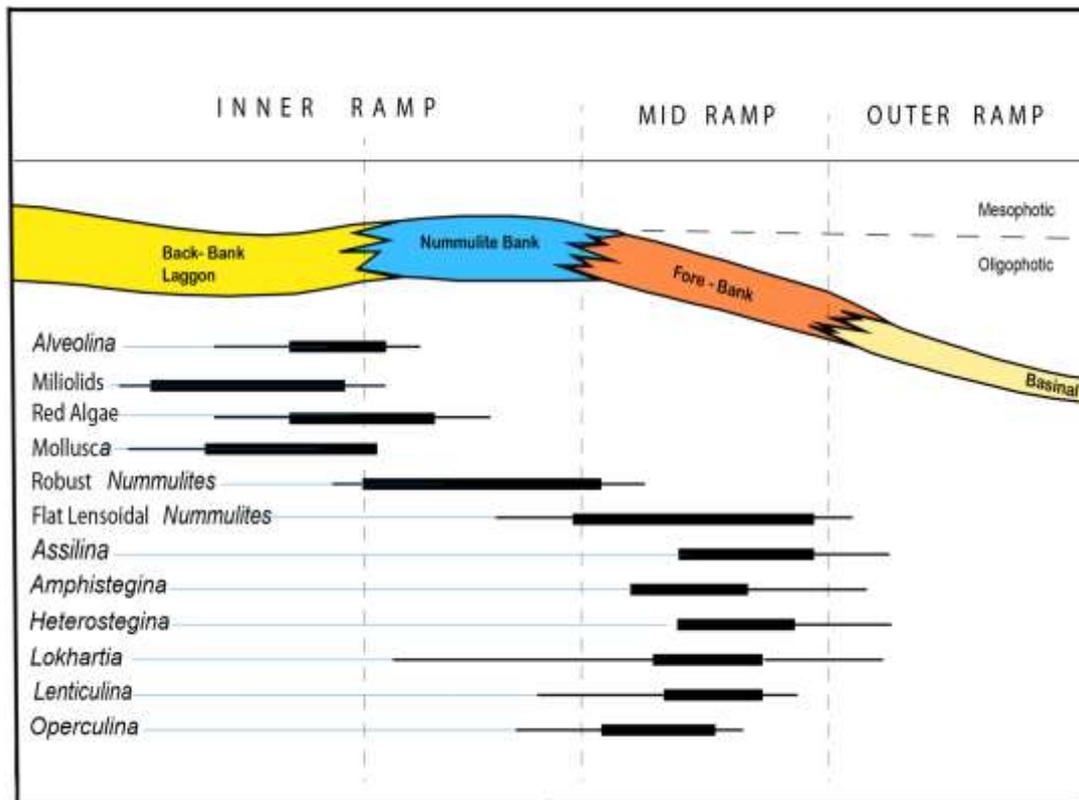
Extensive Cretaceous and Cenozoic shelf carbonate platforms were produced by Larger Benthic Foraminifera (LBF). This group of foraminifera with algal symbionts are restricted to shallow euphotic-mesophotic areas. Differences in light attenuation by the water column are reflected by different forms of wall structures [16]. Nummulitic banks are common in Early and Middle Eocene Tethyan shallow-marine carbonates, especially in oligotrophic settings [11].

The type, distribution, and relative abundance of the Larger Benthic Foraminifera assemblages of the lower cycle of the Eocene Damlouk Member show two important groups of benthic foraminifera associated with distinctive sedimentary facies and environmental conditions. The general environmental setting seems to be controlled by a *Nummulites* bank and the associated environments. These environments represent an Eocene gradually steepened carbonate ramp [1].

Based on that, the examined samples from the studied section were grouped into two facies, each including a different assemblage with different environmental settings. These assemblages and their environmental setting were correlated with other Paleogene Zagros carbonate ramps [17- 21]. Similarities were recognized and thus support the interpretation of paleoecological distribution.

The upper part (A2), where the two samples (8 and 7) are taken from, represents the nummulitic – shelley bank facies of the inner ramp [1]. The indicative LBF assemblage of this facies is generally includes Robust *Nummulites* such as (*Nummulites fabiani*, *Nummulites striatus*, *Nummulites bahyanesis*, *Nummulites sabatacicus* and *Nummulites* sp.). Other associated components include Mollusca shells, red algae fragments, occasional miliolids, and other imperforated benthic foraminifera. The latter components might be derived from the back-bank and associated environment, which is located next to the bank in a landward position but not well presented in the studied section (Figure 11). Bioclasts of corals, Bryozoa are infrequently noticed. These assemblages often occur in a very shallow and highly agitated carbonate bank within the mesophotic environment [21]. Miliolids occurs at depths of 0-100 m and *Nummulites* at depth up to 200m. The rough environmental conditions of this facies yields dense but low diversity assemblage, which thrives during high stand conditions of the marine transgression of the cycle [1].

The second assemblage is associated with the deep marine facies of the rest of the samples with proximal, middle ramp facies or fore-bank assemblages. The sediment of this facies is often thicker and characterized by the middle-outer ramp facies of light gray chalky and marly limestone. It occasionally becomes phosphatic limestone upward the cycle [1]. Diagnostic LBF elements of this assemblage include discoidal and flat *Nummulites* typified by the characteristic occurrence of the very large *Nummulitese gezihensis* foraminifera. In addition *Nummulites brongniari*, *Nummulites moculatus*, *Nummulites beaumonti*, *Nummulites schaubi*, and *Nummulites bahariyaensis* also occurred. Other abundant foraminifera of this assemblage includes species of: *Operculina*, *Assilina*, *Amphistegina*, *Heterostegina*, *Lokhartia*, and *Lenticulina* (Figure 11). Bioclasts of bryozoan, red algae, and Mollusca are infrequently recognized associated with the assemblage. Components of this facies reflect a relatively quiet environment with deeper conditions in the Oligophotic zone [21]. The large and flat characters of these LBF groups suggest a middle ramp setting of relatively deeper water and oligotrophic conditions often associated with fore-bank facies [22, 11, 23, 24]. [25] pointed out that the *Operculina* species occur in low energy and medium light within the lagoon-shelf region. The presence of *Nummulites* suggests shallower inner ramp/ shelf settings [26, 16]. The facies of this assemblage is developed within the middle ramp association during the early stage of transgression as part of the transgressive system tract [1]. The middle ramp environment is characterized by relatively deep water conditions occasionally interrupted by fair weather storms [27]. The storm effect contributes to the localized and dense accumulations of these flat, large, and discoidal benthic foraminifera (Figure 11).



**Figure 11:** Larger benthic foraminifera assemblages are showing distribution in association with sedimentary facies of the carbonate ramp, Damlouk Member, Ratga Formation, W. Desert, Iraq.

### Conclusions

This study has the following conclusions:

- 1-The lower cycle Damlouk (A) of the Damlouk Member, Ratga Formation in the study area is characterized by the diverse and abundant occurrence of larger benthic foraminifera and bioclasts of mollusc, coral, red algae, and Bryozoa.
2. Two biozones have been recognised based on the proposed stratigraphic ranges of the 29 identified larger benthic foraminifera species and calcareous algae of the studied section. These are: *Nummulites gizhensis* - *Nummulites mocolatus* Assemblage Zone, and the *Assilina spira*- *Lokhartia hunti* Concurrent Range Zone, which is extended in age from the Middle to Late Lutetian for the lower unit, and Early Bartonian for the upper unit.
3. Using more considerable foraminifera diversity, distribution, abundance, and association with the different sedimentary facies support the paleoecological interpretation of the inner-middle ramp setting. Robust *Nummulites* dominate the carbonate bank of the inner ramp assemblage. The lenticoidal and flat LBF of *Nummulites* and *Assilina*, *Heterostegina*, *Lokhartia*, *Operculina*, *Amphistegina* and *Lenticulina* dominate the fore-bank assemblages of the middle ramp.

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