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Nannobiostratigraphy and Ostracoda Paleoecology of Fat'ha Formation, Bashiqa Anticline, Northeastern Iraq

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Abstract

Nannofossils and Ostracoda assemblages are diagnosed from fifteen samples of limestone, marls and, clay from Fat'ha Formation at Ba'shiqa anticline, Northeastern Iraq. The objective of this study is to determine the geologic age and paleoecology of this formation which is detailed investigation is carried out, during which twenty-four species of calcareous nannofossils identified, twenty- one is descried from other regions while three are left under an open name because of lack of material or insufficient samples. Besides, seventeen species of Ostracoda fossils were picked and diagnosed, including two subspecies, belonging to ten genera, and four subgenera.

The recorded calcareous nannofossil assemblages include two biozones which are from the lower to the upper part of the section: (1) *Helicosphaera ampliaperta* Interval Biozone (CNM6); (2) *Discoaster signus* Interval Biozone (CNM7). These biozones are correlated with other calcareous nannofossils biozones from both local and regional sections that lead to conclude the age of the Middle Miocene (Burdigalian to Laghian).

The paleoenvironment of the Fat'ha Formation was determined through the use of the environmental evidence of the Ostracoda fossils, which indicated oscillating periods which vary from normal salinity to brackish and saline environments, with the shallow lagoonal environment and sometimes deep lagoonal environment that do not exceed the margin of shelf zone.

Keywords: Calcareous Nannofossils; Ostracoda; Nannobiostratigraphy; Paleoenvironment; Fat'ha Formation; Miocene.

الطباقية الحياتية لمتحجرات النانو و البيئة القديمة للاوستراكودا لتكوين فتحة, طية بعشيقة المحدبة, شمال شرقي العراق

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الخلاصة

تم تشخيص حشود متحجرات النانو الكلسية والاوستراكودا من خلال دراسة خمسة عشر نموذج صخري من حجر الجير و المارل و الطين تمت نمذجتها من تكوين فتحة, طية بعشيقة المحدبة, شمال غرب العراق. كان الهدف من هذه الدراسة هو تحديد العمر الجيولوجي و البيئة القديمة لهذا التكوين ضمن هذه المنطقة,

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حيث بعد المعالجة المختبرية للنماذج امكن تشخيص أربعة و عشرين نوع من متحجرات النانو الكلسية, كان من ضمنها احدى و عشرون نوع موصوفة سابقا من مناطق مختلفة و تركت ثلاث أنواع مفتوحة للتسمية بسبب النقص في عدد العينات المشخصة و عدم وضوحها و عدم كفاية النماذج الصخرية. إضافة لذلك تم التقاط و تشخيص سبعة عشر نوع يعود إلى متحجرات الاوستراكودا بضمنها اثنين تحت نوع تعود جميعها إلى عشرة أجناس بضمنها أربعة تحت جنس.

تم تحديد اثنين من الانطقة الطباقية الحياتية من خلال تجمعات متحجرات النانو الكلسية المسجلة, و هذه الانطقة من الأسفل إلى اعلى المقطع هي: (1) نطاق الفترة الحياتي *Helicosphaera ampliaperta* (CNM6) , (2) نطاق الفترة الحياتي *Discoaster* signus (CNM7). هذه الانطقة الحياتية تمت مقارنتها مع مع الانطقة الحياتية الاخرى لمتحجرات النانو الكلسية من مقاطع محلية و عالمية و التي ادت الى استنتاج ان عمر التكوين هو المايوسين الاوسط (بردوكاليان– لاكيان).

تحديد البيئة القديمة لتكوين الفتحة كان من خلال استخدام الأدلة البيئية التي تم الاستدلال عليها من متحجرات الاوستراكودا و التي دلت على وجود فترات من التذبذب التي تباينت من البيئة البحرية ذات الملوحة الاعتيادية إلى المختلطة إلى عالية الملوحة و حسب انفتاح أو انغلاق الحوض مع البحر ضمن بيئة بحيرات لاكونية ضحلة و أحيانا عميقة بشكل لا تتعدى نطاق الرف القاري.

Introduction

The Fat´ha Formation is first described in Faris Field, Southwestern of Iran, under Lower Fars Formation nomenclature by [1] as listed later by [2], The Formation is re- nomenclature to Gachsaran Formation by [3]. In Iraq, a large number of researchers have studied this formation from many geological aspects due to its economic importance [4, 5], a new type section defined to the Fat´ha Formation in Al-Fat´ha zone (the point of intersection of the Tigris River with a series Makhoul – Hamrin) 10 Km North of Baiji city, then the name of the Formation was changed to Fat´ha Formation [6]. The thickness of the formation in the type section is about 445 meters. The formation consists of homologous and repeated sedimentary cycles of greenish-gray and reddish-brown marl with limestone and evaporates [6]. It is related to the Latest Eocene-Recent Megasequence (AP11) within the Middle Miocene Sequence [7].

Structurally, the studied section is located in the Foot Hill zone (Figure 1). The Bashiqa anticline represents an asymmetrical anticline, about 25 km to the northeast of the city of Mosul, with two plungers, the length of its axis reaches about 15 km and its height is 650 m above sea level, its southwestern limb is more inclined than the northeastern limb, where it ranges between (60-50) degrees, while the dip of the other side ranges between (30-20) degrees respectively [8].

In the studied section, the lithology represents a succession of gypsum, limestone, marly limestone, green marl, and claystone with almost in red color and rich in Ostracoda fossils. It is unconformable with the underlying Pilaspi Formation, while it is conformable with the overlying Injana Formation[2].

Materials and Methods

Fifteen samples were obtained from the outcrop representing the Fat'ha Formation section from the location of Bashiqa village, Northeastern Iraq. Thin sections are prepared for the polarized microscope examination. The extraction of the calcareous nannofossils was done by following the approach of manner pursued by many researchers in this field such as in [9] as follow:

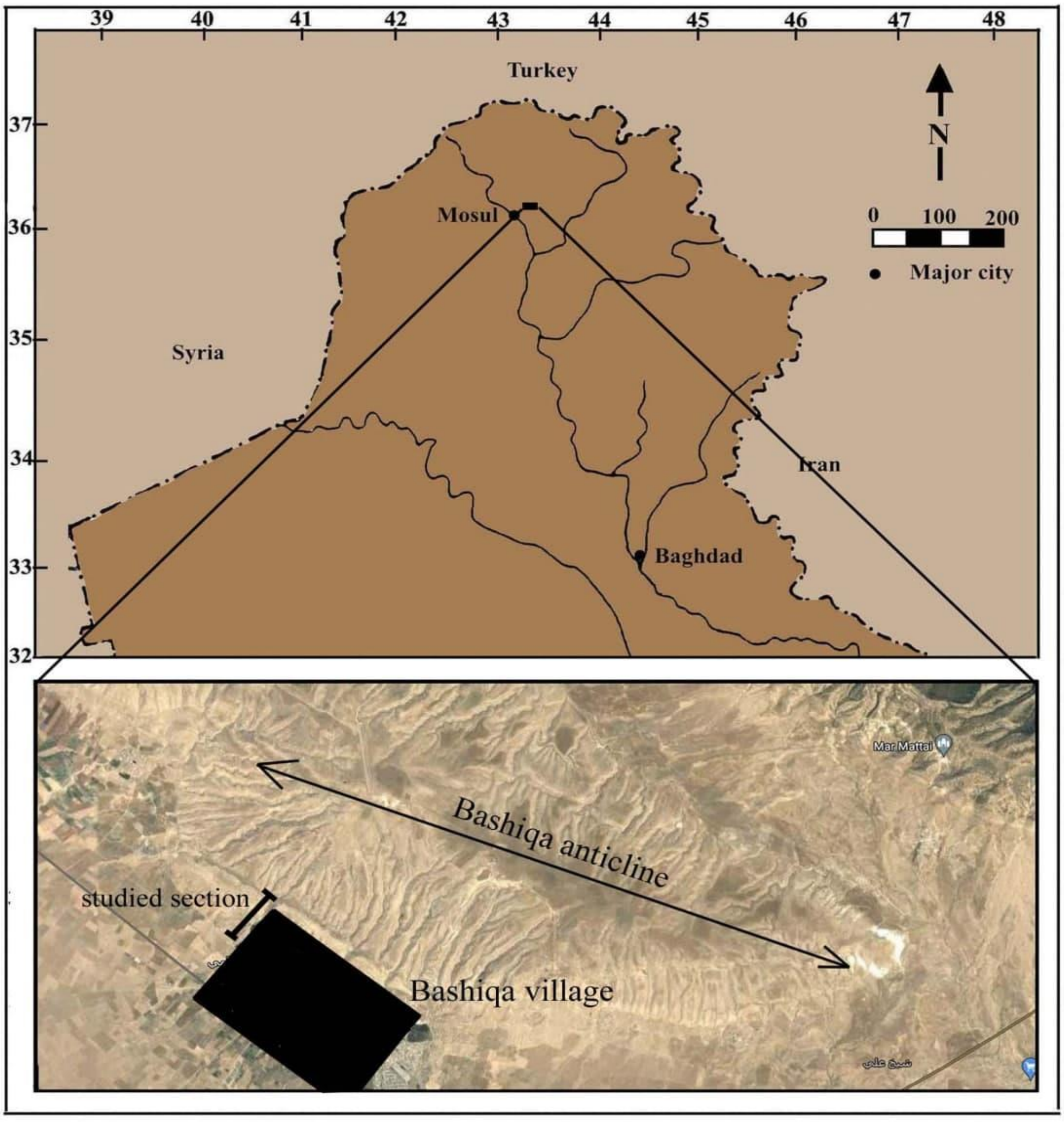
About 5 grams of each rock sample is crushed to pass through a sieve of 45 µm and then soaked in filtered water. A small size drop is added to implement as a dispersant.

A direct low heat source (hotplate) is used to lasting dry the slide and residue, taking into account during all stages of work, be careful and avoid contamination.

Amorphous oleoresin called (Canada balsam) has been placed over an uncontaminated thin coverslip. Then it is flipped over the previously placed dry drop of crushed sample solution and left to dry and stick well, so the sample is then ready for examination under the transmitted microscope.

As to prepare laboratory samples to pick the Ostracoda fossils, the rock samples were processed depending on the laboratory standard methods used internationally and each sample according to its rock composition, where the sedimentation removal depends on the type of the rocks from which the samples used for the study were taken. An example of this is the methods used by [10, 11].

The aim of the current study is systematic palaeontology of both species of calcareous nannofossils and Ostracoda with determining the stratigraphic range of both of them in the studied section . Inference on the biozones that represent the formation using calcareous nannofossils, besides discussing and estimating the paleoenvironment of the formation using Ostracoda fossils.



Figureure 1- Paleogeographic map of Iraq shows the location of the studied section. [7]

Results
Systematic paleontology
1. Calcareous Nannofossils
Family Coccolithaceae Poche
Genus *Coccolithus* Schwarz
Coccolithus miopelagicus Bukry [Pl.1, Figure. a]
Coccolithus pelagicus (Wallich) Schiller [Pl.1, Figure. b]
Coccolithus sp. [Pl.1, Figure. c]
Family Discoasteraceae Tan, 1927
Genus *Discoaster* Tan
Discoaster barbadiensis Tan Sin Hok [Pl.1, Figure. d]
Discoaster bifax Bukry [Pl.1, Figure. e]
Discoaster calculosus Bukry [Pl.1, Figure. f]
Discoaster deflandrei Bramlette and Riedel [Pl.1, Figure. g]
Discoaster cf. deflandrei Bramlette and Riedel [Pl.1, Figure. h]
Discoaster cubensis Furrazola and Iturralde [Pl.1, Figure. i]
Discoaster distinctus Martini [Pl.1, Figure. j]
Discoaster druggii Bramlette and Wilcoxon [Pl.1, Figure. k]
Discoaster exilis Martini and Bramlette [Pl.1, Figure. l]
Discoaster kuepperi Stradner [Pl.2, Figure. a]
Discoaster kugleri Martini and Bramlette [Pl.2, Figure. b]
Discoaster multiradiatus Bramlette & Riedel [Pl.2, Figure. c]
Discoaster nobilis Martini [Pl.2, Figure. d]
Discoaster sanmiguelensis Bukry [Pl.2, Figure. e]
Discoaster signus Bukry Pl.2, Figure. f]
Discoaster nodifer Bramlette & Riedel [Pl.2, Figure. g]
Discoaster cf. nodifer [Pl.2, Figure. h]
Family Helicosphaeraceae Black, 1971
Genus *Helicosphaera* Kamptner
Helicosphaera ampliaperta Bramlette & Wilcoxon [Pl.2, Figure. i]
Helicosphaera mediterranea Muller [Pl.2, Figure. j]
Helicosphaera intermedia Martini [Pl.2, Figure. k]
Helicosphaera sp. [Pl.2, Figure. l]

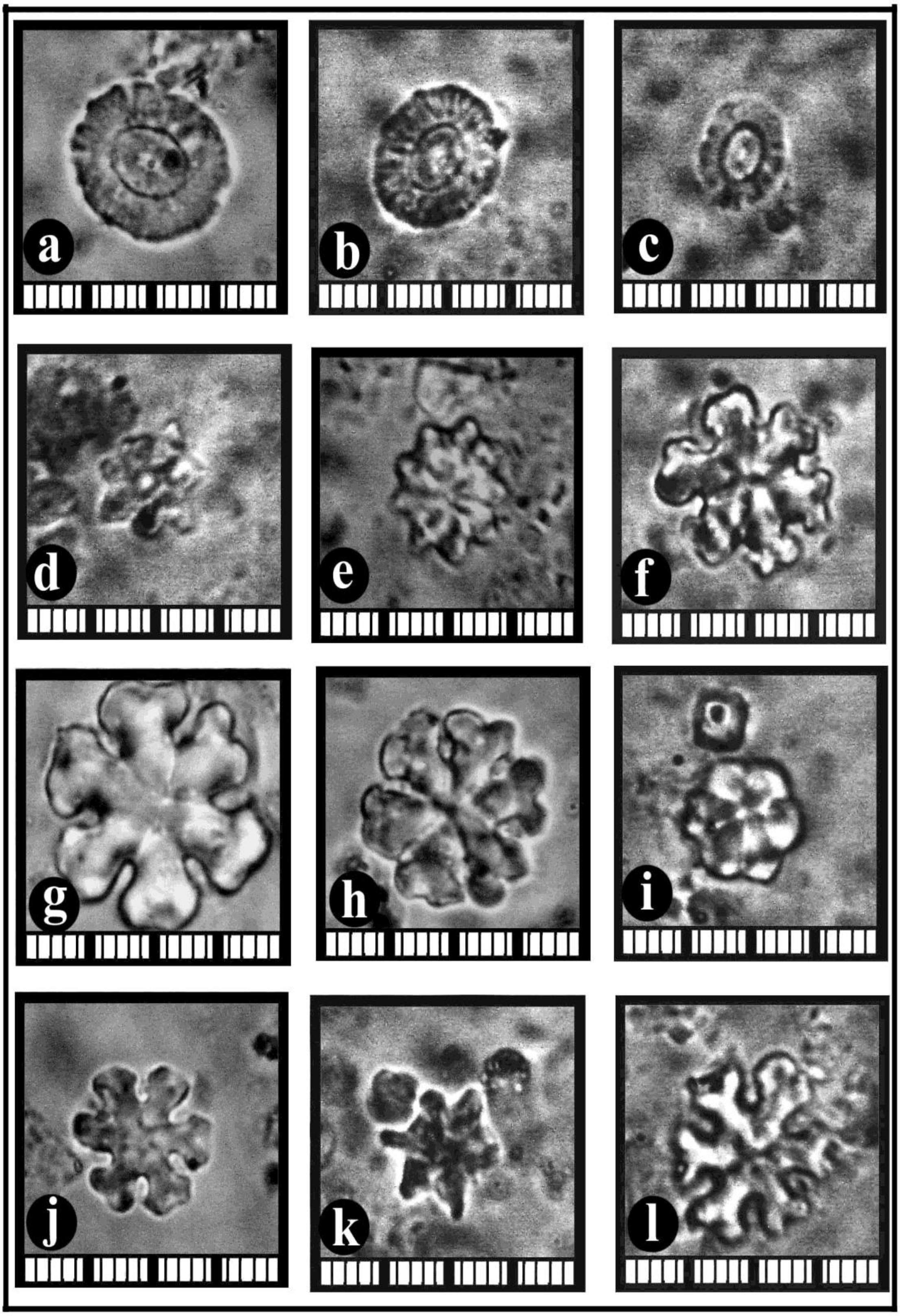


Plate 1- Light photos of significant calcareous nannofossil taxa from Fat'ha Formation (**a**) *Coccolithus miopelagicus* ; (**b**) *Coccolithus pelagicus* ; (**c**) *Coccolithus* sp.; (**d**) *Discoaster barbadiensis* ; (**e**) *Discoaster bifax* ; (**f**) *Discoaster calculosus* ; (**g**) *Discoaster deflandrei* ; (**h**) *Discoaster* cf. *deflandrei* ; (**i**) *Discoaster cubensis* ; (**j**) *Discoaster distinctus* ; (**k**) *Discoaster druggii* ; (**l)** *Discoaster exilis.*

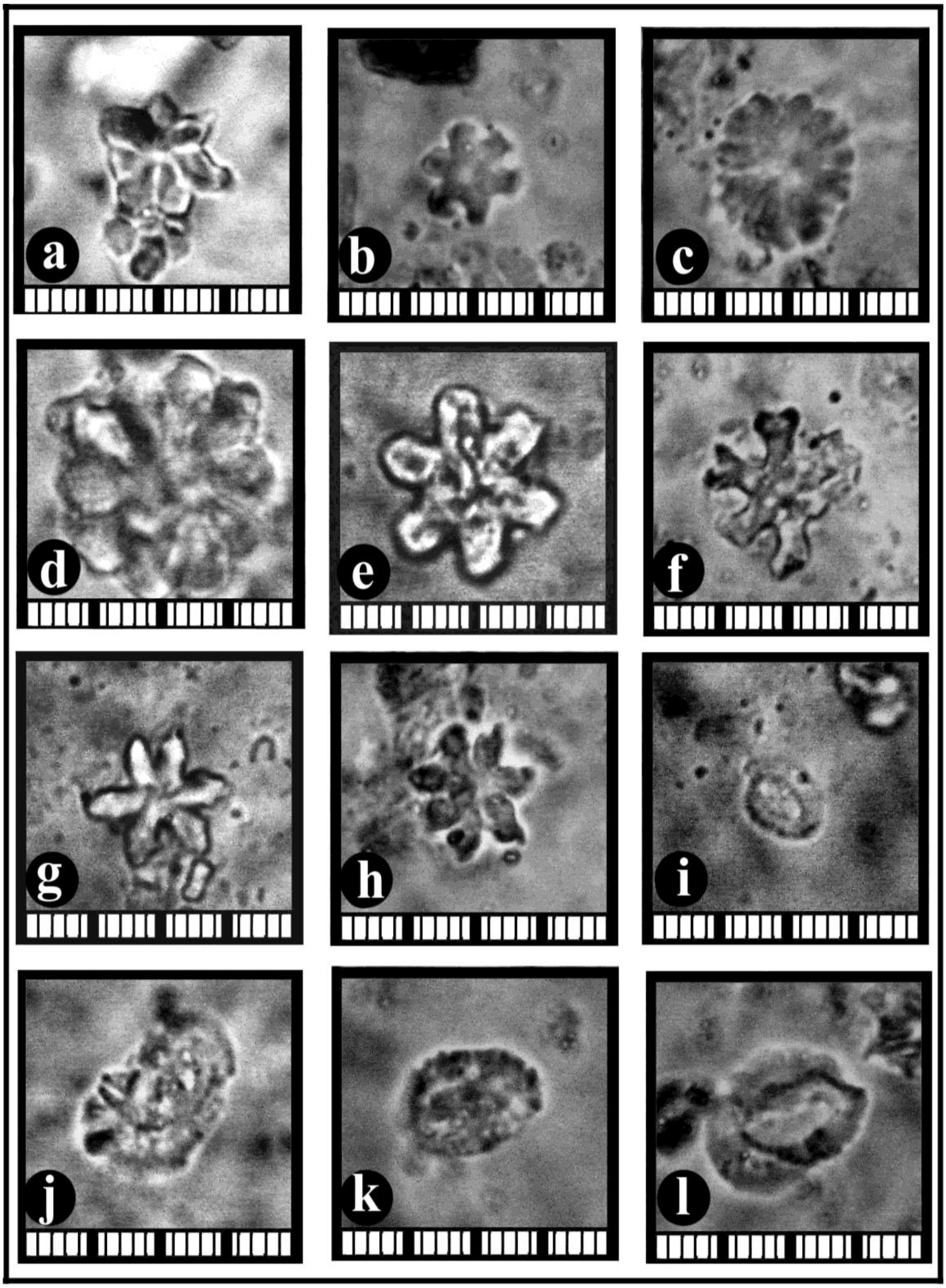


Plate 2- Light photos of significant calcareous nannofossil taxa from Fat'ha Formatio (**a**) *Discoaster kuepperi* ; (**b**) *Discoaster kugleri* ; (**c**) *Discoaster multiradiatus* ; (**d**) *Discoaster nobilis* ; (**e**) *Discoaster sanmiguelensis* ; (**f**) *Discoaster signus* ; (**g**) *Discoaster nodifer* ; (**h**) *Discoaster cf. nodifer*; (**i**) *Helicosphaera ampliapert a* ; (**j**) *Helicosphaera mediterranea* ; (**k**) *Helicosphaera intermedia* ; (**l**) *Helicosphaera* sp.

2. Ostracoda
Superphylum Arthropoda Von Siebold
Phylum Crustacea Pennant
Class Ostracoda Latreille
Order Podocopida Muller
Suborder Platycopina Sars
Superfamily Cytheracea Baird
Family Cytherellidae Sars
Genus *Cytherella* Sars
Cytherella bashiqensis Khalaf [Pl.3, Figure. a]
Cytherella dohukensis Khalaf [Pl.3, Figures. b, c]
Family Cytheruridae G. W. Muller
Genus *Paijenborchellina* Kuznetsova
Paijenborchellina libyca Szczechura [Pl.3, Figures. d, e]
Paijenborchella (*Eupaijenborchella*) *royi* Khosla [Pl.3, Figures .f, g]
Family Cytheridae Baird
Genus *Schneiderella* Stancheva
Schneiderella vulgaris Khalaf [Pl.3, Figures. h, i]
Family Leptocytheridae Hanai
Genus *Leptocythere* Sars
Leptocythere multipunctata multipunctata Sissingh [Pl.3, Figure. j]
Leptocythere (*Leptocythere*) *hajeransis* Khalaf [Pl.3, Figure. k]
Family Cytherideidae Sars
Genus *Miocyprideis* Kollmann
Miocyprideis recta Khalaf [Pl.3, Figure. l]
Miocyprideis chaudhuryi (Lyubimova and Guha) [Pl.4, Figures. a, b]
Genus *Hemicyprideis* Malz&Triebel
Hemicyprideis angulata decrementa Khalaf [Pl.4, Figures. c, d]
Family Trachyleberididae Sylvester& Bradley
Genus *Actinocythereis* Puri
Actinocythereis dextraspina Khalaf [Pl.4, Figure. e]
Actinocythereis libyansis El-Waer [Pl.4, Figure. f]
Actinocythereis iraqensis Khalaf [Pl.4, Figure. g]
Genus *Hermanites* Puri
Hermanites transversicostata Khalaf [Pl.4, Figure. h]
Hermanites compressa Khalaf [Pl.4, Figure. i]
Genus *Quadracythere* Hornibrook
Quadracythere (*Mosulia*) *pulchra* Khalaf [Pl.4, Figures. j, k]
Family Loxoconchidae Sars
Genus *Loxoconcha* Sars
Loxoconcha (*Palmoconcha*) *miocaenica* Khalaf [Pl.4, Figure. l]

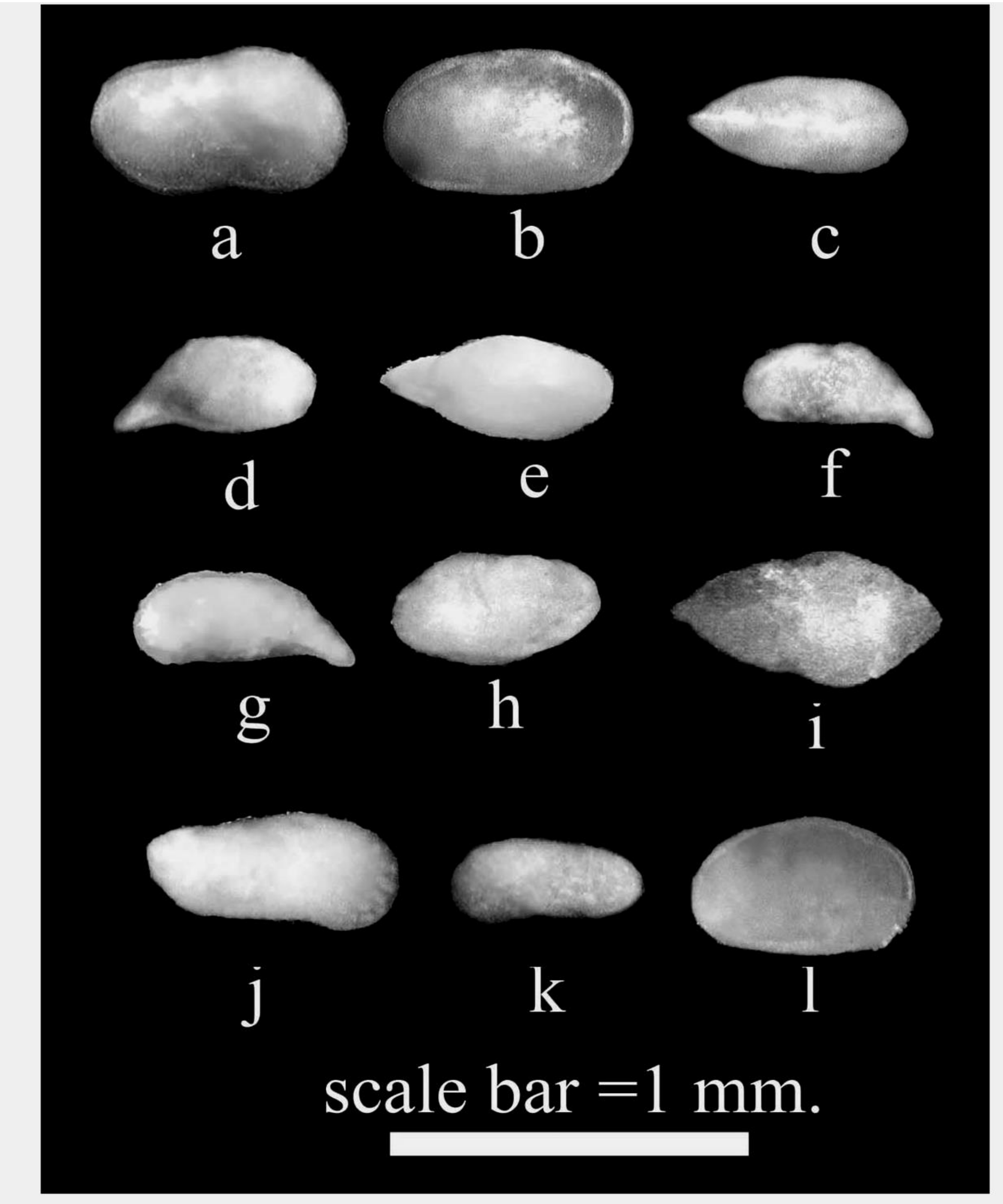


Plate 3- Normal light photos of significant Ostracoda taxa from Fat'ha Formation. (**a**) *Cytherella bashiqensis* Khalaf, LV; (**b**) *Cytherella dohukensis* Khalaf, LV; (**c**) *Cytherella dohukensis* Khalaf, Dorsal View; (**d**) *Paijenborchellina libyca* Szczechura, RV; (**e**) *Paijenborchellina libyca* Szczechura, Dorsal view;(**f**) *Paijenborchella* (*Eupaijenborchella*) *royi* Khosla, LV;(**g**) *Paijenborchella* (*Eupaijenborchella*) *royi* Khosla, RV internal lateral view; (**h**) *Schneiderella vulgaris* Khalaf , LV; (**i**) *Schneiderella vulgaris* Khalaf , Dorsal view; (**j**) *Leptocythere multipunctata multipunctata* Ssisingh, RV; (**k**) *Leptocythere* (*Leptocythere*) *hajeransis* Khalaf, LV; (**l**) *Miocyprideis recta* Khalaf, RV.

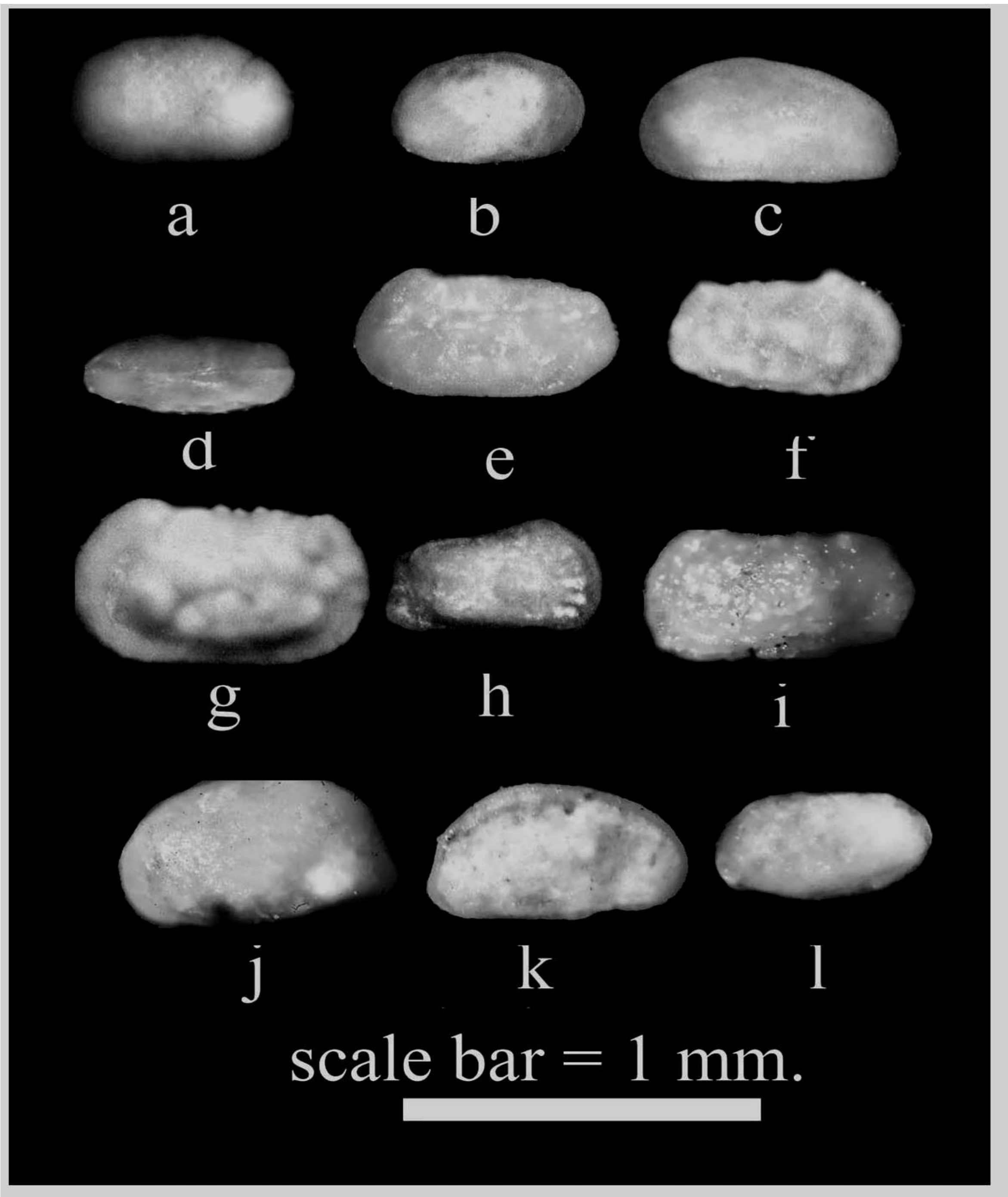


Plate 4- Normal light photos of significant Ostracoda taxa from Fat'ha Formation. **(a**) *Miocyprideis chaudhuryi* (Lyubimova and Guha), LV; **(b**) *Miocyprideis chaudhuryi* (Lyubimova and Guha), RV; (**c**) *Hemicyprideis angulata decrementa* Khalaf, LV; **(d**) *Hemicyprideis angulata decrementa* Khalaf, Dorsal view; **e-** *Actinocythereis dextraspina* Khalaf, LV; **(f**) *Actinocythereis libyansis* El-Waer, RV; (**g**) *Actinocythereis iraqensis* Khalaf, LV; (**h**) *Hermanites transversicostata* Khalaf, RV; (**i**) *Hermanites compressa* Khalaf, LV; (**j**) *Quadracythere* (*Mosulia*) *pulchra* Khalaf, LV; (**k**) *Quadracythere* (*Mosulia*) *pulchra* Khalaf, LV internal lateral view; (**l**) *Loxoconcha* (*Palmoconcha*) *miocaenica* Khalaf, LV.

Discussions

1. Nannobiostratigraphy

Depending on the biostratigraphic distribution of the recorded species, two interval Biozones are identified.(Figure. 2).

1 - *Helicosphaera ampliaperta* Interval Biozone (CNM6)

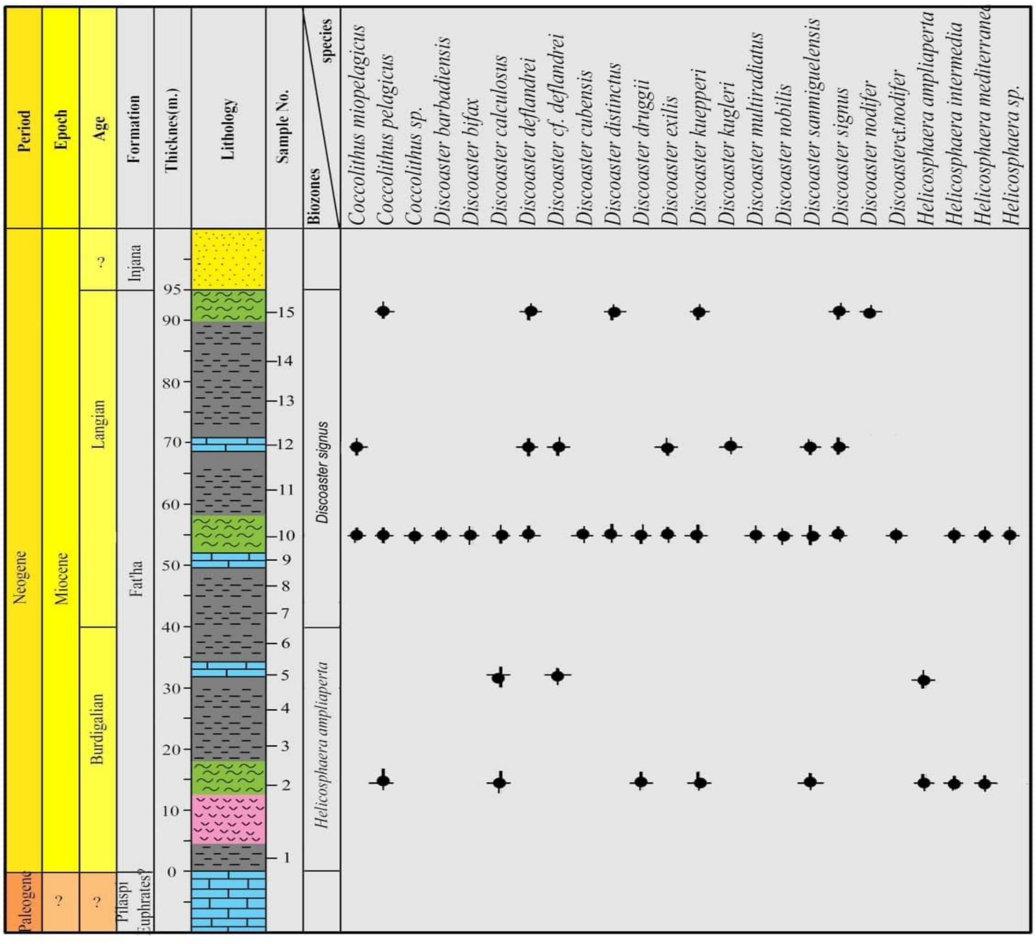
Definition and Boundaries: interval biozone amidst the first occurrence of the *Sphenolithus heteromorphus* and first occurrence of the *Discoaster signus*.

Correlation and Discussion: This biozone roughly agreed with the lower part of biozone NN4 in [12] and is nearly congruent to biozone CN3 in [13]. The latter used the acme of *D. deflandrei* to define the top of biozone CN3, while the apparition of *D.* is used here as a marker for the zonation boundary, therefore it concluded the age of this biozone is Early Middle Miocene(Burdigalian) based on[14].

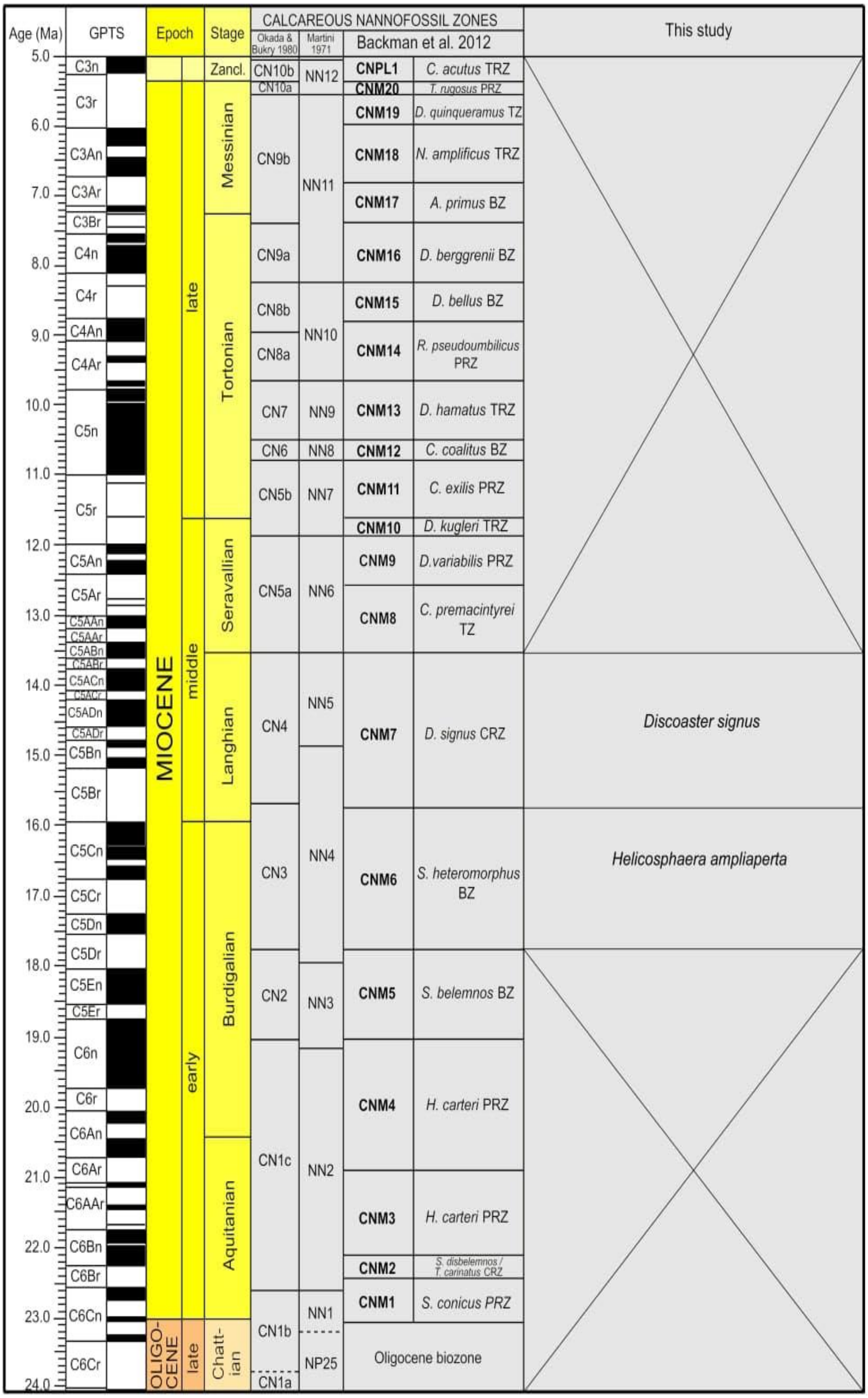
2 – *Discoaster signus* Interval Biozone (CNM7)

Definition and Boundaries: interval biozone amidst the first occurrence of the *D. signus* and the last occurrence of *S. heteromorphus*.

Correlation and Discussion: The top of this biozone corresponds to biozone NN5 in Martini (1971). Biozone CN4 in [13] used two biohorizons to appoint the base of CN4 (Sphenolithus heteromorphus biozone), which is the upper part of *D. deflandrei* and most upper part of *Helicosphaera ampliaperta*, which are approximately are secluded about 0.8 million years, the upper part of *H. ampliaperta* is not used here as a marker for the zonation boundary due to the discontinuous and dispersed distribution at the top of the range, therefore it concluded the age of this biozone is Early Middle Miocene(Langhian) based on [14] (Figure.3).



Figureure 2- Distribution chart for calcareous nannofossils of studied section.



Figureure 3- Correlation chart for calcareous nannofossils of the studied section

2. Paleoenvironment

Ostracoda is microorganisms that are characterized by their sensitivity to environmental conditions and their change [15]. Their species have adapted to live in different aquatic environmental conditions. It is known as one of the important and unique tools that are used to reconstruct the paleoenvironments by being affected by various environmental factors such as depth, temperature, salinity, and the nature of the substrate.

The present study of Ostracoda assemblages in the Bashiqa section included a systematic study that showed 17 species belonging to 7 families (Figure.4), through which it was performed over the paleoenvironmental conditions in which they live are inferred.

Through the distribution of the recorded species of Ostracoda in the present study (Figure. 5), which were compared in terms of age with those from previous studies, all the recorded species within this study showed a close age range and have been previously recorded mostly from the Middle Miocene beds. The age of the Fat'ha Formation was confirmed as the Middle Miocene and conforms with the equivalent strata of this formation or other equivalent formations in different localities in Iraq and adjacent areas (Table 1).

Ostracoda species have a certain internal and external morphology through which they can be deduced from their variables on the Paleoenvironment. Ostracoda has been studied depending on the morphological morphology and its differences from several researchers, such as [16]. Depth is one of the main environmental factors affecting the morphology of Ostracuda specimens, in addition to its association with other environmental factors such as temperature, salinity, oxygen, and food supply.

Often, the presence of Ostracoda genera is in the form of an assemblage, and each assemblage can be an indication of the nature and grade of the environmental and sedimentary conditions, and that the depth factor is evidence of distinct assemblages with formal specifications that reflect the effects of this environmental factor on the members of that assemblage. [17].

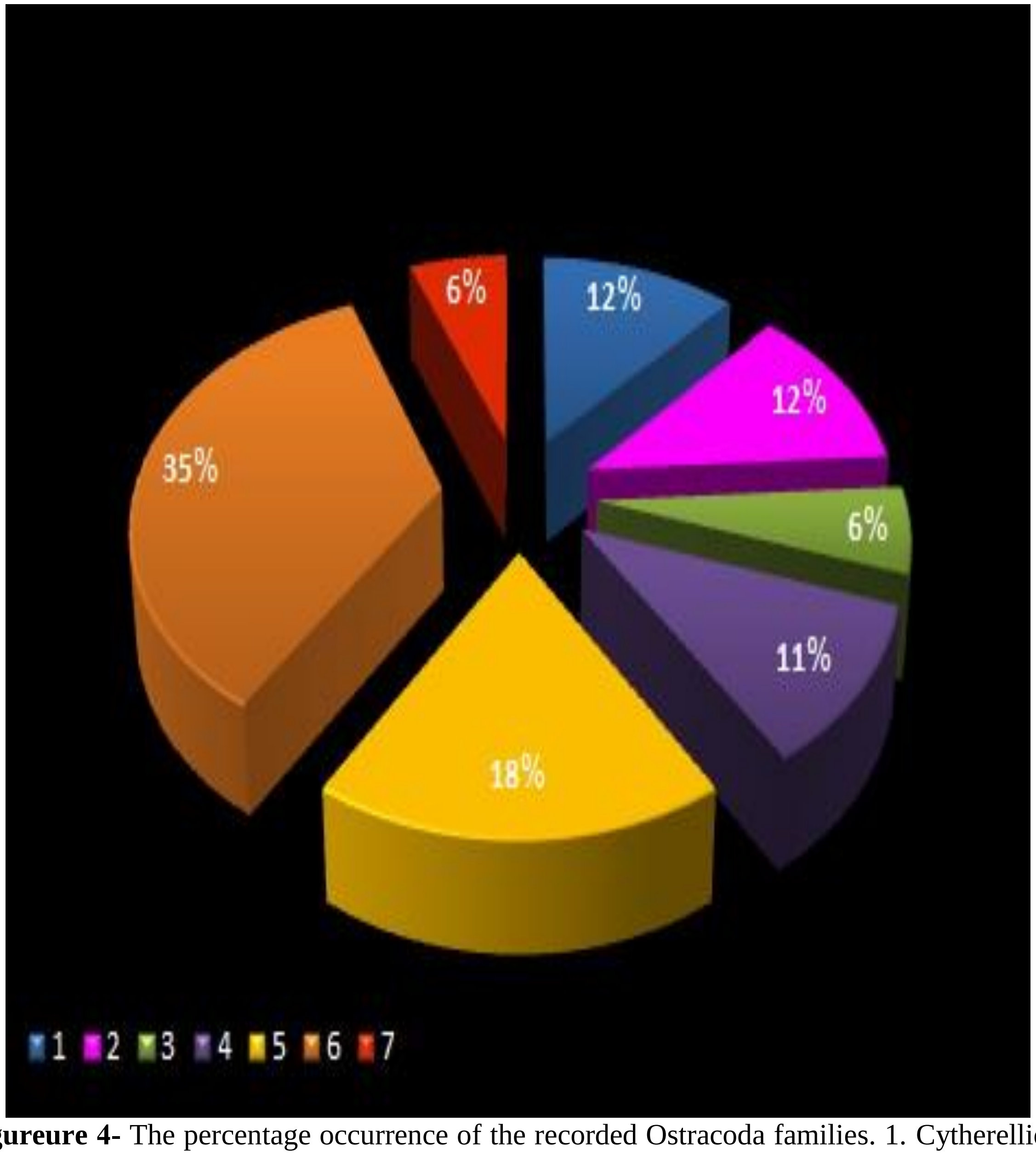
Most of the recorded Ostracoda species are characterized by well-calcified valves, heavy carapace with conspicuous sculpture, and clear eye tubercles such *as Actinocythereis*, *Hermanites*, *Loxoconcha*, *Leptocythere*, *Miocyprideis*, *Paijenborchelina*, and *Schneiderella* with an emphasis on the presence of some species with smooth or poorly ornamented valves species such as *Cytherella*.

The presence of the recorded genera *Hemicyprideis*, *Loxoconcha*, *Miocyprideis* in the current study, is prominent evidence of the fluctuation and change in salinity, whether it was a decrease or an increase, which is reflected in the clear difference in the intensity of the ornamentation and the increase in the size of the nodes. These genera which are characterized by the presence of gradual and fluctuating differences in the valves ornamentation, including the presence and development of nodes and pustulation indicate a fluctuating environment during sedimentation [18]. Besides, it has been pointed out, though many previous studies such as [19] which referred to the environments of the preceding genera in which they habitat within the shallow, coastal, marine, and semi-coastal environments, while [20], referred that the genus *Loxoconcha* indicates the lagoon environment.

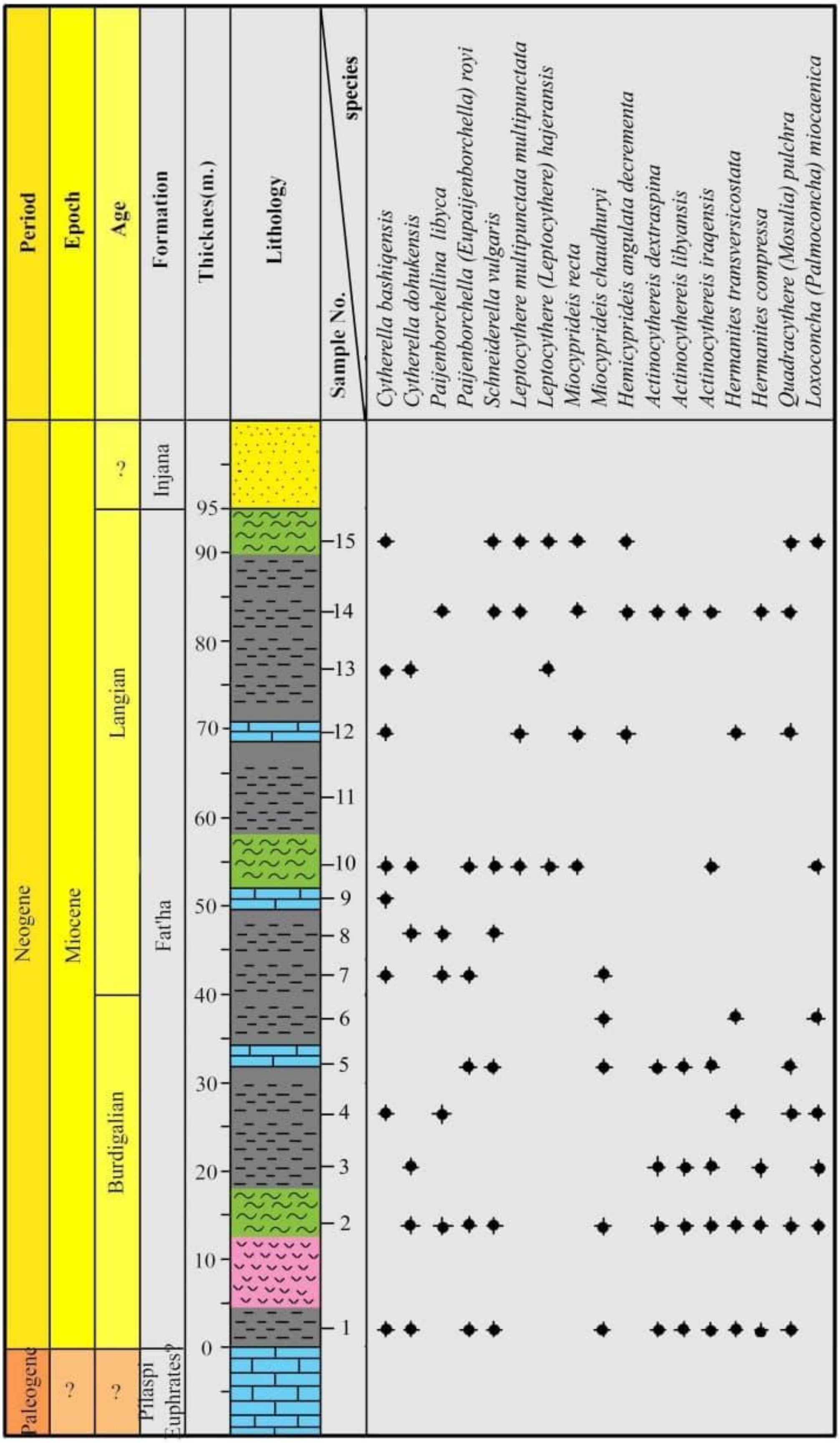
The paleoenvironment of the Bashiqa section was determined as a shallow basin and oscillating salinity environment based on most of the genera and species of Ostracoda that were diagnosed in the current study. Most of the genera recorded herein are characterized by well-calcified valves, strong sculptures, and conspicuous eye tubercle such as the genera: *Hemicyprideis*, *Hermanites*, *Quadracythere*, *Schneiderella*, *Actinocythereis*, and *Paijjenborchallina*.

Also, the deposition of gypsum beds successively between the other beds of limestone or marl and clay gives evidence of the extreme fluctuations in the salinity.

It can be concluded that the Fat'ha Formation deposited in the lagoon and shallow nearshore environments were sometimes changed into a relatively deep environment. The shallow, semi-closed environment (lagoon) that opens to the sea at times and closes at other times is affected by tectonic movements, which consequently leads to a difference in the depth and the type of sediments and makes the degree of salinity fluctuate from hypersaline to normal saline and brackish environments. This is reflected in the existence of the organisms within these environments, including the Ostracoda. As a result of these variables, the Gradual changes in the degree of ornamentation take place on the carapaces of Ostracoda species.



Figureure 4- The percentage occurrence of the recorded Ostracoda families. 1. Cytherellidae Sars, 1866; 2. Cytheruridae G. W. Muller, 1894; 3. Cytheridae Baird,1850; 4. Leptocytheridae Hanai, 1957; 5. Cytherideidae Sars,1925; 6. Trachyleberididae Sylvester & Bradley, 1947; 7. Loxoconchidae Sars,1926.



Figureure 5- Distribution chart for recorded Ostracoda fossils in studied section.

Table 1-The recorded preexisting of the current Ostracoda species in the study area at different localities and regions. (M=Middle, E=Early).

Taxa	Region	Age	Author/s
Cytherella bashiqensis	Iraq	M. Miocene	[21]
Cytherella dohukensis	Iraq	M. Miocene	[21]
Paijenborchellina libyca	Libya Libya Iraq	E. Miocene E. Miocene E. Miocene	[22] [23] [24]
Paijenborchella (Eupaijenborchella) royi	India Iraq	E. Miocene E. Miocene	[25] [26]
Schneiderella vulgaris	Iraq	M. Miocene	[27]
Leptocythere multipunctata multipunctata	Greece	E. Miocene	[28]
Leptocythere (leptocythere) hajeransis	Iraq	M. Miocene	[26]
Miocyprideis chaudhuryi	India Iraq	M. Miocene M. Miocene	[29] [26]
Miocyprideis recta	Iraq	M. Miocene	[26]
Hemicyprideis angulata decrementa	Iraq	M. Miocene	[26]
Actinocythereis dextraspina	Iraq	M. Miocene	[27]
Actinocythereis libyansis	Libya Iraq Iraq	M. Miocene M. Miocene M. Miocene	[30] [24] [31]
Actinocythereis iraqensis	Iraq Iraq Iraq Iraq Iraq	M. Miocene M. Miocene M. Miocene M. Miocene M. Miocene	[32] [33] [24] [34] [31]
Hermanites transversicostata	Iraq Iraq Iraq Iraq	M. Miocene M. Miocene E. Miocene M. Miocene	[32] [24] [34] [31]
Hermanites compressa	Iraq	M. Miocene	[26]
Quadracythere (Mosulia) pulchra	Iraq	M. Miocene	[26]
Loxoconcha (Palmoconcha) miocaenica	Iraq	M. Miocene	[26]

Conclusions

Twenty-four species of calcareous nannofossils identified twenty one are descried from other regions while three are left under an open name because of lack of material or insufficient samples besides seventeen species of Ostracoda fossils including two subspecies, belonging to five families of podocopida. The recorded calcareous nannofossils assemblages include two biozones which are from the lower to the upper part of the section:

1 - *Helicosphaera ampliaperta* Interval Biozone (CNM6)

2 – *Discoaster signus* Interval Biozone (CNM7)

These biozones are correlated with other calcareous nannofossils biozones from both local and regional sections that lead to conclude the age of the Middle Miocene (Burdigalian to Laghian).

Through the inference of the Ostracoda fossils, whose species are adaptable to contrast depths and different salinity concentrations and are affected by the nature of the bottom and the temperature that is reflected on by characteristic features on their carapaces ornamentation and external structures.

The paleoenvironment of the Fat'ha Formation appears to be deposited within a shallow basin with warm water and varying salinity concentration affected by variables geological events so that it opens sometimes to the sea and isolated at other times forming the lagoon.

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