APTIAN PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY AND MICROFACIES ANALYSES OF MUDURNU – NALLIHAN SEQUENCE (ANKARA, TURKEY)

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

DENIZ YAĞMUR KAYHAN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
GEOLOGICAL ENGINEERING

JULY 2019

Approval of the thesis:

APTIAN PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY AND MICROFACIES ANALYSES OF MUDURNU – NALLIHAN SEQUENCE (ANKARA, TURKEY)

submitted by **DENIZ YAĞMUR KAYHAN** in partial fulfillment of the requirements for the degree of **Master of Science in Geological Engineering Department, Middle East Technical University** by,

Prof. Dr. Halil Kalıpçılar
Dean, Graduate School of **Natural and Applied Sciences**

Prof. Dr. Erdin Bozkurt
Head of Department, **Geological Engineering**

Prof. Dr. Sevinç Özkan Altıner
Supervisor, **Geological Engineering, METU**

Examining Committee Members:

Prof. Dr. Muhittin Görmüş
Geological Engineering, Ankara University

Prof. Dr. Sevinç Özkan Altıner
Geological Engineering, METU

Assoc. Prof. Dr. Kaan Sayıt
Geological Engineering, METU

Assist. Prof. Dr. Fatma Toksoy Köksal
Geological Engineering, METU

Assist. Prof. Dr. Ayşe Özdemir
Geophysical Engineering, Van Yüzüncü Yıl University

Date: 17.07.2019

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Surname: Deniz Yağmur Kayhan

Signature:

ABSTRACT

APTIAN PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY AND MICROFACIES ANALYSES OF MUDURNU – NALLIHAN SEQUENCE (ANKARA, TURKEY)

Kayhan, Deniz Yağmur
Master of Science, Geological Engineering
Supervisor: Prof. Dr. Sevinç Özkan Altıner

July 2019, 201 pages

The Mudurnu – Nallıhan Sequence that comprises the Upper Jurassic – Lower Cretaceous carbonate succession was cut by diabase dykes and intercalated with volcano-sedimentary rocks in the Nallıhan region, Ankara, Turkey. The sequence consists of the Yosunlukbayırı Formation and the Soğukçam Limestone. This study focuses on the high-resolution biostratigraphy and microfacies analyses of the Soğukçam Limestone widely exposed in the north of the Nallıhan town. For this purpose, the stratigraphic section was measured (94.73 m thick) and a total of 44 samples were collected from limestone, shale and diabase dyke.

By using planktonic foraminiferal bioevents, the following biozones were established in ascending order: *Globigerinelloides blowi* Zone (Early Aptian), *Leupoldina cabri* Zone (Early Late Aptian) and *Globigerinelloides ferreolensis* Zone (Late Aptian). Eight species of *Hedbergella*, three species of *Globigerinelloides,* and *Leupoldina cabri* were identified in the study. Only the presence of these r-mode opportunistic planktonic foraminifera, *Hedbergella* and *Globigerinelloides,* in the studied samples indicates that eutrophic environmental conditions prevailed in the Aptian time in the studied region. The elongated chamber forms, such as *Hedbergella roblesae* and *Leupoldina cabri*, low-oxygen planktonic foraminifers suggests that the Oceanic

Anoxic Event 1a (the Selli Event) has possibly been recorded in the *Leupoldina cabri* Zone of the studied sequence. In addition, small benthic foraminifera, radiolaria and *Cadosina* sp. were recorded through the measured section.

Based on both lithofacies analysis (determination of the depositional texture), and biofacies analysis (fossil assemblages), microfacies types were defined as MF-1: Radiolarian mudstone / wackestone, MF-2: Planktonic foraminiferal and radiolarian wackestone / packestone and MF-3: Planktonic foraminiferal mudstone / wackestone. In the light of the microfacies analyses, the depositional environments of the Aptian part of the Soğukçam Limestone were determined as toe of slope to deep water basin.

Keywords: Planktonic foraminifera, Biostratigraphy, Aptian, Soğukçam Limestone, Nallıhan/Ankara

ÖZ

MUDURNU – NALLIHAN SEKANSI'NDA (ANKARA, TÜRKİYE) APSİYEN PLANKTONİK FORAMİNİFER BİYOSTRATİGRAFİSİ VE MİKROFASİYES ANALİZLERİ

Kayhan, Deniz Yağmur
Yüksek Lisans, Jeoloji Mühendisliği
Tez Danışmanı: Prof. Dr. Sevinç Özkan Altıner

Temmuz 2019, 201 sayfa

Mudurnu - Nallıhan Sekansı, diyabaz dayklar tarafından kesilen ve Türkiye'de Nallıhan bölgesindeki volkanik-sedimanter kayaçlar ile ardalanmalı olan Üst Jura – Alt Kretase karbonat sekansını içermektedir. Bu sekans, Yosunlukbayırı Formasyonu ve Soğukçam Kireçtaşı'ndan oluşmaktadır. Bu çalışma, Nallıhan civarında yaygın olarak yayılım gösteren Soğukçam Kireçtaşı'nın yüksek çözünürlüklü biyostratigrafisine ve mikrofasiyes analizlerine odaklanmaktadır. Bu amaçla, 94.73 m kalınlığında bir stratigrafik kesit ölçülmüş olup, kireçtaşı, şeyl ve diyabaz dayktan toplamda 44 adet örnek toplanmıştır.

Planktonik foraminiferler kullanılarak, çalışılan istif boyunca *Globigerinelloides blowi* (Erken Apsiyen), *Leupoldina cabri* (Erken Geç Apsiyen) ve *Globigerinelloides ferreolensis* (Geç Apsiyen) biyozonları tanımlanmıştır. Bu çalışmada, *Hedbergella*'ya ait sekiz tür, *Globigerinelloides*'e ait üç tür ve *Leupoldina cabri* tanımlanmıştır. Sadece *Hedbergella* ve *Globigerinelloides* gibi r-mod fırsatçı planktonik foraminiferlerin örneklerde bulunması, Apsiyen'de çalışma bölgesinde, ötrofik çevre koşullarının hüküm sürdüğünü işaret etmektedir. *Hedbergella roblesae* ve *Leupoldina cabri* gibi uzatılmış çemberli, düşük oksijenli planktonik foraminiferler, incelenen sekansın *Leupoldina cabri* biyozonunda Okyanusal Anoksik Olay 1a (Selli Olayı)'nın muhtemel kaydını ortaya koymuştur. Ayrıca, küçük bentik foraminiferler, radyolaryalar ve *Cadosina* sp., ölçülü kesit boyunca gözlemlenmiştir.

Hem litofasiyes analizi hem de biyofasiyes analizine bağlı olarak mikrofasiyes tipleri MF-1: Radyolaryalı çamurtaşı / vaketaşı, MF-2: Planktonik foraminiferli ve radyolaryalı vaketaşı / istiftaşı ve MF-3: Planktonik foraminiferli çamurtaşı / vaketaşı olarak tanımlanmıştır Mikrofasiyes analizleri ışığında, Soğukçam Kireçtaşı'nın Apsiyen kısmının çökelme ortamları, yamaç kenarı – derin su havzası olarak belirlenmiştir.

Anahtar Kelimeler: Planktonik foraminifer, Biyostratigrafi, Apsiyen, Soğukçam Kireçtaşı, Nallıhan/Ankara

To my family…

ACKNOWLEDGEMENTS

Firstly, I would like to express my gratitude to my supervisor Prof. Sevinç Özkan Altıner for her guidance, support, advices and patience. I would like to express my appreciation to Prof. Demir Altıner for his guidance, encouragement and support. Their lectures were very crucial for me while choosing this field of geology.

I would like to thank Assoc.Prof.Dr. Kaan Sayıt for his helps and patience.

I would like to thank our research assistants, Serdar Görkem Atasoy for his helps in fieldwork, and Gamze Tanık for responding my questions. In addition, I would like to thank the members of Stratigraphy, Sedimentology and Micropaleontology Research Group who helped me and answered my questions during my thesis work.

I would like to thank Orhan Karaman for preparing my thin section samples in Sample Preparation Laboratory, Gonca Alptekin for her helps in Analytical Chemistry Laboratory, and Cengiz Mehmet Tan and Serkan Yılmaz for taking SEM photography of my samples in Scanning Electron Microscopy Laboratory. I would like to thank Scientific Research Projects Coordination Unit of METU for their financial support to this study with BAP-YLT-309-2018-3706 project no.

I would like to thank my dear friend and colleague Burçin Kavak for her mental support during my thesis.

At last but does not mean the least, I would like to express my grateful thanks to my father İbrahim Kayhan and my mother Nursabah Kayhan for their endless supports. I appreciate for their helps, emotional support and patience. Moreover, I would like to thank all parts of my family for their supports.

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LIST OF ABBREVIATIONS

FZ: Facies Zone

FO: First Occurrence

LO: Last Occurrence

MF: Microfacies

OAE: Oceanic Anoxic Event

OAE 1a: The Oceanic Anoxic Event 1a (The Selli Event)

OAE 2: The Cenomanian – Turonian Oceanic Anoxic Event

SEM: Scanning Electron Microscopy

SMF: Standard Microfacies

CHAPTER 1

INTRODUCTION

1.1. Purpose and Scope

The Mudurnu-Nallıhan Sequence is composed of Tithonian to Early Hauterivian – aged Yosunlukbayırı Formation and Hauterivian to Aptian – aged Soğukçam Limestone of the Kabalar Group in the Nallıhan area (Ankara, Turkey) (Altıner et al., 1991). The Soğukçam Limestone that is the main unit of this study was originally named by Altınlı (1973a, 1973b), and it was also previously studied by Altınlı (1976, 1977), Saner (1980), Altıner (1991), Altıner and Özkan (1991), Altıner et al. (1991), Özkan (1993a), Özkan-Altıner (1999) and Yılmaz et al. (2004) in the Nallıhan area. Toker (1976) defined this formation as the Nallıhan Formation. Altıner (1991) and Altıner and Özkan (1991) previously defined the biozone of the studied section as the *Hedbergella delrioensis – Hedbergella planispira – Leupoldina – Globigeinelloides* Zone. The one aim of this thesis is determining planktonic foraminiferal biozones in the Nallıhan area via micropaleontological data in detail.

Cretaceous time includes series of oceanic anoxic events (OAEs). The oceanic anoxic event 1a (the OAE 1a, the Selli Event) in Early Aptian (120 Ma) is one of them (Larson & Erba, 1999). Oceanic anoxic events were caused by series of events that started with high amount of CO_2 on the atmosphere and greenhouse effect (Schlanger and Jenkyns, 1976; Schlanger et al., 1981; Gerard & Dols, 1990; Larson, 1991a, 1991b; Tarduno et al., 1991; Barron et al., 1993; Jenkyns, 1999, 2003, 2010; Larson & Erba, 1999; Robinson et al., 2017). The reason of this increasing in CO_2 content in the Selli Event was determined as large igneous provinces in the Pacific Ocean which are the Ontong Java Plateau, the Manihiki Plateau and the Nova Canton Through (Larson, 1991a, 1991b; Bralower et al., 1997; Larson & Erba, 1999; Jones & Jenkyns, 2001; Wignall, 2001; Jahren, 2002; Tremolada et al., 2007). This OAE has important effects on organisms, such as planktonic foraminifera, radiolaria and nannofossils. For this reason, defining planktonic foraminiferal biostratigraphy and performing microfacies analysis of Aptian part of the Soğukçam Limestone in the Nallıhan area enable to observe the effects of the Selli Event. These are important in order to interpret the Early Cretaceous global and paleoceanographic events in the Nallıhan area via micropaleontontological data. Because of the anoxia conditions during this interval by the OAE 1a (the Selli Event), r-mode opportunist forms, like *Hedbergella* and *Globigerinelloides*, dominated that interval (Premoli Silva & Sliter, 1999). There are some hypotheses about planktonic foraminifera with elongated chambers, such as *Leupoldina cabri* and *Hedbergella roblesae*, and their relation with the anoxic conditions (Coccioni et al., 2006; Kopaevich & Gorbachik, 2017). Moreover, minerals, such as glauconite and framboidal pyrite, have been found in some previous studies related with anoxic oceanic events (Bellanca et al., 2002; Michalik et al., 2008; Huck et al., 2010; Yılmaz et al., 2010; Hu et al., 2012; Pictet et al., 2015). Through the stratigraphic section of the study where the related observations were done have been reported in this thesis.

Consequently, the purposes of the study are obtaining and defining micropaleontological data, determining planktonic foraminiferal biozones in detail, observing morphological features of planktonic foraminifera that indicate presence of the Oceanic Anoxic Event 1a (the Selli Event), and performing microfacies analyses on samples from the Soğukçam Limestone in the Nallıhan area. In order to achieve these purposes, detailed literature survey, fieldworks and laboratory works were performed. The laboratory works of the study have contained both sample preparation, and thin section and washing sample analyses. During the investigation of washing samples, size fraction between 63 – 125 µm was chosen. The obtained results were compared to related previous works.

1.2. Geographical Setting

The study area of the thesis that is 158 km away from Ankara is located in north of the Nallıhan town, eastern slopes of the Naldere stream around the Nallıhan area (Figure 1.1). The geographical coordinates of starting point of the stratigraphic section are 40.239526 N and 31.344082 E.

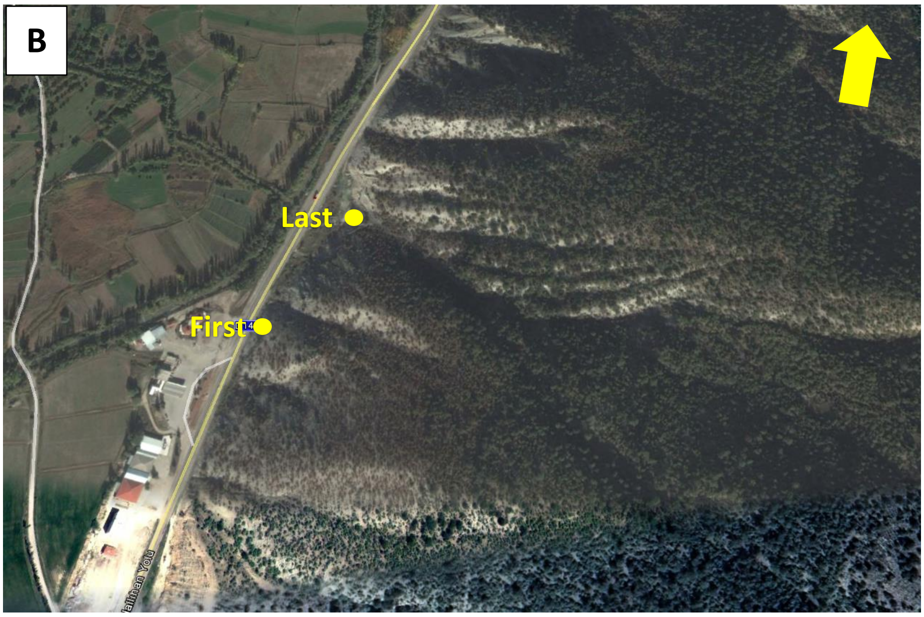


Figure 1.1. A. Map of Turkey where the Nallıhan area is indicated (https://geology.com). B. Location map of the study area where the first and last points of the stratigraphic section were identified (https://earth.google.com).

1.3. Methods of Study

This study contains literature survey, fieldworks and laboratory works. Firstly, articles have been read in order to get information about both geology of the area, planktonic foraminiferal taxonomy, and global biotic and paleoceanographic events in Early Cretaceous. Then, field study has been carried out in the light of this information. In the fieldwork, a total of 44 rock samples were collected in 94.73 m thick measured section containing 40 limestone, 3 shale and 1 diabase dyke samples in the Nallıhan area. The sample intervals were generally around 2 - 3 meters. However, this interval was decreased in initial part of the section where more detailed study has been needed. Through the upper portion where there is slump structure, the sampling interval was increased.

In order to examine samples in the laboratory, thin sections were prepared from the collected samples in the Sample Preparation Laboratory of Middle East Technical University (METU) – Department of Geological Engineering. In this step, the aim is making micropaleontological, microfacies and mineralogical analyses in sedimentary rock samples, and mineralogical analyses in igneous rock sample under the microscope. In order to talk about micropaleontological analysis, planktonic foraminifera investigation in thin section samples have been done mainly under the guidance of Premoli Silva and Verga (2004) and Mikrotax (http://www.mikrotax.org/pforams/index.php?dir=pf_mesozoic). Other fossil assemblages of the study, such as benthic foraminifera and radiolaria, defined based on their definitions in Loeblich and Tappan (1988). Dunham's classification of carbonate rocks (1962) by Embry and Klovan (1971) and Flügel's Standard Microfacies Types (SMF) (2004) were used in microfacies analyses. Thin section photographs have been taken to represent the result of these analyses in the Marine Micropaleontology Laboratory of Department of Geological Engineering at METU.

For detailed micropaleontological analyses, washing samples have been prepared based on special techniques in literature. The main lithology of the study is composed of limestone. In these samples, both Knitter Method (Knitter, 1979) and Lirer Method (Lirer, 2000) were applied in order to find the best washing method (Table 1.1). The Knitter Method (1979) follows some procedure for crushed samples covered with 50% or 65% dilution of acetic acid (CH_3COOH) and chloroform in 1:1 ratio. While starting this method, limestone sample is crushed into at most pea-sized. Then, 20 g crushed samples are put into beaker, and 50% or 65% acetic acid is added to beaker up to 1 cm higher than samples. Next, chloroform in 1:1 ratio (20 ml chloroform for 20 g sample while testing) is added, and top is covered as barrier from air. Different time intervals (from 1 hour to 24 hours) are tried for different dilution (50% and 65% of acetic acid) to find the optimum solution (Table 1.1). After that, these samples are washed under tap water, rubbed and sieved with 425 μm, 250 μm, 125 μm and 63 μm sieves. 50% of acetic acid and 18 hours waiting time give the best solution in all options of the Knitter Method via observation of dried samples. However, clay sized sediments are attached to fossil content, and these lead to problems while observation of fossil under the microscope. Hence, pure water is used after rubbing, and this helps separation of clay particles from fossil content.

In the Lirer Method (2000), crushed samples are covered with 80% of acetic acid. Different from the Knitter Method (1979), chloroform is not used in this method. Similarly, beaker that contains samples and 80% dilution of acetic acid is covered as barrier from air. Various time durations (from 1 hour to 5 hours) are applied to the method, and these durations are not as much as the ones in the Knitter Method because of different concentration of solvent (Table 1.1). Then, samples are washed under tap water, rubbed and sieved with 425 μm, 250 μm, 125 μm and 63 μm sieves. After observation of dried samples under the microscope, this method cannot reach the optimum solution.

Finally, the Knitter Method with 50% dilution of acetic acid and 18 hours duration was determined as the best washing method for these limestone samples, and it applied for 100 g samples with 100 ml chloroform in all limestone samples that have been collected from the study area.

In the Nallıhan area, three shale samples were collected from different levels. In these samples, standard H_2O_2 method is applied with 30% and 50% dilutions, firstly (Table 1.2). For this method, samples are crushed into pea-sized pieces, and they are placed into beaker. These samples are covered with 30% or 50% of H_2O_2 solution in 1:10 ratio (200 ml H_2O_2 solution for 20 g sample). After waiting for different time durations (from 1 day to 5 days), they are washed under tap water, rubbed and sieved with 425 µm, 250 µm, 125 µm and 63 µm sieves. They are dried and then observed under the microscope in order to find the most suitable method. However, the best washing method for shale samples has not been found with standard H_2O_2 method. Hence, the Knitter Method containing 50% diluted acetic acid (CH_3COOH) with chloroform (1:1) method was applied with different time durations (from 1 hour to 10 hours) (Table 1.2). The same procedure that was previously applied for limestone samples was used for shale samples. After testing, the dried samples were investigated under the microscope, and the best method was chosen as the Knitter Method with 50% dilution of acetic acid and 8 hours duration in shale samples. Then, it applied for 100 g samples with 100 ml chloroform in all shale samples that have been collected from the study area.

Table 1.1. *Applied washing methods for limestone samples (The best method is highlighted).*

METHOD	SOLVENT TYPE	TIME DURATION
Knitter	50% diluted CH_3COOH + chloroform (1:1)	1 hour
Knitter	50% diluted CH_3COOH + chloroform (1:1)	4 hours
Knitter	50% diluted CH_3COOH + chloroform (1:1)	12 hours
Knitter	50% diluted CH_3COOH + chloroform (1:1)	18 hours
Knitter	50% diluted CH_3COOH + chloroform (1:1)	24 hours
Knitter	65% diluted CH_3COOH + chloroform (1:1)	1 hour
Knitter	65% diluted CH_3COOH + chloroform (1:1)	2 hours
Knitter	65% diluted CH_3COOH + chloroform (1:1)	4 hours
Knitter	65% diluted CH_3COOH + chloroform (1:1)	6 hours
Knitter	65% diluted CH_3COOH + chloroform (1:1)	8 hours
Knitter	65% diluted CH_3COOH + chloroform (1:1)	12 hours
Knitter	65% diluted CH_3COOH + chloroform (1:1)	18 hours
Knitter	65% diluted CH_3COOH + chloroform (1:1)	24 hours
Lirer	80% diluted CH_3COOH	1 hour
Lirer	80% diluted CH_3COOH	2 hours
Lirer	80% diluted CH_3COOH	5 hours

Table 1.2. *Applied washing methods for shale samples (The best method is highlighted).*

SOLVENT TYPE	**TIME DURATION**
30% diluted H_2O_2	1 day
30% diluted H_2O_2	2 days
30% diluted H_2O_2	5 days
50% diluted H_2O_2	1 day
50% diluted H_2O_2	2 days
50% diluted H_2O_2	5 days
50% diluted CH_3COOH + chloroform (1:1)	1 hour
50% diluted CH_3COOH + chloroform (1:1)	2 hours
50% diluted CH_3COOH + chloroform (1:1)	4 hours
50% diluted CH_3COOH + chloroform (1:1)	6 hours
50% diluted CH_3COOH + chloroform (1:1)	8 hours
50% diluted CH_3COOH + chloroform (1:1)	10 hours

After performing chosen washing methods on all sedimentary samples of the study in Analytical Chemistry Laboratory of Department of Geological Engineering at METU, the samples were examined under the microscope. At this step, the smallest fraction which is 63 µm sieve (samples between 63 and 125µm) was chosen for this examination after investigating larger intervals. Planktonic foraminifera, benthic foraminifera and radiolaria were picked up from washing samples, and they put into holders. They have been identified and classified by using their morphological features as in thin section samples. Range of the fossils were determined via combining and comparing these washing samples with thin section samples. Next, photographs of these fossils have been taken at Scanning Electron Microscopy (SEM) Laboratory of METU – Department of Metallurgical and Materials Engineering.

1.4. Previous Works on the Mudurnu-Nallıhan Sequence

In order to explain the Mudurnu – Nallıhan Sequence, understanding the Jurassic – Lower Cretaceous rocks of the northwestern Anatolia is important which was previously studied by various authors. Granit and Tintant (1960) named the Lower Jurassic part of succession as Bayırköy Sandstone and Middle to Upper Jurassic overlying carbonates as the Yediler Limestone and the Bilecik Limestone in Bilecik - Mekece area. This Bilecik Limestone name was used in several studies for neritic carbonates, such as Altınlı (1965a, 1965b) in Bursa, Eroskay (1965) in Gölpazarı, Altınlı et al. (1970), Altınlı and Saner (1971), and Altınlı and Yetiş (1972) in Bilecik, Altınlı (1973a) in the Middle Sakarya Region, Gürpınar (1976) in Bilecik – İnegöl - Yenişehir, Saner (1980) in Göynük, and Genç et al. (1986) in İnegöl – Bursa – Pazaryeri, in Middle to Late Jurassic age (Figure 1.2). Furthermore, Saner (1978, 1980) in Geyve – Osmaneli – Gölpazarı – Taraklı, Yılmaz (1981) in the southern margin of the Sakarya Continent, and Genç (1986) in Uludağ – İznik, used the Bilecik Limestone name for shallow-marine sediments in the Middle Jurassic and Early Cretaceous. With respect to Saner (1980) and Yılmaz (1981), this Bilecik Limestone was overlaid by the Soğukçam Limestone (Figure 1.2). The Bilecik Limestone was used as group name as the Bilecik Group by Altıner et al. (1991) in Halılar (Edremit) and Bursa – Bilecik.

The Soğukçam Limestone which constitutes the main unit of this study is the younger unit of the Mudurnu – Nallıhan Sequence. It was originally named by Altınlı (1973a, 1973b) as the Soğukçam Formation in the Early Cretaceous in age, medium to thin bedded, whitish, micritic limestone with some cherty parts in the Soğukçam Village in Bolu. Saner (1980) and Yılmaz et al. (1981) observed the same lithology and used this formation name in Göynük and the southern margin of the Sakarya Continent, respectively. Saner (1980) also identified Middle to Upper Jurassic tuff and volcano-clastic sandstone and shale units as the Mudurnu Formation. The Lower Cretaceous

Soğukçam Limestone was observed above the Mudurnu Formation (Figure 1.2). İnci et al. (1988) defined the Soğukçam Limestone as thin to thick bedded, light grey to brown, micritic, arenitic, cherty limestone, green sandstone and tuff layers in the Beypazarı area. Fourquin (1975) described the age of pelagic successions as between Oxfordian and Late Cretaceous in the Mudurnu area. Alkaya (1987) defined the age of the Soğukçam Limestone between Oxfordian – Berriasian based on ammonoids in the Beypazarı area. Its age was determined as from Late Jurassic to Early Cretaceous by studies of Kalafatçıoğlu and Uysallı (1964), and Varol and Kazancı (1981). The Soğukçam Limestone was also used in different studies, like Altınlı (1976, 1977) in Nallıhan, Saner (1980) in Nallıhan and Mudurnu, Yılmaz et al. (1981) in Abant – Dokurcum, Önal et al. (1988) in Çayırhan – Beypazarı, and Altıner et al. (1991) in Mudurnu – Nallıhan – Beypazarı, Bursa – Bilecik and Çerkeş. Toker (1976) defined this formation as the Nallıhan Formation in the Nallıhan area (Figure 1.2).

According to Toker (1976), only one measured section was not enough to explain the geological characteristics of the Nallıhan region. Hence, nineteen stratigraphic sections were measured, and Mesozoic and Cenozoic units were defined in this study. The Nallıhan Formation that was named by Toker (1976) contains biomicrite and micritic limestones at the basement. It continues with littoral and sub-neritic sediments including sandy micrites, dolomitic limestone, biomicrite and intrabiosparite that indicate pelagic limestone. Age of the Nallıhan Formation was defined between Tithonian – Albian. This formation extends in northeast - southeast direction laterally, and has 1400 m thickness. With respect to this study, relation between the Nallıhan Formation and the underlying unit was not determined, but this formation was unconformable with Paleozoic formation through east. The Nallıhan Formation was overlaid by Bozyaka Formation that has 1300 m thickness. *Calpionella* biozone (Tithonian), *Calpionella*, *Tintinnopsella*, *Nannoconus* biozones (Berriassian – Barremian), and *Nannoconus* biozone (Aptian – Albian) were determined within limestones. In order to explain the studied sequence from Lower Cretaceous parts of the study, massive limestones, cream-coloured to yellow limestone with light grey parts and grey to beige-coloured biomicrite were observed in the Nallıhan Formation. Moreover, this interval contained radiolaria, sponge spicules, echinoidea, lamellibranchiate, ostracoda, *Textularia, Calpionella aplina* and *Calpionella elliptica* (Toker, 1976). To sum up, base of the Nallıhan Formation was unknown and the top part was faulted with Upper Cretaceous unit. Moreover, this formation was used as the synonym of the Yosunlukbayırı Formation and the Soğukçam Limestone (Altıner et al., 1991).

Önal et al. (1988) classified the Soğukçam Limestone in three different lithofacies from bottom to top as micritic limestone with chert, sandstone – shale alternation with tuff and massive limestone in Çayırhan, northwestern Ankara. Limestones started with carbonate mudstone and some carbonate wackestone, and continue through carbonate wackestone and carbonate packstone. They were white to grey coloured, moderate to thick bedded with some laminae. The fossil content is composed of *Hedbergella* sp., *Ticinella* sp., *Rotalipora* sp., radiolaria, ammonoid, belemnite and sponge spicule. In addition, Önal et al. (1988) defined the bottom parts as basin and the upper parts as deep shelf margin based on Wilson (1975) carbonate facies types.

Altıner et al. (1991)'s study contains the Yosunlukbayırı Formation and the Soğukçam Limestone of the Kabalar Group in the Mudurnu-Nallıhan sequence in the Nallıhan area. This study also includes data and observations from other locations where the Mudurnu-Nallıhan sequence continues. These areas are Mudurnu, Beypazarı – Çayırhan, Aktaş (Gerede) and Doğdu (Çerkeş). The Nallıhan part of the sequence is composed of series of anticlines and synclines that trending in east – west direction and getting younger through north – south direction. Like Toker (1976)'s observation, basement was not observed in the area. South – verging tectonic slice was expressed in order to trend of structure. At south part, the Mudurnu-Nallıhan sequence is observed as thrust over Paleocene-aged continental clastic units. At north, it has fault-controlled contact with Campanian – Maastrichtian-aged volcano-sedimentary sequence. The Yosunlukbayırı Formation which is not the part of this thesis is older unit of the Mudurnu-Nallıhan sequence. In general, this formation is Tithonian to

Early Hauterivian in age, and its thickness is around 750 m in measured section in the Nallıhan area. It was fed by olistoliths and olistostromes of Callovian and Kimmeridgian carbonates of the Bursa-Bilecik Platform. Then, its depositional regime gets more stable after Berriasian. This formation is composed of wackestones, packstones and boundstones mostly with *Lithocodium*, brachiopod, belemnites, sponge, echinoid, *Chitinoidella*, *Saccocoma* and calpionellid. The overlying Soğukçam Limestone is from Hauterivian to Aptian in age. The thickness of this formation in stratigraphic section of the study is 720 m. Its lower part is composed of medium to thick-bedded, cream-coloured limestones with chert nodules and some mud pebbles, and olistoliths. The fossil content of this part is sponge spicules, echinoid, radiolaria, *Nannoconus* and planktonic foraminifera. Through the upwards, medium-bedded, micritic limestone was investigated which contains belemnites, ammonoites, brachiopods, *Nannoconus* and planktonic foraminifers. At the upper part of the Soğukçam Limestone which is the study area of the thesis, marl and limestone alternation was observed. Slump structures were also recognized, and diabase dyke cut across the units. The shale levels of the Soğukçam Limestone was defined as the anoxia level. Furthermore, Altıner et al. (1991) classified belemnites of the formation in species level. Planktonic and benthic foraminifers are defined especially in species level by Altıner (1991) and Altıner et al. (1991). With respect to Altıner et al. (1991), planktonic foraminifers of the studied section yield Late Hauterivian, Barremian and Aptian age. This formation has more stable regime. Slump, diabase dykes and levels with olistolith indicate tectonic activity in basin (Altıner et al., 1991). Based on Şengör and Yılmaz (1981), the slump structure in pelagic deposits of the Soğukçam Limestone indicated increase in submarine relief. Moreover, the Soğukçam Limestone resembles lithologically the Biancone and Maiolica Formations in the Umbria-Marche Region (Italy) (Altıner et al., 1991; Mekik et al., 1999).

Mekik et al. (1999) previously studied radiolarians from Tithonian – Berriasian deposits of the Yosunlukbayırı Formation and the Soğukçam Limestone of the Sakarya Continent in the northwestern Turkey. Good-preserved radiolarian-rich faunas were obtained in the Soğukçam Limestone part of the study. Mekik et al. (1991) classified radiolarians in species level.

Özkan (1993a) studied calcareous nannofossils in the Nallıhan area. Based on this study, the Soğukçam Limestone starts with medium to thick bedded, nodular, cream coloured clayey limestone. This part contains echinoid fragment-bearing mudstone and wackestone, and planktonic foraminifera, radiolaria and *Nannoconus*-bearing mudstone and wackestone microfacies. Then, the formation continues with olistolith that include matrix with planktonic foraminifers and *Nannoconus*, and medium bedded, belemnite, ammonite, brachiopod, planktonic foraminifers and *Nannoconus*-bearing micritic limestone with a calciturbidite level. Through the upper part of the Soğukçam Limestone, alternation of limestone and marl, and micritic limestone that shows slump structures, and a diabase dyke cut across them. Black shale levels were observed in the study, and planktonic foraminifers become more abundant in upper layers. With a more detailed study, percentages of the abundant nannofossil taxa in Aptian part of the Soğukçam Limestone were defined via counting by Özkan (1993a). Through the black shale levels of the section, nannoconids are missing.

Özkan (1993b) presented calcareous nannofossil biostratigraphy of the Mudurnu-Nallıhan sequence in Mudurnu, Çayırhan Beypazarı, Gerede and Çerkes that includes biozones and bioevents between the Tithonian and Valanginian-aged Yosunlukbayırı Formation and Soğukçam Limestone Formation. Özkan-Altıner (1996) studied calcareous nannofossils of the Soğukçam Limestone in the northwest Anatolia with defining five biozones between Valanginian and Aptian. In addition, three peaks related with abundance of nannoconids were identified via quantitative analysis. Özkan-Altıner (1999) worked on nannoconids from Tithonian to Aptian parts of the Yosunlukbayırı Formation and the Soğukçam Limestone in the northwestern Anatolia. The study area also contained the Nallıhan part of Ankara. Systematic taxonomy of nannoconus was performed via this study. The level of so-called nannoconid crisis (Erba, 1994) as an important decrease in nannoconid abundance was observed (Özkan-Altıner, 1999).

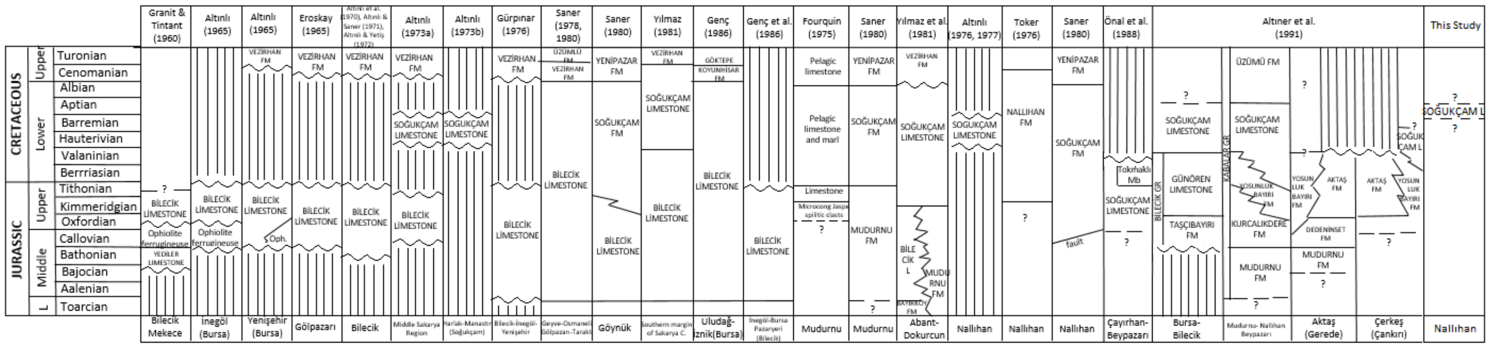


Figure 1.2. Correlations of Jurassic – Cretaceous units of the Northwestern Turkey. The vertical hatchings indicate gaps in the successions (modified from Altıner et al., 1991).

According to Yılmaz et al. (2004), the Soğukçam Limestone in the Nallıhan and the Mudurnu sections includes marls and shales with some radiolaria and planktonic foraminifera at the bottom and planktonic foraminiferal, radiolarian wackestone/packstone facies at the top. Black shales were also observed in both sections. Stable carbon and oxygen isotope variations within cycles were represented. The Selli Event (the OAE 1a) equivalent level was defined, its record was supported by stable carbon and oxygen isotope data (Yılmaz et al., 2004). The thickness of this level was found as 11 m in Nallıhan and 2 m in Mudurnu.

The Soğukçam Limestone that contains Barremian – Aptian, slope/basin pelagic carbonates in the Nallıhan, the Mudurnu and the Göynük areas were studied by Yılmaz (2008). These pelagic carbonate deposits cover the intra-continental Mudurnu Trough deposits (Önal et al., 1988; Altıner, 1991; Altıner et al., 1991; Koçyiğit et al., 1991).

Hu et al. (2012) studied transition from the Early Aptian OAE 1a to oceanic red bed 1 (ORB 1) in the Soğukçam Limestone in the Mudurnu area. The thickness of OAE 1a equivalent level is around 2.1 m. This level contained black shales and grey marlstone. This Selli Event equivalent level gives high total organic carbon (TOC) values ranging between 0.9 and 2.05%. Furthermore, both stable carbon and oxygen isotope analyses were performed. Based on carbon isotope analysis, negative carbon excursion followed by positive shift was defined at this black shale level. The study indicated the relation between rise in oxygen isotope record just before black shale level and warm climatic conditions. Decreasing and increasing trends were related with warm and cool climate cycles. After this level, oxygen isotope values mostly represented increase through ORB 1 which were in cool climates in late Aptian time.

1.5. Regional Geological Setting

Şengör and Yılmaz (1981) defined the evolution of Turkey with two phases as Palaeo-Tethyan and Neo-Tethyan. The mountain belts of Turkey result from continental collisions of two mega continents, Laurasia and Gondwana. Ketin (1966) defined Turkey in three tectonic units which are the Anatolides – Taurides, the Pontides and the Arabian Platform. At past, they were enclosed via oceans, but then, they were separated by sutures (Figure 1.3). The Pontides are in the northern branch of the Neo-Tethys. After closure of this ocean, the Pontides and the Anatolides were separated by the İzmir – Ankara – Erzincan Suture. The Pontides which have Laurasian affinities are in north of the İzmir – Ankara – Erzincan Suture. At Alpine orogeny, they were affected by thrust faulting and folding mechanisms (Okay, 2008). The Sakarya, the İstanbul and the Strandja Zones are the main tectonic units of the Pontides (Okay & Tüysüz, 1999). The Anatolides – Taurides indicate Gondwana affinities. However, they are separated from Gondwana via Neo-Tethys' southern branch. They comprise of the majority of the southern Turkey and separated from the Arabian Platform via Assyrian Suture (Okay, 2008). In addition, they contain Late Ordovician glacial deposits (Monod et al., 2003). The northernmost part of the Arabian Platform is in the southeast Anatolia. It was separated from the Anatolides – Taurides via Neo-Tethys' southern branch that is named by the Assyrian Suture after the closure of the Neo-Tethys (Şengör & Yılmaz, 1981) (Figure 1.3).

The study area in the Nallıhan region, Ankara is located in the Sakarya Continent of Şengör and Yılmaz (1981), the Sakarya Zone of Okay (1989) and the Sakarya Composite Terrane of Göncüoğlu et al. (1997) in the Pontides (Figure 1.3). Based on Şengör and Yılmaz (1981), the Sakarya Continent was an island in the northern branch of Neo-Tethys which was represented by the Intra-Pontide, the Vardar, the İzmir-Ankara and the Ilgaz-Erzincan ophiolitic belts. According to Okay (2008), the Sakarya Zone terrane consists of elongate crustal ribbon between the Aegean in west and the

Eastern Pontides in east. It is an east – west oriented continental fragment which is 1500 km long and 120 km wide. The Sakarya Zone is located between the İstanbul Zone, the Strandja Zone and the eastern Black Sea in north, and the Anatolide-Tauride Blocks in south (Okay & Whitney, 2010).

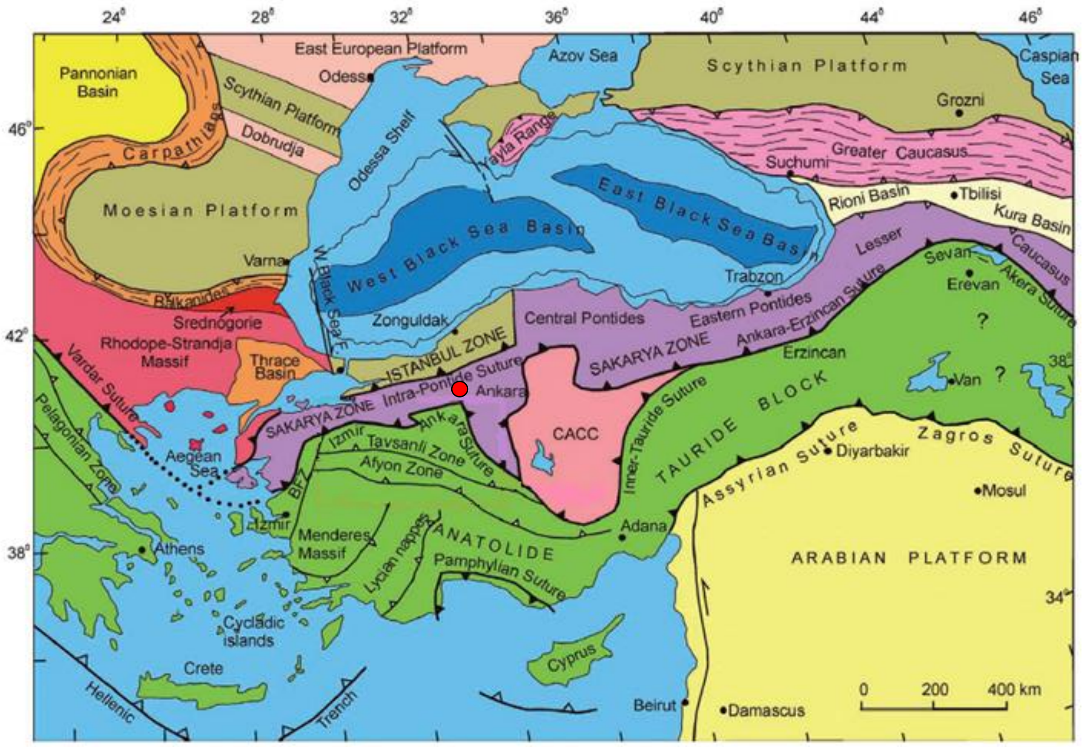


Figure 1.3. Tectonic map of Turkey where the study area in Nallıhan was indicated as a red dot (modified after Okay & Tüysüz, 1999; Okay & Whitney, 2010).

The Sakarya Zone starts with a complex basement. These crystalline basement can be separated as three types. The first one is the Variscan basement with high-grade metamorphism containing marble, metaperidotite, amphibolite and gneiss (Okay, 2008). This basement was only preserved in the easternmost part of the Sakarya Zone (Okay & Leven, 1996). This metamorphism was dated as Carboniferous (330-310 Ma) via dating zircon and monazite (Okay et al., 2006). The second basement is Paleozoic granitoids with Devonian, Carboniferous and Permian crystallization ages (Okay et al., 2006; Topuz et al., 2007). This basement was unconformably overlain by sediments which are Jurassic or younger in age (Okay, 2008). The third one is the Karakaya Complex that is used for strongly deformed and metamorphosed Permian and Triassic orogenic series in the Pontides. Bingöl et al. (1975) firstly presented the Karakaya Formation name for feldspathic sandstone, conglomerate, quartzite, siltstone intercalated with radiolarian chert, mudstone and basalt from Biga Peninsula through Bilecik to Ankara. Then, Tekeli (1981) used the North Anatolian Belt name for orogenic rocks in pre-Jurassic age in the Pontides. Şengör et al. (1984) named the Karakaya Formation as the Karakaya Complex which is restricted to the Sakarya Zone of Okay (1989) or the Sakarya Composite Terrane (Göncüoğlu et al., 1997) in the Pontides. It is absent in the other parts of the Pontides and the Anatolide-Tauride Block (Okay & Göncüoğlu, 2004). The Karakaya Complex is divided into two as the Lower and the Upper Karakaya Complex. The Lower Karakaya Complex was previously mapped by different names, such as the Emir Formation (Akyürek et al., 1984) and the Tokat Group (Koçyiğit, 1987) in the Ankara Region, the Nilüfer Unit in the northwestern Anatolia (Okay et al., 1991). The Lower Karakaya Complex which is a low-grade metamorphic complex dominated by Permo-Triassic metabasite with phyllite and marble. The basement was overlain via thick, strongly deformed clastics and volcanoclastics with exotic blocks of Carboniferous and Permian radiolarian chert and limestone (Okay, 2008). This Upper Karakaya Complex contains several subunits. It includes thick arkositic sandstones in the northwestern Anatolia. In the Ankara Region, it has greywacke with exotic limestone blocks (Okay & Göncüoğlu, 2004). Their ages range between Permian and Late Triassic (Okay, 2008).

The basement was unconformably overlain by sedimentary and volcanic succession in Early Jurassic. This interval was represented by fluvial to shallow marine sandstone, conglomerate and shale in western side of the Sakarya Zone. Through the eastern part of the Sakarya Zone, volcanoclastics intercalation with sandstone was observed by Okay (2008). In Early and Middle Jurassic, granitic rocks were intruded into the basement rock in the Central Pontides (Yılmaz & Boztuğ, 1986). The Lower Jurassic clastics and volcanoclastics are overlain by the Upper Jurassic-Lower Cretaceous limestones (Altıner et al., 1991). These limestones are overlain by deep sea sandstones and shales (Okay, 2008) (Figure 1.4).

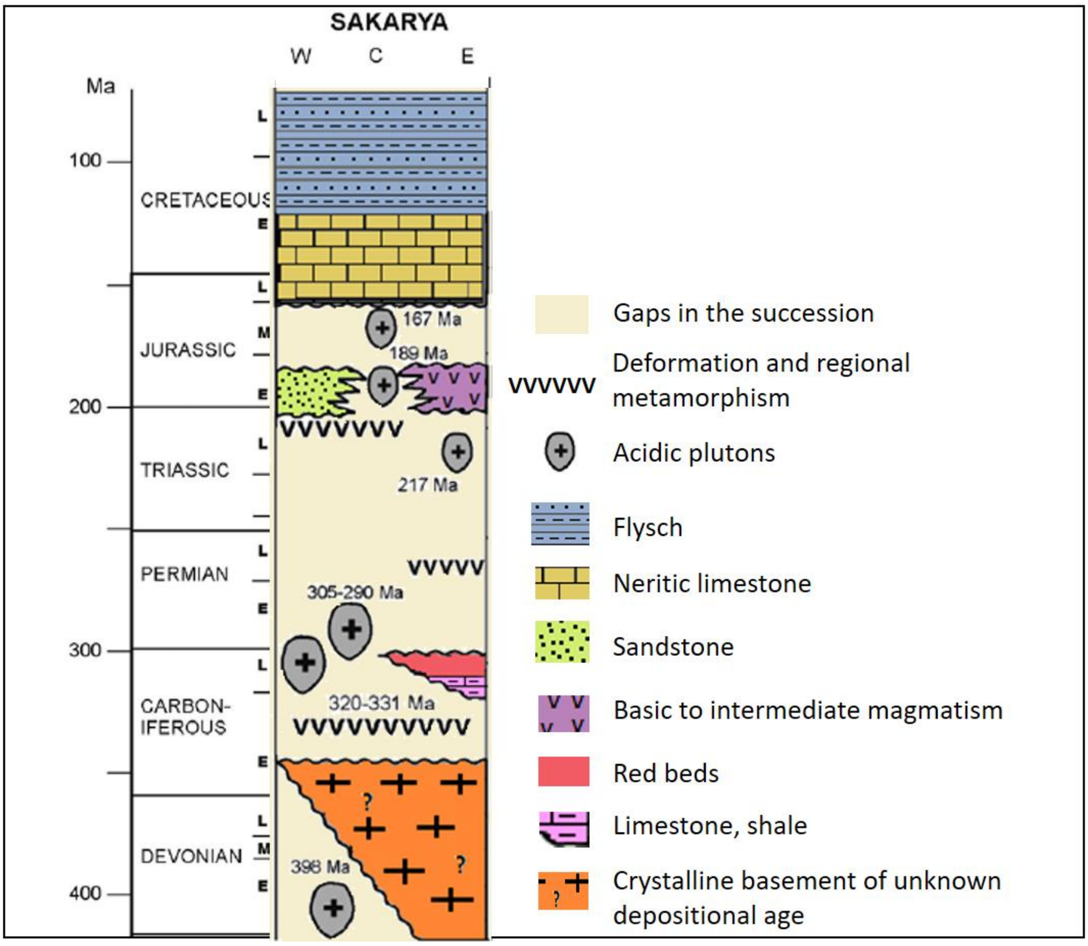


Figure 1.4. Simplified tectonostratigraphic column of the Sakarya Zone (not to scale) (modified from Okay et al., 2008).

The Mudurnu-Nallıhan sequence in the Nallıhan area, Ankara is the main focus of this thesis study. The Mudurnu-Nallıhan sequence exposed in north of Mudurnu and Nallıhan, south of Geyve-Dokurcum, southeast of İznik Lake, south of Aktaş, northwest of Beypazarı, and south and west of Çerkeş. It contains Dogger volcanic and volcanoclastic rocks, and Upper Dogger, Malm and Lower Cretaceous flysch-type lithologic units. The Upper Jurassic – Lower Cretaceous Mudurnu-Nallıhan sequence includes anticlines and synclines trending in east – west direction. The Mudurnu-Nallıhan sequence is composed of the Tithonian – Early Hauterivian aged Yosunlukbayırı Formation and the Hauterivian – Aptian aged Soğukçam Limestone in the Nallıhan area (Figure 1.5). The Mudurnu-Nallıhan sequence is thrust over Paleocene-aged continental clastic units at south part. At north, it has fault-controlled contact with Campanian – Maastrichtian-aged volcano-sedimentary sequence. The Yosunlukbayırı Formation was fed by olistoliths and olistostromes of Callovian and Kimmeridgian carbonates of the Bursa-Bilecik Platform up to getting more stable depositional setting after Berriasian. The Soğukçam Limestone overlies the Yosunlukbayırı Formation. Its lower part is composed of medium to thick-bedded, cream-coloured limestones with chert nodules and some mud pebbles, and olistoliths. Through upwards, medium-bedded, micritic limestone continues. The study area of the thesis is in the upper part of the Soğukçam Limestone that consists of marl and limestone alternation (Figure 1.5). This formation has more stable regime. Slump, diabase dykes and levels with olistolith show tectonic activity in basin (Altıner et al., 1991). With respect to Şengör and Yılmaz (1981), the slump structure in pelagic deposits of the Soğukçam Limestone represents an increase in submarine relief. These slumps are frequently in Tithonian-Berriasian, and less common in Valanginian-Aptian. They go along with slope facies that is near fault controlled margins of Mudurnu and Doğdu Trough deposits (Koçyiğit et al., 1991). The Barremian-Aptian aged slope-basin pelagic deposits of the Soğukçam Limestone cover the intra-continental Mudurnu Trough deposits (Önal et al., 1988; Altıner, 1991; Altıner et al., 1991; Koçyiğit et al., 1991) which are related with a drowning event (Yılmaz, 2008) (Figure 1.6).

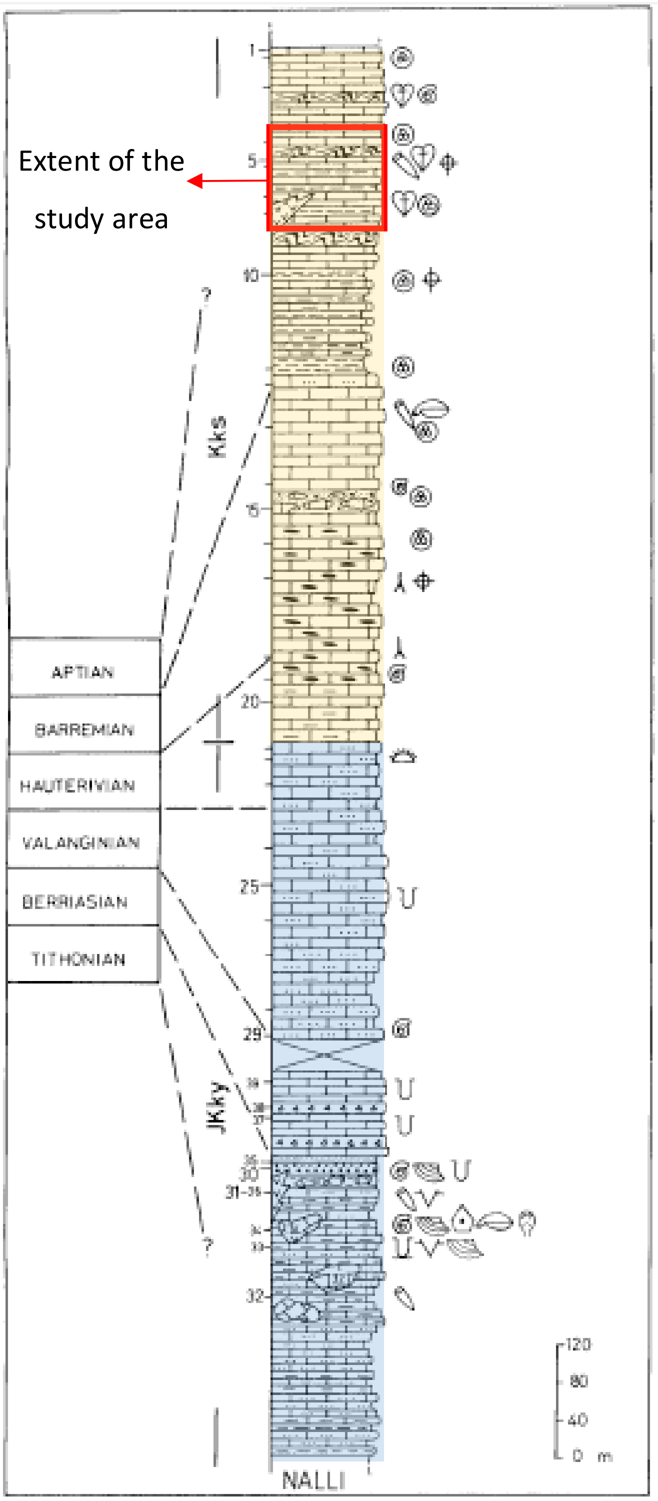


Figure 1.5. NALLI section in the Nallıhan area (JKky: Yosunlukbayırı Formation, Kks: Soğukçam Limestone) (The signed area indicate the extend of thesis field compared to Altıner et al. (1991)) (modified from Altıner et al., 1991).

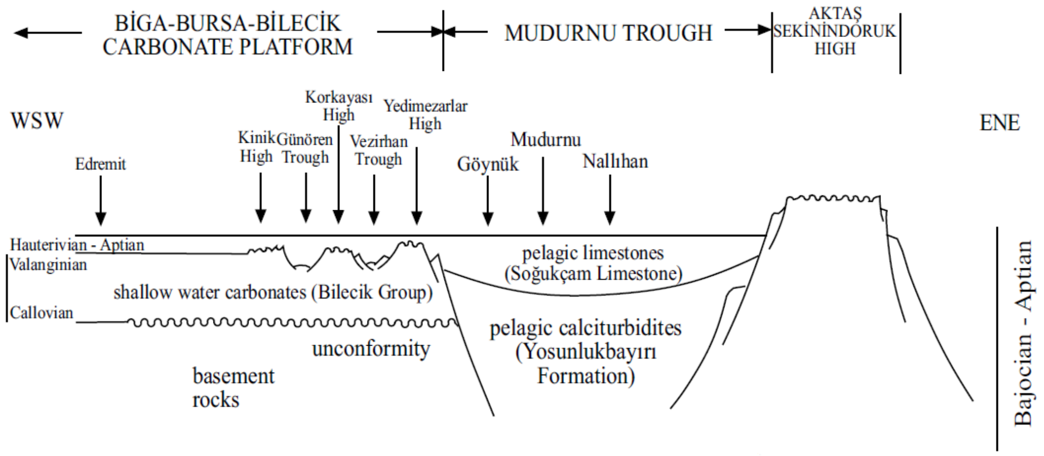


Figure 1.6. Tectono - stratgraphic development in Mudurnu Trough in Aptian time (Koçyiğit et al., 1991).

CHAPTER 2

STRATIGRAPHY

2.1. Lithostratigraphy

2.1.1. The Soğukçam Limestone

The Nallıhan area is located in the northwestern Anatolia, Turkey. The Mudurnu – Nallıhan Sequence in the Nallıhan area is composed of the Kabalar Group's Yosunlukbayırı Formation and the overlying Soğukçam Limestone (Altıner et al., 1991) (Figure 2.1). The study area of the thesis contains the Early Cretaceous part of the Soğukçam Limestone.

The Yosunlukbayırı Formation is the older unit of the Mudurnu – Nallıhan Sequence in Nallıhan. It was used for yellow and green argillaceous limesones, detritic limestones and shales at the base, and medium to thick-bedded, bioturbated, yellow to grey limestones at the top by Altıner et al. (1991). This formation is limited by the Kurcaklıdere Formation at the base, and it was overlaid by the Soğukçam Limestone. The thickness of the formation is 750 m in the Nallıhan area. Its fossil content is composed of *Saccocoma,* belemnites, calpionellids and foraminifera. Its age was determined as Tithonian to Early Hauterivian. It was in an actively subsiding basin, and it was fed by olistoliths and olistostromes of the Callovian to Kimmeridgian carbonates of the Bursa – Bilecik platform. Its depositional regime gets more stable starting from Berriasian (Altıner et al., 1991).

The Soğukçam Limestone is the younger unit of the Mudurnu – Nallıhan Sequence in the Nallıhan area. It was firstly defined by Altınlı (1973a,b) as the Soğukçam

Formation in the Soğukçam Village, Bolu. This formation is composed of medium to thin-bedded, whitish, micritic limestone with some cherty parts as Early Cretaceous in age in the type locality (Altınlı, 1973a,b). In the Nallıhan area, the lower part of the formation contains medium to thick-bedded, cream coloured limestones with chert nodules and some mud pebbles, and olistoliths. It continues with medium-bedded micritic limestone, and marl – limestone alternation. The Kabalar Group's Soğukçam Limestone overlies the Yosunlukbayırı Formation in the Nallıhan area, and the thickness of this formation is 720 m. Its fossil content is composed of planktonic and benthic foraminifera, radiolaria, sponge spicules, ammonites, brachiopods, belemnites, echinoid fragments, and *Nannoconus*. The age of this formation was defined from Hauterivian to Aptian. The Soğukçam Limestone indicated the more stable depositional regime (Altıner et al., 1991). This formation was also observed by several authors in different localities in northwestern Turkey. Saner (1980) defined the same lithology in Göynük. Yılmaz et al. (1981) observed this formation in the southern margin of the Sakarya Continent. İnci et al. (1981) defined the Soğukçam Limestone in the Beypazarı area as thin to thick bedded, light grey to brown, micritic, arenitic, cherty limestone, green sandstone and tuff layers. In addition, Alkaya (1987) observed the formation in the Beypazarı area. Fourquin (1975) defined this formation as pelagic succession in the Mudurnu area instead of the Soğukçam Limestone. The age of the formation was determined as Late Jurassic to Early Cretaceous by Kalafatçıoğlu and Uysallı (1964), and Varol and Kazancı (1981). Furthermore, the Soğukçam Limestone was used in different studies, like Altınlı (1976, 1977) in Nallıhan, Saner (1980) in Nallıhan and Mudurnu, Yılmaz et al. (1981) in Abant – Dokurcum, Önal et al. (1988) in Çayırhan – Beypazarı, and Altıner et al. (1991) in Mudurnu – Nallıhan – Beypazarı, Bursa – Bilecik and Çerkeş. Different from these studies, Toker (1976) defined the formation as the Nallıhan Formation in the Nallıhan area which is the synonym of the Yosunlukbayırı Formation and the Soğukçam Limestone (Altıner et al., 1991) (Figure 1.2).

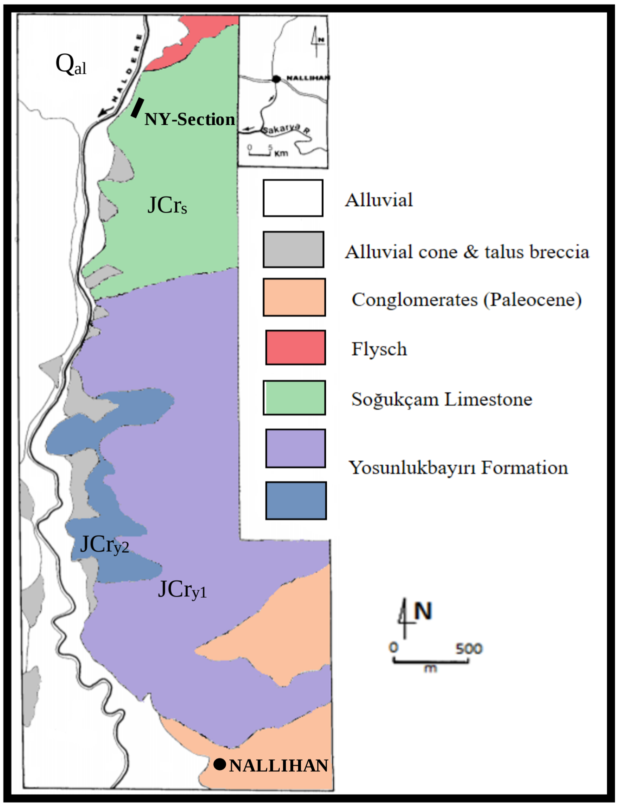


Figure 2.1. The geological map of the Nallıhan region where the location of the measured section was indicated (modified from Altıner et al., 1991).

2.1.2. The Studied Section (The NY-Section)

In this study, 94.73 m thick measured stratigraphic section (the NY-Section) was taken. In this section, a total of 44 samples were collected through the sequence where the lithologic changes were recorded. They are composed of 40 limestone, 3 shale (NY-5, NY-7S and NY-14) and 1 diabase dyke (NY-7D) samples from the area. The sampling intervals are generally around 2 – 3 meters. However, these intervals are decreased in initial part of the section where more detailed studies have been needed, and some lithologies are not as thick as 2 m. The measured section from the Aptian part of the Soğukçam Limestone in the Nallıhan area is in Figure 2.2.

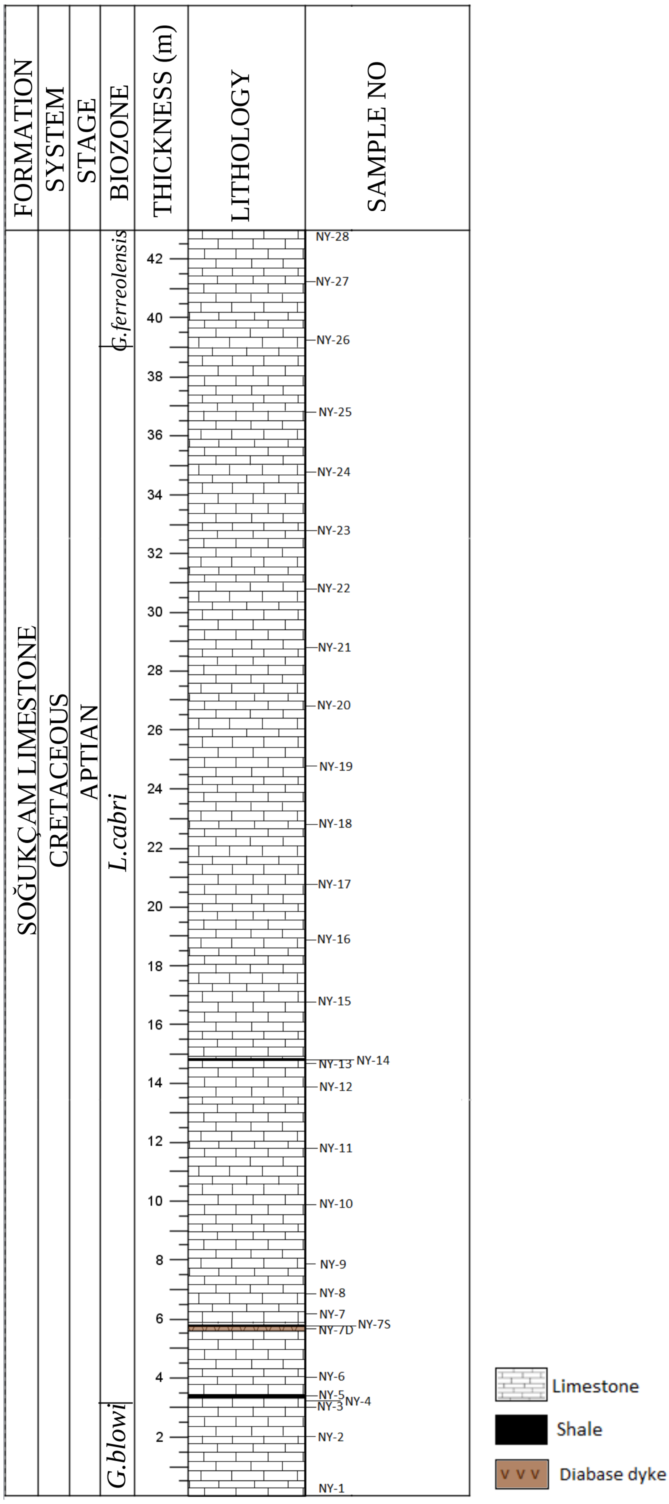


Figure 2.2. Measured stratigraphic section (The NY-Section) of the Soğukçam Limestone in the Nallıhan area.

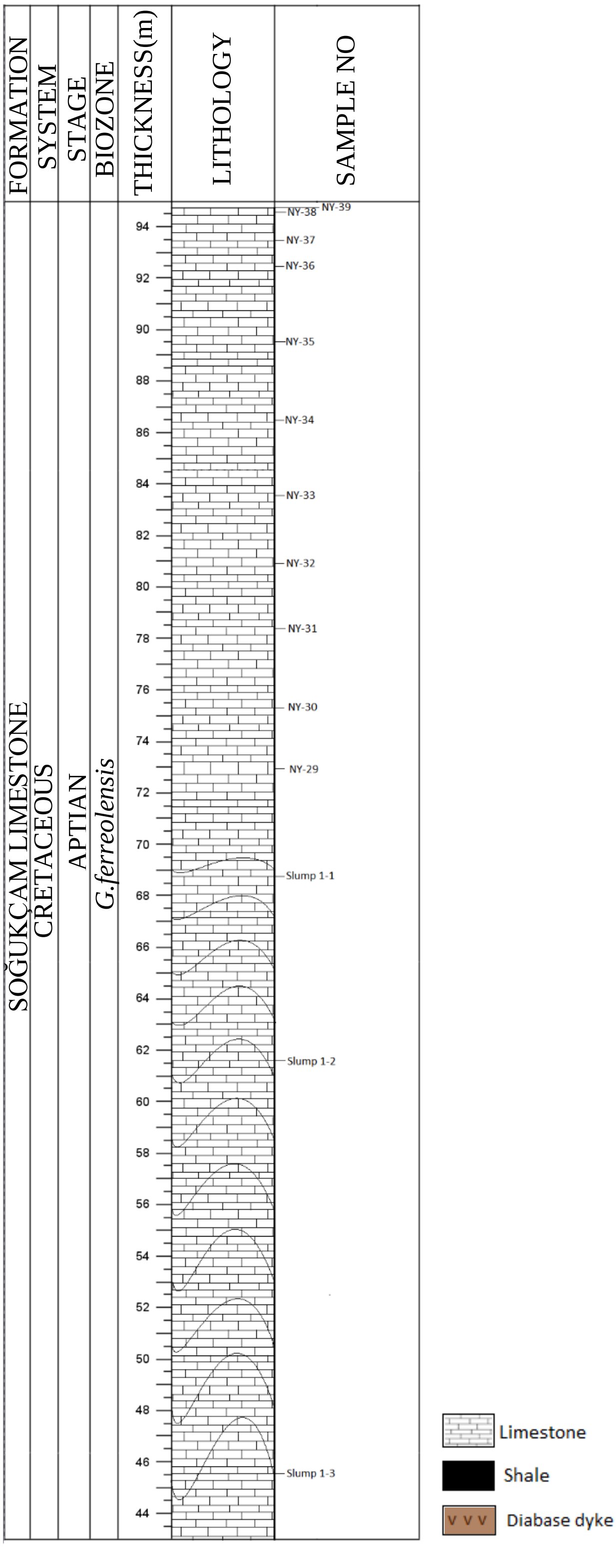
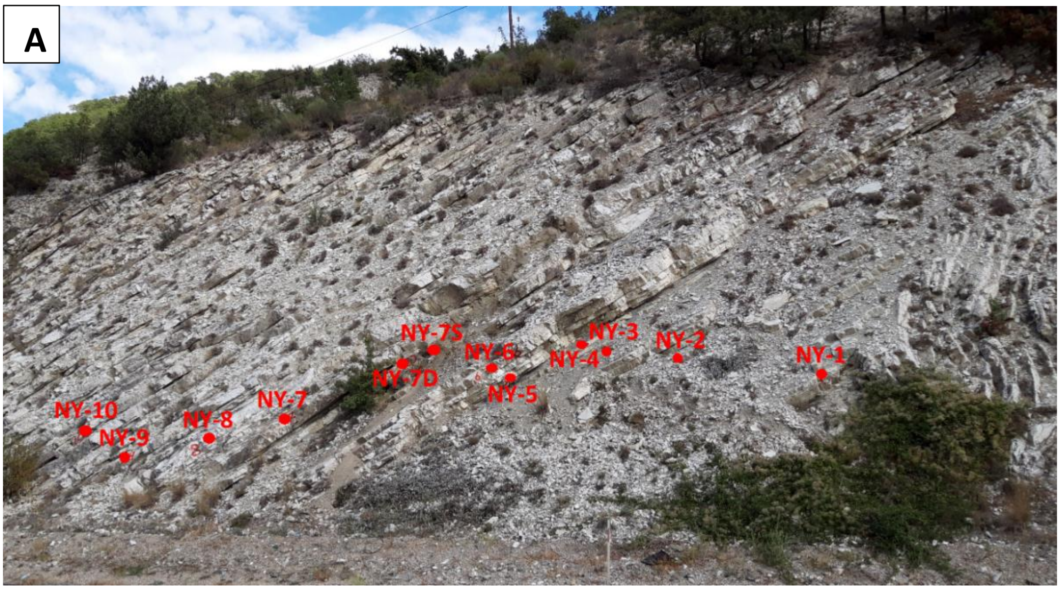


Figure 2.2. continued.

The field study contains both measuring a stratigraphic section and taking samples through this section. The study was started just after a slump structure. Figure 2.3 shows the starting point of the study (NY-1) with indicated points of the first twelve samples (between NY-1 and NY-10). Altıner et al. (1991) defined lithology of the study interval as alternation of marls and limestones. With respect to observations, the main lithology of the studied area is composed of white to cream-coloured, medium to thin bedded limestones. Shale levels are observed in the lower part of the section (NY-5, NY-7S and NY-14) with alternation of limestones as in Altıner et al. (1991)'s study. Their thicknesses are very small compared to limestone levels. Shale level has 15 cm thickness in NY-5, 3 cm in NY-7S and 5 cm in NY-14. In NY-7D, a diabase dyke was observed that cut across limestone and shale levels (Figure 2.3).

The first slump structure was seen just before the measured section (Figure 2.3). The second slump structure that was also defined by Altıner et al. (1991) and Koçyiğit et al. (1991) observed after a thick limestone succession above limestone – shale alternation (between NY-15 and NY-28). The thickness of this structure was measured as 30 m, and three limestone samples were taken through this structure (Figure 2.4). These samples are Slump 1-3, Slump 1-2 and Slump 1-1 starting from the lower part of the section to upper part of it. Because of the structure, sampling intervals are comparatively large with respect to other parts of the measured section. After the slump, limestone succession continues with sample NY-29, and samples were taken in 2 -3 m intervals again. However, stratigraphic section was shifted 30 m laterally before NY-34 because of talus. This change is necessary in order to maintain measurement and sampling processes. These limestone samplings were continued up to sample NY-39 (Figure 2.4).



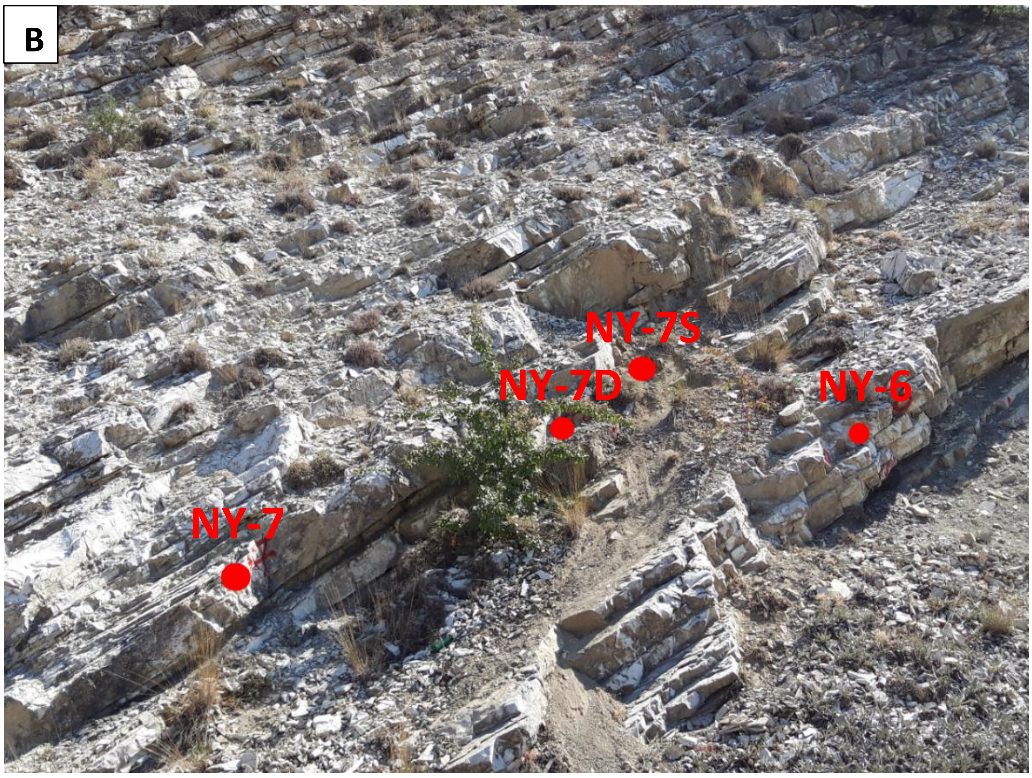


Figure 2.3. A. Field photograph that represents the starting point of the study (NY-1) with indicated locations of first twelve samples of the study. B. Field photograph which includes the sampling points between NY-6 and NY-7 (NY-7S: shale level (3 cm) and NY-7D: diabase dyke (5 cm) in measured section).

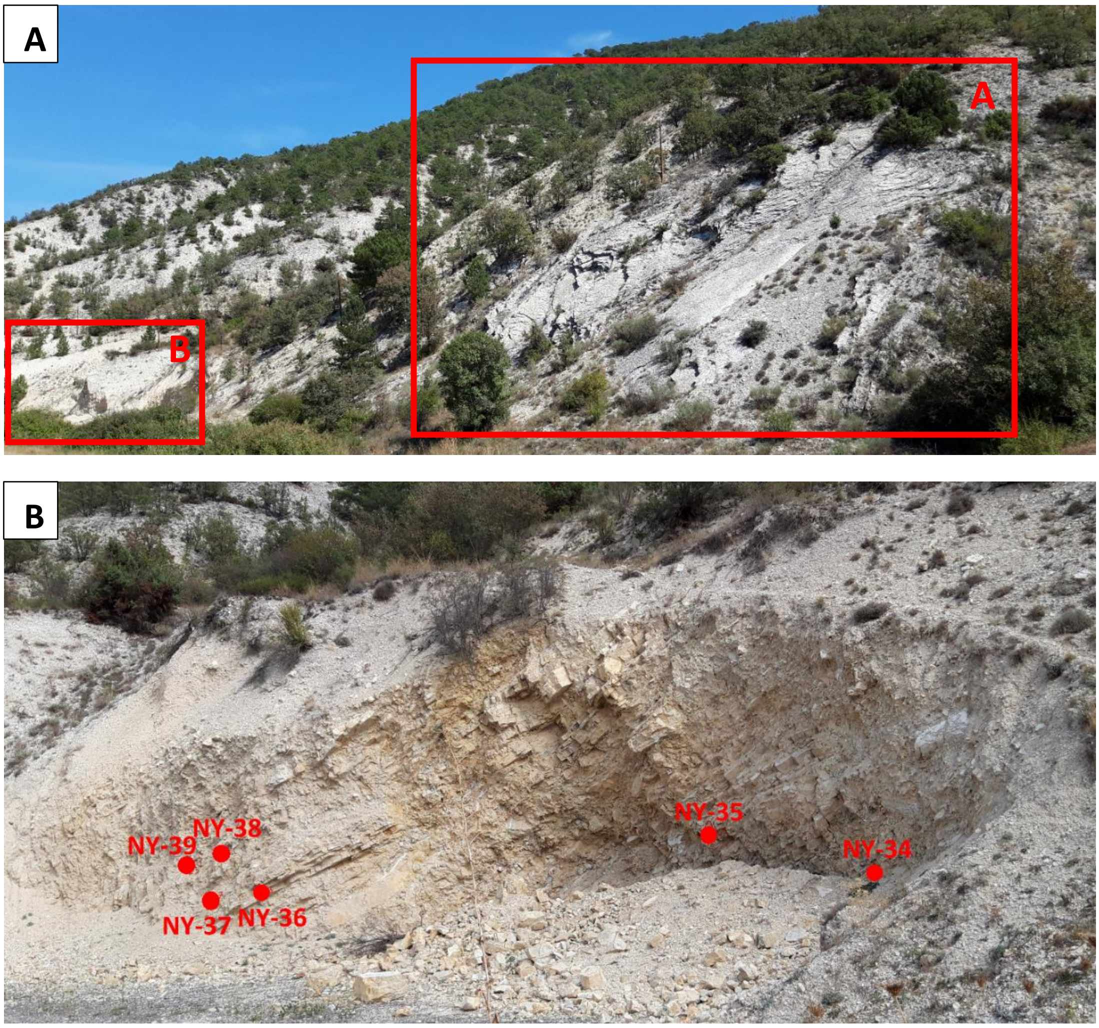
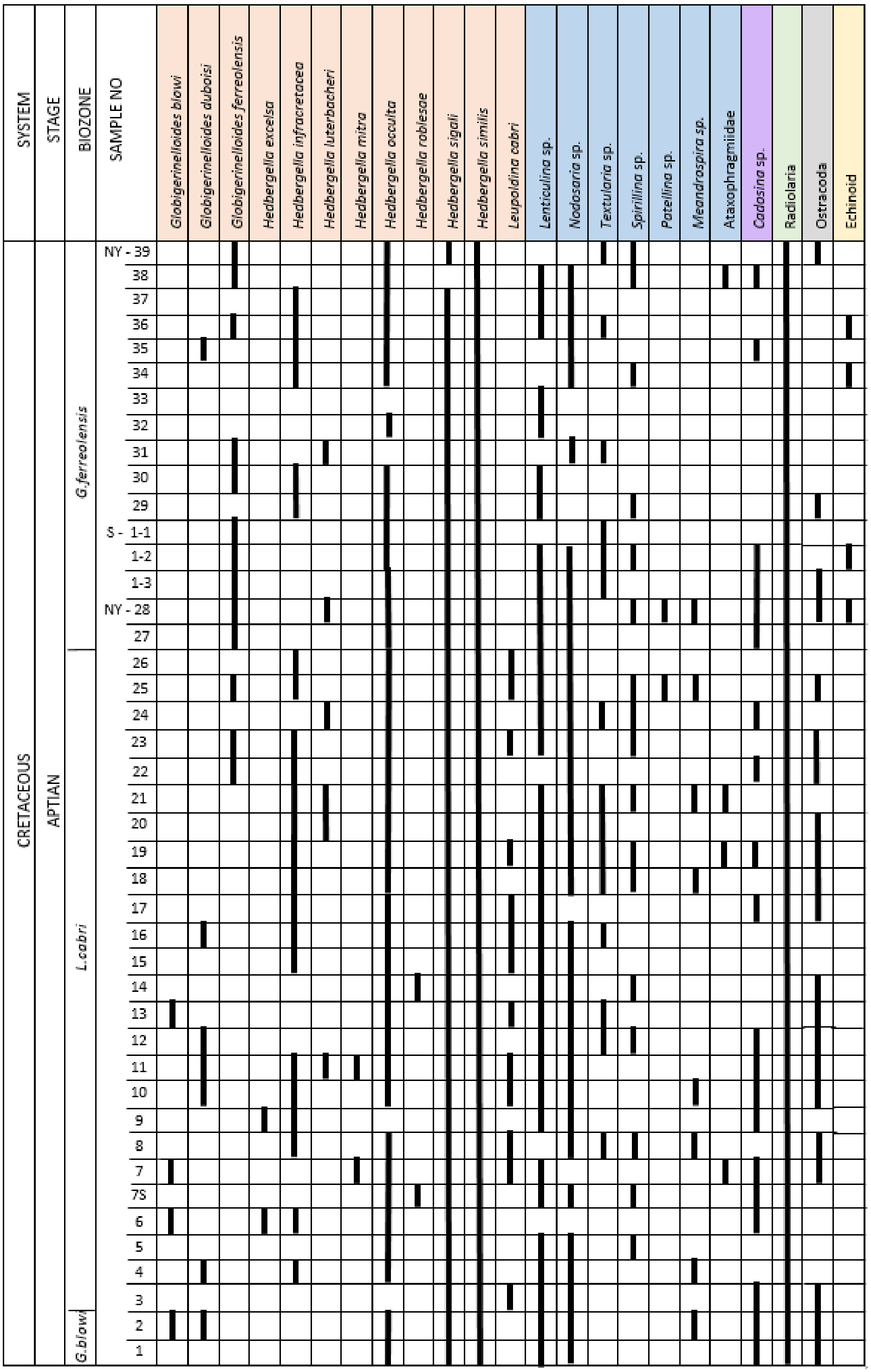


Figure 2.4. A. Field photograph that shows A. The slump structure, and B. The location of samples that have been taken after 30 m lateral shift. B. Field photograph which contains the sampling points of limestone after 30 m lateral shift up to the last sample of the study.

2.2. Biostratigraphy

The studied sequence is composed of planktonic and small benthic foraminifera, radiolaria, *Cadosina* sp. and ostracoda. In this study, planktonic foraminifera were studied in detail through washing samples and thin sections. They have been defined in species level. In addition, benthic foraminifera were studied through thin sections and washing samples, and they have been identified mostly in genus level. The range chart of the observed forms is in Table 2.1. The age of the section was defined as Aptian based on planktonic foraminifera biostratigraphy.

Table 2.1. *Fossil range chart of the studied section.*



2.2.1. Planktonic Foraminifera Biostratigraphy

Biozones of the measured sections from the Mudurnu Trough and the Nallıhan area were previously defined by Altıner (1991) and Altıner and Özkan (1991) based on the paleontological data (Table 2.2). Biozones of the Yosunlukbayırı Formation and the Soğukçam Limestone in the Nallıhan area were named as the *Meandrospira favrei* Zone, the *Hedbergella sigali* Zone and the *Hedbergella delrioensis – Hedbergella planispira – Leupoldina – Globigerinelloides* Zone from older to younger part of the succession between Hauterivian and Aptian. The location which also contains this thesis study was defined as the *Hedbergella delrioensis – Hedbergella planispira – Leupoldina – Globigerinelloides* Zone. The zone was determined starting from the FO of *Globigerinelloides* up to the FO of *Globigerinelloides algerianus* in Mudurnu Trough that also contains the *Globuligerina hoterivica* Zone in Hauterivian and the *Globigerinelloides algerianus* Zone in Aptian (Altıner, 1991; Altıner & Özkan, 1991).

Table 2.2. *Foraminifera biozones of the Mudurnu Trough and the Nallıhan area between Valanginian and Aptian.*

CHRONOSTRATIGRAPHY	**MUDURNU TROUGH** (Altıner, 1991)	**NALLIHAN** (Altıner & Özkan, 1991)
Aptian		
	Globigerinelloides algerianus	
	Hedbergella delrioensis – H.planispira Leupoldina - Globigerinelloides	*Hedbergella delrioensis – H.planispira Leupoldina - Globigerinelloides*
Barremian	*Hedbergella sigali*	*Hedbergella sigali*
Hauterivian	*Globuligerina hoterivica*	?
Hauterivian – Valanginian	*Meandrospira favrei*	*Meandrospira favrei* ?
Valanginian	*Montsalevia salevensis*	

Biozones are defined with respect to the first occurrence (FO) and the last occurrence (LO) of zonal marker planktonic foraminifera in this thesis. Through the measured stratigraphic section three planktonic foraminiferal biozones were identified which are the *Globigerinelloides blowi* Zone, the *Leupoldina cabri* Zone and the *Globigerinelloides ferreolensis* Zone. The succession has started with the *Globigerinelloides blowi* Zone up to the FO of *Leupoldina cabri* in sample NY-3. Next, the *Leupoldina cabri* Zone was defined starting from the FO of *Leupoldina cabri* up to the LO of this form in sample NY-26. The *Globigerinelloides ferreolensis* Zone started by the LO of *Leupoldina cabri*, and this biozone continues through the end of the measured section.

Biozonal schemes that represent planktonic foraminifera zonation containing the study interval by several authors are shown in Figure 2.5. The publications which were used in this scheme have been chosen via defining the *Leupoldina cabri* Zone between the FO and LO of the zonal marker.

Erba et al. (1999) defined the *Leupoldina cabri* Zone starting from the FO of the form through the LO in Southern Alps, Italy. However, they defined the level where *Leupoldina cabri* observed abundant as “common occurrence” (Figure 2.5).

With respect to the study of Cobianchi et al. (1999), the *Globigerinelloides blowi* Zone named from the FO of the form through the FO of *Leupoldina cabri* while following the original description of Moullade (1974). They also defined the *Leupoldina cabri* Zone starting from the FO of it in Southern Italy (Figure 2.5).

Aguado et al. (1999) identified the *Blowiella blowi* Zone up to the FO of *Schackoina cabri*. Then, they used the *Schackoina cabri* Zone up to the FO of *Globigerinelloides ferreolensis* that defined a starting of a biozone, and this zone last up to the FO of *Globigerinelloides algerianus* in southeast Spain (Figure 2.5).

Heldt et al. (2008) defined the *Globigerinelloides blowi* Zone from the FO of the form up to the FO of *Leupoldina cabri*, like Moullade (1974), based on the study in north-central Tunisia. They use the *Leupoldina cabri* Zone as a total range zone instead of an acme zone of Premoli Silva and Verga (2004) because rare specimens of *Leupoldina cabri* were observed in that study. For this reason, this zone was determined between the FO and the LO of the form. The *Globigerinelloides ferreolensis* Zone was defined starting from the LO of *Leupoldina cabri* up to FO of *Globigerinelloides algerianus* (Figure 2.5).

Elkhazri et al. (2013) used a different biozone in their studies in Tunisia. They defined the *Globigerinelloides blowi* and the *Leupoldina cabri* Zone as in other studies. With respect to this publication, the *Globigerinelloides blowi* Zone last up to the FO of *Leupoldina cabri,* and the *Leupoldina cabri* Zone used from its FO to LO. Acme zone of the form was defined different from the other studies that was discussed in this part. Furthermore, they defined the *Hedbergella luterbacheri* Zone above the LO of *Leupoldina cabri* up to the FO of *Globigerinelloides ferreolensis* (Figure 2.5).

Jozsa et al. (2016) defined the *Leupoldina cabri* Zone up to the LO of it. Between the FO of *Hedbergella luterbacheri* and the FO of *Globigerinelloides ferreolensis,* the *Hedbergella luterbacheri* Zone was named. Above this zone, the *Globigerinelloides ferreolensis* Zone was determined by the study in Western Carpathians up to the FO of *Globigerinelloides barri* (Figure 2.5).

Moullade et al. (2015) used the *Globigerinelloides blowi* Zone up to the FO of the *Leupoldina cabri* similar to other studies in southeast France. Then, the *Leupoldina cabri* Zone was named up to the FO of *Praehedbergella luterbacheri,* and above this zone, the *Praehedbergella luterbacheri* Zone was represented up to the FO of *Globigerielloides ferreolensis heptacameratus* that defined a starting of a biozone. After the *Globigerinelloides ferreolensis heptacameratus* Zone, the *Globigerinelloides ferreolensis ferreolensis* Zone was used between the FO of the zonal species and the FO of *Globigerinelloides barri* (Figure 2.5).

Ogg et al. (2016) defined the *Leupoldina cabri* (consistent) Zone between the *Leupoldina cabri* and the *Globigerinlloides ferreolensis* Zones different from the other publications (Figure 2.5).

Brovina (2017) presented the *Hedbergella ruka* and the *Hedbergella excelsa* Zones starting from their FOs between the *Blowiella blowi* and the *Leupoldina cabri* Zones different from other studies. The *Hedbergella luterbacheri* Zone was defined above the *Leupoldina cabri* Zone between the FO of *Hedbergella luterbacheri* and the FO of *Globigerinelloides ferreolensis*. Above this biozone, they named the *Globigerinelloides ferreolensis* Zone by the FO of the zonal marker (Figure 2.5).

With respect to Coccioni et al. (2007), location of the *Leupoldina cabri* Zone has been changed in different studies whether it was defined starting from the FO of *Leupoldina cabri* or its acme zone. Hence, the difference in location of this zone in studies can be related with these two definitions of the *Leupoldina cabri* Zone. In this thesis, *Leupoldina cabri* was observed small in numbers in the measured section from the Nallıhan area. For this reason, the *Leupoldina cabri* Zone was determined starting from its FO up to the LO of the form based on the definition of this biozone. On the other hand, Premoli Silva and Verga (2004) defined this zone as an acme zone. However, this acme zone might not be defined in many studies. In addition, based on their definition, the *Globigerinelloides blowi* Zone extended up to the acme zone of *Leupoldina cabri*, but the *Globigerinelloides ferreolensis* Zone defined as starting from the LO of *Leupoldina cabri*. Actually, the LO of *Leupoldina cabri* does not have to be in the same level with the last point of the acme zone of *Leupoldina cabri*. Hence, using this acme zone might lead a problem while defining the planktonic foraminiferal zones in Aptian. Ogg et al. (2016) used both the *Leupoldina cabri* Zone and its consistent zone separately.

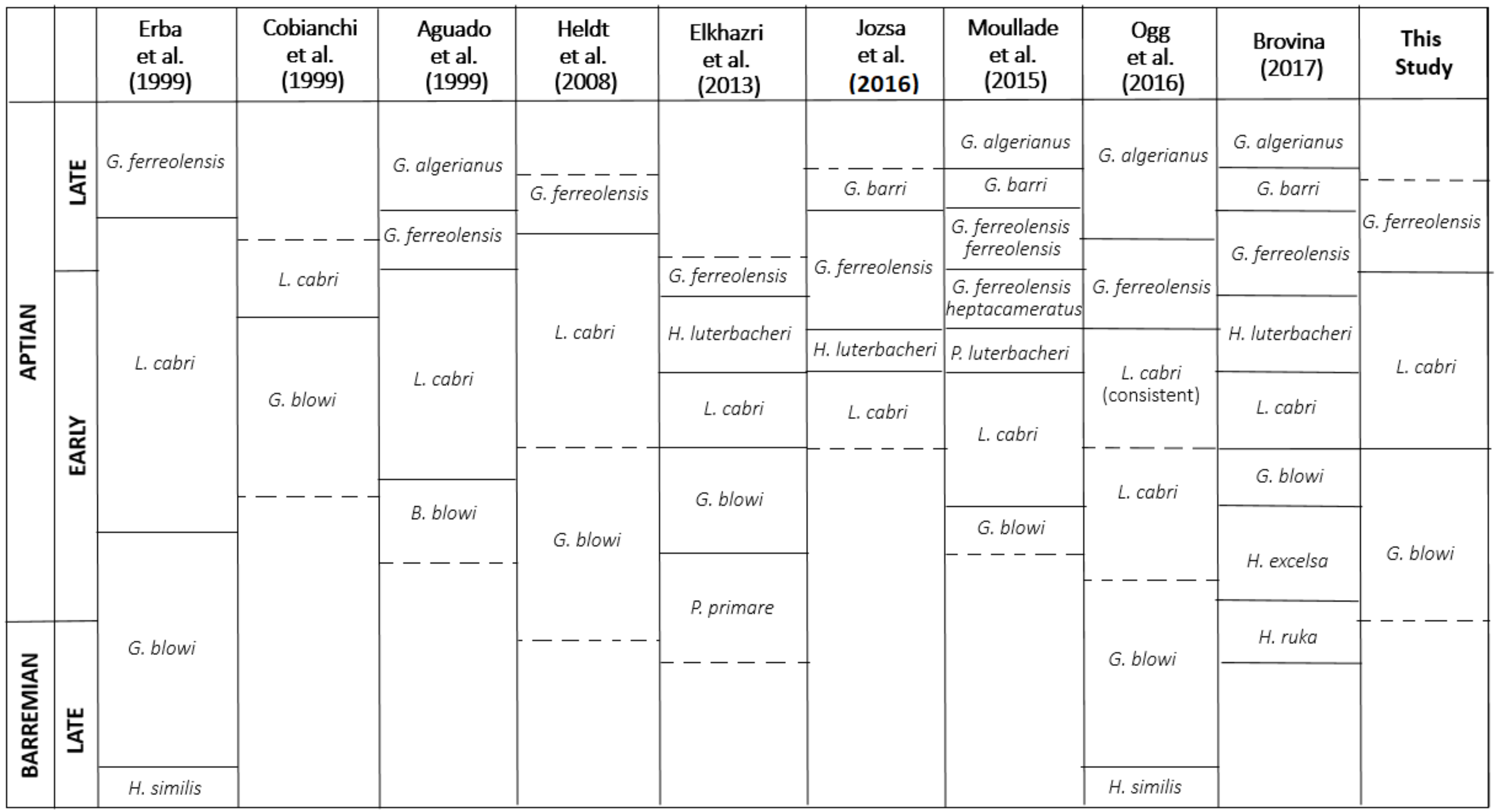


Figure 2.5. Correlation of the planktonic foraminifera zonations of several authors for the Late Barremian – Late Aptian interval containing this study.

2.2.1.1. *Globigerinelloides blowi* Interval Zone

Author: Moullade, 1974

Definition and Remarks: Interval zone is starting from the FO of *Globigerinelloides blowi* to the FO of *Leupoldina cabri* (Moullade, 1974). The extension of this zone was defined as from the FO of *Globigerinelloides blowi* to the acme of *Leupoldina cabri* by Premoli Silva and Verga (2004). Because the measured section of the thesis has not contained the FO of the form, this zone was defined the beginning of the section up to the FO of *Leupoldina cabri* as Moullade (1974) definition of the *Globigerinelloides blowi* Zone.

The *Globigerinelloides blowi* Zone contains *Globigerinelloides blowi, Globigerinelloides duboisi, Hedbergella occulta, Hedbergella sigali* and *Hedbergella similis* in the study area.

With respect to Premoli Silva and Verga (2004), *Hedbergella primare, Guembelitria cenomana* and *Globigerinelloides aptiensis* are firstly appeared in lower part of the *Globigerinelloides blowi* Zone. Through the middle part of the zone, *Hedbergella occulta, Hedbergella excelsa, Hedbergella praetrocoidea, Hedbergella ruka, Hedbergella gorbachikae* and *Globigerinelloides maridalensis* start to be observed. Above them, *Globigerinelloides duboisi* firstly appear. In this zone, abundance and overall size of planktonic foraminifera increase along with the increase in number of species. The upper part of the *Globigerinelloides blowi* Zone is dominated by either clavate forms or leupoldinids that are alternated with globular-chambered forms. In addition, these species are recorded as prior of the Selli Event (Premoli Silva & Verga, 2004).

Stratigraphic Distribution: The first two samples of the measured section (NY-1 and NY-2) defined in the *Globigerinelloides blowi* Zone.

Age: Early Aptian (Bolli et al, 1985; Sliter, 1992), Late Early Barremian to Early Aptian (Premoli Silva & Verga, 2004).

2.2.1.2. *Leupoldina cabri* Range Zone

Author: Sigal, 1977

Definition and Remarks: The *Leupoldina cabri* Zone was firstly defined in the range of zonal marker (Sigal, 1977) which means this zone ranges between the FO and the LO of *Leupoldina cabri.* The definition of the *Leupoldina cabri* Zone is used as an acme zone by Premoli Silva and Verga (2004). Because *Leupoldina cabri* is rare in samples of the stratigraphic section, Sigal (1977) definition of this zone was used in this thesis.

The *Leupoldina cabri* Zone includes *Globigerinelloides blowi, Globigerinelloides duboisi, Globigerinelloides ferreolensis, Hedbergella excelsa, Hedbergella infracretacea, Hedbergella luterbacheri, Hedbergella mitra, Hedbergella occulta, Hedbergella roblesae, Hedbergella sigali, Hedbergella similis* and *Leupoldina cabri*. As Moullade (1961) and Longoria (1974) defined, the FO of *Globigerinelloides ferreolensis* has seven chambers at the last whorl was observed in this zone. This zone contains the form with elongated chambers, like *Hedbergella roblesae* and *Leupoldina cabri.* The top of the zone was determined by the extinction of *Leupoldina cabri* in the thesis study.

The zone was previously defined as *Schackoina cabri* Zone with synonym of *Leupoldina protuberans* Zone (Bolli et al., 1985). This zone is a total range zone that starts at the top of the Selli Event. However, there are rare specimens of *Leupoldina cabri* below the Selli Event, so the zone was extended down and includes the Selli Event (Erba at al., 1999; Premoli Silva et al., 1999). The definition of the *Leupoldina cabri* Zone is used as an acme zone by Premoli Silva and Verga (2004).

The FOs of several species with clavate chambers within genera *Globigerinelloides* and *Hedbergella* are examined at base of *Leupoldina cabri* Zone in association of common, diversified leupoldinids. Moreover, the FO of medium-sized *Globigerinelloides ferreolensis* and *Globigerinelloides praebarri* are in this zone. Moullade (1961) defined that firstly occurred *Globigerinelloides ferreolensis* has seven chambers at the last whorl in the base of Gargasian, then eight to nine-chambered ones appeared through the end of Gargasian. The top of this zone is defined by the extinction of *Leupoldina cabri, Leupoldina pustulans pustulans, Caucasella hoterivica* and the last representative of *Gorbachikella* (Banner & Desai, 1988; Premoli Silva & Verga, 2004).

Stratigraphic Distribution: Samples between NY-3 (the FO of the form) and NY-26 (the LO of the form) assigned in the *Leupoldina cabri* Zone.

Age: Early Late Aptian (Premoli Silva & Verga, 2004).

2.2.1.3. *Globigerinelloides ferreolensis* Range Zone

Author: Sigal, 1977

Definition and Remarks: Range zone of *Globigerinelloides ferreolensis* starting from the LO of *Leupoldina cabri* to the FO of *Globigerinelloides algerianus* (Sigal, 1977). However, only the starting level of the zone was defined in this study by the LO of *Leupoldina cabri*. *Globigerinelloides algerianus* was identified in the section, so end point of the zone has not been presented.

The last representatives of *Leupoldina* extincted at the base of the *Globigerinelloides ferreolensis* Zone. Even though Premoli Silva and Verga (2004) said that the forms with elongated chambers are not as common as the *Leupoldina cabri* Zone, these forms were not observed in the *Globigerinelloides ferreolensis* Zone of the stratigraphic section.

According to Premoli Silva and Verga (2004), abundance and size of species of *Globigerinelloides* and *Hedbergella* increase in the *Globigerinelloides ferreolensis* Zone. In lower and middle parts of the zone, the first thick-walled forms, like *Globigerinelloides barri* and *Hedbergella trocoidea* appear. The last representatives of genus *Leupoldina* extinct at the base of the *Globigerinelloides ferreolensis* Zone. Clavate forms are not as common as the *Leupoldina cabri* Zone.

Stratigraphic Distribution:

Globigerinelloides ferreolensis Zone is identified starting from sample NY-27 (after the LO of *Leupoldina cabri*) to the last sample of the section (sample NY-39).

Age: Late Aptian (Premoli Silva & Verga, 2004).

CHAPTER 3

MICROFACIES ANALYSES

3.1. Microfacies Types

Depositional facies model is an important criteria that have been described by case studies of ancient and modern sediments. Facies Zones (FZ) are belts which have been defined based on sedimentological and biological changes across shelf – slope – basin. The Standard Microfacies Types (SMF) concept emerged from the identification of resemblance in composition and texture of limestones in different age from analogous environments. New ideas related with carbonate models started by “X-Y-Z model” of Irwin (1965). This concept was developed by Flügel (1972) via categorizing Late Triassic platform and reef carbonates with respect to texture and paleontology. Then, Wilson (1975) broadened the concept with 9 Standard Facies Zones (FZ) and 24 Standard Microfacies Types (SMF) for separating major facies belts of an idealized rimmed carbonate shelf. Flügel (2004) defined 10 Facies Zones (FZ) and 26 Standard Microfacies Types (SMF) for the rimmed carbonate platform (Figure 3.3). Moreover, Flügel (2004) emerged 30 Ramp Microfacies Types (RMF) (Figure 3.4) (Flügel, 2010).

While defining the SMF Types, some criteria are used. These are grain types, grain frequencies, grain associations, matrix types, depositional fabrics, depositional texture types and fossil contents. Some SMF Types are simply defined with respect to principal and dominant grains. For instance, limestones containing abundant aggregate grains indicate a specific SMF Type. On the other hand, some SMF Types are determined based on characteristic ecological groups, like abundance of planktonic microfossils and reef – building fossils. In addition, the SMF Types were identified for a model describing sedimentation on rimmed carbonate shelf and warm water platform - reef environments in tropical latitudes. These SMF Types are based on water depth, topography and configuration of shelf. Also, the biggest contradiction occurs between the SMF Types and microfacies types of cold-water carbonates. Because of lack of aggregate grains and ooids, skeletal grain associations, skeletal mineralogy, weak cementation and texture, correlations between SMF Types and temperate, cool – water microfacies types are generally difficult (Flügel, 2010).

Firstly, carbonate rocks have been classified in order to define SMF Types. For carbonate classification, there are two important models by Dunham (1962) (Figure 3.1) and Folk (1959, 1962). Expanded carbonate classification model of Dunham (1962) by Embry and Klovan (1971) has been used in the study because Flügel (2010)'s key to the determination of SMF Types are according to this classification (Figure 3.2).

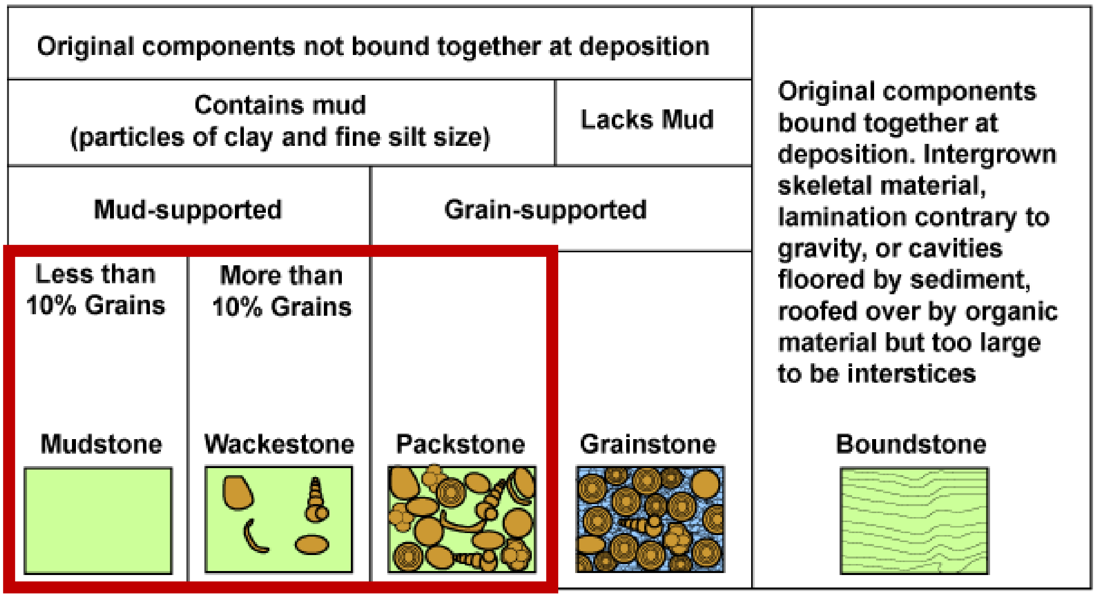


Figure 3.1. Carbonate classification (The ones that were observed in the study have been indicated) (modified from Dunham, 1962).

<table>
<tr><td colspan="6">Allochthonous limestone
original components not organically bound during deposition</td><td colspan="3">Autochthonous limestone
original components organically bound during deposition</td></tr>
<tr><td colspan="4">Less than 10% >2 mm components</td><td colspan="2">Greater than 10% >2 mm components</td><td colspan="3">Boundstone</td></tr>
<tr><td colspan="3">Contains lime mud (<0.02 mm)</td><td>No lime mud</td><td rowspan="3">Matrix supported</td><td rowspan="3">>2 mm component supported</td><td rowspan="3">By organisms which act as barriers</td><td rowspan="3">By organisms which encrust and bind</td><td rowspan="3">By organisms which build a rigid framework</td></tr>
<tr><td colspan="2">Mud supported</td><td colspan="2" rowspan="2">Grain supported</td></tr>
<tr><td>Less than 10% grains (>0.02 mm to <2 mm)</td><td>Greater than 10% grains</td></tr>
<tr><td>Mudstone</td><td>Wackestone</td><td>Packstone</td><td>Grainstone</td><td>Floatstone</td><td>Rudstone</td><td>Bafflestone</td><td>Bindstone</td><td>Framestone</td></tr>
</table>

Figure 3.2. Expanded carbonate classification of Dunham (1962) by Embry and Klovan (1971) (The ones that were observed in the study have been indicated).

After that, microfacies types of the Soğukçam Limestone have been defined for medium to thin bedded limestones containing pelagic content (planktonic foraminifera, radiolaria) with some benthic foraminifera, ostracoda and echinoids. While performing these, 40 limestone samples of the measured section were analysed. Because NY-5, NY-7S and NY-14 are shale samples, and NY-7D is a diabase dyke sample, these 4 samples are not the part of this microfacies analyses.

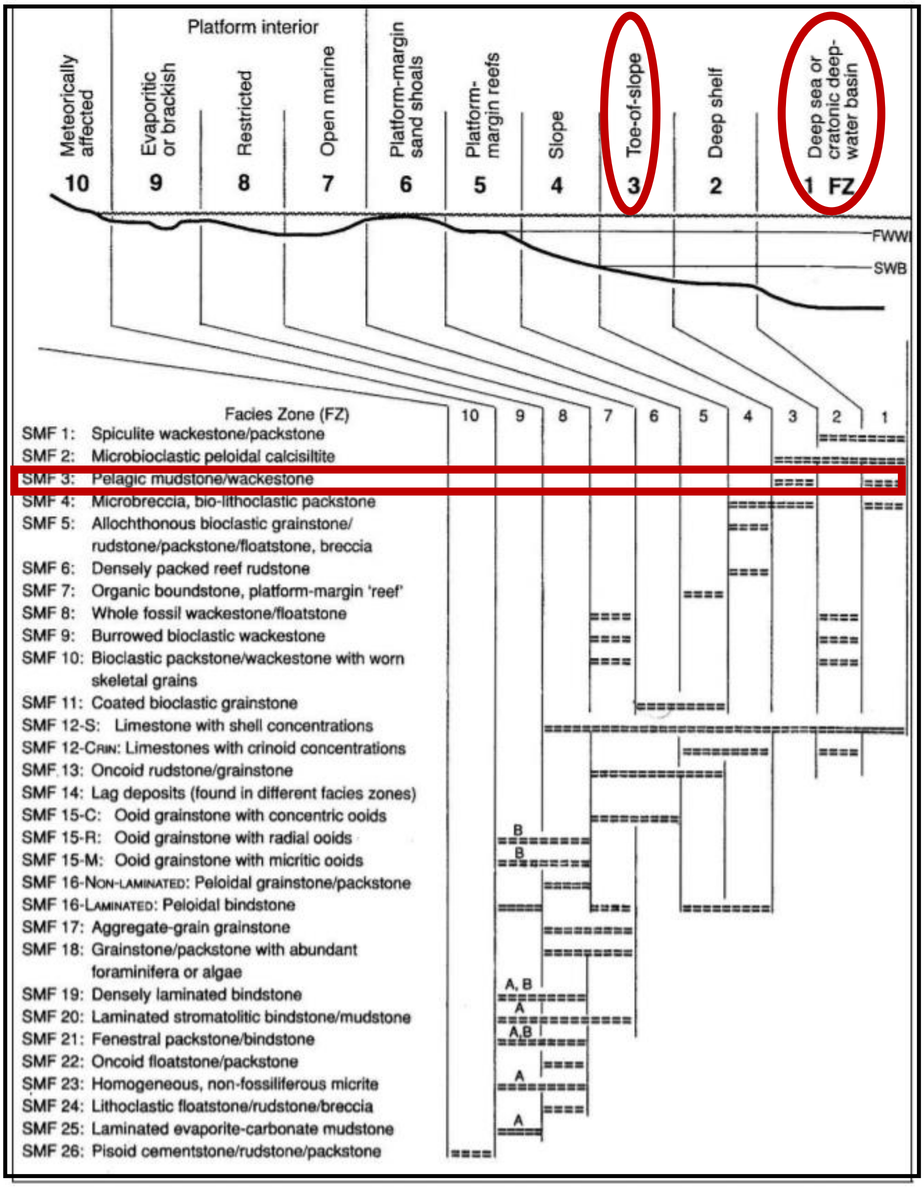


Figure 3.3. Distribution of Standard Microfacies Types (SMF) in Facies Zones (FZ) of rimmed type carbonate platforms (A: evaporitic, B: brackish) (The defined SMF Type and FZ of the study have been indicated) (modified from Flügel, 2010).

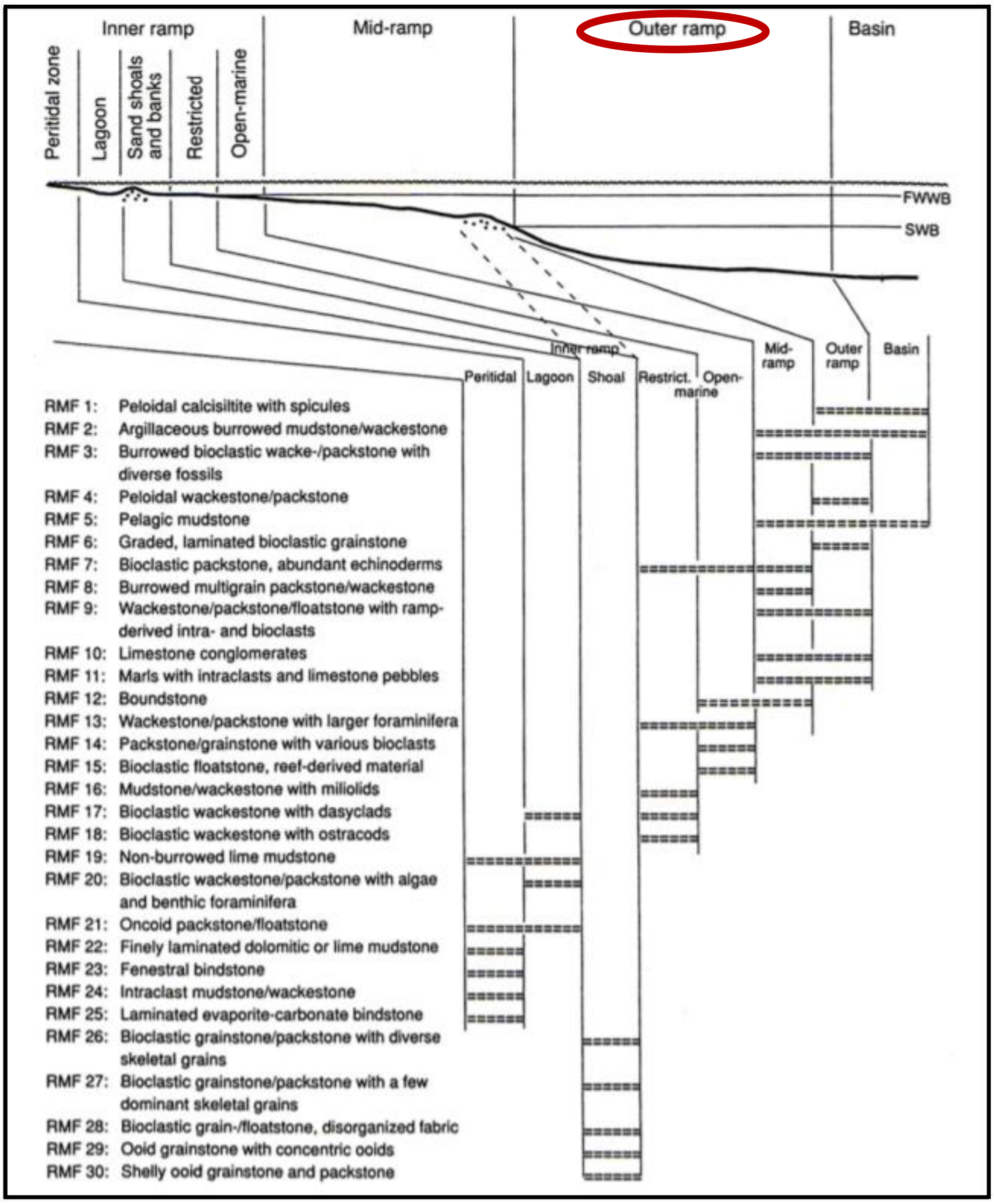


Figure 3.4. Generalized distribution of microfacies types in different parts of a homoclinal carbonate ramp (The defined part of the carbonate ramp have been indicated) (modified from Flügel, 2010).

3.1.1. MF-1: Radiolarian mudstone / wackestone

MF-1 microfacies is mainly composed of radiolarian-dominated limestone with rare planktonic foraminifera, *Lenticulina* sp., *Nodosaria* sp., *Textularia* sp., *Spirillina* sp. *Meandrospira* sp., Ataxophragmiidae, *Cadosina* sp., and ostracoda within micrite. The microfacies MF-1 has been defined in lower part of the section in samples NY-1, NY-2, NY-3, NY-4, NY-6, NY-7, NY-8, NY-9 and NY-10 (Figure 3.5). The contents of some samples are less than 10%, like NY-1 and NY-6 which are defined as mudstone with respect to Dunham (1962), and Embry and Klovan (1971). On the other hand, some samples from this microfacies include fossil content higher than 10%, and they are mud-supported, such as NY-3 and NY-8, that are classified as wackestone.

Based on the Standard Microfacies Types (SMF) of Flügel (2010), the microfacies MF-1 can be classified as SMF 3-RAD (pelagic radiolarians mudstone / wackestone) that indicates FZ-1 (deep sea or cratonic deep-water basin) and FZ-3 (toe of slope). With respect to the Ramp Microfacies Types of Flügel (2010), this microfacies type can indicate the distal part of outer ramp of a homoclinal carbonate ramp. Organic limestone exceedingly rich in radiolaria; limestone with radiolaria (Malanotte Valley, Lombardei, Italy) (Cita et al., 1959), radiolarian wackestone to packstone of the Czajakowa Radiolarite Formation (Pieniny Klippen Belt, Western Carpathians) (Jozsa & Aubrecht, 2008), radiolarian-rich wackestone microfacies; microfacies with radiolarians associated with rare planktonic and benthic foraminifers of M’cherga Formation (northeastern Tunisia) (Elkhazri et al., 2013), microfacies 1: radiolarian microfacies of the Pons Formation (Sierra de los Organos, western Cuba) (Pszczolkowski et al., 2013), radiolarian wackestone and packstone with rare planktonic foraminifera of Dariyan Formation (southwestern Iran) (Yavari et al., 2017) might be similar microfacies in Aptian with MF-1 in this study.

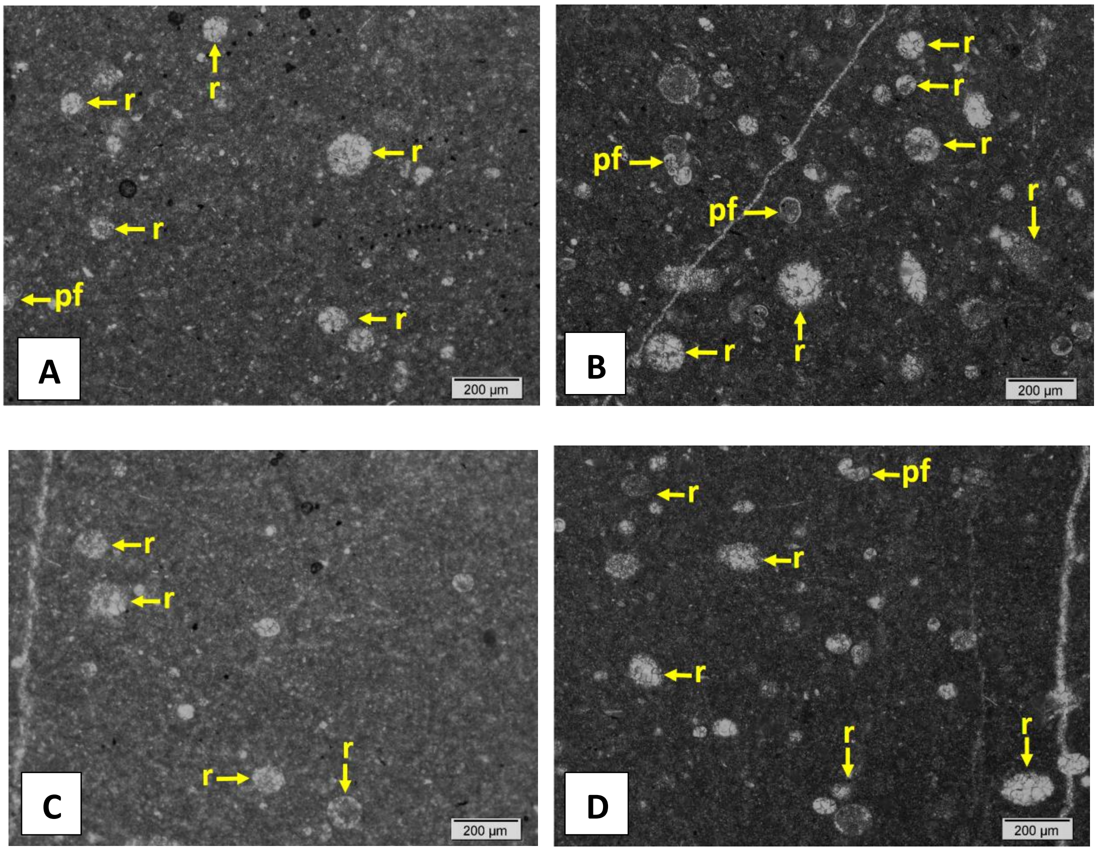


Figure 3.5. MF-1: Radiolarian mudstone / wackestone. (4x) A) NY-1, B) NY-3, C) NY-6, D) NY-9; r: radiolaria, pf: planktonic foraminifera.

3.1.2. MF-2: Planktonic foraminiferal and radiolarian wackestone / packstone

MF-2 microfacies is pelagic limestone that is characterized by both planktonic foraminifera and radiolaria dominated wackestone to packstone. This microfacies type is defined mostly in the middle part of the section in samples NY-11, NY-12, NY-13, NY-15, NY-16, NY-17, NY-18, NY-27, NY-28, Slump 1-3, Slump 1-2, Slump 1-1, NY-29, NY-30, NY-31 and NY-32. The samples also contains rare *Lenticulina* sp., *Nodosaria* sp., *Textularia* sp., *Spirillina* sp. *Patellina* sp., *Meandrospira* sp., *Cadosina* sp., sponge spiculae, echinoid and ostracoda within micrite (Figure 3.6). Different from the microfacies MF-1, all samples of this microfacies types have fossil contents higher that 10%. Even some of the samples are grain supported that are classified as packstone based on Dunham (1962), and Embry and Klovan (1971). Although radiolaria is the only dominant form of the microfacies MF-1, both planktonic foraminifera and radiolaria are dominant in the microfacies MF-2.

With respect to the Standard Microfacies Types (SMF) of Flügel (2010), the microfacies MF-2 can be classified as SMF-3 (pelagic mudstone / wackestone) that indicates FZ-1 (deep sea or cratonic deep-water basin) and FZ-3 (toe of slope). According to the Ramp Microfacies Types of Flügel (2010), this microfacies type can be defined from the distal outer ramp of a homoclinal carbonate ramp. Facies association C: Bioclastic wackestones and packstones containing radiolarians, planktonic foraminifers and sponge spicules of Hamada Formation (North-central Tunisia) (Heldt et al., 2008), radiolarian – foraminiferal wackestone of the Pieniny Limestone Formation (Pieniny Klippen Belt, Western Carpathians) (Jozsa & Aubrecht, 2008), MA-15: Wackestone and packstone with extremely abundant radiolaria, common planktonic foraminifera, and ostracods, and rare pelecypods and ammonites fragments (Sierra del Rosario, eastern Durango state, Mexico) (Nunez-Useche & Barragan, 2012), microfacies with abundant radiolarians and planktonic foraminifers of M'cherga Formation (northeastern Tunisia) (Elkhazri et al., 2013), microfacies 3: radiolarian-foraminiferal microfacies of the Pons Formation (Sierra de los Organos, western Cuba) (Pszczolkowski et al., 2013) might be similar microfacies in Aptian with MF-2 of the study.

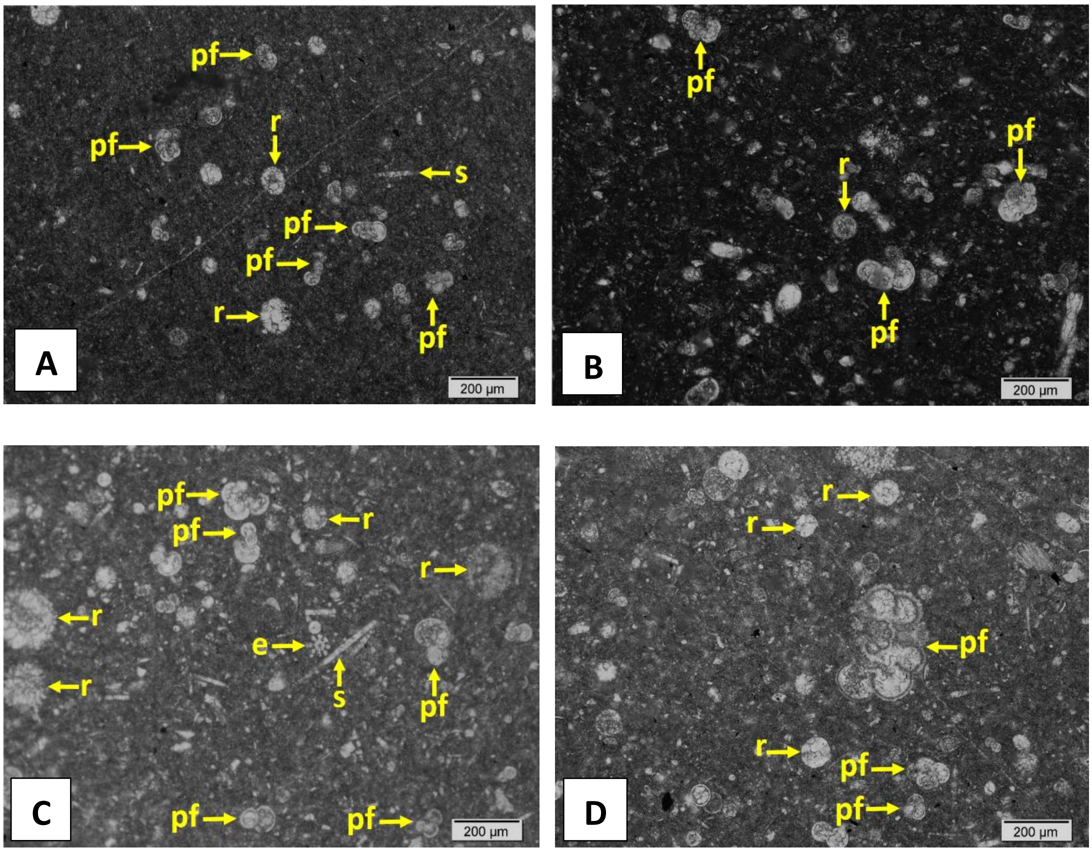


Figure 3.6. MF-2: Planktonic foraminiferal and radiolarian wackestone / packstone. (4x) A) NY-11, B) NY-28, C) Slump 1-2, D) NY-30; r: radiolaria, pf: planktonic foraminifera, s: sponge spicules.

3.1.3. MF-3: Planktonic foraminiferal mudstone / wackestone

Pelagic limestones in MF-3 microfacies are characterized by planktonic foraminifera-dominated mudstone to wackestone within micrite. This microfacies type also contains rare radiolaira, *Lenticulina* sp., *Nodosaria* sp., *Textularia* sp., *Spirillina* sp. *Meandrospira* sp., Ataxophragmiidae, *Cadosina* sp, ostracoda and echinoid. MF-3 has been defined in the middle part of the section in samples NY-19, NY-20, NY-21, NY-22, NY-23, NY-24, NY-25 and NY-26, and in the upper part of the section in samples NY-33, NY-34, NY-35, NY-36, NY-37, NY-38, and NY-39 (Figure 3.7). Like the microfacies MF-2, planktonic foraminifera is the dominant form of the microfacies. The microfacies MF-2 is also radiolaria-rich, but MF-3 contains rare radiolaria. In addition, samples of the microfacies MF-3 are mud-supported, and some samples contains grains less than 10% which are defined as mudstone. There is no sample that are grain-supported and can be defined as packstone, like MF-2.

According to the Standard Microfacies Types (SMF) of Flügel (2010), the microfacies MF-3 can be classified as SMF 3-FOR (pelagic foraminifera mudstone / wackestone) that indicates FZ-1 (deep sea or cratonic deep-water basin) and FZ-3 (toe of slope). Moreover, this microfacies type can be defined from the distal part of outer ramp of a homoclinal carbonate ramp. Facies association A: Silty bioclastic wackestones and packstones containing planktonic, small benthic foraminifers and ostracods; Facies association B: Bioclastic to peloidal packstone containing planktonic, small benthic foraminifers and quartz grain; Facies association D: Mudstones containing planktonic, small benthic foraminifers and ostracods; Facies association E: Mudstones and bioclastic wackestones containing planktonic, small benthic foraminifers and ostracods of Hamada Formation (North-central Tunisia) (Heldt et al., 2008), MA-13: Dark, organic-rich wackestone and mudstone with sulphur minerals (Sierra del Rosario, eastern Durango state, Mexico) (Nunez-Useche & Barragan, 2012), wackestone with planktonic foraminifera; lime mudstone with planktonic foraminifera of Soğukçam Limestone (Mudurnu region, central Turkey) (Hu et al., 2012), microfacies with planktonic foraminifers, rare benthic foraminifers and rare spherical radiolarians of M'cherga Formation (northeastern Tunisia) (Elkhazri et al., 2013), microfacies 2: foraminiferal microfacies of the Pons Formation (Sierra de los Organos, western Cuba) (Pszczolkowski et al., 2013), wackestone facies dominated by planktonic foraminifera of Garau Formation (northwest of Zagros, Iran) (Ezampanah et al., 2013), biomicrite with planktonic foraminifera (planktonic foraminiferal mudstone) of the Parnica Formation (western Carpathians) (Jozsa et al., 2016), planktonic foraminifers wackestone of Dariyan Formation (southwestern Iran) (Yavari et al., 2017) might be similar microfacies in Aptian with MF-3 of the study.

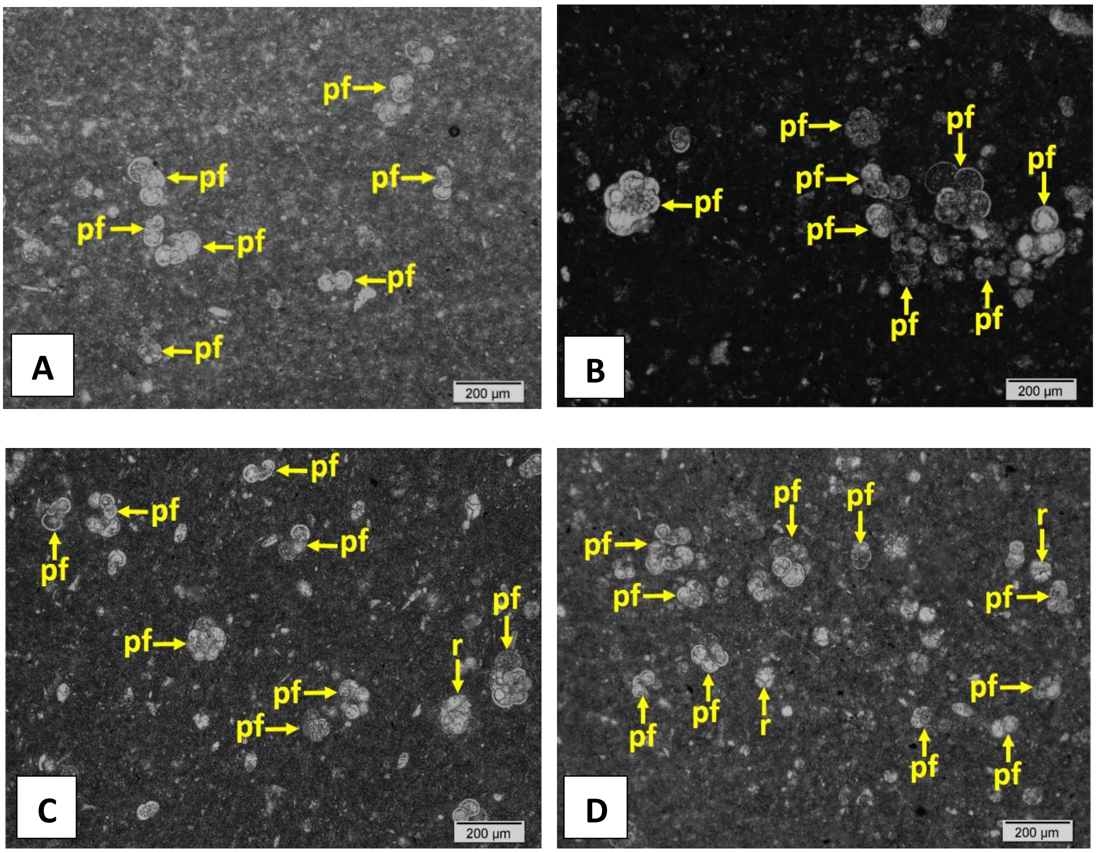


Figure 3.7. MF-3: Planktonic foraminiferal mudstone / wackestone. (4x) A) NY-20, B) NY-25, C) NY-38, D) NY-39; r: radiolaria, pf: planktonic foraminifera.

3.2. Depositional Environments

The Soğukçam Limestone in the Nallıhan area is determined as deposited between toe of slope and deep-water basin with respect to Flügel (2004)'s rimmed type carbonate platforms due to the high planktonic foraminifera and radiolaria content of the pelagic limestones (Table 3.1). After applying microfacies analyses to limestone samples of the section, the Standard Microfacies Types of MF-1, MF-2 and MF-3 are defined as SMF 3-RAD, SMF-3 and SMF 3-FOR, respectively.

When the microfacies types are added to the measured section, this can be understood that the section from the Soğukçam Limestone in the Nallıhan area starts with radiolaria dominated microfacies. The microfacies type of the level between NY-1 and NY-10 is defined as MF-1 (radiolarian mudstone / wackestone). The succession continues with both planktonic foraminifera and radiolaria-rich wackestone / packstone (MF-2) starting from NY-11 to NY-18. Next, radiolaria lost their dominance, and planktonic foraminifera-rich mudstone / wackestone (MF-3) was defined up to NY-26 which is the LO of low-oxygen form *Leupoldina cabri*. After that, both planktonic foraminifera and radiolaria-dominated MF-2 started to be observed with NY-27. This level equals to the starting point of the *Globigerinelloides ferreolensis* Zone in the area. The microfacies MF-2 continues up to NY-32. Then, again MF-3 maintains through the end of the stratigraphic section (Figure 3.8). The increase in abundance of planktonic foraminifera in the upper layers of the Soğukçam Limestone in the Nallıhan area was previously noted by Özkan (1993a). Altıner et al. (1991) said slump and diabase dykes that were also observed in this study indicate tectonic activity in basin in the Mudurnu – Nallıhan Sequence of the Nallıhan area. Based on Şengör and Yılmaz (1981), the slump structure in pelagic deposits of the Soğukçam Limestone indicated an increase in submarine relief.

Table 3.1. *Microfacies types of the studied section from the Nallıhan area.*

Depositional Environment	**Microfacies Type**	**Definition**	**Features**	**Standard Microfacies Types (SMF) (Flügel, 2010)**	**Facies Zone (FZ) (Flügel, 2010)**	**Sample No**
Toe of slope to deep-water basin	MF-1	Radiolarian mudstone / wackestone	Abundant radiolaria with rare planktonic foraminifera, *Lenticulina* sp., *Nodosaria* sp., *Textularia* sp., *Spirillina* sp. *Meandrospira* sp., *Cadosina* sp., Ataxophragmiidae and ostracoda	SMF 3-RAD	FZ-1, FZ-3	NY-1, NY-2, NY-3, NY-4, NY-6, NY-7, NY-8, NY-9, NY-10
Toe of slope to deep-water basin	MF-2	Planktonic foraminiferal and radiolarian wackestone / packstone	Abundant planktonic foraminifera and radiolaria with rare *Lenticulina* sp., *Nodosaria* sp., *Textularia* sp., *Spirillina* sp. , *Patellina* sp., *Meandrospira* sp., *Cadosina* sp., sponge spicules, echinoid and ostracoda	SMF-3	FZ-1, FZ-3	NY-11, NY-12, NY-13, NY-15, NY-16, NY-17, NY-18, NY-27, NY-28, Slump 1-3, Slump 1-2, Slump 1-1, NY-29, NY-30, NY-31, NY-32
Toe of slope to deep-water basin	MF-3	Planktonic foraminiferal mudstone / wackestone	Abundant planktonic foraminifera with rare radiolaria, *Lenticulina* sp., *Nodosaria* sp., *Textularia* sp., *Spirillina* sp. , *Meandrospira* sp., *Cadoosina* sp., Ataxophragmiidae, echinoid and ostracoda	SMF 3-FOR	FZ-1, FZ-3	NY-19, NY-20, NY-21, NY-22, , NY-23, NY-24, NY-25, NY-26, NY-33, NY-34, NY-35, NY-36, NY-37, NY-38, NY-39

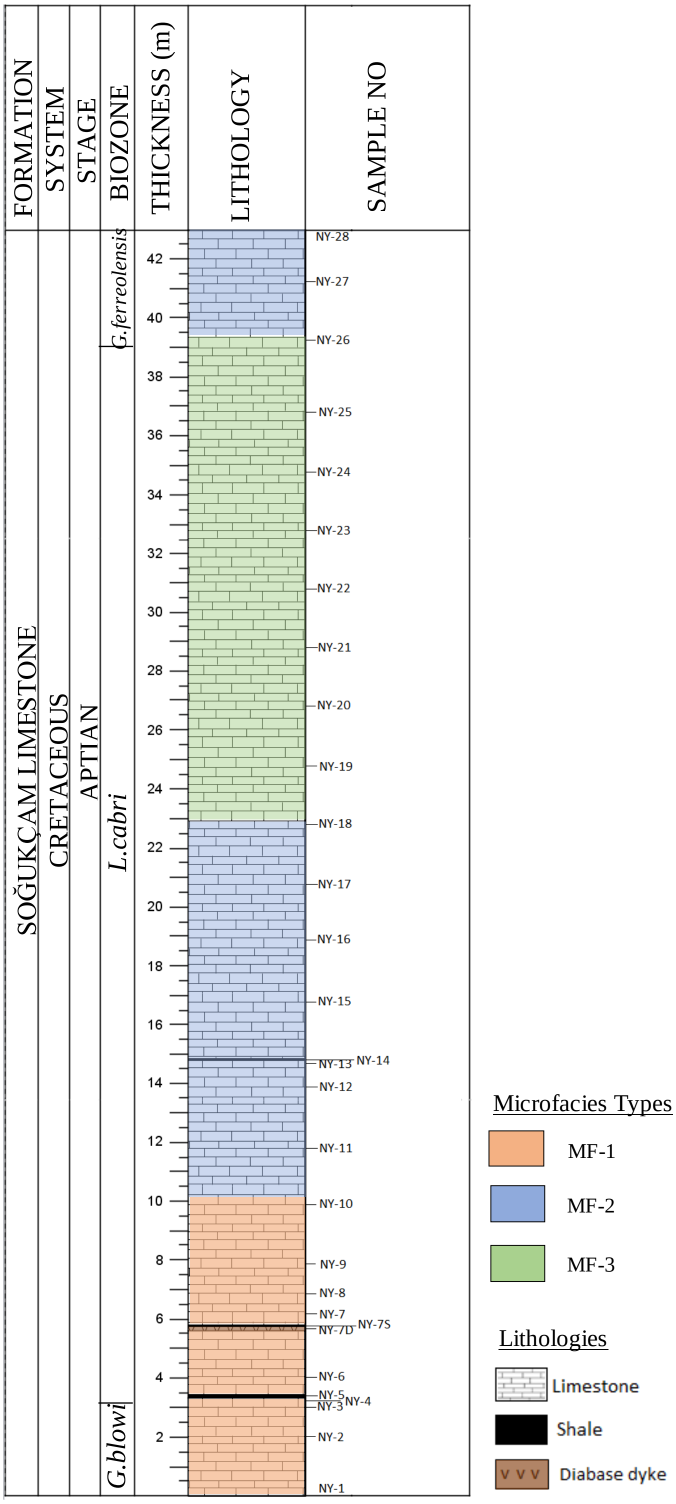


Figure 3.8. Measured stratigraphic section (NY section) of the Soğukçam Limestone in the Nallıhan area with microfacies types (Shale samples: NY-5, NY-7S, NY-14; Diabase dyke sample: NY-7D).

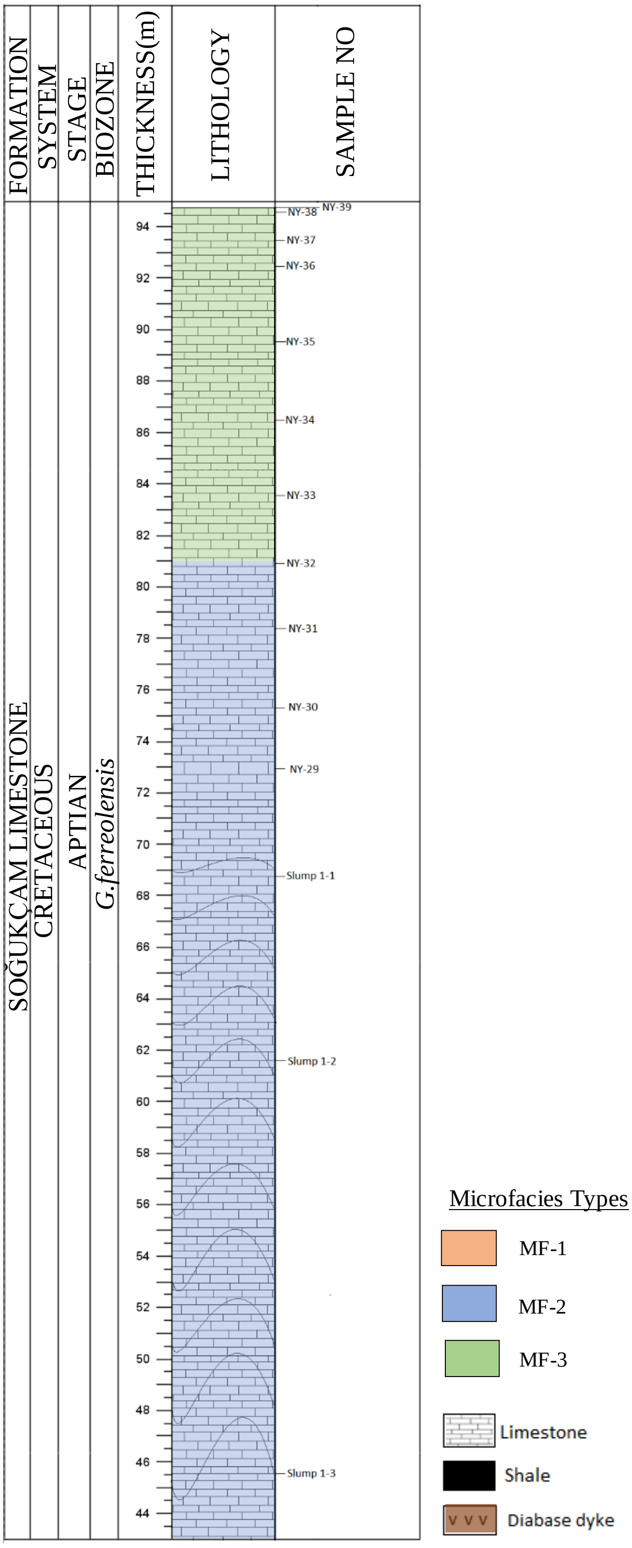


Figure 3.8. continued.

3.3. Mineral Contents

Although the main purpose of this study is to establish the biostratigraphic zonation, the microfacies analysis has been carried out to define the depositional environment of the studied sequence. During the microfacies analysis, the presence of some important minerals, such as pyrite and glauconite, were also recorded. These minerals could be used for explanation of the global biotic and paleoceanographic event recorded in the studied samples.

Mineral that was thought as pyrite framboids are observed in the samples of measured section. Nevertheless, any chemical analysis has not been applied, so this observation just depends on the thin section analysis by the microscope. They have been observed in samples NY-2, NY-9, NY-12, NY-14, Slump 1-3 and Slump 1-2 in the section (Figure 3.9). There are some investigations of this mineral related with oceanic anoxic events of Cretaceous. Based on Yılmaz et al.'s (2010) study about OAE 2 (Cenomanian – Turonian Oceanic Anoxic Event) in the Sakarya Zone, pyrite framboids seems attached to the wall of planktonic foraminifera's chambers. Bellanca et al. (2002) also saw pyrite framboids in black shale that is from the upper part of the Selli equivalent interval in the Hybla Formation, northwestern Sicily. Hu et al. (2012) observed pyritized radiolaria in the Selli Event equivalent black shale level in the Mudurnu area.

In addition, glauconite has been observed in thin section samples of NY-18 (Figure 3.10), NY-22 and NY-25. This mineral was observed in other studies related with oceanic anoxic events. Hu et al. (2012) observed glauconite in silty black shale in the Mudurnu region of the northwestern Turkey. As results of carbon and oxygen isotope analyses, this black shale was found as in the Selli equivalent level with high TOC (Total organic carbon) values in Hu et al. (2012)'s study. Lehmann et al. (2012) observed glauconitic marl just above the Selli equivalent level at southern margin of the Lower Saxony Basin in the northern Germany. Based on Huck et al. (2010), siliciclastic glauconite-rich sedimentary rocks alternation with more argillaceous intervals was in the Lower Aptian part of the Garschella Formation in the Subalpine Chains. Pictet et al. (2015) observed glauconite above the Selli Event equivalent level in Ardeche, France. With respect to the study of Michalik et al. (2008), glauconite grains were in black to dark brown clays in the Konhora Formation which was just below the Selli Level in the Pieniny Klippen Belt in Slovak Western Carpathians.

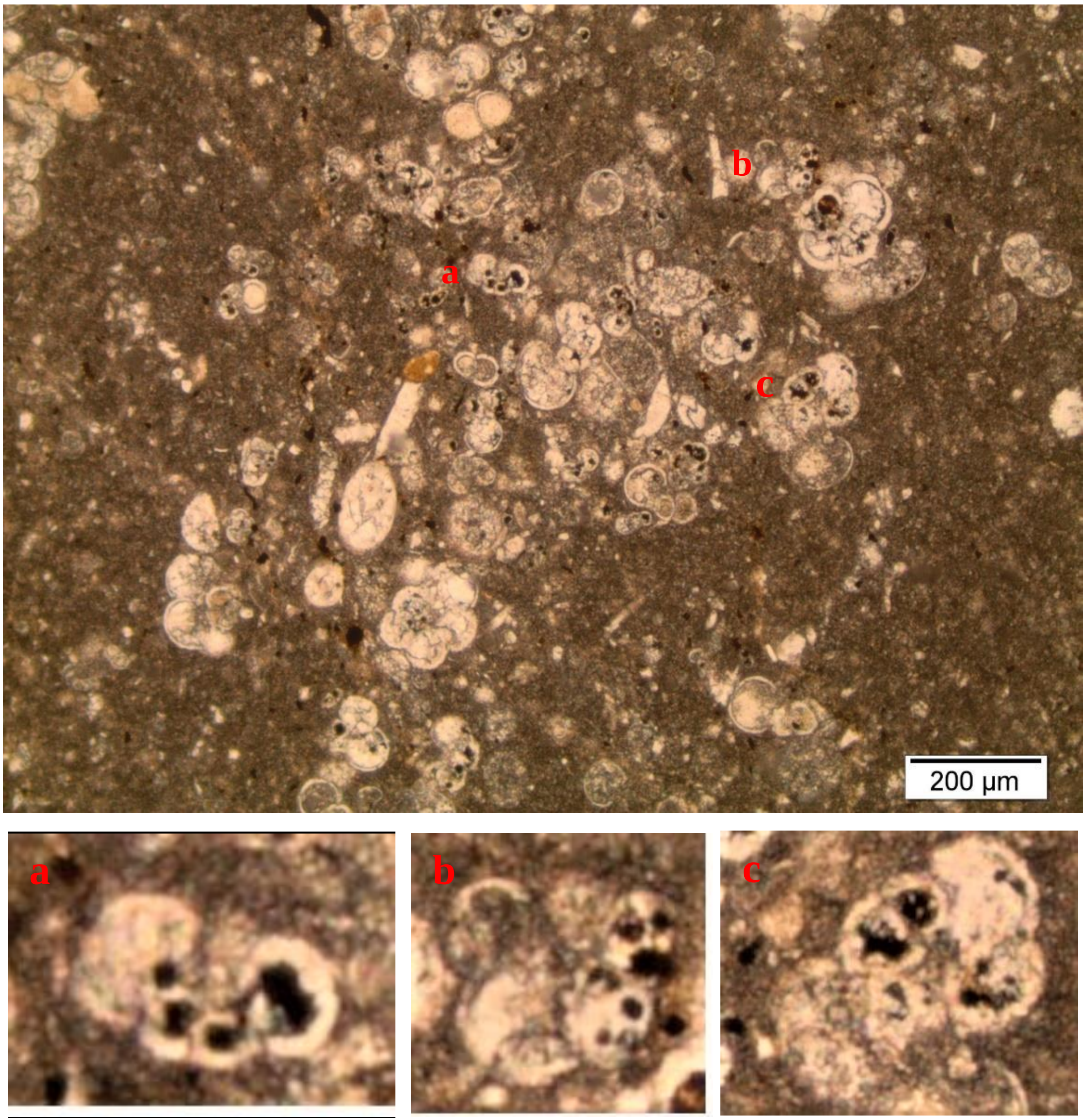


Figure 3.9. Pyrite framboids that attached to the wall of planktonic foraminifera's chambers from sample Slump 1-3.

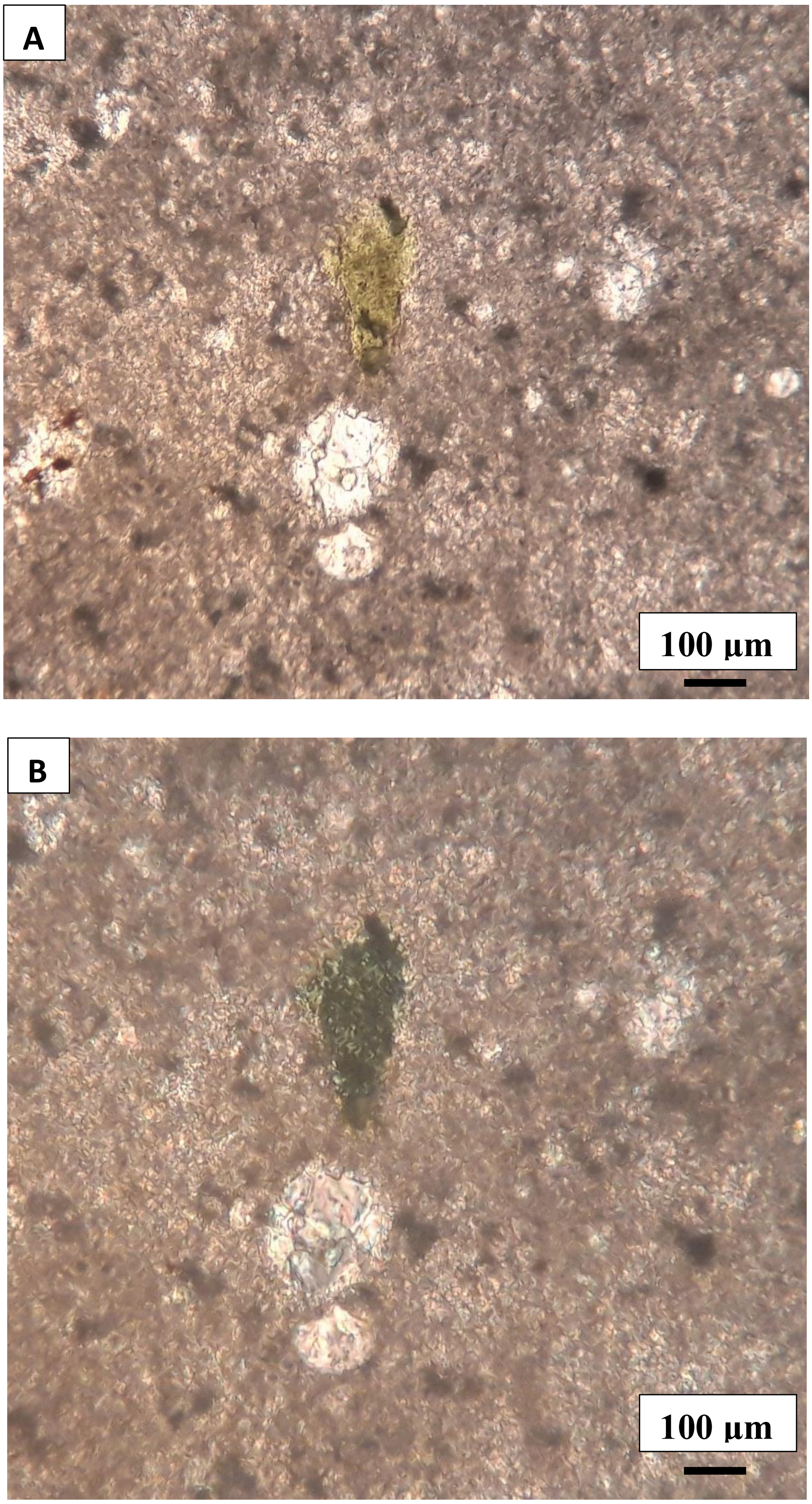


Figure 3.10. Glauconite in sample NY-18. A: Analyser out image, B: Analyser in image.

The dyke sample (NY-7D) was examined under the microscope. Then, it has been defined having basaltic composition with aphanitic (fine grained) texture. The sample was altered. Moreover, plagioclase and olivine were observed, but they are not in their primary composition due to alteration. Chlorite was also recognized in the sample under the microscope. Any impact of metamorphism and deformation was not seen in the sample.

CHAPTER 4

APTIAN PALEONTOLOGICAL DATA FOR THE GLOBAL BIOTIC AND PALEOCEANOGRAPHIC EVENTS

A series of global events had been experienced in the Cretaceous time period (145 – 65 Ma). During that time, there were several intervals with low oxygen content in oceans. These short intervals are called as oceanic anoxic events (OAEs). Early Aptian (120 Ma) was characterized by one of these OAEs. This event is the OAE 1a (the Selli Event) (Figure 4.1). The duration of this event is around 1 m.y. (Larson & Erba, 1999). It was defined at the Maiolica and Marne a Fucoidi pelagic formations transitions in Umbria-Marche, central Italy (Wezel, 1985), and named as "Livello Selli" (Coccioni et al., 1987). This type locality contains organic matter-rich laminated black shales and radiolarian silts alternations. The thickness is between 1 and 3 m (Premoli Silva et al., 1999). In addition, the Selli Event equivalent level was named as "Niveau Goguel" in France (Breeheret, 1988).

The relation between huge amount of oceanic volcanism in Cretaceous and other geological anomalies of that time has been explained as a result of large igneous activities by Schlanger and Jenkyns (1976), Schlanger et al. (1981), Larson (1991a, 1991b), Tarduno et al. (1991), Larson and Erba (1999), Jenkyns (2010) and Robinson et al. (2017). Between these OAEs, the Selli Event was characterized by greenhouse climates which due to increase in CO_2 levels. The causes of this greenhouse condition can be related with the formation of large igneous provinces at that time. In the Pacific Ocean, the Ontong Java Plateau, the Manihiki Plateau and the Nova Canton Trough, between these two plateaus, characterized the Early Aptian time (Larson, 1991a, 1991b; Bralower et al., 1997; Larson & Erba, 1999; Jones & Jenkyns, 2001; Wignall, 2001; Jahren, 2002; Tremolada et al., 2007). This theory has been supported by radiometric and biostratigraphic dating in Larson and Erba (1991). Based on this, the

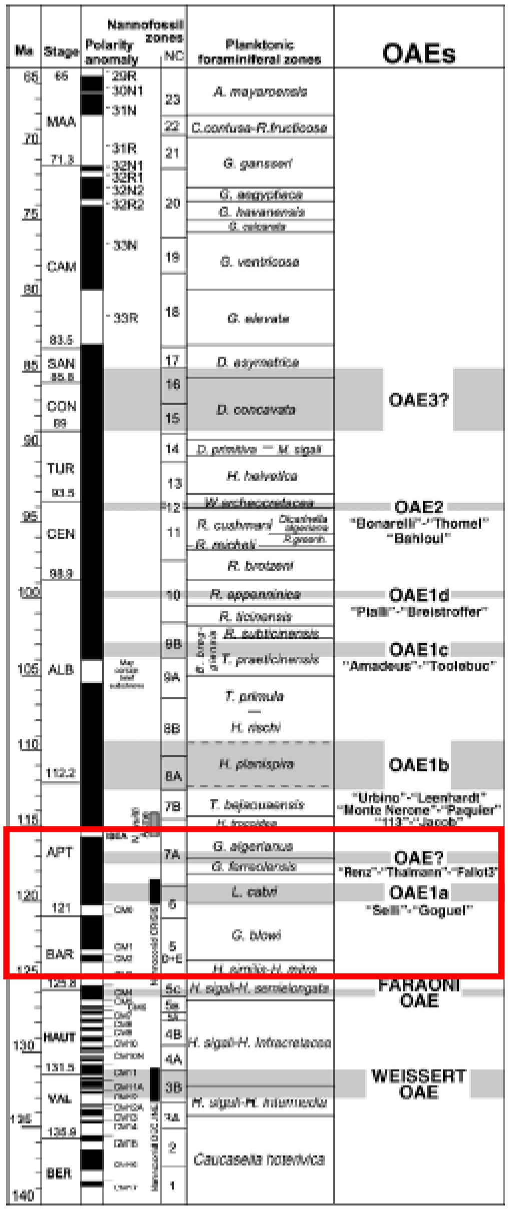


Figure 4.1. Cretaceous OAEs of the Mediterranean Tethys. Time scale after Hardenbol et al. (1998). OAEs modified after Leckie et al. (2002) and Erba (2004). Planktonic foraminiferal zones after Coccioni and Premoli Silva (1994), Premoli Silva and Sliter (1994), Coccioni and Marsili (2004), and Premoli Silva and Verga (2004). Calcareous nannofossils zones after Bralower et al. (1995) (Coccioni et al., 2006).

Ontong Java Plateau and the Manihiki Plateau were dated generally between 125 and 120 Ma which means this interval might indicate the onset of the Selli Event.

According to hypothesis, major control on Cretaceous climate is abundance of CO_2 on the atmosphere. For this reason, current model for oceanic anoxic events (OAEs) starts with CO_2 on the atmosphere that leads to greenhouse effect (Gerard & Dols, 1990; Barron et al., 1993; Jenkyns, 2003, 2010) (Figures 4.2 and 4.3). The effect of carbon release on OAEs might be explorable via carbon-isotope data as negative excursion. As a consequence of sources, like volcanism and methane, hydrates which are isotopically lighter than the ocean-atmosphere carbon reservoir, carbon-isotope data show negative excursion at the beginning of OAEs (Jahren & Arens, 1998; Opdyke et al., 1999; Jahren et al., 2001; Beerling et al., 2002) (Figure 4.4). The negative excursion in carbon-isotope values was generally found near the base of the Selli Event in several localities (Menegatti et al., 1998; Weissert & Erba, 2004; Kuhnt et al., 2011; Stein et al, 2011; Hu et al., 2012; Erba et al., 2016; Li et al, 2016). In addition, greenhouse warming which is onset of OAEs has other effects on increase in organic-carbon deposition (Schlanger & Jenkyns, 1976; Arthur & Schlanger, 1979; Jenkyns, 1980, 1999, 2010; Arthur & Sageman, 1994; Bralower et al., 1994, 1999; Menegatti et al., 1998; Leckie et al., 2002; Erba, 2004; Li et al., 2016; Robinson et al., 2017), such as stratification of restricted basin, nutrient delivering by run-off and wind-driven upwelling (Weissert, 1989; Caldeira & Rampino, 1991; Weissert et al., 1998; Weissert & Erba, 2004; Robinson et al., 2017). Furthermore, nutrience might be taken via the effect of alterations in basalts (Larson & Erba, 1999; Robinson et al., 2017). With the increase in fluvial nutrient flux in the ocean and upwelling by wind velocities, plankton productivity increases (Jenkyns, 1999, 2010). Other source of nutrients has been alteration of basalt via eruption of large igneous provinces. Then, deposition of black shales related with the OAEs resulted from productivity increase and expansion of oxygen-minimum zones. This burial of organic carbon shows positive excursion on carbon-isotope data with elimination of isotopically light inputs (Bralower et al., 1994; Menegatti et al., 1998; Jenkyns, 2010; Robinson et al., 2017).

This reversal in carbon-isotope data might be result from reversal of greenhouse conditions with terminating the OAEs. At the same time, nutrients depleted from the oceans. Consequently, productivity and carbon burial rate also declines with the end of OAEs (Jenkyns, 1999). However, there are some differences between this conceptual model and the Selli Event. In the OAE 1a, positive excursion on carbon-isotope data from black shale show continuous trend even after black shale deposition has been finished (Menegatti et al., 1998; Kuhnt et al., 2011; Stein et al., 2011; Hu et al., 2012; Li et al., 2016; Robinson et al., 2017) (Figure 4.4).

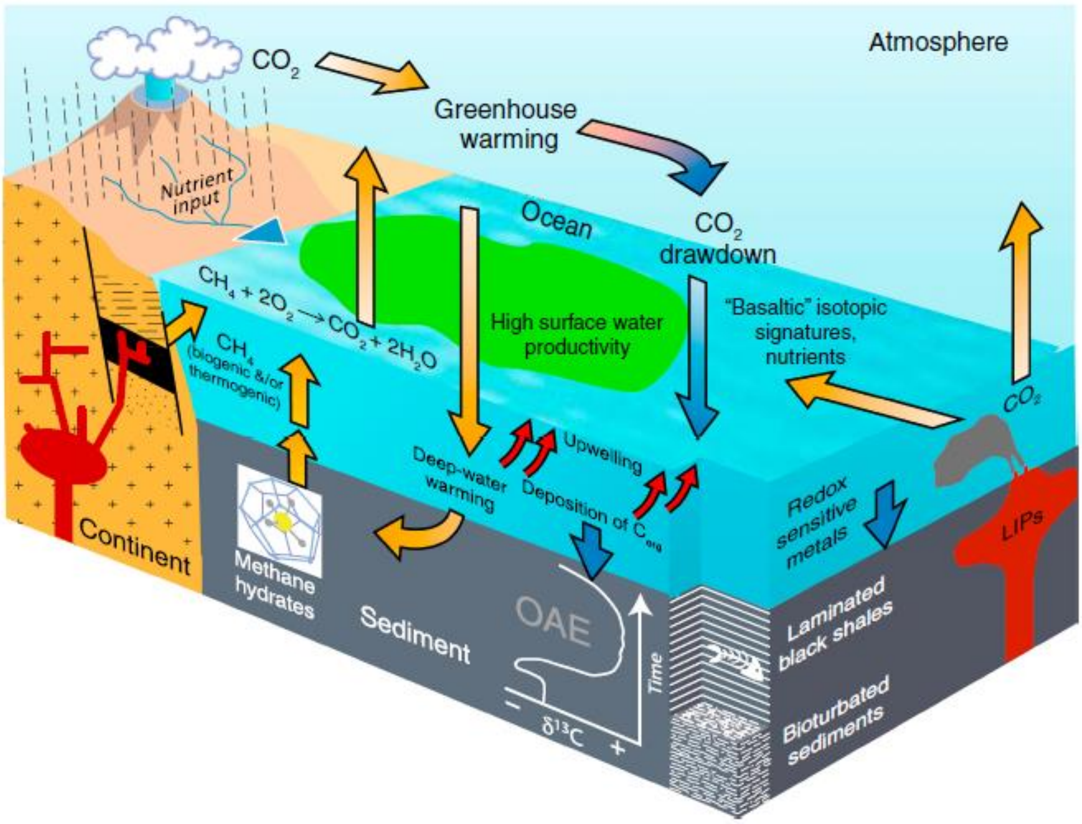


Figure 4.2. Illustration of processes that lead to oceanic anoxic events (Weissert, 2000; Jenkyns, 2003, 2010; Robinson et al., 2017).

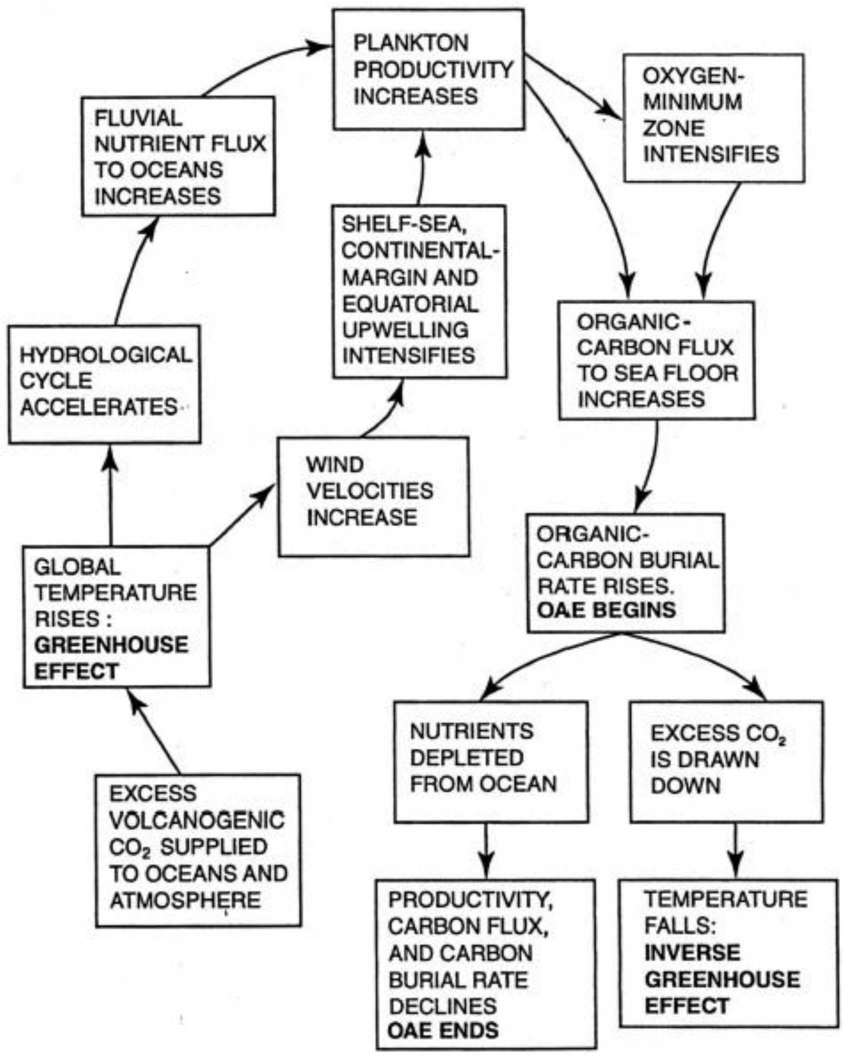


Figure 4.3. Suggested series of events leading to oceanic anoxic event (Jenkyns, 1999).

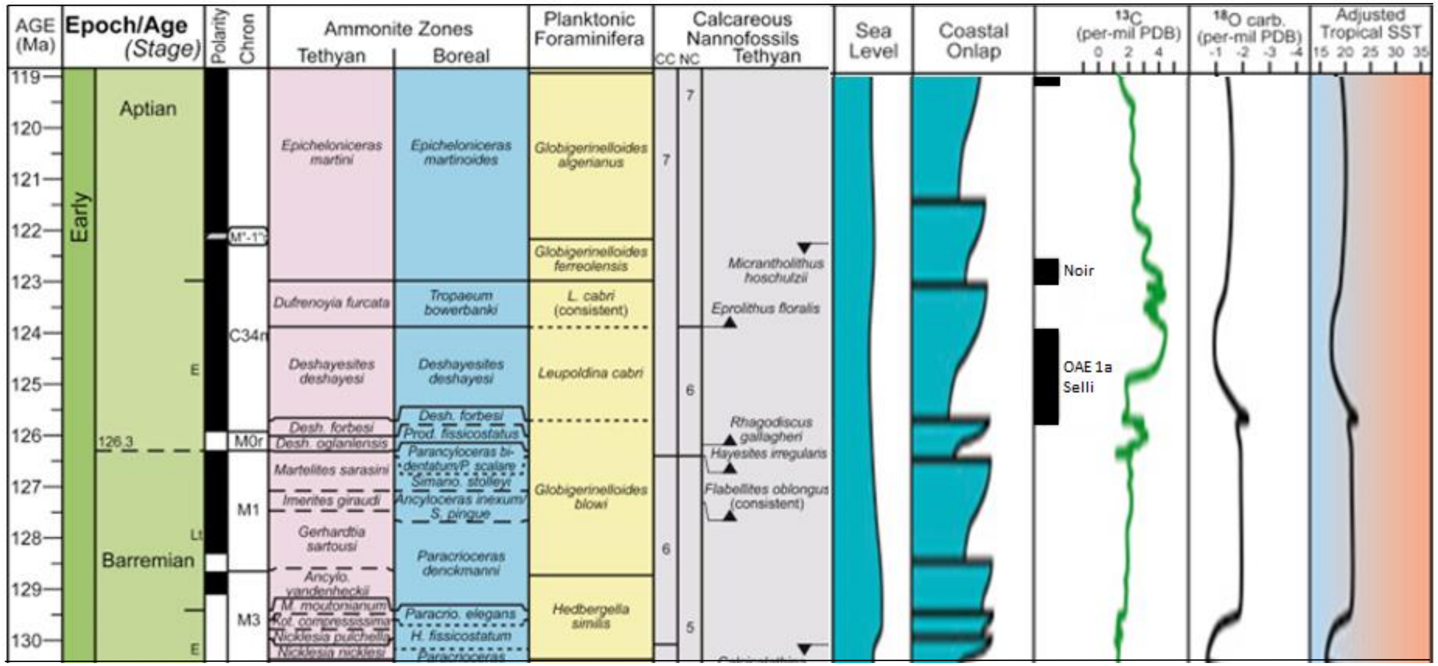


Figure 4.4. Geological time scale from Barremian and Aptian containing planktonic foraminiferal zones and stable carbon isotope values (Ogg et al., 2016).

During the Selli Event (the OAE 1a), climate had control over some organisms. These developments can be seen on morphologies, abundances, diversities and distributions of organisms. These changes in organisms in Aptian, especially planktonic foraminifera, radiolaria and nannofossils (Figure 4.5), have been defined in different studies (Coccioni et al, 1987; Sliter, 1989, 1999; Altıner, 1991; Altıner et al., 1991; Coccioni et al., 1992; Bralower et al., 1993, 1994; Erba, 1994; Erbacher et al., 1996; BouDagher-Fadel et al., 1997; Erbacher & Thurow, 1997; Larson & Erba, 1999; Premoli Silva & Sliter, 1999; Premoli Silva et al., 1999; Leckie et al., 2002; Moullade et al., 2002; Tremolada & Erba, 2002; Erba, 2004; Erba & Tremolada, 2004; Coccioni et al., 2006; Tremolada et al., 2007; de Gea et al., 2008; Heldt et al., 2008; Michalik et al, 2008; Kopaevich & Gorbachik, 2017).

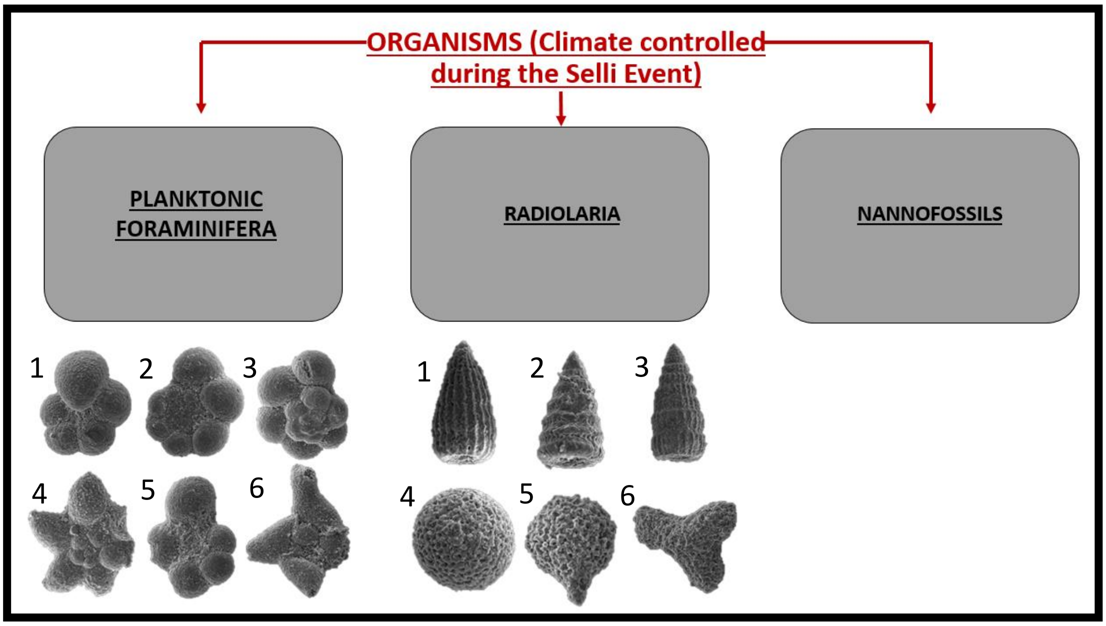


Figure 4.5. Organisms that were controlled by climate during the Selli Event. Planktonic foraminifera: 1. *Hedbergella infracretacea* (pl.2, fig.g); 2. *Hedbergella luterbacheri* (pl.2, fig.i); 3. *Hedbergella occulta* (pl.3, fig.c); 4. *Hedbergella roblesae* (pl.4, fig.d); 5. *Hedbergella similis* (pl.4, fig.i); 6. *Leupoldina cabri* (pl.6, fig.e). Radiolaria: 1. pl.9, fig.g; 2. pl.9, fig.k; 3. pl.9, fig.i; 4. pl.10, fig.a; 5. pl.10, fig.f; 6. pl.10, fig.k.

Planktonic foraminifera evolution in records of Cretaceous is composed of diversification and stasis periods. However, these intervals trends were interrupted by faunal turnover and brief extinctions. The first continuous diversification trend of Cretaceous was interrupted by a moderated turnover near the Selli Event in Aptian (Premoli Silva & Sliter, 1999).

In general, organisms can be classified with respect to their life-history strategies or their reproductive potential as r-mode opportunists, K-mode specialists or r/K-mode intermediate (MacArthur & Wilson, 1967; Valentine, 1973). r-mode opportunists have high reproductive potential, and they inhabit more nutrient-rich waters close to eutrophic side of resource spectrum. K-mode specialists inhabit in highly stable and oligotrophic environments. Organisms that are between these two life-mode strategies are called as r/K-mode intermediate forms. They adapted to mesotrophic environments. The size of planktonic foraminifers is often related to life-history strategies of them (Hallock, 1985). For example, small foraminifers are mostly r-mode opportunists, and large foraminifers are generally K-mode specialists. In addition, r-mode opportunistic planktonic foraminifers mostly have more simple morphology. Number of these species increase rapidly when nutrients get available. On the other hand, K-mode specialist planktonic foraminifers have more advance morphology (Caron & Homewood, 1983; Hallock et al., 1991) (Figure 4.6). Planktonic foraminiferal assemblages in the Selli Event equivalent level contain only r-mode opportunistic organisms between these life-history strategists' forms. These r-mode opportunistic forms are *Hedbergella* and *Globigerinelloides* in this study. In species level, the recorded forms are *Globigerinelloides blowi, Globigerinelloieds duboisi, Globigerinelloides ferreolensis, Hedbergella excelsa, Hedbergella infracretacea, Hedbergella luterbacheri, Hedbergella mitra, Hedbergella occulta, Hedbergella roblesae, Hedbergella sigali* and *Hedbergella similis* (Figure 4.7).

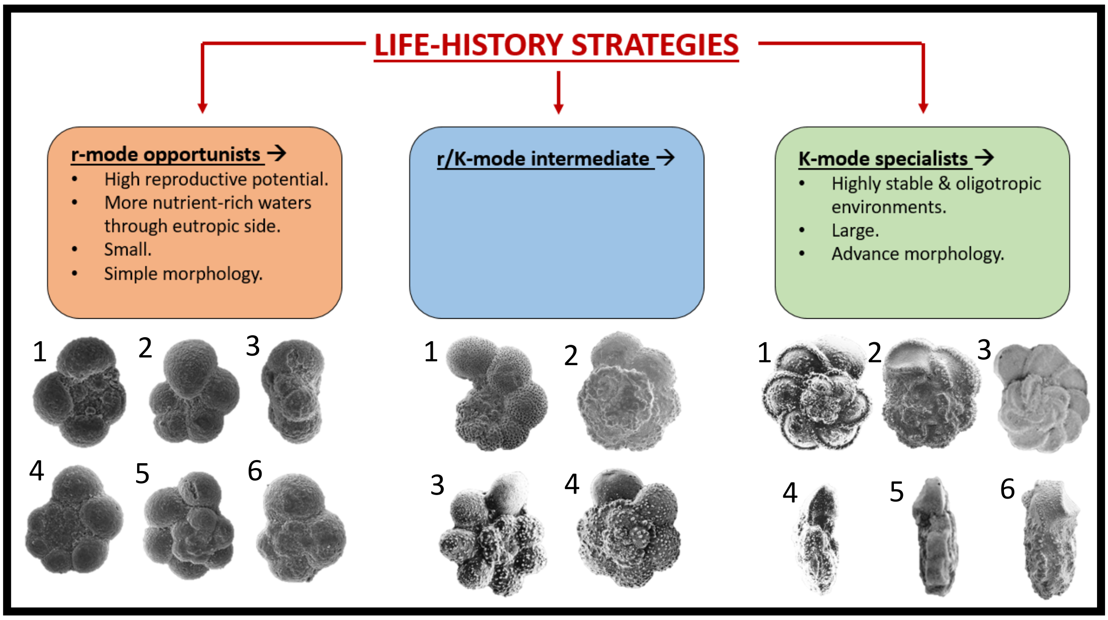


Figure 4.6. Planktonic foraminifera based on their life-history strategies. r-mode opportunists: 1. *Globigerinelloides duboisi* (pl.1, fig.d); 2. *Hedbergella infracretacea* (pl.2, fig.g); 3. *Hedbergella occulta* (pl.3, fig.e); 4. *Hedbergella luterbacheri* (pl.2, fig.i); 5. *Hedbergella occulta* (pl.3, fig.c); 6. *Hedbergella sigali* (pl.5, fig.g). r/K-mode intermediate: 1. *Ticinella primula*, 2. *Praeglobotruncana stephani*, 3. *Ticinella raynaudi*, 4. *Praeglobotruncana delrioensis*. K-mode specialists: 1.,4. *Marginotruncana marginata*, 2.,5. *Marginotruncana coronata*, 3.,6. *Globotruncana linneiana* (http://www.mikrotax.org/pforams/index.php?dir=pf_mesozoic).

In the study, *Hedbergella* is observed as the most abundant form of planktonic foraminifers. Even though, species of *Globigerinelloides* have been defined through the section, they are respectively small in numbers while comparing to species of *Hedbergella*. *Hedbergella* is the most opportunistic and cosmopolitan one between these two genera. *Globigerinelloides* is not as tolerant as them in variable conditions, like the OAE 1a (Premoli Silva & Sliter, 1999). Even though *Hedbergella* inhabit more eutropic environments, *Globigerinelloides* lives through more mesotropic parts of water (Figure 4.7 and 4.8).

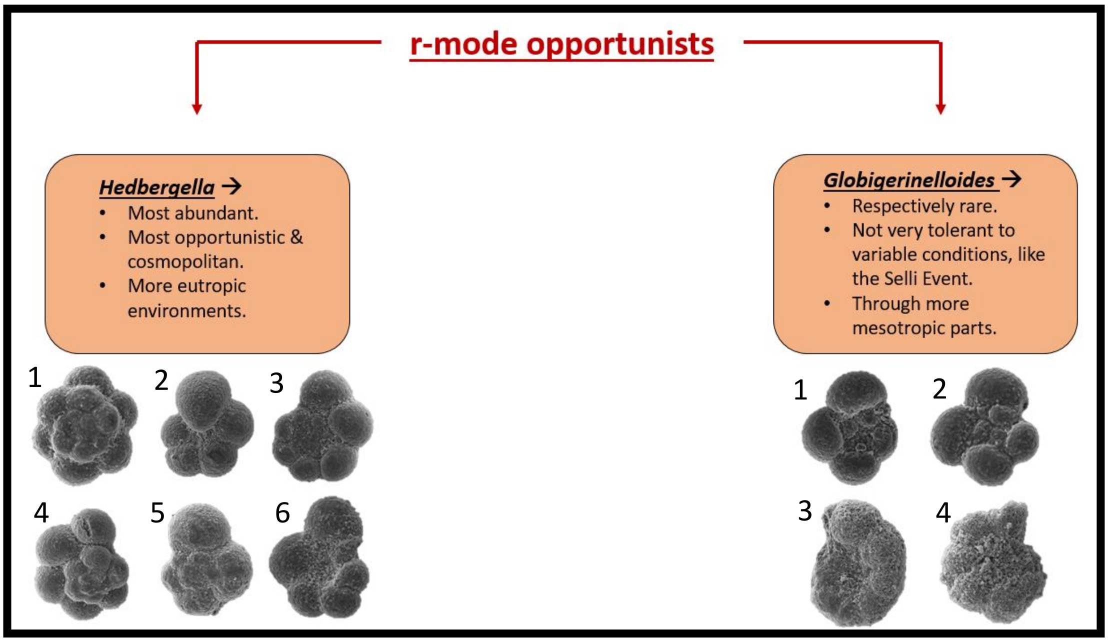


Figure 4.7. r-mode opportunist planktonic foraminifera. *Hedbergella:* 1. *Hedbergella excelsa* (pl.2, fig.a); 2. *Hedbergella infracretacea* (pl.2, fig.g); 3. *Hedbergella luterbacheri* (pl.2, fig.i); 4. *Hedbergella occulta* (pl.3, fig.c); 5. *Hedbergella sigali* (pl.5, fig.g); 6. *Hedbergella similis* (pl.4, fig.i). *Globigerinelloides:* 1.,2. *Globigerinelloides duboisi* (pl.1, figs.d,f); 3.,4. *Globigerinelloides ferreolensis* (pl.1, figs.h,g).

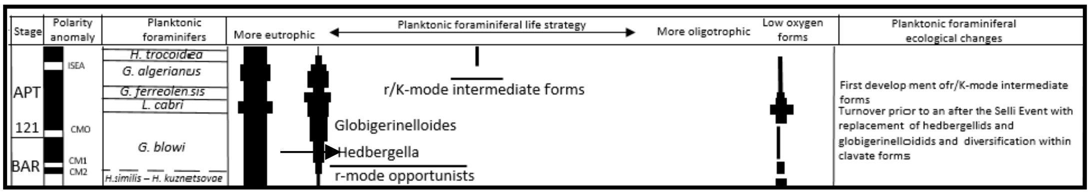


Figure 4.8. Stratigraphic distribution of planktonic foraminifers grouped according to their inferred life strategy (modified from Premoli Silva & Sliter, 1999).

Furthermore, the abundance of *Hedbergella* and *Globigerinelloides* can be explained by weakening and elimination of thermocline and rise of nutricline at the time of the Selli Event in general. Because these both genera are r-mode opportunists, they inhabit more nutrient-rich waters in or near eutrophic environments. This trend of thermocline and nutricline might provide favourable conditions for them, so they can get relatively abundant during the Selli Event. These changes in thermocline and nutricline were previously studied by Erba (2004), but this study was related with phytoplankton changes in the latest Barremian – early Aptian in order to explain nannoconid crisis. Through the measured section, there is no K-mode opportunist forms because they cannot be adapted to extreme conditions, like the OAE 1a.

Moreover, at the beginning of Cretaceous, both *Hedbergella* and *Globigerinelloides* have generally very small size and less abundant. Then, they increase in size and abundance, especially in the *Leupoldina cabri* Zone and the *Globigerinelloides ferreolensis* Zone with respect to Premoli Silva and Sliter (1999). This might be explained by the end of variable conditions, like the OAE 1a and passing from eutropic to more mesotropic conditions that also give possibilities for living of r/K-mode intermediate forms at the end of Aptian (Figure 4.8). The increase in relative abundance of *Hedbergella* and *Globigerinelloides* is also clearly observed in this study after the sample NY-10. This information is obtained by the observation on washing samples without any quantitative analysis because there are huge differences in numbers between the amount of *Hedbergella* and *Globigerinelloides.*

Even though radiolaria are the dominant organisms in the *Globigerinelloides blowi* Zone and the early part of the *Leupoldina cabri* Zone, planktonic foraminifera become dominant and increase in abundance through the middle and late part of the *Leupoldina cabri* Zone and the *Globigerinelloides ferreolensis* Zone. This can be understood by the microfacies types of the study. The earliest samples of the section (between NY-1 – NY-10) are defined as MF-1 (Radiolarian mudstone / wackestone) in microfacies analyses that equals to the *Globigerinelloides blowi* Zone and the early part of the *Leupoldina cabri* Zone. Then, mostly the middle part of the study (between NY-11 – NY-18 and between NY-27 – NY-32) is defined as MF-2 (Planktonic foraminiferal and radiolarian wackestone / packstone) that is in the middle and late part of the *Leupoldina cabri* Zone and the *Globigerinelloides ferreolensis* Zone. Generally, microfacies type of the late part of the section (between NY-19 – NY-26 and between NY-33 - NY-39) is determined as MF-3 (Planktonic foraminiferal mudstone / wackestone) which is around the late part of the *Leupoldina cabri* Zone and the *Globigerinelloides ferreolensis* Zone. Moreover, the passing from MF-3 to

MF-2 is observed in the same level of the LO of *Leupoldina cabri* and the boundary between the *Leupoldina cabri* and the *Globigerinelloides ferreolensis* Zones.

In addition, planktonic foraminifera with elongated chambers, like *Hedbergella roblesae* and *Leupoldina cabri,* have been found in deposition of organic layers of the study (in samples NY-3, NY-7S, NY-7, NY-8, NY-10, NY-11, NY-13, NY-14, NY-15, NY-16, NY-19, NY-23, NY-25 and NY-26) (Figure 4.9). Similar features were observed by Schlanger and Jenkyns (1976), Jenkyns (1980) and Coccioni et al. (2006), and deposition of organic layers which contain planktonic foraminifera with elongated chambers record the oceanic anoxic events (OAEs) in Cretaceous according to them. Furthermore, *Leupoldina cabri* is named as low-oxygen form (Premoli Silva & Verga, 1999). There are different hypotheses about this morphologic characteristic. The first hypothesis is that planktonic foraminifera with elongated chambers can be advantageous for environmental conditions. Because of these elongated chambers, surface per volume ratio increases which helps them to continue sufficient oxygen for metabolic needs. This one mainly focussed on water oxygenation and eutropic conditions. The second hypothesis is that water oxygenation is not the only component responsible for this morphological feature. Other physical, chemical and ecological factors, such as salinity, temperature, trace elements, type of food and productivity, can be related with this characteristic (Coccioni et al., 2006). The third hypothesis is that besides the elongated last chamber, thinning in shell wall support floating of the form in upper water layers that include oxygen sufficient to live (Kopaevich & Gorbachik, 2017). The first and third hypotheses are connected to advantageous morphological features of planktonic foraminifera with elongated chambers to maintain their lives in anoxic conditions. However, the second hypothesis emphasize other environmental conditions during OAEs. Even though anoxia is seen as the most important factor during OAEs, increase in CO_2 which is an important effect that trigger greenhouse effects and anoxic conditions might also be responsible for this morphology. Also, methane hydrates and different sources of nutrients might have some connection with chamber elongation in the last whorl.

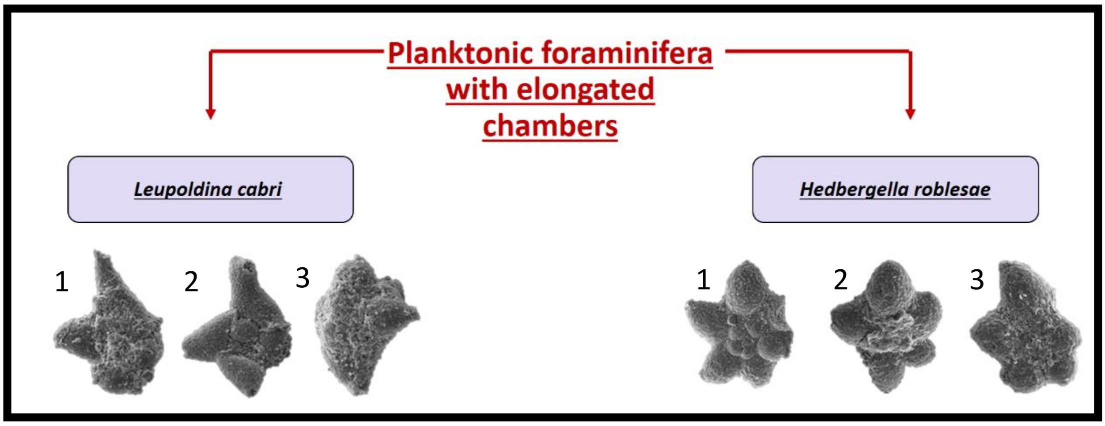


Figure 4.9. Planktonic foraminifera with elongated chambers. *Leupoldina cabri*: 1.,2.,3. pl.6, figs.d,e,b. *Hedbergella roblesae:* 1.,2.,3. pl.4, figs.d,b,c.

The number of species in other words, diversity, is respectively low in Aptian near the Selli Event equivalent levels because of the environment conditions that give opportunities to live only for r-mode opportunist and low-oxygen planktonic foraminifera. This study contains 12 planktonic foraminiferal species from 3 genera. The previous study of Altıner (1991) and Altıner et al. (1991) contains 9 species in the same area. To give examples, Cobianchi et al. (1999) identified 21 planktonic foraminiferal species in the southern Italy in Early and Late Aptian, Elkhazri et al. (2013) observed 15 different species of planktonic foraminifera in Aptian in Tunisia, and Moullade et al. (2015) determined 12 species in *Leupoldina cabri*, *Hedbergella luterbacheri*, *Globigerinelloides ferreolensis heptacameratus and Globigerinelloides ferreolensis ferreolensis* Zones in the southeast France.

Another important biotic event in Aptian is *Globigerinelloides* crisis. This event has been observed by several authors, Coccioni et al. (1992), Coccioni and Premoli Silva (1994), Cobianchi et al. (1997, 1999), and Luciani et al. (2001, 2006) at the top of *Globigerinelloides blowi* Zone or the base of *Leupoldina cabri* Zone. During this interval, species of *Globigerinelloides* were defined as absent or very rare by these authors. This crisis was named as *Globigerinelloides* eclipse. Through the measured section of the thesis, *Globigerinelloides* was recorded relatively rare with respect to *Hedbergella*. Since no appearent changes related with the abundance of

Globigerineollides was recorded through the section, *Globigerinelloides* eclipse has not been clearly defined in this study.

Radiolaria are very abundant in the measured section. Hence, they were represented in the thesis, but they have been classified in class level (Plates 9, 10, 23 and 24). They are the dominant organism in the *Globigerinelloides blowi* Zone and the early part of the *Leupoldina cabri* Zone of planktonic foraminifera in the section. Through the middle and late part of the *Leupoldina cabri* Zone and the *Globigerinelloides ferreolensis* Zone, both radiolarian and planktonic foraminifera are dominant. Even though they have been observed in the late part of the *Leupoldina cabri* Zone and the *Globigerinelloides ferreolensis* Zone, they are not as dominant as other parts of the section. The similar thing was defined by Coccioni et al. (1989), Sliter (1989), Bralower et al. (1993, 1994) as radiolarian-rich shales, and Premoli Silva et al. (1999) as abundance of radiolarian-rich layers through the Selli Event in the Cismon section in the northeastern Italy.

Nannofossils are another fossil assemblages that are affected by the anoxic conditions with nannoconid crisis. Even though they are not the main component of the study, they are important to explain the effects of the Selli Event on organisms in Aptian time. They were explained by an example on phytoplankton changes between the latest Barremian and early Aptian from the study of Erba (2004). Narrow-canal nannoconids inhabited lower photic zone which are the heaviest forms, and wide-canal nannoconids lived in intermediate photic zone that are smaller and lighter than narrow-canal ones. In addition, coccoliths inhabited upper photic zone at the same time. In the latest Barremian (124 – 121.5 Ma), narrow-canal nannoconids are the dominant ones. Through the CMO (Magnetic Chron) (121 – 120.5 Ma) nannoconids abundance decreased, and wide-canal nannoconids were dominant ones. The reason of that is explained by weakening of thermocline due to the initial warming in intermediate waters the Ontong Java Plateau, the Manihiki Plateau and the Nova Canton Through. At the same time, coccolith abundance increased. At onset of the Selli Event (121 Ma), coccoliths, dinoflagellates and cyanobacteria were dominant organisms. By large igneous provinces, thermocline firstly weakened, then eliminated (Erba, 2004). Moreover, *Assipetra* and *Rucinolithus* which are nannoliths were abundant at that time (Tremolada & Erba, 2002; Erba, 2004; Erba & Tremolada, 2004; Tremolada et al., 2007). The nannoconid crisis is an example of Lazarus effect which means they returned after more appropriate conditions, like restoration of thermocline and deepening of nutricline (Flessa & Jablonski, 1983). Nevertheless, in spite of more suitable conditions, they did not reach their abundance, like before the Selli Event (Erba, 1994; Leckie et al., 2002; Erba & Tremolada, 2004).

In addition, when the data of this thesis and Özkan (1993a) are compared based on Altıner et al. (1991)'s stratigraphic section in the Soğukçam Limestone in the Nallıhan area, three very thin black shale levels of these two studies might be seen in the similar levels. The shale levels in Özkan (1993a)'s study (samples 4C(M), 4D(M) and 4E(M)) were indicated in Figure 4.10. The black shale levels in this study are in samples NY-5, NY-7S and NY-14. Özkan (1993a) observed absence of nannoconids in three black shale levels that might indicate the nannoconid crisis which is an important effect of the Selli Event (Figure 4.10). In this thesis study, *Hedbergella roblesae,* which is r-mode opportunist and chamber elongated form, is only identified in last two black shale levels (samples NY-7S and NY-14) in the *Leupoldina cabri* Zone. Based on the hypotheses about the planktonic foraminifera with elongated chambers and the OAE 1a by Coccioni et al. (2006) and Kopaevich and Gorbachik (2017), and the observations of black shale deposition, chamber elongated form and absence of nannoconid in the same levels in the *Leupoldina cabri* Zone can support a probable indication of the OAE 1a in the section around the samples NY-7S and NY-14.

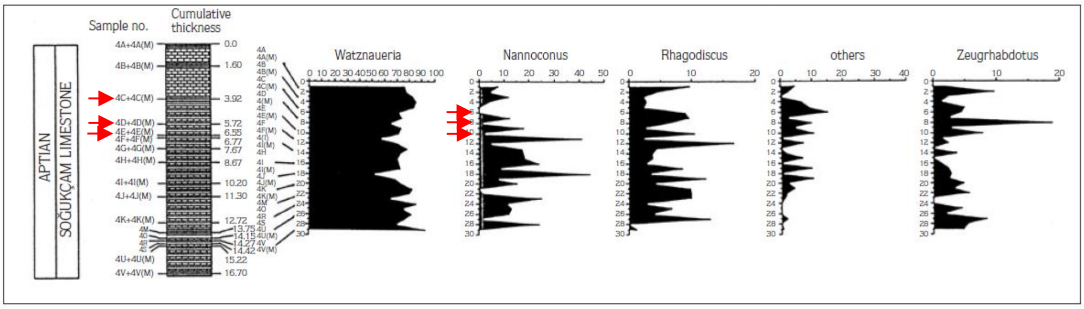


Figure 4.10. Distribution (percentage curves) of the most abundant nannofossil taxa that was counted in the Nallıhan area in Aptian (black shale levels were indicated) (Özkan-Altıner, 1999).

CHAPTER 5

SYSTEMATIC TAXONOMY

In the studied samples, planktonic foraminifers, small benthic foraminifers, radiolaria and ostracods have been observed under the microscopes. The purpose is defining them via using the classification's criteria.

Planktonic foraminifers have been identified via examining thin sections and washing samples, and mainly Premoli Silva and Verga (2004) and Mikrotax (http://www.mikrotax.org/pforams/index.php?dir=pf_mesozoic) are used as guides for them. The observed planktonic foraminifers are classified in genus and species level. Morphological features of them play a crucial role in this identification. Cretaceous planktonic foraminifera classification in genus and species levels is according to the following characters:

- Test outline is the shape of hard part that covers the test, such as lobate, biconvex, plano-convex.
- Chamber arrangement can be uncoiled (serial) or coiled (spiral) (planispiral, trochospiral).
- Shape of chambers, such as globular, spherical, triangular, crescentic.
- Number of chambers in the last whorl.
- Growth rate of chambers (slow, fast, medium) means the degree of change in size of chambers from the proloculus or the early chambers of the form through the last chambers.
- Sutures can be observed in spiral and umbilical sides as the external view of septa. They are defined, like depressed (moderately, strong), raised, and straight, radial, curved in shape.

- Aperture is the main opening of the test. They have different types, such as umbilical, extraumbilical, equatorial, interiomarginal.
- Umbilicus is the depression due to the spiral arrangement of the form (deep, shallow).
- Wall texture of the form.

The sizes of planktonic foraminifera are very small in the study samples, so they are obtained between 63 – 125 µm intervals in sieve analysis. In addition, the sediments on these forms has tried to be subtracted via adding pure water and making good rubbing. However, some sediments are still in the umbilicus of them.

Small benthic foraminifers, such as *Lenticulina* sp., *Nodosaria* sp., *Textularia* sp., *Spirillina* sp., *Patellina* sp., *Meandrospira* sp. and Ataxophragmiidae are defined mostly in thin sections and washing samples. They have been classified based on criteria, such as wall composition, chamber arrangement, etc. in the guide of Loeblich and Tappan (1988). *Cadosina* sp. which is a calcareous dinoflagellate is also identified in thin sections.

Radiolaria are observed in washing samples and thin sections. Even though they are abundant and diverse in the samples, planktonic foraminifers are the main component of the thesis, so radiolaria are classified only in class level (Plates 9, 10, 23 and 24).

5.1. Planktonic Foraminifera

ORDER FORAMINIFERIDA (Eichwald, 1830)

FAMILY GLOBIGERINELLOIDIDAE (Longoria, 1974)

Genus *Globigerinelloides* (Cushman and ten Dam, 1948)

Type species *Globigerinelloides algeriana* (Cushman and ten Dam, 1948)

***Globigerinelloides blowi* (Bolli, 1959)**

Plate 11, Figures a – d

1959 *Planomalina blowi* Bolli, 1959 – figs. 9:7-13, 10:1-12.

1978 *Globigerinelloides blowi* (Bolli, 1959) – Caron, pl. 6, figs. 11,12.

1994 *Globigerinelloides blowi* (Bolli, 1959) – Coccioni and Premoli Silva, p. 680, figs. 14:1-6.

1999 *Blowiella blowi* (Bolli, 1959) – Aguado et al., p. 675, figs. 8:1-6.

1999 *Globigerinelloides blowi* (Bolli, 1959) – Premoli Silva et al., p. 366, pl. 2, figs. 8-9.

2002 *Blowiella blowi* (Bolli, 1959) – Rückheim and Mutterlose, p. 56, figs. 5:4,6.

2003 *Globigerinelloides blowi* (Bolli, 1959) – Verga and Premoli Silva, p. 314, figs. 10:1-12.

2004 *Globigerinelloides blowi* (Bolli, 1959) – Premoli Silva and Verga, p. 96, pl. 26, figs. 4-6; p. 239, pl. 9, figs. 9-10.

2008 *Blowiella blowi* (Bolli, 1959) – Mandic and Lukeneder, p. 906, figs. 7: 6,8.

2013 *Globigerinelloides blowi* (Bolli, 1959) – Pszczolkowski et al., fig. 7.3.

2016 *Globigerinelloides blowi* (Bolli, 1959) – Jozsa et al., p. 20, figs. 5:5-6.

2017 *Blowiella blowi* (Bolli, 1959) – Brovina, p. 521, pl. 1, fig. 1.

Description and Remarks:

Globigerinelloides blowi has planispiral coiling with 4-5 globular chambers in the last whorl. Size of chambers are slowly increasing through the last whorl. The test is lobate, biumbilicate and partially involute. Sutures are radial and strongly depressed on both spiral and umbilical sides. It has equatorial aperture. The wall is calcareous and finely perforate (Table 5.1).

Instead of *Globigerinelloides blowi,* some authors have preferred to use *Blowiella blowi,* like Aguado et al. (1999), Rückheim and Mutterlose (2002), Mandic and Lukeneder (2008) and Brovina (2017) that identified *Blowiella blowi.* Krechmar and Gorbachik (1971) originally defined *Blowiella* which does not contain multilamellar thickening of the wall different from *Globigerinelloides.* In order to explain *Blowiella* in general, Banner and Desai (1988) differentiated this genus from *Globigerinelloides* via its smooth, microperforate and not muricate wall. According to BouDagher-Fadel et al. (1997), *Globigerinelloides* does not have muricate wall, it has microperforate wall, and *Blowiella* and *Globigerinelloides* can be separated by number of chambers in the last whorl. Based on Moullade et al. (2002), presence of perforation cones can be used to differentiate these two genera because only *Globigerinelloides* shows this feature. Consequently, two criteria are used together for this separation which are the number of chambers in the last whorl and absence or presence of perforation cones. *Blowiella* is defined with having planispiral coiling, 4 – 6 globular chambers in the last whorl, thin microperforate wall without perforation cones, and equatorial and relict apertures.

Globigerinelloides blowi has been differentiated from other *Globigerinelloides* forms in this study by its globular chambers, slow growth rate of chambers with respect to *Globigerinelloides duboisi* and low number of chambers in the last whorl while comparing with *Globigerinelloides ferreolensis.*

<u>Stratigraphic Distribution and Occurrence:</u>

Globigerinelloides blowi ranges from the *Globigerinelloides blowi* Zone (Late Early Barremian to Early Aptian) to the *Globigerinelloides algerianus* Zone (Late Aptian) (Premoli Silva & Verga, 2004). In the study, it has been observed both in the *Globigerinelloides blowi* Zone and the *Leupoldina cabri* Zone (Early Late Aptian). In the measured section, it has been identified starting from NY-2 up to NY-13. This form is small in numbers.

***Globigerinelloides duboisi* (Chevalier, 1961)**

Plate 1, Figures a – f; Plate 11, Figures e – g

1961 *Globigerinella duboisi* Chevalier, 1961 – p. 33, pl. 1, figs. 14-18.

1988 *Blowiella duboisi* (Chevalier, 1961) – Banner and Desai, p. 171, pl. 8, figs. 10-12.

1991 *Globigerinella duboisi* (Chevalier, 1961) – Altıner, p. 211, pl. 15, fig. 22.

1999 *Blowiella duboisi* (Chevalier, 1961) – Aguado et al., p. 675, figs. 8:7-13.

1999 *Globigerinelloides duboisi* (Chevalier, 1961) – Premoli Silva et al., p. 367, pl. 3, figs. 2-3.

2003 *Globigerinelloides duboisi* (Chevalier, 1961) – Verga and Premoli Silva, p. 309, figs. 5:1-13; p. 310, figs. 6:1-14.

2004 *Blowiella duboisi* (Chevalier, 1961) – Lipson-Benitah and Almogi-Labin, p. 35, pl. 2, fig. 16.

2004 *Globigerinelloides duboisi* (Chevalier, 1961) – Premoli Silva and Verga, p. 97, pl. 27, figs. 4-6; p. 239, pl. 9, fig. 11.

2008 *Blowiella duboisi* (Chevalier, 1961) – Mandic and Lukeneder, p. 906, fig. 7.4.

2013 *Globigerinelloides duboisi* (Chevalier, 1961) – Elkhazri et al., p. 146, figs. 7:2-3.

2013 *Globigerinelloides duboisi* (Chevalier, 1961) – Pszczolkowski et al., fig. 7.2.

2016 *Globigerinelloides duboisi* (Chevalier, 1961) – Jozsa et al., p.20, figs. 5:1-2.

<u>Description and Remarks:</u>

Globigerinelloides duboisi is composed of planispirally coiled globular chambers. Number of the chambers at final whorl is generally between 4 and 4.5. Growth rate of these chambers is high. The test is finely perforate, biumbilicate and calcareous. The sutures are moderately depressed in spiral and umbilical sides. It has aperture at the base of last chamber (Table 5.1).

Some authors, like Banner and Desai (1988), Aguado et al. (1999), Lipson-Benitah and Almogi-Labin (2004), and Mandic and Lukeneder (2008) used *Blowiella duboisi* name while describing the form. The general description of *Blowiella* is discussed in the remarks of *Globigerinelloides blowi.*

Globigerinelloides duboisi has been differentiated from other *Globigerinelloides* forms in this study by its high growth rate of chambers than *Globigerinelloides blowi* and low number of chambers in the last whorl with respect to *Globigerinelloides ferreolensis.*

<u>Stratigraphic Distribution and Occurrence:</u>

Globigerinelloides duboisi ranges from the *Globigerinelloides blowi* Zone (Late Early Barremian to Early Aptian) to the *Globigerinelloides ferreolensis* Zone (Late Aptian) (Premoli Silva & Verga, 2004). It has been observed in the *Globigerinelloides blowi* Zone, the *Leupoldina cabri* Zone (Early Late Aptian) and the *Globigerinelloides ferreolensis* Zone in this study. It has been defined starting from sample NY-2 to NY-35.

***Globigerinelloides ferreolensis* (Moullade, 1961)**

Plate 1, Figures g – i; Plate 11, Figures h – k; Plate 12, Figures a – l

1967 *Biticinella ferreolensis* (Moullade, 1961) – Moullade, figs. 8-9.

1978 *Globigerinelloides ferreolensis* (Moullade, 1961) - Pflaumann and Krasheninnikov, p. 557, pl. 3, fig. 1.

1984 *Globigerinelloides ferreolensis* (Moullade, 1961) – Leckie, p. 605, pl. 2, figs. 9-12.

1991 *Globigerinelloides ferreolensis* (Moullade, 1961) – Altıner, p. 211, pl. 15, figs. 23-26; p. 213, pl. 16, fig. 1.

1998 *Globigerinelloides ferreolensis* (Moullade, 1961) – Rojay and Altıner, p. 175, pl. 1, figs. 28, 29.

1999 *Globigerinelloides ferreolensis* (Moullade, 1961) – Aguado et al., p. 677, figs. 10:4-12.

2004 *Globigerinelloides ferreolensis* (Moullade, 1961) – Lipson-Benitah and Almogi-Labin, p. 36, pl. 3, fig. 12.

2004 *Globigerinelloides ferreolensis* (Moullade, 1961) – Premoli Silva and Verga, p. 98, pl. 28, figs. 5-8; p. 239, pl. 9, figs. 12-15.

2008 *Globigerinelloides ferreolensis* (Moullade, 1961) – Mandic and Lukeneder, p. 906, fig. 7.7.

Not 2008 *Globigerinelloides ferreolensis* (Moullade, 1961) – Michalik et al., p.881, fig. 9.5.

2013 *Globigerinelloides ferreolensis* (Moullade, 1961) – Ezampanah et al., p. 110, figs. 9:G-H.

2013 *Globigerinelloides ferreolensis* (Moullade, 1961) – Pszczolkowski et al., fig. 7.10.

2014 *Globigerinelloides ferreolensis* (Moullade, 1961) – Afghah and Shaabanpour Haghighi, p. 281, pl. 1, figs. 5,6.

2016 *Globigerinelloides ferreolensis* (Moullade, 1961) – Jozsa et al., p. 16, figs. 2:5-6; p. 21, figs. 6:1-2.

2017 *Globigerinelloides ferreolensis* s.s. (Moullade, 1961) – Brovina, p. 521, pl.1, fig. 7.

Description and Remarks:

Globigerinelloides ferreolensis has planispirally coiled inflated chambers. 7 to 9 chambers can be observed in the last whorl of the form. Growth rate of the chambers is slow. The test is lobate and symmetrical. The wall is perforate and calcareous. Sutures are strongly depressed on both spiral and umbilical sides. Equatorial aperture is located at the base of last chamber. (Table 5.1).

Globigerinelloides ferreolensis has been differentiated from other *Globigerinelloides* forms in this study by its inflated chambers and having high number of chambers in the last whorl. However, this number is not as much as *Globigerinelloides algerianus* (Cushman & ten Dam, 1948) which have 10 to 12 chambers in the last whorl. In addition, *Globigerinelloides barri* (Bolli et al., 1957) shares the some similar features with *Globigerinelloides ferreolensis*, like the same number of chambers in the last whorl (7 – 9), inflated chambers and strongly depressed sutures, but it also has double-apertured last chamber, and this feature has not been observed in the study.

Stratigraphic Distribution and Occurrence:

Globigerinelloides ferreolensis ranges from the *Leupoldina cabri* Zone (Early Late Aptian) to the *Ticinella bejaouaensis* Zone (Latest Aptian) (Premoli Silva & Verga, 2004). It has been observed in the *Leupoldina cabri* Zone and the *Globigerinelloides ferreolensis* Zone (Late Aptian) in this study. It has been defined starting from sample NY-22 to NY-39 that is the last sample of the measured section. Nevertheless, this form is not abundant in samples.

Table 5.1. *Morphological features of species of Genus Globigerinelloides that have been defined in the study (represented in color), and species of Genus Globigerinelloides that have not been defined, but used in comparison.*

Species	Chamber Arrangement	Shape of Chambers	Number of Chambers	Growth Rate of Chambers	Sutures	Aperture
Globigerinelloides blowi	Planispiral	Globular	4 – 5	Slow	Strongly depressed	Equatorial, Relict
Globigerinelloides duboisi	Planispiral	Globular	4 – 4.5	High	Moderately depressed	Equatorial, Relict
Globigerinelloides ferreolensis	Planispiral	Inflated	7 – 9	Slow	Strongly depressed	Equatorial, Relict
Globigerinelloides algerianus	Planispiral	Globular	10 – 12	Slow	Moderately depressed	Equatorial, Relict
Globigerinelloides barri	Planispiral	Inflated	7 – 9	Slow	Strongly depressed	Equatorial, Relict

FAMILY HEDBERGELLIDAE (Loeblich & Tappan, 1961)

Genus *Hedbergella* (Brönnimann & Brown, 1958)

Type species: *Anomalina lorneiana* d'Orbigny var. *trochoidea* Gandolfi, 1942

Hedbergella excelsa (Longoria, 1974)

Plate 2, Figure a; Plate 17, Figure a

1974 *Hedbergella excelsa* Longoria, 1974 – p. 55-56, pl. 18, figs. 6-11, 14-16.

1999 *Blefuscuiana excelsa* (Longoria, 1974) – Aguado et al., p. 673, figs. 6.20.

2002 *Blefuscuiana excelsa sensu stricto* (Longoria, 1974) – Rückheim and Mutterlose, p. 56, fig. 5:1.

2004 *Hedbergella excelsa* (Longoria, 1974) – Premoli Silva and Verga, p.127, pl. 57, figs. 1-4.

2011 *Hedbergella excelsa* (Longoria, 1974) – Huber and Leckie, p. 69, figs. 11:9,10.

2012 *Hedbergella excelsa* (Longoria, 1974) – Petrizzo et al., p.64, pl. 2, fig. 8; p. 65, pl. 3, fig. 1.

2017 *Hedbergella excelsa* (Longoria, 1974) – Brovina, p. 521, pl. 1, fig. 3.

<u>Description and Remarks:</u>

Hedbergella excelsa is a high trochospirally coiled form which composed of 3 whorls. Shape of chambers is inflated, and number of chambers in the last whorl is 6. Growth rate of chambers is slow. Sutures are radial and moderately depressed in spiral and umbilical sides. Umbilicus is deep and narrow. The test is lobate, its wall is smooth (Table 5.2).

Blefuscuiana (Banner & Desai, 1988) is a genus that was defined for *Praehedbergella* (Gorbachik & Moullade, 1973) with 5 or more chambers in each whorl and ranges between Barremian and Late Cretaceous. It was differentiated from Genus *Hedbergella* by microperforations and lack of muricae. Banner et al. (1993) emended the description and said that perforation cones can be used while defining subspecies. Aguado et al. (1999), and Rückheim and Mutterlose (2002) idefined *Blefuscuiana excelsa*.

Hedbergella excelsa can be differentiated from other *Hedbergella* forms in this study by its inflated chambers and high trochospiral coiling. Even though *Hedbergella occulta* has inflated chambers and the same number of chambers at the last whorl, it is not high trochospiral form, like *Hedbergella excelsa*. Hence, it can be recognised from *Hedbergella occulta* by this feature. Similarly, it can be differentiated from *Hedbergella infracretacea* with 6 chambers in the last whorl via coiling axis and shape of chambers because *Hedbergella infracretacea* is characterized by low trochospiral coiling and globular chambers.

Stratigraphic Distribution and Occurrence:

The first occurrence of *Hedbergella excelsa* range starts in the *Globigerinelloides blowi* Zone (Late Early Barremian to Early Aptian). Its range continues through the *Paraticinella bejaouaensis* Zone (Latest Aptian) (Premoli Silva & Verga, 2004). It has been observed in the *Leupoldina cabri* Zone in the study. *Hedbergella excelsa* only identified in some early samples of the section (NY-6 and NY-9).

Hedbergella infracretacea (Glaessner, 1937a,b)

Plate 2, Figures b – g; Plate 13, Figures a – g

1937 *Globigerina infracretacea* Glaessner, 1937a,b – p. 28, fig. 1.

1966 *Globigerina infracretacea* (Glaessner, 1937a,b) – Glaessner, pl. 1, figs. 1-3.

1978 *Hedbergella infracretacea* (Glaessner, 1937a,b) – Caron, p. 663, pl. 1, figs. 5,6.

1990 *Hedbergella infracretacea* (Glaessner, 1937a,b) – Leckie, p. 324, pl. 2, figs. 1-18.

1993 *Blefuscuiana infracretacea aptica* (Glaessner, 1937a,b) – Banner et al., pl. 4, figs. 4-6.

2002 *Blefuscuiana infracretacea occidentalis* (Glaessner, 1937a,b) – Rückheim and Mutterlose, p. 55, fig. 4:1-3.

2002 *Hedbergella infracretacea occidentalis* (Glaessner, 1937a,b) – Rückheim and Mutterlose, p. 55, fig. 4.4.

2004 *Hedbergella infracretacea* (Glaessner, 1937a,b) – Premoli Silva and Verga, p. 129, pl. 59, figs. 3-4; p. 130, pl. 60, figs. 1-2.

2011 *Hedbergella infracretacea* (Glaessner, 1937a,b) – Huber and Leckie, p. 62, figs. 5: 8-12.

2012 *Hedbergella infracretacea* (Glaessner, 1937a,b) – Petrizzo et al., p. 63, pl. 1, figs. 4, 5; p. 64, pl. 2, figs. 1-5.

2016 *Hedbergella infracretacea* (Glaessner, 1937a,b) – Jozsa et al., p. 22, figs. 7:1-2.

<u>Description and Remarks:</u>

Hedbergella infracretacea is composed of low trochospirally coiled 2 – 2.5 whorls of globular chambers. Number of chambers in the last whorl is 5 to 5.5 (sometimes 6). Growth rate of these chambers are slow. Outline of the test is subcircular. The wall is finely perforate. Sutures are moderately depressed on both spiral and umbilical sides. This form has extraumbilical aperture. The umbilicus is shallow and narrow (Table 5.2).

Authors, such as Banner et al. (1993) and Rückheim and Mutterlose (2002) used *Blefuscuiana infracretacea* while defining the form. The general description of *Blefuscuiana* is explained in the remarks of *Hedbergella excelsa*.

Hedbergella infracretacea can be differentiated from other *Hedbergella* forms in this study with 5 chambers in the last whorl (*Hedbergella roblesae* and *Hedbergella similis*) by its globular chambers. Even though emended description of this species by Huber and Leckie (2011) said that number of chambers in the last whorl is between 5 and 5.5, original description also contains forms with 6 chamber in the last whorl. The form in Plate 2, Figure c which has 6 chambers in the last whorl has been identified based on this original description of *Hedbergella infracretacea*. This form in Plate 2, Figure c can be separated from *Hedbergella trocoidea* (Gandolfi, 1942) by number of chambers in the last whorl because it has 7 to 9 chambers in the last whorl which is higher than *Hedbergella infracretacea*'s. *Hedbergella infracretacea* in the indicated figure is very similar to *Hedbergella praetrocoidea* (Gorbachik, 1986), but this spaecis has differences in aperture, and it has wide umbilical area with respect to *Hedbergella infracretacea*.

Stratigraphic Distribution and Occurrence:

Hedbergella infracretacea ranges from the *Leupoldina cabri* Zone (Early Late Aptian) to the *Paraticinella bejaouaensis* Zone (Latest Aptian) (Premoli Silva & Verga, 2004). This species has been observed in the *Leupoldina cabri* Zone and the *Globigerinelloides ferreolensis* Zone (Late Aptian). It is respectively abundant form of the study when it is compared to other species that has been identified through the whole measured section. It has been observed in samples between NY-4 and NY-37 high in numbers.

***Hedbergella luterbacheri* (Longoria, 1974)**

Plate 2, Figures h – i; Plate 13, Figures h – i; Plate 17, Figure b

1974 *Hedbergella luterbacheri* Longoria, 1974 – p. 61, pl. 19, figs. 21-26.

2004 *Hedbergella luterbacheri* (Longoria, 1974) – Premoli Silva and Verga, p. 131, pl. 61, figs. 3a-4c.

2005 *Praehedbergella luterbacheri* (Longoria, 1974) – Moullade et al., p.18, pl. 3, figs. 5-10; p. 19, pl. 4, figs. 1-6.

2011 *Praehedbergella luterbacheri* (Longoria, 1974) – Moullade et al., p. 152, figs. 5:8-13.

2013 *Praehedbergella luterbacheri* (Longoria, 1974) – Elkhazri et al., p. 146, fig. 7.4.

2014 *Hedbergella luterbacheri* (Longoria, 1974) – Afghah and Shaabanpour Haghighi, p. 281, pl. 1, fig. 1.

2016 *Hedbergella luterbacheri* (Longoria, 1974) – Jozsa et al., p. 23, figs. 8:3-4.

2017 *Hedbergella luterbacheri* (Longoria, 1974) – Brovina, p. 521, pl. 1, fig. 5.

<u>Description and Remarks:</u>

Hedbergella luterbacheri is a lobate and very low trochospiral form with three whorls which has 6.5 – 7.5 chambers at the last whorl. These chambers are globular, and growth rate of them is slow. Sutures are radial and moderately depressed on both spiral and umbilical sides. Aperture is extraumbilical to spiroumbilical. Relict apertures are often observed. Umbilicus is shallow and wide (Table 5.2).

Praehedergella was defined in order to separate forms having microstructure of test different from *Hedbergella* by Gorbachik and Moullade (1973). Then, Banner and Desai (1988) and Banner et al. (1993) named this genus for forms with four chambers in the last whorl to differentiate *Blefuscuiana* that has five or more chambers. With respect to Moullade et al. (1998), *Praehedbergella* has long stratigraphic range (Hauterivian – Aptian), and it is the ancestor of younger microperforate *Globigeriacea* having trochospiral or planispiral coiling (BouDagher-Fadel et al., 1997). *Praehedbergella* is defined as the ancestor of *Hedbergella* by BouDagher-Fadel et al. (1988). Moullade et al. (2005, 2011) and Elkhazri et al. (2013) used *Praehedbergella luterbacheri* name while defining this species.

This species can be defined by high number of globular chambers at last whorl (up to 7.5) and its very low trochospiral coiling while comparing it with other *Hedbergella* forms in the samples.

<u>Stratigraphic Distribution and Occurrence:</u>

The first occurrence of *Hedbergella luterbacheri* is in the *Hedbergella similis* Zone (Early Barremian). Its range extends through the *Globigerinelloides algerianus* Zone (Late Aptian) (Premoli Silva & Verga, 2004). This species has been observed in the *Leupoldina cabri* Zone (early late Aptian) and the *Globigerinelloides ferreolensis* Zone (late Apatian). This form is not abundant in samples. It is recorded rarely in samples NY-11, NY-20, NY-21, NY-24, NY-28 and NY-31.

***Hedbergella mitra* (Banner & Desai, 1988)**

Plate 3, Figures a – b

1988 *Blefuscuiana mitra* Banner & Desai, 1988 – p. 163, pl. 6 figs. 4-6.

2004 *Hedbergella mitra* (Banner & Desai, 1988) – Premoli Silva and Verga, p. 132, pl. 62, figs, 3,4; p. 133, pl. 63, figs. 3,4.

2016 *Hedbergella mitra* (Banner & Desai, 1988) – Jozsa et al., p. 23, figs. 8:5-6.

<u>Description and Remarks:</u>

Hedbergella mitra is composed of very low trochospirally coiled globular chambers with 5 to 6 chambers in the last whorl. Its spiral side is flat. The test is lobate. Sutures are moderately depressed on both spiral and umbilical sides. Relict aperture can be observed. Umbilicus is shallow and wide. Its wall is smooth and microperforate (Table 5.2).

Banner and Desai (1988) named the form as *Blefuscuiana mitra*. The general description of Genus *Blefuscuiana* is discussed in the remarks of *Hedbergella excelsa*.

Hedbergella mitra can be differentiated by other *Hedbergella* forms with generally 6 chambers in the last whorl, like *Hedbergella excelsa* and *Hedbergella occulta* by its very low trochospiral coiling.

Stratigraphic Distribution and Occurrence:

Hedbergella mitra ranges only in the *Leupoldina cabri* Zone (Early Late Aptian) (Premoli Silva & Verga, 2004). In the study, this species is observed in samples NY-7 and NY-11 in the *Leupoldina cabri* Zone, like definition.

***Hedbergella occulta* (Longoria, 1974)**

Plate 3, Figures c – h; Plate 14, Figures a – k; Plate 17, Figure c – g

1974 *Hedbergella occulta* Longoria, 1974 – p. 63, pl. 11, figs. 1-3, 7.

1978 *Hedbergella* occulta (Longoria, 1974) - Pflaumann and Krasheninnikov, p. 553, pl. 1, fig. 12.

2004 *Hedbergella occulta* (Longoria, 1974) – Premoli Silva and Verga, p. 133, pl. 63, figs. 3a-4c; p. 251, pl. 21, figs. 3-5.

2011 *Hedbergella occulta* (Longoria, 1974) – Huber and Leckie, p. 69, figs. 11:1-6.

2014 *Hedbergella cf. occulta* (Longoria, 1974) – Afghah and Shaabanpour Haghighi, p. 281, pl. 1, fig. 7.

2016 *Hedbergella occulta* (Longoria, 1974) – Jozsa et al., p. 22, fig. 7.6.

Description and Remarks:

Hedbergella occulta is a low trochospiral form with 6 to 6.5 chambers at the last whorl. Chambers are globular, but through the last chambers, they become inflated. Chamber sizes increase gradually through the outer whorl. Sutures are moderately depressed on both spiral and umbilical sides. Aperture is extraumbilical. The wall is smooth and finely perforate. The umbilical side is deep and circular (Table 5.2).

Hedbergella occulta can be differentiated from other *Hedbergella* forms in this study by its inflated chambers in the last whorl because other species of *Hedbergella* of the study with low trochospiral coiling do not have this feature. In addition, high number of chambers at the last whorl can be useful while defining it.

Stratigraphic Distribution and Occurrence:

Hedbergella occulta ranges starting from the *Globigerinellodes blowi* Zone (Late Early Barremian to Early Aptian) to the *Ticinella bejaouaensis* Zone (Latest Aptian) (Premoli Silva & Verga, 2004). This species has been defined in the *Globigerinelloides blowi* Zone, the *Leupoldina cabri* Zone (Early Late Aptian) and the *Globigerinelloides ferreolensis* Zone (Late Aptian). *Hedbergella occulta* is abundant in samples of the measured section, and it has been observed in almost all samples starting from NY-1 up to NY-39.

***Hedbergella roblesae* (Obregon, 1959)**

Plate 4, Figures a – d; Plate 15, Figure a

1959 *Globigerina roblesae* Obregon – p. 149, pl. 4, fig. 4.

1991 *Hedbergella roblesae* (Obregon, 1959) – Altıner, p. 209, pl. 14, fig. 22.

2004 *Hedbergella roblesae* (Obregon, 1959) – Premoli Silva and Verga, p. 135, pl. 65, figs. 1a-2c; p. 251, pl. 21, figs. 6-8.

2013 *Hedbergella roblesae* (Obregon, 1959) – Ezampanah et al., p. 109, figs. 8:C,D,H.

2013 *Praehedbergella* cf. *roblesae* (Obregon, 1959) – Pszczolkowski et al., fig. 7.14.

2018 *Hedbergella roblesae* (Obregon, 1959) – Monier-Castillo et al., p. 63, fig. 4.E.

Description and Remarks:

Hedbergella roblesae displays very low trochospiral coiling with 5 to 6 chambers at outer whorl. They are globular firstly, then the last three chambers become elongate. Growth rate of chambers is low. Sutures are strongly depressed on both spiral and umbilical sides. The wall is smooth and finely perforate. Aperture is extraumbilical (Table 5.2).

Pszczolkowski et al. (2013) defined this species under *Praehedbergella*, and the general description of this genus is explained in the remarks of *Hedbergella luterbacheri*.

Hedbergella roblesae can be differentiated from other *Hedbergella* forms in this study by three elongated chambers in the last whorl. *Hedbergella roblesae* is very similar to *Hedbergella bizonae* (Chevalier, 1961), but it can be separated by shape of chambers in the last whorl because all chambers of *Hedbergella bizonae* in the last whorl are radially elongated. In addition, *Hedbergella kuhryi* (Longoria, 1974) has similarity with *Hedbergella roblesae*. The last three chambers of these forms are radially elongated in the last whorl. However, there is no 5 chambered form of *Hedbergella kuhryi* even though *Hedbergella roblesae* can be composed of 5 chambers in the last whorl.

Stratigraphic Distribution and Occurrence:

The first occurrence of *Hedbergella roblesae* is in the *Hedbergella similis* Zone (Early Barremian), and it extends up to the *Globigerinelloides algerianus* Zone (Late Aptian) (Premoli Silva & Verga, 2004). The species has been observed only in the *Leupoldina cabri* Zone (Early Late Aptian) in the study. Its range is very limited in the samples of the measured section which is defined only in shale samples NY-7S and NY-14 as very rare.

Hedbergella sigali (Moullade, 1966)

Plate 5, Figures a – i; Plate 15, Figures b – h

1966 *Hedbergella sigali* Moullade, 1966 – p. 87-88, pl. 7, figs. 20-23.

1993 *Praehedbergella sigali* (Moullade, 1966) – Banner et al., pl. 2, fig. 2.

1978 *Hedbergella sigali* (Moullade, 1966) - Pflaumann and Krasheninnikov, p. 553, pl. 1, figs. 1,2.

1991 *Hedbergella sigali* (Moullade, 1966) – Altıner, p. 209, pl. 14, figs. 8-17.

2003 *Praehedbergella sigali* (Moullade, 1966) – Lipson-Benitah and Almogi-Labin, p. 35, pl. 2, figs. 1, 2.

2004 *Hedbergella sigali* (Moullade, 1966) – Premoli Silva and Verga, p. 136, pl. 66, figs. 3a-4c; p. 251, pl. 21, figs. 11-13.

2007 *Hedbergella sigali* (Moullade, 1966) – Okay and Altıner, p. 271, pl. 2, fig. 40.

2013 *Praehedbergella sigali* (Moullade, 1966) – , p. 146, fig. 7.1.

Description and Remarks:

Hedbergella sigali has low trochospiral test with 4 to 4.5 globular chambers at last whorl. Growth rate of the chambers is slow. The form is lobate, ventrally involute and dorsally evolute. Sutures are strongly depressed on both spiral and umbilical sides. The wall is smooth and finely perforate. Aperture can be ventral and umbilical – extraumbilical, and bordered by thin lip (Table 5.2).

Banner et al. (1993), Lipson-Benitah and Almogi-Labin (2003) and Elkhazri et al. (2013) classified the form under *Praehedbergella*. The definition of this genus has been previously given in the remarks of *Hedbergella luterbacheri*.

Hedbergella sigali has been easily differentiated from the other species of *Hedbergella* in the study by having low number of chambers in the last whorl (4 – 4.5 chambers). *Hebergella semielongata* (Longoria, 1974) has also the same number of chambers in the last whorl. However, its last two chambers are elongate that can easily differ this form from *Hedbergella sigali*.

Stratigraphic Distribution and Occurrence:

The first occurrence of *Hedbergella sigali* is at the base of the *Hedbergella sigali* Zone (Late Valanginian to Earliest Barremian). Its range extends up to the *Ticinella bejaouaensis* Zone (Latest Aptian) (Premoli Silva & Verga, 2004). In the study, this species has been defined in the *Globigerinelloides blowi* Zone (Late Early Barremian to Early Aptian), the *Leupoldina cabri* Zone (Early Late Aptian) and the *Globigerinelloides ferreolensis* Zone (Late Aptian). *Hedbergella sigali* is very abundant in samples of the measured section. It has been observed almost in all samples (from NY-1 to NY-39).

Hedbergella similis (Longoria, 1974)

Plate 4, Figures e – i; Plate 15, Figures i – l; Plate 16, Figures a – b

1974 *Hedbergella similis* Longoria, 1974 – p. 68, pl. 16, figs. 10-21.

1978 *Hedbergella* aff. *similis* (Longoria, 1974) - Pflaumann and Krasheninnikov, p. 553, pl. 1, fig. 5.

Not 1988 *Lilliputianella similis* (Longoria, 1974) – Banner and Desai, p. 171, pl. 8, figs. 8-9.

1991 *Hedbergella similis* (Longoria, 1974) – Altıner, p. 209, pl. 14, figs. 13,14.

1993 *Lilliputianella similis* (Longoria, 1974) – Banner et al., pl. 8, fig. 8.

1999 *Hedbergella similis* (Longoria, 1974) – Premoli Silva et al., p. 366, pl. 2, fig. 6.

2003 *Lilliputianella similis* (Longoria, 1974) – Lipson-Benitah and Almogi-Labin, p. 35, pl. 2, figs. 11, 12.

2004 *Hedbergella similis* (Longoria, 1974) – Premoli Silva and Verga, p. 137, pl. 67, figs. 1a-4c.

Description and Remarks:

Hedbergella similis is very low trochospirally coiled form with 5 – 6 chambers at outer whorl. Chambers are globular to sub-globular in initial part. Then, especially the last two chambers generally become slightly radial to elongate. The last chamber at the outer whorl is more elongate in some specimens. The wall is finely perforate and smooth. Sutures are moderately depressed on both spiral and umbilical sides. Also, they are slightly curved. On spiral side, relict apertures might be observed (Table 5.2).

Lilliputinella (Banner & Desai, 1988) was described in order to distinguish species of *Praehedbergella* with ovoid to radially elongate chambers in the last whorl from other species. Even though the number of chambers in the last whorl vary between 4 and 7, *Lilliputinella* have 5 – 7 chambers. Moreover, Banner et al. (1993) and Lipson-Benitah and Almogi-Labin (2003) defined this species under *Lilliputinella*.

Hedbergella similis can be easily differentiated from the other species of *Hedbergella* in this study via more elongated last two chambers in the last whorl. However, this feature is not observed in all individuals of species. If all chambers of the form are globular, number of chambers in the last whorl can be useful feature while identifying it.

Stratigraphic Distribution and Occurrence:

Hedbergella similis ranges from the base of the *Hedbergella similis* Zone (Early Barremian) to the *Globigerinelloides algerianus* Zone (Late Aptian) (Premoli Silva & Verga, 2004). This species has been observed in the *Globigerinelloides blowi* Zone (Late Early Barremian to Early Aptian), the *Leupoldina cabri* Zone (Early Late Aptian) and the *Globigerinelloides ferreolensis* Zone (Late Aptian). It is one of the most abundant form of the study when it is compared to other species that has been identified through the measured section. It has been observed in all samples (from NY-1 to NY-39).

Table 5.2. *Morphological features of species of Genus Hedbergella that has been defined in the study (represented in color) and species of Genus Hedbergella that have not been defined, but used in comparison.*

Species	Chamber Arrangement	Shape of Chambers	Number of Chambers	Growth Rate of Chambers	Sutures	Aperture
Hedbergella excelsa	High Trochospiral	Inflated	6	Slow	Moderately depressed	Umbilical Extraumbilical arch
Hedbergella infracretacea	Low Trochospiral	Globular	5 – 5.5	Slow	Moderately depressed	Extraumbilical
Hedbergella luterbacheri	Very Low Trochospiral	Globular	6.5 – 7.5	Slow	Moderately depressed	Relict
Hedbergella mitra	Very Low Trochospiral	Globular	5 – 6	Slow	Moderately depressed	Relict
Hedbergella occulta	Low Trochospiral	Globular, last two inflated	6 – 6.5	Slow	Moderately depressed	Extraumbilical
Hedbergella roblesae	Very Low Trochospiral	Globular, last three elongate	5 – 6	High	Strongly depressed	Extraumbilical

Table 5.2. *continued*.

Species	Chamber Arrangement	Shape of Chambers	Number of Chambers	Growth Rate of Chambers	Sutures	Aperture
Hedbergella sigali	Low Trochospiral	Globular	4 – 4.5	Slow	Strongly depressed	Ventral, umbilical - exrtaumbilical
Hedbergella similis	Very Low Trochospiral	Globular, last two radially elongate	5 – 6	Slow	Moderately depressed	Relict
Hedbergella bizonae	Very Low Trochospiral	All radially elongate in the last whorl	5 – 6.5	High	Strongly depressed	Extraumbilical arch
Hedbergella kuhryi	Very Low Trochospiral	Globular, last three radially elongate	5.5 – 6	High	Strongly depressed	Extraumbilical arch
Hedbergella praetrocoidea	Low Trochospiral	Globular	6 – 6.5	Slow	Moderately depressed	Arch
Hedbergella semielongata	Very Low Trochospiral	Globular, last two elongate	4 – 4.5	High	Strongly depressed	Extraumbilical arch

Table 5.2. *continued*.

Species	**Chamber Arrangement**	**Shape of Chambers**	**Number of Chambers**	**Growth Rate of Chambers**	**Sutures**	**Aperture**
Hedbergella trocoidea	Low Trochospiral	Inflated	7 – 9	Slow	Moderately depressed	Umbilical arch

FAMILY SCHACKOINIDAE (Pokorny, 1958)

Genus *Leupoldina* (Bolli, 1957)

Type species: *Leupoldina protuberans* (Bolli, 1957) = *Schackoina cabri* (Sigal, 1952)

Leupoldina cabri (Sigal, 1952)

Plate 6, Figures a – e; Plate 16, Figures c – h

1952 *Schackoina cabri* Sigal, 1952 – p. 20-21, fig. 18.

1957 *Schackoina pustulans pustulans* (Sigal, 1952) – Bolli, p. 274, pl. 1, figs. 1-7.

1988 *Leupoldina* gr. *cabri* (Sigal, 1952) – Banner and Desai, p. 177, pl. 10, figs. 1-8.

1991 *Leupoldina cabri* (Sigal, 1952) – Altıner, p. 211, pl. 15, figs. 13-15.

1999 *Schackoina cabri* (Sigal, 1952) – Aguado et al., p. 676, figs. 9:16-20.

1999 *Leupoldina cabri* (Sigal, 1952) – Premoli Silva et al., p. 365, pl. 1, figs. 5-6; p. 367, pl. 3, figs. 8-9.

2002 *Leupoldina cabri* (Sigal, 1952) – Rückheim and Mutterlose, p. 56, fig. 5.10.

2002 *Leupoldina cabri* (Sigal, 1952) – Verga and Premoli Silva, p. 208, figs. 7:1-12; p. 209, figs. 8:1-6.

2004 *Leupoldina cabri* (Sigal, 1952) – Premoli Silva and Verga, p. 149, pl. 79, figs. 1a-4b.

2008 *Leupoldina cabri – pustulans* (Sigal, 1952) – Mandic and Lukeneder, p. 906, fig. 9.1.

2008 *Leupoldina* cf. *cabri* (Sigal, 1952) – Michalik et al., p. 881, fig. 9.8.

2013 *Shackoina (Leupoldina)* sp. gr. *cabri-pustulans* (Sigal, 1952) – Elkhazri et al., p. 146, figs. 7:9-16.

2013 *Leupoldina cabri* (Sigal, 1952) – Ezampanah at al., p. 110, figs. 9:A-D.

2016 *Leupoldina cabri* (Sigal, 1952) – Jozsa et al., p. 19, fig. 4.1.

2017 *Leupoldina cabri* (Sigal, 1952) – Brovina, p. 521, pl. 1, fig. 4.

Description and Remarks:

Leupoldina cabri has variable morphology. The number of chambers at outer whorl can vary between 4 and 6. Shape of chambers is tubulospine. Ampullae can be observed on tubulospine chambers. The form can be semi-involute or involute, and pseudoplanispiral or trochospiral. Its umbilicus is wide.

Leupoldina cabri has been easily defined by its tubulospine chambers. However, their preservation is not very good, so the samples that have been obtained via washing techniques are generally broken. Hence, the test outline cannot be observed well in most of the samples. The ampullae on the tubulospine chambers can be observed in the thin sections (Plate 16, Figures d, e, f, h).

Stratigraphic Distribution and Occurrence:

Leupoldina cabri ranges from the base of the *Leupoldina cabri* Zone (Early Late Aptian) to the top of the *Leupoldina cabri* Zone (Premoli Silva & Verga, 2004). In the study, this species has been observed in the *Leupoldina cabri* Zone. It has been defined in some samples between NY-3 and NY-26, but it is not high in numbers.

5.2. Benthic Foraminifera

ORDER FORAMINIFERIDA (Eichwald, 1830)

SUBORDER LAGENINA (Delage & Herouard, 1896)

SUPERFAMILY NODOSARIOIDEA (Ehrenberg, 1838)

FAMILY VAGINULINIDAE (Reuss, 1860)

SUBFAMILY LENTICULININAE (Chapman et al., 1934)

Genus *Lenticulina* (Lamarck, 1804)

Type species: *Lenticulina rotulatus* (Lamarck, 1804)

***Lenticulina* sp.**

Plate 7, Figures a – f; Plate 18, Figures a – j; Plate 19, Figures a – c

<u>Description and Remarks:</u>

The test is generally planispiral. Also, it can be lenticular, periphery angled or keeled. The chambers are gradually larger in size. Sutures are radial, depressed, and straight or curved. Aperture is radial at peripheral angle (Loeblich & Tappan, 1964, 1988; Hofker, 1983).

<u>Stratigraphic Distribution and Occurrence:</u>

Lenticulina sp. has been defined in the *Globigerinelloides blowi* Zone (Late Early Barremian to Early Aptian), the *Leupoldina cabri* Zone (Early Late Aptian) and the *Globigerinelloides ferreolensis* Zone (Late Aptian) in the study. It was observed through the whole measured section between samples NY-1 and NY-38.

FAMILY NODOSARIIDAE (Ehrenberg, 1938)

SUBFAMILY NODOSARIINAE (Ehrenberg, 1938)

Genus *Nodosaria* (Lamarck, 1816)

Type species: *Nautilus radicula* (Linnaeus, 1758)

***Nodosaria* sp.**

Plate 7, Figures g – i; Plate 19, Figures d – i

Description and Remarks:

The test starts with ovate proloculus that has been followed by uniserially arranged ovate to rectilinear globular chambers. Its wall is smooth, hyaline, calcareous, and perforate with no ornamentation. Aperture can be rounded, radiate or terminal (Loeblich & Tappan, 1988).

Stratigraphic Distribution and Occurrence:

Nodosaria sp. has been defined in the *Globigerinelloides blowi* Zone (Late Early Barremian to Early Aptian), the *Leupoldina cabri* Zone (Early Late Aptian) and the *Globigerinelloides ferreolensis* Zone (Late Aptian) in the study. It was observed through the whole measured section between samples NY-1 and NY-38.

SUBORDER TEXTULARIINA (Delage & Herouard, 1896)

FAMILY TEXTULARIIDAE (Ehrenberg, 1838)

Genus *Textularia* (Defrance, 1824)

***Textularia* sp.**

Plate 8, Figures a – e; Plate 20, Figures a – e

Description and Remarks:

It has biserial chamber arrangement which might contains a third chamber. The wall is agglutinated. The aperture is low arc formed that stays at the base of aperture face (Loeblich & Tappan, 1988).

Stratigraphic Distribution and Occurrence:

Textularia sp. has been defined in the *Leupoldina cabri* Zone (Early Late Aptian) and the *Globigerinelloides ferreolensis* Zone (Late Aptian) in this study. *Textularia* sp. was observed between samples NY-8 and NY-39.

SUBORDER SPIRILLININA (Hohenegger & Piller, 1977)

FAMILY SPIRILLINIDAE (Reuss & Fritsch, 1861)

Genus *Spirillina* (Ehrenberg, 1843)

Type species: *Spirillina vivipara* (Ehrenberg, 1843)

***Spirillina* sp.**

Plate 8, Figures f – i; Plate 20, Figures f – i

Description and Remarks:

Proloculus that is globular is followed by undivided and gradually large tubular second chamber. The test is discoidal. It has planispiral coiling. Its wall is calcareous and hyaline (Loeblich & Tappan, 1988).

Stratigraphic Distribution and Occurrence:

In the study, *Spirillina* sp. has been defined in the *Leupoldina cabri* Zone (Early Late Aptian) and the *Globigerinelloides ferreolensis* Zone (Late Aptian). *Spirillina* sp. was observed in samples between NY-5 and NY-39.

FAMILY PATELLINIDAE (Rhumbler, 1906)

SUBFAMILY PATELLININAE (Rhumbler, 1906)

Genus *Patellina* (Williamson, 1858)

Type species: *Patellina corrugata* (Williamson, 1858)

***Patellina* sp.**

Plate 21, Figures a – b

Description and Remarks:

The test is small. It is conical in dorsal view and flat in ventral side. Short internal radial septa separate long crescentic chambers into chamberlets. Its wall is thin, calcareous, hyaline and perforate. The aperture is elongate which states at the base of last chamber in ventral side (Cushman, 1948).

Stratigraphic Distribution and Occurrence:

Patellina sp. is very rare in the samples, and it has been only observed in samples NY-25 and NY-28 in thin sections.

SUBORDER MILIOLINA (Delage and Herouard, 1896)

SUPERFAMILY CORNUSPIRACEA (Schultze, 1854)

FAMILY CORNUSPIRIDAE (Schultze, 1854)

SUBFAMILY CORNUSPIRINAE (Schultze, 1854)

Genus *Meandrospira* (Loeblich & Tappan, 1946)

Type species: *Mendrospira washitensis* (Loeblich & Tappan, 1946)

***Meandrospira* sp.**

Plate 21, Figures c – h

Description and Remarks:

The proloculus is followed by tubular and undivided second chamber that is bending back and forth. The wall is porcelaneous, calcareous and imperforate. It has simple and terminal aperture (Loeblich & Tappan, 1988).

Stratigraphic Distribution and Occurrence:

Meandrospira sp. has been recognized in the *Leupoldina cabri* Zone (Early Late Aptian) and the *Globigerinelloides ferreolensis* Zone (Late Aptian), and it is very rare in samples of the study. It was observed in samples NY-2, NY-4, NY-8, NY-10, NY-18, NY-21, NY-25 and NY-28.

SUPERFAMILY ATAXOPHRAGMIOIDEA (Schwager, 1877)

FAMILY ATAXOPHRAGMIIDAE (Schwager, 1877)

Ataxophragmiidae

Plate 21, Figures i - k

<u>Description and Remarks:</u>

This form is only defined in family level. Its test has trochospiral coiling firstly. Then, it often become biserial or triserial. The aperture is terminal and high (BouDagher-Fadel, 2018).

<u>Stratigraphic Distribution and Occurrence:</u>

Ataxophragmiidae has been defined in the *Leupoldina cabri* Zone (Early Late Aptian) and the *Globigerinelloides ferreolensis* Zone (Late Aptian), and it is rare in samples of the study. It was observed in samples NY-7, NY-19, NY-21 and NY-38.

5.3. Calcareous Dinoflagellates

ORDER PERIDINIALES (Haeckel, 1894)

FAMILY PERIDINIACEAE (Ehrenberg, 1831)

SUBFAMILY CALCIODINELLOIDEAE (Fensome et al., 1993)

Genus *Cadosina* (Wanner, 1940)

Type species: *Cadosina fusca* (Wanner, 1940)

***Cadosina* sp.**

Plate 22, Figures a – j

<u>Description and Remarks:</u>

The form has globular to ovoid test with single aperture. Its wall is porcellaneous that seems milky white in incident light (Pokorny, 1963).

<u>Stratigraphic Distribution and Occurrence:</u>

Cadosina sp. has been defined in the *Globigerinelloides blowi* Zone (Late Early Barremian to Early Aptian), the *Leupoldina cabri* Zone (Early Late Aptian) and the *Globigerinelloides ferreolensis* Zone (Late Aptian), and it is rare in samples of the study. It was observed between samples NY-1 and NY-38.

CHAPTER 6

DISCUSSION AND CONCLUSION

The Soğukçam Limestone that belongs to the Mudurnu-Nallıhan Sequence, Nallıhan, Ankara was studied in detail. A stratigraphic section (the NY-Section) was measured as 94.73 m in thickness, and a total of 44 samples were collected as 40 limestone, 3 shale and 1 diabase dyke samples.

Through the studied sequence, 12 species from 3 genera of planktonic foraminifera were recorded. These genera are *Hedbergella*, *Globigerinelloides* and *Leupoldina*. Based on planktonic foraminiferal bioevents, such as first occurrence (FO) and last occurrence (LO), three biozones have been identified. They are the *Globigerinelloides blowi* Zone (Early Aptian), the *Leupoldina cabri* Zone (Early Late Aptian) and the *Globigerinelloides ferreolensis* Zone (Late Aptian) starting from the lower part of the section through the top. The *Globigerinelloides blowi* Zone has been defined up to the FO of *Leupoldina cabri*. Because the acme zone of *Leupoldina cabri* has not been determined due to its low abundance, the FO and the LO of *Leupoldina cabri* were used as key factor while defining the *Leupoldina cabri* Zone of the studied section as the original definition of this biozone by Sigal (1977). The *Globigerinelloides ferreolensis* Zone started with the LO of *Leupoldina cabri,* and it has continued through the end of the measured section.

In addition, small benthic foraminifera were identified in generic level. Nevertheless, they were relatively low abundant in the studied samples. Moreover, radiolaria were observed through the studied sequence, and they were only defined in class level because they are beyond the purpose of the thesis. The diversity of radiolaria has been shown on the plates 9, 10, 23 and 24. *Cadosina* sp. which is a calcareous dinoflagellate was also recognized in thin sections of samples.

Microfacies (MF) analyses were performed on the limestone samples. While doing these, both lithofacies features (determination of the depositional texture), and biofacies features (fossil assemblages; planktonic foraminifera and radiolarian) in these samples were used as the main criteria. Especially, radiolaria are the dominant forms at the beginning of the section that is composed of mudstone and wackestone. Hence, these parts (between NY-1 and NY-10) were defined as MF-1: Radiolarian mudstone / wackestone. Then, they start to lose their dominance, and they have almost the same abundance with planktonic foraminifera through the middle part of the stratigraphic section which were named as MF-2: Planktonic foraminiferal and radiolarian wackestone / packstone (between NY-11 and NY-18, NY-27 and NY-32). In addition, through the samples in middle and upper part of the section, radiolaria totally lost their dominance, and planktonic foraminifera become dominant where microfacies was determined as MF-3: Planktonic foraminiferal mudstone / wackestone (between NY-19 and NY-26, NY-33 and NY-39). With respect to the standard microfacies types of Flügel (2004), MF-1, MF-2 and MF-3 were defined as SMF 3-RAD, SMF-3 and SMF 3-FOR, respectively. Based on this information, their deposition environments were defined as toe of slope to deep-water basin.

In addition, the presence of some important minerals could be used for explanation of the global biotic and paleoceanographic events in the light of previous studies. These minerals are framboidal pyrite and glauconite. Even though Bellanca et al. (2002), Yılmaz et al. (2010) and Hu et al. (2012) observed pyrite framboids near the oceanic anoxic events, Michalik et al. (2008), Huck et al. (2010), Hu et al. (2012), Lehmann et al. (2012) and Pictet et al. (2015) identified glauconite the Selli Event.

The Oceanic Anoxic Event 1a (the OAE 1a, the Selli Event) is one of the most important global biotic and paleoceanographic event of Cretaceous. This event was defined as being related with the formation of large igneous provinces in Aptian that trigger series of events starting from the excess CO_2 and greenhouse conditions to the oceanic anoxic event by Schlanger and Jenkyns (1976), Schlanger et al. (1981), Larson (1991a,b), Tarduno et al. (1991), Larson and Erba (1999), Jenkyns (2003, 2010) and

Robinson et al. (2017). The record of the OAEs can be obtained by the stable carbon isotope data. They firstly show negative carbon excusion, then they shift through the positive excursion. Different from other OAEs, the positive excursion continues after the Selli Event equivalent levels. Furthermore, the Selli Event has control over organisms. The changes that were resulted from the OAE 1a can be observed in the record of planktonic foraminifera, radiolaria and nannofossils. This study mainly focuses on the effects of the OAE 1a on the planktonic foraminifera assemblages. The defined planktonic foraminifera of the studied sequence are r-mode opportunistic forms, like *Globigerinelloides* and *Hedbergella*, and low-oxygen forms, such as *Leupoldina* (Premoli Silva & Sliter, 1999). K-mode specialists, like *Marginotruncana* and *Globotruncana*, and r/K-mode intermediate forms, such as *Ticinella* and *Praeglobotruncana* have not been observed through the measured section in the studied interval. Only the presence of the r-mode opportunistic planktonic foraminifera in the studied samples shows that eutrophic environmental conditions prevailed in the Aptian time in the studied region.

Hedbergella is relatively the most abundant and diverse genus between these three genera. Eight species of Genus *Hedbergella* were identified, and especially *Hedbergella infracretacea, Hedbergella occulta, Hedbergella sigali* and *Hedbergella similis* were observed almost starting from the bottom of the section to the top. These small, trochospiral and mostly globular chambered-forms are the most opportunistic planktonic foraminifers, and they have tolerance to extreme environmental conditions (Premoli Silva & Sliter, 1999), like the Selli Event.

Genus *Globigerinelloides* was also observed in a large interval. Three species of this planispiral planktonic foraminifera were defined which are *Globigerinelloides blowi, Globigerinelloides duboisi* and *Globigerinelloides ferreolensis.* Through the section *Globigerinelloides* is relatively less abundant and less diverse with respect to *Hedbergella*. *Globigerinelloides* is less tolerant to variable conditions, like oceanic anoxic events, compared to *Hedbergella* as Premoli Silva and Sliter (1999) said. Even though *Hedbergella* inhabit eutropic environments, *Globigerinelloides* lives through more mesotropic parts of water. The r-mode opportunistic forms indicate the eutrophic environmental conditions in the Aptian time which might be connected with *Globigerinelloides'* less tolerance to conditions, such as the Selli Event at that time.

From Genus *Leupoldina*, only *Leupoldina cabri* was defined in species level. This species with tubulospine chambers was observed small in numbers. *Leupoldina cabri* and *Hedbergellla roblesae* which are planktonic foraminifera with chamber elongation have been observed in deposition of organic layers of the study. Hypothesis about this morphologic characteristic of planktonic foraminifera and its relation with the Selli Event by Coccioni et al. (2006) and Kopaevich and Gorbachik (2017) also support the possible record of this event in the studied section. In addition, Özkan (1993a) defined an absence in nannoconids in the black shale levels of the Soğukçam Limestone, and nannoconid crisis is an important result of the Selli Event in Aptian time. With this study, *Hedbergella roblesae*, the planktonic foraminifera with chamber elongation, have been identified almost in the same black shale levels (NY-7S and NY-14). Both the records of the nannoconid crisis and *Hedbergella roblesae* can support the possible presence of the Selli Event in the *Leupoldina cabri* Zone of the Soğukçam Limestone in the Nallıhan area.

As a conclusion, mainly planktonic foraminifera, small benthic foraminifera and radiolaria were identified through the measured section of the Aptian part of the Soğukçam Limestone in the Nallıhan region. While doing these, planktonic foraminifera were classified in the species level. The biozones were determined in detail by using bioevents as the *Globigerinelloides blowi* Zone, the *Leupoldina cabri* Zone and the *Globigerinelloides ferreolensis* Zone in ascending order. Microfacies analyses were performed, and the depositional environments of the studied sequence were defined as toe of slope to deep water basin. Only the presence of r-mode opportunistic and low-oxygen planktonic foraminifers, such as elongated chambered forms suggests that the Oceanic Anoxic Event 1a (the Selli Event) has possibly been recorded in the *Leupoldina cabri* Zone of the studied sequence.

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APPENDICES

A. Plates and Explanations

PLATE 1

a. *Globigerinelloides duboisi* (Chevalier, 1961), spiral view, NY-12, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

b. *Globigerinelloides duboisi* (Chevalier, 1961), spiral view, NY-2, *Globigerinelloides blowi* Zone, Early Aptian, Soğukçam Limestone

c. *Globigerinelloides duboisi* (Chevalier, 1961), spiral view, NY-10, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. *Globigerinelloides duboisi* (Chevalier, 1961), spiral view, NY-11, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. *Globigerinelloides duboisi* (Chevalier, 1961), side view, NY-16, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

f. *Globigerinelloides duboisi* (Chevalier, 1961), spiral view, NY-35, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

g. *Globigerinelloides ferreolensis* (Moullade, 1961), spiral view, Slump 1-3, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

h. *Globigerinelloides ferreolensis* (Moullade, 1961), spiral view, Slump 1-2, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

i. *Globigerinelloides ferreolensis* (Moullade, 1961), spiral view, Slump 1-1, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 1

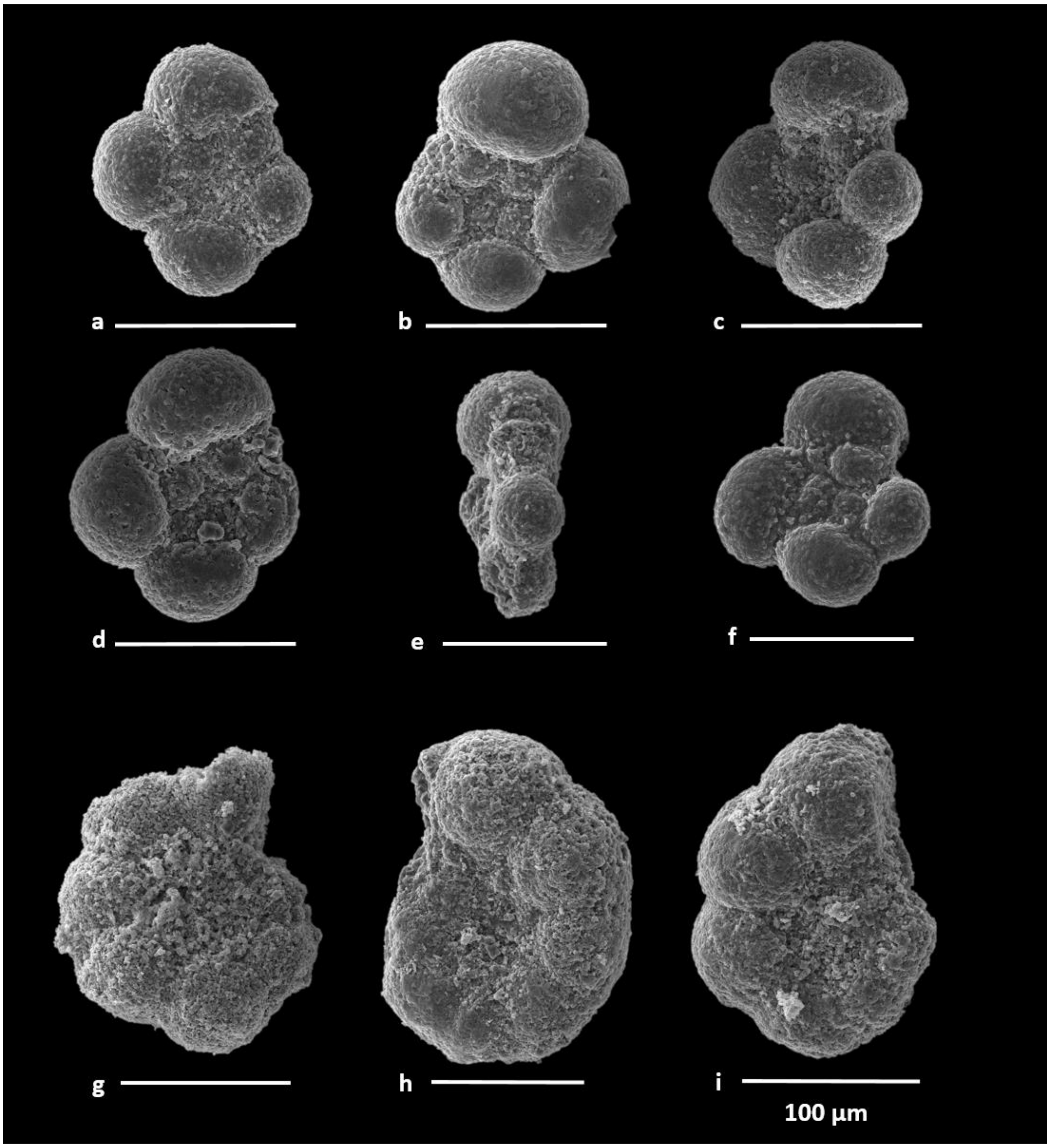


PLATE 2

a. *Hedbergella excelsa* (Longoria, 1974), spiral view, NY-6, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

b. *Hedbergella infracretacea* (Glaessner, 1937a,b), spiral view, NY-6, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. *Hedbergella infracretacea* (Glaessner, 1937a,b), umbilical view, NY-15, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. *Hedbergella infracretacea* (Glaessner, 1937a,b), side view, NY-26, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. *Hedbergella infracretacea* (Glaessner, 1937a,b), umbilical view, NY-30, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

f. *Hedbergella infracretacea* (Glaessner, 1937a,b), spiral view, NY-37, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

g. *Hedbergella infracretacea* (Glaessner, 1937a,b), umbilical view, NY-37, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

h. *Hedbergella luterbacheri* (Longoria, 1974), spiral view, NY-11, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

i. *Hedbergella luterbacheri* (Longoria, 1974), spiral view, NY-20, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

PLATE 2

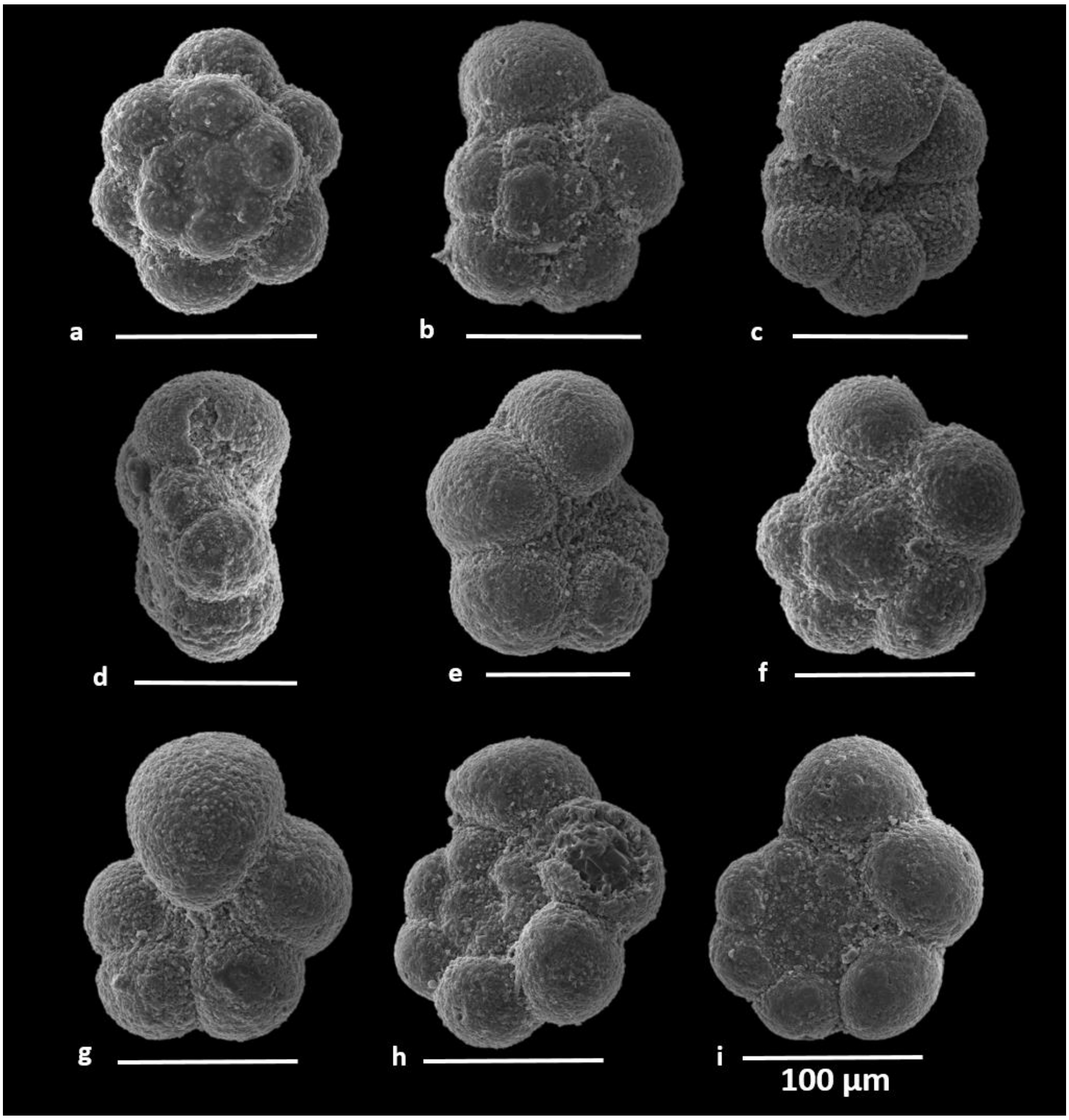


PLATE 3

a. *Hedbergella mitra* (Banner & Desai, 1988), spiral view, NY-7, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

b. *Hedbergella mitra* (Banner & Desai, 1988), umbilical view, NY-11, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. *Hedbergella occulta* (Longoria, 1974), spiral view, NY-11, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. *Hedbergella occulta* (Longoria, 1974), spiral view, NY-21, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. *Hedbergella occulta* (Longoria, 1974), side view, NY-22, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

f. *Hedbergella occulta* (Longoria, 1974), spiral view, NY-24, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

g. *Hedbergella occulta* (Longoria, 1974), umbilical view, NY-36, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

h. *Hedbergella occulta* (Longoria, 1974), umbilical view, NY-36, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 3

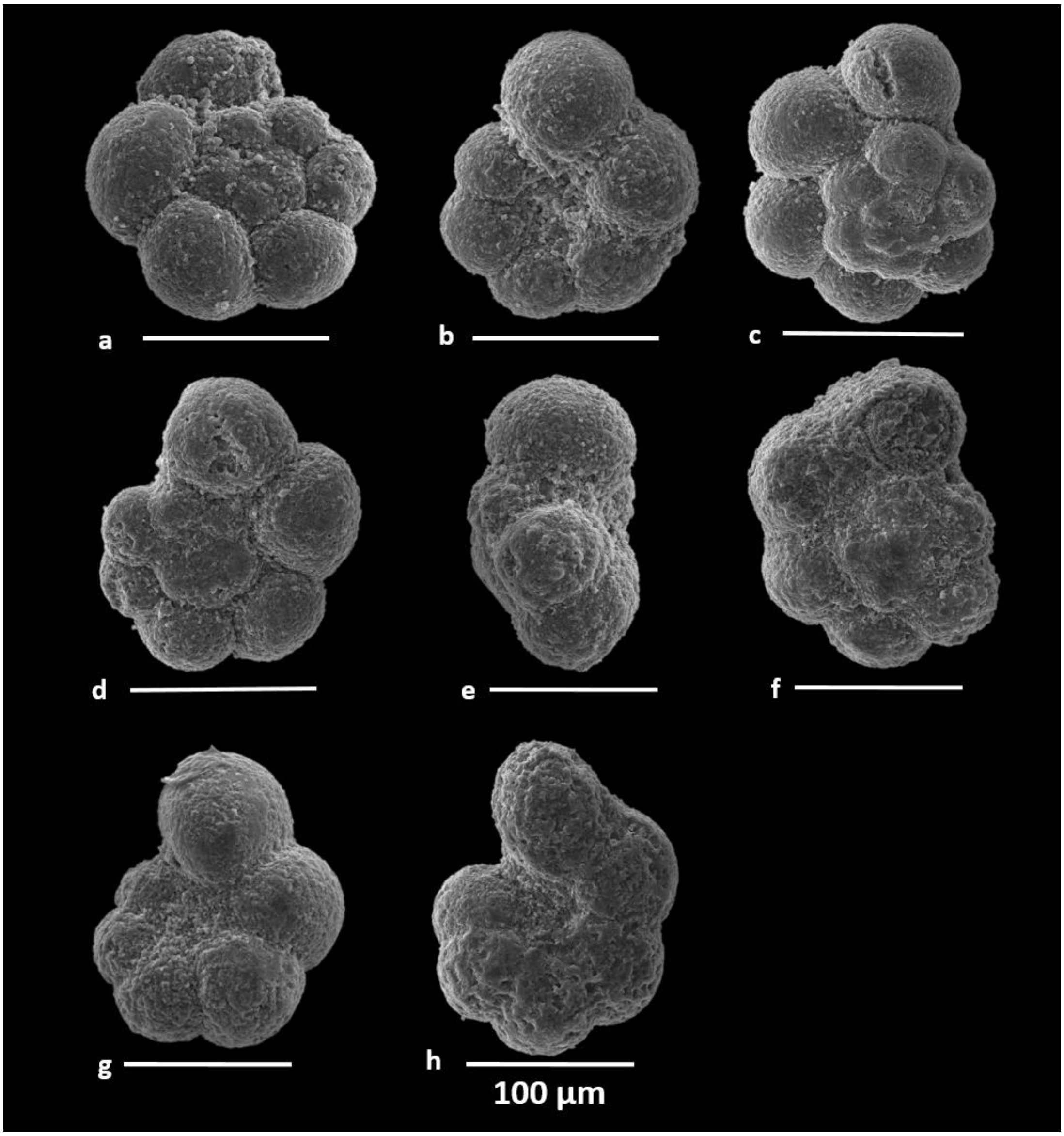


PLATE 4

a. *Hedbergella roblesae* (Obregon, 1959), umbilical view, NY-7S, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

b. *Hedbergella roblesae* (Obregon, 1959), umbilical view, NY-14, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. *Hedbergella roblesae* (Obregon, 1959), umbilical view, NY-14, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. *Hedbergella roblesae* (Obregon, 1959), spiral view, NY-14, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. *Hedbergella similis* (Longoria, 1974), umbilical view, NY-2, *Globigerinelloides blowi* Zone, Early Aptian, Soğukçam Limestone

f. *Hedbergella similis* (Longoria, 1974), side view, NY-10, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

g. *Hedbergella similis* (Longoria, 1974), spiral view, NY-11, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

h. *Hedbergella similis* (Longoria, 1974), umbilical view, NY-28, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

i. *Hedbergella similis* (Longoria, 1974), umbilical view, NY-35, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 4

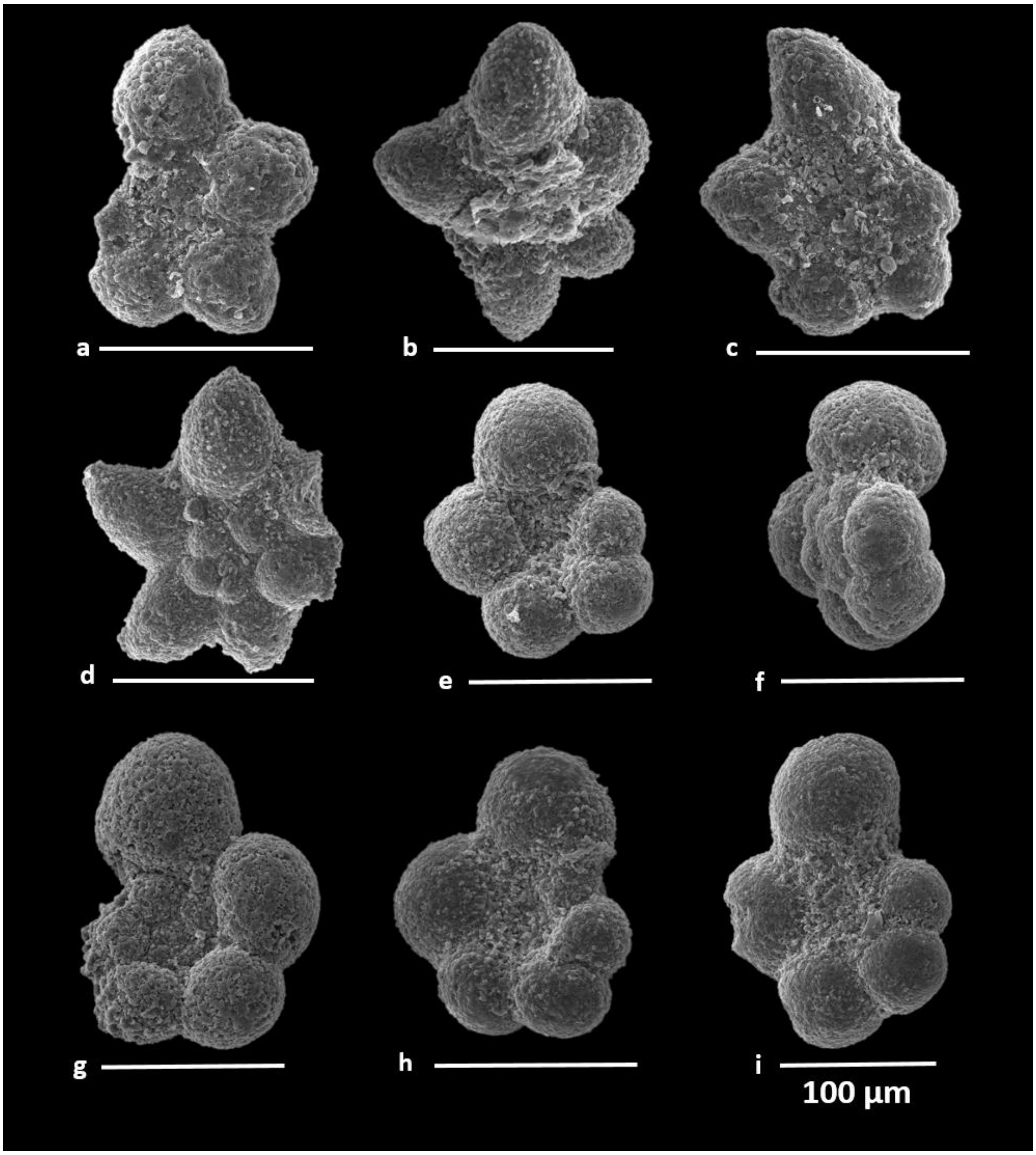


PLATE 5

a. *Hedbergella sigali* (Moullade, 1966), umbilical view, NY-1, *Globigerinelloides blowi* Zone, Early Aptian, Soğukçam Limestone

b. *Hedbergella sigali* (Moullade, 1966), spiral view, NY-1, *Globigerinelloides blowi* Zone, Early Aptian, Soğukçam Limestone

c. *Hedbergella sigali* (Moullade, 1966), umbilical view, NY-2, *Globigerinelloides blowi* Zone, Early Aptian, Soğukçam Limestone

d. *Hedbergella sigali* (Moullade, 1966), spiral view, NY-3, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. *Hedbergella sigali* (Moullade, 1966), umbilical view, NY-10, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

f. *Hedbergella sigali* (Moullade, 1966), umbilical view, NY-10, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

g. *Hedbergella sigali* (Moullade, 1966), spiral view, Slump 1-3, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

h. *Hedbergella sigali* (Moullade, 1966), umbilical view, NY-33, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

i. *Hedbergella sigali* (Moullade, 1966), umbilical view, NY-35, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 5

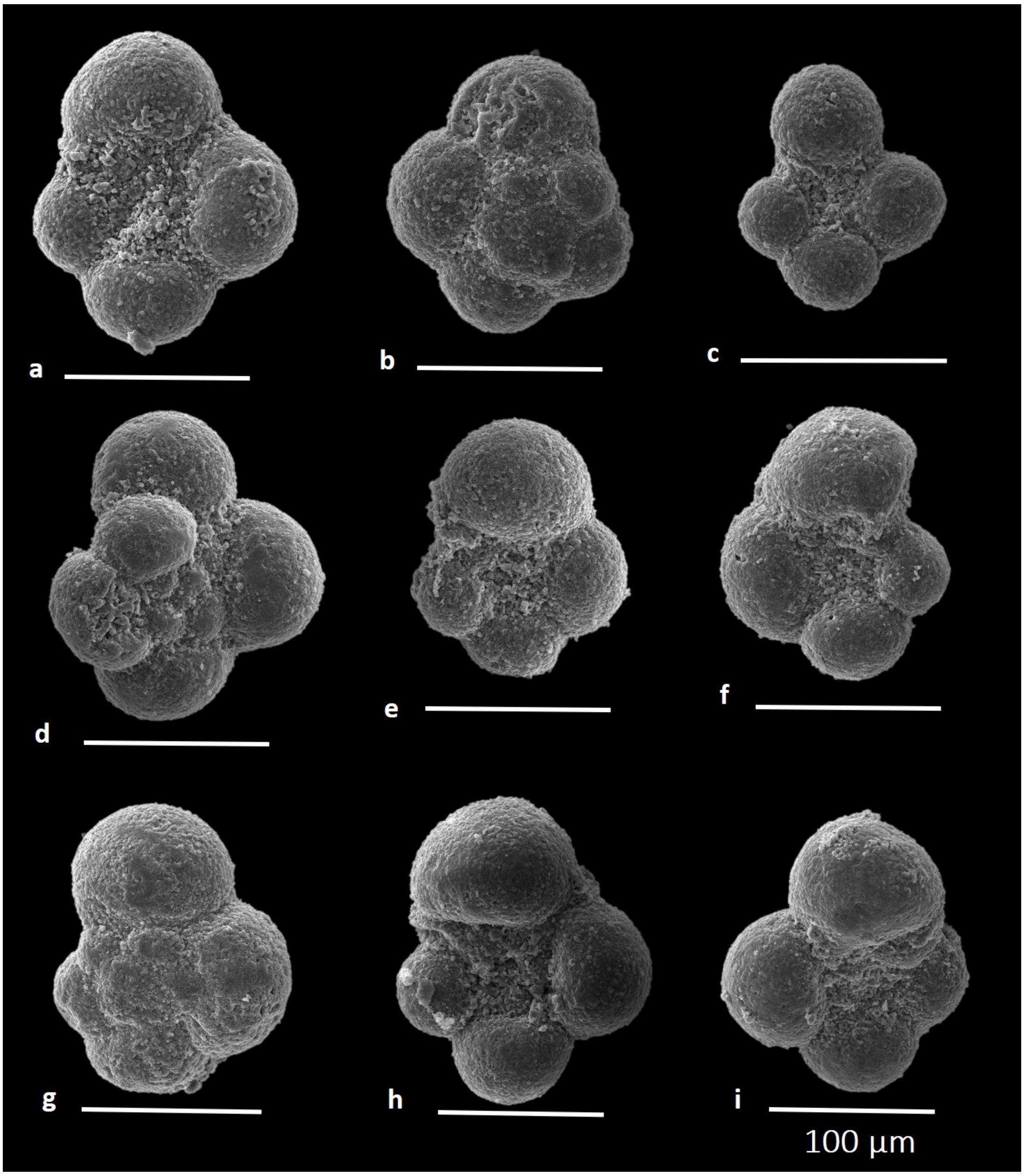


PLATE 6

a. *Leupoldina cabri* (Sigal, 1952), oblique view, NY-3, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

b. *Leupoldina cabri* (Sigal, 1952), oblique view, NY-7, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. *Leupoldina cabri* (Sigal, 1952), umbilical view, NY-10, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. *Leupoldina cabri* (Sigal, 1952), spiral view, NY-13, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. *Leupoldina cabri* (Sigal, 1952), spiral view, NY-15, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

PLATE 6

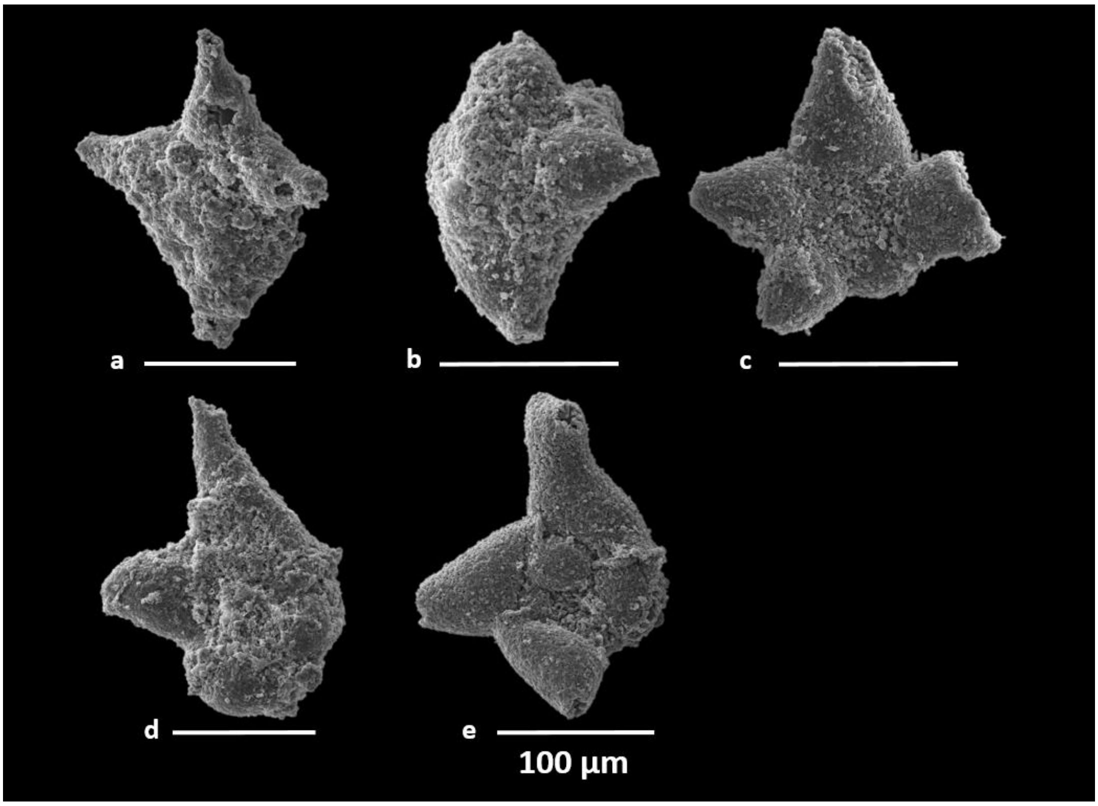


PLATE 7

a. *Lenticulina* sp., spiral view, NY-2, *Globigerinelloides blowi* Zone, Early Aptian, Soğukçam Limestone

b. *Lenticulina* sp., spiral view, NY-5, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. *Lenticulina* sp., spiral view, NY-14, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. *Lenticulina* sp., spiral view, NY-20, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. *Lenticulina* sp., spiral view, NY-26, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

f. *Lenticulina* sp., spiral view, NY-36, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

g. *Nodosaria* sp., longitudinal view, NY-8, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

h. *Nodosaria* sp., longitudinal view, NY-26, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

i. *Nodosaria* sp., longitudinal view, NY-34, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 7

PLATE 8

a. *Textularia* sp., longitudinal view, NY-13, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

b. *Textularia* sp., longitudinal view, NY-16, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. *Textularia* sp., longitudinal view, NY-19, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. *Textularia* sp., longitudinal view, NY-31, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

e. *Textularia* sp., longitudinal view, NY-39, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

f. *Spirillina* sp., spiral view, NY-21, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

g. *Spirillina* sp., spiral view, NY-24, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

h. *Spirillina* sp., spiral view, NY-24, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

i. *Spirillina* sp., spiral view, NY-34, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 8

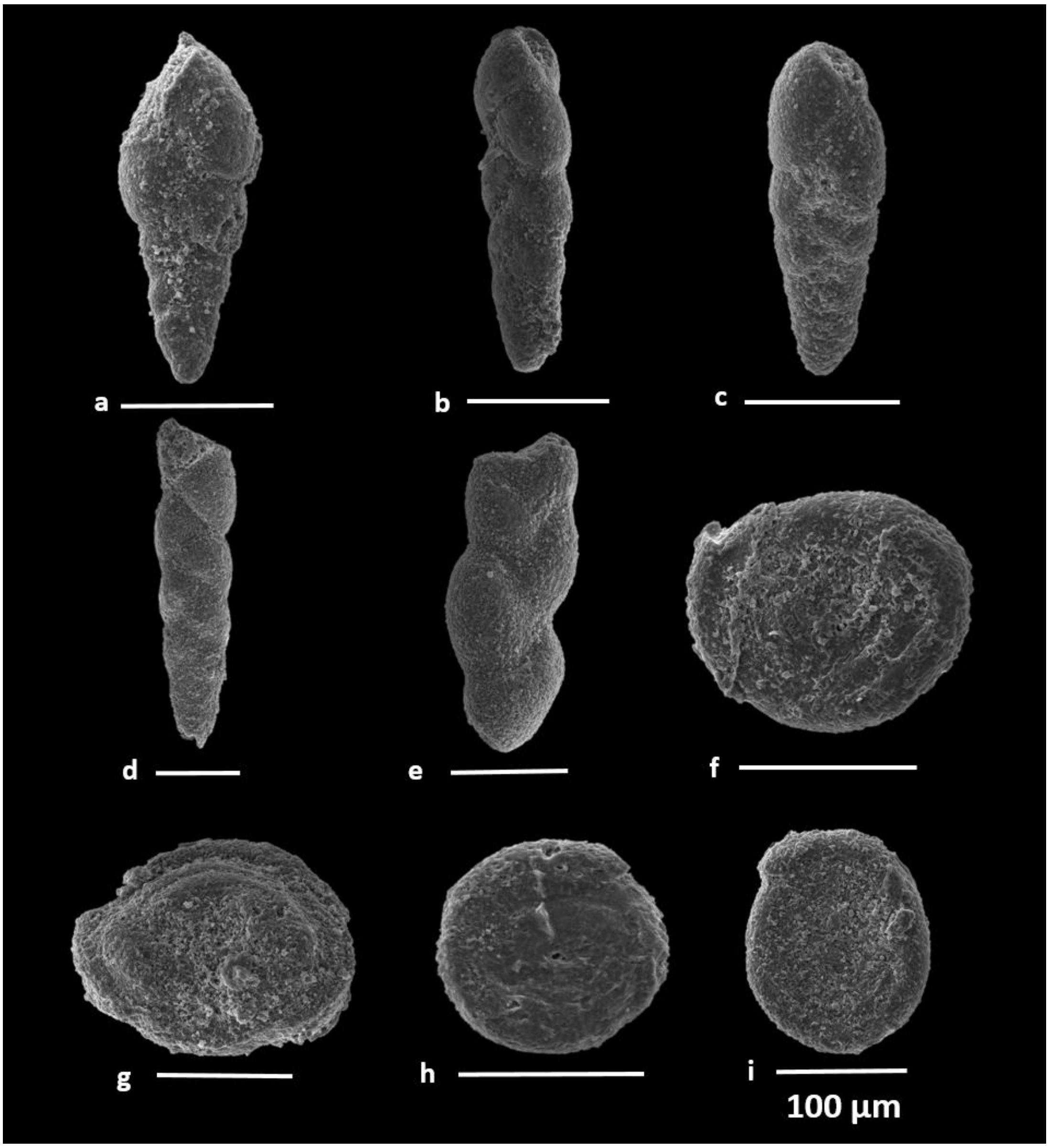


PLATE 9

a. Radiolaria, NY-11, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

b. Radiolaria, NY-14, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. Radiolaria, NY-23, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. Radiolaria, NY-23, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. Radiolaria, NY-23, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

f. Radiolaria, NY-23, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

g. Radiolaria, Slump 1-2, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

h. Radiolaria, Slump 1-2, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

i. Radiolaria, Slump 1-2, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

j. Radiolaria, NY-29, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

k. Radiolaria, NY-29, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

l. Radiolaria, NY-36, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 9

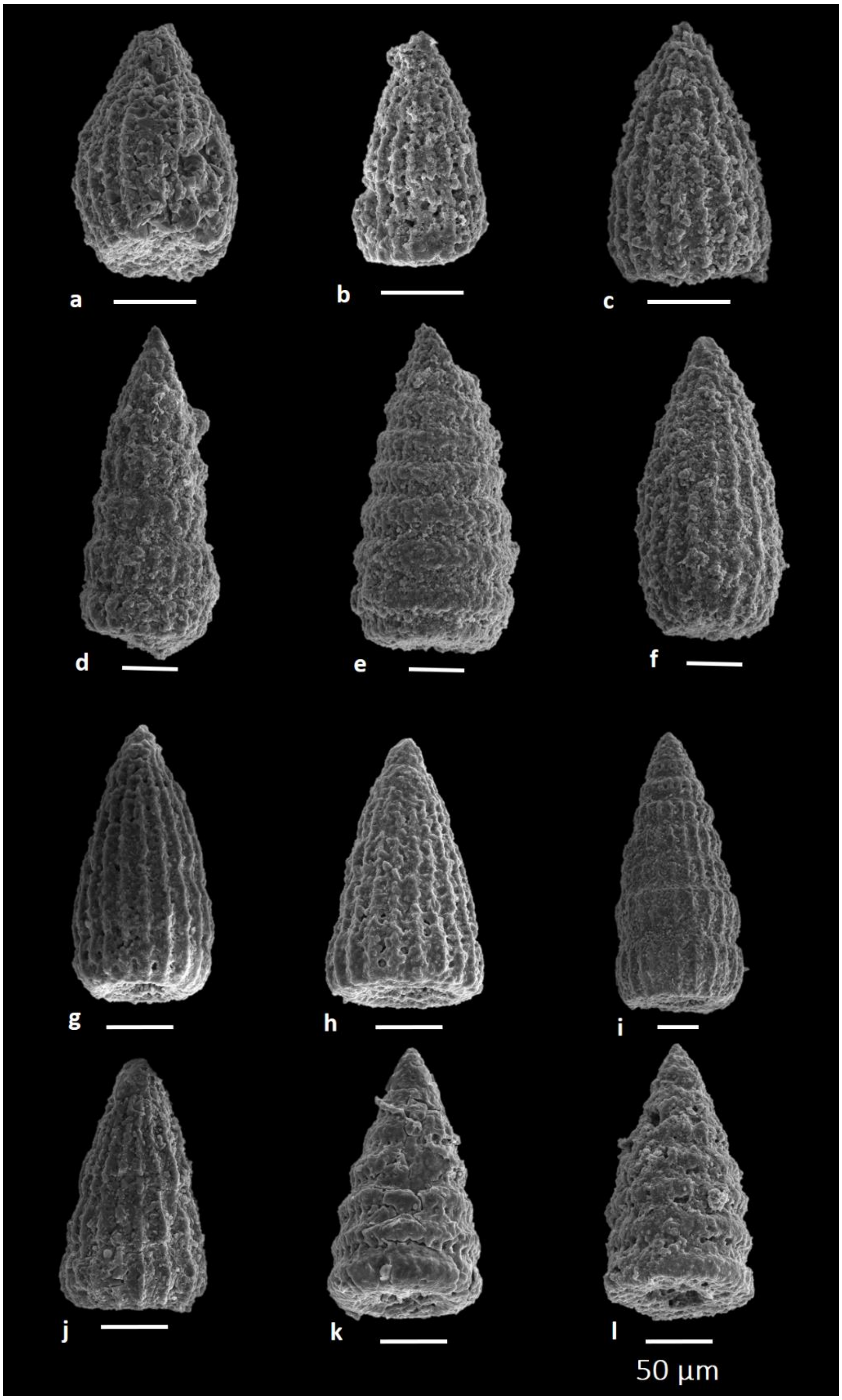


PLATE 10

a. Radiolaria, NY-12, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

b. Radiolaria, NY-16, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. Radiolaria, NY-23, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. Radiolaria, NY-23, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. Radiolaria, NY-26, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

f. Radiolaria, Slump 1-2, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

g. Radiolaria, Slump 1-2, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

h. Radiolaria, NY-36, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

i. Radiolaria, NY-23, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

j. Radiolaria, NY-23, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

k. Radiolaria, NY-23, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

l. Radiolaria, NY-23, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

PLATE 10

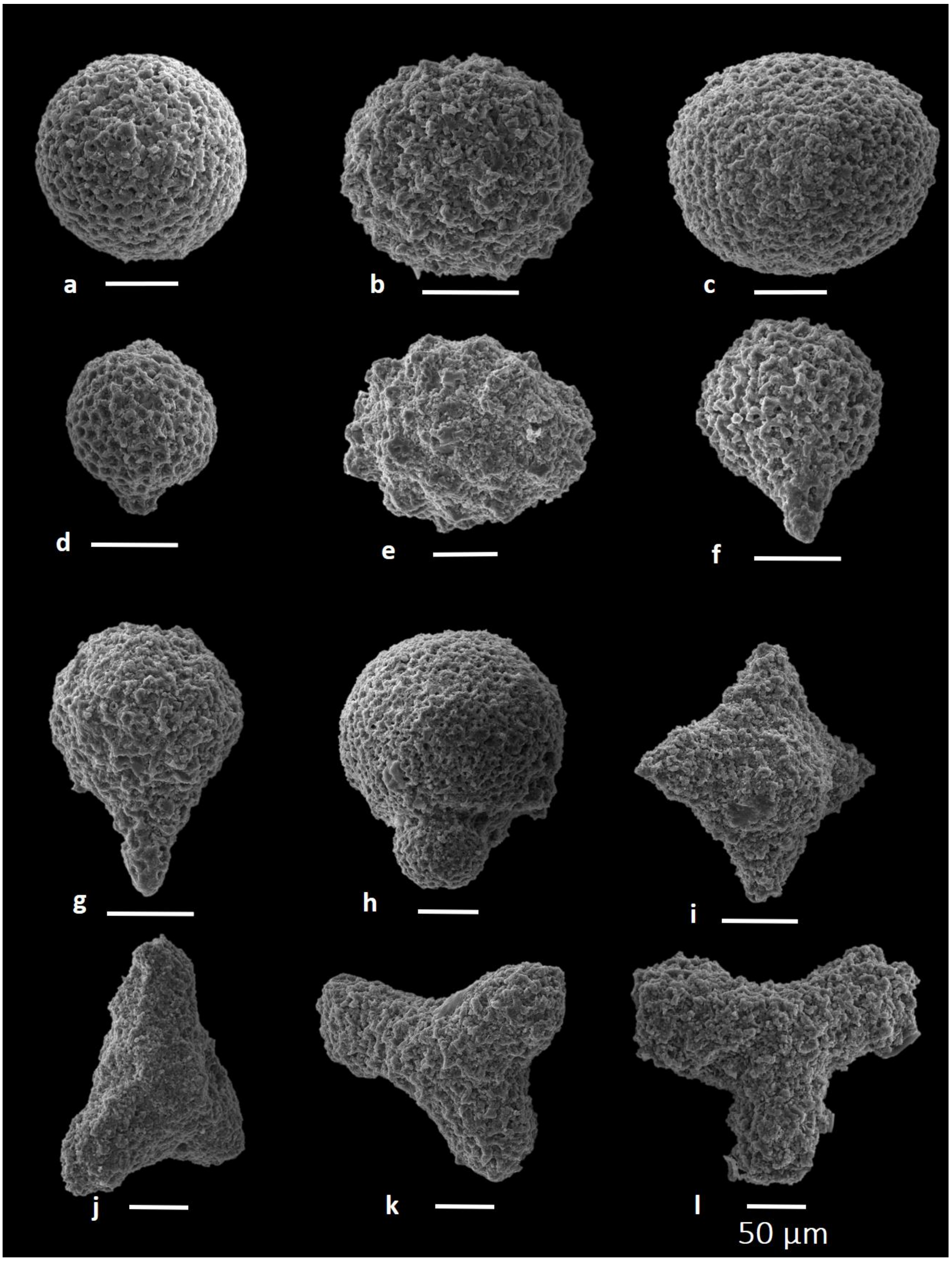


PLATE 11

a. *Globigerinelloides blowi* (Bolli, 1959), axial section, NY-2, *Globigerinelloides blowi* Zone, Early Aptian, Soğukçam Limestone

b. *Globigerinelloides blowi* (Bolli, 1959), tangential section, NY-6, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. *Globigerinelloides blowi* (Bolli, 1959), tangential section, NY-7, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. *Globigerinelloides blowi* (Bolli, 1959), tangential section, NY-13, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. *Globigerinelloides duboisi* (Chevalier, 1961), equatorial section, NY-2, *Globigerinelloides blowi* Zone, Early Aptian, Soğukçam Limestone

f. *Globigerinelloides duboisi* (Chevalier, 1961), axial section, NY-4, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

g. *Globigerinelloides duboisi* (Chevalier, 1961), tangential section, NY-4, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

h. *Globigerinelloides ferreolensis* (Moullade, 1961), equatorial section, NY-22, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

i. *Globigerinelloides ferreolensis* (Moullade, 1961), axial section, NY-22, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

j. *Globigerinelloides ferreolensis* (Moullade, 1961), axial section, NY-22, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

k. *Globigerinelloides ferreolensis* (Moullade, 1961), axial section, NY-22, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

PLATE 11

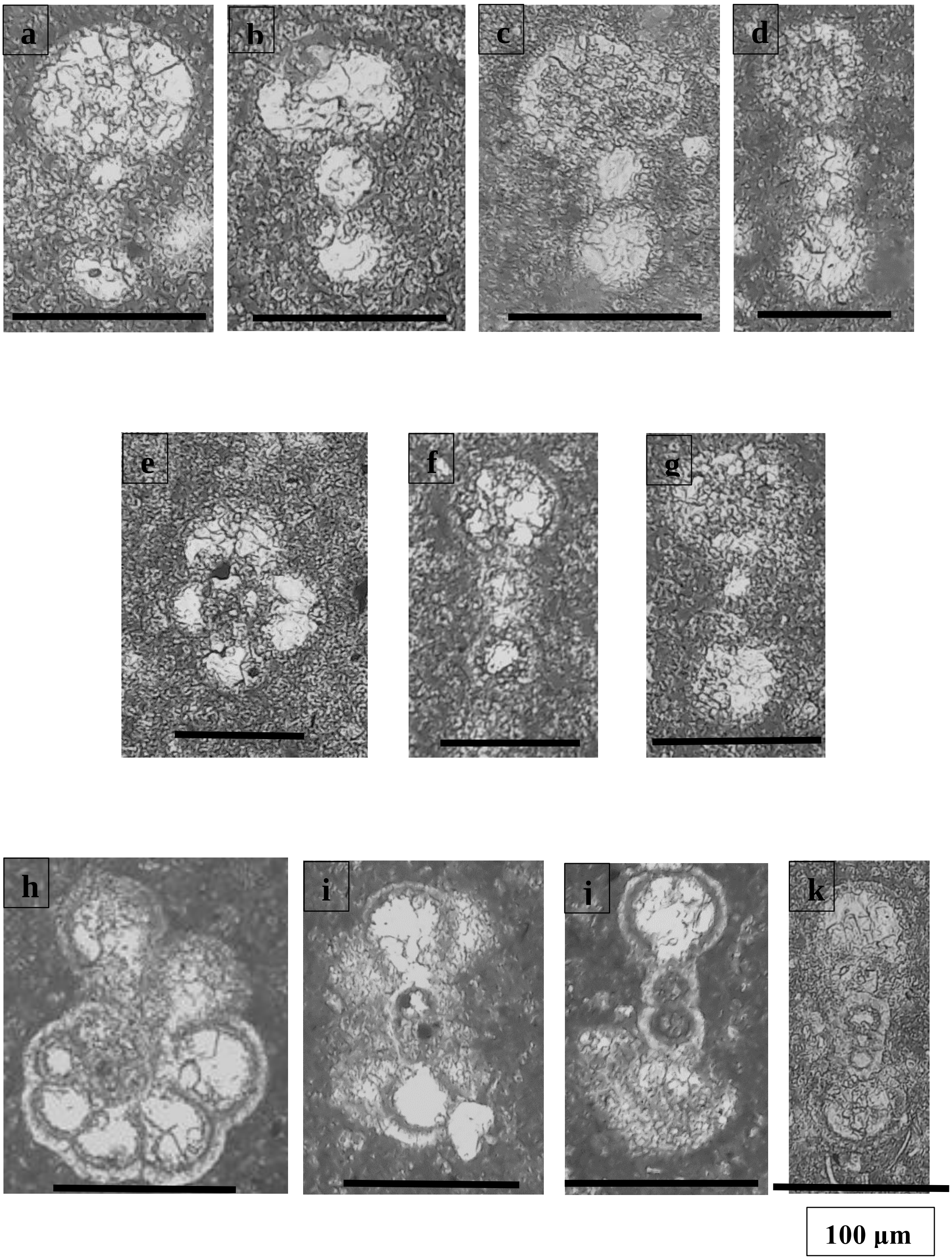


PLATE 12

a. *Globigerinelloides ferreolensis* (Moullade, 1961), axial section, NY-22, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

b. *Globigerinelloides ferreolensis* (Moullade, 1961), tangential section, NY-22, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. *Globigerinelloides ferreolensis* (Moullade, 1961), axial section, NY-27, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

d. *Globigerinelloides ferreolensis* (Moullade, 1961), tangential section, NY-27, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

e. *Globigerinelloides ferreolensis* (Moullade, 1961), tangential section, NY-27, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

f. *Globigerinelloides ferreolensis* (Moullade, 1961), nearly equatorial section, Slump 1-2, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

g. *Globigerinelloides ferreolensis* (Moullade, 1961), oblique section, Slump 1-1, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

h. *Globigerinelloides ferreolensis* (Moullade, 1961), axial section, Slump 1-1, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

i. *Globigerinelloides ferreolensis* (Moullade, 1961), axial section, Slump 1-1, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

j. *Globigerinelloides ferreolensis* (Moullade, 1961), equatorial section, NY-30, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

k. *Globigerinelloides ferreolensis* (Moullade, 1961), tangential section, NY-31, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

l. *Globigerinelloides ferreolensis* (Moullade, 1961), equatorial section, NY-39, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 12

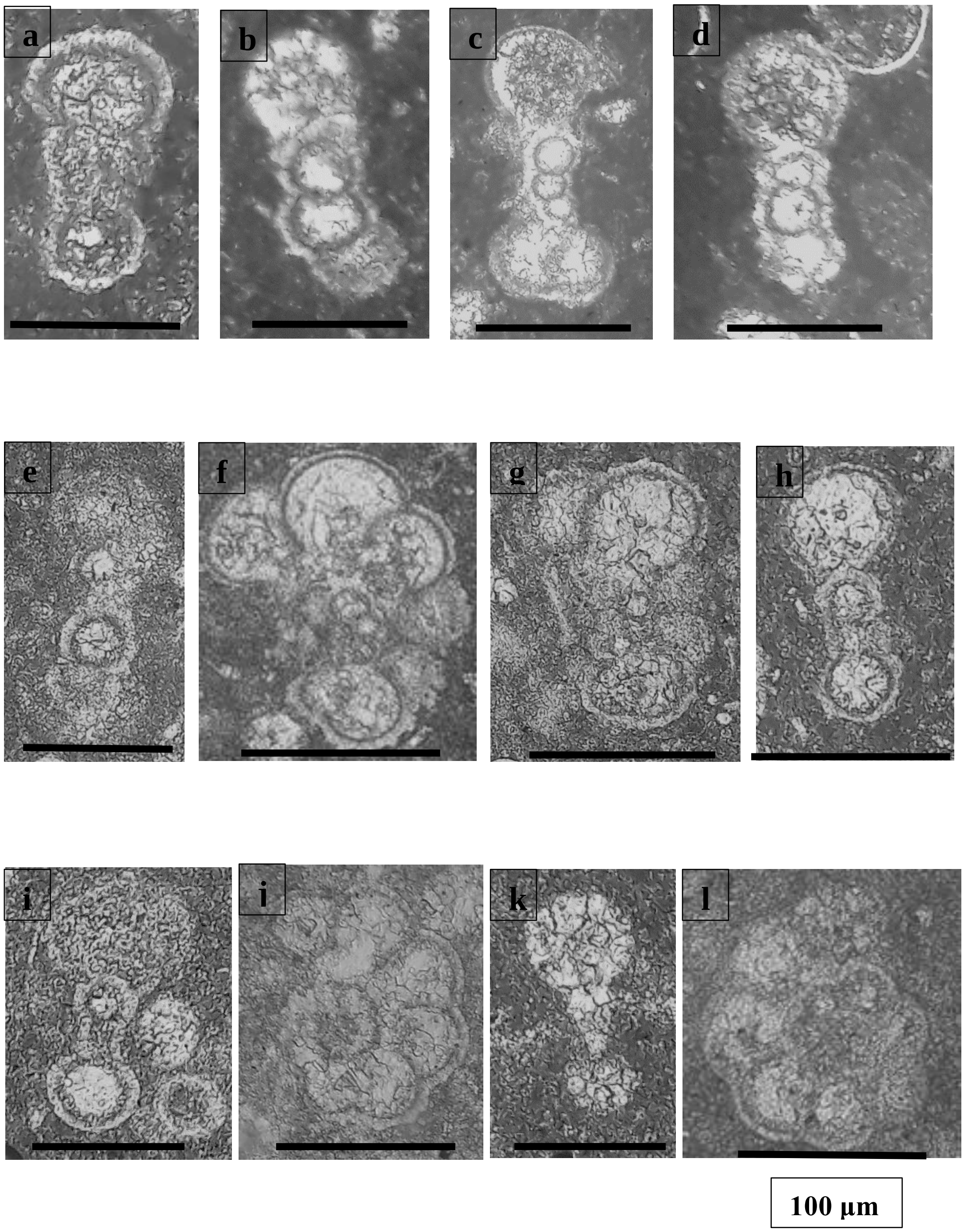


PLATE 13

a. *Hedbergella infracretacea* (Glaessner, 1937a,b), nearly equatorial section, NY-4, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

b. *Hedbergella infracretacea* (Glaessner, 1937a,b), nearly equatorial section, NY-8, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. *Hedbergella infracretacea* (Glaessner, 1937a,b), nearly equatorial section, NY-20, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. *Hedbergella infracretacea* (Glaessner, 1937a,b), equatorial section, NY-22, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. *Hedbergella infracretacea* (Glaessner, 1937a,b), nearly equatorial section, NY-22, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

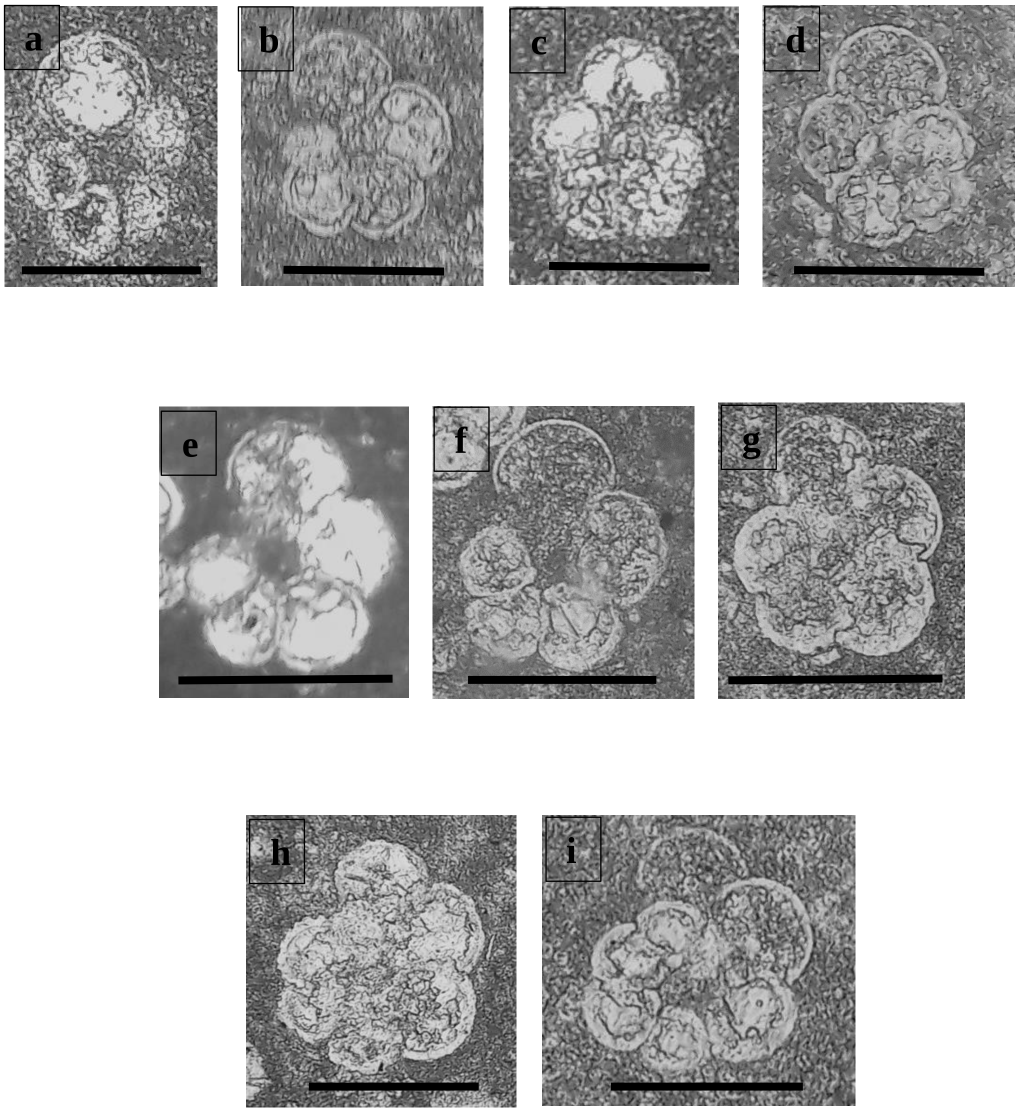
f. *Hedbergella infracretacea* (Glaessner, 1937a,b), nearly equatorial section, NY-25, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

g. *Hedbergella infracretacea* (Glaessner, 1937a,b), nearly equatorial section, NY-30, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

h. *Hedbergella luterbacheri* (Longoria, 1974), nearly equatorial section, NY-28, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

i. *Hedbergella luterbacheri* (Longoria, 1974), nearly equatorial section, NY-31, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 13



100 µm

PLATE 14

a. *Hedbergella occulta* (Longoria, 1974), nearly equatorial section, NY-4, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

b. *Hedbergella occulta* (Longoria, 1974), nearly equatorial section, NY-10, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. *Hedbergella occulta* (Longoria, 1974), nearly equatorial section, NY-10, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. *Hedbergella occulta* (Longoria, 1974), nearly equatorial section, NY-10, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. *Hedbergella occulta* (Longoria, 1974), nearly equatorial section, NY-11, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

f. *Hedbergella occulta* (Longoria, 1974), nearly equatorial section, NY-12, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

g. *Hedbergella occulta* (Longoria, 1974), nearly equatorial section, NY-13, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

h. *Hedbergella occulta* (Longoria, 1974), nearly equatorial section, Slump 1-3, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

i. *Hedbergella occulta* (Longoria, 1974), nearly equatorial section, NY-30, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

j. *Hedbergella occulta* (Longoria, 1974), nearly equatorial section, NY-35, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

k. *Hedbergella occulta* (Longoria, 1974), nearly equatorial section, NY-39, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 14

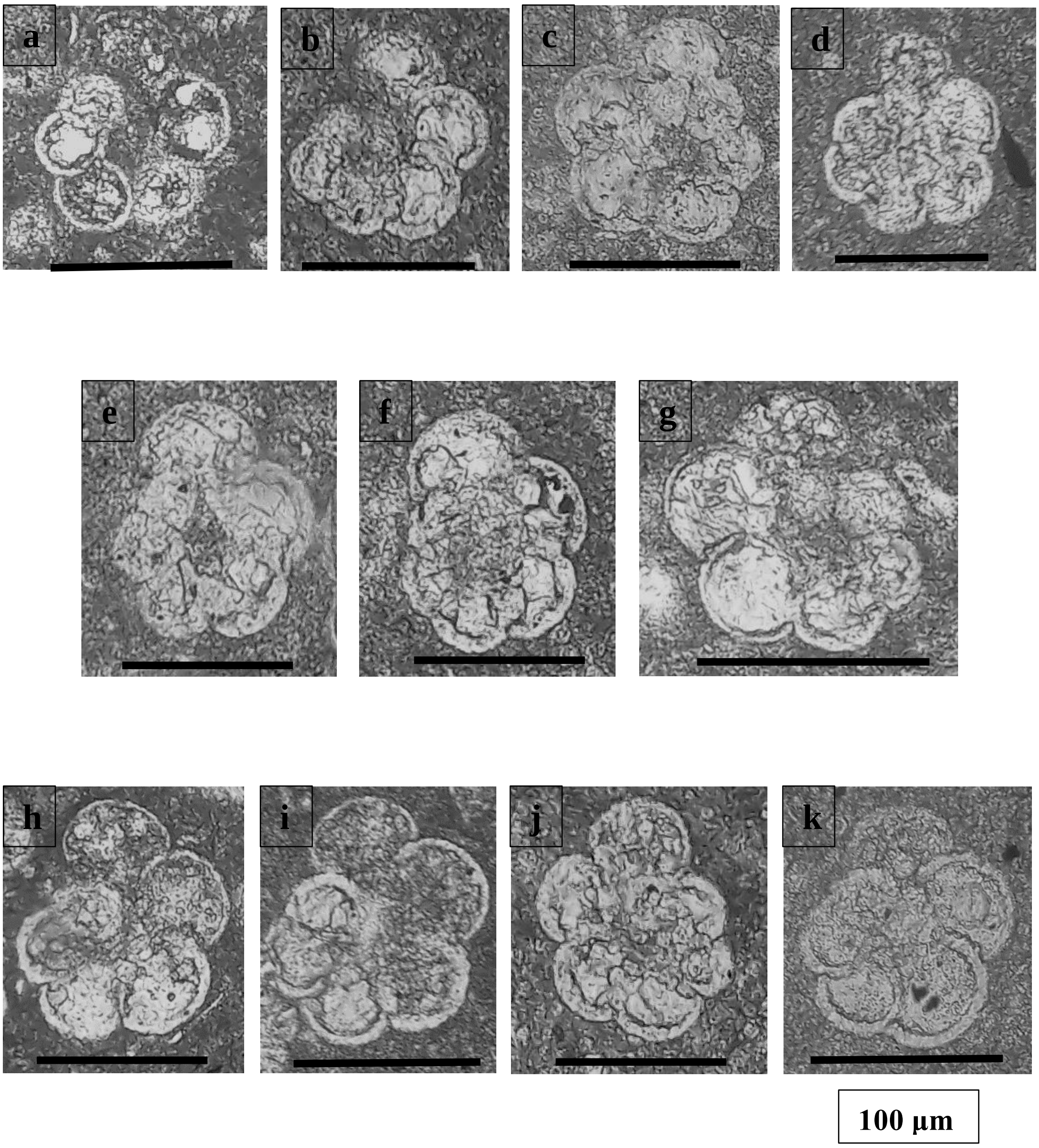


PLATE 15

a. *Hedbergella roblesae* (Obregon, 1959), nearly equatorial section, NY-7S, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

b. *Hedbergella sigali* (Moullade, 1966), nearly equatorial section, NY-7S, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. *Hedbergella sigali* (Moullade, 1966), nearly equatorial section, NY-7S, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. *Hedbergella sigali* (Moullade, 1966), nearly equatorial section, NY-8, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. *Hedbergella sigali* (Moullade, 1966), nearly equatorial section, NY-9, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

f. *Hedbergella sigali* (Moullade, 1966), nearly equatorial section, NY-10, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

g. *Hedbergella sigali* (Moullade, 1966), nearly equatorial section, NY-27, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

h. *Hedbergella sigali* (Moullade, 1966), nearly equatorial section, Slump 1-3, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

i. *Hedbergella similis* (Longoria, 1974), nearly equatorial section, NY-4, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

j. *Hedbergella similis* (Longoria, 1974), nearly equatorial section, NY-7S, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

k. *Hedbergella similis* (Longoria, 1974), nearly equatorial section, NY-7, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

l. *Hedbergella similis* (Longoria, 1974), nearly equatorial section, NY-11, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

PLATE 15

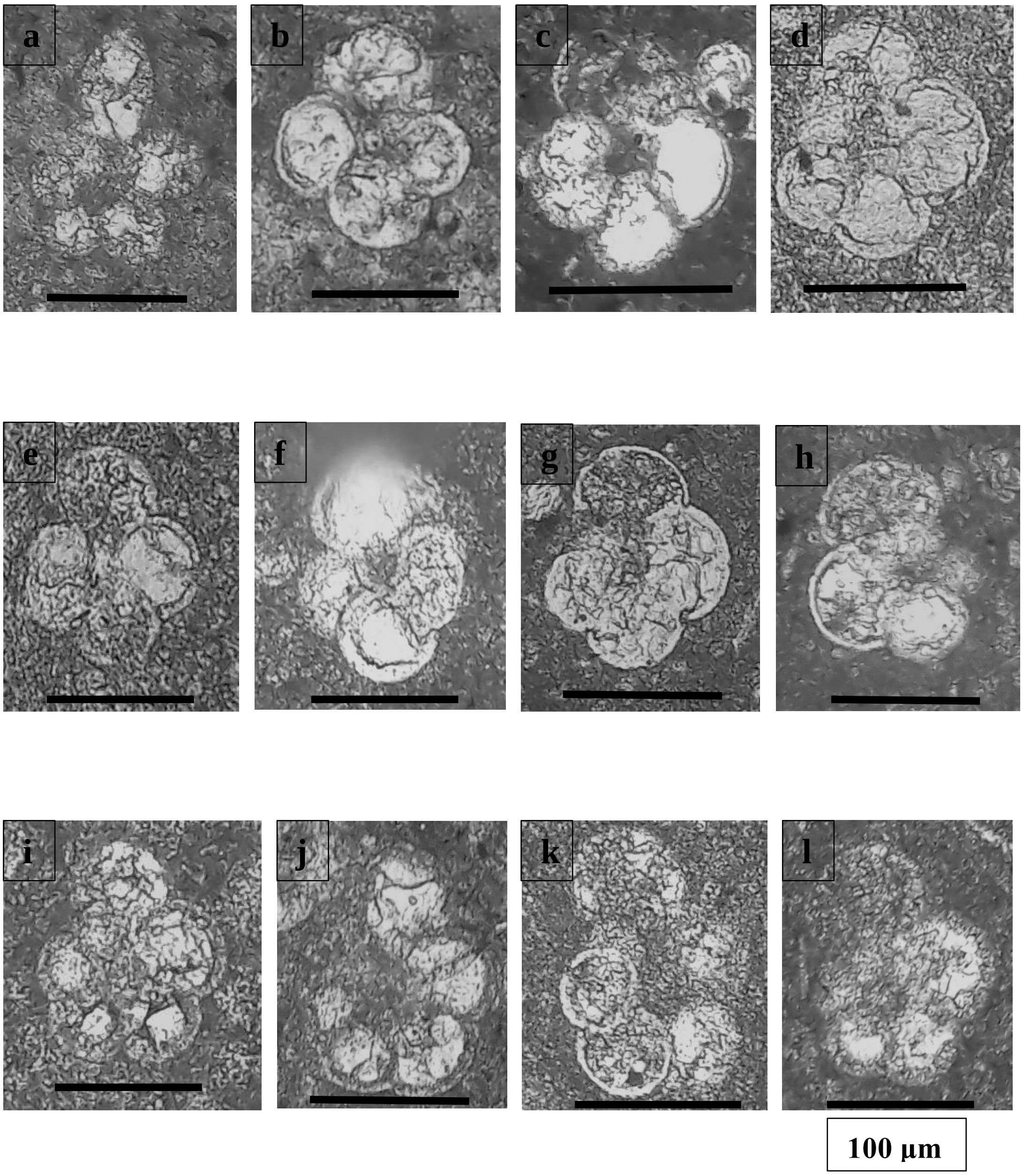


PLATE 16

a. *Hedbergella similis* (Longoria, 1974), nearly equatorial section, NY-16, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

b.*Hedbergella similis* (Longoria, 1974), nearly equatorial section, NY-30, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

c. *Leupoldina cabri* (Sigal, 1952), oblique section, NY-8, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. *Leupoldina cabri* (Sigal, 1952), tangential section, NY-8, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

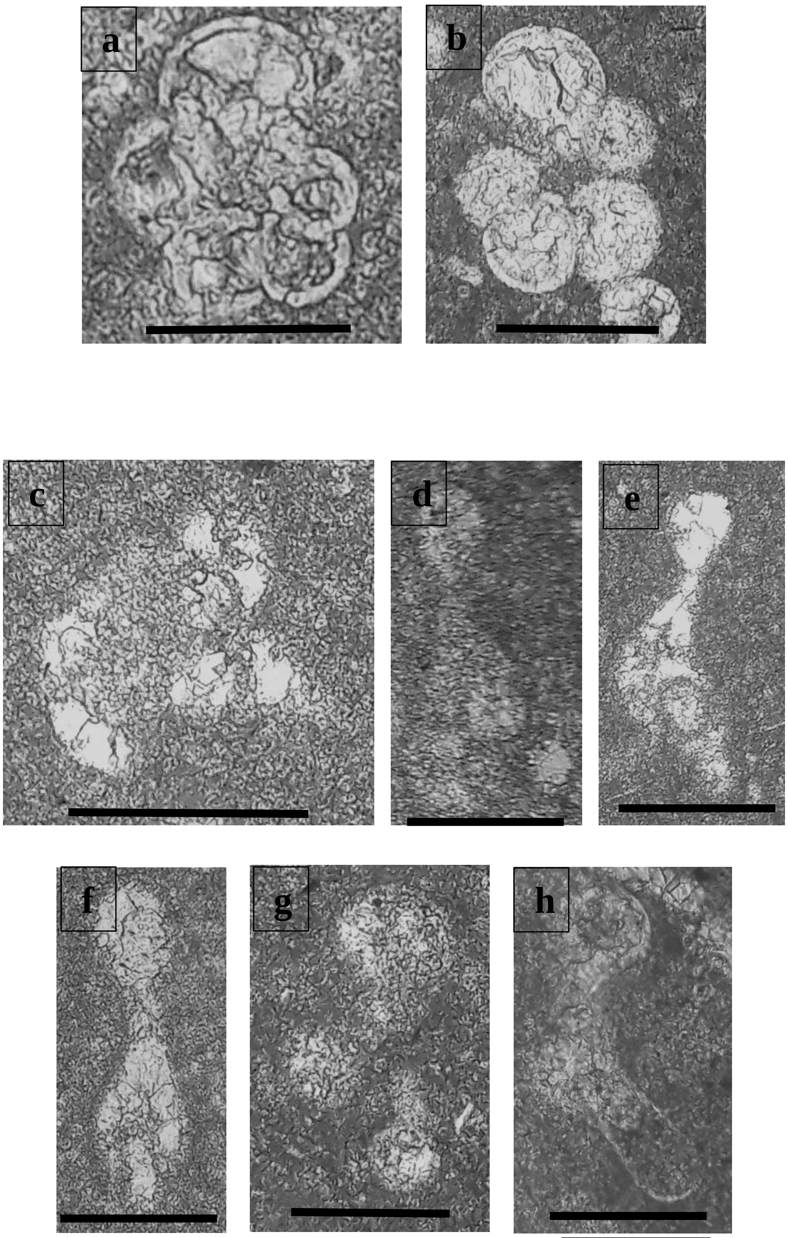
e. *Leupoldina cabri* (Sigal, 1952), tangential section, NY-8, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

f. *Leupoldina cabri* (Sigal, 1952), tangential section, NY-10, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

g. *Leupoldina cabri* (Sigal, 1952), oblique section, NY-11, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

h. *Leupoldina cabri* (Sigal, 1952), oblique section, NY-16, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

PLATE 16



100 µm

PLATE 17

a. *Hedbergella excelsa* (Longoria, 1974), tangential section, NY-9, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

b. *Hedbergella luterbacheri* (Longoria, 1974), axial section, NY-11, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. *Hedbergella occulta* (Longoria, 1974), axial section, NY-1, *Globigerinelloides blowi* Zone, Early Aptian, Soğukçam Limestone

d. *Hedbergella occulta* (Longoria, 1974), axial section, NY-2, *Globigerinelloides blowi* Zone, Early Aptian, Soğukçam Limestone

e. *Hedbergella occulta* (Longoria, 1974), axial section, NY-2, *Globigerinelloides blowi* Zone, Early Aptian, Soğukçam Limestone

f. *Hedbergella occulta* (Longoria, 1974), tangential section, NY-4, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

g. *Hedbergella occulta* (Longoria, 1974), axial section, NY-11, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

h. *Hedbergella* sp., axial section, NY-1, *Globigerinelloides blowi* Zone, Early Aptian, Soğukçam Limestone

i. *Hedbergella* sp., tangential section, NY-3, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

j. *Hedbergella* sp., tangential section, NY-4, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

k. *Hedbergella* sp., axial section, NY-16, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

l. *Hedbergella* sp., axial section, NY-28, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

m. *Hedbergella* sp., axial section, Slump 1-2, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

n. *Hedbergella* sp., axial section, Slump 1-1, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 17

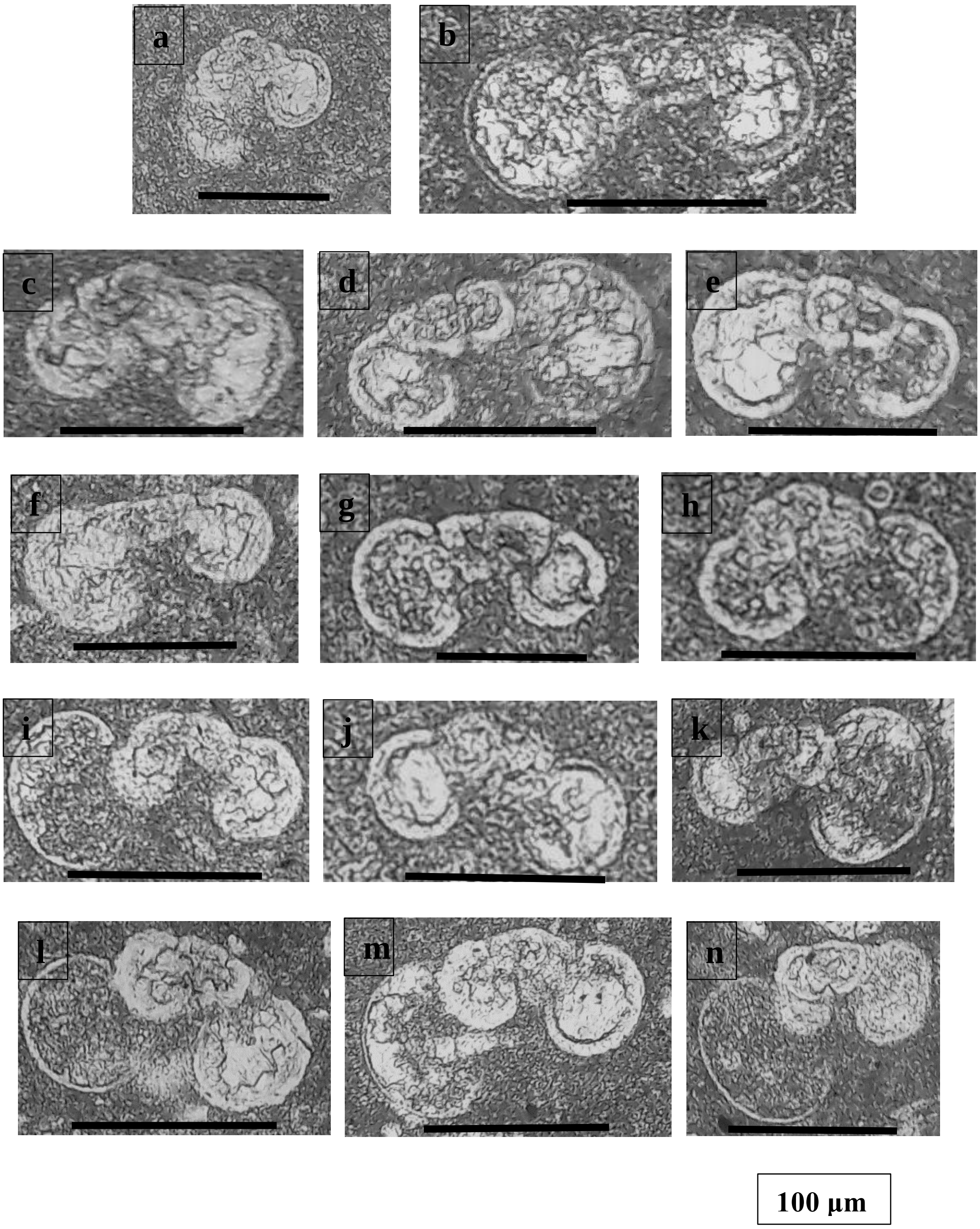


PLATE 18

a. *Lenticulina* sp., axial section, NY-4, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

b. *Lenticulina* sp., axial section, NY-5, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. *Lenticulina* sp., tangential section, NY-7, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. *Lenticulina* sp., tangential section, NY-9, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. *Lenticulina* sp., equatorial section, NY-13, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

f. *Lenticulina* sp., equatorial section, NY-14, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

g. *Lenticulina* sp., nearly equatorial section, NY-14, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

h. *Lenticulina* sp., tangential section, NY-14, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

i. *Lenticulina* sp., axial section, NY-20, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

j. *Lenticulina* sp., tangential section, NY-25, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

PLATE 18

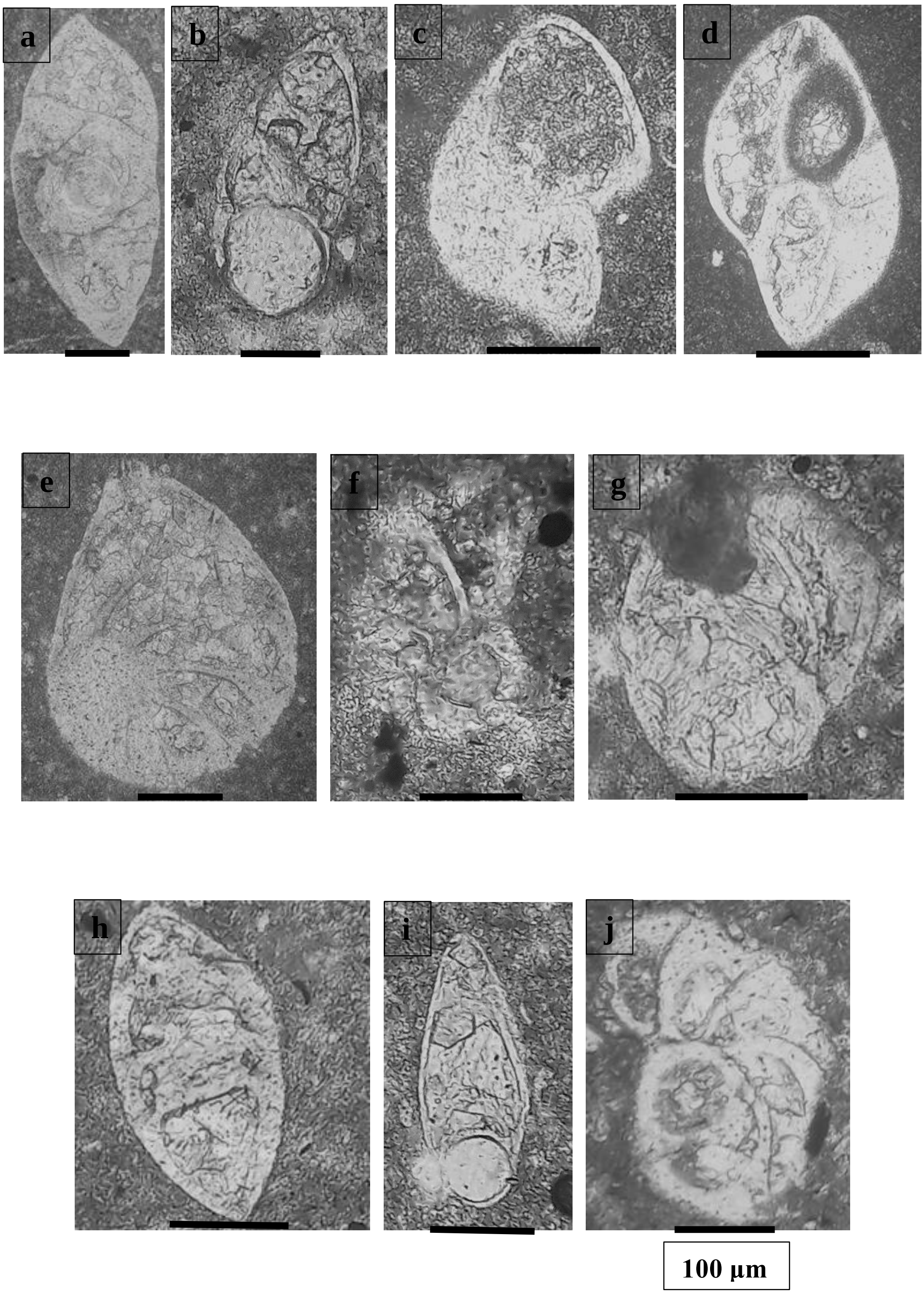


PLATE 19

a. *Lenticulina* sp., axial section, NY-27, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

b. *Lenticulina* sp., tangential section, NY-28, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

c. *Lenticulina* sp., tangential section, NY-38, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

d. *Nodosaria* sp., longitudinal section, NY-10, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. *Nodosaria* sp., longitudinal section, NY-12, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

f. *Nodosaria sp.*, longitudinal section, NY-12, *Leupoldina cabri Zone,* Early Late Aptian, Soğukçam Limestone

g. *Nodosaria* sp., longitudinal section, NY-14, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

h. *Nodosaria* sp., longitudinal section, NY-14, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

i. *Nodosaria* sp., longitudinal section, NY-31, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 19

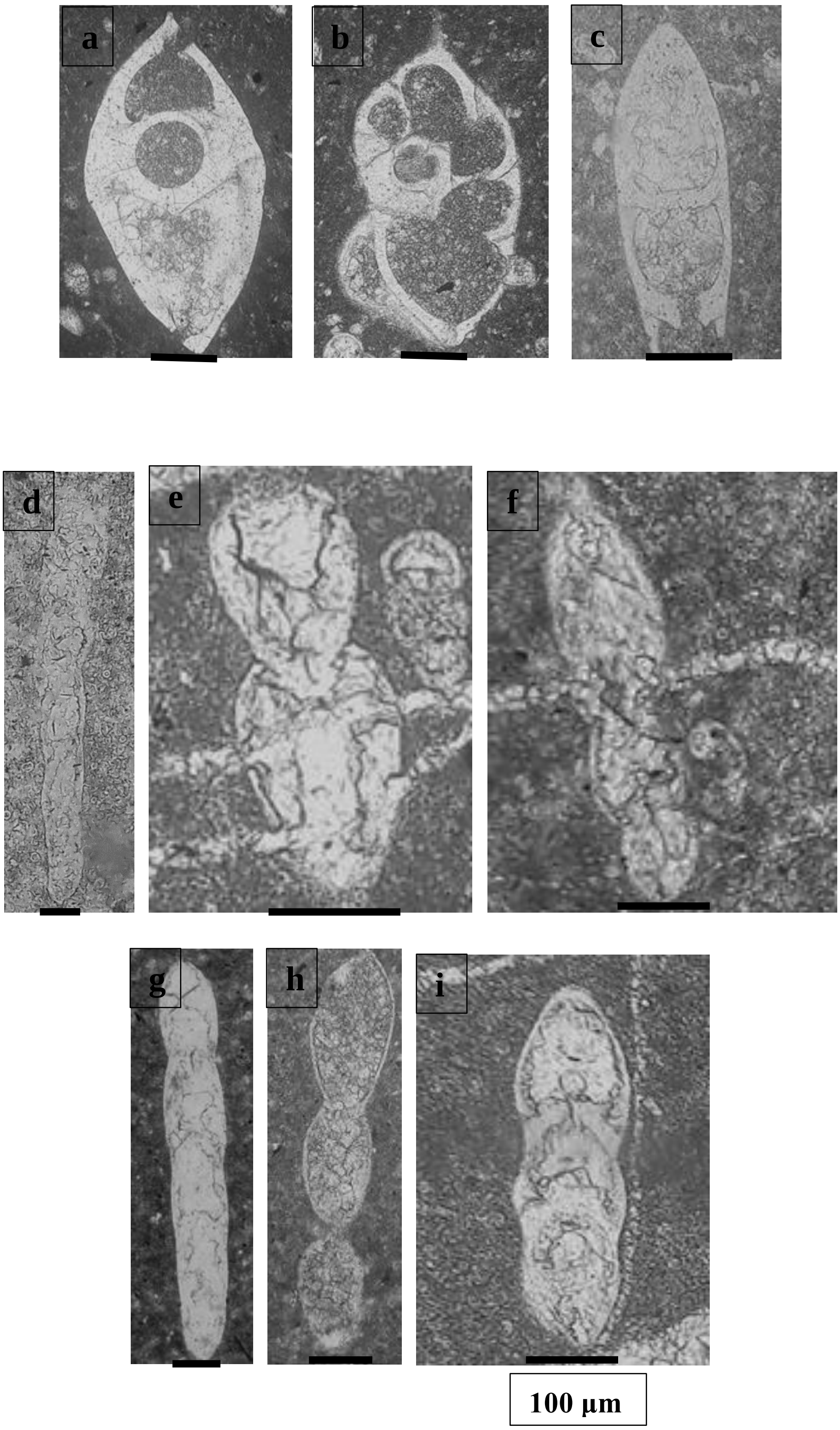


PLATE 20

a. *Textularia* sp., longitudinal section, NY-8, *Leupoldina cabri Zone,* Early Late Aptian, Soğukçam Limestone

b. *Textularia* sp., longitudinal section, NY-16, *Leupoldina cabri Zone,* Early Late Aptian, Soğukçam Limestone

c. *Textularia* sp., longitudinal section, NY-19, *Leupoldina cabri Zone,* Early Late Aptian, Soğukçam Limestone

d. *Textularia* sp., longitudinal section, Slump 1-3, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

e. *Textularia* sp., longitudinal section, Slump 1-2, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

f. *Spirillina* sp., axial section, NY-8, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

g. *Spirillina* sp., equatorial section, NY-28, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

h. *Spirillina* sp., axial section, NY-28, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

i. *Spirillina* sp., axial section, NY-28, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 20

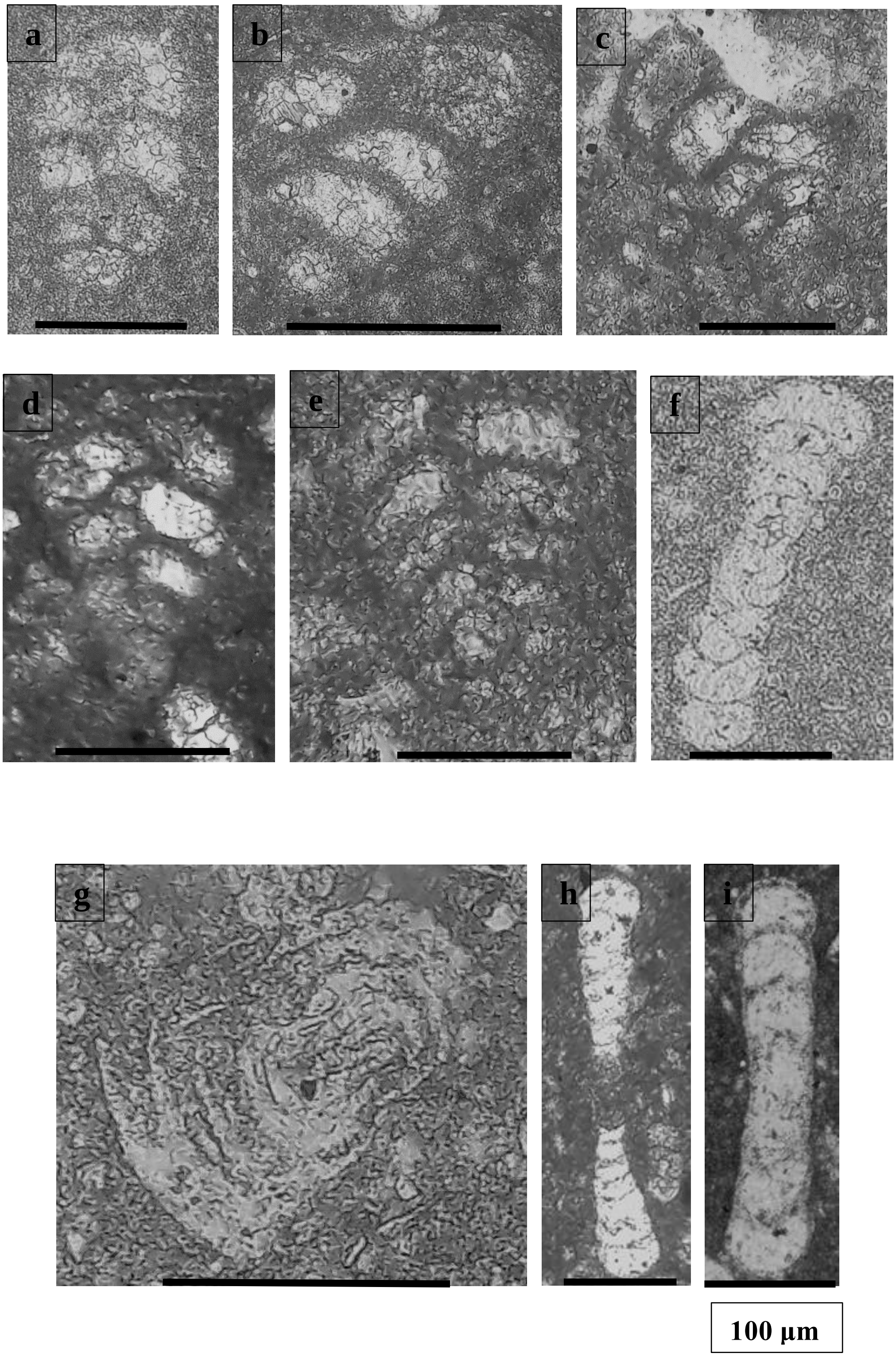


PLATE 21

a. *Patellina* sp., axial section, NY-28, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

b. *Patellina* sp., axial section, NY-28, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

c. *Meandrospira* sp., transverse section, NY-4, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. *Meandrospira* sp., transverse section, NY-8, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. *Meandrospira* sp., longitudinal section, NY-10, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

f. *Meandrospira* sp., longitudinal section, NY-25, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

g. *Meandrospira* sp., transverse section, NY-28, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

h. *Meandrospira* sp., transverse section, NY-28, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

i. Ataxophragmiidae, longitudinal section, NY-7, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

j. Ataxophragmiidae, longitudinal section, NY-19, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

k. Ataxophragmiidae, longitudinal section, NY-38, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 21

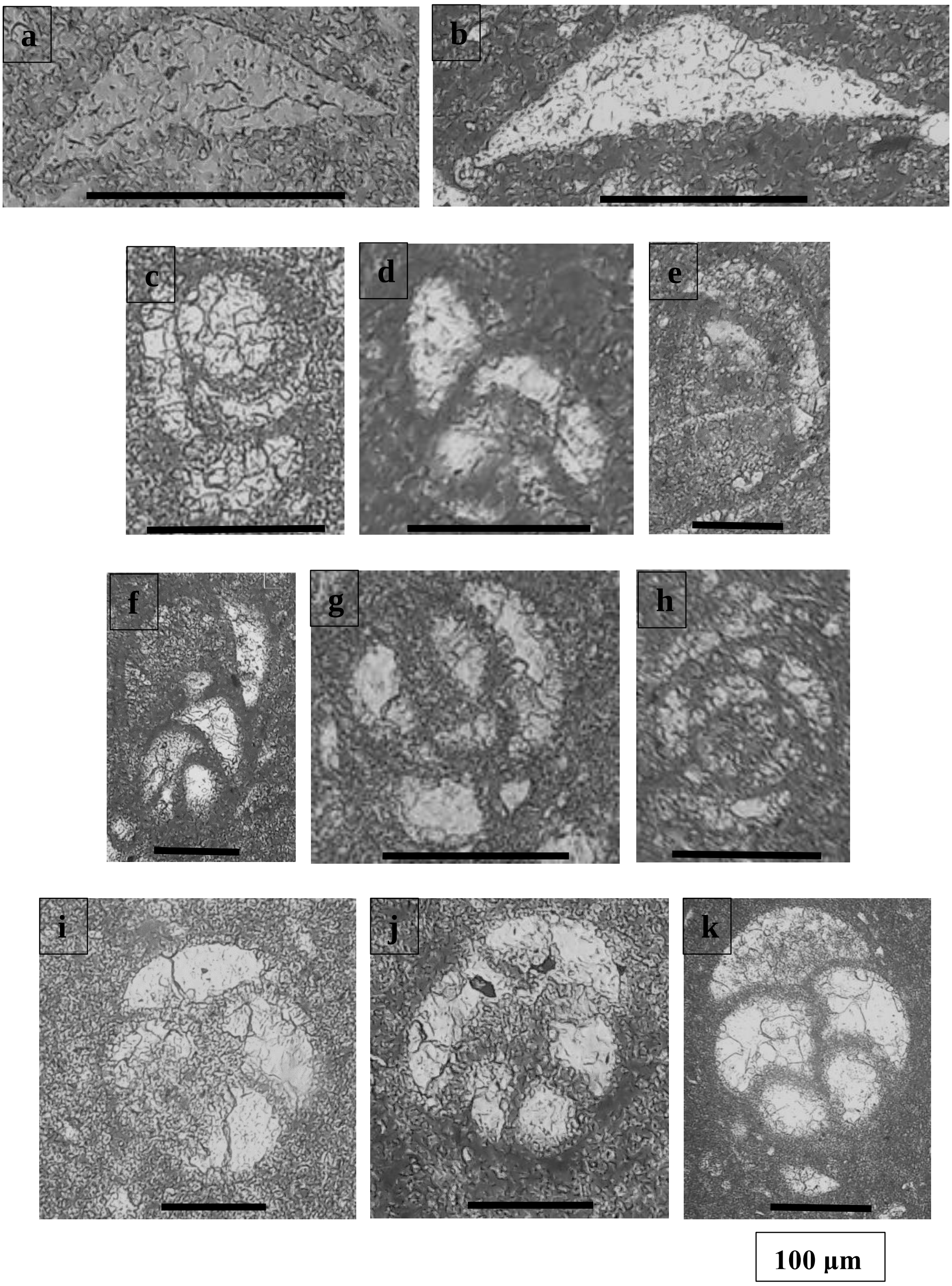


PLATE 22

a. *Cadosina* sp., NY-2, *Globigerinelloides blowi* Zone, Early Aptian, Soğukçam Limestone

b. *Cadosina* sp., NY-6, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

c. *Cadosina* sp., NY-8, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. *Cadosina* sp., NY-10, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. *Cadosina* sp., NY-12, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

f. *Cadosina* sp., NY-22, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

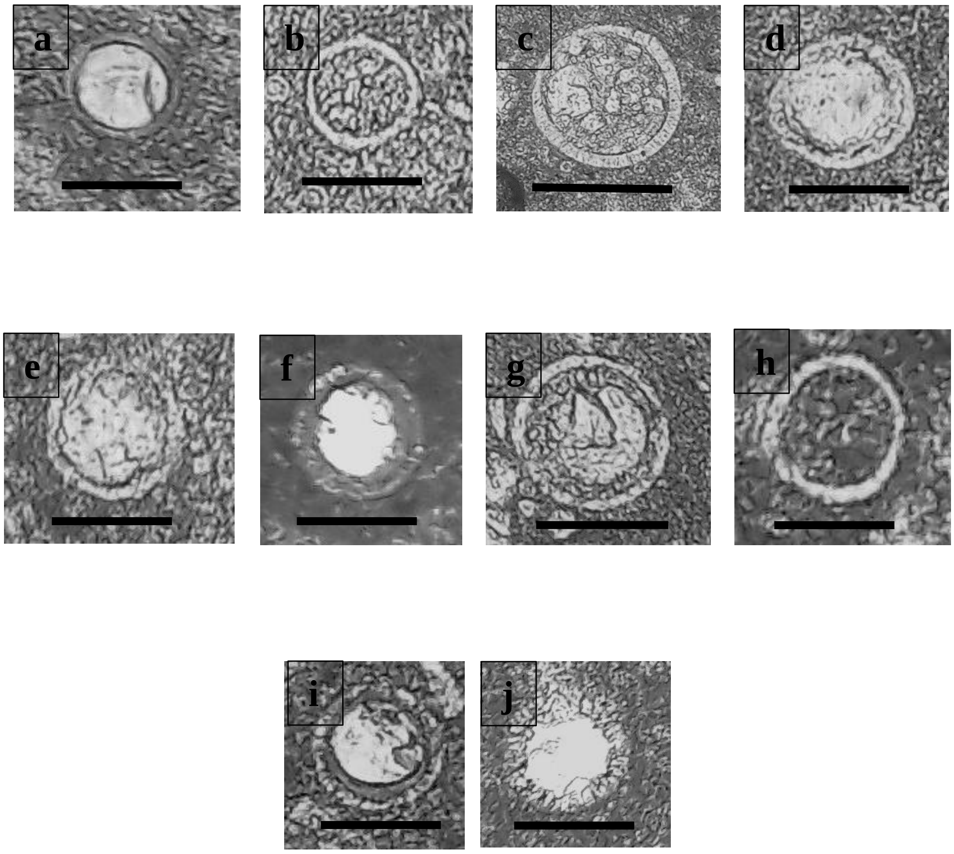
g. *Cadosina* sp., NY-28, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

h. *Cadosina* sp., Slump 1-2, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

i. *Cadosina* sp., Slump 1-2, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

j. *Cadosina* sp., NY-38, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 22



50 μm

PLATE 23

a. Radiolaria, NY-1, *Globigerinelloides blowi* Zone, Early Aptian, Soğukçam Limestone

b. Radiolaria, NY-1, *Globigerinelloides blowi* Zone, Early Aptian, Soğukçam Limestone

c. Radiolaria, NY-3, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

d. Radiolaria, NY-7, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

e. Radiolaria, NY-8, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

f. Radiolaria, NY-10, *Leupoldina cabri* Zone, Early Late Aptian, Soğukçam Limestone

g. Radolaria, NY-27, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

h. Radolaria, NY-27, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

i. Radolaria, NY-28, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

j. Radiolaria, Slump 1-2, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 23

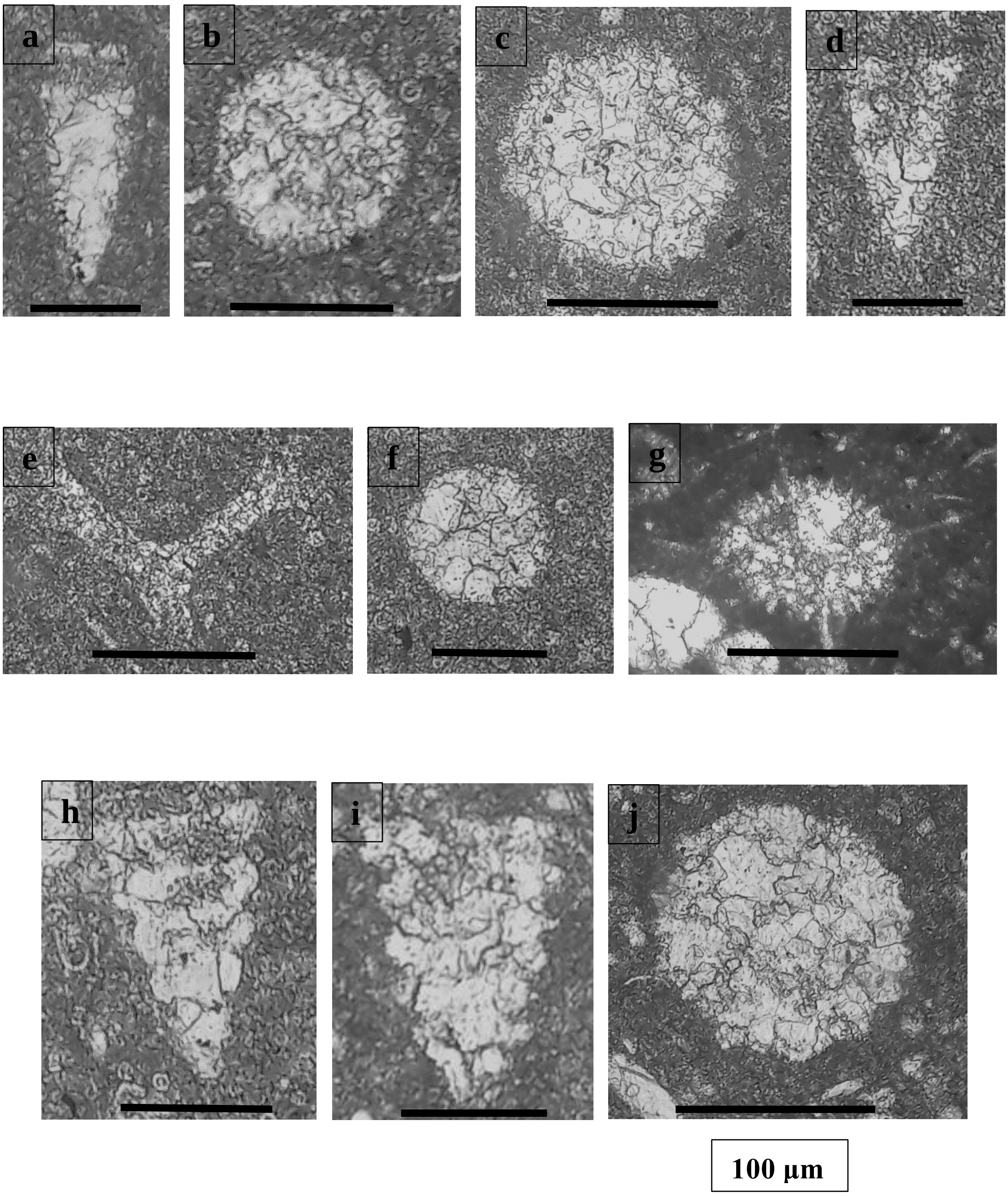


PLATE 24

a. Radiolaria, Slump 1-2, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

b. Radiolaria, Slump 1-1, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

c. Radiolaria, NY-30, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

d. Radiolaria, NY-30, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

e. Radiolaria, NY-30, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

f. Radiolaria, NY-30, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

g. Radiolaria, NY-30, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

h. Radiolaria, NY-39, *Globigerinelloides ferreolensis* Zone, Late Aptian, Soğukçam Limestone

PLATE 24