PLANKTONIC FORAMINIFERA BIOSTRATIGRAPHY AND MICROFACIES
ANALYSIS OF THE CENOMANIAN-CAMPANIAN SUCCESSION
IN THE HAYMANA-POLATLI BASIN (ANKARA, TURKEY)

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ABSTRACT

PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY AND MICROFACIES
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In order to establish the planktonic foraminiferal biostratigraphy of the Cenomanian-Campanian deposits in the Haymana-Polatlı Basin, a stratigraphic section of 93.5 meters was measured and 75 samples were collected. The stratigraphic section starts with limestones containing late Cenomanian rotaliporid and dicarinellid species and continues with early-middle Turonian aged clayey limestones with sporadic shale beds. These units are overlain by red colored Santonian limestones and shales containing abundant globotruncanids. The stratigraphic section ends with monotonous grey colored silty shales of the Campanian, whose silt content increases more towards the upper part.

At the end of detailed taxonomic studies performed on both the washed material and thin sections of the samples, the distributions of planktonic foraminifera throughout the stratigraphic section were determined. Based on these findings, a biostratigraphic framework including 9 biozones and 2 subzones was established. In ascending order, the *Rotalipora cushmani* Zone - *Dicarinella algeriana* Subzone, *Whiteinella archaeocretacea* Zone, *Helvetoglobotruncana helvetica* Zone, *Dicarinella asymetrica* Zone - *Globotruncanita elevata-Dicarinella asymetrica* concurrent range Subzone, *Globotruncanita elevata* Zone, *Globotruncana ventricosa* Zone, *Globotruncanella* spp. Zone, *Globotruncana aegyptiaca* Zone and *Gansserina gansseri* Zone were identified.

Moreover, the evolution of depositional environment reflected by the changing microfacies types through the stratigraphic section was revealed. The microfacies identified from bottom to top were Planktonic Foraminiferal Packstone, Radiolarian Packstone, Packstone with Planktonic Foraminifera and Radiolaria, Radiolaria-bearing Spiculite Packstone, Planktonic Foraminiferal Wackestone, Wackestone with Planktonic Foraminifera and Radiolaria, Silty Wackestone-Mudstone with Planktonic Foraminifera and Wackestone-Mudstone.

The inability to determine the zones representing the late Turonian-Coniacian as well as the observation of an unconformity between the pre-Santonian and Santonian deposits were interpreted as the existence of a hiatus covering this time period.

Keywords: Biostratigraphy, Cenomanian-Campanian, Haymana-Polatlı Basin, planktonic foraminifera, microfacies analysis

ÖZ

HAYMANA-POLATLI HAVZASI'NDA (ANKARA, TÜRKİYE) SENOMANİYEN-KAMPANİYEN İSTİFİNİN PLANKTONİK FORAMİNİFER BİYOSTRATİGRAFİSİ VE MİKROFASİYES ANALİZİ

Sarıaslan, Nisan

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Haymana-Polatlı Havzası'nda çökelen Senomaniyen-Kampaniyen yaşlı istifin planktonik foraminifer biyostratigrafisinin belirlenmesi amacıyla 93.5 metre kalınlığında bir stratigrafik kesit ölçülmüş ve 75 adet örnek toplanmıştır. İstif, geç Senomaniyen rotaliporid ve dicarinellid formlarını içeren kireçtaşları ve erken-orta Turoniyen yaşlı, yer yer şeyl tabakaları içeren killi kireçtaşları ile başlamaktadır. Bu birimler, bol globotruncanidli, kızıl renkli Santoniyen kireçtaşı ve şeylleri ile üzerlenmektedir. İstif, silt yoğunluğu üste doğru gittikçe artan, büyük çoğunluğu gri renkli siltli şeyllerden oluşan monoton Kampaniyen çökelleri ile son bulmaktadır.

Örneklerin hem yıkamalarında hem de ince-kesitlerinde yapılan ayrıntılı taksonomik çalışmalar sonucunda planktonik foraminiferlerin stratigrafik kesit boyunca göstermiş oldukları dağılımlar belirlenmiş, bu bulgulara dayanarak da 9 zon ve 2 altzondan oluşan bir biyostratigrafik çatı ortaya konmuştur. En altta *Rotalipora cushmani* Zonu-*Dicarinella algeriana* Altzonu, üste doğru *Whiteinella archaeocretacea* Zonu, *Helvetoglobotruncana helvetica* Zonu, *Dicarinella asymetrica* Zonu - *Globotruncanita elevata-Dicarinella asymetrica* kesişim Altzonu, *Globotruncanita elevata* Zonu, *Globotruncana ventricosa* Zonu, *Globotruncanella* spp. Zonu, *Globotruncana aegyptiaca* Zonu ve *Gansserina gansseri* Zonu tanımlanmıştır.

Ayrıca, kesit boyunca değişen mikrofasiyes tipleri de çökelim ortamındaki değişimleri saptamak amacıyla belirlenmiştir. Kesitte aşağıdan yukarıya belirlenen mikrofasiyesler Planktonik Foraminiferli İstiftaşı, Radyolaryalı İstiftaşı, Planktonik Foraminifer ve Radyolaryalı İstiftaşı, Radyolaryalı Spiküllü istiftaşı, Planktonik Foraminiferli vaketaşı, Planktonik Foraminifer ve Radyolaryalı vaketaşı, Siltli Planktonik Foraminiferli Vaketaşı-Çamurtaşı ve Vaketaşı-Çamurtaşı'dır.

Geç Turoniyen-Koniasiyen'i temsil eden zonların belirlenememesi ve Santoniyen öncesi ile Santoniyen istifleri arasında bir diskordansın gözlemlenmesi ise bu zaman dilimini kapsayan bir boşluğun varlığını düşündürmektedir.

Anahtar Kelimeler: Biyostratigrafi, Haymana-Polatlı Havzası, planktonik foraminifera Senomaniyen-Kampaniyen, mikrofasiyes analizi

To my beloved family…

ACKNOWLEDGEMENTS

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CHAPTER 1

1. INTRODUCTION

1.1. Purpose and Scope

The primary objective of this study is to establish a detailed biostratigraphic framework based on the planktonic foraminifera for the Upper Cretaceous (Cenomanian-Campanian) succession of the Haymana-Polatlı Basin, Turkey. Other objectives are to identify lithological changes throughout the succession and to establish the evolution of depositional environment by using microfacies data in order to be able to finally define stage boundaries contained in the stratigraphic section.

The Haymana region has always been a popular location for geologists to study the evolution of Cretaceous System in the Central Anatolia. Belonging to the Central Pontides, the Haymana region constitutes an important source of information to understand the evolution of the Pontides, subduction of the Tethyan Ocean floor and opening of the Black Sea (Okay and Altıner, 2016, 2017; Yılmaz et al., 2010). In this sense, biostratigraphic studies represent a crucial tool to decipher the history of paleoevents took place in the region.

In the Ankara region, the lower part of the Upper Cretaceous has not been studied in detail in terms of biostratigraphy; studies regarding the Cretaceous of the Haymana Basin rather focused on the K/P boundary and its vicinity (see Subsection 1.4.1). Therefore, this study aimed to especially focus on the biostratigraphy of the the Lower-Upper Cretaceous (Cenomanian-Campanian) of the Haymana-Polatlı Basin succession. A stratigraphic succession regarding this part of the Cretaceous system outcropping near the Alagöz village, Ankara, was chosen in the aim for providing a complementary analysis to the one

performed by Afridi (2014) discussing the stratigraphical, sedimentological, geochemical and cyclostratigraphical aspects of the Upper Santonian-Campanian part of the same succession. To this end, planktonic foraminifera has been preferred for conducting the biostratigraphic analysis of this study and they have been identified both in washed specimens and in thin section of samples in the section. The planktonic foraminifera represent a very useful biostratigraphic tool for correlating strata in the Cretaceous stratigraphic system, given their widespread and abundant occurrence (BouDagher-Fadel, 2012), especially in the Tethyan region (Premoli-Silva et al., 1999; Premoli-Silva and Sliter, 1999; Petrizzo, 2003; Coccioni et al., 2015).

Given the broad age interval contained in the studied succession, the measured 93.5 m thick stratigraphic section was sampled at relatively larger intervals (~1.2 m) where these were kept smaller in the lower part of the section (Cenomanian-Santonian) due to its being not studied in detail previously.

In brief, the aim of this study is to provide a guiding biostratigraphic framework for the broad age interval (Cenomanian-Campanian) of which the stratigraphic section is composed. Moreover, obtained microfacies data was utilized to detect any changes took place in the depositional environment.

1.2. Geographic Setting

The location of the study area is approximately 40 km southwest of Ankara, in the Alagöz village, Polatlı (Figure 1). It is situated on the topographic map of Ankara – J28-b2 of 1/25.000 scale. GPS recordings give the coordinates of the start point as 39°45'23"N - 32°29'26"E and end point as 39°45'22"N - 32°29'19"N. The measured section is easily accessible from the Eskişehir road.
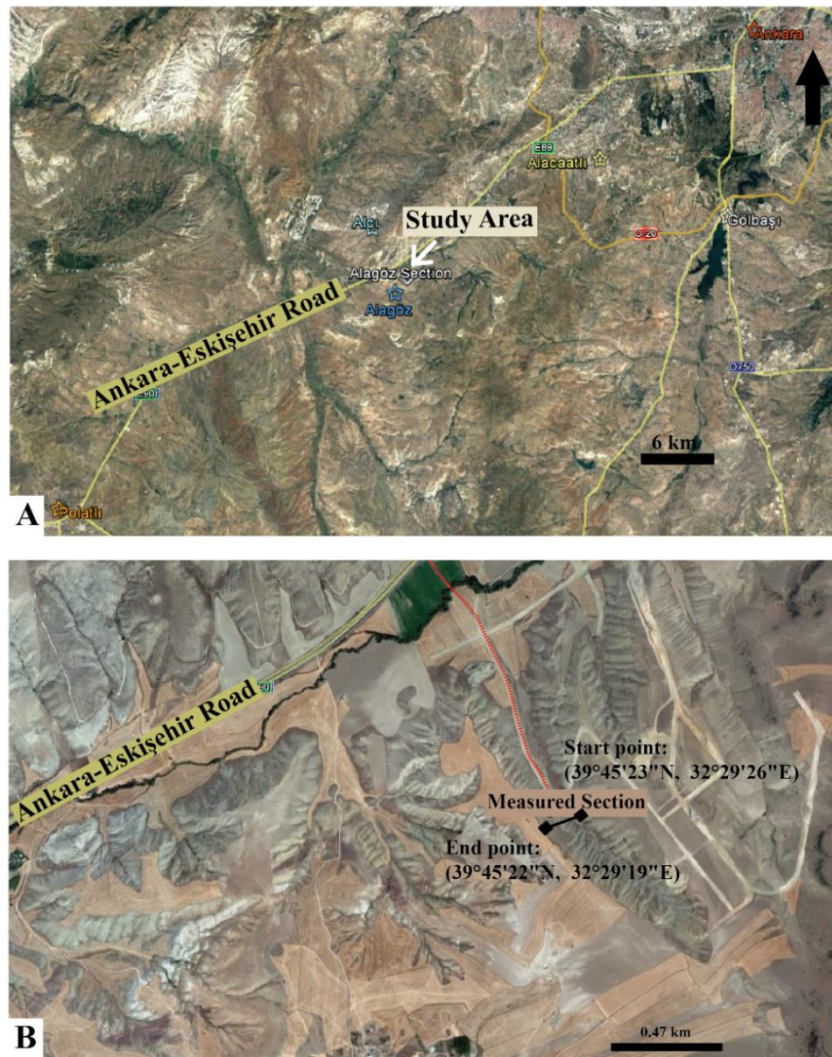
Figure 1. Geographic setting of the study area and the location of the measured section. A. Location of the study area in the Ankara regional setting. B. Access to the measured stratigraphic section from the Eskişehir Road.

1.3. Methods of Study

First of all, a comprehensive literature survey focusing on the Late Cretaceous time interval was done. This included the biostratigraphy and evolution of microfossil assemblages of the study area as well as other study areas with the same age. Then, the field trips and laboratory studies were performed.

In total, there have been four field trips to the Alagöz village in the Haymana Basin. In the first one, the best outcrop for measuring the geological section was selected after the lithological units were identified. 46 samples at variable intervals of 10 cm to 150 cm were collected (Fig. 2, A and B). Remaining 29 samples were collected at the continuation of sequence up to middle part of the previously identified Campanian-Maastrichtian aged Haymana Formation (Fig. 2, C and D). Fewer samples were collected, because this part of the measured section comprised comparatively a much more monotonous succession, although the two sides were more or less of the same thickness. The measured section had 93.5 m of thickness.
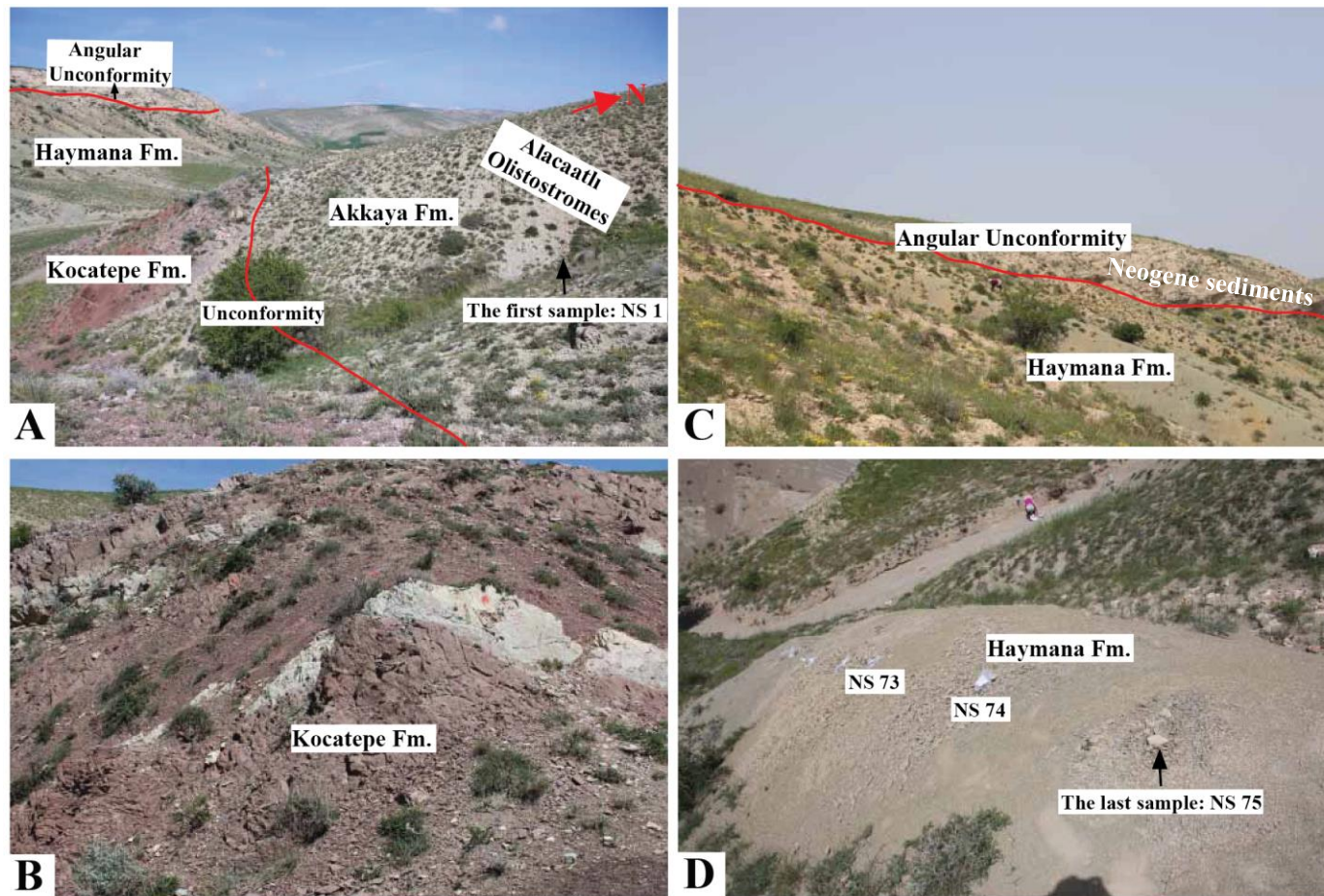
Figure 2. Photographs of the measured section showing the southwestern portion of the outcrop (A and B) and the northeastern portion of the outcrop (C and D).

Laboratory studies were much more time-consuming than the field studies. Nearly two months were spent on conducting trial sessions for determining which combination of crushing and washing method gives the best outcome. In addition to the traditional methods having been applied for years to extract planktonic foraminifera from calcareous rocks, some newer methods have also been utilized. Classical mechanical or chemical methods range from simple washing with tap water to soaking in H_2O_2 at a desired concentration and then rinsing with water (Sohn, 1961; Knitter, 1979; Abramovich et al., 1998; Li and Keller, 1998; Arenillas et al., 2000; Petrizzo, 2000; Green, 2001; Abramovich and Keller, 2002; Petrizzo, 2002). These methods work best for the soft sediments. Among these there are also various freeze-thaw methods which in principal mimic the nature itself (Hanna and Church, 1928; Pojeta and Balanc, 1989). Except for the primary freeze-thaw method with simple water, there are Glauber's salt method, dry ice and liquid nitrogen freeze-thaw methods. In Glauber's salt method (Herrig, 1966; Surlyk, 1972; Schmid, 1974; Wissing and Herrig, 1999; Green, 2001), ordinary water is replaced by a saturated solution of sodium sulfate [Na2SO4×10H2O]. Crystallization of sodium sulfate in the pore system disintegrates the rock in a similar way as in the classic freeze-thaw method. The latest version of freeze-thaw procedures employs the use of liquid nitrogen (LN_2) (Remin et al., 2011). Considering the extremely low boiling temperature of nitrogen which is -195.79 ℃, the most dramatic freeze-thaw effect can be provided by LN_2 compared to regular water, sodium sulfate solution or dry ice.In this method, liquid nitrogen is poured onto the sample which is crushed to a desired size. When all the sample gets frosted, boiling water is added up to where it covers the whole sample. This procedure is repeated for multiple times until a satisfactory result of disintegration is attained, it was 15 in this case. More powerful extraction procedures include soaking the sample in acetic acid at a desired concentration with chloroform added where the volume of chloroform in milliliters is the same number as the weight of sample in grams (e.g. 100 ml of chloroform for 100 g of sample) (Özkan-Altıner and Özcan, 1999). For the hardest, compact calcareous rocks, the use of pure acetic acid is suggested (Bourdon, 1957) which was later described as the "hot acetolysis" method (Bourdon, 1962). Use of H_2O_2 and

dilute CH$_3$COOH is also published as another method for disintegrating stubborn rocks (Costa de Moura et al., 1999).

In general, the collected samples were hard. In the first month, a special selection of 6 representative samples of different hardness level (soft, medium-hard, hard) were crushed to about 5 mm^3 pieces. The aim was to extract as many intact planktonic foraminifera as possible from the samples. The other criterion was that the planktonic foraminifera specimens have the maximum level of test surface cleanliness in terms of not having sedimentary particles or any kind of crystallization on the test. Then, the methods described previously were applied to the samples. In the first trial, cleanest planktonic foraminifera specimens were obtained through the LN$_2$ method compared to others. However, a possible bias was suspected to be caused by the constant size of particles in this first round of trial upon observing the embedded-look of the planktonic foraminifera in sediments of the acetic acid wash results. Moreover, reading about the benefits of powdering the hard and compact Upper Cretaceous and Paleocene samples (Costa de Moura et al., 1999), encouraged to perform a second round of trial with the same selected samples in powder size this time. The second round gave different results than the first and the acetic acid treatment yielded the cleanest specimens. Thus, acetic acid treatment was chosen to be the most effective washing method in this study. An important detail here is rubbing the sediments as rinsing with clean water. Rubbing should be applied softly enough not to harm the fossils and hard enough to get rid of the excessive loose sediments. The trial washes are summarized in Table 1 where the best method is indicated by the orange mark.

Table 1. Summary of the sample washing methods tried during the study for the best result.

Method / Round no.	H2O2 (50%) (for 1, 2, 4, 8, 16, 24, 48, 72 hours)	Acetic acid + Chloroform (for 1, 2, 4, 6 hours)		H2O2 (50%) + Acetic acid (30%) (for 1 hour)	LN2 (15 freeze-thaw cycles)
		Acetic acid (50%)	Acetic acid (30%)		
1st round	✓	✓	✓	✗	✓
2nd round	✓	✗	✓	✓	✓

In addition to the primary cleaning with acetic acid treatment, a secondary fine cleaning was applied to the specimens which were still obscured by sediments. This additional cleaning included the application of soft soap, dishwashing soap and ultrasound. The 62.5 µm sized sieve was used. The best results were received by the ultrasound cleaning.

After these treatments, planktonic foraminifera specimens remained on the 125 µm sized sieve were picked under binocular microscope. Other major groups identified were radiolaria and much fewer ostracoda; these were not collected.

Thin sections were also prepared from each of the 75 samples for microfacies and paleontological analysis. They were examined and photographed under polarized microscope to give supplementary data to the main biostratigraphic data obtained from the washing results. Finally, scanning electron microscope (SEM) photographs of the well-preserved specimens were taken to provide more precise data on the morphology of tests.

1.4. Previous Works

1.4.1. General Geology of the Central Anatolia and the Haymana Region

The first formal investigation into the geology of Turkey was carried out by Chaput who was temporarily in charge of the Department of Geography at the Institute of Geography in Istanbul. He focused on the geology of Turkey between 1936 and 1939 (see Akyol, 1944). Regarding the Haymana Basin, he studied the Triassic-Eocene successions including radiolarites, shales, limestones and flysch deposits and established the basin's first detailed geological and biostratigraphical framework. He detected the tectonic deformation after discovering the occurrence of Upper Cretaceous-Eocene succession together with randomly distributed flysch deposits and concluded that these occurred in the Tertiary Period (Chaput, 1932, 1935a, 1935b, 1936).

In the late 1940's and early 1950's, based on Chaput's pioneering works, the geology of Turkey was studied in more detail. Also, Blumenthal documented some general structural observations in the Central Anatolia which now are classics in the literature (Blumenthal 1941a, 1941b, 1942). Lokman and Lahn (1946) studied the stratigraphy and tectonics of the Haymana Region. They established the lithological and fossil succession from the Senonian up to the Miocene. Thus, it was established that the marine facies ended by the end of Middle Eocene which was followed by freshwater and terrestrial deposits belonging to the Miocene. Lahn (1949) and Egeran and Lahn (1951) defined and discussed the structural evolution, lithological and fossil assemblages of the Central and Northern Anatolia, including the Haymana Basin. Several units in the Haymana succession belonging to various Upper Cretaceous and Lower Paleogene stages were defined by them.

Through the 1950's, Erol (1961) wrote an extensive compilation of all available geological data related to the the orogenic phases of the Ankara Region from various sources and by interpreting these in the light of his own observations and thoughts, he gave a brief summary on this subject. He classified the orogenic phases as pre-Alpine,

Alpine and Epeirogenic and described his interpretations with the referenced data belonging to the geological time intervals pre-Visean to Permian, Kimmeridgian to Oligocene and Miocene to Pleistocene, respectively.

In the beginning of 1960's, petroleum geologists Reckamp and Özbey (1960) and Schmidt (1960) focused on the stratigraphy of the Haymana Basin and provided important data which improved the knowledge on the stratigraphy of the region. Dağer et al. (1963) measured five stratigraphic sections in the Haymana region and described their lithology with the identifiable micro- and macrofauna in detail. In this study, they defined and described Palaeozoic sequences, Carboniferous-Middle Permian, Jurassic, Cretaceous, Tertiary sequences and Pliocene lake successions. Especially in the Cretaceous deposits, many planktonic foraminifera were identified. Erk (1966, 1967) reported on the Late Paleozoic stratigraphy of the Ankara region.

Having reached a satisfactory level of understanding of the Haymana region's geology, researchers started to concentrate on the more specific aspects of the region in the 1970's. Norman and Rad (1971) and Rad (1971) studied the vertical variations in grain size parameters and the heavy mineral abundance of Eocene-aged Harhor Formation in the Çayraz Area, Haymana. From this, they speculated on the climatological and tectonic history of the area.

Petroleum geologist Arıkan (1975) described the structural evolution and detailed sedimentary succession of the Tuz Gölü and Haymana basins. At the end of his paper, he described the geological history of the region containing these two basins and evaluated this in terms of petroleum geological aspects such as surface hydrocarbon indicators, source rocks, reservoir rocks, cap rocks and trap structures.

One of the greatest contributors to the Anatolian stratigraphy and biostratigraphy, Sirel (1975) described the upper Jurassic-Eocene lithostratigraphy and biostratigraphy around the Haymana region. He established the biozones and microfossils characterizing them with corresponding ages of the units. His paleontological identifications included multiple groups of microfossils such as algae, foraminifera, ostracoda and gastropoda. He also

mentioned six new alveolinid species in this study, which were to be described in another study of his (Sirel, 1976).

Ünalan et al. (1976), conducted a very detailed study on the upper Cretaceous-lower Paleogene deposits in the Haymana Basin. The most notable points in this study were defining the formations and their contacts in the region and interpreting its palaeoenvironmental evolution. Erk (1976) studied the monotonous late Paleozoic succession in the Central Anatolia, with flysch formation at bottom and calcareous series on the top. The bottom flysch had been named as "Kulm type flysch" previously (Erk, 1966) and since it had a lack of fossils, sedimentological zonation was applied to this succession instead of biozonation. In the same year, Gökçen (1976) studied the sedimentology of the succession in the southwestern Haymana Basin. Later by the same author, oil-saturated sandstones of the region were also studied in terms of their sedimentological properties (Şenalp and Gökçen, 1978).

First biostratigraphic studies involving planktonic foraminifera and calcareous nannoplanktons in the Haymana Basin were conducted by Toker in the second half of the 1970's and early 1980's (Toker, 1975, 1977, 1979, 1980, 1981). In these, she focused on the biozonations of upper Cretaceous (upper Campanian) to middle Eocene formations in the Haymana Basin with planktonic foraminifera and calcareous nannoplanktons.

Meriç and Görür (1981) corrected the age of Çaldağ Limestone in the Haymana Basin by fossil evidence as Thanetian rather than Montian.

Çetin et al. (1986) provided important sedimentological and petrological data from previously poorly known sequences on the northern flank of the Haymana anticline. They identified the provenance of clastic rocks in the region as being located in the north-northwest of Haymana region. Transportation of sediments is thought to occur from north to south mostly by turbiditic currents. The possibility regarding the former existence of a Danian aged lagoon is also brought up. The authors' interpretation suggested that there was bathyal-abyssal environment in the south to northwest whereas there was neritic environment in the east of the region. Finally, it is suggested that the upper Cretaceous-

lower Paleogene sediments of the Haymana Basin were deposited in subduction zone and fore-arc complex facies between the Kırşehir microplate and the Tethys oceanic plate.

Koçyiğit et al. (1988), discussed the tectonostratigraphical characteristics, nature and type of forearc basin remnants in the active margin of the Northern Neo-Tethys. For that, various geological features and boundary relationships of forearc basin deposits at different domains were studied in detail. The upper limit of the subduction complex development was given as late Santonian to early Campanian in age, but its emplacement age ranged between late Maastrichtian to late Pliocene.

Ocakoğlu and Çiner (1995) studied the basin fill geometries of the Paleocene-lower Eocene units of the Orhaniye-Güvenç region (northwestern Ankara) which hosted a well observable Mesozoic-lower Cenozoic succession. The authors defined the stratigraphy and detailed sedimentology of the geological sections and then attempted to establish the Paleocene-Eocene paleogeography of the region.

Rojay and Süzen (1997) aimed to document the Cretaceous tectonostratigraphy of the southwest Ankara region with their stratigraphic findings and to bring some clarification to the Cretaceous collisional history of the northern branch of Neotethys in Central Anatolia. According to their results, the Cretaceous-Paleogene basins developed on a dynamic accretionary ophiolitic melange prism since the Cenomanian and Cenomanian-Turonian arc-trench; and Maastrichtian-Paleocene fore-arc basins were shifted away from the trench towards magmatic arc, farther north.

Throughout late 1990's and early 2000's, Özkan-Altıner and Özcan published a series of important palaeontological studies involving planktonic foraminifera, large benthic foraminifera and calcareous nannofossils: Özcan and Özkan-Altıner (1997), Özkan-Altıner and Özcan (1997), Özcan and Özkan-Altıner (1999), Özkan-Altıner and Özcan (1999), Özcan and Özkan-Altıner (2001), Özcan et al. (2001) and Özcan (2002). Özcan and Özkan-Altıner (1997) examined the Santonian/Campanian-Eocene shallow water benthic foraminifera of deep-water turbiditic units. They documented the biometric aspects as evolutionary parameters such as embryon-size and number of epi-embryonic

chambers of the genera *Orbitoides* and *Lepidorbitoides*. Two years later (Özcan and Özkan-Altıner, 1999), they published their results for testing the early ontogenic features recognized as evolutionary parameters in the previous study in several flysch successions of Anatolia. Özcan and Özkan-Altıner (1999) established the main evolutionary trends in the two genera which enabled them to correlate these features with time. They distinguished the true phylogenetic stages with the false ones. At the end, they also proposed a correlation scheme of phylogenetic development in *Lepidorbitoides* and *Orbitoides* with the planktonic foraminiferal zones. This correlation scheme was reported in detail the same year in another paper (Özkan-Altıner and Özcan, 1999). In this study, the Upper Cretaceous (Santonian-Maastrichtian) planktonic foraminifera biostratigraphy was established from samples collected from five different locations and the different phylogenetic development stages of *Orbitoides* and *Lepidorbitoides* populations and other larger benthonic foraminifers were calibrated with the planktonic foraminiferal zonation established in the same successions. This study is very important in terms that it added a valuable dimension to the Upper Cretaceous biostratigraphy of the Haymana Basin. Özcan (2002) examined the diverse assemblages of *Discocyclina*, *Orbitoclypeus*, *Nemkovella* and partly *Asterocyclina*, which characterize the lower-upper and late Cuisian shallow benthic zones in the Cuisian-early Lutetian aged Çayraz Formation, the Haymana-Polatlı Basin. Orthophragminids were identified for the first time in Anatolia in this study.

Rojay et al. (2001) sampled the tectonically detached blocks of pillow basalts in the Cretaceous ophiolitic melange from southern Ankara in the aim of defining the missing parts in the evolution of Central Anatolian melange. In between the lobes of pillow basalts, there were also trapped and accumulated pelagic calcareous sediments. Their results collectively supported the presence of a seamount in Dereköy (Haymana region) of the Central Anatolian terrain during the Callovian-Hautervian interval. An alkaline ocean-island basalt setting of Rhaetian age is interpreted for the Dereköy (Haymana) pillow basalts.

Some of the important studies done in recent years regarding the Haymana Basin can be summarized as follows: Hoşgör and Okan (2010) studied the late Paleocene gastropods of

the Haymana-Polatlı Basin. This study deals with the taxonomy and stratigraphy of the gastropoda group and also proposing a new trochoidean species from the early Thanetian in the Haymana-Polatlı Basin. İslamoğlu et al. (2011) described caenogastropods collected in the Macunköy section from the upper part of the Kırkkavak Formation, the Haymana-Polatlı Basin. The result of this study marks the oldest occurrence of angariid gastropoda in the globe and this occurrence was supported by the foraminiferal and red-algae assemblages in the locality. Nairn et al., (2013) discussed and described in detail the tectonostratigraphic evolution of the upper Cretaceous-Cenozoic central Anatolian basins which are the Kırıkkale, Çankırı, Tuz Gölü and Haymana basins. Together with their new stratigraphic and palaeontological data, they tested different hypotheses regarding the collisional history leading to the formation of these basins. Their evidence was consistent with a two-phase, progressive and diachronous continental collision.

Esmeray (2008), Esmeray-Senlet et al. (2015) delineated the K/Pg boundary in the Haymana Basin using planktonic foraminiferal biostratigraphy, microfacies analysis, and sequence stratigraphy. The paleoenvironments, systems tracts and planktonic foraminifera biozones were determined for the pre- and post-boundary successions. Thus, the catastrophic and abrupt occurrence of the K/Pg boundary in the Haymana Basin was detected. Amirov (2008) established the planktonic foraminifera biostratigraphy of the Upper Cretaceous-Paleogene marine succession, sequence stratigraphy and sedimentary cyclicity in the Haymana Basin. Most recently, Okay and Altıner (2016) recognized three unconformity-bounded pelagic carbonate sequences of Berrriasian, Albian-Cenomanian and Turonian-Santonian stages. They also recognized that each depositional sequence was preceded by a period of tilting and submarine erosion during the Berriasian, early Albian and late Cenomanian, corresponding to phases of local extension in the active continental margin. They established the deposition of thick siliciclastic turbidites starting in the late Campanian and continuing into the Paleocene. It is noted that unlike most forearc basins, the Haymana region was a site of deep marine carbonate deposition until the Campanian. This resulted from the fact that the Pontide arc was extensional and the volcanic detritus was trapped in the intra-arc basins and did not reach the forearc or the trench. The opening

of the Black Sea as a backarc basin in the Turonian–Santonian also supports the extensional nature of the arc.

Finally, important studies regarding the CORB's in Turkey were published throughout the 2000's and 2010's. Yılmaz et al. (2004) studied the black shale interval in the Lower Aptian deposits, Nallıhan area of northwestern Turkey and established the OAE1a. Hu et al. (2005) studied CORB's in the Tethys from a number of different localities including the Eastern Pontides, Turkey. They attributed the changes in dissolved oxygen in the deep ocean to the changes in the location and formation of deep water and changes in ocean circulation. Yılmaz (2008) investigated the Aptian-Santonian red beds and black shales in northwestern Turkey in the frame of global anoxic and oxic events. He also applied sequence stratigraphic and cyclostratigraphic approaches. In this study, black shale levels corresponding to OAE1a and OAE1c were established. Formation of oceanic red beds in different locations including central Turkey, was investigated together with other climatic and oceanographic changes accompanying it. These were explained as the inevitable results of oceanic anoxic events by Wang et al. (2011). Hu et al. (2012) studied the stratigraphic transition from the early Aptian oceanic anoxic event 1a (OAE1a) to the oceanic red bed 1 (ORB1) along the pelagic Yenicesihlar section in the Mudurnu region of central Turkey. They estimated the transition as being approximately 1.3 Ma, and the $\delta^{18}O$ values as showing an increase towards the ORB1, when the climate became cooler. Yılmaz et al. (2010) established the OAE2 in the Sakarya Zone, northwestern Turkey by studying three different stratigraphic sections in terms of their sedimentology, cyclostratigraphy and geochemistry. Yılmaz et al. (2012) established the first record of the late Hautervian platform drowning of the Bilecik platform, Sakarya Zone, and associated this event with an Oceanic Anoxic Event. Afridi (2014) studied the Upper Santonian-Campanian successions from the Haymana basin and the Mudurnu-Göynük basin, where the first one is represented by a stratigraphic section equivalent to the section of this thesis study. He established the detailed sedimentology and lithofacies of the rocks to interpret the depositional environment. Moreover, he used the results of geochemical analyses to evaluate the levels of nutrient supply and primary productivity, sedimentary

influx to the basin, sea level change trend, type of source rock and oxygen level in the basin. Finally, he established a high resolution cyclostratigraphic framework for the succession.

1.4.2. Planktonic Foraminifera Biostratigraphy

Cushman first introduced the genus *Globotruncana* in which all trochospiral and keeled (single or double) Cretaceous planktonic foraminifera were included. Grigelis (1958) described *Globigerina oxfordiana* from the Upper Jurassic of Lithuania. Fuchs (1967, 1971, 1973, 1975, 1977) described Triassic and Jurassic planktonic foraminifera and discussed their origin and phylogeny in a series of papers. He argued that the earliest planktonic foraminifera were to be found in the Triassic, whereas these specimens are now thought to be highly recrystallized benthic taxa. In their book, "The Early Evolutionary History of Planktonic Foraminifera", BouDagher-Fadel *et al.* (1997) described the earliest fossil planktonic foraminifera of the Jurassic and the Early Cretaceous which were, of course, recognized by their tests. According to them, the earliest planktonic foraminifera genus is the M. Jurassic *Conoglobigerina*. They also speculated on the *Praegubkinella* (European Toarcian) being the possible ancestors of the "real" planktonic foraminifera. According to the authors, the widespread development of anoxic/dysaerobic environments in the earliest Toarcian (coupled with a major extinction event) might have been the environmental stimulus to the evolutionary development of the planktonic foraminifera from the genus *Praegubkinella* which was the first meroplanktonic (pref. mero- = partially) taxon. Unfortunately, the Triassic-Jurassic planktonic foraminifera are still not clearly understood. However, their Cretaceous descendants increased their scientific popularity since they were first described, because they are much more abundant, diverse and distributed than their ancestors and therefore, constitute an important tool to understand the Cretaceous world. This made planktonic foraminifera the most studied microfossil group among the others. For that reason, there are an excessive number of studies done using planktonic foraminifera; here, only the ones regarding Cenomanian-Campanian planktonic foraminifera of various Tethyan-related sections are given.

Honigstein et al. (1987) and Almogi-Labin et al. (1991) established the planktonic foraminiferal biostratigraphy of Santonian-Campanian boundary and the interval late Coniacian-early Maastrichtian in Israel. They identified five biozones, namely, *D. asymetrica*, *G. elevata*, *G. rosetta*, *G. calcarata* and *G. falsostuarti*.

Chungkham and Jafar (1998) studied the scattered exotic blocks of pelagic limestone in the ophiolitic melange belt of Nagaland-Manipur, India. The authors presented an integrated calcareous nannoplankton and planktonic foraminiferal biostratigraphy comprising latest Santonian/earliest Campanian to late Maastrichtian timeslice. They identified the biozones *D. asymetrica*, *G. elevata*, *G. ventricosa*, *R. calcarata*, *G. havanensis*, *G. aegyptiaca*, *G. gansseri* and *A. mayaroensis* variably in five sections enabling their correlation.

Petrizzo (2000) made a review on the taxonomy and time ranges of upper Turonian-lower Campanian planktonic foraminifera from southern mid-high latitudes. She aimed to provide a reliable bio-chronostratigraphic scale that is useful for mid–high latitudes of the southern oceans by comparing her data with both the low-latitude standard zonation and the planktonic foraminiferal zonal scheme for the circum-Antarctic region.

Arz and Molina (2001) studied the Campanian-Maastrichtian transition at Tercis, Landes/France. The quite diverse planktonic foraminifera assemblage across the boundary yielded six biozones, five of which are included in the Campanian. The authors proposed a new C/M boundary at Tercis section. This boundary was known in the literature to be located in a higher level than the *Radotruncana calcarata* biozone, however in this study it is coincident with the first appearance of *Trinitella scotti* in the *Gansserina gansseri* biozone (latest Campanian). They also correlated the *R. calcarata* zone, which could not be established in the study due to the absence of the nominal taxon in the samples, to the *Heterohelix glabrans* zone.

Petrizzo (2003) compared the occurrence of planktonic foraminiferal bioevents at low, middle, and high latitudes (Petrizzo, 2001; 2002) in another publication where she reviewed the Late Cretaceous planktonic foraminiferal distribution recorded at several

drill sites (DSDP and ODP) in the South Atlantic and south Indian Ocean and from sediment outcrops in the Tethyan region (Gubbio and El Kef).

Chacon et al. (2004) performed the first detailed biostratigraphic analysis of the uppermost Santonian - uppermost Maastrichtian hemipelagic carbonate successions of southeastern Spain. The authors also compared their section with Tercis (France) and Kalaat Senan (Tunisia) stratigraphic sections. Seven biozones of planktic foraminifera were recognized for the time interval studied. These comprised the uppermost part of the *Dicarinella asymetrica* Zone, and the *Globotruncanita elevata*, *Globotruncana ventricosa*, *Globotruncanita calcarata*, *Globotruncana falsostuarti*, *Gansserina gansseri* and *Abathomphalus mayaroensis* zones.

Lamolda et al. (2007) published an instructive report including the planktonic foraminiferal bioevents occurred between the Coniacian-Santonian at Olazagutia, Navarra province, Spain. It was also emphasized that the first occurrence of ''pill-box-like'' morphotypes of *G. linneiana* can be used as a good proxy for the Coniacian/Santonian boundary.

Li et al. (2007) clarified the age and established the biostratigraphy of the Saiqu melange in southern Tibet. The assemblage was considered to be Campanian-early Maastrichtian in age based on planktonic foraminifera species found. Finally, the red member of the Saiqu melange was correlated with the Upper Cretaceous Red Beds (CORB) and this unit was interpreted to have possibly deposited in response to a global oxygenation event as its equivalents did.

Sarı (2006; 2009) identified planktonic foraminifera biozones from numerous stratigraphic sections of Upper Cretaceous hemipelagic and pelagic sequences of the northern Bey Dağları Autochthon (western Taurides) using thin section of samples.

Cetean et al. (2011) studied an upper Santonian to upper Campanian hemipelagic succession from the southern part of the Romanian Eastern Carpathians and established an integrated biostratigraphy based on planktonic foraminifera and calcareous

nannofossils, which they compared with the agglutinated foraminiferal biozonation used for the Carpathians. They were not able to identify planktonic foraminiferal biozones due to the absence of marker species, however they could identify some important bioevents such as the LO of *Globotruncanita elevata* and the FO of *Globotruncanella havanensis* in the *Radotruncana calcarata* biozone.

Ardestani et al. (2012) did a detailed planktonic foraminiferal biostratigraphic study of the Abderaz Formation of the East Kopet Dagh Basin, northeastern Iran. They recognized five successive foraminiferal zones from the lower Turonian to the lowermost Campanian. They also published (Ardestani et al., 2013) their paleoceanographic and paleobiogeographic interpretations regarding the same location.

In a detailed study, Bey et al. (2012) presented the biostratigraphy, lithology and tectonic history of the Ain Medheker (Northeast Tunusia) section interpreting it as representing an early Campanian to early Maastrichtian moderately deep carbonate shelf to distal ramp position.

Wagreich et al. (2012) studied an almost complete Santonian-lower Maastrichtian succession recorded in pelagic to hemipelagic deposits at the Postalm section, Austria, at the NW margin of the Tethys. The authors addressed the biostratigraphy, as well as the astronomical calibration of the *R. calcarata* Zone in the mid-Campanian at Postalm and emphasized the chronostratigraphical importance of the *R. calcarata* in the Tethyan Realm.

Falzoni et al. (2013) established the depth preferences of numerous Santonian-Campanian planktonic foraminifera species based on species-specific stable isotope data (δ^{13}C and δ^{18}O) obtained from very well preserved "pristine" specimens from the Santonian-Campanian sequences in southeastern Tanzania. Combining their geochemical and paleontological data they also inferred the oceanic structure for the Santonian-Campanian interval of the three high-latitude localities they studied: Tanzania, Shatsky Rise and the Exmouth Plateau.

Elamri and Zaghbib-Turki (2014) established the Santonian-Campanian transition in the Kalaat Senan area, Tunisia. The authors proposed to use the LO of *Dicarinella asymetrica* as the index marker of S/C boundary, whereas several species of marginotruncanids were found to have crossed this boundary suffering a gradual extinction. The authors also speculated on the paleoceanographic conditions that have set the ground for the major turnover across S/C boundary, where marginotruncanids and dicarinellids were replaced by the genera *Globotruncanita* and *Globotruncana*.

Rawand et al. (2015) analysed the evolutionary patterns already established for the Turonian-Maastrichtian interval in an Arabian context and they studied the early Turonian to early Maastrichtian planktonic foraminiferal assemblages from two localities in the northeastern Iraq. They made a quantitative analysis of the planktonic foraminifera species and, at the end, established a precise planktonic foraminiferal biozonation and also identified fluctuations in diversity and abundance of major morphotypes as a response to environmental change.

Falzoni et al. (2016) presented the first biostratigraphic, taxonomic and quantitative analysis of Cenomanian/Turonian planktonic foraminiferal assemblages from the Vocontian Basin, southeastern France, entirely studied in washed residues. An apparently earlier extinction of the genus *Rotalipora* is attributed to the presence of a condensed stratigraphic interval of about 3-m thick in the section. Moreover, the authors documented for the first time the occurrence of double-keeled specimens with raised umbilical sutures (i.e., *Marginotruncana caronae*) in the uppermost Cenomanian, which proved that primitive marginotruncanids co-occured with rotaliporids and evolved before the onset of the OAE2, whilst species diversification began immediately after the OAE2 in the earliest Turonian. Lastly, three new species were described: *Pseudoclavihedbergella chevaliensis*, *Praeglobotruncana pseudoalgeriana* and *Praeglobotruncana clotensis*.

Wolfgring *et al.* (2016a) established a well-resolved assessment of foraminiferal communities in the Austrian Alps during the *Radotruncana calcarata* TRZ. They discussed the bioevents that can be observed in the Penninic Realm and concluded that

many of them require further investigations, except for *R. calcarata*, whose evolution is speculated to have occurred within an opening and closing adaptive zone within changing water masses of the late Cretaceous.

Wolfgring and Wagreich (2016b) presented a quantitative study on the planktonic foraminiferal assemblages in the *R. calcarata* TRZ at Postalm section. In their high-resolution examination, they assessed the composition of typical Tethyan pelagic assemblages and dealt with subtle changes in north-western planktonic foraminiferal communities just before major faunal turnover-events (Premoli Silva et al., 1999a).

Wolfgring et al. (2017) studied the Santonian-Campanian boundary interval in the northwestern Turkey in terms of planktonic foraminiferal and nannofossil biostratigraphy, magnetic polarity and magnetic susceptibility. At the end, three of the most cited marker events in the Santonian-Campanian transition in the Tethyan realm were identified. These are the base of magnetochron C33r, the HO of *Dicarinella asymmetrica* and the LO of the nannofossil *Broinsonia parca parca*.

1.5. Regional Geology

Tectonic evolution of Pontides constitute a crucial part in understanding the geology of the Ankara region, which is located in the west of İzmir-Ankara Suture Zone in the Pontide tectonic unit (Figure 3). Central part of the Pontides has a more complete presence of Cretaceous stratigraphic units compared to western and eastern parts. In general, the Pontides display two distinctive and laterally traceable marker horizons throughout, which are the Upper Jurassic-Lower Cretaceous carbonates and the Campanian-Maastrichtian siliciclastics. The stratigraphic units between these two horizons are not well developed and occur in a laterally varying fashion (Okay and Altıner, 2016).

The Haymana region, which is located in the west of Ankara, represents a good opportunity to understand the Cretaceous geology of the Ankara vicinity and the Central Pontides. The Haymana region is dominated by upper Campanian-Middle Eocene siliciclastic sequence over 5000 m in thickness and this constitutes the Haymana Basin.

Older sequences are found in the core of anticlines in this region, largest of which is close to the Haymana town (Okay and Altıner, 2016). The Haymana Basin is the only Central Anatolian basin in the Pontide region (Görür et al., 1998). It is a fore-arc basin above the northward-dipping Tethyan oceanic lithosphere (Görür et al., 1984; 1998; Koçyiğit, 1991; Nairn et al., 2013).

The oldest stratigraphic unit in the Ankara region is Karakaya Complex which is of Late Triassic age (Fig.3). The Karakaya Complex is composed of heavily crushed, scissored and locally slightly metamorphosed sandstone and shale; Carboniferous, Permian and Triassic limestone blocks of varying size are present in the clastics of this unit. In some places, Bayırköy Formation composed of terrestrial-shallow marine conglomerate, sandstone and shale of Early Jurassic age and local levels of ammonitico rosso facies type red nodular limestone occurs on top of the Karakaya Complex. The Bayırköy Formation is followed by marine limestones of Late Jurassic-Early Cretaceous age (Fig. 3).
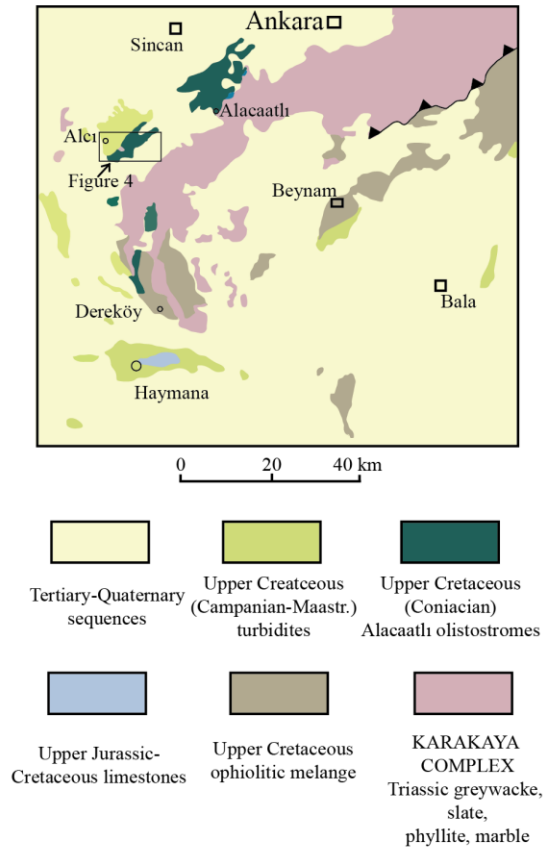
Figure 3. Simplified geological map of the Ankara region (modified from Okay and Altıner, 2017).

This type of shallow marine limestones (Bilecik Group) outcrops in the core of Haymana anticline. Three deep marine limestone-breccia successions of Berriasian, Albian-Cenomanian and Turonian-Santonian age occur on the Bilecik Group limestones with an unconformity in between (Fig. 4). Upper Jurassic-Cretaceous limestone succession is observed as carbonate blocks in the Alacaatlı olistostromes in zones near the İzmir-Ankara Suture Zone (Okay and Altıner, 2016) (Fig.3).

The stratigraphic units of the Haymana region (Figure 5) is described based on Okay and Altıner (2016), as follows:
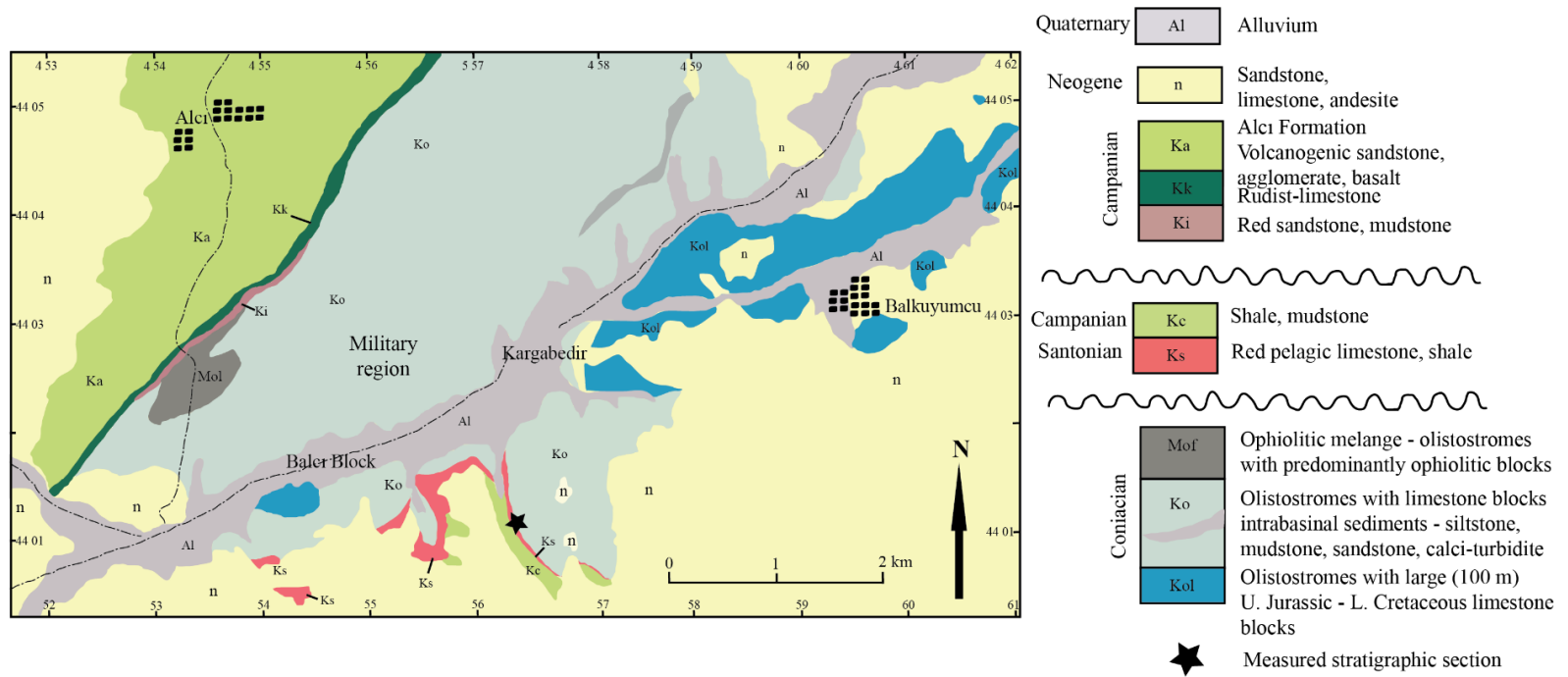
Figure 4. Close-up view of the geological map of the Ankara region around Alcı area (modified from Okay and Altıner, 2017).
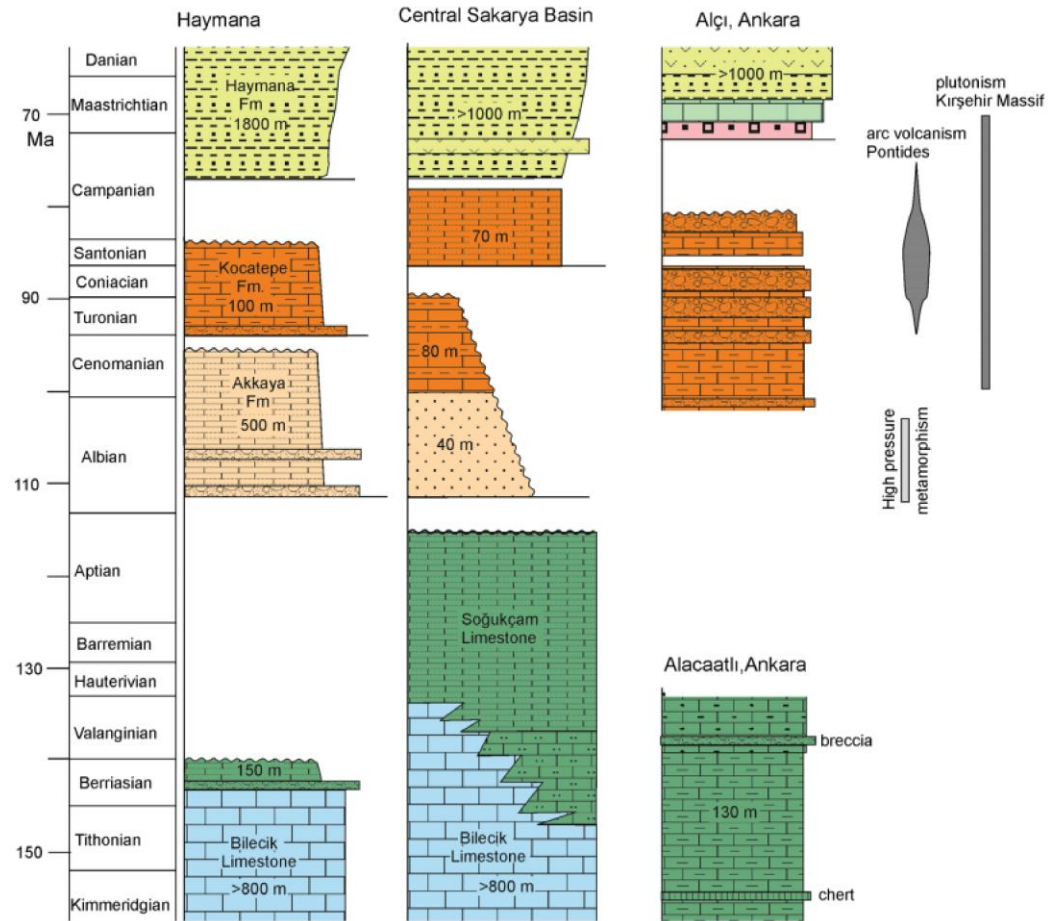
Figure 5. Cretaceous stratigraphic sections from Haymana, Central Sakarya Basin and the Ankara region (taken from Okay and Altıner, 2016).

During the late Jurassic-early Cretaceous, shallow marine limestones, whose collective name is the Bilecik Limestone, were deposited in the Haymana Basin. This unit had previously been divided into two different formations called as the Taşçıbayırı Formation (Callovian-Kimmeridgian) and the Günören Limestone (Kimmeridgian-Hauterivian) in the Western Pontides, thereby raising the previously named Bilecik Limestone into the group rank (Altiner et al., 1991).

In the Early Cretaceous, formation of pelagic limestones and breccias called the Soğukçam Limestone follow the Bilecik Limestone in the Haymana region. This rarely-exposed sequence is described as having been preserved only in a small area east of the town of Haymana, starting with a thin breccia horizon consisting of angular to subrounded clasts of the Bilecik Limestone, on which it lies. In the Central Sakarya Basin, the basal age of the Soğukçam Limestone is time-transgressive and ranges from late Tithonian in the east to Hauterivian in the west; its upper age is late Aptian (Altiner, 1991; Altiner and Özkan, 1991).

The previously-unknown interval of Albian to Cenomanian age is described as glauconite-bearing marly limestone and radiolaria-bearing pelagic limestone with lesser amounts of breccia, calciturbidite and sandstone in the Haymana region. This unit which is composed mainly of Albian deposits and unconformably overlies the underlying Bilecik Limestone and Soğukçam Limestone is called as the Akkaya Formation by Okay and Altıner (2016). In its upper parts, pelagic limestones are intercalated with thin- to medium-bedded fine-grained sandstones with carbonate and quartz grains. This part contains a Cenomanian foraminiferal fauna.

During the late Cretaceous, deposition of a pelagic limestone and shale sequence named as the Kocatepe Formation, occurs in the Haymana region (Yüksel, 1970). The lower part of this pelagic sequence is made up of beige radiolarian micrites of lower middle Turonian age. These are overlain by red pelagic micrites of Santonian age with thin red shale intervals whose frequency increases up-section. The Coniacian stage is observed as pelagic limestones containing a Coniacian (uppermost Turonian-lowermost Santonian)

foraminiferal fauna. A condensed carbonate deposition from early Turonian to late Santonian is also detected by Okay and Altıner (2016) based on the palaeontological data obtained from several sections. This period was characterized by intense submarine volcanism in the outer Pontides, whose only evidence in the Haymana region is rare altered volcanic ash clasts in the limestone beds, which make up less than 2 % of the rock.

The latest Cretaceous witnessed the deposition of thin- to medium-bedded sandstone and shale of the Haymana Formation of Campanian-Maastrichtian age (Yüksel, 1970; Ünalan et al. 1976). The Haymana Formation starts with mudstones and shales with thin sandstone and siltstone beds, representing distal turbidites and basin deposits. This formation gives a broad Campanian age based on planktonic foraminifera and transported benthic foraminifera (Toker 1979; Özkan Altıner and Özcan, 1999). The contact between the Santonian limestone of the Kocatepe Formation and the Campanian-Maastrichtian turbidites has been identified as conformable (e.g., Özcan and Özkan-Altıner 1997; Özkan-Altıner and Özcan, 1999; Huseynov 2007).

With the initiation of the Galatean arc activity in the Maastrichtian, the Haymana-Polatlı Basin started to shallow at its arcward side while its trenchward side was still under deep-marine conditions. This shallowing is reflected in the coarsening-upward sequence character of the units (Haymana Formation) in west-northwest part of the Haymana Basin (Koçyiğit, 1991).

Continued shallowing in the Paleocene resulted in the widespread and rapid fluvial to lacustrine sedimentation (Kartal, Alcı, and Uzunçarşı formations) in the arcward periphery of the Haymana-Polatlı Basin, and olistolith occurrence derived from the reefal buildups in the deep-marine sediments (Yeşilyurt and Kırkkavak formations) in the southeastern part of the Haymana Basin (Koçyiğit, 1991) (Figure 6).

The previously emerged parts of the Haymana-Polatlı Basin periphery were covered by a short-term shallow and transgressing sea in the early to middle Eocene which is attributed to local subsidence along the margin of the forearc basin due to the variation in the isostatic balance caused by the increasing load of basin-filling sediments together

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with the growing and rising accretionary wedge (Koçyiğit, 1991). This event resulted in the deposition of a widespread *Nummulites*-bearing sandy limestone (Akpınar Limestone) and clastics (Beldede and Çayraz formations) (Figure 6).

Retreat of the sea occurred during the Late Eocene and Early Oligocene resulting in becoming of the complete Ankara region a part of the land. This progressing convergence between the Sakarya continent and the Menderes-Tauride block caused the formation of a tectonical stacking up of both the forearc sediments and their basement rocks in an imbricate thrust zone. These were finally thrust onto Upper Eocene-Lower Oligocene fluvial to lacustrine deposits accumulated in the coastal plains and large lakes (Figure 6). Afterwards, the Ankara region continued to experience the effects of the convergent events until the emergence of a strike-slip neotectonic regime during early Quaternary time (Koçyiğit and Doğan, 2016).

In this geological framework, the stratigraphic section studied in this thesis project belongs to the lower to upper parts of the Upper Cretaceous of the Haymana-Polatlı Basin comprising the Akkaya, Kocatepe and Haymana formations (Figure 6).

ERATHEM	SYSTEM	SERIES	THICKNESS (m)	HAYMANA BASIN
				LITHOLOGY DESCRIPTION

HAYMANA BASIN

LITHOLOGY   DESCRIPTION

CENOZOIC	NEOGENE	Quaternary		ALLUVIUM
		Mio-Pliocene	400	CİHANBEYLİ FM: red beds and evaporites
		Mio-Pliocene		OPHIOLITHIC MELANGE - Cretaceous age
	PALEOGENE	Eocene	3-525 / 2-1644 / 1-567	3- ÇAYRAZ FM: limestone and marl 2- BELDEDE and YAMAK FMs: conglomerate and sandstone 1- ESKİPOLATLI FM: marl, sandstone and mudstone
		Paleocene	2-350 / 1-659	2- ILGINLIKDERE FM: conglomerate and sandstone 1- KIRKKAVAK FM: algal limestone and marl
		Paleocene	3-342 / 2-1187 / 1-1362	3- YEŞİLYURT FM: marl and marl with limestone blocks 2- ÇALDAĞ FM: reefal limestone 1- KARTAL FM: continental red clastics
MESOZOIC	CRETACEOUS	Maas / Cam		HAYMANA FM: green and grey shale and turbiditic sandstone - lensoid conglomerate intercalations
		San / Tur	MS	KOCATEPE FM: limestone and shale
		Cen / Alb		AKKAYA FORMATION: limestone and breccia
		Ber		SOĞUKÇAM LIMESTONE: pelagic limestone and breccia
	JURASSIC			BİLECİK LIMESTONE: neritic limestone
	TRIASSIC			KARAKAYA COMPLEX: Greywacke, siltstone, shale with Carboniferous, Permian, Triassic limestone blocks

not to scale

Figure 6. Generalized columnar section of the study area where MS denotes "measured section" (modified from Ünalan et al, 1976 and Okay and Altıner et al., 2016).

CHAPTER 2

2. STRATIGRAPHY

2.1. Lithostratigraphy

The stratigraphic section of this study was measured in the Alagöz village that is located in 40 km north of Haymana district, Ankara, Turkey. The exact coordinates of the section are 39°45'23"N - 32°29'26"E and 39°45'22"N - 32°29'19"N 75, respectively for the start and end points. 75 samples were collected from the section which was measured to be 93.5 m in total. Sampling interval was increased as going towards southern and monotonous parts of the section. This section comprises the Upper Cretaceous carbonate formations of the Haymana region which from older to younger are the Akkaya Formation (Albian-Cenomanian), the Kocatepe Formation (Turonian-Santonian) and the Haymana Formation (Campanian-Maastrichtian) (Figures 7 and 8).

The previously unknown Albian to Cenomanian sequence in the Haymana region has recently been recognized by Okay and Altıner (2016) and called as the Akkaya Formation. This formation was well known in the northern Turkey, most commonly in Boyabat, Sinop (Gedik et al., 1981; Korkmaz et al., 1991) and should not be confused with the Akkaya Formation in the southwestern Turkey (Kaya et al., 2001). The first 13 samples of the stratigraphic section were taken from the Akkaya Formation and these correspond to the first 8.7 m of the section. the Akkaya Formation is composed of breccia deposits which were the product of submarine debris flows (Figure 7. A-C). It mostly comprises very hard limestones and clayey limestones in the northern part; whereas the lithology becomes relatively softer and more shaly towards the south. Color of the formation also changes

from pale colors as green, gray and light brown to darker colors as dark gray and brown from the north to the south of the section (Figure 8).
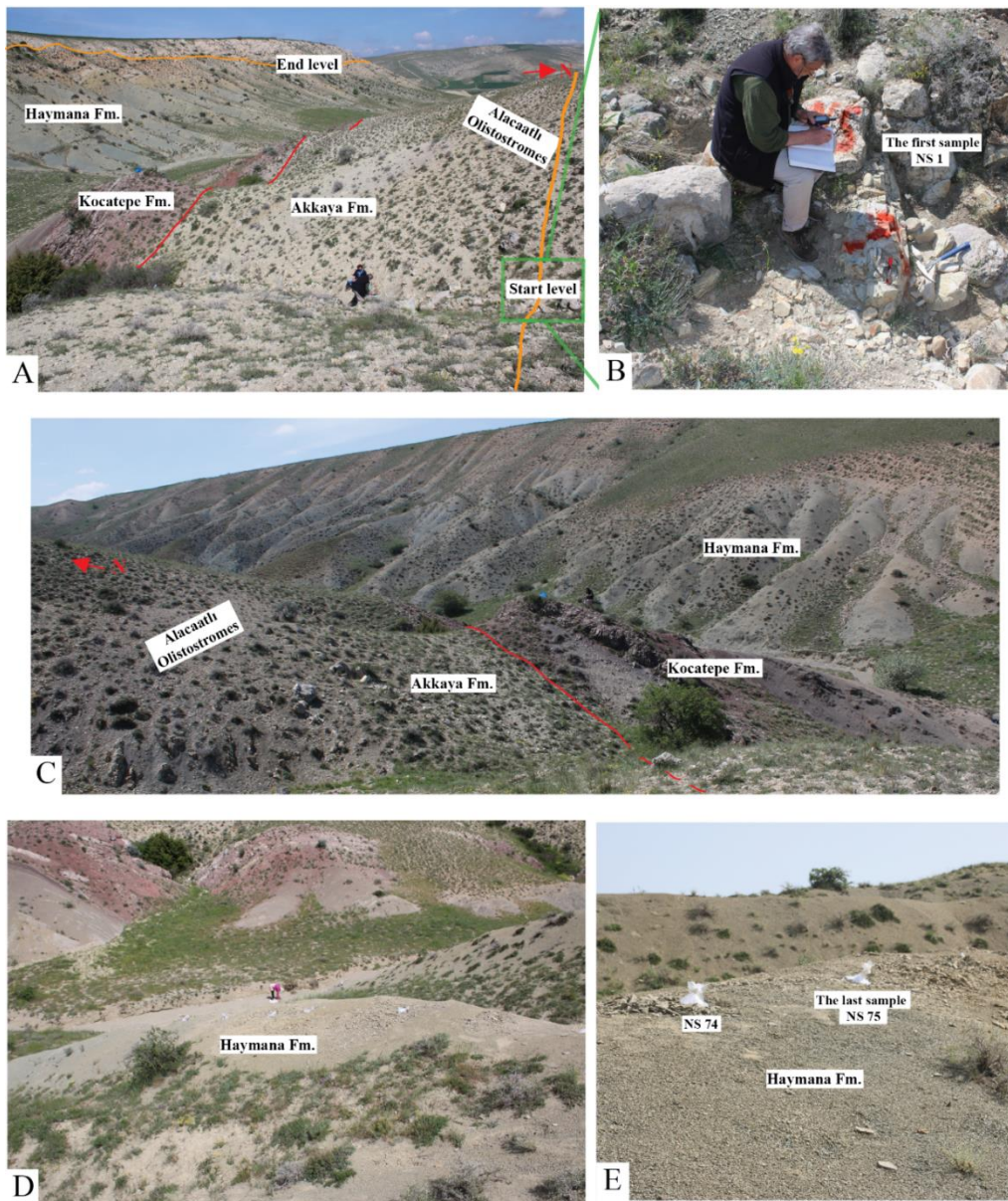
Figure 7. Photographs from the field, A. Limits and geological formations of the measured stratigraphic section, B. Start level of the stratigraphic section, C. Another view of the measured stratigraphic section, D. A view of the southern portion of the measured section, E. A close-up view of the southern portion of the measured stratigraphic section.

A pelagic Upper Cretaceous sequence of mainly limestone and shale of nearly 15 m in thickness, called the Kocatepe Formation (Yüksel, 1970) (Figure 7. A and C), unconformably overlies the Akkaya formation. Lithology becomes dominated more by shales compared to limestones towards the southern part. In addition to the unconformity marking the transition between the two formations, the Kocatepe Formation is also striking with its bright red color on top of the pale colored Akkaya Formation. 25 samples were collected from the Kocatepe Formation.

The Kocatepe formation is followed by medium-bedded silty shale and shale of the conformably overlying Haymana Formation (Figure 7. A, C, D, E.) It starts with a brief interval of red to pink silty shale, then becomes mainly greenish gray in the northeastern and bluish gray in the southwestern parts with intervening brown to yellowish brown levels of mostly silty shale (Figure 8, 9). The Haymana Formation occupies the largest portion of the measured stratigraphic section with 70 m. 37 samples were collected from this unit with relatively larger intervals compared to the northeastern part of the section. Amount of silt in the lithology increases noticeably towards the southwest, which indicates that the Haymana Formation represents distal turbidites and basin deposits on top of the red pelagic limestones of the underlying the Kocatepe Formation.

Figure 8. Lithostratigraphy of the measured section with the planktonic foraminiferal biozones determined in this study (shorter version).
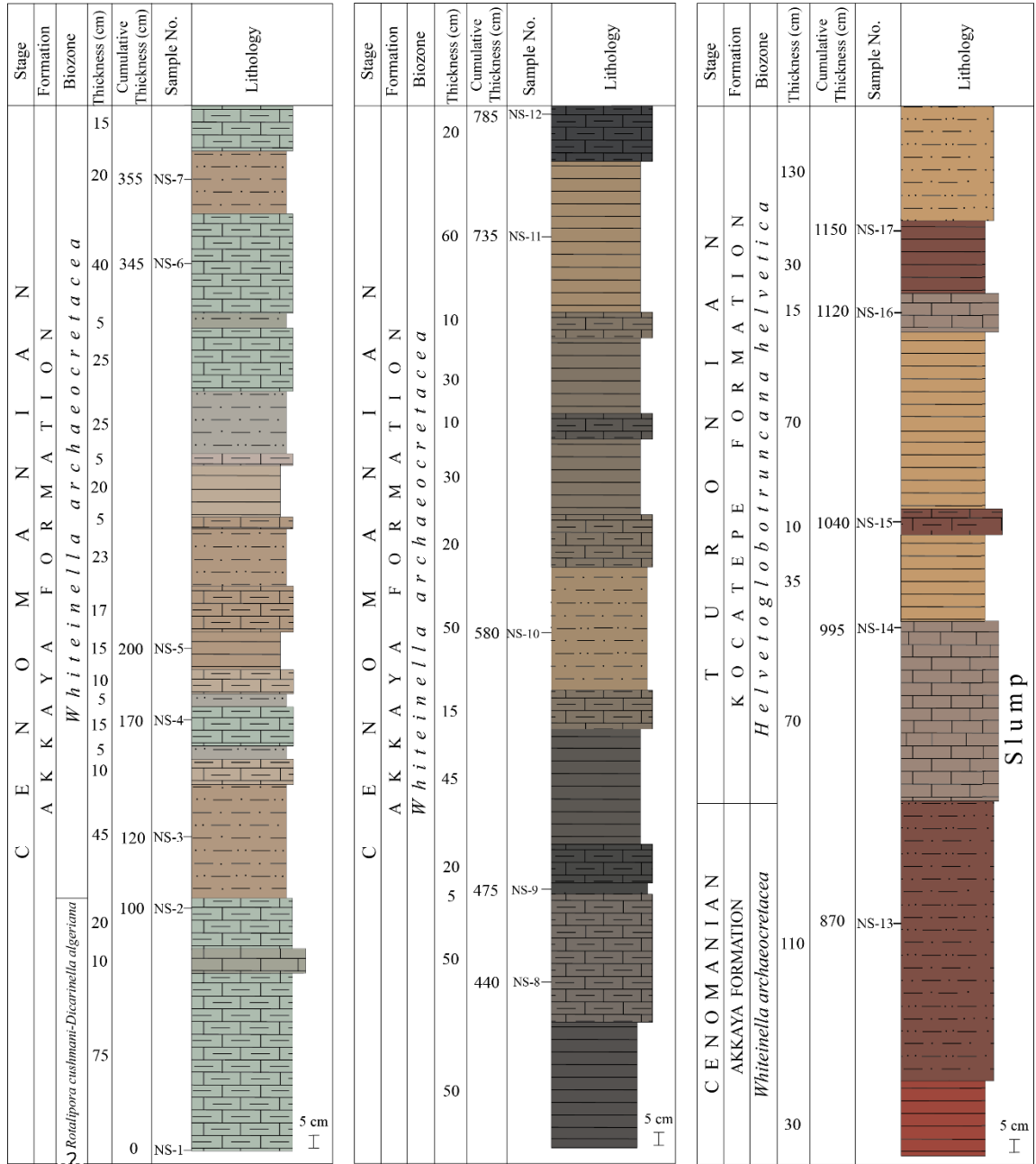
Figure 9. Lithostratigraphy of the measured section with the planktonic foraminiferal biozones determined in this study.

Figure 9. Continued

Figure 9. Continued

Figure 9. Continued

Figure 9. Continued

2.2. Biostratigraphy

The primary aim of this study was to establish a reliable and detailed biostratigraphic framework for the upper Cretaceous pelagic succession of the Haymana Basin. To this end, three formations in the Haymana Basin, the Akkaya, Kocatepe and Haymana Formation's, have been examined in terms of their planktonic foraminiferal content. A 93.5 meters thick sedimentary succession was measured and sampled. At the end, 80 planktonic foraminifera species belonging to 22 different genera are identified and their first and last occurrence levels are recorded (Figure 10). Then, the measured stratigraphic section is divided into ten biozones by using planktonic foraminiferal bioevents.
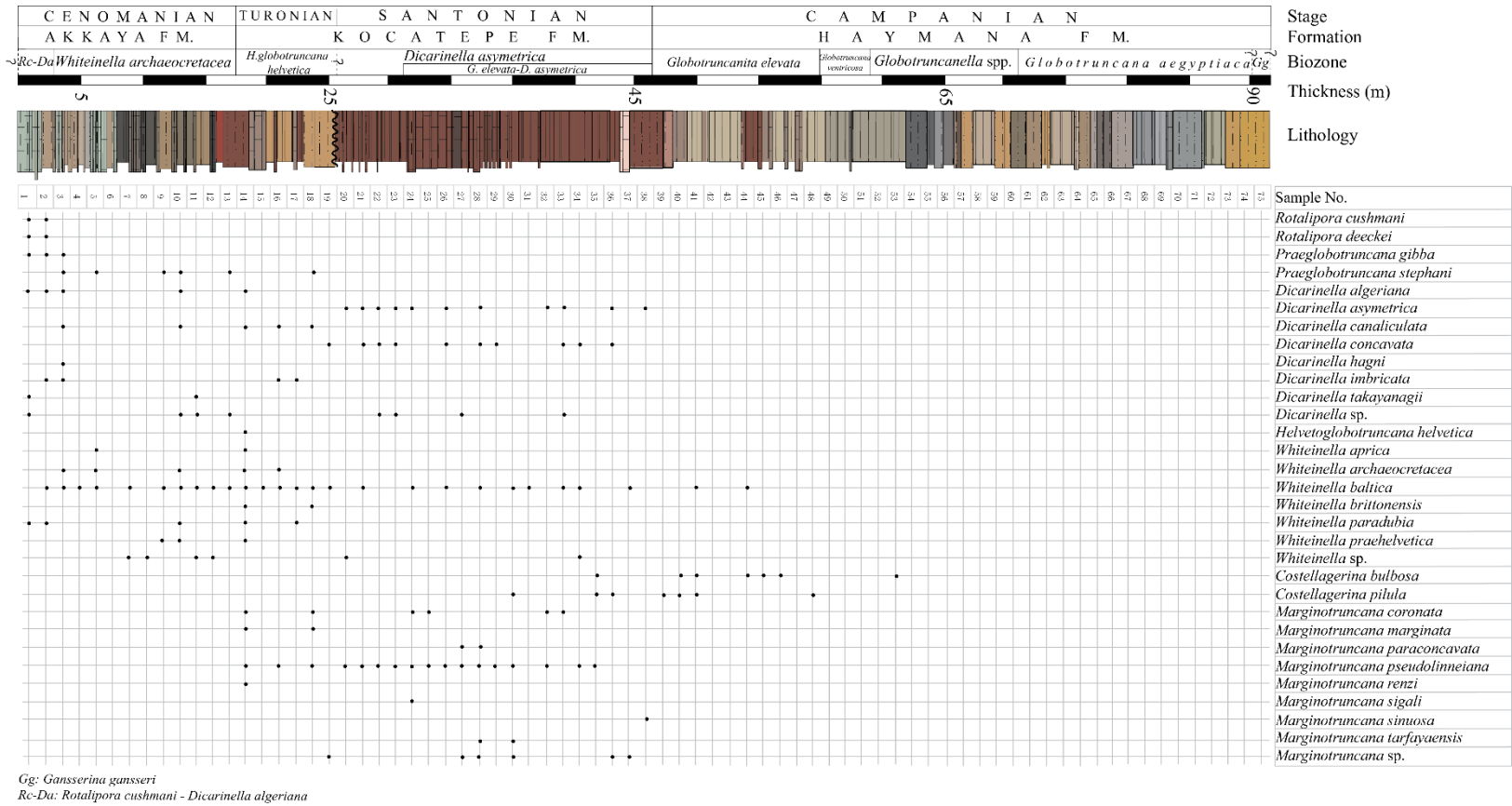
Figure 10. Range chart of the planktonic foraminifera species identified in this study.

Figure 10. Continued.
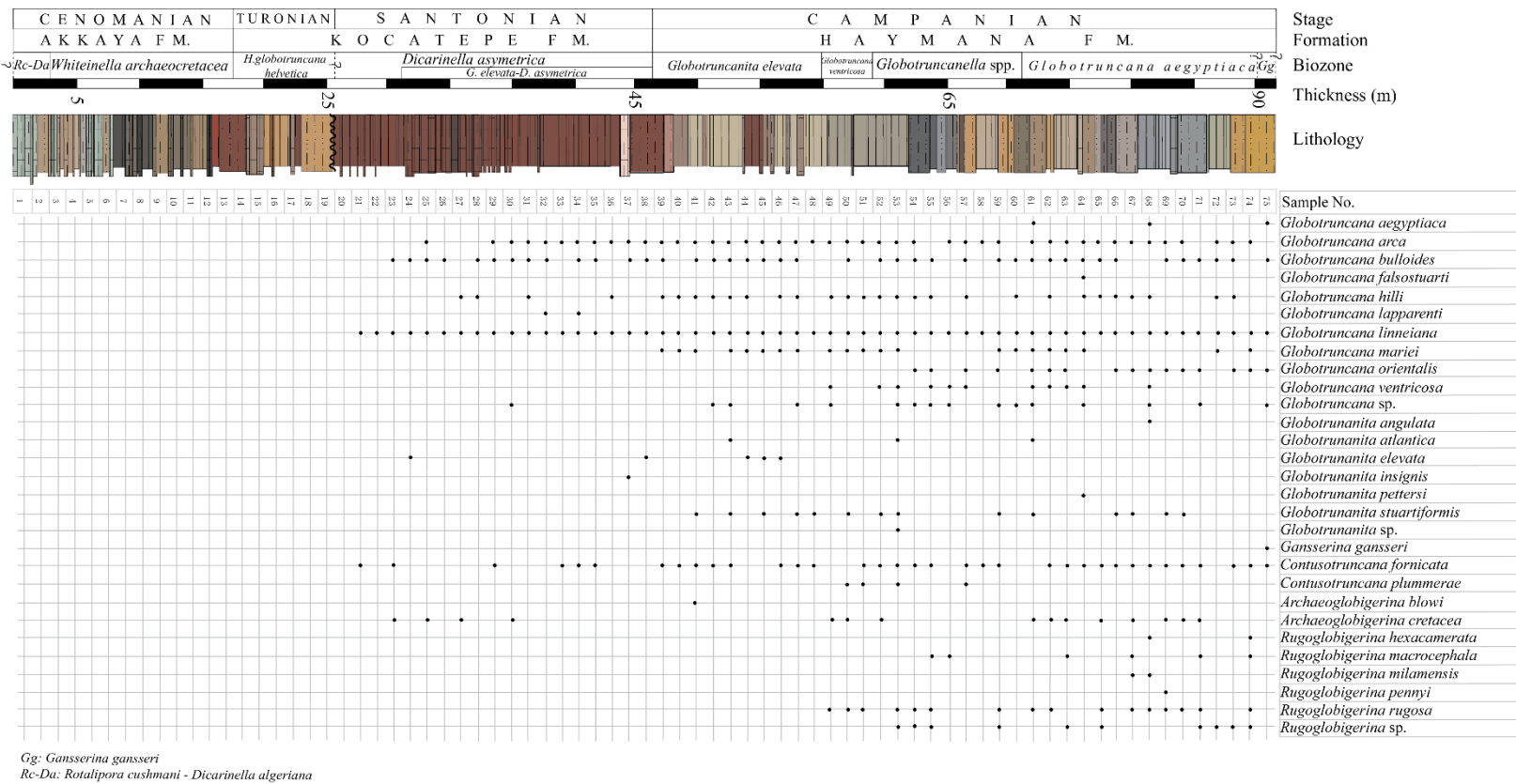
Figure 10. Continued.
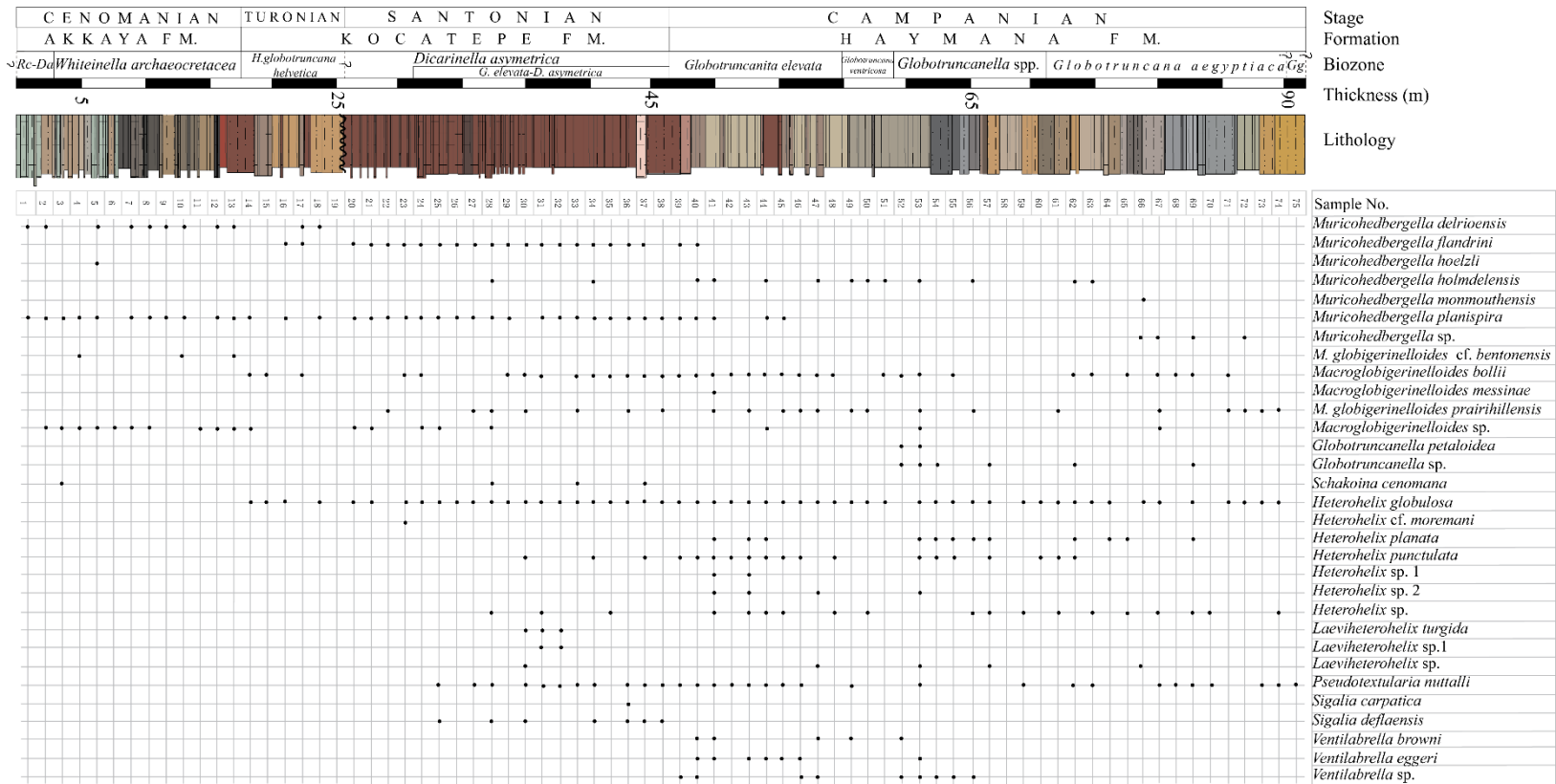
Gg: Gansserina gansseri
Rc-Da: Rotalipora cushmani - Dicarinella algeriana

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Based on the planktonic foraminiferal biostratigraphy, the boundaries between stages Cenomanian-Turonian and Santonian-Campanian are also established. The Cenomanian-Turonian boundary is placed at the lowest occurrence of the important species *Helvetoglobotruncana helvetica*. It is not coincident with a major lithology change; this boundary is represented by dark grey shale and clayey limestones below and light brown limestones above in the measured stratigraphic section. Late Turonian, Coniacian and probably earliest Santonian were absent in the measured stratigraphic section. This hiatus between early Turonian and early Santonian was observed to be coincident with a major lithological boundary between very hard greenish to grey limestones below and relatively softer red limestones and shales above. No stratigraphic discontinuity has been detected throughout the Santonian-Campanian successions which occupy the greatest portion in the measured stratigraphic section. Therefore, the boundary between these two stages could be studied in the most detail. The Santonian-Campanian boundary falls exactly at the transition where the red Santonian limestones leave their place to the light brown Campanian shales. As for the Campanian-Maastrichtian boundary, it is envisaged to be close to the end of the measured stratigraphic section as signaled by the first occurrence of *Globotruncanita pettersi* (NS-64), *Globotruncanita angulata* (NS-68) and *Gansserina gansseri* (NS-75).

The planktonic foraminiferal biozones and stage boundaries established in this study (Figure 11) are given in the following descriptions in detail.

Figure 11. Biozonational comparison chart of the Cenomanian-Campanian planktonic foraminifera.

Stage	Substages	Barr (1972) Lybia	Salaj (1980, 1997) Tunisia	Abdul-Kireem et al. (1996) Egypt	Premoli-Silva & Bolli (1973) Caribbean	Sigal (1977) Mediterranean	Wonders (1980) Western Mediterranean	Robaszynski & Caron (1995) Paris Basin	Vaptzarova (1976) NW Bulgaria	Dimitrova & Valchev (2007) S Bulgaria	Takashima et al. (2010) Yezo Group Japan	Robaszynski et al. (1984) Generalized	Caron (1985) Generalized	Sliter (1989) Generalized	Premoli-Silva & Verga (2004) Generalized	Ardestani et al. (2012) NE Iran	Sari (2006, 2009) Turkey	Bahazadeh et al. (2007) E Iran	Abawi and Mahmood (2005) N Iraq	Ogg and Hinnov (2012) F. Iran	This Study Central Turkey	Datum Markers
Campanian	U	*Globotruncana tricarinata*	Not studied	*Globotruncana ventricosa*	*Globotruncana calcarata*	No data	*Globotruncana ventricosa* / *Globotruncana calcarata*	*R. calcarata*	*Radotruncana calcarata* / *Globotruncana rugosa*	*R. calcarata* / *G. stuartiformis*	Not studied	*R. calcarata*	*R. calcarata*		*Gansserina gansseri* / *G. aegyptiaca* / *G. havanensis* / *R. calcarata*	Not studied	*Gansserina gansseri* / *G. falsostuarti* / *R. calcarata*	Not studied / *R. calcarata*	Not studied	*Gansserina gansseri* / *G. aegyptiaca* / *G. havanensis* / *R. calcarata*	*Gansserina gansseri* / *G. aegyptiaca* / *Globotruncanella* spp.	LO — *G. gansseri* / LO — *G. aegyptiaca* / LO *Globotruncanella petaloidea*
Campanian	L	*Globotruncanita elevata*	*Globotruncanita elevata*	*Globotruncanita elevata*	*Globotruncanita elevata*	*Globotruncanita elevata + G. stuartiformis*	*Globotruncanita elevata*	*Globotruncanita elevata*	*Globotruncanita elevata*	*Globotruncanita elevata*		*Globotruncanita elevata*	*Globotruncanita elevata*	*Globotruncanita elevata*	*Globotruncanita elevata*	*Dicarinella asymetrica*	*Dicarinella asymetrica*	*Dicarinella asymetrica*	*Globotruncanita elevata*	*Contusotruncana plummerae* / *Globotruncanita elevata*	*Globotruncana ventricosa* / *Globotruncanita elevata* / *D. asymetrica - G. elevata*	LO — *G. ventricosa* / HO — *D. asymetrica* / LO — *G. elevata*
Santonian	U	*Globotruncana elevata*	*Dicarinella asymetrica + Dicarinella concavata*	*Dicarinella concavata*	*Globotruncana concavata carinata*	*Globotruncana concavata carinata*	*Globotruncana carinata*	*Dicarinella asymetrica*	*Globotruncana concavata*	*Dicarinella asymetrica*		*Dicarinella asymetrica*	*Dicarinella asymetrica*				*Dicarinella asymetrica*		*Dicarinella asymetrica*	*Contusotruncana fornicata*	*Dicarinella asymetrica*	LO — *D. asymetrica*
Coniacian	L / U / M / L	*Dicarinella concavata* / *D. concavata*		*Dicarinella primitiva*	*Dicarinellea concavata*	*Dicarinella concavata*	*Dicarinella primitiva*	*Dicarinella concavata*	*Marginotruncana renzi*	*C. fornicata* / *Marginotruncana sinuosa* / *Dicarinella concavata* / *Dicarinella primitiva*		*Dicarinella concavata* / *M. pseudolinneiana*	*Dicarinella concavata* / *Dicarinella primitiva*	*Dicarinella concavata*	*Dicarinella concavata*		*Dicarinella concavata*	*Dicarinella concavata*	*Dicarinella concavata* / *D. primitiva*	*Dicarinella concavata*	No Coniacian species were observed	
Turonian	U	*M. sigali*	*M. schneegansi*	*M. schneegansi*	*M. schneegansi*	*M. sigali + M. schneegansi*	*M. sigali*	*M. schneegansi*	*M. renzi + M. sigali*	*M. schneegansi*	*M. schneegansi*	*M. sigali*	*M. sigali*	*Marginotruncana sigali*	*M. sigali / Di. primitiva*	*M. schneegansi*		*M. sigali*		*M. schneegansi*	*H. helvetica*	
Turonian	M	*H. helvetica* / *Dicarinella hagni*	*H. helvetica* / *Dicarinella imbricata*	*H. helvetica* / *Whiteinella archaeocretacea*	Not studied	*H. helvetica* / *Rotalipora cushmani*	*H. helvetica* / *Whiteinella archaeocretacea*	*H. helvetica*	*H. helvetica*	*Dicarinella imbricata*		*H. helvetica* / *Whiteinella archaeocretacea*	*H. helvetica* / *Whiteinella archaeocretacea*	*H. helvetica*	*H. helvetica* / *Whiteinella archaeocretacea*	Not studied		*H. helvetica*	Not studied	*H. helvetica* / *W. archaeocretacea*	*H. helvetica* / *W. archaeocretacea*	LO — *H. helvetica* / HO — *R. cushmani*
Cenomanian	U	*R. cushmani*	Not studied / *Prae-globotruncana delrioensis*	Not studied	No data	Not studied	No data	No data	*R. cushmani*	*R. cushmani* / Not studied		Not studied	Not studied	Not studied	*R. cushmani / D. algeriana*	Not studied	Not studied	Not studied	Not studied	*R. cushmani*	*R. cushmani / D. algeriana*	

Substages — U: Upper, M: Middle, L: Lower

Datum Markers — HO: Highest occurrence, LO: Lowest occurrence; Hiatus (shaded)

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2.2.1. *Rotalipora cushmani* Zone

Definition: Total range zone of *Rotalipora cushmani* (Borsetti, 1962). However, this part of the section corresponds to the uppermost part of the *Rotalipora cushmani* Zone in this study.

Remarks: Although this zone is officially defined as a total-range zone, the lower boundary of this zone is depicted with ambiguity. The first appearance of the nominal species could not be recorded since the first sample of the measured section is above this level. However, the presence of *Rotalipora cushmani* in the first two samples (NS-1 and NS-2) definitely shows that this part of the section is in the *Rotalipora cushmani* biozone. Moreover, coexistence of *Dicarinella algeriana*, *Whiteinella baltica*, *W. paradubia* and *R. cushmani* in these samples supports this interpretation. It is envisaged to cover the uppermost part of the *Rotalipora cushmani* Zone. It corresponds to middle to late portion of the Cenomanian in the measured section and its thickness is 1 meter.

Important planktonic foraminifera identified in this biozone are as follows: *Rotalipora cushmani, Rotalipora deeckei, Praeglobotruncana gibba*, *Whiteinella paradubia* and *Dicarinella algeriana*.

Stratigraphic distribution: From sample NS-1 to sample NS-2

Age: Middle to Late Cenomanian

Dicarinella algeriana Subzone

Definition: Interval between the lowest occurrence of *Dicarinella algeriana* and extinction of the genus *Rotalipora*.

Author: PREMOLI-SILVA and VERGA, 2004

Remarks: This subzone covers only the first two samples (NS-1 and NS-2) of the section where the lowest occurrence of *Dicarinella algeriana* (NS-1) and highest occurrence of the rotaliporids (NS-2) are detected. However, the lower boundary of this zone is

delineated with uncertainty due to the highly possible lower first occurrence of *Dicarinella algeriana* that defines the base of this zone.

Notable planktonic foraminifera characterizing this biozone are as follows: *Rotalipora cushmani, Rotalipora deeckei, Whiteinella gibba*, *Whiteinella paradubia* and *Dicarinella algeriana*.

Stratigraphic distribution: From sample NS-1 to sample NS-2

Age: Late Cenomanian

2.2.2. *Whiteinella archaeocretacea* Zone

Definition: Partial range zone between the highest occurrence of *Rotalipora cushmani* and the lowest occurrence of *Helvetoglobotruncana helvetica*.

Author: BOLLI, 1966

Remarks: *Whiteinella archaeocretacea* is a biozone covering almost 9 meters in the measured stratigraphic section. This zone is commonly characterized by a low-diversity assemblage related to the widespread deposition of organic rich sediments during the OAE2. Assemblages in this interval are known to include rare specimens of *Muricohedbergella*, *Whiteinella* and *Dicarinella* (Premoli-Silva and Verga, 2004). This situation is evident also in this study. The interval from sample NS-6 to sample NS-9 lacks whiteinellid and dicarinellid diversification. Although they occur rarely, W*hiteinella* and *Dicarinella* species start to diversify starting from sample NS-10.

The marker planktonic foraminifera of this biozone are as follows: *Macroglobigerinelloides bentonensis*, *Muricohedbergella planispira, Muricohedbergella delrioensis, Whiteinella baltica, Whiteinella aprica, Whiteinella archaeocretacea, Whiteinella praehelvetica, Whiteinella paradubia, Dicarinella canaliculata* and *Heterohelix moremani*.

Stratigraphic distribution: From sample NS-3 to sample NS-13.

Age: Latest Cenomanian to earliest Turonian

2.2.3. *Helvetoglobotruncana helvetica* Zone

Definition: Total range zone of *Helvetoglobotruncana helvetica*. However, due to not observing the last occurrence of the nominal species, this zone has been used as an assemblage zone of *Helvetoglobotruncana helvetica* in this study.

Author: SIGAL, 1955

Remarks: *Helvetoglobotruncana helvetica* Zone covers almost 7 meters in the Middle Turonian of the measured stratigraphic section. Presence of *H. helvetica* can be given as the hallmark of the Turonian stage. Although previous work suggested that *H. helvetica* is indicative of the mid-Turonian (Salaj, 1980, 1997; Wonders, 1980; Robaszynski et al., 1984; Caron, 1985; Sliter, 1989; Abdel-Kireem et al., 1996; Premoli Silva & Verga, 2004; Abawi & Mahmood, 2005), it is now considered to denote an interval in the early Turonian (Caron *et al.*, 2006; Desmares *et al.*, 2007; Gebhardt *et al.*, 2010; Ogg and Hinnov, 2012; Huber and Petrizzo, 2014; Vahidinia *et al.*, 2014).

This zone is actually defined as a total range zone by using the stratigraphic distribution of *Helvetoglobotruncana helvetica*. The problem with the definition of this zone arises from the fact that the nominal species is found in only one sample (NS-14). This level must be the lowest occurrence (LO) *H. helvetica* since it co-occurs with some other characteristic species as *W. praehelvetica* and *W. archaeocretacea* in sample NS-14. Although the highest occurrence of *H. helvetica* was not detected, the Turonian planktonic foraminiferal fauna suddenly disappears after sample NS-19. Moreover, the highest occurrence of *Praeglobotruncana stephani*, which is known to have its last appearance top in the Turonian stage, and the lowest occurrence of *Dicarinella concavata*, whose first appearance is known as the upper Turonian, also occur in the latest portion of this zone in samples NS-18 and NS-19, respectively. These indicate that the upper boundary of this zone is at least closely approximated in the studied section. Another important point indicated here is that the *Dicarinella concavata* zone may already be present starting from the sample NS-19. However, it is not defined here due to insufficient data and requires

further and more detailed examination of this interval. The upper boundary of this zone is delineated with the unconformity between samples NS-19 and NS-20.

The important planktonic foraminifera observed in this biozone are *Helvetoglobotruncana helvetica, Marginotruncana renzi, Marginotruncana coronata, Marginotruncana pseudolinneiana* and *Heterohelix globulosa*.

Stratigraphic distribution: From sample NS-14 to sample NS-19. Although the last occurrence of the nominal species *H. helvetica* was not observed in the section, this biozone is defined between samples NS-14 and NS-19 based on the presence of secondary characteristic species described above and the lowest occurrence of *Dicarinella asymetrica* in sample NS-20. The boundary between these two samples also correspond to an unconformity in the section.

Age: Early to middle Turonian

2.2.4. *Dicarinella asymetrica* Zone

Definition: Total range zone of *Dicarinella asymetrica*

Author: POSTUMA, 1971

Remarks: *Dicarinella asymetrica* Zone whose lower boundary corresponds to an unconformity in the section starts with the first occurrence of the nominal species *Dicarinella asymetrica* in the first sample above the unconformity, NS-20. This important bioevent is followed by consequent first occurrences of some *Globotruncana* species as *G. linneiana* in sample NS-21 and *G. bulloides* in sample NS-23. It covers almost 7 meters of the measured stratigraphic section.

The marker planktonic foraminifera species characterizing this biozone are *Dicarinella asymetrica*, *Pseudotextularia nuttalli*, *Sigalia deflaensis, Sigalia carpatica*, *Laeviheterohelix turgida*, *Globotruncana linneiana, Globotruncana arca, Globotruncana bulloides* and *Globotruncana hilli*.

Stratigraphic distribution: From sample NS-20 to sample NS-38.

Age: Early Santonian to earliest Campanian

Globotruncanita elevata- Dicarinella asymetrica Concurrent Range Subzone

Definition: The interval between the lowest occurrence of *Globotruncanita elevata* and the highest occurrence of *Dicarinella asymetrica*.

Author: This is not a formal planktonic foraminiferal biozone, but is a concept used by many authors to reach higher resolution in the planktonic foraminiferal biostratigraphy at the S/C boundary (Masters, 1970, 1977; Van Hinte, 1976; Wonders, 1980; Dowsett, 1984).

Remarks: This important biozone is detected to occupy an approximately 6 m interval at the S/C transition of the stratigraphic section. Marginotruncanids gradually disappear towards the top of this zone. The genera *Dicarinella* and *Marginotruncana* completely become extinct at the end. So, the last occurrence of marginotruncanids and *D. asymetrica* are detected in this interval. *Muricohedbergella flandrini* exhibits a very consistent occurrence pattern throughout the previous and this biozone. Contrary to the general opinion (Premoli Silva and Verga, 2004; Babazadeh et al., 2007; Wagreich et al., 2016), *Muricohedbergella flandrini* continues to exist further above the *Globotruncanita elevata-Dicarinella asymetrica* concurrent range Subzone up to the sample NS-40 in this study; this situation may suggest an extension of the range zone of *M. flandrini*.

Stratigraphic distribution: From sample NS-24 to sample NS-38.

Age: Late Santonian or earliest Campanian (Robaszynski et al., 1984; Wagreich, 1992)

2.2.5. *Globotruncanita elevata* Zone

Definition: Partial range zone between the highest occurrence of all *Dicarinella* species to the lowest occurrence of *Globotruncana ventricosa*.

Author: ROBASZYNSKI and CARON, 1995

Remarks: *Globotruncanita elevata* Zone is the second Campanian biozone and it is nearly 15 meters in thickness in the stratigraphic section. Important bioevents in this biozone include the first occurrence of the rare *Globotruncanita atlantica.* This zone comprises the further diversification of the genera *Globotruncana*, *Ventilabrella* and *Heterohelix* as well as frequent occurrences of multiple *Costellagerina* species.

Globotruncanita stuartiformis, Globotruncanita atlantica, Ventilabrella browni and *Ventilabrella eggeri* firstly appeared in this biozone.

Stratigraphic distribution: From sample NS-39 to sample NS-48.

Age: Early Campanian

2.2.6. *Globotruncana ventricosa* Zone

Definition: Interval between the lowest occurrence of *Globotruncana ventricosa* to the lowest occurrence of *Globotruncanella* spp. (substituted for *Radotruncana calcarata*).

Author: ROBASZYNSKI and CARON, 1995

Remarks: *Globotruncana ventricosa* Zone extends along the middle part for 3.5 meters of the recorded Campanian in the measured section. First occurrence of *Contusotruncana plummerae* and Genus Rugoglobigerina in this biozone is noteworthy.

Important lowest occurrences in this biozone belong to *Globotruncana ventricosa*, *Contusotruncana plummerae* and *Rugoglobigerina rugosa.*

Stratigraphic distribution: From sample NS-49 to sample NS-51.

Age: Middle Campanian

2.2.7. *Globotruncanella* spp. Zone

Definition: Interval zone from the lowest occurrence of *Globotruncanella* spp. (substituted for the highest occurrence of *Radotruncana calcarata*) to the lowest occurrence of *Globotruncana aegyptiaca.*

Author: CARON, 1978

Remarks: *Globotruncanella* spp. Zone covers 16 meters in the upper part of the stratigraphic section. This zone is originally named as *Globotruncanella havanensis* Zone, however the nominal species is not found in this study. Therefore, an equivalent bioevent, the diversification of the genus *Globotruncanella*, is used to define this biozone here.

Important bioevents include the lowest occurrence and diversification of the genus *Globotruncanella* including the first appearance of *Globotruncanella petaloidea* and the maximum diversification of the genus *Heterohelix* in sample NS-54.

Stratigraphic distribution: From the sample NS-52 to the sample NS-60.

Age: Late Campanian

2.2.8. *Globotruncana aegyptiaca* Zone

Definition: Interval between the lowest occurrence of *Globotruncana aegyptiaca* to the lowest occurrence of *Gansserina gansseri*.

Author: CARON, 1985

Remarks: *Globotruncana aegyptiaca* zone is the latest biozone completely identified and it covers 33 meters in the measured section. A very important bioevent observed in this zone is the diversification and increasing abundance of the genus *Rugoglobigerina*. Toward the upper part of this zone, they have been observed to fill the niches emptied by disappearing muricohedbergellids and macroglobigerinelloids quite noticeably. This is known as a signal for the transition from *Globotruncana aegyptiaca* zone to *Gansserina gansseri* zone (Premoli Silva and Verga, 2004).

Other important bioevents are the first occurrences of genus *Rugotruncana*, *Globotruncanita angulata*, *Globotruncanita pettersi* and *Muricohedbergella monmouthensis*. The maximum abundance and diversification of globotruncanids is observed in this biozone, coincident with the global abundance data presented by Premoli Silva and Sliter (1999; see Figs 9 and 10).

The marker planktonic foraminifera of this biozone are *Globotruncanita angulata, Globotruncanita pettersi, Rugoglobigerina macrocephala, Rugoglobigerina pennyi* and *Rugoglobigerina hexacamerata*.

Stratigraphic distribution: From the sample NS-61 to the sample NS-74.

Age: Late Campanian to latest Campanian/the beginning of Maastrichtian

2.2.9. *Gansserina gansseri* Zone

Definition: Interval between the lowest occurrence of *Gansserina gansseri* to the lowest occurrence of *Contusotruncana contusa* and *Racemiguembelina fructicosa*.

Author: CARON, 1985

Remarks:

Gansserina gansseri zone begins in the last sample of this study. Its upper boundary was not identified and thus delineated with uncertainty; it should continue higher into the marls of the Haymana Formation. Its lower boundary was also delineated with uncertainty due to lowest occurrences of *Globotruncanita angulata* and *Globotruncanita pettersi* in samples NS-68 and NS-64, respectively.

Gansserina gansseri appears for the first time in this zone. Although in the previous decades *Gansserina gansseri* was thought to have its first occurrence in the Maastrichtian (Barr, 1972; Premoli Silva and Bolli, 1973; Caron, 1985; Sliter, 1989; Li and Keller, 1998; Li et al., 1999), today it is widely accepted to be contained in the latest Campanian (Premoli Silva and Sliter, 1994, 1999; Robaszynski, 1998; Özkan-Altiner and Özcan, 1999; Robaszynski et al., 2000; Chacon et al., 2004; Premoli Silva and Verga, 2004; Sari, 2006, 2009; Ogg and Hinnov, 2012; Beiranvand and Ghasemi-Nejad, 2013). Therefore, it is a highly reliable bioevent to determine the latest Campanian. It is crucial for this study in terms of approximating the Campanian-Maastrichtian boundary that the first occurrence of *G. gansseri* could be observed in the latest sample NS-75 together with the lowest

occurrences of *Globotruncanita angulata* and *Globotruncanita pettersi* in samples NS-68 and NS-64, respectively.

Stratigraphic distribution: Sample NS-75.

Age: Latest Campanian to early Maastrichtian

CHAPTER 3

3. MICROFACIES ANALYSIS

3.1. Types of Microfacies and Depositional Environments

First definitions of "microfacies" were originally coined by Brown (1943) and again independently by Cuvillier (1952) shortly as "petrographic and paleontological criteria studied in thin-sections". Today, microfacies is regarded as the total of all sedimentological and paleontological data which can be described and classified from thin sections, peels, polished slabs or rock samples (Flügel, 2004).

Microfacies analyses can yield a vast amount of information about carbonate rocks, including their depositional and diagenetic history, the biological controls on carbonate sedimentation and the fossil content of these rocks, the relationships between diagenetic processes, porosity and dolomitization. These, in turn, provide the necessary knowledge for evaluating sequence stratigraphic frameworks and depositional models, differentiating paleoclimate changes, tracing platform-basin relationships, evaluating reservoir rocks and limestone resources (Flügel, 2004).

In this study, the samples have been examined in terms of their paleontological and sedimentological content in order to interpret the depositional history of the area and then to combine this result with the other findings of this study. A number of criteria have been evaluated for the samples to this end; these are listed in the Microfacies Analysis Table given. Then, the samples have been named using the data obtained from their microfacies analysis and the usual Dunham Classification (Figure 12) (Dunham, 1962).

Figure 12. Dunham classification (1962).

The data obtained from microfacies analysis is transformed into the kind of practical knowledge described previously by use of facies models. Application of these models to the raw microfacies data gives one the insight into the depositional conditions and history of a carbonate rock. The most frequently used facies models are those hypothesizing on platforms and ramps (Flügel, 2004). One of the most useful facies models belong to Wilson (1975), in which he used idealized facies belts defined along an abstract transect from open-marine deep basins across a slope, a pronounced platform marginal rim (characterized by reefs or/and a zone with sand shoals), and an inner platform to the coast (Figure 13).
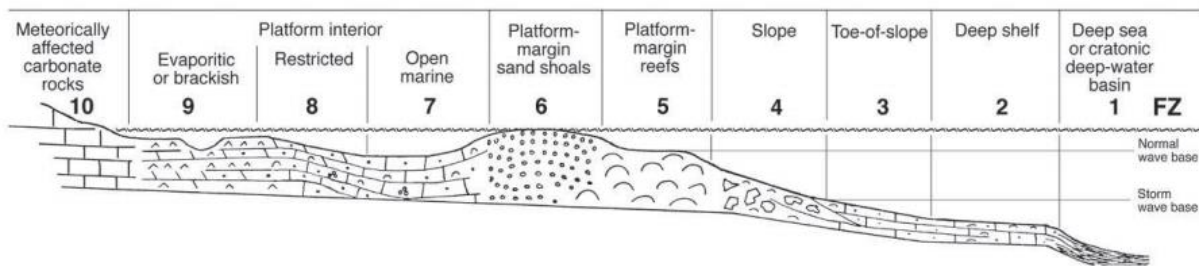
Figure 13. The Standard Facies Zones on a Rimmed carbonate platform of the modified Wilson model (Flügel, 2004).

Based on the recognition of consistently recurrent patterns of carbonate facies in the Phanerozoic stratigraphic record and the environmental interpretation of these patterns by

using characteristics of Holocene sedimentation patterns, Flügel (2004) modified the Wilson model and established the "Standard Facies Zones" exhibiting specific "Standard Microfacies Types (SMF)" (Figure 14).
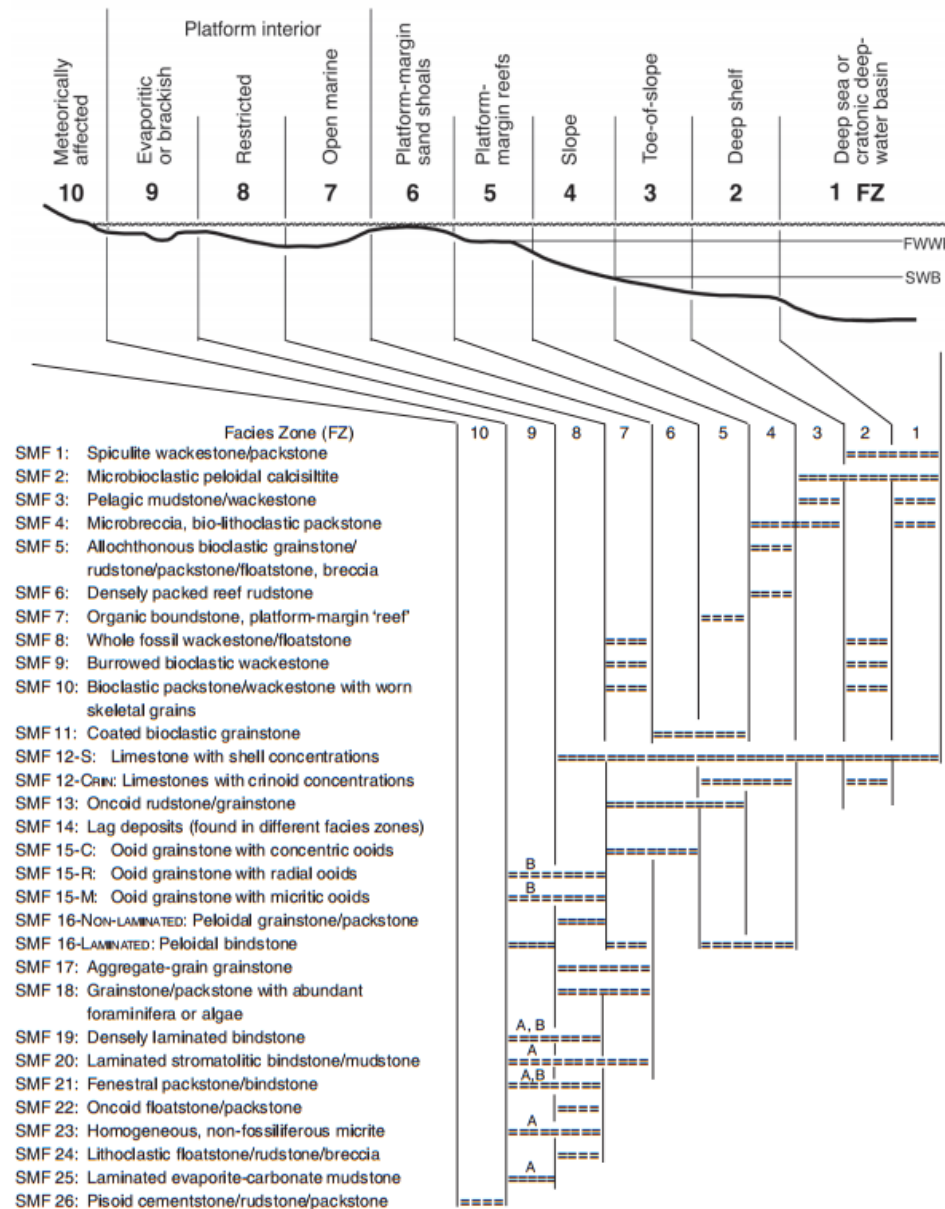
Figure 14. Distribution of Standard Microfacies (SMF) types in the Facies Zones (FZ) of Wilson (1975) on a rimmed carbonate platform model (Flügel, 2004) (A: evaporitic, B: brackish).

However, these facies belt definitions are intended for tropical platforms and are not applicable to platforms in cool-water settings which often correspond better to non-rimmed platforms or ramps (Flügel, 2004). Consequently, Flügel (2004) defined another set of microfacies types called "Ramp Microfacies Types (RMF)" (Fig 15).

Figure 15. Generalized distribution of microfacies types (RMF) in different parts of a homoclinal carbonate ramp (Flügel, 2004).

As he notes, "Some of these Ramp Microfacies Types (RMF) correspond in their criteria to SMF Types of carbonate platforms, but other RMF Types do not. The RMF Types should not be regarded as obligatory categories comparable with the SMF Types. The

latter are better defined and are based on more case studies than the RMF Types, which only reflect a summary of the current state of the art."

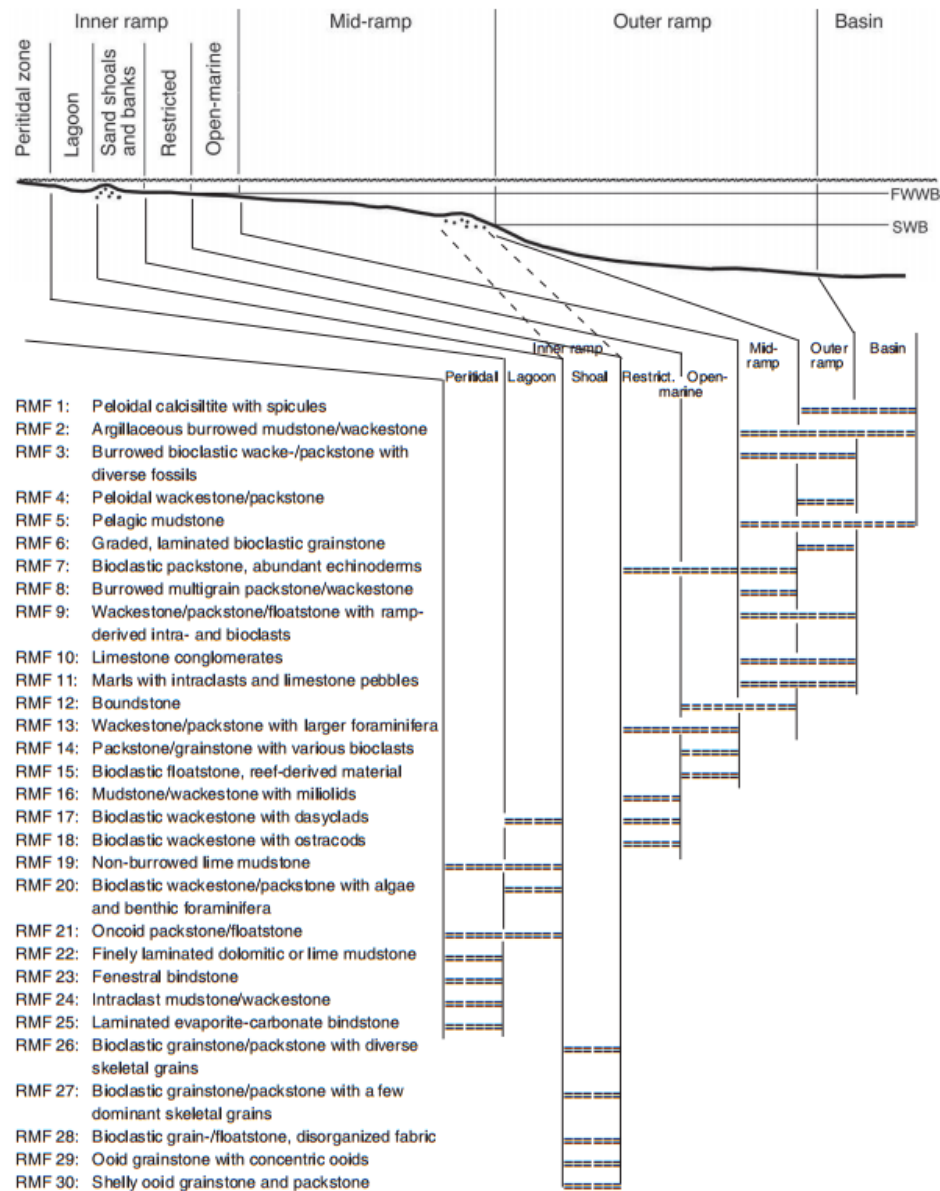In this study, 77 thin sections representing 75 samples have been examined to identify their paleontological (planktonic foraminifera, radiolaria and ostracoda) and sedimentological content. They are named according to Dunham's Classification (1962) and field observations. As a result, 10 different microfacies have been defined. The equivalents among "Standard Microfacies Types (SMF)" and "Ramp Microfacies Types (RMF)" are also given in order to be able to interpret the depositional history of the basin (Table 2).

These microfacies are namely, Planktonic Foraminiferal Packstone, Radiolarian Foraminiferal Packstone, Packstone with Planktonic Foraminifera and Radiolaria, Radiolaria-bearing Spiculite Packstone, Planktonic Foraminiferal Wackestone, Wackestone with Planktonic Foraminifera and Radiolaria, Silty Wackestone-Mudstone with Planktonic Foraminifera and Wackestone-Mudstone.

Table 2. Microfacies types, corresponding depositional environments

No		Microfacies Type	Description	Grain Types/ Fossils	Lithofacies Type	Depositional Environment
I. Packstone	**I.I**	Planktonic Foraminiferal Packstone	Packstone with very abundant planktonic foraminifera and less abundant radiolaria	Planktonic foraminifera, radiolaria, oxide minerals, silica replaced fossils, pyrite and quartz grains, burrowings	SMF 2 & RMF 4	Deeper basin and/or open-marine shelf
	I.II	Radiolarian Packstone	Packstone with very abundant radiolaria	Radiolaria, pyrite and quartz grains, burrowings, ostracods, hyaline shell fragments	SMF 2 & RMF 4	Deep-shelf - toe-of-slope
	I.III	Packstone with Planktonic Foraminifera and Radiolaria	Packstone with even amounts of planktonic foraminifera and radiolaria	Quartz grains, burrowings, spicules, silica replaced fossils	SMF 2 & RMF 4	Deeper basin and/or open-marine shelf
	I.IV	Radiolaria-bearing Spiculite Packstone	Packstone with abundant monaxone megascleres and a less amount of radiolaria	Monaxone megascleres, radiolaria, ostracod, mollusc and hyaline fragments, pyrite and quartz grains, oxide minerals	SMF 1 & RMF 1	Basinal deep-water
II. Wackestone	**II.I**	Planktonic Foraminiferal Wackestone	Wackestone with relatively less planktonic foraminifera	Pyrite and quartz grains, burrowings, oxide minerals	SMF 1 & RMF 1	Basin and/or open-marine shelf
	II.II	Wackestone with Planktonic Foraminifera and Radiolaria	Wackestone with even amounts of planktonic foraminifera and radiolaria	Planktonic foraminifera, radiolaria, quartz grains	SMF 3 & RMF 5	Basin and/or open deep-shelf
III. Wackestone - Mudstone	**III.I**	Silty Wackestone - Mudstone with Planktonic Foraminifera	Wackestone - mudstone abundant pyrite and quartz grains	Planktonic, hyaline and agglutinated benthic foraminifera, oxide minerals, mollusc fragments, bryozoan, silica replacement, hyaline and clay mineral fragments	SMF 3 - FOR & RMF 5	Basin and/or open deep-shelf
	III.II	Wackestone - Mudstone	Wackestone - mudstone with few planktonic foraminifera and radiolaria	Planktonic foraminifera, radiolaria, silica replaced fossils	SMF 3 & RMF 5	Basin and/or open deep-shelf

I. Packstone

  I.I. Planktonic Foraminiferal Packstone

This lithofacies is one of the most common lithofacies types defined in this study; it is seen in samples NS 1, NS 2, NS 18-2 and from NS 23 to NS 39 (Table 3). It is observed mostly in red but also occurs in different colors as greenish gray, reddish gray and light brown. It is characterized by the occurrence of very abundant planktonic foraminifera and consistent presence of radiolaria. Other common features observed are, varying degrees of oxidation related with the occurrence of oxide minerals, silica replacement in fossils, presence of pyrite and quartz minerals in variable amounts and burrowing structures (Figure 16).

This lithofacies is the equivalent of SMF 2 and RMF 4, these are "microbioclastic peloidal calcisiltite" and "peloidal wackestone and packstone", respectively. This microfacies type is common in deeper basins and open-marine shelf.

Figure 16. Photomicrographs of the planktonic foraminiferal packstone (MF I.I). (om: oxide minerals, p: pyrite, pf: planktonic foraminifera, q: quartz grains, r: radiolaria, si: silica replacement) Samples A. NS 1, B. NS 26, C. NS 30, D. NS 38 (Scale bar is 0.2 mm).

I.II. Radiolarian Packstone

This lithofacies type differs from other packstone lithofacies in that it has a distinctively high amount of radiolaria. It is identified in samples NS 3, NS 4, NS 6, NS 12 and NS 17 (Figure 17). Other constituents accompanying radiolaria are detrital grains as quartz and pyrite, burrowing structures, ostracods, echinoderm spines and hyaline shell fragments. Radiolarian packstone occurs in different tones of gray in the geological section, namely greenish gray, dark gray and reddish gray (Table 3).

Radiolarian packstone lithofacies corresponds to SMF 2 and RMF 4 which are "microbioclastic peloidal calcisiltite" and "peloidal wackestone and packstone", respectively. It is common in deeper basins and open-marine shelf environments.
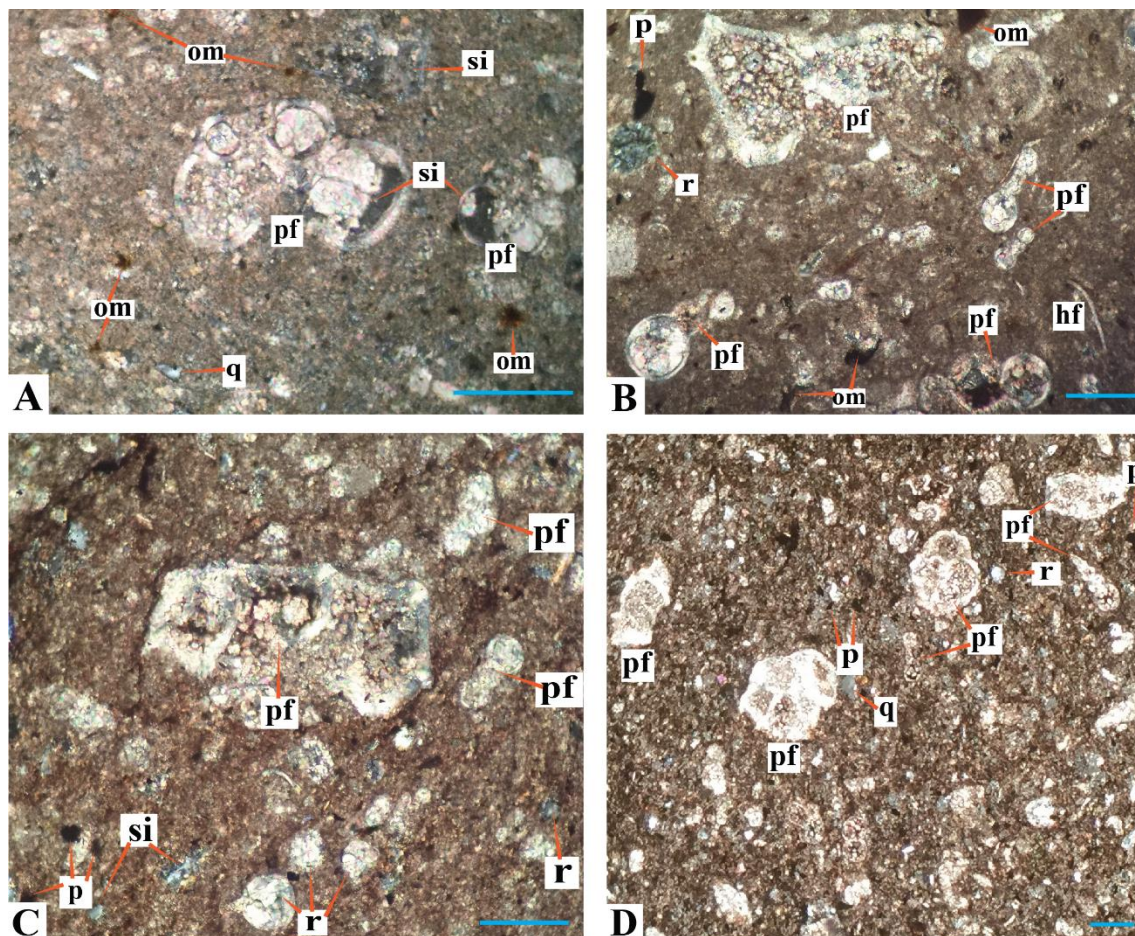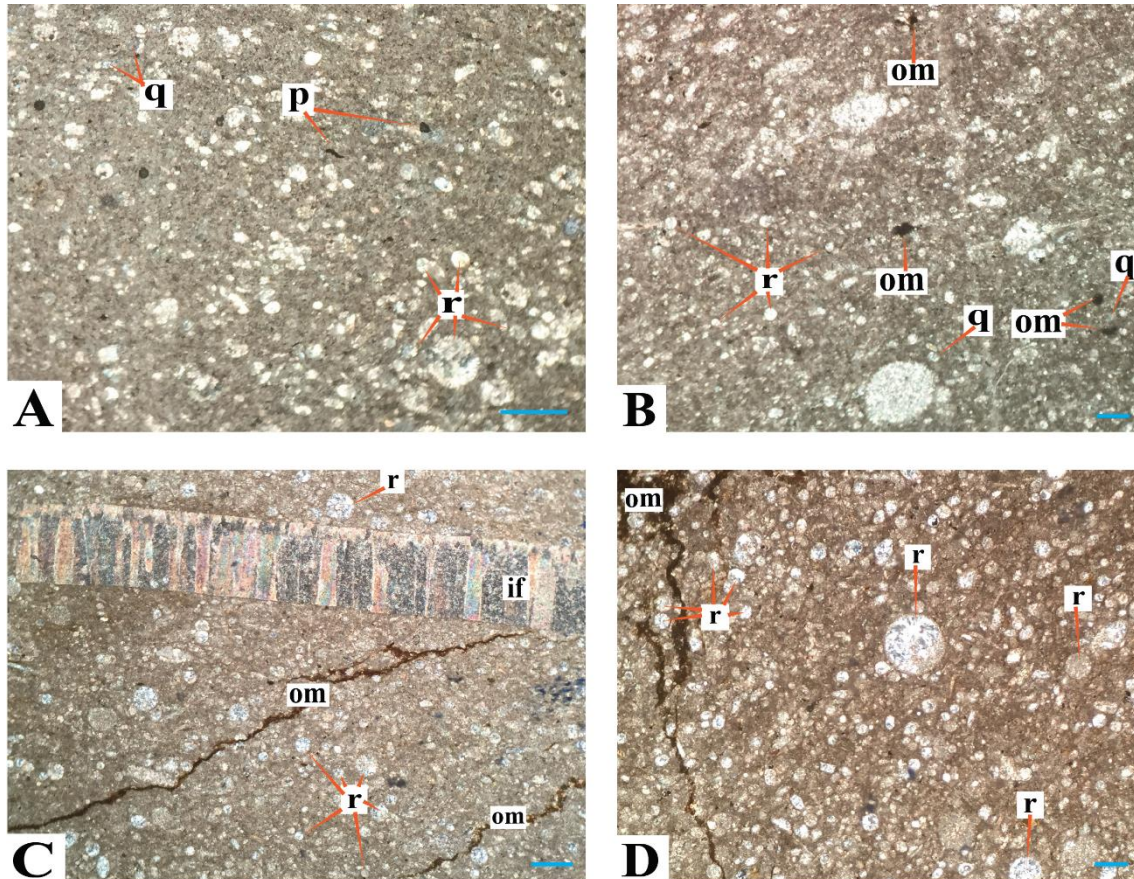

Figure 17. Photomicrographs of radiolarian packstone (MFT I.II). (if: inoceramid fragment, om: oxide minerals, p: pyrite, q: quartz grains, r: radiolaria) Samples A. NS 6, B. NS 12, C. NS 17, D. NS 17 (Scale bar is 0.2 mm).

I.III. Packstone with Planktonic Foraminifera and Radiolaria

Packstone with planktonic foraminifera and radiolaria facies is represented by the even occurrence of planktonic foraminifera and radiolarian tests in the thin section (Figure 18). This microfacies is identified in samples NS 5, NS 11 and NS 22. Other findings are quartz grains, burrowings, spicules and silica replacement in fossils (Table 3). It is light brown in color but becomes red towards the middle part of the Santonian.

This lithofacies is another one that corresponds to SMF 2 and RMF 4, that are "microbioclastic peloidal calcisiltite" and "peloidal wackestone and packstone", respectively. This microfacies is representative of a deep basin and/or open-marine shelf.
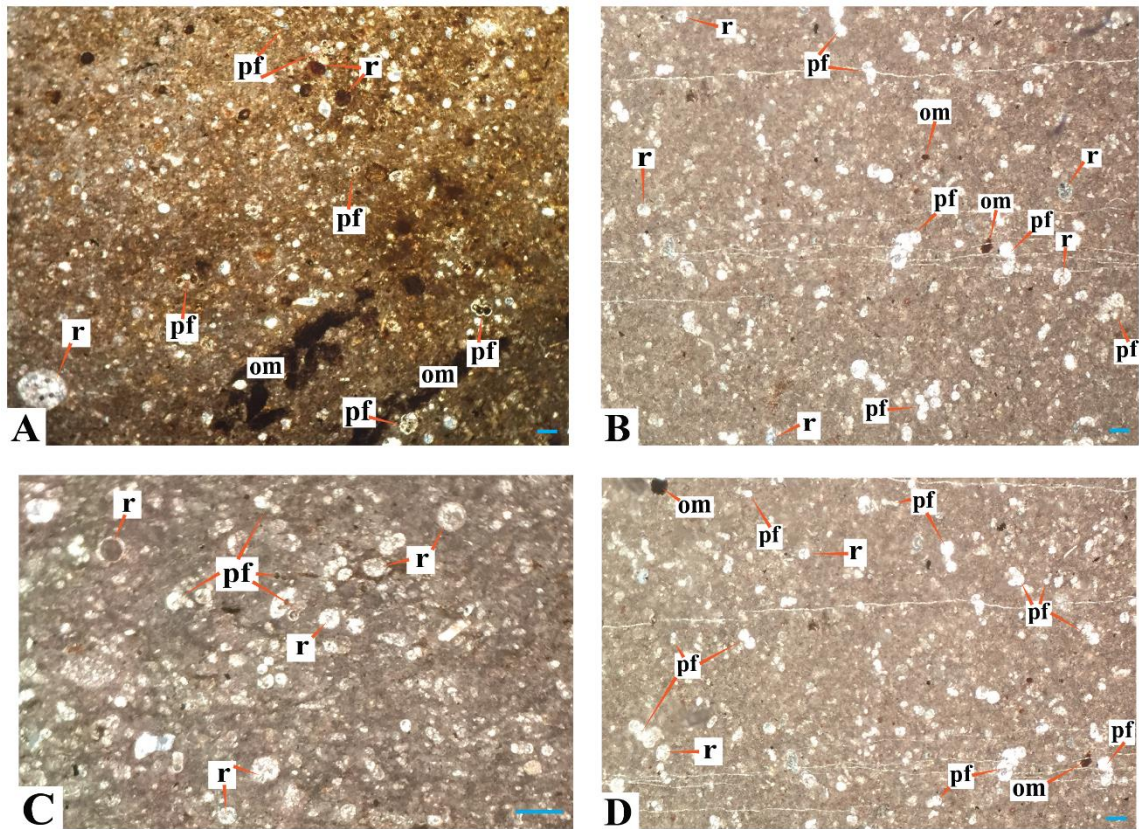
Figure 18. Photomicrographs of packstone with planktonic foraminifera and radiolaria (MFT I.III). (om: oxide minerals, p: pyrite, pf: planktonic foraminifera, q: quartz grains, r: radiolaria, si: silica replacement) Samples A. NS 11, B. NS 11, C. NS 14, D. NS 22 (Scale bar is 0.2 mm).

I.IV. Radiolaria-bearing Spiculite Packstone

Spiculite packstone lithofacies is observed once in the samples (NS 18-1) and is light brown in color. It is dominated by abundant monaxone megascleres (sponge spicules) and a less amount of radiolaria (Table 3). It is interpreted to represent a brief interval of possible deepening at the level it is observed (Figure 19), however the accumulation still occurs above the CCD as implied by the presence of ostracod, mollusc and hyaline

fragments. Occurrence of pyrite and quartz minerals and oxidation stains are also important. Possible causes for concentrations of spicules are given as in-place deposition of spicules derived from the disintegration of soft-bodied demosponges, or an accumulation of spicules of decaying soft sponges within organic mats (Flügel, 2004). Regarding the possible depositional environment of this lithofacies, fossil spiculites are known to be common in deep-marine settings, both in basinal and slope position and they are usually interpreted as deep or cold-water deposits. However, today it is known that many siliceous demosponges live in warm shallow waters, suggesting that ancient spiculites could have originated in shallow-marine shelf and near-coast environments, too (Flügel, 2004).

It can be said that this lithofacies is identical with SMF 1, "spiculite wackestone or packstone" which occurs often in dark colored limestones, and is commonly argillaceous and includes pelagic microfossils such as radiolaria. Abundant siliceous (or calcified) sponge spicules are often oriented in this microfacies type. This lithofacies is the result of a slow sedimentation in a basinal deep-water environment. Its RMF equivalent is RMF 1 which is "calcisiltite and mudstone with peloids, very fine skeletal debris, sponge spicules".
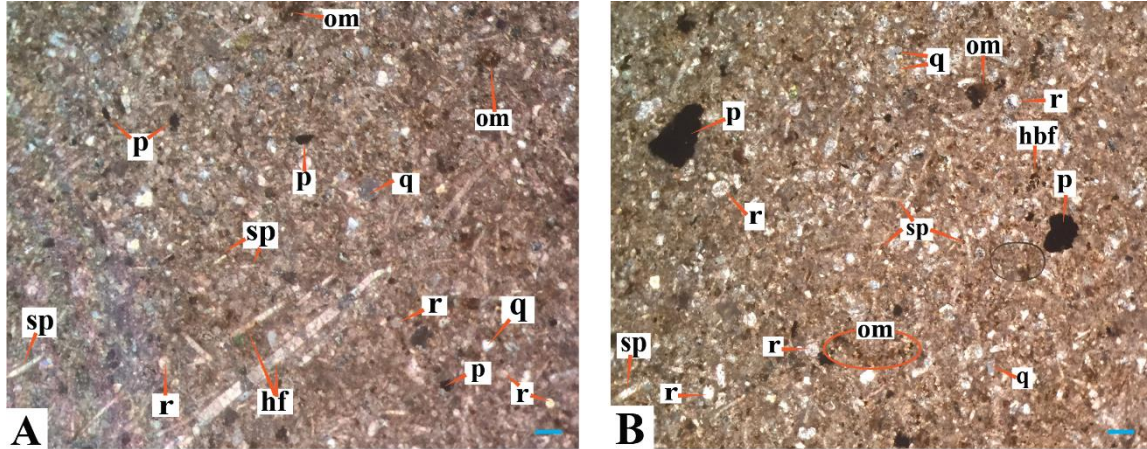
Figure 19. Photomicrographs of radiolaria-bearing Spiculite Packstone (MFT I.IV, Sample NS 18-1). (hbf: benthic foraminifera, hf: hyaline fragment, om: oxide minerals, p: pyrite, pf: planktonic foraminifera, q: quartz grains, r: radiolaria, sp: sponge spicule). Arrows show the direction of current flow (Scale bar is 0.2 mm).

II. Wackestone

II.I. Planktonic Foraminiferal Wackestone

This lithofacies is the most common wackestone lithofacies and is differentiated from the similar packstone microfacies by the fewer occurrence of planktonic foraminifera tests. It is observed in samples NS 21 and from NS 40 to NS 47 (Table 3). Other main constituents are highly to moderately abundant oxidation stains and quartz and pyrite grains (Figure 20). It occurs in dark grey and light brown colors in the geological section.

This lithofacies is almost identical with SMF 1 – Burrowed, which is different from SMF 1 in the dominance of sparsely distributed skeletal grains representing a mixture of benthic and planktonic elements. Burrowed bioclastic wackestone is abundant with fine pelagic and benthic biodetritus. Its very small bioclasts, commonly shell debris, are scattered within a dense, strongly burrowed matrix. It corresponds to RMF 1 in the ramp carbonate microfacies classification scheme. It is found in basinal, open sea shelf and outer ramp carbonates.
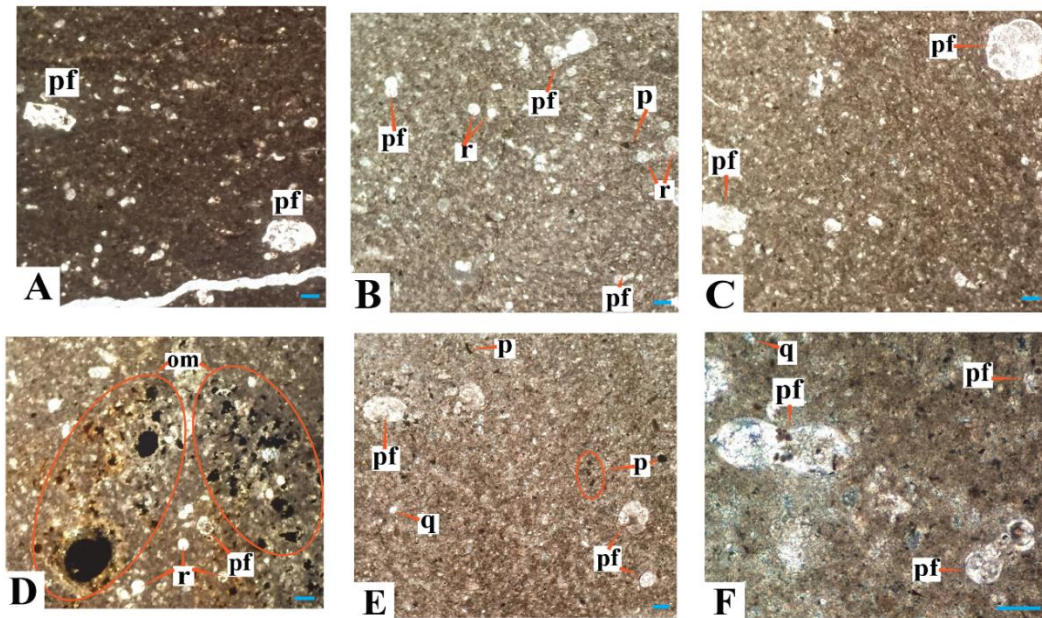
Figure 20. Photomicrographs of planktonic foraminiferal wackestone (MFT II.I). (om: oxide minerals, p: pyrite, pf: planktonic foraminifera, q: quartz grains, r: radiolaria) Samples A. NS 40, B. NS 45, C. NS 42, D. NS 10, E. NS 43, F. NS 10 (Scale bar is 0.2 mm).

II.II. Wackestone with Planktonic Foraminifera and Radiolaria

This wackestone facies includes planktonic foraminifera and radiolaria in even amounts (Table 3). Few quartz grains are also observed (Figure 21). It occurs in samples NS 8, NS 9, NS 10, NS 13 and NS 19.

It corresponds to SMF 3, "pelagic lime mudstone and wackestone with planktonic microfossils". Its RMF equivalent is RMF 5, "pelagic mudstone with planktonic microfossils and open-marine nektonic fossils". This microfacies is found in basin and open deep shelf deposits.

Figure 21. Photomicrographs of wackestone with planktonic foraminifera and radiolaria (MFT II.II). (om: oxide minerals, pf: planktonic foraminifera, q: quartz grains, r: radiolaria) Samples A. NS 8. B. NS 10. C. NS 13. D. NS 2. (Scale bar is 0.2 mm).

III. Wackestone-Mudstone

III.I. Silty Wackestone-Mudstone with Planktonic Foraminifera

Silty Wackestone-Mudstone lithofacies is the most prevalent one among the lithofacies types identified in this study. It is once observed in the Lower Santonian, then occurs strictly in the Middle to Upper Campanian of the measured geological section in samples NS 20 and from NS 48 to NS 75 (Table 3). As its name implies, this lithofacies contains a very high amount of detrital grains as quartz and pyrite, even increasingly towards the Upper Campanian part. Other important characteristic is the presence of oxide minerals representing varying degrees of oxidation. Planktonic foraminifera, hyaline and agglutinated benthic foraminifera are observed abundantly in the Upper Campanian of the

measured geological section. Mollusc, bryozoan fragments, silicification, hyaline and clay fragments are rare in this lithofacies (Figure 22).

Silty wackestone-mudstone lithofacies corresponds to SMF 3-FOR (pelagic foraminifera), "pelagic lime mudstone and wackestone with planktonic microfossils" and RMF 5, "pelagic mudstone with planktonic microfossils and open-marine nektonic fossils". This microfacies is found in basin and open deep shelf depositional environments.
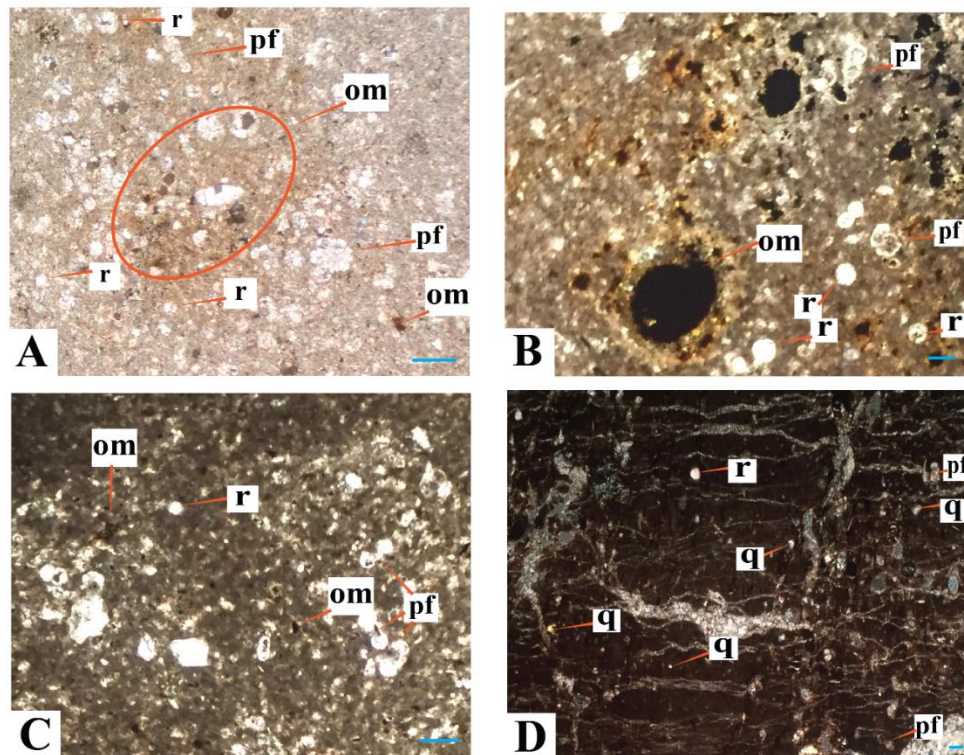
Figure 22. Photomicrographs of silty wackestone-mudstone with planktonic foraminifera (MFT III.I) (af: agglutinated benthic foraminifera, om: oxide minerals, p: pyrite, pf: planktonic foraminifera, q: quartz grains, r: radiolaria) Samples A. NS 51, B. NS 57, C. NS 60, D. NS 58, E. NS 62, F. NS 67 (Scale bar is 0.2 mm).

III.II. Wackestone-Mudstone

Wackestone-Mudstone lithofacies represents an episodic interval where the dicarinellid-dense upper Turonian is interrupted by a short break where the microfacies includes fewer occurrence of planktonic foraminifera and radiolaria (in samples NS 14, NS 15 and NS 16) (Table 3). Silicification of fossils is observed (Fig 23).

The correspondent SMF type to this lithofacies is SMF 3, "pelagic lime mudstone and wackestone with planktonic microfossils" and RMF 5, "pelagic mudstone with planktonic microfossils and open-marine nektonic fossils". This lithofacies type is found in basin and open deep shelf environments.

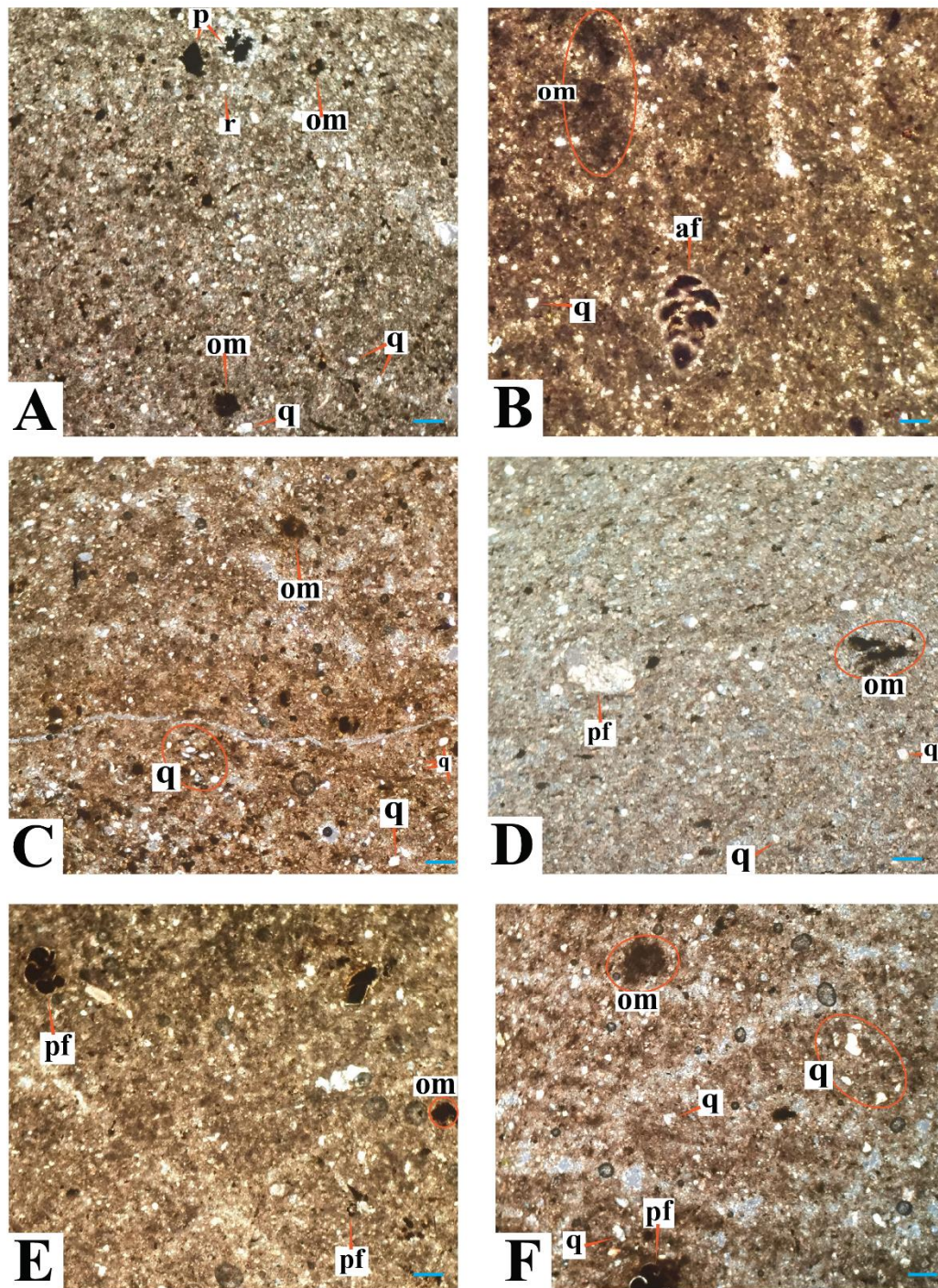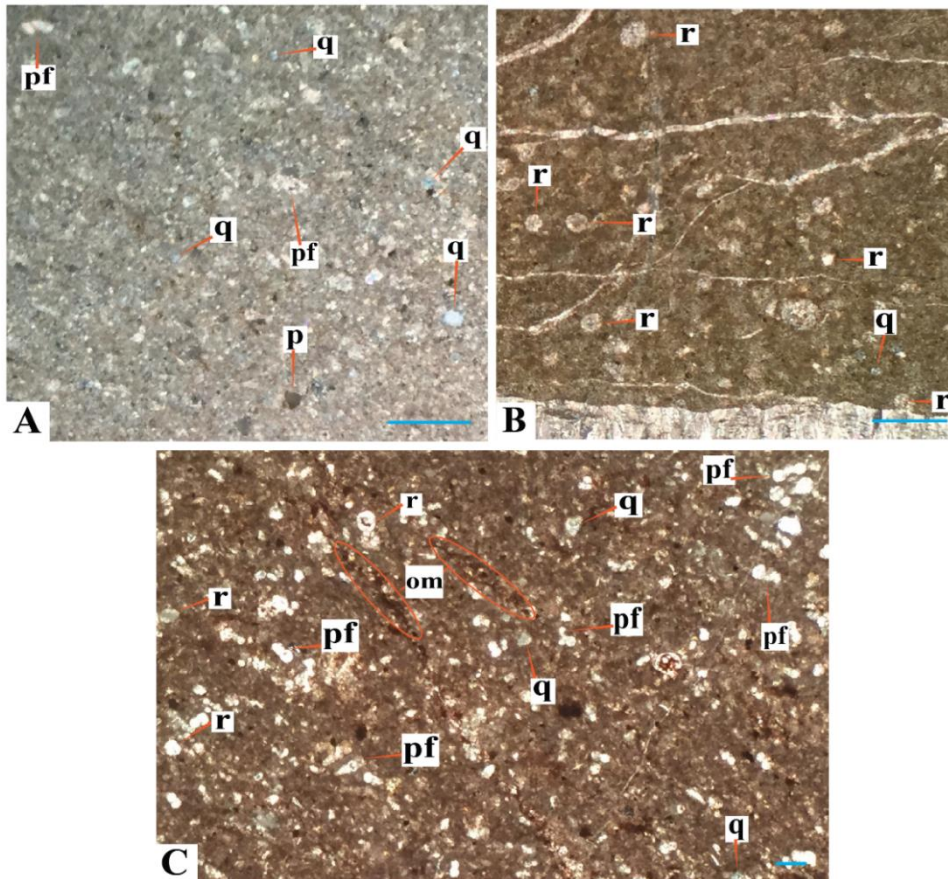Figure 23. Photomicrographs of wackestone-mudstone (MFT III.II). (om: oxide minerals, p: pyrite, pf: planktonic foraminifera, q: quartz grains, r: radiolaria) Samples A. NS 14. B. NS 15. C. NS 16 (Scale bar is 0.2 mm).

3.2. Interpretation of the Microfacies Analysis Results

The results of the microfacies analysis described in the previous part shows no remarkable facies change in the measured stratigraphic section (Table 3 and Figure 24). Although there are sea-level increases recorded globally (e. g., Haq et al., 1987; Skelton, 2003) and locally (e. g., Rojay and Altıner, 1998; Yılmaz et al., 2010) at the stage boundaries detected in this study, the results of this study do not reflect major changes in the sea-level.

Figure 24. Microfacies Evolution Chart showing the changing depositional environments through time for two different models: on a rimmed-shelf and on a ramp platform.

Table 3. Microfacies Analysis Results

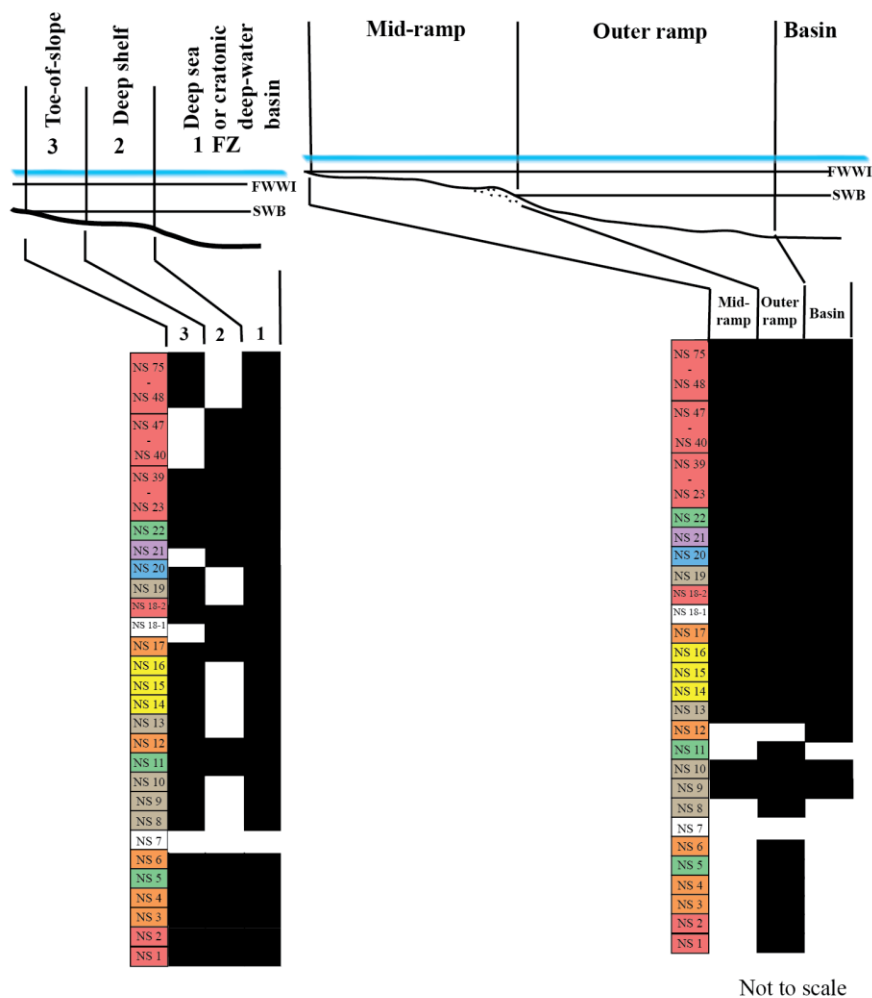| AGE	MICROFACIES TYPE	SAMPLE NO.	Lithology	Color	Planktonic Foraminifera	Radiolaria	Quartz grains	Pyrite grains	Burrowings	Oxidation/Iron oxide minerals	Ostracoda	Hyaline benthic foraminifera	Agglutinated benthic foraminifera	Mollusc fragments	Echinodermata	Bryzoa	Silica replacement	Hyaline fragments	Spicules	Clay content
SANTONIAN	I.I	NS 36	lst	r	**	*	**	*	*	*										
	I.I	NS 35	m	r	**	*	*	*	*	*										
	I.I	NS 34	lst	r	**	*	*	*	*	*										
	I.I	NS 33	lst	r	**	*	*	*	*	*										
	I.I	NS 32	lst	r	**	*				*	*						*			
	I.I	NS 31	lst	r	**	*				*	*						*			
	I.I	NS 30	cl	r	**	*				*	*						*			
	I.I	NS 29	lst	r	**	*				*	*						*			
	I.I	NS 28	cl	r	**	*				*	*						*			
	I.I	NS 27	lst	rg	**	*				*	*						*			
	I.I	NS 26	lst	r	**	*				*	*						*			
	I.I	NS 25	lst	r	**	*				*	*						*			
	I.I	NS 24	lst	lb	**	*				*	*						*			
	I.I	NS 23	lst	r	**	**	*													*
	I.III	NS 22	lst	r	**	**	*										*			
	II.I	NS 21	cl	r	**	**	*										*			
	III.I	NS 20	cl	r	**	**	*										*			*
TURONIAN	II.II	NS 19	ss	r	**	**	*													
	I.I	NS 18-2	ss	lb	**	**				*										
	I.IV	NS 18-1	ss	lb		**	*	*	*	*	*			*	*			*	*	
	II.II	NS 17	sh	rg	*	**		*	*	*	*			*	*			*	*	
	III.II	NS 16	lst	lb	*	**			*									*		*
	III.II	NS 15	cl	lb	*	**											*			
	III.II	NS 14	lst	lb	**	**			*								*		*	
CENOMANIAN	II.II	NS 13	sh	dg	**	**					*									
	I.II	NS 12	cl	dg	*	**			*			*						*		
	I.III	NS 11	sh	lb	*	**	*		*	*			*						*	
	II.II	NS 10	cl	lb	*	**	*	*		*			*							
	II.II	NS 9	ss	g	*	**	*	*		*			*	*			*			*
	II.II	NS 8	cl	lg	*	**	*	*		*							*	*		*
	Undefined	NS 7	ss																	
	I.II	NS 6	cl	lb	*	**	*		*								*	*		
	I.III	NS 5	sh	lb	*	**	*	*	*											
	I.II	NS 4	cl	gg	*	**	*			?								*		
	I.II	NS 3	ss	lb	*	**	*		*											
	I.I	NS 2	cl	gg	*	**														
	I.I	NS 1	cl	gg	*	**	*		*	*	*									

LEGEND

I.I: Planktonic Foraminiferal Packstone
I.II: Radiolarian Packstone
I.III: Packstone with Planktonic Foraminifera and Radiolaria
I.IV: Radiolaria-bearing Spiculite Packstone
II.I: Planktonic Foraminiferal Wackestone
II.II: Wackestone with Planktonic Foraminifera and Radiolaria
III.I: Silty Wackestone-Mudstone with Planktonic Foraminifera
III.II: Wackestone-Mudstone

lst: limestone
ss: silty shale
sh: shale
cl: clayey limestone

* Low abundance
** Medium Abundance

gg: greenish grey
lb: light brown
lg: light grey
g: grey
dg: dark grey
r: red
rg: reddish grey

Table 3. Continued.

AGE	MICROFACIES TYPE	SAMPLE NO.	Lithology	Color	Planktonic Foraminifera	Radiolaria	Quartz grains	Pyrite grains	Burrowings	Oxidation/ Iron oxide minerals	Ostracoda	Hyaline benthic foraminifera	Agglutinated benthic foraminifera	Mollusc fragments	Echinodermata	Bryzoa	Silica replacement	Hyaline fragments	Spicules	Clay content
CAMPANIAN	III.I	NS 75	ss	lb	**		**	**		**										
	III.I	NS 74	ss	lb	**		**	**		**			*							
	III.I	NS 73	ss	lb	**		**	**		**										
	III.I	NS 72	ss	lb	**		**	**	*	**			*							
	III.I	NS 71	ss	lb	**		**	**		**										
	III.I	NS 70	ss	lb	**		**	**	*	**			*							
	III.I	NS 69	ss	lb	**		**	**		**		*	*							
	III.I	NS 68	ss	lb	**		**	**		**		*	*							
	III.I	NS 67	ss	lb	**		**	**		**		*	*	*						
	III.I	NS 66	ss	lb	**		**	**		**		*	*							
	III.I	NS 65	ss	lb	**		**	**	*	**		*	*							
	III.I	NS 64	ss	lb	**		**	**		**										
	III.I	NS 63	ss	lb	**		**	**		**										
	III.I	NS 62	ss	lb	**		**	**		**										
	III.I	NS 61	ss	lb	**		**	**		**		*					*			*
	III.I	NS 60	ss	lb	**		**	**		**					*			*		
	III.I	NS 59	ss	lb	**		**	**		**										
	III.I	NS 58	ss	lb	**		**	**		**										
	III.I	NS 57	ss	lb	**		**	**		**										
	III.I	NS 56	ss	lb	**		**	**		**										
	III.I	NS 55	ss	lb	**		**	**		**										
	III.I	NS 54	ss	lb	**		**	**		**										
	III.I	NS 53	ss	lb	**		**	**		**										
	III.I	NS 52	ss	lb	**		**	**		**		*								
	III.I	NS 51	ss	gg	**		**	**		**										
	III.I	NS 50	ss	lb	**		**	**		**										
	III.I	NS 49	ss	gg	*		**	**		**										
	III.I	NS 48	ss	gg	*		**	**		**										
	II.I	NS 47	lst	g	**		**	**		**		*					*	*		
	II.I	NS 46	sh	lb	**		**	**		**		*					*	*		
	II.I	NS 45	lst	lb	**		**	**												
	II.I	NS 44	lst	lb	**		**	**												
	II.I	NS 43	sh	lb	**		**	**												
	II.I	NS 42	sh	lb	**		**	**												
	II.I	NS 41	sh	lb	**	*	**	**									*		*	
	II.I	NS 40	sh	lb	**	*	**	**												
	I.I	NS 39	sh	r	**	*	**	**	*	**										
	I.I	NS 38	lst	lb	**	*	**	**	*	**										
	I.I	NS 37	sh	r	**	*	**	**	*	**										

LEGEND

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I.IV: Radiolaria-bearing Spiculite Packstone
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III.I: Silty Wackestone-Mudstone with Planktonic Foraminifera
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lst: limestone
ss: silty shale
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* Low abundance
** Medium Abundance

gg: greenish grey
lb: light brown
lg: light grey
g: grey
dg: dark grey
r: red
rg: reddish grey

75

Although the sea-level changes observed from the results are not dramatic, the Cenomanian-Turonian boundary anoxia which is known as the OAE2 and followed by the Upper Cretaceous oceanic red beds (CORBs) is observed to a considerable degree in the samples investigated; observations regarding this are explained in this part. Moreover, the eustatic sea-level highstand occurred during the S/C boundary (Miller et al. 2005; Jarvis et al., 2006; Wagreich and Neuhuber, 2005; Wagreich et al., 2010) is also detected as a consistent change in the microfacies just after the proposed S/C boundary in this study.

OAE2 at the C/T boundary represents the most severe global climatic perturbation in the Cretaceous Period marked by globally distributed organic-carbon deposition (Owens et al., 2017). This boundary indicates a kind of interplay between paleoproductivity, climate induced (Milankovitch bands) small-scale sea-level changes superimposed on larger-scale, volcanism and tectonic movements (Yılmaz et al., 2010).

Due to the large sampling interval of this study (~1.2 m), small-scale sea-level changes could not be observed; however, dark-colored radiolarite lithologies characterizing the pre-C/T boundary successions are clearly present (Table 3). As seen in (Table 3), the interval leading to the C/T boundary comprises radiolaria packstone and wackestone with planktonic foraminifera and radiolaria microfacies of colors ranging between brown and grey tones, with dark grey color occurring at the boundary. Rock colours often bear a genetic significance attesting to redox conditions during deposition and/or early diagenesis. For example, black and green radiolarites, common at the base of Tethyan sections, are indicative of at least dysoxic conditions and the original presence of organic matter (Baumgartner, 2013). This part of the stratigraphic section is followed by post-anoxia wackestones with opportunist planktonic foraminifera (Figure III.II. Wackestone-Mudstone). This is interpreted as the result of a eutrophication process by proliferation of opportunist plankton with the diminishing anoxia. This event is very clearly reflected in the sample interval [NS-12 – NS-16]. In samples NS-12 and NS-13, oceanic anoxia makes its peak with dark-grey-colored radiolaria rich microfacies. It is followed by samples NS-14, NS-15 and NS-16 which solely contain the simplest opportunist planktonic foraminifera morphotypes, such as genera *Macroglobigerinelloides*, *Muricohedbergella*

and *Heterohelix*, together with abundant radiolarians. These results are satisfactorily compatible with the literature. The C/T boundary drowning is reported from all over the globe including the locality itself (e. g., Wang et al., 2005; Yılmaz et al., 2010; Coccioni et al., 2012; Omana et al., 2012, Afridi, 2014; Okay and Altıner, 2016). The sea-level-rise and eutrophication enables the development of opportunist species (Omana et al., 2012) and the decline of other fossil groups during the OAE is attributed to the expansion of anoxic and euxinic conditions that were unfavorable and even toxic to life (Leckie et al., 2002; Snow et al., 2005). Moreover, the radiolarians are also evidence of highly eutrophic conditions (Coccioni and Luciani, 2004).

The intervals corresponding to the OAE2 and post-OAE2 are followed by the upper Cretaceous Oceanic Red Beds (CORBs) which are observed covering almost the exact Santonian stage defined in this study with very abundant keeled planktonic foraminifera (Table 3). This is also completely compatible with the already known red bed occurrence in the highly oxygenated Santonian deep-sea environment and Santonian-early Campanian diversity peak of planktonic foraminifera (Premoli-Silva et al, 1999; Wagreich, 1995; Wang et al., 2005; Hu et al., 2005; Yılmaz, 2008; Yılmaz et al., 2010; Tüysüz et al, 2016).

CHAPTER 4

4. STAGE BOUNDARIES

Two stage boundaries have been identified in this study based on planktonic foraminiferal biostratigraphy. These boundaries are delineated between stages Cenomanian-Turonian and Santonian-Campanian. These identifications have been supported with microfacies data when available, such as in the Cenomanian-Turonian boundary. The Coniacian stage is not recognized to be present in the measured stratigraphic section together with the Uppermost Turonian and Lower Santonian. The discussions regarding these boundaries are given as follows.

4.1. Cenomanian-Turonian Boundary and the Oceanic Anoxic Event 2

The base of Turonian stage is placed at the lowest occurrence of the ammonite *Watinoceras devonense* near the expression of the OAE 2 at Pueblo (Colorado), where its GSSP is located, and almost coincides with the HO of calcareous nannofossil *Microstaurus chiastius* (Kennedy et al. 2005). In planktonic foraminiferal biostratigraphic framework, this boundary is placed within the *W. archaeocretacea* Partial Range Zone (Premoli-Silva et al., 1999; Omana et al., 2012; Kopaevich and Vishnevskaya, 2016; Reolid et al., 2016).

Cenomanian-Turonian (C/T) Boundary interval witnessed major biotic and oceanographic changes (e. g., Kopaevich and Vishnevskaya, 2016; Falzoni et al., 2016), including reductions in paleontological diversity of both benthic and planktic foraminifera, calcareous nannoplankton, ostracods, radiolarians, aragonitic rudist bivalves and ammonoids from marine sediments located around the world. These changes also include major perturbations in oceanic conditions such as a sea-level rise of nearly 300 m relative

to present and an increased water temperature at middle bathyal depths up to 20°. The Oceanic Anoxic Event (OAE 2) occurred during this warming peak with the burial of large amounts of organic matter in outer shelf and deep ocean environments (Omana et al., 2012).

In Central Anatolia, this interval is also characterized by a shale succession with a color ranging between dark grey and black. Occurrence of distinct black shales within the *R. cushmani* zone is observed in the Mudurnu area of the Sakarya Continent and this event has been found coeval with the black shale interval (OAE 2) which has been reported from several locations worldwide. Furthermore, this black shale interval is followed by white pelagic carbonates with the beginning of Turonian, which is next overlain by red-purple marls/mudstones. These red-purple units have abundant planktonic foraminifera and iron minerals indicating oxidizing conditions under which the sedimentation took place (Yılmaz, 2008; Yılmaz et al., 2010).

The Cenomanian-Turonian boundary is delineated between samples NS-13 and NS-14 in this study. The microfacies analysis shows that the color of lithology changes between green and grey tones up to this level, where dark grey color occurs in samples NS-12 and NS-13 in the part closest to the boundary; these become light brown immediately starting from NS-14. These dark grey samples are identified as radiolarian packstone (shale) and planktonic foraminifera wackestone (clayey limestone) facies, respectively. They include sparse planktonic foraminifera and abundant radiolaria. Additionally, burrowing structures and few hyaline fragments are observed in sample NS-12; although these constituents disappear, oxidation/iron oxide minerals are present in sample NS-13. Moreover, a striking disappearance of planktonic foraminifera species takes place in samples NS-12 and NS-13, including the disappearance of *M. bentonensis* in sample NS-13 (Premoli-Silva et al., 1999). The only species present in these two samples are *M. delrioensis*, *M. planispira*, *Macroglobigerinelloides* sp. and *W. baltica*. Except for a *Dicarinella* sp. occurring only in NS-13. The species present in these samples clearly lack complex k-taxa; they are simple and opportunist r-strategists (Petrizzo, 2002). These data are in complete accordance with previous findings which show that only the less

specialized groups such as the younger dicarinellids and whiteinellids, with higher tolerance, together with the opportunistic hedbergellids and heterohelicids, survived this boundary and resumed after the acme of the perturbation ceased. The last but not the least important of these bioevents is the lowest occurrence of *Helvetoglobotruncana helvetica* in sample NS-14, which marks the beginning of *H. helvetica* biozone in the lower to middle Turonian (Premoli-Silva et al., 1999; Kopaevich and Vishnevskaya, 2016; Falzoni et al., 2016; Reolid et al., 2016). Although the boundary is put in the *W. archaeocretacea* zone and *H. helvetica* zone follows this towards the middle Turonian in most of the recent studies (Figure 11), the datum between samples NS-13 and NS-14 corresponds also to the boundary between these two biozones here. This situation can be resulting from the large sampling interval in this study (~ 1.2 m).

4.2. On the absence of the Coniacian stage

In the measured stratigraphic section of this study, Turonian deposits are unconformably overlain by middle Santonian succession. This sudden transition missing the Coniacian stage is explained by Okay and Altıner's (2017) recent study on the geological history of the Alcı and Bağlum regions in the Haymana, Ankara region.

It is known that both the Akkaya Formation and Bilecik Limestone is unconformably overlain by red pelagic Kocatepe Formation in the Ankara region (Yüksel, 1970). Okay and Altıner (2016) describe a section measured at the Küçükyayla Ridge, 8 km northeast of Haymana where the limestone breccia of the Bilecik Limestone is overlain with a pelagic sequence composed of beige and red pelagic limestones. In this section, beige pelagic limestones represent the lower middle Turonian age, whereas red pelagic limestones give a characteristic Santonian age planktonic foraminiferal fauna. The same situation is also recorded in the Çalıçukuru village about 2 km east of Haymana where the Bilecik Limestone is overlain by Turonian-lower Santonian fauna. It is noted that a condensed carbonate deposition is indicated by planktonic foraminiferal data from early Turonian to late Santonian for a period of 10 million years. This period is known to have gone through intense submarine volcanism in the outer Pontides (Okay and Altıner, 2016).

Okay and Altıner (2017) discuss the olistostromes occurring in the zones near the İzmir-Ankara Suture. In these, Upper Jurassic-Cretaceous limestone succession cannot be observed, but it instead occurs as carbonate blocks with differing size in the Alacaatlı Olistostromes which outcrop near Alcı, Ankara (Figures 3, 4).

In the Alcı region, the Alacaatlı olistostromes are unconformably overlain by red micritic limestones and shales. By using planktonic foraminiferal data, this red unit is identified to be middle to upper Santonian and overlain conformably by Campanian succession (Okay and Altıner, 2017).

Oldest blocks identified in the Alacaatlı olistostromes are of late Turonian age, and they are unconformably overlain by middle-late Santonian pelagic limestones. This indicates that the Alacaatlı olistostromes were formed during the Coniacian. The limestone blocks in the Alacaatlı olistostromes have varying ages, namely as Callovian-Oxfordian, Tithonian-Berriasian, Valanginian-Aptian, Albian, Cenomanian and Turonian. These blocks can be correlated in terms of lithology and age with the autochthonous Jurassic-Cretaceous succession observed in the Middle Sakarya Basin or in the Haymana Anticline. Almost all the limestone blocks are of pelagic quality. These show that the Jurassic-Cretaceous succession of the Sakarya Zone were transferred to debris flows in the Coniacian as the subduction was taking place in the Pontides. This tectonic episode is envisaged to occur due to the collision of an aseismic ridge with the Pontides and the consequent rising of the outer parts of the forearc basin. The eroded material was transferred as debris flows into the local depression formed in front of the bulging carbonates with the collision. This episode of olistostrome formation and recycling occurring until the colliding end, was followed by normal forearc deposition back again in the Santonian (Okay and Altıner, 2017).

4.3. Santonian-Campanian Boundary

Since the naming of the Campanian Stage by Coquan in 1857, the definition of its base has been debated (Wagreich et al., 2010; Kita et al., 2017). There is currently no ratified biostratigraphic marker or Global Boundary Stratotype Section and Point (GSSP) for the

base of the Campanian Stage (Ogg and Hinnov, 2012; Coccioni, 2015). Various fossil groups are used in the identification of Santonian-Campanian (S/C) boundary. Main boundary events defining the S/C transition are the extinction of the crinoid *Marsupites testudinarius*, the appearance of the ammonite *Placenticeras bidorsatum* and that of the belemnite *Gonioteuthis granulataquadrata.* These bioevents may also coincide with secondary marker bioevents of the S/C boundary which are the appearance of the planktonic foraminifera *Globotruncanita elevata*, the disappearance of the planktonic foraminifera *Dicarinella asymetrica* together with all other dicarinellids or presence of the concurrent range interval of *G. elevata* and *D. asymetrica* (e.g., Gale et al., 1995; Premoli Silva and Verga, 2004; Gale et al., 2008; Wagreich et al., 2010; Vahidinia et al., 2014; Jaff et al., 2015). Other secondary bioevents include the disappearance of the planktonic foraminifera *Sigalia carpatica*, which is widespread in the Mediterranean region of the Tethys (Premoli Silva and Verga, 2004; Kita et al., 2017) and that of the genus *Marginotruncana* (e. g., Premoli Silva and Verga, 2004; Gale et al., 2008; Vahidinia et al., 2014; Jaff et al., 2015), with *Marginotruncana sinuosa* recorded as having disappeared slightly above the boundary (Gale et al., 2008). Finally, the disappearance of *Muricohedbergella flandrini* also accepted to predate the S/C boundary (e. g., Petrizzo, 2000; Premoli Silva and Verga, 2004; Gale et al., 2008).

Several authors defined the beginning of the Campanian as the first appearance datum of *G. elevata* (Wagreich, 1992), wheras others at the extinction level of *D. asymetrica* or *D. asymetrica* and *D. concavata* together (e.g. Caron, 1985; Premoli Silva and Sliter, 1994). However, Gale et al. (1995, 2008) placed the global S/C boundary as the FO of *Marsupites testudinarius*, within the short *G. elevata-D. asymetrica* concurrent range zone. In their Boreal-Tethyan correlation of the S/C boundary, Wagreich et al. (2010) also show that there is correlation between the *M. testudinarius* zone with parts of the *G. elevata-D. asymetrica* concurrent range zone and thus place the base of the Campanian after the FO of *G. elevata* but before the LO of *D. asymetrica*.

In this study, the S/C boundary is delineated between samples NS-38 and NS-39 in terms of detailed planktonic foraminiferal bioevents. The bioevents observed are the

disappearance of genera *Marginotruncana* and *Sigalia* in sample NS-38, *Dicarinella* in sample NS-36 and the species *Muricohedbergella flandrini* in sample NS-40. Moreover, the overlapping range zones of *D. asymetrica* and *G. elevata* fall between samples NS-24 and NS-38. This interval also represents the transition from the well-known red limestone lithofacies representing the oxygenated Santonian oceans to the light brown Campanian shales. These findings suggest that the S/C boundary can be delineated in the sample NS-38 which is in the concurrent range zone of *G. elevata* and *D. asymetrica* and represent the highest occurrence datum of the genera *Marginotruncana* and *Sigalia*. The genus *Dicarinella* is already extinct in sample NS-38 and the species *M. flandrini* lastly observed in sample NS-40.

CHAPTER 5

5. SYSTEMATIC PALEONTOLOGY

The primary concern of this study was to establish a detailed planktonic foraminiferal biozonation of the measured stratigraphic section. The reason why the taxonomic work is especially important in this study is that more detailed the taxonomic analysis is done, the higher resolution in the biostratigraphic framework can be obtained. From this point of view, utmost importance has been given to determine the diverse and extensive planktonic foraminifera obtained from both washed samples and thin sections of the studied samples.

The taxonomic study has been carried out based on the observations of the shape, number and arrangement of the chambers, properties of sutures and presence or absence of keel/keels, mode of coiling, wall texture properties, peripheral outline, positions of primary and secondary apertures, apertural and surface ornamentations. The harder samples of the section were exposed to the acid treatment for a longer time compared to softer samples, in order to be able to extract planktonic foraminifera. This caused dissolution in the test walls to some degree. However, this situation did not hamper the classification process.

Main sources for the identification of planktonic foraminifera species are Robaszynski *et al*. (1984), Loeblich and Tappan (1988), Nederbragt (1991) and Premoli-Silva and Verga (2004). The online databases CHRONOS, TaxonConcept and mikrotax have also been used. The stratigraphic distribution for each species is given based on the range charts of Premoli-Silva and Verga (2004), unless otherwise stated.

In addition to giving brief descriptions highlighting important morphological features of the species one by one, commentary to identify the planktonic foraminifera are also given

in this chapter to provide a roughly outlined guideline that has been used to identify the planktonic foraminifera in this study.

Phylum Protozoa

Order Foraminiferida EICHWALD, 1830

Suborder Globigerinina DELAGE and HEROURARD, 1896

Superfamily Globotruncanacea BROTZEN, 1942

Family Globotruncanidae BROTZEN, 1942

Genus *Dicarinella* PORTHAULT 1970

Type species: *Dicarinella canaliculata* REUSS, 1854

***Dicarinella algeriana* CARON, 1966**

Pl. 3, fig. 1-2; Pl. 23, fig. 1-4

Dicarinella algeriana KELLER and PARDO, 2004, p. 99, pl. 3, figs. 8 – 11.

Dicarinella algeriana KALANAT *et al.*, 2015, pl. 2, figs. 13 – 15.

Praeglobotruncana algeriana FALZONI *et al.*, 2016, p. 88, fig. 12 – 7-10.

Diagnostic features:

Spiroconvex, underdeveloped double keel that becomes less prominent in the last chamber of the final whorl, 4.5-6 chambers in the last whorl, finely pustulose wall texture.

Remarks:

At the first glance, this species stands out with its moderate to high spiroconvexity. Its underdeveloped keels (especially towards the end of the last whorl) is the other important criterion in its identification.

Stratigraphic distribution:

From *Rotalipora cushmani* zone, *Dicarinella algeriana* subzone (middle to upper Cenomanian) to *Dicarinella concavata* zone (Coniacian)

Occurrence:

NS-1 – NS-14

Dicarinella asymetrica SIGAL, 1952

Pl. 4, fig. 1; Pl. 23, fig. 8-10

Dicarinella asymetrica LAMOLDA *et al.*, 2007, p. 24, fig. 5 – M.

Dicarinella asymetrica ARDESTANI *et al.*, 2012. p. 26, fig. 5 - 1.

Dicarinella asymetrica EGGER et al., 2013, p. 104, fig. 8 – 1-3.

Dicarinella asymetrica LAMOLDA *et al.*, 2014. fig. 11 – G.

Diagnostic features:

Planoconvex/umbilico-convex which is sometimes accompanied by a slightly concave spiral side, closely-spaced double keel, 5-6.5 chambers in the final whorl, petaloid chambers on the spiral side, a well-developed periumbilical ridge

Remarks:

Dicarinella asymetrica is almost impossible to confuse with other contemporary species because of its unique appearance as given in the diagnostic features. The most similar species to *D. asymetrica* can be *D. concavata* both stratigraphic-range-wise and morphology-wise. However, they can confidently be distinguished by the presence of a periumbilical ridge in *D. asymetrica*.

Stratigraphic distribution:

From *Dicarinella concavata* zone (uppermost Coniacian) to *Dicarinella asymetrica* zone (uppermost Santonian to lowermost Campanian)

Occurrence:

NS-20 – NS-38

Dicarinella canaliculata REUSS, 1854

Pl. 4, fig. 3-7; Pl. 23, fig. 5-7

Dicarinella canaliculata PETRIZZO, 2000, p. 502, fig. 15 – 3.

Dicarinella canaliculata FALZONI et al., 2016, p. 75, fig. 5 – 2.

Diagnostic features:

Flat spiral and umbilical sides, wide double keel, crescentic-petaloid spiral chambers, wedge-shaped umbilical chambers, 5.5-7 chambers in the last whorl, smooth texture

Remarks:

Dicarinella canaliculata occurs in high numbers in the lower part of the measured section. It is distinctive among other double keeled species by its flat spiral and umbilical sides and widely separated double keel. Slightly spiroconvex specimens of *D. canaliculata* are also present and these specimens display a jagged appearance in the edge view with the inclined flat chamber surfaces aligned one after the other due to the spiroconvexity, this creates a characteristic look.

Stratigraphic distribution:

From *Dicarinella algeriana* subzone (middle to late Cenomanian) to *Dicarinella concavata* zone (late Coniacian)

Occurrence:

NS-3 –NS-18

<div align="center">

***Dicarinella concavata* BROTZEN, 1934**

Pl. 4, fig. 2; Pl. 23, fig. 11-13

</div>

Dicarinella concavata LAMOLDA *et al.*, 2007, p. 25, fig. 6 – E.

Dicarinella concavata EGGER *et al.*, 2013, p. 104, fig. 8 – 4-6.

Dicarinella concavata KALANAT *et al.*, 2015, pl. 2, figs. 1 – 3.

Diagnostic features:

Planoconvexity/umbilicoconvexity which sometimes results in a slightly concave spiral side, closely-spaced double keel, petaloid chambers on the spiral side, 5 – 7 chambers in the final whorl

Remarks:

Dicarinella concavata is observed frequently in the middle part of the measured section. It is most similar to *D. asymetrica* and they are distinguished by the absence of the periumbilical ridge present in *D. asymetrica*.

Stratigraphic distribution:

From *Dicarinella concavata* (late Turonian) to *Dicarinella asymetrica* zone (early Campanian)

Occurrence:

NS-19 – NS-36

Dicarinella hagni SCHEIBNEROVA, 1962

Pl. 4, fig. 8

Dicarinella hagni FALZONI et al., 2016, fig. 4 – 9.

Dicarinella hagni HUBER et al., 2017, pl. 3 – 1-8.

Diagnostic features:

Biconvex, double keel, petaloid chambers on the spiral side, 5 – 6 chambers in the last whorl

Remarks:

Dicarinella hagni occurs in the lower part of the measured section. This species differs from *D. imbricata* in having a less convex spiral side. It is distinguished from other dicarinellids as D. canaliculata and D. takayanagii in being more convex and a much more closely spaced double keel.

Stratigraphic distribution:

From *Whiteinella archaeocretacea* zone (uppermost Cenomanian - lowermost Turonian) to *M. sigali-D. primitiva* zone (uppermost Turonian)

Occurrence:

NS-3

Dicarinella imbricata **MORNOD, 1950**

Pl. 3, fig. 7-9

Dicarinella imbricata KELLER and PARDO, 2004, p. 99, pl. 3, figs. 9, 10.

Dicarinella imbricata KALANAT et al., 2015, pl. 1, figs. 10 – 12.

Dicarinella imbricata AZADBAKHT et al., 2016, p. 133, pl. 1 – e.

Dicarinella imbricata FALZONI et al., 2016, p. 75, fig. 5 – 1.

Diagnostic features:

Spiroconvex, double keel which border an imperforate peripheral band, subtriangular chambers on the umbilical side, 5 – 6 chambers in the last whorl.

Remarks:

Dicarinella imbricata occurs in the lower part of the measured section. This species resembles *D. hagni*, however it has fewer chambers in the last whorl and a concavo-convex appearance in the side view.

Stratigraphic distribution:

From *Dicarinella algeriana* subzone (middle to late Cenomanian) to *Dicarinella concavata* zone (early Coniacian)

Occurrence:

NS-2 – NS-17

Dicarinella takayanagii HASEGAWA, 1999

Pl. 3, fig. 3-6

Dicarinella takayanagii HASEGAWA, 1999, p. 187, fig. 8, fig. 3 – A-C.

Dicarinella takayanagii FALZONI et al., 2016, p. 84, fig. 10 – 5-8.

Diagnostic features:

Unequally biconvex, low trochospiral, weakly developed double keel with a wide peripheral band, wedge shaped and flat chambers in the final whorl on the spiral side, few number of chambers in the last whorl (4.5-5) enlarging rapidly in size, laterally elongated last chamber

Remarks:

Dicarinella takayanagii is distinguished from other members of the genus *Dicarinella* mainly with its rapidly enlarging chambers with wedge-shaped chambers in the last whorl. Its diagnostically elongated last chamber also differentiates it from other dicarinellids.

Stratigraphic distribution:

Whiteinella archaeocretacea zone (uppermost Cenomanian - lowermost Turonian) (Hasegawa, 1999; Falzoni et al., 2016)

Occurrence:

NS-11

Genus *Marginotruncana* HOFKER, 1956

Type species: *Rosalina marginata* REUSS, 1845

***Marginotruncana coronata* BOLLI, 1945**

Pl. 13, fig. 2-3; Pl. 27, 4-6

Marginotruncana coronata LAMOLDA et al., 2007, p. 25, fig. 6 – I.

Marginotruncana coronata EGGER et al., 2013, p. 105, fig. 9 – 6-8.

Diagnostic features:

Compressed test (evident especially on the last chamber), closely to very closely spaced double keels, perfectly petaloid shaped chambers on the spiral side, 7 chambers in the last whorl.

Remarks:

This species is abundant in the lower to middle part of the measured section. *Marginotruncana coronata* is quite similar to *M. pseudolinneiana* in terms of having a compressed large test, numerous chambers and double keels. However, they are clearly different in details. *M. coronata* has petaloid-shaped chambers contrary to *M. pseudolinneiana*'s crescentic and elongated chambers in the last whorl. *M. coronata* has a much closely spaced double keels and also has a higher trochospiral coiling than *M. pseudolinneiana*.

Stratigraphic distribution:

From *Helvetoglobotruncana helvetica* zone (early to middle Turonian) to *Globotruncanita elevata* zone (early Camp anian)

Occurrence:

NS-14 –NS-33

Marginotruncana marginata REUSS, 1845

Pl. 27, fig. 7-9

Marginotruncana pseudomarginata, NEAGU, 2012, fig. 7, 4A-C.

Marginotruncana marginata ELAMRI and ZAGHBIB-TURKI, 2014, fig. 9 – 8-10.

Diagnostic features:

Biconvex test, closely spaced double keels bordering a narrow peripheral band, inflated chambers on the spiral side, depressed sutures on both sides, deep and wide umbilicus.

Remarks:

Marginotruncana marginata is abundant in the lower part of the section. It is distinguished from other marginotruncanids by its inflated chambers at first. *M. marginata* may also have its closely-spaced double keel facing toward umbilical side, this can aid in its identification additional to its chamber shape.

Stratigraphic distribution:

From *Helvetoglobotruncana helvetica* zone (early to middle Turonian) to *Dicarinella asymetrica* zone (early Campanian)

Occurrence:

NS-14 – NS-18

Marginotruncana paraconcavata PORTHAULT, 1970

Pl. 13, fig. 6-8

Marginotruncana paraconcavata LAMOLDA *et al.*, 2007, p. 25, fig. 6 – N.

Marginotruncana paraconcavata DUBICKA *et al.*, 2014, p. 47, fig. 4 – E.

Diagnostic features:

Planoconvex test, closely spaced double keels bordering an imperforate peripheral band, flat to concave surfaced petaloid-shaped spiral chambers elongated in the direction of coiling, 4-6 chambers in the last whorl slowly increasing in size.

Remarks:

Marginotruncana paraconcavata catches the eye with its planoconvex test at first. It is unlike all other marginotruncanids, however can be very similar to the contemporaneous species *D. concavata*. But, they can be confidently distinguished by their umbilical chamber shape and size. *M. paraconcavata* has trapezoidal chambers exhibiting v-shaped sutures (if observable, not in this study) in the umbilical side. Moreover, the planoconvexity is not as pronounced in *M. paraconcavata* as it is in *D. concavata*.

Stratigraphic distribution:

From *Dicarinella concavata* zone (early Coniacian) to *Dicarinella asymetrica* zone (early Campanian)

Occurrence:

NS-27 – NS-28

Marginotruncana pseudolinneiana **PESSAGNO, 1967**

Pl. 13, fig. 1; Pl. 27, 1-3

Marginotruncana pseudolinneiana LAMOLDA et al., 2007, p. 25, fig. 6 – J.

Marginotruncana pseudolinneiana ARDESTANI *et al.*, 2012. p. 24, fig. 3 - 3.

Marginotruncana pseudolinneiana EGGER et al., 2013, p. 105, fig. 9 – 2-5.

Diagnostic features:

Perfectly flat on both sides (some specimens may exhibit slight spiroconvexity or spiroconcavity), widely spaced double keels, crescent shaped chambers on the spiral side, subrectangular shaped chambers on the umbilical side, 7-8 slowly enlarging chambers in the last whorl bordered by U-shaped raised sutures.

Remarks:

Marginotruncana pseudolinneiana is the most abundant marginotruncanid in the measured section. *M. pseudolinneiana* is very similar to *G. linneiana* as also indicated by their names. However, this morphological resemblance does not imply an ancestor-descendant relationship. *M. pseudolinneiana* has an extraumbilical-umbilical primary aperture, as *G. linneiana* has an umbilical one. In the edge view, *M. pseudolinneiana* is clearly thinner and longer than *G. linneiana* which has a chunky look and resembles a box. *D. canaliculata* is another resembling species, they can be distinguished by *M. pseudolinneiana*'s horse-shoe shaped umbilical and cresentic, rather than petaloid, spiral chambers. *M. pseudolinneiana* is also much more slender-looking in the edge view and it has a higher number of chambers in the last whorl. Finally, not to confuse *M. pseudolinneiana* with *M. coronata*, it would be enough to notice the wider-spaced double keel and crescentic chambers on the spiral side of *M. pseudolinneiana*.

Stratigraphic distribution:

From *Helvetoglobotruncana helvetica* zone (early to middle Turonian) to *Globotruncanita elevata* zone (early Campanian)

Occurrence:

NS-14 – NS-35

Marginotruncana renzi GANDOLFI, 1942

Pl. 27, fig. 5

Marginotruncana renzi PREMOLI SILVA and VERGA, 2004, Pl. 28, 3-9; Pl. 90, 3-4.,

Diagnostic features:

Slightly trochospiral and equally biconvex test, double keel, shallow and wide umbilicus.

Remarks:

Marginotruncana renzi is once identified in thin section in the lower part of the section. It co-occurs with abundant *Marginotruncana coronata* specimens where the two can look quite similar to each other. *M. renzi* is distinguished from *M. coronata* by its slightly umbilicus-facing double keel, resulting from not being as compressed as *M. coronata* tests are. Furthermore, *M. renzi* is distinguished from another contemporaneous species, *M. marginata* by its non-inflated chambers.

Stratigraphic distribution:

From *Helvetoglobotruncana helvetica* zone (early to middle Turonian) to *Dicarinella asymetrica* zone (early Santonian)

Occurrence: NS-14

Marginotruncna sigali REICHEL, 1950

Pl. 27, fig. 10

Marginotruncana sigali PREMOLI SILVA and VERGA, 2004, Pl. 29, 1-9; Pl. 91, 3-4.

Diagnostic features:

Moderately high trochospiral and equally biconvex test, single keel.

Remarks:

Marginotruncana sigali is also once identified in a thin section sample in the lower part of the section. It is characteristic for its bilateral symmetry across its single keel in the peripheral view.

Stratigraphic distribution:

From *Helvetoglobotruncana helvetica* zone (early to middle Turonian) to *Dicarinella asymetrica* zone (early Santonian)

Occurrence: NS-24

Marginotruncana sinuosa PORTHAULT, 1970

Pl. 13, fig. 5

Marginotruncana sinuosa LAMOLDA et al., 2007, p. 25, fig. 6 – M.

Marginotruncana sinuosa EGGER et al., 2013, p. 105, fig. 9 – 9-11.

Diagnostic features:

Moderately to highly trochospiral test with a sinuous edge view, double keel, strongly elongated crescentic chambers on the spiral side, chambers are elongated in the direction of coiling on both sides, curved oblique and raised sutures on the spiral side, V-shaped raised sutures on the umbilical side, 5-6 chambers in the last whorl.

Remarks:

Marginotruncana sinuosa is distinguished from similar marginotruncanids, such as *M. sigali*, *M. undulata* and *M. tarfayaensis*, by its quite strongly elongated chambers and clearly separate double keels. Another species it resembles the most is *C. fornicata* which occurs together with *M. sinuosa* from Turonian up to the end-Santonian. Actually, it is thought that *M. sinuosa* could be the ancestor of C. fornicata (Robaszynski et al., 1979; Caron, 1985). When it comes to distinguish these two, *M. sinuosa* does not have chambers as elongated and undulated as those of *C. fornicata* and *C. fornicata* mostly occurs in a much higher trochospiral. Finally, *M. sinuosa* is known to have prominently globular chambers in the early whorls (Robaszynski et al., 1979; Caron, 1985), but unfortunately this detail could not be observed here due to problematic preservation. *M. sinuosa* is found just below the proposed Santonian-Campanian boundary in the measured section.

Stratigraphic distribution:

From *Helvetoglobotruncana helvetica* zone (early to middle Turonian) to *Dicarinella asymetrica* zone (early Campanian)

Occurrence:

NS-38

<center>*Marginotruncana tarfayaensis* **LEHMANN, 1963**</center>

<center>Pl. 13, fig. 4</center>

Marginotruncana tarfayaensis LAMOLDA et al., 2007, p. 25, fig. 6 – L.

Marginotruncana tarfayaensis WALASZCZYK *et al.*, 2012, p. 585, fig. 5 - 5.

Diagnostic features:

Slightly trochospiral and inequally biconvex large test, very closely spaced double keels, petaloid chambers on the spiral side, reniform chambers on the umbilical side, compressed chambers especially towards the edges, 6-7 chambers on the spiral side.

Remarks:

Marginotruncana tarfayaensis is observed in the middle part of the measured section. It can be similar to *M. coronata* and *M. pseudolinneiana*, but it has much more closely spaced keels and noticeably compressed chambers. It is distinguished from *M. sinuosa* by its non-elongated chambers and closely spaced double keel.

Stratigraphic distribution:

From *Marginotruncana sigali   Dicarinella primitiva* zone (late Turonian) to *Dicarinella asymetrica* zone (early Campanian)

Occurrence:

NS-28 – NS-30

Subfamily Globotruncaninae BROTZEN, 1942

Genus *Globotruncana* CUSHMAN, 1927

Type species: *Pulvinulina arca* CUSHMAN, 1926

Globotruncana aegyptiaca NAKKADY, 1950

Pl. 5, fig. 13, 18

Globotruncana aegyptiaca JAFF *et al.*, 2015. p. 128, pl. 3, figs. 1, 2.

Globotruncana aegyptiaca SARI *et al.*, 2016. p. 101, fig. 10, D.

Diagnostic features:

Planoconvex, double keels bordering an imperforate peripheral band of variable thickness, umbilical keel never placed at the maximum width of the last chamber, petaloid chambers on both sides, inflated spiral chambers (in some cases), few number (3-5) of rapidly enlarging chambers.

Remarks:

The *Globotruncana aegyptiaca* morphotype identified in this study is the one with quite inflated chambers. *G. aegyptiaca* is similar to *G. rosetta*. They are distinguished by *G. aegyptiaca*'s characteristic widely spaced double keels and *G. rosetta*'s weakly developed umbilical keel. *G. ventricosa* shares the just mentioned double keel structure with *G. aegyptiaca*, however it also has a much higher number of chambers in its last whorl. The chambers of *G. ventricosa* are also never inflated.

Stratigraphic distribution:

From *Globotruncana aegyptiaca* zone (late Campanian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

NS-61 – NS-75

Globotruncana arca CUSHMAN, 1926

Pl. 6, fig. 7-18; Pl. 24, fig. 6-9

Globotruncana arca, GEORGESCU, 2006, p. 112, fig. 7 – 3-6.

Globotruncana arca ARDESTANI *et al.*, 2012. p. 27, fig. 6 - 1.

Globotruncana arca SARI *et al.*, 2016. p. 101, fig. 10, E.

Diagnostic features:

Biconvex, double keels, petaloid shaped chambers on the spiral side, 6-7 chambers slowly increasing in size in the final whorl.

Remarks:

Globotruncana arca is another globotruncanid present in almost all samples covering the middle-upper parts of the measured section. It resembles *G. mariei*, but *G. arca* has a

higher number of chambers and a slower rate of chamber size increase. *G. arca* is also rather spiroconvex, especially compared to biconvex *G. mariei*. *C. fornicata* is also similar to *G. arca*, however the latter has chambers that are fewer in number and more elongated in shape. *G. arca* also has petaloid chambers on the umbilical side, unlike *C. fornicata*'s reniform umbilical chambers. It is distinguished from *G. orientalis* by its more distantly spaced double keel and more curved sutures on the spiral side.

Stratigraphic distribution:

From *Dicarinella asymetrica* zone (Santonian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

NS-25 – NS-74

Globotruncana bulloides VOGLER, 1941

Pl. 7, fig. 10-12; Pl. 24, fig. 1-3

Globotruncana bulloides PETRIZZO *et al.*, 2011. p. 396, fig. 5 – 4, 8.

Globotruncana bulloides ARDESTANI *et al.*, 2012. p. 25, fig. 4 – 2.

Globotruncana bulloides, ELAMRI and ZAGHBIB-TURKI, 2014, p. 196, fig. 9 – 11, 12.

Globotruncana bulloides SARI *et al.*, 2016. p. 101, fig. 10, F.

Diagnostic features:

Planiform to slightly convex on both sides, double keels separated by a wide imperforate peripheral band, perfectly petaloid shaped chambers on the spiral side, 5-6 chambers in the final whorl.

Remarks:

Globotruncana bulloides occurs abundantly in the measured section. Moreover, it exhibits a considerable variation in its morphological properties. Therefore, it has required extra attention to establish the morphological limits of this species. *G. bulloides* is observed having chambers both with a flat and inflated surface. This resulted in planiform and biconvex morphotypes, respectively. Morphologically closest species to *G. bulloides* is *G. linneiana*. However, they can be differentiated by comparing the two in the edge view. The one having the closer double keel and inflated chambers/biconvexity would be *G. bulloides*. Moreover, *G. bulloides* has a characteristic layout of its chambers in the final whorl; they do not overlap as they do in *G. linneiana*, they are rather separately formed.

Stratigraphic distribution:

From *Dicarinella asymetrica* zone (Santonian) to *Abathomphalus mayaroensis* zone (middle Maastrichtian)

Occurrence:

NS-23 – NS-75

Globotruncana falsostuarti SIGAL, 1952

Pl. 5, fig. 12

Globotruncana falsostuarti CHACON *et al.*, 2004. p. 589, fig. 3 – G.

Globotruncana falsostuarti PREMOLI-SILVA and VERGA *et al.*, 2004. p. 107, pl. 37, fig. 1, 2; p. 241, pl. 11, fig. 13-15; p. 242, pl. 12, fig. 1-6.

Globotruncana falsostuarti DARVISHZAD *et al.*, 2007. p. 141, pl. 1, fig. 12.

Globotruncana falsostuarti ROBASZYNSKI and MZOUGHI, 2010. pl. 2, fig. 2.

Diagnostic features:

Equal to inequal biconvexity, closely spaced double keels, petaloid shaped chambers on the spiral side, straight or slightly curved sutures on the spiral side joining the suture around the previous coil at acute to right angles (towards the end of last chamber), numerous chambers (7-8) in the last whorl very slowly increasing in size.

Remarks:

Globotruncana falsostuarti is observed in only one sample in the uppermost part of the measured section. This species is distinguished from *G. arca* by its sutures on the spiral side, higher number of chambers in the last whorl and most importantly its double keel getting closer in the middle of each chamber. It is differentiated from *G. orientalis*, again, with how its double keel gets closer in the middle of chambers and also by not having merging keels in the last chamber and not having a planiform spiral side. Finally, *G. esnehensis* and *G. dupeublei* are also very similar to this species. However, they both have a single keel unlike double keels of *G. falsostuarti*.

Stratigraphic distribution:

From *Globotruncana ventricosa* zone (middle Campanian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

NS-64

Globotruncana hilli PESSAGNO, 1967

Pl. 7, fig. 1-9; Pl. 24, fig. 4, 5

Globotruncana hilli PETRIZZO, 2000, p. 503, fig. 18 – 3.

Globotruncana hilli SARI *et al.*, 2016, p. 101, fig. 10, G.

Diagnostic features:

Planiform on both sides, double keel separated by an imperforate peripheral band, petaloid chambers on the spiral side, 4.5-5.5 chambers moderately increasing in size in the final whorl, noticeably smaller test size compared to other globotruncanids.

Remarks:

Globotruncana hilli is another very abundant and frequently occurring species in the measured section. It is immediately identified with its relatively small test, box-like apperance in the edge view, prominent beaded spiral and umbilical sutures and a widely spaced double keel. Roughly speaking, *G. hilli* looks like a smaller version of *G. linneiana*. Therefore, their size and number of chambers in the last whorl must be compared to eliminate this problem. Finally, *G. hilli* may have inflated chambers on the spiral side and its texture can range between smooth and finely pustulose. *G. hilli* has more distantly spaced keels, a greater rate of chamber size increase and a noticeably smaller test size compared to *G. bulloides*.

Stratigraphic distribution:

From *Dicarinella asymetrica* zone (Santonian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

NS-39 – NS-73

Globotruncana insignis GANDOLFI, 1955

Pl. 24, fig. 13-14

Globotruncana insignis JANSEN and KROON, 1987, pl. 2, fig. 1, 2.

Globotruncana insignis FALZONI and PETRIZZO, 2011, fig. 4 – 10, 11; fig. 5 – 3, 4.

Diagnostic features:

Prominently planoconvex test, single keel, acute periphery.

Remarks:

The species is distinguished from *G. gansseri* by the acute peripheral angle and narrow umbilicus.

Stratigraphic distribution:

From *Globotruncana ventricosa* zone (middle Campanian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

NS-37

Globotruncana lapparenti PESSAGNO, 1967

Pl. 24, fig. 10-12

Globotruncana lapparenti PREMOLI SILVA and VERGA, 2004, Pl. 13, 1-5; Pl. 38, 3-4, Pl. 39, 1.

Diagnostic features:

Trochospiral and equally biconvex test, double keel.

Remarks:

Being diagnosed only in thin section samples, *Globotruncana lapparenti* is differentiated from *Globotruncana linneiana* by its trochospiral and biconvexity. It has a lower trochospiral than *Globotruncana arca*; has non-inflated chambers compared to *Globotruncana bulloides*.

Stratigraphic distribution:

From *Dicarinella concavata* zone (Coniacian) to *Gansserina gansseri* zone (middle Maastrichtian)

Occurrence:

NS-32 – NS-34

Globotruncana linneiana

Pl. 6, fig. 1-6; Pl. 25, fig. 1-14

Globotruncana linneiana PETRIZZO *et al.*, 2011. p. 389, fig. 2 – 9; p. 394, fig. 3 – 3.

Globotruncana linneiana ARDESTANI *et al.*, 2012. p. 25, fig. 4 – 1; fig. 5 – 4.

Globotruncana linneiana, ELAMRI and ZAGHBIB-TURKI, 2014, p. 195, fig. 8 – 13-15.

Globotruncana linneiana LAMOLDA *et al.*, 2014. fig. 11 – D-E.

Globotruncana linneiana SARI *et al.*, 2016. p. 101, fig. 10, H.

Diagnostic features:

Planiform on both sides, a well-developed double keel separated by a wide imperforate peripheral band, crescentic to petaloid shaped chambers on the spiral side, 5-7 chambers in the last whorl.

Remarks:

Globotruncana linneiana is a very abundant and numerically the most frequently occurring species in the measured section. It has a plain morphology with no convexity or significant ornamentation on either side of the test; it can have a finely pustulose texture, though. It resembles a box in the edge view just like *G. hilli*. However it differs from *G. hilli* in having a larger test, more chambers and flat surfaced chambers on the spiral side.

Stratigraphic distribution:

From *Dicarinella asymetrica* zone (Santonian) to *Abathomphalus mayaroensis* zone (middle Maastrichtian)

Occurrence:

NS-14 – NS-75

Globotruncana mariei BANNER and BLOW, 1960

Pl. 5, fig. 4-8

Globotruncana mariei GEORGESCU, 2006, p. 112, fig. 7 – 8.

Globotruncana mariei FAROUK, 2014, p. 243, fig. 6 – 10-12.

Diagnostic features:

Equally biconvex test, double keel, petaloid chambers on the spiral side, 4.5-5.5 chambers in the last whorl.

Remarks:

Globotruncana mariei is observed frequently between the middle-upper parts of the measured section. It has slightly elongated petaloid shaped chambers on the spiral side and a biconvex test. The most similar species to *G. mariei* is *G. arca*, especially when the latter has less than six chambers. To distinguish these two, the rate of chamber size increase in the last whorl and the degree of convexity on the spiral side should be checked.

The specimen with the rapidly enlarging chambers and the lower spiroconvexity would be *G. mariei*, in addition to that *G. arca* mostly has equal to or more than 6 chambers in the last whorl. Other similar species are *G. orientalis* and *G. rosetta*. *G. mariei* has much fewer chambers than *G. orientalis* in the last whorl and also its double keel is always present as two separate keels unlike *G. orientalis* and *G. rosetta*.

Stratigraphic distribution:

From *Globotruncanita elevata* zone (early Campanian) to *Abathomphalus mayaroensis* zone (middle Maastrichtian)

Occurrence:

NS-14 – NS-74

Globotruncana orientalis EL NAGGAR, 1966

Pl. 5, fig. 1-3

Globotruncana orientalis FALZONI *et al.*, 2013, p. 17, fig. 2 – 6.

Globotruncana orientalis, ELAMRI and ZAGHBIB-TURKI, 2014, p. 195, fig. 8 – 13-15.

Globotruncana orientalis SARI *et al.*, 2016. p. 101, fig. 10, J.

Diagnostic features:

Equal to inequal biconvexity, closely spaced double keel with the umbilical one less developed and disappearing/merging with the other one at the last chamber, straight to slightly curved spiral sutures, 5-7 petaloid spiral chambers increasing very slowly in size.

Remarks:

Globotruncana orientalis is a common species in the measured section. It is distinguished from *G. arca* by its closely spaced double keel (becoming a single keel in the last chamber)

and straighter sutures on the spiral side. It differs from *G. falsostuarti* in that the latter has a narrower keel band in the middle of its chambers.

Stratigraphic distribution:

From *Globotruncanita elevata* zone (early Campanian) to *Abathomphalus mayaroensis* zone (middle Maastrichtian)

Occurrence:

NS-54 – NS-75

Globotruncana ventricosa WHITE, 1928

Pl. 5, fig. 9-11; Pl. 24, fig. 15

Globotruncana ventricosa PETRIZZO, 2000, p. 503, fig. 17 – 1.

Globotruncana ventricosa PETRIZZO *et al.*, 2011. p. 389, fig. 2 – 1-5, 10-14.

Globotruncanita ventricosa SARI *et al.*, 2016. p. 103, fig. 12, L.

Diagnostic features:

Prominently planoconvex test, a moderately spaced double keel bordering an imperforate peripheral band, petaloid shaped chambers on the spiral side, umbilical keel never placed at the maximum width of the last chamber, high number (5 – 9) of rapidly enlarging chambers in the last whorl.

Remarks:

Globotruncana ventricosa occurs at a moderate frequency in the upper part of the measured section. It is a quite important form, thus its correct identification is crucial in this study. *G. ventricosa* can look very similar to *G. linneiana* at first sight. Although they both have planiform spiral sides, unlike *G. linneiana*, *G. ventricosa* has a very convex umbilical side. This species may also resemble *G. aegyptiaca* in some cases. They are distinguished by *G. ventricosa*'s characteristic loss of umbilical keel at the last chamber.

It also has a much higher number of chambers in its last whorl and its chambers are never inflated.

Stratigraphic distribution:

From *Globotruncana ventricosa* zone (middle Campanian) to *Contusotruncana contusa-Racemiguembelina fructicosa* zone (middle Maastrichtian)

Occurrence:

NS-49 – NS-68

<div align="center">

Genus *Globotruncanita* REISS, 1957

Type species: *Rosalina stuarti de lapparent*, 1918

***Globotruncanita angulata* TILEV, 1951**

Pl. 8, fig. 6

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Globotruncanita angulata ROBASZYNSKI and MZOUGHI, 2010. pl. 5, fig. 1.

Globotruncanita angulata ORABI and ZAHRAN, 2013. p. 81, pl. 2 – 1, 2.

Globotruncanita angulata SARI *et al.*, 2016. p. 103, fig. 12, B.

Diagnostic features:

Strong planoconvexity/umbilicoconvexity, straight spiral sutures joining the peripherical suture at acute angles in the beginning of the last whorl and at almost right angles towards the end of it, trapezoidal shaped chambers on the spiral side, 5-6 chambers in the last whorl.

Remarks:

Globotruncanita angulata is observed in the washed specimen as only one specimen, but this still made an important contribution to develop the biostratigraphic framework of the measured section. This species is similar to *G. gansseri*. They can be accurately

differentiated by *G. angulata*'s straight sutures on the spiral side. Another single-keeled form *G. angulata* is similar with is *G. pettersi*. However, after close examination one can easily notice how *G. pettersi* has curved sutures and fewer chambers compared to G. angulata. Moreover, *G. angulata* is almost hemi-spherical whereas *G. pettersi* has a more conical shape in the side view.

Stratigraphic distribution:

From *Globotruncana aegyptiaca* zone (late Campanian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

NS-69 – NS-71

Globotruncanita atlantica CARON, 1972

Pl. 8, fig. 1, 2

Globotruncanita atlantica CHEN *et al.*, 2011, fig. 3 – 10.

Globotruncanita cf. atlantica CHEN *et al.*, 2011, fig. 3 – 19.

Globotruncanita atlantica PETRIZZO *et al.*, 2011. p. 395, fig. 4 – 3-10.

Diagnostic features:

Strongly spiroconvex, single keel, strongly elongated crescentic to triangular shaped chambers on the spiral side, 6 – 7 chambers in the last whorl.

Remarks:

Globotruncanita atlantica marks the middle to upper part of the Campanian. So, detecting its interval of occurrence is quite important and it is found just in coherence with this assumption in the measured section. This species looks like an inverted bowl in the spiral view. Another form with this look is *G. conica*, however it has straight sutures as opposed

to the curved sutures of *G. atlantica* in the spiral view; therefore they are impossible to confuse with each other.

Stratigraphic distribution:

From *Globotruncanita elevata* zone (early Campanian) to *Globotruncana ventricosa* zone (middle Campanian)

Occurrence:

NS-43 – NS-61

<center>

***Globotruncanita elevata* BROTZEN, 1934**

Pl. 23, fig. 14-15

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Globotruncana elevata LONGORIA and VONFELDT, 1991, p. 225, pl. 3, figs. 1 – 10; p. 235, pl. 8, figs. 1 – 6; p. 237, pl. 10, figs.13; p. 241, pl. 11, figs. 5, 9, 12, 17.

Globotruncana elevata PETRIZZO, 2000, p. 503, fig. 18 – 6.

Globotruncanita elevata FALZONI et al., 2013, p. 17, fig. 2 – 9.

Globotruncanita elevata SARI *et al.*, 2016. p. 103, fig. 12, C.

Diagnostic features:

Umbilicoconvex with a slightly elevated middle part of the spiral side, crescentic chambers on the spiral side, deep and large umbilicus, numerous chambers (5-9) in the last whorl.

Remarks:

Globotruncanita elevata could only be identified in thin section in this study. Its hallmark feature is the raised middle part of its spiral side, as the name implies. This feature together with the observation of a single keel are found enough to identify this species and distinguish it from others.

Stratigraphic distribution:

From *Dicarinella asymetrica* zone (Santonian) to *Globotruncana ventricosa* zone (middle Campanian)

Occurrence:

NS-38 – NS-46

Globotruncanita pettersi Gandolfi, 1955

Pl. 8, fig. 7

Globotruncanita pettersi ROBASZYNSKI and MZOUGHI, 2010. pl. 5, fig. 2.

Globotruncanita pettersi SARI *et al.*, 2016. p. 103, fig. 12, F.

Diagnostic features:

Umbilicoconvex and conical shape in the side view, smaller test compared to tests of congener species, trapezoidal shaped chambers with curved sutures on the spiral side, 4-5 chambers in the last whorl.

Remarks:

Globotruncanita pettersi is observed as only one in the measured section, but this has been enough to define its morphological properties. Its rapidly enlarging trapezoidal shaped chambers on the spiral side and single keel characterize *G. pettersi*. It lacks *G. angulata*'s characteristic straight spiral sutures. Finally, to differentiate *G. pettersi* from *G. gansseri*, they must be examined in the edge view. *G. pettersi* has a last chamber with a straight outline, whereas *G. gansseri* has a last chamber with a clearly curved outline observed in the side view. Furthermore, *G. pettersi* has curved sutures and fewer chambers compared to *G. angulata*. In the side view, *G. angulata* is almost hemi-spherical whereas *G. pettersi* has a more conical shape as a result of its acute peripheral angle.

Stratigraphic distribution:

From *Gansserina gansseri* zone (Santonian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

NS-64

Globotruncanita stuartiformis DALBIEZ, 1955

Pl. 8, fig. 3-5

Globotruncana stuartiformis LONGORIA and VONFELDT, 1991, p. 231, pl. 6, figs. 1 – 12; p. 237, pl. 9, figs. 1 – 3; p. 237, pl. 10, figs: 2, 5, 8, 11, 14, 16; p. 241, pl. 11, figs. 8, 13, 14.

Globotruncana stuartiformis PETRIZZO, 2000, p. 503, fig. 18 – 4.

Globotruncanita stuartiformis, GEORGESCU, 2006, p. 107, fig. 4 – 14-15.

Globotruncanita stuartiformis ROBASZYNSKI and MZOUGHI, 2010. pl. 3, fig. 3.

Globotruncanita stuartiformis FALZONI et al., 2013, p. 17, fig. 2 – 5.

Globotruncanita stuartiformis SARI *et al.*, 2016. p. 103, fig. 12, G.

Diagnostic features:

Low trochospiral coiling with an equal to inequal biconvexity, single keel, triangular to sub-triangular shaped chambers on the spiral side with steeply sloping sutures towards the periphery in the last ones, 5 – 7 chambers in the last whorl.

Remarks:

Globotruncanita stuartiformis is the most frequently observed *Globotruncanita* species in the measured section. It is differentiated from other *Globotruncanita* forms very simply by its spiral chamber shape and lateral profile.

Stratigraphic distribution:

From *Dicarinella asymetrica* zone (Santonian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

 NS-41 – NS-70

Genus *Contusotruncana* KORCHAGIN, 1982

Type species: *Pulvinulina arca contusa* CUSHMAN, 1926

Contusotruncana fornicata PLUMMER 1931

Pl. 2, fig. 1-5

Contusotruncana fornicata LAMOLDA et al., 2007, p. 25, fig. 6 – A.

Contusotruncana fornicata FALZONI et al., 2013, p. 17, fig. 2 – 1.

Contusotruncana fornicata SARI *et al.*, 2016. p. 101, fig. 10, A.

Diagnostic features:

Spiroconvex, circular to lobate outline of the test, well-developed double keel, very strongly elongated crescentic shaped chambers on the spiral side, few chambers in the last whorl (most of the time 4, but may also be 5).

Remarks:

Contusotruncana fornicata is a very abundant species in general. It is recorded continuously from almost bottom to top in the measured section. Spiroconvexity of this species is quite variable, all degrees have been observed in this study. The hallmark of *C. fornicata* is its narrow and strongly elongated chambers in the direction of coiling. It has a potentially problematic resemblance to *M. sinuosa*, where the two can be differentiated

in that *M. sinuosa* does not have chambers as elongated and undulated as *C. fornicata*'s and *C. fornicata* mostly occurs in a much higher trochospiral.

Stratigraphic distribution:

Dicarinella concavata zone (early Coniacian) to *Abathomphalus mayaroensis* zone (middle Maastrichtian)

Occurrence:

NS-21 – NS-75

<p style="text-align:center">***Contusotruncana plummerae* GANDOLFI, 1955**</p>

<p style="text-align:center">Pl. 2, fig. 6</p>

Contusotruncana plummerae PETRIZZO *et al.*, 2011. p. 396, fig. 5 – 1-3, 5-7.

Contusotruncana plummerae JAFF *et al.*, 2015. p. 128, pl. 3, figs. 13, 14.

Diagnostic features:

Slightly to highly spiroconvex, circular to lobate outline of the test, well-developed double keel, crescentic shaped chambers on the spiral side, distorted horse-shoe shaped chambers on the umbilical side, 4 – 5 chambers in the last whorl.

Remarks:

Although not as abundant as *C. fornicata*, *Contusotruncana plummerae* is also an abundant and extensively-occurring species in the measured section. In the author's opinion, it is like an inflated and distorted version of *C. fornicata*. Therefore, it is distinguished from *C. fornicata* firstly by its inflated chambers, on both sides. Moreover, its umbilical sutures do not display the broad V-shape which is present in *C. fornicata*, they are rather depressed except for the edge of last chamber. The space between the keels of *C. plummerae* is also broader than the one between the keels of *C. fornicata*.

Stratigraphic distribution:

From *Globotruncana ventricosa* zone (middle Campanian) to *Contusotruncana contusa-Racemiguembelina fructicosa* zone (middle Maastrichtian)

Occurrence:

NS-50 – NS-57

<div align="center">

Genus *Gansserina* CARON et al., 1984

Type Species: *Globotruncana gansseri* BOLLI, 1951

***Gansserina gansseri* BOLLI, 1951**

Pl. 8, fig. 8

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Gansserina gansseri CHACON *et al.*, 2004, fig. 4 – G, H.

Gansserina gansseri COCCIONI and PREMOLI-SILVA, 2015, pl. 1, figs. 9a-c.

Gansserina gansseri JAFF *et al.*, 2015. p. 128, pl. 3, figs. 5, 6.

Diagnostic features:

Strongly planoconvex, sub-triangular shaped chambers on the spiral side, finely to heavily pustulose test, 4.5-5.5 chambers with curved sutures in the last whorl.

Remarks:

Only one *Gansserina gansseri* specimen is found uppermost part of the measured section. This has been a very nice ending to the biostratigraphic zonation, since it signals the lowermost part of *G. gansserina* biozone marking the Latest Campanian. It is quite similar to *G. pettersi* and *G. angulata* at first sight. However, it can be distinguished from both by the curved outline of its last chambers in the edge view. Moreover, *G. gansseri* has mostly a larger test and a higher number of chambers than *G. pettersi*; it has curved spiral sutures compared to *G. angulata*.

Stratigraphic distribution:

Globotruncana aegyptiaca zone (latest Campanian) to *Abathomphalus mayaroensis* zone (middle Maastrichtian)

Occurrence:

NS-75

Genus *Rugotruncana* BRONNIMANN and BROWN

Type species: *Rugotruncana tilevi* BRONNIMANN and BROWN, 1956, junior synonym of *Globigerina circumnodifer* FINLAY, 1940

Rugotruncana circumnodifer FINLAY, 1940

Pl. 20, fig. 4-7

Rugotruncana subcircumnodifer GEORGESCU, 2005, p. 93, fig. 3 – 7-9.

Rugotruncana subcircumnodifer, GEORGESCU, 2006, p. 107, fig. 4 – 9-12.

Rugotruncana circumnodifer GEORGESCU and HUBER, 2007. p. 155, pl. 1, figs. 1 – 4; pl. 3, figs. 1 – 5.

Rugotruncana circumnodifer KALANAT *et al.*, 2015, pl. 3, figs.19 - 21.

Diagnostic features:

Low to medium high spire, double keel with an imperforate peripheral band, meridional costallae which may disappear towards the last chambers, 4.5-5.5 chambers in the final whorl, large aperture.

Remarks:

Rugotruncana is accepted as a monotypic genus due to the poor understanding of the species and its high morphological variability (Georgescu and Huber, 2007). Therefore, it is accepted as a monotypic genus in also this study. *Rugotruncana circumnodifer* is very

simply a double-keeled rugoglobigerinid or archaeoglobigerinid, depending on the characteristics of its wall texture. Its texture ranges between scatteredly pustulose and meridionally costallate, this is the case in this measured section, too.

Stratigraphic distribution:

Globotruncana ventricosa zone (middle Campanian) to *Abathomphalus mayaroensis* zone (middle Maastrichtian)

Occurrence:

NS-62 – NS-72

<center>Genus Praeglobotruncana BERMUDEZ, 1952</center>

<center>Type species: Globorotalia delrioensis PLUMMER, 1931</center>

<center>Praeglobotruncana gibba KLAUS, 1960</center>

<center>Pl. 15, fig. 7-9; Pl. 28, fig. 5-9</center>

Praeglobotruncana gibba PERYT, 1983, pl. 32, figs. 1, 2, 4, 5.

Praeglobotruncana gibba PETRIZZO, 2000, pl. 3, fig. 9, 5a-c.

Praeglobotruncana gibba DUBICKA and MACHALSKI, 2016, fig. 6, i1, i2.

Diagnostic features:

High trochospiral spiroconvex test, single keel, petaloid chambers on spiral side, 5-6.5 chambers in the final whorl, deep and narrow umbilicus.

Remarks:

Praeglobotruncana gibba has the highest trochospire among praeglobotruncanids. It is observed in the lowermost part of the measured stratigraphic section.

Stratigraphic distribution:

From *Rotalipora cushmani* zone (late Cenomanian) to *Helvetoglobotruncana helvetica* zone (Turonian)

Occurrence:

NS-62 – NS-72

Praeglobotruncana stephani GANDOLFI, 1942

Pl. 15, fig. 1-6; Pl. 28, fig. 10-15

Praeglobotruncana stephani PETRIZZO, 2000, p. 499, fig. 9 – 4.

Praeglobotruncana stephani NISHI *et al*., 2003, p. 878, fig. 10 – 5.

Praeglobotruncana stephani KELLER and PARDO, 2004, p. 98, pl. 2, figs. 12-14, 15, 16.

Praeglobotruncana stephani FALZONI *et al.*, 2016, p. 74, fig. 4 – 4.

Diagnostic features:

Highly spiroconvex/concavoconvex, single keel, petaloid shaped chambers on the spiral side with raised and beaded sutures, triangular to subtriangular shaped chambers on the umbilical side with depressed sutures, 4-6 chambers in the last whorl

Remarks:

Praeglobotruncana stephani occurs far more frequently than its congener *P. gibba* in the measured section. *P. stephani* has a lower spire than *P. gibba*.

Stratigraphic distribution:

Rotalipora subticinensis subzone (late Albian) to *Helvetoglobotruncana helvetica* zone (early Turonian)

Occurrence:

NS-3 – NS-13

Subfamily GLOBOTRUNCANELLINAE MASLAKOVA, 1964

Genus *Globotruncanella* REISS, 1957

Type species: *Globotruncana citae* BOLLI, 1951 (= Globotruncana
havanensis VOORWIJK, 1937 = Globorotalia *pschadae* KELLER,
1946)

Globotruncanella petaloidea GANDOLFI, 1955

Pl. 20, fig. 1-3

Globotruncanella petaloidea PREMOLI-SILVA and VERGA, 2004, p. 114, p. 44, figs.
1, 2.

Globotruncanella petaloidea OBAIDALLA, 2005, p. 215, pl. 1, fig. 5.

Globotruncanella petaloidea JAFF *et al.*, 2015. p. 130, pl. 4, figs. 1, 2.

Diagnostic features:

Spiroconvex and compressed test, petaloid shaped chambers on the spiral side, depressed
sutures on both sides, 4 chambers in the last whorl, finely pustulose wall texture

Remarks:

Globotruncanella petaloidea is observed in one sample in the measured stratigraphic
section. It is a distinct form with its compressed test and few number of chambers in the
last whorl. Among other globotruncanellids, *G. petaloidea* is distinguished by its rapidly
enlarging 4 (always) chambers in the last whorl, unlike *G. havanensis* which has 4.5 to 5
more or less constantly sized chambers in the last whorl. It is not as spiroconvex as *G.
pschadae* as well as not having as compressed chambers as the latter does.

Stratigraphic distribution:

Radotruncana calcarata zone (late Campanian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

NS-52 – NS-53

Subfamily ROTALIPORINAE Sigal, 1958
Genus *Rotalipora* Brotzen, 1942

Type species: *Rotalipora turonica* Brotzen, 1942

Rotalipora cushmani MORROW, 1934

Pl. 28, fig. 3-4

Rotalipora cushmani DIMITROVA and VALCHEV, 2007, pl.1, fig. 1.

Rotalipora cushmani COCCIONI et al., 2016, pl.1, fig. 1-16.

Diagnostic features:

Trochoid test, convex spiral side with inflated chambers, scalloped periphery, sutures deeply grooved.

Remarks:

Rotalipora cushmani is observed in the first sample in thin section of the measured stratigraphic section. It has a characteristic form with its inflated chambers and wide and shallow umbilicus.

Stratigraphic distribution:

Rotalipora globotruncanoides zone (early Cenomanian) to *Whiteinella archaeocretacea* zone (latest Cenomanian-earliest Turonian)

Occurrence:

NS-1

Rotalipora deeckei FRANCKE, 1925

Pl. 28, fig. 1-2

Rotalipora deeckei KOPAEVICH and VISHNEVSKAYA., 2016, fig.8, j-l.

Rotalipora deeckei FALZONI et al., 2016, fig.4, 2A-C.

Diagnostic features:

Low trochospiral test with a flat spiral side, single keel, high rate of chamber size increase, peri-umbilical ridge, deep and narrow umbilicus.

Remarks:

Rotalipora deeckei is the other rotaliporid found in the first first sample in thin section of the measured stratigraphic section. Its distinctive morphological features are the raised middle part of the test due to being low trochospiral, flat spiral chamber surface and a deep but narrow umbilicus.

Stratigraphic distribution:

Rotalipora greenhornensis subzone (middle Cenomanian) to *Dicarinella algeriana* subzone (late Cenomanian)

Occurrence:

NS-1

Family RUGOGLOBIGERINIDAE SUBBOTINA, 1959

Genus *Rugoglobigerina* BRONNIMANN, 1952

Type species: *Globigerina rugosa* PLUMMER, 1927

***Rugoglobigerina hexacamerata* BRONNIMANN, 1952**

Pl. 16, fig. 22

Rugoglobigerina hexacamerata ARZ and MOLINA, 2001, p. 346, pl. 1, figs. 9-11.

Rugoglobigerina hexacamerata FALZONI *et al.*, 2014. p. 91, fig. 2, 2; p. 92, fig. 3 – 5, 6.

Rugoglobigerina cf. hexacamerata FALZONI *et al.*, 2014. p. 93, fig. 4 – 5, 6; p. 94, fig. 5 – 2.

Diagnostic features:

Spiroconvex, six chambers increasing very slowly in size in the last whorl, meridionally costellate and coarsely rugose wall texture.

Remarks:

This species is observed as only one specimen in the uppermost part of the measured section. *Rugoglobigerina hexacamerata* draws the attention with its rugoglobigerinid texture, at first. After making sure that this specimen is a *Rugoglobigerina* species, it can be distinguished from other rugoglobigerinid species by its numerous chambers (5.5 – 6.5, but ideally 6) with a very low rate of size increase and, again, a very low trochospiral coil. If observable, its large aperture covered with tegilla can also aid in its identification.

Stratigraphic distribution: *Radotruncana calcarata* zone (late Campanian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

NS-68 - NS-74

Rugoglobigerina macrocephala BRONNIMANN, 1952

Pl. 16, fig. 16-18

Rugoglobigerina macrocephala GEORGESCU, 2005, p. 93, fig. 3 – 1, 2.

Rugoglobigerina macrocephala SARI *et al.*, 2016. p. 103, fig. 12, J.

Diagnostic features:

Very large last chamber covering almost the half of the test diameter, 3 – 3.5 chambers increasing very rapidly in size in the last whorl, meridionally costallate and coarsely rugose wall texture.

Remarks:

Rugoglobigerina macrocephala occurs at a moderate frequency in the upper portion of the measured section. *R. macrocephala* differs from other rugoglobigerinids by its few number of chambers in the last whorl and distinctly large last chamber.

Stratigraphic distribution:

Globotruncana aegyptiaca zone (late Campanian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

 NS-55 - NS-74

Rugoglobigerina milamensis SMITH and PESSAGNO, 1973

Pl. 16, fig. 20-21

Rugoglobigerina milamensis FALZONI *et al.*, 2014. p. 92, fig. 3 – 9, 10.

Rugoglobigerina cf. milamensis FALZONI *et al.*, 2014. p. 93, fig. 4 – 9, 10.

Rugoglobigerina milamensis SARI *et al.*, 2016. p. 103, fig. 12, K.

Diagnostic features:

Five chambers (may be six) moderately increasing in size in the last whorl coiled in a high trochospiral, meridionally costellate and coarsely rugose wall texture.

Remarks:

R. milamensis is identified in the uppermost part of the measured section. The greatest difference between *R. milamensis* and other rugoglobigerinids is its strong spiroconvexity. A high trochospiral coil coupled with rugoglobigerinid wall texture are the main criteria in identifying this species. It can be, in some cases, said to resemble *R. pennyi* among the rugoglobigerinids, however its fewer number of chambers and noticeably higher trochospire would eliminate any possible confusion.

Stratigraphic distribution:

Globotruncana aegyptiaca zone (late Campanian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

NS-67 – NS-68

Rugoglobigerina pennyi BRONNIMANN, 1952

Pl. 16, fig. 19; Pl. 22, fig. 14

Rugoglobigerina pennyi GEORGESCU, 2005, p. 93, fig. 3 – 4-6.

Rugoglobigerina pennyi FALZONI et al., 2013, p. 17, fig. 2 – 7.

Rugoglobigerina pennyi FALZONI *et al.*, 2014. p. 92, fig. 3 – 9.

Rugoglobigerina cf. pennyi FALZONI *et al.*, 2014. p. 93, fig. 4 – 7, 8, 9; p. 94, fig. 5 – 3, 4.

Diagnostic features:

Presence of six chambers (may be seven) very slowly or not increasing in size in the last whorl coiled in a moderate trochospiral, meridionally costellate and coarsely rugose wall texture.

Remarks:

Only one specimen is identified as *Rugoglobigerina pennyi* in the measured section. *R. pennyi* resemble *R. milamensis* in the high number of chambers in its last whorl, but *R. pennyi* has an obviously lower trochospire than the latter. Another rugoglobigerinid *R. pennyi* occurring together with and resembling it is *R. hexacamerata*. However, in this case *R. hexacamerata*'s almost planispiral coil would differentiate these two.

Stratigraphic distribution:

Globotruncana aegyptiaca zone (late Campanian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

NS-69

Rugoglobigerina rugosa PLUMMER, 1926

Pl. 16, fig. 1-15; Pl. 22, fig. 13

Rugoglobigerina rugosa PETRIZZO, 2000, p. 501, fig. 14 – 5.

Rugoglobigerina rugosa GEORGESCU, 2005, p. 93, fig. 3 – 3, 4.

Rugoglobigerina rugosa FALZONI *et al.*, 2014. p. 91, fig. 2, 1; p. 92, fig. 3 – 2, 3, 4; p. 101, fig. 11 – 5.

Rugoglobigerina cf. rugosa FALZONI *et al.*, 2014. p. 93, fig. 4 – 1-4; p. 94, fig. 5 – 1, 5, 6.

Rugoglobigerina rugosa SARI *et al.*, 2016. p. 103, fig. 12, L.

Diagnostic features:

Presence of 4-5 chambers rapidly increasing in size in the last whorl coiled in a moderate to high trochospiral, meridionally costellate and coarsely rugose wall texture.

Remarks:

Rugoglobigerina rugosa has the highest occurrence number among the Genus *Rugoglobigerina* in the measured section. It is distinguished from other rugoglobigerinids described previously, by the combination of its few number of chambers and low to high trochospire. Moreover, it occurs much before all the other *Rugoglobigerina* species in the stratigraphic record and thus, its identification can be problematic as it occurs with costellagerinids. As also described in detail in the *Costellagerina* species descriptions, *R. rugosa* can be quite similar to *C. pilula* and *C. bulbosa*. They can be distinguished only based on the intensity and continuity of rugosities and costallae and features of the primary aperture. When observable, primary aperture is another criteria in distinguishing these two genera; it is interiomarginal-umbilical in the costellagerinids, whereas it is umbilical in rugoglobigerinid species.

Stratigraphic distribution:

Globotruncanita elevata zone (early Campanian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

NS-49 - NS-74

Subfamily Archaeoglobigerininae subfam. nov. SALAJ, 1987

Genus *Archaeoglobigerina* PESSAGNO, 1967

Archaeoglobigerina blowi PESSAGNO, 1967

Pl. 22, fig. 1

Archaeoglobigerina blowi NISHI *et al.*, 2003, p. 879, fig. 11 – 13.

Archaeoglobigerina blowi GEORGESCU, 2005, p. 92, fig. 2 – 1-3.

Archaeoglobigerina blowi GEORGESCU, 2006, p. 114, fig. 8 – 8-10.

Archaeoglobigerina blowi FALZONI *et al.*, 2014. p. 101, fig. 11 – 7, 8.

Diagnostic features:

Chambers with a high rate of size increase, imperforate peripheral band, moderately to slightly muricate wall texture.

Remarks:

Archaeoglobigerina blowi is observed in one specimen in the mid-section. In the thin section view, it has a thicker and more muricate wall compared to muricohedbergellids. However, when compared to genera *Whiteinella* and *Rugoglobigerina*, *A. blowi* has a thinner and less coarse test wall. Moreover, *A. blowi* displays its imperforate peripheral band in an equatorial section and this is the main criterion in its identification.

Stratigraphic distribution:

From *Marginotruncana sigali-Dicarinella primitiva* zone (late Turonian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

NS-41

Archaeoglobigerina cretacea

Pl. 14, fig. 5

Archaeoglobigerina cretacea PETRIZZO, 2000, p. 501, fig. 14 – 2.

Archaeoglobigerina cretacea GEORGESCU, 2005, p. 92, fig. 2 – 4-6.

Archaeoglobigerina cretacea GEORGESCU, 2006, p. 114, fig. 8 – 14-16.

Archaeoglobigerina cretacea ARDESTANI *et al.*, 2012. p. 25, fig. 4 - 4.

Diagnostic features:

An almost circular test outline with a very low rate of chamber size increase, presence of a double keel, moderately to densely muricate wall texture.

Remarks:

Archaeoglobigerina cretacea occurs frequently in the measured section. It is distinctly different than *A. blowi* in terms of its wall texture, number of chambers in the last whorl, general test outline, rate of chamber size increase and most importantly with its possession of a double keel instead of an imperforate peripheral band as *A. blowi* has. It is much more densely muricate than *A. blowi* which can even have a smooth texture. It always has globular and very slowly enlarging chambers contrary to *A. blowi*'s, they are not as inflated as *A. blowi*'s, though. It also has 5-6 chambers, whereas *A. blowi* has 4-5 chambers

Stratigraphic distribution:

From *Marginotruncana sigali-Dicarinella primitiva* zone (late Turonian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

NS-23 – NS-71

<div align="center">

Superfamily Planomalinoidea BOLLI *et al.*, 1957

Family Schakoinidae POKORNY, 1958

Genus *Schakoina* THALMANN, 1932

***Schackoina cenomana* SCHACKO, 1897**

Pl. 28, fig. 16

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Schakoina cenomana PETRIZZO, 2000, p. 501, fig. 13 – 5.

Schakoina cenomana EGGER *et al.*, 2013, p. 107, fig. 11 – 13.

Schakoina cenomana FALZONI *et al.*, 2016, p. 75, fig. 5 – 10.

Diagnostic features:

Slightly compressed funnel-shaped chambers in the last whorl, presence of mostly 4 chambers in the last whorl.

Remarks:

Although *Schakoina cenomana* is known to occur throughout a long geological time span (late Albian-Maastrichtian), it is encountered only a couple of times in the lower part of the measured section. It is immediately recognized by the shape and few number of chambers in the last whorl. The chambers are known to range in the degree which they are elongated vertically, however here, they were short and of the standard funnel shape.

Stratigraphic distribution:

From *Rotalipora appenninica* zone (late Albian) to *Abathomphalus mayaroensis* zone (late Maastrichtian)

Occurrence:

NS-3 – NS-28

Family Globigerinelloididae LONGORIA, 1974

Subfamily Globigerinelloidinae LONGORIA, 1974

Genus *Globigerinelloides* CUSHMAN & TEN DAM, 1948

Type species: *Globigerinelloides algeriana* CUSHMAN & TEN DAM, 1948

Macroglobigerinelloides bentonensis MORROW, 1934

Pl. 21, fig. 1

Globigerinelloides bentonensis KELLER AND PARDO, 2004, p. 101, pl. 5, figs. 15 - 18.

Macroglobigerinelloides bollii LAMOLDA et al., 2007, p. 23, fig. 4 – C.

Diagnostic features:

7-9 chambers in the last whorl with a rapid increase in chamber size (sometimes creating an anomalously large last chamber), smooth wall texture.

Remarks:

In the measured section, *Macroglobigerinelloides bentonensis* occurs rarely. It is identified when a globigerinid form was found with a combination of smooth wall texture together with an abnormally shaped large last chamber.

Stratigraphic distribution:

From *Ticinella primula* zone (late Maastrichtian) to *Whiteinella archaeocretacea* (latest Cenomanian-earliest Turonian)

Occurrence:

NS-4 – NS-13

<p align="center">*Macroglobigerinelloides bollii* PESSAGNO, 1967</p>

<p align="center">Pl. 21, fig. 3-9; Pl. 22, fig. 15-19</p>

Macroglobigerinelloides bollii PETRIZZO, 2000, p. 499, fig. 10 – 1.

Macroglobigerinelloides bollii LAMOLDA *et al.*, 2007, p. 23, fig. 4 – A.

Macroglobigerinelloides bollii EGGER *et al.*, 2013, p. 107, fig. 11 – 6-10.

Diagnostic features:

6-7 chambers in the last whorl, slowly increasing chamber size, smooth wall texture.

Remarks:

Macroglobigerinelloides bollii is one of the most frequently occurring species in the measured section. It literally occurs through the whole middle to upper portion of the measured section. It is differentiated from other contemporaneous macroglobigerinelloids by its simple and well-defined morphological features. These are its pustule-free smooth texture, numerous globular chambers and low to moderate rate of chamber size increase.

Stratigraphic distribution:

From *Marginotruncana sigali   Dicarinella primitiva* zone (late Turonian) to *Gansserina gansseri* zone (latest Campanian-early Maastrichtian)

Occurrence:

NS-14 – NS-71

Macroglobigerinelloides messinae BRONNIMANN, 1952

Pl. 21, fig. 2

Macroglobigerinelloides messinae PREMOLI SILVA and VERGA, 2004, Pl. 85, 4-6.

Diagnostic features:

Small and compressed test, 4.5-5.5 chambers in the last whorl.

Remarks:

Macroglobigerinelloides messinae is distinguished from other macroglobigerinellids as *M. bolli*, *M. prairihillensis* and *M. bentonensis* by its fewer chambers and compressed test which makes it appear in hourglass shape in the lateral view.

Stratigraphic distribution:

From *Dicarinella asymetrica* zone (Santonian) to *Abathomphalus mayaroensis* zone (upper Maastrichtian)

Occurrence:

NS-41

Macroglobigerinelloides prairihillensis PESSAGNO, 1967

Pl. 21, fig. 10-12; Pl. 22, fig. 20-21

Macroglobigerinelloides prairihillensis PETRIZZO, 2000, p. 499, fig. 10 – 7.

Macroglobigerinelloides prairihillensis JAFF *et al.*, 2015. p. 130, pl. 4, figs. 9, 10.

Diagnostic features:

High rate of chamber size increase coupled with a laterally elongated large last chamber, 6-7 chambers in the last whorl, finely to normally muricate wall texture

Remarks:

Macroglobigerinelloides prairihillensis is a common species throughout the middle to upper portion of the measured section. In the samples, *M. prairihillensis* was always standing out with its distinctively large and laterally elongated last chamber and differentiated from other globigerinelloides by this trait.

Stratigraphic distribution:

From *Dicarinella asymetrica* zone (Santonian) to *Contusotruncana contusa-Racemiguembelina fructicosa* zone (middle Maastrichtian)

Occurrence:

NS-22 – NS-74

Superfamily Rotaliporacea SIGAL, 1958

Family Hedbergellidae LOEBLICH & TAPPAN, 1961

Subfamily Helvetoglobotruncaninae LAMOLDA, 1976

Genus *Helvetoglobotruncana* CARON et al., 1984

Type Species: *Helvetoglobotruncana helvetica* BOLLI, 1951

***Helvetoglobotruncana helvetica* BOLLI, 1951**

Pl. 9, fig. 1-2; Pl. 29, fig. 9-12

Helvetoglobotruncana helvetica PETRIZZO, 2000, fig. 12 – 5a-c.

Helvetoglobotruncana helvetica HUBER and PETRIZZO, 2014, fig. 4 – 1; fig. 11.

Diagnostic features:

Low trochospiral planoconvex test, single keel, petaloid and flattened chambers on spiral side, raised and beaded sutures on spiral side, adumbilically offset last chamber, deep and wide umbilical-extraumbilical aperture, 5-8 chambers in the last whorl.

Remarks:

Helvetoglobotruncana helvetica is differentiated from the similar *H. praehelvetica* by its well-developed pustulose keel, raised inner-whorl chambers relative to the final whorl chambers, petaloid and flattened spiral chambers with raised and curved sutures and finally by a last chamber that is offset towards the umbilical side.

Stratigraphic distribution:

From *Helvetoglobotruncana helvetica* zone (Turonian) to *Helvetoglobotruncana helvetica* zone (Turonian)

Occurrence:

NS-14

Genus *Muricohedbergella* HUBER & LECKIE, 2011

Type species: *Muricohedbergella delrioensis* CARSEY, 1926

Muricohedbergella delrioensis CARSEY, 1926

Pl. 19, fig. 14-15; Pl. 22, 8-10

Muricohedbergella delrioensis KELLER AND PARDO, 2004, p. 101, pl. 5, figs. 5 - 9.

Muricohedbergella delrioensis EGGER *et al*., 2013, p. 106, fig. 10 – 8, 9, 13.

Muricohedbergella delrioensis DIONNE *et al.*, 2016. p. 130, fig. 4, 6 - 8.

Diagnostic features:

Having fewer (5 - 6) and larger chambers in the last whorl compared to other species with globular chambers in this genus, often slightly offset last chamber towards the umbilical side.

Remarks:

This species stands out among the other contemporary muricohedbergellids with its fewer and inflated globular chambers. Moreover, its last chamber can often be observed as located towards the dorsal side. It occurs not very commonly in the measured section, but when it occurs it is present in the lower part of the section.

Stratigraphic distribution:

From *Muricohedbergella planispira* zone (early Albian) to *Dicarinella concavata* zone (latest Coniacian)

Occurrence:

NS-1 – NS-18

<p align="center">*Muricohedbergella flandrini* **PORTHAULT, 1970**</p>

<p align="center">Pl. 20, fig. 8-10; Pl. 21 fig. 6-7</p>

Muricohedbergella flandrini ARDESTANI *et al.*, 2012. p. 26, fig. 5 - 3.

Muricohedbergella flandrini EGGER et al., 2013, p. 106, fig. 10 – 10-12.

Muricohedbergella flandrini KALANAT et al., 2015, pl. 3, figs.19 - 21.

Diagnostic features:

Strongly compressed oval shape and few number (4.5-5) of chambers in the last whorl, very narrow umbilicus.

Remarks:

Muricohedbergella flandrini is a very abundant form in the lower part of the measured section. It is easily discernable with its characteristic chamber shape and remarkably compressed look in the side view. It ranges between small and large in size above the 125 μm sieve washed sample.

Stratigraphic distribution:

From *Helvetoglobotruncana helvetica* zone (early to middle Turonian) to *Dicarinella asymetrica* zone (Santonian)

Occurrence:

NS-16 – NS-40

Muricohedbergella holmdelensis OLSSON, 1964

Pl. 14, fig. 11-15, Pl. 22, fig. 11-12

Muricohedbergella holmdelensis PETRIZZO, 2000, p. 498, fig. 8 – 3.

Muricohedbergella holmdelensis BOUDAGHER-FADEL, 2012, p. 105, fig. 14 – 16.

Diagnostic features:

Planoconvex with tapering form of the last chamber in the edge view.

Remarks:

This species occurs starting from the lower part up to the end of the measured section. It is characterized by its high rate of chamber size increase, sometimes yielding a distinctively large last chamber, and moderate number (5-6) of chambers in the last whorl. However, it is only distinguished by its edge view which displays a marked planoconvexity and tapering shape of the last chamber.

Stratigraphic distribution:

From *Dicarinella concavata* (latest Turonian-Coniacian) to *Guembelitria cretacea* (earliest Danian) (Arz and Arenillas, 2016)

Occurrence:

NS-28 – NS-74

Muricohedbergella hoelzli OLSSON, 1964

Pl. 14, fig. 1-4

Muricohedbergella hoelzli PETRIZZO, 2000, p. 498, fig. 8 – 4.

Muricohedbergella hoelzli BOUDAGHER-FADEL, 2012, p. 105, fig. 19 – 21.

Diagnostic features:

Spiroconvex, globular chambers with moderately depressed sutures, with a low rate of size increase, 5-7 chambers in the last whorl, moderately muricate test

Remarks:

This rarely occurring species can be distinguished from *M. flandrini* by its smaller chambers and having more chambers in the last whorl. Its chambers are also petaloid in shape on both sides, contrary to *M. flandrini*'s oval/spatulate-shaped chambers. It is distinguished from *W. aprica* by its less depressed sutures and umbilical/extra-umbilical aperture.

Stratigraphic distribution:

From *Whiteinella archaeocretacea* (latest Cenomanian) to *Marginotruncana sigali-Dicarinella primitiva* (latest Turonian)

Occurrence:

NS-5

Muricohedbergella monmouthensis OLSSON, 1960

Pl. 22, fig. 2

Muricohedbergella monmouthensis PREMOLI SILVA and VERGA, 2004, Pl. 97, 1-4; Pl. 30, 9-10.

Diagnostic features:

Trochospiral and inequally biconvex test, globular chambers with strongly depressed sutures, high rate of chamber size increase, finely pustulose wall texture.

Remarks:

M. monmouthensis is observed once in the upper part of the section. The specimen is distinguished from planispira/nearly-planispiral muricohedbergellids as *M. planispira* and *M. holmdelensis* by its trochospiral. It differs from *M. flandrini* in having perfectly globular chambers. Moreover, *M. monmouthensis* has a more finely pustulose wall texture compared to whiteinellids.

Stratigraphic distribution:

From *Globotruncana ventricosa* (middle Campanian) to *Abathomphalus mayaroensis* (upper Maastrichtian)

Occurrence:

NS-66

Muricohedbergella planispira TAPPAN, 1940

Pl. 14, fig. 6-10; Pl. 22, fig. 3- 4

Muricohedbergella planispira KELLER AND PARDO, 2004, p. 102, pl. 6, figs. 1 - 5.

Muricohedbergella planispira EGGER et al., 2013, p. 107, fig. 11 – 1, 2.

Muricohedbergella planispira DIONNE *et al.*, 2016. p. 130, fig. 4, 9 - 10.

Muricohedbergella planispira FALZONI et al., 2016, p. 88, fig. 12 – 6.

Diagnostic features:

Perfectly planispiral 5-7 chambers in the last whorl with almost the same size.

Remarks:

Muricohedbergella planispira is a very common form up to the middle part of the measured section. Although it displays a range of differentiation of total size and rate of chamber size increase, it still can be easily identified among the other muricohedbergellids with being perfectly planispiral, its having generally more chambers and not showing a high (mostly none) rate of chamber size increase.

Stratigraphic distribution:

From *Muricohedbergella planispira* zone (early Albian) to *Globotruncanita elevata* zone (early Campanian)

Occurrence:

NS-1 – NS-45

Genus *Whiteinella* PESSAGNO, 1967

Type species: *Whiteinella archaeocretacea*

Whiteinella aprica LOEBLICH and TAPPAN, 1961

Pl. 29; fig. 3

Whiteinella aprica KELLER AND PARDO, 2004, p. 100, pl. 4, figs. 5, 6, 9.

Whiteinella aprica DIONNE *et al.*, 2016. p. 131, fig. 5, 1 - 3.

Diagnostic features:

Planoconvex, inflated globular chambers on both sides with a low rate of size increase and strongly depressed sutures, 5.5-6 chambers in the last whorl, coarsely hispid wall texture.

Remarks:

Whiteinella aprica specimens are identified in the lower part of the measured section. It is distinguished from muricohedbergellids by its strongly depressed sutures, globular chambers, characteristic whitenellid wall texture and umbilical aperture.

Stratigraphic distribution:

From *Dicarinella algeriana* subzone (middle to late Cenomanian) to *Dicarinella concavata* zone (latest Turonian)

Occurrence:

NS-5 – NS-14

Whiteinella archaeocretacea **PESSAGNO, 1967**

Pl. 29, fig. 4, 5

Whiteinella archaeocretacea KELLER AND PARDO, 2004, p. 100, pl. 4, figs. 1, 2.

Whiteinella archaeocretacea LAMOLDA et al., 2007, p. 24, fig. 5 – L.

Whiteinella archaeocretacea KALANAT et al., 2015, pl. 3, figs. 10 - 12.

Whiteinella archaeocretacea FALZONI *et al.*, 2014. p. 101, fig. 11 – 6.

Diagnostic features:

Low spire, strongly depressed sutures on both sides, 5-6 chambers in the last whorl with a compressed last chamber, large umbilical/extraumbilical aperture.

Remarks:

Whiteinella archaeocretacea is observed rarely in the middle portion of the measured section. It differs from *W. aprica* in having more compressed chambers in general and mostly a smaller number of chambers in the last whorl. On the other hand, this species is distinguished from *W. inornata* by having not as compressed chambers as the latter and more chambers in the last whorl.

Stratigraphic distribution:

From *Whiteinella archaeocretacea* zone (latest Cenomanian) to *Dicarinella concavata* zone (latest Turonian)

Occurrence:

NS-2 – NS-16

Whiteinella baltica DOUGLAS and RANKIN, 1969

Pl. 19, fig. 1-11; Pl. 29, fig. 1-2

Whiteinella baltica KELLER AND PARDO, 2004, p. 99, pl. 3, figs. 12 – 14, 14, 16.

Whiteinella baltica EGGER et al., 2013, p. 106, fig. 10 – 1-3.

Whiteinella baltica KALANAT et al., 2015, pl. 1, figs. 13 - 15.

Diagnostic features:

Equally biconvex trochospiral test with a characteristic quadrate test outline, four chambers in the last whorl.

Remarks:

Whiteinella baltica is one of the most abundant species in the measured section, it occurs from the lower to middle parts of the measured section. The moderately muricate or pustulose wall texture coupled with four perfectly globular chambers with a high rate of size increase coiled in a low trochospire summarizes the morphology of *W. baltica*. Furthermore, it has a large interiomarginal, umbilical-extraumbilical aperture and, if observable, this aperture is covered with a large porticus. It is easily distinguished from other whitenellids with these characteristic properties.

Stratigraphic distribution:

From *Rotalipora greenhornensis* subzone (middle Cenomanian) to *Dicarinella asymetrica* (Santonian)

Occurrence:

NS-2 – NS-53

Whiteinella brittonensis TAPPAN, 1961

Pl. 19, fig. 12-13

Diagnostic features:

Moderately high trochospiral spiroconvex test, muricate wall texture, 5-6 chambers in the last whorl.

Remarks:

Whiteinella brittonensis is distinguished from other whiteinellids by its higher trochospiral (except for *Whiteinella paradubia*). It also has more chambers than *W. baltica*.

Stratigraphic distribution:

From *Dicarinella algeriana* subzone (late Cenomanian) to *Dicarinella concavata* (Coniacian)

Occurrence:

NS-14 – NS-38

Whiteinella paradubia SIGAL, 1952

Pl. 29, fig. 6-8

Diagnostic features:

High trochospiral spiroconvex test, moderately pustulose wall texture, 6 chambers in the last whorl, wide and shallow aperture.

Remarks:

Whiteinella paradubia is frequently observed in the lowermost part of the measured stratigraphic section. It is distinguished from other whiteinellids by its distinctively high trochospire.

Stratigraphic distribution:

From *Dicarinella algeriana* subzone (late Cenomanian) to *Dicarinella concavata* (Coniacian)

Occurrence:

NS-1 – NS-17

Whiteinella praehelvetica TRUJILLO, 1960

Pl. 9, fig. 3-6; Pl. 29, fig. 13-14

Whiteinella praehelvetica PETRIZZO, 2000, fig. 12 – 4a-c.

Helvetoglobotruncana praehelvetica HUBER and PETRIZZO, 2014, fig. 4 – 2, 3; fig. 10.

Helvetoglobotruncana praehelvetica VAHIDINIA et al., 2014, pl. 3, fig. 9.

Helvetoglobotruncana praehelvetica FALZONI et al., 2016, fig. 5, 11A-C.

Diagnostic features:

Low to middle conically trochospiral spiroconvex test, petaloid and inflated chambers on spiral side, depressed sutures on both sides, deep and wide interiomarginal aperture, 5-6 chambers in the last whorl, moderately pustulose wall texture.

Remarks:

H. praehelvetica occurs before *H. helvetica* in the measured geological section. It can be said to be a more primitive version of the latter in that it lacks a keel and a non-umbilical aperture unlike globotruncanids additional to its having a lumpy texture.

Stratigraphic distribution:

From *Rotalipora cushmani* zone (late Cenomanian) to *Helvetoglobotruncana helvetica* zone (Turonian)

Occurrence:

NS-14

<center>**Genus *Costellagerina* EL-NAKHAL, and CIFELLI, 1983**</center>

<center>Type species: *Rugoglobigerina bulbosa* Belford, 1960</center>

<center>***Costellagerina bulbosa* PETTERS, EL-NAKHAL, and CIFELLI, 1983**</center>

<center>Pl. 1, fig. 5-17</center>

Costellagerina bulbosa PETRIZZO, 2000, p. 501, fig. 14 – 3.

Costellagerina bulbosa ARDESTANI *et al.*, 2012. p. 24, fig. 3 - 2.

Costellagerina bulbosa FALZONI *et al.*, 2014. p. 101, fig. 11 – 2, 4.

Diagnostic features:

Globular shaped 4-5 chambers in the last whorl, aligned and fused single pustules into short ridges forming thin and discontinuous costae.

Remarks:

In some cases, *Costellagerina bulbosa* can resemble *R. rugosa* very much. This is the major problem in the identification of this species, where these occur together especially in the middle part of the measured section. This problem arises due to the high variability of the meridional ornamentation, the umbilical structure, and the presence of an imperforate peripheral band which can be observed in rugoglobigerinids. This issue can be overcome by firstly examining the wall texture of the specimen in detail. In *Costellagerina*, the meridional ornamentation is formed by the alignment of single pustules plus few pustules fused into short ridges so that costae are thin and discontinuous (Petrizzo and Premoli-Silva, 2000). Secondly, if the aperture is well-preserved and not infilled, then the presence of portici and tegilla should be checked. *Costellagerina* species possess only portici. Although the problematic discrimination between the genera

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Rugoglobigerina and *Costellagerina* is further revealed by the fact that the extinction level of the *Costellagerina* species has not been precisely established (Petrizzo and Premoli Silva, 2000; Premoli Silva and Verga, 2004), with a somewhat rough generalization, the pre-Middle Campanian meridionally costellate hedbergellids are most of the time *Costellagerina*.

Stratigraphic distribution:

From *Dicarinella asymetrica* (Santonian) to *Globotruncanita elevata* (early Campanian)

Occurrence:

NS-35 – NS-53

Costellagerina pilula **BELFORD, 1960**

Pl. 1, fig. 1-4

Costellagerina pilula LAMOLDA *et al.*, 2007, p. 24, fig. 5 – I, J.

Costellagerina pilula ARDESTANI *et al.*, 2012. p. 24, fig. 3 - 1.

Costellagerina pilula FALZONI *et al.*, 2014. p. 101, fig. 11 – 1, 3.

Costellagerina pilula LAMOLDA *et al.*, 2014. fig. 11 – H.

Diagnostic features:

Aligned and fused single pustules into short ridges forming thin and discontinuous costae, globular shaped chambers, moderate number (5-6) of chambers in the last whorl.

Remarks:

Costellagerina pilula stands out with its texture at first. But again, its occurrence together with rugoglobigerinids and *C. bulbosa* can pose serious identification problems. As stated just previously, the difference between *C. pilula* and rugoglobigerinids lie in its having a porticus instead of tegillum and a different arrangement (discontinuous and short) and

thickness (thinner) of the meridional costae. More specifically, based on the observation of the morphological variability of *C. pilula* during the Santonian and of *R. rugosa* in the upper Campanian-Maastrichtian, the chamber growth rate can be used as a criterion (Falzoni et al., 2014). This rate is slower in *C. pilula*. This observation is consistent with test dissections illustrated by Huber (1994) showing that early growth rate in the topotypes of *C. pilula* is slower than in topotypes of *R. rugosa* and, thus they are likely not phyletically related. Moreover, the inner whorl in *C. pilula* is raised on spiral view, whereas it tends to be more depressed in *R. rugosa*. When it comes to discriminate between two costellagerinid species *C. bulbosa* and *C. pilula*, a difference in the number of chambers is evident at first. *C. pilula* has more numerous chambers as well as having a clearly noticable lower rate of chamber size increase. Moreover, these two species are not known to produce intermediate morphotypes (Petrizzo, 2000), whose presence can be very problematic. Thus they are reported to have sufficient differences for being kept as two separate forms even if they exhibit the same stratigraphic range (Petrizzo and Premoli-Silva, 2000).

Stratigraphic distribution:

From *Dicarinella asymetrica* (Santonian) to *Globotruncanita elevata* (early Campanian)

Occurrence:

NS-30 – NS-53

Superfamily HETEROHELICACEA CUSHMAN, 1927

Family HETEROHELICIDAE CUSHMAN, 1927

Subfamily HETEROHELICINAE CUSHMAN, 1927

Genus *Heterohelix* EHRENBERG, 1843

Type species: *Textularia americana* EHRENBERG, 1843

Heterohelix globulosa EHRENBERG, 1840

Pl. 11, fig. 1-6; Pl. 26, fig. 1-11

Heterohelix striata ARDESTANI *et al.*, 2012. p. 27, fig. 6 - 3.

Heterohelix striata JAFF *et al.*, 2015. p. 132, pl. 5, fig. 10.

Heterohelix globulosa JAFF *et al.*, 2015. p. 132, pl. 5, figs. 6, 7.

Heterohelix globulosa DIONNE *et al.*, 2016. p. 130, fig. 4, 1 - 3.

Diagnostic features:

Depressed and slightly curved sutures, globular shaped moderately enlarging 11-15 chambers, fine costae.

Remarks:

Heterohelix globulosa is one of the mostly occurring species in the measured section. It has a quite simple morphology making its identification very easy. Its rate of chamber size increase may range between moderate to high and test size also ranges between 100-200 microns. But it is always cone shaped, has globular chambers and finely striated all over the test.

Stratigraphic distribution:

From *Helvetoglobotruncana helvetica* (early to middle Turonian) to *Abathomphalus mayaroensis* (latest Maastrichtian)

Occurrence:

NS-14 – NS-74

Heterohelix planata CUSHMAN, 1938

Pl. 10, fig. 1-5

Heterohelix planata PETRIZZO, 2000, p. 500, fig. 11 – 5.

Heterohelix planata, GEORGESCU, 2006, p. 107, fig. 4 – 4, 5.

Heterohelix planata EGGER *et al.*, 2013, p. 109, fig. 13 – 7-15.

Diagnostic features:

Rapidly flaring subtriangular shaped compressed test with subrectangular – reniform chambers, depressed triangular areas in the adult part, straight and depressed sutures slightly oblique to the growth axis, possible presence or absence of an incipient planispiral coil in the juvenile stage, fine costae.

Remarks:

Heterohelix planata is identified in the upper part of the measured section. It occurs mostly as a large test which has well-developed reniform chambers in the adult stage. Its another characteristic feature is the depressed area in the latest parts of the adult portion along the median suture. Finally, if observable, the semi-developed planispirally coiled part at the bottom of the test can be a very important clue in the identification of this species. If the test is not well preserved, than the roundness at the juvenile stage of the test, instead of a pointed end, would signal the planispiral coiling at the beginning.

Stratigraphic distribution:

From *Dicarinella asymetrica* (late Santonian) to *Abathomphalus mayaroensis* (latest Maastrichtian)

Occurrence:

NS-41 – NS-69

Heterohelix punctulata CUSHMAN, 1938

Pl. 10, fig. 6-8

Heterohelix punctulata NEDERBRAGT, 1991, p. 349, pl. 3, fig. 6.

Heterohelix punctulata ABRAMOVICH *et al.*, 2003, p. 6, pl. 1, fig. 9; p. 8, pl. 2, fig. 5.

Heterohelix punctulata PREMOLI-SILVA and VERGA, 2004, p. 143, pl. 73, figs. 1-5; p. 253, pl. 23, fig. 5.

Diagnostic features:

Broad rounded and long test, very rapid flaring of chambers in the initial part of the test, subparalleling globular chamber growth in the remaining part, fine costae.

Remarks:

Heterohelix punctulata occurs frequently from the middle to uppermost part of the measured section. Its long and rectangular-shaped (except for the initial part) test resulting from subparalleling globular chamber growth quickly draws attention and gives *H. punctulata* a unique appearance.

Stratigraphic distribution:

From *Dicarinella asymetrica* (late Santonian) to *Abathomphalus mayaroensis* (latest Maastrichtian)

Occurrence:

NS-30 – NS-75

Heterohelix **sp. 1**

Pl. 10, fig. 9-10

Diagnostic features:

Moderately flaring compressed test, initially globular chambers becoming more reniform shaped in the remaining part, low rate of chamber size increase, depressed sutures, fine costae.

Remarks:

Heterohelix sp. 1 is present in the middle part of the measured section. It is different than *H. planata* in having broader and fewer chambers. It is not as rectangular-shaped as *Pseudotextularia nuttalli* is both in lateral and side views. It is also distinguished by genus *Sigalia* by its non-petaloid reniform-shaped chambers.

Stratigraphic distribution:

Globotruncanita elevata (lower Campanian)

Occurrence:

NS-41

Heterohelix **sp. 2**

Pl. 10, fig. 11-14

Diagnostic features:

Triangular-shaped test, initially globular chambers becoming more reniform shaped in the remaining part, high rate of chamber size increase, depressed sutures, fine costae.

Remarks:

Heterohelix sp. 2 is present in the middle part of the measured section. It is different than *H. planata* which has a compressed test, in having a thick one. It also has a larger flare than other contemporaneous heterohelicids.

Stratigraphic distribution:

From *Globotruncanita elevata* (lower Campanian) to *Globotruncanella* spp. (middle to upper Campanian)

Occurrence:

NS-41 – NS-53

Genus *Laeviheterohelix* NEDERBRAGT, 1991

Type species: *Gumbelina pulchra* BROTZEN, 1936

Laeviheterohelix turgida, NEDERBRAGT, 1991

Pl. 12, fig. 1-4; Pl. 26, fig. 12

Laeviheterohelix turgida, GEORGESCU, 2006, p. 107, fig. 4 – 21.

Diagnostic features:

Subglobular juvenile chambers becoming more reniform in the adult stage, inflated chambers, strongly depressed sutures (deepest near the median suture), pinched edges, pore mounds on the test wall, thick flanges at the aperture.

Remarks:

Laeviheterohelix turgida is observed from middle to upper parts in the measured section. As all other, *Laeviheterohelix* specimens are not well preserved and thus, the texture cannot be confidently used as a criterion for their identification. Fortunately, *L. turgida* has characteristic strongly inflated reniform chambers with depressions between them as

well as pinched edges and thick flanges (the last two are not always observable though). These make its identification possible among other congener species.

Stratigraphic distribution:

From *Dicarinella asymetrica* (early Santonian) to *Globotruncanita elevata* (early Campanian)

Occurrence:

NS-14 – NS-45

Laeviheterohelix sp. 1

Pl. 12, fig. 5-8; Pl. 26, fig. 13

Diagnostic features:

Overlapping reniform chambers, moderately depressed sutures, pore mounds, smooth texture, flanges may be present at the aperture.

Remarks:

Laeviheterohelix sp. 1 is observed in the middle part of the section. It is differentiated from other laeviheterohelicids by its distinctively more robust test.

Stratigraphic distribution:

G. elevata-D. asymetrica (middle to late Santonian)

Occurrence:

NS-31 – NS-32

<div align="center">**Genus *Ventilabrella* CUSHMAN, 1928**</div>

<div align="center">Type species: *Ventilabrella eggeri* CUSHMAN, 1928</div>

<div align="center">***Ventilabrella browni* MARTIN, 1972**</div>

<div align="center">Pl. 18, figs. 1-4</div>

Ventilabrella browni BOUDAGHER-FADEL, 2012, p. 110, pl. 4.19 – 31.

Diagnostic features:

High proliferation, flabelliform compressed test, a numerous chambered test with 6-8 subglobular chambers in the biserial portion and up to 10 subglobular to pyriform chambers in the multiserial portion, thick to fine costae from lower to upper part of the test.

Remarks:

Ventilabrella browni occurs in the middle portion of the measured section. It is the *Ventilabrella* species having the highest number of chambers in among all *Ventilabrella* specimens. It is noticably thinner/more compressed than the thick *Ventilabrella* species *V. eggeri* and *V. austinana*.

Stratigraphic distribution:

From *Globotruncana ventricosa* (middle Campanian) to *Abathomphalus mayaroensis* (latest Maastrichtian)

Occurrence:

NS-40 – NS-52

Ventilabrella eggeri CUSHMAN, 1928

Pl. 18, figs. 5-7

Ventilabrella eggeri PETRIZZO, 2000, p. 500, fig. 11 – 10.

Ventilabrella eggeri, GEORGESCU, 2006, p. 109, fig. 5 – 1-6.

Ventilabrella browni BOUDAGHER-FADEL, 2012, p. 110, pl. 4.19 – 9-11.

Ventilabrella eggeri, ELAMRI and ZAGHBIB-TURKI, 2014, p. 195, fig. 8 – 8.

Diagnostic features:

Moderate proliferation, globular chambers, thick costae.

Remarks:

Ventilabrella eggeri is the most frequently occurring *Ventilabrella* species in the measured section. It stands out among its congeners with its thickly costate texture at first. It is neither as proliferating and compressed as *V. browni*, nor has as globular chambers and fine costae as *V. austinana* does.

Stratigraphic distribution:

From *Dicarinella concavata* (latest Coniacian) to *Globotruncana ventricosa* (middle Campanian)

Occurrence:

NS-40 – NS-53

Genus *Pseudotextularia* RZEHAK, 1891

Type species: *Cuneolina elegans* RZEHAK, 1891

Pseudotextularia nuttalli VOORWIJK, 1937

Pl. 11, fig. 7-11

Pseudotextularia nuttalli LAMOLDA et al., 2007. p. 28, figs 4N1-2, O1-2.

Pseudotextularia nuttalli EGGER et al., 2013, p. 108, fig. 12 – 5-7.

Diagnostic features:

Low flaring angle of the test, wide and elongate chambers in the edge view, fine costae.

Remarks:

Being one of the most common planktonic foraminifera species in the measured section, *Pseudotextularia nuttalli* occurs from the recorded lower portion up to the end of measured section. The lateral elongation of the chambers can reach extreme levels in some specimens, so this species is primarily identified by its appearance in the edge view. Moreover, it is differentiated from the very similar *P. elegans* by its much finer costae.

Stratigraphic distribution:

From *Dicarinella concavata* (middle Coniacian) to *Abathomphalus mayaroensis* (latest Maastrichtian)

Occurrence:

NS-14 – NS-75

Genus *Sigalia* REISS, 1957

Type species: *Guembelina deflaensis* SIGAL, 1952

Sigalia carpatica SALAJ and SAMUEL, 1963

Pl. 17, fig. 5

Sigalia carpatica LAMOLDA et al., 2007, p. 23, fig. 4 – P, S.

Sigalia carpatica EGGER et al., 2013, p. 108, fig. 12 – 1, 2.

Sigalia carpatica FALZONI et al., 2013, p. 17, fig. 2 – 2.

Sigalia carpatica LAMOLDA et al., 2014, fig. 11 – A, C.

Diagnostic features:

Biserial test, petaloid chambers, raised and beaded sutures, smooth wall texture in between sutures.

Remarks:

Sigalia carpatica is observed in the middle part of the measured section. It is differentiated from the sister species *S. deflansis* by having a smooth texture between its raised and beaded sutures.

Stratigraphic distribution:

From *Dicarinella concavata* (middle Coniacian) to *Dicarinella asymetrica* (early Santonian)

Occurrence:

NS-36

Sigalia deflaensis SIGAL, 1952

Pl. 17, fig. 1-4

Sigalia deflaensis LAMOLDA *et al.*, 2007, p. 23, fig. 4 – Q, R.

Sigalia deflaensis EGGER *et al.*, 2013, p. 107, fig. 11 – 15; p. 108, fig. 12 – 15, 16.

Diagnostic features:

Biserial test, petaloid chambers, depressed sutures, costate wall texture.

Remarks:

Sigalia deflaensis occurs abundantly in the middle part of the measured section. This species differs from *V. eggeri* in its rounded shoulders on the last two chambers with raised sutures along the earlier chambers. Finally, it is differentiated from *S. carpatica* by having a costate wall texture.

Stratigraphic distribution:

From *Dicarinella concavata* (middle Coniacian) to *Dicarinella asymetrica* (late Santonian)

Occurrence:

NS-25 – NS-38

CHAPTER 6

6. DISSCUSSIONS AND CONCLUSIONS

Near the Alagöz Village, Polatlı (Ankara, Turkey), a 93.5 m thick lower Upper Cretaceous stratigraphic section composed of limestones and shales was measured and 75 samples were collected. This section comprised Cenomanian of the Akkaya Formation, Turonian and Santonian of the Kocatepe Formation and Campanian of the Haymana Formation. The primary aim of this thesis study has been to establish a reliable biostratigraphic framework for this extensive interval in the Haymana-Polatlı Basin, which was not studied in detail previously in terms of biostratigraphy.

To this end, washed samples and thin sections of the samples were examined at first. As a result, 80 planktonic foraminifera species belonging to 23 different genera and 6 different families have been identified and their first and last occurrences have been established. These species were assigned to families *Globotruncanidae*, *Globigerinelloidae*, *Rugoglobigerinidae*, *Schakoinidae*, *Hedbergellidae* and *Heterohelix*; to genera *Helvetoglobotruncana*, *Rotalipora*, *Praeglobotruncana*, *Dicarinella*, *Costellagerina*, *Whiteinella*, *Macroglobigerinelloides*, *Muricohedbergella*, *Marginotruncana*, *Archaeoglobigerina*, *Schakoina*, *Contusotruncana*, *Globotruncana*, *Globotruncanita*, *Globotruncanella*, *Rugoglobigerina*, *Rugotruncana*, *Heterohelix*, *Laeviheterohelix*, *Pseudotextularia*, *Sigalia*, *Ventilabrella* and *Gansserina*. Accordingly, 9 biozones and 2 subzones have been defined in the Cenomanian, Turonian, Santonian and Campanian stages. These biozones are *Rotalipora cushmani* (Middle to Upper Cenomanian)-*Dicarinella algeriana* (Upper Cenomanian), *Whiteinella archaeocretacea* (Upper Cenomanian-Lower Turonian), *Helvetoglobotruncana helvetica* (Turonian),

Dicarinella asymetrica (Santonian) - *Globotruncanita elevata- Dicarinella asymetrica* (Middle to Upper Santonian), *Globotruncanita elevata* (Lower Campanian), *Globotruncana ventricosa* (Middle Campanian), *Globotruncanella* spp. (Upper Campanian), *Globotruncana aegyptiaca* (Upper Campanian) and *Gansserina gansseri* (Uppermost Campanian).

In the second phase of this study, a sedimentological investigation was conducted on the samples to gain insight on the depositional history of the measured section. Although this analysis cannot directly indicate any stage boundary, it was useful in determining especially the Cenomanian-Turonian transition with the occurrence of black shales at this level. This analysis yielded 8 microfacies types which namely were Planktonic Foraminiferal Packstone, Radiolarian Packstone, Packstone with Planktonic Foraminifera and Radiolaria, Radiolaria-bearing Spiculite Packstone, Planktonic Foraminiferal Wackestone, Wackestone with Planktonic Foraminifera and Radiolaria, Silty Wackestone-Mudstone with Planktonic Foraminifera and Wackestone-Mudstone. These microfacies types were described and interpreted across time; no significant change in the depositional environment was detected. It was hypothesized to change between toe-of-slope, deep shelf and deep basin on a rimmed carbonate platform model, whereas it ranged between mid-ramp, outer-ramp and basin on a homoclinal carbonate ramp model.

Combining the results of biostratigraphical and sedimentological analyses, two stage boundaries in the Upper Cretaceous were explicitly defined in this study. These are the Cenomanian-Turonian (C/T) boundary and the Santonian-Campanian (S/C) boundary.

The Cenomanian-Turonian boundary is placed at the lowest occurrence of the marker species *Helvetoglobotruncana helvetica*. There is no major lithology change at this proposed boundary; dark grey shale and clayey limestones below and light brown limestones above the boundary are found in the measured stratigraphic section. The characteristic fossil-barren black/dark grey shales at the Cenomanian-Turonian boundary corresponding to the Oceanic Anoxic Event 2 (OAE2) was also clearly observed in the results of both washed samples and thin section of the samples. In sample NS-13 on top

of which the C/T Boundary is delineated, the lithology is dark grey and contains only the opportunist species *Muricohedbergella delrioensis*, *Macroglobigerinelloides planispira*, *Macroglobigerinelloides sp.* and *Whiteinella baltica* and abundant radiolaria. First occurrence of *Helvetoglobotruncana helvetica* in sample NS-14 is a global proof for the already occurred onset of the stage Turonian.

Planktonic foraminiferal data regarding latest Turonian, Coniacian and earliest Santonian were not found in the measured stratigraphic section. This absence between early Turonian and early Santonian was observed to be coincident with a major lithological boundary between very hard greenish to grey limestones below and relatively softer red limestones and shales above. This finding has been found totally compatible with the Okay and Altıner's studies (2016, 2017) regarding the geology of the study area. These suggest that olistostromal units of pre-Santonian age in the Ankara region are unconformably overlain by red Middle to Upper Santonian pelagic limestones. In this sense, the results of this study also support the interpretation that the Jurassic-Cretaceous succession of the Sakarya Zone were transferred to debris flows in the Coniacian as the subduction was taking place in the Pontides and this episode of olistostrome formation and recycling occurring until the colliding end, was followed by normal forearc deposition back again in the Santonian.

A stratigraphic discontinuity has not been detected throughout the Santonian-Campanian succession which correspond to the thickest portion in the section. Therefore, the boundary between these two stages could be studied in the most detail. The main bioevents marking this boundary are the appearance of the planktonic foraminifera *Globotruncanita elevata*, the disappearance of the planktonic foraminifera *Dicarinella asymetrica* together with the genera *Dicarinella*, *Marginotruncana*, *Sigalia*, the species *Muricohedbergella flandrini* and/or presence of concurrent range zone of *G. elevata* and *D. asymetrica*, all of which were detected in this study (see Subsection 4.3 for details). The extinction of *Muricohedbergella flandrini* slightly after the proposed boundary (at NS-38) after its almost complete occurrence between NS-16 – NS-40, is thought to perhaps suggest a longer stratigraphic range for this species. Lithologically, the S/C boundary falls exactly

at the transition where the red Santonian limestones are followed by the light brown Campanian shales. The transition has been observed to be conformable.

The last boundary between Campanian-Maastrichtian was not clearly observed, however it has been envisaged to be close to the end of the measured stratigraphic section as signaled by the first occurrences of *Globotruncanita pettersi* (NS-64), *Globotruncanita angulata* (NS-68) and *Gansserina gansseri* (NS-75).

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APPENDIX

PLATE 1

Scale bar = 100 µm

Figure 1: *Costellagerina pilula* BELFORD, sample no. NS 30, *G. elevata-D. asymetrica* concurrent range subzone, spiral view

Figure 2: *Costellagerina pilula* BELFORD, sample no. NS 30, *G. elevata-D. asymetrica* concurrent range subzone, spiral view

Figure 3: *Costellagerina pilula* BELFORD, and CIFELLI, sample no. NS 41, *G. elevata* zone, spiral view

Figure 4: *Costellagerina pilula* BELFORD, sample no. NS 41, *G. elevata* zone, spiral view

Figure 5: *Costellagerina bulbosa* S. W. PETTERS, EL-NAKHAL, and CIFELLI, sample no. NS 41, *G. elevata* zone, spiral view

Figure 6: *Costellagerina bulbosa* S. W. PETTERS, EL-NAKHAL, and CIFELLI, sample no. NS 44, *G. elevata* zone, spiral view

Figure 7: *Costellagerina bulbosa* S. W. PETTERS, EL-NAKHAL, and CIFELLI, sample no. NS 41, *G. elevata* zone, spiral view

Figure 8: *Costellagerina bulbosa* S. W. PETTERS, EL-NAKHAL, and CIFELLI, sample no. NS 41, *G. elevata* zone, spiral view

Figure 9: *Costellagerina bulbosa* S. W. PETTERS, EL-NAKHAL, and CIFELLI, sample no. NS 44, *G. elevata* zone, spiral view

Figure 10: *Costellagerina bulbosa* S. W. PETTERS, EL-NAKHAL, and CIFELLI, sample no. NS 44, *G. elevata* zone, spiral view

Figure 11: *Costellagerina bulbosa* S. W. PETTERS, EL-NAKHAL, and CIFELLI, sample no. NS 44, *G. elevata* zone, spiral view

Figure 12: *Costellagerina bulbosa* S. W. PETTERS, EL-NAKHAL, and CIFELLI, sample no. NS 46, *G. elevata* zone, spiral view

Figure 13: *Costellagerina bulbosa* S. W. PETTERS, EL-NAKHAL, and CIFELLI, sample no. NS 46, *G. elevata* zone, spiral view

Figure 14: *Costellagerina bulbosa* S. W. PETTERS, EL-NAKHAL, sample no. NS 40, *G. elevata* zone, umbilical view

Figure 15: *Costellagerina bulbosa* S. W. PETTERS, EL-NAKHAL, sample no. NS 41, *G. elevata* zone, umbilical view

Figure 16: *Costellagerina bulbosa* S. W. PETTERS, EL-NAKHAL, sample no. NS 40, *G. elevata* zone, lateral view

Figure 17: *Costellagerina bulbosa* S. W. PETTERS, EL-NAKHAL, sample no. NS 41, *G. elevata* zone, lateral view
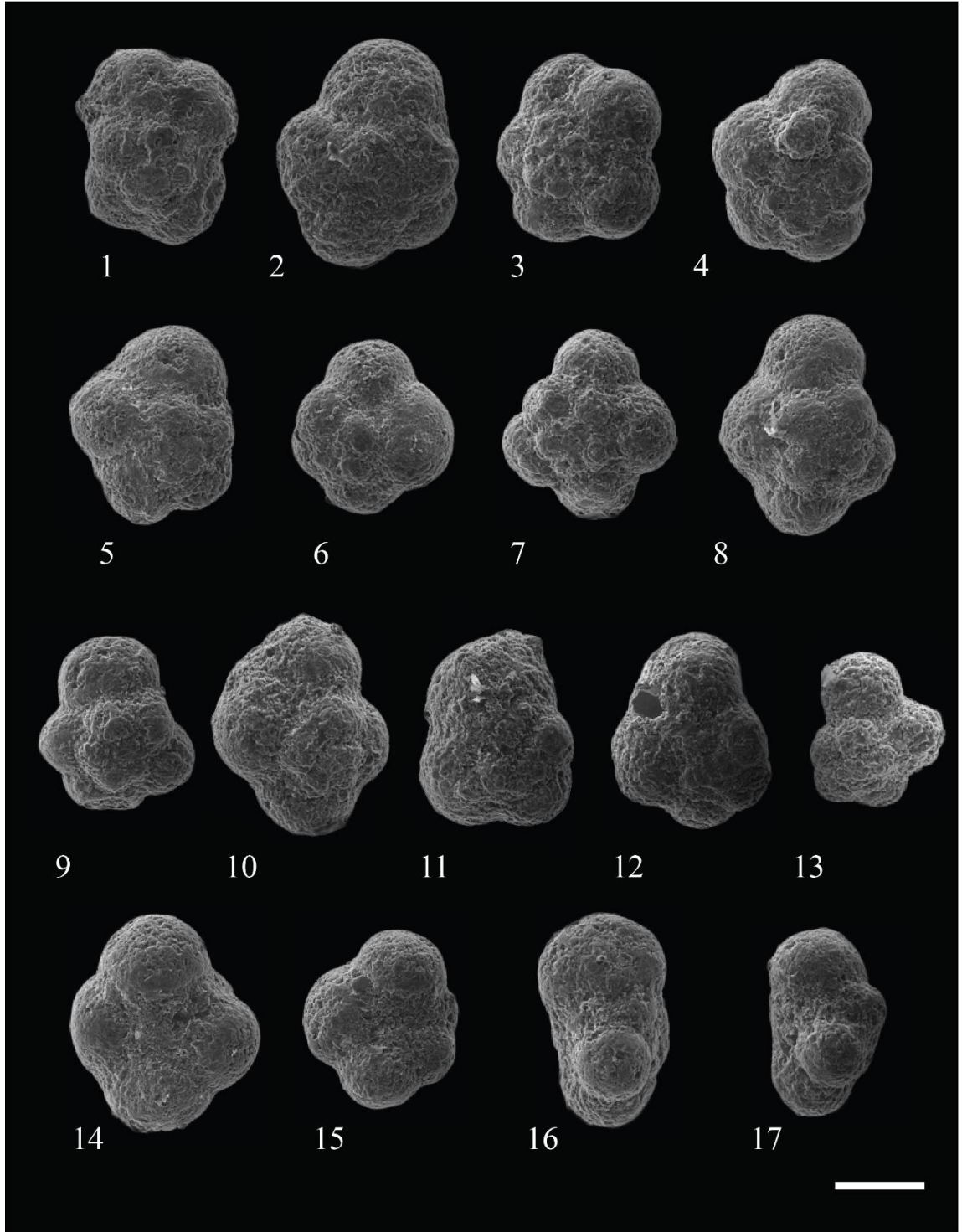
PLATE 2

Scale bar = 100 µm

Figure 1: *Contusotruncana fornicata* PLUMMER, sample no. NS 40, *G. elevata* zone, spiral view

Figure 2: *Contusotruncana fornicata* PLUMMER, sample no. NS 55, *Globotruncanella* spp. zone, spiral view

Figure 3: *Contusotruncana fornicata* PLUMMER, sample no. NS 73, *G. aegyptiaca* zone, spiral view

Figure 4: *Contusotruncana fornicata* PLUMMER, sample no. NS 40, *G. elevata* zone, umbilical view

Figure 5: *Contusotruncana fornicata* PLUMMER, sample no. NS 53, *Globotruncanella* spp. zone, lateral view

Figure 6: *Contusotruncana* cf. *plummerae* GANDOLFI, sample no. NS 50, *G. ventricosa* zone, lateral view
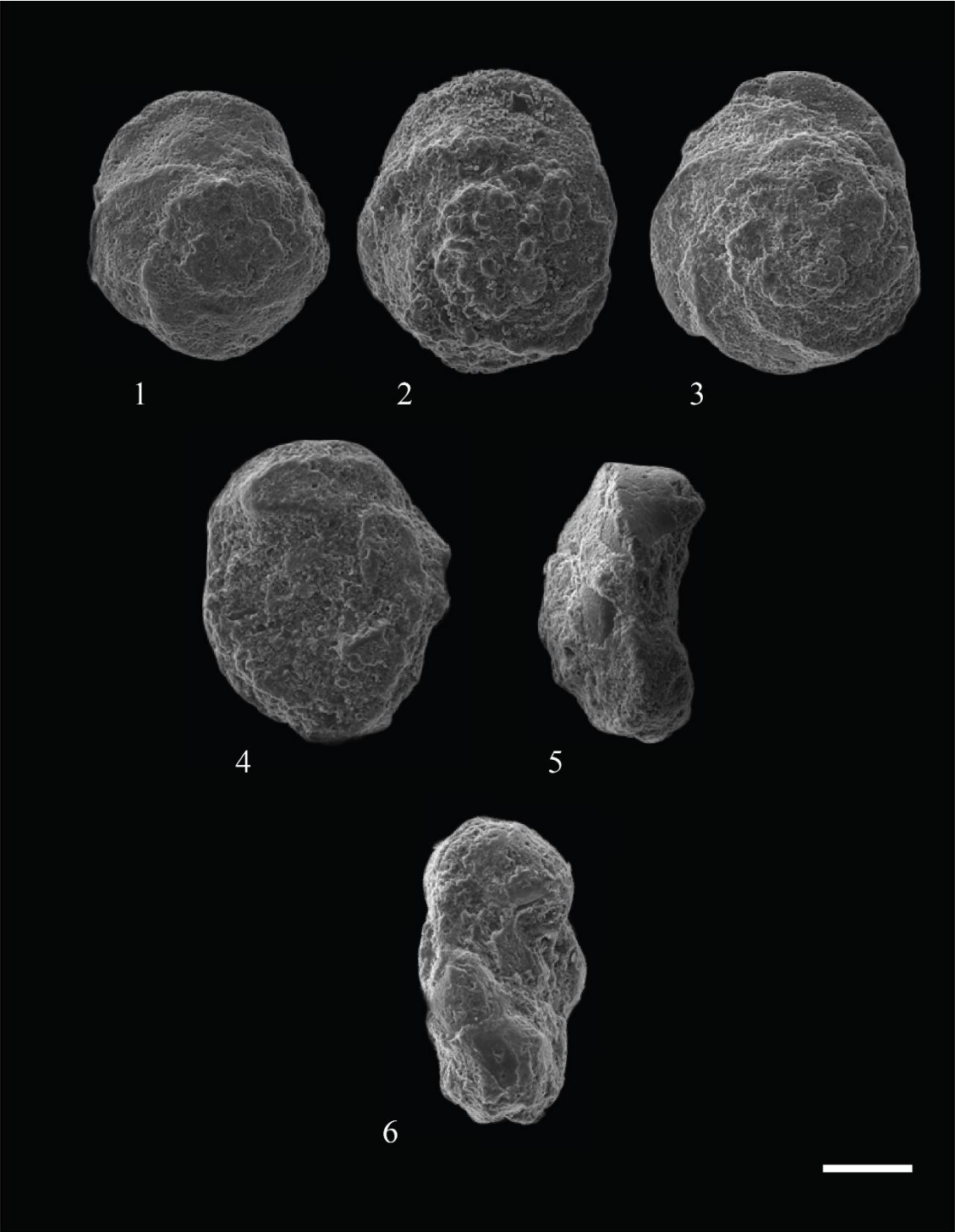
PLATE 3

Scale bar = 100 µm

Figure 1: *Dicarinella algeriana* CARON, sample no. NS 3, *W. archaeocretacea* zone, spiral view

Figure 2: *Dicarinella algeriana* CARON, sample no. NS 10, *W. archaeocretacea* zone, lateral view

Figure 3: *Dicarinella takayanagii* HASEGAWA, sample no. NS 11, *W. archaeocretacea* zone, spiral view

Figure 4: *Dicarinella takayanagii* HASEGAWA, sample no. NS 11, *W. archaeocretacea* zone, spiral view

Figure 5: *Dicarinella takayanagii* HASEGAWA, sample no. NS 1, *D. algeriana* subzone, spiral view

Figure 6: *Dicarinella takayanagii* HASEGAWA, sample no. NS 11, *W. archaeocretacea* zone, umbilical view

Figure 7: *Dicarinella imbricata* MORNOD, sample no. NS 17, *H. helvetica* zone, spiral view

Figure 8: *Dicarinella imbricata* MORNOD, sample no. NS 17, *H. helvetica* zone, spiral view

Figure 9: *Dicarinella imbricata* MORNOD, sample no. NS 17, *H. helvetica* zone, umbilical view

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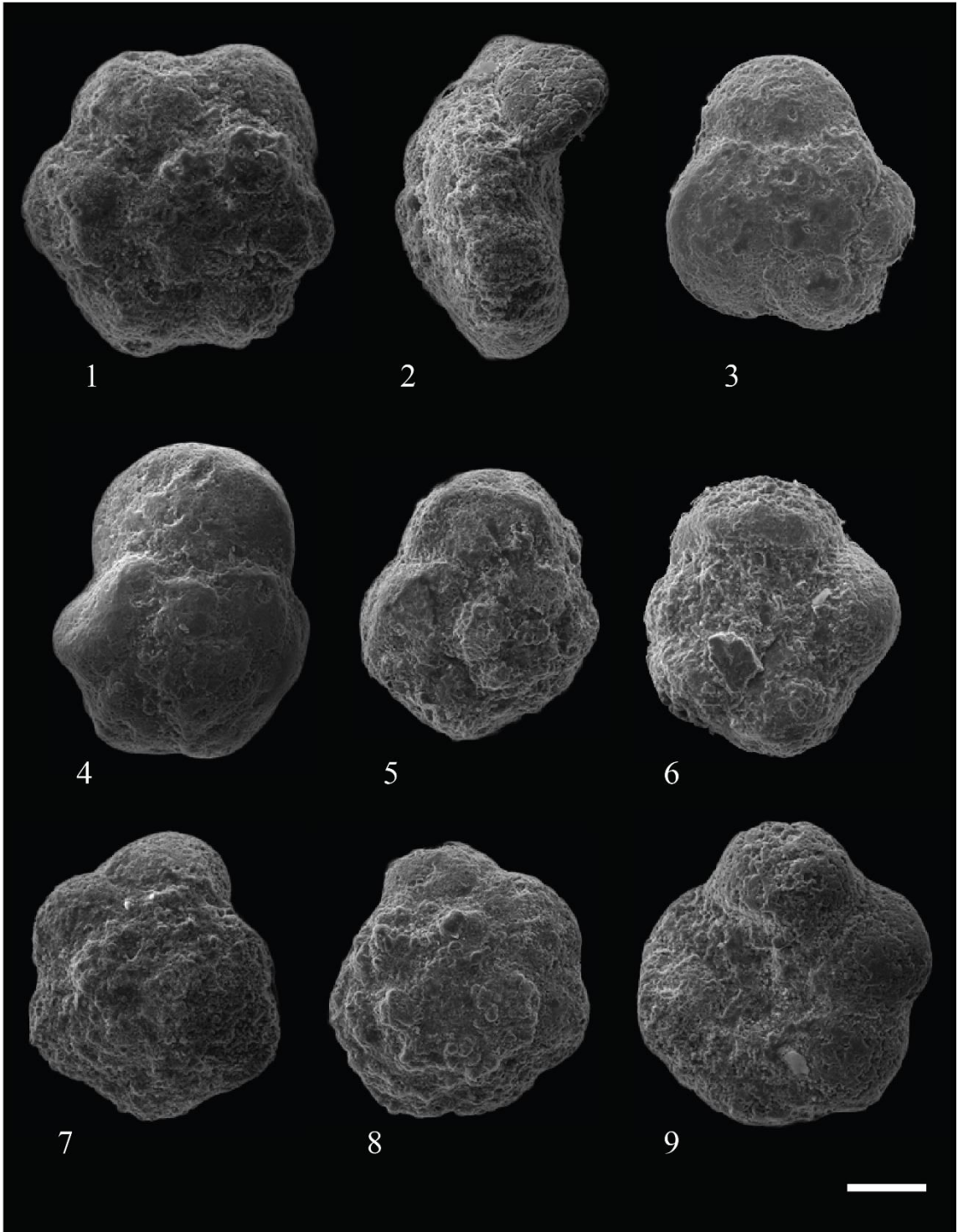
PLATE 4

Scale bar = 100 µm

Figure 1: *Dicarinella asymetrica* SIGAL, sample no. NS 28, *G. elevata-D. asymetrica* subzone, spiral view

Figure 2: *Dicarinella concavata* BROTZEN, sample no. NS 28, *G. elevata-D. asymetrica* subzone, spiral view

Figure 3: *Dicarinella canaliculata* REUSS, sample no. NS 3, *W. archaeocretacea* zone, spiral view

Figure 4: *Dicarinella canaliculata* REUSS, sample no. NS 10, *W. archaeocretacea* zone, spiral view

Figure 5: *Dicarinella canaliculata* REUSS, sample no. NS 3, *W. archaeocretacea* zone, spiral view

Figure 6: *Dicarinella canaliculata* REUSS, sample no. NS 3, *W. archaeocretacea* zone, lateral view

Figure 7: *Dicarinella canaliculata* REUSS, sample no. NS 3, *W. archaeocretacea* zone, lateral view

Figure 8: *Dicarinella hagni* SCHEIBNEROVA, sample no. NS 3, *W. archaeocretacea* zone, spiral view
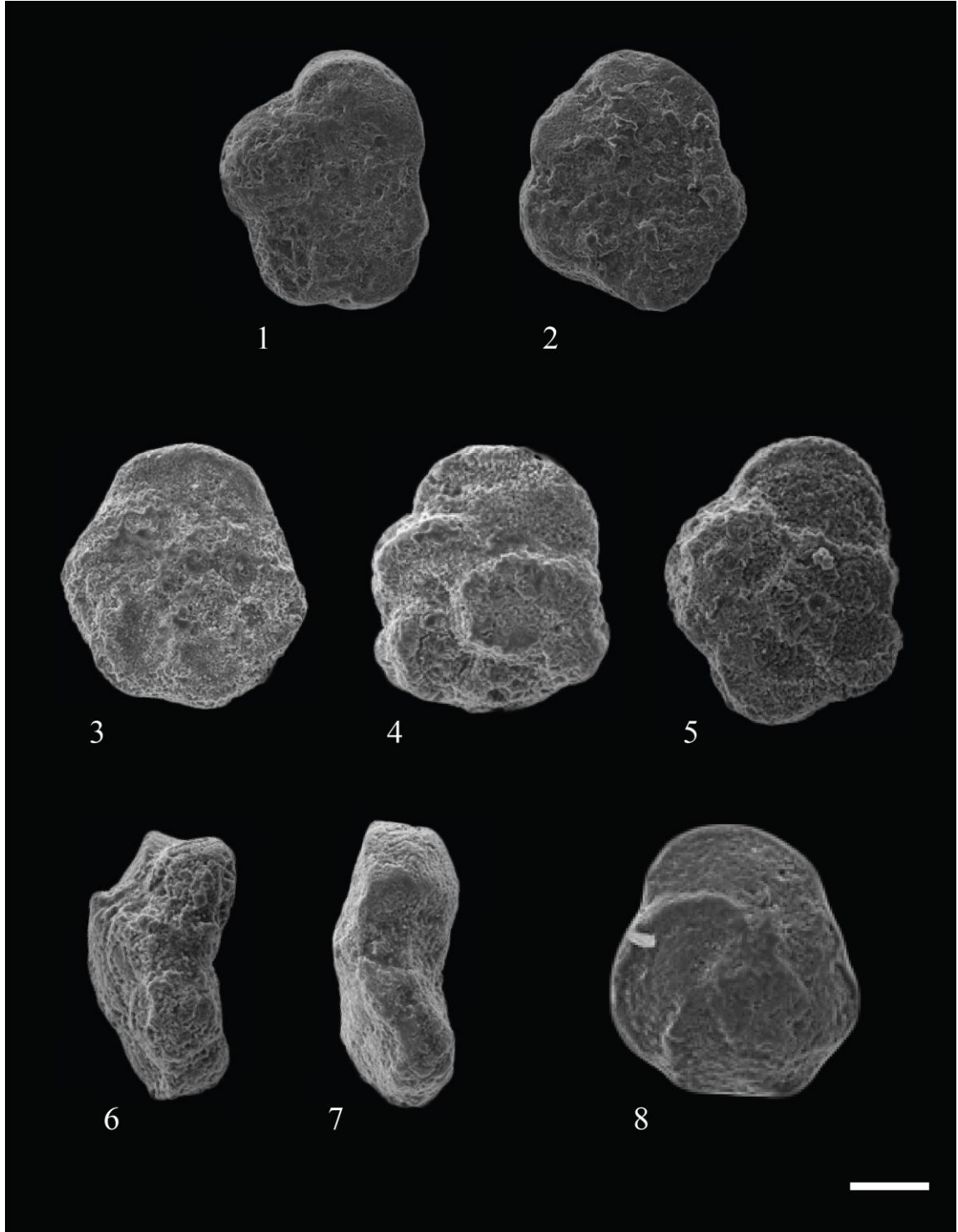
PLATE 5

Scale bar = 100 µm

Figure 1: *Globotruncana orientalis* EL NAGGAR, sample no. NS 59, *Globotruncanella* spp. zone, spiral view

Figure 2: *Globotruncana orientalis* EL NAGGAR, sample no. NS 57, *Globotruncanella* spp. zone, lateral view

Figure 3: *Globotruncana orientalis* EL NAGGAR, sample no. NS 39, *G. elevata* zone, lateral view

Figure 4: *Globotruncana mariei* BANNER and BLOW, sample no. NS 39 *G. elevata* zone, spiral view

Figure 5: *Globotruncana mariei* BANNER and BLOW, sample no. NS 39, *G. elevata* zone, spiral view

Figure 6: *Globotruncana mariei* BANNER and BLOW, sample no. NS 41, *G. elevata* zone, umbilical view

Figure 7: *Globotruncana mariei* BANNER and BLOW, sample no. NS 50, *G. ventricosa* zone, spiral view

Figure 8: *Globotruncana mariei* BANNER and BLOW, sample no. NS 50, *G. ventricosa* zone, umbilical view

Figure 9: *Globotruncana ventricosa* WHITE, sample no. NS 62, *G. aegyptiaca* zone, spiral view

Figure 10: *Globotruncana ventricosa* WHITE, sample no. NS 62, *G. aegyptiaca* zone, spiral view

Figure 11: *Globotruncana ventricosa* WHITE, sample no. NS 53, *Globotruncanella* spp. zone, lateral view

Figure 12: *Globotruncana falsostuarti* SIGAL, sample no. NS 64, *G. aegyptiaca* zone, spiral view

Figure 13: *Globotruncana aegyptiaca* NAKKADY, sample no. NS 72, *G. aegyptiaca* zone, spiral view

Figure 14: *Globotruncana aegyptiaca* NAKKADY, sample no. NS 70, *G. aegyptiaca* zone, umbilical view

Figure 15: *Globotruncana aegyptiaca* NAKKADY, sample no. NS 61, *G. aegyptiaca* zone, umbilical view

Figure 16: *Globotruncana aegyptiaca* NAKKADY, sample no. NS 61, *G. aegyptiaca* zone, umbilical view

Figure 17: *Globotruncana aegyptiaca* NAKKADY, sample no. NS 61, *G. aegyptiaca* zone, lateral view

Figure 18: *Globotruncana aegyptiaca* NAKKADY, sample no. NS 68, *G. aegyptiaca* zone, lateral view
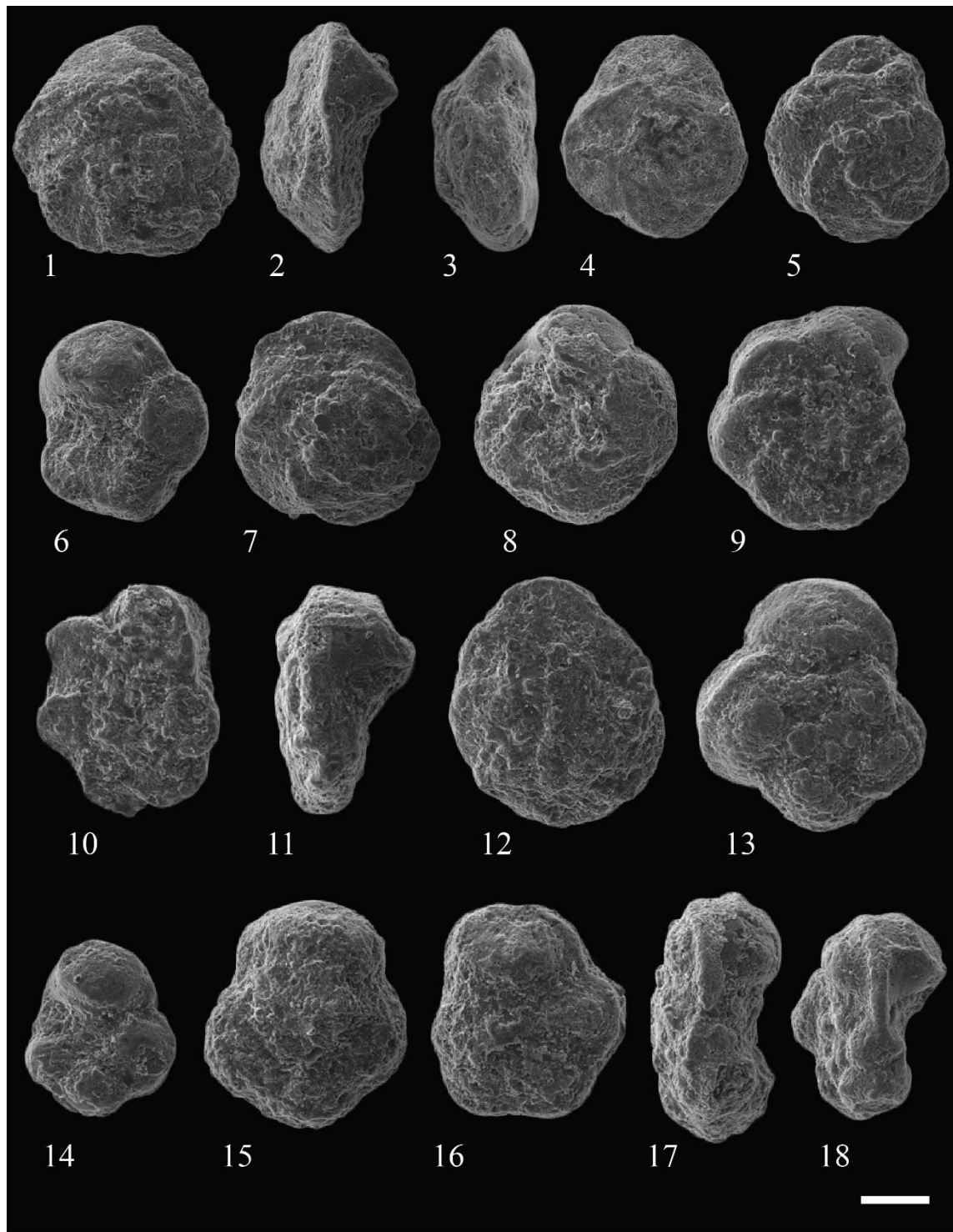
PLATE 6

Scale bar = 100 µm

Figure 1: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 61, *D. aegyptiaca* zone, spiral view

Figure 2: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 74, *D. aegyptiaca* zone, spiral view

Figure 3: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 31, *G. elevata-D. asymetrica* concurrent range subzone, umbilical view

Figure 4: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 52, *Globotruncanella* spp. zone, umbilical view

Figure 5: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 33, *G. elevata-D. asymetrica* concurrent range subzone, lateral view

Figure 6: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 43, *G. elevata* zone, lateral view

Figure 7: *Globotruncana arca* CUSHMAN, sample no. NS 61, *G. aegyptiaca* zone, spiral view

Figure 8: *Globotruncana arca* CUSHMAN, sample no. NS 43, *G. elevata* zone, spiral view

Figure 9: *Globotruncana arca* CUSHMAN, sample no. NS 50, *G. ventricosa* zone, spiral view

Figure 10: *Globotruncana arca* CUSHMAN, sample no. NS 52, *Globotruncanella* spp. zone, spiral view

Figure 11: *Globotruncana arca* CUSHMAN, sample no. NS 56, *Globotruncanella* spp. zone, spiral view

Figure 12: *Globotruncana arca* CUSHMAN, sample no. NS 54, *Globotruncanella* spp. zone, spiral view

Figure 13: *Globotruncana arca* CUSHMAN, no. NS 54, *Globotruncanella* spp. zone, spiral view

Figure 14: *Globotruncana arca* CUSHMAN, sample no. NS 31, *G. elevata-D. asymetrica* concurrent range subzone, spiral view

Figure 15: *Globotruncana arca* CUSHMAN, sample no. NS 51, *G. ventricosa* zone, umbilical view

Figure 16: *Globotruncana arca* CUSHMAN, sample no. NS 42, *G. elevata* zone, umbilical view

Figure 17: *Globotruncana arca* CUSHMAN, sample no. NS 39, *G. elevata-D. asymetrica* concurrent range subzone, lateral view

Figure 18: *Globotruncana arca* CUSHMAN, sample no. NS 39, *G. elevata-D. asymetrica* concurrent range subzone, lateral view
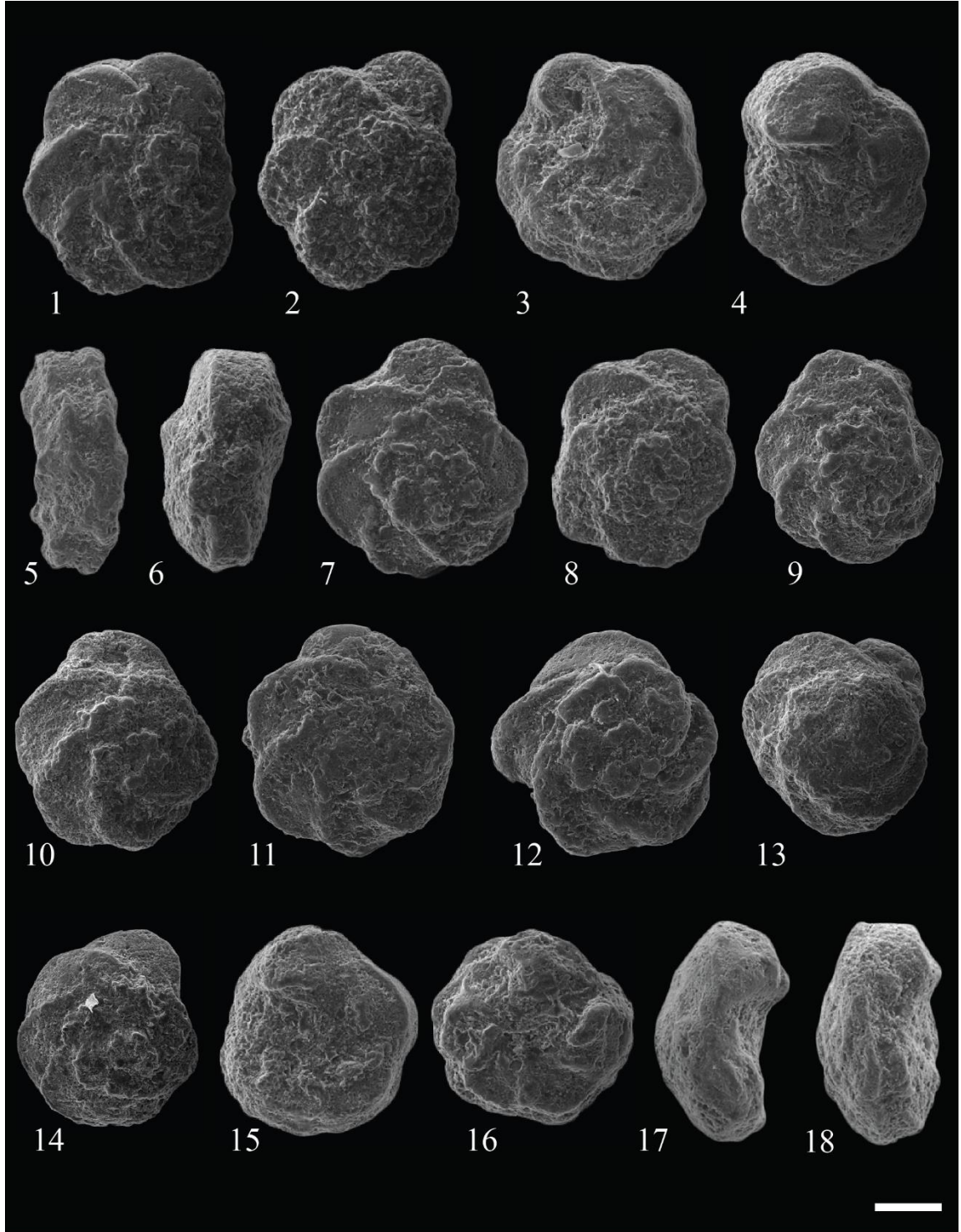
PLATE 7

Scale bar = 100 µm

Figure 1: *Globotruncana hilli* PESSAGNO, sample no. NS 68, *G. aegyptiaca* zone, spiral view

Figure 2: *Globotruncana hilli* PESSAGNO, sample no. NS 44, *G. elevata* zone, spiral view

Figure 3: *Globotruncana hilli* PESSAGNO, sample no. NS 49, *G. ventricosa* zone, spiral view

Figure 4: *Globotruncana hilli* PESSAGNO, sample no. NS 52, *Globotruncanella* spp. zone, spiral view

Figure 5: *Globotruncana hilli* PESSAGNO, sample no. NS 68, *G. aegyptiaca* zone, lateral view

Figure 6: *Globotruncana hilli* PESSAGNO, sample no. NS 55, *Globotruncanella* spp. zone, lateral view

Figure 7: *Globotruncana hilli* PESSAGNO, sample no. NS 36, *G. elevata-D. asymetrica* concurrent range subzone, lateral view

Figure 8: *Globotruncana hilli* PESSAGNO, sample no. NS 49, *G. ventricosa* zone, lateral view

Figure 9: *Globotruncana hilli* PESSAGNO, sample no. NS 47, *G. elevata* zone, umbilical view

Figure 10: *Globotruncana bulloides* VOGLER, sample no. NS 62, *D. asymetrica* zone, spiral view

Figure 11: *Globotruncana bulloides* VOGLER, sample no. NS 30, *G. elevata-D. asymetrica* concurrent range subzone, umbilical view

Figure 12: *Globotruncana bulloides* VOGLER, sample no. NS 57, *Globotruncanella* spp. zone, lateral view
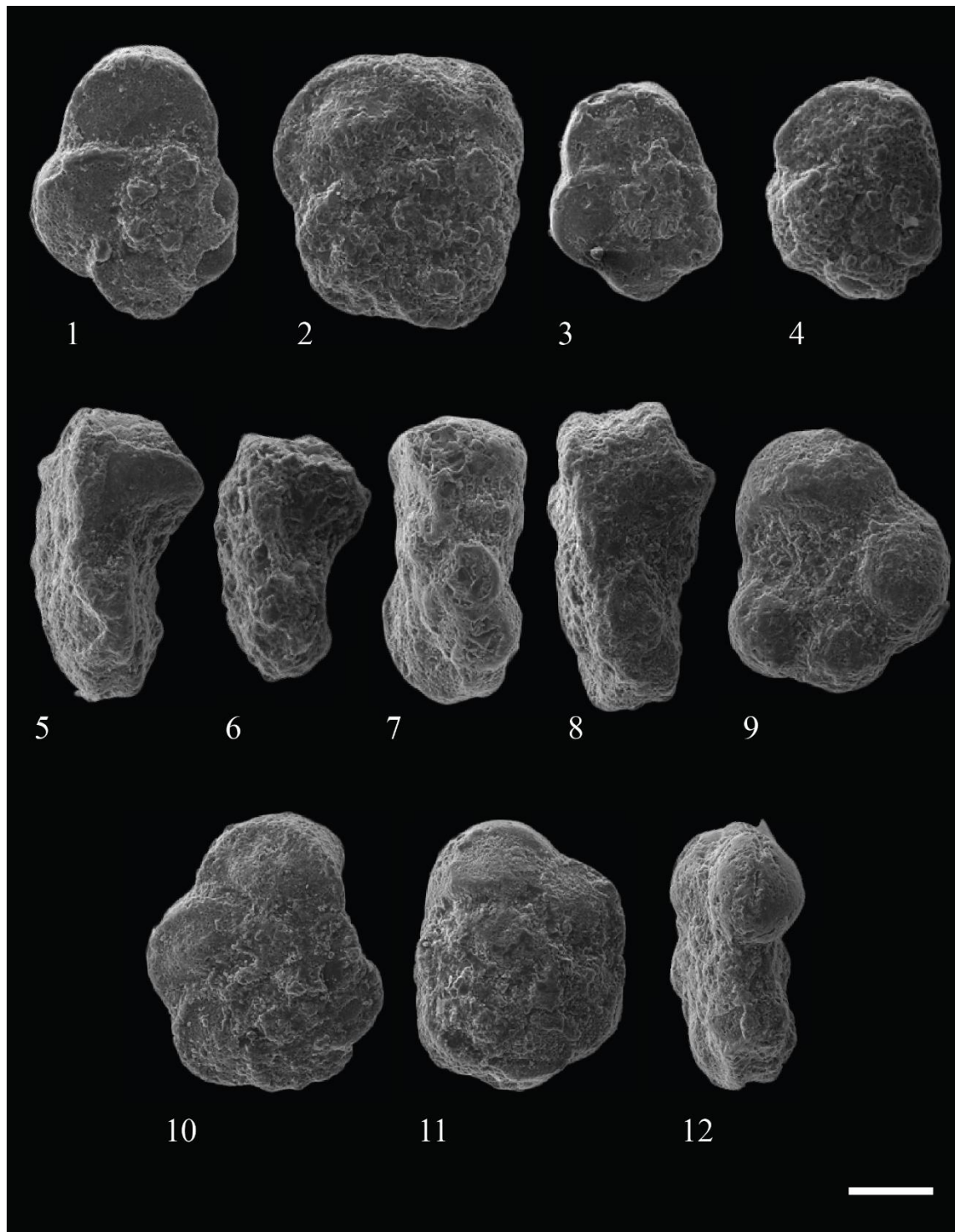
PLATE 8

Scale bar = 100 µm

Figure 1: *Globotruncanita atlantica* CARON, sample no. NS 43, *G. elevata* zone, spiral view

Figure 2: *Globotruncanita atlantica* CARON, sample no. NS 53, *Globotruncanella* spp. zone, spiral view

Figure 3: *Globotruncanita stuartiformis* DALBIEZ, sample no. NS 52, *Globotruncanella* spp. zone, spiral view

Figure 4: *Globotruncanita stuartiformis* DALBIEZ, sample no. NS 70, *G. aegyptiaca* zone, spiral view

Figure 5: *Globotruncanita stuartiformis* DALBIEZ, sample no. NS 48, *G. elevata* zone, lateral view

Figure 6: *Globotruncanita angulata* TILEV, sample no. NS 68, *G. aegyptiaca* zone, spiral view

Figure 7: *Globotruncanita pettersi* GANDOLFI, sample no. NS 64, *G. aegyptiaca* zone, spiral view

Figure 8: *Gansserina gansseri* BOLLI, sample no. NS 75, *G. gansseri* zone, lateral view
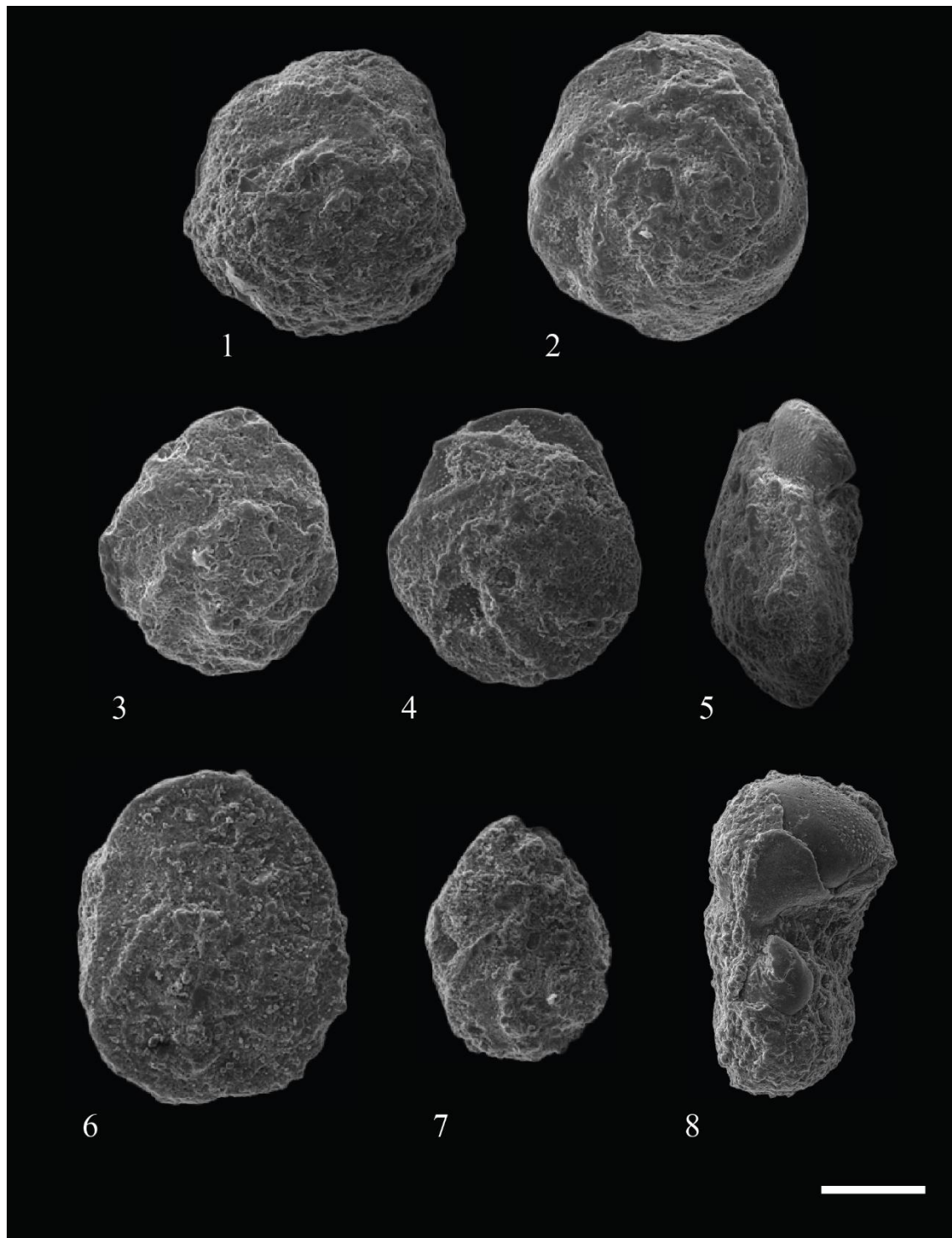
PLATE 9

Scale bar = 100 µm

Figure 1: *Helvetoglobotruncana helvetica* BOLLI, sample no. NS 14, *H. helvetica* zone, lateral view

Figure 2: *Helvetoglobotruncana helvetica* BOLLI, sample no. NS 14, *H. helvetica* zone, umbilical view

Figure 3: *Whiteinella praehelvetica* TRUJILLO, sample no. NS 14, *H. helvetica* zone, spiral view

Figure 4: *Whiteinella praehelvetica* TRUJILLO, sample no. NS 14, *H. helvetica* zone, spiral view

Figure 5: *Whiteinella praehelvetica* TRUJILLO, sample no. NS 14, *H. helvetica* zone, lateral view

Figure 6: *Whiteinella praehelvetica* TRUJILLO, sample no. NS 14, *H. helvetica* zone, lateral view
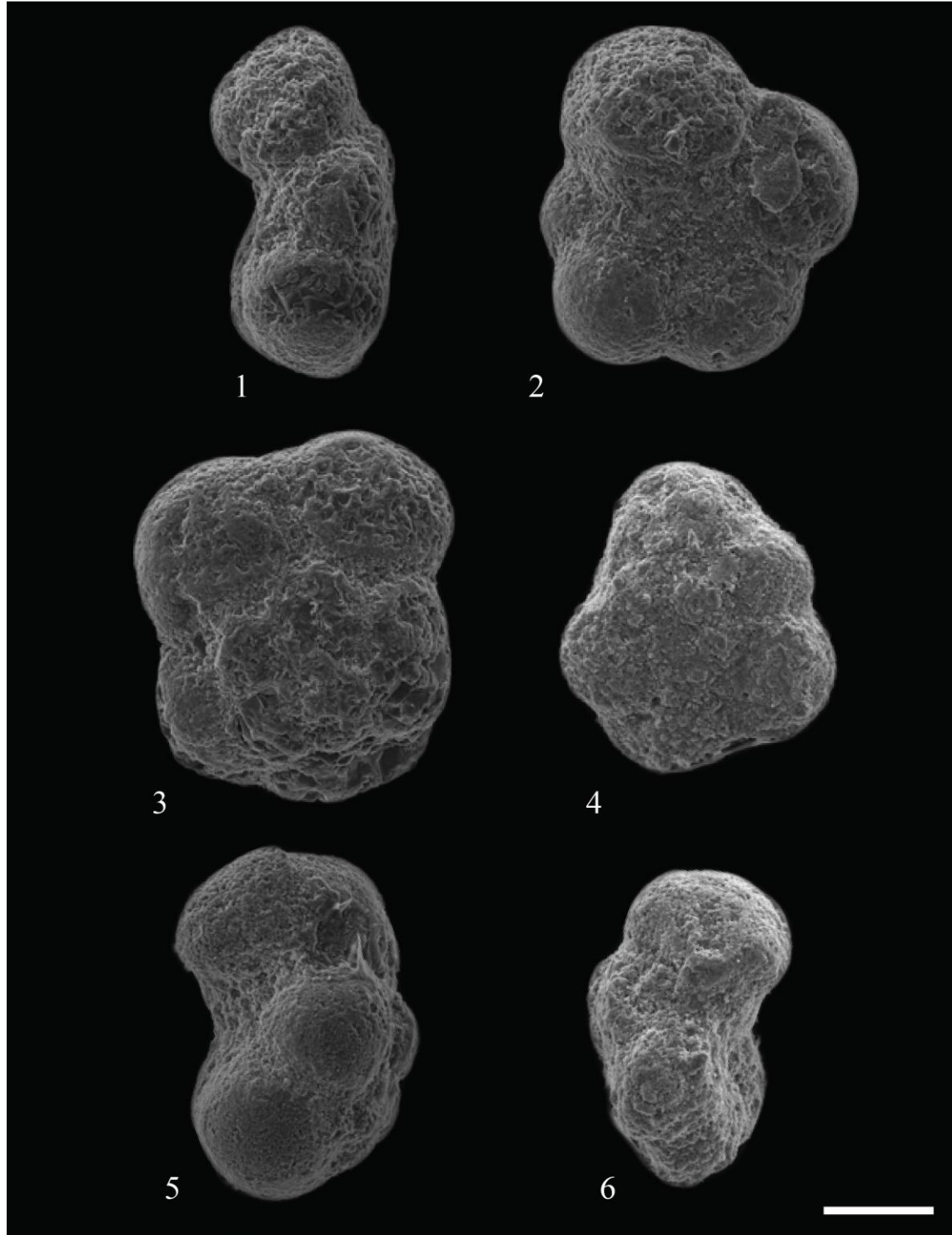
PLATE 10

Scale bar = 100 µm

Figure 1: *Heterohelix planata* CUSHMAN, sample no. NS 57, *Globotruncanella* spp. zone, side view

Figure 2: *Heterohelix planata* CUSHMAN, sample no. NS 62, *G. aegyptiaca* zone, side view

Figure 3: *Heterohelix planata* CUSHMAN, sample no. NS 62, *G. aegyptiaca* zone, side view

Figure 4: *Heterohelix planata* CUSHMAN, sample no. NS 62, *G. aegyptiaca* zone, side view

Figure 5: *Heterohelix planata* CUSHMAN, sample no. NS 64, *G. aegyptiaca* zone, side view

Figure 6: *Heterohelix punctulata* CUSHMAN, sample no. NS 40, *G. elevata* zone, side view

Figure 7: *Heterohelix punctulata* CUSHMAN, sample no. NS 41, *G. elevata* zone, side view

Figure 8: *Heterohelix punctulata* CUSHMAN, sample no. NS 41, *G. elevata* zone, side view

Figure 9: *Heterohelix* sp. 1, sample no. NS 41, *G. elevata* zone, side view

Figure 10: *Heterohelix* sp. 1, sample no. NS 43, *G. elevata* zone, side view

Figure 11: *Heterohelix* sp. 2, sample no. NS 47, *G. elevata* zone, side view

Figure 12: *Heterohelix* sp. 2, sample no. NS 41, *G. elevata* zone, side view

Figure 13: *Heterohelix* sp. 2, sample no. NS 43, *G. elevata* zone, side view

Figure 14: *Heterohelix* sp. 2, sample no. NS 53, *Globotruncanella* spp. zone, side view
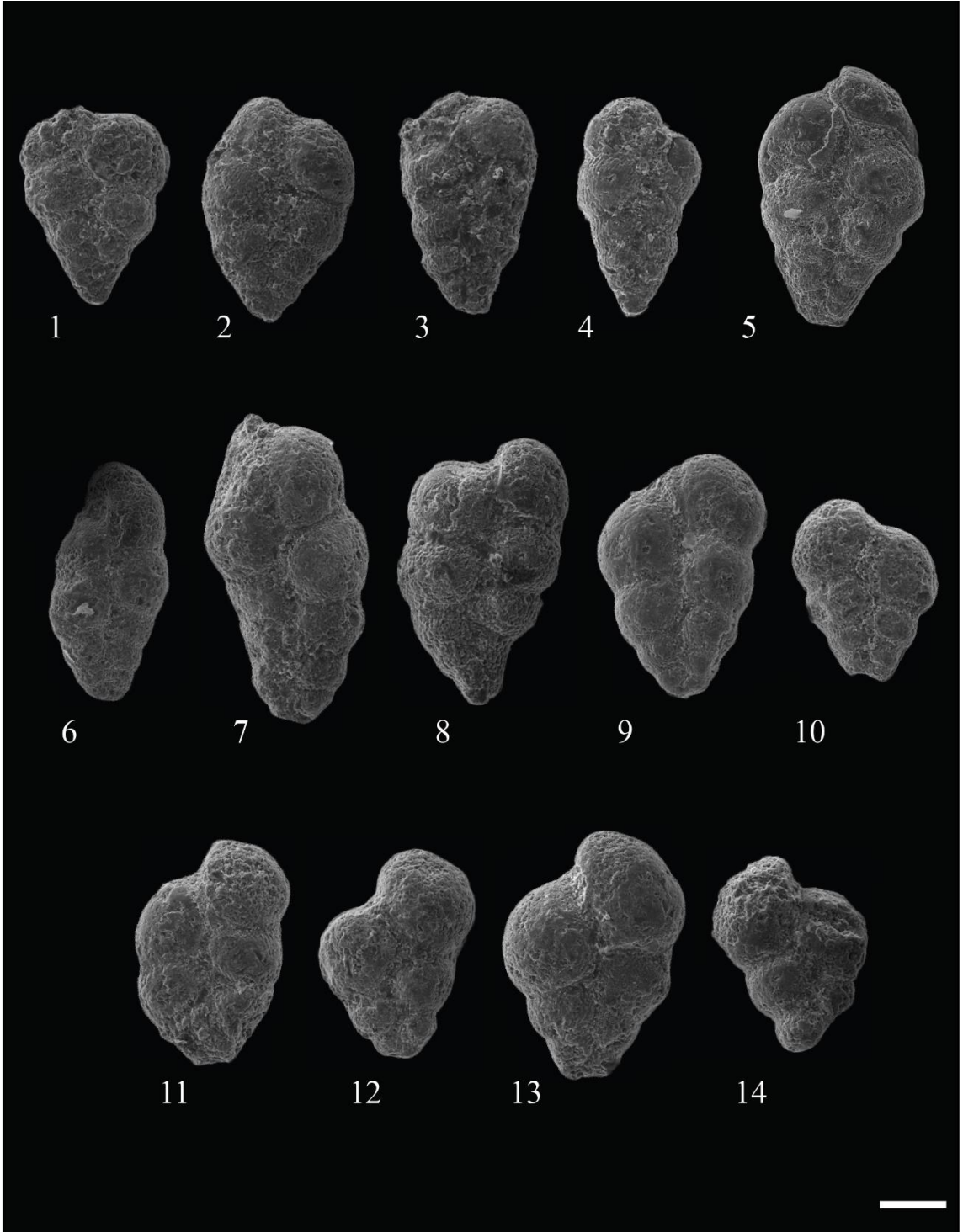
PLATE 11

Scale bar = 100 µm

Figure 1: *Heterohelix globulosa* EHRENBERG, sample no. NS 61, *G. aegyptiaca* zone, side view

Figure 2: *Heterohelix globulosa* EHRENBERG, sample no. NS 62, *G. aegyptiaca* zone, side view

Figure 3: *Heterohelix globulosa* EHRENBERG, sample no. NS 75, *G. gansseri* zone, side view

Figure 4: *Heterohelix globulosa* EHRENBERG, sample no. NS 75, *G. gansseri* zone, side view

Figure 5: *Heterohelix globulosa* EHRENBERG, sample no. NS 75, *G. gansseri* zone, side view

Figure 6: *Heterohelix globulosa* EHRENBERG, sample no. NS 44, *G. elevata* zone, lateral view

Figure 7: *Pseudotextularia nuttalli* VOORWIJK, sample no. NS 36, *G. elevata-D. asymetrica* concurrent range subzone, side view

Figure 8: *Pseudotextularia nuttalli* VOORWIJK, sample no. NS 37, *G. elevata-D. asymetrica* concurrent range subzone, side view

Figure 9: *Pseudotextularia nuttalli* VOORWIJK, sample no. NS 31, *G. elevata-D. asymetrica* concurrent range subzone, lateral view

Figure 10: *Pseudotextularia nuttalli* VOORWIJK, sample no. NS 36, *G. elevata-D. asymetrica* concurrent range subzone, lateral view

Figure 11: *Pseudotextularia nuttalli* VOORWIJK, sample no. NS 41, *G. elevata* zone, lateral view

PLATE 12

Scale bar = 100 µm

Figure 1: *Laeviheterohelix turgida* NEDERBRAGT, sample no. NS 30, *G. elevata-D. asymetrica* concurrent range subzone, side view

Figure 2: *Laeviheterohelix turgida* NEDERBRAGT, sample no. NS 30, *G. elevata-D. asymetrica* concurrent range subzone, side view

Figure 3: *Laeviheterohelix turgida* NEDERBRAGT, sample no. NS 31, *G. elevata-D. asymetrica* concurrent range subzone, side view

Figure 4: *Laeviheterohelix turgida* NEDERBRAGT, sample no. NS 32, *G. elevata-D. asymetrica* concurrent range subzone, lateral view

Figure 5: *Laeviheterohelix* sp. 1, sample no. NS 31, *G. elevata-D. asymetrica* concurrent range subzone, side view

Figure 6: *Laeviheterohelix* sp. 1, sample no. NS 31, *G. elevata-D. asymetrica* concurrent range subzone, side view

Figure 7: *Laeviheterohelix* sp. 1, sample no. NS 31, *G. elevata-D. asymetrica* concurrent range subzone, side view

Figure 8: *Laeviheterohelix* sp. 1, sample no. NS 32, *G. elevata-D. asymetrica* concurrent range subzone, side view

Figure 9: *Heterohelix* cf. *moremani*, sample no. NS 30, *G. elevata-D. asymetrica* concurrent range subzone, side view
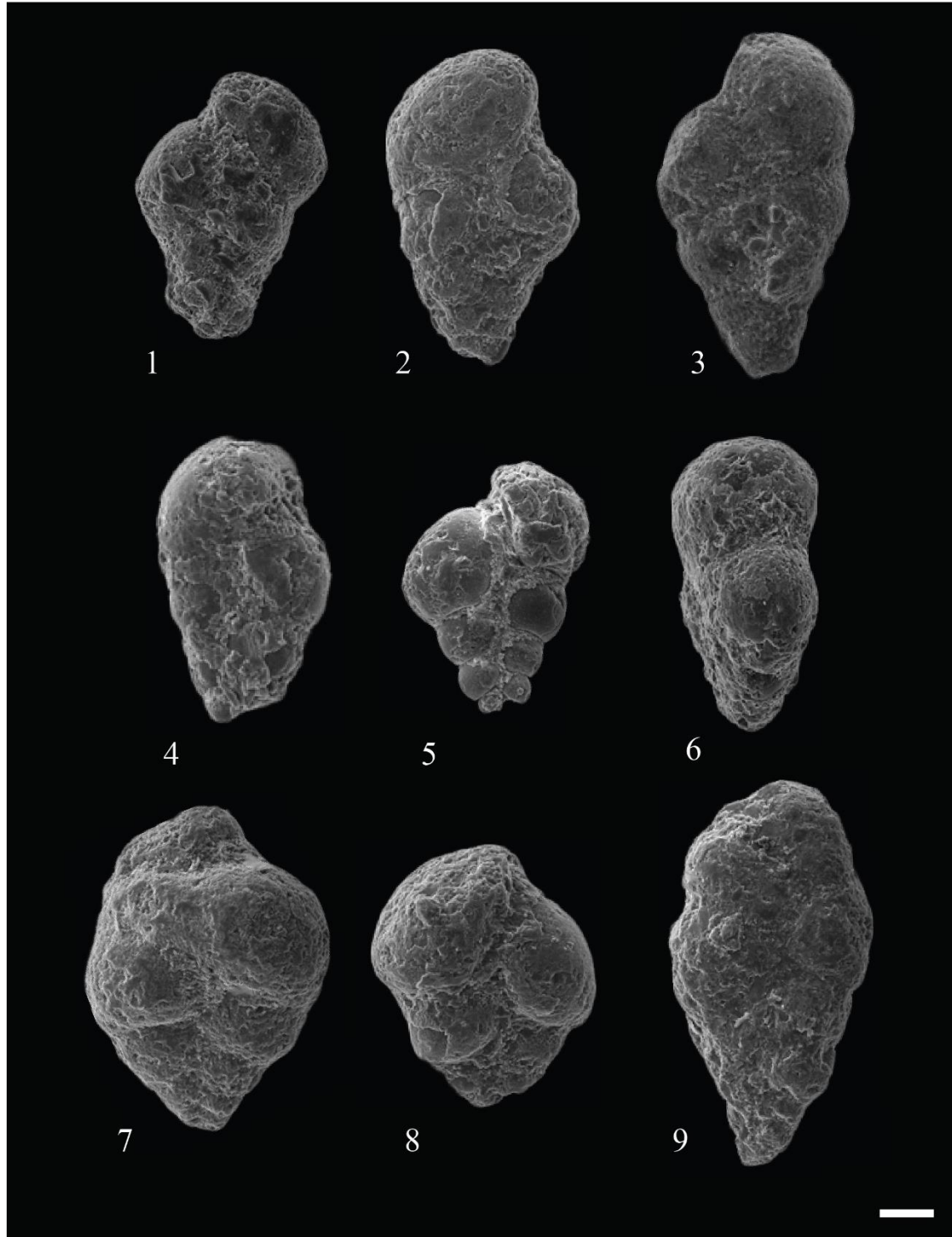
PLATE 13

Scale bar = 100 µm

Figure 1: *Marginotruncana pseudolinneiana* PESSAGNO, sample no. NS 18, *H. helvetica* zone, spiral view

Figure 2: *Marginotruncana coronata* BOLLI, sample no. NS 36, *G. elevata-D. asymetrica* concurrent range subzone, spiral view

Figure 3: *Marginotruncana coronata* BOLLI, sample no. NS 18, *H. helvetica* zone, spiral view

Figure 4: *Marginotruncana tarfayaensis* LEHMANN, sample no. NS 37, *G. elevata-D. asymetrica* concurrent range subzone, spiral view

Figure 5: *Marginotruncana sinuosa* PORTHAULT, sample no. NS 38, *G. elevata-D. asymetrica* concurrent range subzone, spiral view

Figure 6: *Marginotruncana paraconcavata* PORTHAULT, sample no. NS 28, *G. elevata-D. asymetrica* concurrent range subzone, spiral view

Figure 7: *Marginotruncana* cf. *paraconcavata* PORTHAULT, sample no. NS 28, *G. elevata-D. asymetrica* concurrent range subzone, umbilical view

Figure 8: *Marginotruncana paraconcavata* PORTHAULT, sample no. NS 28, *G. elevata-D. asymetrica* concurrent range subzone, lateral view
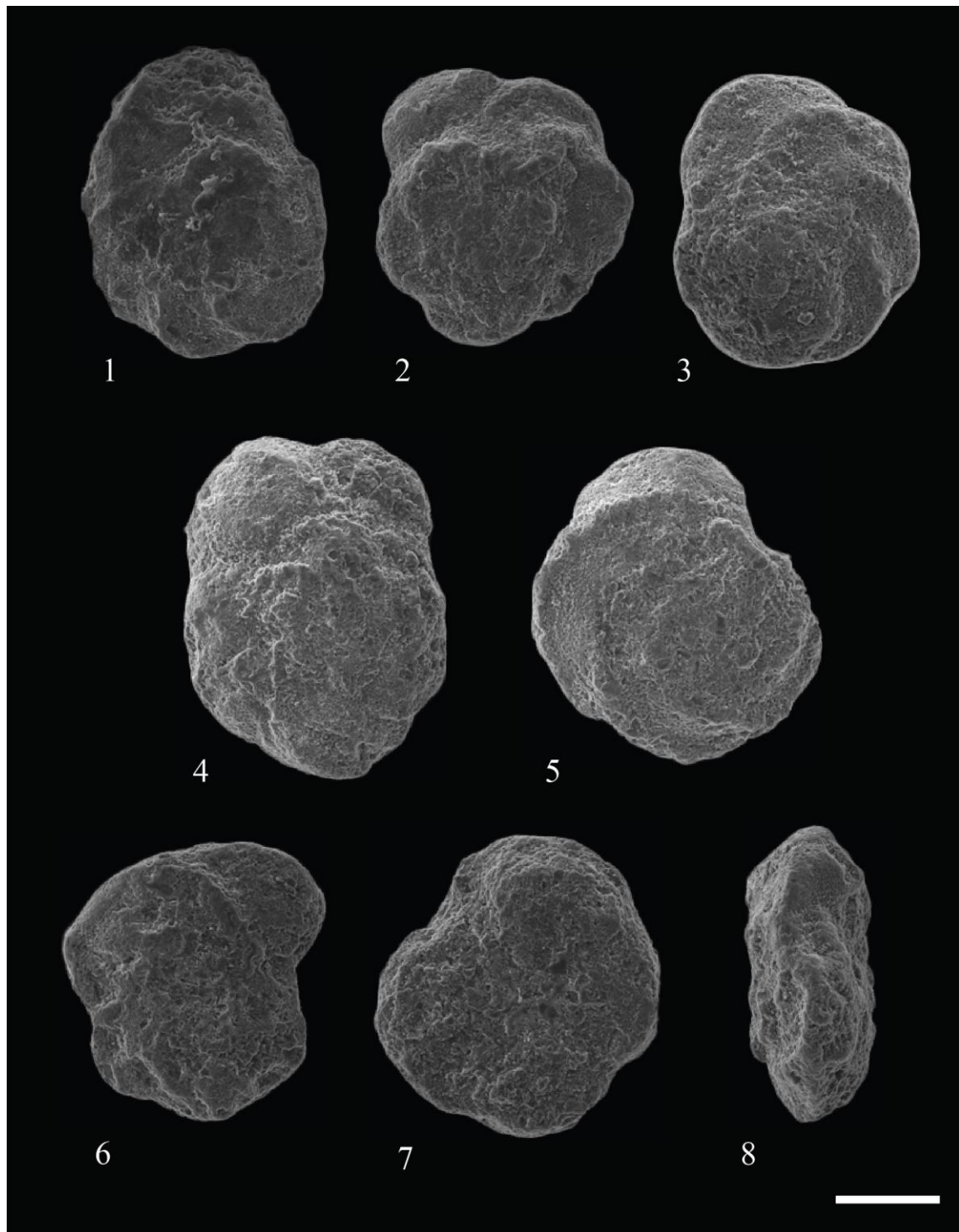
PLATE 14

Scale bar = 100 µm

Figure 1: *Muricohedbergella hoelzli* HAGN and ZEIL, sample no. NS 5, *W. archaeocretacea* zone, spiral view

Figure 2: *Muricohedbergella hoelzli* HAGN and ZEIL, sample no. NS 5, *W. archaeocretacea* zone, umbilical view

Figure 3: *Muricohedbergella hoelzli* HAGN and ZEIL, sample no. NS 5, *W. archaeocretacea* zone, spiral view

Figure 4: *Muricohedbergella hoelzli* HAGN and ZEIL, sample no. NS 5, *W. archaeocretacea* zone, lateral view

Figure 5: *Archaeoglobigerina cretacea* D'ORBIGNY, sample no. NS 70, *G. aegyptiaca* zone, lateral view

Figure 6: *Muricohedbergella planispira* TAPPAN, sample no. NS 13, *W. archaeocretacea* zone, spiral view

Figure 7: *Muricohedbergella planispira* TAPPAN, sample no. NS 10, *W. archaeocretacea* zone, spiral view

Figure 8: *Muricohedbergella planispira* TAPPAN, sample no. NS 10, *W. archaeocretacea* zone, spiral view

Figure 9: *Muricohedbergella planispira* TAPPAN, sample no. NS 35, *G. elevata-D. asymetrica* concurrent range subzone, spiral view

Figure 10: *Muricohedbergella planispira* TAPPAN, sample no. NS 36, *G. elevata-D. asymetrica* concurrent range subzone, lateral view

Figure 11: *Muricohedbergella holmdelensis* OLSSON, sample no. NS 28, *G. elevata-D. asymetrica* concurrent range subzone, spiral view

Figure 12: *Muricohedbergella holmdelensis* OLSSON, sample no. NS 28, *G. elevata-D. asymetrica* concurrent range subzone, spiral view

Figure 13: *Muricohedbergella holmdelensis* OLSSON, sample no. NS 50, *G. ventricosa* zone, lateral view

Figure 14: *Muricohedbergella holmdelensis* OLSSON, sample no. NS 36, *G. elevata-D. asymetrica* concurrent range subzone, lateral view

Figure 15: *Muricohedbergella holmdelensis* OLSSON, sample no. NS 53, *Globotruncanella* spp. zone, lateral view
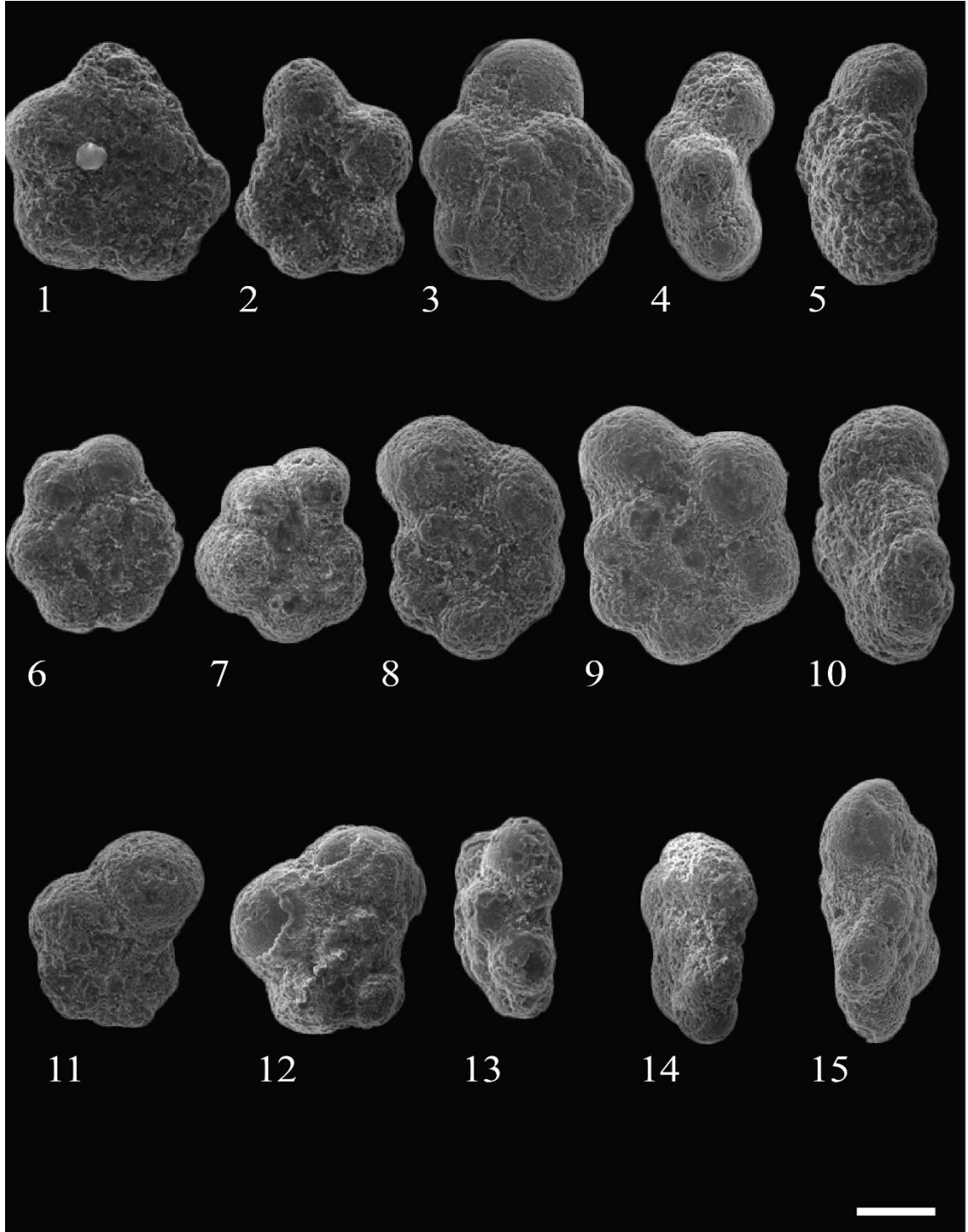
PLATE 15

Scale bar = 100 μm

Figure 1: *Praeglobotruncana stephani* GANDOLFI, sample no. NS 5, *W. archaeocretacea* zone, spiral view

Figure 2: *Praeglobotruncana stephani* GANDOLFI, sample no. NS 3, *W. archaeocretacea* zone, spiral view

Figure 3: *Praeglobotruncana stephani* GANDOLFI, sample no. NS 5, *W. archaeocretacea* zone, spiral view

Figure 4: *Praeglobotruncana stephani* GANDOLFI, sample no. NS 3, *W. archaeocretacea* zone, spiral view

Figure 5: *Praeglobotruncana stephani* GANDOLFI, sample no. NS 10, *W. archaeocretacea* zone, umbilical view

Figure 6: *Praeglobotruncana stephani* GANDOLFI, sample no. NS 10, *W. archaeocretacea* zone, lateral view

Figure 7: *Praeglobotruncana gibba* KLAUS, sample no. NS 3, *W. archaeocretacea* zone, spiral view

Figure 8: *Praeglobotruncana gibba* KLAUS, sample no. NS 3, *W. archaeocretacea* zone, spiral view

Figure 9: *Praeglobotruncana gibba* KLAUS, sample no. NS 3, *W. archaeocretacea* zone, umbilical view
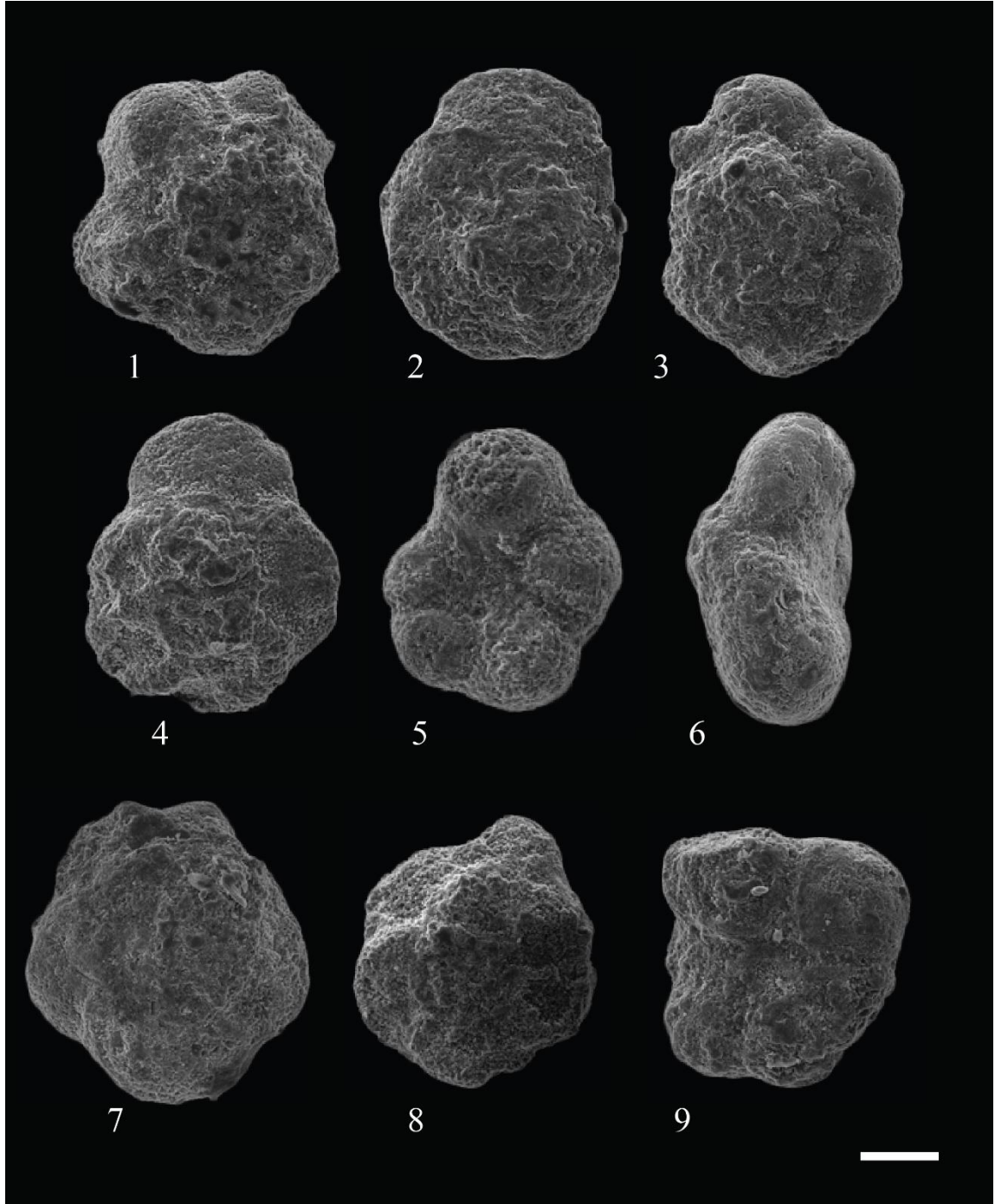
PLATE 16

Scale bar = 100 µm

Figure 1: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 49, *G. ventricosa* zone, spiral view

Figure 2: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 51, *G. ventricosa* zone, spiral view

Figure 3: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 53, *Globotruncanella* spp. zone, spiral view

Figure 4: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 53, *Globotruncanella* spp. zone, spiral view

Figure 5: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 53, *Globotruncanella* spp. zone, spiral view

Figure 6: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 53, *Globotruncanella* spp. zone, umbilical view

Figure 7: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 62, *G. aegyptiaca* zone, spiral view

Figure 8: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 68, *G. aegyptiaca* zone, umbilical view

Figure 9: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 69, *G. aegyptiaca* zone, spiral view

Figure 10: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 71, *G. aegyptiaca* zone, umbilical view

Figure 11: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 71, *G. aegyptiaca* zone, spiral view

Figure 12: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 71, *G. aegyptiaca* zone, umbilical view

Figure 13: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 74, *G. aegyptiaca* zone, spiral view

Figure 14: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 74, *G. aegyptiaca* zone, umbilical view

Figure 15: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 74, *G. aegyptiaca* zone, umbilical view

Figure 16: *Rugoglobigerina macrocephala* BRONNIMANN, sample no. NS 74, *G. aegyptiaca* zone, spiral view

Figure 17: *Rugoglobigerina macrocephala* BRONNIMANN, sample no. NS 67, *G. aegyptiaca* zone, spiral view

Figure 18: *Rugoglobigerina macrocephala* BRONNIMANN, sample no. NS 53, *Globotruncanella* spp. zone, umbilical view

Figure 19: *Rugoglobigerina pennyi* BRONNIMANN, sample no. NS 62, *G. aegyptiaca* zone, spiral view

Figure 20: *Rugoglobigerina milamensis* SMITH and PESSAGNO, sample no. NS 74, *G. aegyptiaca* zone, spiral view

Figure 21: *Rugoglobigerina milamensis* SMITH and PESSAGNO, sample no. NS 67, *G. aegyptiaca* zone, spiral view

Figure 22: *Rugoglobigerina hexacamerata* BRONNIMANN, sample no. NS 68, *G. aegyptiaca* zone, spiral view
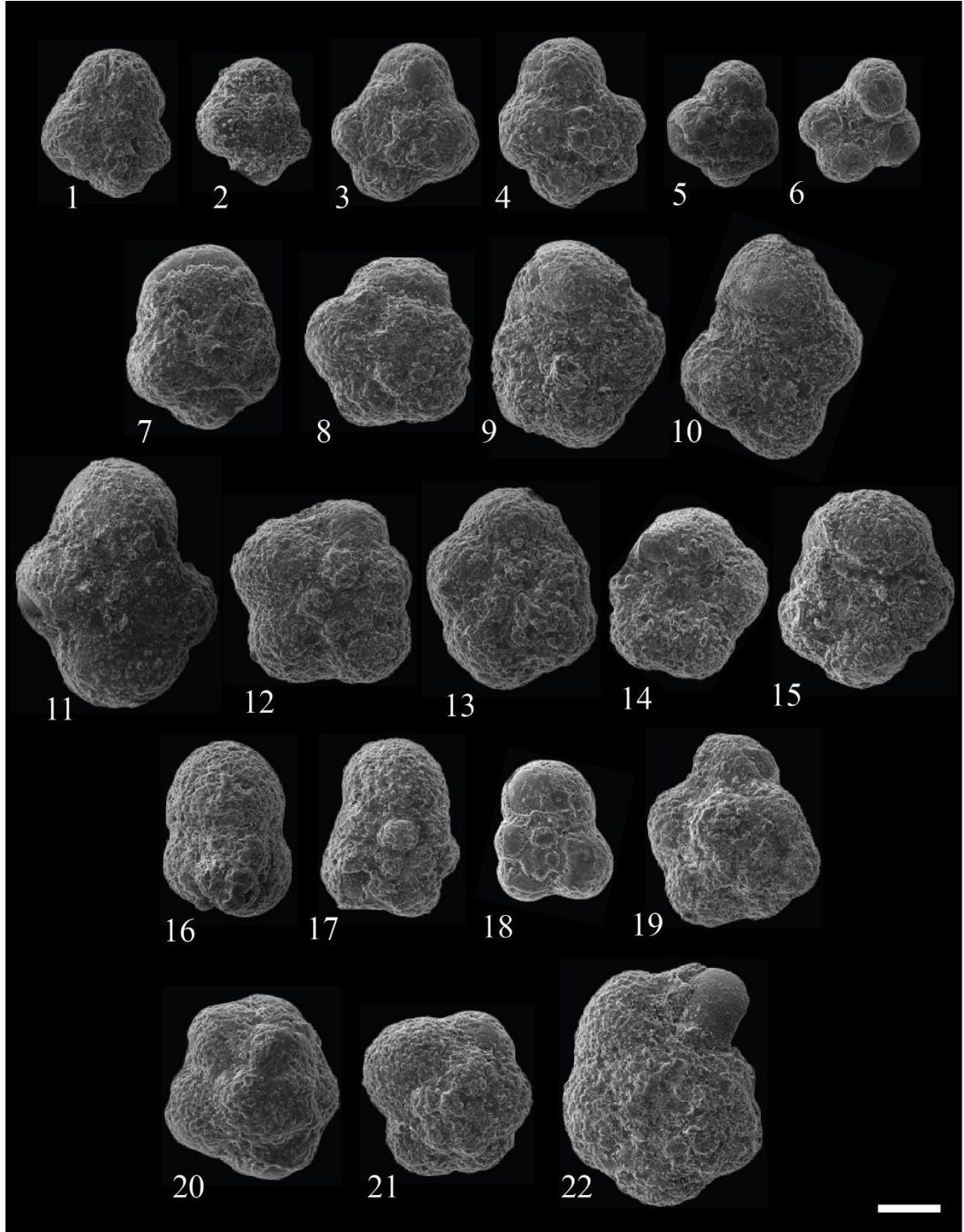
PLATE 17

Scale bar = 100 µm

Figure 1: *Sigalia deflaensis* SIGAL, sample no. NS 25, *G. elevata-D. asymetrica* concurrent range subzone, side view

Figure 2: *Sigalia deflaensis* SIGAL, sample no. NS 28, *G. elevata-D. asymetrica* concurrent range subzone, side view

Figure 3: *Sigalia deflaensis* SIGAL, sample no. NS 30, *G. elevata-D. asymetrica* concurrent range subzone, side view

Figure 4: *Sigalia deflaensis* SIGAL, sample no. NS 28, *G. elevata-D. asymetrica* concurrent range subzone, lateral view

Figure 5: *Sigalia carpatica* SALAJ and SAMUEL, sample no. NS 36, *G. elevata-D. asymetrica* concurrent range subzone, side view

Figure 6: *Sigalia* sp., sample no. NS 37, *G. elevata-D. asymetrica* concurrent range subzone, side view

Figure 7: *Sigalia* sp., sample no. NS 37, *G. elevata-D. asymetrica* concurrent range subzone, side view
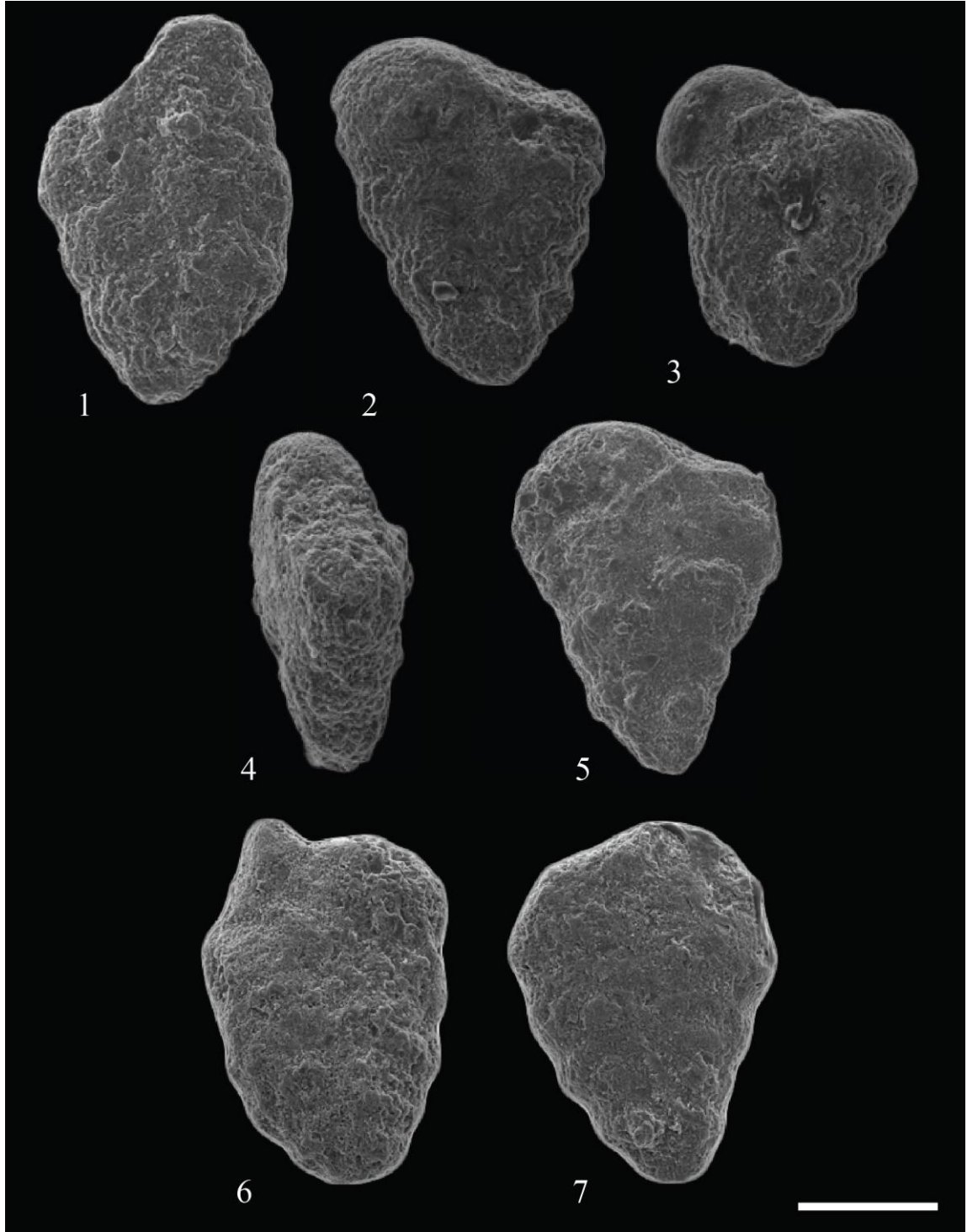
PLATE 18

Scale bar = 100 µm

Figure 1: *Ventilabrella browni* MARTIN, sample no. NS 40, *G. elevata* zone, side view

Figure 2: *Ventilabrella browni* MARTIN, sample no. NS 40, *G. elevata* zone, side view

Figure 3: *Ventilabrella browni* MARTIN, sample no. NS 47, *G. elevata* zone, side view

Figure 4: *Ventilabrella browni* MARTIN, sample no. NS 47, *G. elevata* zone, side view

Figure 5: *Ventilabrella eggeri* CUSHMAN, sample no. NS 40, *G. elevata* zone, side view

Figure 6: *Ventilabrella eggeri* CUSHMAN, sample no. NS 40, *G. elevata* zone, side view

Figure 7: *Ventilabrella eggeri* CUSHMAN, sample no. NS 42, *G. elevata* zone, side view

Figure 8: *Ventilabrella* sp. CUSHMAN, sample no. NS 53, *Globotruncanella* spp. zone, side view

Figure 9: *Ventilabrella* sp., sample no. NS 30, *G. elevata-D. asymetrica* concurrent range subzone, side view

Figure 10: *Ventilabrella* sp., sample no. NS 47, *G. elevata* zone, side view
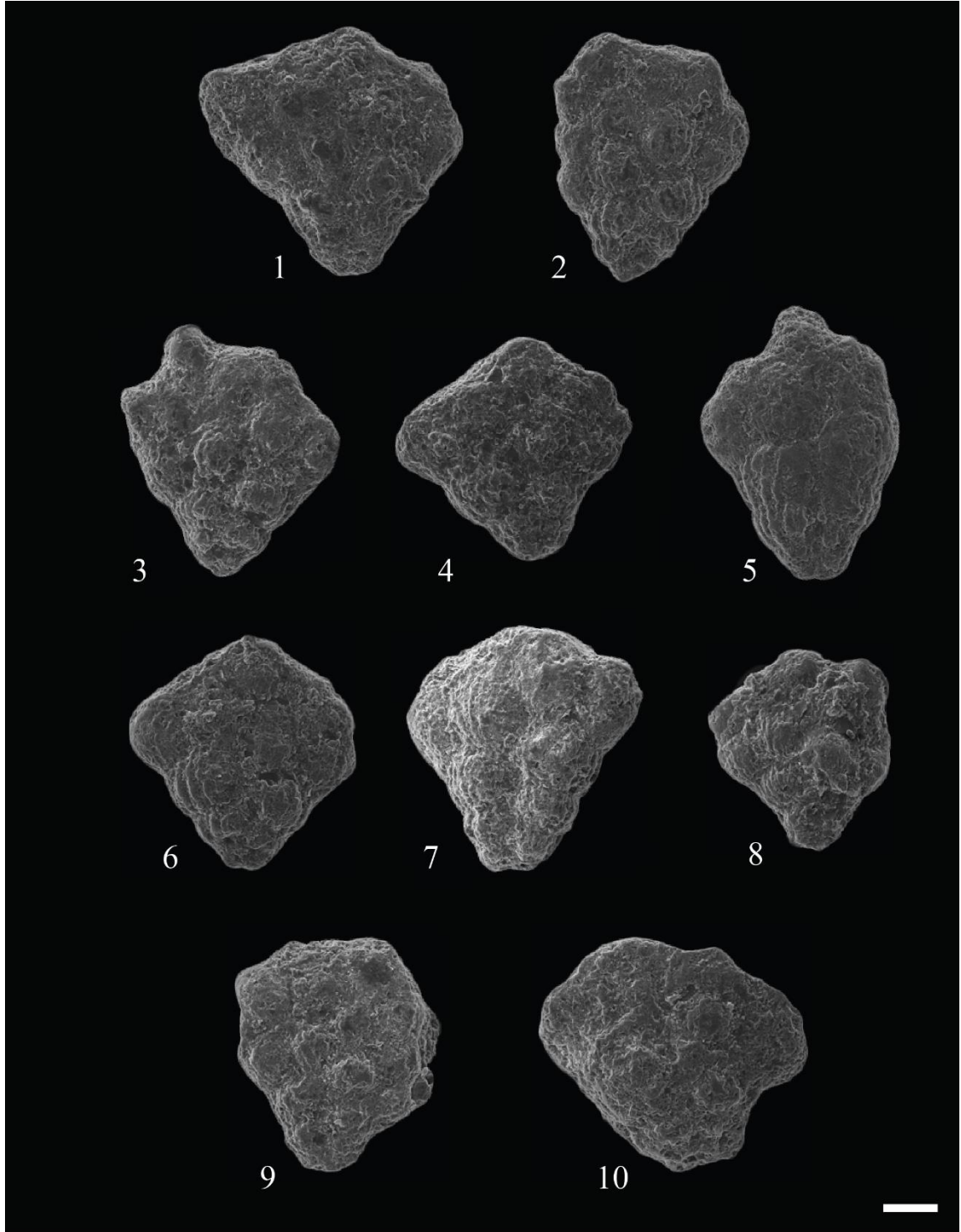
PLATE 19

Scale bar = 100 µm

Figure 1: *Whiteinella baltica* DOUGLAS and RANKIN, sample no. NS 21, *D. asymetrica* zone, spiral view

Figure 2: *Whiteinella baltica* DOUGLAS and RANKIN, sample no. NS 37, *G. elevata-D. asymetrica* concurrent range subzone, spiral view

Figure 3: *Whiteinella baltica* DOUGLAS and RANKIN, sample no. NS 17, *H. helvetica* zone, spiral view

Figure 4: *Whiteinella baltica* DOUGLAS and RANKIN, sample no. NS 17, *H. helvetica* zone, spiral view

Figure 5: *Whiteinella baltica* DOUGLAS and RANKIN, sample no. NS 33, *G. elevata-D. asymetrica* concurrent range subzone, spiral view

Figure 6: *Whiteinella baltica* DOUGLAS and RANKIN, sample no. NS 9, *W. archaeocretacea* zone, spiral view

Figure 7: *Whiteinella baltica* DOUGLAS and RANKIN, sample no. NS 3, *W. archaeocretacea* zone, spiral view

Figure 8: *Whiteinella baltica* DOUGLAS and RANKIN, sample no. NS 44, *G. elevata* zone, spiral view

Figure 9: *Whiteinella baltica* DOUGLAS and RANKIN, sample no. NS 5, *W. archaeocretacea* zone, lateral view

Figure 10: *Whiteinella baltica* DOUGLAS and RANKIN, sample no. NS 13, *W. archaeocretacea* zone, lateral view

Figure 11: *Whiteinella baltica* DOUGLAS and RANKIN, sample no. NS 3, *W. archaeocretacea* zone lateral view

Figure 12: *Whiteinella brittonensis* TAPPAN, sample no. NS 18, *H. helvetica* zone, umbilical view

Figure 13: *Whiteinella brittonensis* TAPPAN, sample no. NS 14, *H. helvetica* zone, umbilical view

Figure 14: *Muricohedbergella delrioensis* CARSEY, sample no. NS 18, *H. helvetica* zone lateral view

Figure 15: *Muricohedbergella delrioensis* OLSSON, sample no. NS 14, *H. helvetica* zone spiral view
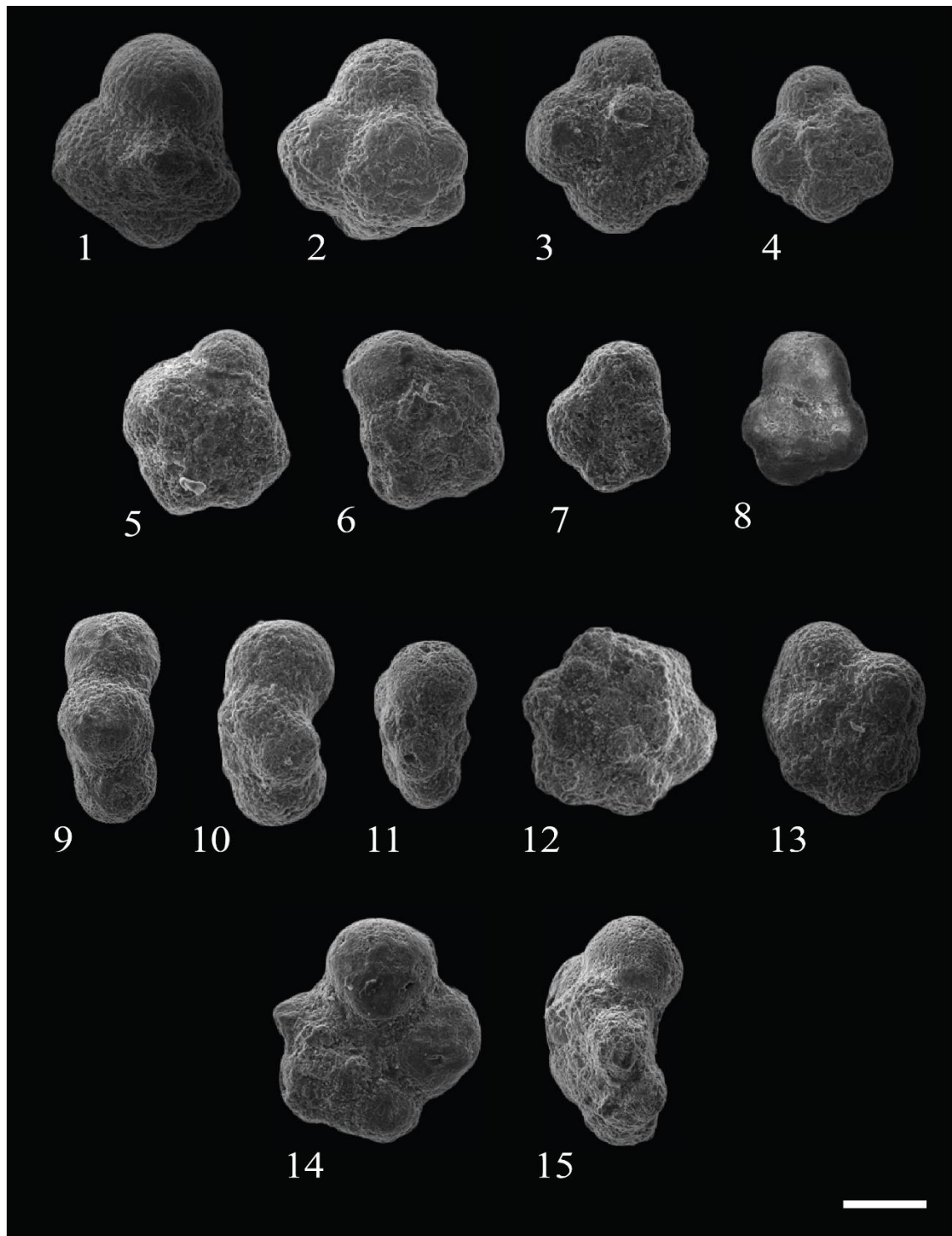
PLATE 20

Scale bar = 100 µm

Figure 1: *Globotruncanella petaloidea* GANDOLFI, sample no. NS 52, *Globotruncanella* spp. zone, spiral view

Figure 2: *Globotruncanella petaloidea* GANDOLFI, sample no. NS 53, *Globotruncanella* spp. zone, umbilical view

Figure 3: *Globotruncanella petaloidea* GANDOLFI, sample no. NS 52, *Globotruncanella* spp. zone, lateral view

Figure 4: *Rugotruncana circumnodifer* FINLAY, NS 62, *G. aegyptiaca* zone, spiral view

Figure 5: *Rugotruncana circumnodifer* FINLAY, NS 66, *G. aegyptiaca* zone, spiral view

Figure 6: *Rugotruncana circumnodifer* FINLAY, NS 66, *G. aegyptiaca* zone, lateral view

Figure 7: *Rugotruncana circumnodifer* FINLAY, NS 67, *G. aegyptiaca* zone, umbilical view

Figure 8: *Muricohedbergella flandrini* PORTHAULT, sample no. NS 37, *G. elevata-D. asymetrica* concurrent range subzone, spiral view

Figure 9: *Muricohedbergella flandrini* PORTHAULT, sample no. NS 28, *G. elevata-D. asymetrica* concurrent range subzone, umbilical view

Figure 10: *Muricohedbergella flandrini* PORTHAULT, sample no. NS 36, *G. elevata-D. asymetrica* concurrent range subzone, lateral view
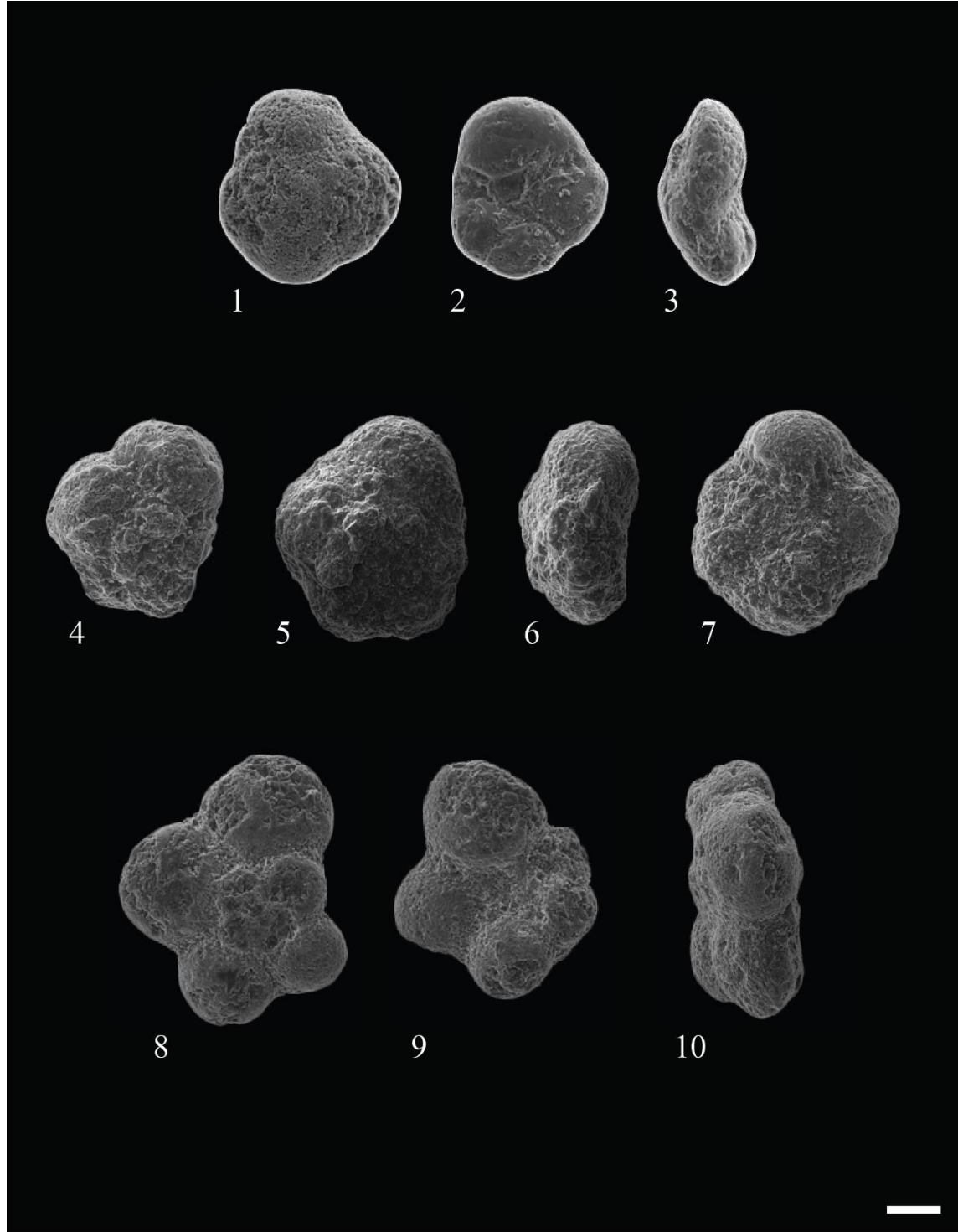
PLATE 21

Scale bar = 100 µm

Figure 1: *Macroglobigerinelloides cf. bentonensis* MORROW, sample no. NS 10, *W. archaeocretacea* zone, lateral view

Figure 2: *Macroglobigerinelloides messinae* BRONNIMANN, sample no. NS 41, *G. elevata* zone, umbilical view

Figure 3: *Macroglobigerinelloides bollii* PESSAGNO, sample no. NS 38, *G. elevata-D. asymetrica* concurrent range subzone, umbilical view

Figure 4: *Macroglobigerinelloides bollii* PESSAGNO, sample no. NS 38, *G. elevata-D. asymetrica* concurrent range subzone, lateral view

Figure 5: *Macroglobigerinelloides bollii* PESSAGNO, sample no. NS 40, *G. elevata* zone, lateral view

Figure 6: *Macroglobigerinelloides bollii* PESSAGNO, sample no. NS 53, *Globotruncanella* spp. zone, umbilical view

Figure 7: *Macroglobigerinelloides bollii* PESSAGNO, sample no. NS 38, *G. elevata-D. asymetrica* concurrent range subzone, umbilical view

Figure 8: *Macroglobigerinelloides bollii* PESSAGNO, sample no. NS 62, *G. aegyptiaca* zone, umbilical view

Figure 9: *Macroglobigerinelloides bollii* PESSAGNO, sample no. NS 65, *G. aegyptiaca* zone, umbilical view

Figure 10: *Macroglobigerinelloides prairihillensis* PESSAGNO, sample no. NS 37, *G. elevata-D. asymetrica* concurrent range subzone, lateral view

Figure 11: *Macroglobigerinelloides prairihillensis* PESSAGNO, sample no. NS 49, *G. ventricosa* zone, umbilical view

Figure 12: *Macroglobigerinelloides prairihillensis* PESSAGNO, sample no. NS 49, *G. ventricosa* zone, lateral view
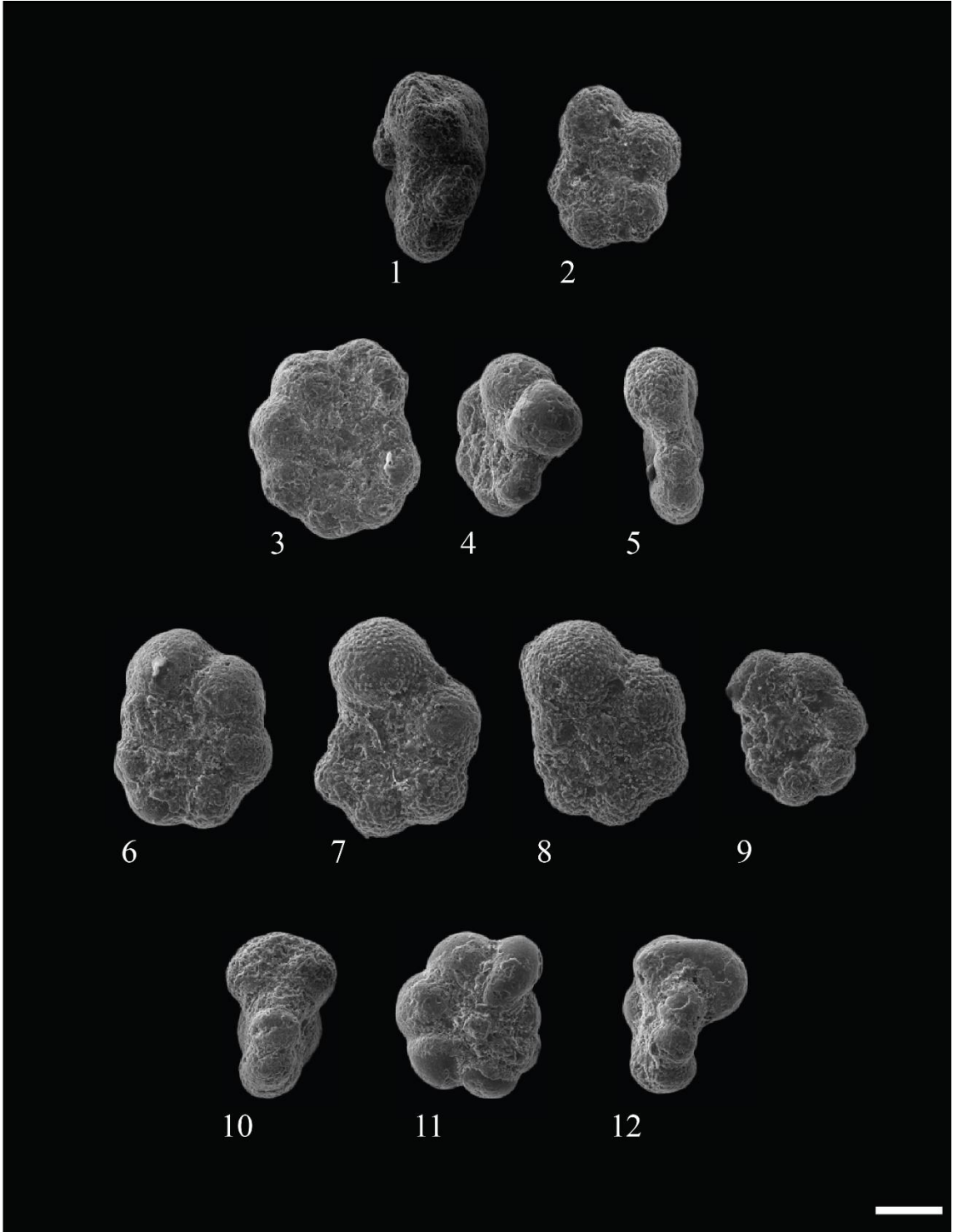
PLATE 22

Figure 1: *Archaeoglobigerina blowi* PESSAGNO, sample no. NS 41, *G. elevata* zone, X150

Figure 2: *Muricohedbergella monmouthensis* TAPPAN, sample no. NS 66, *G. aegyptiaca* zone, X150

Figure 3: *Muricohedbergella planispira* TAPPAN, sample no. NS 8, *W. archaeocretacea* zone, X150

Figure 4: *Muricohedbergella planispira* TAPPAN, sample no. NS 1, *D. algeriana* subzone, X150

Figure 5: *Muricohedbergella flandrini* PORTHAULT, sample no. NS 29, *G. elevata-D. asymetrica* concurrent range subzone, X100

Figure 6: *Muricohedbergella flandrini* PORTHAULT, sample no. NS 26, *G. elevata-D. asymetrica* concurrent range subzone, X100

Figure 7: *Muricohedbergella flandrini* PORTHAULT, sample no. NS 26, *G. elevata-D. asymetrica* concurrent range subzone, X100

Figure 8: *Muricohedbergella delrioensis* CARSEY, sample no. NS 18, *H. helvetica* zone, X130

Figure 9: *Muricohedbergella delrioensis* CARSEY, sample no. NS 14, *H. helvetica* zone, X130

Figure 10: *Muricohedbergella delrioensis* CARSEY, sample no. NS 2, *D. algeriana* subzone zone, X150

Figure 11: *Muricohedbergella holmdelensis* OLSSON, sample no. NS 26, *G. elevata-D. asymetrica* concurrent range subzone, X130

Figure 12: *Muricohedbergella holmdelensis* OLSSON, sample no. NS 26, *G. elevata-D. asymetrica* concurrent range subzone, X130

Figure 13: *Rugoglobigerina rugosa* PLUMMER, sample no. NS 66, *G. aegyptiaca* zone, X100

Figure 14: *Rugoglobigerina pennyi* BRONNIMANN, sample no. NS 72, *G. aegyptiaca* zone, X100

Figure 15: *Macroglobigerinelloides bollii* PESSAGNO, sample no. NS 46, *G. elevata* zone, X100

Figure 16: *Macroglobigerinelloides bollii* PESSAGNO, sample no. NS 41, *G. elevata* zone, X130

Figure 17: *Macroglobigerinelloides bollii* PESSAGNO, sample no. NS 24, *G. elevata-D. asymetrica* concurrent range subzone, X130

Figure 18: *Macroglobigerinelloides bollii* PESSAGNO, sample no. NS 23, *D. asymetrica* zone, X100

Figure 19: *Macroglobigerinelloides bollii* PESSAGNO, sample no. NS 22, *D. asymetrica* zone, X100

Figure 20: *Macroglobigerinelloides prairihillensis* PESSAGNO, sample no. NS 33, *G. elevata-D. asymetrica* concurrent range subzone, X150

Figure 21: *Macroglobigerinelloides prairihillensis* PESSAGNO, sample no. NS 24, *G. elevata-D. asymetrica* concurrent range subzone, X150

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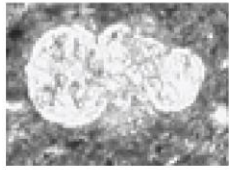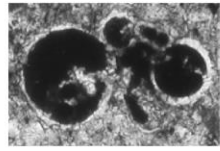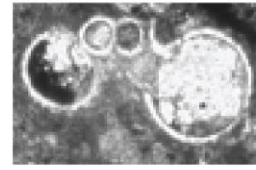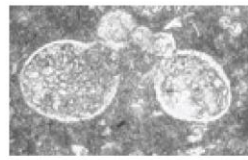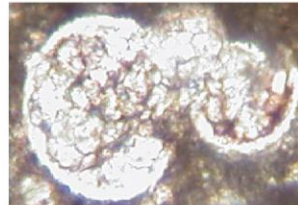
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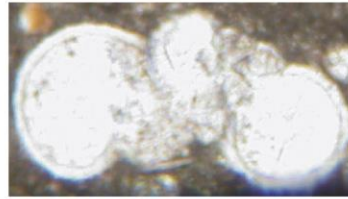
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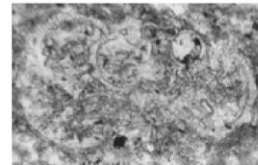
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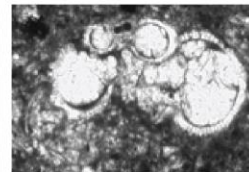
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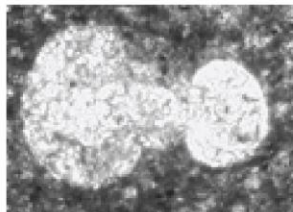
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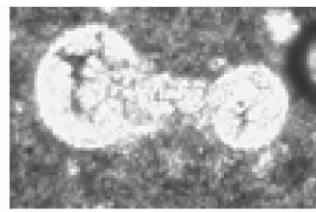
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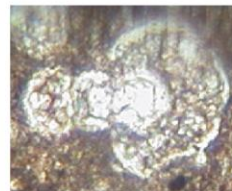
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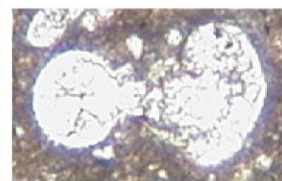
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PLATE 23

Figure 1: *Dicarinella algeriana* CARON, sample no. NS 3, *W. archaeocretacea* zone, X150

Figure 2: *Dicarinella algeriana* CARON, sample no. NS 3, *W. archaeocretacea* zone, X150

Figure 3: *Dicarinella algeriana* CARON, sample no. NS 3, *W. archaeocretacea* zone, X150

Figure 4: *Dicarinella algeriana* CARON, sample no. NS 1, *D. algeriana* subzone, X150

Figure 5: *Dicarinella canaliculata* ROSALINA, sample no. NS 14, *H. helvetica* zone, X90

Figure 6: *Dicarinella canaliculata* ROSALINA, sample no. NS 14, *H. helvetica* zone, X100

Figure 7: *Dicarinella canaliculata* ROSALINA, sample no. NS 18, *H. helvetica* zone, X100

Figure 8: *Dicarinella asymetrica* SIGAL, sample no. NS 20, *D. asymetrica* zone, X130

Figure 9: *Dicarinella asymetrica* SIGAL, sample no. NS 24, *G. elevata-D. asymetrica* concurrent range subzone, X130

Figure 10: *Dicarinella asymetrica* SIGAL, sample no. NS 33, *G. elevata-D. asymetrica* concurrent range subzone, X80

Figure 11: *Dicarinella concavata* BROTZEN, sample no. NS 20, *D. asymetrica* zone, X130

Figure 12: *Dicarinella concavata* BROTZEN, sample no. NS 24, *G. elevata-D. asymetrica* concurrent range subzone, X80

Figure 13: *Dicarinella concavata* BROTZEN, sample no. NS 33, *G. elevata-D. asymetrica* concurrent range subzone, X80

Figure 14: *Globotruncanita elevata* BROTZEN, sample no. NS 24, *G. elevata-D. asymetrica* concurrent range subzone, X80

Figure 15: *Globotruncanita elevata* BROTZEN, sample no. NS 24, *G. elevata-D. asymetrica* concurrent range subzone, X80

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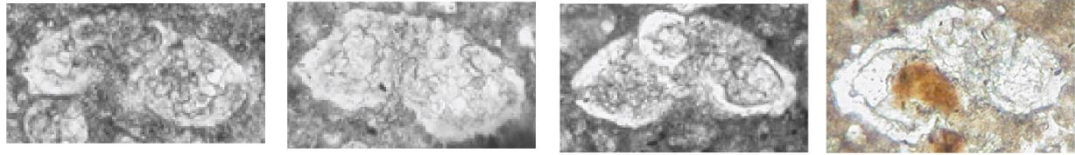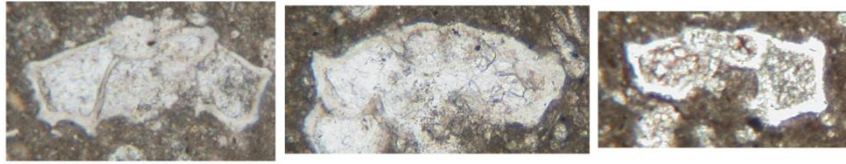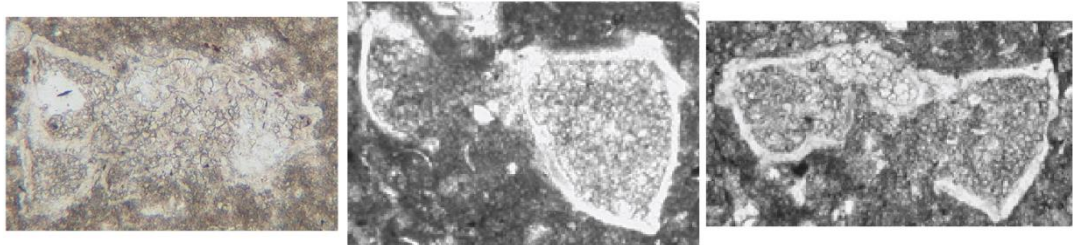
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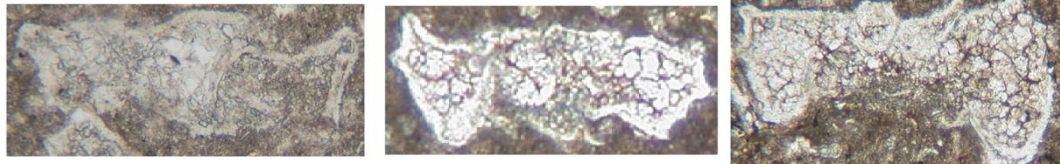
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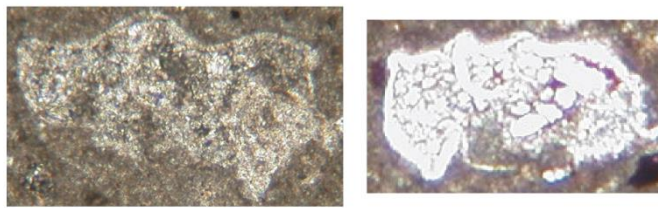
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PLATE 24

Figure 1: *Globotruncana bulloides* VOGLER, sample no. NS 62, *G. aegyptiaca* zone, X110

Figure 2: *Globotruncana bulloides* VOGLER, sample no. NS 62, *G. aegyptiaca* zone, X110

Figure 3: *Globotruncana bulloides* VOGLER, sample no. NS 62, *G. aegyptiaca* zone, X110

Figure 4: *Globotruncana hilli* PESSAGNO, sample no. NS 68, *G. aegyptiaca* zone, X130

Figure 5: *Globotruncana hilli* PESSAGNO, sample no. NS 68, *G. aegyptiaca* zone, X110

Figure 6: *Globotruncana arca* CUSHMAN, sample no. NS 39, *G. elevata* zone, X80

Figure 7: *Globotruncana arca* CUSHMAN, sample no. NS 39, *G. elevata* zone, X80

Figure 8: *Globotruncana arca* CUSHMAN, sample no. NS 61, *G. aegyptiaca* zone, X80

Figure 9: *Globotruncana arca* CUSHMAN, sample no. NS 61, *G. aegyptiaca* zone, X120

Figure 10: *Globotruncana lapparenti,* BROTZEN, sample no. NS 34, *G. elevata-D. asymetrica* concurrent range subzone, X80

Figure 11: *Globotruncana* cf. *lapparenti,* BROTZEN, sample no. NS 32, *G. elevata-D. asymetrica* concurrent range subzone, X80

Figure 12: *Globotruncana lapparenti,* BROTZEN, sample no. NS 34, *G. elevata-D. asymetrica* concurrent range subzone, X110

Figure 13: *Globotruncanita insignis* GANDOLFI, sample no. NS 37, *G. elevata-D. asymetrica* concurrent range subzone, X150

Figure 14: *Globotruncanita insignis* GANDOLFI, sample no. NS 37, *G. elevata-D. asymetrica* concurrent range subzone, X150

Figure 15: *Globotruncanita* cf. *ventricosa* WHITE, sample no. NS 37, *G. elevata-D. asymetrica* concurrent range subzone, X150

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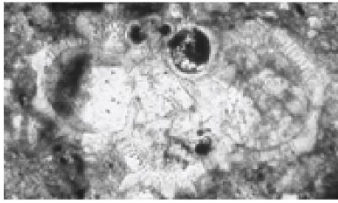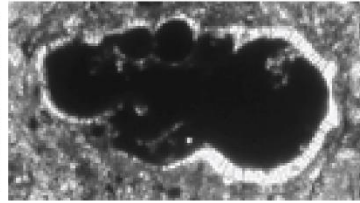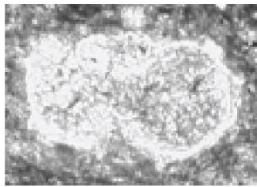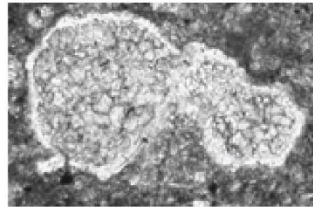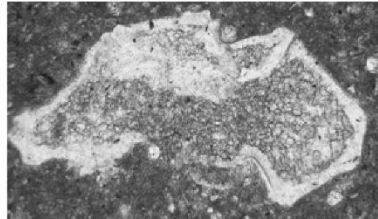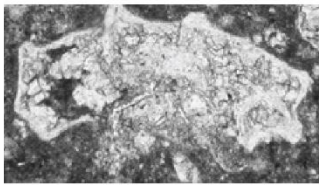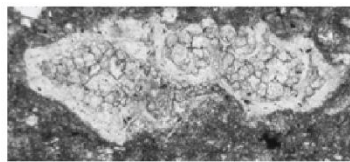
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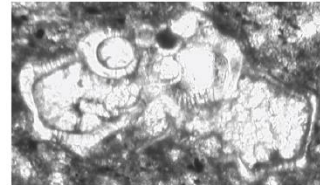
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PLATE 25

Figure 1: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 72, *G. aegyptiaca* zone, X120

Figure 2: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 70, *G. aegyptiaca* zone, X100

Figure 3: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 43, *G. elevata* zone, X120

Figure 4: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 41, *G. elevata* zone, X150

Figure 5: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 41, *G. elevata* zone, X120

Figure 6: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 32, *G. elevata-D. asymetrica* concurrent range subzone, X100

Figure 7: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 29, *G. elevata-D. asymetrica* concurrent range subzone, X100

Figure 8: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 26, *G. elevata-D. asymetrica* concurrent range subzone, X120

Figure 9: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 26, *G. elevata-D. asymetrica* concurrent range subzone, X120

Figure 10: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 26, *G. elevata-D. asymetrica* concurrent range subzone, X120

Figure 11: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 24, *G. elevata-D. asymetrica* concurrent range subzone, X120

Figure 12: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 24, *G. elevata-D. asymetrica* concurrent range subzone, X80

Figure 13: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 24, *G. elevata-D. asymetrica* concurrent range subzone, X100

Figure 14: *Globotruncana linneiana* D'ORBIGNY, sample no. NS 23, *D. asymetrica* zone, X100

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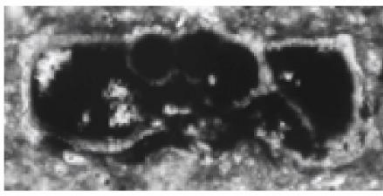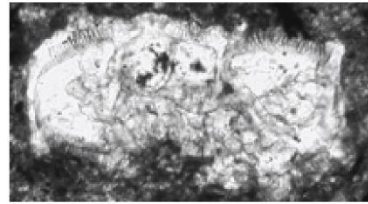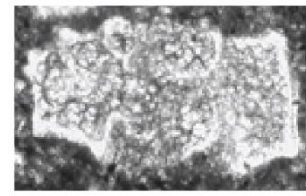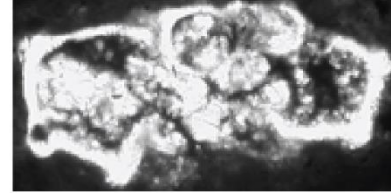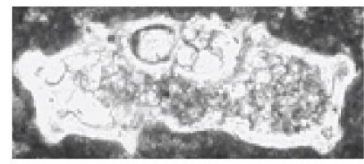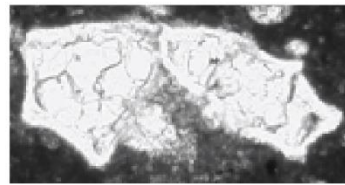
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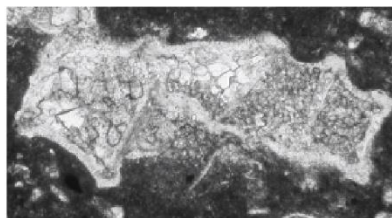
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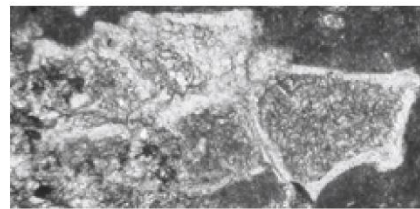
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PLATE 26

Figure 1: *Heterohelix globulosa* EHRENBERG, sample no. NS 71, *G. aegyptiaca* zone, X180

Figure 2: *Heterohelix globulosa* EHRENBERG, sample no. NS 66, *G. aegyptiaca* zone, X150

Figure 3: *Heterohelix globulosa* EHRENBERG, sample no. NS 55, *Globotruncanella* spp. zone, X250

Figure 4: *Heterohelix globulosa* EHRENBERG, sample no. NS 45, *G. elevata* zone, X150

Figure 5: *Heterohelix globulosa* EHRENBERG, sample no. NS 38, *G. elevata-D. asymetrica* concurrent range subzone, X150

Figure 6: *Heterohelix globulosa* EHRENBERG, sample no. NS 37, *G. elevata-D. asymetrica* concurrent range subzone, X150

Figure 7: *Heterohelix globulosa* EHRENBERG, sample no. NS 36, *G. elevata-D. asymetrica* concurrent range subzone, X180

Figure 8: *Heterohelix globulosa* EHRENBERG, sample no. NS 30, *G. elevata-D. asymetrica* concurrent range subzone, X250

Figure 9: *Heterohelix globulosa* EHRENBERG, sample no. NS 24, *G. elevata-D. asymetrica* concurrent range subzone, X200

Figure 10: *Heterohelix globulosa* EHRENBERG, sample no. NS 22, *G. asymetrica* zone, X180

Figure 11: *Heterohelix globulosa* EHRENBERG, sample no. NS 25, *G. elevata-D. asymetrica* concurrent range subzone, X180

Figure 12: *Laeviheterohelix turgida* NEDERBRAGT, sample no. NS 45, *G. elevata* zone, X150

Figure 13: *Laeviheterohelix* sp. 1, sample no. NS 38, *G. elevata-D. asymetrica* concurrent range subzone, X150

Figure 14: *Heterohelix moremani* CUSHMAN, sample no. NS 23, *D. asymetrica* zone, X150

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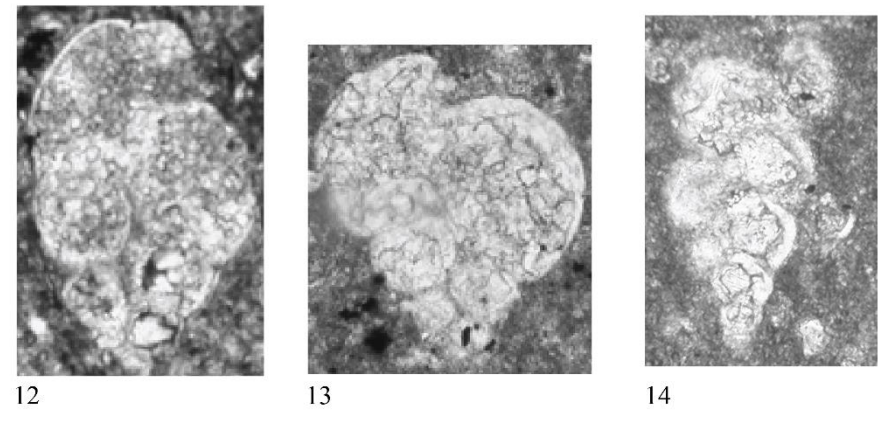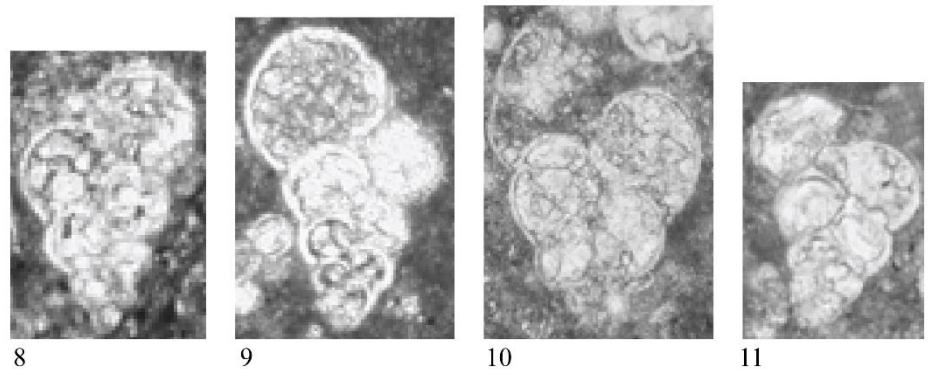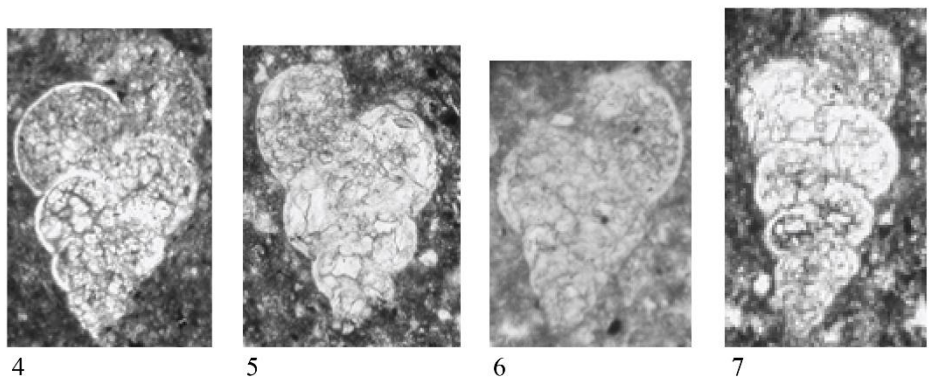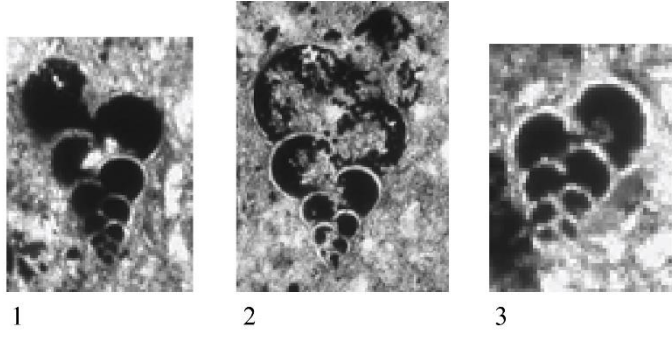
PLATE 27

Figure 1: *Marginotruncana pseudolinneiana* PESSAGNO, sample no. NS 14, *H. helvetica* zone, X110

Figure 2: *Marginotruncana pseudolinneiana* PESSAGNO, sample no. NS 18, *H. helvetica* zone, X100

Figure 3: *Marginotruncana pseudolinneiana* PESSAGNO, sample no. NS 20, *D. asymetrica* zone, X100

Figure 4: *Marginotruncana coronata* BOLLI, sample no. NS 14, *H. helvetica* zone, X110

Figure 5: *Marginotruncana renzi* GANDOLFI, sample no. NS 14, *H. helvetica* zone, X100

Figure 6: *Marginotruncana coronata* BOLLI, sample no. NS 14, *H. helvetica* zone, X100

Figure 7: *Marginotruncana marginata* REUSS, sample no. NS 14, *H. helvetica* zone, X150

Figure 8: *Marginotruncana marginata* REUSS, sample no. NS 14, *H. helvetica* zone, X150

Figure 9: *Marginotruncana marginata* REUSS, sample no. NS 18, *H. helvetica* zone, X110

Figure 10: *Marginotruncana sigali* REICHEL, sample no. NS 24, *G. elevata-D. asymetrica* concurrent range subzone, X90
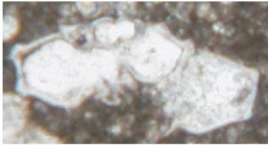
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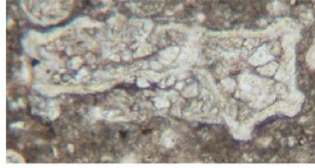
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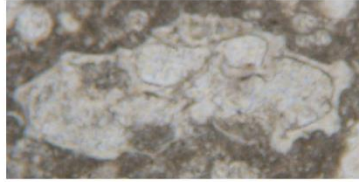
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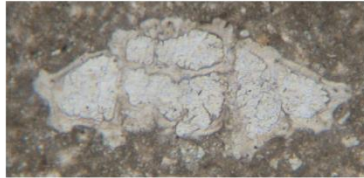
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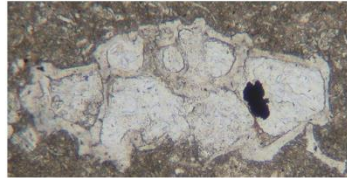
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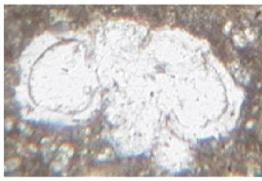
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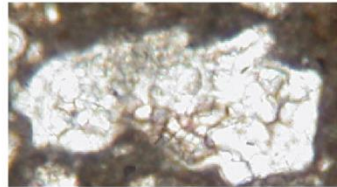
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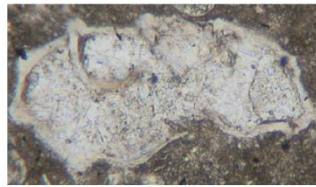
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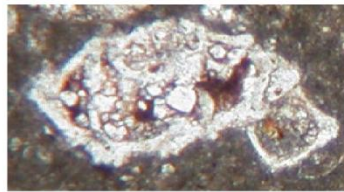
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PLATE 28

Figure 1: *Rotalipora deeckei* FRANKE sample no. NS 1, *D. algeriana* subzone, X80

Figure 2: *Rotalipora deeckei* FRANKE sample no. NS 1, *D. algeriana* subzone, X70

Figure 3: *Rotalipora cushmani* RENZ, sample no. NS 1, *D. algeriana* subzone, X90

Figure 4: *Rotalipora cushmani* RENZ, sample no. NS 2, *D. algeriana* subzone, X80

Figure 5: *Praeglobotruncana gibba* KLAUS, sample no. NS 2, *D. algeriana* subzone, X110

Figure 6: *Praeglobotruncana gibba* KLAUS, sample no. NS 1, *D. algeriana* subzone, X100

Figure 7: *Praeglobotruncana gibba* KLAUS, sample no. NS 1, *D. algeriana* subzone, X120

Figure 8: *Praeglobotruncana gibba* KLAUS, sample no. NS 2, *D. algeriana* subzone, X110

Figure 9: *Praeglobotruncana gibba* KLAUS, sample no. NS 2, *D. algeriana* subzone, X120

Figure 10: *Praeglobotruncana stephani* GANDOLFI, sample no. NS 1, *D. algeriana* subzone, X120

Figure 11: *Praeglobotruncana stephani* GANDOLFI, sample no. NS 1, *D. algeriana* subzone, X110

Figure 12: *Praeglobotruncana stephani* GANDOLFI, sample no. NS 1, *D. algeriana* subzone, X120

Figure 13: *Praeglobotruncana stephani* GANDOLFI, sample no. NS 2, *D. algeriana* subzone, X110

Figure 14: *Praeglobotruncana stephani* GANDOLFI, sample no. NS 2, *D. algeriana* subzone, X120

Figure 15: *Praeglobotruncana stephani* GANDOLFI, sample no. NS 18, *H. helvetica* zone, X110

Figure 16: *Schakoina cenomana* SCHAKO, sample no. NS 33, *G. elevata-D. asymetrica* concurrent range subzone, X100

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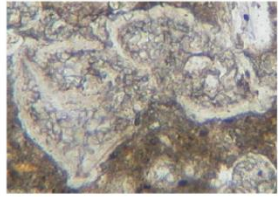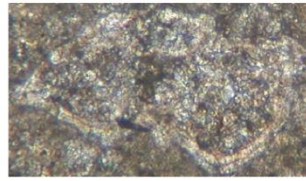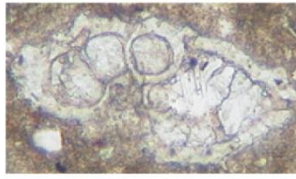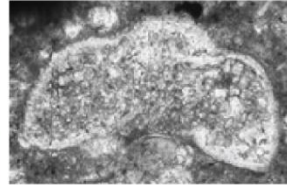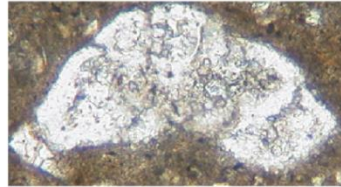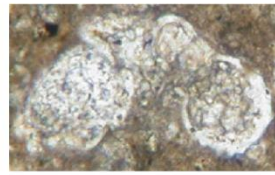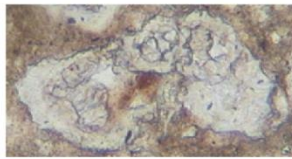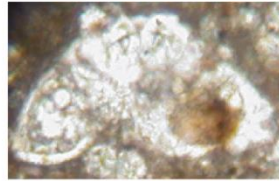
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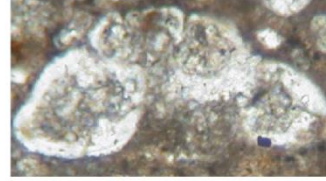
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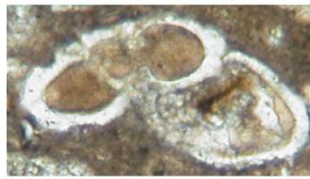
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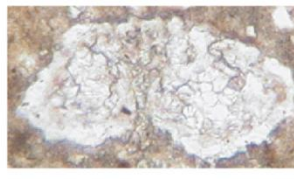
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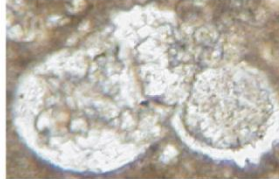
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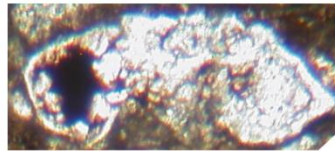
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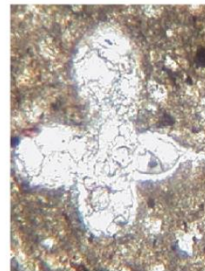
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PLATE 29

Figure 1: *Whiteinella baltica* DOUGLAS AND RANKIN, sample no. NS 14, *H. helvetica* zone, X100

Figure 2: *Whiteinella baltica* DOUGLAS AND RANKIN, sample no. NS 14, *H. helvetica* zone, X100

Figure 3: *Whiteinella aprica* LOEBLICH AND TAPPAN, sample no. NS 14, *H. helvetica* zone, X120

Figure 4: *Whiteinella archaeocretacea* PESSAGNO, sample no. NS 14, *H. helvetica* zone, X120

Figure 5: *Whiteinella archaeocretacea* PESSAGNO, sample no. NS 14, *H. helvetica* zone, X120

Figure 6: *Whiteinella paradubia* SIGAL, sample no. NS 14, *H. helvetica* zone, X100

Figure 7: *Whiteinella paradubia* SIGAL, sample no. NS 14, *H. helvetica* zone, X100

Figure 8: *Whiteinella paradubia* SIGAL, sample no. NS 17, *H. helvetica* zone, X100

Figure 9: *Helvetoglobotruncana helvetica* BOLLI, sample no. NS 14, *H. helvetica* zone, X130

Figure 10: *Helvetoglobotruncana helvetica* BOLLI, sample no. NS 14, *H. helvetica* zone, X130

Figure 11: *Helvetoglobotruncana helvetica* BOLLI, sample no. NS 14, *H. helvetica* zone, X130

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Figure 12: *Helvetoglobotruncana helvetica* BOLLI, sample no. NS 14, *H. helvetica* zone, X130

Figure 13: *Whiteinella praehelvetica* TRUJILLO, sample no. NS 14, *H. helvetica* zone, X100

Figure 14: *Whiteinella praehelvetica* TRUJILLO, sample no. NS 14, *H. helvetica* zone, X100
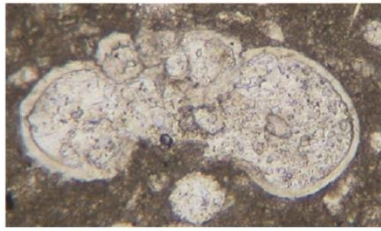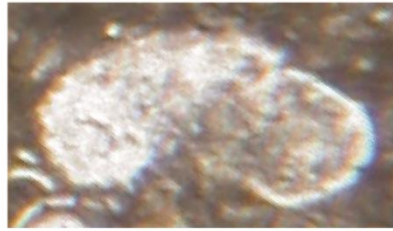
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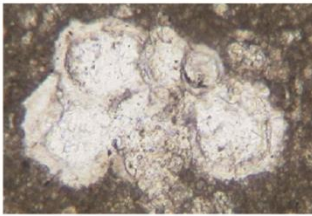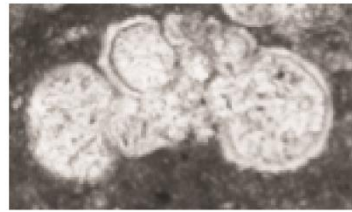
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