# DEEP SEA BENTHIC FORAMINIFERAL DIVERSITY AND ABUNDANCE CHANGES ACROSS CRETACEOUS-PALEOGENE BOUNDARY BEDS IN THE HAYMANA BASIN (ANKARA, TURKEY): PALEOENVIRONMENTAL IMPLICATIONS

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

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# ABSTRACT

## DEEP SEA BENTHIC FORAMINIFERAL DIVERSITY AND ABUNDANCE CHANGES ACROSS CRETACEOUS-PALEOGENE BOUNDARY BEDS IN THE HAYMANA BASIN (ANKARA, TURKEY): PALEOENVIRONMENTAL IMPLICATIONS

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In order to establish the taxonomy of deep-sea (small) benthic foraminifera and to evaluate their paleoenvironment and paleoecology in terms of relative abundances and diversity, a 14.53 meters-thick section was measured from the Haymana Formation and the Yeşilyurt Formation containing Cretaceous-Paleogene boundary beds in the northern part of the Haymana Basin, Central Turkey. 17 mudstone samples corresponding to 3.15 meters of the upper Maastrichtian and 8 mudstone-marl samples representing 1.21 meters of the lower Danian were studied in detail, around 300 benthic foraminifera individuals were picked from >125 μm fraction for each sample.

Three biozone were established for the first time from Turkey; which are *Bolivinoides draco* Zone and *Eouvigerina subsculptura* Acme Zone (newly proposed) for the Maastrichtian and BB1 Zone for the Danian. As a part of the quantitative assessment, morphogroup analysis were performed with intent to infer infauna-epifauna ratio. Calcareous and agglutinated taxa were categorized into 15 morphogroups overall. Calcareous taxa are assigned as CI1 (cylindrical tapered), CI2 (flattened tapered), CI3 (rounded planispiral), CI4 (spherical) for infaunal group and CE1 (planoconvex trochospiral), CE 2 (biconvex trochospiral), CE3 (rounded trochospiral), CE4 (palmate), CE5 (branching) for epifaunal groups. Agglutinated taxa were sorted by AI1 (elongate multilocular), AI2 (flattened trochospiral), AI3 (elongate tapered) for infaunal groups and AE1 (coiled flattened & streptospiral), AE2 (elongate keeled), AE3 (tubular-branching) for epifaunal groups. Morphogroup analysis shows that the relative abundance of infaunal groups make up average 75% of the total Maastrichtian assemblage. This relatively high infaunal abundance suggests meso- to eutrophic conditions accordingly with the presence of common species preferring high nutrient levels.

Quantitative analysis also showed that calcareous taxa is more abundant with respect to agglutinated taxa, with relative abundance of average 73.9% in Maastrichtian and average 89.0% in Danian, offering a depositional setting well above the Calcium Carbonate Compensation Depth (CCD). Moreover, open marine conditions and upper bathyal environment (~200-600m) are suggested for the whole studied section based on the benthic foraminiferal diversity and associations. A remarkable change from highly diverse Maastrichtian benthic foraminifera assemblage to poor-moderately diverse Danian benthic foraminifera assemblage is assessed at the transition from the Haymana Formation to the Yeşilyurt Formation. This change is revealed for the first time in Turkey and associated with disappearance of 53% of Maastrichtian taxa as well as the high abundance of epifaunal taxa (average 75.8%) after the boundary which possibly resulted from decline of primary productivity at the K-Pg boundary.

**Keywords:** Cretaceous-Paleogene boundary, deep sea benthic foraminifera, quantitative analysis, paleoenvironment, Haymana Basin

# ÖZ

# HAYMANA HAVZASI’NDA (ANKARA, TÜRKİYE) KRETASE-PALEOJEN SINIR TABAKALARINDAKİ DERİN DENİZ BENTİK FORAMİNİFERLERİNİN ÇEŞİTLİLİK VE BOLLUKLARINDAKİ DEĞİŞİMLER: PALEORTAMSAL GÖSTERGELERİ

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Derin deniz bentik foraminiferlerin taksonomilerini ortaya koymak, bolluk ve çeşitlilikleri dikkate alarak paleoortam ve paleoekolojilerini değerlendirmek amacıyla, Haymana Baseni’nin kuzey kesimindeki lokasyondan, K-Pg sınır tabakalarının bulunduğu Haymana Formasyonu ve Yeşilyurt Formasyonu’ndan 14.53 metre kalınlığında bir kesit ölçülmüştür. Kesitin Üst Maastrihtiyen kısmının 3.15 metrelik bir uzunluğuna denk gelen 17 adet çamurtaşı örneği ve Alt Danian kısmının 1.21 metrelik kısmına denk gelen 8 adet çamurtaşı-marn örneği detaylı olarak çalışılmış, her örnek için 125 µm’lik elek üzerinde kalan fraksiyondan yaklaşık 300 bentik foraminifer bireyi toplanmıştır.

3 adet biyozon Türkiye’den ilk kez belirlenmiş olup, bunlar; Maastrihtiyen için *Bolivinoides draco* Zonu ve *Eouvigerina subsculptura* Acme Zonu (yeni önerilen) ve Daniyen için BB1 Zonu’dur. Infaunal - epifaunal bentik foraminifer oranının

ortaya konulması amacıyla, numerik analizlerin bir kısmı olan morfogrup analizi yapılmıştır. Kalkerli ve aglutine taxa toplamda 15 morfogruba ayrılmıştır. Kalker kavkılılar infaunal gruplar için; CI1 (silindirik incelen), CI2 (basık incelen), CI3 (yuvarlak planispiral), CI4 (küresel); epifaunal gruplar için CE1 (planokonveks trokospiral), CE2 (bikonveks trokospiral), CE3 (yuvarlak trokospiral), CE4 (palmiye şekilli), CE5 (kollara ayrılan) olarak belirlenmiştir. Aglutine kavkılılar infaunal gruplar için; AI1 (uzun çok localı), AI2 (basık trokospiral), AI3 (uzun incelen) ve epifaunal gruplar için AE1 (basık sarınımlı & streptospiral), AE2 (uzun karinalı), AE3 (boru şekilli-dallanan) şeklinde kategorize edilmiştir. Morfogrup analizi ile Maastrihtiyen'de infaunal formların bolluk açısından bütün topluluğun ortalama 75%'ini oluşturduğu belirlenmiştir. Bu göreceli yüksek infaunal topluluk, yüksek besin seviyelerinde yaşamayı tercih eden türlerin de varlığı ile birlikte meso- ötrofik ortamı işaret etmektedir.

Numerik analiz aynı zamanda kalkerli kavkıların Maastrihtiyen'de ortalama 73.9%, Daniyen'de ortalama 89.0% oranla ile, aglutine kavkılara oranla daha bol bulunduğunu göstermiştir. Bu sonuç, Kalsiyum Karbonat Kompanzasyon Derinliği (CCD)'nin üzerinde bir depolanma ortamını göstermektedir. Ayrıca, foraminifer topluluğu ve çeşitliliği baz alınarak, açık deniz ve üst batiyal (~200-600 m) ortamı önerilmiştir. Haymana Formasyonu-Yeşilyurt Formasyonu geçişinde çok çeşitli Maastrihtiyen bentik foraminifer topluluğundan, az-ortalama çeşitli Daniyen topluluğuna önemli bir değişim gözlenmiştir. Bu geçiş, Türkiye'den ilk kez belirtilmiş olup, Maastrihtiyen formlarının 53% oranında fosil kaydından kaybolması ve epifaunal formların ortalama 75.8% bolluğunda toplulukta bulunmasıyla birlikte belirlenmiştir. Sınırdan sonra epifaunal formların bol miktarda bulunması yüksek ihtimalle K-Pg sınırındaki birincil verimlilikteki düşüş sonucunda gelişmiştir.

**Anahtar Kelimeler:** Kretase-Paleojen sınırı, derin denizel bentik foraminifer, numerik analiz, paleoortam, Haymana Havzası

*to my beloved family...*

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# TABLE OF CONTENTS

CHAPTERS

4. PALEOENVIRONMENTAL AND PALEOECOLOGICAL

APPENDICES

# LIST OF TABLES

TABLES

# LIST OF FIGURES

FIGURES

# CHAPTER 1

# INTRODUCTION

## 1.1 Purpose and Scope

One of the most catastrophic mass extinctions throughout the Phanerozoic is coinciding with the Cretaceous-Paleogene (K-Pg) boundary. The K-Pg boundary event is pointing a severely affected pelagic ecosystem (Speijer, 1994). Planktonic foraminifera experienced a clear mass extinction. On the other hand, the influence of the boundary event on benthic foraminifera communities was said to be much more toward the shallower part of the basins (Peryt et al., 2002 and references therein). They survived fairly the K-Pg boundary events in both shallow and deep environments (Culver, 2003).

The Haymana Basin is comprising of many Cretaceous-Paleogene shallow-marine and deep-marine flychoidal successions including the K-Pg boundary, with well preserved and abundant microfossil records including foraminifera. Comprehensive K-Pg boundary studies were conducted by Esmeray (2008), Esmeray et al. (2015) and Karabeyoğlu (2017) based on the planktonic foraminifera from the basin.

Karabeyoğlu (2017) measured a stratigraphic section from the Haymana Basin and revealed a planktonic foraminifera biostratigraphy, response of planktonic foraminifera assemblages to the K-Pg boundary event and lithological changes through this transition. With this thesis, a detailed work on the benthic foraminifera community of the same measured section are intended, since it is expected to be well calibrated with the previously established planktonic foraminifera stratigraphy.

Benthic foraminifera is considered as one of the main important communities in marine environment. They are very sensitive to environmental changes (Gooday, 2003). Therefore, in many K-Pg localities, rearrangement in the community structure of deep-water benthic foraminifera were observed right after the K-Pg boundary event (Peryt et al. 2002, Coccioni and Marsili, 2007). There are few studies regarding the taxonomy and paleoenvironmental response of bathyal benthic foraminifera from the K-Pg sections based on the quantitative data representing the northern border of Tethyan realm and Turkey. Those include studies of Gawor-Biedowa (1992), Görmüş (1994a) regarding the Late Cretaceous small benthic foraminifera taxonomy and a recent publication by Vellekoop et al. (2017) covering a quantitative benthic foraminifera study at a K-Pg boundary section from the Mudurnu-Göynük Basin. There is, yet no established environmental response of deep-water benthic foraminifera associations to the K-Pg boundary event with the documented taxonomy from the Haymana region based on a quantitative assessment.

Concisely, the purpose of this study is to accomplish a high resolution quantitative study of the Maastrichtian-Danian deep-water benthic foraminifera from the Haymana Formation and the Yeşilyurt Formation including the deep marine K-Pg boundary beds in the Haymana Basin, Central Turkey. With this thesis, presenting the relative abundances and diversity of benthic foraminifera species, revealing the response of these associations to the boundary event and demonstrating the past environment as well as the taxonomy of the foraminifera were aimed to be carried out for the first time from this deep marine Maastrichtian-Danian succession in the northern region of the Haymana Basin, Turkey.

To achieve this, ~300 benthic foraminifera individuals were picked for each sample from the representative splits of 25 washed samples. Taxonomy of the deep water benthic foraminifera were studied in detail. Biozones were established based on the recorded bioevents through the studied section. Morphogroup analysis were implemented based on the quantitative assessment in order to construct the paleonvironment and investigate the paleobathymetry. As a result of the quantitative survey, ratio of calcareous- agglutinated taxa, relative abundances of each benthic foraminifera species and morphotypes as well as their diversity of the fauna with the computed biodiversity indices were revealed. Additionally, the response of the benthic foraminifera fauna to the K-Pg boundary event was established.

## 1.2 Geographic Setting

The research area is located between Haymana town and Çayraz village, approximately 2 km southwest of Çayraz village and 59 km southwest of Ankara (Figure 1A, B, C). The latitude and the longitude of the measured section are 39°27'53N and 32°31'41E, respectively. It is placed on the J29–A1 topographic map of Ankara with the scale of 1/25000.

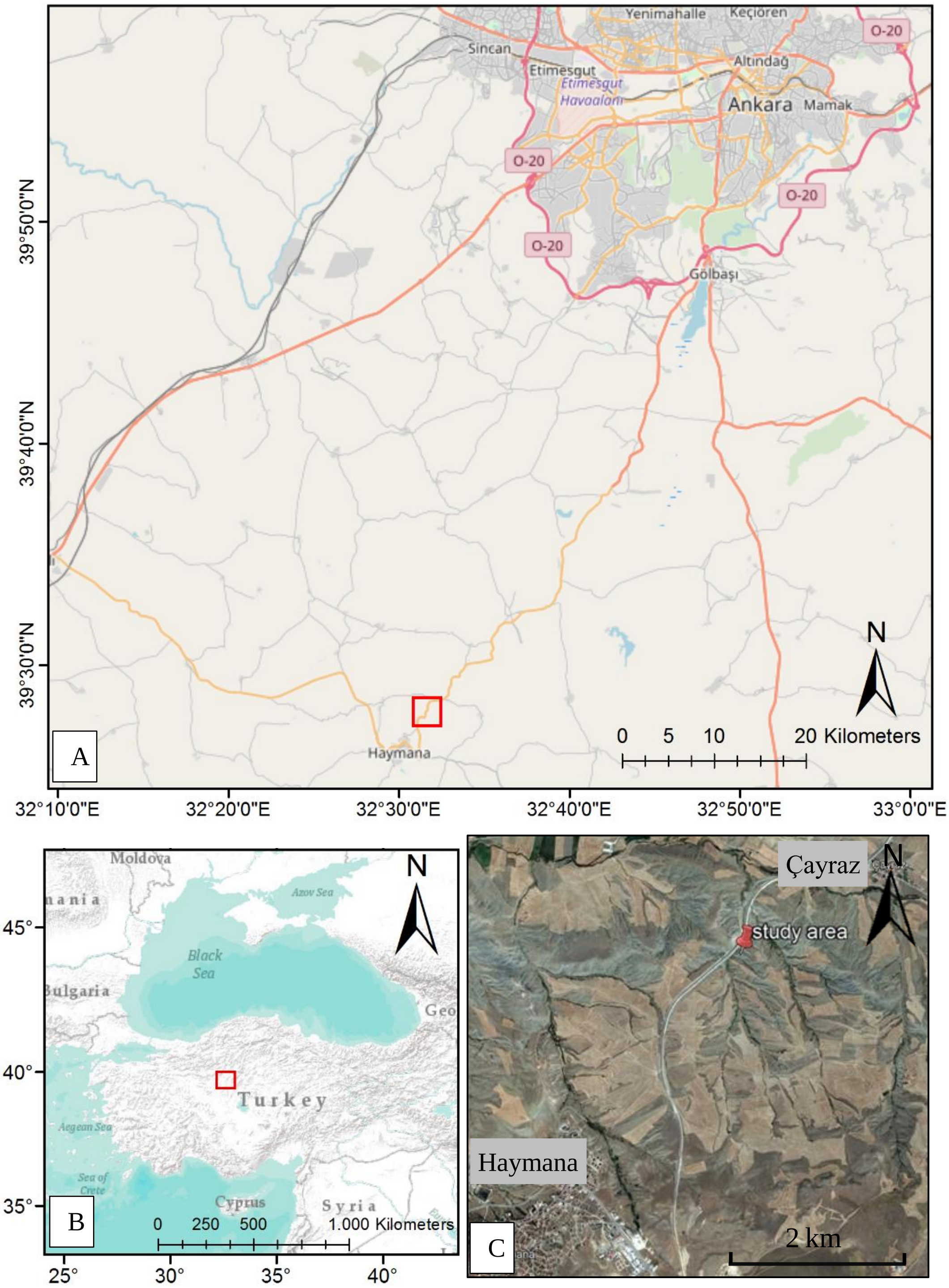

Figure 1: Location map of the research area which is shown with the red rectangles near Haymana (A), on the Turkey map (B) and red pin on the Google Earth image (C).

## 1.3 Materials and Methods

This thesis work is comprising of both field and laboratory works accompanied by a broad literature survey.

In the field survey, a 14.53 m stratigraphic section in total was measured from mudstone and marl-calcareous mudstone alternations with sample resolution ranging from 5 cm to 20 cm, via two consecutive field excursions. On the first field work, a 9.70 m thick section was measured which represented in this work by UH samples. This section includes 51 samples tagged as UH-1 to UH-51. The highest two samples, UH-50 and UH-51, are representing the lowermost Danian stage coinciding with the Yeşilyurt Formation, whereas 49 samples tagged from UH-1 to UH-49, are the uppermost Maastrichtian samples belonging to the Haymana Formation. Samples were collected from unweathered parts of the beds by digging a small trench to reach the fresh portion of rock body.

On the second field work, a 5.03 m long section was measured including marl and calcareous mudstone levels of the Yeşilyurt Formation, except for the first sample, UKHB-1, which belongs to the Haymana Formation and taken just below the boundary. 38 samples in overall have been collected through this interval. Samples are tagged as from UKHB-1 to UKHB-38.

Not all of the collected samples have been used for the benthic foraminifera analysis. The studied samples, which are 25 in total, corresponds to 3.15 m below and 1.21 m above the K-Pg boundary. After the field survey, laboratory works were carried out which detailed in the below section.

### 1.3.1 Sample Preparation for Foraminifera Analysis

Rock samples collected from the field were washed and prepared in micropaleontology laboratory of the Department of Geological Engineering, Middle East Technical University. A series of widely-used micropaleontological methods for foraminifera extraction including some mechanical and chemical techniques were used for this process, following the stages used in the work of Karabeyoğlu (2017).

As the mechanical process, samples were crushed and cut into pieces by a hammer about maximum volume of 5 mm$^3$. This technique was applied for increasing surface area of the sample (Hodgkinson, 1991). It was paid attention that the samples were not completely become powder, because too much crushing may cause breaking of foraminifera tests. In the chemical treatment stage, 100 g of the crushed rocks per sample were disaggregated with 200 ml of 50% Hyrogen Peroxide ($H_2O_2$) solution for 20 minutes in a glass beaker.

After that chemical operation, at the end of 20 minutes, samples were washed under tap water using the sieve with openings of 38 µm, 63 µm, 125 µm, 150 µm, 250 µm and 425 µm. Hand rubbing was also applied very gently during wet sieving process to move away leftover clasts on foraminifera tests. Then, samples on each sieve were transferred into glass petri dishes by using distilled water. Each sieve was cleaned carefully by brushing after washing process to make them get ready for the following washing process.

Washed samples were left for drying in oven at 50°C. Paper bags were prepared for storing of dried samples for each sieve fraction. Labeling was paid attention throughout the sample preparation process to avoid any confusion between the samples.

### 1.3.2 Benthic Foraminifera Analysis

25 washed samples were used for quantitative benthic foraminiferal analysis. 17 samples out of 25 represent the uppermost Maastrichtian part of the Haymana Formation, whereas the other 8 samples belong to the lowermost Danian part of the Yeşilyurt Formation.

Although there are arguments stating the importance of using smaller fractions (>63 µm) in foraminiferal studies due to the presence of small paleoenvironmental indicator forms (Schröeder et al., 1987), there are also many benthic foraminiferal studies in which the larger fraction (>125 µm or even larger) was used regarding the paleoecological and paleoenvironmental investigations (Table 1). Moreover, some benthic foraminifera datasets with smaller size fraction (>63 µm) were argued to be skewed to the datasets with larger size fraction (Ernst et al., 2006 and references therein).

Table 1: Benthic foraminifera studies with larger fraction used in the paleoecological and paleoenvironmental investigations.

| Size fraction | Time interval | Author |
|---|---|---|
| > 150 µm | K-Pg boundary | Dailey (1983) |
| > 150 µm | K-Pg boundary | Keller (1988) |
| >149 µm | K-Pg boundary | Nomura (1991) |
| > 125 µm | K-Pg boundary | Widmark&Malmgren(1992a) |
| > 125 µm | K-Pg boundary | Coccioni and Galeotti (1994) |
| 125 - 595 µm | K-Pg and P-E boundary | Speijer (1994) |
| 125 - 595 µm | K-Pg boundary | Speijer et al (1996) |
| >100 µm | K-Pg boundary | Peryt et al. (1997) |
| > 125 µm | Campanian to Paleocene | Van den Akker et al (2000) |
| 125 - 500 µm | Late Campanian - Early Maastrichtian | Friedrich et al. (2005) |
| 125 - 630 µm | Latest Paleocene | Stassen et al. (2009) |
| 125 - 630 µm | Latest Danian | Sprong et al. (2012) |
| > 125 µm | Latest Maastrichtian | Woelders and Speijer (2015) |

In this study, benthic foraminifera analysis was conducted initially by using >63 µm fraction, but later this lower limit was increased to >125 µm fraction due to very small foraminiferal populations and difficulties in small benthic foraminifera taxonomy as well as taphonomic obstacles. Furthermore, using smaller size fractions need extra workforce and regarded as time consuming (Schröeder et al., 1987). Besides, more particularly, the taxonomical assignment of small and/or juvenile specimens under the binocular microscope with maximum 100x magnification would be problematic. Therefore, the larger (>125 µm) fraction, was decided to be adopted for this study, expecting more appropriate taxomonic identification.

For each sample, approximately 300 benthic foraminifera individuals were picked from >125 µm fraction from the representative splits. This threshold value was chosen, because minimum 300 benthic foraminifera specimens for one sample was considered as the best representative size for diversity calculations (Thomas, 1989). All benthic foraminifera specimens have been picked from the processed split per sample. Picked specimens were stored in cardboard micropaleontology slides.

Benthic foraminifera species were identified by using Nikon SMZ-645 model binocular microscope under both transmitted and reflected light. Scanning electron microscope (SEM) images were also used for identification of external morphological features of foraminifera. Representative individuals of the identified species were picked from both quantitatively analysed splits and unprocessed splits for the scaning electron microscope anaysis (Figure 2A). They were carefully arrayed on SEM specimen holder (Figure 2B). SEM photographs were taken at the Department of Metallurgical and Materials Engineering - Scanninng Electron Microscope Laboratory, Middle East Technical University (Figure 3).

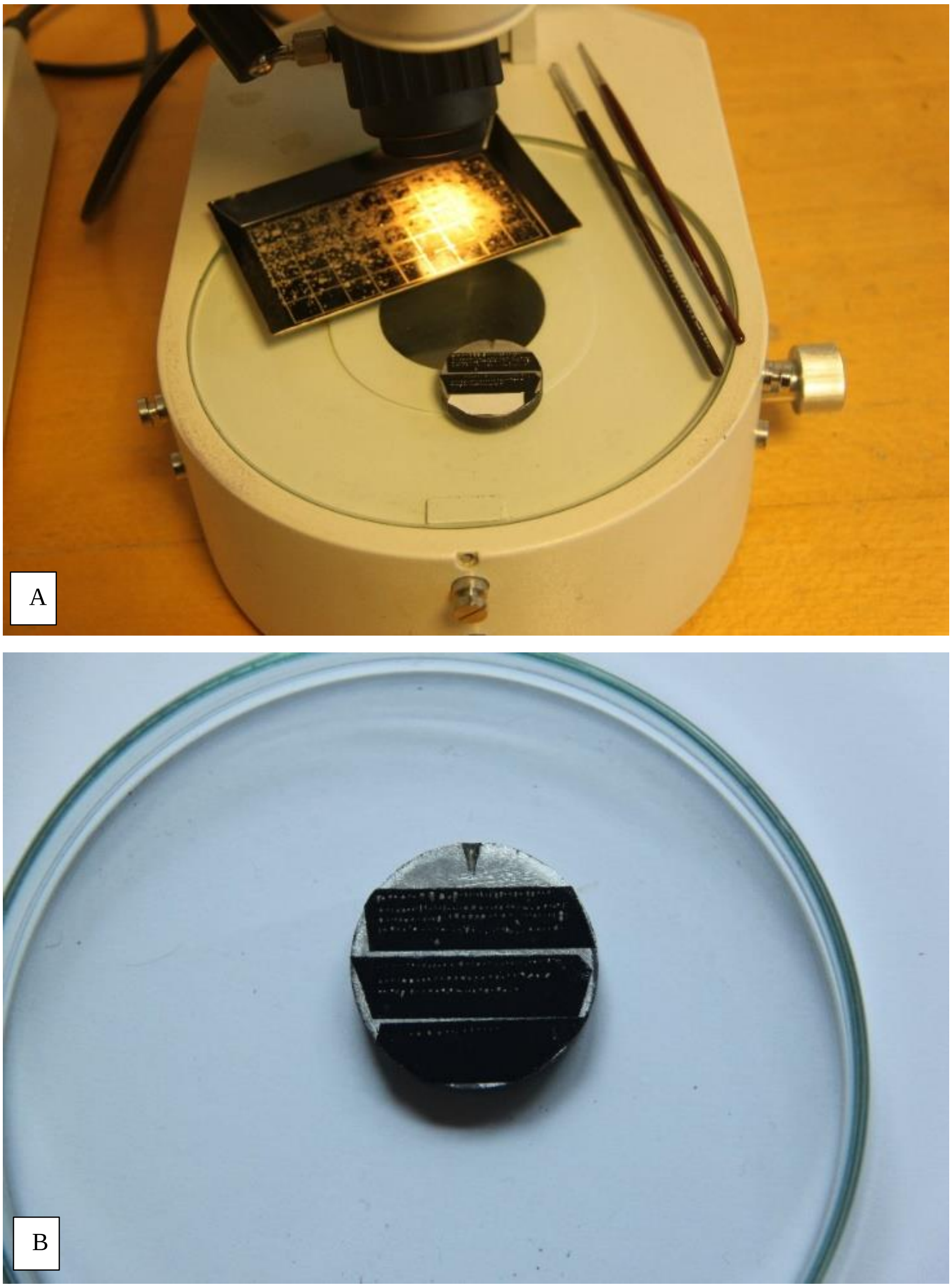

Figure 2: Selection of SEM samples on the picking tray (A), organization of SEM sample array (B).

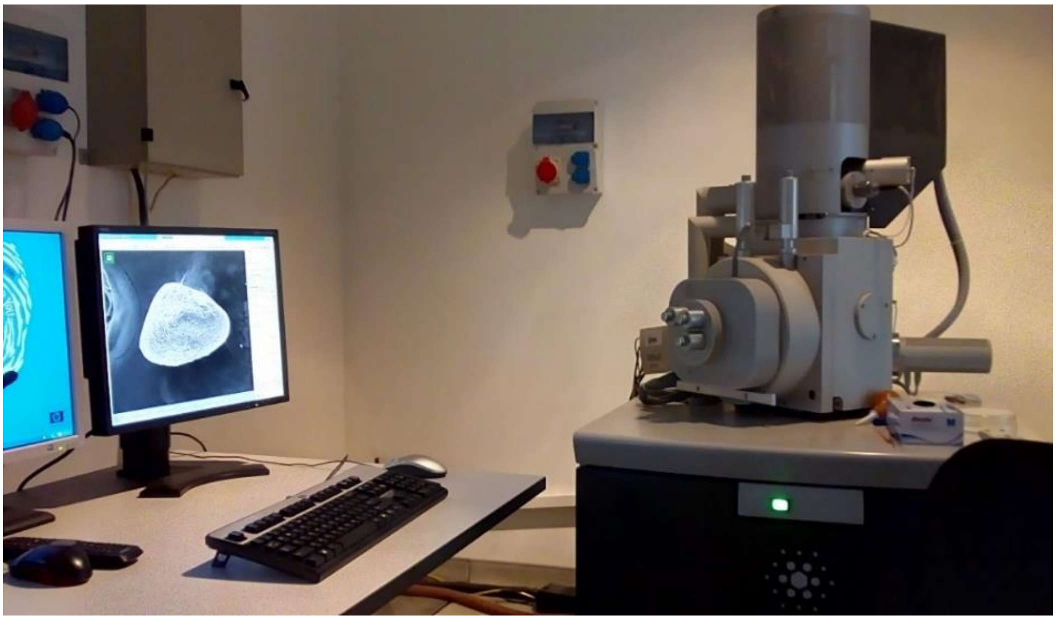

Figure 3: SEM imaging of microfossils in the Metallurgical and Materials Engineering - Scanninng Electron Microscope Laboratory, METU.

## 1.4 Previous Works

### 1.4.1 Previous Works on Cretaceous and Paleogene Small Benthic foraminifera including K-Pg studies

Plummer (1926) made a contribution by working on small benthic foraminifera species appertaining to Midway Formation in Texas. She stated that this fauna was a specific assemblage involved in that part of the geological sequence. She introduced the systematical classification of the most common forms which are distinctive for the Midway unit.

Another contribution to systematics of small benthic foraminifera come from Cushman (1926). Foraminiferal assemblage from Upper Cretaceous Velasco shale in Mexico, illustrating and defining the most common species. He also pointed the close affinity of Velasco and Europian fauna of Late Cretaceous, stating that many species of Velasco fauna and that of Upper Cretacous European localities had been very alike. Cushman (1946) performed a broad taxonomical study of foraminifera from the material come from mostly Texas and also Mississippi, Alabama, Tennessee, Arkansas and Louisiana, around 600 foraminifera species were and illustrated in that publication. Cushman (1951) thereafter published a taxonomy paper considering the Paleocene foraminifera from those localities and additionally from Trinidad, Cuba, Haiti and Central part of the America.

Starting from the 1970s, in addition to taxonomical works, many studies regarding Cretaceous and Paleogene small benthic foraminiferal paleogeography and paleoenvironment as well as their response to the K-Pg boundary events were published. Sliter and Baker (1972) proposed a paleobathymetrical model for Cretaceous neritic and bathyal benthic foraminifera genera, commenting their anology to the recent communities.

Berggren and Aubert (1975) provided a remarkable work on Paleocene benthic foraminifera considering paleogeography and bathymetry of foraminiferal associations from Tethys and Atlantic regions. They established two important cosmopolitan benthic foraminifera assemblages, Midway type Fauna and Velasco Type Fauna, for middle to outer shelf and bathyal to abyssal environments, respectivley. Taxonomical revisions on Paleocene small benthic foraminifera species were also revealed.

Haig (1979) reported three different mid-Cretaceous small benthic foraminifera assemblages as well as planktonic foraminifera association. Each of them is accompanied by distinct ecological units. Relatively low diversified *Ammobaculites* association refers to shallower, epicontinental environment and includes large number of siliceous agglutinated foraminifera, whereas *Marssonella* association reflects more open marine (continental shelf) conditions including calcite cemented agglutinated foraminifera and diverse calcareous foraminifera. *Recurvoides* association was comprising of siliceous agglutinated taxa and usually devoid of calcareous foraminifera. It corresponded to much deeper oceanic environment. Differentiation of each association with respect to different water depth intervals were also disscussed. Moreover, he emphasized the cosmopolitan distribution nature of small benthic foraminifera and their restricted usage as being indicator of “provincialism”.

Van Morkhoven et al. (1986) discussed the taxonomy, biostratigraphy as well as paleobathymetry of Cenozoic cosmopolitan deep sea benthic foraminifera. They argued that deep water benthic foraminifera species generally have relatively long stratigraphic ranges. Moreover, they also mentioned that one of the difficulties during their taxonomy works was phenotypic variations of species due to the different environmental parameters in distinct bathymetrical position in one chronocline.

Berggren and Miller (1989) presented Cenozoic deep water benthic foraminifera biozonations regarding two different zones which are bathyal and abyssal, publishing fourteen biozonations for bathyal environment and twelve for abyssal environment. Efficiency of benthic foraminifera in biostratigraphical purposes was fairly limited if compared to planktonic foraminifera due to their facies dependency and also diachronic occurrences. Besides, they recognized in their study that many some deep sea benthic foraminifera taxa are useful for biostratigraphic investigations.

Kuhnt et al. (1989) worked on the Late Cretaceous deep water agglutinated foraminifera assemblages from North Atlantic and Western Tethyan localities. Six different Turonian – Maastrichtian deep water agglutinated foraminifera assemblages were recognized based on the different latitude and bathymetrical divisions. Those were high latitude slope assemblages, low-middle latitude slope assemblages, flysch type assemblages, scaglia type (deep water limestone) assemblages, abyssal mixed calcareous and agglutinated assemblages and abyssal entirely agglutinated assemblages. They also revealed five bathymetrical zonations for low-middle latitudes.

Koutsoukos and Hart (1990) established a broad comprehensive study regarding Late Aptian to Maastrichtian neritic-lower bathyal benthic foraminifera morphogroups and their connection with some ecological parameters such as trophic structures and depth-related parameters. It was stated that benthic foraminifera morphogroups are well reactive to ecological variations. They offered the morphogroup analysis as an effective appliance to understand paleoceanography and paleoenvironment. Moreover, the authors remarked a caution that taphonomic process should always be taken into account in interpretations about the paleocommunity structures.

Widmark and Malmgren (1992a) revealed the response of deep water benthic foraminifera at K-T boundary in three DSDP sites; 525, 527 and 465. Their results showed that deep water benthic foraminifera were not critically influenced by the boundary event, because the most of the Maastrichtian forms were argued not to have been affected by the boundary event. Relative abundance of infaunal taxa were diminished at the South Atlantic localities through the boundary, probably showing a diminishing of the primary productivity. It was suggested that before and concurrently with the K-T boundary, deep water settings in higher latitudes were offered to be more unstable, namely stressed when compared to that in lower latitudes.

Widmark and Malmgren (1992b) worked on Late Cretaceous deep sea (bathyal - abyssal) benthic foraminifera from different geographic locations from DSDP in an attempt to analyze their pretended cosmopolitan character. Their statistical analysis showed that particularly 9% of the taxa were actually assigned as cosmopolitan, as an opposing argument of general cosmopolitan aspect of deep water benthic foraminifera of the Late Cretaceous.

Gawor-Biedowa (1992) and Bolli et al. (1994) revealed taxonomy and stratigraphic distribution of small benthic foraminifera from Campanian and Maastrichtian deposits of Lublin Upland, Eastern Poland and South Caribbean Region, respectively. The latter author provided extensively taxonomic lists of Early Cretaceous to Middle Miocene deep water benthic foraminifera corresponding with planktonic foraminifera biozonations. They also stressed the necessity of taxonomical revision in most the benthic foraminifera groups.

Speijer (1994) revealed a comprehensive work on paleoceanography and paleoecology of small benthic foraminifera assemblages in the southern Tethyan localities across Cretaceous/Paleocene (K-P) boundary and Paleocene/Eocene (P-E) boundary. Their basic distribution along these transitions and response to that boundaries were discussed. Those bioevents were said to be related with insufficient oxygen levels at corresponding time intervals. It is mentioned that a selective extinction occurred at the K-P boundary where endobenthic forms experienced more cruel extinction due their relatively large food requirement when compared to epibenthic taxa which effected less from the event. A lessening food supply to bottom environment was offered to describe this boundary event. At the P-E boundary, on the other hand, an extinction of cosmopolitan benthic foraminifera species was observed.

Widmark and Speijer (1997b) performed cluster analysis of the most common Late Maastrichtian upper bathyal to abyssal benthic foraminiferal taxa from Tethyan localities in order to observe biogeographic and bathymetric distribution of groups. Their quantitative study resulted in five distinct foraminiferal assemblages as follows; marginal tethyan assemblage, shallow bathyal assemblage, deeper bathyal assemblage, abyssal tethyan assemblage and northwestern tethyan assemblage. They also remarked about ratio of epibenthic and endobenthic morphogroups in those localities, concluding that for broad part of Late Cretaceous bathyal localities were nearly mesotrophic environment. In the same year, Widmark (1997) provided a broad taxonomical work on deep water benthic foraminifera from Cretaceous-Paleogene boundary beds from the South Atlantic ocean at DSDP sites, as well as revealing their paleoecology and boundary responses.

Studies focusing on the paleoenvironmental response of small benthic foraminifera to the K-Pg boundary event were carried out mostly starting from around 1990s. They were broadly studied by quantitative methods. In some works, taxonomy of foraminifera was also given by author(s). Researches including outer neritic and bathyal settings were given as follows:

Keller (1988) carried out a quantitative analysis of the Latest Cretaceous to Paleocene benthic foraminifera from upper slope to outer shelf environment at El Kef, Tunisia, revealing their response to K-T boundary. A shallowing trend were proposed after the boundary which changed to outer to middle shelf environment, suggesting sea level regression at that time. 50% disappearance in benthic foraminifera assemblage was offered regarding the boundary due to this regression event. Infaunal and epifaunal taxa which adapting the low oxygen conditions were proposed as surviving taxa in P0, a, b and P1a interval. Benthic foraminifera fauna experienced long recovery period after the boundary event.

Kaiho (1992) published the response of upper bathyal benthic foraminifera in Hokkaido, Japan across a K-T boundary section reporting a bathymetrical shallow trend slightly below the boundary. Benthic foraminiferal assemblage indicated a lowered oxygen conditions. The rate of extinction was small which given as 10% for calcareous benthic foraminifera.

Coccioni and Galeotti (1998) remarked a considerable change in community structure of benthic foraminifera at the K-T boundary based on their quantitative data which compiled from eight stratigraphic sections from Denmark, Tunisia, Spain and Italy. They mentioned two distinct domains regarding the earliest Paleocene community response which were epifaunally dominant area and infaunally dominant area. It was also concluded that the fauna in deeper water settings had been less effected by K-T event.

Frenzel (2000) established a quantitative work on Early Maastrichtian benthic foraminifera from Rugen Chalk, Germany together with broadly refined benthic foraminifera taxonomy. He also remarked about the paleoecology of the region stating that the oxygen at the bottom was fair and still not a limiting factor for the benthic community in the late Early Maastrichtian. The benthic foraminifera associations indicated a minor amount of shallowing sea conditions and increase in the temperature towards upward of the succession, which pursuing the higher productivity possibly resulted from the upwelling.

Alegret and Thomas (2001) established a taxonomical paper considering bathyal benthic foraminiferal taxonomy in Mexico region, including many cosmopolitan species from the Mendez Formation and the Velasco Formation. The authors presented a taxonomic revision of the deep sea species, namely the Velasco-type ben-thic foraminiferal assemblage, across the Cretaceous- Paleogene transition from the Gulf of Mexico. Alegret et al. (2001) revealed a quantitative analysis of Mexican fauna across K-T transition from several upper-lower bathyal sections. They offered a slight benthic foraminifera extinction right at the boundary which associated with change in the community structure, following by gradual recovery stage. After the boundary, a decrease in food supply was also suggested.

Peryt et al. (2002) mentioned outer shelf to upper bathyal benthic foraminifera assemblages and revealed their response to K/P boundary event at the Aı¨n Settara, Tunisia. They suggested a diversity fall at the K-Pg boundary and critical change in the community structure across the boundary. It was also suggested that highly diverse late Maastrichtian association were dramatically recouped by epifaunal morphogroups after the boundary, witnessing short-lived disappearance of infaunal morphotypes.

Alegret et al. (2003) carried out a quantitative work on the Upper Cretaceous to Lower Paleogene benthic foraminifera assemblages in order to investigate paleoenvironment and paleobathymetrical changes at the K-Pg transition in Agost, Spain. The authors suggested a sea level increasing from upper bathyal to middle bathyal for the Cretaceous part of their studied section. They proposed no bathymetrical change at the boundary. Only 5% of assemblages were offered as extinct taxa. Change in the community structure was offered after the boundary. Their study also suggested that low oxygen conditions were developed just after the boundary which inferred from the short-living high relative abundances of opportunistic species.

Culver (2003) compiled the published literature about the response of small benthic foraminifera to the K-T boundary event. The author stated that in shallow (neritic) and intermediate bathymetric (outer neritic to middle bathyal) settings, the ecological changes started before the boundary, whereas in more deeper settings the changes began at the boundary. Moreover, he also concluded that there seems to be selective survivorship of epifaunal species to Danian accompanied with relatively short interval of infaunal taxa dominance just after the boundary. It was also summarized that the small benthic foraminifera did not show mass extinction regardless of their bathymetrical position, preferred microhabitat, latitudinal situation.

Peryt et al. (2004) established outer shelf to upper bathyal agglutinated benthic foraminiferal response with respect to the K-T boundary. Their quantitative study remarked a considerable change in benthic foraminifera assemblages at the boundary which switched from a mesotrophic highly diverse late Maastrichtian assemblage to the epifaunal taxa dominated assemblages. A decline in primary productivity and modification in phytoplankton balance was suggested for those structural change in benthic foraminifera community.

A quantitative study from Bidart, France were performed by Alegret et al. (2004) considering Late Cretaceous – Early Paleogene upper to middle bathyal benthic foraminifera revealing their paleoenvironmental response to K-Pg boundary. Their study proposed that Upper Maastrichtian section was deposited in mesotrophic environment. The K-Pg boundary was remarked by distinctly drop in the nutrient supply.

Coccioni and Marsili (2007) reported a high resolution quantitative outer neritic to uppermost bathyal benthic foraminifera study at Elles, Tunisia across the K-Pg transition. Their data suggested a distinct drop in diversity, heterogeneity, genus and species richness as well as infaunal taxa at the boundary, associated with temporary disappearance of other benthic foraminifera taxa. The extinction rate was given as 3%, following a graded recovery phase.

From Turkey, Görmüş (1990, 1994a, 1994b) studied Campanian-Maastrichtian small benthic foraminifera in the Hekimhan and Darende regions, as well as focusing on the larger benthic foraminifera and their quantitative data (Görmüş, 1992a, 1992b). He also identified a new species from the Campanian-Maastrichtian sediments (Görmüş, 1999). Most recently, Vellekoop et al. (2017) published a paper regarding a K-Pg section at Okçular. They carried out palynological and benthic foraminiferal analysis in order to observe ecological changes through the section. Their benthic foraminiferal morphotype study served the evidence of domination epifaunal taxa right after the K-Pg boundary.

### 1.4.2 Previous Works on the Haymana Basin

The Haymana Basin was studied originally by Chaput (1932, 1935a, 1935b, 1936) in an effort to establish a comprehensive lithostratigraphy of the region. Triassic to Eocene rocks had been reported from these studies. Following the work of Chaput, Lokman and Lahn (1946), Lahn (1949) and Egeran and Lahn (1951) investigated the geology of the basin within stratigraphic and tectonic framework. Lokman and Lahn (1946) identified Upper Cretaceous-Eocene flysch facies with various marine fossil records. Marine system was said to be ended in Middle Eocene, continuing into freshwater and terrestrial rocks including limestone, marl, conglomerate and sandstone representing probably the Miocene age. It is mentioned that structure of the basin has typical features of Alpine orogenic event. Lahn (1949) and Egeran and Lahn (1951) discussed tectonic history of Central and Northern Anatolia as well as the Haymana Basin. Lahn (1949) mentioned also the Upper Cretaceous-Eocene rock successions in the region with their fossil assemblages such as *Hippurites*, *Gryphea* and *Ndihea* from Senonian marls, *Cyclolites* from the Maastrichtian marls and *Lithothamnium* covered in the thin bedded limestone at the changeover of Cretaceous – Paleocene. Larger foraminifera, *Nummulites* and *Assilina*, were also reported from the arenaceous Eocene flysch rocks.

The Haymana Basin was studied by petroleum geologists with the intent of petroleum exploration supplying significant stratigraphic data in 1960's. Works performed by Rigo de Righi and Cortesini (1959), Schmidt (1960) and Reckamp and Özbey (1960) may be regarded as the base study for other researchers.

One of the early sedimentological studies in the Haymana Basin carried out by Norman and Rad (1971) and Rad (1971) who worked on sandstone - mudstone – shale units of the Eocene Harhor Formation. They made interpretations about the origin of the sediments depending on the heavy mineral and textural analysis. They stated that sediments were originated from a variety of different rock sources. Sediment transportation took place in two phases. Sediments were initially concentrated in relatively shallower setting, thereafter transported into deeper parts of the basin by turbidity currents.

Arıkan (1975) examined oil prospects of the Haymana Basin and the Tuz Gölü Basin. He investigated stratigraphy and tectonic development of these basins. He claimed that the Haymana Basin and the Tuz Gölü Basin were once connected in

Late Senonian – Early-Middle Eocene. Moreover, it was reported that hydrocarbons had been observed in the outcrops in the form of oil and asphalt. In the northern flank of the Haymana anticline, oil sands were said to be exposed which corresponding the Lower Paleocene. Asphalts were observed several places in the Haymana region; from the uppermost Cretaceous sandstones, Paleocene limestones and sandstones in the northern and northeastern parts as well as possibly Paleocene aged limestones in the southern and southeastern localities of the region. Şenalp and Gökçen (1978) also pointed out the petroleum potential of the Haymana Formation based on the presence of oil saturated turbiditic sandstone channel fills. Coşkun et al. (1990) examined also hydrocarbon potential of the Haymana region (as cited in Esmeray, 2008). Their study revealed that shales belonging to the Haymana Formation and the Yeşilyurt Formation might have been regarded as source rocks, whereas sandstones of the Ilgınlıkdere Formation and the Haymana Formation might have represented reservoir rocks. Aydemir and Ates (2006) carried out geophysical investigation on the Haymana and the Tuz Gölü Basin conducting three-dimensional modeling. Their study suggested a hydrocarbon potential for the Haymana Basin. Çemen et al, (1999) proposed that Tuz Gölü Basin and Haymana Basin were developed seperately until Eocene and brought together at the end of Eocene.

Sirel (1975) established general lithostratigraphy and biostratigraphy of the Haymana Basin, examining Upper Jurassic, Paleocene, Eocene and Neogene age successions. He assigned the ages of the Çaldağ Formation, Kartal Formation and Kırkkavak Formation as Upper Jurrasic, Lower Paleocene and Middle-Upper Paleocene, respectively. Sirel et al. (1986) studied lithostratigraphy and biostratigraphy of Maastrichtian to Lower Paleocene sedimentary successions in the Haymana-Polatlı region. They remarked important changes in paleogeography, sedimentology and fossil assemblages at the end of the Cretaceous possibly related with tectonic activity. The most of the benthic foraminifera was said to be disappeared which corresponds that time. The conformable boundary relationship between the Danian-Lower Thanetian Çaldağ limestone and the Maastrichtian Beyobaşı Formation were stated.

Ünalan et al. (1976) established detailed lithostratigraphy of the Haymana– Polatlı region. They reported eleven Upper Cretaceous-Lower Tertiary formations with a continuous deposition up to 5800 m thickness, except for a local unconformity between the Cuisian-Lutetian Çayraz Formation and the Ilerdian-Cuisian Eskipolatlı Formation. Neogene units was said to cover these formations by an unconformity. They illustrated measured stratigraphic section of each formation remarking fossil assemblages of the rock units mainly based on foraminifera and algae. Their study revealed the lateral and horizontal transitions of the formations together with paleogeography and paleoenvironment of the region. Moreover, the link between the Tuz Gölü and the Haymana Basin were demonstrated, similar to the argument of Arıkan (1975). Gökçen (1976) also studied the stratigraphy and tectonics of the Haymana region. Görür (1981) followed the formation names refined by work of Ünalan et al. (1976) in his stratigraphic works in the Haymana and the Tuz Gölü Basins.

Çetin et al. (1986) studied Upper Cretaceous – Early Tertiary successions from the Haymana region and carried out a series of sedimentological analysis. Their petrographic studies suggested that the paleotransportation direction was from north to south via turbidity currents with various energy gradients.

From the beginning of early 1960s, detailed paleontological works were carried out in the Haymana Basin. Sirel (1976a, 1976b, 1976c) presented the taxonomy of *Alveolina, Assilina* and *Nummulites* from the Eocene strata. Sirel (1976a) published six new *Alveolina* species from the southern part of the Polatlı. Toker (1975, 1977, 1979, 1981) carried out the earlier works on planktonic foraminifera and nannoplankton biostratigraphy in the Haymana region. Toker (1981) proposed 16 nannobiozones for Campanian to Middle Eocene (Lutetian) sequence of the measured sections including the Campanian-Maastrichtian Haymana Formation, the Upper Maastrichtian Kavak Formation and the Eocene Çayraz Formation and other formations in the region.

Matsumaru (1997) worked on Maastrichtian Beyobaşı Formation and identified some larger benthic foraminifera species (*Pseudorbitoides trechmanni, Omphalocyclus macroporus, Orbitoides apiculatu, Pseudomphalocyclus blumenthali, Hellenocyclina beotica, Siderolites calcitrapoides*). Sirel (1999) introduced a new foraminifera family Orduellinidae under the superfamily Orbitoidacea from Paleocene Çaldağ Formation as well as four new foraminifera genera. Meriç and Görür (1981) revised the age of the Çaldağ Formation as Montian – Thanetian, which was previously described as Montian.

At the end of 1990s and with the begging of 2000s, remarkable paleontological works were carried out in Haymana area regarding larger benthic and planktonic foraminifera. Özcan and Özkan-Altiner (2001) and Özcan and Özkan-Altıner (1999) established the taxonomy and evolution of *Lepidorbitoides* regarding its ontogeny from the Haymana and other flysch basins. Özkan-Altıner and Özcan (1999) revealed planktonic foraminiferal biostratigraphy based on the major bioevents from the Upper Cretaceous-Lower Tertiary successions developed in the fore-arc basins which located in the northern, northeastern and central parts of the Anatolian including the Haymana region. This data was correlated with the age ranges of the larger benthic foraminifera containing *Orbitoides* and *Lepidorbitoides*. *Omphalocyclus macroporus, Pseudosiderolites vidali, Siderolites calcitrapoides, S. denticulatus*, *Clypeorbis mamillata* and *Hellenocyclina beotica* were also identified from the same succession. A detailed stratigraphy of this succession was established by these authors based on the integrated usage of both planktonic and larger benthic foraminifera biozonations.

Özcan et al. (2001) reported the Thanetian Orthophragminae, *Orbitoclypeus*, from shallow marine deposits in the Haymana - Polatlı region. *Discocyclina seunes*, *D.* sp. 1 and *Orbitoclypeus neumannae* were identified. *Orbitoclypeus haymanaensis* was proposed as new species. These association was calibrated with planktonic foraminifera and nannoplankton assemblages within this succession, thus the assemblage was dated as Thanetian.

Özcan (2002) worked on the Çayraz Formation (Cuisian-Early Lutetian) which contains very rich large benthic foraminifera associations in the Haymana-Polatlı basin. Taxonomical studies and biometrical morphology analysis of *Discocylina*, *Orbitoclypeus* and *Nemkovella* groups were carried out by this author. The resulting data was compared with other Tethyan European and Crimea sections, which revealing the similarity of evolutionary trends of this larger benthic foraminiferal assemblage between the Çayraz and those Tethyan localities.

Alkan (2005) studied paleoecology of the Maastrichtian Beyobaşı Formation and the Danian Çaldağ Formation based on benthic foraminifera species. Inner shelf environment was offered for the Beyobaşı Formation, whereas the low energy shelf environment with rim was proposed for the Danian Çaldağ Formation.

Another recent studies on paleontology conducted by Hoşgör and Okan (2011) since they offered a new Gastropod species from shallow marine succession of Haymana Polatlı Basin. Thanetian Kırkkavak Formation yields one of the oldest *Angaria* species which is found in Tethyan localities. The Paleocene Çaldağ and Kırkkavak Formations were studied by Hoşgör (2012) in the same region. A variety of gastrpod species belonging to *Campanil, Cerithium, Ampullina, Velates, Eotympanotonus* and bivalve species of *Gryphaea, Turkostrea, Pycnodonta, Chlamys, Nemocardium* species were identified. Islamoglu et al. (2011) also reported 21 Caenogastropoda species from the Kırkkavak Formation in Haymana-Polatlı basin. The assemblage was mentioned to be indicating the early Ypresian age.

Dinçer (2016) published recently an isotope and paleontology study on two Eocene formations, namely, the Çayraz Formation and the Altıpınar Formation, regarding Eocene large benthic foraminifera in order to investigate the paleoenvironment. *Nummulites, Lochartia, Alveolina* and *Assilina* species were identified. Isotopic study showed that benthic foraminifera diversity were decreased, while paleotemperature was increased.  Moreover, it was stated that nutrient supply is one of the controlling parameter with regard to the diversity as well as abundance benthic foraminifera.

Esmeray (2008) and Esmeray-Senlet et al. (2015) defined the Cretaceous/Paleogene boundary in the Haymana Basin based on the biostratigraphy, sequence stratigraphy, planktonic foraminifera taxonomy and mineralogical observations. A detailed planktonic foraminifera biozonations were constructed. Different microfacies types were established. Paleonvironment of the studied area was offered as slope to basin environment resulting from the microfacies analysis. Amirov (2008) studied planktonic foraminifera biostratigraphy and sedimentary cyclicity within the sequence stratigraphic framework from Upper Cretaceous-Paleocene successions in the Haymana Basin. Karabeyoğlu (2017) recently worked on the planktonic foraminifera in the Haymana Basin across Maastrichtian - Danian transition. K-Pg boundary in this region was refined revealing the taxonomy of planktonic foraminifera as well as their relative abundances. The blooms of *Guembelitria cretacea* in the late Maastrichtian and in the early Danian  P0 Zone as well as the bloom of *Thoracosphaera* and echinoid fecal pellets in the P0 Zone were established in that study.

Including the tectonic development of the basin around the 1990s, the works carried out by Koçyiğit et al. (1988), Koçyiğit, (1991), Rojay and Süzen (1997), Rojay (2013)  and Okay and Altıner (2016) revealed that the Haymana Basin had in fore-arc to fore-land basin evolution during  the Late Cretaceous to Eocene.

As one of the recent study from the Haymana region, Okay and Altiner (2016) worked on the Cretaceous successions in the stratigraphic and tectonic framework. They revealed three unconformity-bounded pelagic carbonate sequences corresponding to Berriasian, Albian–Cenomanian and Turonian–Santonian stages. The authors also remarked a considerable change in the sedimentary regime in Campanian, which switched from carbonate to siliciclastic deposition at that time.

## 1.5 Regional Geology

The Haymana region is located in the Central Anatolia, within the Pontide unit and in the north of the İzmir-Ankara-Erzincan suture which delimiting the Anatolide-Tauride Block and the Pontides (Okay and Altiner, 2016). The region is enclosed by Sakarya Zone to the north, Central Anatolian Crystalline Complex to the east and Anatolide-Tauride Block to the south-southwest (Figure 4). The Haymana Basin is inclusive of this region and considered as a forearc basin during Late Cretaceous - the Late Eocene by various authors (Koçyiğit et al., 1988; Koçyiğit, 1991; Görür et al. 1998; Kaymakçı, 2000; Nairn et al, 2013) (Figure 5). It was suggested that the basin was developed at the time of convergence of Anatolide-Tauride Platform and the Pontides along the northern subduction during the closure of Neo-Tethys in Neo-Tethyan phase (Sengör and Yilmaz, 1981) between the magmatic arc and the trench (Koçyiğit et al., 1988; Koçyiğit, 1991; Rojay, 2013; Okay and Altiner, 2016).

The Triassic units of Karakaya Complex was considered as the oldest basement in the Haymana region. The Karakaya Complex was suggested as being strongly deformed and alternatively metamorphosed (Okay, 1989).

From the early Cretaceous to the late Santonian a pelagic carbonate deposition took place in the Haymana region, consisting of shallow marine carbonate rocks following a deeper marine carbonate sequence (Okay and Altıner, 2016). The Upper Jurassic–Lower Cretaceous shallow water limestones namely the Bilecik Limestone is overlain by Berriasian aged pelagic Soğukçam limestone. These two carbonate units are unconfirmably overlain by the Akkaya Formation from Albian to Cenomanian. The Kocatepe Formation unconfirmably overlies the Akkaya Formation and the Bilecik Limestone in the region. The Kocatepe Formation is consisting of Turonian to Santonian pelagic deposits, particularly limestone and shale.

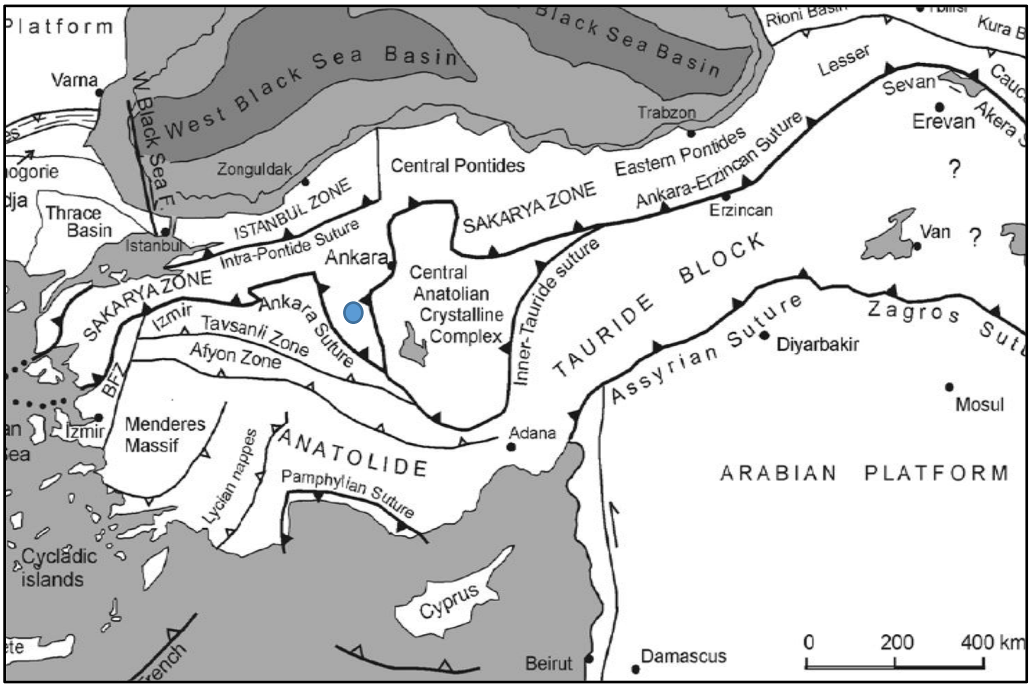

Figure 4: Major tectonic units of Turkey. Note that the blue circle is representing the location of the Haymana region (Okay, 2008).

Haymana Basin

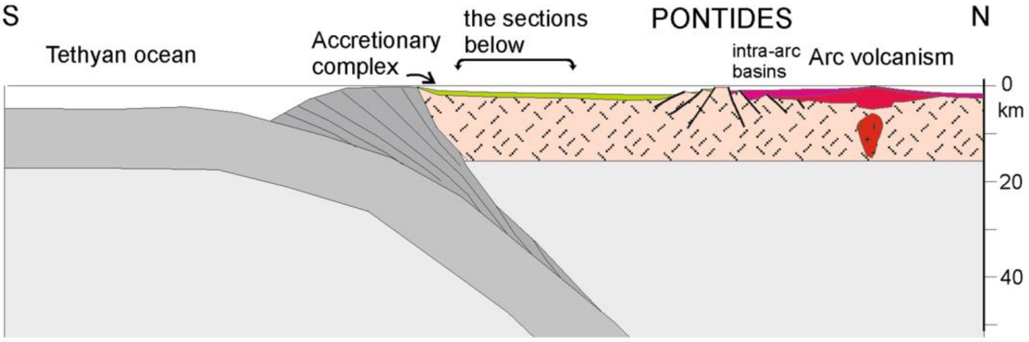

Figure 5: The Haymana Basin in the forearc position (Okay and Altiner, 2016).

The upward parts of the Cretaceous system is represented by clastic turbiditic deposits of Campanian–Maastrichtian Haymana Formation (Okay and Altıner, 2016). Ünalan et al. (1976) mentioned that the Haymana Formation was made up of grey shales interbedded with sandstone including also sandstone and conglomerates lenses. It is conformably underlying the Çaldağ Formation and the Yeşilyurt Formation. The Beyobaşı Formation is comprising of conglomerate, sandstone and limestone and regarded as deposited in shallower shelf settings with the diverse fauna.

In the Early Paleocene, the Kartal Formation was deposited in the shallowest parts on the basin bearing conglomerates, sandstone and sandstone marl alternations. This unit also has few limestone layers up to few meters including *Miliolidae*, algae, *Ostrea* and gastropoda. The Kartal Formation is laterally passing into the Çayraz Formation as going to the inside of the basin (Figure 6 and 7). The Çaldağ Formation comprises of limestone and limestone-marl alternations with fauna including algae, Echinodermata, coral, bryozoa, foraminifera including *Miliolidae.* A high energy zone (Y-zone of Irwin, 1965) was offered for the Çaldağ Formation. As going through more deeper parts of the basin, the Çaldağ Formation passes through the Yeşilyurt Formation which consisting of shales and limestone lenses with diverse pelagic fossils (Ünalan et al. 1976).

The Upper Paleocene Kırkkavak Formation is characterized by marl and limestone alternations overlain by limestone with abundant algae and *Miliolidae,* and locally sandstone, thin bedded limestones alternating with shales. The lower part of the formation contains *Alveolina primaeva*, *Discocyclina seunesi* and *Kathina subsphraerica* representing Thanetian stage. The Ilgınlıkdere Formation is Ilerdian in age and consisting of conglomerate-sandstone-shale alternations at the base. Shale units are including pelagic fossils and becoming more common in the upper parts of the formation. The Eskipolatlı Formation is also Ilerdian aged and made up of mostly beige colored shales (Ünalan et al, 1976).

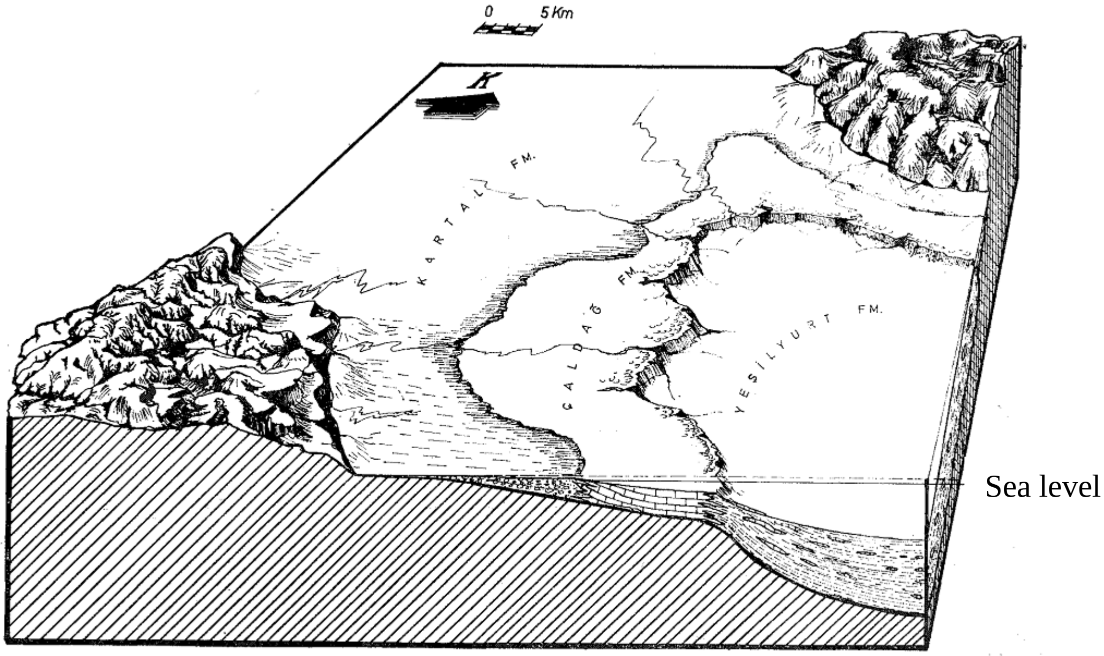

Figure 6: Block diagram of paleoenvironments of the Kartal, Çaldağ and Yeşilyurt Formations (Ünalan et al. 1976).

The Lower Eocene formations are the Beldede Formation, the Çayraz Formation and the Yamak Formation as descending order regarding their age. Taking as reference of their paleoenvironmental arrangement, the Beldede Formation was settling in the shallowest part of the basin (Figure 7). It consists of conglomerate-sandstone-sandy marl alternations. This unit is considered as mostly fluvial deposit, but occasionally shallow marginal marine deposits can be seen due to the presence of *Ostrea*, *Cerithium* ve *Nummulites*.

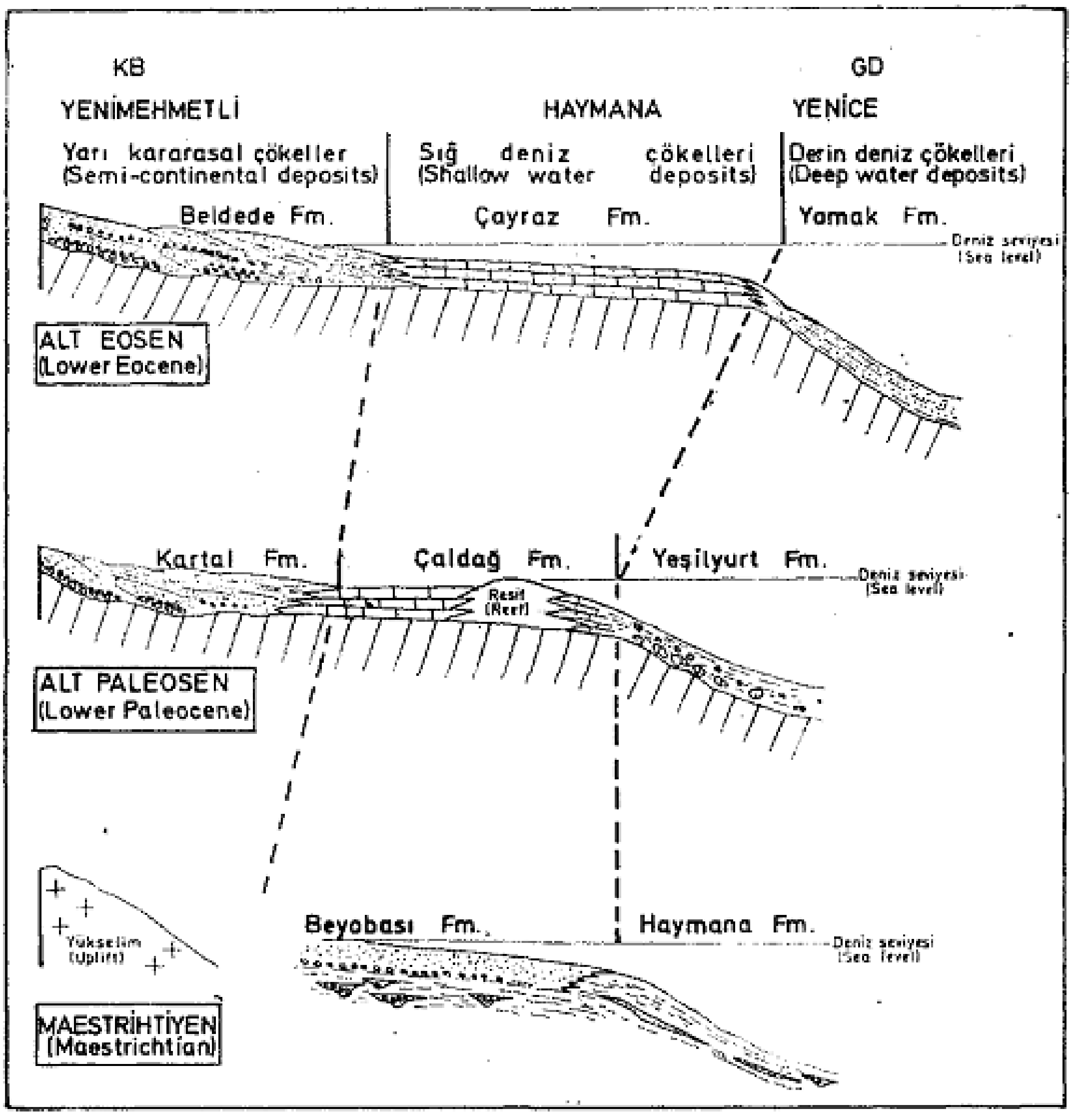

Figure 7: Lateral paleoenvironmental changes of the Maastrichtian-Eocene formations in the Haymana Basin (Ünalan et al., 1976).

The Çayraz Formation represents entirely shallow marine environment regarding the presence of *Alveolina canavar, A. bayburtensis*, *A. cayrasi*, *Nummulites laevigatus*, *N. lehneri*, *N. helveticus* and *Assilina exponens*. It was mentioned that the formation was laterally shifting into the Yamak Formation. The depositional setting of the latter one was interpreted as beyond the shelf, since it is comprising of turbiditic deposits as well as due to the presence of transported fossils (Ünalan et al. 1976).

Above mentioned Upper Cretaceous-Lower Tertiary deposits were covered unconfirmably by Neogene deposits which mostly include terrestrial deposits and volcanics (Ünalan et al. 1976) (Figure 8 and 9).

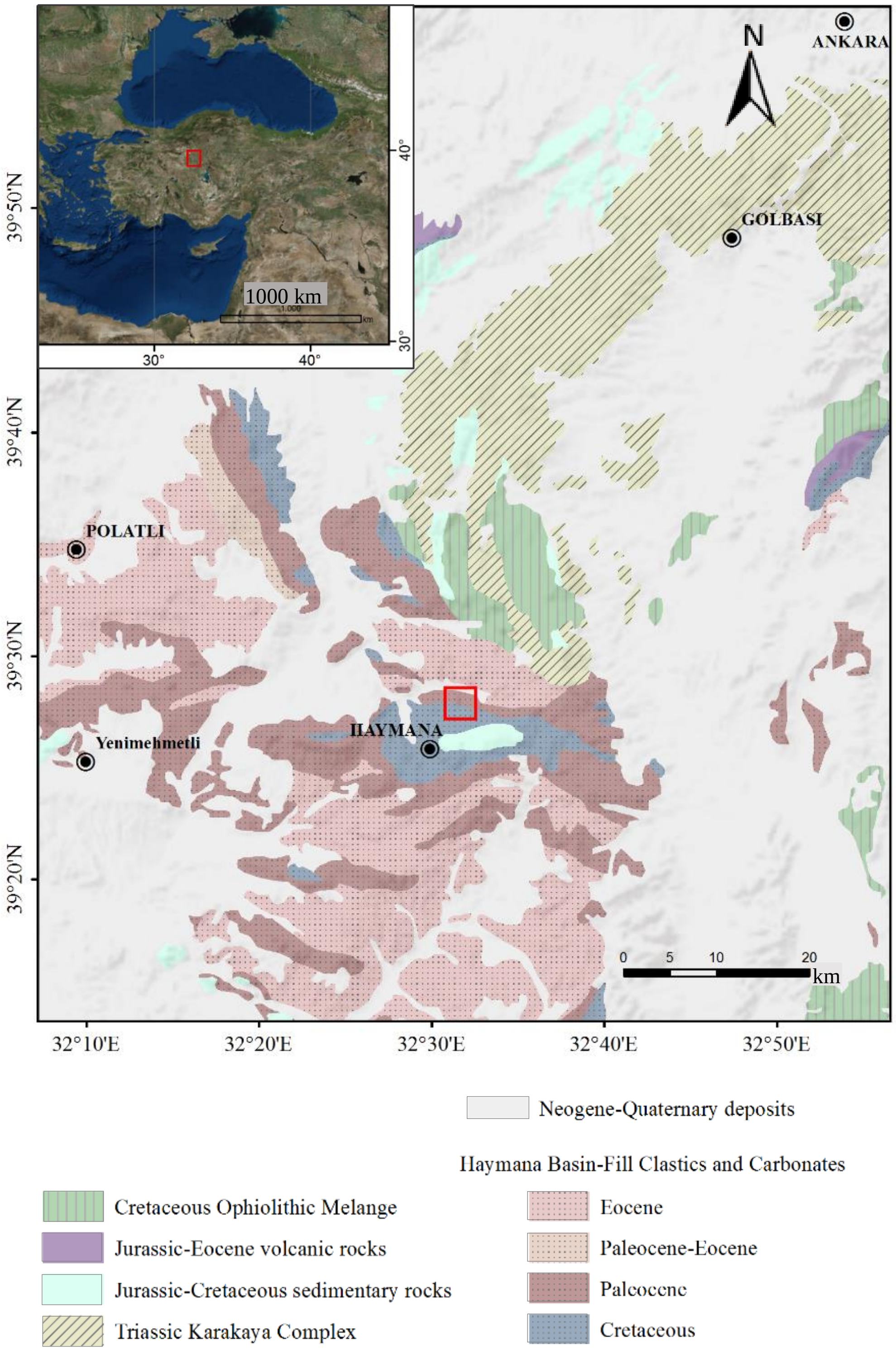

Figure 8: Geological map of the Haymana region (modified from 1/ 500 000 geological map of Turkey established by General Directorate of Mineral Research and Exploration). The red rectangles show the research area.

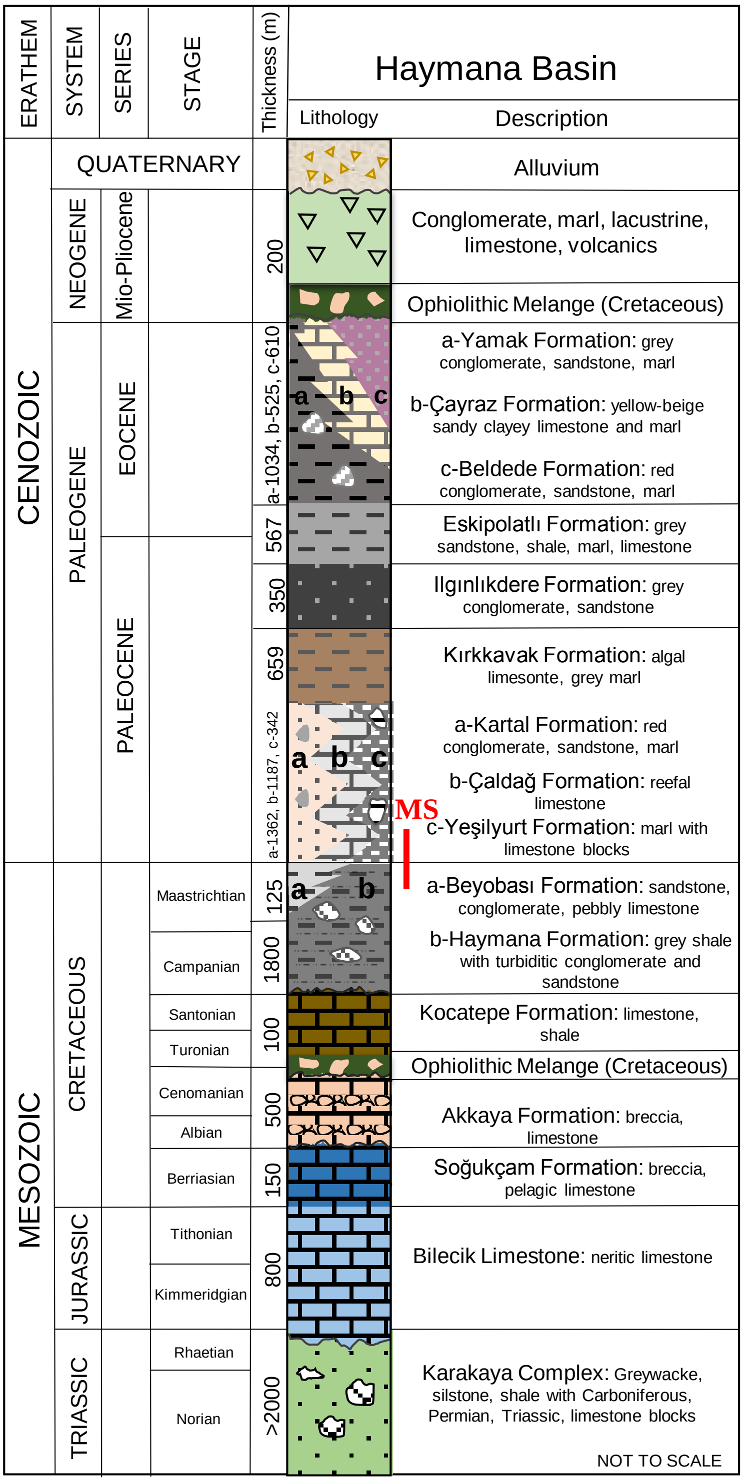

Figure 9: Generalized columnar section of the Haymana Basin. The red line demonstrating the measured section (MS: measured section, not to scale, modified after Ünalan et al., 1976 and Okay and Altıner, 2016 ).

# CHAPTER 2

# STRATIGRAPHY

## 2.1 Lithostratigraphy of the Studied Section

Various rock units from Triassic to Recent are exposed in the Haymana region. The Upper Cretaceous to Eocene deposits are particularly outcropping widespread in the region. The studied section is located between the Haymana Formation and the Yeşilyurt Formation. The section is composing of the Maastrichtian grey mudstones of the Haymana Formation and the Danian beige colored calcareous mudstone-marl alternations of the Yeşilyurt Formation. Therefore, only the lithostratigraphy of these two formations is given in detail.

### The Haymana Formation

*Defination*: This unit was defined previously by various authors with the same name (Ünalan et al., 1976 and references therein).

*Type locality, type section and outrcops*: The most typical and widespread locality of this formation was mentioned to be near the Haymana, hence the type section is located at the south of the Haymana. Besides, the formation is outcropping between Beyobaşı-Eskiköseler village as well as Boyalık village and Culuk village (Ünalan et al., 1976).

*Contacts*: The Haymana Formation is conformably overlain by the Beyobaşı Formation, the Çaldağ Formation and the Yeşilyurt Formation. It is also laterally passing into the Maastrichtian Beyobaşı Formation. The red pelagic limestones of the Kocatepe Formation are underlying the Haymana Formation. The relationship between the Kocatepe Formation and the Campanian-Maastrichtian turbiditic succession was reported as conformable (Özcan and Özkan-Altiner, 1997; Özkan-Altiner and Özcan, 1999).

*Lithology*: The Haymana Formation is comprising of mostly mudstone and shales interbedded with sandstone as well as conglomerate lenses (Okay and Altıner, 2016). Sediments of sandstones were said to be originated from the underlying ophiolithic mélange. Flute casts, load coasts, graded bedding, convolute and parallel lamination were observed in the sandstone levels (Ünalan et al., 1976). These sedimentological characteristics are pointing a turbiditic deposition (Okay and Altıner, 2016 and references therein).

*Thickness*: The thickness of the formation was reported as 1800 m by Okay and Altıner (2016).

*Age*: Late Campanian to Maastrichtian age was assigned depending on the benthic and planktonic foraminiferal studies (Okay and Altıner, 2016 and references therein).

### The Yeşilyurt Formation

*Defination*: This formation was defined by Ünalan et al. (1976) under the same name. It was formerly termed as the Çaldağ Formation in the previous studies (Ünalan et al., 1976 and references therein).

*Type locality, type section and outcrops*: Its type locality was reported at near the Haymana region as well as the eastern and southeastern portion of this area. Grain size of sediments and thicknesses of the limestone blocks decrease as going through the southeastern direction away from the type section.

*Contacts*: The relationship between the underlying Haymana Formation and the overlying Kırkkavak Formation is conformable according to Ünalan et al. (1976). It passes laterally into the Çaldağ Formation in the northern and western directions. It was mentioned that the limestone content of the formation is diminishing in the eastern and southeastern regions Ünalan et al. (1976).

*Lithology*: This formation is characterized by shales with abundant pelagic fauna enclosing limestone blocks with various sizes. Size of these limestone lenses varies from sand size up to 3 m blocks. These limestone clasts or blocks were considered as originated from the coeval Çaldağ Formation which located on the shelf based on the paleontological and lithological observations. The limestone blocks were mentioned to had been located in front of the shelf via turbidy currents(Ünalan et al., 1976).

*Thickness*: The thickness was defined as 342 m in the type section, 403 m in the east of the Karahoca, 341 m in the south of the Haymana and 234 m in the south of the Çayraz village (Ünalan et al., 1976).

*Age*: The formation was reported as the lower Paleocene based on the pelagic fossil content which is composing of *Globigerina bulloides, G. pseudobulloides, G. triloculinoides, Rugoglobigerina rugosa* and *Globorotalia pseudobulloides* within the shale units. It was also dated as Montian, since the fossil content of the limestone blocks was found to be similiar to that of the Çaldağ Formation (Ünalan et al. 1976, and references therein)

In this study, a 14.53 meter thick stratigraphic section was measured at the transition between the Haymana Formation and the Yeşilyurt Formation including the K-Pg boundary beds from Ankara, near the center of the Haymana district. 89 samples were collected with sampling resolution ranging from 5 to 20 cm intervals via two field excursions. Only 4.36 m thick portion of this section, which is located between the samples UH-33 and UKHB-10, was studied in this thesis (Figure 10).

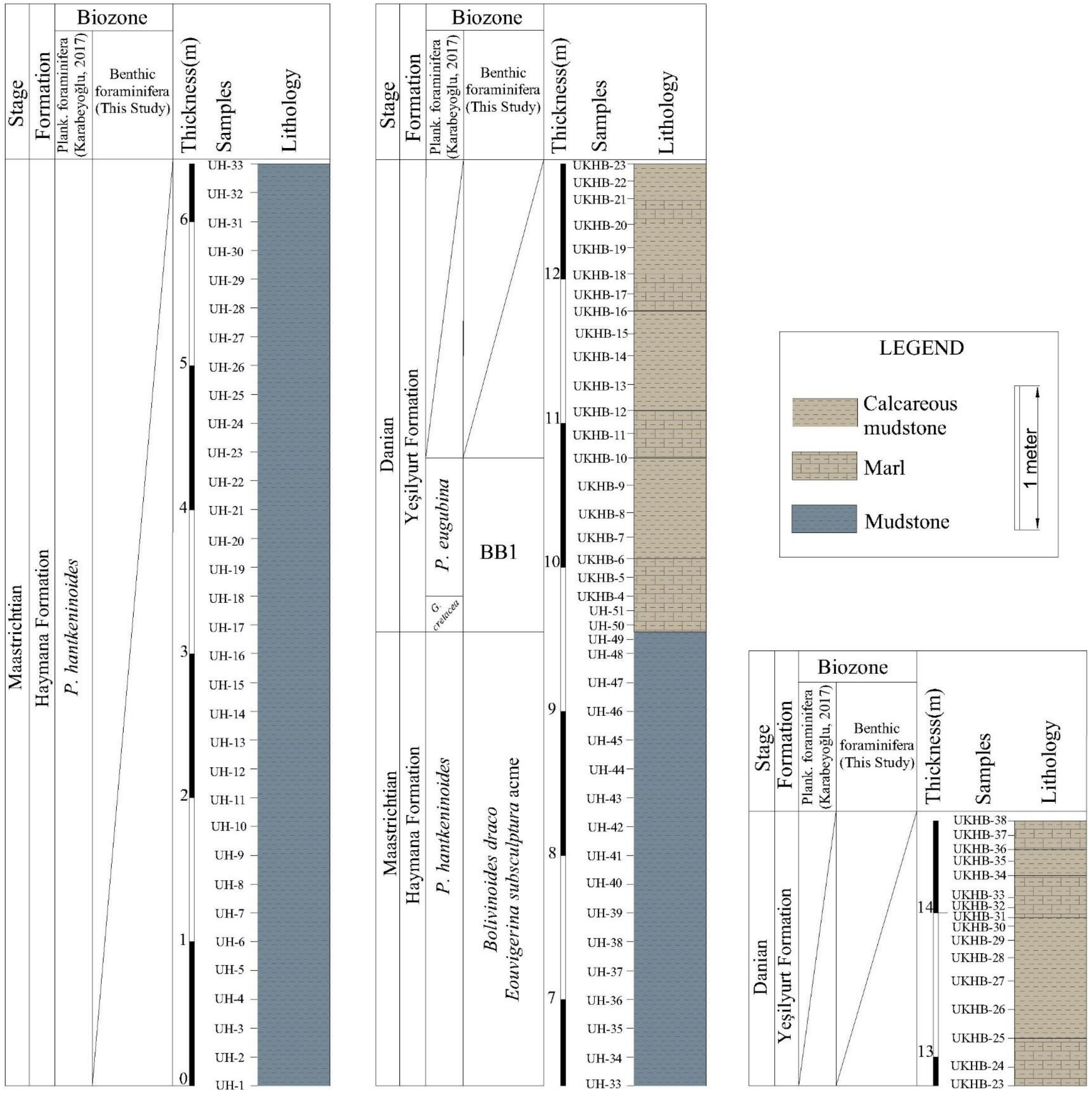

Figure 10: Lithostratigraphy of the measured section calibrated with the planktonic and benthic foraminifera biozonations (modified from Karabeyoğlu, 2017).

Samples tagged from UH-1 to UH-49 correspond to the Maastrichtian part of the measured section, spanning 9.55 m in total up to the K-Pg boundary (Figure 10 and 11). This sampling interval includes grey colored Maastrichtian mudstones of the Haymana Formation (Figure 12B). Two samples (UH-50 and UH-51) belong to the Danian portion spanning 15 cm just above the K-Pg boundary which comprising of the beige colored marl-calcareous mudstone levels of the Yeşilyurt Formation. UKHB samples begin 5 cm below the boundary with sample UKHB-1 which is coinciding with sample UH-49. Samples from UKHB-2 to UKHB-38 are covering 4.98 m section in total and corresponding the Danian Yeşilyurt Formation. The sampling trends regarding the entire UH and UKHB samples are shown in the Figure 11 and 12A.

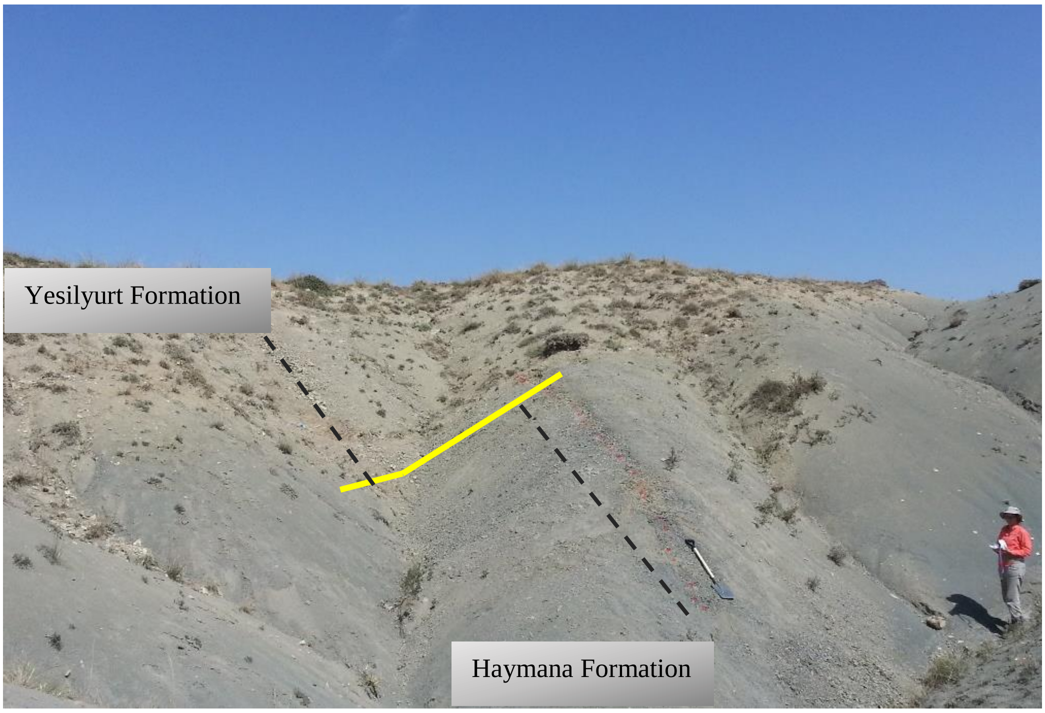

Figure 11: Field photograph showing the measured section, across grey colored mudstones of the Upper Maastrichtian Haymana Formation and light beige colored marl-calcareous mudstone of the Lower Danian Yeşilyurt Formation. Yellow line depicting approximate location of the K-Pg boundary. Dashed lines indicating the sampling trends.

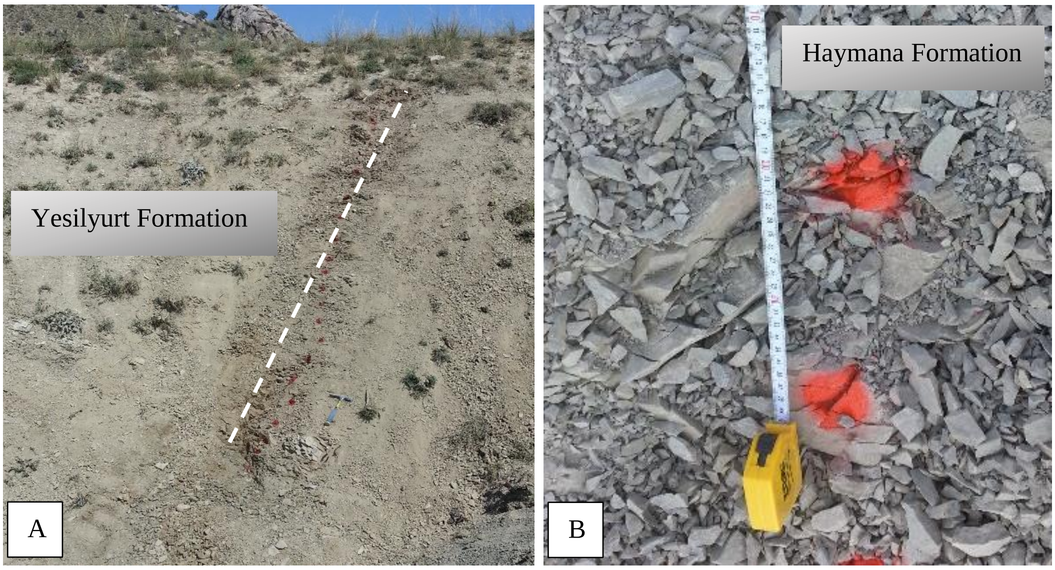

Figure 12: The Lower Danian part of the measured section represented by beige colored the Yeşilyurt Formation with calcareous mudstones-mudstones alternations, dashed line indicating the sampling trend (A). Grey mudstones of the Upper Maastrichtian part of the Haymana Formation with sampling space of 20 cm (B) (Karabeyoğlu, 2017).

The Global Boundary Stratotype Section and Point (GSSP) for the Danian stage was affirmed by International Commission on Stratigraphy (ICS) in 1991, (Molina et al., 2006). The GSSP was offered at the base of the boundary clay at El Kef, Tunisia. This locatiliy was preferred, because it is a complete section with rich and good preserved fauna, being without any hiatus and satisfactory thick sediment accumulation. Moreover, the section bears many key stratigraphical horizons such as the boundary clay, Ir anomaly, TOC peak, etc.

In the Haymana Basin, the K-Pg boundary of the measured section was previously delineated by Karabeyoğlu (2017). The boundary was represented by the noticeable planktonic foraminiferal bioevents based on the last appearance of Cretaceous taxa corresponding to biozones of *Plummerita hantkeninoides* Zone followed by *Guembelitria cretacea* and *Parvularugoglobigerina eugubina* Zone. Moreover, *Thoracosphaera* bloom and the peak values of echinoidea fecall pellets were reported right above the boundary. In addition to the faunal changes, the transition in the sedimentary regime was also revealed. A 2–3 mm thick red colored oxidized layer was reported at the transition from grey colored Maastrichtian mudstone levels to beige colored Danian calcareous mudstone-marl alternations (Figure 13). Furthermore, a microfacies analysis was conducted by the same author for the entire measured section. The microfacies types were recognized as descending order as follows: mudstone levels for the Maastrichtian part and calcareous mudstone -marl alternations for the Danian part (Figure 10).

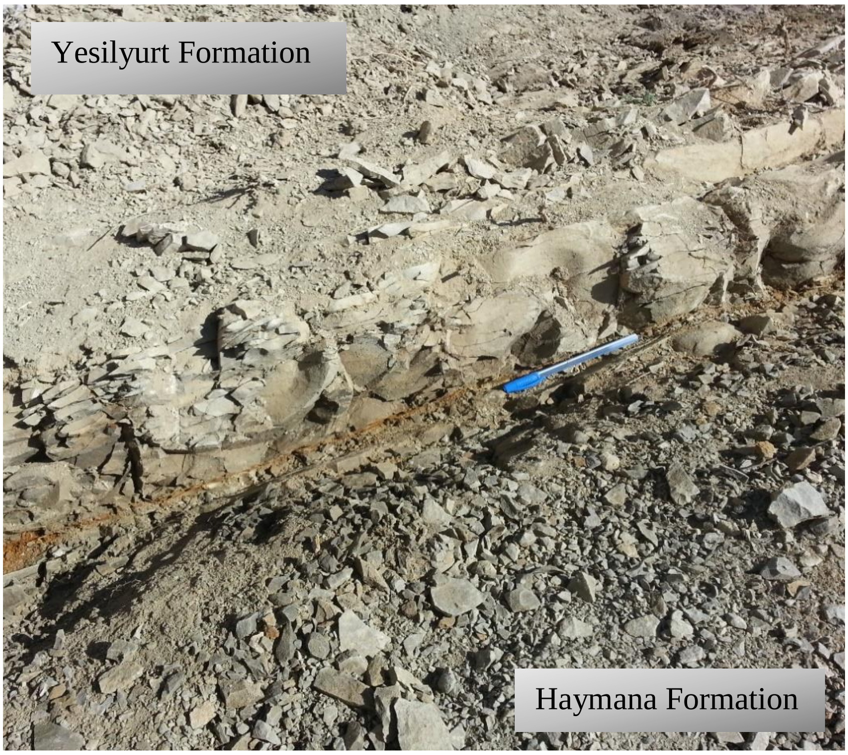

Figure 13: The 2-3 mm thick reddish layer representing the K-Pg boundary and transition from the grey colored Haymana Formation to the beige colored Yeşilyurt Formation (Karabeyoğlu, 2017).

In this thesis, the mudstone samples from the Maastrichtian Haymana Formation corresponding to 3.15 meters below the K-Pg boundary and the marl-calcareous mudstone samples from the Danian Yeşilyurt Formation representing 1.21 meters above the boundary were studied. 25 Analyzed samples yielded a considerable amount of mud sized sediments after subjected to the washing process. One sample, UH-51, yielded a large amount of undissolved rock chunks, thus it was excluded from the quantitative study (Table 2). Except for this sample, mud size fraction (< 63 µm) is changing between min. 94.3% and max. 98.0% in the 25 washed samples, whereas sand size fraction ( > 63 µm) is changing between min. 2.0% and max. 5.7% (Table 2). A comparison chart showing the change between mud size and sand size fractions within these samples can be found in Figure 14. These percentages of the grain size supports aforementioned microfacies analysis of Karabeyoğlu (2017) which are mudstone for the Maastrichtian and calcareous mudstone-mudstone alternating levels for the Danian. Moreover, the processed samples are comprising of abundant benthic foraminifera, planktonic foraminifera and rarely echinoidae spines, ostracoda shells and fish teeth (Plate 24).

Table 2: Residue mass for sand-size and mud-size fractions after washing of 100 g dry 26 samples through the studied interval ([*]unprocessed sample).

| **SAMPLES** | **SIEVE FRACTIONS (grams)** | |
|---|---|---|
| | Sand size (> 63 µm) (grams) | Mud size (< 63 µm) (grams) |
| **UKHB-10** | 3,2 | 96,8 |
| **UKHB-9** | 5,3 | 94,7 |
| **UKHB-8** | 4,0 | 96,0 |
| **UKHB-7** | 3,7 | 96,3 |
| **UKHB-6** | 2,5 | 97,5 |
| **UKHB-5** | 2,2 | 97,8 |
| **UKHB-4** | 4,5 | 95,5 |
| **UH-51[*]** | 74,5 | 25,5 |
| **UH-50** | 5,7 | 94,3 |
| **UH-49** | 3,3 | 96,7 |
| **UH-48** | 2,7 | 97,3 |
| **UH-47** | 2,4 | 97,6 |
| **UH-46** | 2,6 | 97,4 |
| **UH-45** | 3,0 | 97,0 |
| **UH-44** | 3,7 | 96,3 |
| **UH-43** | 2,9 | 97,1 |
| **UH-42** | 3,1 | 96,9 |
| **UH-41** | 3,1 | 96,9 |
| **UH-40** | 3,8 | 96,2 |
| **UH-39** | 5,1 | 94,9 |
| **UH-38** | 3,6 | 96,4 |
| **UH-37** | 3,3 | 96,7 |
| **UH-36** | 2,0 | 98,0 |
| **UH-35** | 2,4 | 97,6 |
| **UH-34** | 3,1 | 96,9 |
| **UH-33** | 2,8 | 97,2 |

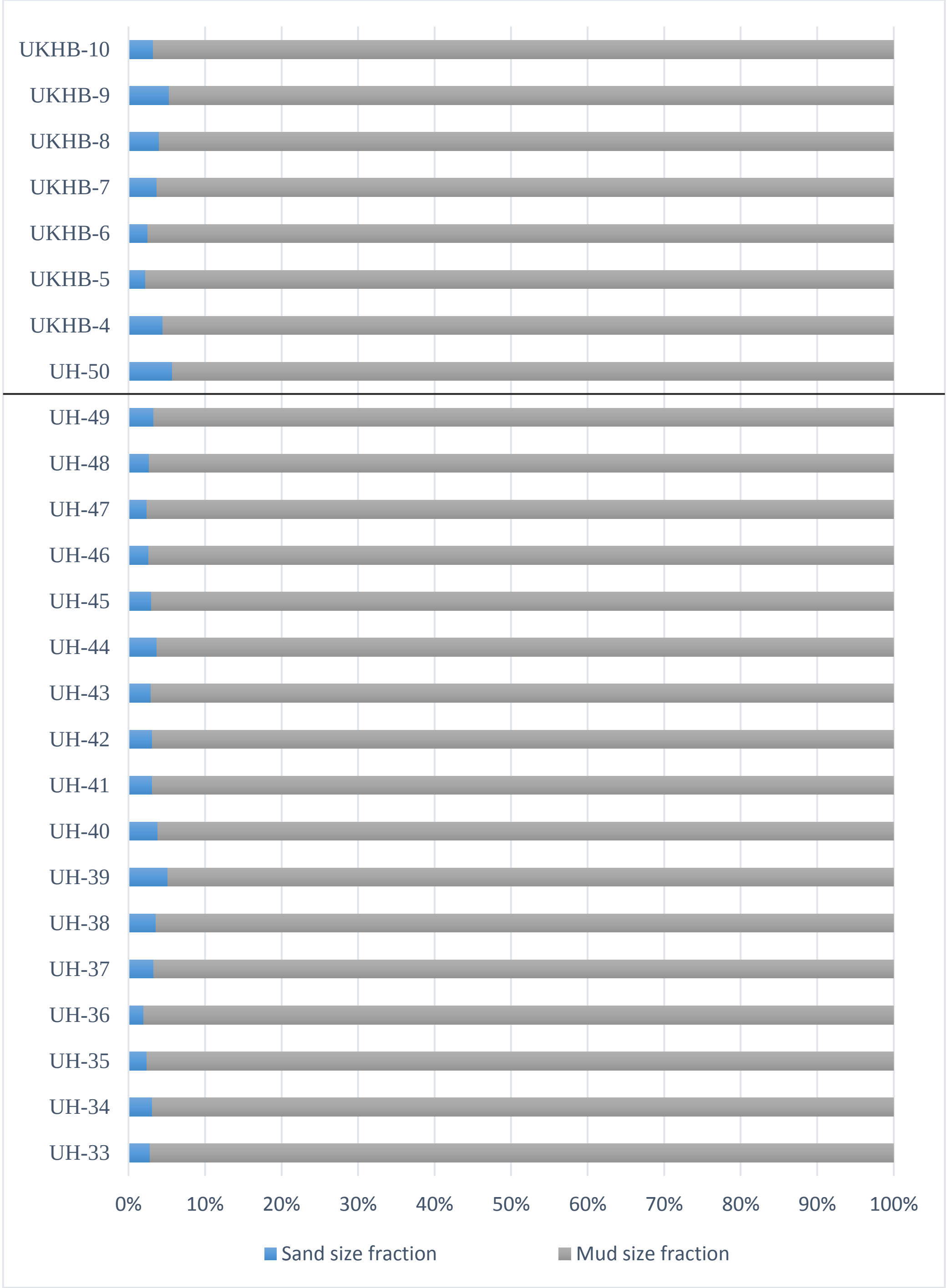

Figure 14: Comparison chart showing the percentages of sand size fraction and mud size fraction recovered from 25 analysed samples. Note that the K-Pg boundary is located between samples UH-49 and UH-50.

## 2.2 Biostratigraphy of the Studied Section

Biostratigraphy is the crucial part of the earth science studies. Paleontology allows us to assign ages to different rock units and to make regional correlation using the evolutionary changes of microfossils throughout the geological history. Foraminifera is one of the widely used microfossil group to construct the biostratigraphical framework of a region, since they serve relatively good stratigraphic resolution. Planktonic foraminifera are usually considered as good biostratigraphical useful taxa due to their much potential dispersal rate while living or after death and their high evolutionary rate. Moreover, benthic foraminifera was also considered as an effective group in the biostratigraphical studies even more than planktonic foraminifera. This was particularly for the cases such as constructing the biostratigraphy of the Upper Cretaceous European basins (Peryt and Dubicka, 2015).

Most of the biostratigraphic works regarding the planktonic foraminiferal biozonation schemes were done on purpose of hydrocarbon exploration after being aware of efficiency of this microfossil group in worldwide lithological correlation. In the 20th century, those biozone charts were extensively become applicative with the organizations of Deep Sea Drilling Projects (DSDP) and Ocean Drilling Programs (ODP&IODP) (Berggren and Pearson, 2005). DSDP also led the progresses in the studies of taxonomy, paleobathymetry and biostratigraphy of deep-water benthic foraminifera (Berggren and Miller, 1989).

In this study, three benthic foraminifera biozones were established (Figure 15). These biozones are reported for the first time from Turkey. *Bolivinoides draco* Zone is established for 3.15 m the latest Maastrichtian interval before the K-Pg boundary. As an equivalent biozone to *Bolivinoides draco* Zone, a new *Eouvigerina subsculptura* Acme Zone is proposed with this study for the same part, since this taxon was found abundant to very abundant in all Maastrichtian samples.

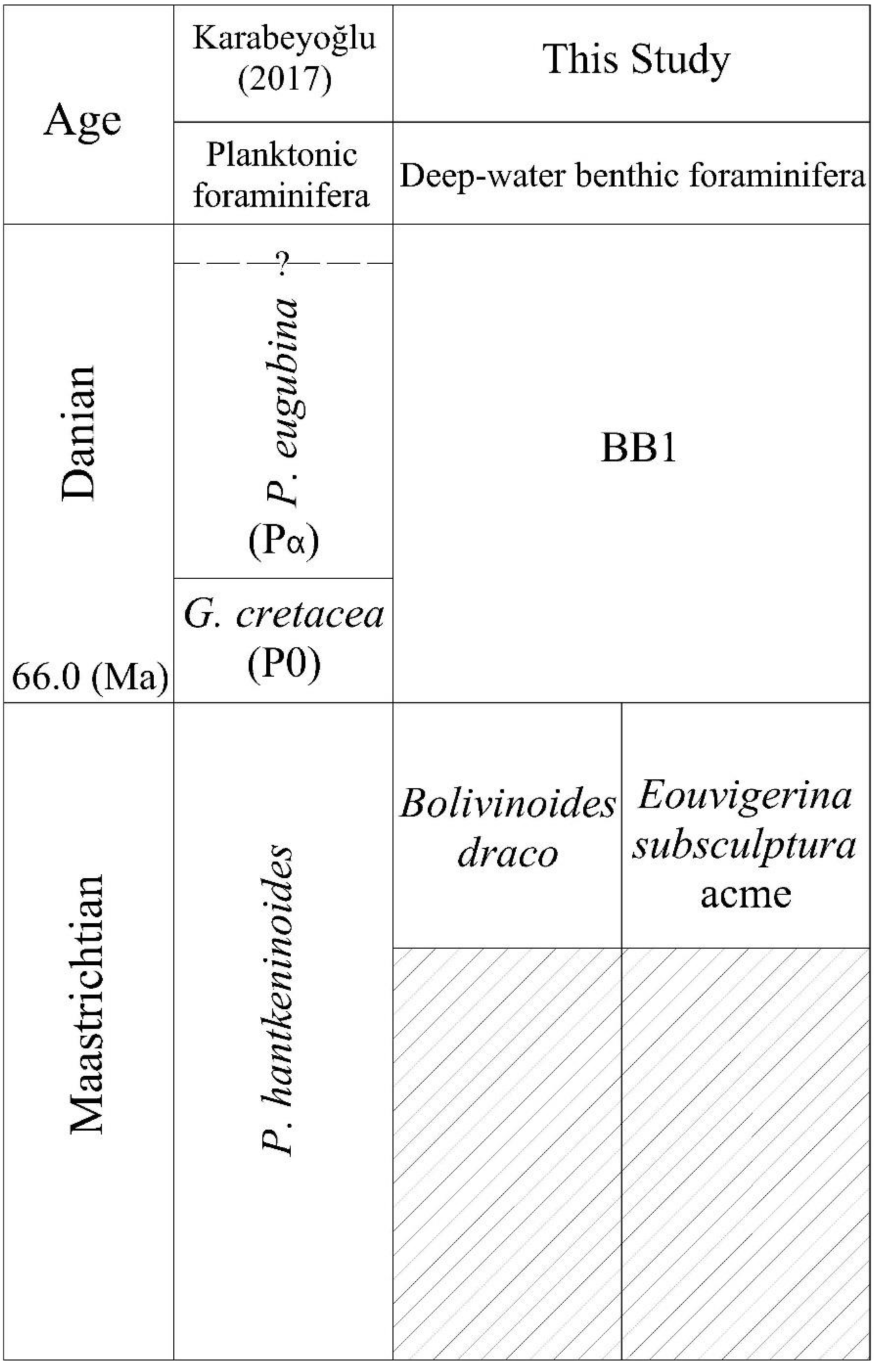

Figure 15: Benthic foraminifera biozones established from the Haymana Basin in this study and their calibration with previously defined planktonic foraminifera biozones by Karabeyoğlu (2017).

For the Danian part which corresponding to 1.21 m part of the studied section after the K-Pg boundary, *Angulogavelinella avnimelechi-Anomalinoides rubiginosus* Zone (BB1) is established. El-Nady (2006) and Berggren and Miller (1989) were followed for the descriptions of the biozones.

Planktonic foraminifera biozonations for the same measured section were previously constructed by Karabeyoğlu (2017). Three different planktonic foraminifera biozones were established by this author for the uppermost Maastrichtian and the lowermost Danian of the measured section. These biozones were *Plummerita hantkeninoides* Zone, *Guembelitria cretacea* Zone and *Parvularugoglobigerina eugubina* Zone, from the lowest to the highest respectively. The top boundary of the latter biozone was undetermined in that study, therefore the rest of the Danian section was remained unzoned.

Details of the deep-water benthic foraminifera biozones established in this thesis as well as the planktonic foraminifera biozones constructed by Karabeyoğlu (2017) are given in below sections.

### 2.2.1 Deep-Sea Benthic Foraminifera Biozonation

#### *Bolivinoides draco* Zone

**Definition**: This zone represents the interval zone between the last appearance datum of *Bolivinoides miliaris* and the last appearance datum of the nominated taxon.

**Age**: Maastrichtian

**Author**: Marsson (1878)

**Remarks:** *Bolivinoides draco* Zone covers the whole studied Maastrichtian section which spanning 3.15 m thick portion below the K-Pg boundary. *B. miliaris* was not recorded in any sample in this interval, but *B. draco* was found in most of the Maastrichtian samples. The first occurrence of *B. draco* was recorded from the first sample (UH-33) in the studied section, hence the whole Maastrichtian section was assigned as *Bolivinoides draco* Zone up to the K-Pg boundary.

This zone is equivalent to *Eouvigerina subsculptura* Acme Zone which newly offered in this study. For the rest of the associated benthic foraminifera taxa to *B. draco*, see *Eouvigerina subsculptura* Acme Zone below. Moreover, *B. draco* is also associated with planktonic foraminifera species *Abathomphalus mayaroensis* and *Plummerita hantkeninoides* in the Late Maastrichtian according to Anan (2011a). The Maastrichtian part of the same measured section was previously assigned as *P. hantkeninoides* Zone by Karabeyoğlu (2017). Thus, *B. draco* Zone defined in this study is well calibrated with previously established *P. hantkeninoides* Zone by that author.

### *Eouvigerina subsculptura* Acme Zone (Newly Proposed in This Study)

**Definition**: This zone is represented by the abundant occurrence of *Eouvigerina subsculptura* (average 18.1% in the late Maastrichtian, up to 23.0%) in the benthic foraminiferal assemblage throughout the studied Maastrichtian interval. The lowest boundary of the zone is corresponding to the first sample (UH-33) which is located 3.15 m below the K-Pg boundary. The upper boundary of this zone is defined as a drastic decrease in the relative abundance and consequent disappearance of the nominate taxon which is also coinciding with the K-Pg boundary event.

**Age**: The Late Maastrichtian

**Author**: Vardar and Özkan-Altıner (this study)

**Remarks:** This proposed biozone is 3.15 m thick in the Haymana Basin and is equivalent to *Bolivinoides draco* Zone defined in this thesis, which covering the whole studied section before the K-Pg boundary. The position of this offered biozone is placed at the upper parts of *Plummerita hantkeninoides* Zone which previously determined by Karabeyoğlu (2017) for the same measured section with thickness of 9.55 m (Figure 15).

The nominated taxon, *Eouvigerina subsculptura*, is considered as an opportunistic ecomarker species adjusted to the upper and middle bathyal settings with large amount of organic matter in the Late Maastrichtian deep-sea Tethys (Widmark & Speijer, 1997a). Besides, this species was reported to be extinct at the K-Pg boundary, since it would be linked with huge food fluxes or specific food supply (Widmark & Speijer 1997a, and references therein). In the studied material, the relative abundance of this species is decreasing dramatically right after the K-Pg boundary. Specimen belong to this taxon were recorded in one Danian sample (UH-50), though these would be possibly reworked. Thus, this species are considered here as suspicious survivor (See Discussion and Conclusion Chapter).

Benthic foraminifera assemblage represents an upper bathyal setting in this study. The index taxon was found together with *Angulogavelinella angustiumbilicata*, *Anomalinoides acutus*, *Anomalinoides affinis/welleri*, *Bathysiphon* spp., *Bolivina incrassata*, *Bolivinoides draco*, *Bulimina strobila*, *Cibicides* sp. 2, *Cibicidoides alleni*, *Cibicidoides* spp., *Clavulinoides trilatera*, *Gyroidinoides* spp., *Heterostomella austinana*, *Lenticulina* sp. 1, *Lenticulina* spp., *Praebulimina reussi*, *Pseudouvigerina plummerae*, *Pseudogaudryina* sp. 1, *Pseudogaudryina* sp. 2, *Pseudogaudryina* sp. 3, *Sitella* spp., *Sliteria varsoviensis*, *Spiroplectinella* sp. 1, *Verneuilina* sp. 1, *Verneuilina* spp. and *Verneuilina* ? sp. For the relative abundances of these taxa, see Appendix C.

### ***Angulogavelinella avnimelechi-Anomalinoides rubiginosus* Zone (BB1)**

**Definition**: This zone is originally defined as concurrent partial ranges of the index taxa between the last occurrence of *Bolivinoides draco* and the last occurences of *Angulogavelinella avnimelechi* and *Neoflabellina jarvisi.*

**Age**: Paleocene

**Author**: Berggren and Miller (1989)

**Remarks:** This zone is defined in this study primarly depending on the associated benthic foraminifera taxa. Additionally, it is replacing both *Bolivinoides draco* Zone and its equivalent *Eouvigerina subsculptura* Acme Zone (new) right after the K-Pg boundary. In this sense, these two equivalent underlying biozones representing the Haymana Formation are replaced by BB1 zone in the Danian corresponding to the Yeşilyurt Formation after the boundary event. Therefore, the lower boundary of BB1 Zone in the Haymana Basin was delineated between these two formations just after the *Bolivinoides draco* Zone and its equivalent *Eouvigerina subsculptura* Acme Zone (new). The upper boundary of BB1 Zone is not defined in this study, since the studied stratigraphic section include only the lowermost Danian part of the Yeşilyurt Formation.

The index species *Angulogavelinella avnimelechi* and *Neoflabellina jarvisi* were not recovered from any of the Paleocene samples. On the other hand, *Anomalioides rubiginosus* occurred common to abundant through this interval, except for the last sample UKHB-10 in which it was not encountered. *Loxostomoides applinae* which is restricted to neritic to upper bathyal environments was recorded as very rare to rare in this interval in the most of the Danian samples. *Tappanina selmensis* is present throughout the studied interval in the smaller fraction (63 – 125 µm). Its occurrences were noted only based on the presence-absence data. All these taxa were reported as associated taxa by the original authors of this biozone. Hence, their occurences in the studied samples agree with this assigned biozone.

BB1 Zone corresponds to the planktonic foraminifera biozones Pα to P6 according to Berggren and Miller (1989). In this study, planktonic foraminifera biozones established by Karabeyoğlu (2017) P0(*Guembelitria cretacea*) Zone and Pα(*Parvularugoglobigerina eugubina*) Zone for the studied section coincide with BB1 Zone established here. BB1 zone in this study is covering a 1.21 m thick lowermost Danian portion of the Yeşilyurt Formation.

### 2.2.2 Planktonic Foraminifera Biozonation

#### *Plummerita hantkeninoides* Zone

**Definition**: Total range zone of *Plummerita hantkeninoides* was defined by the first appearance datum of this taxon and the mass extinction of Cretaceous species coinciding with K-Pg boundary.

**Age**: The late Maastrichtian

**Author**: Masters (1984)

**Remarks:** This biozone is corresponding whole Maastrichtian part of the measured section which is spanning 9.55 m below the K-Pg boundary. *Plummerita hantkeninoides* Total Range Zone is useful in the Tethyan localities due to its nonappearance in higher latitudes (Li and Keller, 1998). Although *Plummerita hantkeninoides* was found very rare in the Maastrichtian material studied by Karabeyoğlu (2017), the zone was established for the whole 9.55 m thick Maastrichtian section (up to the K-Pg boundary) by this author based on the presence of this species in the first Maastrichtian sample (UH-1).

#### *Guembelitria cretacea* P0 Zone

**Definition**: Interval, partial range zone, between the last appearance datum of characteristic Cretaceous taxa at the K-Pg boundary and the first appearance datum of *Parvularugoglobigerina eugubina* (Karabeyoğlu, 2017). Meanwhile, this biozone corresponds to the last appearance datum of tropical species *Plummerita hantkeninoides* and/or *Abathomphalus mayaroensis* just at the boundary, and the first appearance datum of *Parvularugoglobigerina eugubina* (Arenillas et al., 2000).

**Age**: The earliest Danian (Berggren and Pearson, 2005)

**Author:** Keller (1988), initially defined by Smit (1982)

**Remarks:** *Guembelitria cretacea* is a survivor species that cross the K-Pg boundary and entitled to an opportunistic taxon. *Guembelitria* species in the Danian are considered as one and only Cretaceous survivors (Gallala et al., 2009 and references therein).

This biozone is either called as *Guembelitria cretacea* or P0. In the measured section, it is covering 0.25 m beginning with K-Pg boundary and spanning until *Parvularugoglobigerina eugubina* Zone (Karabeyoğlu, 2017).

### Pα (*Parvularugoglobigerina eugubina*) Zone

**Definition:** This biozone is constructed by using total range zone of *Parvularugoglobigerina eugubina*, which is corresponding to the interval starting with its first appearance datum and ending by its last appearance datum.

**Age:** Danian (Berggren and Pearson, 2005)

**Author:** Liu (1993) with emendation of *Globorotalia (Turborotalia) longiapertura* Zone of Blow (1979), *Globigerina eugubina* Zone of Luterbacher and Premoli Silva (1964). (Berggren and Pearson, 2005)

**Remarks:** In the measured section, the base limit of this biozone is corresponding to 0.25 m after the K-Pg boundary. The top boundary of this biozone was not defined (Karabeyoğlu, 2017).

# CHAPTER 3

# QUANTITATIVE ANALYSIS OF DEEP-WATER BENTHIC FORAMINIFERA IN THE HAYMANA BASIN

## 3.1 Introduction

An abundance matrix, which is composed of taxa names and individual counts of each taxon from a given assemblage, is widely used type of paleontological dataset in quantitative paleoecological studies. Presence-absence data which assigned by only one and zero type data, on the other hand, would be more useful for stratigraphic purposes  (Hammer and Harper, 2006).

In this study, benthic foraminiferal taxa have been counted from samples which represent different stratigraphical horizons. For each sample, approximately 300 benthic foraminifera individuals were picked from >125 μm fraction from the representative splits. This threshold value was chosen, because minimum 300 benthic foraminifera specimens for one sample is the best representative size for diversity calculations according to Thomas (1989). All benthic foraminifera specimens were picked from the processed split per sample. Picked specimens were stored in cardboard micropaleontology slides. An abundance matrix was produced based on this taxon counts in order to make paleocommunity analysis. The constructed dataset including absolute counts of the taxa is given in Appendix E. This dataset was converted into another dataset representing the percentages (%) of identified taxa at specific (Appendix C) and genus level (Appendix D) to differentiate their relative abundance within the assemblage.

Conditional formatting with different color has been applied to make a visual distinction on the relative abundances of each taxon in each dataset following the divisions of Alegret and Thomas (2001) (Table 3). Every individual, even if appears in one sample only one time was taken into consideration in this study. For presence-absence data tracking, taxa with counts of ≥1 on absolute count dataset is given at Appendix E.

Table 3: Reference division categories used in this study for relative abundances and absolute count matrices. Classes for relative abundances were adapted from Alegret and Thomas (2001) (See Appendix C and D).

| Assigned conditions | Relative abundance (%) | Assigned color |
|---|---|---|
| **very abundant** | > 15 | Red |
| **abundant** | 5 – 15 | Yellow |
| **common** | 2 – 5 | Green |
| **rare** | 1 – 2 | Grey |
| **very rare** | < 1 | White |

## 3.2 Morphogroup Analysis

Benthic foraminifera are very common in marine environments. They have various test shapes and wall structures. Corliss and Chen (1988) revealed a morphotype study of deep-water benthic foraminifera at Norwegian Sea. Their study showed that species with different test morphology prefer to live in different microhabitat and bathymetry. These differentiations in each groupings of the benthic foraminifera morphotypes would be associated with organic carbon flux. Therefore, they would be used as a paleoenvironmental proxy and would be a link to the past oceanic environment.

Based on the test shape, benthic foraminifera adopt to live within sediment or top of the sediment surface layer. As the most general statement, benthic foraminifera with tests with shapes of cylindrical tapering, flattened tapering, rounded planispiral and spherical are considered to live within the bottom sediments. On the other hand, test shapes of planoconvex, rounded and biconvex trochospiral, palmate and branching morphotypes usually prefer to live at the top of the sediment layer (Alegret et al., 2003). Considerable amount of changes in relative abundances of morphogroups within a community would refer variation in the environmental parameters (Setoyama et al., 2017 and references therein).

In the case of assignment of morphogroups attention must be paid, because benthic foraminifera may change its habitat both vertically and horizontally even within hours (Bornmalm et al., 1997). Moreover, some statistical works suggested that the appointment of infaunal morphogroups has accuracy of 75% (Buzas et al., 1993).

In this study morphogroup analysis was carried out in order to determine infauna-epifauna ratio and to investigate paleoenvironmental changes in terms of organic matter flux. This ratio is commonly used in paleoceanographic studies as an indicator of food delivery to the sea bottom (Gooday, 2003). Identified species were categorized into different morhpogroups accordingly with previously published literature of deep water benthic foraminifera. Morphotype classifications were mainly adapted from Alegret et al. (2003). Additionally, the lists of Koutsoukos and Hart (1990), Thomas (1990), Widmark and Malmgren (1992) and Kaminski and Gradstein (2005) were used. The compiled index for classified morphogroups for this study is given in Appendix B.

Infaunal calcareous morphogroups are assigned as CI11, CI2, CI3 and CI4 for cylindrical tapered, flattened tapered, rounded planispiral and spherical calcareous foraminifera taxa, respectively (Figure 16, Table 4). Epifaunal calcareous taxa is sorted by CE1, CE2, CE3, CE4 and CE5 for planoconvex trochospiral, biconvex trochospiral, rounded planispiral, palmate and branching morpotypes, respectively (Figure 16, Table 4).

Infaunal agglutinated taxa is classified as AI1, AI2 and AI3 for elongate multilocular, flattened trochospiral and elongate tapered taxa, accordingly (Figure 16, Table 5). Moreover, epifaunal agglutinated taxa are assorted by AE1, AE2 and AE3 for coiled flattened & streptospiral, elongate keeled and tubular & branching forms, respectively (Figure 16, Table 5).

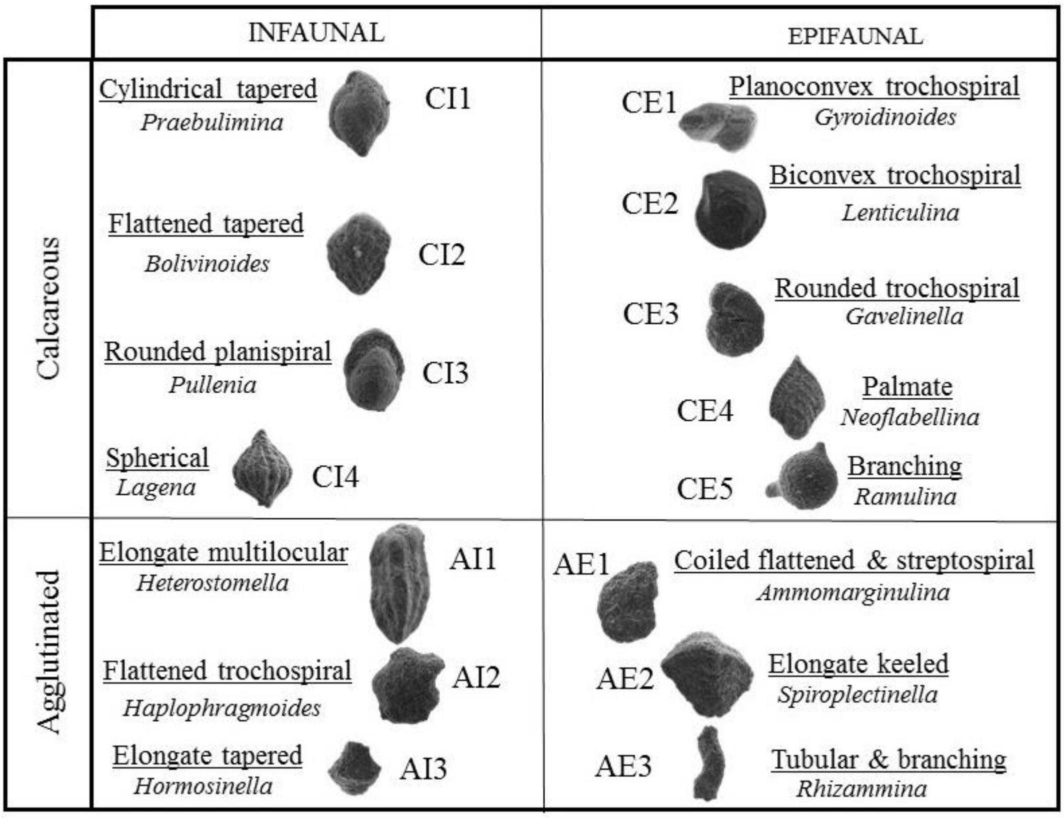

Figure 16: Assigned classes for calcareous and agglutinated infaunal-epifaunal morphogroups with one representatine genera identified in the Haymana Basin.

Table 4: Microhabitat and morphogroup categories for calcareous tests.

| **Test shape** | **Assigned categories** | **Microhabitat** |
|---|---|---|
| Cylindrical tapered | CI1 | Infaunal |
| Flattened tapered | CI2 | Infaunal |
| Rounded planispiral | CI3 | Infaunal |
| Spherical | CI4 | Infaunal |
| Planoconvex trochospiral | CE1 | Epifaunal |
| Biconvex trochospiral | CE2 | Epifaunal |
| Rounded trochospiral | CE3 | Epifaunal |
| Palmate | CE4 | Epifaunal |
| Brancing | CE5 | Epifaunal |

Table 5: Microhabitat and morphogroup categories for agglutinated tests.

| **Test shape** | **Assigned categories** | **Microhabitat** |
|---|---|---|
| Elongate multilocular | AI1 | Infaunal |
| Flattened trochospiral | AI2 | Infaunal |
| Elongate tapered | AI3 | Infaunal |
| Coiled flattened & streptospiral | AE1 | Epifaunal |
| Elongate keeled | AE2 | Epifaunal |
| Tubular & branching | AE3 | Epifaunal |

Morphogroup analysis suggested that for the whole studied section, calcareous taxa is more abundant with respect to agglutinated taxa. In the Maastrichtian section their values are between 67.7% - 77.8% (average 73.9%) (Table 6). The relative abundance of agglutinated taxa is between 22.2% - 32.3% (average 26.1%) (Table 6). For the Danian part on the other hand, calcareous taxa is dominant with respect to agglutinated taxa, up to 93.7%. These values suggest a deposition environment well above Calcium Carbonate Compensation Depth (CCD) for the whole studied section.

Overall infaunal taxa including both calcareous and agglutinated morhopgroups together are relatively more abundant in Maastrichtian (average 75%) when compared to whole calcareous and agglutinated epifaunal morphogroups (average 25%). Just below the boundary (below approximately 15 cm), infaunal morphogroups including both calcareous and agglutinated taxa constitute up to 83% and 89% as maximum, in UH-48 and UH-49, respectively (Table 6).

In the Danian part, just after the boundary, there is a considerably change in the relative abundances of the morphogroups. Infaunal – epifaunal ratio is switched from infaunally abundant to epifaunally abundant assemblage. Epifaunal morphotypes make up 66.9 – 83.9% in this part, whereas infaunal morphogroups have only value of 16.1 – 33.1% of total fauna (Table 6). This dominance offers that the amount of nutrients for benthic foramimifera is lesser in Danian compared to Maastrichtian (Alegret et al., 2003), because high abundances of infaunal taxa implies the high organic carbon flux (Thomas, 1990). (See Disscussion and Conclusion Chapter).

In the Maastrichtian section, the most important morphogroups among the calcareous taxa are CI1 (cylindrical tapered), CE2 (biconvex trochospiral) and CE1 (planoconvex trochospiral) with the average relative abundances of 48%, 18% and 3%, respectively (Figure 17). Besides, the most significant classes are AI1 (elongate multilocular) and AE2 (elongate keeled) among the agglutinated taxa holding the average relative abundances of 23% and 2%, respectively in this part (Figure 18).

In the Danian, the relative abundance of CE2 (53%) and CE1 (22%) increase, whereas that of CI1 (8%) decrease (Figure 17). Among the agglutinated groups, AI1 decreases its relative abundance to average 11%, while AE2 was not present in the Danian samples (Figure 18).

The changes in the relative abundance of all morphogroups are given in Figure 19 for the calcareous groups and in Figure 20 for the agglutinated groups. Regarding the changes in all morphogroups including both calcareous and agglutinated classes together, a chart is given in Figure 21.

Table 6: Table showing numerical ratio of agglutinated-calcareous (%), epifauna – infauna (%) regarding total benthic foraminifera assemblage. Note that K-Pg boundary is located between UH-49 and UH-50 indicated by black line.

| **Stage** | **Samples** | **Agglutinated (%)** | **Calcareous (%)** | **Epifauna (%)** | **Infauna (%)** |
|---|---|---|---|---|---|
| Danian | UKHB-10 | 10,3 | 89,7 | 66,9 | 33,1 |
| | UKHB-9 | 16,8 | 83,2 | 71,8 | 28,2 |
| | UKHB-8 | 11,6 | 88,4 | 75,4 | 24,6 |
| | UKHB-7 | 16,4 | 83,6 | 75,9 | 24,1 |
| | UKHB-6 | 6,3 | 93,7 | 81,5 | 18,5 |
| | UKHB-5 | 7,9 | 92,1 | 83,9 | 16,1 |
| | UKHB-4 | 10,9 | 89,1 | 73,0 | 27,0 |
| | UH-50 | 7,7 | 92,3 | 77,7 | 22,3 |
| Maastrichtian | UH-49 | 31,4 | 68,6 | 10,1 | 89,9 |
| | UH-48 | 29,4 | 70,6 | 16,5 | 83,5 |
| | UH-47 | 31,3 | 68,8 | 23,9 | 76,1 |
| | UH-46 | 32,3 | 67,7 | 25,8 | 74,2 |
| | UH-45 | 26,3 | 73,7 | 24,5 | 75,5 |
| | UH-44 | 22,8 | 77,2 | 26,2 | 73,8 |
| | UH-43 | 23,1 | 76,9 | 21,2 | 78,8 |
| | UH-42 | 22,7 | 77,3 | 19,6 | 80,4 |
| | UH-41 | 22,3 | 77,7 | 28,7 | 71,3 |
| | UH-40 | 22,2 | 77,8 | 27,8 | 72,2 |
| | UH-39 | 24,5 | 75,5 | 25,2 | 74,8 |
| | UH-38 | 22,3 | 77,7 | 24,8 | 75,2 |
| | UH-37 | 27,4 | 72,6 | 27,8 | 72,2 |
| | UH-36 | 29,2 | 70,8 | 28,9 | 71,1 |
| | UH-35 | 28,8 | 71,2 | 31,9 | 68,1 |
| | UH-34 | 24,7 | 75,3 | 29,3 | 70,7 |
| | UH-33 | 22,3 | 77,7 | 33,5 | 66,5 |

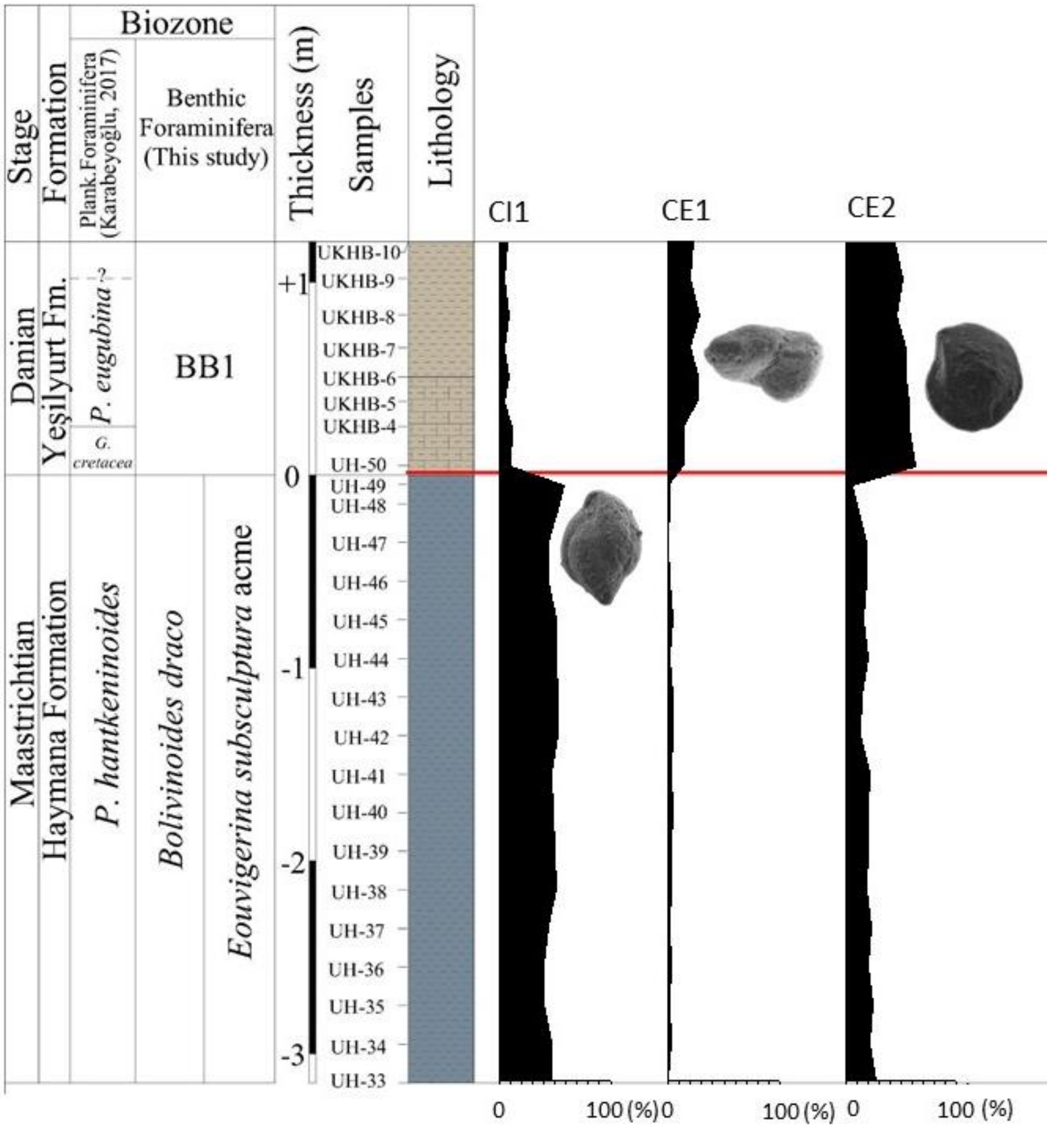

Figure 17: Relative abundances of the common calcareous morphogroups through the studied section (CI1: cylindrical tapered, infaunal; CE1: planoconvex trochospiral, epifaunal; CE2: biconvex trochospiral, epifaunal).

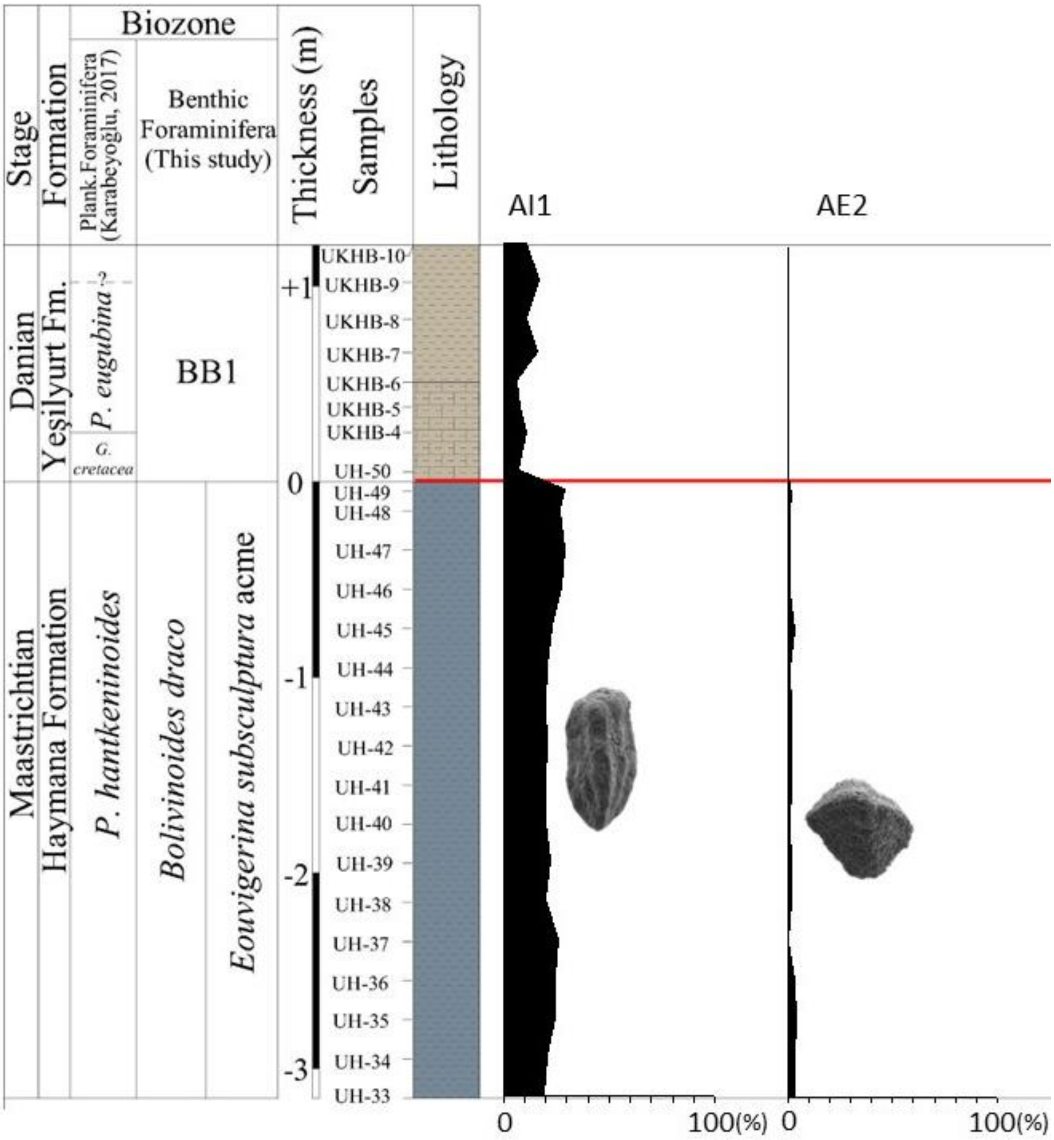

Figure 18: Relative abundances of the common agglutinated morphogroups through the studied section (AI1: elongate multilocular, infaunal; AE2: elongate keeled, epifaunal).

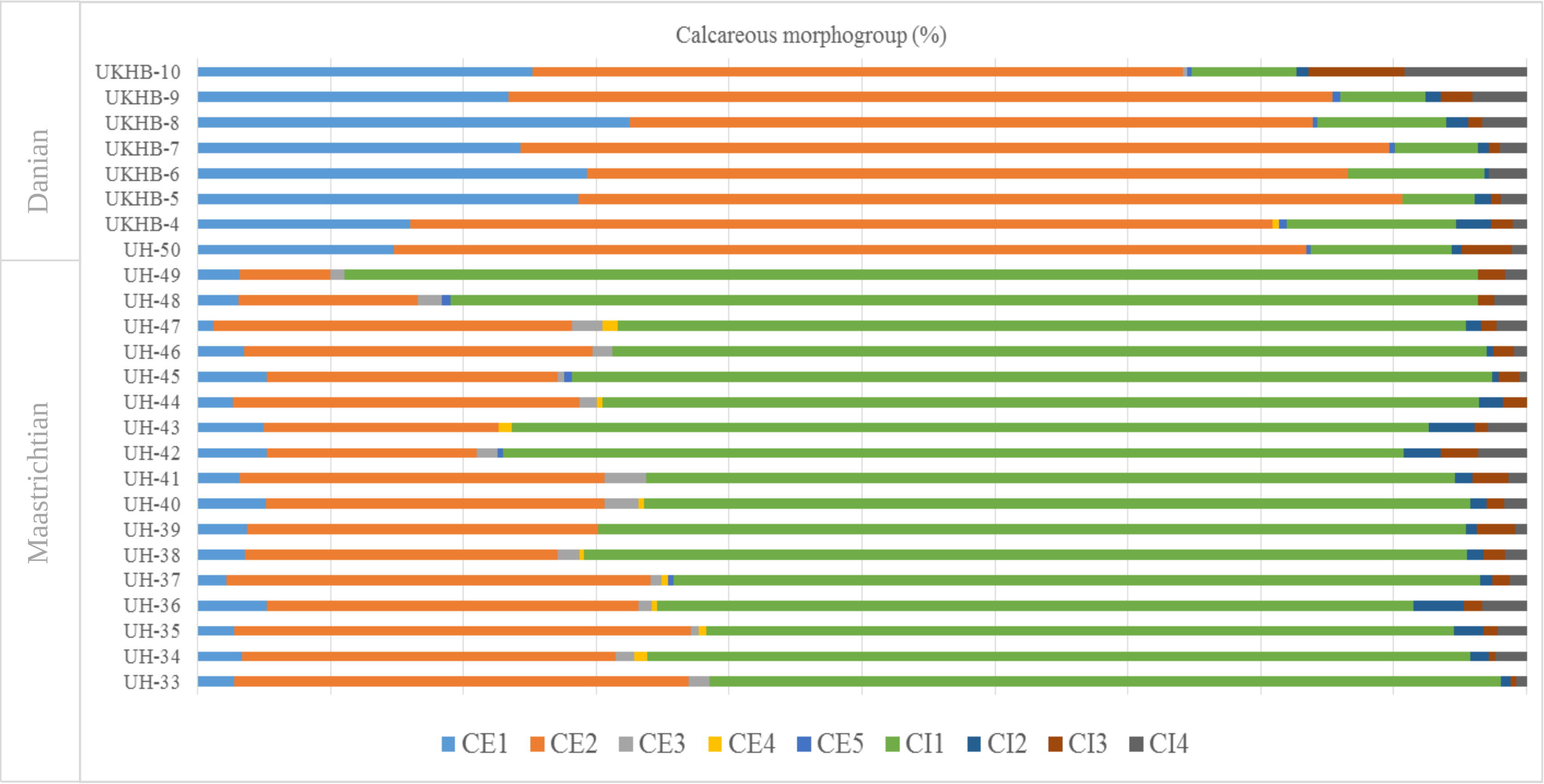

Figure 19: Calcareous epifaunal and infaunal benthic foraminifera distribution chart based on calcareous morphotypes exclusively. Note that K-Pg boundary is located between samples UH-49 and UH-50

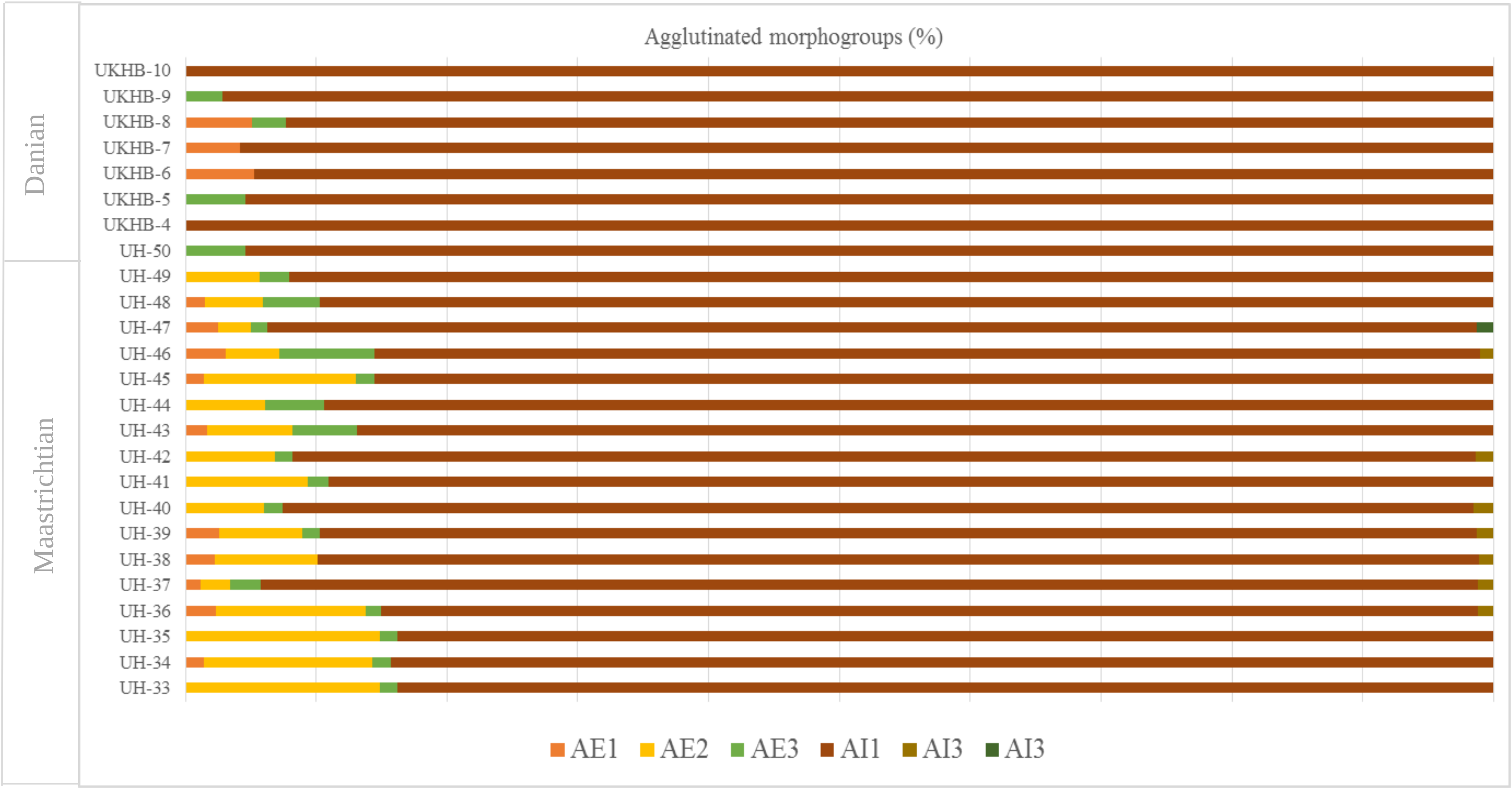

Figure 20: Agglutinated epifaunal and infaunal benthic foraminifera distribution chart based on agglutinated morphotypes exclusively. Note that K-Pg boundary is located between samples UH-49 and UH-50.

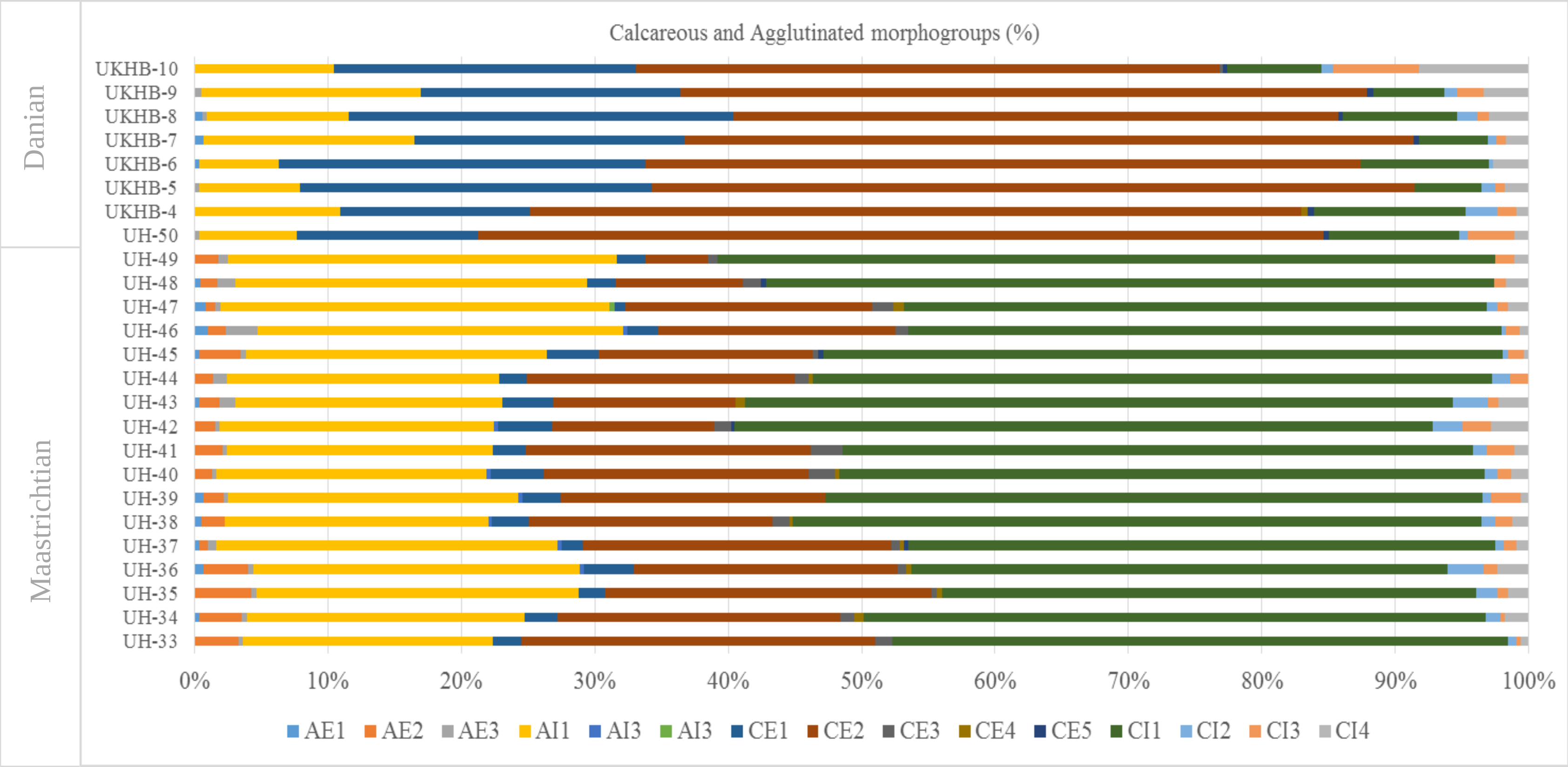

Figure 21: Both calcareous and agglutinated epifaunal and infaunal benthic foraminifera distribution chart based on all morphotypes. Note that K-Pg boundary is located between samples UH-49 and UH-50

## 3.3 Relative Abundances of the Most Common Benthic Foraminifera in the Haymana Formation and the Yeşilyurt Formation

The upper Maastrichtian Haymana formation contains common to abundant infaunal forms such as *Eouvigerina subsculptura*, *Heterostomella austinana*, *Praebulimina reussi* and *Sitella* spp. (including *Sitella cushmani*) together up to average of 43.8% of the whole benthic foraminiferal assemblage throughout this section (Figure 22).

*Eouvigerina subsculptura* is abundant to very abundant in whole Maastrichtian section. Its relative abundance oscillates between 11.2% and 23.0% with an average value of 18.1% for whole Maastrichtian section. It has the lowest value in UH-36, and the highest value in UH-43. *Heterostomella austinana* is common to abundant in whole section with average 6.7%. *Sitella cushmani* together with other *Sitella* species has relative abundance of average 6.8% and found to be somewhat rare in UH-35 with the lowest abundance of 1.5%. *Cibicidoides* spp. is also rare to abundant in all Maastrichtian samples, exclusive of UH-49.

*Sliteria varsoviensis* seems to be more abundant in the lower parts of the Maastrichtian section, which has pick abundance of 6.4% in sample UH-35. It has somewhat a decreasing trend towards top of the Maastrichtian section. After UH-35, its abundance fluctuates from very rare to common. It was not recovered in samples UH-41 and UH-43. The opposite trend is perceivable for *Pseudouvigerina plummerae* which has begun to become more common/abundant starting from UH-37, until the boundary, with the peak value of 8.9% in UH-38, except between UH-42 – UH-44 in which occurs as rare to very rare. It is found to be very rare or absent in the lower part of the section.

*Bulimina strobila* is found to be rare to common from UH-34 to UH-49, except interval between UH-37 - UH-39. It has become more abundant just before the boundary, in UH-49 increasing its abundance to 5.6%.

*Verneuilina* species is rare to common in whole Maastrichtian samples, except for UH-39, UH-40 and UH-46 in which they were found to be very rare. *Verneuilina*

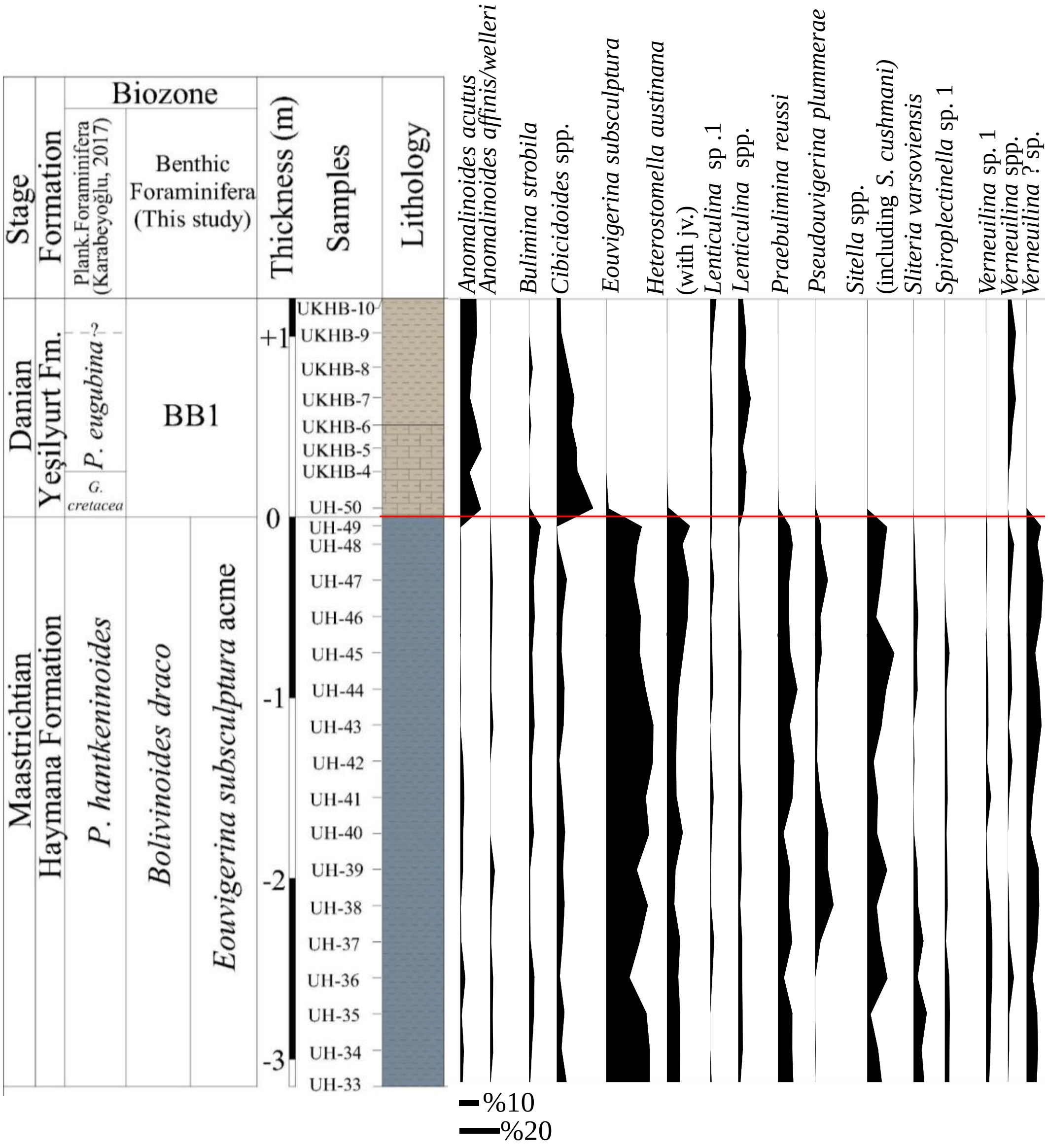

Figure 22: The relative abundance chart for the most common Maastrichtian species in the studied section in the Haymana Basin**.**

sp.1 itself seems to be common in the lower parts of the studied section between UH-34 and UH-38, and also UH-41. *Spiroplectinella* sp. 1 is similar to *Verneuilina* sp.1, recovered as common in the lower portions between UH-33 – UH-36 and also UH-45. In the rest of the section, it is rare to very rare and not present in UH-47 and UH-48.

*Lenticulina* sp. 1, *Lenticulina* sp. 2 and *Lenticulina* spp. together are also rare to common in all samples, apart from UH-43 and UH-48 in which they are very rare. *Anomalinoides acutus* together with *Anomalinoides affinis/welleri* and *Anomalinoides* spp. is present throughout the section, abundant in UH-36, rare to common rest of the section, exclusive of UH-38 and UH-49 in which they are very rare. It has the peak value with 5.5% in UH-36.

The lower Danian Yeşilyurt Formation, on the other hand, is comprising of mostly epifaunal species including *Alabamina wilcoxensis*, *Anomalinoides acutus* and *Lenticulina* spp. are common to abundant in this portion with values of average of 5.7%, 7.3% and 3.6%, respectively (Figure 23).

*Anomalinoides* is abundant throughout the Danian section,with peak value of 14.6% in UH-50. *Cibicidoides* has its the uttermost value in UH-50 with 24.7%. *Gyroidinoides* spp. is found as common to abundant from UKHB-4 toward the top of the section. *Osangularia* is abundant, average 10.4%, between samples UKHB-4 and UKHB-9. In UH-50 and UKHB-10 it is very rare.

*Cibicides* sp. 1 appears in UKHB-6 as rare, thereafter become common to abundant with average 4.8% until the uppermost sample. *Pulsiophonina prima* and *Stensioeina* ? aff. *beccariformis* appear also up to the section as common or abundant. *Verneuilina* spp. is found as rare to common with average 2.6%.

For the paleoenvironmental and ecological concern of the relative abundance of the species, see Chapter 4 Section 4.2 and Chapter 6. For presence-absence data tracking, taxa with counts of ≥1 on absolute count dataset is given at Appendix E.

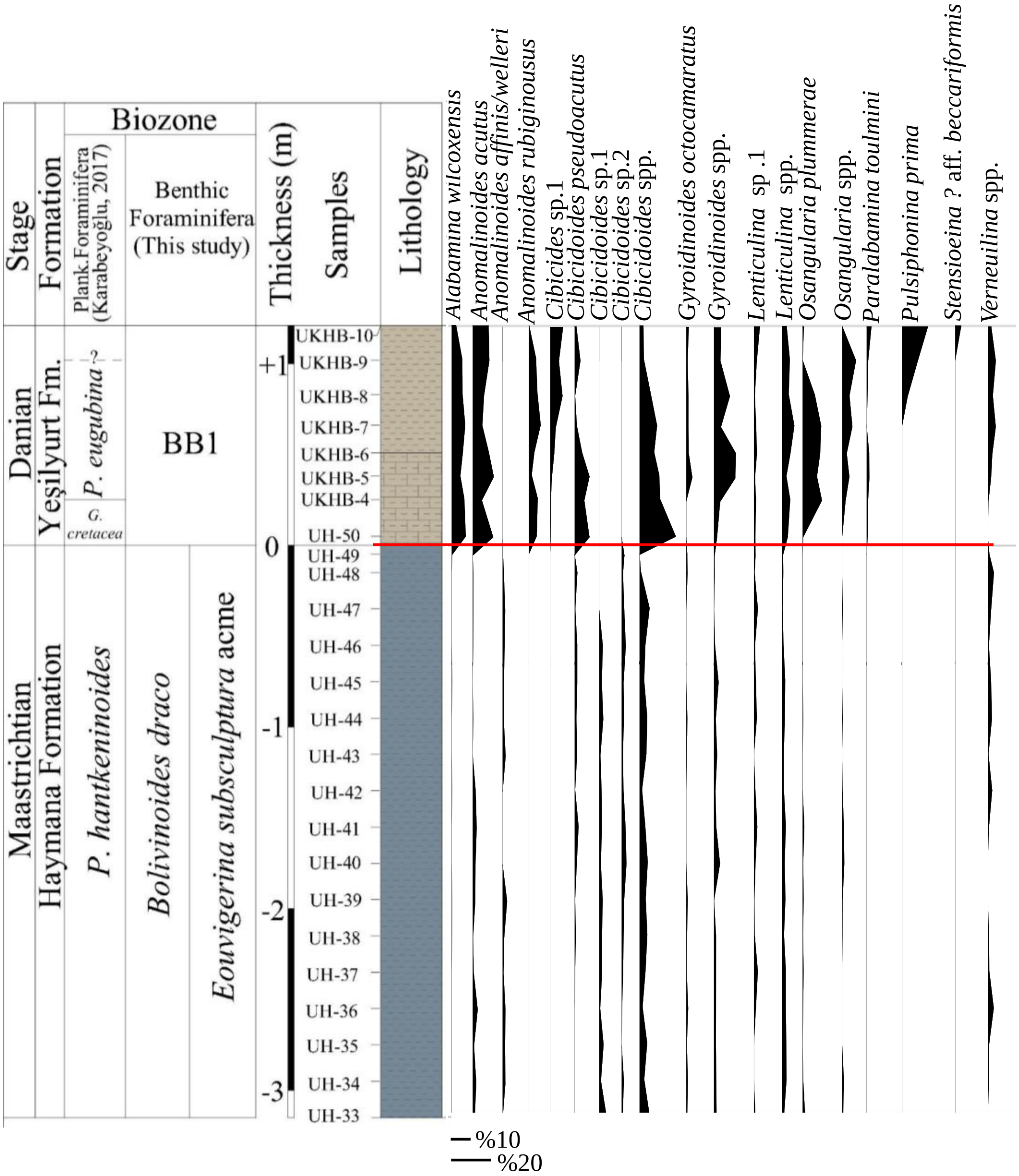

Figure 23: The relative abundance chart for the most common Danian species in the studied section in the Haymana Basin.

## 3.4 Biodiversity Indices

Estimation of biodiversity indices is vital element for ecological investigations (Hammer and Harper, 2006). In order to estimate those in this study, a quantitative assessment of a community was achieved using a dataset composing of individual counts of taxa.

Total number of species (S), Fisher α and Shannon's H are considered as widely used diversity measures in foraminiferal researches (Hayek and Buzas, 2013). The authors also pointed that Berger-Parker index was generally used in the planktonic communities, but not frequently used in the benthic literature. Moreover, they stressed the simplicity and usefulness of Berger-Parker index as diversity measure. The authors also suggested that the number of species should always be given with the number of individual counted from per split, rather than making estimations. Furthermore, Fisher α index is considered as less sensitive to the sample size (Setoyama et al., 2017). Therefore, above mentioned indices were chosen for this study in order to test the diversity of the deep water benthic foraminifera community in the studied samples.

The biodiversity indices were calculated by using PAST (Paleontological Statistics version 3.18) program package (Hammer et al., 2001). The notes on those indices which were adapted from (Hammer, 2002; Hammer and Harper, 2006) and their formula (Table 7) are given as follows:

- N and S values are number of specimens counted and that of taxa identified in a given assemblage, respectively.
- Fisher α index is considered as less sensitive to differences in sample size. To estimate this index, N and S values are needed.
- Shannon's H is heterogeneity index. To estimate this index, N and S values are needed.
- Berger-Parker dominance index, simple computes ratio of the most common taxon to N.

Table 7: Formula of the diversity indices used for estimation of benthic foraminifera association in this study following the recommendation of Hayek and Buzas (2013)

| | | |
|---|---|---|
| **# of specimens (individuals) per split** | N | |
| **# of taxa per sample** | S | |
| **Shannon's H index** | H | $H = -\Sigma p_i \ln p_i$ |
| **Berger–Parker index** | BP | $BP = \max p_i$ where $p$ $(=n_i/\Sigma n)$ |
| **Fisher's alpha (α) index** | α | $S = \alpha * \ln(1 + (N/\alpha))$ |

The computed biodiversity indices in this study are given in Table 8. Indetermined tests were excluded from the abundance matrix in the determination of the biodiversity indices.

According to the numerical results, the computed Fisher α index is oscillating between 13.2 and 22.1 (minimum and maximum) with average value 17.2 in the Maastrichtian. In the Danian, it decreases in sample UH-50 to 10.9 and begins to increase as from UKHB-7 as going up to the Danian section reaching the maximum value of 17.6 for the Danian section. For the whole Danian part, the average Fisher α is 12.5. These results were compared with the Fisher α values of the El Kef section in Tunisia, since the El Kef was reported as upper bathyal by Speijer (1994) (Table 9). Moreover, this locality was known as Global Stratotype Section and Point (GSSP) for the K-Pg boundary. In the El Kef section this index is average 19.2 for the Maastrichtian, average 6.6 in the earliest Paleocene and average 10.9 in the early Paleocene (Table 9). In the Haymana Basin, Fisher α values are indicating a highly diverse fauna in the Maastrichtian section which average of 17.2 and relatively less diverse, namely poor to moderately diverse fauna in whole the Danian section which average of 12.5 (Table 8).

Table 8: Estimated biodiversity indices for Haymana section, ratio of agglutinated-calcareous (%), epifauna–infauna (%). (AF: agglutinated foraminifera, CF: calcareous foraminifera). The black line showing the K-Pg boundary.

| Age | Samples | AF | CF | epifauna % | infauna % | Taxa_S | Individuals counted | fisher α | Shannon H | Berger-Parker % |
|---|---|---|---|---|---|---|---|---|---|---|
| **The early Danian** | UKHB-10 | 10,3 | 89,7 | 66,9 | 33,1 | 54 | 363 | 17,6 | 3,4 | 16,8 |
| **The early Danian** | UKHB-9 | 16,8 | 83,2 | 71,8 | 28,2 | 39 | 209 | 14,1 | 3,1 | 11 |
| **The early Danian** | UKHB-8 | 11,6 | 88,4 | 75,4 | 24,6 | 46 | 342 | 14,3 | 3,2 | 10,2 |
| **The early Danian** | UKHB-7 | 16,4 | 83,6 | 75,9 | 24,1 | 41 | 294 | 13 | 3,1 | 11,2 |
| **The early Danian** | UKHB-6 | 6,3 | 93,7 | 81,5 | 18,5 | 36 | 308 | 10,6 | 2,9 | 14,3 |
| **The early Danian** | UKHB-5 | 7,9 | 92,1 | 83,9 | 16,1 | 30 | 285 | 8,5 | 2,8 | 13,7 |
| **The early Danian** | UKHB-4 | 10,9 | 89,1 | 73 | 27 | 33 | 212 | 11 | 2,9 | 14,2 |
| **The earlist Danian** | UH-50 | 7,7 | 92,3 | 77,7 | 22,3 | 36 | 288 | 10,9 | 2,7 | 25,4 |
| **Maastrichtian** | UH-49 | 31,4 | 68,6 | 10,1 | 89,9 | 43 | 283 | 14,1 | 2,7 | 22,6 |
| **Maastrichtian** | UH-48 | 29,4 | 70,6 | 16,5 | 83,5 | 50 | 234 | 19,5 | 3,1 | 19,7 |
| **Maastrichtian** | UH-47 | 31,3 | 68,8 | 23,9 | 76,1 | 49 | 258 | 17,9 | 3,1 | 16,3 |
| **Maastrichtian** | UH-46 | 32,3 | 67,7 | 25,8 | 74,2 | 56 | 301 | 20,3 | 3 | 21,9 |
| **Maastrichtian** | UH-45 | 26,3 | 73,7 | 24,5 | 75,5 | 49 | 263 | 17,7 | 3,1 | 19,4 |
| **Maastrichtian** | UH-44 | 22,8 | 77,2 | 26,2 | 73,8 | 49 | 291 | 16,9 | 3 | 23 |
| **Maastrichtian** | UH-43 | 23,1 | 76,9 | 21,2 | 78,8 | 47 | 268 | 16,5 | 2,9 | 28,4 |
| **Maastrichtian** | UH-42 | 22,7 | 77,3 | 19,6 | 80,4 | 61 | 326 | 22,1 | 3,1 | 29,8 |
| **Maastrichtian** | UH-41 | 22,3 | 77,7 | 28,7 | 71,3 | 52 | 287 | 18,6 | 3,2 | 24,4 |
| **Maastrichtian** | UH-40 | 22,2 | 77,8 | 27,8 | 72,2 | 51 | 303 | 17,6 | 3 | 26,1 |
| **Maastrichtian** | UH-39 | 24,5 | 75,5 | 25,2 | 74,8 | 48 | 318 | 15,7 | 3,1 | 18,9 |
| **Maastrichtian** | UH-38 | 22,3 | 77,7 | 24,8 | 75,2 | 54 | 399 | 16,8 | 3 | 25,6 |
| **Maastrichtian** | UH-37 | 27,4 | 72,6 | 27,8 | 72,2 | 47 | 323 | 15,1 | 3 | 21,1 |
| **Maastrichtian** | UH-36 | 29,2 | 70,8 | 28,9 | 71,1 | 55 | 301 | 19,7 | 3,3 | 15,6 |
| **Maastrichtian** | UH-35 | 28,8 | 71,2 | 31,9 | 68,1 | 44 | 259 | 15,2 | 3 | 24,7 |
| **Maastrichtian** | UH-34 | 24,7 | 75,3 | 29,3 | 70,7 | 44 | 283 | 14,6 | 2,9 | 26,9 |
| **Maastrichtian** | UH-33 | 22,3 | 77,7 | 33,5 | 66,5 | 43 | 332 | 13,2 | 2,8 | 26,2 |

Table 9: Fisher α values of El Kef (Speijer, 1994) and Haymana Basin (This study)

| **Age** | **Fisher α**<br>**El Kef, Tunisia** | **Fisher α**<br>**The Haymana Basin**<br>**(This study )** |
|---|---|---|
| **The early Paleocene** | 10.9 | - |
| **The earliest Paleocene** | 6.6 | 12.5 |
| **The Maastrichtian** | 19.2 | 17.2 |

Estimated Berger Parker index (BP) seems to be slightly higher during the whole of the Maastrichtian section, from UH-33 to UH-49 with average BP=23.0% and in the lowermost Danian sample UH-50 with BP=25.4%. Those BP values are associated with the most abundant *Eouvigerina subsculptura* (relative abundance with average 18.1%) in the Maastrichtian and *Cibicidoides* spp. (relative abundance with 17.5%) in the earliest Danian, respectively. For the rest of the Danian section, from UKHB-4 to UKHB-10, Berger Parker value is average of BP=13.1% which is lower than the Maastrichtian and the earliest Danian. Correspondingly, there is no very abundant taxa whose relative abundance is > 15% observed in the early Danian.

Estimated Shannon H index for the Haymana Basin is oscillating between 2.7 and 3.4 throughout the studied section (Table 8). According to Friedrich and Hemleben (2007), the values between 2.5 – 3.4 is common in open marine conditions. Therefore, open marine setting are assigned for whole studied section.

The relationship between the species richness and Fisher α and Shannon-H can be explained as follows; higher Fisher α and Shannon-H values indicate higher diversities, while high dominance is associated with low diversity (Elamri et al., 2018).

# CHAPTER 4

# PALEOENVIRONMENTAL AND PALEOECOLOGICAL INTERPRETATIONS

## 4.1 Benthic Foraminifera Associations and Paleobathymetry

Foraminifera, benthic or planktonic mode, live within many different environment distributed both laterally (from marginal marine to deep marine) and vertically (along water column) (BouDagher-Fadel, 2008). Throughout the geological record, this eukaryotic organisms took the records of paleoeocology and paleoceanography and help scientist to understand paleoenvironment.

Benthic foraminifera constitute different associations in different facies due to the various physical and chemical parameters, since they closely interact with bottom sediment layer. Distribution of deep water benthic foraminifera over the basin is affected by several factors, such as bottom water oxygenation and nutrition levels, waterdepth, presence or absence of calcium carbonate and some other oceanographic parameters (Kuhnt et al., 1989). The waterdepth itself is not a controlling factor (Van Der Zwaan et al., 1999), but particularly food and oxygen are considered as two dominant parameters which effect the distribution of benthic foraminifera (Jorissen et al., 1995).

Benthic foraminifera are known as powerful indicators of paleobathymery (Molina et al., 2004). Distribution of the species along different bathymetrical intervals are depending on the variations in organic flux (food) and oxygen (Van Der Zwaan et al., 1999). Usage of planktonic-benthic foraminifera ratio (P/B), as a quantitative manner, together with more generalized bathymetrical schemes in order to make cross-check were suggested for the assignments of paleobathymetry (Van Der Zwaan et al., 1999). Moreover, it was also suggested by these authors that the assessment of paleowater depth should not be based on single marker species.

In this study bathymetrical assignment was carried out concerning the constituents of the assemblage. The Maastrichtian samples include calcareous taxa made up of *Bolivinoides draco*, *Eouvigerina subsculptura*, *Gyroidinoides octocameratus*, *Gyroidinoides* sp. 1, *Gyroidinoides* spp., *Laevidentalina constricta*, *Laevidentalina monile*, *Laevidentalina* spp., *Lagena globosa*, *Lagena* cf. *sulcate*, *Lagena* sp. 1, *Lagena* spp., *Lenticulina* sp. 1, *Lenticulina* sp. 2, *Lenticulina* spp., *Nonionellina* sp. 1, *Pseudouvigerina plummerae*, *Pullenia jarvisi*, *Pullenia* sp. 1, *Pullenia* spp., *Pyramidina minuta* and *Sitella* spp. together with average 33.4% of the total assemblage for those samples. This assemblage is very similar to Shallow Bathyal Assemblage (SBA) offered by Widmark and Speijer (1997b). Shallow Bathyal Assemblage (SBA) stands for the Late Maastrichtian upper bathyal environments in the Central Tethys, holding relative abundance of 32 to 60% in the southern margin of Central Tethys with preference of upper bathyal settings. In the southern parts of Central Tethys, the percentages of SBA within the total assemblage is 32.4% in El Kef (Tunisia), 36.7% in Wadi Nukhl (Egypt) and 59.7% in Nahal Avdat (Israel) section which were all inferred as upper bathyal settings (~400 m) by Widmark and Speijer (1997b) (Figure 24). In the northern parts of the Central Tethys, this assemblage was reported to be holding relative abundance of 22.7% in Caravaca, (Spain) which was referred as middle bathyal setting (~800 m) by the same authors. In this thesis, in the Haymana section the relative abundance of this assemblage is recorded as 33.4% as mentioned above which favours the upper bathyal environment (Figure 24).

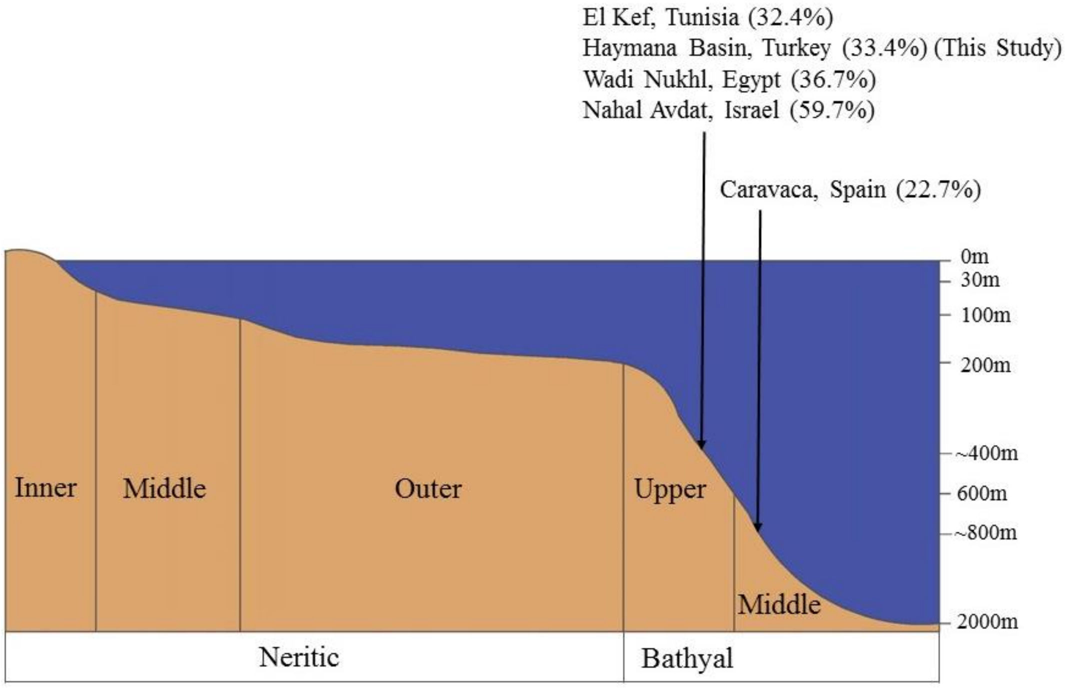

Figure 24: Interpreted paleobathymetric position of the studied section and other localities with percentages of Shallow Bathyal Assemblage (SBA) of Widmark and Speijer (1997b). Image modified after MacLeod and Keller (1994).

High relative abundance of SBA endobenthic forms implies large amount of food flux at the upper bathyal environments (Widmark and Speijer, 1997b). In this study, identified infaunal taxa among the above mentioned calcareous species corresponding to SBA has overall relative abundance of average 30.2% within the assemblage, which means relatively abundant group throughout the studied Maastrichtian section.

The Maastrichtian assemblage is containing a mixture of calcareous and agglutinated taxa in the studied section. Calcareous cemented agglutinated taxa including *Clavuinoides trilatera*, *Arenobulimina* spp., *Dorothia pupa*, *Dorothia* sp., *Gaudryina* sp. 1, *Gaudryina* sp., *Verneuilina* sp. 1, *Verneuilina* sp. 2, *Verneuilina* spp. and *Heterostomella austinana* and *Heterostomella* sp. 1 together constitute average 10.8% of the total assemblage. This association is similar to mixed calcareous and agglutinated assemblage in low and mid-latitude slope Deep Water Agglutinated biofacies offered by Kuhnt et al. (1989). This biofacies is also characterized by highly diverse abundant mixed calcareous and agglutinated benthic foraminifer which are belonging to mostly calcareous cemented forms. Estimated Fisher α also agrees with highly diversified Maastrichtian fauna. Low and mid-latitude slope assemblages were differentiated by Kuhnt et al. (1989) in terms of bathymetrical situations. According to the authors, the upper slope was characterized by fair benthic diversity, rare flysch forms and common calcareous agglutinated forms, when compared to middle slope where flysch forms which are in considering amount. Furthermore, calcareous taxa are very variable due to the local carbonate lysocline and/or dissolution.

According to bathymetric division of Berggren and Miller (1989) upper bathyal environment corresponds to 200-600 meter interval. Karabeyoğlu (2017) previously calculated P/B ratio spanning 3.55 m below K-Pg boundary in the studied section. The paleowater depth was offered as ~400 m by the same author. Paleobathymetrical assignment with benthic foraminiferal data in this study agrees with that numerical assignment calculated by this author based on the P/B ratio.

In the smaller fraction (63 – 125 μm) two species were recorded based on only their presence-absence data; *Tappanina selmensis* and *Spiroplectammina* aff. *S. spectabilis*. *Tappanina selmensis* is considered to be mainly a neritic species, though it may hold an opportunistic strategy in nutrient rich and/or dysoxic settings independent from bathymetry and also may be found in the bathyal environment (Van Morkhoven, 1986). This small form was found in all studied section. *Spiroplectammina* aff. *S. spectabilis* was found in only Maastrichtian samples. *Spiroplectammina spectabilis* was reported to be adapted to bathyal to abyssal environments (Kaminski and Gradstein, 2005). Therefore, the presence of those two also agree with the assigned bathyal location of the studied section.

There is no perceivable bathymetrical change for the studied the Danian part after the boundary event. Almost all of the studied samples are devoid of planktonic foraminifera in the studied size fraction (> 125 µm), thus a numerical bathymetry estimation with P/B ratio could have not been applied for the Danian samples. However, for the assemblage point of view, foraminifera assemblage constitutes of *Alabamina wilcoxensis*, *Anomalinoides acutus*, *Anomalinoides rubiginosus*, *Cibicides* sp.1, *Cibicidoides pseudoacutus*, *Cibicidoides* spp., *Dorothia* spp., *Gyroidinoides* spp. *Lenticulina* spp., *Loxostomoides applini*, *Pulsihponina prima*, *Osangularia*, *Verneuilina* spp., which are recorded as rare to abundant in the studied Danian section. Among this assemblage, *Anomalinoides rubiginosus*, *Loxostomoides applini* and *Tappanina selmensis* (from 63–125 µm fraction) were reported from assemblages of Paleocene bathyal benthic foraminifera zonation (BB1) offered by Berggren and Miller (1989). *Loxostomoides applini* is an indicator of Paleocene neritic environment, but also ranges to upper bathyal (Van Morkhoven, 1986). Besides, it is component of neritic Midway Type fauna of Berggren and Aubert (1975) together with *Alabamina wilcoxensis, Anomalinoides acutus, Osangularia plummerae* and *Pulsihponina prima.* Therefore, the presence of both bathyal taxa and shelf taxa together, possibly no bathymetrical change was applied for the studied Danian section after the K-Pg boundary event.

## 4.2 Paleoecological Remarks for Maastrichtian and Danian Benthic Foraminifera Species

Widmark and Speijer (1997a) established five paleoecological important species from Tethyan Late Maastrichtian bathyal to abyssal settings, which are *Eouvigerina subsculptura*, *Sliteria varsoviensis*, *Gavelinella beccariformis* and *Gavelinella pertusa, Nuttallides truempyi.* In the Maastrichtian samples, two of those were recorded in this study, *Eouvigerina subsculptura* and *Sliteria varsoviensis,* whereas *Gavelinella pertusa*, *Gavelinella beccariiformis* and *Nuttallides truempyi* were not encountered. Widmark and Speijer (1997a) mentioned *Gavelinella pertusa* as typical boreal species which adapted to neritic to middle bathyal settings in the Late Maastrichtian. The authors also reported that *Gavelinella beccariiformis* and *Nuttallides truempyi* are abundant constituents in middle bathyal-abyssal settings with oligotrophic conditions provided that the endobenthic populations are less than 20% of the whole assemblage. Since mesotrophic to eutrophic conditions in the upper bathyal setting were assigned for the Maastrichtian part of the studied section, the aforementioned three ecomarker species were not recorded in the studied Maastrichtian materials.

*Eouvigerina subsculptura* is considered as an opportunistic form, which adapts high food fluxes in upper to middle bathyal settings (Widmark and Speijer, 1997a). This form together with abundant *Gavelinella beccariiformis* and *Nuttallides truempyi* often indicates fairly oxic surroundings. Later study by Widmark (2000) also supports the idea of preference of *E. subsculptura* through those bathyal settings with large organic-carbon fluxes. It is also stated that as being distant from the hypothetical upwelling site forecasted by Parrish and Curtis (1982), the abundance of *E. subsculptura* decreases.

The ecomarker species *Sliteria varsoviensis*, is mentioned to be well adapted to Maastrichtian upwelling belts holding an opportunistic mode where somewhat high food flux in mesotrophic environment (Widmark and Speijer, 1997a). The Maastrichtian *Praebulimina* species are linked with high organic flux and low oxic conditions at the bottom (Friedrich and Hemleben, 2007). *Heterostomella* spp. and *Sitella* spp. are also indicators of the environments with high organic matter flux (Speijer, 1994).

In the Maastrichtian section, presence of all morphogroups together may indicate mesotrophic conditions (Setoyama et al., 2017 and references therein). Besides, the much relative abundances of infaunal taxa (average 75% for whole Maastrichtian) including bi–tri serial taxa such as *Bulimina strobila, Eouvigerina subsculptura, Heterostomella* spp., *Praebulimina reussi, Sitella* spp. and *Verneuilina* as well as trochospiral form *Sliteria varsovienses,* may suggest a high food flux for this section, which make the environment far away from oligotrophic conditions and possibly closing eutrophic conditions, for more particularly through the upper parts of the Maastrichtian just below the K-Pg boundary. However, there is no clear distinction could have been made between mesotrophic and eutrophic environment due to the unpredicted oxygen levels.

In the Danian section, on the other hand, the assemblage is outnumbered by epifaunal taxa which constitutes average of 75.8% of tha total assemblage. This section includes mainly trochospiral forms including mostly *Alabamina wilcoxensis*, *Anomalinoides acutus*, *Anomalinoides rubiginosus*, *Cibicides* sp.1, *Cibicidoides pseudoacutus*, *Cibicidoides* spp., *Gyroidinoides* spp. *Lenticulina* spp., *Pulsihponina prima*, and *Osangularia* spp.. The change in the assemblage structure from abundant infaunal to abundant epifaunal association, suggests a lowered food flux to benthic foraminifera in the Danian when compared to the Maastrichtian for the studied interval. This shift is considered as a result of sudden decline in the primary productivity right at the K-Pg boundary and consequent interruption in the organic carbon flux (Culver, 2003).

# CHAPTER 5

# SYSTEMATIC PALEONTOLOGY

Taxonomical identification of small benthic foraminifera genera and species were mainly based on the external morphological features. Taxonomical study was carried out by using wall composition and structure, coiling type (chamber arrangement), number of chambers in the last coil, shape of test, primary aperture, and shape of apertural face, surface ornamentations, characteristic of sutures on both spiral and umbilical sides. To gain better understanding about the morphology of benthic foraminifera, the glossary of Hottinger (2006) was utilized.

In search of original definitions of the species Ellis and Messina (1940) foraminiferal catalog was broadly studied. Moreover, Cushman (1946), Berggren and Aubert (1975), Van Morkhoven et al. (1986), Kaminski et al. (1988), Gawor-Biedowa (1992), Bolli et al. (1994), Speijer (1994), Alegret and Thomas (2001) and Widmark (1997) were used for more detailed descriptions of Tethyan and cosmopolitan forms. Additional publications were also reviewed for some taxa. Loeblich and Tappan (1988) was followed for suprageneric and generic classifications. 3 suborders, 23 superfamily, 32 subfamily, 71 genus and 82 species were identified in this study.

This chapter is not dealing with the literature revision of the benthic foraminifera species, only their brief taxonomic descriptions and distinguishing features were given for specific and generic level. Variability of the species were also remarked whenever possible. Due to the preservation and complex taxonomy of deep-water benthic foraminifera, some affiliations were needed to be used for the assignment of the species. The affiliation “spp.” was used for more than one different populations and “sp.” for one population grouped under a genus. Besides, “aff.” was put after the genus name for a specific taxon, when some morphological features of the convenient species were not clearly observed. Bolli et al. (1994) revealed the Early Cretaceous-Middle Miocene deep-water benthic foraminifera stratigraphy stressing the need for the taxonomical revisions of many benthic foraminifera groups. Moreover, Widmark (1997) assumed that there was an overabundance of the Upper Cretaceous benthic foraminifera species in the literature.

Plates were designed for illustration of the identified benthic foraminifera taxa. The micrographs introducing the images of scanning electron and light microscope as well as transmitted light images are given in Appendix A. The systematic classification of identified taxa is given in alphabetical order as follows:

### Phylum PROTOZOA

### Order FORAMINIFERIDA Eichwald, 1830

### Suborder LAGENINA Delage and Herouard, 1896

### Superfamily NODOSARIACEA Ehrenberg, 1838

### Family ELLIPSOLAGENIDAE A. Silvestri, 1923

### Subfamily OOLININAE Loeblich and Tappan, 1961

### Genus *Oolina* d'Orbigny, 1839

*Oolina* is unilocular. Its test shape is spherical or oval. The lowest part of test may be pointed. Test surface may be smooth or decorated with thin elongate striations. It has terminal and rounded aperture developed on more or less pronounced neck.

### *Oolina* sp.1

Plate 2, Fig. 5

**Diagnostic features & Remarks:**

Shape of this form is somewhat elongated, not completely globular. Test is decorated with fine longitudinal striations. Aperture is terminal, circular, located on the slightly developed neck.

**Occurrence:**

UH-37, UKHB-10

## Family LAGENIDAE Reuss, 1862

## Genus *Lagena* Walkerand Jacob, 1798

Test is unilocular, its shape may be globular or ellipsoidal. Wall is calcareous, and surface may be decorated by striae or more thick costae. Aperture is terminal, developed on a distinct neck.

### *Lagena globosa* (Montagu, 1941)

Plate 1, Fig. 12

1953 *Lagena globosa* (Montagu). LeRoy, pl. 8, fig. 15

**Diagnostic features & Remarks:**

Shape of test is almost spherical. Surface is smooth. Aperture is at the end of the shortly developed neck.

**Stratigraphic distribution in the literature:**

Late Cretaceous and Early Tertiary (LeRoy, 1953)

**Occurrence:**

UH-35, UH-41, UKHB-10

### *Lagena* cf. *sulcata* (Walker and Jacob, 1978)

Plate 1, Fig. 11

1988 *Lagena sulcata* (Walker and Jacob). Keller, p. 160, pl. 4, figs. 11-12

1997 *Lagena* cf. *sulcata* (Walker and Jacob). Widmark, p. 28, fig. 11h

**Diagnostic features & Remarks:**

Unilocular test is pointed at both extremities and mostly globular in outline. Test is decorated by many longitudinal costae. Aperture is produced on a slim neck.

Hermelin and Malmgren (1980) published a biometric study on the Latest Maastrichtian *Lagena sulcata*. Their study revealed that the dissimilarities of costate *Lagena* in different stratigraphic levels, which were most probably resulted from its ecological variation. Taxonomic revision of *Lagena* was also suggested in that study. Widmark (1997) referred their work and used “cf.” for costate *Lagena* forms. Therefore, this taxon is allocated under *Lagena* “cf.” *sulcata* in this study following Widmark (1997).

**Stratigraphic distribution in the literature:**

Maastrichtian-Danian in the South Atlantic (Widmark, 1997).

**Occurrence:**

UH-36, UH-37 UH-42, UH-43, UH-47, UH-48, UH-49, UKHB-10

### *Lagena* sp. 1

Plate 1, Fig. 13

**Diagnostic features & Remarks:**

This form is distinguished from *Lagena* cf. *sulcata* by its elongated test and neck. All other features are similar to that species.

**Occurrence:**

UH-34, UH-38

## Family NODOSARIIDAE Ehrenberg, 1838

## Subfamily NODOSARIINAE Ehrenberg, 1838

## Genus *Laevidentalina* Loeblich and Tappan, 1986

Test is uniserial, elongate and arcuate. Sutures may be horizontal to more or less oblique. Wall is calcareous, very slightly perforated with secondary lamination. Test surface is smooth, not ornamented. Aperture is terminal developed by radiating slits.

### *Laevidentalina constricta* (Franke, 1928)

Plate 1, Fig. 6

1941 *Dentalina cylindracea* (Reuss). Marie, pl. 12, fig. 135

1994 *Glandulina* (?) *cylindracea constricta* (Franke). Bolli et al., p. 201, figs. 34.17

2000 *Laevidentalina constricta* (Franke). Frenzel, p. 62, fig. 26.a-b

**Diagnostic features & Remarks:**

Shape of test and chambers are elongated and slightly arcuate. The first chamber is kind of acuminated at the base, but not very sharpened. Its height is twice as its width. Test is constricted in the middle part between two chambers.

Variabilities of this species in the studied samples are the length of chambers, the degree of constriction in the middle part between two chambers and the degree of sharpening of the initial tip. *Laevidentalina constricta* has only two chambers in the studied specimens.

**Stratigraphic distribution in the literature:**

Turonian-Maastrichtian (Frenzel, 2000), Late Maastrichtian-Early Eocene (Bolli et al., 1994)

**Occurrence:**

UH-36, UH-38, UH-43, UKHB-10

### *Laevidentalina monile* (Von Hagenow, 1842)

Plate 1, Fig. 7

2000 *Laevidentalina monile*. Frenzel, pl. 11, fig. 3

**Diagnostic features & Remarks:**

*Laevidentalina monile* has smooth wall and is consisting of uniserial two chambers which nearly spherical in shape. Test is elongate and slightly arcuate. Initial part of the test is rounded. Sutures between chambers are deeply incised.

**Stratigraphic distribution in the literature:**

Late Turonian-Maastrichtian (Frenzel, 2000)

**Occurrence:**

UH-37, UH-41, UH-48

*Laevidentalina* ? sp. 1

Plate 1, Fig. 9

**Diagnostic features & Remarks**:

This taxon has elongated test and uniserial chambers. Its generic affiliation was remained uncertain, because the specimens belong to this taxon were found as broken in the studied samples. Therefore, it was not possible to understand whether the test is arcuate or rectilinear as well as not possible to identify apertural features. Additionally, this taxon is very similar to the specimen illustrated by Kaiho (1992) as *Nodosaria longiscata*.

**Occurrence:**

UH-33, UH-35, UH-38, UH-39, UH-41, UH-42, UH-45, UH-46, UH-47, UH-48, UKHB-4, UKHB-6, UKHB-9, UKHB-10

### Genus *Pseudonodosaria* Boomgaart, 1949

Cylindrical, rounded test is elongated in the growth axis and somewhat conical. Initial chambers are embracing and expanding as added. Sutures are flush and horizontal. Aperture is terminal and radiate.

### *Pseudonodosaria manifesta* (Reuss, 1851)

Plate 2, Fig. 6

1975 *Pseudoglandulina manifesta* (Reuss). Berggren and Aubert. p. 173, pl. 12, fig. 10

2000 *Pseudonodosaria manifesta.* Frenzel, pl. 20, fig.9

**Diagnostic features & Remarks:**

Test is circular in transverse section. Early chambers are less inflated and more overlapping than the later ones. Sutures between later chambers are more incised. Terminal aperture is consisting of radiating slits.

**Stratigraphic distribution in the literature:**

Santonian-Maastrichtian (Frenzel, 2000), Late Cretaceous (Cushman, 1946)

**Occurrence:**

UH-40, UH-42, UH-48, UH-49

## Genus *Pyramidulina* Fornasini, 1894

*Pyramidulina* has rectilinear, uniserial test. Test surface is decorated by longitudinal ridges. Aperture is developed at the end of short neck.

### *Pyramidulina* spp.

Plate 2 Fig. 7, Plate 3 Fig. 1

**Diagnostic features & Remarks:**

Rectilinear uniserial tests with various chamber shapes and ornamented by longitudinal costae with various thicknesses are grouped under this taxon.

Tests were mostly recorded as broken specimens.

**Occurrence:**

UH-34, UH-38, UH-42, UH-43, UH-46, UH-48, UH-49, UKHB-5, UKHB-6, UKHB-7, UKHB-10

### Subfamily FRONDICULARIINAE Reuss, 1860

### Genus *Frondicularia* Defrance, 1826

Palmate to lanceolate test is flattened with considerably arched chambers. Wall is calcareous. Aperture is terminal and radiate.

*Frondicularia* spp.

Plate 1, Fig. 1

**Diagnostic features** & **Remarks**:

Flattened tests with inverted "V" shaped (chevron shaped) chambers are included in this group. Some tests have very fine striations.

This taxon was rarely recorded in the studied material. Tests were usually found as broken specimens.

**Occurrence:**

UH-36, UH-43, UKHB-4

### Family POLYMORPHINIDAE d'Orbigny, 1839

### Subfamily POLYMORPHININAE d'Orbigny, 1839

### Genus *Globulina* d'Orbigny, 1839

Test is spherical or oval in shape. Chambers are added in five planes in early stage, later diminished to three planes. Aperture is terminal, radiate. It may be covered by fistulose development of radiating tubes which have open ends.

#### *Globulina prisca* (Reuss, 1862)

Plate 1, Fig. 2

1992 *Globulina prisca* (Reuss). Gawor-Biedowa, pl.8, fig. 8

1994 *Globulina* cf. *prisca* (Reuss). Bolli, p. 199, fig. 33.8-9

**Diagnostic features & Remarks**:

This species has fistulose aperture. Due to the preservation, chamber arrangement of this forms is not always examined clearly. This species has variability in degree of sharpening of basal portion of test, that of elongation of the test and density of tubular projections.

**Stratigraphic distribution in the literature:**

Early Maastrichtian – Early Eocene (Bolli, 1994).

**Occurrence:**

UKHB-10

### Genus *Guttulina* d'Orbigny, 1839

Inflated chambers arranges in five planes with strongly overlapping previous whorls. Aperture is terminal and radiate.

#### *Guttulina trigonula* (Reuss)

Plate 1, Figs. 3-4

1946 *Guttulina trigonula* (Reuss). Cushman, pl. 40, figs. 6

1992 *Guttulina trigonula* (Reuss). Gawor-Biedowa, pl. 8, fig.7

1994 *Guttulina trigonula* (Reuss). Bolli et al., p. 199, fig. 33.10-12

**Diagnostic features& Remarks**:

*Guttulina trigonula* has a rounded test with quinqueloculine chamber arrangement. Test is truncated at the base.

The studied specimens have somewhat dull wall texture. Convexity of chambers, test size and the degree of elongation of the test are included in the variability of this species.

**Stratigraphic distribution in the literature:**

Campanian (*Globotruncana stuarti* Zone) – Early Eocene (*Globorotalia subbotinae* Zone) (Bolli et al., 1994).

**Occurrence:**

UH-33, UH-35, UH-36, UH-41, UKHB-8, UKHB-10

### Genus *Pyrulina* Marie, 1941

Fusiform test is elongated and rounded in transverse section with terminal and radiated aperture. Base of test is rounded to weakly pointed. Chambers are overlapping and arranged in 120° planes aside as a first phase, later becoming biserial.

*Pyrulina* sp.

Plate 3, Fig. 2

**Diagnostic features & Remarks:**

Small, fusiform tests with radial aperture are grouped under this taxon. In well preserved specimens polymorphinid chamber arrangement is seen, but most of the specimens were poorly preserved.

**Occurrence:**

UH-36, UH-49, UKHB-10

### Subfamily RAMULININAE Brady, 1884

### Genus *Ramulina* Jones, 1875

Spherical or irregular chambers are roughly joined each other by straight or branching tubes. Wall is calcareous. Test surface may be smooth or hispid. Apertures are developed at the end of open tubes.

### *Ramulina* sp. 1

Plate 3, Figs. 3, 4

**Diagnostic features & Remarks:**

This species has almost spherical test with hispid surface. Tests were commonly found as fragmented specimens.

**Occurrence:**

UH-37, UH-42, UH-50, UKHB-4, UKHB-7, UKHB-8, UKHB-9, UKHB-10

### *Ramulina* sp. 2

Plate 3, Fig. 5

**Diagnostic features & Remarks:**

This species is distinguished from *Ramulina* sp. 1 by many branching tubes and relatively smooth surface of test. Tests were commonly found as fragmented specimens.

**Occurrence:**

UH-45, UH-48

## Family VAGINULINIDAE Reuss, 1860

## Subfamily LENTICULININAE Chapman, Parr, and Collins, 1934

### Genus *Lenticulina* Lamarck, 1804

Chamber arrangement is panispiral, infrequently some species may be weakly trochospiral or asymmetrical. Chambers are gradually increasing in size as added. Last chambers may tend to uncoiling. Wall is calcareous and perforated. Aperture is developed at the peripheral angle. It may be radiate or slitlike, or very slightly produced.

### *Lenticulina* sp. 1

Plate 2, Fig. 1

**Diagnostic features & Remarks:**

Test is involute, planispiral and biumbonate. Shape of test is quite circular in side view. Final whorl is consisting of about seven chambers. Aperture is mostly invisible.

**Occurrence:**

Throughout the Maastrichtian and Danian section, except for UH-34, UH-35, UH-43

### *Lenticulina* sp. 2

Plate 2, Fig. 2

**Diagnostic features & Remarks:**

This form is distinguished by other *Lenticulina* species by its distinct acute angle, more or less developed keel? like structure. Chambers are also more curved and more in number. Aperture is usually invisible.

**Occurrence:**

UH-33, UH-35, UH-38, UH-39, UH-44, UKHB-10

### Genus *Marginulinopsis* A. Silvestri, 1904

Early small and compact planispiral stage is followed by uncoiled part with straight and depressed sutures. Chambers are inflated. Wall is calcareous. Surface may be decorated by longitudinal ridges. Aperture is terminal and developed at the dorsal angle.

*Marginulopsis multicostata* (Lipnik, 1961)

Plate 2, Fig. 3

1994 *Marginulopsis multicostata* (Lipnik). Bolli et al, figs. 29.30-31

**Diagnostic features & Remarks:**

This species has inflated, uncoiled last chambers. Test is decorated with many longitudinal costae.

Bolli et al. (1994) mentioned a variety of Cretaceous species belonging to *Marginulopsis.* Among these noticed species only *Marginulinopsis curvisepta*, *Marginulinopsis multicostata* and *Marginulinopsis praetschoppi* possess test surfaces ornamented by elongated ridges (Aly, 2016). In the illustrated specimens of Bolli et al. (1994), the costae ornamentations of *Marginulinopsis curvisepta* and *Marginulinopsis praetschoppi* are more thicker and sparse than that of *Marginulinopsis multicostata.* Moreover, *Marginulinopsis praetschoppi* seems to be more flattened in the side view when compared other two.

Our studied specimens are assigned to *Marginulopsis multicostata*, since the ornamentations are thinner and denser and very resemble to the specimen illustrated in Bolli et al. (1994).

**Stratigraphic distribution in the literature:**

Campanian (*Globotruncana stuarti* Zone) (Bolli et al., 1994)

**Occurrence:**

UH-47

### Genus *Saracenaria* Defrance, 1824

Planispiral portion is followed by flaring and nearly rectilinear stage. Apertural face is typically wide, carinate on this is common. Aperture is radiate at the dorsal side of the periphery.

### *Saracenaria* sp.

Plate 3, Fig. 6

**Diagnostic features & Remarks:**

All forms with planispiral early part, with later flaring chambers with very broad apertural face are allocated in this taxa. Most of the specimens have triangular in shape when looked from the top-apertural view.

**Occurrence:**

UH-33, UH-39, UH-41, UH-45, UH-49, UKHB-6, UKHB-7, UKHB-9, UKHB-10

## Subfamily MARGINULININAE Wedekind, 1937

### Genus *Vaginulinopsis* Silvestri, 1904

Very small involute coiled early part is followed by uncoiled and rectilinear series. Test may be laterally compressed. Sutures are horizontal, straight and might be more or less incised in the uncoiled phase. Test surface is unornamented. Aperture is developed at the dorsal angle, terminal.

*Vaginulinopsis* ? sp.

Plate 3, Fig. 7

**Diagnostic features & Remarks:**

The tests with almost invisible initial coiled part and following uncoiled portion. Sutures are nearly horizontal and slightly depressed in this stage. Tests were recovered mostly as broken specimens.

**Occurrence:**

UKHB-5, UKHB-7, UKHB-8, UKHB-9

### Subfamily PALMULINAE Saidova, 1981

### Genus *Neoflabellinela* Bartenstein, 1948

Test is big, palmate and flattened. Test margin is truncated and may possess keel. Chambers are arranged planispiral in initial part, then flaring turning into uniserial.

*Neoflabellinela jarvisi* (Cushman 1935)

Plate 2, Fig. 4

1986 *Neoflabellinela jarvisi* (Cushman). Van Morkhoven, fig.30.18-19,25

**Diagnostic features & Remarks:**

This species is characterized by single or more semicircular loops at the top-pointed ends of straight and steep sutures, and papillae test surface between the sutures. Test shape is almost rhomboidal to ovoid. Some individuals have more curved test sides, while others have more parallel developed sides. Test size is variable.

**Stratigraphic distribution in the literature:**

Late Cretaceous (Maastrichtian) - Late Paleocene (P5) (Van Morkhoven et al., 1986), Paleocene (Bolli et al., 1994)

**Occurrence:**

UH-34, UH-35, UH-43, UH-47

### Suborder ROTALIlNA Delage and Herouard, 1896

### Superfamily ASTERIGERINACEA d'Orbigny, 1839

### Family EPISTOMARIIDAE Hofker, 1954

### Subfamily NUTTALLIDINAE Saidova, 1981

### Genus *Nuttallinella* Belford, 1959

Trochospiral test has two or three coils with narrow chambers and oblique sutures on spiral side; nearly radial, straight or curved sutures on umbilical side. Test periphery is possessing a broad keel. Wall is calcareous. Aperture is interiomarginal and elongate opening.

*Nuttallinella* spp.

Plate 4, Figs. 1, 2

**Diagnostic features & Remarks:**

This taxon is characterized by its thickened spiral and intercamaral sutures and its distinct well developed keel. Umbilicus was remained open. The convexity of spiral and umbilical sides are varying among the group.

**Occurrence:**

UH-38, UH-39, UH-41, UH-42, UH-43, UH-46, UH-47, UH-48, UH-49

## Superfamily BOLIVINACEA Glaessner, 1937

## Family BOLIVINIDAE Glaessner, 1937

### Genus *Bolivina* d'Orbigny, 1839

Biserial elongate test oval or rhomboidal in shape and relatively compressed. Chambers are elongated and long. Sutures are flush to little incised. Aperture a small loop shaped with thickened one margin.

#### *Bolivina decurrens* (Ehrenberg, 1854)

Plate 4, Figs. 3, 4

2012 *Bolivina decurrens* (Ehrenberg). Dubicka and Peryt, p. 277, fig.4A-C

**Diagnostic features & Remarks:**

*Bolivina decurrens* is distinguished by spines at the ends of the broad and low chambers, giving an impression of ragged test margin and almost rhomboidal test shape. Chambers are bent downward direction.

**Stratigraphic distribution in the literature:**

Late Campanian-Maastrichtian (Gawor-Biedowa, 1992)

**Occurrence:**

UH-34, UH-42

### *Bolivina incrassata* (Reuss 1851)

Plate 4, Figs. 5, 6

1986 *Coryphostoma incrassata* (Reuss). Van Morkhoven et al., p. 383, pl. 126

1992 *Bolivina crassa* (Reuss). Gawor-Biedowa, pl. 19, figs. 1a-b, 2a-b, 3a-b

1997 *Brizalina incrassata*. (Reuss). Widmark, p. 33, fig.13.C-D

2000 *Bolivina incrassata* (Reuss 1851). Frenzel, pl.23, figs. 5-9.

**Diagnostic features & Remarks:**

Test is usually opaque and compressed to some extent. Chambers are numerous and fairly inflated. Sutures are oblique and locally thickened.

Gawor-Biedowa (1992) examined three different generations of this species, two of which are megalosperic and one of which is micropsheric. The first one of the megalosperic generation is consisting of usually ten chamber pairs, with long and slim test shape. The other megalospheric generation is short and having wider test shape includig nearly seven chamber pairs. The tests of microspheric generations, on the other hand, have smaller and more pointed initial extremity and more expanding test shape with relatively more chamber pairs when compared to megalospheric generations, which is approximately thirteen chamber pairs.

Number of chambers, amount of enlargement of test with respect to growth axis and degree of protrusion of sutures are included in variability of this species, in the studied materials. Moreover, fine striations on test surface which is one characteristic of this species, are not observed in the studied specimens, most probably due to the recrystallization.

**Stratigraphic distribution in the literature:**

Late Cretaceous (late Campanian-late Maastrichtian) (Van Morkhoven, 1986)

**Occurrence**:

UH-33, UH-34, UH-35, UH-36, UH-37, UH-38, UH-41, UH-43, UH-44, UH-45

## Family BOLIVINOIDIDAE Loeblich and Tappan, 1984

### Genus *Bolivinoides* Cushman, 1927

Test is biserial, rhomboidal, somewhat expanding against apertural end. Test is laterally compressed. In transverse section, it seems as lenticular. Chambers are elongated. Test surface may be smooth or ornamented with tubercles or costae. Aperture is areal and elongate, with internal tootplate.

### *Bolivinoides decoratus* (Jones, 1886)

Plate 4, Fig. 7

1994 *Bolivinoides decoratus* (Jones). Speijer, p. 61, pl. 9, fig. 2.

2016 *Bolivinoides decoratus* (Jones). Dubicka and Peryt, p. 81, figs 4.1-4.4.

**Diagnostic features & Remarks:**

Test is small and rhomboidal. In transverse section, it is oval-shaped and compressed. On chamber surfaces, there are four to five protrusions, joining into irregular costae.

**Stratigraphic distribution in the literature:**

Campanian – Maastrichtian (Dubicka and Peryt, 2016), Late Maastrichtian – Early Paleocene (Speijer, 1994)

**Occurrence:**

Throughout Danian section except for UKHB-5

### *Bolivinoides draco* (Marsson 1878)

Plate 4, Fig. 8

1878 *Bolivina draco* (Marsson) p. 157, pl. 3, fig. 25a-d.

1970 *Bolivinoides draco* (Marsson). Barr, pl. 99, figs.2a-b, 3a-b

1986 *Bolivinoides draco* (Marsson). Van Morkhoven et al., p. 379, pl. 124, figs. 2 a-b.

1992 *Bolivinoides draco* (Marsson). Gawor-Biedowa, pl. 20, fig. 8.

1997- *Bolivinoides draco* (Marsson). Widmark, p. 33, fig.13.F

2002 *Bolivinoides draco draco* (Marsson). Reich and Frenzel (2002) p. 115, pl. 10, fig.6

2006 *Bolivinoides draco draco* (Marsson). El-Nady, pl. 1, figs. 12-14

2016 *Bolivinoides draco* (Marsson). Dubicka and Peryt, p. 84, figs 6.6-6.10.

2016 *Bolivinoides draco* (Marsson). Machalski et al., p. 219, fig. 10. B

**Diagnostic features & Remarks:**

Test is biserial and rhomboidal in outline. Test margin is acute. There are two characteristic central longitudinal ribs on test surface as ornamentation. Apertural end of the test is smooth, unornamented.

**Stratigraphic distribution in the literature:**

Regarded as excellent index fossil for the Maastrichtian in North Africa, Australia, North and South America, Middle East and Europe (Barr, 1970).

Late Maastrichtian (Dubicka and Peryt, 2016).

**Occurrence:**

Throughout Maastrichtian section except for UH-37, UH-43, UH44, UH-45, UH-48, UH-49

## Family BOLIVINIDAE Glaessner, 1937

### Genus *Loxostomoides* Reiss, 1957

Test is elongate and biserial. Chambers are becoming higher as added. Wall is calcareous and finely perforated. Test surface is smooth and may be finely costate. Aperture is interiomarginal in early stage, later it becomes terminal and slit with lip.

*Loxostomoides applini* (Plummer 1926)

Plate 5, Figs. 1, 2

1926 *Bolivina applini* Plummer. p. 69, pl. 4, fig.1

1994 *Loxostomoides applinae* (Plummer). Bolli et al., p. 201, fig. 34.26-27

1994 *Loxostomoides applini* (Plummer). Speijer, p. 51, pl. 4, fig.3.

2006 *Loxostomoides applini* (Plummer). Ortiz and Thomas, p. 141, pl. 9, fig. 3.

2014 *Loxostomum applinae* (Plummer). Orabi and Khalil, supplementary pl. 1., fig 12

**Diagnostic features & Remarks:**

This species is characterized by fine longitudinal striations ornamenting the earlier part of the test and the crenulated base of the latter chambers. Test is also very slender, elongate, and oval in transverse section.

**Stratigraphic distribution in the literature:**

Index species for Paleocene (Van Morkhoven et al., 1986)

**Occurrence:**

UKHB-4, UKHB-6, UKHB-7, UKHB-8, UKHB-10

### Genus *Tappanina* Montanaro Gallitelli, 1955

This genus is small, slightly rotated around axis of coiling and possessing carinated angles and flattened sides. In transverse section, test is rhomboidal to quadrangular. Aperture is interiomarginal basal with a slight indentation.

#### *Tappanina selmensis* (Cushman, 1933)

Plate 5, Figs. 3, 4

1946 *Bolivinita selmensis* (Cushman). Cushman, pl. 49, fig. 1-2

1946 *Bolivinita costifera* (Cushman). Cushman, pl. 49, fig. 3

1986 *Tappanina selmensis* (Cushman). Van Morkoven, p. 333, pl. 108

1994 *Tappanina selmensis* (Cushman). Speijer, p. 57, pl. 7, fig. 2

**Diagnostic features & Remarks:**

This species is characterized by its small test and concave chambers on which there are lateral carina along sutures presenting s characteristic zig-zag display at the test periphery. In apertural view, test is rhomboidal or rectangular.

*Tapannina selmensis* is distinguished from *Eouvigerina subsculptura* by its small test and the absence of apertural neck.

This species is recorded only in 63 µm-125 µm fraction, due to its small test.

**Stratigraphic distribution in the literature:**

Middle Paleocene (*Globorotalia angulata* Zone) – Early Eocene (*Globorotalia subbotina* Zone) (Bolli et al., 1994)

**Occurrence**:

Throughout the studied section.

### Superfamily BULIMINACEA Jones, 1875

### Family BULIMINIDAE Jones, 1875

### Genus *Bulimina* d'Orbigny, 1826

Test is elongate and triserial. Last chambers may have a tendency to uniserial arrangement. Wall is calcareous, perforate and smooth. Lower margins of chambers may be ornamented. Aperture is typical looped-shaped.

*Bulimina arkadelphiana* Cushman and Parker var. *midwayensis*

(Cushman and Parker, 1936)

Plate 5, Fig. 5

1994 Bulimina midwayensis (Cushman and Parker). Bolli et al., p. 205, figs. 36.19 - 21

1997 Bulimina arkadelphiana midwayensis (Cushman and Parker). Ayyad et al., p. 154, fig.9-d.

**Diagnostic features & Remarks:**

Test is ornamented by blunt projections on the lower part of the chambers, but the last chambers are smooth, unormamented. They are relatively more inflated.

Some specimens have a basal spine, whereas some have not. Additionally, test size is varying among different specimens.

**Stratigraphic distribution in the literature:**

Campanian (*Globotruncana stuarti* Zone) – Late Paleocene (*Globorotalia pseudomenardii* Zone).

**Occurrence**:

UH-33, UH-34, UH-36, UH-41, UH-43, UH-46, UH-47, UH-49

### *Bulimina strobila* (Marie, 1941)

Plate 5, Figs. 6, 7, 8

1941 *Bulimina strobila* Marie. pl. 32, figs. 302a-d

1976 *Bulimina asperoculata* (Brotzen). Aubert and Berggren: p. 421, pI. 5, fig. 4

1988 *Bulimina farafraensis* (LeRoy). Keller, p. 159 pl. 3, figs. 13-14

1994 *Bulimina strobila* (Marie). Speijer, p. 57, pl. 7, fig. 3

**Diagnostic features & Remarks:**

*Bulimina strobila* has small test with rounded edges and concave sides. As growing, the test is becoming almost equally tripartite consisting of three equal lobes. On the test surface, characteristic longitudinal irregular ridges and grooves are beginning from the base, gradually fading upward and failing to reach to last three chambers. Test is stretched more at its base more than at the apertural end.

Some tests are twisted in the studied samples. Moreover, degree of sharpening of initial part is rather variable.

**Stratigraphic distribution in the literature:**

Late Maastrichtian – Early Paleocene (Speijer, 1994)

**Occurrence:**

From UH-33 to UH-50, UKHB-6, UKHB-8

## Family REUSSELLIDAE Cushman, 1933

### Genus *Reussella* Galloway, 1933

Triserial and triangular test have carinate margins. Sutures are bent. Wall is perforated. Aperture an elongate narrow opening, interiomarginal.

### *Reussella* ? sp. 1

Plate 5, Fig. 9

**Diagnostic features:**

Small, triserial test is pointed in the initial end. Angles are acute and ragged.

Aperture of this taxon seems like subterminal and little more widened opening rather than being slit. However, the other morphological features make it closer to *Reusella*. Therefore, generic assignment of this taxon remained uncertain.

**Occurrence:**

Throughout the Danian section, except for UKHB9

## Superfamily CASSIDULINACEA d'Orbigny, 1839

## Family CASSIDULINIDAE d'Orbigny, 1839

## Subfamily CASSIDULININAE d'Orbigny, 1839

## Genus *Globocassidulina* Voloshinova, 1960

Biserially enrolled test is globular or lenticular in shape. Angled and radial sutures are kind of depressed. Aperture may be elliptical opening or curved.

### *Globocassidulina* sp.

Plate 5, Fig. 10

**Diagnostic features & Remarks:**

Small, subspherical test with biserially enrolled chambers and depressed sutures observed from outside of the tests are allocated to this taxon. Test surface is not smooth, but somewhat roughened.

**Occurrence:**

UKHB-8, UKHB-9, UKHB-10

## Superfamily CHILOSTOMELLACEA Brady, 1881

### Family ALABAMINIDAE Hofker, 1951

### Genus *Alabamina* Toulmin, 1941

Test is trochospiral with spiral side evolute and umbilical side involute. Sutures may be depressed, oblique, smoothly curved or straight on spiral side. On umbilical side, they are radial. Umbilical area is closed. Wall is finely perforated. Indentation of apertural face is the major characteristic of this genus. This folding appears like a false secondary aperture, but there is indeed no opening into chamber lumen.

*Alabamina wilcoxensis* (Toulmin, 1941)

Plate 6, Figs. 1, 2, 3

1994 *Alabamina wilcoxensis* (Toulmin). Speijer, p. 61, pl. 9, fig. 7

1988 *Alabamina midwayensis* (Brotzen). Keller, p. 158, pI. 2, figs. 5-7

2001 *Alabamina wilcoxensis* (Toulmin). Alegret and Thomas, p. 293, pl. 1, fig. 3a-c

**Diagnostic features & Remarks:**

The most characteristic feature of this species are planoconvex test with apparently more convex umbilical side with an acute periphery. The last whorl is consisting of usually five to six chambers. Sutures on spiral side are weakly depressed, while sutures on umbilical side are radial.

Some studied specimens have slightly convex spiral side. This species are differentiated from *Gyroidinoides* species by characteristic apertural indentation. Apertural indentation is another distinguishing parameter of typical *Alabamina wilcoxensis.*

**Stratigraphic distribution in the literature:**

Early Eocene (Globorotalia subbotinae Zone) (Bolli et al., 1994)

**Occurrence:**

UH-38, UH-39, UH-42, UH-45, UH-49, and throughout Maastrichtian section.

### Family CHILOSTOMELLIDAE Brady, 1881

### Subfamily CHILOSTOMELLINAE Brady, 1881

### Genus *Allomorphina* Reuss, 1849

Trochospiral, involute test is oval in shape. The last coil has three chambers. Aperture is slit-like, interiomarginal with lip.

*Allomorphina* sp. 1

Plate 6, Figs. 5, 6

**Diagnostic features & Remarks**

Small test is characterized by nearly triangular test in spiral and umbilical view, open umbilicus, with more or less developed apertural lip. Sutures on the spiral side are depressed, on the umbilical side they are flush to slightly depressed.

**Occurrence:**

UH-33, UH-35, UH-37, UH-40, UH-42, UH-49

### Genus *Chilostomella* Reuss, 1849

This genus is planispiral, involute with firmly enveloping chambers. Ovoid test is rounded in transverse section. Aperture is slitlike opening, interiomarginal-equatorial.

*Chilostomella* sp.

Plate 8, Fig. 4

**Diagnostic features & Remarks:**

Small strongly involute test with smooth surface is attained to this taxon. Equatorial, interiomarginal aperture has an elevated one margin.

**Occurrence:**

UKHB-10

## Family GAVELINELLIDAE Hofker, 1956

## Subfamily GAVELINELLINAE Hofker, 1956

### Genus *Angulogavelinella* Hofker, 1957

Test is biconvex, lenticular and low trochospiral. Whorls include many chambers. Spiral side is evolute and umbilical side involute. Umbilicus is small. Test periphery is with carina which is poreless. Wall is calcareous. On spiral side, wall is perforated while it is nonperforated on umbilical side.

### *Angulogavelinella angustiumbilicata* (Weidich 1995)

Plate 6, Figs. 7, 8, 9, 10

1995 *Angulogavelinella angustiumbilicata* Weidich, fig. 10, pl.5 figs.1-4

**Diagnostic features & Remarks:**

Test is biconvex, lenticular, low trochospiral, circular. It has evolute spiral side and involute umbilical side. Sutures are on the spiral side distinct locally may be limbate. On the umbilical side, chambers are crescent shaped, sutures are little curved as well as limbate. Umbilicus is small and deep. There are irregularities around umbilicus. Periphery is acute and keeled. Wall is imperforated on spiral side, perforated on umbilical side.

The thickened sutures restricted to exclusively around umbilicus region is the most characteristic feature of *Angulogavelinella angustiumbilicata*, which makes it different from a similar form *Angulogavelinella bettenstaedti.* Sutures on this side also curved more pronounced than *A. bettenstaedti*.

Genus *Angulogavelinella* has bilamellar wall as stated by Weidich (1995).

**Stratigraphic distribution in the literature:**

The Latest Campanian – The Late Maastrichtian (Weidich, 1995)

**Occurrence:**

UH-33, UH-35, UH-38, UH-40, UH-41, UH-43, UH-44, UH-46, UH-48

### Genus *Gavelinella* Brotzen, 1942

Test is trochospiral biconvex with flattened sides. Spiral side is evolute while umbilical side is involute. Wall is calcareous and perforated. Aperture is interiomarginal, extending almost periphery to umbilicus with a thin lip. Umbilicus is partially obscured by umbilical flaps from chambers.

### *Gavelinella* aff. *monterelensis* (Marie, 1941)

Plate 8, Figs. 5, 6, 7

1992 *Gavelinella monterelensis* (Marie). Gawor-Biedowa, pl. 36, figs. 1-2

2000 *Brotzenella monterelensis* (Marie). Frenzel, pl. 43, figs. 3-6

2012 *Gavelinella monterelensis.* Dubicka and Peryt, p. 277, fig. 4.F.1-3

**Diagnostic features & Remarks:**

Relatively flattened test is big and robust. The final coil is consisting of many chambers up to thirteen. Spiral side of *Gavelinella* aff. *monterelensis* is strikely similar to *Anomalinoides acutus,* since both species have thickened, slightly curved sutures on the spiral side, distinct knob on this side and possessing many chambers in the final whorl. However, the first taxon has much more bigger and robust test. Umbilical features also differs in amount of the thickening of sutures through the umbilicus and also differs in pore sizes. *Anomalinoides acutus* has coarser pores scattered on the ventral side.

Characteristics of the sutures on spiral side are variable in the present literature. Some forms have thickened sutures (Frenzel, 2000), whereas some have flush even depressed sutures (Walaszczyk et al., 2016). Hence, "aff." was attributed for this taxon.

Amount and size of the central boss on spiral side and umbilical boss on umbilical side were included in the variability of this taxon in the studied material.

**Stratigraphic distribution in the literature:**

Campanian to Late Maastrichtian (Frenzel, 2000)

**Occurrence:**

UH-33, UH-34, UH-36, UH-38, UH-40, UH-41, UH-42, UH-45, UH-46, UH-47, UH-48

### *Gavelinella* sp. 1

Plate 8, Figs. 8, 9, 10

**Diagnostic features & Remarks:**

This taxon is distinguished by evolute to slight partially evolute spiral side and very thick, limbate, curved sutures on both side of the test. Test is perforated on both side, with distinctly dense and coarse perforations on the umbilical sides. Test margin is rounded to subacute. The final coil is comprising of about eleven chambers.

The coarse perforation exclusively on the one side of the test is common in the majority of Cretaceous *Gavelinella* species, as pointed by (Dubicka et al., 2015). In the studied specimens there are coarse perforations scattered on the umbilical side, and relatively sparse on the spiral side. Thickened and limbate sutures on both side of the test together with the other mentioned features, this taxon is allocated to *Gavelinella*.

**Occurrence:**

Throughout Maastrichtian section, except for UH-34, UH-35, UH-39, UH-43, UH-45

### Genus *Paralabamina* Hansen, 1970

Test is trochospiral, biconvex and nearly circular in outline. Umbilical side is somewhat more convex than spiral side. The last coil is consisting of near six chambers. Periphery may be rounded or subacute. Wall is calcareous, perforated. Perforations are somewhat more dense and big on spiral side, compared to perforations on umbilical side. Aperture is interiomarginal placed on umbilical side with thin lip. Umbilicus is not open.

### *Paralabamina* sp. 1

Plate 11, Figs. 1, 2, 3

**Diagnostic features & Remarks:**

This species has a hyaline acute keeled periphery which is very slightly lobate. Test is elevated in the central part on both side. On the spiral side, chambers are crescentic. The last coil has six to seven chambers.

*Paralabamina* sp. 1 has a closed umbilicus.

**Occurrence:**

UH-35-40, UH-42-45, UH-47-49

### *Paralabamina toulmini* Brotzen (1948))

Plate 10, Figs. 6, 7, 8

1948 *Eponides toulmini*. Brotzen (fide Ellis and Messina, 1940)

1992 *Paralabamina toulmini* (Brotzen). Gawor-Biedowa, pl. 32, figs. 4-6

**Diagnostic features & Remarks:**

*Paralabamina toulmini* has coarsely punctate spiral side with raised sutures which can be locally transparent on this side. Umbilical side is smooth. Sutures on this side are depressed. Test is biconvex with always more convex umbilical side. Test margin is acute. Chambers are increasing in size as added.

The studied materials are close to Poland specimens shown by Gawor-Biedowa (1992). The thickness of the sutures on the spiral side are variable. They become locally narrower. Most of the studied specimens have nearly flat spiral side.

**Stratigraphic distribution in the literature:**

Late Cretaceous-Early Eocene (Gawor-Biedowa, 1992)

**Occurrence**:

UH-50, UKHB-4, UKHB-5, UKHB-6, UKHB-8, UKHB-9, UKHB-10

### Subfamily GYROIDINOIDINAE Saidova, 1981

### Genus *Gyroidinoides* Brotzen, 1942

Test is planoconvex and trochospiral. Spiral side is flat and evolute, whereas umbilical side is convex and involute. Sutures are radial on umbilical side. Wall is calcareous, perforate and surface is smooth. Aperture is an interiomarginal slit which is extending from periphery to umbilicus.

*Gyroidinoides octocameratus* (Cushman and Hanna, 1927)

Plate 9, Figs. 1, 2, 3

1927 *Gyroidina soldanii* d'Orbigny *octocamerata* (Cushman and Hanna) (fide Ellis and Messina 1940)

1994 *Gyroidinoides octocameratus* (Cushman and Hanna). Speijer, p. 51, pl. 4, fig. 4

**Diagnostic features & Remarks:**

Sutures on flat spiral side are gently depressed and slightly oblique. Umbilical side is more convex with typical depressed umbilical area. Final whorl is comprising of eight chambers.

The studied specimens have rounded to subacute periphery and large apertural face.

**Stratigraphic distribution in the literature:**

Late Maastrichtian-Early Paleocene in El Kef (Speijer, 1994)

**Occurrence:**

Throughout the studied section, except for UH-40, UH-41, UH-42, UH-45, UH-46, UH-47, UH-50, UKHB-4

*Gyroidinoides* sp. 1

Plate 9, Figs. 4, 5, 6

**Diagnostic features & Remarks:**

Test is planoconvex with considerably convex umbilical side. Coils are narrow. In spiral and umbilical view test is nearly circular. Spiral sutures are flush in earlier ones, depressed in later. Apertural face is large.

**Occurrence**:

UH-36, UH-39, UKHB-5, UKHB-6, UKHB-7, UKHB-8, UKHB-9

### Genus *Sliteria* (Gawor-Biedowa 1992)

Test is low trochospiral. Spiral side is partially involute, and depressed in the middle. Near this depressed area, sutures are kind of elevated and ended with spines. Umbilical side is involute with umbilical flaps covering umbilicus. Periphery of test is rounded. Wall and septa are trilamellar. Aperture is interiomarginal with a thin lip.

*Sliteria varsoviensis* (Gawor-Biedowa, 1992)

Plate 11, Figs. 7, 8, 9, 10

1992 *Sliteria varsoviensis* (Gawor-Biedowa). pl. 33, figs. 9-13

1994 *Gavelinella m*artini (Sliter). Speijer, p. 64, pl. 2, fig. 1a-c

1997 *Sliteria varsovienis* (Gawor-Biedowa). Widmark and Speijer, p. 148, pl. 1, fig. 1-3

**Diagnostic features & Remarks:**

Test is small, low trochospiral. Spiral side is partially involute and characteristically concave in the middle part. This concavity is about one-third of whole test diameter. There are nod-like ornamentations (spines) on this side. Umbilical side is involute. Test periphery is broadly rounded. Chambers on umbilical side have flap-like extensions against small umbilicus. Apertural face is large, almost flat, trapezoidal. The last chamber apparently inclines towards spiral side, which is typical for *Sliteria varsoviensis*. Aperture is interiomarginal with narrow lip, a large slit which continues to umbilical side. Seven to eight chambers are visible on the umbilical side in well preserved specimens.

Gawor-Biedowa (1992) mentioned *Gyroidinoides quadratus martini* as very close species to *Sliteria varsovienis.* The latter species differs from the first in terms of having visible umbilical flaps, slightly smaller size and coarse pores near umbilicus on the ventral side. Additionally, *Gyroidinoides quadratus martini* has also somewhat flattened umbilical side.

In the studied specimens, the depressed central areas in the spiral sides were usually filled with the sediment, hence the nodose ornamentations were not usually seen clearly. Apertural flaps were noticeable. Size of test is variable.

**Stratigraphic distribution in the literature:**

Maastrichtian in Poland (Gawor-Biedowa, 1992)

**Occurrence:**

UH-33-40, UH-42, UH-43-49

### Genus *Stensioina* Brotzen, 1936

Test is trochospiral, planoconvex or inequally biconvex. Spiral side is flat and evolute with slowly expanding whorl. Sutures are limbate on this side, looking like networking irregular ridges.

*Stensioina excolata* (Cushman 1926)

Plate 12, Figs. 1, 2

1946 *Stensioina excolata* (Cushman). Cushman., pl. 66, fig 17a-c.

1994 *Stensioina excolata* (Cushman). Bolli et al., figs. 45.31-33

1986 *Stensioina excolata* (Cushman). Van Morkhoven et al., p. 381, pl. 125, figs. 1-3.

**Diagnostic features & Remarks:**

The irregular ornamentation created by thickened costae on the spiral side is the most distinctive feature of this species. Flat spiral side, limbate and raised sutures on the umbilical side are also characteristic features.

This species is an index fossil for the Late Cretaceous. (Van Morkhoven et al., 1986).

**Stratigraphic distribution in the literature:**

Late Cretaceous (Campanian to Maastrichtian). (Holbourn et al., 2013)

**Occurrence:**

UH-40, UH-42, UH-44, UH-45

### *Stensioina* ? aff. *S. beccariformis*

Plate 12, Figs. 3, 4

**Diagnostic features & Remarks:**

Rounded very low trochospiral test has lobate periphery. Sutures on the umbilical side are becoming thicker trough the umbilicus. Test is fairly perforated. Apertural face is large and somewhat rounded.

This taxon is lacking the typical thickened costae constructing an irregular sutures of genus *Stensioeina* on the spiral side. Moreover, some individuals included under this taxon had near partially evolute spiral side which makes this taxon close to *Anomalinoides*.

This taxon was close to *Stensioina beccariformis* based on its umbilical features. There are thread-like lines radiating from the umbilicus to some extent and small depressions between them. Moreover, it is possessing around nine chambers in the final whorl and very rounded periphery. However, it lacks the extensional growth covering the umbilicus which is one of the typical features of *Stensioina beccariformis.*

**Occurrence**:

UKHB-10

## Family HETEROLEPIDAE Gonzäles-Donoso, 1969

### Genus *Anomalinoides* Brotzen, 1942

Test is with low trochospiral coil. Spiral side is partially evolute, while umbilical side is involute. Wall is distinctly perforated, calcareous. Aperture is extraumbilical, basal slit which continue to periphery.

*Anomalinoides acutus* (Plummer 1926)

Plate 7, Figs. 1, 2, 3, 4

1926 *Anomalina ammonoides* (Reuss) var. *acuta* Plummer, p. 189, pl. 10, figs. 2a-c

2001 *Anomalinoides acutu*s (Plummer). Alegret and Thomas, p. 293, pl.1, fig. 9

**Diagnostic features & Remarks:**

The most characteristic features of this species are very compressed test, distinct knob and limbate thickened sutures on the spiral side. The final whorl consists of nearly fourteen, narrow and slightly curved chambers. Test is much perforated on the umbilical side when compared to spiral side. Test periphery is subacute. There is an irregular plug developed in the central part on on the spiral side.

**Stratigraphic distribution in the literature:**

Reported from Paleocene Midway Formation (Berggren and Aubert, 1975)

**Occurrence**:

Throughout the studied section, except for UH-43, UH-45, UH-49

### *Anomalinoides rubiginosus* (Cushman, 1926)

Plate 7, Figs. 9, 10, 11

1986 *Anomalinoides rubiginosus* (Cushman). Van Morkhoven, p. 367, pl. 119, fig. 1-2

1991 *Anomalinoides danicus* (Brotzen). Nomura, p.26, pl. 2, fig. 4 a-c

1992 *Gavelinella danica* (Brotzen). Gawor Biedowa, pl.35, fig. 11-13

2009 *Anomalinoides rubiginosus* (Cushman). Giusberti, p. 106, pl.1, fig. 1

**Diagnostic features & Remarks:**

This species is easily distinguished from other *Anomalinoides* species based on its characteristic coarsely pitted wall texture on both side of the test and irregular ornamentations on the umbilical side. The spiral side is kind of convex, whereas the umbilical side is concave. The final coil possesses around nine chambers. It has a distinct white, opaque, glossy wall texture.

Degree of ornamentation on the umbilical side and the angularity of the test periphery are variable in the studied material. Some specimens have slightly more angular periphery.

**Stratigraphic distribution in the literature:**

Late Cretaceous (Campanian) - Paleocene (Van Morkhoven, 1986)

**Occurrence:**

Throughout Danian section, except for UKHB-10

## *Anomalinoides welleri/affinis* group

Plate 7, Figs. 5, 6, 7, 8

1975 *Anomalinoides welleri* (Plummer). Aubert and Berggren, p. 164, pl. 5, figs. 3 a-c

1976 *Anomalinoides welleri* (Plummer). Aubert and Berggren, p. 463, pl. 9, figs. 5a-c

1994 *Anomalinoides welleri* (Plummer). Bolli et al., p. 221, fig.44.23-25

1994 *Anomalinoides affinis* (Hantken), Speijer, pl. 3, fig. 6

**Diagnostic features & Remarks:**

This taxon is distinguished from other *Anomalinoides* species by its coarsely perforated test and the periumbilical ridge produced by joining of sutures around the open umbilicus. Test is very low trochospiral coiled and flattened with subacute to somewhat rounded margin, partially evolute to evolute spiral side and involute umbilical side. Moreover, sutures are limbate but flush with the surface on both sides, sometimes locally more visible through umbilicus, except for the latter ones which is slightly depressed. Umbilicus is open.

Berggren and Aubert (1975) considered *Anomalinoides welleri* as conspecific to *Anomalina praespissiformis* of Cushman and Bermudez.

Salaj et al. (1976) described a similar form as *Anomalinoides affinis* from Paleocene Tunisia. He also regarded *A. welleri* identified by Berggren and Aubert (1975) as a conspecific form to his material.

Bolli et al. (1994) mentioned that this extensive in Late Cretaceous to Early Paleocene taxa had been assigned under various names such as *A. brotzeni* Said and Kenawy, *loweryi* Mallory, *praespissiformsi* Cushman and Bermudez, *pseudowelleri* Olsson and *regina* Martin.

Speijer (1994) reported very similar form as *A. affinis*, regarding *A. welleri* is a junior synonym.

Regarding this disagreements on this species in the literature, in this study this taxon was kept under the name of *Anomalinoides welleri/affinis* group.

**Stratigraphic distribution in the literature:**

Santonian (*Globotruncana fornicata* Zone) - Late Paleocene (*Globorotalia pseudomenardii* Zone) (Bolli et al., 1994)

**Occurrence:**

Throughout Maastrichtian section, except for UH-33, UH-40, UH-41, UH-42

*Anomalinoides* sp. 1

Plate 8, Figs. 1, 2, 3

**Diagnostic features & Remarks:**

This relatively small taxon is diagnosed based on its curved and limbate sutures on both side of the test very strongly embracing final whorl. Biumbilicate test angle has acute margin.

**Occurrence:**

Throughout Danian section, except for UKHB-5 and UKHB-9

## Family OSANGULARIIDAE Loeblich and Tappan, 1964

### Genus *Osangularia* Brotzen, 1940

Test is trochospiral, biumbonate, lenticular and carinated. Spiral side is evolute with slightly expanding coils. Sutures on this side are prominent, at an angle and bent. Umbilical side is involute, with depressed, curved and radial sutures. Wall is calcareous and slightly perforated. Test surface is smooth. *Osangularia* has areal aperture, which is oblique. Apertural face is folded. This indentation may give an impression of false interiomarginal aperture.

*Osangularia plummerae* (Brotzen, 1940)

Plate 10, Figs. 1, 2, 3, 4, 5

1940 *Osangularia plummerae* (Brotzen). p. 30, fig. 8 (Speijer, 1994)

1975 *Osangularia plummerae* (Brotzen). Berggren and Aubert, p. 161, pl. 3, figs.6 a-g

1992 *Osangularia plummerae* (Brotzen). p. 252, pl. 4, figs. 2a-c

1994 *Osangularia plummerae* (Brotzen). Speijer, p. 57, pl. 7, fig.5

**Diagnostic features & Remarks:**

Biconvex test with eight to nine chambers in the final whorl. Acute periphery with more or less developed flange can be observed in finely preserved specimens.

**Stratigraphic distribution in the literature:**

Paleocene (Berggren and Aubert, 1975)

**Occurrence:**

Throughout the studied section, except for UH-35, UH-42, UH-43, UH-45, UH-46, UH-47, UH-48, UH-49, UKGB 9

## Family ORIDORSALIDAE Loeblich and Tappan, 1984

### Genus *Oridorsalis* Andersen, 1961

Test is biconvex and low trochospiral made up of three gradually expanding coil. Spiral side is evolute, umbilical side is involute. Sutures are radial and depressed. Wall is calcareous and very finely perforated. Surface is smooth. Umbilicus is closed. Primary aperture is an interiomarginal opening beginning from approximately periphery continuing to near umbilicus. Secondary apertures, which characterize the genus, are positioned; on spiral side where spiral and intercemaral sutures are intersecting; on umbilical side around midway of sutures where they have curvature.

### *Oridorsalis*? sp. 1

Plate 9, Figs. 7, 8, 9, 10, 11

**Diagnostic features & Remarks:**

Test is small and biconvex. Coils are narrow. Chambers are gradually increasing in size as added. The ultimate whorl is consisting of seven and half chamber. Test surface is smooth and shiny in well preserved specimens. Aperture is located on the umbilical side, extending from almost periphery to near umbilicus, but not reaching the umbilicus.

Secondary apertures, if exist, are not observed in the studied specimens, though this may be resulted from recrystallization. Therefore, the generic level of this taxa remains uncertain.

The convexity of spiral side is changing among the specimens studied. Some has more convex spiral side, whereas others have nearly symmetrical biconvexity.

**Occurrence:**

UH-33, UH-34, UH-37, UH-38, UH-39, UH-42, UH-43, UH-45, UH-47

### Family QUADRIMORPHINIDAE Saidova, 1981

### Genus *Quadrimorphina* Finlay, 1939

Test is ovate, biconvex. Chambers are kind of elongated in last whorl. Chamber arrangement is low trochospiral. Test margin is rounded. Wall is calcareous, finely perforate. Test surface is smooth. Aperture is extraumbilical-interiomarginal, covered by big lip.

*Quadrimorphina allomorphinoides* (Reuss, 1860)

Plate 11, Figs. 4, 5, 6

1926 *Discorbis allomorphmoides* (Reuss). Cushman, pl. 21, figs. 5a-c

1983 *Quadrimorphina allomorphinoides* (Reuss). Dailey, p. 776, pl. 4, fig. 9

1997 *Quadrimorphina allomorphinoides* (Reuss). Widmark, p. 58, fig. 26 f-g

2001 *Quadrimorphina allomorphinoides* (Reuss). Alegret and Thomas, p. 311, pl. 10, fig. 7

2016 *Quadrimorphina allomorphinoides*. Alegret et al., p. 52, pl. 1, figs. 14-16

**Diagnostic features & Remarks:**

Biconvex, elliptical test has somewhat elongate, inflated final chamber. It covers quite half of the test length. Chambers are increasing in size as added. Periphery is broadly rounded. The last whorl is made up of about four chambers. Umbilicus is masked by distinct plate-like triangular extension.

**Stratigraphic distribution in the literature:**

Maastrichtian - Paleocene in Mexico (Alegret and Thomas, 2001)

**Occurrence:**

UH-34, UH-35, UH-36, UH-39, UH-40, UH-42, UH-43, UH-50, UKHB-9, UKHB-10

### Superfamily DISCORBINELLACEA Sigal, 1952

### Family PARRELLOIDIOAE Hofker, 1956

### Genus *Cibicides* de Montfort, 1808

Test is planoconvex and trochospiral. Spiral side is flat or concave, evolute. Sutures on this side may be thickened. Umbilical side is much convex and involute with depressed sutures. Wall is calcareous. Perforations of spiral side are coarser than that of umbilical side. Aperture is interiomarginal extending onto both umbilical and spiral side.

*Cibicides* sp. 1

Plate 12, Figs. 5, 6, 7

**Diagnostic features & Remarks:**

This species has a quite circular small test with evolute, flat to concave spiral side and involute, convex umbilical side. The final coil is consisting of around eleven chambers. It has an umbonal boss. Test is shiny on umbilical side, but relatively rough on spiral side.

**Occurrence:**

Throughout the Danian section.

*Cibicides* sp. 2

Plate 12, Figs. 8, 9, 10

**Diagnostic features & Remarks:**

Concavo-convex test is characterized with a prominent umbonal knob by which it is distinguished from *Cibicides* sp. 1. Moreover, test of *Cibicides* sp. 2 is more robust than that of *Cibicides* sp. 1.

**Occurrence:**

UH-35, UH-36, UH-38, UH-42, UH-43, UH-45, UH-46

## Genus *Cibicidoides* Thalmann, 1939

Test is biconvex, biumbonate and trochospiral. Sutures may be curved and thickened on spiral side. On umbilical side, they are radial and almost straight. Periphery may be subacute, acute and even carinate. Wall is perforated on spiral side while it is imperforate or very rarely perforated. Aperture is interiomarginal and equatorial.

### *Cibicidoides alleni* (Plummer, 1927)

Plate 13, Figs. 1, 2, 3

1975 *Cibicidoides alleni*. Berggren and Aubert, pl. 7, figs. 2-3

**Diagnostic features & Remarks:**

This species has biconvex test with distinct central calcite plug.

*Cibicidoides alleni* differs from *Cibicidoides* sp. 1 by its more developed central shell material and relatively more punctate spiral side.

**Stratigraphic distribution in the literature:**

Paleocene--Early Eocene (Berggren and Aubert, 1975)

**Occurrence:**

UH-35, UH-40, UH-41, UH-42

### *Cibicidoides pseudoacutus* (Nakkady, 1950)

Plate 13, Figs. 4, 5, 6

1950 *Anomalina pseudoacuta* Nakkady, pl. 90, figs. 29-32

1994 *Cibicidoides pseudoacutus* (Nakkady). Speijer, p. 57, pl. 7, fig. 6a-c

1988 *Anomalinoides acuta* (Plummer). Keller, p. 158, pl. 2, figs. 9, 10.

2001 *Cibicidoides pseudoacutus* (Nakkady). Alegret and Thomas, p. pl. figs.

2002 *Cibicidoides pseudoacutus* (Nakkady). Galeotti and Coccioni, p. 198, fig1.

**Diagnostic features & Remarks:**

The most characteristic feature of this species partially involute spiral side, secondary calcite plug in the middle of the test and depressed spiral suture on this side and sutures are thickening toward the spiral slit forming flap-like extensions. Moreover, perforations on the spiral side is coarser than that on the umbilical side.

*Cibicidoides pseudoacutus* has nearly equally biconvex test by which it differs from *Cibicidoides* sp.1 and *Cibicidoides* sp. 2. The latter two species have also biconvex test, however their umbilical side is always more convex. It resembles to *C. alleni* and *Cibicidoides* sp. 1 by possessing central calcite plug on the spiral side, but differs from both by having characteristic flaplike extension on this side. Central plug on the spiral side in *C. alleni* and *C. pseudoacutus* are more developed, protruding when compared to the central plug of *Cibicidoides* sp. 1 which thinner and horizontal.

**Stratigraphic distribution in the literature:**

Around Cretaceous-Tertiary in Tunisia (Galeotti and Coccioni, 2002)

**Occurrence:**

Throughout studied section except for UH-33, UH-34, UH-35, UH-36, UH-49

### *Cibicidoides* sp. 1

Plate 13, Figs. 7, 8, 9

**Diagnostic features & Remarks:**

Test is planoconvex to slightly biconvex with acute and somewhat pinched periphery. Spiral side is flat to slightly convex with a smooth horizontal central plug. Umbilical side is more convex, with a clear shell material (umbilical boss). Last whorl is consisting of about nine chambers. Aperture is interiomarginal.

This taxon differs from *Cibicidoides alleni* by relatively acute even pinched periphery and less developed central shell material on spiral side. In side view, it is more like bell shaped, whereas *C. alleni* has near equally biconvex test with distinct spiral calcite plug distinguished from side view. It differs from *Cibicidoides* sp. 2 by flush sutures on spiral side and lesser number of chambers in the last whorl.

**Occurrence**:

Throughout Maastrichtian samples except for UH-47, UH-48, UH49

### *Cibicidoides* sp. 2

Plate 14, Figs. 1, 2, 3

**Diagnostic features & Remarks:**

Biconvex test is more convex at umbilical side. On the spiral side, sutures are thickened and slightly oblique. Perforations on this side is somewhat coarser than on umbilical side. On the umbilical side, sutures are flush with the surface, locally ver slightly thickened, radial and curved. Early whorls are covered by later wall materials, but not much as in *Cibicidoides alleni*. Periphery is subacute and thickened as in *Cibicidoides* sp. 1, but the latter species has somewhat pinched periphery. This species differs from *Cibicidoides* sp. 1 in higher number of chambers in the final whorl which is about thirteen, and differs from *Cibicidoides* *pseudoacutus* by absence of flaplike extensions toward the center of the test on the spiral side.

**Occurrence**:

Throughout Maastrichtian section except for UH-35.

### Superfamily EOUVIGERINACEA Cushman, 1927

### Family EOUVIGERINIDAE Cushman, 1927

### Genus *Eouvigerina* Cushman, 1926

Test is biserial throughout and long, with last chamber(s) almost in uniserial arrangement. Transverse section is subquadrate. Wall is smooth or finely hispid. Aperture is terminal at the end of a distinct neck and phialine lip.

#### *Eouvigerina subsculptura* (McNeil and Caldwell 1981)

Plate 14, Figs. 4, 5, 6

1933 *Eouvigerina aculeata* (Cushman). (fide Ellis and Messina, 1940)

1981 *Eouvigerina subsculptura* (nomen novum). Mcneil and Caldwell, p. 21, pl. 18, figs. 20- 21. (Widmark, 1997)

1994 *Eouvigerina subsculptura* (McNeil and Caldwell). Bolli et al., p. 203, fig. 35.12-13

1994 *Eouvigerina subsculptura* (McNeil and Caldwell). Speijer, p 45, pl. 1, fig. 7

1997 *Eouvigerina subsculptura* (McNeil and Caldwell). Widmark, p.37, fig14d.

2001 *Eouvigerina subsculptura* (McNeil and Caldwell). Alegret and Thomas, p. 303 pl. 6, figs. 1-2

### Diagnostic features & Remarks:

The most distinguishing feature of this species is the distinct rims across the chambers, indistinct earlier chambers and the latter chambers with tendency to uniserial arrangement. The lower part of the chambers are somewhat concave. Test is slender. Test margin is slightly lobate. *Eouvigerina subsculptura* is distinguished by *Tappanina selmensis* by its bigger test and possessing terminal aperture on a distinct neck. Test surface is mainly hispid or even rugose in the studied materials. The rims over the chambers are imperforate.

A possible senior synonym of *E. subsculptura* in the literature is *E. aegyptiaca* as remarked by Speijer (1994). The close relationship between those two both in morphological and stratigraphical aspects was also noted by Anan (2011b and references therein).

### Stratigraphic distribution in the literature:

Late Maastrichtian (*Abathomphalus mayaroensis* Zone) (Bolli et al., 1994), Maastrichtian (Widmark, 1997) for *Eouvigerina subsculptura*.

Maastrichtian in Egypt as well as in United Arab Emirates, Spain, Mexico, Atlantic and Indian Ocean, Tunisia for *Eouvigerina aegyptiaca* (Anan 2011b and references therein).

### Occurrence:

Throughout the Maastrichtian section and UH-50.

### Superfamily FURSENKOINACEA Loeblich and Tappan, 1961

### Family FURSENKOINIDAE Loeblich and Tappan, 1961

### Genus *Coryphostoma* Loeblich and Tappan, 1962

Test is slender, biserial. Transverse section is circular to elliptical. Final chambers have a tendency to uniserialism and they are higher, cuneate in shape. Surface is smooth. Wall is calcareous, little punctate. Aperture is interiomarginal in earlier part, later turning into terminal.

#### *Coryphostoma plaitum* (Carsey 1926)

Plate 14, Figs. 7, 8

1992 *Coryphostoma plaita* (Carsey). Gawor-Biedowa, pl.25, fig. 7

1994 *Coryphostoma plaitum* (Carsey). Speijer, p. 45, pl. 1, fig. 6

**Diagnostic features & Remarks:**

This species with biserial chamber arrangement is very slender in shape. It possesses numerous chambers around nine chamber pairs and depressed sutures. Some tests are twisted. In the studied material, the height of chambers were increasing as going through the apertural end.

**Stratigraphic distribution in the literature:**

Campanian-Maastrichtian (Gawor-Biedowa, 1992)

**Occurrence**:

UH-42

### Superfamily NONIONACEA Schultze, 1854

### Family NONIONIDAE Schultze, 1854

### Subfamily NONIONINAE Schultze, 1854

### Genus *Nonionella* Cushman, 1926

*Nonionella* has low trochospiral coil. Broad and low chambers are increasing quickly in size as added which giving the impression of flaring test. Spiral side is partially evolute and has a distinct umbonal boss. Umbilical side is involute. Extensions from chambers exist on this side are hanging over the umbilicus.

*Nonionella* sp.

Plate 15, Figs. 1, 2

**Diagnostic features & Remarks:**

Small, low trochospiral tests with somewhat elongated chambers are included in this taxon. Spiral side has apparent umbonal boss.

**Occurrence**:

UH-38, UH-40, UH-41, UH-50, UKHB-7, UKHB-8, UKHB, 9,UKHB-10

### Genus *Nonionellina* Voloshinova, 1958

This genus has similar morphological features with *Nonionella*. It has trochospiral in early stage, like *Nonionella.* However, *Nonionellina* is different from it by means of later almost planispiral coiling and also by open umbilicus which is not masked by projections of chambers.

## *Nonionellina* sp. 1

Plate 15, Figs. 3, 4, 5

**Diagnostic features & Remarks:**

This species has very low trochospiral nearly planispiral last whorl, biumbilicate test, seven to eight chambers in the final coil and rounded and slightly lobate periphery. Inflated, elongate chambers are increasing in size as added. There are distinctly coarse perforations on the umbilical side. On this side, small umbilicus is somewhat more opened compared to the umbilicus on spiral side which is narrower. Spiral side is a little more involute. Sutures are depressed on both side with more incision through the umbilicus. Aperture is interiomarginal almost equatorial, extending to both sides.

The studied specimens are close to El Kef taxon assigned as *Anomalinoides simplex* by Speijer (1994), in the aspects of umbilical features such as coarse perforations on this side, open but somewhat small umbilicus; in the aspects of side view such as broad, rounded, slightly elongating toward one side and interiomarginal somewhat equatorial aperture; and also in the aspects of number of chambers (around seven) and involute last whorl. However, Haymana specimens are different by nearly more elongated chambers narrowing through the test center, particulary on the spiral side and slightly more elongated test shape.

In the present study, this taxon is allocated to *Nonionella*, since it has high rate of chamber growth, involute and very low trochospiral approaching planispiral coiling on both spiral and umbilical side. Test size is variable among specimens.

**Occurrence**:

Throughout the studied section, except for UH-34, UH-35, UH-40, UH-43, UH-48, UKHB-6, UKHB-7, UKHB-8, UKHB-9

### Subfamily PULLENIINAE Schwager, 1877

### Genus *Pullenia* Parker and Jones, 1862

This genus has spherical or more flattened, planispiral and involute test. Sutures are radial. Wall is calcareous, with numerous fine pores. Aperture is a long equatorial and interiomarginal slit.

### *Pullenia jarvisi* (Cushman, 1936)

Plate 15, Figs. 6, 7

1936 *Pullenia jarvisi* (Cushman). Cushman, pl. 13, figs.6 a-b

1992 *Pullenia jarvisi* (Cushman). Gawor-Biedowa, p.146, pl. 30, figs. 3-4

1997 *Pullenia jarvisi* (Cushman).Widmark, p. 56, fig. 25e-f

2001 *Pullenia jarvisi* (Cushman). p. 311, pl. 10, fig. 6

**Diagnostic features & Remarks:**

This species has relatively flattened and biumbilicate test with four to five chambers in final coil and lobate periphery. Chambers are increasing in size as added.

Degree of test compression was changing among the studied specimens. However, still the relatively compressed test and lobate periphery are standing to be fair distinguishing feature of this species.

**Stratigraphic distribution in the literature:**

Santonian (*Globotruncana fornicata* Zone) – Early Eocene (*Globorotalia aragonensis* Zone) (Bolli et al., 1994)

**Occurrence**:

UH-36, UH-38, UH-44, UH-46, UH-47, UKHB-7, UKHB-9, UKHB-10

### *Pullenia* sp. 1

Plate 16, Figs. 1, 2

**Diagnostic features & Remarks:**

Planispiral involute test has four to five chambers in the final convolution. Apertural face is convex. *Pullenia* sp. 1 is distinguished from *Pullenia jarvisi* by non-lobulate periphery, more convex and higher apertural face and relatively small test.

**Occurrence**:

UH-34, UH-35, UH-39, UH-41, UH-42, UH-44, UH-45, UH-46

## Superfamily PLEUROSTOMELLACEA Reuss, 1860

## Family PLEUROSTOMELLIDAE Reuss, 1860

## Subfamily PLEUROSTOMELLINAE Reuss, 1860

## Genus *Pleurostomella* Reuss, 1860

Earlier chambers are biserial or alternating-cuneate, then uniserial. Elongated test is tiny. Wall is calcareous, perforated. Terminal aperture has double teeth.

### *Pleurostomella* ? sp.

**Diagnostic features & Remarks**

Prolonged tests with alternating chambers were allocated this taxon. Apertural ends are broken in most of the specimens, therefore apertural characteristics could not have been observed.

**Occurrence:**

UH-38, UH-44, UH-46, UH-48, UKHB-8

### Superfamily SIPHONINACEA Cushman, 1927

### Family SIPHONINIDAE Cushman, 1927

### Subfamily SIPHONININAE Cushman, 1927

### Genus *Pulsiphonina* Brotzen, 1948

Test is biconvex, lenticular and trochospiral. Test margin is ragged or it may be with keel. Chambers are crescentic on spiral side, whilst they are subtriangular on umbilical side. Sutures are oblique, elevated and beaded on spiral side; depressed, bended and almost radial on umbilical side. Aperture is short interiomarginal slit on umbilical side near periphery, with a thin lip.

*Pulsiphonina prima* (Plummer, 1926)

Plate 16, Figs 3, 4, 5

1926 *Siphonina prima* (Plummer) (fide Ellis and Messina, 1940)

1946 *Siphonina prima* (Plummer). Cushman, pl. 59, figs. 3-5

1994 *Pulsiphonina prima* (Plummer). Speijer, p. 63, pl. 10, fig. 1

**Diagnostic features & Remarks**

This species has a small, quite circular test with somewhat lobulated periphery. Test margin is strongly acute and serrate. Sutures on spiral part are obliquely curved; umbilical sutures are depressed and radial. Umbilicus is very small whenever visible, not deep. The last whorl is comprising of about five chambers. Aperture is located on the umbilical side at the periphery, very short slit without a distinct neck.

According to Plummer (1926), this species would probably be an ancestor of Cenozoic *Siphonina* species regarding the apertural structures. *Siphonina* species has a developed short neck with a phialine lip, whereas *Pulsiphonina prima* has not possess a distinct neck, only small opening with tentative narrow lip.

Aperture is hardly visible in the studied specimens under the binocular microscope. Moreover, some specimens have a visible open umbilicus, whereas it is generally not observable in the most of the specimens.

**Stratigraphic distribution in the literature:**

Paleocene-Eocene (Berggen and Aubert, 1975)

**Occurrence:**

UKHB-8, UKHB-9, UKHB-10

### Superfamily TURRILINACEA Cushman, 1927

### Family TURRILINIDAE Cushman, 1927

### Genus *Praebulimina* Hofker, 1953

Test is egg-shaped, ovoid, triserial. Wall is calcareous, finely perforate, opaque. Test surface is smooth. Aperture is a loop beginning from the base of apertural face. It has an internal tootplate.

#### *Praebulimina reussi* (Morrow, 1934)

Plate 16, Fig. 6

1992 *Praebulimina reussi* (Morrow). Gawor-Biedowa, pl. 21, figs. 5-8

1994 *Praebulimina reussi* (Morrow). Speijer, p. 45, pl. 1, fig. 11

1997 *Praebulimina reussi* (Morrow). Widmark, p. 37, fig14f.

**Diagnostic features & Remarks:**

Test is triserial, smooth. Last chamber is curved and rounded at the top. Aperture is characteristic subterminal, comma-shaped, upward from the base of apertural face.

Gawor-Biedowa (1992) mentioned two varieties of this species which possibly representing two different generations. One variation has slender, not well broadened test and last whorl overlapping utmost 2/3 of total test height. On the contrary, the second one has more overweight and rapidly broadening test with final chamber series which overlapping near 3/4 of total test height.

In the studied specimens, the degree of overlapping of the last chamber series is changing among different individuals.

**Stratigraphic distribution in the literature:**

Conician-Santonian (*Globotruncana concavata* Zone) to Late Maastrichtian (*Abathomphalus mayaroensis* Zone) (Bolli et al., 1994)

**Occurrence:**

Throughout Maastrichtian section and UH-50

### Genus *Pseudouvigerina* Cushman, 1927

Test is small, tapering and triserial. Transverse section is triangular. Wall is calcareous and perforate. Test surface may be smooth or pustulose. At margins, single or double longitudinal carinae may exist. Aperture is terminal, circular and surrounded with thin rim. It has also internal toothplate.

#### *Pseudouvigerina plummerae* (Cushman 1927)

Plate 16, Figs. 7, 8, 9; Plate 17, Figs. 1, 2

1994 *Pseudouvigerina plummerae* (Cushman). Bolli et al., p. 203, fig. 35.34

1994 *Pseudouvigerina plummerae* (Cushman). Speijer, p. 51, pl. 4, fig.2.

1997 *Pseudouvigerina plummerae* (Cushman). Widmark, p.37, fig14g.

**Diagnostic features & Remarks:**

This species has characteristic two rows of keel at the edges. The keel is imperforate. Crenulated test margins has broad undulations. Aperture is terminal and circular and have thickened rim.

This form does not have a well-developed apertural neck, but has a thick rim surrounding aperture in the studied material.

**Stratigraphic distribution in the literature:**

Maastrichtian (*Globotruncana gansseri* Zone to *Abathomphalus mayaroensis* Zone) (Bolli et al., 1994)

**Occurrence:**

Throughout Maastrichtian section, except for UH-33, UH-35 and also occurs in UH-50

### *Pseudouvigerina* sp. 1

Plate 17, Fig. 3

**Diagnostic features & Remarks:**

Triserial test has a rounded terminal aperture and finely perforated test. Sutures are indistinct. It differs from *Pseudouvigerina plummerae* by relatively small test with unkeeled and subacute margins.

**Occurrence:**

UKHB-9, UKHB-10

## Genus *Pyramidina*

Triserial test with latter chambers tending to become near uniserial. Chambers are more or less elongate. Sutures are flush or gently incised. Aperture is nearly terminal, high looped opening.

### *Pyramidina minuta* (Marsson, 1878)

Plate 17, Figs. 4, 5, 6

1992 *Pyramidina minuta* (Marsson). Gawor-Biedowa, pl. 23, fig. 7-8

2000 *Cuneus minutus* (Marsson). Frenzel, pl. 27, figs. 1-5

**Diagnostic features & Remarks:**

Chambers are arranged in triserial mode. Test is slightly expanding. Margins are rounded, sutures are invisible at this portion. Sides are concave. Aperture is extending from base of the apertural face upward as a high looped opening and becoming nearly areal and subterminal. Wall is smooth, unornamented, very finely perforated.

Gawor-Biedowa (1992) mentioned the variabilities of this species as following; prolongation of the last chamber, convexity of chambers, rounding of test margin, incision of sutures and acuminating of initial part of the test. The author also stated that some of their specimens were slightly twisted. In our studied material, some specimens have twisting test, too.

**Stratigraphic distribution in the literature:**

Maastrichtian-Paleocene (Gawor-Biedowa, 1992)

**Occurrence:**

UH-34, UH-42, UH-43, UH-45, UH-47, UH-49

### Genus *Sitella* Voloshina, 1974

Test is high trochospiral. Shape of chambers are elongate. They are strongly overlapping. There are four to five chambers per whorl. Sutures may be slightly depressed. Wall is calcareous and smooth. Aperture is distinguishing upside-down “T” shaped opening.

*Sitella cushmani* (Sandidge, 1932)

Plate 17, Figs. 7, 8

1932 *Buliminella cushmani* Sandidge (fide Ellis and Messina, 1940)

1953 *Buliminella cushmani* (Sandidge). Le Roy, pl. 8, fig. 12

1994 *Turrilina cushmani* (Sandidge). Bolli et al., p. 205, fig. 36.6

1994 *Sitella cushmani* (Sandidge). Speijer, p. 45, pl. 1, fig. 9

2001 *Sitella cushmani* (Sandidge). Alegret and Thomas, p. 311, pl. 10, fig. 13

2011a *Sitella cushmani* (Sandidge). Anan, pl. 1, fig. 8

2014 *Buliminella cushmani* (Sandidge, 1932). Orabi and Khalil, supplementary pl. 1, fig. 13

**Diagnostic features & Remarks:**

Test is high trochospiral, tightly coiled. The last coil is consisting of four chambers. Sutures are depressed or flush with the surface. Transverse section is circular. Initial end is pointed, while apertural end is more smoothly tapering.

**Stratigraphic distribution in the literature:**

Maastrichtian (*Globotruncana lapparenti tricarinata* Zone to *Abathomphalus mayaroensis* Zone) (Bolli et al., 1994).

Abundant occurences reported from the Maastrichtian rocks from Egypt (Anan 2011a and references therein).

**Occurrence:**

Throughout the Maastrichtian section.

### Suborder TEXTULARIINA Delage and Herouard, 1896

### Superfamily AMMODISCACEA Reuss, 1862

### Family AMMODISCIDAE Reuss, 1862

### Subfamily AMMODISCINAE Remis, 1862

### Genus *Ammodiscus* Reuss, 1862

*Ammodiscus* has tubular second chamber which enrolls planispirally, with simple interior. Aperture is located at the end of the tube.

*Ammodiscus* spp.

Plate 18, Fig. 1

**Diagnostic features & Remarks:**

Very finely agglutinated tests with a variety of size were included in this taxon.

**Occurrence:**

UH-36, UH-37, UH-46, UH-47

### Subfamily AMMOVERTELLININAE Saidova, 1981

### Genus *Glomospira* Rzehak, 1885

Streptospiral test is bilocular with nonseptate elongate tubular second chamber and finely agglutinated wall.

*Glomospira* spp.

Plate 18, Fig. 2

**Diagnostic features & Remarks:**

Streptospiral tests with very finely to finely agglutinated tests were included this taxon.

**Occurrence:**

UH-34, UH-38, UH-39, UH-45, UH-46, UH-48

### Superfamily ASTRORHIZACEA Brady, 1881

### Family BATHYSIPHONIDAE Avnimelech, 1952

### Genus *Bathysiphon* M. Sars, 1872

Unbranched horizontal tubular test have agglutinated wall and aperture at the open ends.

*Bathysiphon* spp.

Plate 18, Fig. 3

**Diagnostic features & Remarks:**

A variety of straight, nonbranching, tubular agglutinated tests are allocated this taxon.

**Occurrence:**

UH-33, UH-33, UH-36, UH-37, UH-39, UH-40, UH-41, UH-42, UH-43, UH-44, UH-45, UH-46, UH-48, UH-49

### Superfamily ATAXOPHRAGMIACEA Schwager, 1877

### Family ATAXOPHRAGMIIDAE Schwager, 1877

### Subfamily ATAXOPHRAGMIINAE Schwager, 1877

### Genus *Arenobulimina* Cushman, 1927

Test is high trochospiral. Each coil has four or more chambers. Wall is agglutinated. Aperture is interiomarginal.

*Arenobulimina* spp.

Plate 18, Fig. 4

**Diagnostic features & Remarks:**

High trochospiral, small tests with fine to medium agglutinated walls are included in this taxon. The convexity and rounding of the last chambers are variable among the individuals.

**Occurrence:**

UH-36, UH-41, UH-42, UH-43, UH-46, UH-47

### Family RHABDAMMINIDAE Brady, 1884

### Subfamily RHABDAMMININAE Brady, 1884

### Genus *Rhizammina* Brady, 1879

Elongate, sparsely branching, tubular agglutinated tests are cementing foreign materials like sand particles, other microorganism tests like foraminifera or radiolaria. Apertures are located at the end of the tubes.

#### *Rhizammina* sp. 1

Plate 18, Figs. 5, 6

**Diagnostic features & Remarks:**

This agglutinated form is characterized by its irregular, elongated, tubular test form. Wall is coarsely agglutinated.

This taxon is counted as a rare form in Maastrichtian samples.

**Occurrence:**

UH-34, UH-37, UH-44, UH-46, UH-47, UH-48

### Superfamily HAPLOPHRAGMIACEA Eimer and Pickert, 1899

### Family AMMOSPHAEROIDINIDAE Cushman, 1927

### Subfamily AMMOSPHAEROIDININAE Cushman, 1927

### Genus *Ammosphaeroidina* Cushman, 1910

Rounded test has streptospiral chamber arrangement. Inflated chambers are strongly overlapping. The last three chambers are exclusively visible at the outside of the test. The genus has coarsely agglutinated test wall with an interiomarginal aperture.

*Ammosphaeroidina* ? sp.

**Diagnostic features & Remarks:**

Streptospirally (?) enrolled test have strongly overlapping chambers. Outside of the test, only the final chambers are visible. Wall moderate to coarsely agglutinated. Tests are small. This taxon is very rarely recorded. Only about three chambers are visible from external view.

**Occurrence:**

UKHB-7, UKHB-8

### Subfamily RECURVOIDINAE AlekseychikMitskevich, 1973

### Genus *Recurvoides* Earland, 1934

Subglobular test is coiled streptospirally with final coils closing to trochospiral or planispiral coiling even may change coiling direction by $90^o$. The former chambers are not observable outside of the test. Wall is agglutinated. Aperture is areal.

*Recurvoides* spp.

Plate 18, Fig. 7

**Diagnostic features & Remarks:**

Streptospiral coiled tests with coarsely to medium agglutinated wall are included this taxon.

**Occurrence:**

UH-37, UH-44, UH-47

### Superfamily HORMOSINACEA Haeckel, 1894

### Family HORMOSINIDAE Haeckel, 1894

### Subfamily REOPHACINAE Cushman, 1910

### Genus *Hormosinella* Shchedrina, 1969

Ovate to fusiform chambers are connected by elongate necks arranged in uniserial, end of which there are apertures. Wall is agglutinated. Large tests are found in commonly broken pieces.

*Hormosinella* sp.

Plate 19, Fig. 1

**Diagnostic features & Remarks:**

Shape of chambers are variable. They are nearly discoidal and flattened but some specimens have more inflated ones. Tests were found as fragments.

**Occurrence:**

UH-36,UH-37, UH-38, UH-39 UH-40, UH-42, UH-46

### Superfamily LITUOLACEA de Blainville, 1827

### Family HAPLOPHRAGMOIDIDAE Maync, 1952

### Genus *Haplophragmoides* Cushman, 1910

Planispiral test is involute to a little evolute. Periphery is somewhat lobate. Wall is agglutinated. Aperture is equatorial.

*Haplophragmoides* sp.

Plate 19, Fig. 2

**Diagnostic features & Remarks:**

Test is lobulated, involute and somewhat asymmetrical planispiral. Wall is medium grained.

**Occurrence:**

UH-47

### Family LITUOLIDAE de Blainville, 1827

### Subfamily AMMOMARGINULININAE Podobina, 1978

### Genus *Ammomarginulina* Wiesner, 1931

Flattened, agglutinated test has planispiral initial part becaming later uncoiled. Terminal aperture is located at the dorsal angle.

*Ammomarginulina* aff. *aubertae* (Gradstein and Kaminski, 1989)

Plate 19, Fig. 3

2005 *Ammomarginulina aubertae* (Gradstein and Kaminski). Kaminski and Gradstein , pl. 72b, figs. 1a-c, 2a-c, 3a-c

**Diagnostic features & Remarks:**

This taxon has slightly lobulate, evolute, initially planispiral later nearly uncoiled test. The uncoiled uniserial part is tangential with respect to the planispiral portion. Umbilicus is open and coil suture is visible. Aperture is areal in the coiled part becoming terminal and located on very short neck in the uncoiled part. Periphery is rounded to slightly lobulated.

The chambers are hardly visible in the studied materials. The number of chambers and sutural characteristics were not clearly observed. Wall is medium to coarse grained.

**Stratigraphic distribution in the literature:**

Maastrichtian to Miocene (Kaminski and Gradstein, 2005)

**Occurrence:**

UH-43, UH-46, UH-47

### Superfamily SPIROPLECTAMMINACEA Cushman, 1927

### Family SPIROPLECTAMMINIDAE Cushman, 1927

### Subfamily SPIROPLECTAMMININAE Cushman, 1927

### Genus *Spiroplectammina* Cushman, 1927

Test is elongate, narrow, planispiral in initial stage, later becoming biserial. Wall is agglutinated and noncanaliculate. Aperture is basal interiomarginal.

*Spiroplectammina* aff. *S. spectabilis* (Grzybowski, 1898),

emend. Kaminski, 1984

Plate 19, Fig. 4

**Diagnostic features & Remarks:**

Relatively flattened test is comprising of two phase of chamber arrangement. The first stage is the planispiral and the successive stage is biserial. In the latter stage, sides are parallel. Aperture is interiomarginal.

Based on the personal communication with Prof. Dr. M. Kaminski, this taxon was assigned under the name of *Spiroplectammina* aff. *S. spectabilis.* He suggested a search on the cement type for this taxon, since it is also close to *Bolivinopsis*, or may possibly be an intermediate form. Kaminski and Lazarus (2009) nominated a lectotype, *Spiroplecta rosula,* as type species of *Bolivinopsis*.

*Spiroplectammina* aff. *S. spectabilis* has small test in the studied samples, since it was only recorded in 63 μm-125 μm fraction only based on the presence-absence data.

**Stratigraphic distribution in the literature:**

Maastrichtian - Late Eocene (Kaminski and Gradstein, 2005) for *Spiroplectammina spectabilis*.

Late Cretaceous (Frenzel, 2000) for *Bolivinopsis rosula*.

**Occurrence:**

UH-37, UH-39, UH-40, UH-42, UH-44, UH-46, UH-47, UH-48

### Genus *Spiroplectinella* Kisel'man, 1972

Test have an early stage planispiral coiling part, later biserial section which expands rapidly. In sectional view shape of test is rhomboidal. Wall is noncanaliculate and agglutinated. Aperture is interiomarginal.

### *Spiroplectinella knebeli* (LeRoy, 1953)

Plate 19, Fig. 5

1953 *Spiroplectinella knebeli* (LeRoy). p. 51, pl. 2, figs. 10-11.

**Diagnostic features & Remarks:**

The characteristic feature of this species are convex apertural face and rapidly flaring test. Test starts with indistinct planispiral part and continue to biserial arrangement. It has an acute and somewhat bluntly jagged margin. Test is more or less equidimensional with respect to height and width. Chambers and sutures are distinct, rather raised, gently inclining down and slightly arched.

In the studied specimens, the degree of rounding of the initial part is varying. Some specimens have more tapering initial extremity.

**Stratigraphic distribution in the literature:**

Upper Cretaceous – Lower Tertiary (Le Roy, 1953), Paleocene (P4 Zone) (Aubert and Berggren, 1976)

**Occurrence**:

Throughout Maastrichtian section, except for UH-37, UH-38, UH-39, UH-41, UH-42, UH-47, UH-49

### *Spiroplectinella* sp. 1

Plate 19, Figs. 5, 6

**Diagnostic features & Remarks:**

This form has very fine grained agglutinated wall with much cement. The base of the test is almost flattened, but in some specimens it is somewhat rounded. Test margin is acute. In apertural view, test is rhomboidal. Sutures of are bent downward, rather indistinct.

The apertural face of this species is more gently rounded when compared to *Spiroplectinella knebeli*. The latter species also has more distinct sutures and chambers.

**Occurrence**:

Throughout Maastrichtian section, except for UH-47, UH-48

### Superfamily TEXTULARIACEA Ehrenberg, 1838

### Family EGGERELLIDAE Cushman, 1937

### Subfamily DOROTHIINAE Balakhmatova, 1972

### Genus *Dorothia* Plummer, 1931

This genus has early chambers with trochospiral arrangement, later becoming biserial. Sides of test has almost straight. In transverse section, test is almost rounded. Wall is finely agglutinated and canaliculated. Aperture is interiomarginal.

*Dorothia pupa* (Reuss, 1860)

Plate 20, Fig. 3

1992 *Dorothia pupa* (Reuss). Gawor-Biedowa, pl. 7, fig. 11

1994 *Dorothia pupa* (Reuss). Bolli et al., p. 181, fig. 24-29

2001 *Dorothia pupa* (Reuss). Alegret and Thomas, p. 301 pl. 5, figs 16-17.

**Diagnostic features & Remarks:**

*Dorothia pupa* has a stout test, with short multiserial stage and distinctly inflated last two chambers.

**Stratigraphic distribution in the literature:**

Early Maastrichtian (*Globotruncana lapparenti* Zone) - Late Paleocene (*Globorotalia velascoensis* Zone) (Bolli et al., 1994)

**Occurrence:**

UH-34, UH-35

*Dorothia* sp. 1

Plate 20, Fig. 4

**Diagnostic features & Remarks:**

This form is different from other *Dorothia* species by its long, nearly parallel sides and almost circular biserial portion in transverse section. Test surface is smooth. Sutures are flush, locally depressed.

**Occurrence:**

UKHB-8, UKHB-10

### Genus *Marssonella* Cushman, 1933

This genus differs from *Dorothia* by more distinct conical test shape, instead of having parallel sides. Additionally, it has flat or concave apertural face.

*Marssonella oxycona* (Reuss, 1860)

Plate 20, Fig. 7, 8

1988 *Dorothia oxycona* (Reuss). Kaminski et al., p. 225 pl. 9, fig. 9.

1988 *Dorothia oxycona* (Reuss). Keller, p. 160, pl.4, figs. 1-2

1990 *Marssonella oxycona* (Reuss). Hemleben et al. p. 230, pl. 12, figs.5-6

2001 *Marssonella oxycona* (Reuss). Alegret and Thomas, p. 307 pl. 8, fig 14.

2004 *Marssonella oxycona* (Reuss). Peryt et al., p. 412, pl. 3, fig. 13

**Diagnostic features & Remarks:**

*Marssonella oxycona* has a conical test which is rounded in transverse section and non-inflated distinct chambers. Sutures are slightly depressed and locally flush. This species has a distinguishing flat apertural face.

**Stratigraphic distribution in the literature:**

Maastrichtian-Early Eocene (Kaminski et al., 1988)

**Occurrence:**

UH-40, UH-41 for Maastrichtian section, and throughout Danian section.

*Marssonella indetata* (Cushman and Jarvis, 1928)

Plate 20, Figs. 5, 6

1946 *Marssonella indetata* (Cushman and Jarvis). Cushman, pl. 12, figs. 6-7

1988 *Dorothia indentata* (Cushman and Jarvis). Kaminski et al., p. 225, pl. 9, figs. 7-8

**Diagnostic features & Remarks:**

The elevated and dislocated sutures, which are forming collar like circular rims on the test surface are main distinguishing features of *Marssonella indetata*. Moreover, apertural face is concave, sharply eroded, including irregular depressions.

**Stratigraphic distribution in the literature:**

Paleocene-Early Eocene (Kaminski et al., 1988)

**Occurrence:**

UKHB-4, UKHB-7, UKHB-8, UKHB-10

### Family PSEUDOGAUDRYINIDAE Loeblich and Tappan, 1985

### Subfamily PSEUDOGAUDRYININAE Loeblich and Tappan, 1985

### Genus *Pseudogaudryina*

Triserial stage is followed by biserial part, but test retains its triangular shape completely. In biserial stage, two sets of chambers are unlike to each other. Shape of chambers in one serial is four-sided, whereas shape of chambers in the other serial is triangular. Wall is agglutinated and canaliculate. Aperture is interiomarginal small opening.

*Pseudogaudryina* sp. 1

Plate 21, Fig. 1, 2

**Diagnostic features & Remarks:**

This taxon is distinguished from other *Pseudogaudryina* species by big test, flush sutures and slightly dislocated final chambers. The final chambers have also more acute outside margins. In apertural view, test is more or less triangular appeared as constricted in two sides.

**Occurrence:**

UH-33, UH-36, UH-39, UH-41, UH-44, UH-47, UH-48

*Pseudogaudryina* sp. 2

Plate 21, Fig. 3, 4, 5

**Diagnostic features & Remarks:**

This species resembles to *Pseudogaudryina* sp. 1, but differs from it by more distinct, thickened but locally incised sutures, smoothly finished and more finely agglutinated wall. Test angles are also relatively more acute and test itself is relatively small than *Pseudogaudryina* sp. 1.

The specimen reported from Trinidad by Kaminski et al. (1988) as *Gaudryina pyramidata* (Cushman) seems close to *Pseudogaudryina* sp. 2 based on the external morphologies. Both Trinidad material and our specimens have completely triangular test shape and thickened sutures. However, since there is no other side/apertural view of that illustrated form, there can not be carry on any other comparison with our specimens.

**Occurrence:**

UH-36, UH-37, UH-38, UH-39, UH-40, UH-41, UH-42, UH-46, UH-48

### *Pseudogaudryina* sp. 3

Plate 21, Fig. 6, 7

**Diagnostic features & Remarks:**

This species is different from other *Pseudogaudryina* forms by its nearly equidimensional triangular test, almost tetrahedron in shape, but slightly more elongated through the growth axis. Wall is medium to coarsely agglutinated. Test size is varying among specimens.

**Occurrence:**

UH-38, UH-40, UH-42, UH-43, UH-45

## Genus *Clavulinoides* Cushman, 1936

Test is elongate and triangular. Chamber are initially arranged as triserial, then they distinctly continue to uniserial arrangement. Wall is agglutinated, outer part of test has canaliculated wall. Aperture is interiomarginal in the first stage, then becoming terminal, rounded in the later stage.

### *Clavulinoides amorpha* (Cushman 1926) emend. (Alegret and Thomas, 2001)

Plate 20, Fig. 1

1926 *Clavulina amorpha* (Cushman). (fide Ellis and Messina, 1940)

1988 *Clavulinoides amorpha* (Cushman). Kamisnki et al., p. 223, pl. 8, fig. 13.

2001 *Clavulinoides amorpha* (Cushman). Alegret and Thomas, p. 301, pl. 5, fig1-3

**Diagnostic features & Remarks:**

The most distinctive feauture of *Clavulinoides amorpha* from other *Clavulinoides* species is rounded uniserial part giving an impression of columnar shape and somewhat inflated last chambers. In our specimens, chambers are hardly visible. Wall is medium to coarsely agglutinated.

**Stratigraphic distribution in the literature:**

Cretaceous-Paleocene (Alegret et al., 2001), Late Paleocene (*Globorotalia pseudomenardii* Zone) (Bolli et al., 1994)

**Occurrence:**

UH-50, UKHB-4, UKHB-5, UKHB-6, UKHB-7, UKHB-8, UKHB-9

### *Clavulinoides trilatera* (Cushman, 1926)

Plate 20, Fig. 2

1926 *Clavulina trilatera* (Cushman). (fide Ellis and Messina, 1940)

1997 *Clavulinoides trilatera* (Cushman). Ayyad, p. 151, fig.6i

1988 *Clavulinoides trilatera* (Cushman). Kaminski et al. 1988, p. 195, pl. 9, fig. 2

2001 *Clavulinoides trilatera* (Cushman). Alegret and Thomas. p. 301, pl. 5, figs.6-8

2004 *Clavulinoides trilatera* (Cushman). Peryt et al., p. 412, pl. 3, figs. 10-12

2009 *Clavulinoides trilatera* (Cushman). Giusberti, p. 106, pl. 1, fig. 1

**Diagnostic features & Remarks:**

*Clavulinoides trilatera* has elongate, completely triangular test which is narrowing in both ends. Sides are parallel. Wall is almost fine to medium grained, rather smoothly finished. It has terminal and circular aperture on weakly developed neck.

**Stratigraphic distribution in the literature:**

Cretaceous-Paleocene (Alegret et al., 2001), Paleocene (*Globorotalia pusilla* pusilla Zone – *G. pseudomenardii* Zone) (Bolli et al., 1994)

**Occurrence:**

Throughout the studied section except for UH-38, UH-41, UH-42, UH-45, UH-48, UH-50, UKHB-5, UKHB-8, UKHB-9, UKHB-10

### Superfamily TROCHAMMINACEA Schwager, 1877

### Family TROCHAMMINIDAE Schwager, 1877

### Subfamily TROCHAMMININAE Schwager, 1877

### Genus *Trochammina* Parker and Jones, 1859

Trochospiral test has radial sutures and rounded periphery. Surface of test is usually smooth. Aperture is umbilical-extraumbilical.

*Trochammina* spp.

**Diagnostic features & Remarks:**

Agglutinated, trochospiral tests with various amount of flattening and various chamber shapes are grouped under this taxon.

**Occurrence:**

UH-38, UKHB-6, UKHB-8

### Superfamily VERNEUILINACEA Cushman, 1911

### Family TRITAXIIDAE Plotnikova, 1979

### Genus *Tritaxia* Reuss, 1860

Test is triangular and triserial in initial part, then becoming uniserial with less chambers. Wall is agglutinated and robust. Aperture is interiomarginal in triserial part, then passing into terminal, may be depressed or at the end of a short neck.

### *Tritaxia* sp.1

Plate 23, Fig. 6

**Diagnostic features & Remarks:**

Test is carinate, triangular. Sides are concave. Margins are acute. Aperture is terminal, almost circular. Initial chamber arrangement type is triserial. Last few chambers are uniserial.

**Occurrence:**

UKHB-6, UKHB-7, UKHB-9, UKHB-10

### *Tritaxia* ? sp. 2

Plate 23, Fig. 7

**Diagnostic features & Remarks:**

This taxon is distinguished from *Tritaxia* sp.1 by subterminal oval aperture and subrounded edges. The final chamber is a little dispositioned like approaching the uniserial, but not completely uniserial.

Generic affiliation of this taxon remains uncertain due to the apertural structure and incomplete uniserial arrangement of the last few chambers. In some specimens the location of the aperture is slightly approaching to terminal position. Although Banner and Desai (1985) argued that some of *Verneuilina* species with Cretaceous aged had a subterminal aperture and tendency to uniserial arrangement in the terminal part, this taxon is kept under *Tritaxia* in the present study. It might be an intergrading form between these two genera. Moreover, the degree of rounding of the edges are variable.

**Occurrence:**

UH-33, UH-37, UH-46, UH-48, UKHB-5, UKHB-6, UKHB-7, UKHB-10

### Family VERNEUILINIDAE Cushman, 1911

### Subfamily BARBOURINELLINAE Saidova, 1981

### Genus *Heterostomella* Reuss, 1866

Test is initially triserial and later becoming biserial. Test margins have distinct longitudinal ridges. Wall is agglutinated. Aperture is interiomarginal in initial part, then becoming terminal and rounded. Aperture may also be on a neck.

#### *Heterostomella austinana* (Cushman 1946)

Plate 23, Figs. 1, 2

1946 *Heterostomella austinana* (Cushman). Cushman, pl. 11, figs. 2-7

1994 *Heterostomella austinana* (Cushman). Speijer, p. 45, pl. 1, fig.2

2004 *Heterostomella austinana* (Cushman). Peryt et al., p. 412, pl.3, figs. 6-9.

**Diagnostic features & Remarks:**

This species is characterized by large linear depressions It has also smoothly truncated chamber margins. Aperture is terminal, rounded at the end of very short neck.The neck is usually not seen clearly in most of the specimens. Some individuals have only slightly developed neck. When the neck is not available, a rounded trace is apparent at the terminal apertural face. Moreover, in the original description of this species the growth axis is mentioned to be straight. In the studied samples some individuals have arcuate test.

**Stratigraphic distribution in the literature:**

*Plummerita hantkeninoides* Zone - *Guembelitria cretacea* Zone (Peryt, 2004)

**Occurrence:**

Throughout the Maastrichtian section and UH-50

### *Heterostomella* sp. 1

Plate 23, Fig. 3, 4

**Diagnostic features & Remarks:**

This form is distinguished from *Heterostomella austinana* by its bigger, white, robust test with relatively more irregular decorations. Transverse section is nearly rounded.

**Occurrence:**

UH-33, UH-35, UH-36, UH-38, UH-39, UH-40, UH-44, UH-45, UH-46, UH-47, UH-50

## Genus *Verneuilina* d'Orbigny, 1839

Test is triserial throughout. Wall is finely to coarsely agglutinated. Aperture is interiomarginal and arched opening.

### *Verneuilina* sp.1

Plate 24, Figs. 1, 2

**Diagnostic features & Remarks:**

Test is triserial throughout. Wall is moderately agglutinated. Test surface is rough. Last chambers are inflated. Angles are rounded. Aperture is an interiomarginal arch. This form is distinguished from other *Verneuilina* species by its brooken-white colored and somewhat bigger test.

**Occurrence:**

UH-33-45, UH-47-49

### *Verneuilina* sp.2

Plate 24, Figs. 3, 4

**Diagnostic features & Remarks:**

This form is distinguished from *Verneuilina* sp.1 by its more elongated test with more acute angles. The final chambers are also inflated, however not that much as in *Verneuilina* sp. 1.

**Occurrence:**

UH-36, UH-40, UH-41, UH-43, UH-44, UH-47

## Subfamily VERNEUILININAE Cushman, 1911

## Genus *Gaudryina* d'Orbigny, 1839

Test is triserial in early stage later biserial. Transverse section is triangular or rounded in shape Wall is agglutinated, noncanaliculate.

### *Gaudryina* sp. 1

Plate 22, Figs. 3, 4

**Diagnostic features & Remarks:**

Elongate and triangular test is triserial in most of the part, but the last chambers are biserial. Test margin is subacute.

This form is very similar to *Verneuilina* sp. 1 by the aspects of wall texture and acuity of the test margins. However, it is different from the latter species by the distinct last two biserial chambers and more elongated test.

**Occurrence:**

UH-34, UH-35, UH-36, UH-37, UH-40, UH-41, UH-42, UH-43, UH-46, UH-49

### Subfamily VERNEUILINOIDINAE Suleymanov, 1973

### Genus *Eggerellina* Marie, 1941

Triserial test with nearly spherical or ovoid and overlapping chambers has depressed sutures. Polished test wall is agglutinated calcite particles with much cement. Aperture is simple narrow cut developing upward from the base of the apertural face.

#### *Eggerellina* sp. 1

Plate 22, Figs. 1, 2

**Diagnostic features & Remarks:**

Relatively small inflated test is distinguished by its smooth, very finely agglutinated wall and strongly overlapping last chambers. Initial apex is somewhat tapering. The top part of the test is broadly rounded. One of the last three chambers is hardly visible from above due to the strong embracing of the last two chambers.

This characteristic is also pointed by Marie (1941). She discussed that some *Eggerellina* species may show only some part of the upper exterior of three or two chambers when observed at the top of the test. This may give an impression of false decline in number of chambers.

**Occurrence:**

UH-33, UH-34, UH-35, UH-37, UH-38, UH-39, UH-42, UH-43, UH-45, UH-49

# CHAPTER 6

# DISCUSSION AND CONCLUSION

A 14.53 m thick stratigraphic section corresponding to the flyschoidal mudstones and mudstone-marl alternations of the Upper Maastrichtian Haymana Formation and the Lower Danian Yeşilyurt Formation was measured in the Haymana Basin, Central Turkey. In order to reveal the changes in the benthic foraminifera associations, diversity and distribution trough the section as well as to establish their response to the K-Pg boundary and their taxonomy, a quantitative analysis was performed over > 125 µm fraction corresponding the 4.36 m thick portion of the whole measured section.

25 washed samples in total were quantitatively analyzed from 3.15 m part of the uppermost Maastrichtian and 1.21 m portion of the lowermost Danian sections of the Haymana Formation and the Yeşilyurt Formation, respectively. Approximately 300 benthic foraminifera individuals were picked from each sample.

Three benthic foraminifera biozones were established for the first time from Turkey based on the bioevents across the Maastrichtian and the Danian interval in the studied section. *Bolivinoides draco* Zone and its equivalent *Eouvigerina subsculptura* acme Zone (newly proposed) were established for the 3.15 m thick uppermost Maastrichtian portion, whereas *Angulogavelinella avnimelechi-Anomalinoides rubiginosus* Zone (BB1) was established for the 1.21 m thick lowermost Danian part of the measured section. This integrated usage of deep-water benthic foraminifera biozones with the previously established planktonic foraminifera biozones by Karabeyoğlu (2017) in the same measured stratigraphic section served a well calibrated foraminiferal bioevents across the K-Pg boundary beds from the Haymana Basin, thus from the Tethyan realm.

A morphogroup analysis was carried out regarding the test shape of the species to infer infauna-epifauna ratio of the assemblages. As the most general statement, benthic foraminifera with test shapes of cylindrical tapered, flattened tapered, rounded planispiral, spherical, elongate multilocular and flattened trochospiral shapes are considered as living as infaunal within the sediment surface. Furthermore, foraminifera with planoconvex trochospiral, biconvex trochospiral, rounded trochospiral, palmate, branching, tubular, coiled flattened & streptospiral and elongate keeled morphology are regarded as living as epifaunal on the sediment surface (Alegret et al., 2013). According to these preferences, the calcareous taxa were divided into 9 categories as follows; CI1 (cylindrical tapered), CI2 (flattened tapered), CI3 (rounded planispiral), CI4 (spherical) for infaunal taxa and CE1 (planoconvex trochospiral), CE2 (biconvex trochospiral), CE3 (rounded trochospiral), CE4 (palmate), CE5 (branching) for epifaunal taxa. Furthermore, agglutinated taxa were categorized into 6 groups which are AI1 (elongate multilocular), AI2 (flattened trochospiral), AI3 (elongate tapered) for infaunal taxa and AE1 (coiled flattened & streptospiral), AE2 (elongate keeled), AE3 (tubular-branching) for epifaunal taxa. In the Maastrichtian, the most abundant calcareous morphogroup was found as CI1 (48%), whereas AI1 (23%) was recorded as the most abundant agglutinated class. In the Danian, AI1 is still the most abundant group among the agglutinated taxa, but it decreased its relative abundance to average 11%. In this section, the most abundant morphogroup is CE2 and CE1 with the average relative abundances of 53% and 22%, respectively.

Over all infaunal and epifaunal groups, together both agglutinated and calcareous morphotypes, have relative abundances of average 75% and average 25%, respectively, in the Maastrichtian. Infaunal taxa is increasing its abundance as closing to the boundary with the peak value of 89.9% in the last Maastrichtian sample (UH-49), just 5 cm below the boundary. In the Danian, infaunal groups were decreased in abundance to average 24.7%, whereas epifaunal groups were increased in abundance to average 75.8% (Figure 25).

The relative abundance of calcareous taxa overall is average 73.9%, whereas agglutinated taxa is average 26.1% through the Maastrichtian (Figure 25). For Danian part, the percentages are changing to average 89.0% for calcareous taxa and average 11.0% for agglutinated taxa (Figure 25). These values offers a depositional setting quite above the Calcium Carbonate Compensation Depth (CCD) of the basin, assigned for the whole studied section. Moreover, based on the benthic foraminifera associations upper bathyal environment was assigned for the whole studied section. The assemblage in the whole studied Maastrichtian section was found to be very similar to the Late Maastrichtian Shallow Bathyal Assemblage (SBA) offered by Widmark and Speijer (1997b) holding the relative abundance of 33.4% (Figure 24). This result was compared with the other Central Tethyan localities including the upper bathyal El Kef (Tunisia), Wadi Nukhl (Egypt), Nahal Avdat (Israel) and the middle bathyal Caravaca (Spain). The relative abundance of this assemblage in the Haymana Basin was found close to that of the upper bathyal localities in the Central Tehys, since the assemblage was becoming less abundant as going deeper seetings such as in the middle bathyal Caravaca (Spain) and in the bathyal or even deeper Western Tehys (Widmark and Speijer, 1997b). Thus, the studied Maastrichtian section was referred to the upper bathyal environment (~200-600 m). After the boundary, there is probably no change in the paleobathymetry, since neritic and bathyal taxa were found together in the Danian samples (See Chapter 4, Section 4.1).

The Maastrichtian section consist of high diverse assemblage with *Eouvigerina subsculptura, Heterostomella austinana, Sitella* spp. together with *Sitella cushmani, Pseudouvigerina plummerae, Bulimina strobila, Verneuilina* spp. as well as *Cibicidoides* spp., *Sliteria varsoviensis*. *Eouvigerina subsculptura* as the most abundant species in this section with average 18.1%. In the lower part of the section,

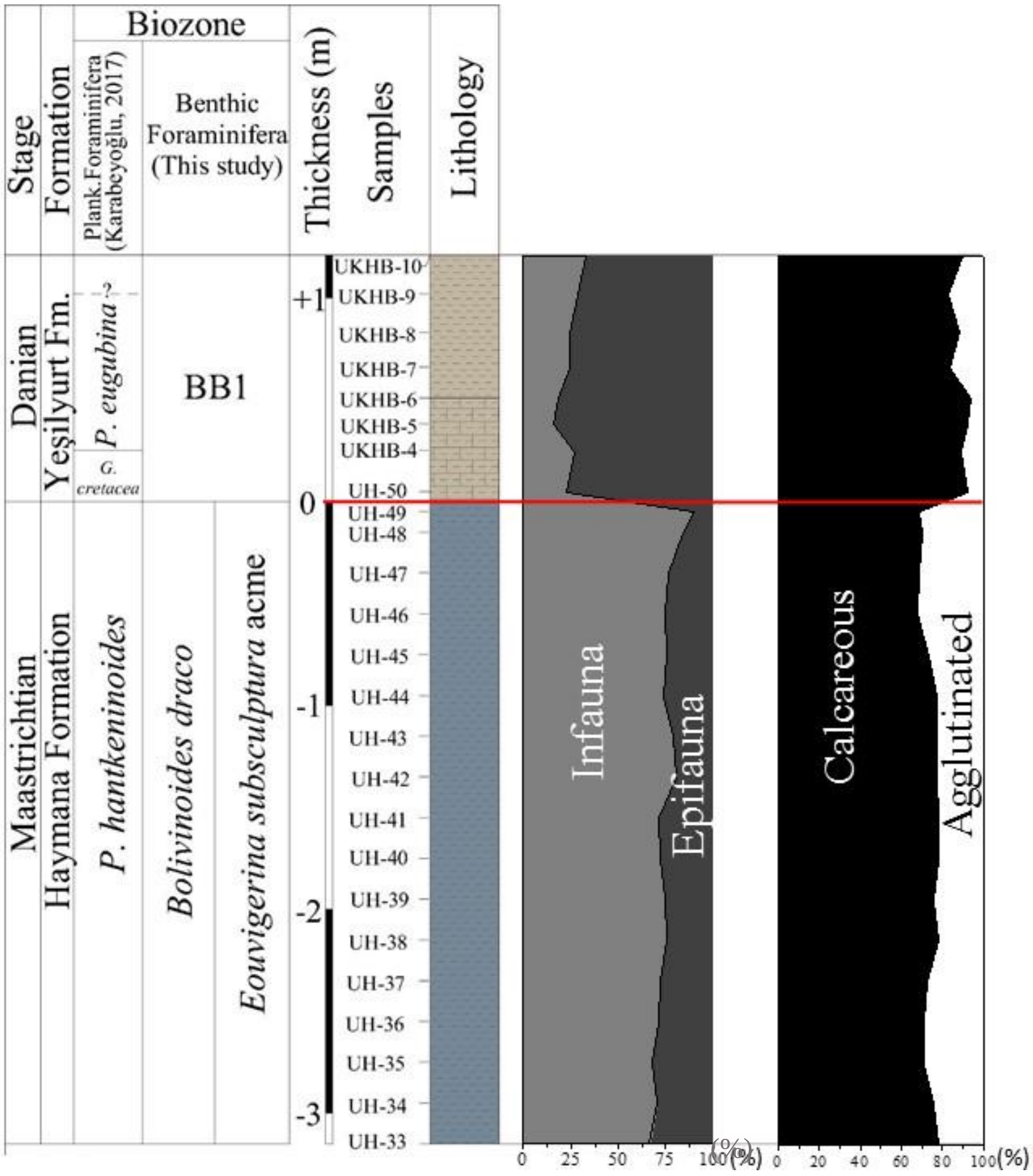

Figure 25: Relative abundances (%) calcareous-gglutinated foraminifera taxa and infauna-epifauna taxa distributed through the studied section.

*Verneuilina* sp.1, *Spiroplectinella* sp.1, *Sliteria varsoviensis* are *Lenticulina* spp. are more common to abundant. Through the top of the Maastrichtian section, *Pseudouvigerina plummerae* is becoming more common to abundant, while relative abundance of *Sliteria varsoviensis* is fluctuating, but the latter species is holding more or less a decreasing trend. *Bulimina strobila* has its peak value (5.6%) just below the boundary in sample UH-49, whereas in the same sample infaunal forms overall also have the peak value of 89.9%. Among these infaunal forms, morphogroups CI1 and AI1 have their maximum relative abundance of 58% and 29%, respectively in this sample. In this sense, there is a general trend indicating a possible increasing food for benthic foraminifera community towards the boundary. Most of the above mentioned taxa have preference for high food supply (See Chapter 4, Section 4.2), therefore possibly the meso- to eutrophic conditions were prevailed based on the assemblage as well as the relatively higher infaunal percentage (average 75%) in the late Maastrichtian.

There is a remarkable change in the benthic foraminifera assemblage as passing from the Haymana Formation to the Yeşilyurt Formation. The Lower Danian Yeşilyurt Formation section contains epifaunally outnumbered poor to moderately diverse assemblage which consisting of *Alabamina wilcoxensis*, *Anomalinoides acutus*, *Anomalinoides rubiginosus*, *Cibicidoides pseudoacutus*, *Cibicidoides* spp., *Gyroidinoides* spp. *Lenticulina* spp., *Osangularia plummerae* and *Osangularia spp*. *Verneuilina* spp. as well as mostly in the higher levels *Tritaxia* spp., *Lenticulina* sp.1, *Pulsihponina prima* and *Cibicides* sp.1. In this Danian section, the only taxa with very abundant category (> 15%) is opportunistic *Cibicidoides* spp. (17.5%) in sample UH-50 in *Guembelitria cretacea* Zone. Similar to that interval, Peryt et al. (2002) revealed also an epifaunaly dominated interval, mainly by *Cibicidoides* group, corresponding the *Guembelitria cretacea* Zone from a K-Pg locality in Ain Settera, Tunisia. This change right at the K-Pg boundary may indicate a diminished food supply in the Danian for benthic foraminiferal fauna when compared to the Maastrichtian, turning the environment into more oligotrophic conditions in the Danian as offered by Peryt et al. (2002). This event might be possibly resulted from fall of primary productivity at the K-Pg boundary due to the extinction of planktonic organisms and the consequent interrupt of organic carbon flux (Culver, 2003). Additionally, relative abundaces of some serial infauna taxa including *Eouvigerina, Bolivinoides*, *Sitella*, *Reussella* and *Praebulimina* were reported to have been decreased or extinct ensuing the K-Pg boundary as stated by Widmark and Speijer (1997a and references therein). The authors also argued that these failure in the infaunal taxa is conspicuous in the upper bathyal localities such as El Kef, Nahal Avdat and Wadi Nukhl. In the Haymana Basin, the response of infaunal groups was found to be very similar to that of these Tethyan localites. In this sense, this established response of benthic foraminifera communities for the studied section, which is the observable decrease in the infauna taxa, supports above mentioned paleobathymetric assignment of the studied section (Figure 25).

The estimated biodiversity indices suggests that an open marine conditions based on the Shannon (H) index for average of 3.0 for whole studied section with minimum 2.7 and maximum 3.4. Moreover, Fisher α index indicates a highly diverse Maastrichtian fauna and relatively less diverse, namely poor to moderately diverse fauna in the Danian (Figure 26). It was reported that Higher Fisher α and Shannon-H values indicate higher diversities, while high dominance is associated with low diversity (Elamri et al., 2018).

At the Maastrichtian-Danian transition, based on only 82 identified taxa at specific level, 30 out of 73 identified Maastrichtian species apparently cross the boundary. 4 of the whole Maastrichtian taxa, which are Eouvigerina subsculptura, Heterostomella austinana, Heterostomella sp. 1 and Praebulimina reussi, are found in the first Danian sample (UH-50) which corresponds to reworked levels, P0 G. cretacea zone. These four taxa were recorded only in this sample, thereafter they disappeared from the record for the rest of the Danian section. This zone was reported earlier as reworking zone by Karabeyoğlu (2017). Furthermore, *Eouvigerina subsculptura* is mentioned to be extinct at the K-Pg boundary (Widmark and Speijer, 1997a). Therefore, these four Cretaceous taxa remained as suspicious survivors.

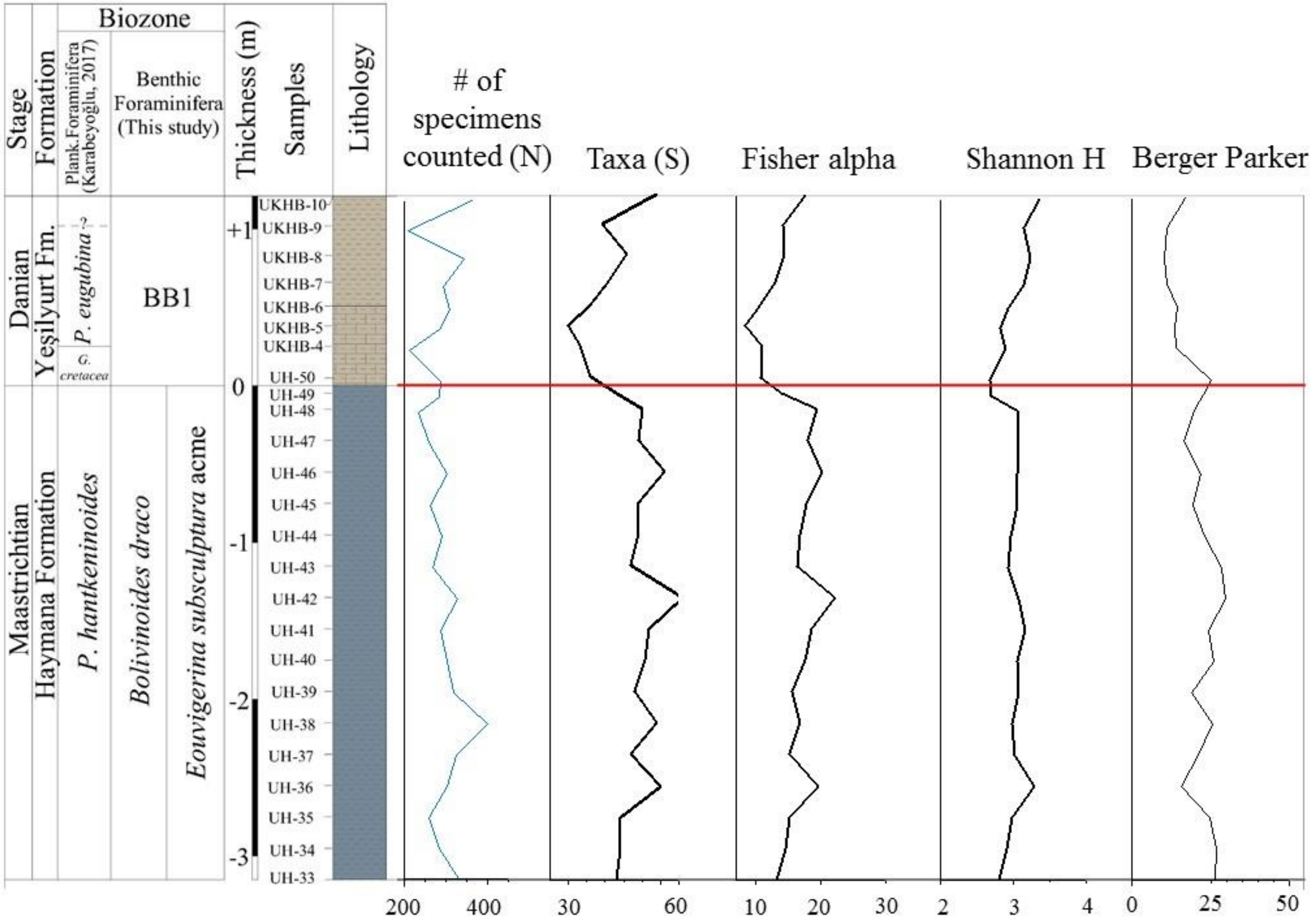

Figure 26: Distribution of estimated biodiversity indices through the studied samples. Not that red line corresponds to the of K-Pg boundary.

39 out of 73 Maastrichtian species was disappeared from the record and did not reappear in the studied interval, with the corresponding disappearance of 53%. Moreover, 9 new taxa appears in the Danian. There is an abrupt faunal response based on the dataset of relative abundance of species, many species assigned as epifaunal mode increased in the abundance right after the boundary event (Figure 27).

In conclusion, a total of 4.36 m thick stratigraphic section was quantitatively studied including mudstone and marl-calcareous mudstone samples of the Haymana Formation and the Yeşilyurt Formation from the Haymana Basin, Central Turkey. 3 suborders, 23 superfamily, 32 subfamily, 71 genus and 82 species were recognized after carrying out a detailed taxonomical study. The studied section was divided into three biozones. For the Maastrichtian part, *Bolivinoides draco* Zone and equivalent *Eouvigerina subsculptura* acme Zone (new in this study) were established. *Eouvigerina subsculptura* was found to be very abundant in all Maastrichtian samples (average 18.1%, up to 23.0%). Therefore, the acme zone of this index species was offered for this stratigraphic portion. *Angulogavelinella avnimelechi-Anomalinoides rubiginosus* Zone (BB1 Zone) was defined for the Danian part based on the benthic foraminiferal assemblage. Then, the K-Pg boundary was represented between the above mentioned two formations, through which a noticeable change in the assemblage composition was recorded.

Morphogroup analyses resulted that meso-eutrophic conditions were prevailed for the studied Maastrichtian section. Open-marine upper bathyal environment (~200-600 m) was offered based on the relative abundances of benthic foraminifera associations as well as their diversity for the whole studied section. Fisher α values show highly diverse fauna in the Maastrichtian (average 17.2) and poor to moderately diverse fauna in the Danian (average 12.5). Calcareous taxa were found to be abundant with respect to agglutinated taxa throughout the section which imply the deposition above the CCD level.

Considerable change was recorded from infaunally abundant highly diverse Maastrichtian assemblage to epifaunally dominant poor-moderately diverse Danian fauna after the K-Pg boundary. Moreover, just after the boundary in the Danian section, *Cibicidoides* spp. was recorded very abundant. This response probably resulted from the decline in the primary productivity coinciding at the K-Pg boundary event which resulted from the extinction of the planktonic organisms and interrupt in the organic carbon flux (Culver, 2003). These results are also pointing a possible diminished food supply in the Danian.

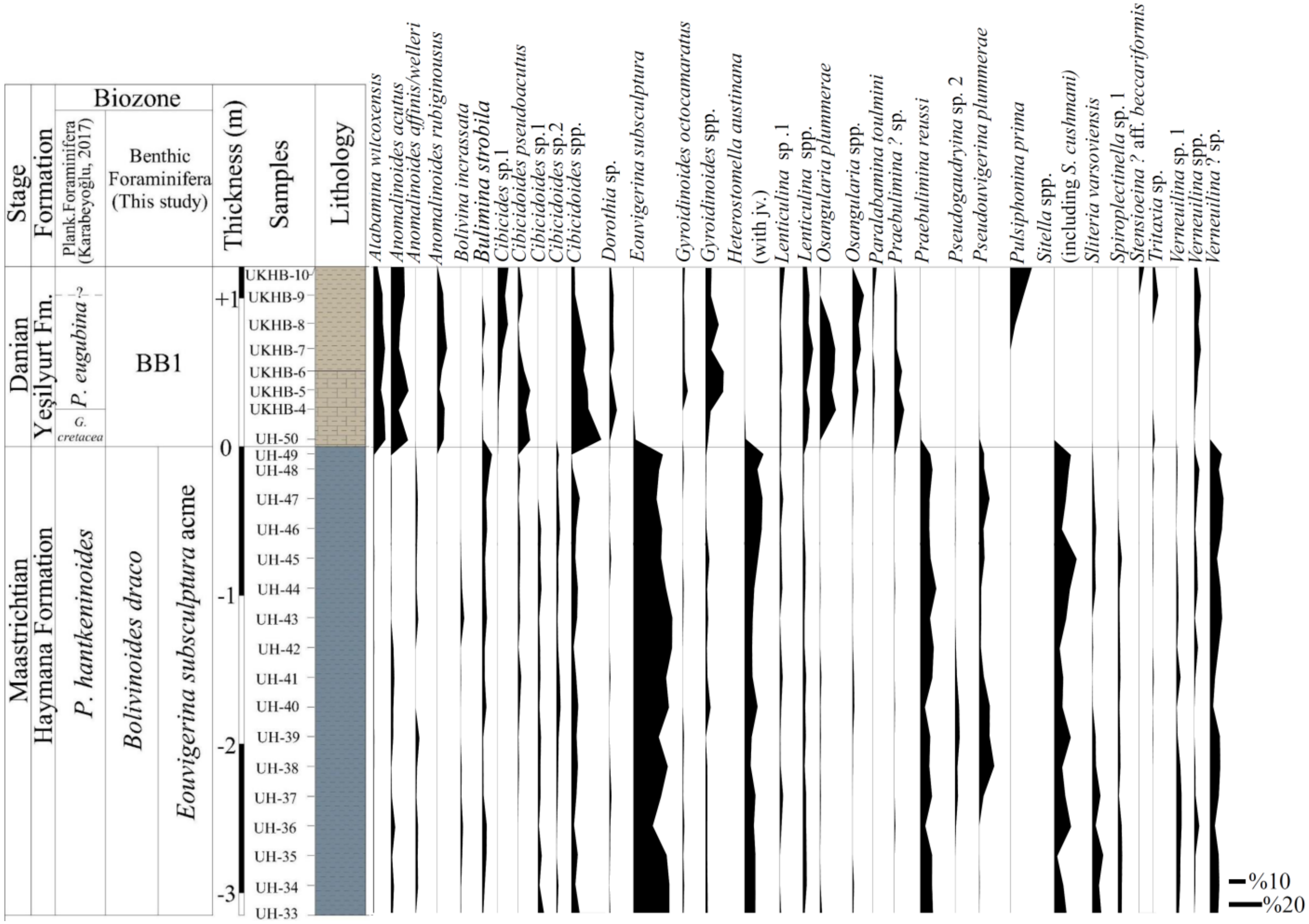

Figure 27: Relative abundances of the most common Maastrichtian and Danian benthic foraminifera taxa through the studied interval.

# REFERENCES

Alegret, L., Kaminski, M. A., & Molina, E. (2004). Paleoenvironmental Recovery After the Cretaceous Paleogene Boundary Crisis: Evidence From the Marine Bidart Section (SW France). *Palaios, 19,* 574–586.

Alegret, L., Molina, E., & Thomas, E. (2001). Benthic foraminifera at the Cretaceous-Tertiary boundary around the Gulf of Mexico. *Geology, 29*(10), 891–894.

Alegret, L., Molina, E., & Thomas, E. (2003). Benthic foraminiferal turnover across the Cretaceous/Paleogene boundary at Agost (southeastern Spain): paleoenvironmental inferences. *Marine Micropaleontology, 48,* 251–279. https://doi.org/10.1016/S0377-8398(03)00022-7

Alegret, L., Ortiz, S., Arreguín-Rodríguez, G. J., Monechi, S., Millán, I., & Molina, E. (2016). Microfossil turnover across the uppermost Danian at Caravaca, Spain: Paleoenvironmental inferences and identification of the latest Danian event. *Palaeogeography, Palaeoclimatology, Palaeoecology, 463,* 45–59. https://doi.org/10.1016/j.palaeo.2016.09.013

Alegret, L., & Thomas, E. (2001). Upper Cretaceous and lower Paleogene benthic Foraminifera from northeastern Mexico. *Micropaleontology, 47*(4), 269–316.

Alkan, Z., Özce, F. S., & Erdem, N. Ö. (2005). Haymana (Ankara güneybatısı) yöresi Maastrihtiyen-Daniyen bentik foraminifer paleoekolojisi. *Cumhuriyet Üniversitesi Mühendislik Fakültesi Dergisi, Seri A*-*Yerbilimleri*, *22*(1–2), 31–49.

Aly, H. A. (2016). Review of the Foraminiferal Genus *Marginulinopsis* Silvestri, 1904 to Identify the *Wignallyi* N. Genus. *Nature and Science*, *14*(11), 158–168.

Amirov, E. (2008). *Planktonic Foraminiferal Biostratigraphy, Sequence Stratigraphy and Foraminiferal Response to Sedimentary Cyclicity in the Upper Cretaceous-Paleocene of the Haymana Basin (Central Anatolia, Turkey)*. Ankara: MSc. Thesis, Middle East Technical University.

Anan, H. S. (2011a). Additional to the Maastrichtian foraminifera of the Middle East. *Revue de Paleobiologie*, *30*(1), 295–311.

Anan, H. S. (2011b). Maastrichtian small benthic foraminifera from Middle East and their distribution in the Tethys. *Revue de Paleobiologie, 30*(1), 13–30.

Arenillas, I., Molina, E., Arz, J. A., & Dupuis, C. (2000). The Cretaceous/Paleogene (K/P) Boundary at Ain Settara, Tunisia: Sudden Catastrophic Mass Extinction in Planktic Foraminifera. *Journal of Foraminiferal Research*, *30*(3), 202–218. https://doi.org/10.2113/0300202

Arıkan, Y. (1975). Tuzgölü havzasının jeolojisi ve petrol imkanları. *MTA Bülteni, 85,* 17–38.

Aubert, J., & Berggren, W. A. (1976). Paleocene Benthic Foraminiferal Biostratigraphy and Paleoecology of Tunisia. *Bull. Centre Rech. Pau - SNPA, 10*(2), 379–469.

Aydemir, A., & Ates, A. (2006). Structural interpretation of the Tuzgolu and Haymana Basins, Central Anatolia, Turkey, using seismic, gravity and aeromagnetic data. *Earth Planets Space*, *58,* 951–961. https://doi.org/10.1186/BF03352600

Ayyad, S. N. ., Abed, M. M., & Zied, R. H. A. (1997). Biostratigraphy of the Upper Cretaceous rocks in Gebel Arif El-Naga, northeastern Sinai, Egypt, based on benthonic foraminifera. *Cretaceous Research*, *18,* 141 – 159.

Banner, F. T., & Desai, D. (1985). The genus *Clavulinoides* Cushman emended and the new Cretaceous genus *Clavulinopsis*. *Journal of Foraminiferal Research, 15*(2), 79–90. https://doi.org/10.2113/gsjfr.15.2.79

Barr, F. T. (1970). The foraminiferal Genus *Bolivinoides* from the Upper Cretaceous Of Libya. *Journal Of Paleontology*, *44*, 642–654.

Berggren, W. A., & Aubert, J. (1975). Paleocene benthonic foraminiferal biostratigraphy, paleobiogeography and paleoecology of Atlantic-Tethyan regions: Midway-type fauna. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *18*, 73–192.

Berggren, W. A., & Miller, K. G. (1989). Cenozoic bathyal and abyssal calcareous benthic foraminiferal zonation. *Micropaleontology*, *35*(4), 308–320. https://doi.org/10.2307/1485674

Berggren, W. A., & Pearson, P. N. (2005). A Revised Tropical to Subtropical Paleogene Planktonic Foraminiferal Zonation. *The Journal of Foraminiferal Research*, *35*(4), 279–298. https://doi.org/10.2113/35.4.279

Bolli, H. M., Beckmann, J. P., & Saunders, J. B. (1994). Benthic foraminiferal biostratigraphy of the south Caribbean region.

Bornmalm, L., Corliss, B. H., & Tedesco, K. (1997). Laboratory observations of rates and patterns of movement of continental margin benthic foraminifera. *Marine Micropaleontology*, *29*(3–4), 175–184. https://doi.org/10.1016/S0377-8398(96)00013-8

BouDagher-Fadel, M. K. (2008). *Evolution and Geological Significance of Larger Benthic Foraminifera*. *Developments in Palaeontology and Stratigraphy* (Vol. 21). https://doi.org/10.1016/S0920-5446(08)00004-6

Brotzen, F. (1948). The Swedish Paleocene and its foraminiferal fauna. *Sveriges Geologiska Undersökning, Ser. C, 493*, *42*(2), 140.

Buzas, M. A., Culver, S. J., & Jorissen, F. J. (1993). A statistical evaluation of the microhabitats of living (stained) infaunal benthic foraminifera. *Marine Micropaleontology*, *20*(3–4), 311–320. https://doi.org/10.1016/0377-8398(93)90040-5

Chaput, E. (1932). Observations géologiques en Asie Mineure: Le Crétacé supérieur dans l’Anatolie Centrale. *C. R. A. S.*, *194*, 1960–1961.

Chaput, E. (1935a). L’Eocene du plateau de Galatie (Anatolie Centrale). *C. R. A. S.*, *200*, 767–768.

Chaput, E. (1935b). Les plissements Tertiare de l’Anatolie Centrale. *C. R. A. S.*, *201*, 1404–1405.

Chaput, E. (1936). *Voyages d’études géologiques et géomorphologiques en Turquie*. *Mém. Inst. Françaiş D’Archaéo*. İstanbul.

Coccioni, R., & Galeotti, S. (1994). K-T boundary extinction: geologically instantaneous or gradual event? Evidence from deep-sea benthic foraminifera. *Geology*, *22*(9), 779–782.

Coccioni, R., & Galeotti, S. (1998). What happened to small benthic foraminifera at the Cretaceous/Teritiary boundary? *Bull. Soc. Géol. France*, *169*(2), 271–279.

Coccioni, R., & Marsili, A. (2007). The response of benthic foraminifera to the K-Pg boundary biotic crisis at Elles (northwestern Tunisia). *Palaeogeography, Palaeoclimatology, Palaeoecology*, *255*(1–2), 157–180. https://doi.org/10.1016/j.palaeo.2007.02.046

Corliss, B. H., & Chen, C. (1988). Morphotype patterns of Norwegian Sea deep-sea benthic foraminifera and ecological implications. *Geology*, *16*(8), 716–719. https://doi.org/10.1130/0091-7613(1988)016<0716:MPONSD>2.3.CO

Culver, S. J. (2003). Benthic foraminifera across the Cretaceous-Tertiary (K-T) boundary: A review. *Marine Micropaleontology*, *47*(3–4), 177–226.

Cushman, J. A. (1926). The Foraminifera of the Velasco Shale of the Tampico Embayment. *American Association of Petroleum Geologists Bulletin*, *10*, 581–612.

Cushman, J. A. (1946). Upper Cretaceous foraminifera of the Gulf coastal region of the United States and adjacent areas. *United States Geological Survey Professional Paper*, *206*, 1–241.

Cushman, J. A. (1951). Paleocene foraminifera of the Gulf Coastal Region of the United States and adjacent areas. *Geological Survey Professional Paper*, *232*.

Çemen, I., Göncüoglu, M., & Dirik, K. (1999). Structural Evolution of the Tuzgölü Basin in Central Anatolia, Turkey. *The Journal of Geology*, *107*(6), 693–706. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10517884

Çetin, H., Demirel, İ. H., & Gökçen, S. L. (1986). Haymana ( Sw Ankara ) doğusu ve batısındaki Üst Kretase-Alt Tersiyer istifinin sedimantolojik ve sedimanter petrolojik incelenmesi. *Türkiye Jeoloji Kurumu Bülteni*, *29*, 21–33.

Dailey, D. H. (1983). 34. Late Cretaceous and Paleocene Benthic Foraminifers From Deep Sea Drilling Project Site 516, Rio Grande Rise, Western South Atlantic Ocean. *Sites The Journal Of 20Th Century Contemporary French Studies*, 757–782.

Dinçer, F. (2016). Eocene benthic foraminiferal assemblages from Central Anatolia (Turkey): Biostratigraphy, stable isotope data, paleoenvironmental and paleontological interpretations. *Journal of African Earth Sciences*, *114*, 143–157. https://doi.org/10.1016/j.jafrearsci.2015.11.024

Dubicka, Z., & Peryt, D. (2012). Latest Campanian and Maastrichtian palaeoenvironmental changes: Implications from an epicontinental sea (SE Poland and western Ukraine). *Cretaceous Research*, *37*, 272–284. https://doi.org/10.1016/j.cretres.2012.04.009

Dubicka, Z., & Peryt, D. (2016). *Bolivinoides* (benthic foraminifera) from the Upper Cretaceous of Poland and Western Ukraine: Taxonomy, Evolutionary Changes and Stratigraphic Significance. *Journal of Foraminiferal Research*, *46*(1), 75–94.

Dubicka, Z., Złotnik, M., & Borszcz, T. (2015). Test morphology as a function of behavioral strategies - Inferences from benthic foraminifera. *Marine Micropaleontology, 116,* 38–49. https://doi.org/10.1016/j.marmicro.2015.01.003

Egeran, E. N., & Lahn, E. (1951). Kuzey ve Orta Anadolu’nun tektonik durumu hakkında not. *MTA Bülteni,* (41), 23–28.

El-Nady, H. (2006). Contribution to the stratigraphic significance of the Genus *Bolivinoides* and their paleoecology across the Campanian/Maastrichtian boundary in the Gabal El-Mouriefik section, Eastern Sinai, Egypt. *Revue de Paleobiologie*, *25*(2), 671–692.

Elamri, Z., Farouk, S., & Zaghbib-Turki, D. (2018). Benthic foraminiferal paleoenvironmental reconstruction from the Upper Coniacian-Lower Campanian succession in north-western Tunisia. *Revue de Micropaleontologie*, *61*(1), 23–36. https://doi.org/10.1016/j.revmic.2017.11.003

Ellis, B., & Messina, A. (1940). *Catalogue of Foraminifera*. New York: American Museum of Natural History.

Ernst, S. R., Guasti, E., Dupuis, C., & Speijer, R. P. (2006). Environmental perturbation in the southern Tethys across the Paleocene/Eocene boundary (Dababiya, Egypt): Foraminiferal and clay mineral records. *Marine Micropaleontology*, *60*(1), 89–111. https://doi.org/10.1016/j.marmicro.2006.03.002

Esmeray-Senlet, S., Özkan-Altiner, S., Altiner, D., & Miller, K. G. (2015). Planktonic foraminiferal biostratigraphy, microfacies analysis, sequence stratigraphy, and sea-level changes across the cretaceous-paleogene boundary in the Haymana Basin, Central Anatolia, Turkey. *Journal of Sedimentary Research, 85*(5), 489–508. https://doi.org/10.2110/jsr.2015.31

Esmeray, S. (2008). *Cretaceous/Paleogene Boundary in the Haymana Basin,* *Central Anatolia, Turkey: Micropaleontological, Mineralogical and Sequence Stratigraphic Approach*. Ankara: MSc. Thesis, Middle East Technical University.

Frenzel, P. (2000). Die benthischen Foraminiferen der Rügener Schreibkreide (Unter-Maastricht, NE-Deutschland). *Neue Paläontol. Abh.*, *3*, 1–361.

Friedrich, O., & Hemleben, C. (2007). Early Maastrichtian benthic foraminiferal assemblages from the western North Atlantic (Blake Nose) and their relation to paleoenvironmental changes. *Marine Micropaleontology*, *62*, 31–44. https://doi.org/10.1016/j.marmicro.2006.07.003

Friedrich, O., Herrle, J. O., & Hemleben, C. (2005). Climatic changes in the Late Campanian - Early Maastrichtian: micropaleontological and stable isotopic evidence from an epicontinental sea. *Journal of Foraminiferal Research*, *35*(3), 228–247. https://doi.org/10.2113/35.3.228

Galeotti, S., & Coccioni, R. (2002). Changes in coiling direction of *Cibicidoides pseudoacutus* (Nakkady) across the Cretaceous-Tertiary boundary of Tunisia: palaeoecological and biostratigraphic implications. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *178*, 197–210. https://doi.org/10.1016/S0031-0182(01)00396-0

Gallala, N., Zaghbib-Turki, D., Arenillas, I., Arz, J. A., & Molina, E. (2009). Catastrophic mass extinction and assemblage evolution in planktic foraminifera across the Cretaceous/Paleogene (K/Pg) boundary at Bidart (SW France). *Marine Micropaleontology*, *72*, 196–209. https://doi.org/10.1016/j.marmicro.2009.05.001

Gawor-Biedowa, E. (1992). Campanian and Maastrichtian foraminifera from the Lublin Upland, eastern Poland. *Palaeontologia Polonica*, *52*, 3–187.

Gooday, A. J. (2003). Benthic foraminifera (protista) as tools in deep-water palaeoceanography: Environmental influences on faunal characteristics. *Advances in Marine Biology*, *46*, 1–90.

Gökçen, S. L. (1976). Haymana güneyinin sedimentolojik incelemesi. *I. Stratigrafik Birimler ve Tektonik*, *2*, 161–201.

Görmüş, M. (1990). *Stratigraphy and Foraminiferal Micropaleontology of Upper Cretaceous in Hekimhan, NW Malatya, Turkey*. University of Hull.

Görmüş, M. (1992a). Hekimhan (KB Malatya) Yöresindeki İstiflerin Biyostratigrafik İncelemesi. *Türkiye Jeoloji Kurultayı Bülteni*, *7*, 179–191.

Görmüş, M. (1992b). Quantitative Data on the Relationship between the Orbitoides genus and its Environment. *Revista Espanola de Micropaleontologia*, *XXIV*(3), 13–26.

Görmüş, M. (1994a). Campanian-Maastrichtian Foraminiferid Fauna in the Hekimhan Area. *10th. Petroleum Congress, Geology*, 165–198.

Görmüş, M. (1994b). Hekimhan (KB Malatya) Yöresindeki Üst Kretase Çökellerinde Fasiyes-Organizma Dağılımı. *Doğa Yerbilimleri Dergisi*, *3*(1), 1–15.

Görmüş, M. (1999). Pseudedomia hekimhanensis n.sp from the Late Campanian? to Maastrichtian of Hekimhan, NW Malatya, Turkey. *Journal of Foraminiferal Research*, *29*(3), 64–70.

Görür, N. (1981). Tuzgölü-Haymana havzasının stratigrafik analizi. In *İç Anadolunun Jeolojisi Sempozyumu* (pp. 60–66). Ankara: Türkiye Jeoloji Kurultayı.

Görür, N., Tüysüz, O., & Celal Şengör, A. M. (1998). Tectonic evolution of the central anatolian basins. *International Geology Review*, *40*(9), 831–850. https://doi.org/10.1080/00206819809465241

Haig, D. W. (1979). Global Distribution Patterns for Mid-Cretaceous Foraminiferids. *Journal of Foraminiferal Research*, *9*(1), 29–40. https://doi.org/10.2113/gsjfr.9.1.29

Hammer, O. (2002). *Palaeontological community and diversity analysis – brief notes*. Zürich.

Hammer, Ø., & Harper, D. A. T. (2006). *Paleontological Data Analysis*. Blackwell Publishing.

Hammer, Ø., Harper, D. A. T., & Ryan, P. D. (2001). Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica*, *4*(1), 9.

Hayek, L.-A. C., & Buzas, M. A. (2013). On the Proper and Efficient Use of Diversity Measures with Individual Field Samples. *The Journal of Foraminiferal Research*, *43*(3), 305–313. https://doi.org/10.2113/gsjfr.43.3.305

Hemleben, C., Kaminski, M. A., Kuhnt, W., & Seott, D. B. (1990). Paleoecology, Biostratigraphy, Paleoceanography and Taxonomy of Agglutinated Foraminifera. In *Proceedings of the NATO Advanced Study Institute* (pp. 3–1017). Springer Science+Business Media Dordrecht.

Hermelin, J. O. R., & Malmgren, B. A. (1980). Multivariate analysis of environmentally controlled variation in Lagena: Late Maastrichtian, Sweden. *Cretaceous Research*, *1*(3), 193–206.

Hodgkinson, R. L. (1991). Microfossil Processing: A Damage Report. *Micropaleontology*, *37*(3), 320. https://doi.org/10.2307/1485894

Holbourn, A., Henderson, A. S., & Macleod, N. (2013). Atlas of Benthic Foraminifera. *Wiley-Blackwell*, 654.

Hoşgör, I., & Okan, Y. (2011). A New Species of Angariid Gastropod from the Early Thanetian of the Haymana-Polatli Basin, Turkey. *Turkish Journal of Earth Sciences*, *20*, 243–253. https://doi.org/10.3906/yer-0909-3

Hoşgör, İ. (2012). *Haymana-Polatlı Havzası Paleosen Mollusklarının Taksonomik Tanımlanması, Paleoekolojisi, Paleocoğrafyası ve Bentik Foraminiferlerle*

*Biyostratigrafik Deneştirilmesi*. Ankara: PhD. Tez, Ankara Üni. Fen Bilimleri Ens.

Hottinger, L. (2006). Illustrated glossary of terms used in foraminiferal research. *Carnets de Géologie (Notebooks on Geology)*, *2*(Mémoires), 44–64. https://doi.org/10.4267/2042/5832

Huseynov, A. (2007). *Sedimentary cyclicity in the Upper Cretaceous successions of the Haymana Basin (Turkey): depositional sequences as response to relative sea—level changes*. Ankara: MSc. Thesis, Middle East Technical University.

Islamoglu, Y., Dominici, S., & Kowalke, T. (2011). Early Eocene Caenogastropods (Mollusca, Gastropoda) from Haymana-Polatli Basin, Central Anatolia (Turkey): taxonomy and palaeoecology. *Geodiversitas*, *33*(2), 303–330. https://doi.org/10.5252/g2011n2a7

Jorissen, F. J., de Stigter, H. C., & Widmark, J. G. V. (1995). A conceptual model explaining benthic foraminiferal microhabitats. *Marine Micropaleontology*, *26*, 3–15. https://doi.org/10.1016/0377-8398(95)00047-X

Kaiho, K. (1992). A low extinction rate of intermediate-water benthic foraminifera at the Cretaceous/Tertiary boundary. *Marine Micropaleontology*, *18*, 229–259. https://doi.org/10.1016/0377-8398(92)90014-B

Kaminski, M. A., & Gradstein, F. M. (2005). Atlas of Paleogene Cosmopolitan Deep Water Agglutinated Foraminifera. Retrieved from http://www.nhm2.uio.no/norges/atlas/

Kaminski, M. A., Gradstein, F. M., Berggren, W. A., Geroch, S., & Beckmann, J. P. (1988). Flysch-Type Agglutinated Foraminiferal Assemblages From Trinidad : Taxonomy , Stratigraphy and Paleobathymetry. *Abhandlungen Der Geologischen Bundesanstalt*, *41*, 155–227.

Kaminski, M. A., & Lazarus, D. B. (2009). The lectotype of *Spiroplecta rosula*

Ehrenberg, 1854 – the type species of Bolivinopsis Yakovlev, 1891 (Foraminifera). *Journal of Micropalaeontology*, *28,* 189–190. https://doi.org/doi: 10.1144/jm.28.2.189

Karabeyoğlu, A. U. (2017). *Planktonic Foraminiferal Diversity and Abundance Changes Across Cretaceous-Paleogene Boundary Beds in The Haymana Basin and New Observations on The Extinction Horizon*. Ankara: MSc. Thesis, Middle East Technical University.

Kaymakçı, N. (2000). *Tectono-stratigraphical evolution of the Çankırı Basin (Central Anatolia, Turkey).* Utrecht: PhD Thesis, Utrecht University.

Keller, G. (1988). Biotic turnover in benthic foraminifera across the Cretaceous/Tertiary boundary at El Kef, Tunisia. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *66*(3–4), 153–171.

Koçyiğit, A. (1991). An example of an accretionary forearc basin from northern Central Anatolia and its implications for the history of subduction of Neo-Tethys in Turkey. *Geological Society of America Bulletin*, *103*(1), 22–36. https://doi.org/10.1130/0016-7606(1991)103<0022:AEOAAF>2.3.CO;2

Koçyiğit, A., Özkan, S., & Rojay, B. (1988). Examples from the forearc basin remnants at the active margin of northern Neo-Tethys: development and emplacement ages of the Anatolian Nappe, Turkey. *Middle East Technical University Journal of Pure and Applied Sciences*, *20*(1–3), 183–210.

Koutsoukos, E. A. M., & Hart, M. B. (1990). Cretaceous foraminiferal morphogroup distribution patterns, palaeocommunities and trophic structures: A case study from the Sergipe Basin, Brazil. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, *81*(3), 221–246.

Kuhnt, W., Kaminski, M. A., & Moullade, M. (1989). Late Cretaceous deep-water agglutinated foraminiferal assemblages from the North Atlantic and its marginal seas. *Geologische Rundschau*, *78*(3), 1121–1140. https://doi.org/10.1007/BF01829336

Lahn, E. (1949). On the Geology of Central Anatolia. *Türkiye Jeoloji Kurumu Bülteni*, *1*.

LeRoy, L. W. (1953). Biostratigraphy of the Maqfi Section, Egypt. *Geological Society of America Memoirs, 54,* 1–73. https://doi.org/https://doi.org/10.1130/MEM54

Li, L., & Keller, G. (1998). Maastrichtian climate, productivity and faunal turnovers in planktic foraminifera in South Atlantic DSDP sites 525A and 21. *Marine Micropaleontology, 33*, 55–86. https://doi.org/10.1016/S0377-8398(97)00027-3

Loeblich, A. R., & Tappan, H. (1988). *Foraminiferal Genera and Their Classification*. New York: Van Nostrand and Reinhold Company.

Lokman, K., & Lahn, E. (1946). Géologie de la région de Haymana. *MTA Bülteni, 36*, 292–300.

Machalski, M., Vellekoop, J., Dubicka, Z., Peryt, D., & Harasimiuk, M. (2016). Late Maastrichtian cephalopods, dinoflagellate cysts and foraminifera from the Cretaceous-Paleogene succession at Lechówka, southeast Poland: Stratigraphic and environmental implications. *Cretaceous Research*, *57*, 208–227. https://doi.org/10.1016/j.cretres.2015.08.012

MacLeod, N., & Keller, G. (1994). Comparative biogeographic analysis of planktic foraminiferal survivorship across the Cretaceous/Tertiary (K/T) boundary. *Paleobiology*, *20*(2), 143–177. https://doi.org/10.1017/S0094837300012653

Marie, P. (1941). Les foraminiferes de la craie a Belemnitella mucronata du bassin de Paris. *Muséum National D'histoire Naturelle*, *12*(1), 1–296.

Matsumaru, K. (1997). On *Pseudorbitoides trechmanni* douvillé (Orbitoidal Foraminifera) from Turkey. *Revue de Micropaleontologie, 40*(4), 339–346. https://doi.org/10.1016/S0035-1598(97)90684-X

Meriç, E., & Görür, N. (1981). Haymana-Polatlı havzasındaki Çaldağ kireçtaşının kireçtaşının yaş konağı. *MTA Bülteni*, *93/94*, 137–142.

Molina, E., Alegret, L., & Arenillas, I. (2004). The Cretaceous/Paleogene boundary at the Agost section revisited: paleoenvironmental reconstruction and mass extinction pattern. *Journal of Iberian Geology*, *31*, 135–148.

Molina, E., Alegret, L., Arenillas, I., Arz, J. a., Gallala, N., Hardenbol, J., … Zaghbib-Turki, D. (2006). The Global Boundary Stratotype Section and Point for the base of the Danian Stage (Paleocene, Paleogene, "Tertiery", Cenozoic) at El Kef , Tunisia- Original definition and revision. *Episodes*, *29*(1989), 265–273.

Nairn, S. P., Robertson, A. H. F., Ünlügenç, U. C., Tasli, K., & İnan, N. (2013). Tectonostratigraphic evolution of the Upper Cretaceous–Cenozoic central Anatolian basins: an integrated study of diachronous ocean basin closure and continental collision. *Geological Society, London, Special Publications*, *372*(1), 343–384. https://doi.org/10.1144/SP372.9

Nakkady, S. E. (1950). A New Foraminiferal Fauna from the Esna Shales And Upper Cretaceous Chalk of Egypt. *Journal of Paleontology*, *24*(6), 675–692.

Nomura, R. (1991). Paleoceanography of Upper Maastrichtian to Eocene Benthic Foraminiferal Assemblages at Sites 752, 753, and 754, Eastern Indian Ocean. In J. Weissel, J. Pierce, E. Taylor, & J. Alt (Eds.), *Proceedings of the Ocean Drilling Program, Scientific Results* (Vol. 121, pp. 3–29).

Norman, T., & Rad, M. R. (1971). Çayraz (Haymana) civarının Horhor (Eosen) formasyonunda alttan üste doğru doku parametrelerinde ve ağır mineral bolluk derecelerinde değişmeler. *TJK Bülteni*, *14*(2), 205–225.

Okay, A. I. (1989). Tectonic Units and Sutures in the Pontides, Northern Turkey. In *Tectonic Evolution of the Tethyan Region* (pp. 109–116). https://doi.org/10.1007/978-94-009-2253-2_6

Okay, A. I. (2008). Geology of Turkey: A synopsis. *Anschnitt, 21,* 19–42. https://doi.org/10.1007/s004100050572

Okay, A. I., & Altiner, D. (2016). Carbonate sedimentation in an extensional active margin: Cretaceous history of the Haymana region, Pontides. *International Journal of Earth Sciences*, *105*, 2013–2030. https://doi.org/10.1007/s00531-016-1313-4

Orabi, O. H., & Khalil, H. M. (2014). Calcareous benthonic foraminifera across the Cretaceous/Paleocene transition of Gebel Um El-Ghanayem, Kharga Oasis, Egypt. *Journal of African Earth Sciences*, *96*, 110–121. https://doi.org/10.1016/j.jafrearsci.2014.03.017

Ortiz, S., & Thomas, E. (2006). Lower-middle Eocene benthic foraminifera from the Fortuna Section (Betic Cordillera, southeastern Spain). *Micropaleontology*, *52*(2), 97–150. https://doi.org/10.2113/gsmicropal.52.2.97

Özcan, E. (2002). Cuisian orthophragminid assemblages (*Discocyclina*, *Orbitoclypeus* and *Nemkovella*) from the Haymana-Polatli Basin (central Turkey): Biometry and description of two new taxa. *Eclogae Geologicae Helvetiae*, *95*, 75–97.

Özcan, E., Sirel, E., Altıner-Özkan, S., & Çolakoğul, S. (2001). Late Paleocene Orthophragminae (Foraminifera) from the Haymana-Polatli Basin, central Turkey and description of a new taxon, *Orbitoclypeus haymanaensis*. *Micropaleontology*, *47*(4), 339–357. https://doi.org/10.2113/47.4.339

Özcan, E., & Ozkan-Altiner, S. (2001). Description of an early ontogenetic evolutionary step in *Lepidorbitoides: Lepidorbitoides bisambergensis asymmetrica* subsp. n., early maastrichtian (Central Turkey). *Rivista Italiana Di Paleontologia E Stratigrafia*, *107*(1), 137–144.

Özcan, E., & Özkan-Altiner, S. (1997). Late Campanian-Maastrichtian evolution of orbitoidal foraminifera in Haymana basin succession (Ankara, Central

Turkey). *Revue de Paleobiologie*, *16*(1), 271–290.

Özcan, E., & Özkan-Altiner, S. (1999). The genus *Lepidorbitoides*: Evolution and stratigraphic significance in some Anatolian basins (Turkey). *Revue de Micropaleontologie*, *42*(2), 111–131. https://doi.org/10.1016/S0035-1598(99)90109-5

Özkan-Altiner, S., & Özcan, E. (1999). Upper Cretaceous planktonic foraminiferal biostratigraphy from NW Turkey: Calibration of the stratigraphic ranges of larger benthonic foraminifera. *Geological Journal*, *34*, 287–301. https://doi.org/10.1002/(SICI)1099-1034(199907/09)34:3<287::AID-GJ828>3.0.CO;2-B

Peryt, D., Alegret, L., & Molina, E. (2002). The Cretaceous/Palaeogene (K/P) boundary at Aı¨n Settara, Tunisia: restructuring of benthic foraminiferal assemblages. *Terra Nova*, *14*(2), 101–107.

Peryt, D., Alegret, L., & Molina, E. (2004). Agglutinated foraminifers and their response to the Cretaceous/Paleogene (K/P) boundary event at Ain Settara, Tunisia. In M. Bubik & M. A. Kaminski (Eds.), *Proceedings of the Sixth International Workshop on Agglutinated Foraminifera.* (pp. 393–412). Grzybowski Foundation Special Publication.

Peryt, D., & Dubicka, Z. (2015). Foraminiferal bioevents in the upper campanian to lowest maastrichtian of the middle vistula river section, Poland. *Geological Quarterly*, *59*(4), 814–830. https://doi.org/10.7306/gq.1252

Peryt, D., Lahodynsky, R., & Durakiewicz, T. (1997). Deep-water agglutinated foraminiferal changes and stable isotope profiles across the Cretaceous-Paleogene boundary in the Rotwandgraben section, Eastern Alps (Austria). *Palaeogeography, Palaeoclimatology, Palaeoecology*, *132*(1–4), 287–307. https://doi.org/10.1016/S0031-0182(97)00056-4

Plummer, H. J. (1926). Foraminifera of the Midway Formation inTexas. *University of Texas Bulletin*, *2644*, 4–206.

Rad, M. R. (1971). *Vertical variations in textural parameters and heavy mineral abundance of Harhor formation (Eocene) in the Çayraz (Haymana) area.* Ankara: MSc. Thesis, Middle East Technical University.

Reckamp, J. U., & Özbey, S. (1960). *Petroleum geology of Temelli and Kuştepe structures, Polatlı area*. Ankara.

Reich, M., & Frenzel, P. (2002). Die Fauna und Flora der Rügener Schreibkreide (Maastrichtium, Ostsee). *Archiv Für Geschiebekunde, 3*(2/4), 73–284.

Rigo de Righi, M., & Cortesini, A. (1959). *Regional studies in central Anatolian basin. Progress Report 1*. Ankara.

Rojay, B. (2013). Tectonic evolution of the Cretaceous Ankara Ophiolitic Mélange during the Late Cretaceous to pre-Miocene interval in Central Anatolia, Turkey. *Journal of Geodynamics, 65*, 66–81.

Rojay, B., & Süzen, M. L. (1997). Tectonostratigraphic evolution of an arctrench basin on accretionary ophiolitic melange prism, Central Anatolia, Turkey. *The Bulletin of Turkish Association of Petroleum Geologists, 9*(1), 1–12.

Salaj, J., Pozaryska, K., & Szczechura, J. (1976). Foraminiferida, Zonation and Subzonation of The Paleocene of Tunisia. *Acta Paleontologica Polonica, 21*(2).

Schmidt, G. C. (1960). *AR/MEM/365-266-367 sahalarının nihai terk raporu*. Ankara.

Schröeder, C. J., Scotta, B., & Medioli, F. S. (1987). Can smaller benthic foraminifera be ignored in paleoenvironmental analyses? *JournaI of Foraminifeal Research*, *17*(2), 101–105. https://doi.org/10.2113/gsjfr.17.2.101

Setoyama, E., Kaminski, M. A., & Tyszka, J. (2017). Late Cretaceous – Paleogene foraminiferal morphogroups as palaeoenvironmental tracers of the rifted Labrador margin , northern proto-Atlantic. In *Proceedings of the Ninth*

*International Workshop on Agglutinated Foraminifera* (Vol. Grzybowski, pp. 179–220).

Sirel, E. (1975). Polatlı (GB Ankara) güneyinin stratigrafisi. *Bulletin of the Geological Society of Turkey*, *18*, 181–192.

Sirel, E. (1976a). Description of six new species of the *Alveolina* found in the South of Polatlı (sw Ankara) region. *Bulletin of the Geological Society of Turkey*, *19*, 19–22.

Sirel, E. (1976b). Haymana (G Ankara) yöresi İlerdiyen, Küiziyen ve Lütesiyen'deki *Nummulites*, *Assilina* ve *Alveolina* cinslerinin bazı türlerinin tanımlamaları ve stratigrafik dağılımları. *Türkiye Jeoloji Kurumu Bülteni*, *19*, 31–44.

Sirel, E. (1976c). Polatlı (GB Ankara) güneyinde bulunan *Alveolina, Nummulites, Ranikothalia* ve *Assilina* cinslerinin bazı türlerinin sistematik inclemeleri. *Türkiye Jeoloji Kurumu Bülteni*, *19/2*, 89–103.

Sirel, E. (1999). Four new genera (*Haymanella*, *Kayseriella*, *Elazigella* and *Orduella*) and one new species of *Hottingerina* from the Paleocene of Tlrkey. *Micropaleontology*, *45*(2), 113–137.

Sirel, E., Dağer, Z., & Sözeri, B. (1986). Some biostratigraphic and paleogeographic observations on the Cretaceous-Tertiary boundary in the Haymana-Polatlı region (Central Turkey). In O. Walliser (Ed.) (pp. 385–396).

Sliter, W. V., & Baker, R. a. (1972). Cretaceous bathymetric distribution of benthic foraminifers. *Journal of Foraminiferal Research*, *2*(4), 167–183. https://doi.org/10.2113/gsjfr.2.4.167

Speijer, R. P. (1994). *Extinction and recovery patterns in benthic foraminiferal paleocommunities across the Cretaceous/Paleogene and Paleocene/Eocene boundaries*. *Geologica Ultraiectina*. Utrecht: PhD Thesis, Utrecht University.

Speijer, R. P., & Van Der Zwaan, G. J. (1996). Extinction and survivorship of southern Tethyan Benthic foraminifera across the Cretaceous/Palaeogene boundary. *Geological Society, London, Special Publications*, *102*(1), 343–371. https://doi.org/10.1144/GSL.SP.1996.001.01.26

Sprong, J., Kouwenhoven, T. J., Bornemann, A., Schulte, P., Stassen, P., Steurbaut, E., … Speijer, R. P. (2012). Characterization of the Latest Danian Event by means of benthic foraminiferal assemblages along a depth transect at the southern Tethyan margin (Nile Basin, Egypt). *Marine Micropaleontology, 86–87,* 15–31. https://doi.org/10.1016/j.marmicro.2012.01.001

Stassen, P., Dupuis, C., Morsi, A. M., Steurbaut, E., & Speijer, R. P. (2009). Reconstruction of a latest Paleocene shallow-marine eutrophic paleoenvironment at Sidi Nasseur (Central Tunisia) based on foraminifera, ostracoda, calcareous nannofossils and stable isotopes (δ13C, δ18O). *Geologica Acta*, *7*(1–2), 93–112. https://doi.org/10.1344/105.000000273

Şenalp, M., & Gökçen, S. L. (1978). Haymana (GB Ankara) Yöresindeki Petrol lü Kumtaşlarının Sedimantolojik incelemesi. *Türkiye Jeoloji Kurumu Bülteni, 21*, 87–94.

Şengör, A. M. C., & Yilmaz, Y. (1981). Tethyan evolution of Turkey: A plate tectonic approach. *Tectonophysics*, *75*(3–4). https://doi.org/10.1016/0040-1951(81)90275-4

Thomas, E. (1989). Development of Cenozoic deep-sea benthic foraminiferal faunas in Antarctic waters. *Geological Society, London, Special Publications*, *47*(1), 283–296. https://doi.org/10.1144/GSL.SP.1989.047.01.21

Thomas, E. (1990). Late Cretaceous-early Eocene mass extinctions in the deep sea. *Geological Society of America Special Paper*, *247*, 481–495.

Thomas, E. (1990). Late Cretaceous through Neogene deep-sea benthic foraminifers (Maud Rise, Weddell Sea, Antarctica). *Proceedings of the Ocean Drilling Program, Scientific Results, 113,* 571–594.

Toker, V. (1975). *Haymana yöresinin (SW Ankara) planktonik foraminifera ve nannoplanktonlarla biyostratigrafik incelenmesi*. Ankara Üniversitesi Fen Fakültesi. Ankara, PhD. Thesis: Ankara Üni. Fen Fak.

Toker, V. (1977). Haymana ve Kavak formasyonlarındaki planktonik foraminifera ve nannoplanktonlar. In *TBTAK VI. Bilim Kongresi* (pp. 57–70).

Toker, V. (1979). Haymana yöresi (GB Ankara) Üst Kretase planktonik foraminiferaları ve biyostratigrafi incelemesi. *TJK Bülteni, 22*, 121–132.

Toker, V. (1980). Haymana yöresi (GB Ankara) nannoplankton biyostratigrafisi. *TJK Bülteni*, *23*(2), 165–178.

Toker, V. (1981). Haymana yöresi (GB Ankara) Tersiyer oluşuklarının planktonik foraminiferlerle biyostratigrafik incelemesi. *KTÜ Yer Bilimleri Dergisi, Jeoloji*, *1–2*, 115–126.

Totman Parrish, J., & Curtis, R. L. (1982). Atmospheric circulation, upwelling, and organic-rich rocks in the Mesozoic and Cenozoic eras. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *40*(1–3), 31–66. https://doi.org/10.1016/0031-0182(82)90084-0

Ünalan, G., Yüksel, V., Tekeli, T., Gönenç, O., Seyirt, Z., & Hüseyin, S. (1976). Haymana-Polatli yöresinin (güneybatı Ankara) Üst Kretase-Alt Tersiyer stratigrafisi ve paleocoğrafik evrimi. *Türkiye Jeoloji Kurumu Bülteni*, *19*, 159–176.

Van den Akker, T. J. H. A., Kaminski, M. A., Gradstein, F. M., & Wood, J. (2000). Campanian to Palaeocene biostratigraphy and palaeoenvironments in the Foula Sub-basin, west of the Shetland Islands, UK. *Journal of Micropaleontology*. https://doi.org/10.1144/jm.19.1.23

Van Der Zwaan, G. J., Duijnstee, I. A. P., Den Dulk, M., Ernst, S. R., Jannink, N. T., & Kouwenhoven, T. J. (1999). Benthic foraminifers: Proxies or problems? A review of paleocological concepts. *Earth Science Reviews, 46*(1–4), 213–

236. https://doi.org/10.1016/S0012-8252(99)00011-2

Van Morkhoven, F. P. C. M., Berggren, W. A., Edwards, A. S., & Oertli, H. . (1986). Cenozoic Cosmopolitan Deep-Water Benthic Foraminifera. *Bulletin Des Centres de Recherches Exploration-Production Elf-Aquitaine Mem 11*, 1–421.

Vellekoop, J., Woelders, L., Açikalin, S., Smit, J., Van De Schootbrugge, B., Yilmaz, I. O., Brinkhuis, H., Speijer, R. P. (2017). Ecological response to collapse of the biological pump following the mass extinction at the Cretaceous-Paleogene boundary. *Biogeosciences*, *14*, 885–900. https://doi.org/10.5194/bg-14-885-2017

Walaszczyk, I., Dubicka, Z., Olszewska-Nejbert, D., & Remin, Z. (2016). Integrated biostratigraphy of the Santonian through Maastrichtian (Upper Cretaceous) of extra-Carpathian Poland. *Acta Geologica Polonica*, *66*(3), 313–350. https://doi.org/10.1515/agp-2016-0016

Weidich, K. F. (1995). The genus *Angulogavelinella* Hofker, 1957, and its species (Foraminiferida, Rotaliina, Upper Cretaceous-lower Tertiary). *Journal of Foraminiferal Research*, *25*(4), 309–333. https://doi.org/10.2113/gsjfr.25.4.309

Widmark, J. G. V. (1997). Deep-sea benthic foraminifera from Cretaceous-Paleogene boundary strata in the South Atlantic- taxonomy and paleoecology. *Fossils and Strata*, *43*, 1–94.

Widmark, J. G. V. (2000). Biogeography of terminal Cretaceous benthic foraminifera: Deep-water circulation and trophic gradients in the deep South Atlantic. *Cretaceous Research*, *21*, 367–379. https://doi.org/10.1006/cres.1999.0193

Widmark, J. G. V., & Malmgren, B. A. (1992a). Benthic foraminiferal changes across the Cretaceous/Tertiary boundary in the deep sea; DSDP sites 525, 527, and 465. *Journal of Foraminiferal Research*, *22*(2), 81–113.

https://doi.org/10.2113/gsjfr.22.2.81

Widmark, J. G. V., & Malmgren, B. A. (1992b). Biogeography of terminal Cretaceous deep-sea benthic foraminifera from the Atlantic and Pacific Oceans. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *92*, 375–405. https://doi.org/10.1016/0031-0182(92)90092-J

Widmark, J. G. V, & Speijer, R. P. (1997a). Benthic foraminiferal ecomarker species of the terminal Cretaceous (late Maastrichtian) deep-sea Tethys. *Marine Micropaleontology*, *31*, 135–155.

Widmark, J. G. V, & Speijer, R. P. (1997b). Benthic Foraminiferal Faunas and Trophic Regimes at the Terminal Cretaceous Tethyan Seafloor. *Palaios*, *12*, 354–371. https://doi.org/10.2307/3515335

Woelders, L., & Speijer, R. P. (2015). Stable seafloor conditions, sea level and food supply during the latest Maastrichtian at Brazos River, Texas. *Marine Micropaleontology*, *121*, 41–51. https://doi.org/10.1016/j.marmicro.2015.10.002

# APPENDIX A

# PLATES AND EXPLANATIONS

## PLATE 1

Figure A1 Explanations:

### Suborder LAGENINA Delage and Herouard, 1896

### Superfamily NODOSARIACEA Ehrenberg, 1838

1. *Frondicularia* sp. sample no. UH-34, Maastrichtian, side view, >125 µm fraction
2. *Globulina prisca* (Reuss, 1862), sample no. UKHB-10, Danian, side view, >125 µm fraction
3. *Guttulina trigonula* (Reuss). sample no. UH-40, Maastrichtian, side view, >125 µm fraction
4. *Guttulina trigonula* (Reuss). sample no. UKHB-10, Danian, apertural view, >125 µm fraction
5. *Globulina* sp., sample no. UKHB-9, Danian, side view, >125 µm
6. *Laevidentalina constricta* (Franke, 1928) sample no. UKHB-10, Danian, side view, >125 µm fraction
7. *Laevidentalina monile* (Von Hagenow, 1842) sample no. UH-37, Maastrichtian, side view, >125 µm fraction, light microscope image

8. *Laevidentalina* sp. sample no. UH-36, Maastrichtian, side view, >125 µm fraction
9. *Laevidentalina*? sp. 1 sample no. UH-36, Maastrichtian, side view, >125 µm fraction
10. *Laevidentalina* sp. sample no. UH-36, Maastrichtian, side view, >125 µm fraction
11. *Lagena* cf. *sulcata* (Walker and Jacob, 1978 ) sample no. UH-34, Maastrichtian, side view, >125 µm fraction
12. *Lagena globosa* (LeRoy, 1953). sample no. UH-34, Maastrichtian, side view, >125 µm fraction
13. *Lagena* sp. 1 sample no. UH-34, Maastrichtian, side view, >125 µm fraction

# PLATE 1

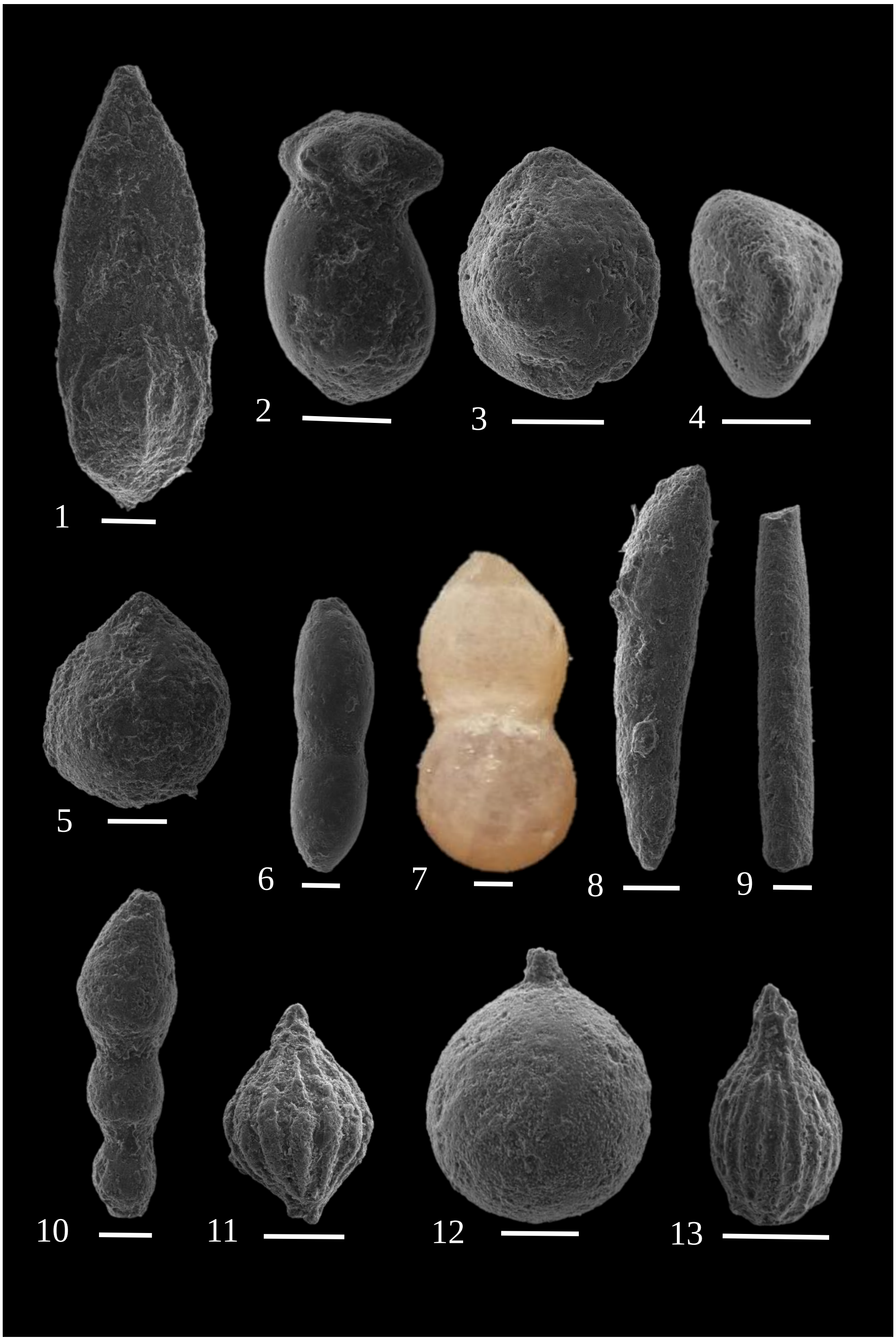

Figure A1: SEM and light microscope images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

## PLATE 2

Figure A2 Explanations:

### Superfamily NODOSARIACEA Ehrenberg, 1838

1. *Lenticulina* sp.1 sample no. UKHB-10, Danian, side view, >125 µm fraction
2. *Lenticulina* sp.2 sample no. UKHB-9, Danian, side view, >125 µm fraction
3. *Marginulopsis multicostata* (Lipnik, 1961) sample no. UH-34, Maastrichtian, side view, >125 µm fraction
4. *Neoflabellinela jarvisi* (Cushman, 1935) sample no. UH-34, Maastrichtian, side view, >125 µm fraction
5. *Oolina* sp.1 sample no. UH-37, Maastrichtian, side view, >125 µm fraction
6. *Pseudonodosaria manifesta* (Reuss, 1851) sample no. UH-42, Maastrichtian, side view, >125 µm fraction
7. *Pyramidulina* sp. sample no. UH-36, Maastrichtian, side view, >125 µm fraction

## PLATE 2

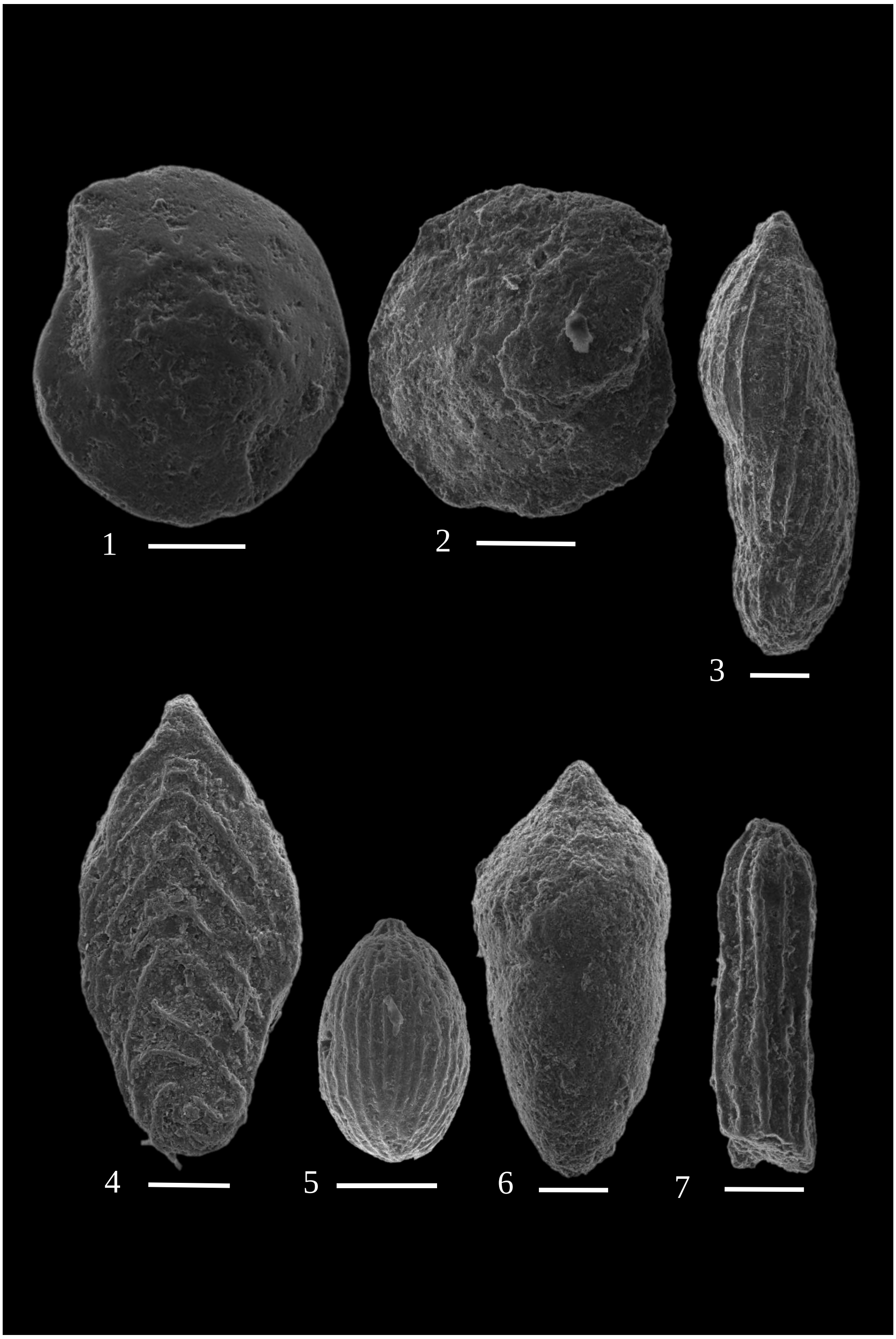

Figure A2: SEM images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

# PLATE 3

Figure A3 Explanations:

## Superfamily NODOSARIACEA Ehrenberg, 1838

1. *Pyramidulina* sp. sample no. UH-36, Maastrichtian, side view, >125 μm fraction
2. *Pyrulina* sp., sample no. UH-36, Maastrichtian, side view, >125 μm fraction
3. *Ramulina* sp. 1, sample no. UH-49, Maastrichtian, side view, >125 μm fraction
4. *Ramulina* sp. 1 sample no. UH-49, Maastrichtian, side view, >125 μm fraction
5. *Ramulina* sp. 2, sample no. UH-40, Maastrichtian, side view, >125 μm fraction
6. *Saracenaria* sp. sample no. UKHB-9, Danian, side view, >125 μm fraction
7. *Vaginulinopsis* ? sp sample no. UKHB-9, Danian, side view, >125 μm fraction

## PLATE 3

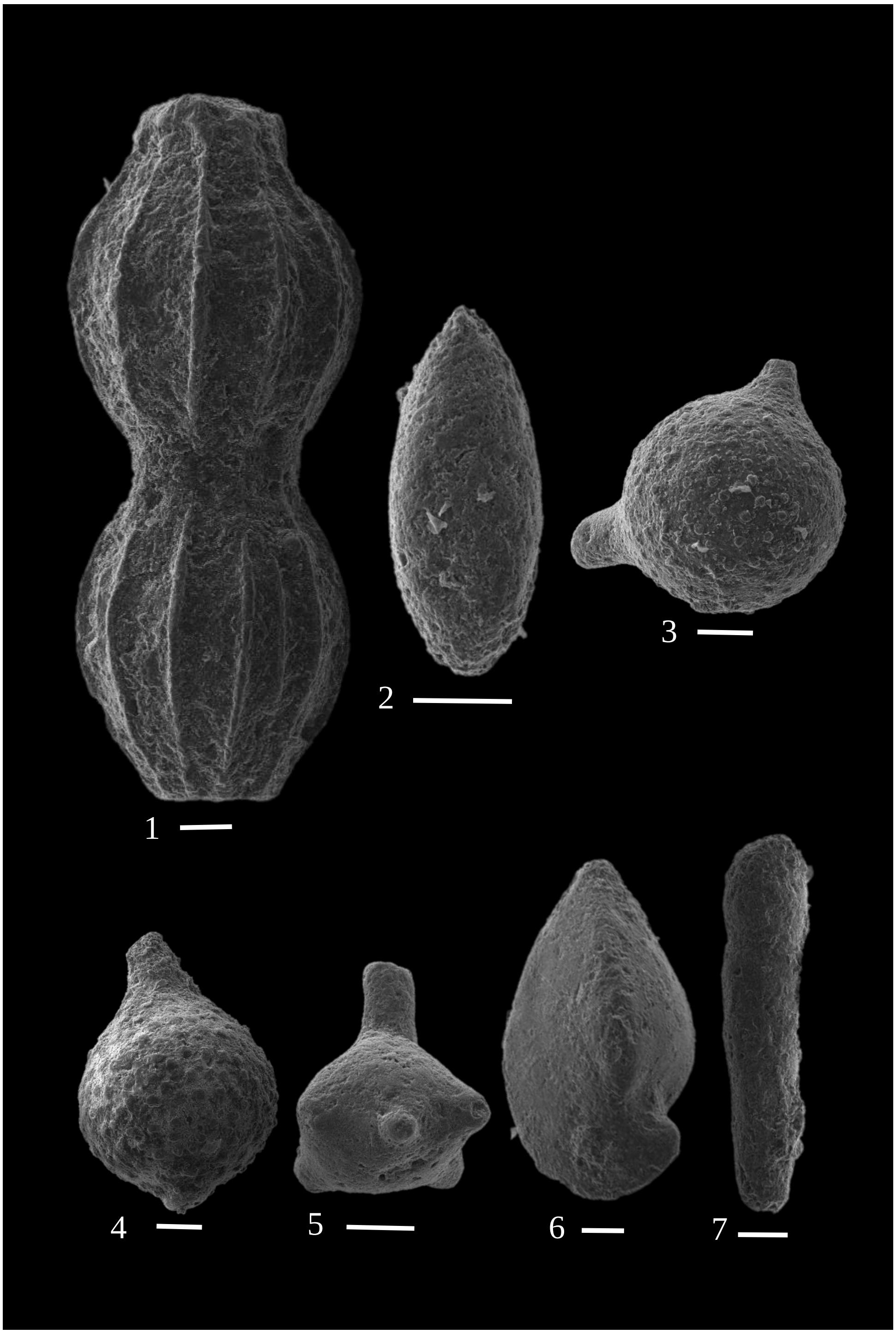

Figure A3: SEM images of benthic foraminifera taxa. Scale bar = 100 μm, otherwise stated.

## PLATE 4

Figure A4 Explanations:

### Suborder ROTALIlNA Delage and Herouard, 1896

### Superfamily ASTERIGERINACEA d'Orbigny, 1839

1. *Nuttallinella* sp. sample no. UH-49, Maastrichtian, spiral view, >125 µm fraction
2. *Nuttallinella* sp. sample no. UH-40, Maastrichtian, umbilical view, >125 µm fraction

### Superfamily BOLIVINACEA Glaessner, 1937

3. *Bolivina decurrens* (Ehrenberg, 1854) sample no. UH-34, Maastrichtian, side view, >125 µm fraction, under transmitted light
4. *Bolivina decurrens* (Ehrenberg, 1854), sample no. UH-34, Maastrichtian, side view, >125 µm fraction
5. *Bolivina incrassata* (Reuss, 1851) sample no. UH-38, Maastrichtian, side view, >125 µm fraction
6. *Bolivina incrassata* (Reuss, 1851) sample no. UH-38, Maastrichtian, side view, >125 µm fraction, under transmitted light
7. *Bolivinoides decoratus* (Jones, 1886) sample no. UKHB-4, Danian, side view, >125 µm fraction
8. *Bolivinoides draco* (Marsson, 1878) sample no. UH-36, Maastrichtian, side view, >125 µm fraction

**PLATE 4**

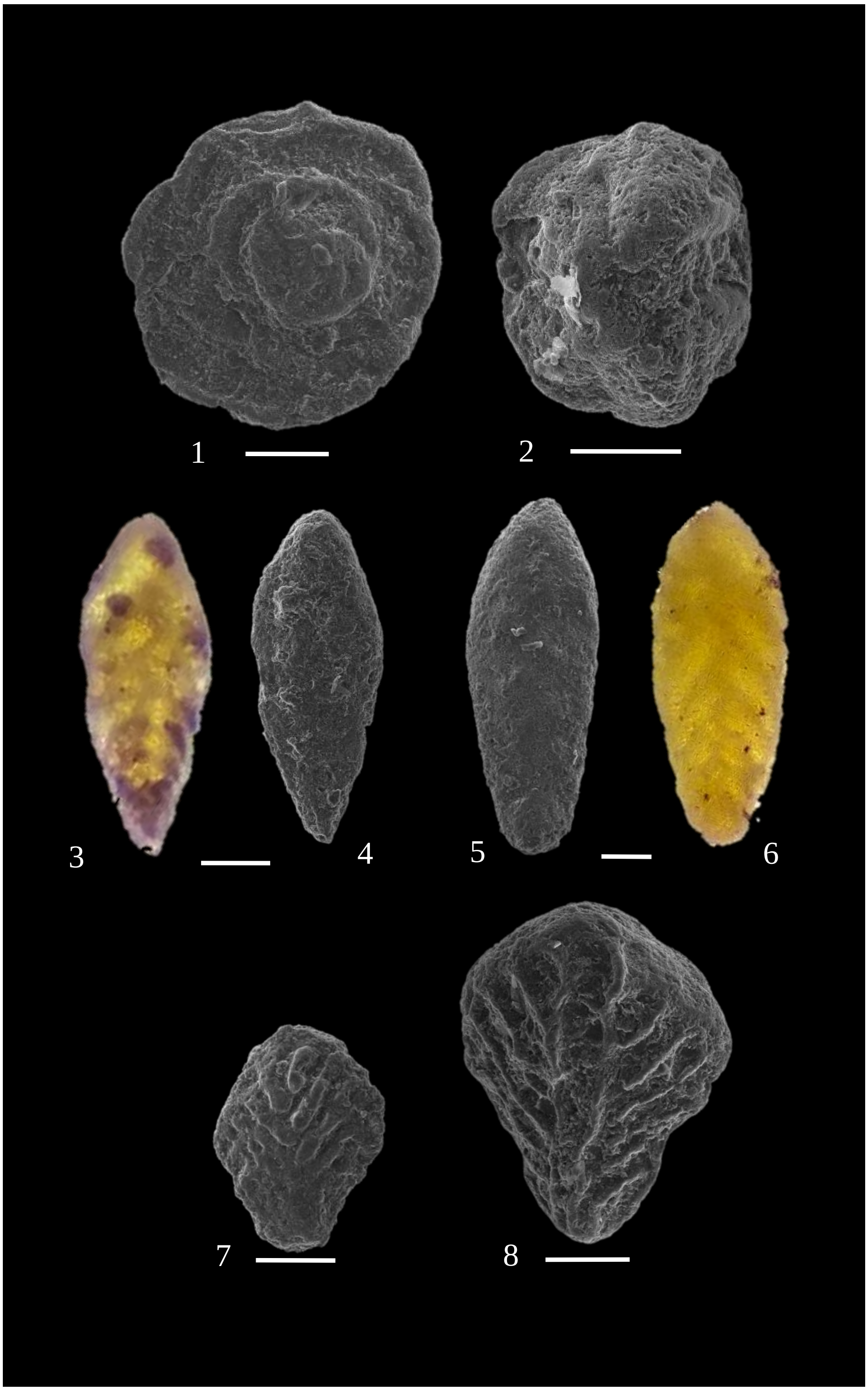

Figure A4: SEM and transmitted light images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

## PLATE 5

Figure A5 Explanations:

### Superfamily BOLIVINACEA Glaessner, 1937

1. *Loxostomoides applini* (Plummer, 1926) sample no. UKHB-4, Danian, side view, >125 µm fraction
2. *Loxostomoides applini* (Plummer, 1926) sample no. UKHB-8, Danian, side view, >125 µm fraction
3. *Tappanina selmensis* (Cushman, 1933) sample no. UKHB-9, Danian, side view, 63-125 µm fraction
4. *Tappanina selmensis* (Cushman, 1933) sample no. UKHB-9, Danian, apertural view, 63-125 µm fraction

### Superfamily BULIMINACEA Jones, 1875

5. *Bulimina arkadelphiana* Cushman and Parker var. *midwayensis* (Cushman and Parker, 1936) sample no. UH34, Maastrichtian, side view, >125 µm fraction
6. *Bulimina strobila* (Marie, 1941) sample no. UH-47, Maastrichtian, side view, >125 µm fraction
7. *Bulimina strobila* (Marie, 1941) sample no. UH-34, Maastrichtian, apertural view, >125 µm fraction
8. *Bulimina strobila* (Marie, 1941) sample no. UH-34, Maastrichtian, side view, >125 µm fraction
9. *Reussella* ? sp. 1 sample no. UH-50, Danian, side view, >125 µm fraction

### Superfamily CASSIDULINACEA d'Orbigny, 1839

10. *Globocassidulina* sp. sample no. UKHB-9, Danian, side view, >125 μm fraction

## PLATE 5

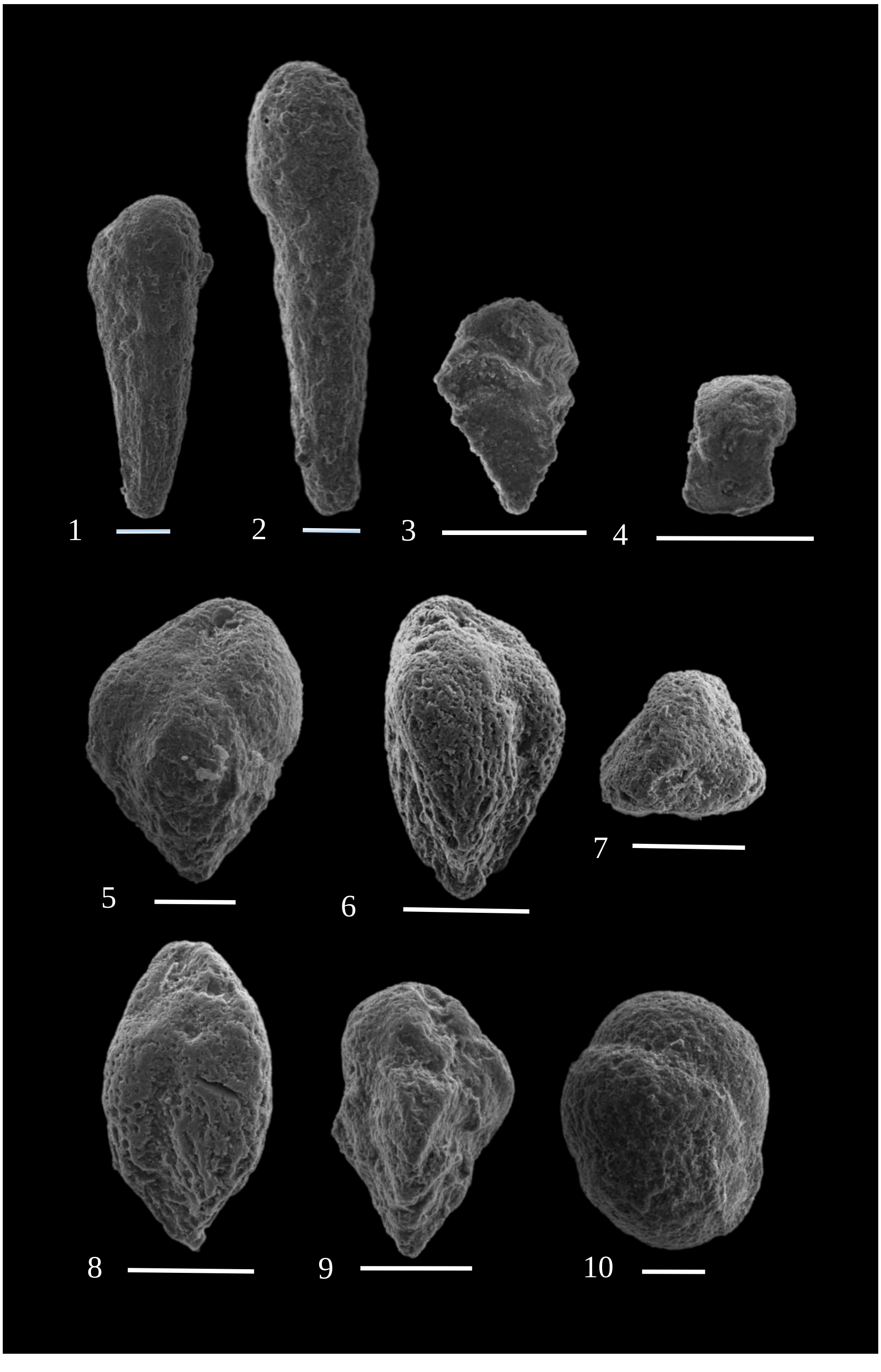

Figure A5: SEM images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

# PLATE 6

Figure A6 Explanations:

## Superfamily CHILOSTOMELLACEA Brady, 1881

1. *Alabamina wilcoxensis* (Toulmin, 1941) sample no. UKHB-4, Danian, spiral view, >125 μm fraction
2. *Alabamina wilcoxensis* (Toulmin, 1941), sample no. UKHB-4, Danian, side view, >125 μm fraction
3. *Alabamina wilcoxensis* (Toulmin, 1941) sample no. UKHB-4, Danian, umbilical view, >125 μm fraction, under transmitted light
4. *Alabamina* sp. (Toulmin, 1941). sample no. UKHB-4, Danian, close view of aperture, >125 μm fraction,
5. *Allomorphina* sp. 1 sample no. UH-40, Maastrichtian, spiral view, >125 μm fraction
6. *Allomorphina* sp. 1 sample no. UH-35, Maastrichtian, umbilical view, >125 μm fraction,
7. *Angulogavelinella angustiumbilicata* (Weidich, 1995) sample no. UH-40, Maastrichtian, spiral view, >125 μm fraction
8. *Angulogavelinella angustiumbilicata* (Weidich, 1995) sample no. UH-34, Maastrichtian, side view, >125 μm fraction
9. *Angulogavelinella angustiumbilicata* (Weidich, 1995) sample no. UH-40, Maastrichtian, umbilical view, >125 μm fraction
10. *Angulogavelinella angustiumbilicata* (Weidich, 1995) sample no. UH-40, Maastrichtian, close view to umbilicus, >125 μm fraction

## PLATE 6

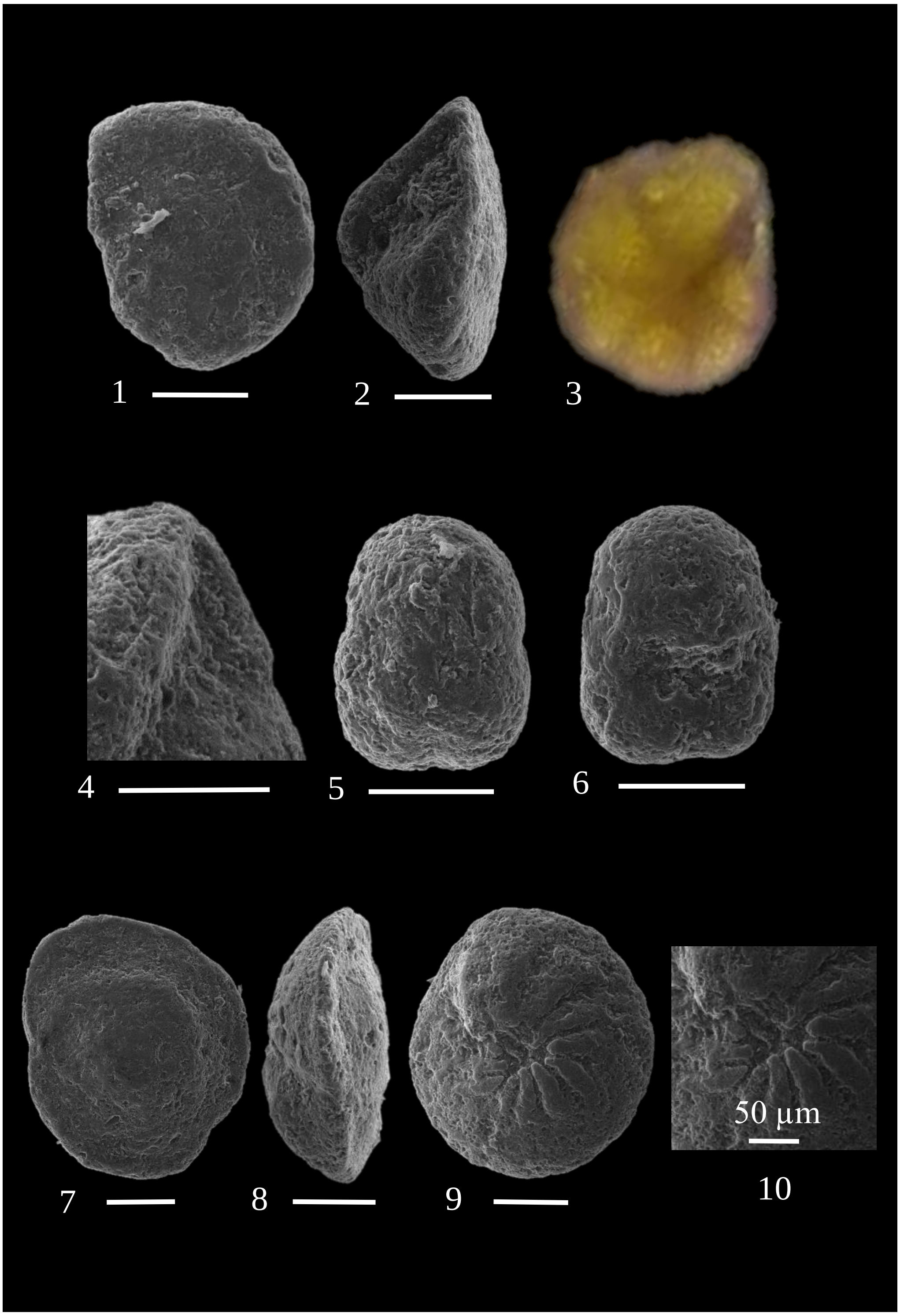

Figure A6: SEM and transmitted light images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

## PLATE 7

Figure A7 Explanations:

### Superfamily CHILOSTOMELLACEA Brady, 1881

1. *Anomalinoides acutus* (Plummer, 1926) sample no. UH-41, Maastrichtian, spiral view, >125 µm fraction
2. *Anomalinoides acutus* (Plummer, 1926), sample no. UH-34, Maastrichtian, side view, >125 µm fraction
3. *Anomalinoides acutus* (Plummer, 1926) sample no. UH-50, Danian, umbilical view, >125 µm fraction
4. *Anomalinoides acutus* (Plummer, 1926) sample no. UKHB-10, Danian, close view to umbilicus, >125 µm fraction
5. *Anomalinoides affinis*/*welleri* group sample no. UH-47, Maastrichtian, spiral view, >125 µm fraction
6. *Anomalinoides affinis*/*welleri* group sample no. UH-47, Maastrichtian, side view, >125 µm fraction
7. *Anomalinoides affinis*/*welleri* group sample no. UH-45, Maastrichtian, umbilical view, >125 µm fraction
8. *Anomalinoides affinis*/*welleri* group sample no. UH-45, Maastrichtian, close view to umbilicus, >125 µm fraction
9. *Anomalinoides rubiginosus* (Cushman, 1926) sample no. UKHB-4, Danian, spiral view, >125 µm fraction
10. *Anomalinoides rubiginosus* (Cushman, 1926) sample no. UKHB-4, Danian, side view, >125 µm fraction
11. *Anomalinoides rubiginosus* (Cushman, 1926) sample no. UH-50, Danian, umbilical view, >125 µm fraction

# PLATE 7

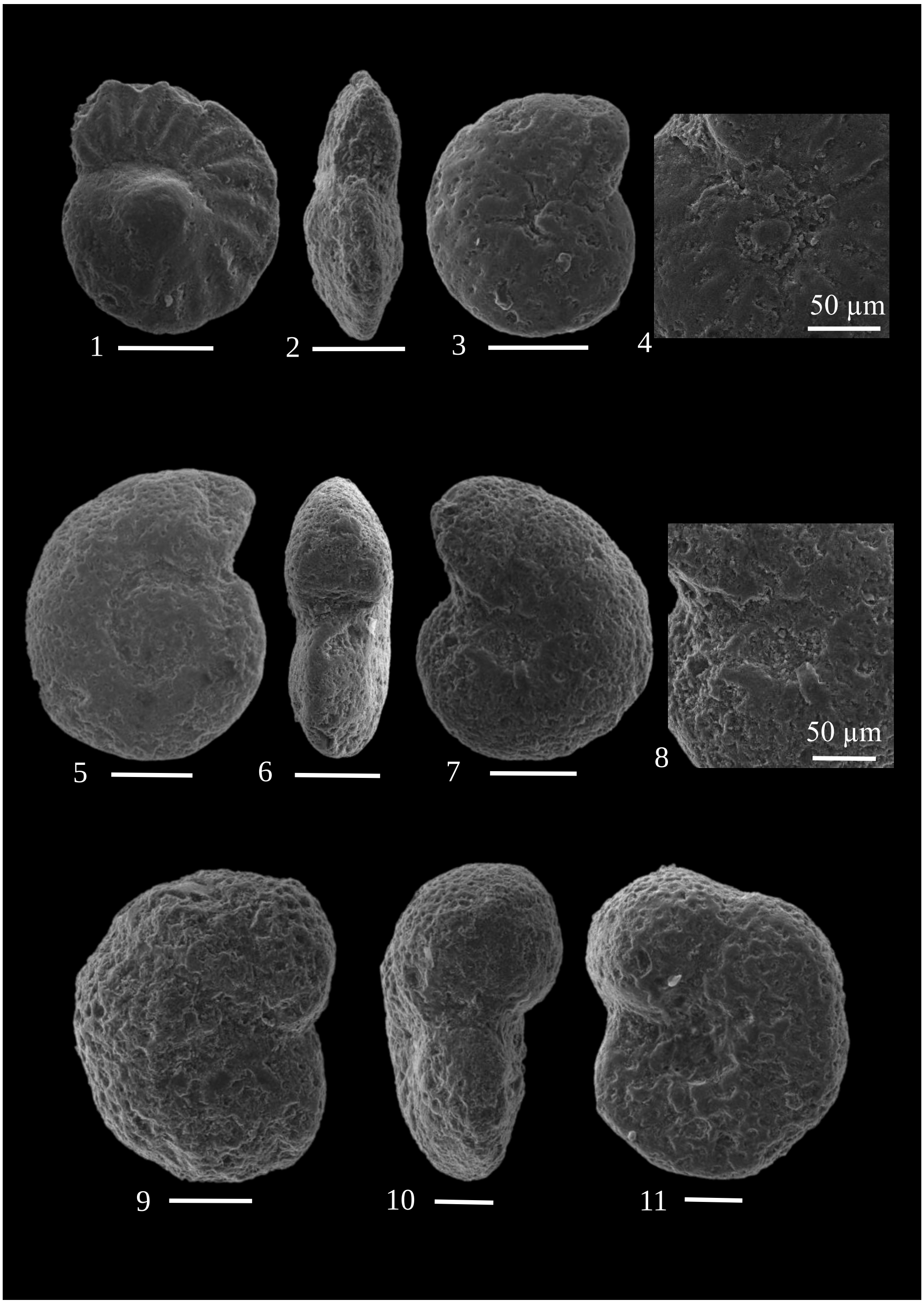

Figure A7: SEM images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

# PLATE 8

Figure A8 Explanations:

## Superfamily CHILOSTOMELLACEA Brady, 1881

1. *Anomalinoides* sp .1 sample no. UKHB-8, Danian, spiral view, >125 µm fraction
2. *Anomalinoides* sp .1 sample no. UKHB-7, Danian, side view, >125 µm fraction
3. *Anomalinoides* sp .1 sample no. UKHB-8, Danian, umbilical view, >125 µm fraction
4. *Chilostomella* sp. sample no. UKHB-10, Danian, side view, >125 µm fraction
5. *Gavelinella* aff. *monterelensis* (Marie, 1941) sample no. UH-34, Maastrichtian, spiral view, >125 µm fraction
6. *Gavelinella* aff. *monterelensis* (Marie, 1941) sample no. UH-34, Maastrichtian, side view, >125 µm fraction
7. *Gavelinella* aff. *monterelensis* (Marie, 1941) sample no. UH-47, Maastrichtian, umbilical view, >125 µm fraction
8. *Gavelinella* sp. 1 sample no. UH-40, Maastrichtian, spiral view, >125 µm fraction
9. *Gavelinella* sp. 1 sample no. UH-40, Maastrichtian, side view, >125 µm fraction
10. *Gavelinella* sp. 1 sample no. UH-40, Maastrichtian, umbilical view, >125 µm fraction

## PLATE 8

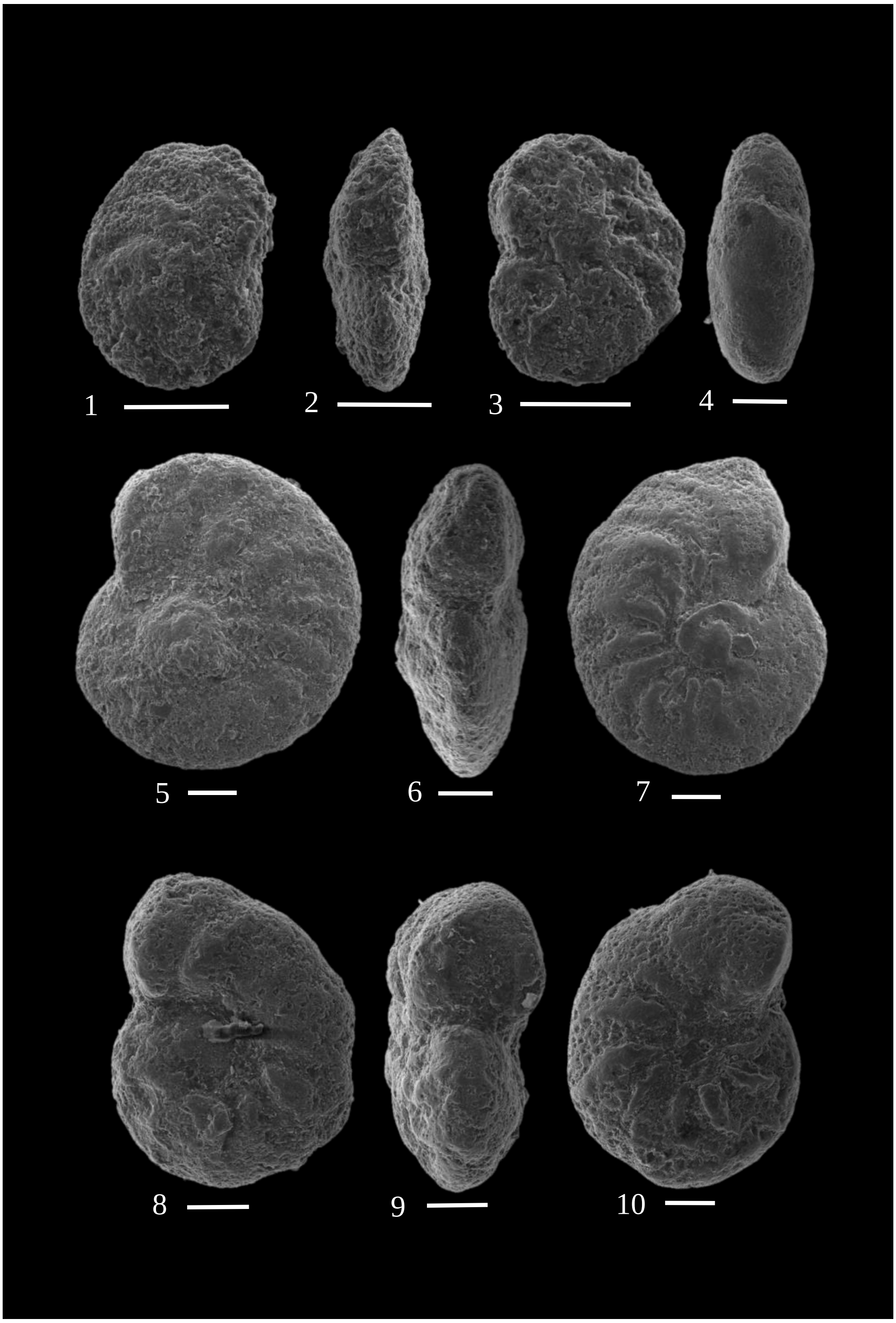

Figure A8: SEM images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

## PLATE 9

Figure A9 Explanations:

### Superfamily CHILOSTOMELLACEA Brady, 1881

1. *Gyroidinoides octocameratus* (Cushman and Hanna, 1927) sample no. UH-34, Maastrichtian, spiral view, >125 μm fractioni
2. *Gyroidinoides octocameratus* (Cushman and Hanna, 1927) sample no. UH-47, Maastrichtian, side view, >125 μm fractioni
3. *Gyroidinoides octocameratus* (Cushman and Hanna, 1927) sample no. UH-34, Maastrichtian, umbilical view, >125 μm fractioni
4. *Gyroidinoides* sp. 1 sample no. UKHB-6, Danian, spiral view, >125 μm fraction
5. *Gyroidinoides* sp. 1 sample no. UKHB-6, Danian, side view, >125 μm fraction
6. *Gyroidinoides* sp. 1 sample no. UKHB-9, Danian, umbilical view, >125 μm fractions
7. *Oridorsalis*? sp. 1 sample no. UH-34, Maastrichtian, spiral view, >125 μm fraction
8. *Oridorsalis*? sp. 1 sample no. UH-34, Maastrichtian, side view, >125 μm fraction
9. *Oridorsalis*? sp. 1 sample no. UH-47, Maastrichtian, umbilical view, >125 μm fraction
10. *Oridorsalis*? sp. 1 sample no. UH-37, Maastrichtian, spiral view, >125 μm fraction, under transmitted light
11. *Oridorsalis*? sp. 1 sample no. UH-37, Maastrichtian, umbilical view, >125 μm fraction, under transmitted light

## PLATE 9

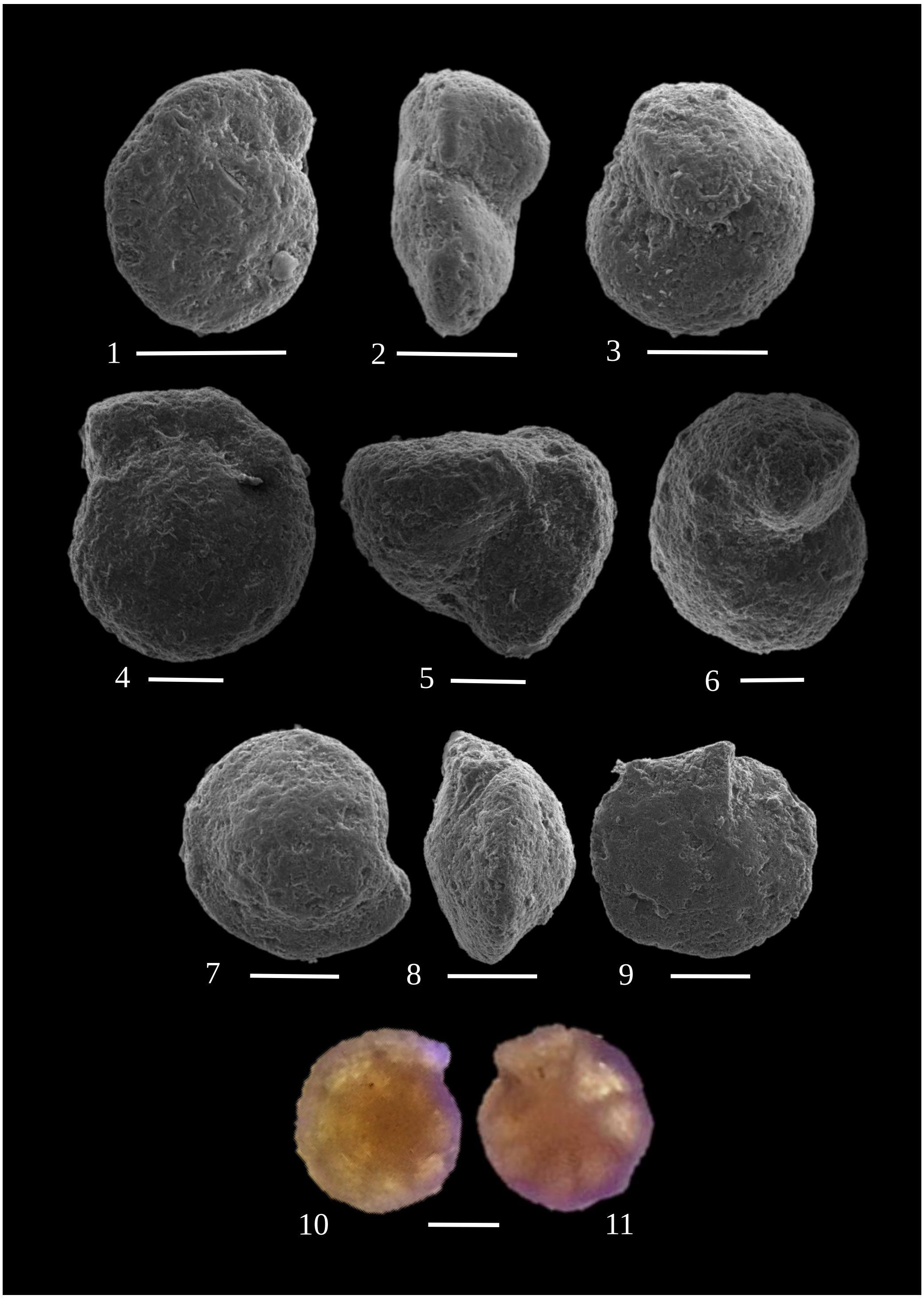

Figure A9: SEM and transmitted light images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

## PLATE 10

Figure A10 Explanations:

### Superfamily CHILOSTOMELLACEA Brady, 1881

1. *Osangularia plummerae* (Brotzen, 1940) sample no. UKHB-4, Danian, spiral view, >125 µm fractions
2. *Osangularia plummerae* (Brotzen, 1940) sample no. UKHB-4, Danian, side view, >125 µm fractions
3. *Osangularia plummerae* (Brotzen, 1940) sample no. UKHB-4, Danian, close view to areal aperture, >125 µm fractions
4. *Osangularia plummerae* (Brotzen, 1940) sample no. UKHB-4, Danian, umbilical view, >125 µm fractions
5. *Osangularia plummerae* (Brotzen, 1940) sample no. UH-33, Maastrichtian, umbilical view, >125 µm fractions, under transmitted light
6. *Paralabamina*. *toulmini* (Brotzen, 1948) sample no. UKHB-10, Danian, spiral view, >125 µm fractions
7. *Paralabamina*. *toulmini* (Brotzen, 1948) sample no. UKHB-10, Danian, side view, >125 µm fractions
8. *Paralabamina toulmini* (Brotzen, 1948) sample no. UKHB-10, Danian, umbilical view, >125 µm fractions

## PLATE 10

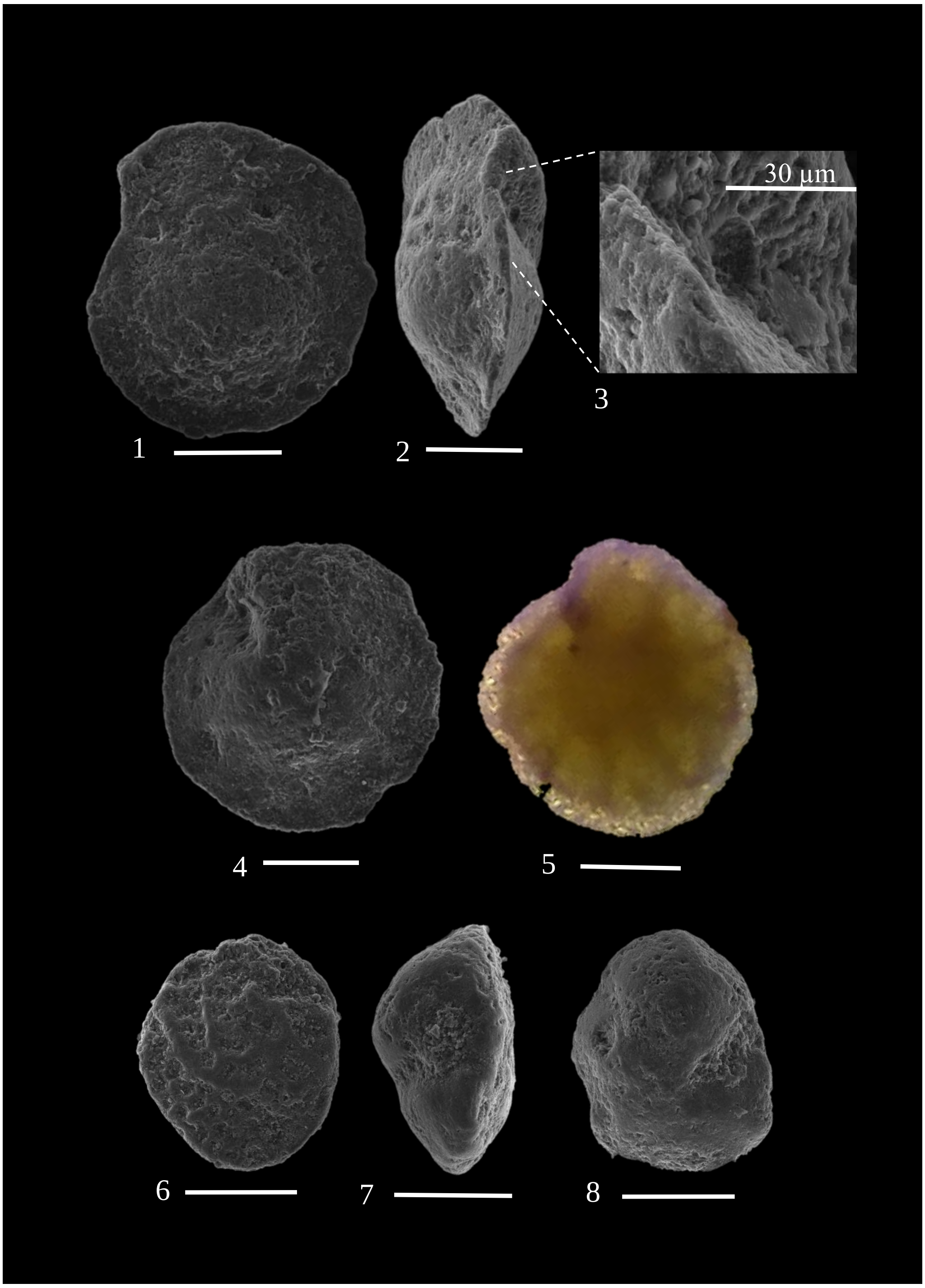

Figure A10: SEM and transmitted light images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

## PLATE 11

Figure A11 Explanations:

### Superfamily CHILOSTOMELLACEA Brady, 1881

1. *Paralabamina* sp. 1 sample no. UH-34, Maastrichtian, spiral view, >125 µm fractions
2. *Paralabamina* sp. 1 sample no. UH-42, Maastrichtian, umbilical view, >125 µm fractions
3. *Paralabamina* sp. 1 sample no. UH-42, Maastrichtian, spiral view, >125 µm fractions, under transmitted light
4. *Quadrimorphina allomorphinoides* (Reuss, 1860) sample no. UKHB-10, Danian, spiral view, >125 µm fractions
5. *Quadrimorphina allomorphinoides* (Reuss, 1860) sample no. UH-42, Maastrichtian, side view, >125 µm fractions
6. *Quadrimorphina allomorphinoides* (Reuss, 1860) sample no. UKHB-10, Danian, umbilical view, >125 µm fractions
7. *Sliteria varsoviensis* (Gawor-Biedowa, 1992) sample no. UH-34, Maastrichtian, spiral view, >125 µm fractions
8. *Sliteria varsoviensis* (Gawor-Biedowa, 1992) sample no. UH-34, Maastrichtian, side view, >125 µm fractions
9. *Sliteria varsoviensis* (Gawor-Biedowa, 1992) sample no. UH-34, Maastrichtian, umbilical view, >125 µm fractions
10. *Sliteria varsoviensis* (Gawor-Biedowa, 1992) sample no. UH-34, Maastrichtian, close view to umbilical area with umbilical flaps, >125 µm fractions

## PLATE 11

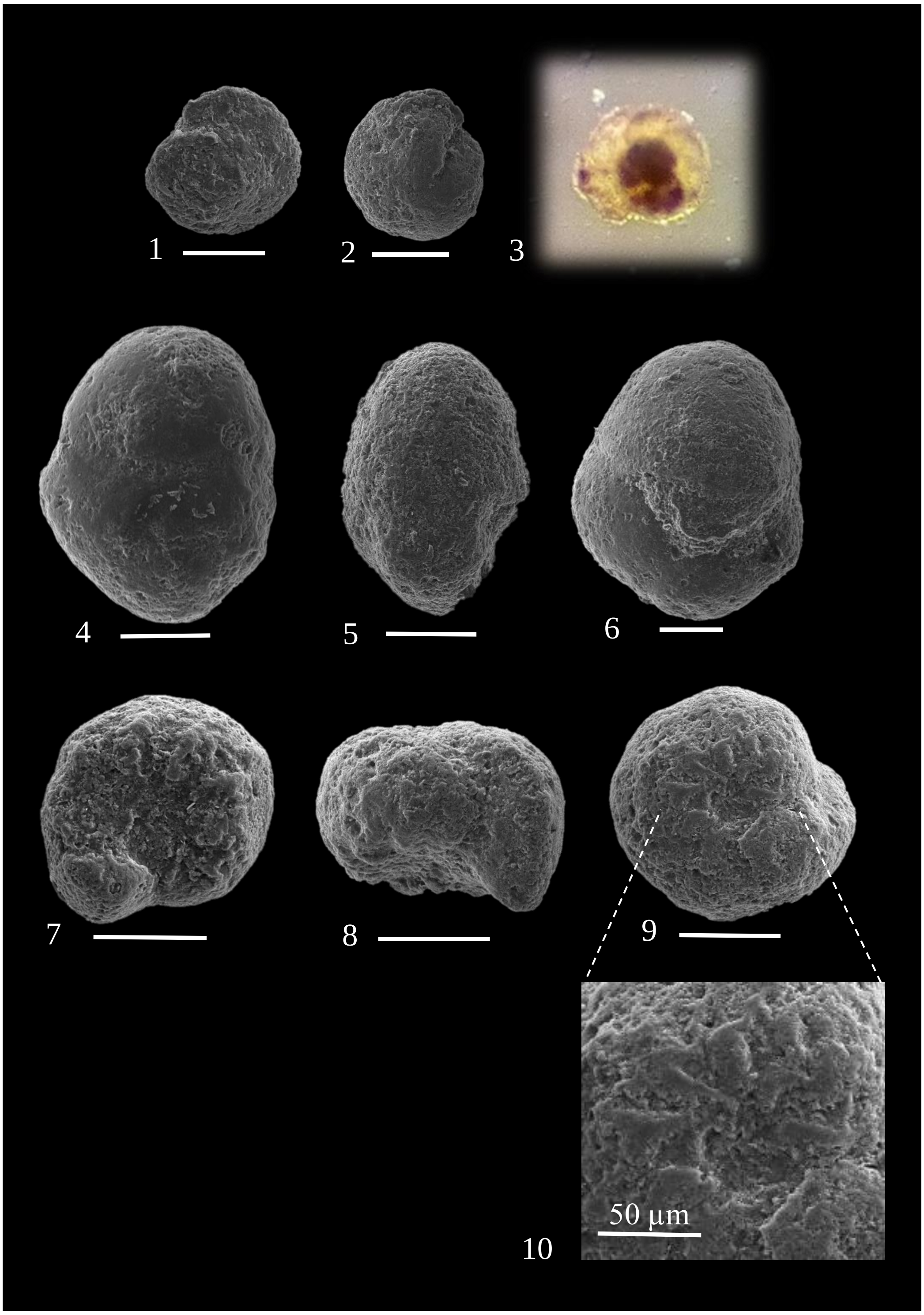

Figure A11: SEM and transmitted light images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

## PLATE 12

Figure A12 Explanations:

### Superfamily CHILOSTOMELLACEA Brady, 1881

1. *Stensioina excolata* (Cushman, 1926) sample no. UH-40, Maastrichtian, spiral view, >125 μm fractions
2. *Stensioina excolata* (Cushman, 1926) sample no. UH-44, Maastrichtian, side view, >125 μm fractions
3. *Stensioina* ? aff. *S. beccariformis* sample no. UKHB-10, Danian, side view, >125 μm fractions
4. *Stensioina* ? aff. *S. beccariformis* sample no. UKHB-10, Danian, umbilical view, >125 μm fractions

### Superfamily DISCORBINELLACEA Sigal, 1952

5. *Cibicides* sp. 1 sample no. UKHB-10, Danian, spiral view, >125 μm fractions
6. *Cibicides* sp. 1 sample no. UKHB-10, Danian, side view, >125 μm fractions
7. *Cibicides* sp. 1 sample no. UKHB-10, Danian, umbilical view, >125 μm fractions
8. *Cibicides* sp. 2 sample no. UH-38, Maastrichtian, spiral view, >125 μm fractions
9. *Cibicides* sp. 2 sample no. UH-46, Maastrichtian, side view, >125 μm fractions
10. *Cibicides* sp. 2 sample no. UH-49, Maastrichtian, umbilical view, >125 μm fractions

## PLATE 12

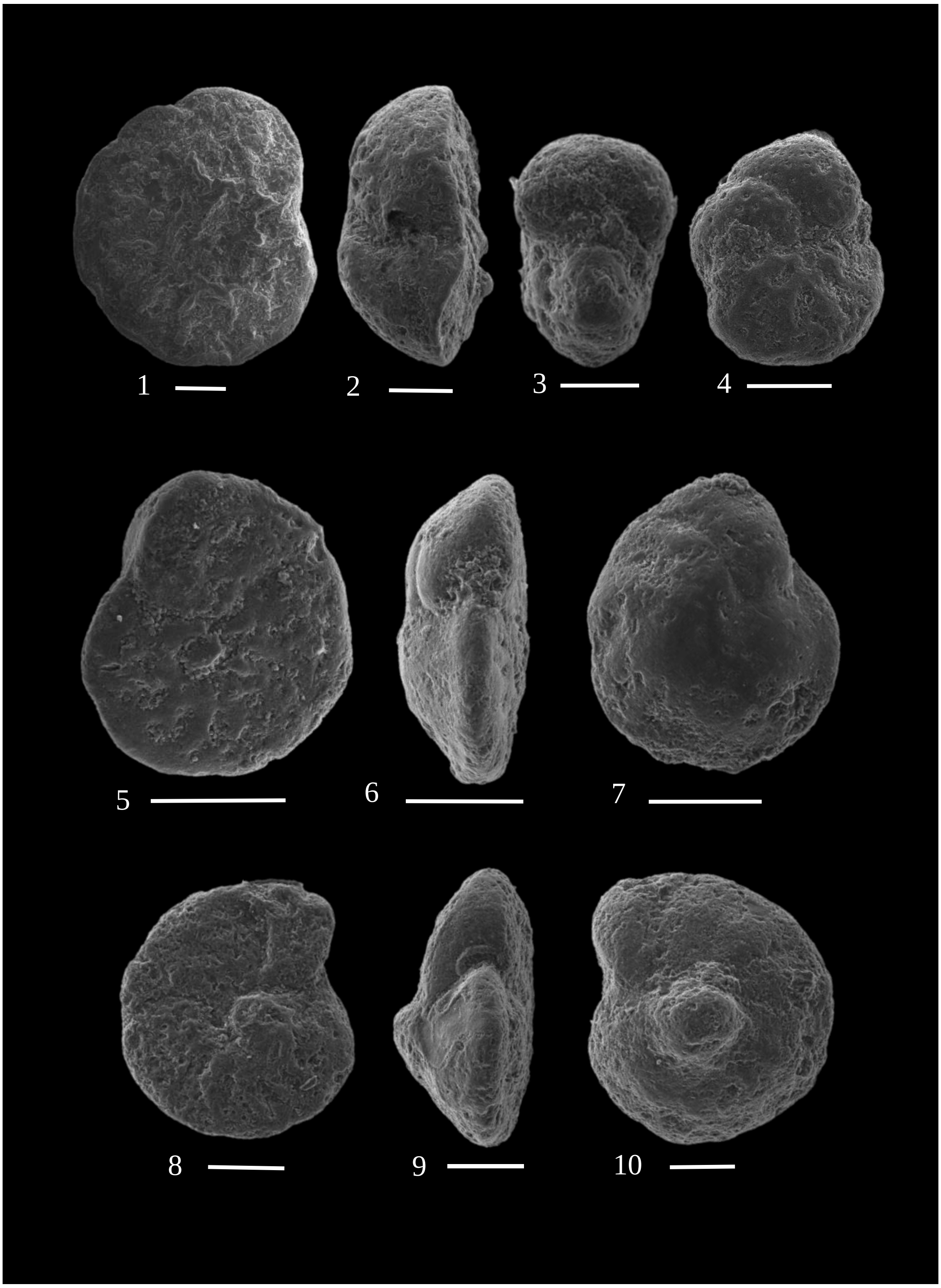

Figure A12: SEM images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

## PLATE 13

Figure A13 Explanations:

### Superfamily DISCORBINELLACEA Sigal, 1952

1. *Cibicidoides alleni* , sample no. UH-41, Maastrichtian, spiral view, >125 µm fraction
2. *Cibicidoides alleni* sample no. UH-41, Maastrichtian, side view, >125 µm fraction
3. *Cibicidoides alleni* sample no. UH-41, Maastrichtian, umbilical view, >125 µm fraction
4. *Cibicidoides pseudoacutus* (Nakkady, 1950) sample no. UH-50, Danian, spiral view, >125 µm fractions
5. *Cibicidoides pseudoacutus* (Nakkady, 1950) sample no. UH-50, Danian, side view, >125 µm fractions
6. *Cibicidoides pseudoacutus* (Nakkady, 1950) sample no. UH-50, Danian, umbilical view, >125 µm fractions
7. *Cibicidoides* sp. 1 ample no. UH-45, Maastrichtian, spiral view, >125 µm fraction
8. *Cibicidoides* sp. 1 ample no. UH-34, Maastrichtian, side view, >125 µm fraction
9. *Cibicidoides* sp. 1 ample no. UH-34, Maastrichtian, umbilical view, >125 µm fraction

## PLATE 13

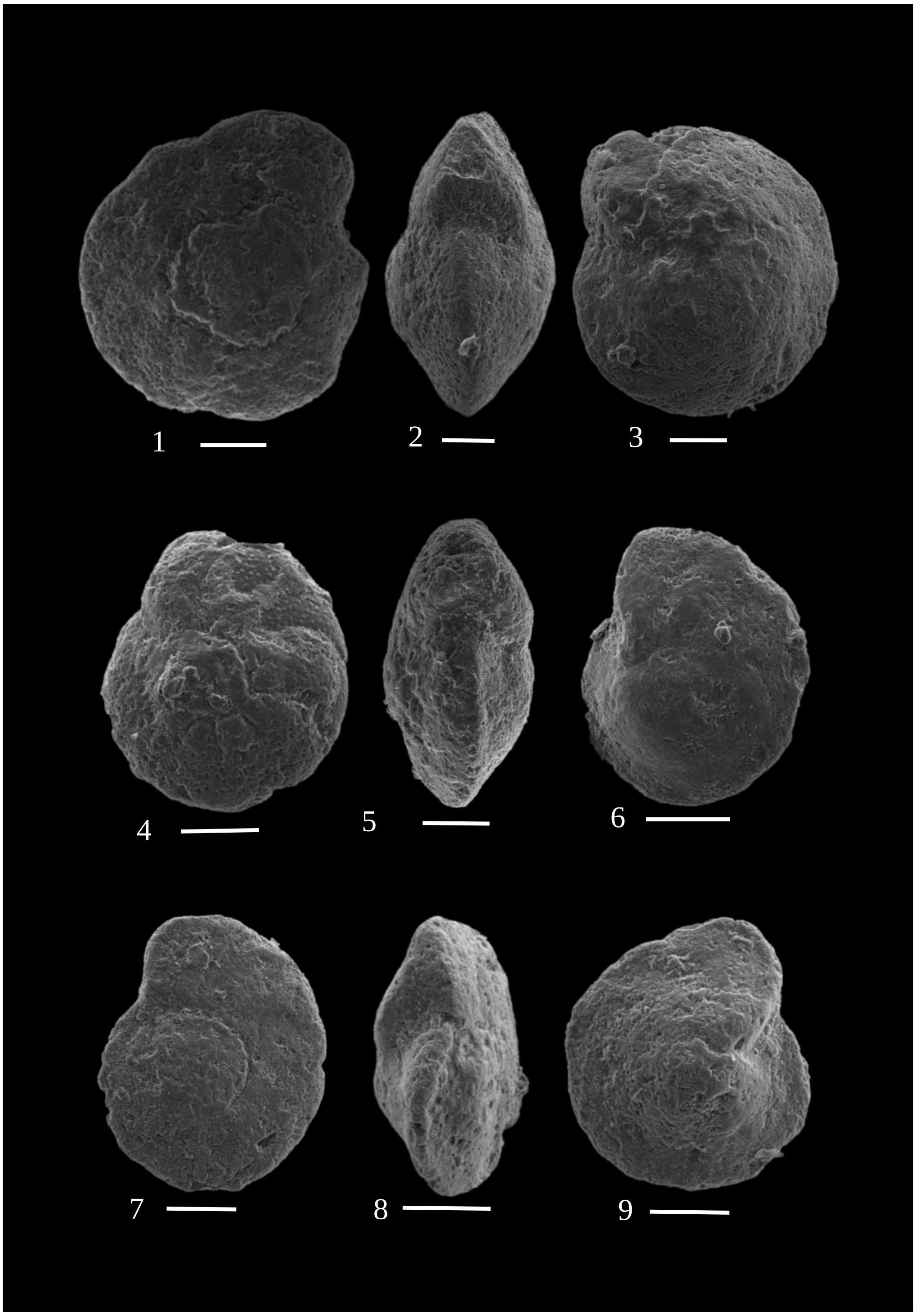

Figure A13: SEM images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

## PLATE 14

Figure A14 Explanations:

### Superfamily DISCORBINELLACEA Sigal, 1952

1. *Cibicidoides* sp. 2, sample no. UH-40, Maastrichtian, spiral view, >125 μm fraction
2. *Cibicidoides* sp. 2, sample no. UH-40, Maastrichtian, side view, >125 μm fraction
3. *Cibicidoides* sp. 2, sample no. UH-42, Maastrichtian, umbilical view, >125 μm fraction

### Superfamily EOUVIGERINACEA Cushman, 1927

4. *Eouvigerina subsculptura* (McNeil and Caldwell, 1981), sample no. UH-34, Maastrichtian, side view, >125 μm fraction
5. *Eouvigerina subsculptura* (McNeil and Caldwell, 1981), sample no. UH-42, Maastrichtian, edge view, >125 μm fraction
6. *Eouvigerina subsculptura* (McNeil and Caldwell, 1981), sample no. UH-42, Maastrichtian, close view of wall texture and imperforate rim on chamber, >125 μm fraction

### Superfamily FURSENKOINACEA Loeblich and Tappan, 1961

7. *Coryphostoma plaitum* (Carsey, 1926), sample no. UH-42, Maastrichtian, side view, >125 μm fraction, under transmitted light
8. *Coryphostoma plaitum* (Carsey, 1926), sample no. UH-42, Maastrichtian, side view, >125 μm fraction

## PLATE 14

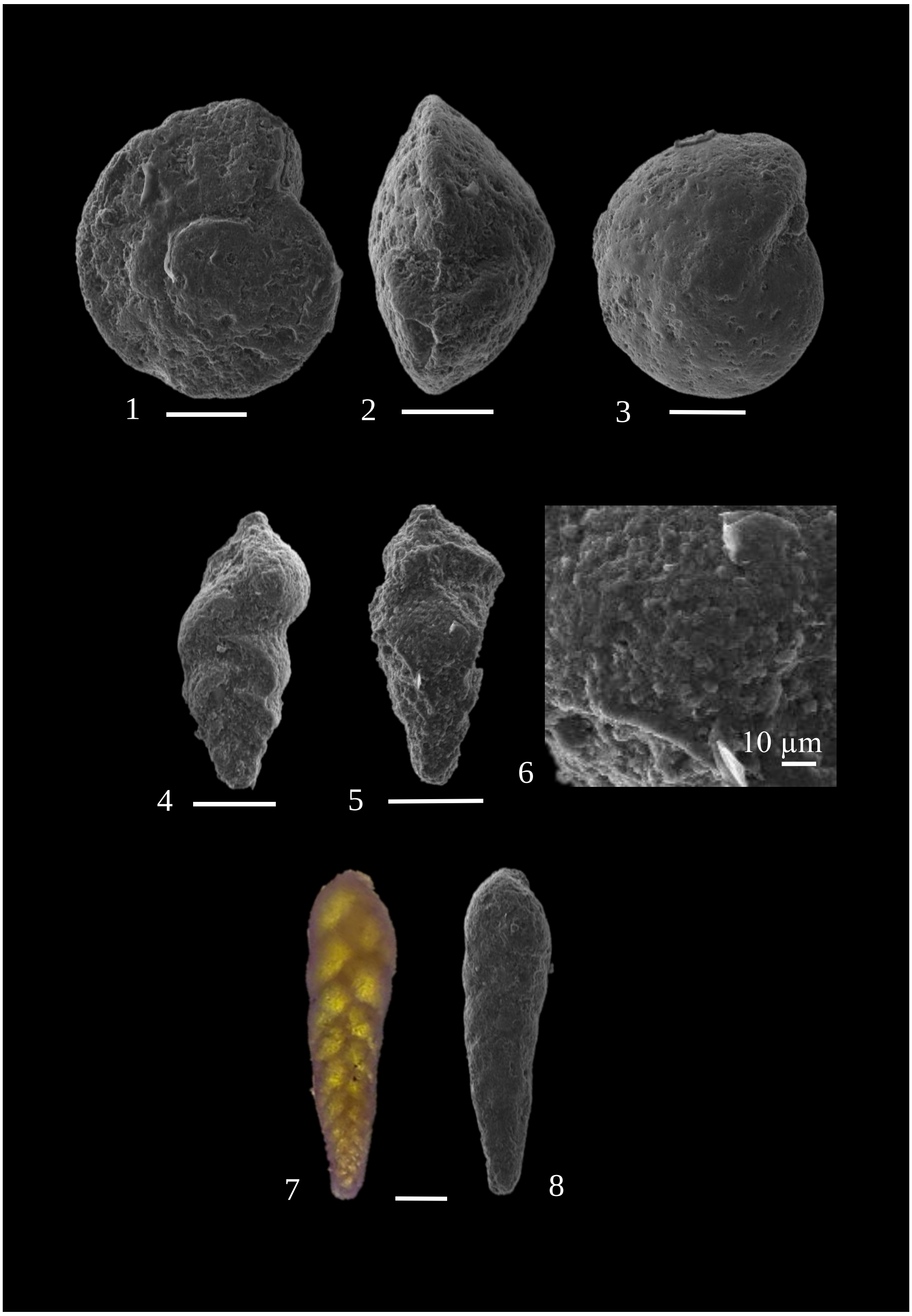

Figure A14: SEM and transmitted light images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

## PLATE 15

Figure A15 Explanations:

### Superfamily NONIONACEA Schultze, 1854

1. *Nonionella* sp., sample no. UKHB-10, Danian, spiral view, >125 µm fraction
2. *Nonionella* sp., sample no. UKHB-10, Danian, umbilical view, >125 µm fraction
3. *Nonionellina* sp. 1, sample no. UH-34, Maastrichtian, spiral view, >125 µm fraction
4. *Nonionellina* sp. 1, sample no. UH-34, Maastrichtian, side view, >125 µm fraction
5. *Nonionellina* sp. 1, sample no. UH-34, Maastrichtian, umbilical view, >125 µm fraction
6. *Pullenia jarvisi* (Cushman, 1936), sample no. UH-34, Maastrichtian, side view, >125 µm fraction
7. *Pullenia jarvisi* (Cushman, 1936), sample no. UH-34, Maastrichtian, apertural view, >125 µm fraction

## PLATE 15

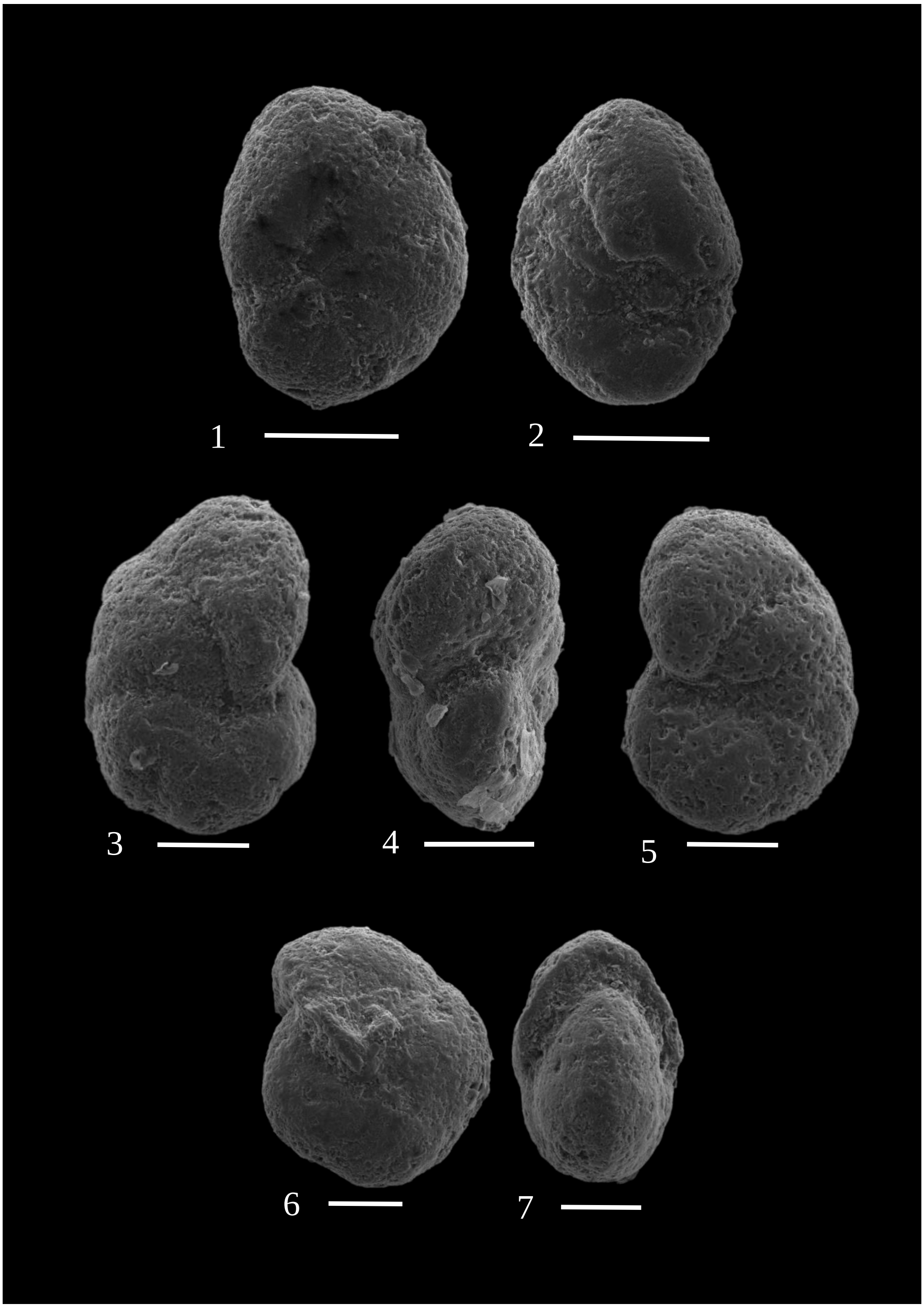

Figure A15: SEM images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

## PLATE 16

Figure A16 Explanations:

### Superfamily NONIONACEA Schultze, 1854

1. *Pullenia* sp. 1, sample no. UH-42, Maastrichtian, side view, >125 µm fraction, under transmitted light
2. *Pullenia* sp. 1, sample no. UH-34, Maastrichtian, side view, >125 µm fraction

### Superfamily SIPHONINACEA Cushman, 1927

3. *Pulsiphonina prima* (Plummer, 1926), sample no. UKHB-10, Danian, spiral view, >125 µm fraction
4. *Pulsiphonina prima* (Plummer, 1926), sample no. UKHB-10, Danian, umbilical view, >125 µm fraction
5. *Pulsiphonina prima* (Plummer, 1926) sample no. UKHB-10, Danian, close view to aperture, >125 µm fraction

### Superfamily TURRILINACEA Cushman, 1927

6. *Praebulimina reussi* (Morrow, 1934), sample no. UH-47, Maastrichtian, side view, >125 µm fraction
7. *Pseudouvigerina plummerae* (Cushman, 1927) sample no. UH-47, Maastrichtian, side view, >125 µm fraction
8. *Pseudouvigerina plummerae* (Cushman, 1927) sample no. UH-47, Maastrichtian, apertural view, >125 µm fraction
9. *Pseudouvigerina plummerae* (Cushman, 1927) sample no. UH-47, Maastrichtian, close view to aperture with toothplate, >125 µm fraction

**PLATE 16**

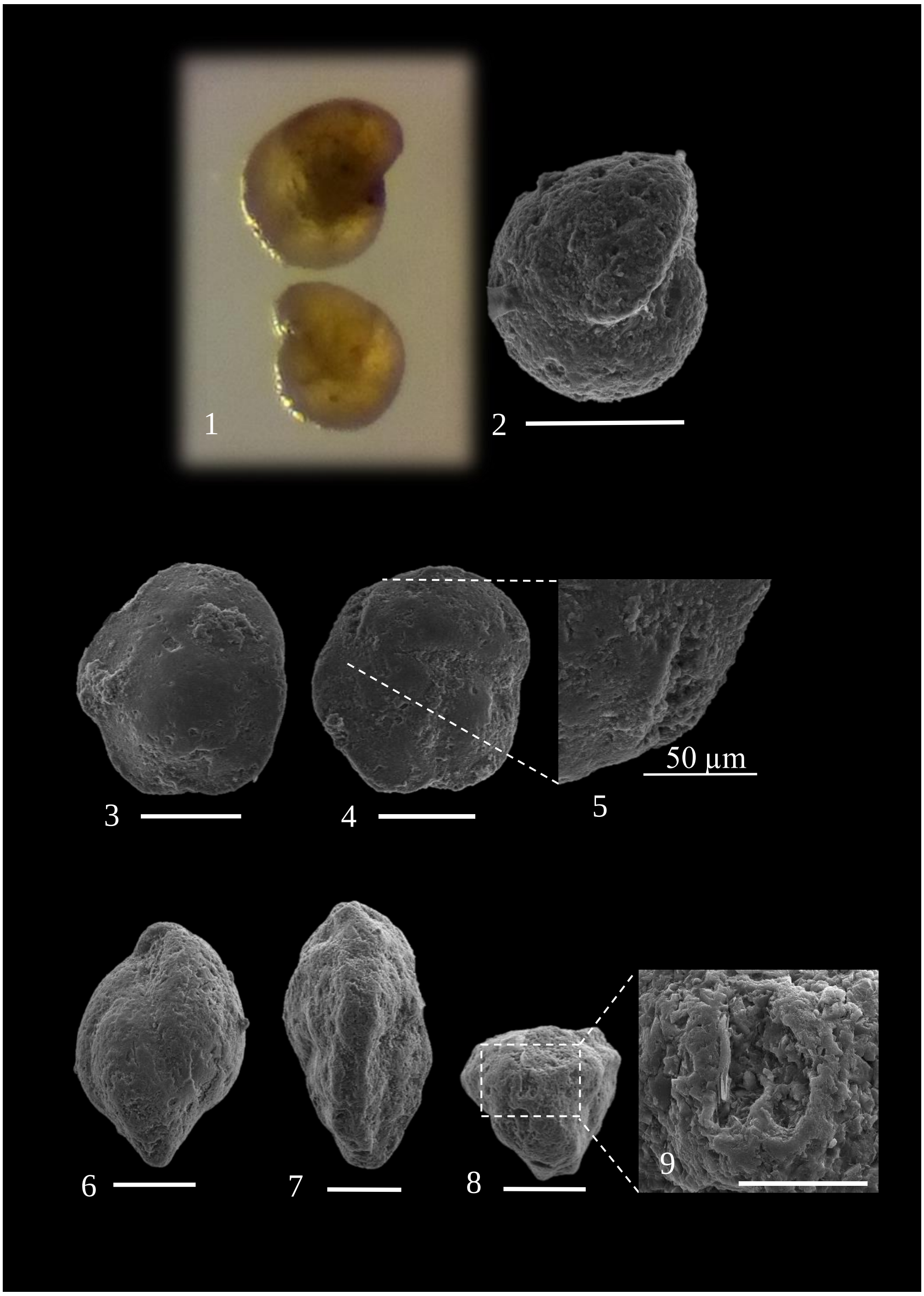

Figure A16: SEM and transmitted light images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

# PLATE 17

Figure A17 Explanations:

## Superfamily TURRILINACEA Cushman, 1927

1. *Pseudouvigerina plummerae* (Cushman, 1927) sample no. UH-47, Maastrichtian, close view to crenulated edges, >125 µm fraction
2. *Pseudouvigerina plummerae* (Cushman, 1927) sample no. UH-47 Maastrichtian, side view, >125 µm fraction
3. *Pseudouvigerina* sp. 1, sample no. UKHB-9, Danian, side view, >125 µm fraction
4. *Pyramidina minuta* (Marsson, 1878), sample no. UH-34, Maastrichtian, apertural view, >125 µm fraction
5. *Pyramidina minuta* (Marsson, 1878), sample no. UH-34, Maastrichtian, side view, >125 µm fraction
6. *Pyramidina minuta* (Marsson, 1878), sample no. UH-34, Maastrichtian, side view, >125 µm fraction
7. *Sitella cushmani* (Sandidge, 1932), sample no. UH-34, Maastrichtian, side view, >125 µm fraction
8. *Sitella cushmani* (Sandidge, 1932) sample no. UH-34, Maastrichtian, close view to inverted “T” shaped aperture, >125 µm fraction

## PLATE 17

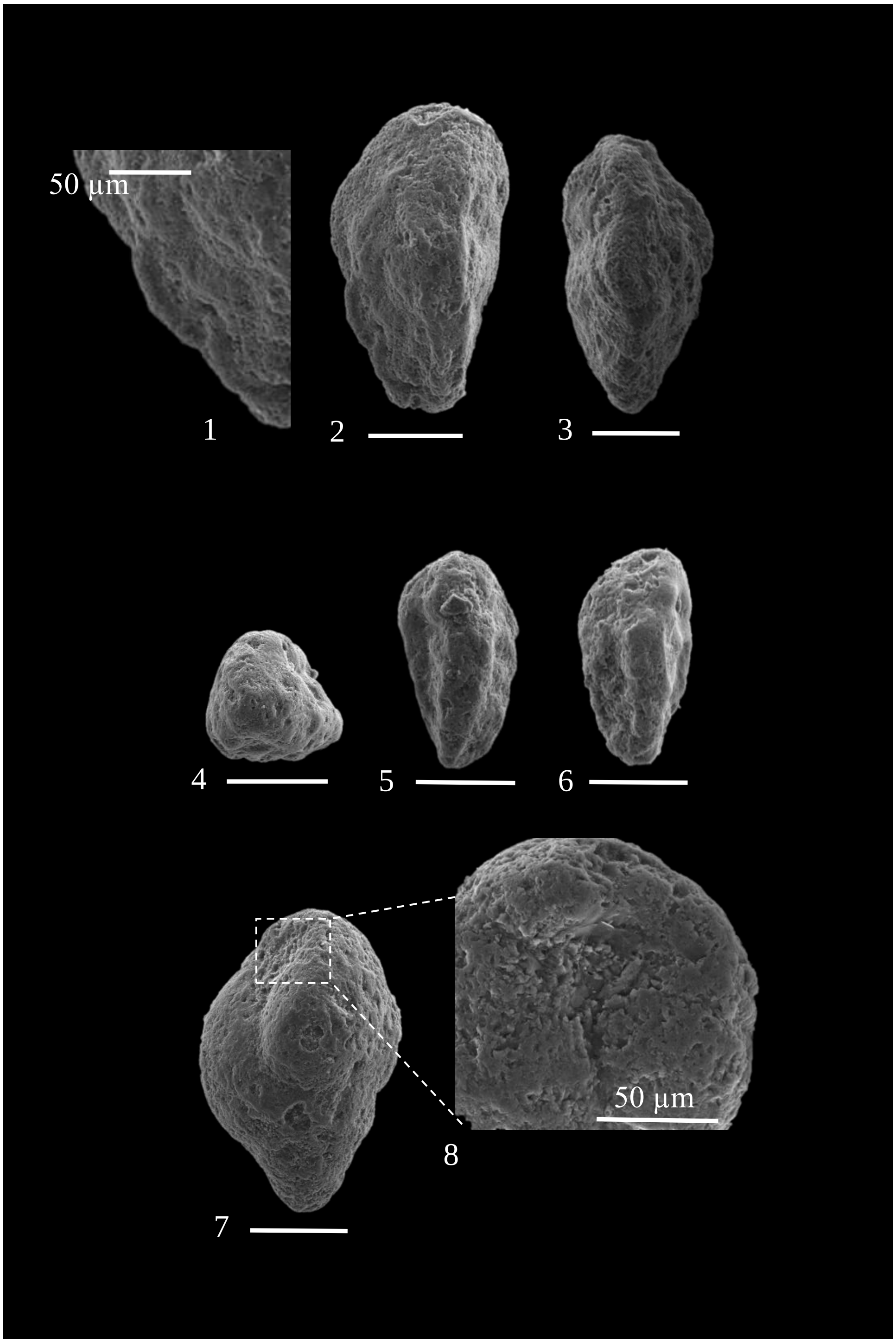

Figure A17: SEM images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

## PLATE 18

Figure A18 Explanations:

### Suborder TEXTULARIINA Delage and Herouard, 1896

### Superfamily AMMODISCACEA Reuss, 1862

1. *Ammodiscus* sp. sample no. UH-36, Maastrichtian, side view, >125 µm fraction
2. *Glomospira* sp. sample no. UH-37, Maastrichtian, side view, >125 µm fraction, light microscope image

### Superfamily ASTRORHIZACEA Brady, 1881

3. *Bathysiphon* sp. sample no. UH-49, Maastrichtian, side view, >125 µm fraction

### Superfamily ATAXOPHRAGMIACEA Schwager, 1877

4. *Arenobulimina* sp., sample no. UH-41, Maastrichtian, side view, >125 µm fraction
5. *Rhizammina* sp. 1, sample no. UH-46, Maastrichtian, side view, >125 µm fraction
6. *Rhizammina* sp. 1, sample no. UH-46, Maastrichtian, side view, >125 µm fraction

### Superfamily HAPLOPHRAGMIACEA Eimer and Pickert, 1899

7. *Recurvoides* sp., sample no. UH-37, Maastrichtian, side view, >125 µm fraction

## PLATE 18

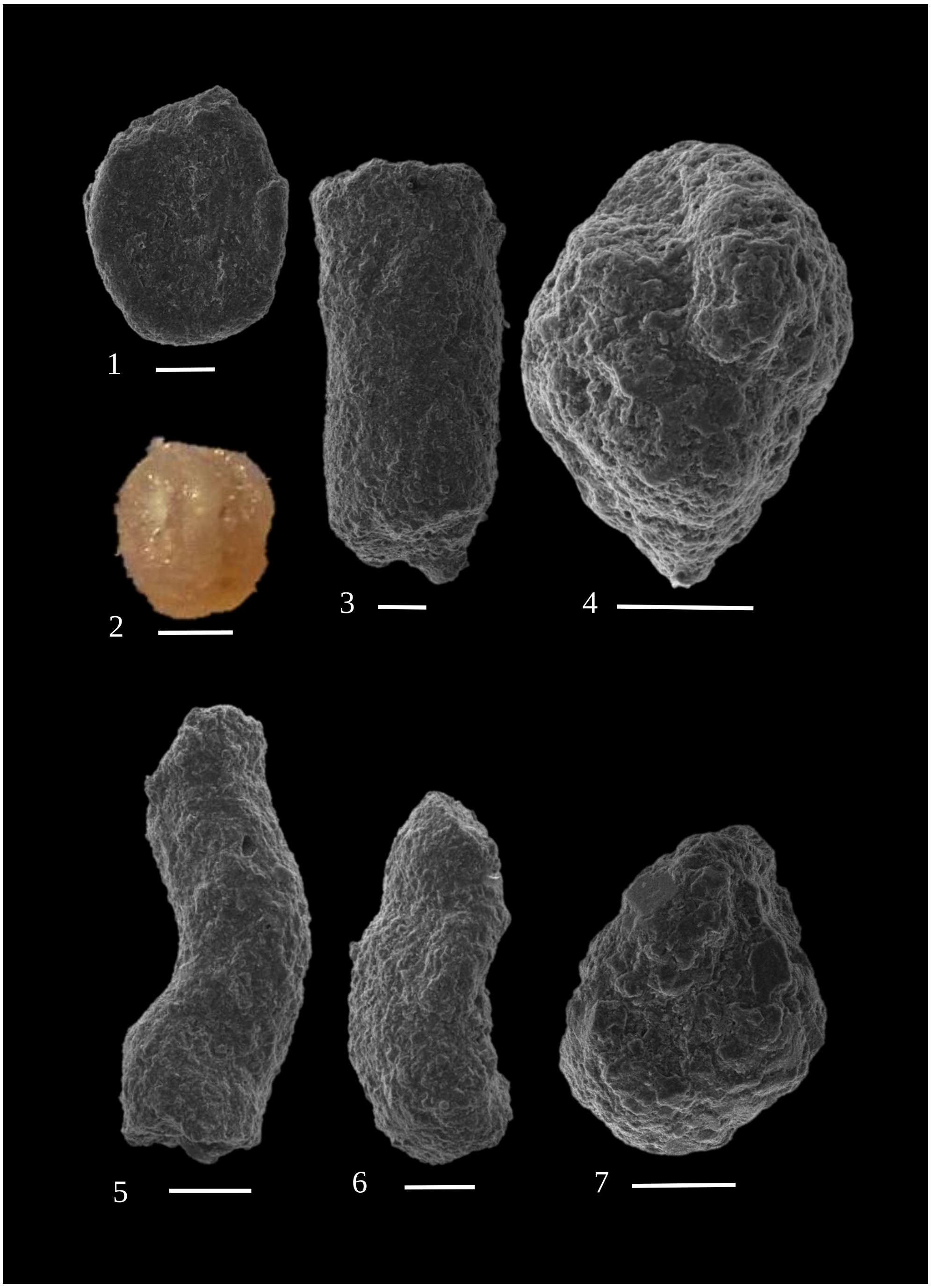

Figure A18: SEM and light microscope images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

## PLATE 19

Figure A19 Explanations:

### Superfamily HORMOSINACEA Haeckel, 1894

1. *Hormosinella* sp., sample no. UH-46, Maastrichtian, side view, >125 µm fraction

### Superfamily LITUOLACEA de Blainville, 1827

2. *Haplophragmoides* sp., sample no. UH-49, Maastrichtian, side view, >125 µm fraction
3. *Ammomarginulina* aff. *A. aubertae* (Gradstein & Kaminski, 1989), sample no. UH-49, Maastrichtian, side view, >125 µm fraction

### Superfamily SPIROPLECTAMMINACEA Cushman, 1927

4. *Spiroplectammina* aff. *S. spectabilis* (Grzybowski, 1898), emend. Kaminski, 1984, sample no. UH-47, Maastrichtian, side view, 63-125 µm fraction
5. *Spiroplectinella knebeli* (LeRoy, 1953), sample no. UH-45, Maastrichtian, side view, >125 µm fraction
6. *Spiroplectinella* sp. 1, sample no. UH-34, Maastrichtian, side view, >125 µm fraction
7. *Spiroplectinella* sp. 1, sample no. UH-34, Maastrichtian, apertural view, >125 µm fraction

## PLATE 19

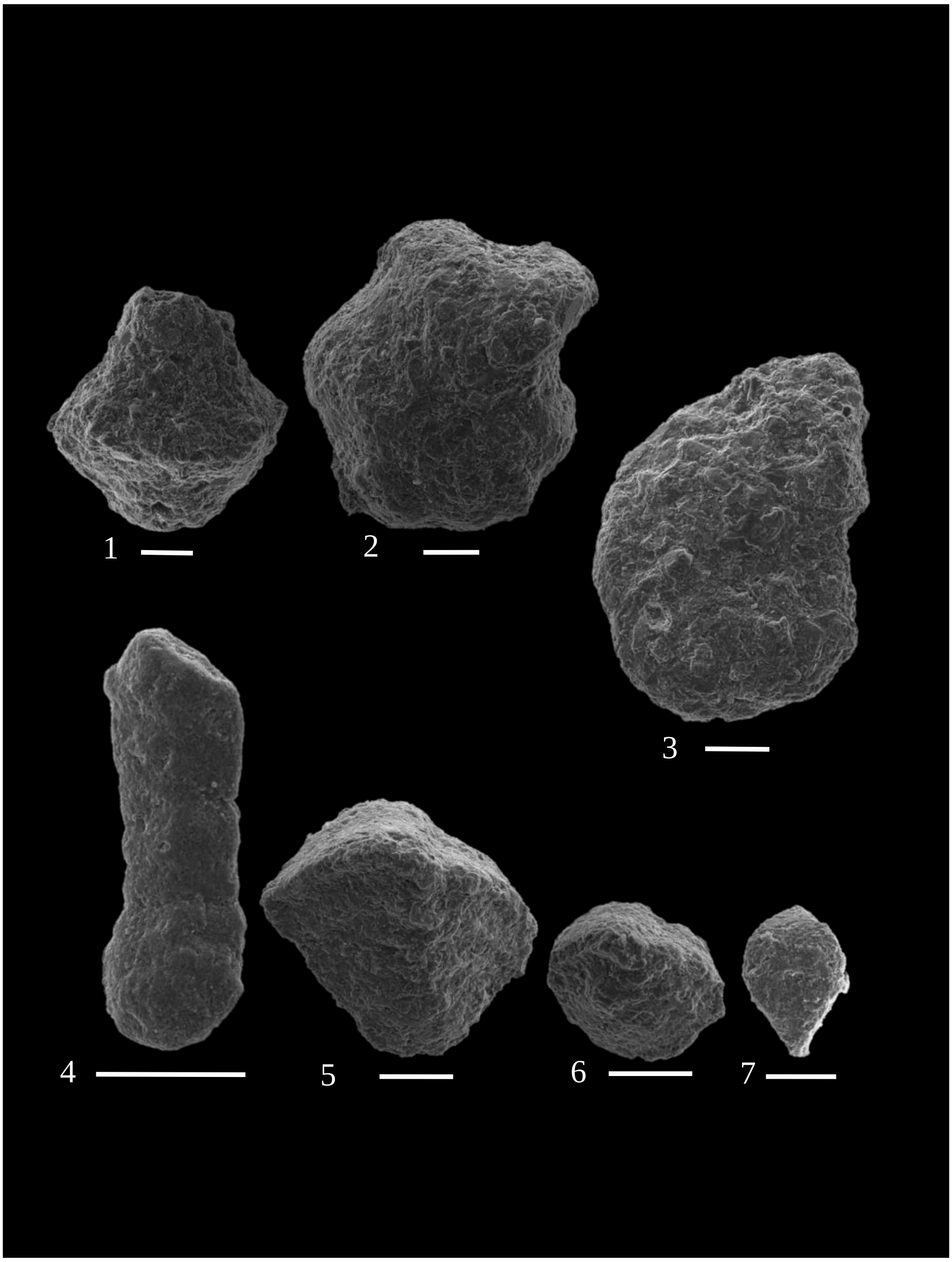

Figure A19: SEM images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

# PLATE 20

Figure A20 Explanations:

## Superfamily TEXTULARIACEA Ehrenberg, 1838

1. *Clavulinoides amorpha* (Cushman, 1926) emend. (Alegret and Thomas, 2001), sample no. UKHB-4, Danian, side view, >125 µm fraction
2. *Clavulinoides trilatera (*Cushman, 1926), sample no. UH-49, Maastrichtian, side view, >125 µm fraction
3. *Dorothia pupa* (Reuss 1860) , sample no. UH-40, Maastrichtian, side view, >125 µm fraction
4. *Dorothia* sp. 1, sample no. UKHB-10, Danian, side view, >125 µm fraction
5. *Marssonella indetata* (Cushmaii and Jarvis, 1928) , sample no. UKHB-4, Danian, side view, >125 µm fraction
6. *Marssonella indetata* (Cushmaii and Jarvis, 1928) , sample no. UKHB-8, Danian, side view, >125 µm fraction, light microscope image
7. *Marssonella oxycona* (Reuss, 1860) sample no. UH-50, Danian, side view, >125 µm fraction
8. *Marssonella oxycona* (Reuss, 1860) sample no. UKHB-10, Danian, apertural view, >125 µm fraction

# PLATE 20

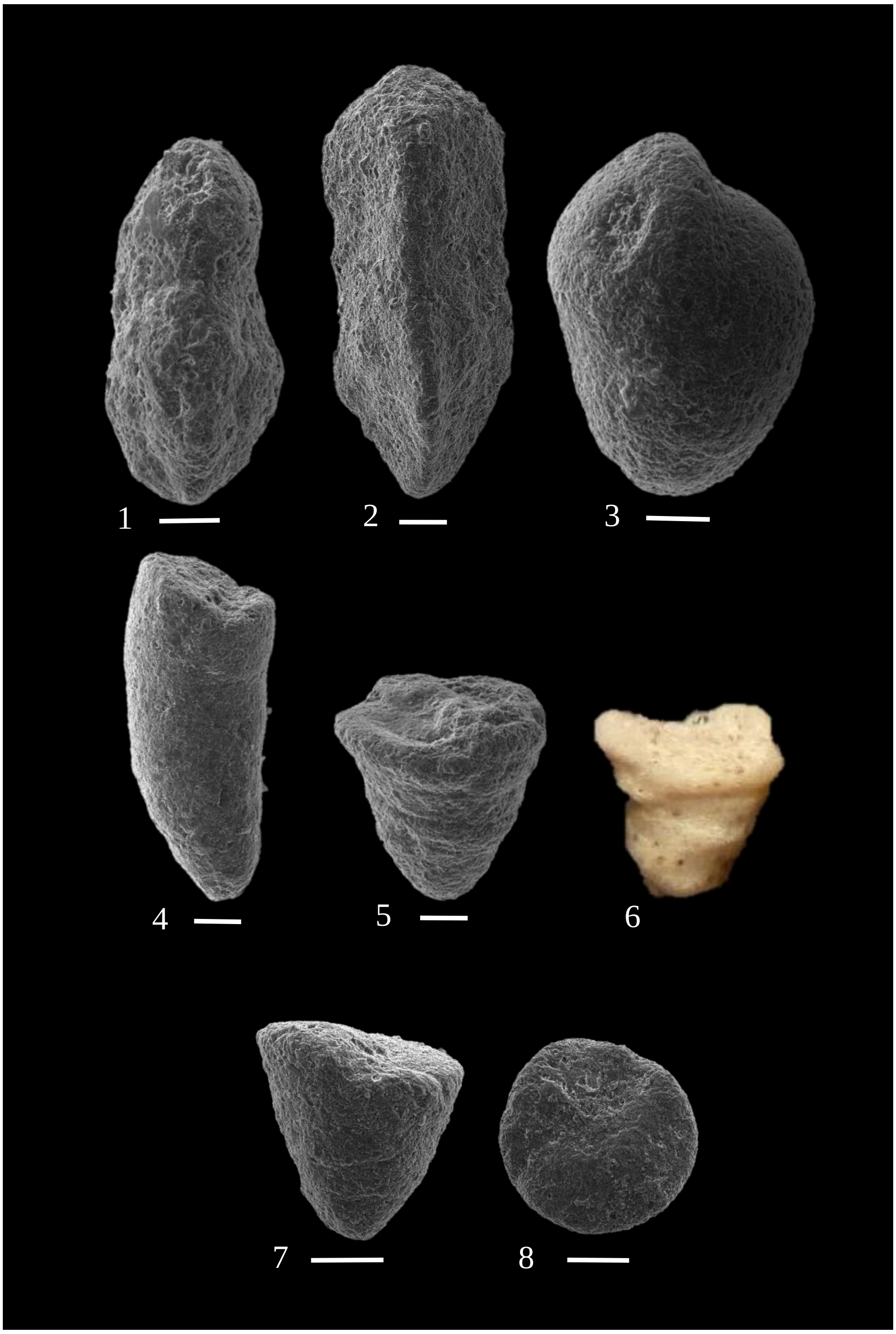

Figure A20: SEM and light microscope images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

## PLATE 21

Figure A21 Explanations:

### Superfamily TEXTULARIACEA Ehrenberg, 1838

1. *Pseudogaudryina* sp. 1, sample no. UH-41, Maastrichtian, side view, >125 µm fraction
2. *Pseudogaudryina* sp. 1, sample no. UH-41, Maastrichtian, apertural view, >125 µm fraction
3. *Pseudogaudryina* sp. 2, sample no. UH-41, Maastrichtian, side view, >125 µm fraction
4. *Pseudogaudryina* sp. 2, sample no. UH-48, Maastrichtian, apertural view, >125 µm fraction
5. *Pseudogaudryina* sp. 2, sample no. UH-48, Maastrichtian, close view to aperture, >125 µm fraction
6. *Pseudogaudryina* sp. 3 sample no. UH-40, Maastrichtian, side view, >125 µm fraction
7. *Pseudogaudryina* sp. 3 sample no. UH-40, Maastrichtian, apertural view, >125 µm fraction

## PLATE 21

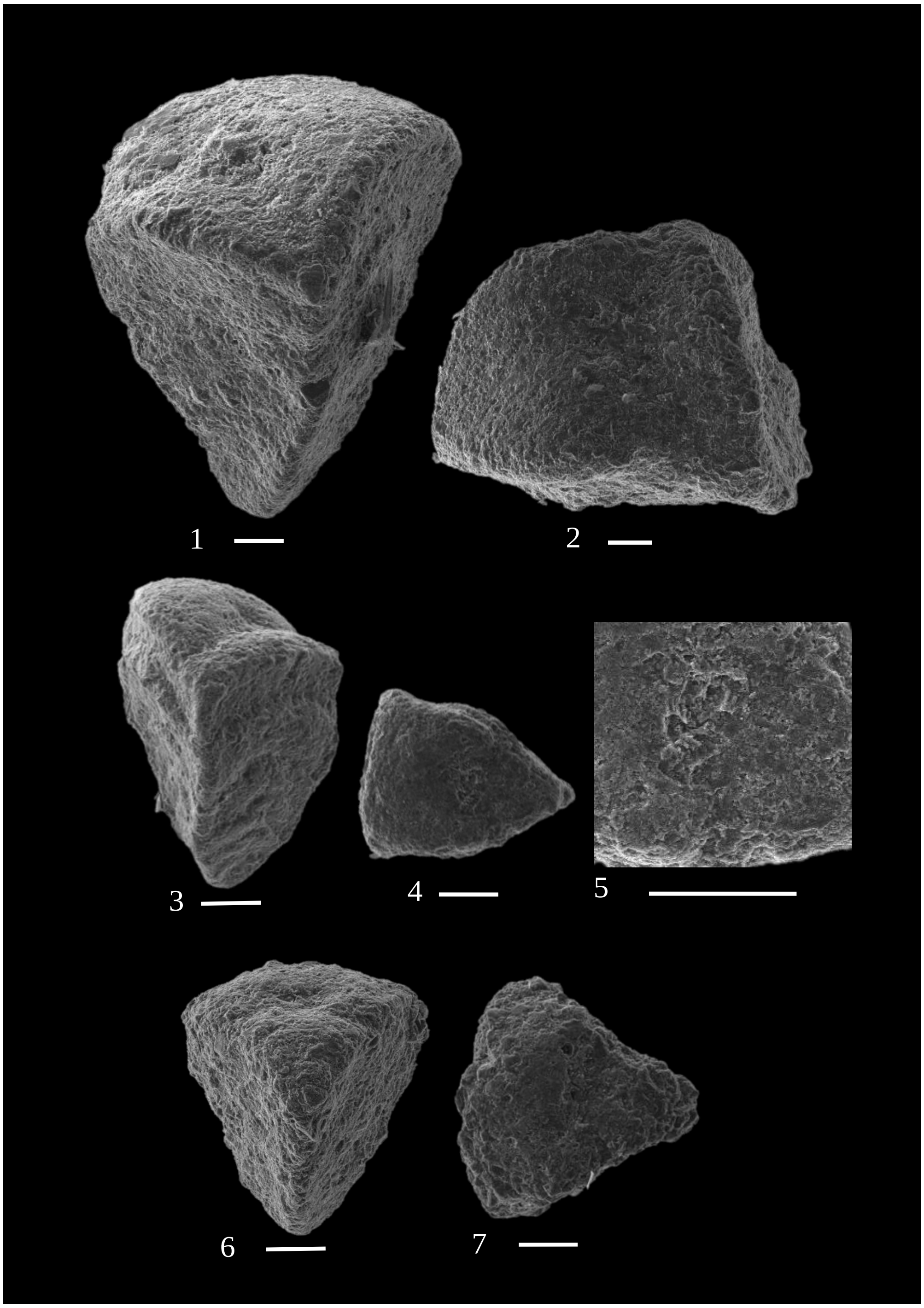

Figure A21: SEM images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

# PLATE 22

Figure A22 Explanations:

## Superfamily VERNEUILINACEA Cushman, 1911

1. *Eggerellina* sp. 1, sample no. UH-34, Maastrichtian, side view, >125 μm fraction
2. *Eggerellina* sp. 1, sample no. UH-34, Maastrichtian, apertural view, >125 μm fraction
3. *Gaudryina* sp. 1, sample no. UH-34, Maastrichtian, side view, >125 μm fraction
4. *Gaudryina* sp. 1, sample no. UH-42, Maastrichtian, side view, >125 μm fraction

## PLATE 22

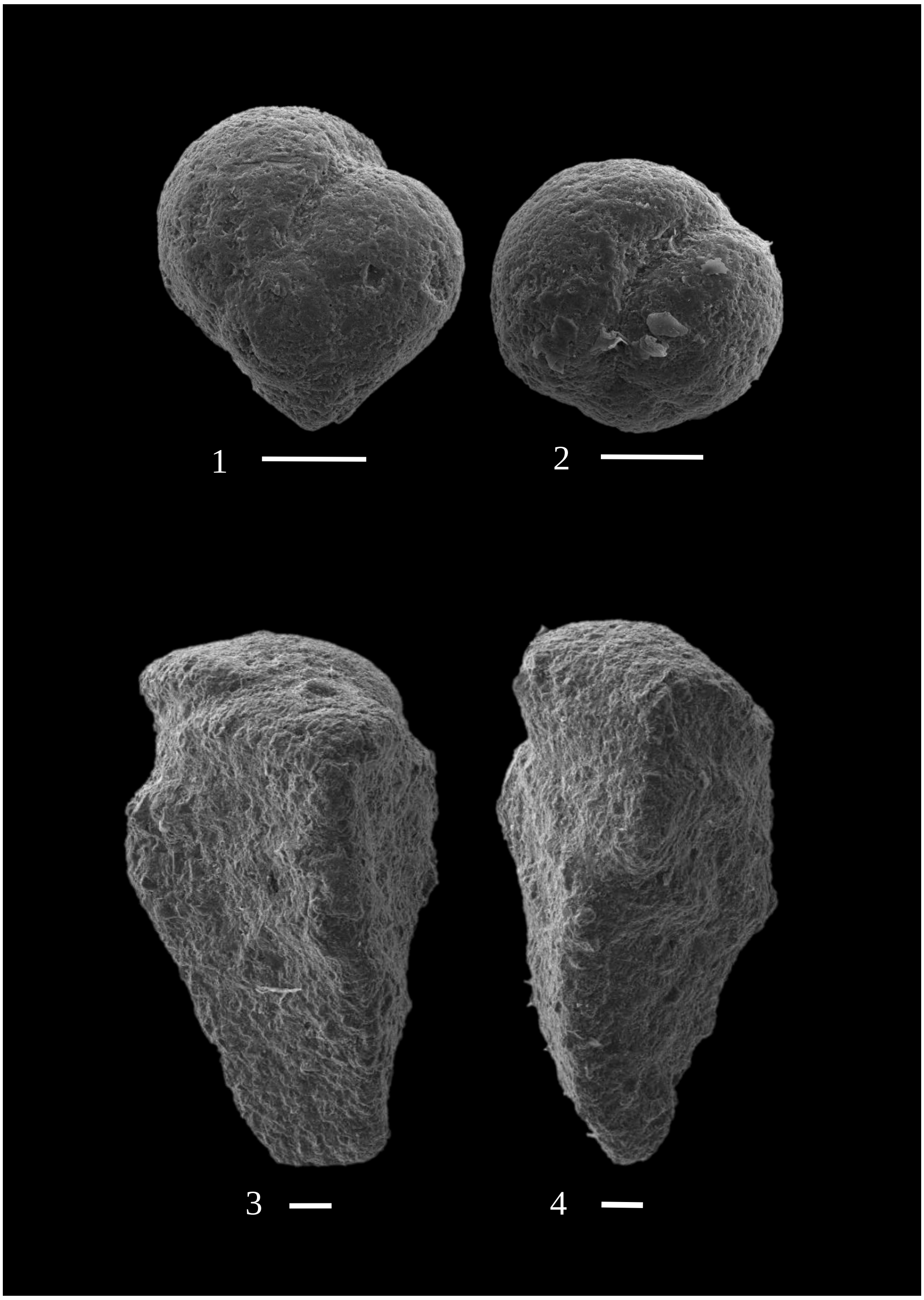

Figure A22: SEM images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

# PLATE 23

Figure A23 Explanations:

## Superfamily VERNEUILINACEA Cushman, 1911

1. *Heterostomella austinana* (Cushman, 1946) sample no. UH-45, Maastrichtian, side view, >125 μm fraction
2. *Heterostomella austinana* (Cushman, 1946) juvenile specimen, sample no. UH-45, Maastrichtian, side view, >125 μm fraction
3. *Heterostomella* sp. 1, sample no. UH-49, Maastrichtian, side view, >125 μm fraction
4. *Heterostomella* sp. 1 juvenile specimen, sample no. UH-40, Maastrichtian, side view, >125 μm fraction
5. *Heterostomella* sp. 1, sample no. UH-36, Maastrichtian, apertural view, >125 μm fraction
6. *Tritaxia* sp.1 sample no. UKHB-9, Danian, side view, >125 μm fraction
7. *Tritaxia*? sp.2 sample no. UH-37, Maastrichtian, side view, >125 μm fraction

# PLATE 23

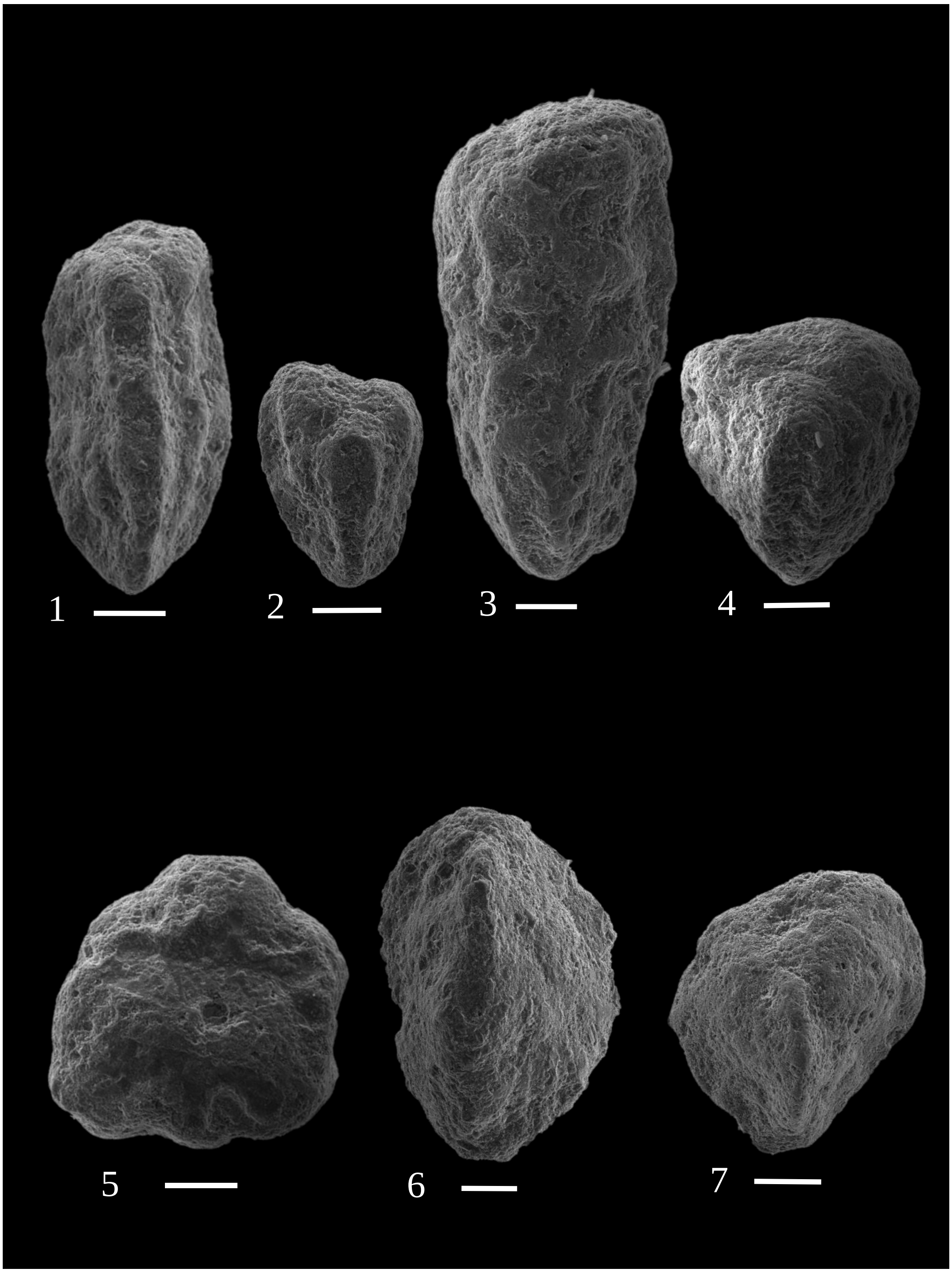

Figure A23: SEM images of benthic foraminifera taxa. Scale bar = 100 µm, otherwise stated.

# PLATE 24

Figure A24 Explanations:

## Superfamily VERNEUILINACEA Cushman, 1911

1. *Verneuilina* sp.1, sample no. UH-37, Maastrichtian, side view, >125 μm fraction
2. *Verneuilina* sp.1, sample no. UH-37, Maastrichtian, apertural view, >125 μm fraction
3. *Verneuilina* sp.2, sample no. UH-37, Maastrichtian, side view, >125 μm fraction
4. *Verneuilina* sp.2, sample no. UH-37, Maastrichtian, apertural view, >125 μm fraction
5. Echinoidea spine, sample no. UKHB-4, Danian
6. Fish tooth, sample no. UKHB-10, Danian, light microscope image

# PLATE 24

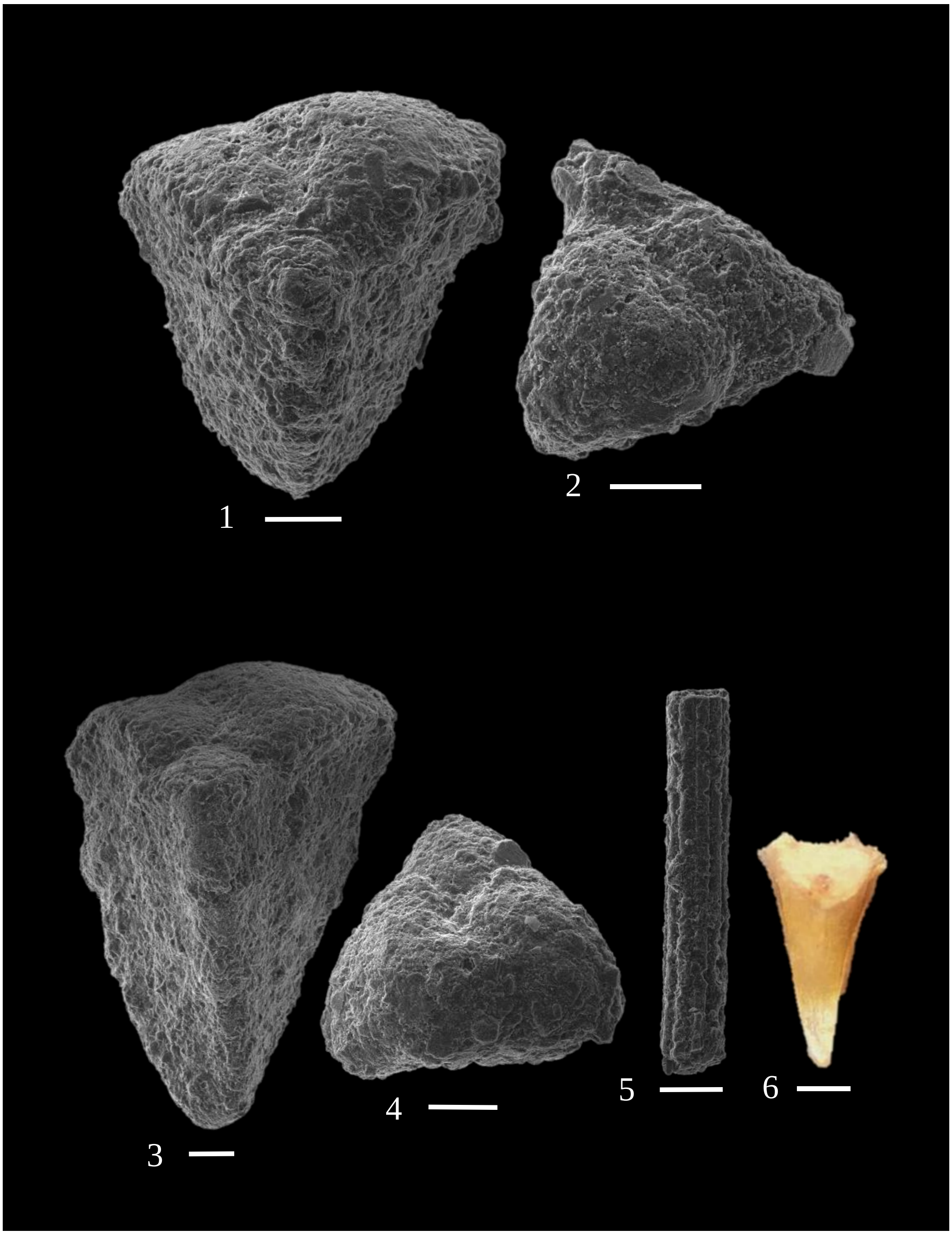

Figure A24: SEM and light microscope images of benthic foraminifera and other taxa. Scale bar = 100 µm, otherwise stated.

# APPENDIX B

# ASSIGNED MORPHOTYPES

Table B1: Epifaunal morphotype categories

| Species | Morphotype | Infaunal/Epifaunal |
|---|---|---|
| *Alabamina wilcoxensis* | planoconvex trochospiral | epifaunal |
| *Alabamina?* sp. | planoconvex trochospiral | epifaunal |
| *Allomorphina* sp. 1 | rounded trochospiral | epifaunal |
| *Allomorphina* sp. | rounded trochospiral | epifaunal |
| *Ammodiscus* spp. | coiled flattened&streptospiral | epifaunal |
| *Ammomarginulina* aff. *aubertae* | coiled flattened&streptospiral | epifaunal |
| *Ammosphaeroidina?* sp. | coiled flattened&streptospiral | epifaunal |
| *Angulogavelinella angustiumbilicata* | biconvex trochospiral | epifaunal |
| *Angulogavelinella* sp. | biconvex trochospiral | epifaunal |
| *Anomalinoides acutus* | biconvex trochospiral | epifaunal |
| *Anomalinoides welleri/affinis* | biconvex trochospiral | epifaunal |
| *Anomalinoides rubiginosus* (including jv.) | biconvex trochospiral | epifaunal |
| *Anomalinoides* sp.1 | biconvex trochospiral | epifaunal |
| *Anomalinoides* spp. | biconvex trochospiral | epifaunal |
| *Bathysiphon* spp. | tubular or branching | epifaunal |
| *Cibicides* sp. | planoconvex trochospiral | epifaunal |
| *Cibicides* sp. 1 | planoconvex trochospiral | epifaunal |
| *Cibicides* sp. 2 | planoconvex trochospiral | epifaunal |
| *Cibicidoides alleni* | biconvex trochospiral | epifaunal |
| *Cibicidoides pseudoacutus* | biconvex trochospiral | epifaunal |
| *Cibicidoides* sp. 1 | biconvex trochospiral | epifaunal |
| *Cibicidoides* sp. 2 | biconvex trochospiral | epifaunal |
| *Cibicidoides* spp. | biconvex trochospiral | epifaunal |

Table B1: Continued

| Species | Morphotype | Infaunal/Epifaunal |
|---|---|---|
| *Frondicularia* spp. | palmate | epifaunal |
| *Gavelinella* aff. *monterelensis* | rounded trochospiral | epifaunal |
| *Gavelinella* sp. 1 | rounded trochospiral | epifaunal |
| *Glomospira* sp. | coiled flattened&streptospiral | epifaunal |
| *Gyroidinoides octocameratus* | planoconvex trochospiral | epifaunal |
| *Gyroidinoides* sp. 1 | planoconvex trochospiral | epifaunal |
| *Gyroidinoides* spp. | planoconvex trochospiral | epifaunal |
| *Lenticulina* sp. 1 | biconvex trochospiral | epifaunal |
| *Lenticulina* sp. 2 | biconvex trochospiral | epifaunal |
| *Lenticulina* spp. | biconvex trochospiral | epifaunal |
| *Neoflabellina jarvisi* | palmate | epifaunal |
| *Neoflabellina* sp. | palmate | epifaunal |
| *Nuttallinella* spp. | planoconvex trochospiral | epifaunal |
| *Oridorsalis?* sp. 1 | biconvex trochospiral | epifaunal |
| *Osangularia plummerae* | biconvex trochospiral | epifaunal |
| *Osangularia* spp. | biconvex trochospiral | epifaunal |
| *Paralabamina* sp. 1 | biconvex trochospiral | epifaunal |
| *Paralabamina toulmini* | biconvex trochospiral | epifaunal |
| *Pulsiphonina prima* | biconvex trochospiral | epifaunal |
| *Ramulina* sp. 1 | branching | epifaunal |
| *Ramulina* sp. 2 | branching | epifaunal |
| *Recurvoides* sp. | coiled flattened&streptospiral | epifaunal |
| *Rhizammina* sp. 1 | tubular or branching | epifaunal |
| *Sliteria varsoviensis* | biconvex trochospiral | epifaunal |
| *Spiroplectammina* ? sp. | elongate keeled | epifaunal |
| *Spiroplectinella knebeli* | elongate keeled | epifaunal |
| *Spiroplectinella* sp. 1 | elongate keeled | epifaunal |
| *Spiroplectinella* sp. | elongate keeled | epifaunal |
| *Stensioeina* aff. *beccariformis* | Plano-convex trochospiral | epifaunal |
| *Stensioeina excolata* | planoconvex trochospiral | epifaunal |
| *Trochammina* spp. | coiled flattened&streptospiral | epifaunal |

Table B2: Infaunal morphotype categories.

| Species | Morphotype | Infaunal/Epifaunal |
|---|---|---|
| *Arenobulimina* spp. | elongate multilocular | infaunal |
| *Bolivina decurrens* | flattened tapered | infaunal |
| *Bolivina incrassata* | flattened tapered | infaunal |
| *Bolivinoides decoratus* | flattened tapered | infaunal |
| *Bolivinoides draco* | flattened tapered | infaunal |
| *Bolivinoides* sp. | flattened tapered | infaunal |
| *Bulimina arkadelphiana* var. *midwayensis* | cylindrical tapered | infaunal |
| *Bulimina strobila* | cylindrical tapered | infaunal |
| *Bulimina?* sp. | cylindrical tapered | infaunal |
| *Clavulinoides amorpha* | elongate multilocular | infaunal |
| *Clavulinoides trilatera* | elongate multilocular | infaunal |
| *Clavulinoides?* sp. | elongate multilocular | infaunal |
| *Coryphostoma plaitum* | flattened tapered | infaunal |
| *Dorothia pupa* | elongate multilocular | infaunal |
| *Dorothia* sp. | elongate multilocular | infaunal |
| *Dorothia* sp. 1 | elongate multilocular | infaunal |
| *Eggerellina* sp. 1 | elongate multilocular | infaunal |
| *Eouvigerina subsculptura* | cylindrical tapered | infaunal |
| *Gaudryina* sp. 1 | elongate multilocular | infaunal |
| *Gaudryina* sp. | elongate multilocular | infaunal |
| *Gaudryina?* sp | elongate multilocular | infaunal |
| *Globocassidulina* sp. | spherical-globose | infaunal |
| *Globulina prisca* | spherical-globose | infaunal |
| *Globulina* sp. | spherical-globose | infaunal |
| *Guttulina trigonula* | spherical-globose | infaunal |
| *Haplophragmoides* sp. | flattened trochospiral | infaunal |
| *Heterostomella austinana* (including juveniles) | elongate multilocular | infaunal |
| *Heterostomella* sp. 1 (including juveniles) | elongate multilocular | infaunal |
| *Hormosinella* sp. | elongate tapered | infaunal |
| *Laevidentalina constricta* | cylindrical tapered | infaunal |
| *Laevidentalina monile* | cylindrical tapered | infaunal |
| *Laevidentalina* spp. | cylindrical tapered | infaunal |
| *Laevidentalina?* sp. 1 | cylindrical tapered | infaunal |
| *Lagena globosa* | spherical-globose | infaunal |
| *Lagena* cf. *sulcata* | spherical-globose | infaunal |
| *Lagena* sp. 1 | spherical-globose | infaunal |
| *Lagena spp.* | spherical-globose | infaunal |

Table B2: Continued

| Species | Morphotype | Infaunal/Epifaunal |
|---|---|---|
| *Loxostomoides applini* | cylindrical tapered | infaunal |
| *Marssonella oxycona* | elongate multilocular | infaunal |
| *Marssonella indentata* | elongate multilocular | infaunal |
| *Nodosaria* sp. | cylindrical tapered | infaunal |
| *Nonionella* sp. | rounded planispiral | infaunal |
| *Nonionellina* sp. 1 | rounded planispiral | infaunal |
| *Oolina* sp. 1 | spherical-globose | infaunal |
| *Pleurstomella?* sp. | cylindrical tapered | infaunal |
| *Praebulimina reussi* | cylindrical tapered | infaunal |
| *Pseudogaudryina* sp. 1 | elongate multilocular | infaunal |
| *Pseudogaudryina* sp. 2 | elongate multilocular | infaunal |
| *Pseudogaudryina* sp. 3 | elongate multilocular | infaunal |
| *Pseudogaudryina* spp. | elongate multilocular | infaunal |
| *Pseudonodosaria manifesta* | cylindrical tapered | infaunal |
| *Pseudonodosaria?* sp. | cylindrical tapered | infaunal |
| *Pseudouvigerina plummerae* | cylindrical tapered | infaunal |
| *Pseudouvigerina* sp. 1 | cylindrical tapered | infaunal |
| *Pullenia jarvisi* | rounded planispiral | infaunal |
| *Pullenia* spp. | rounded planispiral | infaunal |
| *Pullenia* sp. 1 | rounded planispiral | infaunal |
| *Pyramidina minuta* | cylindrical tapered | infaunal |
| *Pyramidulina* spp. | cylindrical tapered | infaunal |
| *Pyrulina* sp. | cylindrical tapered | infaunal |
| *Quadrimorphina allomoprhinoides* | spherical-globose | infaunal |
| *Quadrimorphina* sp. | spherical-globose | infaunal |
| *Reussella?* sp. 1 | cylindrical tapered | infaunal |
| *Reussella?* spp. | cylindrical tapered | infaunal |
| *Sitella spp.* (including *Sitella cushmani)* | cylindrical tapered | infaunal |
| *Tritaxia* spp. | elongate multilocular | infaunal |
| *Tritaxia* sp. 1 | elongate multilocular | infaunal |
| *Tritaxia?* sp. 2 | elongate multilocular | infaunal |
| *Vaginulopsis?* sp. | flattened tapered | infaunal |
| *Verneuilina* sp. 1 | elongate multilocular | infaunal |
| *Verneuilina* sp. 2 | elongate multilocular | infaunal |
| *Verneuilina* spp. | elongate multilocular | infaunal |
| *Verneuilina?* sp. | elongate multilocular | infaunal |

# APPENDIX C

## RELATIVE ABUNDANCE (%) AT SPECIFIC LEVEL

Table C1: Relative abundance (%) of the species in the studied samples.

| | UH33 | UH-34 | UH-35 | UH-36 | UH-37 | UH-38 | UH-39 | UH-40 | UH-41 | UH-42 | UH-43 | UH-44 | UH-45 | UH-46 | UH-47 | UH-48 | UH-49 | UH-50 | UKHB-4 | UKHB-5 | UKHB-6 | UKHB-7 | UKHB-8 | UKHB-9 | UKHB-10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split |
| *Alabamina wilcoxensis* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,2 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,3 | 7,4 | 6,7 | 4,5 | 5,9 | 7,1 | 5,7 | 5,6 | 2,3 |
| *Alabamina?* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,3 | 0,0 | 0,8 | 0,4 | 0,0 | 0,0 |
| *Allomorphina* sp. 1 | 0,5 | 0,0 | 0,3 | 0,0 | 0,2 | 0,0 | 0,0 | 0,3 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 |
| *Allomorphina* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,2 | 0,0 | 0,6 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Ammodiscus* spp. | 0,0 | 0,0 | 0,0 | 0,5 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Ammomarginulina* aff. *aubertae* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Ammosphaeroidina ?* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,2 | 0,0 | 0,0 |
| *Angulogavelinella angustiumbilicata* | 0,2 | 0,0 | 0,6 | 0,0 | 0,0 | 0,2 | 0,0 | 0,3 | 0,5 | 0,0 | 0,3 | 0,9 | 0,0 | 0,3 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Angulogavelinella* sp. | 0,0 | 0,8 | 0,0 | 1,2 | 0,2 | 1,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,6 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Anomalinoides acutus* | 1,0 | 1,7 | 0,6 | 2,4 | 0,5 | 0,2 | 1,2 | 1,3 | 1,9 | 1,4 | 0,0 | 0,3 | 0,0 | 0,3 | 0,3 | 0,3 | 0,0 | 9,8 | 4,3 | 10,2 | 7,8 | 4,7 | 5,5 | 8,1 | 7,7 |
| *Anomalinoides affinis/welleri* | 0,0 | 1,4 | 1,2 | 1,4 | 0,5 | 0,8 | 2,2 | 0,0 | 0,0 | 0,0 | 1,5 | 0,6 | 0,6 | 1,0 | 1,3 | 0,7 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Anomalinoides rubiginosus* (including jv.) | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 3,8 | 4,3 | 1,3 | 2,7 | 5,8 | 4,2 | 3,5 | 0,0 |
| *Anomalinoides*sp.1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 1,0 | 0,3 | 0,0 | 0,7 | 0,5 | 0,4 | 0,0 | 0,2 |
| *Anomalinoides* spp. | 1,5 | 1,1 | 0,6 | 1,7 | 1,2 | 0,0 | 0,0 | 0,5 | 0,0 | 0,7 | 1,2 | 0,6 | 1,3 | 0,5 | 1,9 | 1,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 1,9 | 1,3 | 0,4 | 0,4 |
| *Arenobulimina* spp. | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,7 | 0,3 | 0,0 | 0,0 | 0,3 | 0,6 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Bathysiphon* spp. | 0,2 | 0,0 | 0,3 | 0,2 | 0,2 | 0,0 | 0,2 | 0,3 | 0,3 | 0,2 | 0,9 | 0,6 | 0,3 | 1,0 | 0,0 | 0,7 | 0,5 | 0,2 | 0,0 | 0,3 | 0,0 | 0,0 | 0,2 | 0,4 | 0,0 |
| *Bolivina decurrens* | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Bolivina incrassata* | 0,2 | 0,3 | 0,9 | 1,4 | 0,5 | 0,6 | 0,0 | 0,0 | 0,3 | 0,0 | 2,1 | 0,9 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Bolivinoides decoratus* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 1,0 | 0,0 | 0,2 | 0,3 | 0,4 | 0,4 | 0,6 |
| *Bolivinoides draco* | 0,2 | 0,3 | 0,3 | 0,5 | 0,0 | 0,2 | 0,5 | 0,8 | 0,5 | 0,7 | 0,0 | 0,0 | 0,0 | 0,3 | 0,6 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Bolivinoides* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,7 | 0,0 | 0,0 | 0,0 | 0,4 | 0,0 | 0,0 |
| *Bulimina arkadelphiana* var. *midwayensis* | 0,2 | 0,8 | 0,0 | 1,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,6 | 0,0 | 0,0 | 0,8 | 0,3 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Bulimina strobila* | 0,5 | 1,4 | 2,4 | 2,6 | 0,7 | 0,6 | 0,5 | 2,4 | 1,4 | 1,4 | 2,7 | 2,0 | 1,6 | 2,8 | 2,3 | 4,3 | 5,6 | 0,5 | 0,0 | 0,0 | 1,0 | 0,0 | 1,8 | 0,0 | 0,0 |
| *Chilostomella* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 |

Table C1: Continued

| | UH33 | UH-34 | UH-35 | UH-36 | UH-37 | UH-38 | UH-39 | UH-40 | UH-41 | UH-42 | UH-43 | UH-44 | UH-45 | UH-46 | UH-47 | UH-48 | UH-49 | UH-50 | UKHB-4 | UKHB-5 | UKHB-6 | UKHB-7 | UKHB-8 | UKHB-9 | UKHB-10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.spli | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split |
| *Cibicides* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,4 |
| *Cibicides* sp. 1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,3 | 0,8 | 2,0 | 2,7 | 5,9 | 4,2 | 6,2 |
| *Cibicides* sp. 2 | 0,0 | 0,0 | 0,3 | 0,2 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,2 | 0,3 | 0,0 | 0,3 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Cibicidoides alleni* | 0,0 | 0,0 | 0,6 | 0,0 | 0,0 | 0,0 | 0,0 | 0,8 | 1,1 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Cibicidoides pseudoacutus* | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,6 | 0,2 | 1,1 | 1,9 | 0,2 | 1,2 | 0,9 | 1,3 | 1,3 | 0,3 | 1,3 | 0,0 | 7,2 | 4,7 | 7,2 | 3,7 | 1,1 | 0,2 | 2,8 | 0,8 |
| *Cibicidoides* sp. 1 | 3,7 | 0,8 | 2,1 | 0,5 | 1,4 | 1,4 | 1,7 | 0,8 | 1,4 | 1,2 | 0,6 | 2,0 | 1,3 | 1,8 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Cibicidoides* sp. 2 | 0,5 | 1,1 | 0,0 | 0,2 | 0,7 | 1,0 | 1,2 | 2,4 | 1,9 | 0,9 | 0,6 | 1,1 | 1,0 | 2,0 | 1,3 | 0,7 | 1,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Cibicidoides* spp. | 4,9 | 2,2 | 3,7 | 1,4 | 2,9 | 3,8 | 3,0 | 4,0 | 2,7 | 1,2 | 3,3 | 3,7 | 2,2 | 2,8 | 4,8 | 0,7 | 0,0 | 17,5 | 10,0 | 9,6 | 7,1 | 8,5 | 5,5 | 2,1 | 1,9 |
| *Clavulinoides amorpha* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 1,2 | 1,3 | 0,3 | 0,2 | 0,3 | 0,2 | 0,4 | 0,0 |
| *Clavulinoides trilatera* | 0,5 | 0,3 | 0,9 | 0,2 | 0,2 | 0,0 | 0,7 | 0,8 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,5 | 0,3 | 0,0 | 0,5 | 0,0 | 0,3 | 0,0 | 0,2 | 0,3 | 0,0 | 0,0 | 0,0 |
| *Clavulinoides?* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,3 | 0,3 | 0,0 | 1,0 | 0,0 | 1,2 | 0,3 | 0,0 | 0,0 | 0,3 | 0,4 | 0,4 | 0,0 |
| *Coryphostoma plaitum* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Dorothia pupa* | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Dorothia* sp. | 0,5 | 0,0 | 0,3 | 0,5 | 1,2 | 0,4 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 1,0 | 0,0 | 0,3 | 0,0 | 0,3 | 0,2 | 4,3 | 2,4 | 0,5 | 2,7 | 2,2 | 2,5 | 0,8 |
| *Dorothia* sp. 1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,2 |
| *Eggerellina* sp. 1 | 0,7 | 0,3 | 0,6 | 0,0 | 0,2 | 0,4 | 0,5 | 0,0 | 0,0 | 0,5 | 0,9 | 0,0 | 1,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Eouvigerina subsculptura* | 21,2 | 21,2 | 19,6 | 11,2 | 16,3 | 20,2 | 14,8 | 20,9 | 19,2 | 22,8 | 23,0 | 19,2 | 16,3 | 16,8 | 13,5 | 15,1 | 17,2 | 1,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Frondicularia* spp. | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Gaudryina* sp. 1 | 0,0 | 0,8 | 0,9 | 0,2 | 0,2 | 0,0 | 0,0 | 1,1 | 0,5 | 0,2 | 0,3 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Gaudryina* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 1,9 | 1,8 | 0,0 | 1,5 |
| *Gaudryina? sp* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 1,2 | 0,0 | 0,3 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 |
| *Gavelinella* aff. *monterelensis* | 0,2 | 0,8 | 0,0 | 0,2 | 0,0 | 0,4 | 0,0 | 0,3 | 0,8 | 0,2 | 0,0 | 0,0 | 0,3 | 0,5 | 0,3 | 0,7 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Gavelinella* sp. 1 | 0,2 | 0,0 | 0,0 | 0,2 | 0,2 | 0,6 | 0,0 | 1,1 | 0,8 | 0,2 | 0,0 | 0,3 | 0,0 | 0,3 | 1,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Globocassidulina* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,9 | 1,4 | 1,5 |
| *Globulina prisca* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 1,0 |
| *Globulina* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,2 | 0,0 | 0,0 | 0,4 | 0,8 |
| *Glomospira* sp. | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,2 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Guttulina trigonula* | 0,2 | 0,0 | 0,3 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,2 |
| *Gyroidinoides octocameratus* | 0,5 | 0,8 | 0,3 | 1,0 | 0,2 | 0,4 | 0,7 | 0,0 | 0,0 | 0,0 | 0,3 | 0,6 | 0,0 | 0,0 | 0,0 | 0,7 | 0,5 | 0,0 | 0,0 | 2,9 | 1,2 | 1,1 | 1,1 | 0,7 | 1,2 |
| *Gyroidinoides* sp. 1 | 0,0 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,8 | 0,5 | 1,1 | 0,4 | 0,4 | 0,0 |
| *Gyroidinoides* spp. | 1,2 | 1,1 | 0,9 | 1,0 | 1,0 | 1,0 | 0,0 | 2,9 | 1,1 | 0,7 | 1,5 | 0,9 | 2,2 | 0,5 | 0,0 | 0,3 | 0,3 | 1,4 | 3,0 | 10,4 | 10,8 | 3,3 | 7,7 | 3,2 | 3,5 |
| *Haplophragmoides* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Heterostomella austinana* (including juveniles) | 6,3 | 6,4 | 6,4 | 5,5 | 6,5 | 3,6 | 4,2 | 7,7 | 4,7 | 4,5 | 4,8 | 5,7 | 8,0 | 10,2 | 10,6 | 7,5 | 11,0 | 0,7 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Heterostomella* sp. 1 (including juveniles) | 0,2 | 0,0 | 0,9 | 0,5 | 0,0 | 0,6 | 0,2 | 0,8 | 0,0 | 0,0 | 0,0 | 0,3 | 0,3 | 1,0 | 1,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |

Table C1: Continued

| | UH33 | UH-34 | UH-35 | UH-36 | UH-37 | UH-38 | UH-39 | UH-40 | UH-41 | UH-42 | UH-43 | UH-44 | UH-45 | UH-46 | UH-47 | UH-48 | UH-49 | UH-50 | UKHB-4 | UKHB-5 | UKHB-6 | UKHB-7 | UKHB-8 | UKHB-9 | UKHB-10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split |
| *Hormosinella* sp. | 0,0 | 0,0 | 0,0 | 0,2 | 0,2 | 0,2 | 0,2 | 0,3 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Laevidentalina constricta* | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,2 |
| *Laevidentalina monile* | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Laevidentalina* spp. | 0,0 | 0,0 | 0,6 | 0,2 | 0,0 | 0,4 | 0,7 | 0,3 | 0,3 | 0,9 | 0,3 | 0,3 | 0,6 | 0,3 | 0,0 | 1,0 | 0,3 | 1,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,7 | 0,0 |
| *Laevidentalina*? sp. 1 | 0,2 | 0,0 | 0,3 | 0,0 | 0,0 | 0,2 | 0,5 | 0,0 | 0,3 | 0,2 | 0,0 | 0,0 | 0,6 | 0,3 | 0,3 | 0,3 | 0,0 | 0,0 | 0,7 | 0,0 | 0,2 | 0,0 | 0,0 | 0,4 | 0,2 |
| *Lagena globosa* | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 |
| *Lagena* cf. *sulcata* | 0,0 | 0,0 | 0,0 | 0,5 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,9 | 0,0 | 0,0 | 0,0 | 0,6 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 |
| *Lagena* sp. 1 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Lagena* spp. | 0,2 | 0,0 | 0,3 | 0,0 | 0,0 | 0,8 | 0,2 | 0,0 | 0,3 | 0,7 | 0,0 | 0,0 | 0,3 | 0,3 | 0,6 | 1,0 | 0,0 | 0,5 | 0,7 | 1,1 | 1,7 | 1,4 | 1,1 | 0,4 | 0,6 |
| *Lenticulina* sp. 1 | 0,7 | 0,0 | 0,0 | 1,0 | 1,9 | 0,4 | 0,2 | 0,8 | 1,6 | 0,7 | 0,0 | 1,4 | 1,0 | 0,5 | 1,9 | 0,3 | 0,8 | 0,7 | 1,0 | 0,5 | 1,5 | 1,1 | 0,4 | 1,4 | 2,9 |
| *Lenticulina* sp. 2 | 0,7 | 0,0 | 0,6 | 0,0 | 0,0 | 0,6 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,4 |
| *Lenticulina* spp. | 1,0 | 2,2 | 2,1 | 1,9 | 1,9 | 1,0 | 1,7 | 1,3 | 1,9 | 0,9 | 0,9 | 1,4 | 1,6 | 0,8 | 0,3 | 0,7 | 0,5 | 2,9 | 4,0 | 2,1 | 4,2 | 6,0 | 3,3 | 3,9 | 2,3 |
| *Loxostomoides applini* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,5 | 1,6 | 1,8 | 0,0 | 1,2 |
| *Marginulopsis multicostata* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Marssonella oxycona* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,3 | 0,8 | 0,7 | 1,4 | 0,2 | 1,1 | 1,0 |
| *Marssonella indentata* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,7 | 0,0 | 0,0 | 0,8 | 0,4 | 0,0 | 0,2 |
| *Neoflabellina jarvisi* | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,6 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Neoflabellina* sp. | 0,0 | 0,3 | 0,0 | 0,0 | 0,2 | 0,2 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Nodosaria* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,3 | 0,3 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Nonionella* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,5 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,3 | 0,2 | 0,4 | 1,2 |
| *Nonionellina* sp. 1 | 0,2 | 0,0 | 0,0 | 0,2 | 0,7 | 0,6 | 1,0 | 0,0 | 0,3 | 0,9 | 0,0 | 0,6 | 0,3 | 0,3 | 0,3 | 0,0 | 0,5 | 1,9 | 1,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 1,7 |
| *Nuttallinella* spp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,4 | 0,7 | 0,0 | 0,8 | 1,6 | 0,9 | 0,0 | 0,0 | 0,3 | 0,6 | 0,7 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Oolina* sp. 1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 |
| *Oridorsalis?* sp. 1 | 0,2 | 0,3 | 0,0 | 0,0 | 0,5 | 0,4 | 0,7 | 0,0 | 0,0 | 0,2 | 0,3 | 0,0 | 0,3 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Osangularia plummerae* | 1,2 | 0,3 | 0,0 | 0,2 | 0,5 | 0,2 | 0,5 | 0,3 | 0,8 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 9,4 | 7,0 | 8,6 | 9,0 | 5,9 | 0,0 | 0,6 |
| *Osangularia* spp. | 0,5 | 0,8 | 0,0 | 0,0 | 0,0 | 0,2 | 0,2 | 1,1 | 0,8 | 0,2 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 1,7 | 3,5 | 2,2 | 4,9 | 3,5 | 6,7 | 0,0 |
| *Paralabamina* sp. 1 | 0,0 | 0,0 | 0,6 | 0,2 | 0,2 | 0,6 | 0,2 | 0,8 | 0,0 | 0,7 | 0,9 | 0,9 | 0,6 | 0,0 | 0,6 | 0,7 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Paralabamina toulmini* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,7 | 1,3 | 1,2 | 0,0 | 0,4 | 0,7 | 2,3 |
| *Pleurstomella?* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,6 | 0,0 | 0,3 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 |
| *Praebulimina reussi* | 7,6 | 7,0 | 7,0 | 2,9 | 6,9 | 5,3 | 5,9 | 2,6 | 7,1 | 8,0 | 5,7 | 9,5 | 6,1 | 5,4 | 5,5 | 7,2 | 5,9 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Praebulimina ?* sp. | 0,0 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,3 | 0,3 | 2,4 | 5,7 | 2,7 | 4,4 | 1,4 | 1,3 | 1,4 | 0,0 |
| *Pseudogaudryina* sp. 1 | 0,2 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,2 | 0,0 | 0,5 | 0,5 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Pseudogaudryina* sp. 2 | 0,0 | 0,0 | 0,0 | 0,5 | 1,7 | 1,4 | 2,7 | 2,4 | 1,1 | 0,5 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Pseudogaudryina* sp. 3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,5 | 0,0 | 0,2 | 0,3 | 0,0 | 0,6 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Pseudogaudryina* spp. | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 1,0 | 0,0 | 0,0 | 0,3 | 1,1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |

Table C1: Continued

| | UH33 | UH-34 | UH-35 | UH-36 | UH-37 | UH-38 | UH-39 | UH-40 | UH-41 | UH-42 | UH-43 | UH-44 | UH-45 | UH-46 | UH-47 | UH-48 | UH-49 | UH-50 | UKHB-4 | UKHB-5 | UKHB-6 | UKHB-7 | UKHB-8 | UKHB-9 | UKHB-10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split |
| *Pseudonodosaria manifesta* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,8 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Pseudonodosaria?* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,3 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,4 |
| *Pseudouvigerina plummerae* | 0,0 | 0,3 | 0,0 | 0,0 | 2,6 | 8,9 | 6,2 | 6,3 | 2,7 | 0,9 | 1,2 | 1,1 | 3,2 | 2,6 | 6,1 | 3,0 | 3,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Pseudouvigerina* sp. 1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,4 | 0,4 |
| *Pullenia jarvisi* | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 1,1 | 0,8 |
| *Pullenia* spp. | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,5 | 0,3 | 0,5 | 0,5 | 0,6 | 0,0 | 0,3 | 0,0 | 0,0 | 0,7 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,4 | 0,0 | 1,0 |
| *Pullenia* sp. 1 | 0,0 | 0,3 | 0,6 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,5 | 0,2 | 0,0 | 0,3 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Pulsiphonina prima* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 2,9 | 7,7 | 12,7 |
| *Pyramidina minuta* | 0,0 | 0,6 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 1,2 | 0,6 | 0,0 | 0,6 | 0,0 | 0,6 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Pyramidulina* spp. | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,2 | 0,6 | 0,0 | 0,0 | 0,3 | 0,0 | 0,7 | 0,3 | 0,0 | 0,0 | 0,3 | 0,2 | 0,3 | 0,0 | 0,0 | 0,2 |
| *Pyrulina* sp. | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 |
| *Quadrimorphina allomoprhinoides* | 0,0 | 0,8 | 0,3 | 0,5 | 0,0 | 0,0 | 0,2 | 0,5 | 0,0 | 0,9 | 0,6 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,4 | 1,2 |
| *Quadrimorphina* sp. | 0,0 | 0,3 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Ramulina* sp. 1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,3 | 0,0 | 0,0 | 0,3 | 0,2 | 0,4 | 0,2 |
| *Ramulina* sp. 2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Recurvoides* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Reussella?* sp. 1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,7 | 0,3 | 0,3 | 0,2 | 0,3 | 0,9 | 0,0 | 0,4 |
| *Reussella?* spp. | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 1,0 | 0,5 | 0,0 | 0,5 | 0,2 | 1,1 | 1,9 |
| *Rhizammina* sp. 1 | 0,0 | 0,3 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,8 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Saracenaria* sp. | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,2 | 0,3 | 0,0 | 0,7 | 1,0 |
| *Sitella* spp. (including *Sitella cushmani*) | 7,3 | 5,3 | 1,5 | 9,8 | 6,5 | 4,6 | 9,6 | 4,8 | 5,2 | 3,1 | 6,9 | 9,2 | 13,1 | 4,3 | 6,8 | 8,5 | 9,7 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Sliteria varsoviensis* | 5,4 | 3,9 | 6,4 | 1,9 | 4,8 | 2,2 | 2,0 | 0,3 | 0,0 | 0,5 | 0,0 | 2,0 | 1,6 | 2,3 | 1,3 | 0,7 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Spiroplectammina ?* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,6 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Spiroplectinella knebeli* | 0,5 | 0,3 | 0,9 | 0,2 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,3 | 0,3 | 0,3 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Spiroplectinella* sp. 1 | 2,2 | 2,2 | 2,4 | 2,1 | 0,5 | 1,4 | 1,2 | 0,8 | 1,4 | 1,2 | 0,9 | 0,9 | 2,2 | 0,5 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Spiroplectinella* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 1,1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Stensioeina ?* aff. *beccariformis* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 2,9 |
| *Stensioeina excolata* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,2 | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Tritaxia* spp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,7 | 0,0 | 1,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 3,2 | 1,2 |
| *Tritaxia* sp. 1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,3 | 0,0 | 0,7 | 0,6 |
| *Tritaxia?* sp. 2 | 0,2 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,7 | 0,0 | 0,0 | 0,0 | 0,5 | 0,2 | 0,3 | 0,0 | 0,0 | 0,4 |
| *Trochammina* spp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,2 | 0,0 | 0,0 |
| Uniserial tests | 0,0 | 0,0 | 0,6 | 0,7 | 1,4 | 0,0 | 0,0 | 0,3 | 0,0 | 1,2 | 1,2 | 0,3 | 0,3 | 0,3 | 0,6 | 1,0 | 0,8 | 0,2 | 0,3 | 1,3 | 1,2 | 0,5 | 1,1 | 0,4 | 0,6 |
| *Vaginulopsis?* sp. | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,8 | 0,0 | 0,3 | 0,2 | 0,4 | 0,0 |
| *Verneuilina* sp. 1 | 1,5 | 2,2 | 2,4 | 3,1 | 3,1 | 2,4 | 0,7 | 0,3 | 2,5 | 0,5 | 1,2 | 1,1 | 0,6 | 0,0 | 0,3 | 0,7 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |

Table C1: Continued

| | UH33 | UH-34 | UH-35 | UH-36 | UH-37 | UH-38 | UH-39 | UH-40 | UH-41 | UH-42 | UH-43 | UH-44 | UH-45 | UH-46 | UH-47 | UH-48 | UH-49 | UH-50 | UKHB-4 | UKHB-5 | UKHB-6 | UKHB-7 | UKHB-8 | UKHB-9 | UKHB-10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split |
| *Verneuilina* sp. 2 | 0,0 | 0,0 | 0,0 | 0,7 | 0,0 | 0,0 | 0,0 | 0,3 | 0,5 | 0,0 | 0,3 | 0,6 | 0,0 | 0,0 | 0,6 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Verneuilina* spp. | 0,0 | 0,6 | 0,6 | 2,9 | 0,7 | 0,6 | 0,0 | 0,0 | 0,5 | 2,1 | 0,3 | 2,0 | 1,6 | 0,5 | 1,6 | 3,0 | 0,8 | 0,0 | 0,3 | 1,6 | 2,2 | 3,8 | 2,4 | 3,9 | 1,7 |
| *Verneuilina?* sp. | 4,9 | 5,6 | 5,2 | 2,9 | 5,3 | 6,1 | 5,9 | 1,9 | 3,0 | 5,2 | 7,3 | 6,3 | 4,2 | 7,1 | 8,1 | 5,2 | 7,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Indet tests | 19,0 | 20,9 | 20,8 | 28,2 | 22,7 | 21,0 | 21,7 | 19,8 | 21,2 | 23,5 | 19,0 | 16,6 | 16,0 | 23,2 | 16,8 | 23,3 | 23,9 | 30,9 | 29,1 | 23,8 | 24,7 | 19,5 | 24,7 | 26,7 | 24,5 |

# APPENDIX D

## RELATIVE ABUNDANCE (%) AT GENUS LEVEL

Table D1: Relative abundance (%) of the genus in the studied samples.

| | UH-33 | UH-34 | UH-35 | UH-36 | UH-37 | UH-38 | UH-39 | UH-40 | UH-41 | UH-42 | UH-43 | UH-44 | UH-45 | UH-46 | UH-47 | UH-48 | UH-49 | UH-50 | UKHB-4 | UKHB-5 | UKHB-6 | UKHB-7 | UKHB-8 | UKHB-9 | UKHB-10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split |
| *Alabamina* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,2 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,3 | 7,4 | 6,7 | 4,5 | 5,9 | 7,1 | 5,7 | 5,6 | 2,3 |
| *Alabamina?* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,3 | 0,0 | 0,8 | 0,4 | 0,0 | 0,0 |
| *Allomorphina* | 0,5 | 0,0 | 0,3 | 0,0 | 0,2 | 0,0 | 0,0 | 0,3 | 0,3 | 0,5 | 0,0 | 0,6 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 |
| *Ammodiscus* | 0,0 | 0,0 | 0,0 | 0,5 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Ammomarginulina* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Ammosphaeroidina* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,2 | 0,0 | 0,0 |
| *Angulogavelinella* | 0,2 | 0,8 | 0,6 | 1,2 | 0,2 | 1,2 | 0,0 | 0,5 | 0,5 | 0,0 | 0,3 | 0,9 | 0,6 | 0,3 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Anomalinoides* | 2,4 | 4,2 | 2,4 | 5,5 | 2,2 | 1,0 | 3,4 | 1,9 | 1,9 | 2,1 | 2,7 | 1,4 | 1,9 | 1,8 | 3,5 | 2,0 | 0,3 | 14,6 | 9,4 | 11,5 | 11,2 | 12,9 | 11,5 | 11,9 | 8,3 |
| *Arenobulimina* | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,7 | 0,3 | 0,0 | 0,0 | 0,3 | 0,6 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Bathysiphon* | 0,2 | 0,0 | 0,3 | 0,2 | 0,2 | 0,0 | 0,2 | 0,3 | 0,3 | 0,2 | 0,9 | 0,6 | 0,3 | 1,0 | 0,0 | 0,7 | 0,5 | 0,2 | 0,0 | 0,3 | 0,0 | 0,0 | 0,2 | 0,4 | 0,0 |
| *Bolivina* | 0,2 | 0,6 | 0,9 | 1,4 | 0,5 | 0,6 | 0,0 | 0,0 | 0,3 | 0,2 | 2,1 | 0,9 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Bolivinoides* | 0,2 | 0,3 | 0,3 | 0,5 | 0,0 | 0,2 | 0,5 | 0,8 | 0,5 | 0,9 | 0,0 | 0,3 | 0,0 | 0,3 | 0,6 | 0,0 | 0,0 | 0,5 | 1,7 | 0,0 | 0,2 | 0,3 | 0,9 | 0,4 | 0,6 |
| *Bulimina* | 0,7 | 2,2 | 2,4 | 3,6 | 0,7 | 0,6 | 0,5 | 2,4 | 1,6 | 1,4 | 3,3 | 2,0 | 1,6 | 3,6 | 2,6 | 4,3 | 5,9 | 0,5 | 0,0 | 0,0 | 1,0 | 0,0 | 1,8 | 0,0 | 0,0 |
| *Chilostomella* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 |
| *Cibicides* | 0,0 | 0,0 | 0,3 | 0,2 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,2 | 0,3 | 0,0 | 0,3 | 0,5 | 0,0 | 0,0 | 0,0 | 0,2 | 0,3 | 0,8 | 2,0 | 2,7 | 5,9 | 4,2 | 6,7 |
| *Cibicidoides* | 9,0 | 4,2 | 6,4 | 2,1 | 5,3 | 6,7 | 6,2 | 9,0 | 9,1 | 3,8 | 5,7 | 7,7 | 5,8 | 7,9 | 6,5 | 2,6 | 1,3 | 24,7 | 14,7 | 16,8 | 10,8 | 9,6 | 5,7 | 4,9 | 2,7 |
| *Clavulinoides* | 0,5 | 0,3 | 0,9 | 0,2 | 0,2 | 0,0 | 0,7 | 0,8 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,5 | 0,3 | 0,0 | 0,5 | 1,2 | 1,7 | 0,3 | 0,5 | 0,5 | 0,2 | 0,4 | 0,0 |
| *Clavulinoides?* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,3 | 0,3 | 0,0 | 1,0 | 0,0 | 1,2 | 0,3 | 0,0 | 0,0 | 0,3 | 0,4 | 0,4 | 0,0 |
| *Coryphostoma* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Dorothia* | 0,5 | 0,3 | 0,6 | 0,5 | 1,2 | 0,4 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 1,0 | 0,0 | 0,3 | 0,0 | 0,3 | 0,2 | 4,3 | 2,4 | 0,5 | 2,7 | 2,4 | 2,5 | 1,0 |
| *Eggerellina* | 0,7 | 0,3 | 0,6 | 0,0 | 0,2 | 0,4 | 0,5 | 0,0 | 0,0 | 0,5 | 0,9 | 0,0 | 1,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Eouvigerina* | 21,2 | 21,2 | 19,6 | 11,2 | 16,3 | 20,2 | 14,8 | 20,9 | 19,2 | 22,8 | 23,0 | 19,2 | 16,3 | 16,8 | 13,5 | 15,1 | 17,2 | 1,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Frondicularia* | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Gaudryina* | 0,0 | 0,8 | 0,9 | 0,2 | 0,2 | 0,0 | 0,2 | 1,1 | 0,5 | 0,2 | 0,3 | 0,0 | 0,0 | 0,3 | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 1,9 | 1,8 | 0,0 | 1,5 |
| *Gaudryina?* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 1,2 | 0,0 | 0,3 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 |

Table D1: Continued

| | UH-33 | UH-34 | UH-35 | UH-36 | UH-37 | UH-38 | UH-39 | UH-40 | UH-41 | UH-42 | UH-43 | UH-44 | UH-45 | UH-46 | UH-47 | UH-48 | UH-49 | UH-50 | UKHB-4 | UKHB-5 | UKHB-6 | UKHB-7 | UKHB-8 | UKHB-9 | UKHB-10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split |
| *Gavelinella* | 0,5 | 0,8 | 0,0 | 0,5 | 0,2 | 1,0 | 0,0 | 1,3 | 1,6 | 0,5 | 0,0 | 0,3 | 0,3 | 0,8 | 1,3 | 1,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Globocassidulina* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,9 | 1,4 | 1,5 |
| *Globulina* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,2 | 0,0 | 0,0 | 0,4 | 1,9 |
| *Glomospira* | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,2 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Guttulina* | 0,2 | 0,0 | 0,3 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,2 |
| *Gyroidinoides* | 1,7 | 2,0 | 1,2 | 2,4 | 1,2 | 1,4 | 1,2 | 2,9 | 1,1 | 0,7 | 1,8 | 1,4 | 2,2 | 0,5 | 0,0 | 1,0 | 0,8 | 1,4 | 3,0 | 14,2 | 12,5 | 5,5 | 9,3 | 4,2 | 4,8 |
| *Haplophragmoides* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Heterostomella* | 6,6 | 6,4 | 7,3 | 6,0 | 6,5 | 4,2 | 4,4 | 8,5 | 4,7 | 4,5 | 4,8 | 6,0 | 8,3 | 11,2 | 11,6 | 7,5 | 11,0 | 1,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Hormosinella* | 0,0 | 0,0 | 0,0 | 0,2 | 0,2 | 0,2 | 0,2 | 0,3 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Laevidentalina* | 0,0 | 0,0 | 0,6 | 0,5 | 0,2 | 0,6 | 0,7 | 0,3 | 0,5 | 0,9 | 0,6 | 0,3 | 0,6 | 0,3 | 0,0 | 1,3 | 0,3 | 1,0 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,7 | 0,2 |
| *Laevidentalina?* | 0,2 | 0,0 | 0,3 | 0,0 | 0,0 | 0,2 | 0,5 | 0,0 | 0,3 | 0,2 | 0,0 | 0,0 | 0,6 | 0,3 | 0,3 | 0,3 | 0,0 | 0,0 | 0,7 | 0,0 | 0,2 | 0,0 | 0,0 | 0,4 | 0,2 |
| *Lagena* | 0,2 | 0,3 | 0,6 | 0,5 | 0,5 | 1,0 | 0,2 | 0,0 | 0,5 | 1,2 | 0,9 | 0,0 | 0,3 | 0,3 | 1,3 | 1,3 | 0,3 | 0,5 | 0,7 | 1,1 | 1,7 | 1,4 | 1,1 | 0,4 | 1,0 |
| *Lenticulina* | 2,4 | 2,2 | 2,8 | 2,9 | 3,8 | 2,0 | 2,2 | 2,1 | 3,6 | 1,6 | 0,9 | 3,2 | 2,6 | 1,3 | 2,3 | 1,0 | 1,3 | 3,6 | 5,0 | 2,7 | 5,6 | 7,1 | 3,7 | 5,3 | 5,6 |
| *Loxostomoides* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,5 | 1,6 | 1,8 | 0,0 | 1,2 |
| *Marginulopsis* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Marssonella* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 1,0 | 0,8 | 0,7 | 2,2 | 0,7 | 1,1 | 1,2 |
| *Neoflabellina* | 0,0 | 0,6 | 0,3 | 0,0 | 0,2 | 0,2 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,6 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Nodosaria* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,3 | 0,3 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Nonionella* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,5 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,3 | 0,2 | 0,4 | 1,2 |
| *Nonionellina* | 0,2 | 0,0 | 0,0 | 0,2 | 0,7 | 0,6 | 1,0 | 0,0 | 0,3 | 0,9 | 0,0 | 0,6 | 0,3 | 0,3 | 0,3 | 0,0 | 0,5 | 1,9 | 1,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 1,7 |
| *Nuttallinella* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,4 | 0,7 | 0,0 | 0,8 | 1,6 | 0,9 | 0,0 | 0,0 | 0,3 | 0,6 | 0,7 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Oolina* | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 |
| *Oridorsalis?* | 0,2 | 0,3 | 0,0 | 0,0 | 0,5 | 0,4 | 0,7 | 0,0 | 0,0 | 0,2 | 0,3 | 0,0 | 0,3 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Osangularia* | 1,7 | 1,1 | 0,0 | 0,2 | 0,5 | 0,4 | 0,7 | 1,3 | 1,6 | 0,2 | 0,0 | 0,6 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,2 | 11,0 | 10,4 | 10,8 | 14,0 | 9,5 | 6,7 | 0,6 |
| *Paralabamina* | 0,0 | 0,0 | 0,6 | 0,2 | 0,2 | 0,6 | 0,2 | 0,8 | 0,0 | 0,7 | 0,9 | 0,9 | 0,6 | 0,0 | 0,6 | 0,7 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Paralabamina* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,7 | 1,3 | 1,2 | 0,0 | 0,4 | 0,7 | 2,3 |
| *Pleurstomella?* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,6 | 0,0 | 0,3 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 |
| *Praebulimina* | 7,6 | 7,0 | 7,0 | 3,3 | 6,9 | 5,3 | 5,9 | 2,9 | 7,1 | 8,0 | 5,7 | 9,7 | 6,1 | 5,4 | 5,5 | 7,5 | 6,2 | 2,9 | 5,7 | 2,7 | 4,4 | 1,4 | 1,3 | 1,4 | 0,0 |
| *Pseudogaudryina* | 0,2 | 0,0 | 0,3 | 0,7 | 1,7 | 1,6 | 3,0 | 2,9 | 1,6 | 1,4 | 0,3 | 0,3 | 1,6 | 0,3 | 0,3 | 1,0 | 1,1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Pseudonodosaria* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,8 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Pseudonodosaria?* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,3 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,4 |
| *Pseudouvigerina* | 0,0 | 0,3 | 0,0 | 0,0 | 2,6 | 8,9 | 6,2 | 6,3 | 2,7 | 0,9 | 1,2 | 1,1 | 3,2 | 2,6 | 6,1 | 3,0 | 3,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,4 | 0,4 |
| *Pullenia* | 0,0 | 0,3 | 0,6 | 0,5 | 0,0 | 0,2 | 0,7 | 0,3 | 1,1 | 0,7 | 0,6 | 0,6 | 0,6 | 0,5 | 0,3 | 0,7 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,4 | 1,1 | 1,9 |
| *Pulsiphonina* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 2,9 | 7,7 | 12,7 |
| *Pyramidina* | 0,0 | 0,6 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 1,2 | 0,6 | 0,0 | 0,6 | 0,0 | 0,6 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Pyramidulina* | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,2 | 0,6 | 0,0 | 0,0 | 0,3 | 0,0 | 0,7 | 0,3 | 0,0 | 0,0 | 0,3 | 0,2 | 0,3 | 0,0 | 0,0 | 0,2 |
| *Pyrulina* | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 |
| *Quadrimorphina* | 0,0 | 1,1 | 0,3 | 0,7 | 0,0 | 0,0 | 0,2 | 0,8 | 0,0 | 0,9 | 0,6 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,4 | 1,2 |
| *Ramulina* | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,0 | 0,2 | 0,3 | 0,0 | 0,0 | 0,3 | 0,2 | 0,4 | 0,2 |
| *Recurvoides* | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |

Table D1: Continued

| | UH-33 | UH-34 | UH-35 | UH-36 | UH-37 | UH-38 | UH-39 | UH-40 | UH-41 | UH-42 | UH-43 | UH-44 | UH-45 | UH-46 | UH-47 | UH-48 | UH-49 | UH-50 | UKHB-4 | UKHB-5 | UKHB-6 | UKHB-7 | UKHB-8 | UKHB-9 | UKHB-10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split |
| *Reussella?* | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,3 | 0,0 | 0,0 | 0,7 | 1,3 | 0,8 | 0,2 | 0,8 | 1,1 | 1,1 | 2,3 |
| *Rhizammina* | 0,0 | 0,3 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,8 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Saracenaria* | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,3 | 0,0 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,2 | 0,3 | 0,0 | 0,7 | 1,0 |
| *Sitella* | 7,3 | 5,3 | 1,5 | 9,8 | 6,5 | 4,6 | 9,6 | 4,8 | 5,2 | 3,1 | 6,9 | 9,2 | 13,1 | 4,3 | 6,8 | 8,5 | 9,7 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Sliteria* | 5,4 | 3,9 | 6,4 | 1,9 | 4,8 | 2,2 | 2,0 | 0,3 | 0,0 | 0,5 | 0,0 | 2,0 | 1,6 | 2,3 | 1,3 | 0,7 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Spiroplectammina ?* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,6 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Spiroplectinella* | 2,7 | 2,5 | 3,4 | 2,4 | 0,5 | 1,4 | 1,2 | 1,1 | 1,6 | 1,2 | 1,2 | 1,1 | 2,6 | 0,8 | 0,0 | 0,7 | 1,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Stensioeina* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,2 | 0,0 | 0,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 2,9 |
| *Tritaxia* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,5 | 0,0 | 0,0 | 0,0 | 0,3 | 0,3 | 0,0 | 0,7 | 0,0 | 1,2 | 0,0 | 0,0 | 0,2 | 0,3 | 0,0 | 3,9 | 1,9 |
| *Tritaxia?* | 0,2 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,0 | 0,7 | 0,0 | 0,0 | 0,0 | 0,5 | 0,2 | 0,3 | 0,0 | 0,0 | 0,4 |
| *Trochammina* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,2 | 0,0 | 0,0 |
| *Uniserial* | 0,0 | 0,0 | 0,6 | 0,7 | 1,4 | 0,0 | 0,0 | 0,3 | 0,0 | 1,2 | 1,2 | 0,3 | 0,3 | 0,3 | 0,6 | 1,0 | 0,8 | 0,2 | 0,3 | 1,3 | 1,2 | 0,5 | 1,1 | 0,4 | 0,6 |
| *Vaginulopsis?* | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,8 | 0,0 | 0,3 | 0,2 | 0,4 | 0,0 |
| *Verneuilina* | 1,5 | 2,8 | 3,1 | 6,7 | 3,8 | 3,0 | 0,7 | 0,5 | 3,6 | 2,6 | 1,8 | 3,7 | 2,2 | 0,5 | 2,6 | 3,6 | 1,3 | 0,0 | 0,3 | 1,6 | 2,2 | 3,8 | 2,4 | 3,9 | 1,7 |
| *Verneuilina?* | 4,9 | 5,6 | 5,2 | 2,9 | 5,3 | 6,1 | 5,9 | 1,9 | 3,0 | 5,2 | 7,3 | 6,3 | 4,2 | 7,1 | 8,1 | 5,2 | 7,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| *Indet* | 19,0 | 20,9 | 20,8 | 28,2 | 22,7 | 21,0 | 21,7 | 19,8 | 21,2 | 23,5 | 19,0 | 16,6 | 16,0 | 23,2 | 16,8 | 23,3 | 23,9 | 30,9 | 29,1 | 23,8 | 24,7 | 19,5 | 24,7 | 26,7 | 24,5 |

# APPENDIX E

## ABSOLUTE COUNTS

Table E1: Absolute counts of benthic foraminifera individuals for each sample.

| | UH33 | UH34 | UH35 | UH36 | UH37 | UH38 | UH39 | UH40 | UH41 | UH42 | UH43 | UH44 | UH45 | UH46 | UH47 | UH48 | UH49 | UH50 | UKHB4 | UKHB5 | UKHB6 | UKHB7 | UKHB8 | UKH9 | UKHB10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split |
| *Alabamina wilcoxensis* | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 31 | 20 | 17 | 24 | 26 | 26 | 16 | 11 |
| *Alabamina?* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 3 | 2 | 0 | 0 |
| *Allomorphina* sp. 1 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Allomorphina* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Ammodiscus* spp. | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Ammomarginulina* aff. *aubertae* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Ammosphaeroidina ?* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 |
| *Angulogavelinella angustiumbilicata* | 1 | 0 | 2 | 0 | 0 | 1 | 0 | 1 | 2 | 0 | 1 | 3 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Angulogavelinella* sp. | 0 | 3 | 0 | 5 | 1 | 5 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Anomalinoides acutus* | 4 | 6 | 2 | 10 | 2 | 1 | 5 | 5 | 7 | 6 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 41 | 13 | 38 | 32 | 17 | 25 | 23 | 37 |
| *Anomalinoides affinis/welleri* | 0 | 5 | 4 | 6 | 2 | 4 | 9 | 0 | 0 | 0 | 5 | 2 | 2 | 4 | 4 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Anomalinoides rubiginosus* (including jv.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 13 | 5 | 11 | 21 | 19 | 10 | 0 |
| *Anomalinoides*sp.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 3 | 2 | 2 | 0 | 1 |
| *Anomalinoides* spp. | 6 | 4 | 2 | 7 | 5 | 0 | 0 | 2 | 0 | 3 | 4 | 2 | 4 | 2 | 6 | 3 | 0 | 0 | 1 | 0 | 0 | 7 | 6 | 1 | 2 |
| *Arenobulimina* spp. | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 3 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Bathysiphon* spp. | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 3 | 2 | 1 | 4 | 0 | 2 | 2 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| *Bolivina decurrens* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Bolivina incrassata* | 1 | 1 | 3 | 6 | 2 | 3 | 0 | 0 | 1 | 0 | 7 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Bolivinoides decoratus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 1 | 1 | 2 | 1 | 3 |
| *Bolivinoides draco* | 1 | 1 | 1 | 2 | 0 | 1 | 2 | 3 | 2 | 3 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Bolivinoides* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 |
| *Bulimina arkadelphiana* var. *midwayensis* | 1 | 3 | 0 | 4 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 3 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Bulimina strobila* | 2 | 5 | 8 | 11 | 3 | 3 | 2 | 9 | 5 | 6 | 9 | 7 | 5 | 11 | 7 | 13 | 21 | 2 | 0 | 0 | 4 | 0 | 8 | 0 | 0 |
| *Chilostomella* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

Table E1: Continued

| | UH33 | UH34 | UH35 | UH36 | UH37 | UH38 | UH39 | UH40 | UH41 | UH42 | UH43 | UH44 | UH45 | UH46 | UH47 | UH48 | UH49 | UH50 | UKHB4 | UKHB5 | UKHB6 | UKHB7 | UKHB8 | UKH9 | UKHB10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split |
| *Cibicides* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| *Cibicides* sp. 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 8 | 10 | 27 | 12 | 30 |
| *Cibicides* sp. 2 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Cibicidoides alleni* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Cibicidoides pseudoacutus* | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 4 | 7 | 1 | 4 | 3 | 4 | 5 | 1 | 4 | 0 | 30 | 14 | 27 | 15 | 4 | 1 | 8 | 4 |
| *Cibicidoides* sp. 1 | 15 | 3 | 7 | 2 | 6 | 7 | 7 | 3 | 5 | 5 | 2 | 7 | 4 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Cibicidoides* sp. 2 | 2 | 4 | 0 | 1 | 3 | 5 | 5 | 9 | 7 | 4 | 2 | 4 | 3 | 8 | 4 | 2 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Cibicidoides* spp. | 20 | 8 | 12 | 6 | 12 | 19 | 12 | 15 | 10 | 5 | 11 | 13 | 7 | 11 | 15 | 2 | 0 | 73 | 30 | 36 | 29 | 31 | 25 | 6 | 9 |
| *Clavulinoides amorpha* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 4 | 1 | 1 | 1 | 1 | 1 | 0 |
| *Clavulinoides trilatera* | 2 | 1 | 3 | 1 | 1 | 0 | 3 | 3 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 0 | 2 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| *Clavulinoides?* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 3 | 0 | 5 | 1 | 0 | 0 | 1 | 2 | 1 | 0 |
| *Coryphostoma plaitum* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Dorothia pupa* | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Dorothia* sp. | 2 | 0 | 1 | 2 | 5 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 3 | 0 | 1 | 0 | 1 | 1 | 13 | 9 | 2 | 10 | 10 | 7 | 4 |
| *Dorothia* sp. 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| *Eggerellina* sp. 1 | 3 | 1 | 2 | 0 | 1 | 2 | 2 | 0 | 0 | 2 | 3 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Eouvigerina subsculptura* | 87 | 76 | 64 | 47 | 68 | 102 | 60 | 79 | 70 | 97 | 76 | 67 | 51 | 66 | 42 | 46 | 64 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Frondicularia* spp. | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Gaudryina* sp. 1 | 0 | 3 | 3 | 1 | 1 | 0 | 0 | 4 | 2 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Gaudryina* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 7 | 8 | 0 | 7 |
| *Gaudryina? sp* | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| *Gavelinella* aff. *monterelensis* | 1 | 3 | 0 | 1 | 0 | 2 | 0 | 1 | 3 | 1 | 0 | 0 | 1 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Gavelinella* sp .1 | 1 | 0 | 0 | 1 | 1 | 3 | 0 | 4 | 3 | 1 | 0 | 1 | 0 | 1 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Globocassidulina* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 7 |
| *Globulina prisca* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| *Globulina* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 4 |
| *Glomospira* sp. | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Guttulina trigonula* | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| *Gyroidinoides octocameratus* | 2 | 3 | 1 | 4 | 1 | 2 | 3 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 11 | 5 | 4 | 5 | 2 | 6 |
| *Gyroidinoides* sp. 1 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 4 | 2 | 1 | 0 |
| *Gyroidinoides* spp. | 5 | 4 | 3 | 4 | 4 | 5 | 0 | 11 | 4 | 3 | 5 | 3 | 7 | 2 | 0 | 1 | 1 | 6 | 9 | 39 | 44 | 12 | 35 | 9 | 17 |
| *Haplophragmoides* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Heterostomella austinana* (including juveniles) | 26 | 23 | 21 | 23 | 27 | 18 | 17 | 29 | 17 | 19 | 16 | 20 | 25 | 40 | 33 | 23 | 41 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Heterostomella* sp. 1 (including juveniles) | 1 | 0 | 3 | 2 | 0 | 3 | 1 | 3 | 0 | 0 | 0 | 1 | 1 | 4 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table E1: Continued

| | UH33 | UH34 | UH35 | UH36 | UH37 | UH38 | UH39 | UH40 | UH41 | UH42 | UH43 | UH44 | UH45 | UH46 | UH47 | UH48 | UH49 | UH50 | UKHB4 | UKHB5 | UKHB6 | UKHB7 | UKHB8 | UKH9 | UKHB10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split |
| *Hormosinella* sp. | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Laevidentalina constricta* | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| *Laevidentalina monile* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Laevidentalina* spp. | 0 | 0 | 2 | 1 | 0 | 2 | 3 | 1 | 1 | 4 | 1 | 1 | 2 | 1 | 0 | 3 | 1 | 4 | 0 | 0 | 1 | 0 | 0 | 2 | 0 |
| *Laevidentalina*? sp. 1 | 1 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 1 | 1 | 0 | 0 | 2 | 1 | 1 | 1 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 1 |
| *Lagena globosa* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Lagena* cf. *sulcata* | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Lagena* sp. 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Lagena* spp. | 1 | 0 | 1 | 0 | 0 | 4 | 1 | 0 | 1 | 3 | 0 | 0 | 1 | 1 | 2 | 3 | 0 | 2 | 2 | 4 | 7 | 5 | 5 | 1 | 3 |
| *Lenticulina* sp. 1 | 3 | 0 | 0 | 4 | 8 | 2 | 1 | 3 | 6 | 3 | 0 | 5 | 3 | 2 | 6 | 1 | 3 | 3 | 3 | 2 | 6 | 4 | 2 | 4 | 14 |
| *Lenticulina* sp. 2 | 3 | 0 | 2 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| *Lenticulina* spp. | 4 | 8 | 7 | 8 | 8 | 5 | 7 | 5 | 7 | 4 | 3 | 5 | 5 | 3 | 1 | 2 | 2 | 12 | 12 | 8 | 17 | 22 | 15 | 11 | 11 |
| *Loxostomoides applini* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 6 | 8 | 0 | 6 |
| *Marginulopsis multicostata* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Marssonella oxycona* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 3 | 5 | 1 | 3 | 5 |
| *Marssonella indentata* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 3 | 2 | 0 | 1 |
| *Neoflabellina jarvisi* | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Neoflabellina* sp. | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Nodosaria* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Nonionella* sp. | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 1 | 6 |
| *Nonionellina* sp. 1 | 1 | 0 | 0 | 1 | 3 | 3 | 4 | 0 | 1 | 4 | 0 | 2 | 1 | 1 | 1 | 0 | 2 | 8 | 3 | 2 | 0 | 0 | 0 | 0 | 8 |
| *Nuttallinella* spp. | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 3 | 7 | 3 | 0 | 0 | 1 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Oolina* sp. 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Oridorsalis?* sp. 1 | 1 | 1 | 0 | 0 | 2 | 2 | 3 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Osangularia plummerae* | 5 | 1 | 0 | 1 | 2 | 1 | 2 | 1 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 28 | 26 | 35 | 33 | 27 | 0 | 3 |
| *Osangularia* spp. | 2 | 3 | 0 | 0 | 0 | 1 | 1 | 4 | 3 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 5 | 13 | 9 | 18 | 16 | 19 | 0 |
| *Paralabamina* sp. 1 | 0 | 0 | 2 | 1 | 1 | 3 | 1 | 3 | 0 | 3 | 3 | 3 | 2 | 0 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Paralabamina toulmini* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 5 | 5 | 0 | 2 | 2 | 11 |
| *Pleurstomella?* sp. | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| *Praebulimina reussi* | 31 | 25 | 23 | 12 | 29 | 27 | 24 | 10 | 26 | 34 | 19 | 33 | 19 | 21 | 17 | 22 | 22 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Praebulimina* ? sp. | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 10 | 17 | 10 | 18 | 5 | 6 | 4 | 0 |
| *Pseudogaudryina* sp. 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 2 | 2 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Pseudogaudryina* sp. 2 | 0 | 0 | 0 | 2 | 7 | 7 | 11 | 9 | 4 | 2 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Pseudogaudryina* sp. 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Pseudogaudryina* spp. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table E1: Continued

| | UH33 | UH34 | UH35 | UH36 | UH37 | UH38 | UH39 | UH40 | UH41 | UH42 | UH43 | UH44 | UH45 | UH46 | UH47 | UH48 | UH49 | UH50 | UKHB4 | UKHB5 | UKHB6 | UKHB7 | UKHB8 | UKH9 | UKHB10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split |
| *Pseudonodosaria manifesta* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Pseudonodosaria?* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 |
| *Pseudouvigerina plummerae* | 0 | 1 | 0 | 0 | 11 | 45 | 25 | 24 | 10 | 4 | 4 | 4 | 10 | 10 | 19 | 9 | 11 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Pseudouvigerina* sp. 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| *Pullenia jarvisi* | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 4 |
| *Pullenia* spp. | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 2 | 2 | 2 | 0 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 5 |
| *Pullenia* sp. 1 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Pulsiphonina prima* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 22 | 61 |
| *Pyramidina minuta* | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 2 | 0 | 2 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Pyramidulina* spp. | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| *Pyrulina* sp. | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Quadrimorphina allomoprhinoides* | 0 | 3 | 1 | 2 | 0 | 0 | 1 | 2 | 0 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 6 |
| *Quadrimorphina* sp. | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Ramulina* sp. 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| *Ramulina* sp. 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Recurvoides* sp. | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Reussella?* sp. 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 1 | 1 | 4 | 0 | 2 |
| *Reussella?* spp. | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 3 | 2 | 0 | 2 | 1 | 3 | 9 |
| *Rhizammina* sp. 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Saracenaria* sp. | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 5 |
| *Sitella* spp. (including *Sitella cushmani*) | 30 | 19 | 5 | 41 | 27 | 23 | 39 | 18 | 19 | 13 | 23 | 32 | 41 | 17 | 21 | 26 | 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Sliteria varsoviensis* | 22 | 14 | 21 | 8 | 20 | 11 | 8 | 1 | 0 | 2 | 0 | 7 | 5 | 9 | 4 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Spirolectammina?* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Spiroplectinella knebeli* | 2 | 1 | 3 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Spiroplectinella* sp. 1 | 9 | 8 | 8 | 9 | 2 | 7 | 5 | 3 | 5 | 5 | 3 | 3 | 7 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Spiroplectinella* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Stensioeina ?* aff. *beccariformis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 |
| *Stensioeina excolata* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Tritaxia* spp. | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 9 | 6 |
| *Tritaxia* sp. 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 3 |
| *Tritaxia?* sp. 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 2 |
| *Trochammina* spp. | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| Uniserial tests | 0 | 0 | 2 | 3 | 6 | 0 | 0 | 1 | 0 | 5 | 4 | 1 | 1 | 1 | 2 | 3 | 3 | 1 | 1 | 5 | 5 | 2 | 5 | 1 | 3 |
| *Vaginulopsis?* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 1 | 1 | 1 | 0 |
| *Verneuilina* sp. 1 | 6 | 8 | 8 | 13 | 13 | 12 | 3 | 1 | 9 | 2 | 4 | 4 | 2 | 0 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table E1: Continued

| | UH33 | UH34 | UH35 | UH36 | UH37 | UH38 | UH39 | UH40 | UH41 | UH42 | UH43 | UH44 | UH45 | UH46 | UH47 | UH48 | UH49 | UH50 | UKHB4 | UKHB5 | UKHB6 | UKHB7 | UKHB8 | UKH9 | UKHB10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split | 5.split | 5.split | 5.split | 5.split | 5.split | 5.split | 4.split |
| *Verneuilina* sp. 2 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Verneuilina* spp. | 0 | 2 | 2 | 12 | 3 | 3 | 0 | 0 | 2 | 9 | 1 | 7 | 5 | 2 | 5 | 9 | 3 | 0 | 1 | 6 | 9 | 14 | 11 | 11 | 8 |
| *Verneuilina?* sp. | 20 | 20 | 17 | 12 | 22 | 31 | 24 | 7 | 11 | 22 | 24 | 22 | 13 | 28 | 25 | 16 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Indet tests | 78 | 75 | 68 | 118 | 95 | 106 | 88 | 75 | 77 | 100 | 63 | 58 | 50 | 91 | 52 | 71 | 89 | 129 | 87 | 89 | 101 | 71 | 112 | 76 | 118 |
| Total | **410** | **358** | **327** | **419** | **418** | **505** | **406** | **378** | **364** | **426** | **331** | **349** | **313** | **392** | **310** | **305** | **372** | **417** | **299** | **374** | **409** | **365** | **454** | **285** | **481** |
| Indet_excluded | *332* | *283* | *259* | *301* | *323* | *399* | *318* | *303* | *287* | *326* | *268* | *291* | *263* | *301* | *258* | *234* | *283* | *288* | *212* | *285* | *308* | *294* | *342* | *209* | *363* |