CAMPANIAN-MAASTRICHTIAN PLANKTONIC FORAMINIFERAL INVESTIGATION AND BIOSTRATIGRAPHY (KOKAKSU SECTION, BARTIN, NW ANATOLIA): REMARKS ON THE CRETACEOUS PALEOCEANOGRAPHY BASED ON QUANTITATIVE DATA

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ABSTRACT

CAMPANIAN-MAASTRICHTIAN PLANKTONIC FORAMINIFERAL INVESTIGATION AND BIOSTRATIGRAPHY (KOKAKSU SECTION, BARTIN, NW ANATOLIA): REMARKS ON THE CRETACEOUS PALEOCEANOGRAPHY BASED ON QUANTITATIVE DATA

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The aim of this study is to delineate the Campanian-Maastrichtian boundary by using the planktonic foraminifers. In this manner, Kokaksu Section (Bartın, NW Anatolia) was selected and the Akveren Formation, characterized by a calciturbiditic-clayey limestone and marl intercalation of Campanian-Maastrichtian age, was examined. 59 samples were emphasized for the position of boundary.

Late Campanian-Maastrichtian planktonic foraminifers were studied in thin section and by washed samples. Two different biostratigraphical frameworks have been established. The globotruncanid zonation consists of the Campanian *Globotruncana aegyptiaca* Zone, the Upper Campanian-Middle Maastrichtian *Gansserina gansseri* Zone and the Upper Maastrichtian *Abathomphalus mayaroensis* Zone, whereas the heterohelicids biozonation includes the Campanian *Pseudotextularia elegans* Zone, the Lower Maastrichtian *Planoglobulina acervuloinides*

Zone, the Middle Maastrichtian *Racemiguembelina fructicosa* Zone and the Upper Maastrichtian *Pseudoguembelina hariensis* Zone. The Campanian-Maastrichtian boundary was determined as the boundary between *Pseudotextularia elegans* and *Planoglobulina acervuloinides* zones and the Cretaceous-Tertiary boundary was designated by total disappearance of Late Cretaceous forms. Heterohelicid biozonation has been established in this study for the first time in Turkey.

Collecting 300 individuals from each sample, diversity and abundance of the assemblages were analyzed in terms of genus and species. Their evaluation of are important in observation of evolutionary trends and ecological changes. Moreover, the evolution of different morphotypes is important in this evaluation. Such a study is new in Turkey in terms of the examination of the responses of planktonic foraminifers to environmental changes.

Taxonomic framework has been constructed to define each species and the differences of comparable forms have been discussed. Both scanning electron microscope (SEM) photographs and thin section photographs were used in order to show these distinctions.

Keywords: Planktonic foraminifera, Biostratigraphy, Diversity-Abundance, Campanian – Maastrichtian, Saltukova-Bartın (NW Anatolia, Turkey)

ÖZ

KAMPANİYEN-MAASTRİHTİYEN SINIRINDA PLANKTONİK FORAMİNİFERA ÇALIŞMASI (KOKAKSU KESİTİ, BARTIN, KUZEYBATI ANADOLU): KUANTİTATİF VERİYE DAYALI KRETASE PALEOŞİNOGRAFİSİ ÜZERİNE NOTLAR

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Bu çalışmanın amacı Üst Kretase'de Kampaniyen-Maastrihtiyen sınırının planktonic foraminiferden yararlanarak belirlenmesidir. Bu bağlamda seçilen Saltukova Bölgesi'ndeki (Bartın, KB Anadolu) Kokaksu kesiti seçilmiş ve kesit boyunca Kampaniyen-Maastrihtiyen yaşlı, killi kireçtaşı, marn ve kalsitürbidit ardalanmaları ile karakterize olan Akveren Formasyonu çalışılmıştır. Sınırı belirleyebilmek amacıyla 59 kesitin ayrıntılı çalışması yapılmıştır.

Üst Kampaniyen-Maastrihtiyen planktonik foraminiferleri ince kesitler ve yıkama örnekleri ile çalışılmıştır. İki değişik biyozonasyon ayırtlanmıştır. Globotrunkanid biyozonasyonu Kampaniyen yaşlı *Globotruncana aegyptiaca* Zonu, Geç Kampaniyen-Orta Maastrihtiyen yaşlı *Gansserina gansseri* Zonu ve Üst Maastrihtiyen yaşlı *Abathomphalus mayaroensis* Zonundan, heterohelisid biozonasyonu ise Kampaniyen yaşlı *Pseudotextularia elegans* Zonu ile Erken Maastrihtiyen *Planoglobulina acervuloinides,* Orta Maastrihtiyen *Racemiguembelina fructicosa* ve Geç Maastrihtiyen *Pseudoguembelina hariensis* zonlarını içerir. Bu çalışmada

Kampaniyen-Maastrihtiyen sınırı *Pseudotextularia elegans* ve *Planoglobulina acervuloinides* zonlarının sınırı olarak, Kretase-Tersiyer sınırı ise Üst Kretase formlarının tamamen yok olması ile belirlenmiştir. Heterohelicid biyozonasyonu Türkiye'de ilk defa bu çalışmada kullanılmıştır.

Her örnekten 300 tane birey toplanarak cins ve tür bazında çeşitlilik ve bolluk analizleri yapılmıştır. Bu bireylerin tanınması ve değerlendirilmesi, planktonik foraminiferlerin evrimsel trendlerinin ortaya konulması ve ekolojik olayların etkisini gözlemleyebilmek açısından önemlidir. Bu analizlerin yanı sıra çeşitli morfotiplerin çeşitlilik ve bollukları da ekolojik değişimlerin incelenmesi bakımından önemlidir. Üst Kretase planktonik foraminiferlerinin ekolojik değişimler sonucunda gösterdiği evrimsel değişimler Türkiye'de ilk defa bu çalışma ile incelenmiştir.

Bu çalışmadaki türlerin tanımlanması ve benzer türlerin arasındaki farklılıkların ortaya konulabilmesi amacı ile yapılan taksonomik çalışmalar sistematik paleontoloji bölümünde açıklanmıştır. Bu çalışmalar sırasında elektron mikroskobu (SEM) ve ince kesit fotoğraflarından yararlanılmıştır.

Anahtar kelimeler: Planktonik foraminifer, Biyostratigrafi, Çeşitlilik-Bolluk, Kampaniyen-Maastrihtiyen, Saltukova-Bartın (KB Anadolu, Türkiye)

To my family…

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CHAPTER I

INTRODUCTION

1.1. Purpose and Scope

Planktonic Foraminifera is an ideal fossil group especially for biostratigraphy, recognition of environmental changes and the estimation of the ancient climatic and oceanographic conditions. With their widespread geographic distribution due to the planktonic mode of life, their small size, abundance in the rock that supply numerous specimens easily, high species diversity due to rapid evolution; they can be used as guide fossils.

The main objective of this study is to examine the Campanian and Maastrichtian stages, to establish the biozonational frame for this interval and to delineate the Campanian – Maastrichtian boundary by using the planktonic foraminiferal bioevents. For this purpose, Saltukova region (Bartın, NW Anatolia); where the Upper Cretaceous – Lower Tertiary carbonates are exposed well, has been selected. The boundary has been defined in the section measured within the Akveren Formation that mainly consists of clayey limestones, marls and calciturbidite beds. 59 samples along the measured section have been emphasized including the Upper Campanian – Maastrichtian carbonates. By the observations with both thin sections and washing residues, the study has been concluded at the top of the Cretaceous without examining the Paleocene forms, in detail.

Concerning the scope of the study, a quantitative analysis has been carried out in order to get the abundance and diversity of planktonic foraminiferal species. In this manner, changes in diversity and abundance of the planktonic foraminifers have been documented and discussed in this study. As the latest Cretaceous biostratigraphy has gained a great importance and hence been studied by many different authors, various biozonations have been presented in many different studies (Robaszynski *et al.*, 1984; Caron, 1985; Özkan-Altıner and Özcan, 1999; Premoli-Silva and Sliter, 1999; Chacon, 2004; Obaidalla, 2005). In these studies, the position of the Campanian – Maastrichtian boundary has been discussed, as well. In this study, latest Campanian-Maastrichtian biostratigraphy has been presented by using both globotruncanid and heterohelicid biozonations and the position of the Campanian – Maastrichtian boundary has been defined with respect to these biozones.

With the increasing curiosity to the response of the planktonic foraminifers to the ecological changes, many studies have been carried out with the quantitative evaluation of the forms (Sliter, 1972; Li and Keller, 1998; Nederbragt, 1998; Barrera and Savin, 1999; Premoli-Silva and Sliter, 1999; Arz and Molina, 2001; Nederbragt *et al.*, 2001; Keller *et al.*, 2002; Petrizzo, 2002). In this content, this thesis concerns a similar study that has discussed the ecological changes throughout the measured section with respect to the relative abundances of the studied forms.

In order to reach our purposes mentioned above, first of all, taxonomical study has been carried out including the remarks on the species. Accordingly, descriptions, differences from the original definitions of forms and the distinctions of the resembling forms have been discussed in the chapter of systematic paleontology.

1.2. Geographic Setting

The studied stratigraphic section, previously named as the Kokaksu Section (Özkan-Altıner and Özcan, 1999), is located along the Filyos Stream at the north of Saltukova Village, Bartın (Figure 1), in the 1:25 000 scale topographic map of Zonguldak-E33-b3 quadrant. By the GPS recordings, the starting point was measured as 36 42 43 94 E, 44 98 538 N and the end of the section was measured as 36 42 43 97 E, 45 98 311 N.

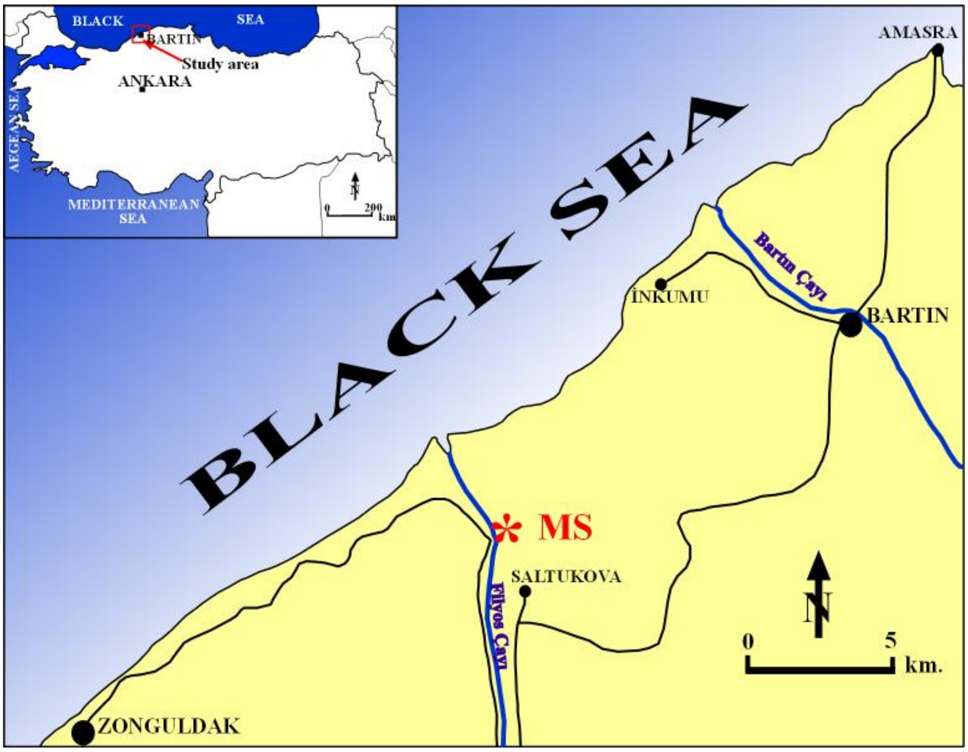


Figure 1. Location map of the study area. MS indicates the location of the measured section.

1.3. Method of Study

This study consisted of field and laboratory works. In the field study, a stratigraphic section was measured through the succession, which was 300 m in thickness. Succession was examined bed by bed, lithological and biological properties were recognized by hand lens and 205 samples were collected along the section. The measured section consists of carbonate rocks with the intercalation of some calciturbidite beds.

The laboratory work includes the preparation of thin sections and trail of the different washing methods for different lithofacies. For the thin section studies, unoriented sections were prepared from all of the samples collected in the field study, in order to recognize the faunal content. In that manner, bio- and chronostratigraphic subdivisions have been established. During the development of the laboratory studies, not all of the gathered samples were analyzed. After the investigation of approximately 110 samples from the top of the sequence, a non-detailed biozonation was constructed and considering the approximate position of the Cretaceous-Tertiary boundary, it is decided to limit the study with 59 samples. So, other part of the laboratory work was the testing of the washing methods on these 59 samples for extracting the individual planktonic foraminifers from the rock. First of all standard washing techniques, such as hydrogen peroxide treatment and Knitter Method (Knitter, 1979), were tried to extract the individual forms. However, since these methods have not become successful in our samples, different washing methods have been searched from different articles on planktonic foraminifera to extract the forms (Table 1). The methods that have been tried in our samples were listed in Appendix A. The best techniques decided were described below:

For limestones, samples were cut into small pieces and placed into the glass jars. 50% of acetic acid solution was added onto the samples up to a level to cover the whole sample and after chloroform was added to each jar, tap of the jars were closed tightly. The amount of chloroform was determined as to be same as the weight of the sample (like 20 ml of chloroform for 20 gr of sample). After waiting 2 hours, the lids were opened and the samples were washed under water by standard method and picked from the 63 μm size aperture sieve with the elimination of the particle size greater than 425 μm. After this treatment, the samples with high clay content were cleaned from the attached sediment particles by another treatment with sodium polyphosphate. In this part, samples were added sodium polyphosphate and water, and mixering. After waiting for about two

Table 1. Database of Methodology

AUTHOR(S)	YEAR	LOCATION	LITHOLOGY	AGE	WASHING METHOD	SIEVE SIZE	COLLECTED INDIVIDUALS
Abramovitch & Keller	2002	Elles, Tunisia	Marly shale with marly limestone & clay layer	Late Maastrichtian	Washing, dried at 50°C	63 & 150 µm	250-300 specimens from each sample
Abramovitch et al.	1998	Southern Israel	Marl, chalk, chalk-marl alternations	Maastrichtian	Disintegration & washing, drying at 60°C, Soiltest splitter	63 & 149 µm	250-300 specimens from each sample
Arenillas et al.	2000	El Kef, Tunisia	Hemipelagic brown-gray marls (40% CaCO3) with sporadic limestone intercalations, black clay layer, marly clay (10% CaCO3)	K/T boundary	Disintegration in tap water with diluted H2O2, sieving, dried at 50°C	63 µm	~300 specimens from each sample
Barrera & Savin	1999	Pacific, Atlantic & Indian Basins	?	Late Campanian - Maastrichtian	Wet sieving, drying under 50°C, ultrasonic cleaning in distilled water	63 µm	?
Canudo	1997	El Kef, Tunisia	Bioturbated grey marls (35-45% CaCO3), black clay layer, dark grey clayey marls	K/T boundary	Disintegration in water, ultrasonic agitation for 10-15 s, sieving, dried at 50°C	63 µm	300-400 specimens from each sample
Chunghham & Jafar	1998	Manipur, NE India	Olistolithic pelagic limestones	Santonian - Maastrichtian	Modified maceration technique	60 & 100 µm	300-500 specimens from each sample
Kaiho & Lamolda	1999	Caracava, Spain	Marl (& a fallout lamina & blackish-gray clays)	K/T boundary	Disintegration of 50 gr. sample with 5% H2O2, washing, drying at 50°C	63 µm	?
Karoi-Yaakoub et al.	2002	Elles I & El Melah, Tunisia	Limestone, marls, marly limestone layers, marly shales, shales, clays	K/T boundary	Soaking into water & dilute H2O2 & washing	38 & 63 µm	250-300 specimens from each sample
Keller	1988	El Kef, Tunisia	White-grey clayey marl with ~40% CaCO3, 50 m thick black clay unit, dark grey clay, grey clay-rich shale, marly sediments	K/T boundary	Repeated soaking in calgon with dilute H2O2, several washing	63 & 150 µm	~300 specimens from each sample
Keller et al.	2002	Tunisia	Gray marls & silty shales, gray calcareous siltstones, calcarenites	K/T boundary	Sieving	38 & 63 µm	~300 specimens from each sample
Klasz et al.	1995	Senegal (WAfrica)	Sandy-shaly facies overlain by limestone layers with some shaly intercalations	Turonian	?	63 µm	?
Kucera & Malmgren	1998	DSDP Sites 356, 516, 525, 527; South Atlantic Ocean	?	Last 800 kyr of Cretaceous	Immersed in de-ionized water, mechanical disaggregation on rotating table, washing, dry sieving, microsplitter	63 µm (washing) & 125 µm (dry sieve)	At least 50 specimens from each sample
Kucera & Malmgren	1996	DSDP Sites 356, 527, 525A, 384, 548A, 465A, ODP Sites 761C and 762C, El Kef, Caracava	?	Last 60 kyr of Cretaceous	Mechanical disaggregation on rotating table, washing, dry sieving	63 µm (washing) & 125 µm (dry sieve)	At least 50 specimens from each sample
Li & Keller	1998	South Atlantic DSDP Sites 525A & 21	Biogenic carbonate	Maastrichtian	Disintegration in water & washing	63 (for site 525A) & 106 (for site 21) µm	~300 specimens from each sample
Luciani	2002	Ain Settara, Tunisia	Silty marls & a thin dark clay layer	K/T boundary	Disintegration in dilute H2O2 (20 %) & sieving, dried at 50°C	38 µm	300-500 specimens from each sample
Lüning et al.	1998	Eastern Sinai, Egypt	Hemipelagic marls & chalks	Late Maastrichtian	Washing twice after H2O2 & highly concentrated tenside REWOQUAT treatment, dry sieving	63 µm (washing) & 63, 125, 250, 630 µm (dry sieve)	~300 specimens from each sample
Nederbragt	1998	Atlantic Ocean (from 17 sites)	?	Late Maastrichtian	Overnight drying at 50°C, soaking in tap water & sieving, soaking in 10% H2O2solution with pyrophospate & washing, dry sieving	125 µm	~300 specimens from each sample
Nederbragt	1991	El Kef & DSDP Sites 21, 95, 356, 357	Marls with rare limestone intercalations (El Kef), marly calcareous chalk & mudstones (Site 356), nanno- & micritic chalks & marly limestone (Site 357), nanno chalks (Site 95), nanno foram oozes (Site 21)	Late Albian - Maastrichtian	Washing over a 63 mm screen, dry sieving over 125 mm screen	63 & 125 µm	150-300 specimens from each sample
Nederbragt et al.	2001	DSDP Site 547; North Atlantic	Hemipelagic clays, mud breccias	Albian - Cenomanian	Rinsing, microsplitter, dry sieving	45 & 125 (dry sieving) µm	200 planktonic forams from each sample
Olsson	1997	El Kef, Tunisia	Bioturbated grey marls (35-45% CaCO3), black clay layer, dark grey clayey marls	K/T boundary	Sodium carbonate cleaning or sodium tetraphenal borate	43 & 63 µm	3901 to 124 specimens/gr
Orue-etxebarria	1997	El Kef, Tunisia	Bioturbated grey marls (35-45% CaCO3), black clay layer, dark grey clayey marls	K/T boundary	?	40 & 63 µm	250-500 specimens from each sample
Ottens & Nederbragt	1992	El Kef, Tunisia	?	Late Cretaceous	Washing, dry sieving	45 or 63 µm (washing) & 125 µm (dry sieve)	~300 specimens from each sample
Özkan Altıner & Özcan	1999	NW Turkey	Calcareous sediments, clayey limestones, marls & calciturbiditic limestones with olistostromal horizons	Santonian - Danian	Standart H2O2 method or 0.5 cm %65 asetic acid, 100 ml chloroform	?	?
Petrizzo	2002	ODP Sites 762 & 763, eastern Indian Ocean	Pelagic calcareous clays & chalks	Turonian - Campanian	H2O2, washing	40, 150 & 250 µm	?
Petrizzo	2001	Kerguelen Plateau (ODP Leg 183)	Pelagic calcareous ooze & chalks, zeolitic sand & clay, nannofossil claystone	Upper Cretaceous	Sieving & dried	40, 150 & 250 µm	?
Petrizzo	2000	Exmouth Plateau, NW Australia	Pelagic calcareous clays & chalks	UpperTuronian - Lower Campanian	H2O2, washing, ultrasonic treatment	40, 150 & 250 µm	?
Stüben et al.	2003	Elles, Tunisia	Dark gray marls with some sandy to silty interlayers	Late Maastrichtian	Disintegration in water & washing	63 µm	30 planktonic forams from each sample
Thomas	1990	Maud Rise, Antarctica	Biogenic sediments, calcareous chalks & oozes	Upper Maastrichtian - lowermost Eocene	Drying at 75°C, soaking in Calgon, washing, drying at 75°C	63 µm	~300 specimens from each sample
Tur et al.	2001	NE Caucasus	Hemipelagic marly limestones & marls	Late Albian - Coniacian	Warming up to 80-100°C for 48 hr, 98% acetic acid for several days, ammoniun oxide for 1-2 hr, washing, dried at 50°C for a day	?	?
Van Marle et al.	1987	Australian - Irian Jaya continental margin, eastern Indonesia	?	Late Cenozoic	Preservation of samples in 60% ethanol in a cold-storage container, drying, washing, drying	63 & 125 µm	300-400 specimens from each sample
Weber et al.	2001	Kirchode I borehole, NW Germany	Clayey marlstones & mudstones alternating with claystones	Late Albian	Sieving	125 µm	300 specimens from each sample

hours for the settling of the particles, the solution was siphoned to obtain clean specimens. On the other hand, the samples with lower clay content were cleaned from attached particles by ultrasonic cleaning techniques or calgon treatment. As a last step, all samples were sieved with dry sieves of 63 µm.

On the other hand, for the marls, two different methods were applied. The first method is to wash with standard hydrogen peroxide (H_2O_2) method. Treated with 35% or 50% of solution for 5-10 minutes, the samples were washed with 63 µm size aperture sieve with the elimination of the particle size greater than 425 µm. This method rarely gave a perfect solution in cleaning, so the second method is the acetic acid method that was described above, but this time the waiting period was a little bit lesser (1-1.5 hours). For the additional cleaning of the attached sediments sodium polyphosphate method, ultrasonic cleaning technique or calgon methods and dry sieving were applied.

After extracting fossils by those methods, laboratory works were carried out by picking up the specimens. The identification and counting of the planktonic foraminifers were performed from the washing samples. The aim in counting is to reach 300 specimens from each sample. Washing of a 20 gm sample was enough since the samples are rich in planktonic foraminiferal abundance.

The following step is the evaluation of the collected forms in terms of the changes in abundance and diversity. In this manner, excel charts and “R” program has been used for the statistical interpretation of the data.

1.4. Previous Works

Pontides is an attractive region for the geologists due to its petroleum and coal resources. Taşman (1933), Pelin (1977), Saner (1981), Gedik and Korkmaz (1984), Robinson *et al.* (1996), Görür and Tüysüz (1997) and Robinson (1997) have studied the petroleum potential of the region, while Spratt (1855), Arni (1938, 1940, 1941), Tokay (1961, 1981), Canca (1994) and Şengör (1995) discussed the coal basins and Wedding (1968, 1969) studied the potential for carbon gases around Amasra, Cide and Ulus regions. In this manner, opening history of the Black Sea Basin gains importance. Brinkmann (1974) is one of the earliest studies on Black Sea that described Paleozoic to Cenozoic evolution of the basin and its relation with Anatolia. Görür (1988) mentioned the timing of opening of the basin. With respect to his age determination onset of subduction-related volcanism was in Aptian-Albian, while the acceleration in block faulting and subsidence, which represents a rifting event, was in Cenomanian and a uniform and thermally induced subsidence was observed after Senonian. In the study of Görür *et al.* (1993), Cretaceous red pelagic carbonates were examined to give a detailed explanation on sedimentation and tectonic changes, timing and mechanisms during the evolutionary stages of the basin.

In the concept of this thesis, the previous studies on the geology and the tectonic evolution of the Western Pontides are important. The geological works, starting with the studies of Fratschner (1952) and Tokay (1952, 1954/1955), continued with the establishment of the stratigraphic framework of the region with the maps of wide areas by Ketin and Gümüş (1963), Akyol *et al.* (1974), Saner *et al.* (1979), Siyako *et al.* (1980), Kaya and Dizer (1982) Kaya *et al.* (1982/1983, 1986a), Şahintürk and Özçelik (1983), Yergök *et al.* (1987), Aydın *et al.* (1987), Akman (1992) and Tüysüz *et al.* (1997). Tüysüz e*t al.* (1989), Derman (1990a), Tüysüz e*t al.* (1990a), Yiğitbaş *et al.* (1990), Okay and Şahintürk (1997) studied the geological evolution of the Pontides. Derman (1990b), Tüysüz e*t al.* (1990b) discussed the stratigraphy and sedimentation in Pontides. Okay (1989), Tüysüz (1993), Ustaömer and Robertson (1997), Yiğitbaş *et al.* (1999), Sunal and Tüysüz (2002) studied the tectonic units and tectonic evolution of the region. Sarıbudak *et al.* (1989) discussed the location of Western Pontides during Triassic time. Tüysüz (1999) discussed the geology of the Western Pontides for its Cretaceous sedimentary basins. In this study, two main tectonic units of the region, which are İstanbul Zone and Central Pontides, were distinguished. As the stratigraphy of the basins was investigated; it was suggested that Zonguldak-Ulus Basin of İstanbul Zone was a single basin during Late Barremian and Maastrichtian and they were separated by Cide Uplift and Devrek Basin after Maastrichtian. İstanbul Zone was originally located to the south of Odessa Shelf and moved southward along two transform faults and juxtaposed with Central Pontides during Cenomanian as it can be understood from their different pre-Upper Cretaceous stratigraphy. The studied region for this thesis also takes place within the Zonguldak Basin of the İstanbul Zone. Yiğitbaş *et al.* (1999) studied the Pre-Cenozoic tectono-stratigraphy and evolution of Western Pontides. They have designated four major time spans; one of which is the Late Cretaceous and Western Pontides formed by the amalgamation of different units within this time interval. The investigation includes Pontide, Armutlu-Ovacık and Sakarya tectonic zones. The location of the present study is within the İstanbul-Zonguldak unit of Pontide Zone in the study of Yiğitbaş *et al.* (1999). When we consider the post-collisional stage in Tertiary, paleostress analysis of Western Pontides was reported by Sunal and Tüysüz (2002). Their study area includes Kurucaşile (Bartın) and Cide (Kastamonu) along which Intra-Pontide suture can be traced and which they have introduced basement, syn-rift and post-rift units, and structures of the region in detail. The last important study in Western Pontides is the anthology prepared by Tüysüz *et al.* (2004) that describes all of the lithostratigraphic units of the area.

Besides the geological studies, there are also the paleontological works in the Western Pontides. The earliest study noticed here is the work of Sirel (1973) on the description of the new species *Cuvillierina* from the Maastrichtian of Cide (NE Zonguldak, northern Turkey). Dizer and Meriç (1982) established the planktonic foraminiferal biostratigraphy for the Upper Cretaceous and the Paleocene in Northwestern Anatolia. Varol (1983) discussed the Late Cretaceous – Paleocene calcareous nannofossils from the Kokaksu Section. In 1991, a new foraminiferal genus of Maastrichtian age was distinguished again in Cide and named as *Cideina* by Sirel (1991). Sarıca (1993) examined the Cretaceous – Tertiary boundary in Gökçeağaç (Kastamonu) by the help of planktonic foraminifers. Another study by Sirel (1996) discussed the description, and geographic and stratigraphic distribution of Maastrichtian to Paleocene form; *Laffitteina marie,* all around Turkey including the Northern Turkey. Georgescu (1997) studied the Upper Jurassic-Cretaceous planktonic biofacies successions of the Western Black Sea Basin. Kırcı and Özkar (1999) examined the planktonic foraminiferal biostratigraphy of The Akveren Formation in Cide (Kastamonu). The study of Özkan-Altıner and Özcan (1999) also included the paleontological work that constructs the Upper Cretaceous biostratigraphy for the Northwestern Anatolia by using planktonic foraminifers.

The study area in which Campanian-Maastrichtian aged Akveren Formation was exposed around the Bartın region, with particularly the Kokaksu Section was studied by many authors. Tokay (1955) studied the geology of the Bartın Region and discussed the Devonian to Quaternary stratigraphy with the discussion on the tectonics and paleogeography of the region. For Maastrichtian, Tokay has defined *G. arca* (Cushman), *G. lapparenti lapparenti* (Bolli), *G. lapparenti tricarinata* (Quereau), *G. ventricosa* (White), *G. lapparenti coronata* (Bolli), *Globigerina cretacea* (d'Orbigny), *Gümbelina globulosa* (Ehrenberg), *Globotruncana linnei-stuarti* (Vogler), *Globotruncana stuarti* (J. de Lapp.), *G. globulosa* (Tokay), *G. citae* (Bolli), *G. lapparenti bulloides* (Vogler), *Globigerinella aspera* (Ehrenberg) and *G. aequilateralis* (Brady) from planktonic foraminifers. In addition, he reported the presence of *Inoceramus* sp., *Micraster* sp., *Stomiosphaera orbulinaria* (J. de Lapp.), *Cadosina sphaerica* (Kaufmann), *Pithonella ovalis* (Kaufmann), *Siderolites heracleae* (Arni), *Inoceramus balticus* (Boehm), *Belemnitella mucronata* (Schloth.), *Coraster villanovae* cotteau var. *alapliensis* Lamb., *Echinocorys ovatus* (Leske) and *Monolepidorbis douvilleri* (Astre). Dizer (1972) studied the Cretaceous-Tertiary boundary of the Northeast Turkey, along the Kokaksu Section. She described a stratigraphy for the section from the Late Campanian to the Late Paleocene and correlated it with other sections form NE Turkey. In this study, the Late Campanian-Late Paleocene planktonic foraminiferal zonation was constructed, consisting of *Globotruncana calcarata* (Late Campanian), *Globotruncana gansseri, Globotruncana contusa contusa, Abathomphalus mayaroensis* (Maastrichtian), *Globorotalia compressa/Globigerina daubjergensis* (Danien), *Globorotalia psudomenardii* (Middle Paleocene) and *Globorotalia velascoensis* (Late Paleocene) zones. Another investigation on the Cretaceous-Paleocene zonation of Kokaksu Section has been carried out by Varol (1983) by using calcareous nannofossils. Eight biostratigraphic zones for the Late Cretaceous and five for the Paleocene were described and the position of the Cretaceous-Tertiary boundary was defined in this study. Mentioned also the Kokaksu Section, Derman (1990a) investigated the geological evolution of Western Black Sea Region during Late Jurassic and Early Cretaceous. In the study published by Özkan-Altıner and Özcan (1997, 1999), nine sections were measured from different regions of NW Turkey. One of them was the KOK-section at the same locality, Saltukova. They have considered the microfacies changes around the Cretaceous-Tertiary boundary and made the zonation by using calcareous nannofossils, planktonic and benthic foraminifers. For the KOK section, six planktonic foraminiferal zones were described as *R. calcarata, G. havanensis, G. aegyptiaca, G. gansseri, A. mayaroensis and M. pseudobulloides.* It is also mentioned that the diversity and abundance of planktonic foraminifers in the NW Anatolia are very rich in contrast to Haymana region.

Planktonic foraminifers gain importance in the identification of the Cretaceous-Tertiary boundary and its worldwide correlation. Due to their importance, there were many studies on these forms. The first study on planktonic foraminifers was built by Cushman by introducing the genus *Globotruncana* in 1927. In his taxonomy, all the trochospiral coiled forms bearing one or two keels have put into this genus (Cushman, 1927). After 1942, other structures like apertures and the systems covering the umbilicus; such as tegilla and portici, and number of keels gained importance and detailed taxonomic works have been carried out (Brotzen, 1942; Reichel, 1950; Bolli *et al.*, 1957, Brönnimann, 1952; Brönnimann and Brown, 1956; Pessagno, 1967). Robaszynski *et al.* (1984) studied one of the significant revisions on the taxonomy of the planktonic foraminifers, since the usage of scanning electron microscope (SEM) has been started. Caron (1985) contributes with the detailed study including the taxonomy of the Cretaceous planktonic foraminifera, their phylogenesis, genus and species descriptions, biozonation and the comparison of the zones and the stratigraphic distribution of the species. The Hauterivian-Maastrichtian period was defined with 28 planktonic foraminiferal biozones in her study. In addition to these extensive studies on globotruncanids, the first detailed taxonomical study on the Late Cretaceous heterohelicids has been prepared by Nederbragt (1990, 1991), which considers the taxonomy, paleogeography and stratigraphic distribution of the Heterohelicidae species. Longoria and Von Feldt (1991) published an article on single-keeled globotruncanids (genus *Globotruncanita* Reiss). They discussed the previous nomenclature and reclassified the forms under genus *Globotruncanita* based on the rule that “there wasn’t any stage with double keels, whether merging from double keels to single keel or diverging from single keel to double keels, in the ontogenic development of this genus”. Besides detailed taxonomy, phylogenetic development of *Globotruncanita* was reinterpreted with the discussions on the previous works and biochronology of the genus was studied. Norris (1992) studied umbilical structures in Late Cretaceous planktonic foraminifera. He discussed the description, differences and variations in different forms and suggested that portici and tegilla can be used in marking the possible phylogenetic lineage; however tegilla has no generic significance since its several types have evolved several times, where as portici delineates phylogenetic groups since it shows little variation within taxa. Lastly a manual for the Cretaceous planktonic foraminifers was prepared by Premoli-Silva and Verga (2004). In this practical manual, the classification of the forms has been summarized by the help of charts and a catalogue has been presented from the SEM and thin-section photographs of different studies previously published.

After the first detailed biozonations of Robaszynski *et al.* (1984) and Caron (1985), there are various studies that have carried out different biozonations for Upper Cretaceous (Manipur; Northeastern India by Chungkham and Jafar (1998), Robaszynski, 1998 (worldwide), NW Turkey by Özkan-Altıner and Özcan (1999), Northern California; USA by Sliter (1999), Kalaat Senan; Tunisia by Robaszynski *et al.* (2000), Tercis; France by Odin *et al.* (2001), Prebetic Zone; SE Spain by Chacon *et al.* (2004) and Wadi Nukhul; SW Sinai by Obaidalla (2005)). In these studies, there are some discussions on the position of the Campanian – Maastrichtian stage boundary (Arz and Molina, 2001; Gardin *et al.*, 2001; Küchler *et al.*, 2001; Odin, 2001). The Campanian - Maastrichtian boundary will be discussed in Chapter 2, in detail.

Besides the biostratigraphical studies and taxonomic works, there are many different studies on planktonic foraminifera for defining the Cretaceous-Tertiary boundary. In Turkey, this boundary was defined by Toker (1979) in Haymana area (SW Ankara), by Özkan (1985) and Özkan and Altıner (1987) in

Gercüş area (SW Turkey), by Yakar (1993) in Adıyaman region and by Özkan-Altıner and Özcan (1997, 1999) in 9 different localities in NW Turkey. In El Kef (Tunisia), the most complete Cretaceous-Tertiary boundary section in the world was defined and studied by many authors (Keller, 1988; Keller *et al.*, 1996; Canudo, 1997; Ginsburg, 1997 b; Keller, 1997; Kouwenhoven, 1997; Lipps, 1997; Masters, 1997; Olsson, 1997; Orue-etxebarria, 1997; Smit and Nederbragt, 1997; Smit *et al.*, 1997; Arenillas *et al.*, 2000). Premoli-Silva and Sliter (1994) studied the Cretaceous planktonic foraminifers from the Bottaccione section (Italy). They prepared a detailed distribution chart for 147 species and defined 19 zones and 4 subzones. Besides biostratigraphy, their study contained quantitative analysis with several diversity charts that reflect the evolutionary trends and the consideration of paleoceanographic changes. Nederbragt (1998) constructed the quantitative biogeography for late Maastrichtian from different Atlantic sections and confirmed the presence of Australian, Transitional and Tethyan Realms. Other studies on this boundary were examined at Caracava; Spain by Kaiho and Lamolda (1999), at Kalaat Senan; Tunisia by Robaszynski *et al.* (2000), at Ain Settara; Tunisia by Arenillas *et al.* (2000), at Elles 1 and El Melah; Tunisia by Karoui-Yaakoub *et al.* (2002) and at Wadi Nukhul; SW Sinai by Obaidalla (2005).

Nowadays, paleoecology and paleoceanography become the focus of the most studies; and the usage of planktonic foraminifers is very widespread in these works. The fluctuations in diversity and relative abundance of various morphotypes can be used to interpret changes in the oceanic environment (Sliter, 1972; Leckie, 1989; Ottens and Nederbragt, 1992; Li and Keller, 1998; Nederbragt, 1998; Barrera and Savin, 1999; Premoli-Silva and Sliter, 1999; Premoli-Silva *et al.*, 1999; Arz and Molina, 2001; Nederbragt *et al.*, 2001; Abramovich and Keller, 2002; Keller *et al.*, 2002; Petrizzo, 2002). In some of these environmental studies, stable isotope analysis with oxygen, carbon or strontium isotopes obtained from the planktonic foraminifers gains great importance in the estimation of paleotemperature, paleodepth and paleoclimate (Hilbrecht *et al.*, 1992; Mulitza *et al.*, 1997; Norris and Wilson, 1998; Price *et al.*¸1998; Barrera and Savin, 1999; Zeebe, 2001; Keller, 2002; Norris *et al.*, 2002; Stüben *et al.,* 2003).

By the help of the previous studies, this study aims to present the planktonic foraminiferal content of the Late Campanian-Maastrichtian, Cretaceous - Tertiary boundary at the Kokaksu Section and response of foraminifers to the events near this boundary with the help of the quantitative analysis.

1.5. Regional Geological Setting

Being the northernmost tectonic element of Asia Minor (Ketin, 1966), the Pontides is one of the compressive belts that enclose the Black Sea (Tüysüz, 1999). Geographically, the Pontides are examined under three parts as Eastern, Central and Western Pontides, which also show different geological characteristics (Tüysüz, 1993). Eastern Pontides is the part that lies towards the east of Samsun; Western Pontides extends to the west of Kastamonu whereas Central Pontides is the part that takes place between Eastern and Western Pontides, which corresponds to the central part of the Sakarya Zone of Okay (1989). In another point of view, the Pontides are also separated into three zones such as Strandja Zone, İstanbul Zone and Sakarya Zone from west to east (Okay, 1989; Okay *et al.*, 1994).

Yiğitbaş *et al.* (1999) separated the Western Pontides into three different tectonic zones (the Pontide Zone, the Armutlu-Ovacık Zone and the Sakarya Zone), which corresponds to the Rhodope-Pontide fragment, the Intra-Pontide Suture and the Sakarya continent of Şengör and Yılmaz (1981). On the other hand, Tüysüz (1999) and Sunal and Tüysüz (2002) limit the Western Pontide to the İstanbul Zone, which is bounded by Araç-Daday-İnebolu Shear Zone in the east, Intra-Pontide Suture in the south and Western Black Sea Fault in the west (Figure 2). The İstanbul Zone corresponds to the Pontide Zone of Yiğitbaş *et al.* (1999).

In this study, classifications of Tüysüz (1999) and Sunal and Tüysüz (2002) are taken into consideration. In the Western Pontides, basement units start with a Paleozoic sedimentary sequence of Ordovician to Carboniferous aged Atlantic-type continental margin facies (Tüysüz, 1999). This sequence ends with the Zonguldak Formation that consists of river, swamp and delta clastic sediments

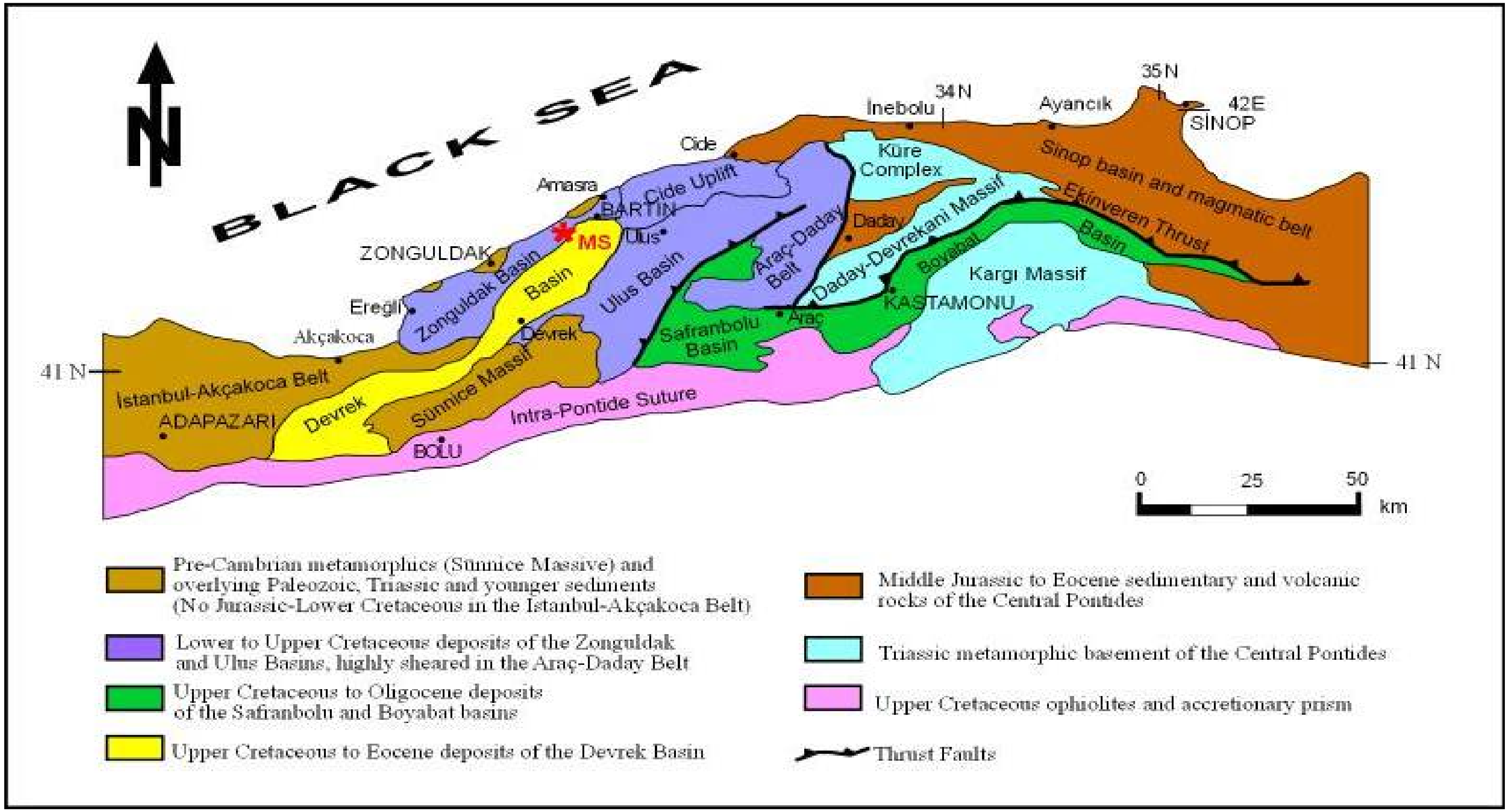


Figure 2. Tectonostratigraphic map of the Western Pontides (Modified from Sunal and Tüysüz, 2002). MS indicates the measured section.

with coal deposits in Namurian to Westphalian age (Sunal and Tüysüz, 2002) (Figure 3). The Permo-Triassic aged terrestrial units of Çakraz Formation Çakraboz Formation (Figure 3). This formation is Late Triassic in age and contains lacustrine limestones, marls and mudstones with varve structures. Middle Jurassic-aged Himmetpaşa formation is composed of the coal bearing terrestrial sediments, shallow to deep marine turbiditic clastics and shallow marine clastics unconformably overlie this formation. Another unconformable unit is the Çakraboz Formation (Figure 3). This formation is Late Triassic in age and contains lacustrine limestones, marls and mudstones with varve structures. Middle Jurassic-aged Himmetpaşa formation is composed of the coal bearing terrestrial sediments, shallow to deep marine turbiditic clastics and shallow marine clastics. Platform-type neritic carbonates in the Late Jurassic, which were the product of the Mesozoic transgression that covered the whole Pontides, were named as the İnaltı Formation (Sunal and Tüysüz, 2002) (Figure 3). Tüysüz (1999) suggests no evidence for a pre-Cretaceous compressional deformation of regional metamorphism in the east of Akçakoca-Bolu Line in contrast to the basement units of Central Pontides.

The basement units are overlain by the “syn-rift” and “post-rift” units of Sunal and Tüysüz (2002), which correspond to the cover rocks of Tüysüz (1993) and Yiğitbaş *et al.* (1999), while Tüysüz (1999) represents them as “Cretaceous Sedimentary Basins in İstanbul Zone”, which are the Zonguldak Basin, the Ulus Basin, the Cide Uplift and the Devrek Basin.

The Zonguldak Basin, which extends from Ereğli to Amasra, was deposited over the limestones of İnaltı Formation in northern parts and over the Paleozoic rocks in the south. İnpiri Formation is formed by the Upper Barremian – Lower Albian clastics and carbonates lying on the İnaltı Formation by an angular unconformity (Tüysüz, 1999). On the other hand, to the east of Zonguldak; organic-rich gray-black lagoonal shales and marls in the Aptian age conformably overlie the limestones (Kilimli Formation). Unconformably overlying Velibey Formation consists of the yellowish, medium- to high-thickly bedded quartz arenites with conglomerate and local limestone interbeds of Albian age. The Sapça Formation

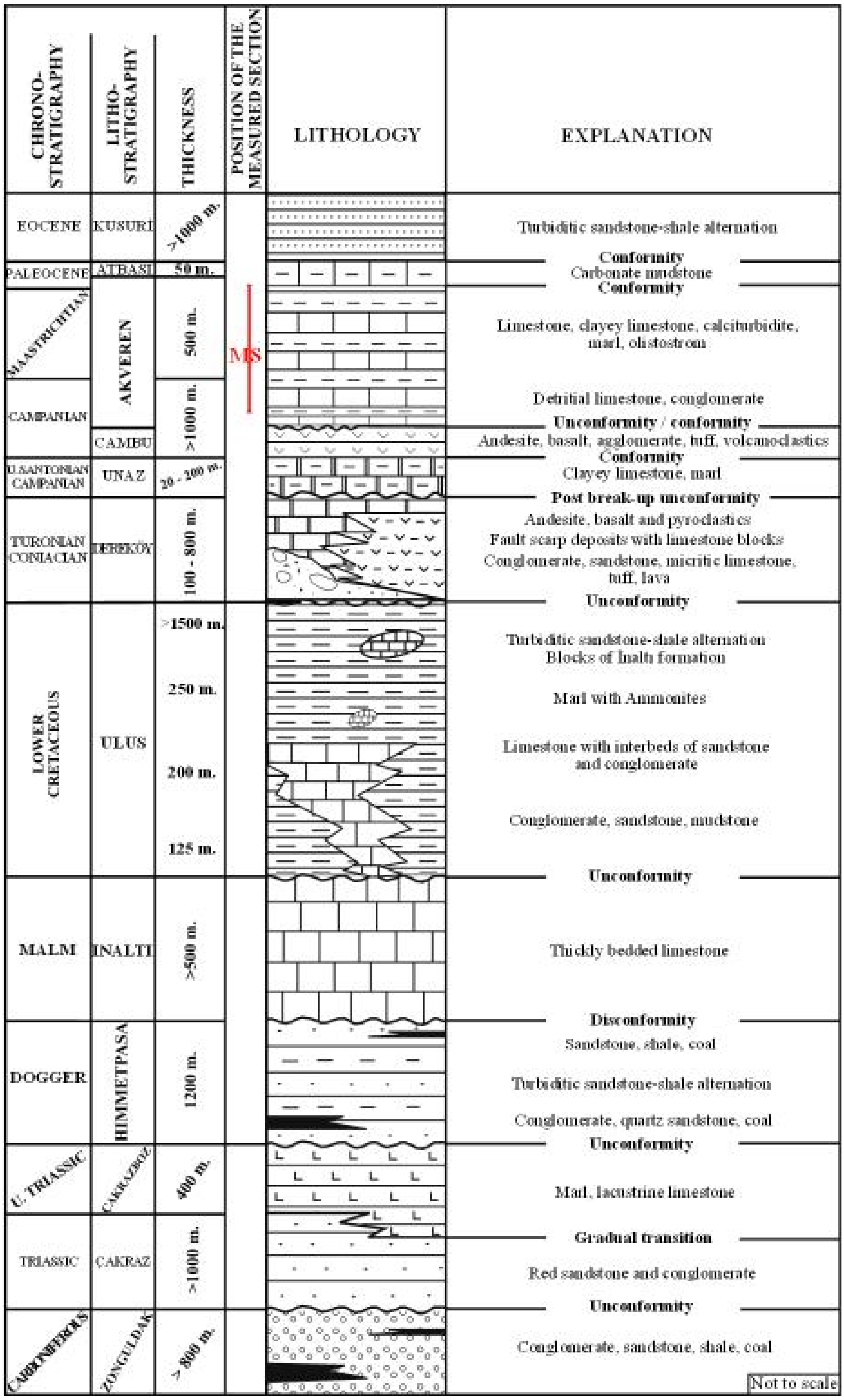


Figure 3. Generalized columnar section of the study area (Simplified from Sunal & Tüysüz, 2002). The measured section (MS) is shown by the red line.

shows an alternation of turbiditic sandstones, marls, sandy limestones and blue to black shales with abundant glauconite of Albian age. Blue to black organic-rich shales and argillaceous limestone of the Tasmaca Formation give the Cenomanian age. All of the Lower Cretaceous rocks in the Zonguldak Basin show a southward-deepening character and they are separated from the Upper Cretaceous units by a Cenomanian unconformity. The Dereköy Formation consists of the first magmatic rocks of the Western Pontides that are basaltic and andesitic lava and their pyroclasts alternating with shallow to deep marine carbonates and clastics of Middle Turonian age. The Dereköy Formation represents the "syn-rift units" of Sunal and Tüysüz (2002), whereas the "post-rift units" starts with the Unaz Formation. This formation contains Late Santonian to Campanian-aged pelagic limestones. Because of the horst-graben topography that developed during the deposition of the Dereköy Formation, the contacts of the Unaz Formation show different characteristics in different regions. In the Zonguldak Basin; a slightly angular or parallel unconformity (post-break-up unconformity defined by Görür *et al.*, 1993) was observed between these two formations (Tüysüz, 1999). The Unaz Formation accepted as a marker horizon for the Western Pontides, which indicates the stopping of the volcanism. Sunal and Tüysüz (2002) and Yiğitbaş *et al.* (1999) suggest the domination of the Andean-type island arc magmatism along the southern Black Sea coast in response to the northward subduction of Neotethys under the Pontide Zone. This magmatism is indicated by the thick volcano-sedimentary successions of the Campanian-aged Cambu Formation. Uplift of the southern parts during Late Campanian and Early Maastrichtian and the ongoing volcanic activity show the termination of the Neotethys by the collision of the Pontides with the Sakarya Continent. With the continuous sedimentation in the northern Black Sea during the post-arc period, the Akveren and the Atbaşı Formations were deposited as pelagic limestones, marls and calciturbidites. The youngest deposition in the Western Pontides, seen in the Zonguldak Basin, can be observed as the siliciclastic, upward-coarsening turbidite sequence of Eocene, which was named as the Kusuri Formation (Figure 3).

The Ulus Basin is the largest sedimentary basin in the Western Pontides. In fact, there was a single basin including the Zonguldak Basin and the Ulus Basin before the development of the Tertiary Cide Uplift and the Devrek Basin. Because of this, up to Görür (1997) the Ulus Formation was defined as the syn-rift deposits of the Western Black Sea Basin, while it is considered as a separate basin containing the Cretaceous sediments of the Ulus Formation after Tüysüz (1999). The Ulus Basin is unconformably overlain by the Latest Cretaceous to Eocene fill of the Devrek Basin.

The Cide Uplift overlies the Upper Jurassic platform carbonates. Here, the sedimentation starts with Late Barremian – Aptian aged alluvial fan deposits with complexly channeled coarse red clastics passing southward into beach sandstones and conglomerates and then into marls (Tüysüz, 1999). This lower part of the sequence grades upwards into turbiditic sandstone-shale alternation. The Cide Uplift was elevated at the end of the Cretaceous and thrusted over the sediments of the Zonguldak and the Devrek Basins after the medial Eocene.

The Devrek Basin is a Latest Cretaceous- to Eocene-aged basin that formed by Maastrichtian carbonates and calciturbidites, which unconformably overlie the Ulus Formation and the Sünnice Massif. Basal unit of sediments was controlled by faults that generated the uplift of the Ulus Basin and the Sünnice Massif during the deposition of the Devrek Basin (Tüysüz, 1999).

By the Late Eocene, there began a compressional regime in the Western Pontide Basins. As a result, after the closing of the Intra-Pontide Suture, the Western Pontides was uplifted and the Devrek Basin was closed. Latest Eocene to Early Miocene was the time for the imbrication of all Western Pontides and southern passive margin sediments of the Western Black Sea Basin by mainly north-vergent thrusts (Tüysüz, 1999; Sunal and Tüysüz, 2002).

Under this general concept, our study area is located in the Zonguldak Basin and the measured section is from the Akveren Formation that is Campanian-Maastrichtian in age. The litho- and biostratigraphic details for the study area will be discussed in the following chapter.

CHAPTER II

LITHOSTRATIGRAPHY AND BIOSTRATIGRAPHY

2.1 Lithostratigraphy

In the study area, Upper Campanian- Paleocene carbonate deposits are widely exposed (Figure 4). This unit, named as the Akveren Formation, conformably overlies the volcano-sedimentary rocks of the Cambu Formation in Early Campanian age (Sunal & Tüysüz, 2002) (Figure 5). This study has been focused on the Uppermost Campanian – Maastrichtian part of the Akveren Formation with the emphasis on the Campanian – Maastrichtian boundary (Appendix B).

2.1.1 The Akveren Formation

The Akveren Formation is Campanian – Paleocene in age that has been deposited in the Zonguldak Basin. It is represented by clayey limestones, marls, carbonate muds and calciturbidites. Tüysüz (1993) defends that the turbiditic property, sedimentary structures and fossil content of the Akveren Formation indicates its deposition in a deep marine environment. The Akveren Formation overlies the Cambu Formation between Cide and Kurucaşile, whereas the Gürsökü Formation and the Kale Formation were observed beneath this formation in other areas. The formation is overlain by the Atbaşı Formation (Tüysüz *et al.*, 2004) (Figure 5).

The Akveren Formation is named under the Amasra Group in the Northern Belt of the Western Pontides (Tüysüz *et al.*, 2004). The first usage of this formation was by Gayle (1959) as "Akveren beds" for the clayey limestones exposed to the south of Ayancık. After this first usage, Ketin and Gümüş (1963)

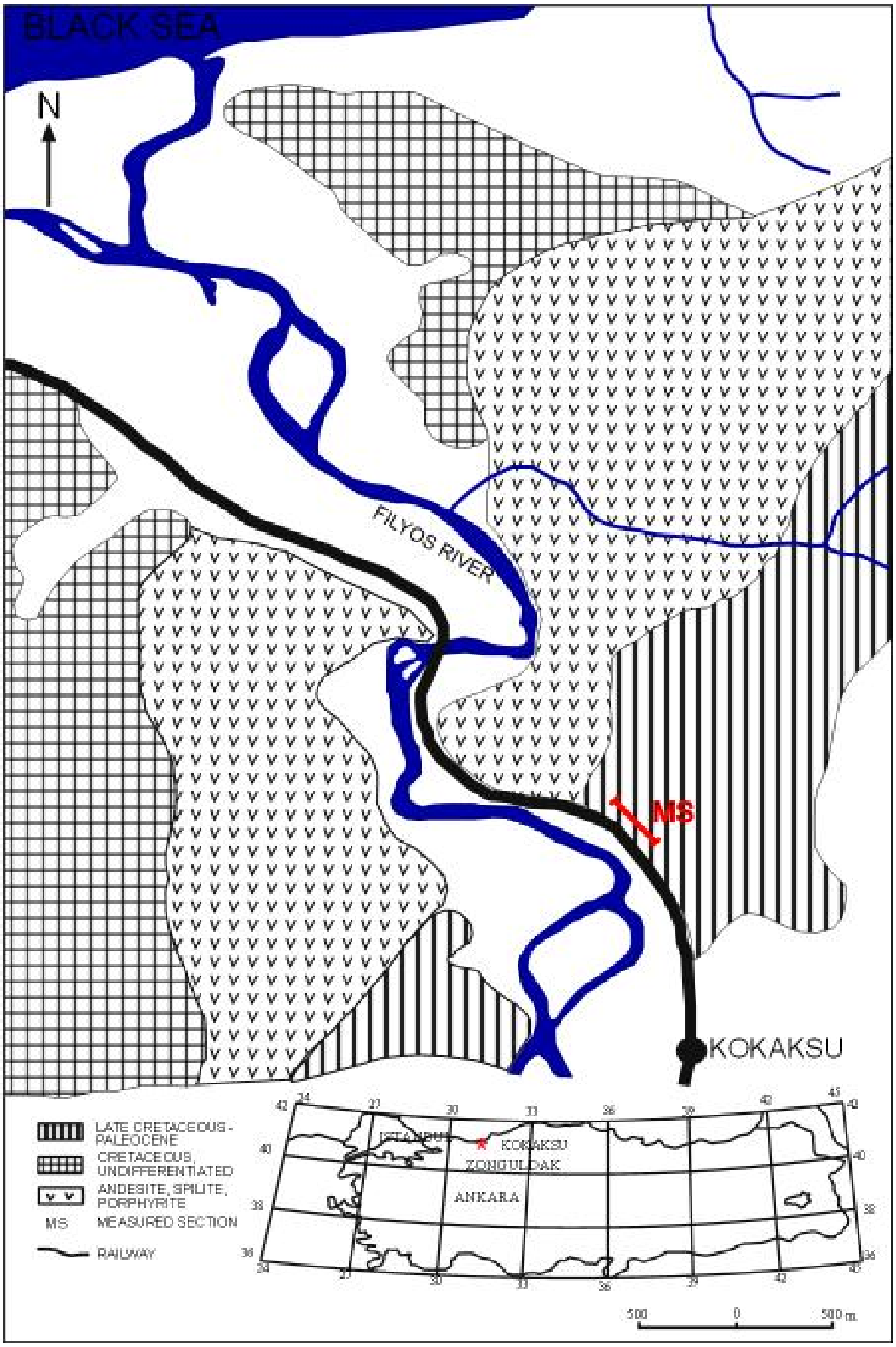


Figure 4. Geologic map of the study area (Varol, 1983).

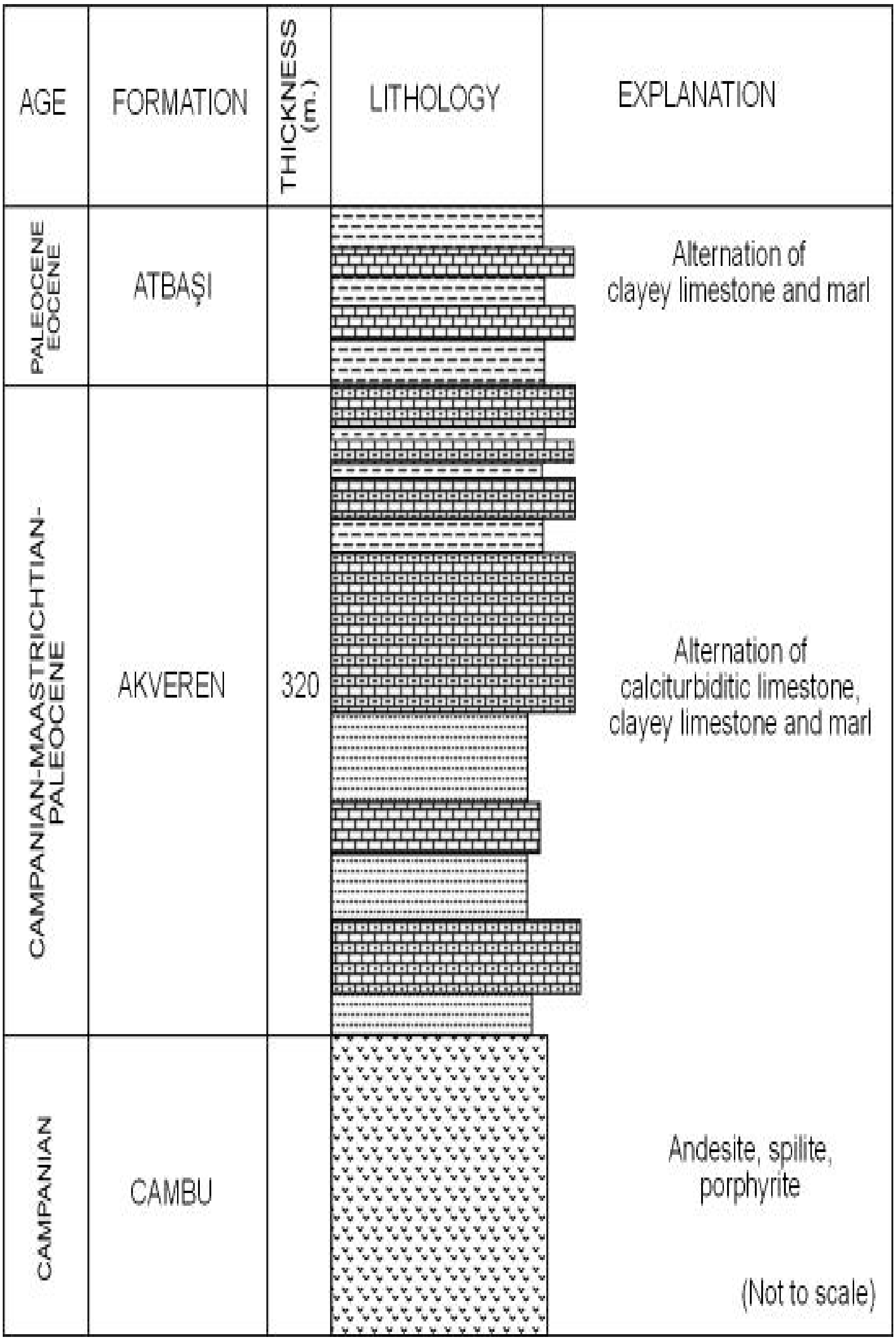


Figure 5. Generalized stratigraphic section of Saltukova region; Bartın (Özkan-Altıner & Özcan, 1997; Sunal & Tüysüz, 2002).

described the alternation of calciturbiditic limestones, sandy micritic limestones and marls that overlies the Late Santonian – Early Maastrichtian aged Gürsökü Formation firstly as the Akveren Formation. However, in this study, the type locality and the type section were not mentioned for the formation. Gedik and Korkmaz (1984) measured the type section from Aksöke between the coordinates 62.735-66.155 and 62.884-66.287 in the 1:25 000 scale topographic map of E33-b3 quadrant. Later, a type locality was suggested as to be between Doğaşı and Kayadibiçavuş Villages that are between Kurucaşile and Bartın (Akman, 1992).

The thickness of the formation was measured as 390 m. near Cide-Kurucaşile (Akyol *et al.*, 1974). After that, Aydın *et al.* (1986) measured a succession of approximately 1000m. in the Kastamonu region. Akman (1992) indicated the thickness as 593 m. in the Doğaşı-Kayadibiçavuş section. In the north of Saltukova Town (Bartın), this formation was measured with a thickness of 312 m (Özkan-Altıner & Özcan, 1997). The same formation was named as a member of the Hisarköy Formation by Akyol *et al.* (1974). This formation is also the deep marine equivalent of the Alaplı Formation of the Southern Belt in the Western Pontides.

The age of the Akveren Formation is discussed by many authors. It is defined as Maastrichtian by Ketin and Gümüş (1963), as Maastrichtian – Paleocene by Gedik and Korkmaz (1984), as Maastrichtian – Early Paleocene by Aydın *et al.* (1986), as Campanian – Paleocene by Akman (1992) and as Maastrichtian by Tüysüz *et al.* (1997).

The Akveren Formation gradually passes to Atbaşı Formation, Paleocene in age, which is also represented by pelagic mudstones and marls or the Kusuri Formation, Eocene in age, which consists of siliciclastic turbidites (Tüysüz, 1999; Sunal & Tüysüz, 2002).

As previously mentioned, the stratigraphic section has been measured through the Akveren Formation (Figure 6A). However, this study doesn’t include base and top of the Akveren Formation. Along the measured section, an alternation of clayey limestones, marls and calciturbidites was observed (Figure 6, 7). In the lower parts of the succession, which has also been measured in the field study, the percentage of clayey limestones is higher (Figure 6B). However towards the top of the formation, marls become dominant with respect to limestones (Figure 7, 8). Since there aren’t any lithological changes, the recognition of Cretaceous – Tertiary boundary has been difficult in the field study. For this reason, the laboratory works gain a great importance in the interpretation of the boundary.

Figure 6. A. The location of the measured section along the road cut, B. An alternation of clayey limestone and marls in the lower part of the measured section (Number 123 indicates the position of sample 123).

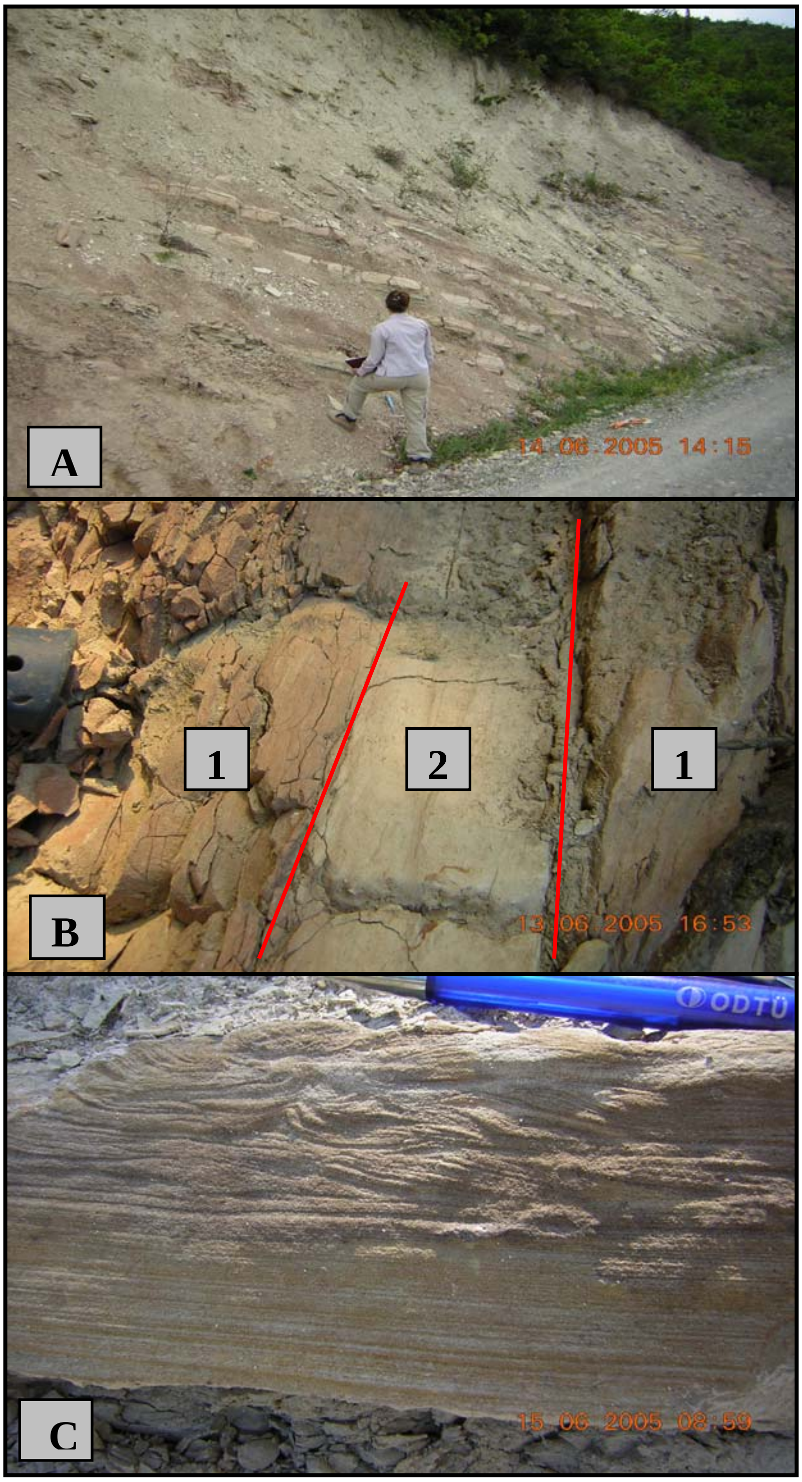


Figure 7. A. Limestone-marl alternations, B. Close-up view for limestone-marl alternations (1= marl, 2= clayey limestone), C. Calciturbidite intercalation.

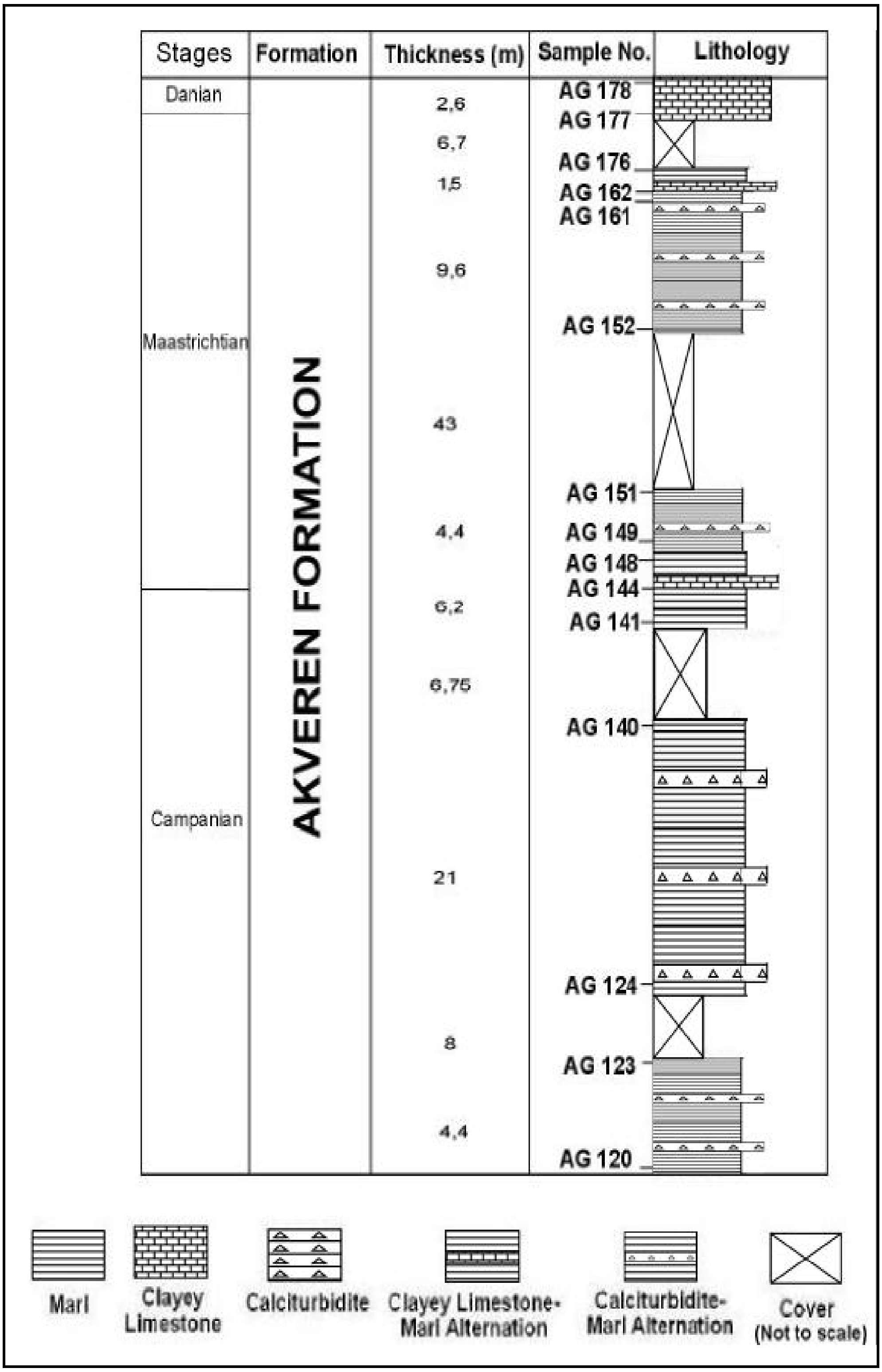
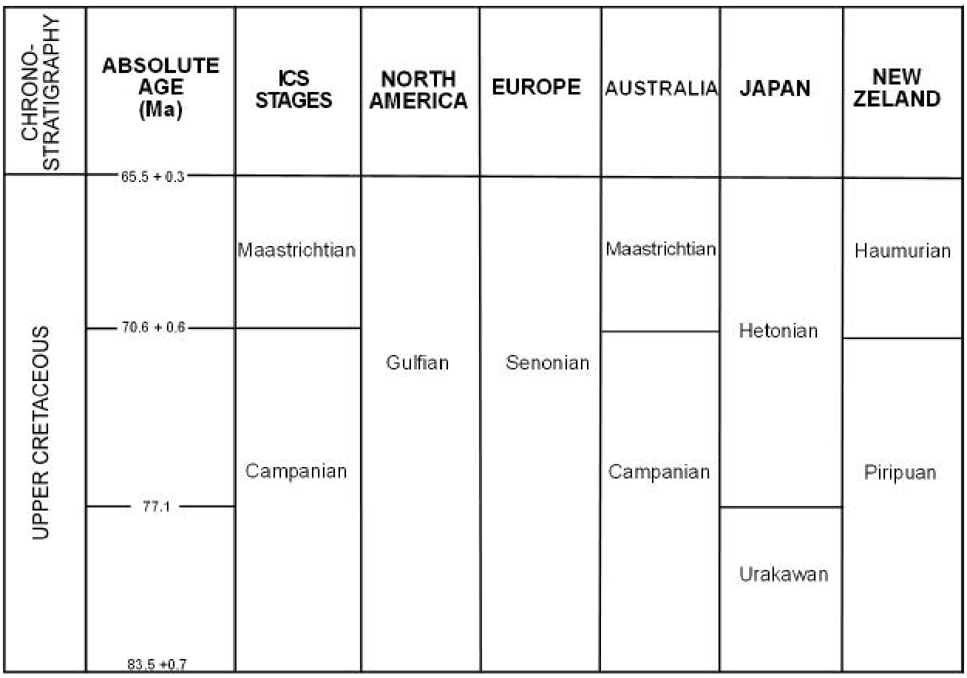


Figure 8. Lithostratigraphy of the measured section.

2.2 Biostratigraphy

The studied section of the Akveren Formation includes the Campanian and Maastrichtian stages which are the uppermost part of the Cretaceous. These stages comprise a period of 83.5 ± 0.7 Ma to 70.6 ± 0.6 Ma and from 70.6 ± 0.6 Ma to 65.5 ± 0.3 Ma, respectively in the standards of the International Comission on Stratigraphy (ICS). However, for the different studies, different regional chronostratigraphical units are being used in place of these two stages (Table 2).

Table 2. Choronostratigraphic divisions of Uppermost Cretaceous in different regions (modified from the web site of the International Comission on Stratigraphy (ICS) (www.stratigraphy.org)



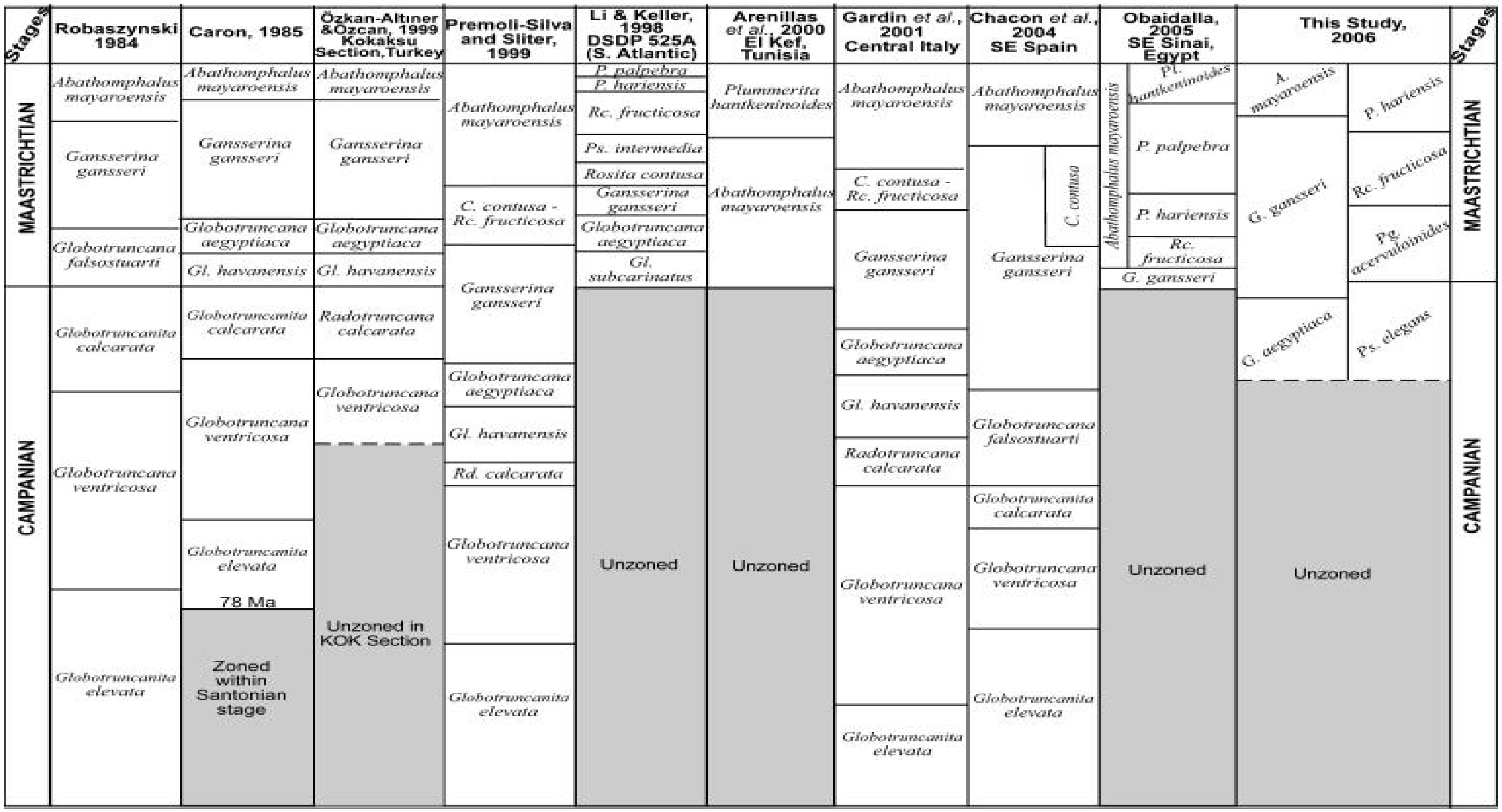
CHRONO-STRATIGRAPHY	ABSOLUTE AGE (Ma)	ICS STAGES	NORTH AMERICA	EUROPE	AUSTRALIA	JAPAN	NEW ZELAND
UPPER CRETACEOUS	65.5 + 0.3	Maastrichtian	Gulfian	Senonian	Maastrichtian	Hetonian	Haumurian
	70.6 + 0.6	Campanian			Campanian		Piripuan
	77.1					Urakawan	
	83.5 +0.7						

The first important biostratigraphic study using the planktonic foraminifera was carried out by Robaszynski *et al.* (1984). In this study Campanian stage was separated into three zones that are *Globotruncanita elevata* interval zone, *Globotruncana ventricosa* interval zone and *Globotruncanita* *calcarata* interval zone. Maastrichtian stage was also separated into three zones: *Globotruncana falsostuarti*, *Gansserina gansseri* and *Abathomphalus mayaroensis* interval zones (Table 3). After this study, Caron (1985) stated another detailed study with *Globotruncanita elevata*, *Globotruncana ventricosa* and *Globotruncanita calcarata* biozones for Campanian and *Globotruncanella havanensis, Globotruncana aegyptiaca, Gansserina gansseri* and *Abathomphalus mayaroensis* biozones for Maastrichtian (Table 3).

In 1995, the Campanian – Maastrichtian boundary was shifted into the *Gansserina gansseri* Zone by Robazynski and Caron (1995). According to Premoli-Silva and Sliter (1999), while *Globotruncanita elevata*, *Globotruncana ventricosa, Radotruncana calcarata, Globotruncanella havanensis* and *Globotruncana aegyptiaca* are Campanian biozones, *Gansserina gansseri* zone contains the Campanian – Maastrichtian stage boundary and *Contusotruncana contusa - Racemiguembelina fructicosa* and *Abathomphalus mayaroensis* are Maastrichtian biozones (Table 3). In the previous study of Özkan-Altıner and Özcan (1999) that was also performed in the study area of this thesis, *Globotruncanita elevata*, *Globotruncana ventricosa* and *Radotruncana calcarata* zones were described for Campanian and *Globotruncanella havanensis, Globotruncana aegyptiaca, Gansserina gansseri* and *Abathomphalus mayaroensis* zones were described for Maastrichtian. Some of the other worldwide biozonations for Campanian and Maastrichtian stages are shown in Table 3.

Becoming one of the main objectives of this study, Uppermost Campanian–Maastrichtian biozonation is established based on the samples collected from the Akveren Formation by means of planktonic foraminifera. The samples in this study have yielded a great diversification with low to high preservation of the specimens. In the measured section, two different biozonations are defined for the Upper Campanian – Maastrichtian interval. One of the biozonation carried out by using Globotruncanids, and Heterohelicids are used for the second biozonation (Table 3). Details for those two biozonations will be given in the following sections (Figure 9).

Table 3. Correlation of planktonic foraminiferal biozonations from different localities.



Stages
MAASTRICHTIAN
CAMPANIAN

Robaszynski 1984
Abathomphalus mayaroensis
Gansserina gansseri
Globotruncana falsostuarti
Globotruncanita calcarata
Globotruncana ventricosa
Globotruncanita elevata

Caron, 1985
Abathomphalus mayaroensis
Gansserina gansseri
Globotruncana aegyptiaca
Gl. havanensis
Globotruncanita calcarata
Globotruncana ventricosa
Globotruncanita elevata
78 Ma
Zoned within Santonian stage

Özkan-Altıner &Özcan, 1999 Kokaksu Section,Turkey
Abathomphalus mayaroensis
Gansserina gansseri
Globotruncana aegyptiaca
Gl. havanensis
Radotruncana calcarata
Globotruncana ventricosa
Unzoned in KOK Section

Premoli-Silva and Sliter, 1999
Abathomphalus mayaroensis
C. contusa - Rc. fructicosa
Gansserina gansseri
Globotruncana aegyptiaca
Gl. havanensis
Rd. calcarata
Globotruncana ventricosa
Globotruncanita elevata

Li & Keller, 1998 DSDP 525A (S. Atlantic)
P. palpebra
P. hariensis
Rc. fructicosa
Ps. intermedia
Rosita contusa
Gansserina gansseri
Globotruncana aegyptiaca
Gl. subcarinatus
Unzoned

Arenillas *et al.*, 2000 El Kef, Tunisia
Plummerita hantkeninoides
Abathomphalus mayaroensis
Unzoned

Gardin *et al.*, 2001 Central Italy
Abathomphalus mayaroensis
C. contusa - Rc. fructicosa
Gansserina gansseri
Globotruncana aegyptiaca
Gl. havanensis
Radotruncana calcarata
Globotruncana ventricosa
Globotruncanita elevata

Chacon *et al.*, 2004 SE Spain
Abathomphalus mayaroensis
C. contusa
Gansserina gansseri
Globotruncana falsostuarti
Globotruncanita calcarata
Globotruncana ventricosa
Globotruncanita elevata

Obaidalla, 2005 SE Sinai, Egypt
Abathomphalus mayaroensis
Pl. hantkeninoides
P. palpebra
P. hariensis
Rc. fructicosa
G. gansseri
Unzoned

This Study, 2006
A. mayaroensis
G. gansseri
G. aegyptiaca
P. hariensis
Rc. fructicosa
Pg. acervulinoides
Ps. elegans
Unzoned

2.2.1 Globotruncanid Biozonation

In this biozonation, Upper Campanian is represented by the *Globotruncana aegyptiaca* Zone and the Campanian - Maastrichtian boundary is drawn into lowermost part of the *Gansserina gansseri* Zone. However, uppermost Maastrichtian is represented by the *Gansserina gansseri* Zone and *Abathomphalus mayaroensis* Zone. Here the Campanian – Maastrichtian boundary is within the *Gansserina gansseri* Zone. In this first zonation, the biozone boundaries aren't distinct since the forms that define the boundaries are very rare especially during Maastrichtian. For this reason, a new biozonation is needed to be constructed by using heterohelicids.

2.2.1.1 *Globotruncana aegyptiaca* Zone

Definition: Interval from the first occurrence of *Globotruncana aegyptiaca* to the first occurrence of *Gansserina gansseri*.

Author: Caron, 1985

Remarks: *Globotruncana aegyptiaca* Zone is the oldest globotruncanid zone that is defined in this study. However, the base of the zone hasn't been recognized in the studied range of the measured section. We can observe the first occurrence of *Globotruncanita conica* within this zone, while *Globotruncana arca, G. falsostuarti, G. orientalis, Rugoglobigerina rotundata, Rg. rugosa, Heterohelix globulosa, Hx. labellosa, Pseudotextularia elegans and Ps. nuttalli* are highly abundant. Other than these forms, the following species are observed within this zone: *Globotruncana aegyptiaca, G. bulloides, G. dupeublei, G. esnehensis, G. insignis, G. linneiana, G. mariei, G. rosetta, G. ventricosa, Globotruncanita angulata, Gt. conica, Gt. pettersi, Gt. stuarti, Gt. stuartiformis, Contusotruncana contusa, C. fornicata, C. patelliformis, C. plicata, C. plummerae, C. walfishensis, Globotruncanella havanensis, Gl. pshadae, Gl. petaloidea, Rugoglobigerina hexacamerata, Rg. macrocephala, Rg. milamensis, Rg. pennyi, Heterohelix navarroensis, Hx. planata, Hx. punctulata, Hx. semicostata, Pseudotextularia intermedia, Gublerina acuta, Gb. cuvilleri, Planoglobulina multicamerata, Laeviheterohelix glabrans, Lh. dentata* (Table 4). This zone is approximately

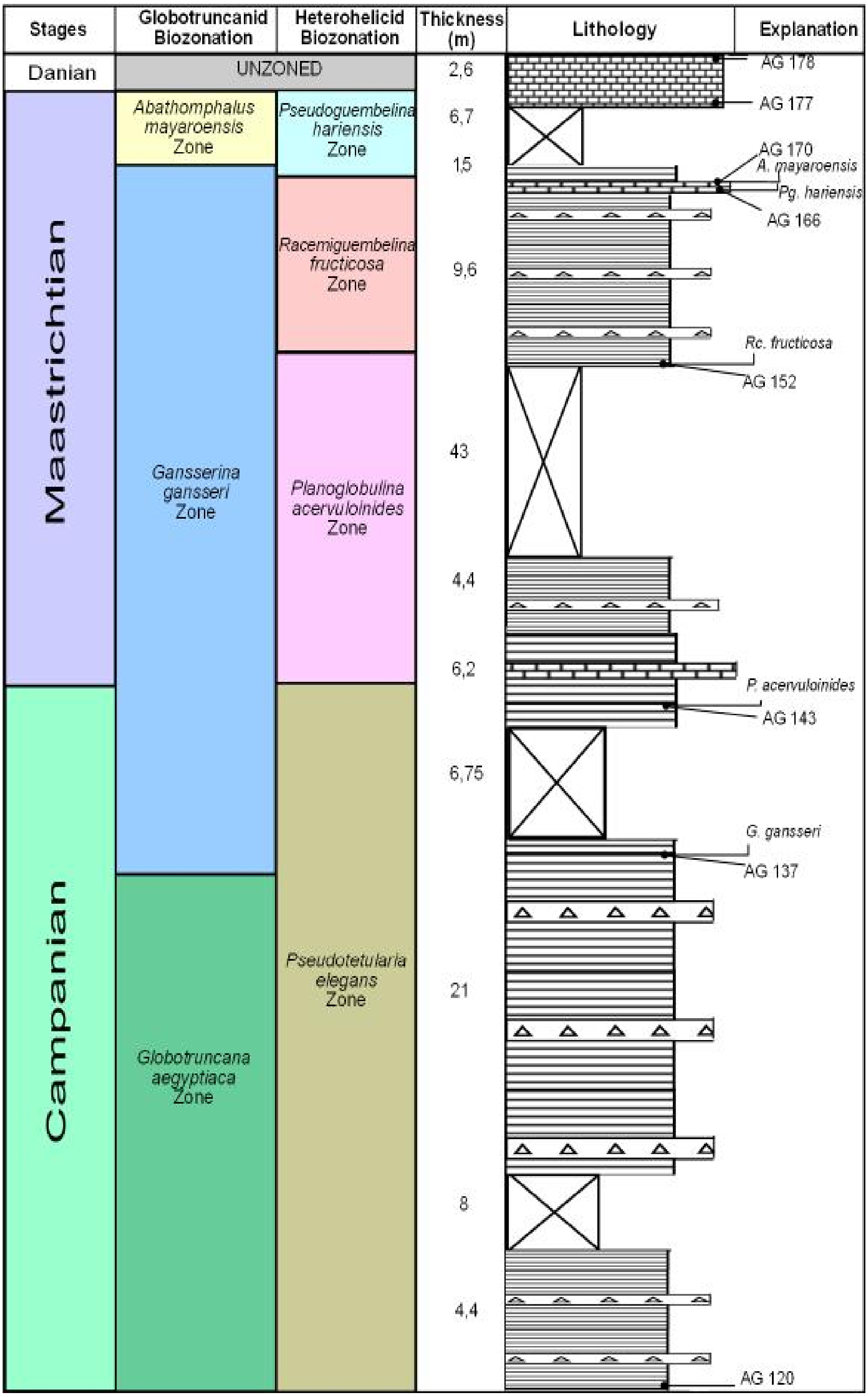


Figure 9. Biostratigraphy of the measured section (See Figure 8 for the explanation, covers are not to scale).

equivalent to *Pseudotextularia elegans* Zone. Marl – calciturbidite alternations were observed throughout the zone (Figure 9).

Stratigraphic distribution: From AG 120 to AG 136.

Range: Upper Campanian

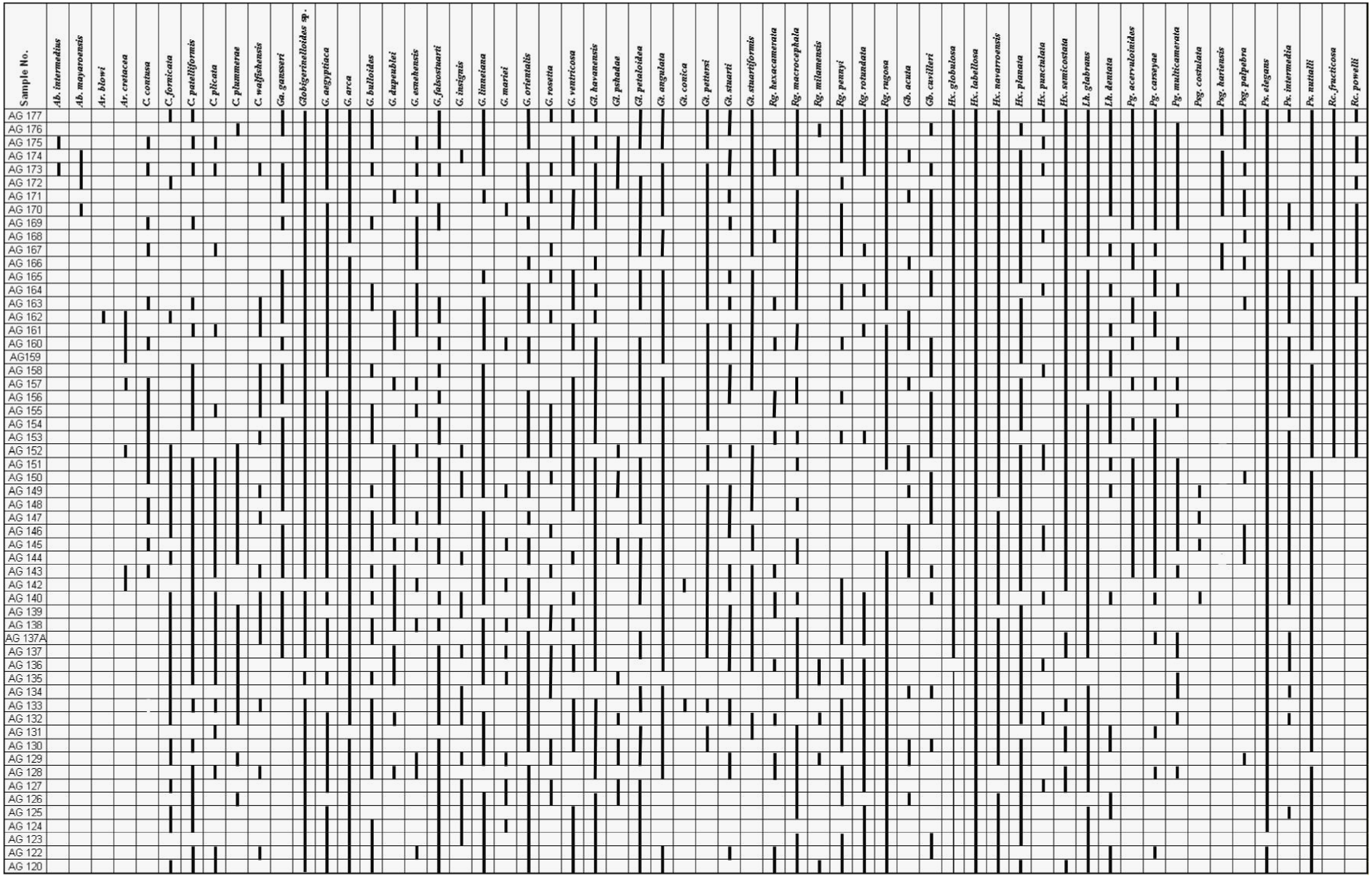
2.2.1.2 *Gansserina gansseri* Zone

Definition: Interval from the first occurrence of *Gansserina gansseri* to the first occurrence of *Abathomphalus mayaroensis.*

Author: Brönnimann, 1952

Remarks: Overlying the *Globotruncana aegyptiaca* Zone, this long ranged zone includes many different species. The total ranges of *Archaeoglobigerina cretacea* and *Pseudoguembelina costulata* occur within this zone. Here, we can also observe the first occurrences of *Pseudoguembelina palpebra* and *Racemiguembelina powelli* and the last occurrence of *Globotruncanita conica.Globotruncana arca, G. linneiana, Globotruncanella havanensis, Globotruncanita angulata, Gt. pettersi, Heterohelix globulosa, Hx. labellosa, Hx. navarroensis, Hx. planata, Hx. semicostata, Laeviheterohelix glabrans, Pseudotextularia elegans* and *Ps. nuttalli* are very abundant within the *Gansserina gansseri* Zone. Besides the abundant forms, this zone also includes *Archaeoglobigerina. blowi, Gansserina gansseri, Globotruncana aegyptiaca, G. bulloides, G. dupeublei, G. esnehensis, G. falsostuarti, G. insignis, G. mariei, G. orientalis, G. rosetta, , G. ventricosa, Globotruncanita angulata, Gt. pettersi, Gt. stuarti, Gt. stuartiformis, Contusotruncana contusa, C. fornicata, C. patelliformis, C. plicata, C. plummerae, C. walfishensis, Globotruncanella pshadae, Gl. petaloidea, Rugoglobigerina hexacamerata, Rg. macrocephala, Rg. pennyi, Rg. rotundata, Rg. rugosa, Heterohelix punctulata, Pseudotextularia intermedia, Racemiguembelina fructicosa, Gublerina acuta, Gb. cuvilleri, Planoglobulina acervuloinides* and *Racemiguembelina fructicosa* zones. The Campanian – Maastrichtian boundary lies within this zone. This zone starts with marl – calciturbidite alternations at its base. Then the sequence continues with a

Table 4. Foraminiferal distribution charts.



clayey limestone – marl alternation that is followed by the part which consists of another marl – calciturbidite alternation and lasts with clayey limestone – marl alternation (Figure 9).

Stratigraphic distribution: From AG 137 to AG 169.

Range: Uppermost Campanian – Maastrichtian.

2.2.1.3 *Abathomphalus mayaroensis* Zone

Definition: Interval from the first occurrence of *Abathomphalus mayaroensis* to the end of the Maastrichtian.

Author: Brönnimann, 1952

Remarks: This is the uppermost zone of Maastrichtian stage that has ended with the Cretaceous – Tertiary boundary. The evolution of the *Abathomphalus intermedius* is also within this zone. This zone is rich in *Globotruncana arca, G.orientalis, G. ventricosa, Globotruncanella havanensis, Gl. petaloidea, Globotruncanita angulata, Gt. pettersi, Rugoglobigerina macrocephala, Rg. rugosa, Heterohelix globulosa, Hx. labellosa, Hx. navarroensis, Hx. semicostata, Laeviheterohelix glabrans, Lh. dentata, Planoglobulina acervuloinides, Pg. carseyae, Pg. multicamerata, Pseudotextularia elegans, Ps. nuttall* and,*Racemiguembelina fructicosa.* In this zone, the fossil assemblage consists of *Abathomphalus mayaroensis, Gansserina gansseri, Globotruncana aegyptiaca, G. bulloides, G. dupeublei, G. esnehensis, G. falsostuarti, G. insignis, G. linneiana, G. mariei, G. rosetta, Globotruncanita stuarti, Gt. stuartiformis, Contusotruncana contusa, C. fornicata, C. patelliformis, C. plicata, C. plummerae, C. walfishensis, Globotruncanella havanensis, Gl. pshadae, Gl. petaloidea, Rugoglobigerina hexacamerata, Rg. milamensis, Rg. pennyi, Rg. rotundata, Heterohelix planata, Hx. punctulata, , Pseudotextularia intermedia, Gublerina acuta, Gb. cuvilleri, Pseudoguembelina hariensis, Psg. palpebra,* (Table 4). This zone is the equivalent to *Pseudoguembelina hariensis* Zone in the biozonation which is using the Heterohelicids in this study. The samples in this zone are composed mainly of clayey limestones (Figure 9).

Stratigraphic Distribution: From AG 170 to AG 177.

Range: Uppermost Maastrichtian.

2.2.2 Heterohelicid Biozonation

Since there is indefiniteness in the boundaries of the globotruncanid zonation because of the rareness of the forms defining the boundaries of the zones especially in the Maastrichtian stage, another biozonation is carried out by using the heterohelicids.

After the detailed studies of Nederbragt (1990, 1991) on the heterohelicids, there has been a limited usage of those forms on the Upper Cretaceous biozonation (Li & Keller, 1998; Robasyznski, 1998; Obaidalla, 2005) (Table 3). This study is the first study in Turkey that a heterohelicid biozonation was established.

The heterohelicid biozonation in this study is based on the biostratigraphic study of Robaszynski (1998). In this biozonation, Campanian is defined by *Pseudotextularia elegans* zone and Maastrichtian is divided into *Planoglobulina acervuloinides***,** *Racemiguembelina fructicosa* and *Pseudoguembelina hariensis* zones.

2.2.2.1 *Pseudotextularia elegans* Zone

Definition: Interval from the first occurrence of *Pseudotextularia elegans* to first occurrence of *Planoglobulina acervuloinides.*

Author: Robaszynski, 1998

Remarks: This zone comprises the lower part of the measured section. The base of this zone hasn’t been observed in this study. Different from the biozonation of Robaszynski (1998), the presence of *Pseudoguembelina excolata* Zone couldn’t be recorded and this zone is extended up to the lower boundary of *Planoglobulina acervuloinides* Zone. First occurrence of

Globotruncanita conica can be recorded within this zone. Besides an increase in the abundance of *Contusotruncana fornicata, Globotruncanella havanensis, Rugoglobigerina pennyi* and *Rg. rotundata;* this zone comprises several species of planktonic foraminifera (Table 4): *Archaeoglobigerina cretacea, Globotruncana aegyptiaca, G. arca, G. bulloides, G. dupeublei, G. esnehensis, G. falsostuarti, G. insignis, G. linneiana, G. mariei, G. orientalis, G. rosetta, , G. ventricosa, Globotruncanita angulata, Gt. pettersi, Gt. stuarti, Gt. stuartiformis, Contusotruncana contusa C. patelliformis, C. plicata, C. plummerae, C. walfishensis, Globotruncanella pshadae, Gl. petaloidea, Rugoglobigerina hexacamerata, Rg. macrocephala, Rg. milamensis, Rg. rugosa, Heterohelix globulosa, Hx. labellosa, Hx. navarroensis, Hx. planata, Hx. punctulata, Hx. semicostata, Pseudotextularia elegans, Ps. intermedia, Ps. nuttalli, Gublerina acuta, Gb. cuvilleri, Planoglobulina carseyae, Pg. multicamerata, Laeviheterohelix glabrans, Lh. dentata*. This zone is approximately equivalent to *Globotruncana aegyptiaca* Zone. This interval consists of calciturbidite – marl alternation that ends up with a clayey limestone unit at the top (Figure 9).

Stratigraphic distribution: From AG 120 to AG 142.

Range: Uppermost Campanian.

2.2.2.2 *Planoglobulina acervuloinides* Zone

Definition: Interval from the first appearance of *Planoglobulina acervuloinides* to first appearance of *Racemiguembelina fructicosa.*

Author: Robaszynski, 1998

Remarks: Since the *Pseudoguembelina excolata* Zone was not recorded in this study, this zone directly overlies the *Pseudotextularia elegans* Zone. The first occurrence of *Planoglobulina acervuloinides* is also used to determine the position of Campanian – Maastrichtian boundary. The first occurrence of *Pseudoguembelina palpebra* and the last occurrence of *Pseudoguembelina costulata* take place within this zone. With the increasing abundance of *Contusotruncana fornicata, C. patelliformis, C. plicata, C. plummerae, Gansserina gansseri, Planoglobulina carseyae* and *Pg. multicamerata,* this zone contains the following forms (Table 4): *Globotruncana aegyptiaca, G. arca, G. bulloides, G. dupeublei, G. esnehensis, G. falsostuarti, G. insignis, G. linneiana, G. mariei, G. orientalis, G. rosetta, , G. ventricosa, Globotruncanita angulata, Gt. pettersi, Gt. stuarti, Gt. stuartiformis, Contusotruncana contusa, C. walfishensis, Globotruncanella havanensis, Gl. pshadae, Gl. petaloidea, Rugoglobigerina macrocephala, Rg. rugosa, Heterohelix globulosa, Hx. labellosa, Hx. navarroensis, Hx. planata, Hx. punctulata, Hx. semicostata, Pseudotextularia elegans, Ps. intermedia, Ps. nuttalli, Gublerina acuta, Gb. cuvilleri, Planoglobulina acervuloinides, Laeviheterohelix glabrans, Lh. dentata.* This zone matches with the lower part of *Gansserina gansseri* Zone. The base of this zone indicates the Campanian – Maastrichtian boundary. This Zone consists of clayey limestone – marl alternations with some calcitubiditic intercalations into the marl units at the top of the sequence (Figure 9).

Stratigraphic distribution: From AG 143 to AG 151.

Range: Lower Maastrichtian.

2.2.2.3 *Racemiguembelina fructicosa* Zone

Definition: Interval from the first occurrence of *Racemiguembelina fructicosa* to first occurrence of *Pseudoguembelina hariensis.*

Author: Li and Keller, 1998.

Remarks: This zone is the mostly used heterohelicid biozone (Li & Keller, 1998; Premoli-Silva and Sliter, 1999; Gardin *et al.,* 2001; Obaidalla, 2005) (Table 3). In some of these biozonations, this zone is equivalent to the *Contusotruncana contusa* Zone (Premoli-Silva and Sliter, 1999; Gardin *et al.,* 2001) and Obaidalla (2005) mentioned that this zone corresponds to the lowermost part of the *Abathomphalus mayaroensis* Zone (Table 3). In this study, *Racemiguembelina fructicosa* Zone is definitely below the *Abathomphalus mayaroensis* Zone and we can't compare it with the range of *Contusotruncana contusa*, since this form has a wide range. The first occurrence of *Racemiguembelina powelli* is at the base of this zone and the last occurrence of *Archaeoglobigerina cretacea* takes place within this zone. *Archaeoglobigerina blowi* is represented in a single sample within this zone (AG 162) (Table 4). The following species are recorded in this zone (Table 4): *Gansserina gansseri, Globotruncana aegyptiaca, G. arca, G. bulloides, G. dupeublei, G. esnehensis, G. falsostuarti, G. insignis, G. linneiana, G. mariei, G. orientalis, G. rosetta, , G. ventricosa, Globotruncanita angulata, Gt. pettersi, Gt. stuarti, Gt. stuartiformis, Contusotruncana contusa, C. fornicata, C. patelliformis, C. plicata, C. walfishensis, Globotruncanella havanensis, Gl. petaloidea, Rugoglobigerina hexacamerata, Rg. macrocephala, Rg. pennyi, Rg. rotundata, Rg. rugosa, Heterohelix globulosa, Hx. labellosa, Hx. navarroensis, Hx. planata, Hx. punctulata, Hx. semicostata, Pseudotextularia elegans, Ps. intermedia, Ps. nuttalli, Racemiguembelina fructicosa, Gublerina acuta, Gb. cuvilleri, Planoglobulina acervuloinides, Pg. carseyae, Pg. multicamerata, Pseudoguembelina palpebra, Laeviheterohelix glabrans, Lh. dentata.* *Racemiguembelina fructicosa* Zone includes the interval which matches with the upper part of the *Gansserina gansseri* Zone. *Racemiguembelina fructicosa* Zone consists of mostly of calciturbidite – marl alternations except the clayey limestone units at its top (Figure 9).

Stratigraphic distribution: From AG 152 to AG 165.

Range: Middle to Upper Maastrichtian.

2.2.2.4 *Pseudoguembelina hariensis* Zone

Definition: Interval of total range of *Pseudoguembelina hariensis.*

Author: Li and Keller, 1998

Remarks: This zone is the uppermost heterohelicid biozone in this study. The first and last occurrences of *Abathomphalus intermedius* and *A. mayaroensis* takes place within this zone (Table 4). In this zone, *Globotruncana arca, Globotruncanella petaloidea, Globotruncanita pettersi, Gt.stuartiformis, Rugoglobigerina macrocephala, Rg. rugosa, Heterohelix globulosa, Hx. labellosa, Hx. navarroensis, Hx. semicostata, Laeviheterohelix glabrans, Planoglobulina acervuloinides, Pg. carseyae, Pseudotextularia elegans, Ps. nuttalli, Racemiguembelina fructicosa* and *Rc. powelli* shows almost a continuous distribution. This interval comprises the planktonic foraminiferal assemblages below (Table 4): *Gansserina gansseri, Globotruncana aegyptiaca, G. bulloides, G. dupeublei, G. esnehensis, G. falsostuarti, G. insignis, G. linneiana, G. mariei, G. orientalis, G. rosetta, , G. ventricosa, Globotruncanita angulata, Gt. stuarti, Contusotruncana contusa, C. fornicata, C. patelliformis, C. plicata, C. walfishensis, Globotruncanella havanensis, Gl. pshadae, Rugoglobigerina hexacamerata, Rg. milamensis, Rg. pennyi, Rg. rotundata, Heterohelix planata, Hx. punctulata, Pseudotextularia intermedia, Gublerina acuta, Gb. cuvilleri, Planoglobulina multicamerata, Pseudoguembelina hariensis, Psg. palpebra, Laeviheterohelix dentata.* The lower boundary of this zone is just drawn under the *Abathomphalus mayaroensis* Zone. This zone mainly consists of clayey limestone (Figure 9).

Stratigraphic distribution: From AG 166 and AG 177.

Range: Uppermost Maastrichtian.

2.2.3 Problematic Boundaries Across The Measured Section

2.2.3.1 Campanian – Maastrichtian Boundary Across The Measured Section

Defining the end of the Mesozoic with one of the greatest mass extinctions at the Cretaceous – Tertiary boundary, Maastrichtian is an important stage within the Cretaceous system. Choronologically, first stratotype of Maastrichtian stage was proposed by Dumont (1849) as "Systéme Maestrichtien" which was corresponding to the Maastricht Formation in Limburg (Jagt, 2001; Odin, 2001). However, after the detailed studies of Maastrichtian Working Group members (1993 – 1999), the lower boundary defined by Dumont (1849) was considered to be located definitely above the real Campanian – Maastrichtian boundary (Odin, 2001; Odin and Lamaurelle, 2001; Odin and the Maastrichtian Working Group members, 2001). In the studies of the Maastrichtian Working Group, the "Global Standard-stratotype Section and Point" (GSSP) was chosen from Tercis les Bains (Landes, France) and ratified by International Commission of Stratigraphy (ICS). As a result of detailed studies by several authors, 18 different fossil groups were compared and 12 possible biohorizons were discussed. Two of these horizons include the first occurrences of planktonic foraminifers *Contusotruncana contusa* and *Rugoglobigerina scotti.* Consequently, the Campanian – Maastrichtian boundary was defined with the first occurrence of *Pachydiscus neubergicus* (ammonite) (Odin and Lamaurelle, 2001; Odin and the Maastrichtian Working Group members, 2001). After the determination of the GSSP for the Campanian – Maastrichtian boundary in Tercis, its correlation was examined with the different sections around the world (Gardin *et al.*, 2001; Küchler *et al.*, 2001; Odin, 2001). In terms of planktonic foraminiferal evaluation, the boundary is defined much closed to the *Rugoglobigerina scotti*/ *Contusotruncana contusa* Biozone (Odin *et al.*, 2001), within the *Globotruncana falsostuarti* Interval Zone (Ion and Odin, 2001) or in the middle part of the *Gansserina gansseri* Biozone which was first mentioned by Robaszynski and Caron (1995) and it is correlated with the first occurrence of *Rugoglobigerina scotti* (Arz and Molina, 2001). So, the previous suggestion on "*Radotruncana calcarata* Biozone" as the upper boundary of Campanian becomes invalid since the range of this form is decided within the Campanian.

In this study, as it is indicated in the studies of the Maastrichtian working group at Tercis (Odin, 2001; Odin and Lamaurelle, 2001; Odin and the Maastrichtian Working Group members, 2001), the first occurrence of *Planoglobulina acervuloinides* (Sample AG 143) marks the Campanian – Maastrichtian Boundary. This boundary also coincides with the global data in terms of the first occurrence of *Contusotruncana contusa* at sample AG 143; however, this form hasn't been used for the biozonation since its range extends throughout the measured section.

2.2.3.2 Cretaceous – Tertiary Boundary Across The Measured Section

Cretaceous – Tertiary boundary sections are one of the most studied sequences in the world. Various fossil assemblages were used for determining the age and depositional environments of the sequences, such as planktonic and benthic foraminifera, calcareous nannofossils, belemnites and ammonites (Canudo, 1997; Ginsburg, 1997; Keller, 2001; Keller, 1997; Kouwenhoven, 1997; Lipps, 1997; Luciani, 2002; Masters, 1997; Olsson, 1997; Smit & Nederbragt, 1997, etc.).

Since the Cretaceous – Tertiary boundary shows a great extension of mass extinctions, causes and characteristics of these enormous extinctions have become an important discussion. The first theory was the bolide impact that suddenly ceased the life. The crater in the Yutacan, Mexico and the distinct clay level with an iridium anomaly through the boundaries in measured sections verify this idea. However, by the following detailed studies, it is argued that the bolide impact wasn't the only cause of the boundary extinction and there became long period extinction events around the boundary due to the changes in the environmental conditions (Canudo, 1997; Keller, 2001; Keller, 1997; Luciani, 2002; Masters, 1997; Olsson, 1997; Smit & Nederbragt, 1997).

Among the continuing discussion, another point is whether the K/T extinction was a single event or kept on as gradual, stepwise events. Some researchers defended that most of the species became extinct as a result of bolide impact and the observed Cretaceous species in the Danian samples were the result of reworking. Other groups argued that many species survived from the extinction event and continued to live on in Danian (Keller, 1998; Keller et al., 2002; Obaidalla, 2005). Forms smaller than the original Cretaceous species that has been observed above the boundary can be thought as “survivors” (Keller et al., 2002). On the other hand, the pre-boundary extinction is thought to be resulted from the insufficient sampling in the ongoing studies or differences in the taxonomic nomenclature for different authors. El Kef blind test is one of the most significant projects in this manner. A blind test was carried out to find out the characteristics of the Cretaceous – Tertiary extinction by numerous authors (Canudo, 1997; Ginsburg, 1997; Keller, 1997; Kouwenhoven, 1997; Lipps, 1997; Masters, 1997; Olsson, 1997; Orue-etxebarria, 1997; Smit and Nederbragt, 1997). However, in this project, the authors have not reached an agreement on these subjects yet and the discussions are going on.

During the fieldwork in the study area, it was difficult to define the Cretaceous – Tertiary boundary, since there isn’t any change in the lithology of the measured sequence. However, during the laboratory studies, by the help of both thin sections and the washing specimens from the collected samples, a detailed observation has been carried out. Throughout this laboratory work, in the studied section the Cretaceous – Tertiary boundary is determined with the complete disappearance of the Cretaceous forms and evolution of the Danian species (Figure 10). These species are smaller sized forms with globular chambers and they are not bearing keels or any other complex structures. So, all through the measured section; AG 177 is determined as the last Cretaceous sample and AG 178 is the first Paleocene sample. Since the Paleocene biostratigraphy isn't an objective of this study, Paleocene forms haven't been studied and the study was ended by the determination of the Cretaceous/ Tertiary boundary.

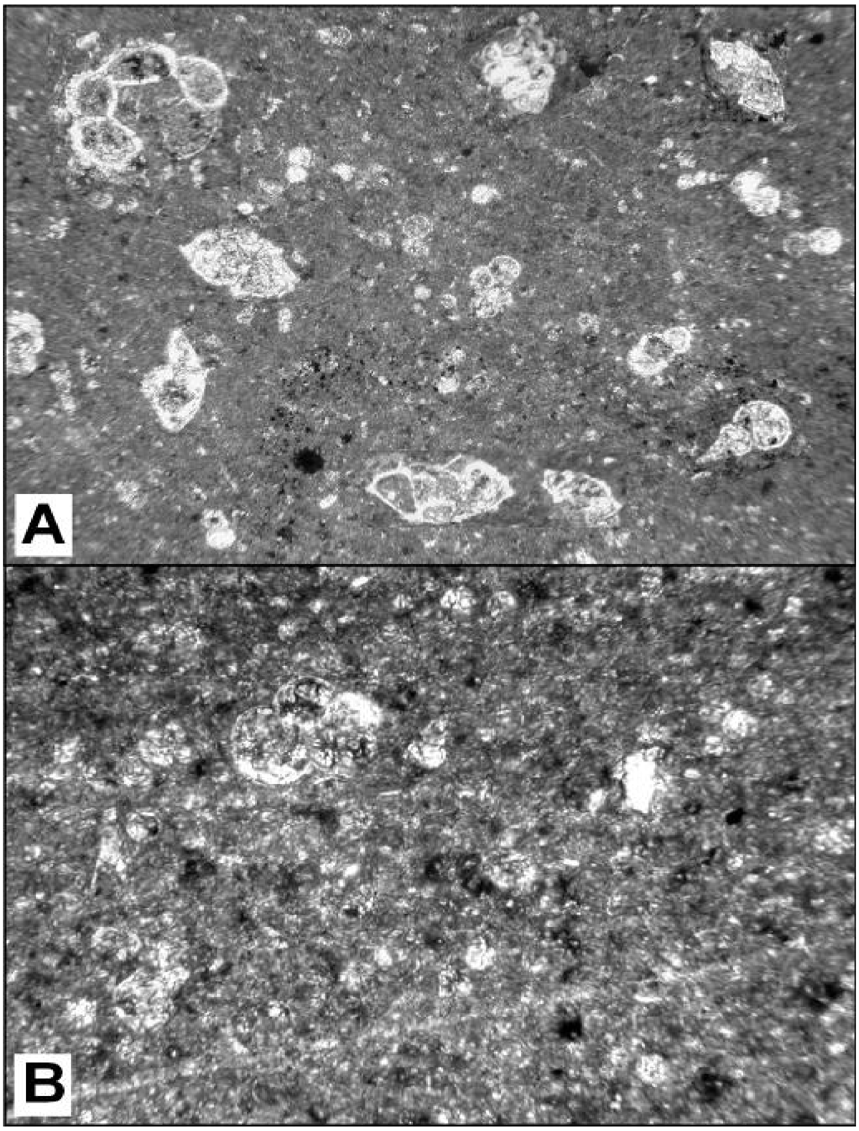


Figure 10. Changes in planktonic foraminiferal assemblages of the Cretaceous and Danian samples: **A.** High diversity of Cretaceous forms with complex morphologies such as double-keel forms from sample AG 177, **B.** Danian species with simple morphology such as globular chambers in throcospiral form from sample AG 178.

CHAPTER III

EVOLUTIONARY TRENDS AND RESPONSE OF PLANKTONIC FORAMINIFERS TO ECOLOGICAL CHANGES

3.1 Introduction

Planktonic Foraminifera is an important fossil group for the paleoecologic and paleoceanographic studied. This group has already been used in most of the studies in literature for this purpose. (Sliter, 1972; Leckie, 1989; Ottens and Nederbragt, 1992; Shanin, 1992; Premoli-Silva and Sliter, 1994; Li and Keller, 1998; Nederbragt, 1998; Barrera and Savin, 1999; Premoli-Silva and Sliter, 1999; Arz and Molina, 2001; Nederbragt et al., 2001; Abramovich and Keller, 2002; Keller et al., 2002; Petrizzo, 2002).

On this basis, the response of planktonic foraminifers to the environmental changes will be discussed in this section for the Late Campanian – Maastrichtian interval. First of all, as the most significant effect on the evolution of the planktonic foraminifers, the Cretaceous paleoceanography will be summarized briefly and then the evolution of the planktonic foraminifers with respect to the environmental changes will be discussed. Later on, we will examine the patterns of evolutionary changes that were observed in our samples. These changes will be discussed in terms of species diversity and generic diversity and abundance. Lastly, response of our forms to those patterns will be mentioned with respect to different morphotypes in terms of diversity, abundance, response to the lithological changes and changes with respect to time.

3.2 Cretaceous Paleoceanography

It is a fact that evolutionary changes are parallel to changes in the physical and chemical properties of the oceans. So before discussing the evolution of the planktonic foraminifera, it will be useful to examine the Cretaceous paleoceanography from the early Valanginian, in which the first diversification among the planktonic foraminifera is observed, to the Cretaceous / Tertiary boundary. While Early Cretaceous will be briefly explained only by its important events (details on figure 11), Campanian and Maastrichtian stages (83.5 Ma to 65 Ma), which are important for the further part of the study, will be emphasized (Figure 11) The importance of these events with the connection to the planktonic foraminiferal evolution will be discussed in the following sections.

When we look at Early Cretaceous, there was a warm and humid climatic regime than the today's conditions (Premoli-Silva & Sliter, 1999; Zeebe, 2001). There were two important events during this period; Selli Event and Bonarelli Event. Selli Event was an episode in which a widespread organic carbon-rich sediment deposition is observed. So, during the late early Aptian, due to the increasing nutrient supply in surface waters during the sea level rise, productivity increased, which was resulted in the expansion of oxygen-depleted waters. The late Cenomanian Bonarelli Event is a worldwide anoxic event, characterized by highest accumulation of organic matter of marine origin in pelagic sediments with the less stable conditions and nutrient rich waters controlled by an upwelling regime. There was a very high primary productivity due to the increasing nutrient supply. After the Bonarelli Event, tropical paleoenvironmental conditions expanded towards the subantarctic regions through the Coniacian. Cenomanian through Coniacian interval was represented as a "temperature maximum" revealed by the oxygen isotope studies (Barrera & Savin, 1999). Santonian was considered as an ecotone between the earlier Greenhouse ocean with its variable sediments and weal bioprovinces, and later modern

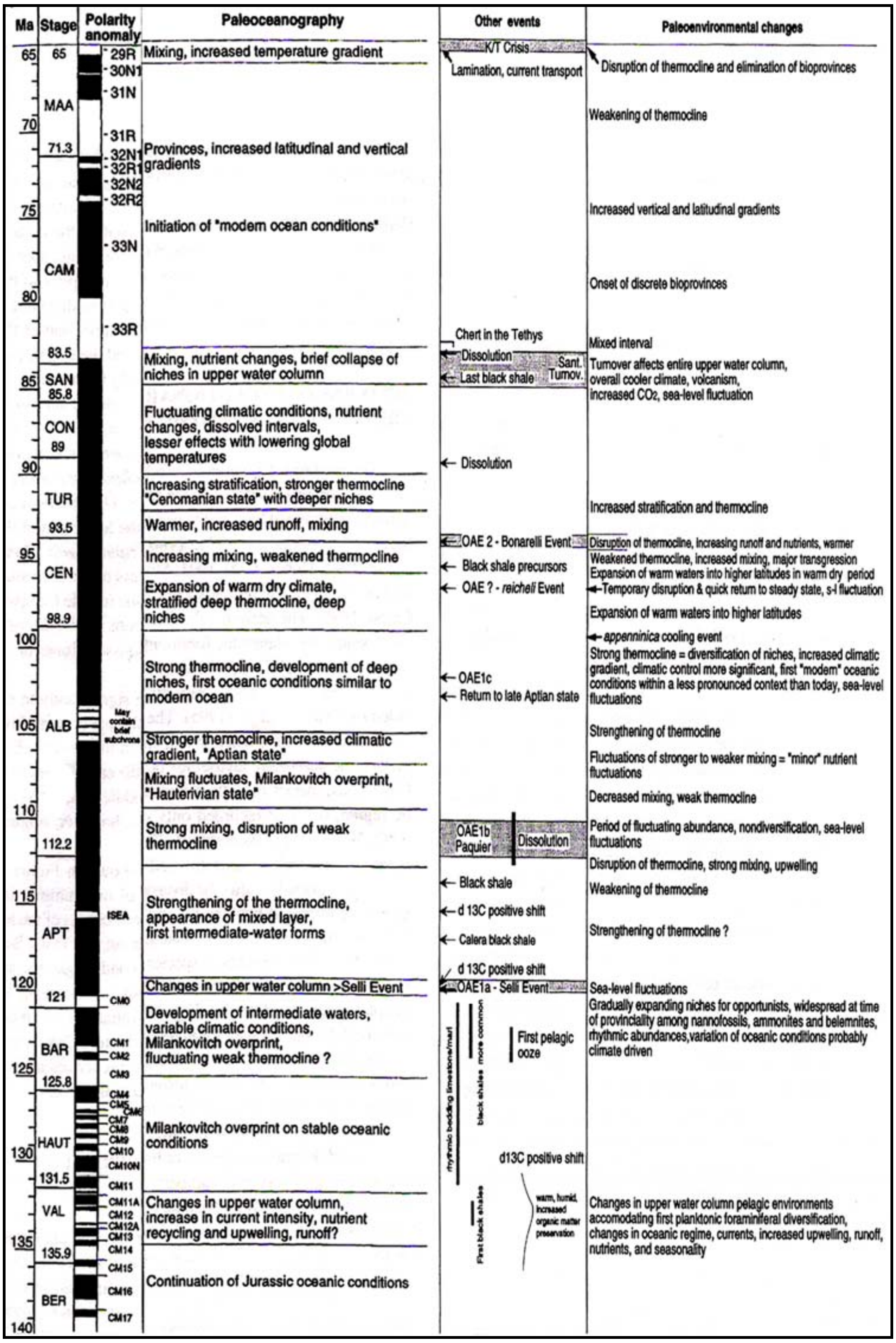


Figure 11. Major paleocenography and paleoenvironmental changes through Cretaceous plotted against major stratigraphic events, magnetostratigraphy, and absolute age (Modified from Premoli Silva & Sliter, 1999).

ocean with more uniform carbonate deposition and well-defined bioprovinces (Premoli Silva & Sliter, 1999).

By the Campanian, tropical surface waters became more stable with a lower nutrient content as they are today. There was the onset of the bioprovinces resulted from the increasing latitudinal and vertical temperature gradients.

From late Campanian through Maastrichtian, three major marine regressions influenced the climatic conditions, which became cooler (Barrera & Savin, 1999). Those were corresponding to the second order global sea-level curve of Haq et al (1987), which were at about 75 – 74 Ma, 71.5 – 70.5 Ma and 67 – 65.5 Ma (Figure 12).

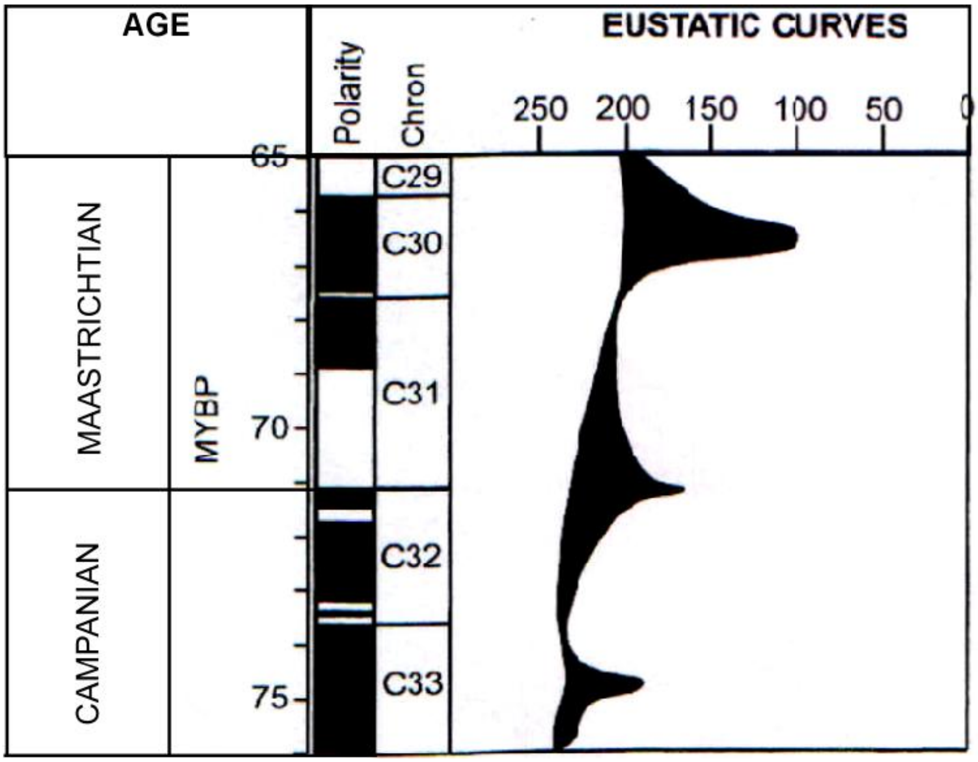


Figure 12. Plot of the sea level curve of Haq *et al.* (1987). Three episodes of marine regression correspond to the time intervals between 75 and 74 Ma, between 71.5 and 70.5 Ma, and between 67 and 65.5 Ma. (From Barrera & Savin, 1999)

By the studies with oxygen isotopes, the increasing δ^{18} O values of foraminiferal tests pointed out the global cooling of surface and intermediate waters from 75 to 65.5 Ma. Although in most of the previous studies it was suggested that there is no direct evidence for continental glaciation before the Oligocene, by the isotope studies that were carried out by using planktonic and benthic foraminiferal record, the idea that "Even in the greenhouse state of the Late Cretaceous, continental ice may also have existed as small ice sheets" was come to the point (Barrera & Savin, 1999; Miller et al., 2003). At 71 Ma, a maximum of 25 % of the average δ^{18} O values might be explained with an increase in continental ice volume during the short intervals of peak Milankovitch forcing, with ~25 m. of eustatic lowering or deep water cooling of 3-4°C (Miller et al., 2003).

During Maastrichtian, another episode of cooler intermediate waters with an even larger sea level fall than the previous period from 67.5 Ma to 65.4 Ma, which was recorded from South Atlantic, Indian and Pacific Oceans were developed. This trend was terminated at 65.4 Ma with the global warming by about 2°C of both surface and intermediate waters (Barrera & Savin, 1999; Stüben et al., 2003). Increasing nutrient input to the oceans caused to a shift to unstable conditions and increased productivity. During the Late Maastrichtian, a reduction in the surface-to-deep gradient was formed (Stüben et al., 2003). Progressive weakening of the thermocline was realized until the end of the stage (65.5 Ma) (Premoli Silva & Sliter, 1999; Stüben et al, 2003).

The effects of the Campanian – Maastrichtian paleoceanography on the evolution of the planktonic foraminifers in the studied section will be discussed in the following sections of this chapter.

3.3 Evolution Of The Planktonic Foraminifera

If we make an observation among the Cretaceous forms, the planktonic foraminifera include a great amount of species diversification. Although these forms can be found from the rocks as old as Middle Jurassic, their major evolution was during the Cretaceous (Leckie, 1989). After analyzing the Cretaceous record, the following results have been presented; three-fold pattern in their evolution with numerous originations of the new forms with new morphologies (polytaxic times), turnovers and declines in diversity during the intervening times with returns to simple test morphologies, stasis and extinctions; related to the ongoing paleoenvironmental events and climatic and oceanographic changes in the world's ocean associated with the significant plate tectonic reorganization and fluctuations in the sea level (Figure 13) during this period as stated in the previous sections (Leckie, 1989; Premoli Silva & Sliter, 1999).

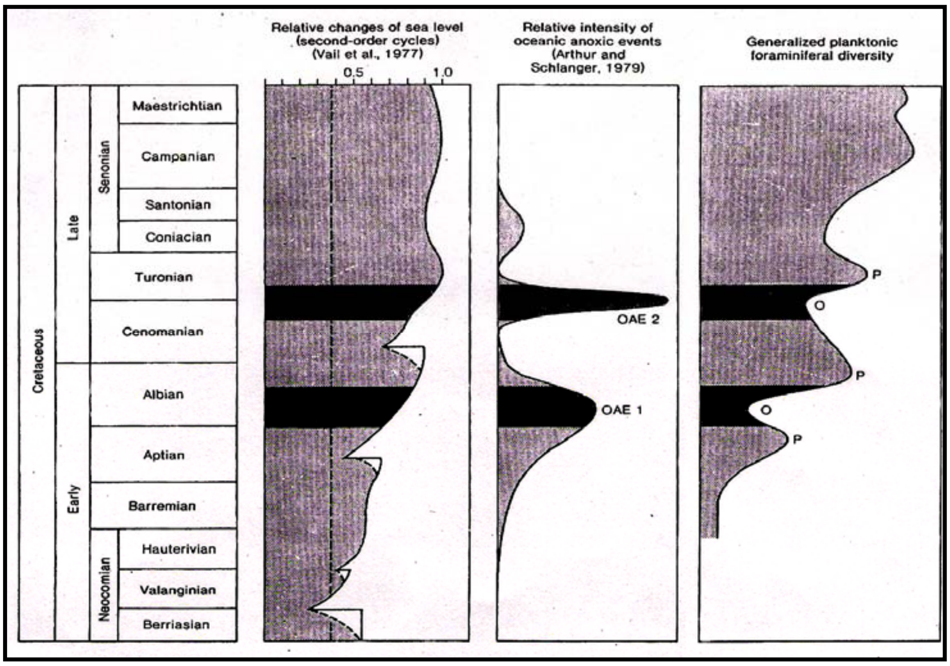


Figure 13. Correlation of global sea level changes, oceanic anoxic events and generalized diversity trends in planktonic foraminifera. O=Oligotaxic, P=Polytaxic (Modified from Leckie, 1989).

Their first diversification had an onset in the early Valanginian and continued until the early late Aptian (Figure 14). These relatively slow and gradual radiations may have been related to creation of widespread epicontinental seas associated with the rise of global sea level and highstand phase of the world's ocean. During this interval, the diversification involved only the hedbergellids and globigerinelloids which were the simple forms with smaller sizes, inflated globular chambers with little chamber overlap, simple umbilical apertures (*Hedbergella*) or planispiral morphotypes (*Globigerinelloides*) as well as morphotypes with radially elongated chambers (*Leupoldina*). These first occurrences characterized by lower abundances restricted mainly to shallow marginal seas, while also a benthic stage in their life cycles was suggested (Leckie, 1989; Hilbrecht & Thierstein, 1996). The first appearances of the primitive apertural plates and accessory apertures (*Ticinella*) and peripheral keels (*Planomalina*) were during the late Aptian. Latest Aptian marks a decline in diversity with a lost in all radially elongate planispiral species and the keeled forms.

The second diversification takes place from the Aptian / Albian boundary as a small rebound with acceleration in the late Albian and a slight decrease in the latest Albian (Figure 14). After the disappearance of intermediate forms just before the boundary, during early to middle Albian, there initially developed the small-sized forms followed with the reappearance of *Hedbergella*, *Globigerinelloides* and primitive *Ticinella* that were increasing in size during their evolutionary stages. During mid- to late Albian, *Favusella*, which was a cancellate taxa, became abundant in warm neritic carbonate environments. *Rotalipora*, a keeled form, were another taxa appeared in late Albian. Here, one of the suggestions on the causes of the first occurrence of keel-bearing planktonic foraminifera is the connection through the Tethyan and Boreal realms during the eustatic highstands or tectonic episodes that caused the formation of warmer, less dense water bodies and new niches for a variability of forms. In this interval, the forms with radially elongated chambers; *Clavihedbergella* and

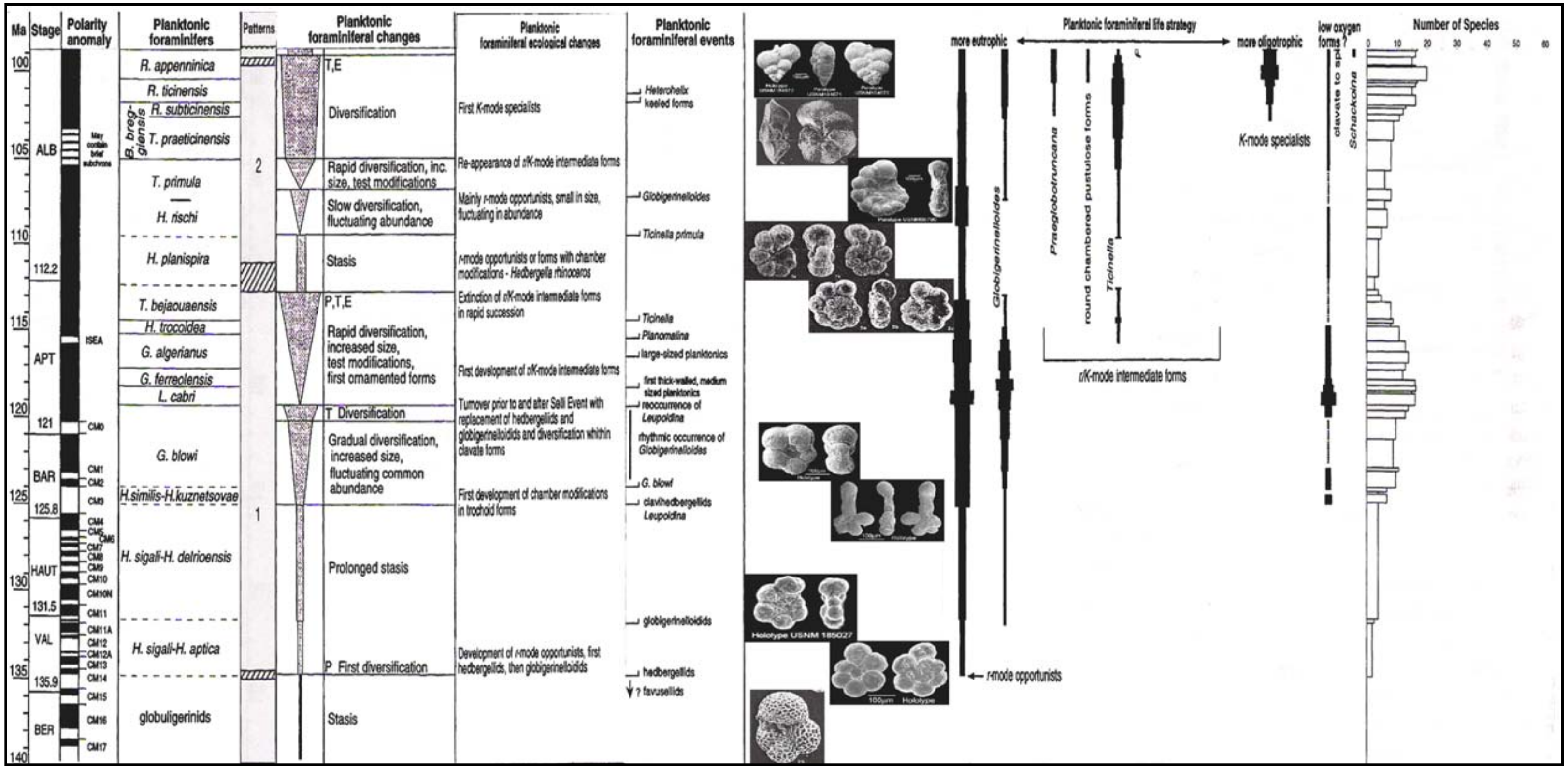


Figure 14. Evolutionary pattern of Lower Cretaceous (Berriasian – Albian) planktonic foraminifera with the polarity anomaly, zonation, evolutionary changes, first and last occurrences, life strategies and species diversity (from Premoli Silva & Sliter 1999, images from Caron, 1985).

Schackoina, were continuing to diversify and the first appearances of thin, biserial *Heterohelix* and keeled forms *Praeglobotruncana* and *Planomalina* were observed.

Second evolutionary pattern among the planktonic foraminifera terminated with a demise in *Ticinella* and *Planomalina* (Leckie, 1989) (Figure 14). After this decrease in the latest Albian, the third stage of the diversification of the planktonic foraminifers continued until the end of the Cretaceous. Here, short periods of rapid diversifications were recognized, followed by the turnovers and longer periods of stasis. During the Late Cenomanian, first appearance of the double-keeled genus *Dicarinella* was observed (Figure 15). This second episode of keel formation can also be related to the beginning of a second onlap episode during Cenomanian-Turonian (Gasinski, 1997). Near the Cenomanian/Turonian stage boundary, Bonarelli Event took place that is characterized by the dominancy of large, inflated *Whiteinella* (Premoli Silva & Sliter, 1999). *Marginotruncana* and *Dicarinella* were rapidly diversifying in the middle Turonian, while there was a decline among *Praeglobotruncana*. The evolution of the species has continued by the first occurrences of the genera *Globotruncana*, *Contusotruncana* and *Globotruncanita* during the Coniacian through Santonian (Figure 15).

In the early Campanian, again a decrease was observed and the assemblages were dominated by juvenile *Globotruncana* and simple *Heterohelix* (Premoli Silva & Sliter, 1999; Petrizzo, 2002). Followed by a continuous increasing from the late early Campanian up to the base of the Maastrichtian, species richness was represented by highest diversification with more than 60 forms. In this interval, it can be recognized that globotruncanids reached their maximum diversification, before one of the major extinctions in Cretaceous/Tertiary boundary (Figure 15). During this interval, there were the first occurrences of some new forms such as archaeoglobigerinids, but their abundance was low except at very high latitudes. However, after maximum diversity has been reached for planktic

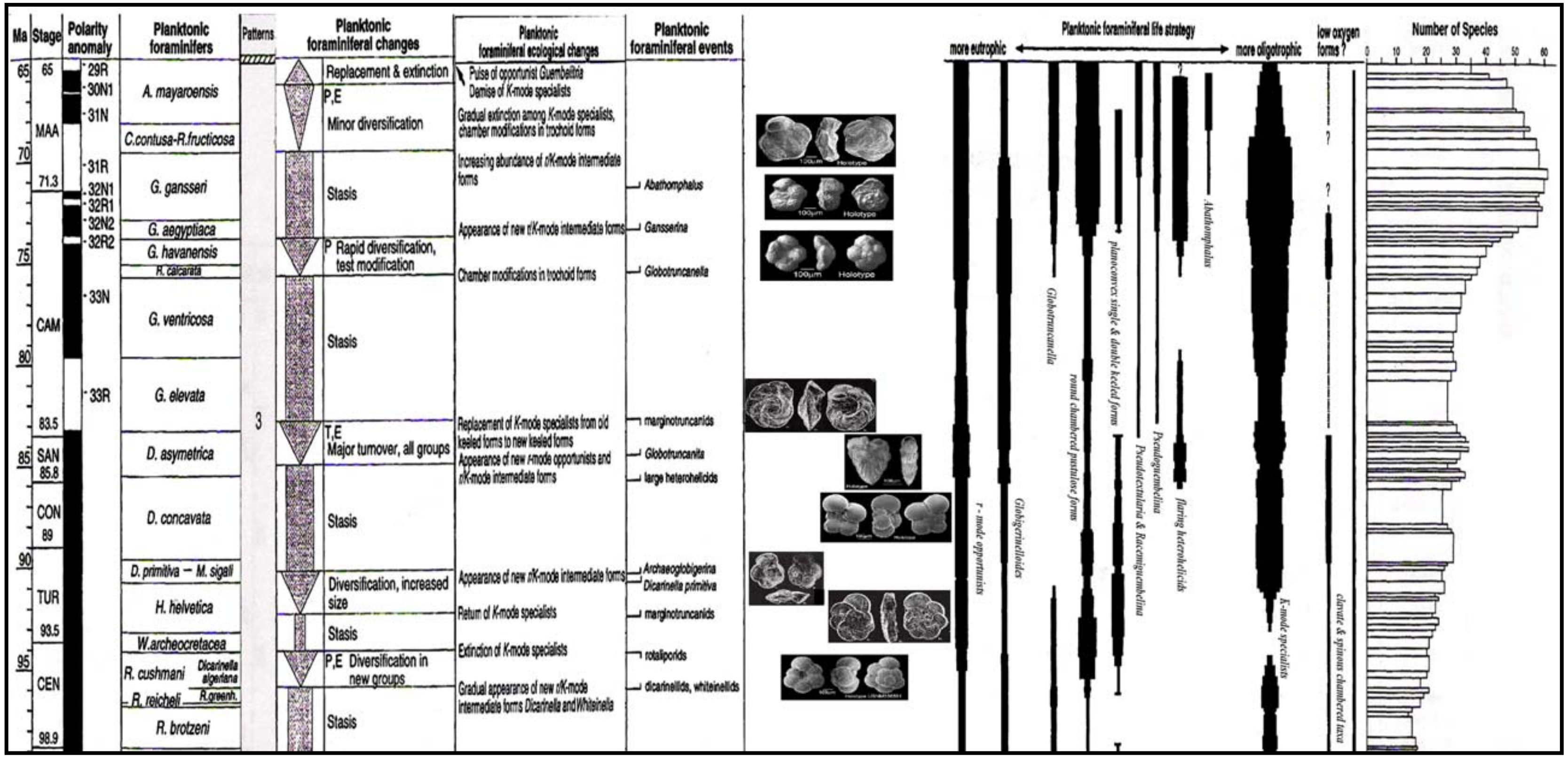


Figure 15. Evolutionary pattern of the Upper Cretaceous (Cenomanian-Maastrichtian) planktonic foraminifera with the polarity anomaly, zonation, evolutionary changes, first and last occurrences, life strategies and species diversity (from Premoli Silva & Sliter 1999, images from Caron, 1985). Red line indicates the studied interval.

foraminifers; the number of extinctions became larger than the number of the first appearances towards the end of the Cretaceous (Figure 16). In the uppermost Cretaceous, there was a change in dominancy in diversity and abundance from the hedbergellid-dominated Early and early Late Cretaceous towards the domination of heterohelicids. At the end of the third evolutionary stage, diversity decreased to about 30 species just before the Cretaceous/Tertiary boundary.

To summarize, there were almost three peaks in the planktonic foraminiferal evolution during the Cretaceous record as discussed previously, with the largest diversification during Campanian-Maastrichtian; which gains this period the importance for the further detailed studies (Figure 15, 16).

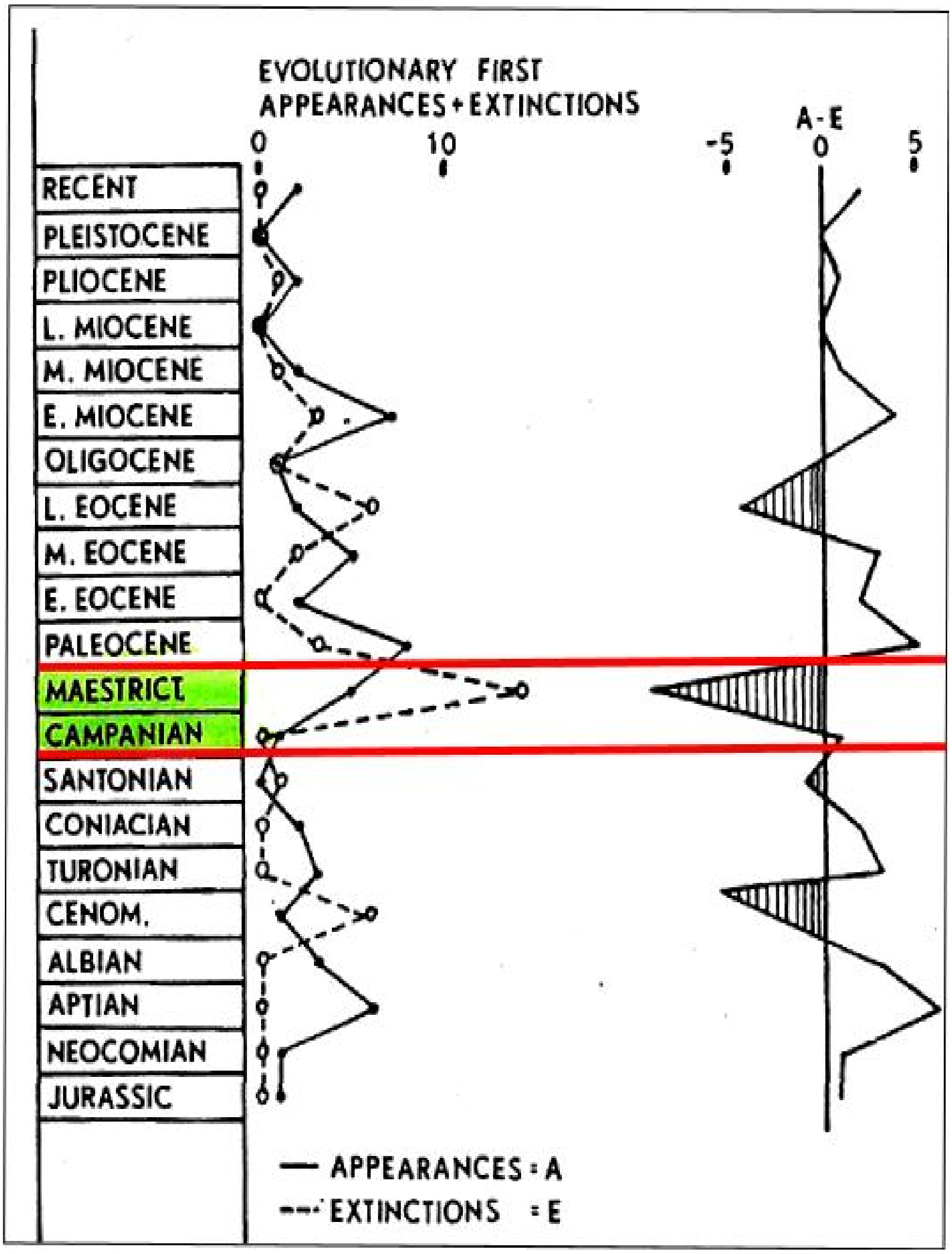


Figure 16. Evolutionary appearances and extinctions of planktonic foraminifera (from Frerichs, 1971).

3.4 Patterns Of Evolutionary Changes In The Studied Samples

3.4.1 Species Diversity

For the analysis of the species diversity, 300 individuals were counted from washed specimens of each sample. Consequent to those countings, 16 genera and 58 species were recognized (Appendix C). Through the measured section, four zones can be distinguished. The first zone is observed along the *Pseudotextularia elegans* Zone (from sample AG 120 to AG 140). Towards the top of this interval (sample AG 138), globotruncanids have reached their maximum species diversity with 10 species. This increase in the diversity of the globotruncanids coincides with the global data (Premoli-Silva and Sliter, 1999; Petrizzo, 2002). In this first zone, the species diversity increases in the general trend with an average of 28.3 species; however three local sudden decreases can be observed in AG 123, AG 131 and AG 134 (Figure 17). This can be related to the sudden decrease in the relative abundance of *Contusotruncana* and *Globotruncana* at those samples. The second zone is from the *Planoglobulina acervuloinides* Zone towards the middle part of the *Racemiguembelina fructicosa* Zone that coincides with the middle part of the *Gansserina gansseri* Zone (from sample AG 142 to AG 158). The mean of the species diversity at this zone is 34.1 and its maximum peak is at the point which it passes to *Racemiguembelina fructicosa* Zone (AG 152) (Figure 17). This increase in the base of the *Racemiguembelina fructicosa* Zone can be related with the increase in the abundance of heterohelicids and racemiguembelinids and it can be correlated with the regression during 71.5 Ma to 70.5 Ma in the curve of Haq *et al.* (1987) (Figure 18).

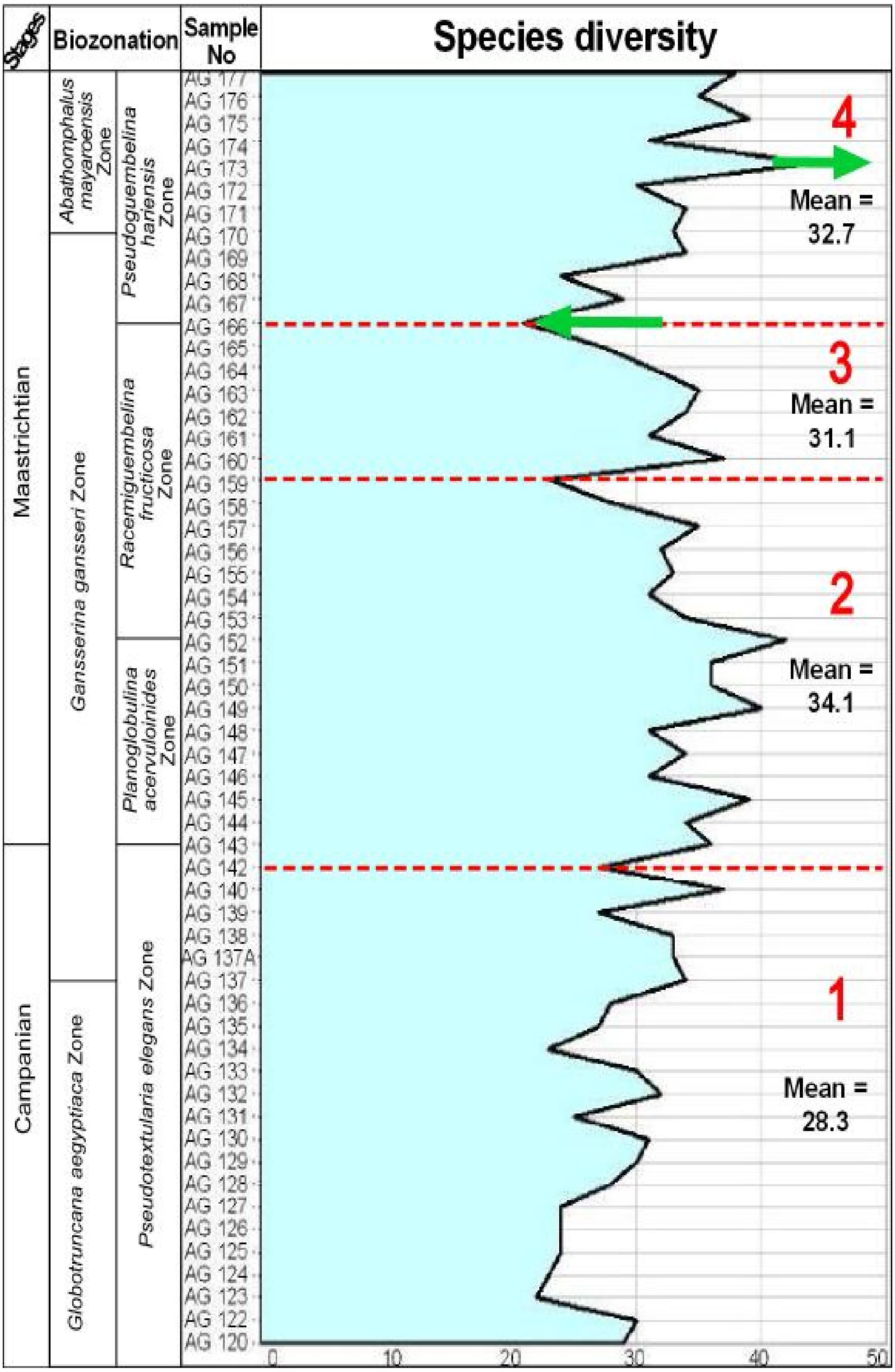


Figure 17. Diversity of species throughout the measured section.

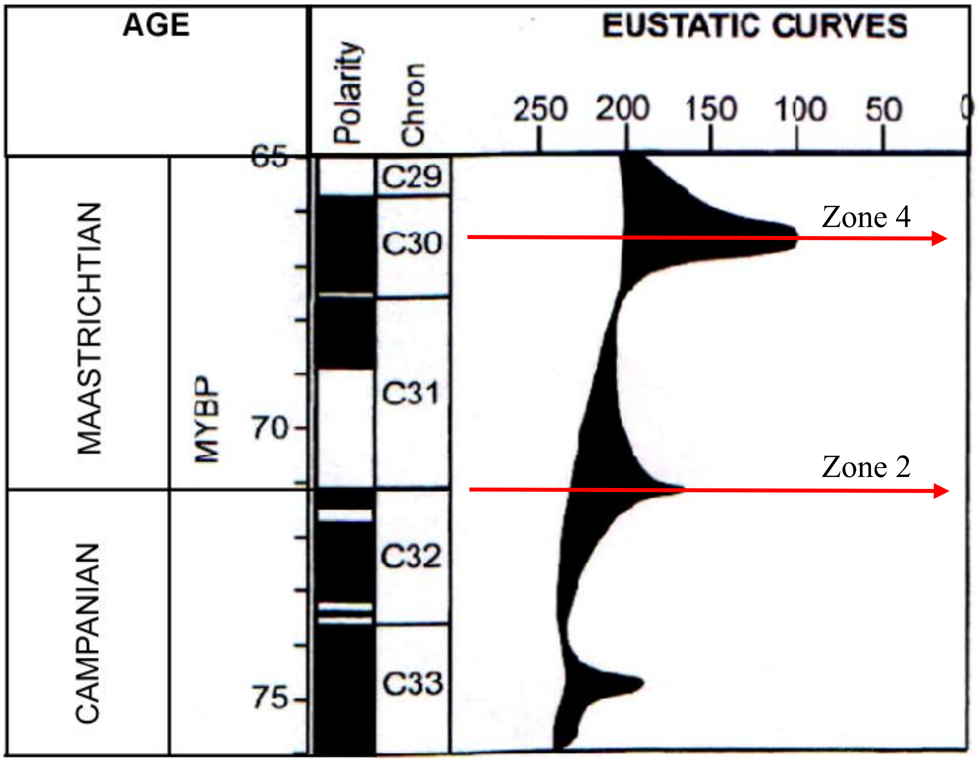


Figure 18. The possible positions of Zone 2 and Zone 4 of the species and generic diversity curves with respect to the Late Cretaceous sea level falls represented by Haq *et al.* (1987).

On the other hand, the species of genus *Globotruncana* are also abundant in this period. The third zone can be observed at the top of the *Racemiguembelina fructicosa* and *Gansserina gansseri* zones (from sample AG 159 to AG 165). In this zone, the keeled planktonic forms can be observed together with the unkeeled forms and heterohelicids and there is an increase in the abundance and diversity of the heterohelicids as it is mentioned by Shanin (1992). However, there is a little decline in the mean of the species diversity (31.1) with respect to the second zone. In this zone, the maximum diversity has been reached at sample AG 160 (Figure 17). The last zone of the species diversity is through the *Pseudoguembelina hariensis* Zone (from sample AG 166 to AG 177). In this interval the mean value for species diversity is 32.7. Also, we can see the maximum species diversity in sample AG 173 with 44 species (Figure 17), which is the maximum species diversity all through the measured section. This increase reflects the increase in relative abundance of *Globotruncanita* and *Planoglobulina* at this sample. The maximum abundance of the *Abathomphalus* can be observed also in AG 173. In this uppermost zone, we can see the predomination of the heterohelicids with the maximum abundance in sample AG 173. This increase is correlatable with the global studies (Shanin, 1992; Keller, 1998; Premoli-Silva and Sliter, 1994 and 1999; Keller et al., 2002; Petrizzo, 2002). Furthermore, this can be related to the regression of Haq *et al.* (1987) between 67 and 65.5 Ma (Figure 18).

If we look at the overall trend of species diversity, there is an increase throughout the section (Figure 17). However, distinct decrease in the diversity is observed at the zone boundaries (samples AG 142, AG 159 and AG 166). When we look at those points, two of them coincide with the boundaries of the biozones (sample AG 142 and AG 166). The more important is that we can realize that all of them are clayey limestones. So, we can think that the boundaries of these zones and the sudden decrease in the species diversity may be related with the lithology change. The relationship of the lithology change on the planktonic foraminifers will be discussed in the following sections. On the other hand, when we observe the means of the species diversity, we can realize relatively high values in the second and fourth zones. As we mentioned before, the increase in the second zone can be related to the increase in the diversity of heterohelicids and the last zone reflects a final diversification along both the globotruncanids and the heterohelicids. And when we think about causes of the increase of the mean diversities in those samples, we can realize the possible coincidence with the regressions in the sea level curve of Haq *et al.* (1987) (Figure 18).

To conclude, the overall species diversity shows an increasing trend through the Campanian – Maastrichtian interval. The minimum diversity occurs in the boundary of the *Racemiguembelina fructicosa* and *Pseudoguembelina hariensis* zones (AG 166), whereas the maximum diversity occurs with 44 species at sample AG 173, which belongs to *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* Zones (Figure 17). This evolutionary pattern in which the maximum species diversity is observed at the top of the Maastrichtian is quit a different than the pattern of Premoli-Silva and Sliter (1999), which suggests the maximum species diversity during the Late Campanian – Early Maastrichtian interval (Figure 14, 15). On the other hand, the species abundance and diversity along the measured section are correlable with the global data in terms of the changes in the diversity and abundance of globotruncanid and heterohelicid species (Shanin, 1992; Keller, 1998; Premoli-Silva and Sliter, 1994 and 1999; Keller et al., 2002; Petrizzo, 2002). Moreover, our pattern can be correlatable with the lithological changes and global regression in the sea level curves of Haq *et al.* (1987) (Figure 18).

3.4.2 Generic Diversity And Abundance

As mentioned before, counting 300 specimens of each sample, a total of 16 genera from were defined in this study. Similar to species diversity, generic diversity also shows an increasing trend. If we compare the diversity patterns of species and genera (Figure 17, 19), there is a distinct similarity in the curves. Again, we can catch up 4 parallel zones in the generic diversity curve (Figure 19) with the same boundaries like in the species diversity curve. So, the first zone is up to the top of the *Pseudotextularia elegans* Zone (from sample AG 120 to AG 140) with the mean diversity of 9.6 (Figure 19). It includes the sample with the with the minimum diversity (7 genera) end of *Globotruncana aegyptiaca* Zone (AG 136). During this first zone, *Globotruncana* and *Heterohelix* are the dominant forms in the studied section as it is mentioned also by Premoli-Silva and Sliter (1999) and Petrizzo (2002). The position of the second zone in generic diversity is from *Planoglobulina acervuloinides* Zone towards the middle part of the *Racemiguembelina fructicosa* Zone that coincides with the middle part of the *Gansserina gansseri* Zone (sample AG 142 to AG 158). In this interval, we can observe the maximum generic diversity of the measured section with 16 species. This increase coincides with the base of *Planoglobulina acervuloinides* Zone (AG 143) (Figure 19). The mean diversity value for this zone is 13.6. The third zone is between AG 159 and AG 165 (upper parts of *Racemiguembelina fructicosa* and *Gansserina gansseri* zones), while the fourth zone includes AG 166 to AG 177 (along *Pseudoguembelina hariensis* and *Abathomphalus mayaroensis* zones) (Figure 19). The mean of the diversity decreases a little in the third zone (12.4). Within the fourth zone in the generic diversity curve, the maximum diversity is also examined in AG 173, like in the species diversity and the mean value for this zone is 13 genera. During the last two zones, we can see the increase in the abundance of the species of *Heterohelix*, which coincides with global data as mentioned by Shanin (1992), Keller (1998), Premoli -

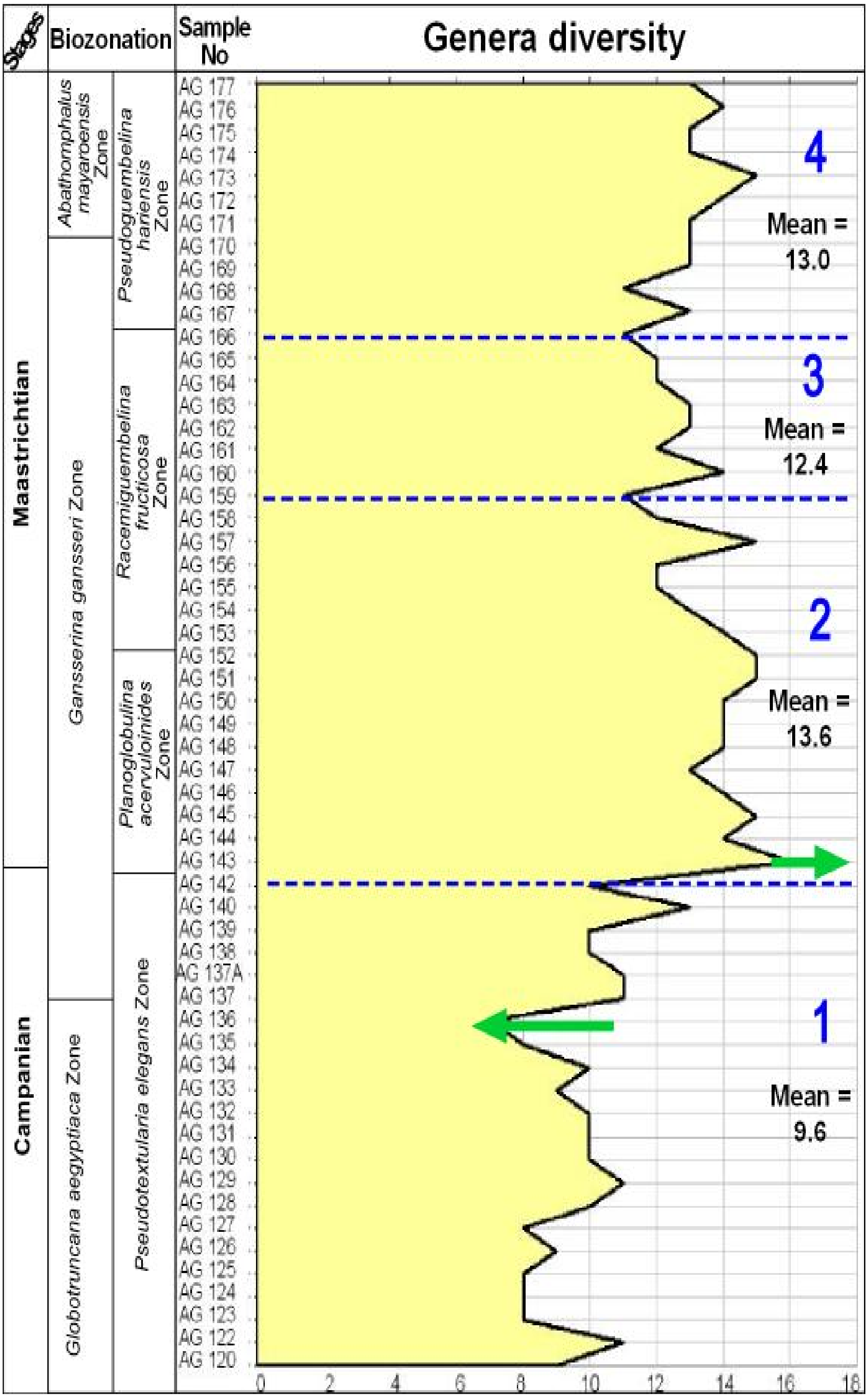


Figure 19. Diversity of genera throughout the measured section.

Silva and Sliter (1994 and 1999) and Keller et al. (2002).

Consequently, the trend of the generic diversity is almost similar with the trend in the species diversity. The difference of two curves is that we can observe the maximum species diversity within the fourth zone (AG 173), while the maximum generic diversity is within the second zone (base of Maastrichtian; AG 143) that is correlatable to the worldwide studies (Premoli-Silva and Sliter, 1999). The mean values of the generic diversity also follow a similar pattern with the species diversity as it becomes higher in the second and fourth zones. As mentioned in the species diversity section, this zonation can be related with the regressions in the global sea level chart of Haq *et al.* (1987) and the boundaries of the zones coincides with the lithology changes (samples including clayey limestone; AG 142, AG 159 and AG 166) (Figure 18).

In the next step is to examine the relative abundances and diversity for each genus separately (Figure 20). Genus *Abathomphalus* is one of the less abundant and less diversified forms represented by only two species (*A.intermedius* and *A.mayaroensis*) (Table 4, Figures 20, 21). The relative abundance of the species of this genus is not more than 1% in the samples. The existence of this form coincides with the fourth zones of the species and genera diversity curves and the zone of this form can be observed in sample AG 173 where we also realized the maximum species diversity (Figures 17, 19).

Archaeoglobigerina is the other form that shows both low abundance and low diversity also with two species (A. blowi and A. cretacea) (Table 4, Figures 20, 22). This genus doesn’t show a regular distribution within the section. The first occurrence of this form is at the base of the second zone in the species and genera diversity curves; however the maximum abundance of this genus is during the third zone (AG 161).

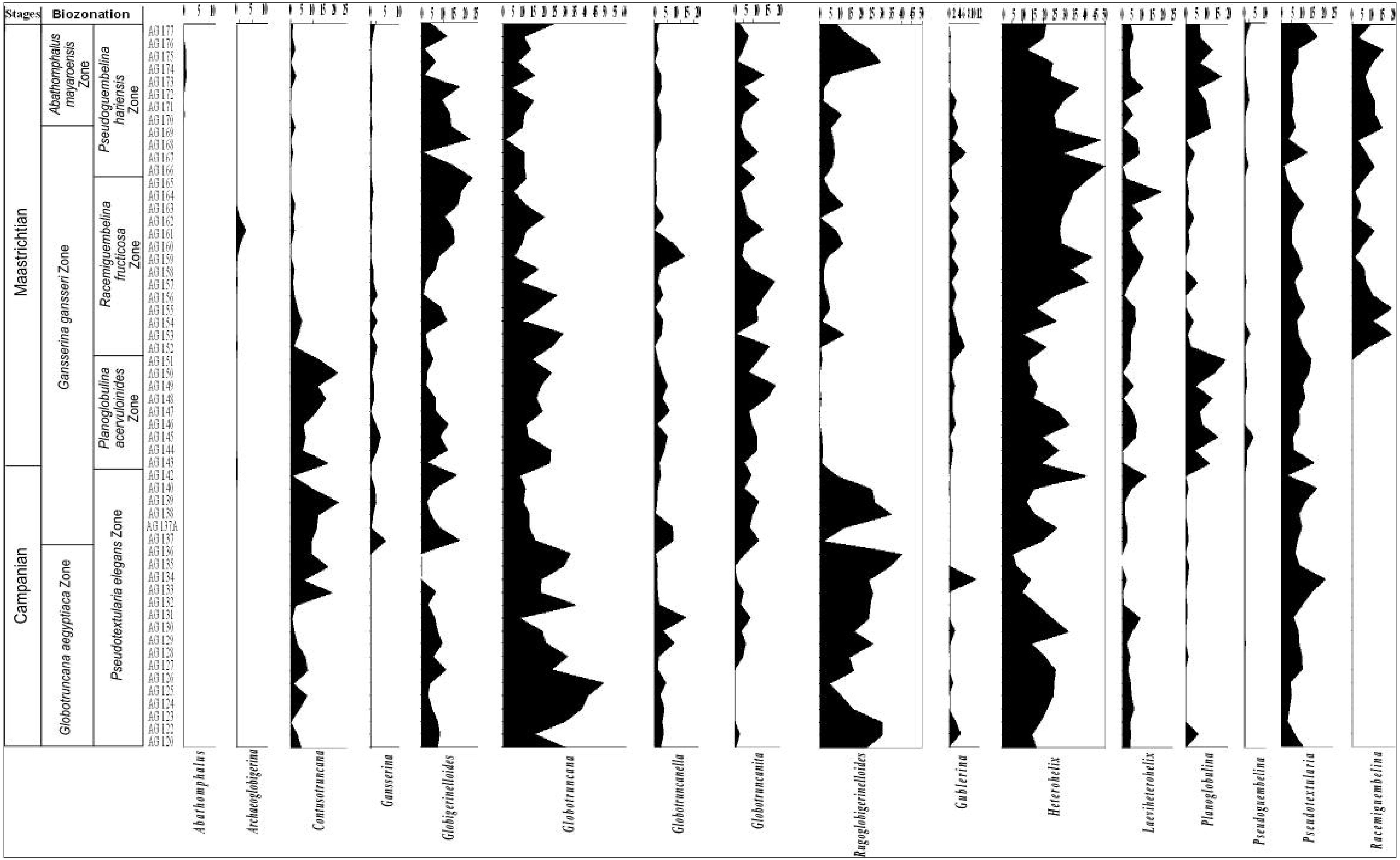


Figure 20. Relative abundance of planktonic foraminifera (given in %) in the studied stratigraphic interval.

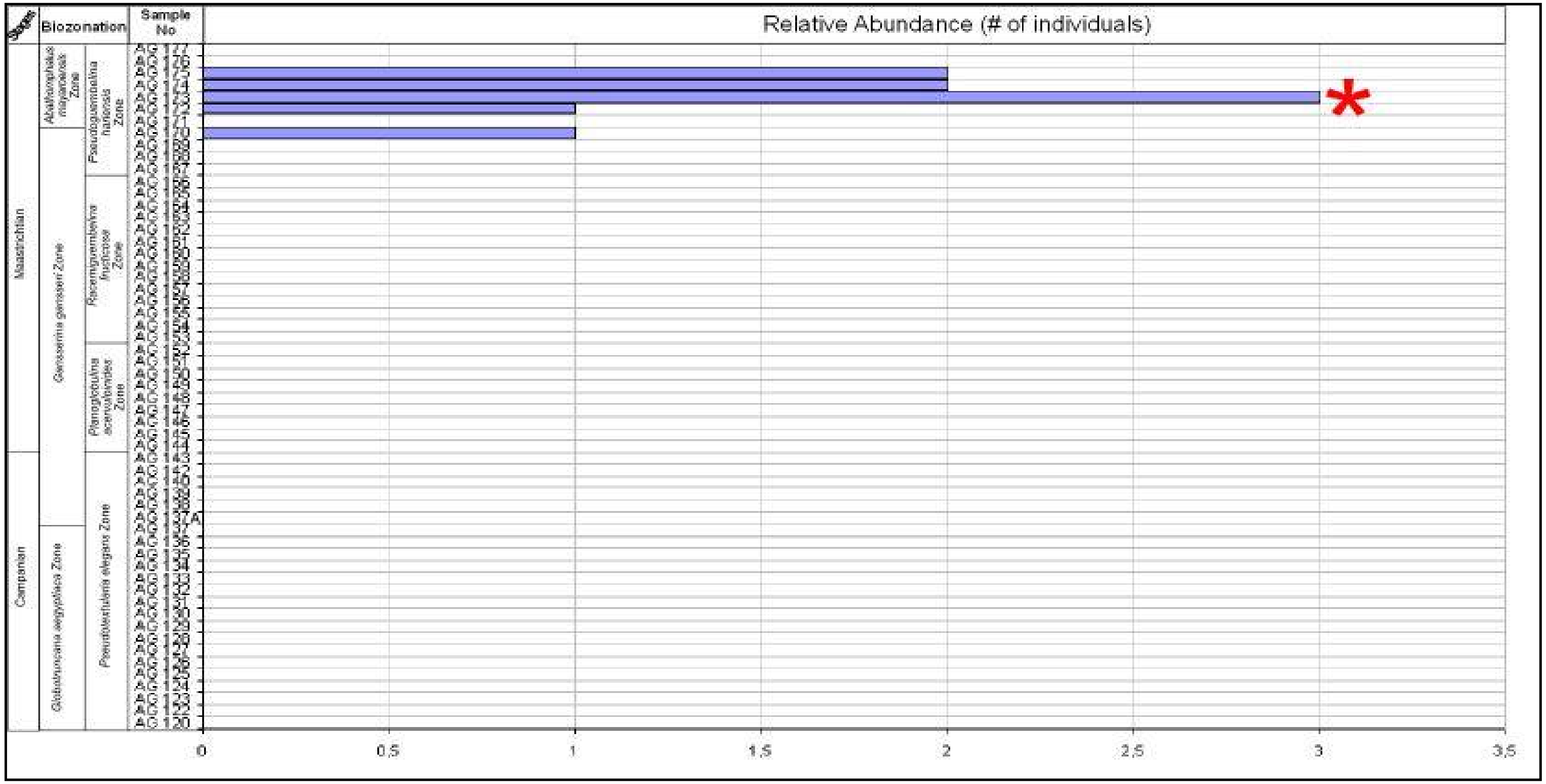


Figure 21. Relative abundance of genus *Abathomphalus* (Number of individuals within 300 counted individuals which picked up from each sample).

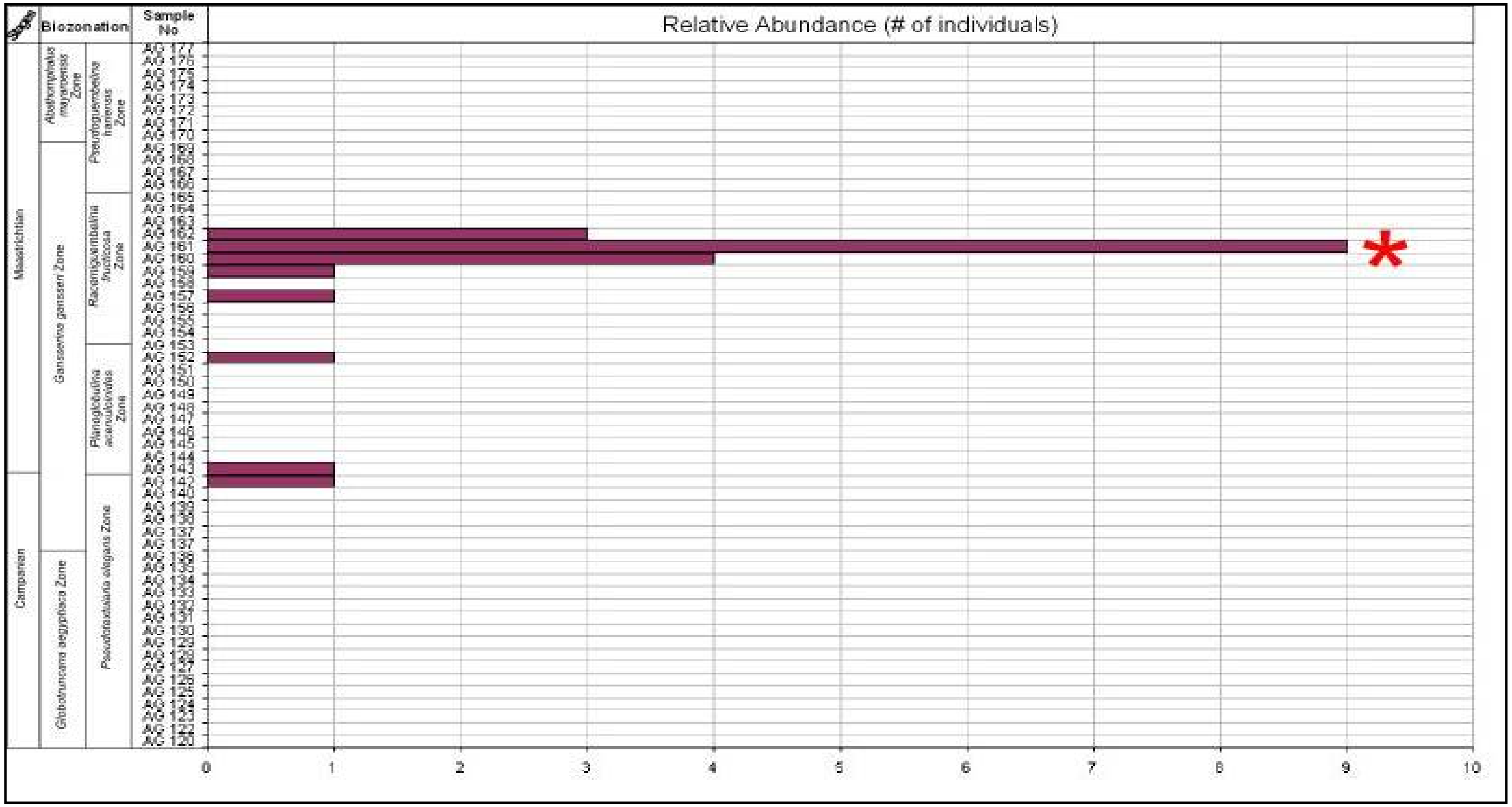


Figure 22. Relative abundance of genus *Archaeoglobigerina* (Number of individuals within 300 counted individuals which picked up from each sample).

Genus *Contusotruncana* is more abundant in the lower parts of the section (Figures 20, 23). It is mostly observed within *Pseudotextularia elegans* and *Planoglobulina acervuloinides* zones. This genus reached its maximum diversity within the *Planoglobulina acervuloinides* Zone with 5 species (Table 4). Passing to the *Racemiguembelina fructicosa* Zone, there is an abrupt decrease in the abundance of *Contusotruncana*. In spite of this decline, this genus weren't extinct up to the end of Maastrichtian.

After its evolution at the base of *Gansserina gansseri* Zone with a peak in abundance at sample AG 137, genus *Gansseri* was observed more or less continuously right through the measured section (Figures 20, 24). On the other hand, since it is represented with a single species that named the biozone, its diversity and abundance aren't as high as other forms.

Being absent only in two of the studied samples, *Globigerinelloides* is one of the most abundant genera (Figures 20, 25). At first sight, we can observe a general increase in its abundance during the Maastrichtian with a peak at the top of *Racemiguembelina fructicosa* Zone that is also the upper boundary of zone 3 of diversity curves (AG 165). During this study, this genus wasn't studied in terms of species, so we can't observe the species diversity for *Globigerinelloides.*

Looking at the relative abundance of *Globotruncana* (Figures 20, 26), we can distinguish a continuous existence with two different diversity patterns. The first one is within the *Pseudotextularia elegans* Zone and the second pattern is through *Planoglobulina acervuloinides* and *Racemiguembelina fructicosa* zones. In the studied section, totally 12 different species were distinguished within this genus. However, maximum diversity was observed in the interval that is form the base of the *Gansserina gansseri* Zone to the top of the *Planoglobulina acervuloinides* Zone with 10 species (AG 138 and AG 149) (Table 4).

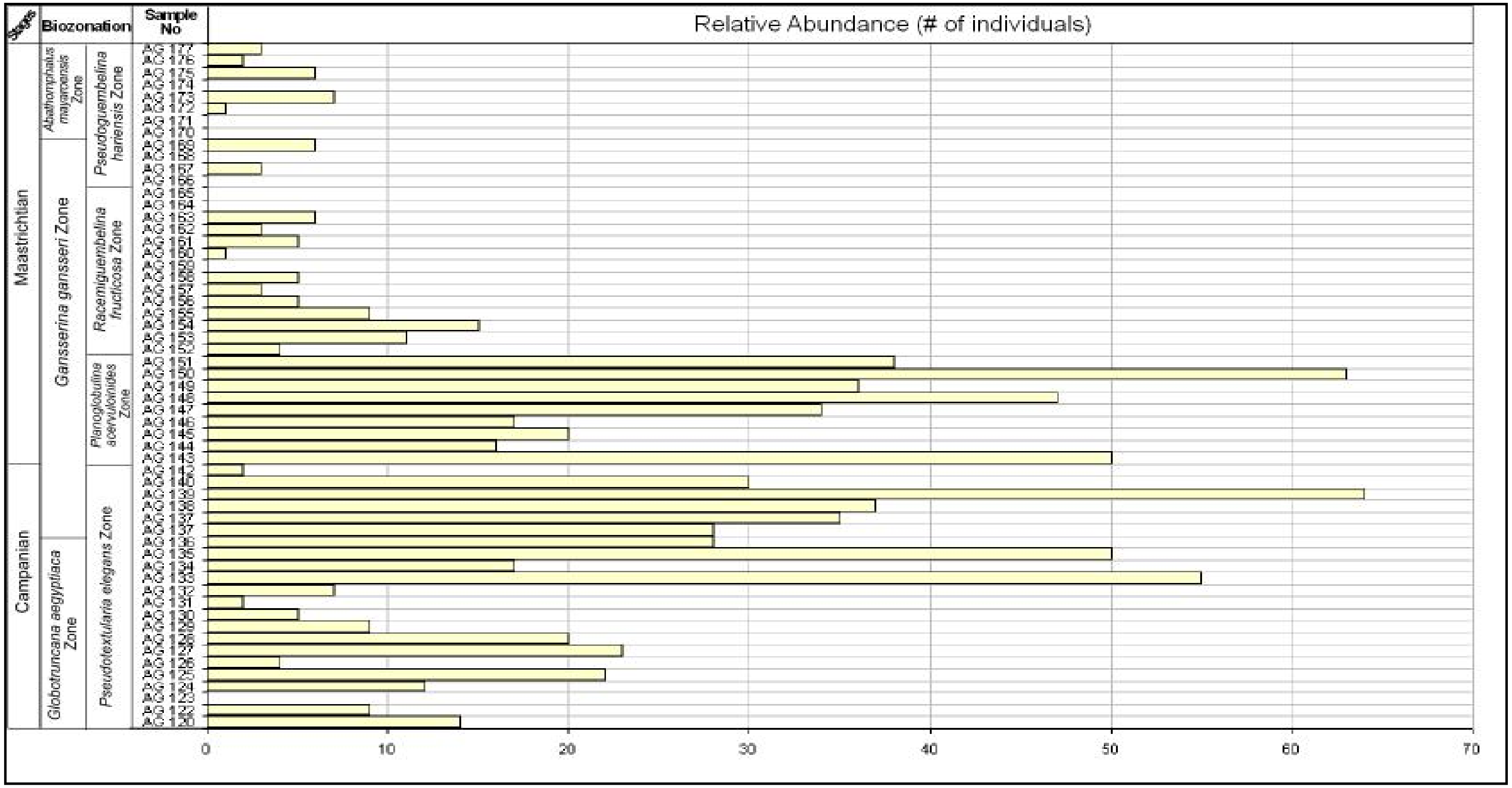


Figure 23. Relative abundance of genus *Contusotruncana* (Number of individuals within 300 counted individuals which picked up from each sample).

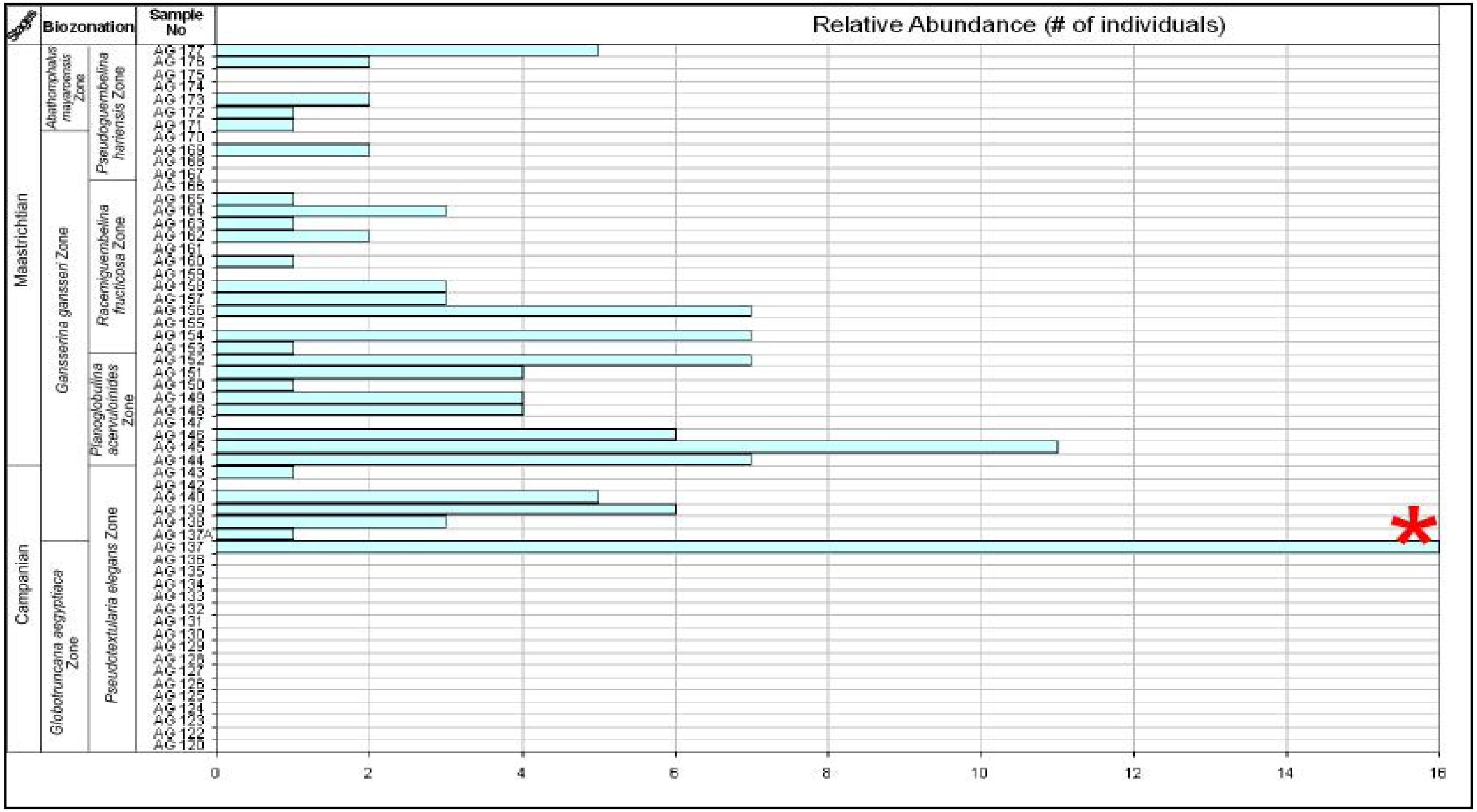


Figure 24. Relative abundance of genus *Gansserina* (Number of individuals within 300 counted individuals which picked up from each sample).

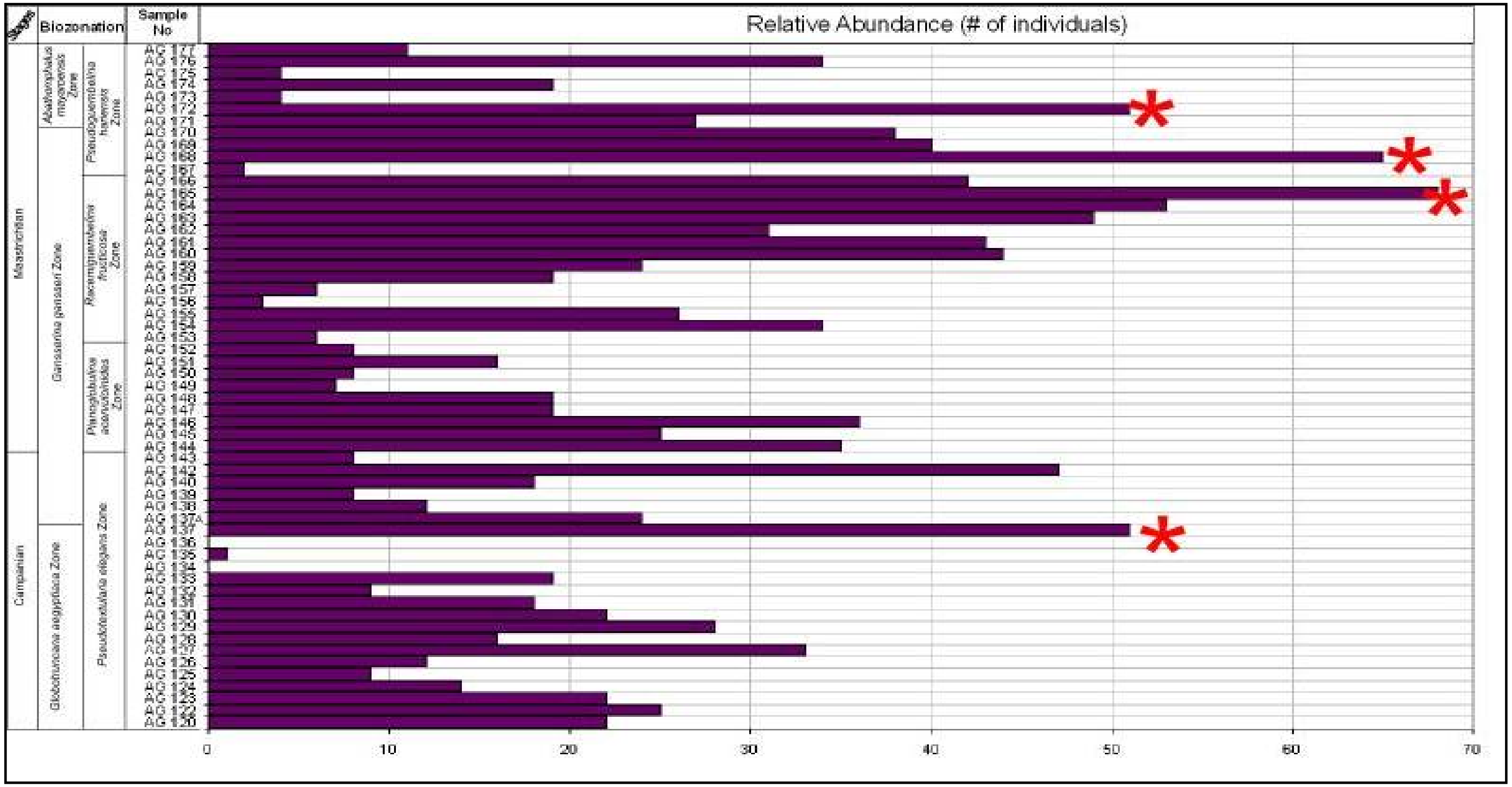


Figure 25. Relative abundance of genus *Globigerinelloides* (Number of individuals within 300 counted individuals which picked up from each sample).

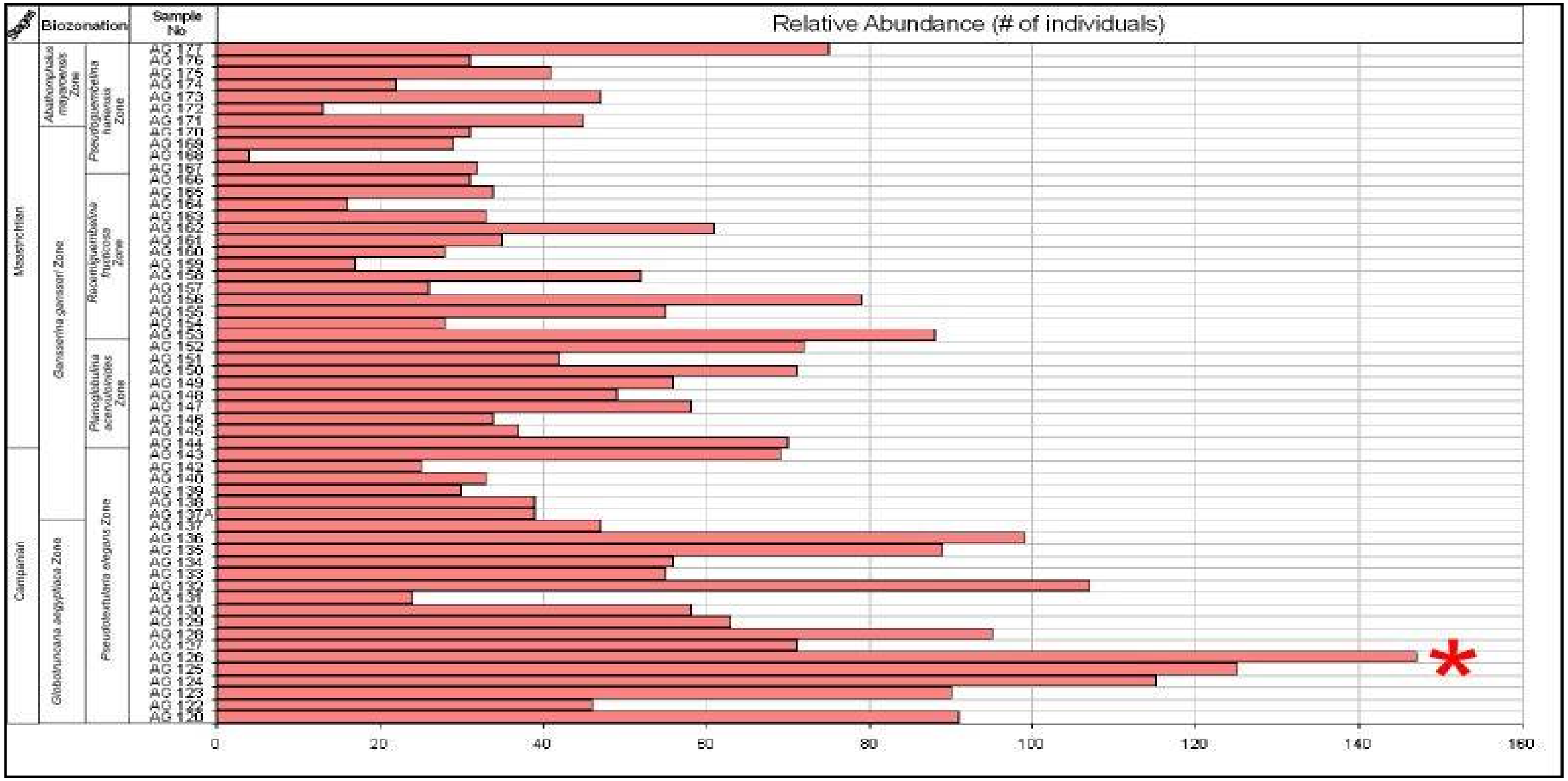


Figure 26. Relative abundance of genus *Globotruncana* (Number of individuals within 300 counted individuals which picked up from each sample).

The evolutionary trend of genus *Globotruncanella* looks like the one of genus *Contusotruncana*, as this form is also abundant in the lower parts of the section and it shows a decline towards the upper parts. Its abundance peaks twice in AG 131 and AG 159 and it shows continuity in the evolution pattern with the specimens only absent in one sample (AG 161) (Figures 20, 27). Its second peak (AG 159) coincides with the base of the third zone in the species and diversity curves (Figure 17, 19). Three different species that belongs to this genus were identified within the studied section. Those species are abundant through the section except the absence of *Globotruncanella pshadae* from the base of *Racemiguembelina fructicosa* Zone to the top of the *Gansserina gansseri* Zone (Table 4).

Being less abundant during the Campanian, genus *Globotruncanita* shows a continuous distribution through the Maastrichtian. The diversity of this genus is maximum at the top of the *Pseudotextularia elegans* Zone (AG 142) that is also the base of the second zone in the diversity curves (Figure 17, 19) with 5 species (Table 4). The abundance pattern for this form has also two peaks, one of which is in *Planoglobulina acervuloinides* Zone (AG 149) and the other one in *Racemiguembelina fructicosa* Zone (AG 157) that also coincides with the second zone in the diversity curves (Figures 17, 19, 20, 28).

Genus *Rugoglobigerina* is one of the most abundant forms. Different than the other genera, there seems an abrupt disappearance of this genus throughout the *Planoglobulina acervuloinides* Zone in a general view (Figures 20, 29). This disruption separates the diversity pattern of the form into two zones. Observing these two zones, *Rugoglobigerina* is more abundant in the lower parts of the section (within the *Pseudotextularia elegans* Zone) and it has another peak in the *Abathomphalus mayaroensis* Zone (AG 174) (Figure 29). If we look at the diversity of this genus, *Rugoglobigerina* is represented with 6 species, which we can observe all of them in two samples (AG 120 and AG 136) (Table 4).

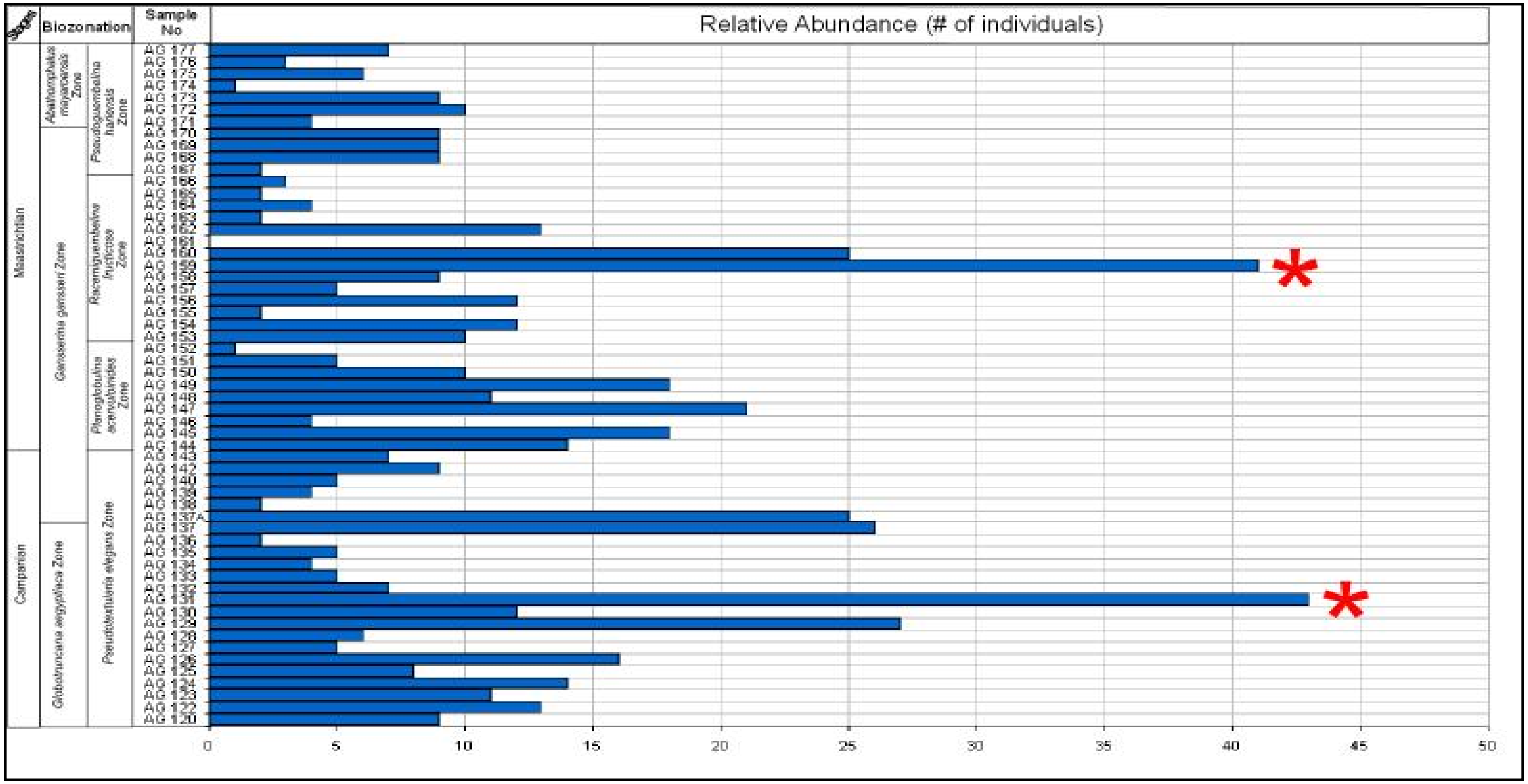


Figure 27. Relative abundance of genus *Globotruncanella* (Number of individuals within 300 counted individuals which picked up from each sample).

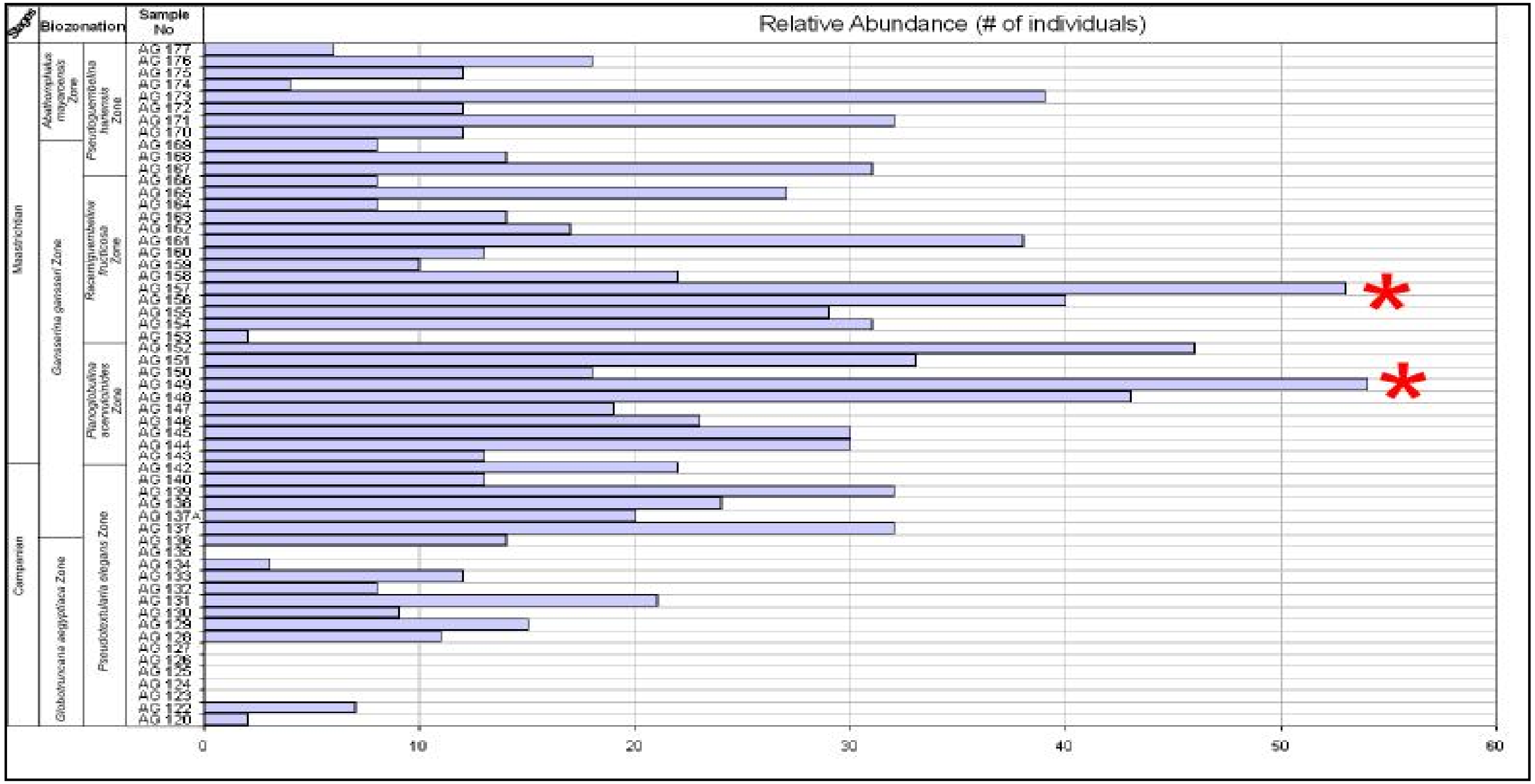


Figure 28. Relative abundance of genus *Globotruncanita* (Number of individuals within 300 counted individuals which picked up from each sample).

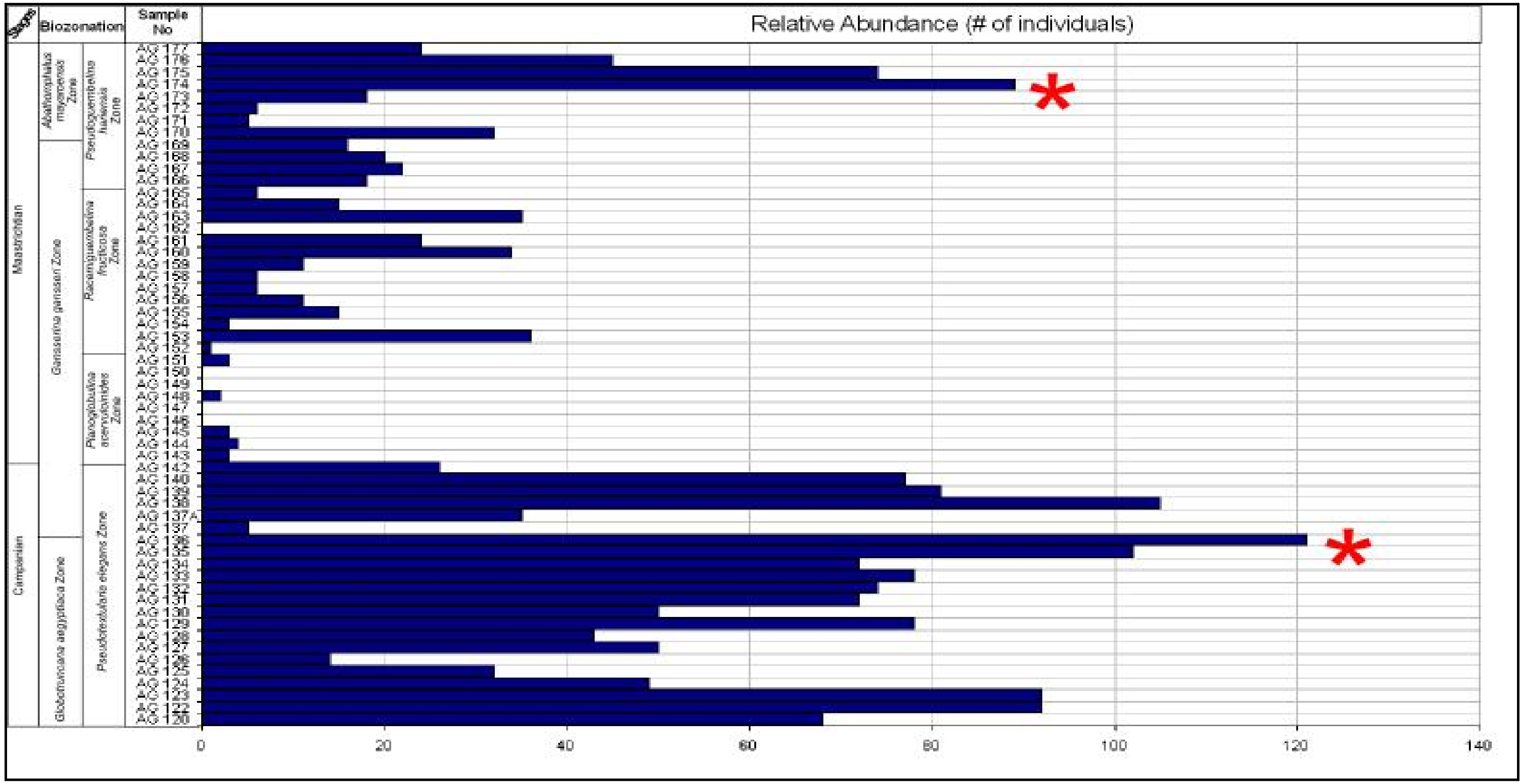


Figure 29. Relative abundance of genus *Rugoglobigerina* (Number of individuals within 300 counted individuals which picked up from each sample).

In spite of its maximum abundance at the top of the Campanian, *Gublerina* is more abundant within the Maastrichtian samples (Figures 20, 30). Being represented only with two species; *Gublerina acuta* and *Gublerina cuvillieri* (Table 4), makes it relatively less abundant with respect to most of the other Heterohelicids.

As a cosmopolitan form, *Heterohelix* are common in all of the samples through the measured section (Figures 20, 31). This form is the most diversified form within the heterohelicids in terms of species and thus it is also highly abundant. The maximum diversity is reached in samples AG 145, AG 146, AG 151, AG 152 and AG 173 with 6 species (*Hx. globulosa, Hx labellosa, Hx. navarroensis, Hx. planata, Hx. punctulata* and *Hx. semicostata*) (Table 4). When we look at the relative abundance graph for this genus (Figure 31), two peaks can be observed in sample AG 142 (the last Campanian sample) and AG 166 (lower boundary of *Pseudoguembelina hariensis* Zone) which are the lower boundaries of second and fourth zones of the diversity curves (Figure 17, 19). At the lowermost sample of *Pseudoguembelina hariensis* Zone (AG 166) the abundance of this genus is almost 50% of total abundance. Since the second and fourth zones are thought to reflect the regression at the sea level curve of Haq *et al.* (1987) (Figure 18), here peaks in the abundance of genus *Heterohelix* can be related to environmental changes during this sea level fall. In a general view, the sudden increases in the abundance pattern of this genus may also be related with the lithology changes since the peaks are also observed in the samples bearing clayey limestone.

Laeviheterohelix is the other cosmopolitan heterohelicid. It is also abundant throughout the section (Figures 20, 32). However, since it isn’t diversified as *Heterohelix* and represented only by two species; *L. dentata* and *L. glabrans*, this low diversification also reflected into its abundance and the relative abundance of this form is lower than *Heterohelix*. The

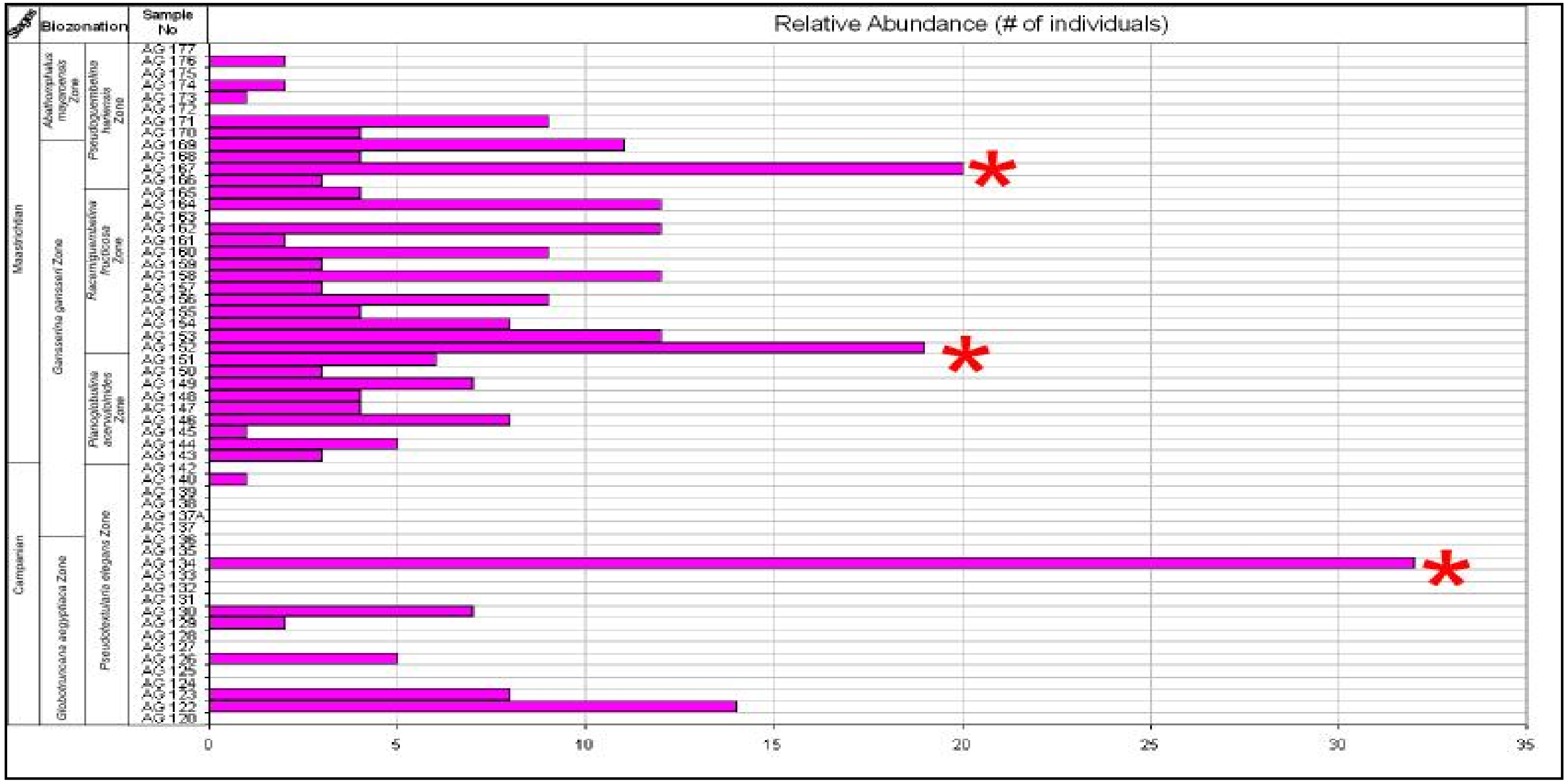


Figure 30. Relative abundance of genus *Gublerina* (Number of individuals within 300 counted individuals which picked up from each sample).

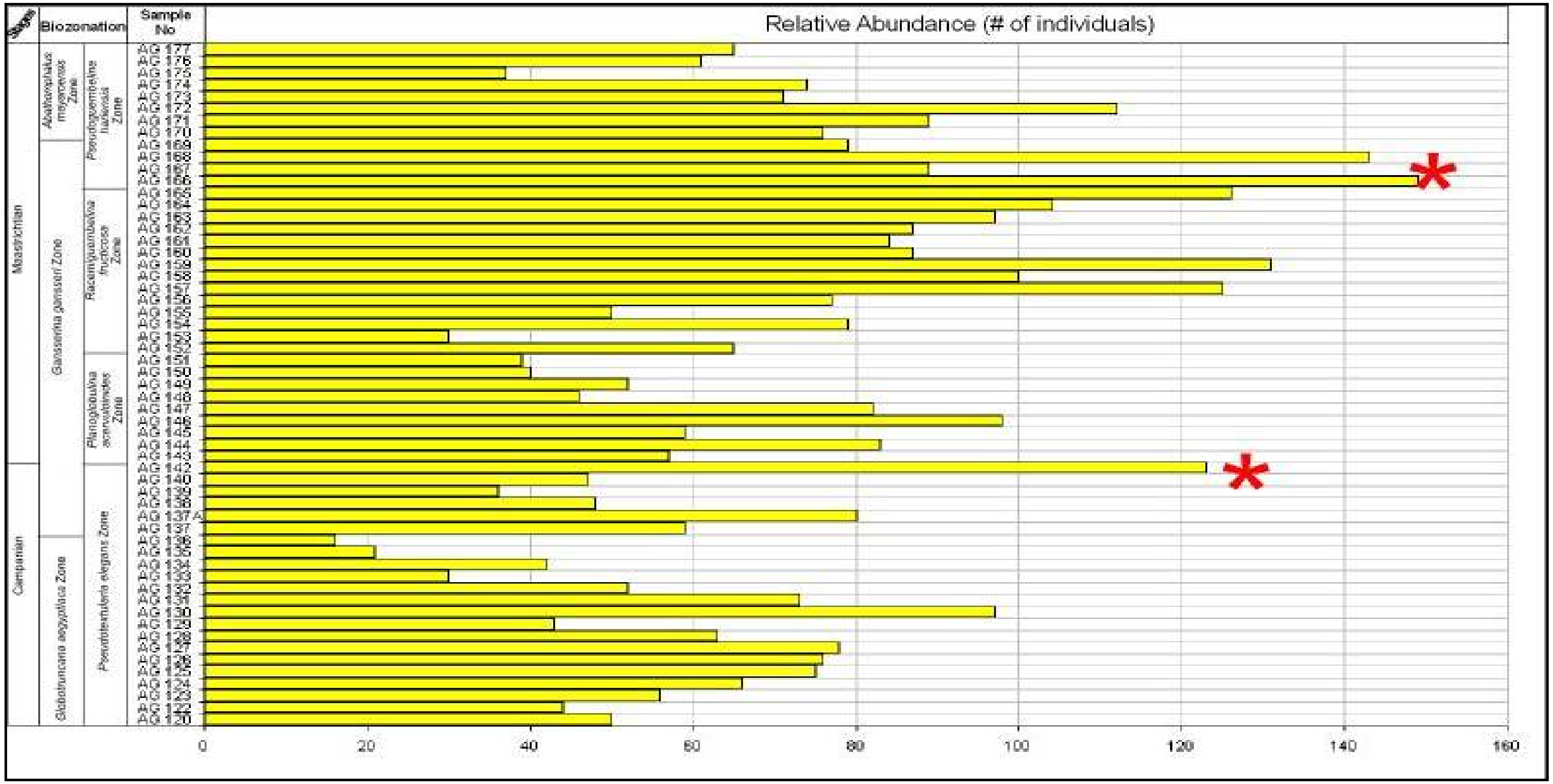


Figure 31. Relative abundance of genus *Heterohelix* (Number of individuals within 300 counted individuals which picked up from each sample).

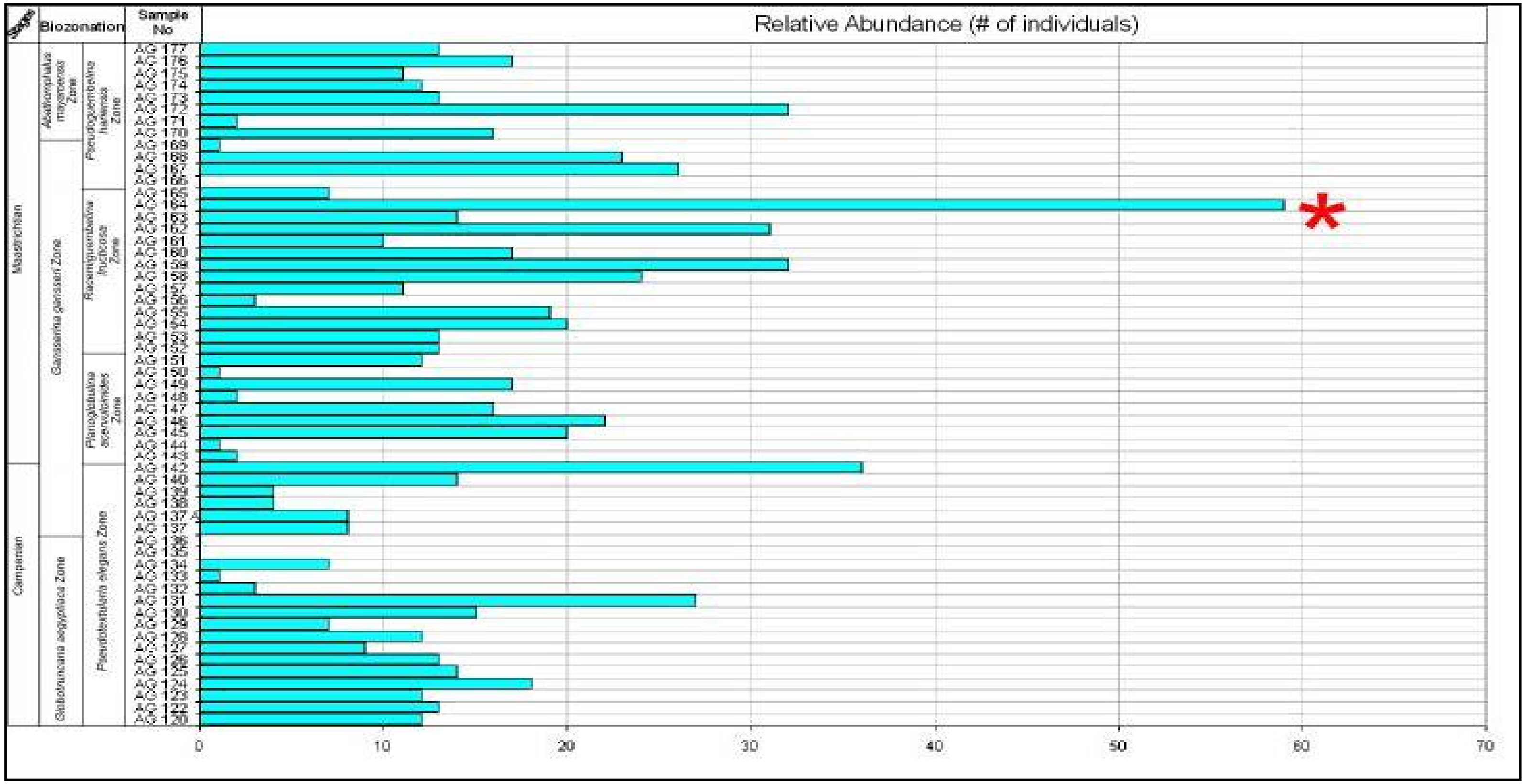


Figure 32. Relative abundance of genus *Laeviheterohelix* (Number of individuals within 300 counted individuals which picked up from each sample).

distribution of these two species is almost continuous within the *Abathomphalus mayaroensis* Zone (Table 4). Maximum abundance is at the top of *Racemiguembelina fructicosa* Zone for this genus (AG 164) (Figure 32).

Genus *Planoglobulina* illustrates two different peaks (Figures 20, 33). The first peak reflects the evolution and life span of *Planoglobulina acervuloinides* (from sample AG 143 to AG 151), while the second peak is observed within the *Pseudoguembelina hariensis* Zone (from sample AG 169 to AG 177) (Figure 33). This genus includes 3 species (*Pl. acervuloinides, Pl. carseyae* and *Pl. multicamerata*) throughout the studied section all these three forms have a continuous distribution within the zones (Table 4). So, we can conclude that the diversity and abundance of this genus is parallel to each other.

Genus *Pseudoguembelina* shows a similar evolutionary pattern with *Planoglobulina*; however it has a less continuous distribution within the section (Table 4, Figures 20, 34). The first pattern for this genus is within the *Planoglobulina acervuloinides* Zone (AG 143) and ends at the base of *Racemiguembelina fructicosa* Zone (AG 153) with a maximum at AG 145 (Figure 34). The second pattern reflects the evolution of *Pseudoguembelina hariensis*, which forms the uppermost biozone in Maastrichtian (from sample AG 166 to AG 177) (Figure 34). The relative abundance of this form is the lowest within the heterohelicids. This genus includes 3 species; *P. costulata, P.hariensis* and *P. palpebra*, whose ranges are shorter with respect to most of the other species in the studied section (Table 4).

Pseudotextularia is another regularly distributed genus. It is present in all of the samples with relatively high abundance (Figures 20, 35). The peak point for the abundance of this form is at the top of the *Globotruncana aegyptiaca* Zone (AG 134) (Figure 35). It is represented with 3 species through the section (Table 4).

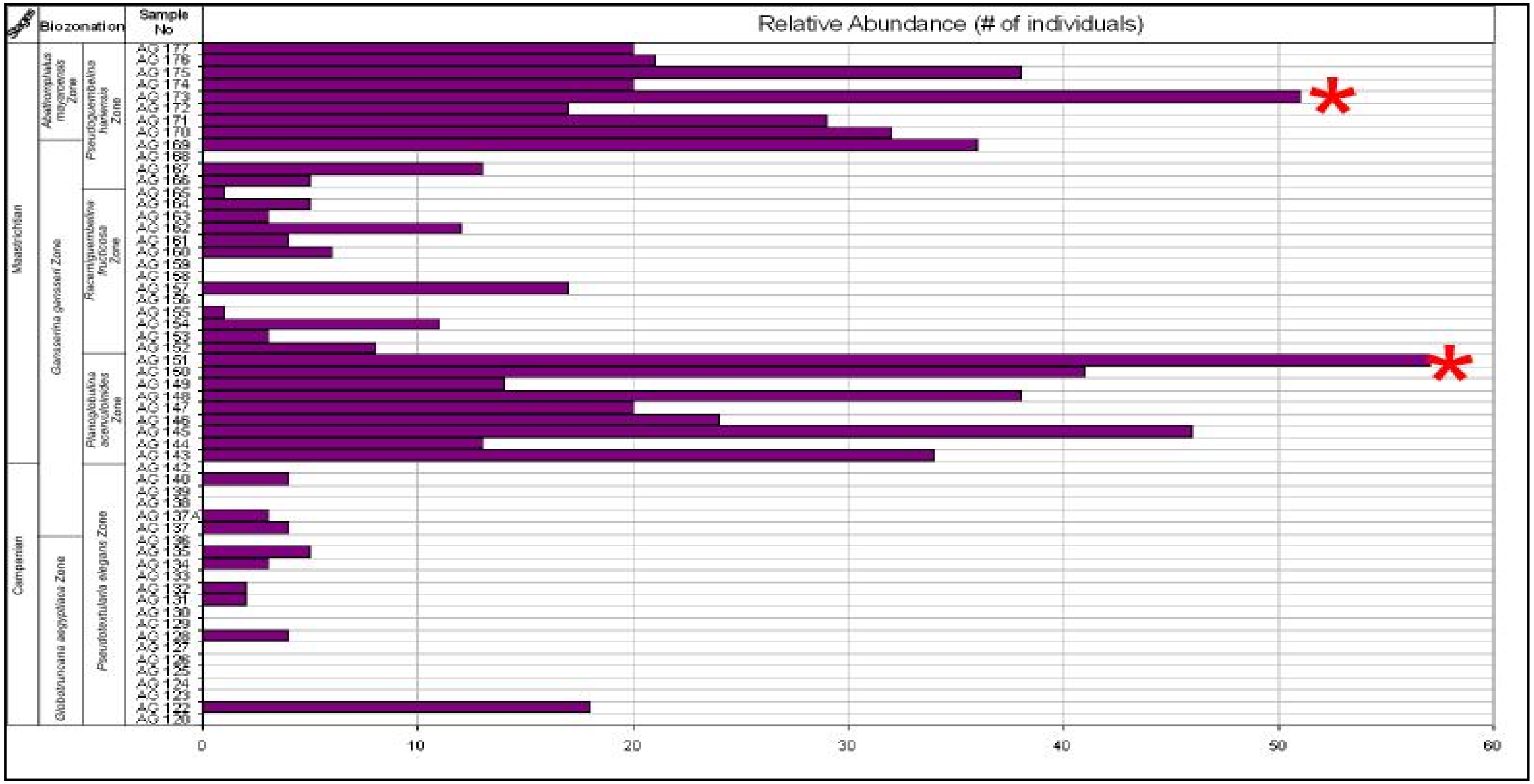


Figure 33. Relative abundance of genus *Planoglobulina* (Number of individuals within 300 counted individuals which picked up from each sample).

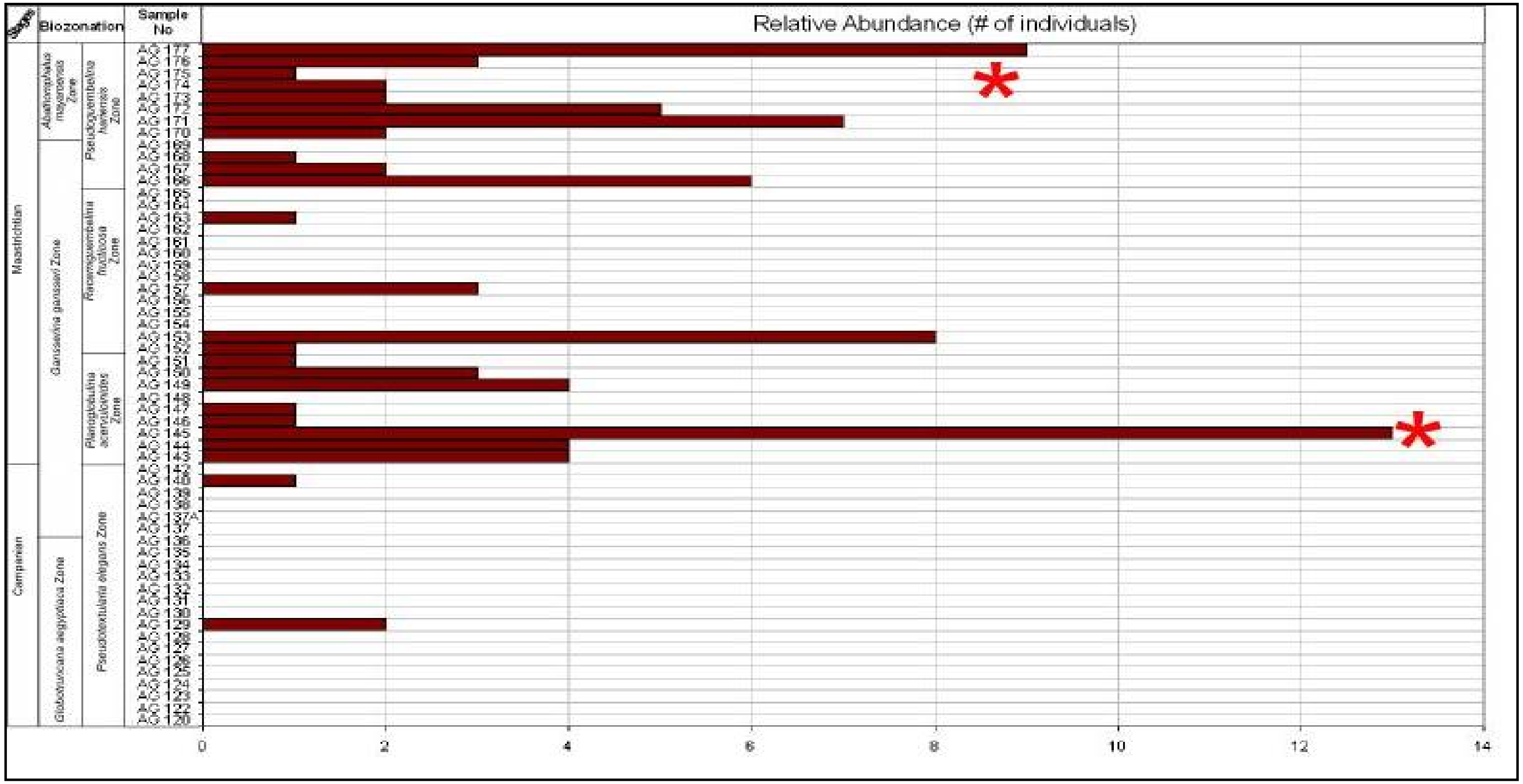


Figure 34. Relative abundance of genus *Pseudoguembelina* (Number of individuals within 300 counted individuals which picked up from each sample).

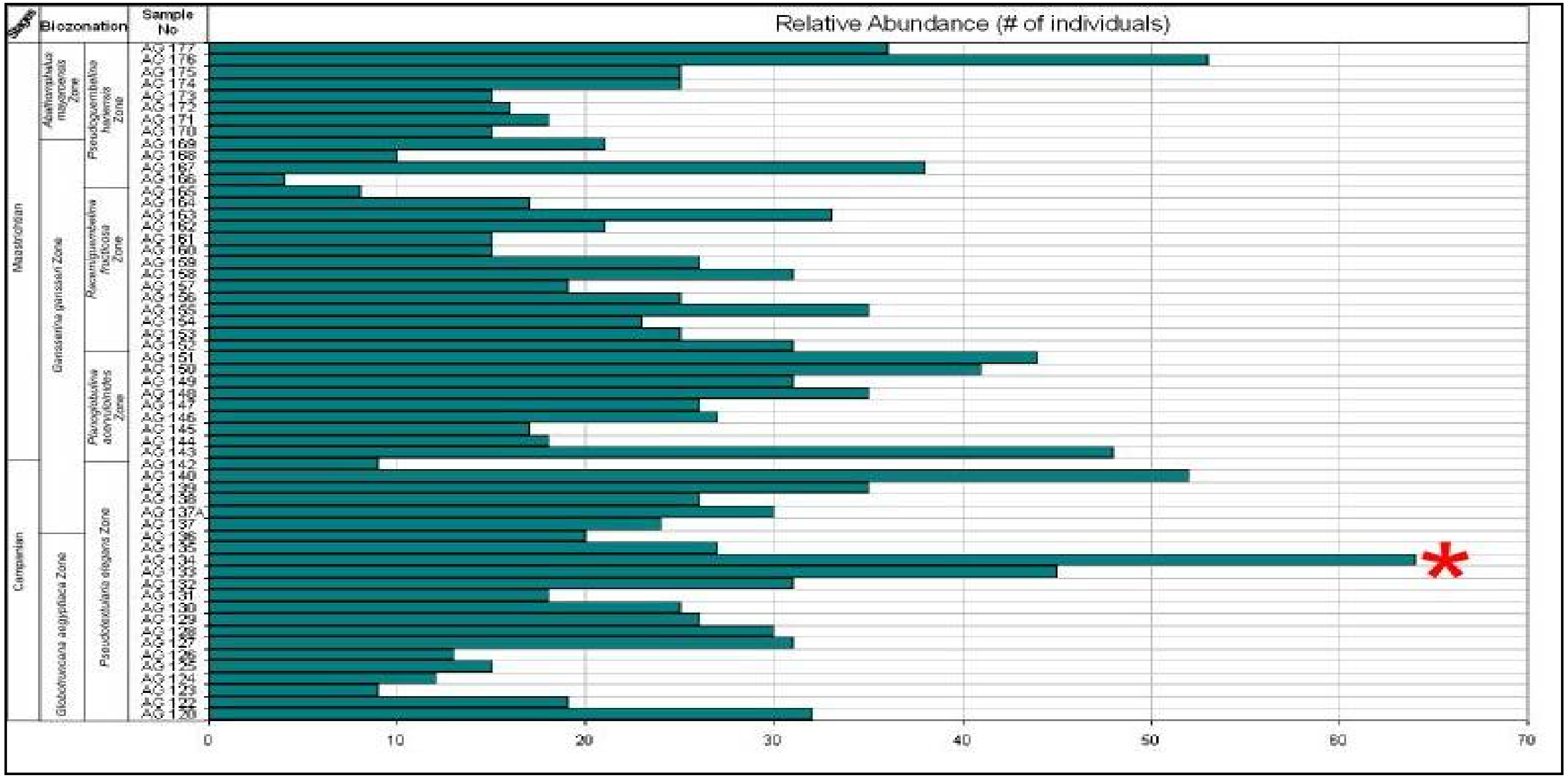


Figure 35. Relative abundance of genus *Pseudotextularia* (Number of individuals within 300 counted individuals which picked up from each sample).

Lastly, genus *Racemiguembelina* exhibits continues pattern after its first occurrence by the *Racemiguembelina fructicosa* Zone (Figures 20, 36). Although it is represented by only two species; *R. fructicosa* and *R. powelli,* its relative abundance is mostly higher than other genera with a peak at the base of this zone (AG 153, 155).

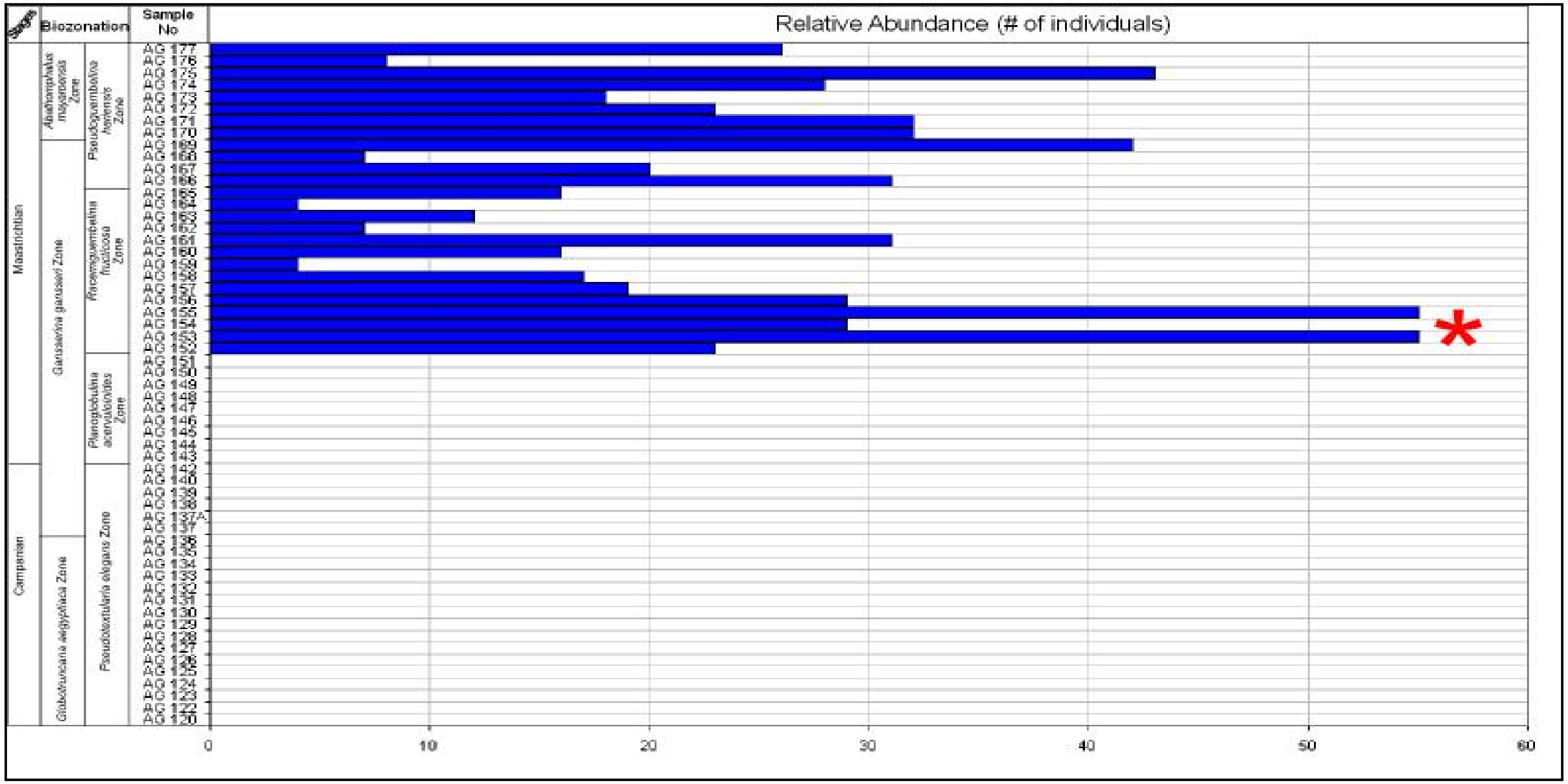


Figure 36. Relative abundance of genus *Racemiguembelina* (Number of individuals within 300 counted individuals which picked up from each sample).

3.5 Response Of Planktonic Foraminifera To Ecological Changes

3.5.1 General Descriptions Of The Morphotypes

Nowadays, paleoecology and paleoceanography become the most studied subjects and usage of planktonic foraminifera is very widespread in these studies. The fluctuations in diversity and relative abundance of various morphotypes can be used to interpret changes in the oceanic environment (Shanin, 1992; Premoli-Silva and Sliter, 1994; Nederbragt, 1998; Barrera and Savin, 1999; Premoli-Silva and Sliter, 1999; Keller *et al.*, 2002; Petrizzo, 2002).

In order to understand the response of planktonic foraminifers to ecological changes, the recorded planktonic foraminifers were arranged into 3 major groups based on the gross morphology and degree of ornamentation. Here, the classification of Premoli-Silva and Sliter (1999) is taken into consideration:

1. **Morphotype (1Simple Morphotypes):** This group consists of only biserial heterohelicids and planispiral forms. *Heterohelix*, *Laeviheterohelix* and *Globigerinelloides* are within this group.

2. **Morphotype 2 (Complex Morphotypes):** This group comprises the genera *Globotruncanita*, *Globotruncana*, *Contusotruncana* and *Abathomphalus*. The general characteristic of these morphotypes are their truncated margins in additional to their keel(s). *Globotruncanita* bears single keel and it has an acute margin and raised sutures. *Globotruncana* has single or double keels with its truncated margin and raised sutures. *Contusotruncana* differs from *Globotruncana* with its closely spaced keels and spiroconvex test. The other double-keeled form is *Abathomphalus* with its truncated margins and raised sutures only on its spiral side.

3. **Morphotype 3 (Intermediate Morphotypes):** The rest of the planktonic foraminifera are included to this group. Heterohelicids with a multiserial part following the biserial chambers, low to medium-high trochospiral forms lacking true keel and keeled forms with hemispherical

tests are included in this group. *Pseudotextularia* and *Pseudoguembelina* are complex heterohelicids with or without striations. *Pseudoguembelina* consists of supplementary apertures. *Planoglobulina* and *Gublerina* are the flaring forms that have more than 2 chambers per row following a biserial stage. In these forms, there is a 2-dimensional proliferation. *Racemiguembelina* is highly costate form that shows a 3-dimensional proliferation. *Rugoglobigerina* and *Archaeoglobigerina* have subglobular chambers and rugosities on the surface and these forms don't have any keel. G*lobotruncanella* bears a subacute to acute periphery and they are lacking of true keels. *Gansserina* is the single-keeled, planoconvex form with a hemispherical test, which don't have truncated margins.

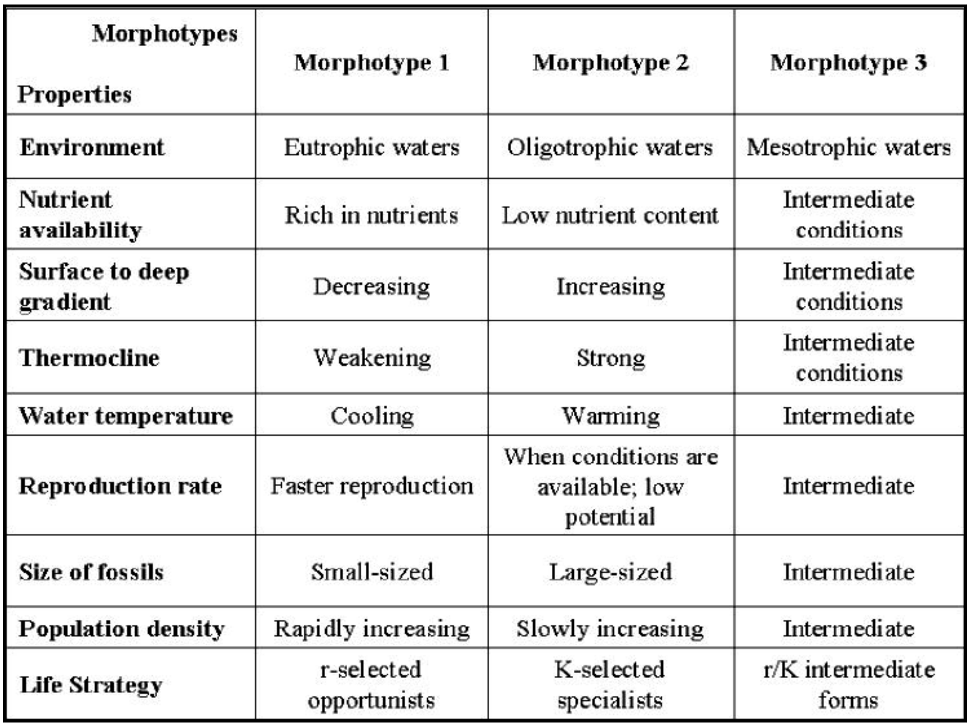
Regarding their life strategies, these morphotypes defined in the previous section (morphotype 1, morphotype 2 and morphotype 3), were considered as the opportunists (r – strategists), the intermediate group (r/K intermediates) and specialists (K – strategists), respectively (Premoli Silva & Sliter, 1994 and 1999; Petrizzo, 2002) (Table 5).

1.r-selected opportunists: They are the small-sized forms, which have rapidly increased their population densities by faster reproduction. They are the most tolerant forms that can maintain adaptation to eutrophic waters which supply cool, unstable conditions with the nutrient-rich environments, decreasing surface to deep gradient and weakening thermocline.

2. K-selected specialists: They are the most suitable group for warm oligotrophic waters, which are the low-nutrient environments with stable conditions, strong thermpcline and increasing surface to deep gradient. These forms are larger sized and have long individual life, but low reproductive potential.

3. r/K intermediates: Between the two end groups of life strategies (r- strategists and K-strategists); there was also a large intermediate group that has lived in mesotrophic waters.

Table 5. Adaptations of organisms to different environmental conditions.



Morphotypes **Properties**	**Morphotype 1**	**Morphotype 2**	**Morphotype 3**
Environment	Eutrophic waters	Oligotrophic waters	Mesotrophic waters
Nutrient availability	Rich in nutrients	Low nutrient content	Intermediate conditions
Surface to deep gradient	Decreasing	Increasing	Intermediate conditions
Thermocline	Weakening	Strong	Intermediate conditions
Water temperature	Cooling	Warming	Intermediate
Reproduction rate	Faster reproduction	When conditions are available; low potential	Intermediate
Size of fossils	Small-sized	Large-sized	Intermediate
Population density	Rapidly increasing	Slowly increasing	Intermediate
Life Strategy	r-selected opportunists	K-selected specialists	r/K intermediate forms

Regarding to the evolutionary patterns of the Cretaceous planktonic foraminifera as mentioned above, the diversity patterns and abundance data of the studied section are examined in terms of genus, species and morphotypes and their relation with the change in lithology and time will be discussed here. To evaluate the response of planktonic foraminifers to ecologic changes, genus and species data were computed for the collected 300 specimens of the measured section (Table 6) and graphs were obtained by using excel and R programs.

Table 6. Distribution in terms of ecologic morphotypes throughout the measured section.

Stages	Globotruncanid Zonation	Heterohelicid Zonation	Sample No	Lithology	r - strategists (eutrophic)	K - strategists (oligotrophic)	r / K intermediates (mesotrophi
MAASTRICHTIAN	***Abathomphalus mayaroensis*** **Zone**	***Pseudoguembelina hariensis*** **Zone**	AG 177	Limestone	89	84	127
			AG 176	Limestone	112	51	137
			AG 175	Marl	52	61	187
			AG 174	Limestone	105	28	167
			AG 173	Marl	88	96	116
			AG 172	Limestone	195	27	78
			AG 171	Marl	118	77	105
			AG 170	Limestone	130	44	126
	Gansserina gansseri **Zone**		AG 169	Marl	120	43	137
			AG 168	Limestone	231	18	51
			AG 167	Marl	117	66	117
			AG 166	Limestone	191	39	70
		Racemiguembelina fructicosa **Zone**	AG 165	Marl	201	61	38
			AG 164	Marl	216	24	60
			AG 163	Marl	160	53	87
			AG 162	Marl	149	81	70
			AG 161	Marl	137	78	85
			AG 160	Marl	148	42	110
			AG 159	Limestone	187	27	86
			AG 158	Marl	143	79	78
			AG 157	Marl	142	82	76
			AG 156	Marl	83	124	93
			AG 155	Marl	95	93	112
			AG 154	Limestone	133	74	93
			AG 153	Marl	48	102	150
			AG 152	Marl	86	122	92
		Planoglobulina acervuloinides **Zone**	AG 151	Marl	67	113	120
			AG 150	Marl	49	152	99
			AG 149	Marl	76	146	78
			AG 148	Marl	67	139	94
			AG 147	Marl	117	111	72
			AG 146	Limestone	156	74	70
			AG 145	Marl	104	87	109
			AG 144	Limestone	119	116	65
CAMPANIAN		***Pseudotextularia elegans*** **Zone**	AG 143	Marl	67	132	101
			AG 142	Limestone	206	49	45
			AG 140	Marl	79	76	145
			AG 139	Marl	48	126	126
			AG 138	Marl	64	100	136
			AG 137A	Marl	112	94	94
			AG 137	Marl	118	107	75
	Globotruncana aegyptiaca **Zone**		AG 136	Marl	16	141	143
			AG 135	Marl	22	139	139
			AG 134	Marl	49	76	175
			AG 133	Marl	50	122	128
			AG 132	Marl	64	122	114
			AG 131	Marl	118	47	135
			AG 130	Limestone	134	72	94
			AG 129	Marl	78	87	135
			AG 128	Marl	91	126	83
			AG 127	Marl	120	94	86
			AG 126	Marl	101	151	48
			AG 125	Marl	98	147	55
			AG 124	Limestone	98	127	75
			AG 123	Marl	90	90	120
			AG 122	Marl	82	62	156
			AG 120	Marl	84	107	109

3.5.2 Diversity And Abundance Of Morphotypes

As grouping the genera within three different morphotypes, it is important to evaluate the attitude of diversity and abundance for them since they reflect the ecological changes. Previously mentioned; morphotype 1 consists of small, biserial heterohelicids, which are cosmopolitan, opportunistic forms (r – strategists) that lived in eutrophic conditions; such as nutrient-rich, unstable waters. Morphotype 2 is the most complex and less tolerant forms that can live only in oligotrophic waters that are more stable and have low nutrient content. Morphotype 3 was formed by the intermediate forms between those two end members.

When we compare the evolutionary patterns 3 morphotypes separately, we can realize that Morphotype 1 (r – strategists) is more abundant during the Maastrichtian after a decline in the abundance at the boundary of *Globotruncana aegyptiaca* and *Gansserina gansseri* Zones (AG 136) (Figure 37). On the peak observed during the Campanian, the maximum abundance can be examined in AG 130. Throughout the Maastrichtian, two peaks can be observed in their diversity patterns. The first peak is from the base of the *Gansserina gansseri* Zone up to the top of the *Planoglobulina acervuloinides* Zone (from sample AG 137 to AG 149) with the maximum abundance at the top of *Pseudotextularia elegans* Zone (AG 142). The second peak starts at the top of *Racemiguembelina fructicosa* Zone and continues up to the base of *Abathomphalus mayaroensis* Zone. Here, we can see the maximum abundance of this morphotype in sample AG 168 with 231 individuals (Figure 37). These peaks are relative with the increase in the abundance of *Heterohelix* and *Laeviheterohelix* in these samples (Figure 20). As the r-strategists reflect the eutrophic waters with cool, unstable conditions, nutrient-rich environments, decresing surface to deep gradient and weakening thermocline; their increase in the Late Maastrichtian indicates the domination of these conditions and it is

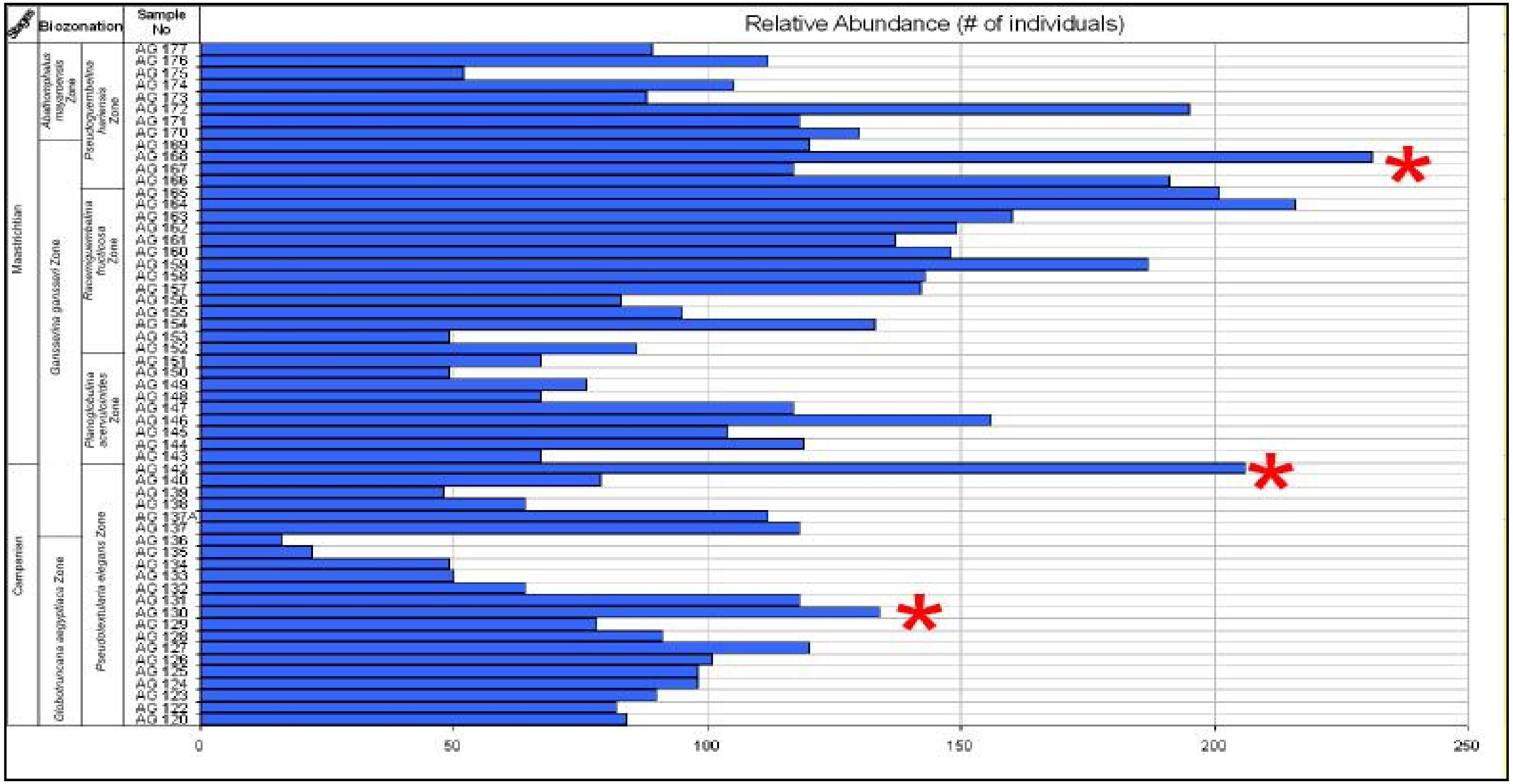


Figure 37. Relative abundance of Morphotype 1 (r – strategists) (Number of individuals within 300 counted individuals which picked up from each sample).

correlatable with the previous studies of Shanin (1992), Keller (1998), Premoli-Silva and Sliter (1994 and 1999) and Keller *et al.* (2002).

Moreover, when we look at the positions of the zones, as it was mentioned in the previous sections (Figures 17, 18, 19), they reflect the cooling of oceanic waters and regression during the uppermost Cretaceous (Haq *et al.*, 1987).

Relative abundance of morphotype 2 (K – Strategists) can be examined within two zones. The first zone reflects a pattern that is more abundant in Morphotype 2. This zone is from the base of the measured section upto the middle parts of *Racemiguembelina fructicosa* and *Gansserina gansseri* biozones (AG 158) (Figure 38). In this zone, there is an increase in *Globotruncana, Globotruncanita* and *Contusotruncana* abundances (Figure 20). Here, the maximum abundance is reached with almost 150 individuals of this morphotype in samples AG 126 and AG 150. After the abrupt decline in the abundance in sample AG 159, we can recognize a second zone, which is relatively low abundant in terms of Morphotype 2 (Figure 38). The changes in abundance of this morphotype can also be explained by the change in paleoceanographic conditions towards the end of the Maastrichtian and our data is correlatable with the global studies (Shanin, 1992; Keller 1998; Premoli-Silva and Sliter, 1994 and 1999; Keller *et al.,* 2002).

Four zones can be examined for the Morphotype 3 (intermediate forms) (Figure 39). The first one is just at the base of the section (from sample AG 120 to AG 126) with a peak point at AG 122; the second zone is starts from just at the top of the first zone and it continues up to the top of the *Pseudotextularia elegans* Zone section (from sample AG 127 to AG 142) with its peak at sample AG 140. The third zone includes the total interval of *Planoglobulina acervuloinides* and *Racemiguembelina fructicosa* zones (from sample AG 143 to AG 165). This zone peaks the base of the *Racemiguembelina fructicosa* Zone (AG 153). The last peak can be observed at the top of the section (from sample AG 166 to AG 177) with its

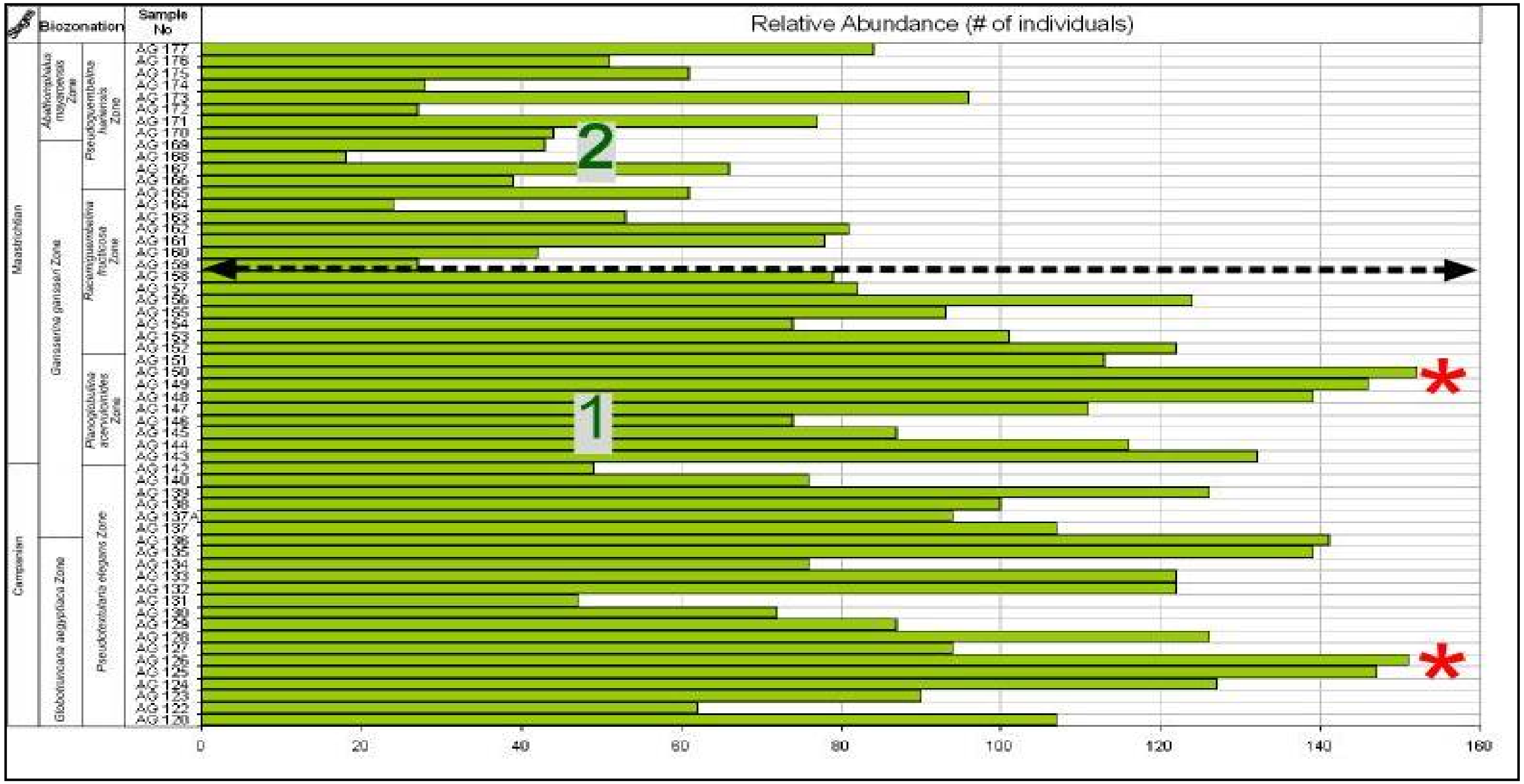


Figure 38. Relative abundance of Morphotype 2 (K – strategists) (Number of individuals within 300 counted individuals which picked up from each sample).

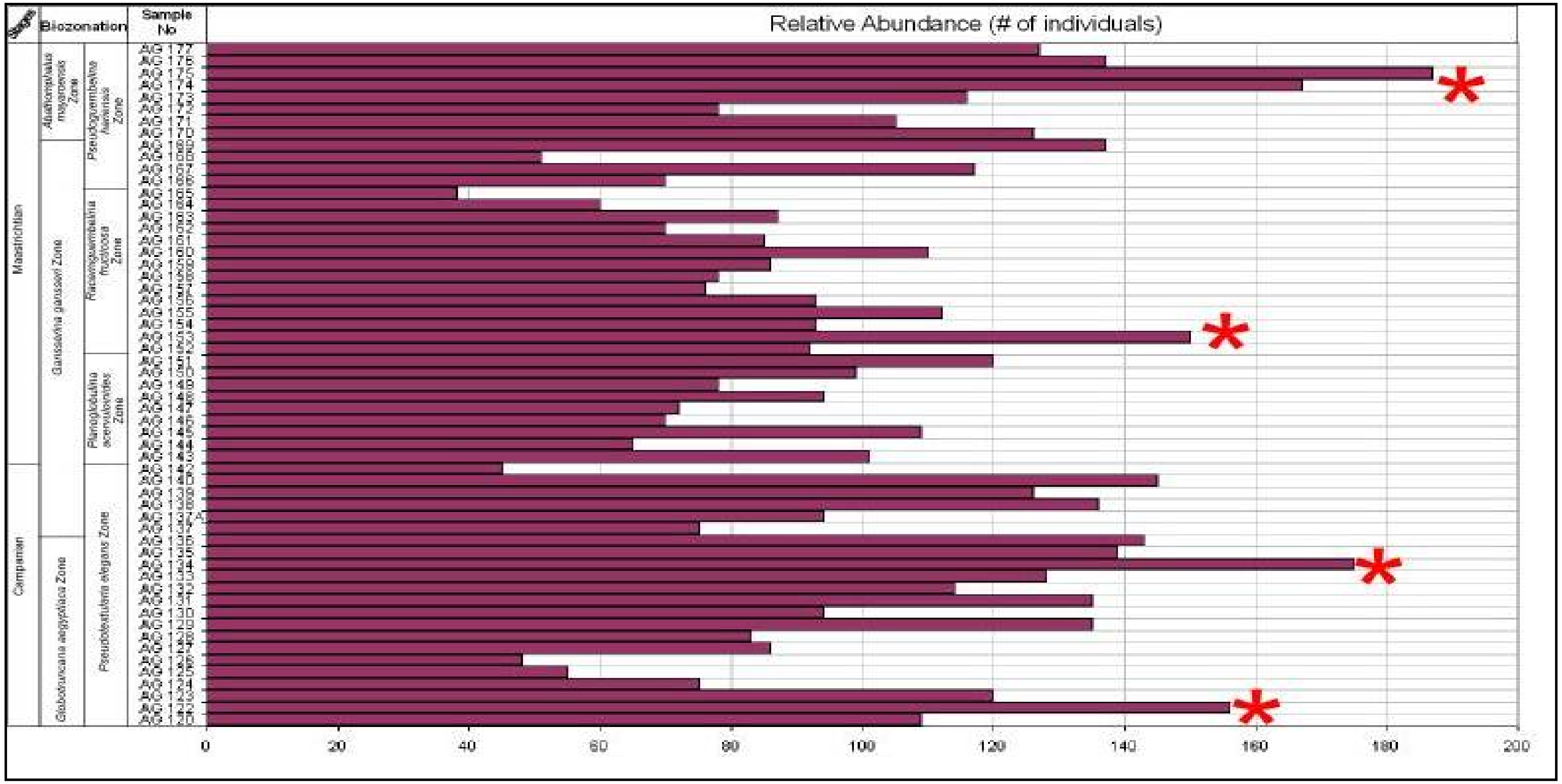


Figure 39. Relative abundance of Morphotype 3 (r/K – intermediates) (Number of individuals within 300 counted individuals which picked up from each sample).

peak at sample AG 175. All of these peaks contain more than 150 individuals of Morphotype 3 (Figure 39).

In a more general trend, the diversity patterns of Morphotype 2 (K-strategists) and Morphotype 3 (r/K intermediate forms) looks like each other. However, the opposite trends in their distribution can be seen in the biozone boundaries respectively. If we compare r- strategists, there will be observed just the opposite pattern with respect to other morphotypes (Figure 40).

Eliminating the intermediate forms from the system for a while, if we look at the changes in diversity patterns of Morphotype 1 (r – strategists) and Morphotype 2 (K – strategists), there is totally an opposite pattern (Figure 41). Since these morphotypes reflect the ecologic conditions, we can discuss these conditions by the changes in the patterns of these two morphotypes (Figure 41). At the first sight, we can separate three zones through out the measured section that we can interpret the ecologic conditions. These three zones show abrupt changes in the trends of the morphotypes. The first zone is at the top of *Globotruncana aegyptiaca* Zone (from sample AG 131 to AG 137, where K – strategists increase suddenly and r –strategists decline in abundance. Since the K – strategists are the least tolerant species to the ecologic changes; we can evaluate that scenery as the existence of the oligotrophic conditions (stable waters with low nutrient content) comprises the increase in the specialist forms. A similar pattern can be observed throughout the *Planoglobulina acervuloinides* Zone that we can evaluate as the second zone for oligotrophic conditions. The last zone shows the opposite trend with the first two zones. Here, we can clearly observe the sudden increase in the abundance of r – strategists and a distinct decrease in the abundance of the K – strategists. Therefore, that can be evaluated as the sovereignty of the eutrophic; unstable and nutrient-rich, waters that are more suitable for the cosmopolitan forms. This zone continues from the *Racemiguembelina fructicosa* Zone till the *Abathomphalus mayaroensis* Zone and the Maastrichtian stage ends with more or less eutrophic

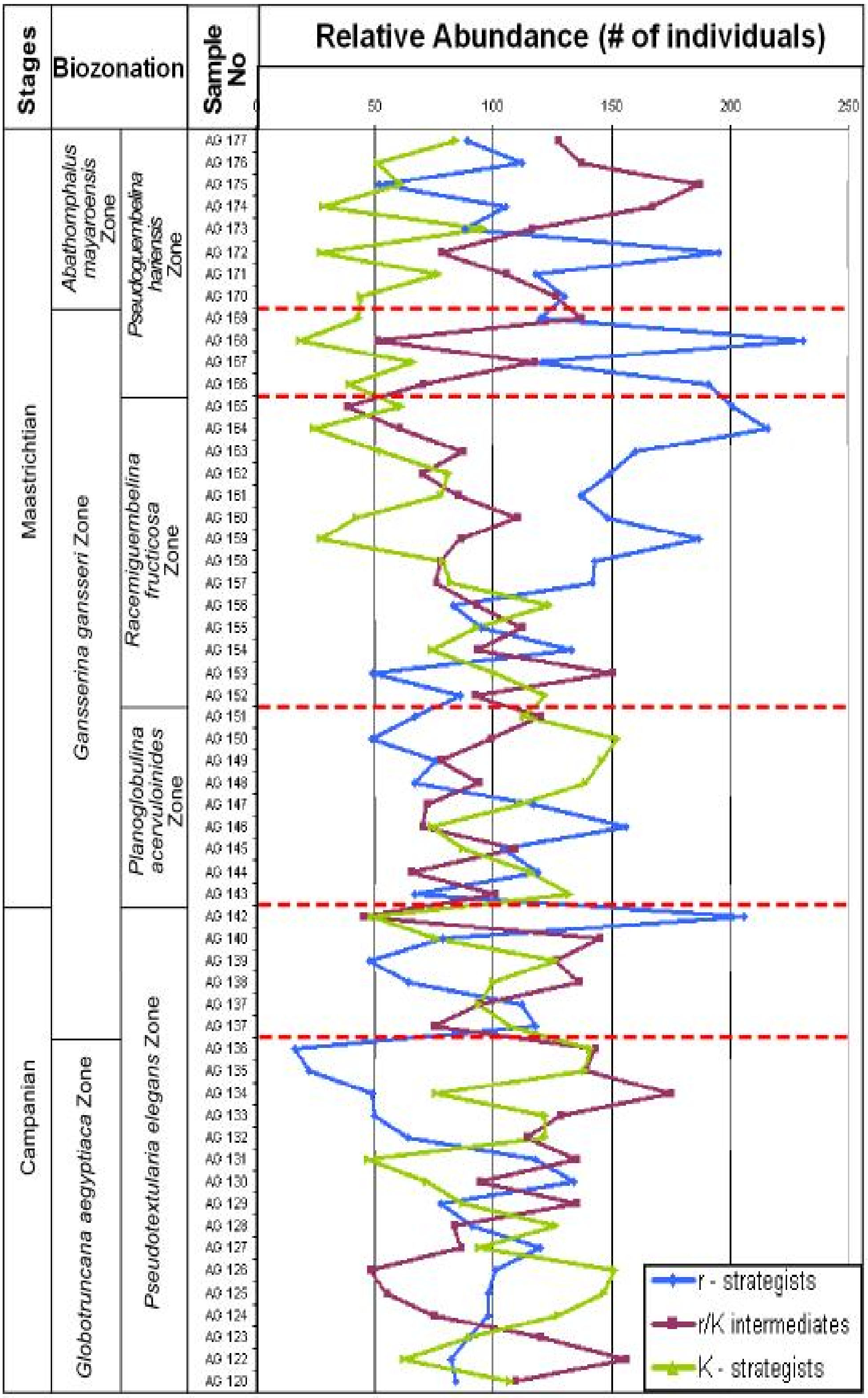


Figure 40. Comparison of relative abundances of the three morphotypes. Red lines indicate the biozone boundaries.

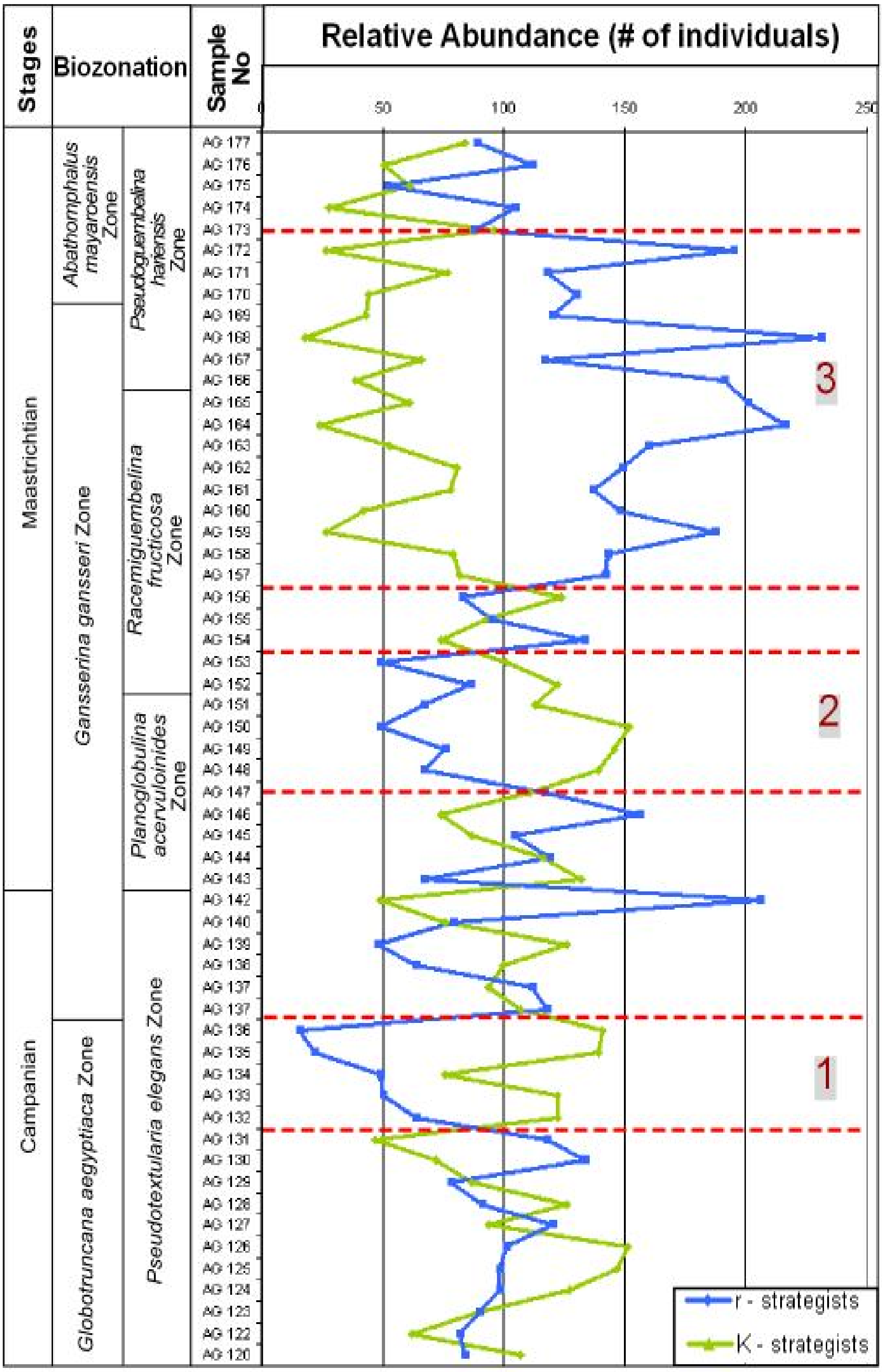


Figure 41. Comparison of relative abundances of Morphotype 1 (r – strategists) and Morphotype 2 (K – strategists). Red lines indicate the biozone boundaries.

conditions. As mentioned before, the distribution of the morphotypes at figure 41; especially in the Late Cretaceous, shows us the harmony of our data with the global studies as we can observe the similar adaptations of the morphotypes to the changing paleoceanographic conditions (Shanin, 1992; Keller, 1998; Premoli-Silva and Sliter, 1994 and 1999; Keller et al., 2002).

In order to check the response of planktonic foraminifers to ecologic changes, the recognized planktonic foraminifers were rearranged into two other groups of morphotypes. The second arrangement was based on the arrangement of chambers and presence/absence of keel(s) and the third arrangement compared the uncoiled forms with coiled forms:

Our second arrangement is based on the study of Shanin (1992). According to this arrangement, Morphotype A consists of all of the heterohelicids (*Gublerina, Heterohelix, Laeviheterohelix, Planoglobulina, Pseudoguembelina, Pseudotextularia* and *Racemiguembelina*). Morphotype B includes planispiral genus *Globigerinelloides* and non-keeled trochospiral genera; *Archaeoglobigerina, Globotruncanella* and *Rugoglobigerina*. Morphotype C compreses the trochospiral genera that bear keel(s) (*Abathomphalus, Contusotruncana, Gansserina, Globotruncana* and *Globotruncanita*). Here, Morphotype A is mostly the dominant group in the samples and it mostly shows opposite trends with respect to morphotypes B and C, such as the relative abundance of Morphotype A increases where the relative abundances of Morpho type B and Morphotype C decreases and vica versa (Figure 42, 43). Here, the trends of morphotypes A and C have great peak starting form the *Racemiguembelina fructicosa* Zone up to the end of Maastrichtian. Such a peak can be observed all through the Maastrichtian for morphotypes A and B; and from the *Planoglobulina acervuloinides* Zone to the middle parts of *Racemiguembelina fructicosa* Zone for morphotypes B and C. If we compare Morphotype B and Morphotype C, also they mostly show the opposite trends in *Gansserina gansseri* and *Abathomphalus mayaroensis* zones and in the base of the measured section, whereas their evolution trends becomes more or less

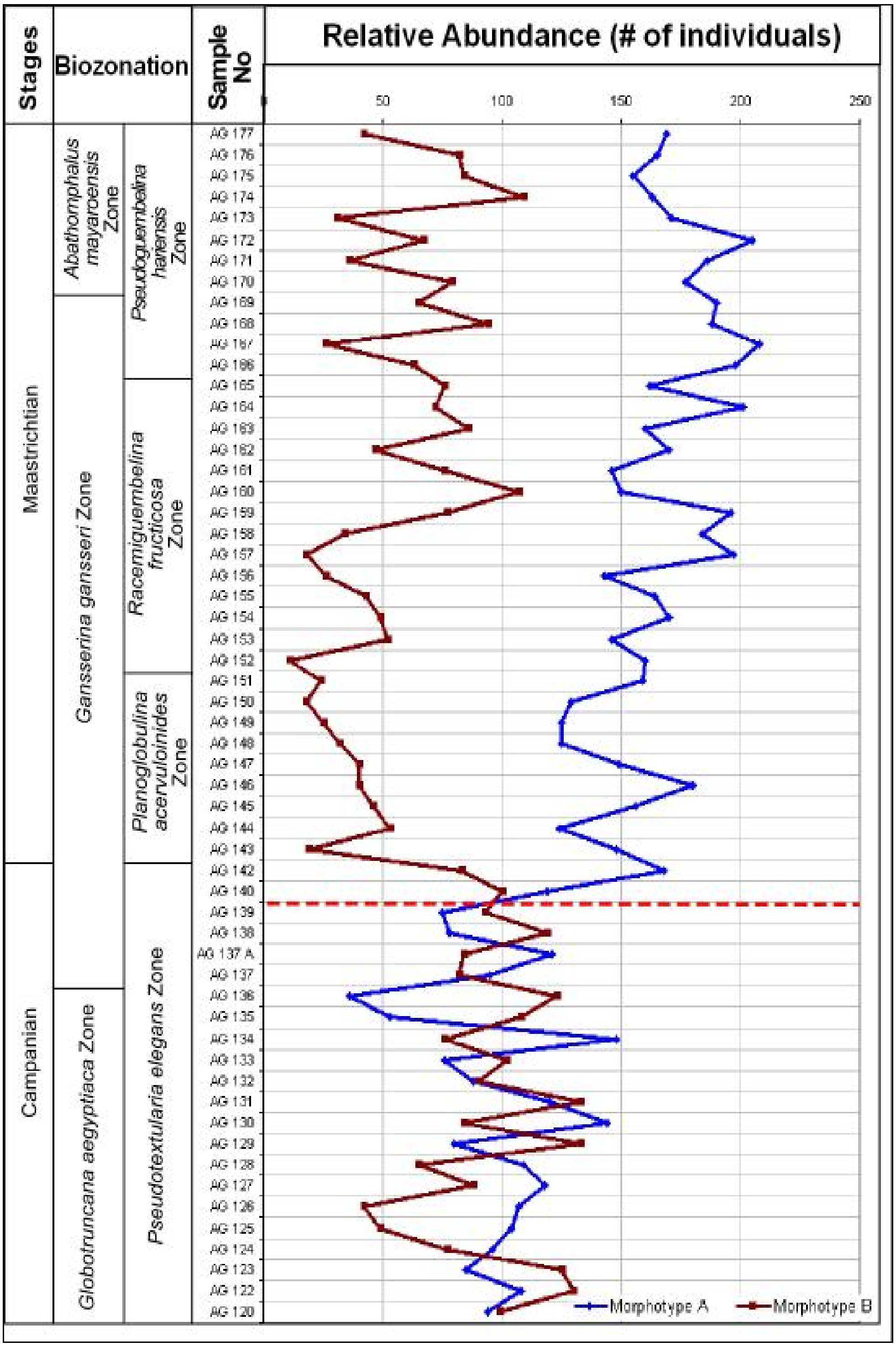


Figure 42. Comparison of relative abundances of Morphotype A and Morphotype B.

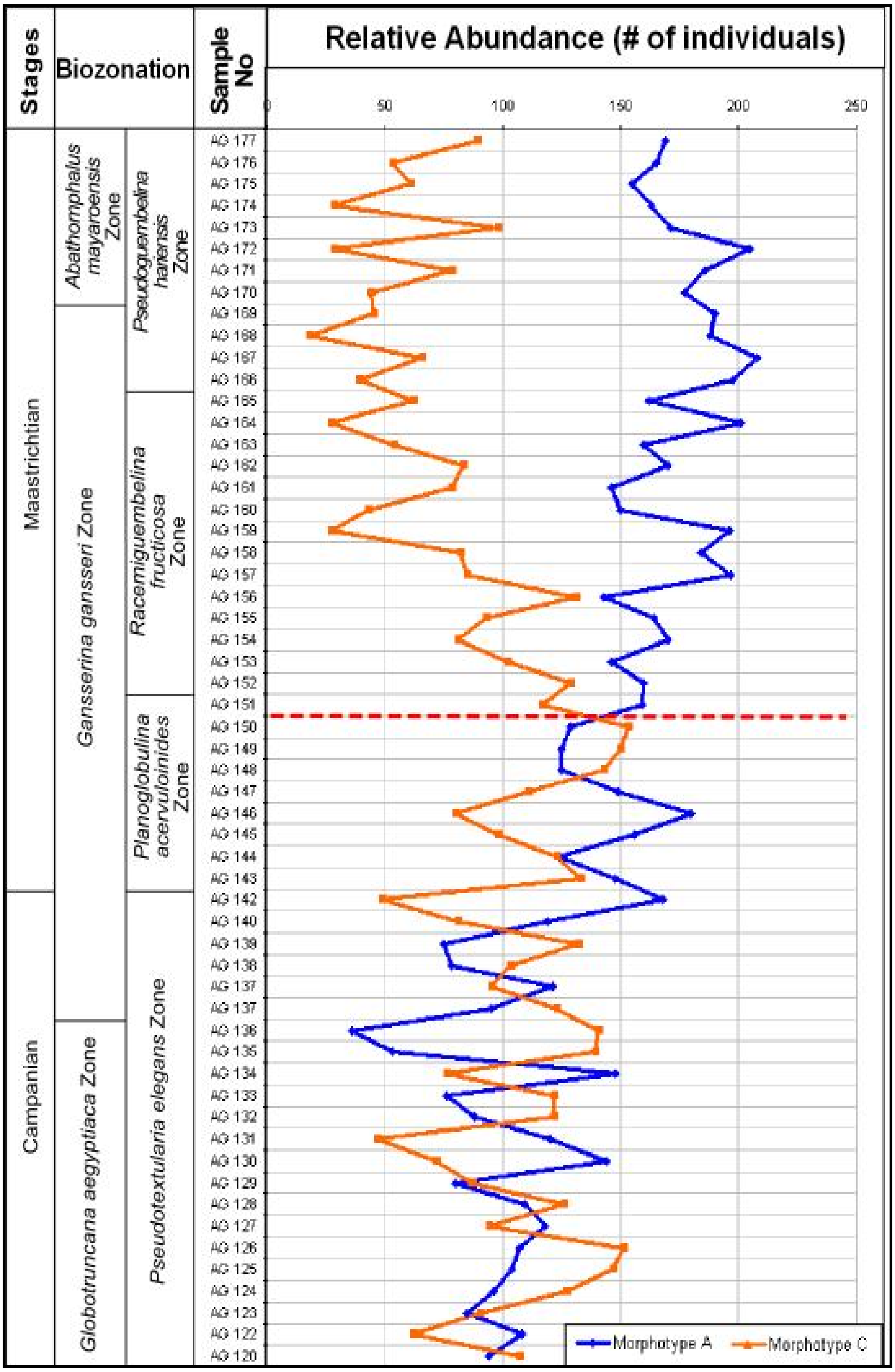


Figure 43. Comparison of relative abundances of Morphotype A and Morphotype C.

parallel throughout the upper part of *Globotruncana aegyptiaca* Zone (between samples AG 129 and 137 A), in which the Morphotype A becomes almost less abundant with respect to the other two groups (Figure 44, 45). According to Shanin (1992), while the keeled forms occured together with the unkeeled ones and heterohelicids during the *Globotruncana aegyptiaca* and *Gansserina gansseri* zones, the predomination of the heterohelicids can be observed during the *Abathomphalus mayaroensis* Zone. As being observed from the graphs, this is also correlatable with our data.

In the last arrangement where we compare coiled and uncoiled forms, we can see the most perfect change in the evolutionary trends of those forms in opposite direction. Here, the coiled forms are very dominant during the Campanian and the peak between those two groups is very distinct (Figure 46). At the basal part of Maastrichtian, the relative abundance of the groups becomes very close to each other. Beginning with sample AG 157, the uncoiled forms become more abundant with respect to the coiled forms until the end of the Maastrichtian; however the peaks between the two groups aren’t as much as it was at the Campanian (Figure 46).

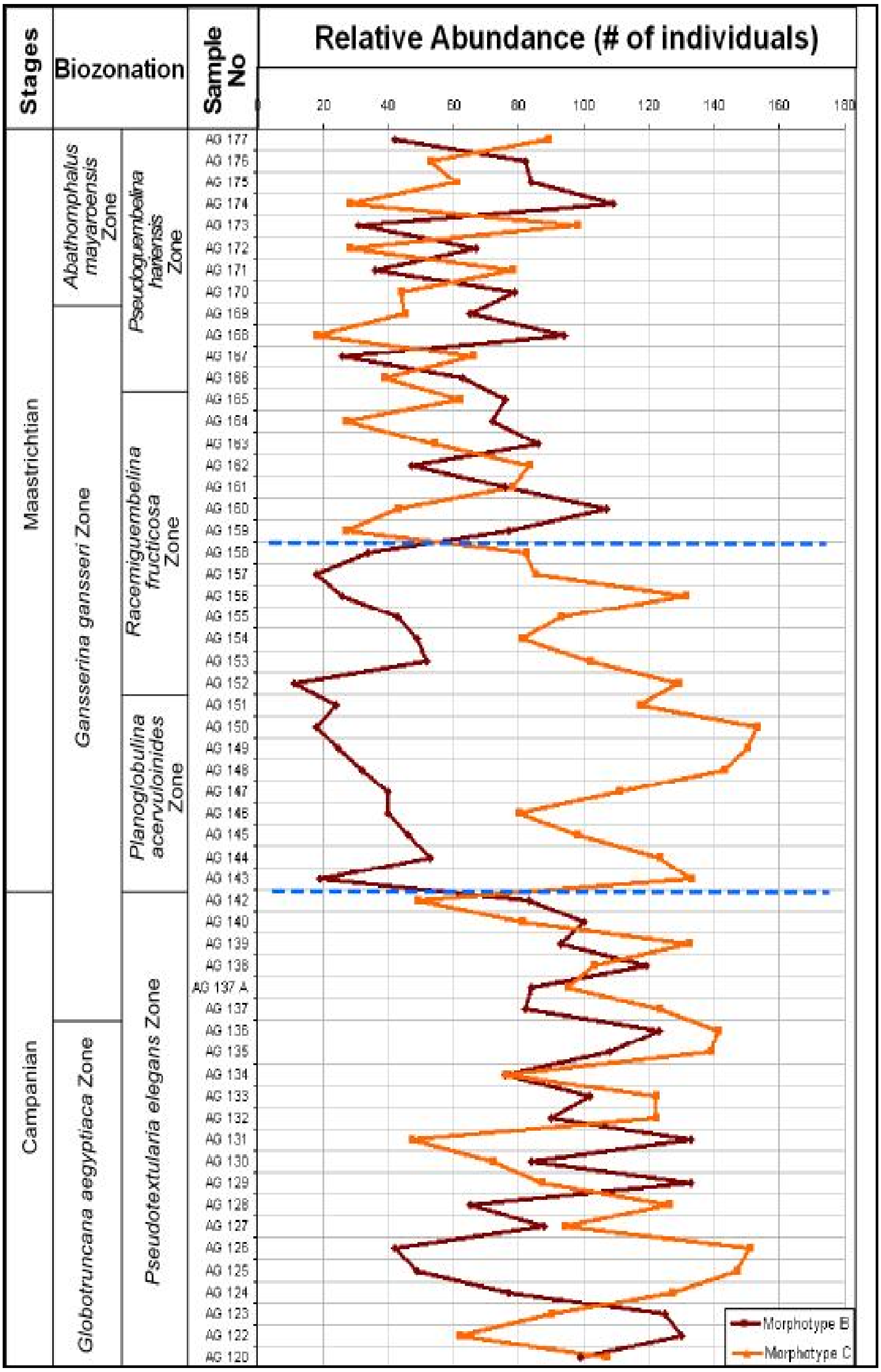


Figure 44. Comparison of relative abundances of Morphotype B and Morphotype C.

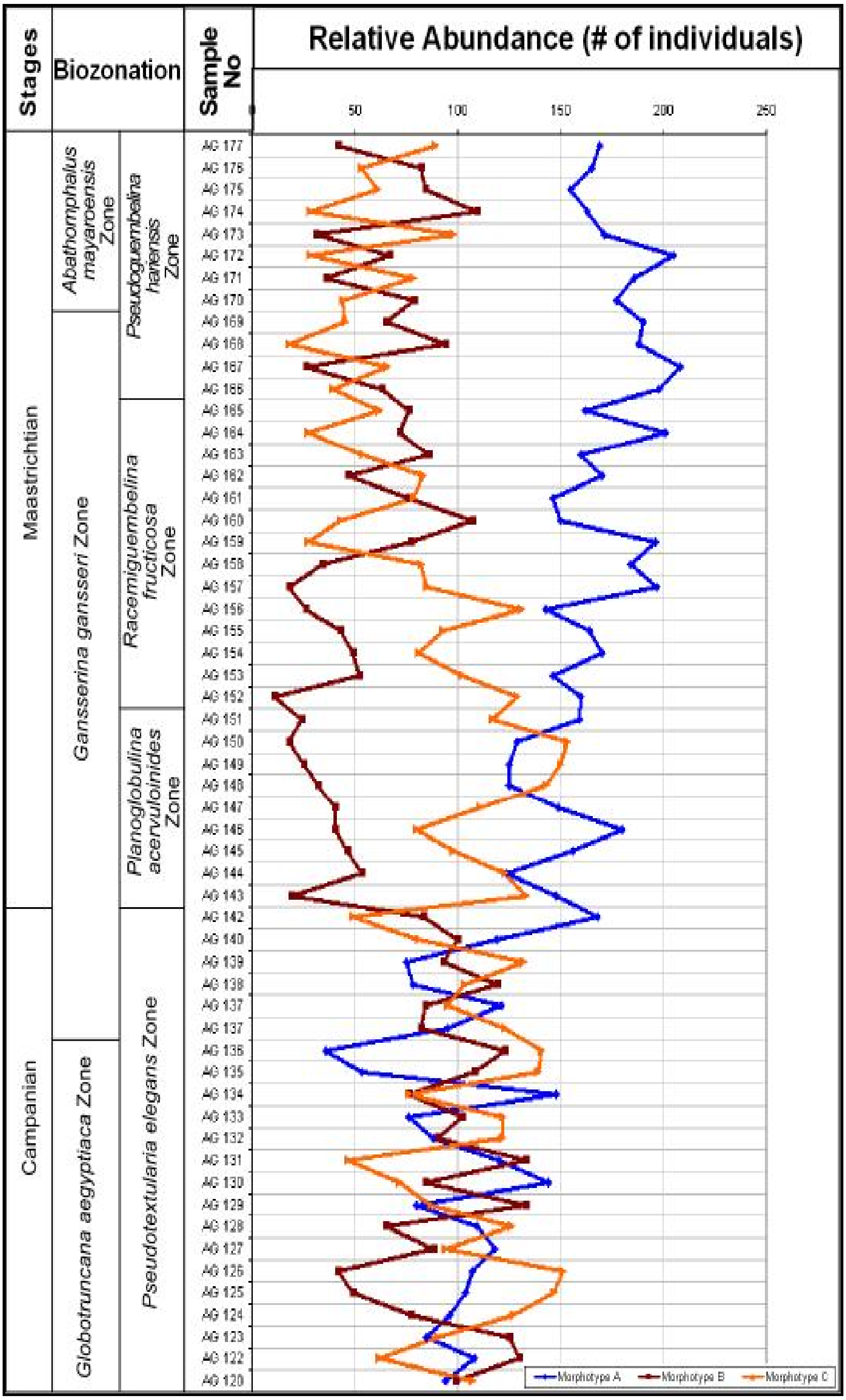


Figure 45. Comparison of relative abundances of Morphotypes A, B and C.

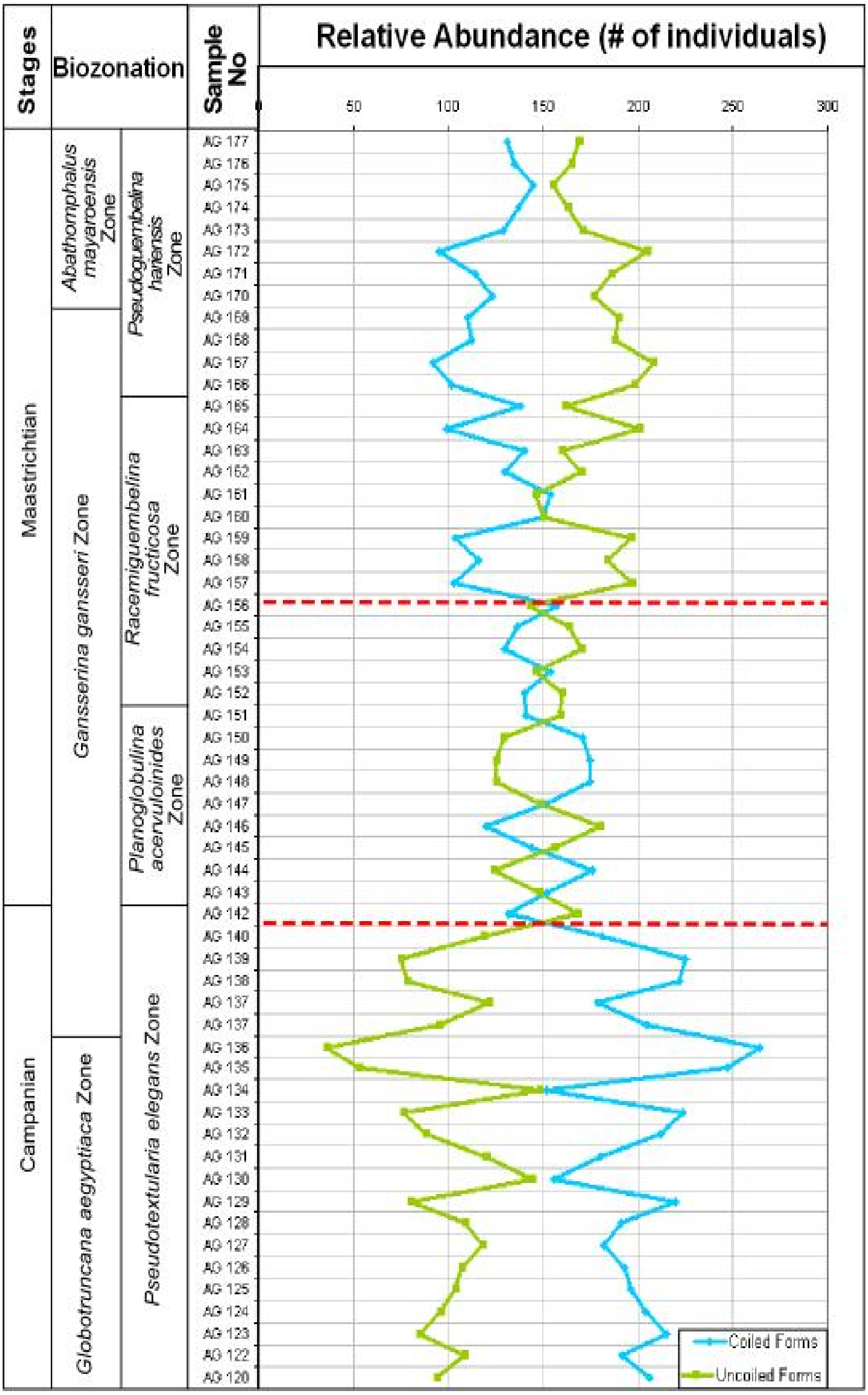


Figure 46. Comparison of relative abundances of coiled and uncoiled forms.

3.5.3 Evolutionary Trends With Respect To Lithological Changes

In our data, the abundant lithology is the marl and there are only a few clayey limestones (2 samples containing calciturbidite are excluded from the evaluation). Throughout the measured section, only the uppermost part that is included in *Pseudoguembelina hariensis* Zone (from sample AG 166 to AG 177) shows systematic alternations in lithology. Therefore, the effects of change in lithology to the evolutionary trends of the morphotypes have been examined.

As seen in the Figure 47, it can be easily realized that there is a distinct increase in the abundance of Morphotype 1 (r – strategists) in clayey limestones and Morphotype2 (K – strategists) increase in abundance when the lithology turns into marl. The peaks in abundance of two morphotypes in clayey limestones can be easily recognized; however the difference in the abundance of two forms is relatively small in the samples that contain marl.

Since the lower parts of the measured section almost contains marl except 7 samples which are non – systematicly distributed, the lithological effect on the evolution of the morphotypes can't be observed. So, our comparison becomes limited to the uppermost part of the measured section. However, in the lower parts of Campanian which has not been considered in this study, it is suggested to apply this analysis in a sequence that shows a clear alternation of the lithology.

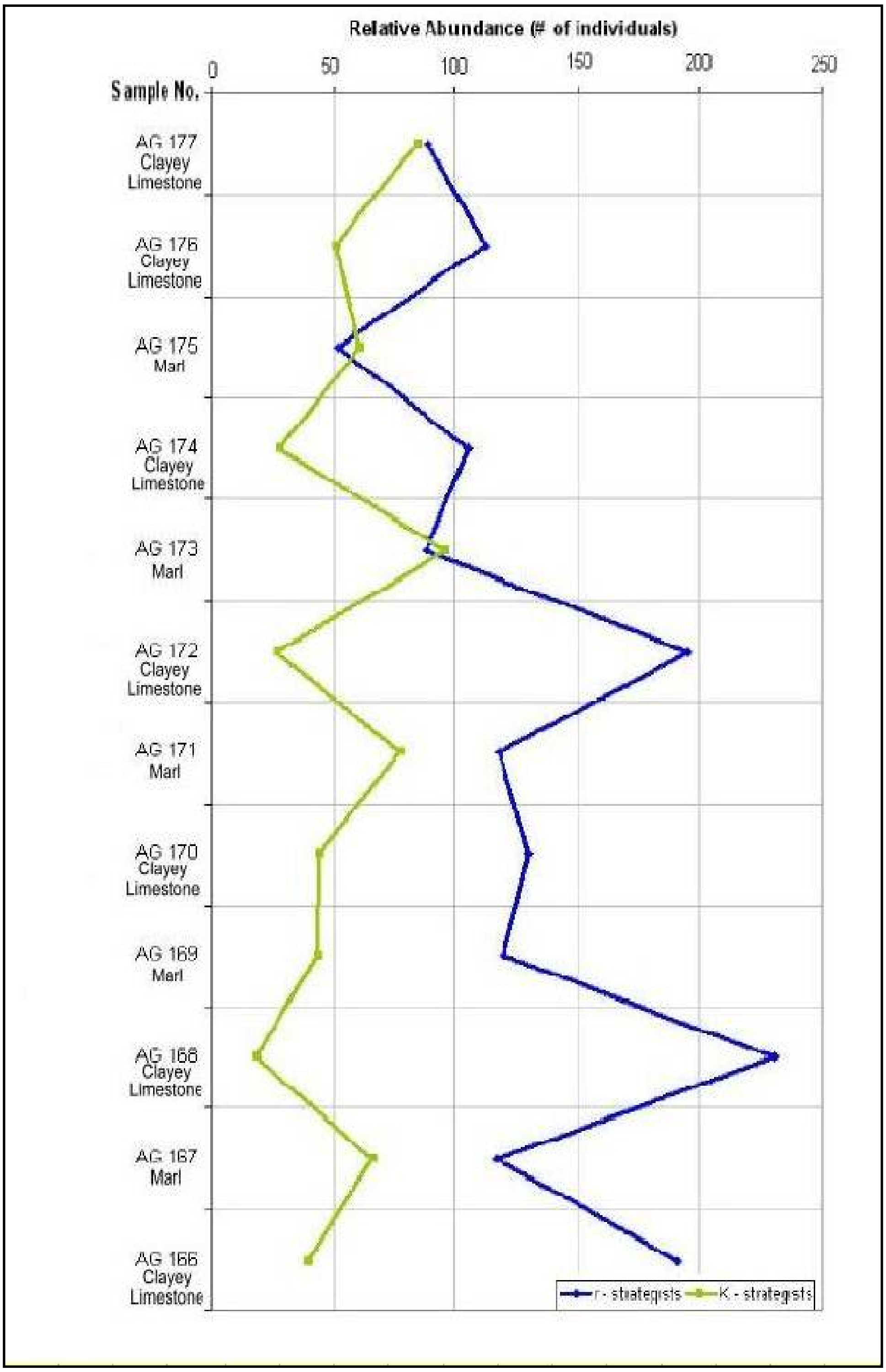


Figure 47. Effects of Lithology to the evolutionary trends of Morphotypes 1, 2, and 3.

3.5.4 Clusters WithinThe Data

Cluster analysis is an exploratory data analysis tool which aims at sorting different objects into groups in a way that the degree of association between two objects is maximal if they belong to the same group and minimal otherwise.

In this study, using the R program, it is controlled that if our data can be clustered with respect to some variables. So, after trying different methods within the program, we have obtained the best results by using the "ward" method that was applied to our data after using the logarithmic transformation.

For the species data, we obtained 4 different clusters. First and second clusters obtained by the program are quite similar in character. They reflect the forms that are relatively low abundant throughout the measured section (Figure 48). However their difference is that the species clustered in the second zone were defined in a limited number of samples. The abundance of third cluster is higher than the first two groups, respectively. These forms are either common in Maastrichtian samples and absent in the Campanian or they have a wide range, but they are absent at least at half of the samples. The last cluster includes the most abundant species. They are mostly present all through the measured section or after a certain time interval in this study.

The clustering of the genera resembles the species clusters in terms of the number of clusters separated and their characteristics. Accordingly, the program groups the genera into four clusters again (Figure 49). If we look at the clustered genera, Cluster 1 includes the genera relatively more abundant in uppermost Maastrichtian (*Abathomphalus, Pseudoguembelina*), whereas *Archaeoglobigerina*, the genus in Cluster 2, is relatively more abundant in the middle part of the measured section. Here, the similarity of these two clusters is that they both consist of the genera with low diversity and low abundance. Cluster 3 includes the genera that are abundant in all parts of the measured section. These genera are also show high diversity

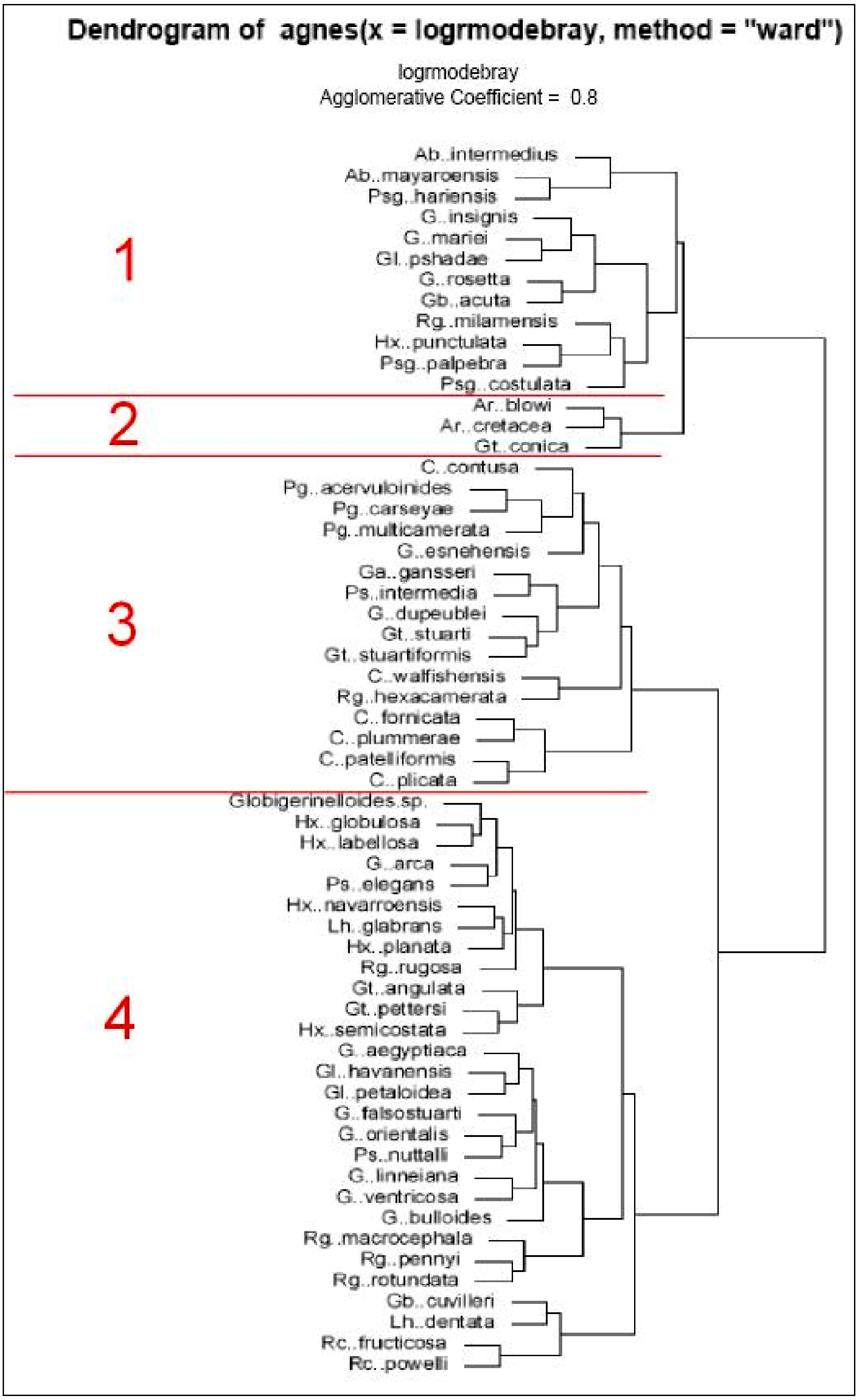


Figure 48. Clusters for the species data.

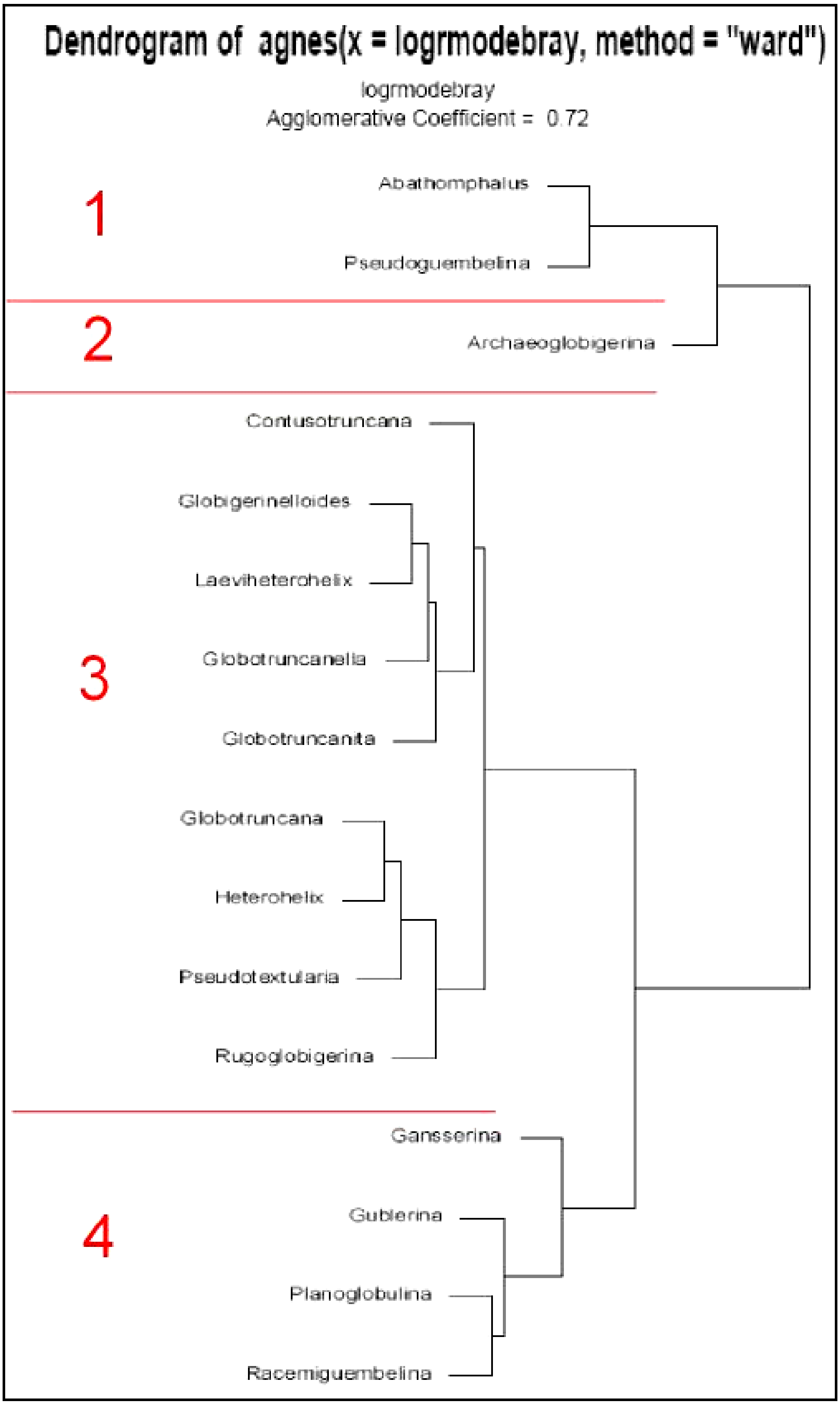


Figure 49. Clusters for the generic data.

throughout the measured section. In that manner, the third cluster includes a variety of genera which show much different morphology. The last cluster; cluster 4, includes the genera that are more abundant in some distinct part of the measured section. These genera have diversified up to three species (*Planoglobulina*).

After the clustering of our data with respect to the species and genera distribution (r-mode clustering), another clustering method has been applied. In this method, data was clustered with respect to the sample numbers and we tried to find out if our data can be clustered by any certain variable of the samples (Q-mode clustering). Here we can think of two different variables; lithology and time. Considering the lithology, most of the samples of this study are marls and our samples have not showed a systematic marl-limestone alternation. So, as expected, the program couldn't cluster the data with respect to lithology. Therefore, we can obtain a clustering with respect to time (Figure 50). Here, as indicated by PsZ, our first cluster points out the samples from the *Pseudoguembelina hariensis* Zone. Here the exception is the sample AG 163 which belongs to the *Racemiguembelina fructicosa* and *Gansserina gansseri* zones. The samples, which are included the second cluster, are the ones that belong to the interval between the base of the *Racemiguembelina fructicosa* Zone (RaZ) and the top of the *Gansserina gansseri* Zone (GaZ) ranging form sample AG 152 (first sample of the *Racemiguembelina fructicosa* Zone) to AG 169 (last sample of the *Gansserina gansseri* Zone). The third cluster consists of all of the samples of Planoglobulina acervuloinides Zone ranging from sample AG 143 to AG 151. These samples are indicated as PlZ in figure 50. The last cluster includes mainly the Campanian samples (from sample AG 120 to AG 142). So they are grouped as PeZ which indicates the *Pseudotextularia elegans* Zone. Consequently, the sample clustering gives us a distribution with respect to time. In this cluster, we can verify the Campanian – Maastrichtian boundary that has previously placed by the biostratigraphical studies. Also the Maastrichtian stage has been clustered in

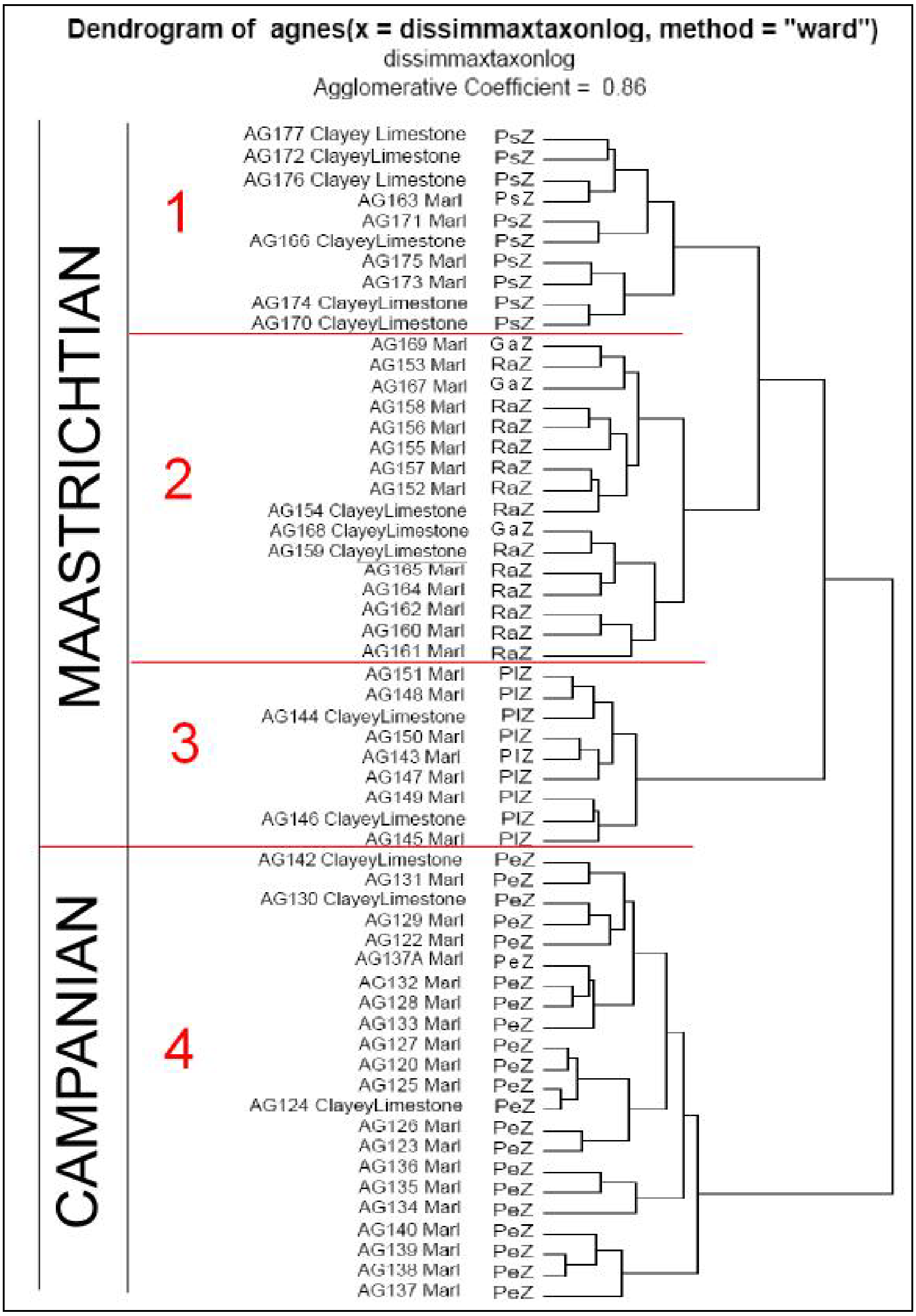


Figure 50. Analysis that distinguish the clusters within the biozones. PsZ= *Pseudoguembelina hariensis* Zone, GaZ= *Gansserina gansseri* Zone, RaZ= *Racemiguembelina fructicosa* Zone, PlZ= *Planpglobulina acervuloinides* Zone, PeZ= *Pseudotextularia elegans* Zone.

terms of the biozones that we established before and we can observe the clustering of the samples which belong to the Planoglobulina acervuloinides Zone (Cluster 3), *Racemiguembelina fructicosa* and *Gansserina gansseri* zones (Cluster 2) and the *Pseudoguembelina hariensis* Zone (Cluster 1).

As the last clustering shows a distinction with respect to the biozones (Figure 51), the next step is the “Detrended Correspondance Analysis (DCA)” by the use of R program. Correspondence analysis is a method of factoring categorical variables and displaying them in a property space, which maps their association in two or more dimensions. The technique defines a measure of distance between any two points, where points are the values (categories) of the discrete variables. Correspondence analysis determines which category values are close together. However, this analysis can suffer the problem of arch effect. The arch effect occurs when one variable has a unimodal distribution with respect to a second. In that case, different from standart correspondence analysis, detrended correspondence analysis (DCA) was invented to correct this problem. Detrending removes the arch effect by dividing the map into a series of vertical partitions, thus dividing the map along the primary (horizontal) axis. DCA is common in ecological uses of correspondence analysis. The difficulty is to interpret what the axis of the graphs prepared by the program stand for. The variable which the program uses has to be understood by the researcher for the further interpretations.

In our data, we can easily observe that the clustering of the DCA analysis is with respect to time variable like it is in the Q-mode cluster analysis. Figure 51 gives us the clustering of the samples of Campanian and Maastrichtian, respectively. Moreover, by using the DCA analysis, we can obtain the clustering with respect to both globotruncanid and heterohelicid biozonation (Figures 52, 53). In both of these graphs, the Campanian-Maastrichtian boundary can be observed distinctly.

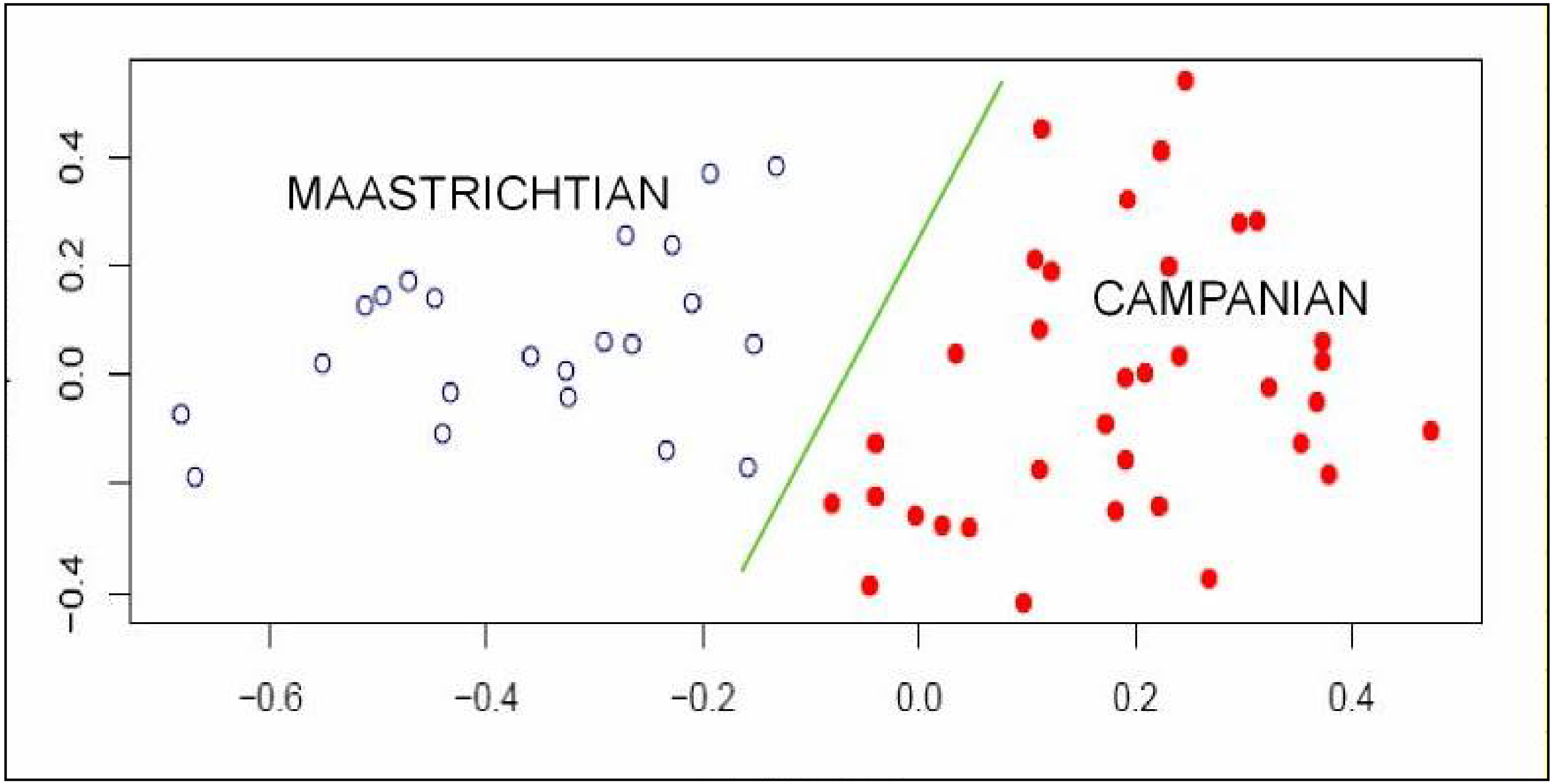


Figure 51. DCA Analysis that shows the clustering in time. Recognize the separation of the Campanian and the Maastrichtian samples.

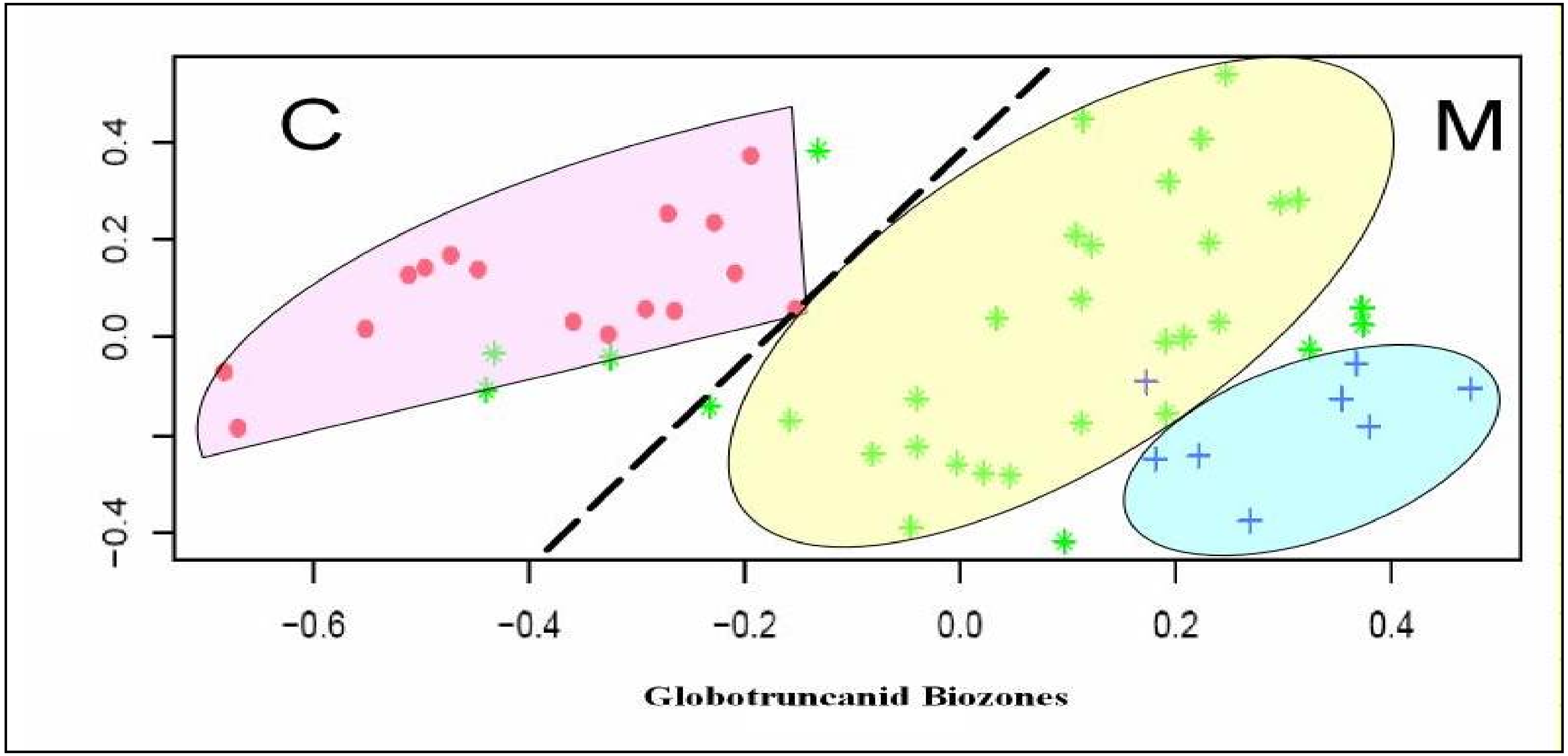


Figure 52. DCA Analysis that shows the clustering with respect to globotruncanid biozonation. Red color = *Globotruncana aegyptiaca* Zone, green color= *Gansserina gansseri* Zone, blue color= *Abathomphalus mayaroensis* Zone, C= Campanian, M= Maastrichtian.

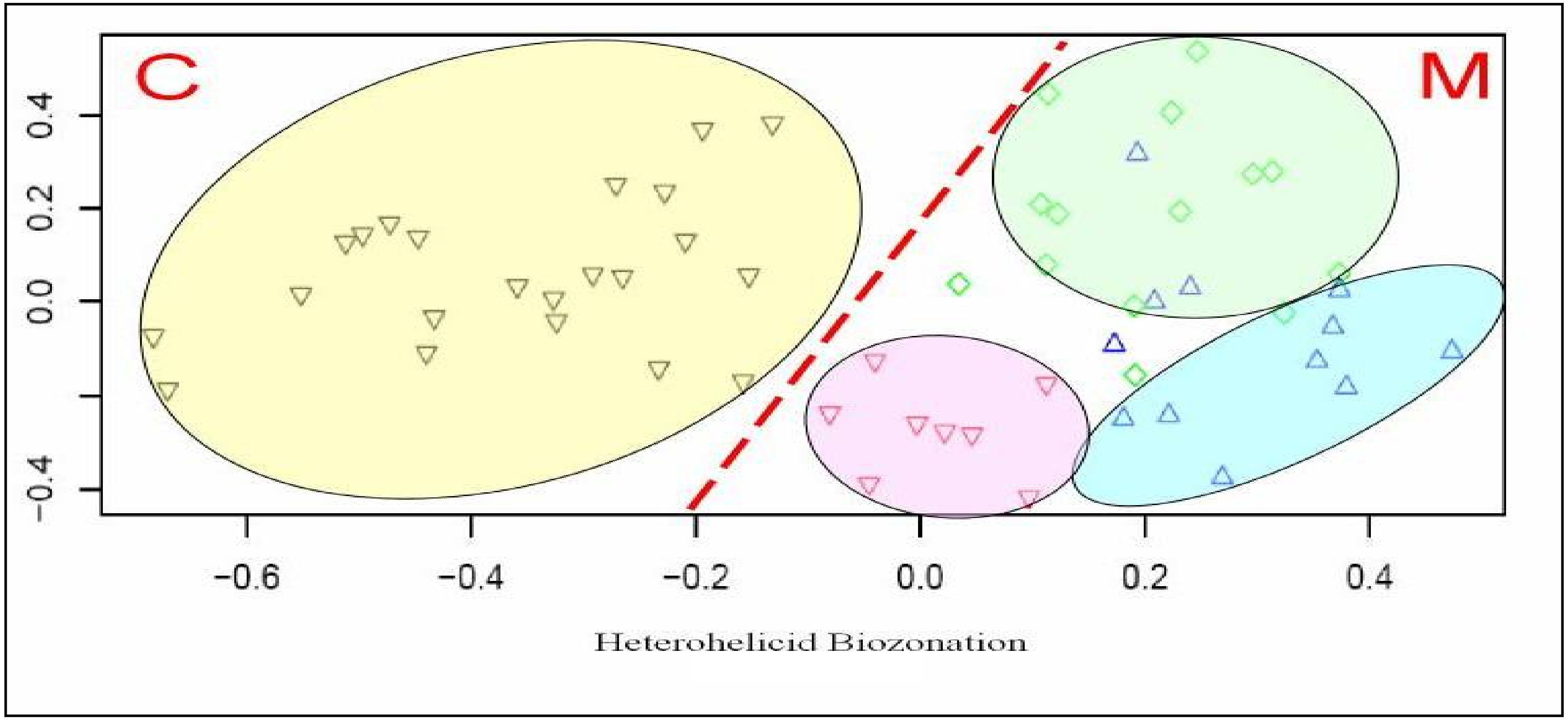


Figure 53. DCA Analysis that shows the clustering with respect to heterohelicid biozonation. Blcak color= *Pseudotextularia elegans* Zone, red color = *Planoglobulina acervuloinides* Zone, green color= *Racemiguembelina fructicosa* Zone, blue color= *Pseudoguembelina hariensis* Zone, C= Campanian, M= Maastrichtian.

CHAPTER IV

SYSTEMATIC PALEONTOLOGY

Based on thin sections and washed specimens of the planktonic foraminifera obtained from the samples gathered from the measured section, a detailed systematic micropaleontological study was carried out.

In the classification of the planktonic foraminifera; wall structure, wall composition, chamber architecture, presence or absence of keel(s) and ornamentations and position of primary aperture designate the subfamily level. The category of protection of primary aperture (portici or tegilla), degree of trochospire and presence or absence of adumbilical ridges is used in genera descriptions, whereas shape of chambers, number of chambers in last whorl, rate of increase of chamber size, diameter of umbilicus, degree of peripheral angle, symmetry of profile, width of keel band, character of spiral suture and inflation of chambers are needed for identification of the species.

In the present study, based on the criteria above, 16 different genera and 58 species were defined (Appendix D). In this chapter, only the most recent publications and the manuals are used for the synonmy list. The taxonomy of the globotruncanids is carried out by considering the definitions of Robaszynski *et al.* (1984) and the classification of Nederbragt (1991) is used in the taxonomy of heterohelicids. Since the detailed definitions were described by those authors before, the definitions of the species were not given in this section. However, the species characteristics that are observed in this study will be explained and discussed as remarks for each form separately. Here, the most common problem in the recognition of the forms is the absence of most ornamentation such as pustules, costae, apertural structures (tegilla, portici, apertural flanges, etc.) because of the acid treatment during the preparation of samples.

Phylum Protozoa

Suborder Globigerinina

Superfamily Globotruncanacea BROTZEN, 1942

Family Globotruncanidae BROTZEN, 1942

Subfamily Globotruncaninae BROTZEN, 1942

Genus *Contusotruncana* KORCHAGIN, 1982

Type species: *Pulvinulina arca contusa* CUSHMAN, 1926

Contusotruncana contusa CUSHMAN, 1926

Pl. 1, fig. 1; Pl. 11, fig. 1

Contusotruncana contusa CUSHMAN, 1926, p. 23, no type figures.

Rosita contusa ROBASZYNSKI *et al.*, 1984, p. 247, pl. 36, figs. 1-2; p. 249, pl. 37, figs. 1-3.

Rosita contusa ÖZKAN and ALTINER, 1987, p.275, pl. 4, figs. 4-6.

Contusotruncana contusa NORRIS, 1992, p.171, pl. 2, figs. a, b.

Contusotruncana contusa KUCERA and MALMGREN, 1996, p.34, pl. 1, figs. 1-12.

Contusotruncana contusa CHUNGKHAM and JAFAR, 1998, p. 75, pl. 1, figs. 3 a-c.

Contusotruncana contusa ÖZKAN-ALTINER and ÖZCAN, 1999, p. 294, pl. 2, fig. 2.

Contusotruncana contusa ROBASZYNSKI *et al.*, 2000. p. 479, p. 19, fig. 16.

Contusotruncana contusa CHACON et al., 2004, p. 589, fig. 3 A; p. 590, fig. 4 C, D.

Remarks:

This form is one of the forms that can easily be recognized with its typically conical, pyramid-like shape. It can be compared with *Globotruncanita conica* because of the shape of its test; however these two forms are distinguished by the double-keeled structure of *Contusotruncana contusa*. This form has globular initial chambers followed by very elongated crescentic chambers in the spiral side and generally 5 or 6 trapezoidal chambers are observed in the last tour of the test form the umbilical side. This form is distinguished from *Contusotruncana plicata* and *Contusotruncana patelliformis* in its larger test and higher trochospire; from *Contusotruncana walfischensis* in its undulated appearance in the spiral side and its distinctly larger test. *Contusotruncana contusa* has been used in many biostratigraphical studies as a zone-defining form mostly as an alternative of *Racemiguembelina fructicosa* Zone (Li and Keller, 1998; Premoli-Silva, 1999; Gardin *et al.*, 2001; Chacon *et al.*, 2004). However, such a biozonation isn't involved in this study because of the rareness of this species in our samples.

Occurrence:

From sample AG 143 (base of the *Planoglobulina acervuloinides* Zone) to AG 175 (upper parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Contusotruncana fornicata PLUMMER 1931

Pl. 1, fig. 2

Contusotruncana fornicata PLUMMER 1931, p. 130, pl. 13, figs. 4 a-c.
Rosita fornicata ROBASZYNSKI *et al.*, 1984, p. 251, pl. 38, figs. 1-4.
Rosita fornicata ÖZKAN and ALTINER, 1987, p.275, pl. 4, figs. 1-3;
p.277, pl. 5, fig 7.

Contusotruncana fornicata NORRIS, 1992, p. 171, pl. 2, figs. d-g.

Contusotruncana fornicata NEDERBRAGT, 1998, p. 399, pl. 1, fig. 3.

Contusotruncana fornicata ROBASZYNSKI *et al*., 2000. p. 481, p. 20, fig. 3.

Remarks:

This species is a low trochospiral form. It can be spiroconvex or biconvex in appearance. In this study, mostly the biconvex forms are observed and in these cases, *Contusotruncana fornicata* resembles *Globotruncana arca* in the lateral view. However, from the spiral and umbilical sides, these two forms can simply be separated by their chamber shape. Here, in contrast to *Globotruncana arca*, the chambers of this form are clearly more elongated both in spiral and in umbilical views. Also the lower chamber number (mostly 4 or 5) of *Contusotruncana fornicata* in its last tour and its more closely spaced keels with a narrow imperforate peripheral band are other differences from *Globotruncana arca*. Within the genus, this form looks like *Contusotruncana patelliformis* and *Contusotruncana plummerae*. Its difference from *Contusotruncana patelliformis* is that *Contusotruncana fornicata* has a low convex spiral side, whereas it can be differentiated from the biconvex *Contusotruncana plummerae* in the absence of the inflated chambers in its last whorl. The stratigraphic range of *Contusotruncana fornicata* is from the top of the *Dicarinella concavata* Zone (Santonian) to the middle part of the *Ganserina gansseri* Zone (middle Maastrichtian) (Robaszynski *et al*., 1984).

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Contusotruncana patelliformis GANDOLFI, 1955

Pl. 1, fig. 3; Pl. 11, fig. 2

Contusotruncana patelliformis GANDOLFI, 1955, p. 54, pl. 4, figs. 2 a-c.

Rosita patelliformis ROBASZYNSKI *et al.*, 1984, p. 253, pl. 39, figs. 1-3.

Contusotruncana patelliformis ROBASZYNSKI *et al.*, 2000, p. 481, p. 20, fig. 5.

Contusotruncana patelliformis PREMOLI-SILVA and VERGA, 2004, p. 79, p. 9, figs. 2-4.

Remarks:

Contusotruncana patelliformis looks like the other spiroconvex species of the genus *Contusotruncana.* Actually it has a lower trochospire than *Contusotruncana contusa* and *Contusotruncana plicata* and higher trochospire than *Contusotruncana fornicata.* Moreover, the diameter of the test of this form is larger than all other members of genus *Contusotruncana*. Its range is Campanian-Maastrichtian (Robaszynski *et al.*, 1984) and it is more abundant below the *Racemiguembelina fructicosa* Zone in this study.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Contusotruncana plicata WHITE, 1928

Pl. 11, figs. 3-5

Contusotruncana plicata WHITE, 1928, p.285, pl. 38.

Rosita plicata ROBASZYNSKI *et al.*, 1984, p. 255, pl. 40, figs. 1-2.

Rosita plicata ÖZKAN and ALTINER, 1987, p.273, pl. 3, figs. 10-12; p. 275, pl. 5, fig. 8.

Contusotruncana plicata ÖZKAN-ALTINER and ÖZCAN, 1999, p. 294, pl. 2, fig. 4.

Contusotruncana plicata ROBASZYNSKI *et al.*, 2000. p. 469, p. 14, fig. 3.

Contusotruncana plicata PREMOLI-SILVA and VERGA, 2004, p. 80, p. 10, figs. 1, 2.

Remarks:

Since the spiroconvex appearance of the other members of the genus *Contusotruncana*, this species can be confused with *Contusotruncana contusa, Contusotruncana fornicata* and *Contusotruncana patelliformis.* As mentioned above, the degree of trochospire helps in deciding the species. In this manner, *Contusotruncana plicata* has a lower trochospire than *Contusotruncana contusa* and it has a higher trochospire than the other two forms. Test of this form is highly lobate and its chambers have a distinguishing view with their bulging, inflated appearances. The range of the form is middle and upper Maastrichtian (Robaszynski *et al.*, 1984). Here, it is richer in the lower and middle parts of the measured section (Late Campanian (AG 133) to the top of the *Planoglobulina acervuloinides* Zone (AG 151)).

Occurrence:

From sample AG 120 (base of the measured section) to AG 175 (upper parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Contusotruncana plummerae **GANDOLFI, 1955**

Pl. 2, fig. 1

Contusotruncana plummerae GANDOLFI, 1955, p. 340, pl. 2, figs. 3 a-c.
Rosita plummerae ROBASZYNSKI *et al.*, 1984, p. 257, pl. 41, figs. 1-6.
Contusotruncana plummerae ROBASZYNSKI *et al.*, 2000. p. 481, p. 20, fig. 6.
Contusotruncana plummerae PREMOLI-SILVA and VERGA, 2004, p. 80, p. 10, figs. 3, 4; p. 81, pl. 11, fig.1.

Remarks:

This form is the only species belongs to the genus *Contusotruncana* without having an exact spiroconvex appearance of its test and the position of its keels in the middle part of the test. By this appearance it can be classified under the genus *Globotruncana*. However its closely spaced keels with a narrow imperforate peripheral band and portici that cover its umbilicus are provide it to be included in genus *Contusotruncana*. Its inflated chambers are another characteristic of this form. The stratigraphic range of this from is form the *Globotruncanita elevata* Zone to the lower part of the *Gansserina gansseri* Zone (Robaszynski *et al.*, 1984). In this study, similar to *Contusotruncana plicata*, it is richer in the lower and middle parts of the measured section (Late Campanian (AG 132) to the top of the *Planoglobulina acervuloinides* Zone (AG 151)).

Occurrence:

From sample AG 126 (middle parts of the *Globotruncana aegyptiaca* and *Pseudotextularia elegans* zones) to AG 176 (upper parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Contusotruncana walfishensis TODD, 1970

Pl. 2, fig. 2; Pl. 11, fig. 6

Contusotruncana walfishensis TODD, 1970, p. 153, pl. 5, figs. 8 a-b.

Rosita walfishensis ROBASZYNSKI *et al.*, 1984, p. 259, pl. 42, figs. 1-4.

Rosita walfishensis ÖZKAN and ALTINER, 1987, p.273, pl. 3, figs. 13-15; p. 275, pl. 5, fig. 11.

Contusotruncana walfishensis NORRIS, 1992, p. 171, pl. 2, fig. c.

Contusotruncana walfishensis ROBASZYNSKI *et al.*, 2000. p. 481, p. 20, fig. 9.

Contusotruncana walfishensis CHACON et al., 2004, p. 589, fig. 3 B; p. 590, fig. 4 E, F.

Contusotruncana walfishensis PREMOLI-SILVA and VERGA, 2004, p. 81, p. 11, figs. 2-4.

Remarks:

Contusotruncana walfishensis is the one of the most typical forms with its robust test in contrast to its small size. Actually, it dislikes the other species of *Contusotruncana* with this property. In this study, it is one of the uncommon species, generally rare than 2%. Its range has been defined as from the upper part of the *Globotruncana falsostuarti* Zone through the *Abathomphalus mayaroensis* Zone which includes Maastrichtian except its base (Robaszynski *et al.*, 1984).

Occurrence:

From sample AG 122 (lower parts of the *Globotruncana aegyptiaca* and *Pseudotextularia elegans* zones) to AG 173 (middle parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Genus *Gansserina* CARON et al., 1984

Type Species: *Globotruncana gansseri* BOLLI, 1951

Gansserina gansseri BOLLI, 1951

Pl. 2, fig. 3; Pl. 12, figs. 15, 16

Globotruncana gansseri BOLLI, 1951, pl. 35, figs. 1-3.
Gansserina gansseri ROBASZYNSKI *et al.*, 1984, p. 295, pl. 52, figs. 1-4.
Gansserina gansseri ÖZKAN and ALTINER, 1987, p.275, pl. 4, figs. 10-12.
Gansserina gansseri NORRIS, 1992, p.169, pl. 1, figs. k-m.
Gansserina gansseri CHUNGKHAM and JAFAR, 1998, p. 75, pl. 1, figs. 4 a-c. *Gansserina gansseri* ÖZKAN-ALTINER and ÖZCAN, 1999, p. 294, pl. 2, fig. 8, 10.
Gansserina gansseri ROBASZYNSKI *et al.*, 2000. p. 473, p. 16, fig. 1-3; p. 479, p. 19, fig. 13.
Gansserina gansseri CHACON et al., 2004, p. 589, fig. 3 D; p.590, fig. 4 G, H.
Gansserina gansseri OBAIDALLA, 2005, p. 215, pl. 1, fig. 1.

Remarks:

It is one of the most debatable forms due to its resemblance to *Globotruncanit*a *angulata.* These two forms can be separated by the hemispherical test, its depressed umbilical sutures, the absence of sutural ridges, the pustules developed in its surface. The definition that is used for *Gansserina gansseri* by Robaszynski *et al.* (1984) isn’t used in the recognition of the form in this study. Since the adumbilical ridges are observed in some of the photographs of this form published in the different studies (Robaszynski *et al.*, 1984; Norris, 1992; Özkan-Altıner and Özcan, 1999; Robaszynski *et al.*, 2000; Obaidalla, 2005), the item of “the absence of the adumbilical ridges” isn’t taken into consideration. In that manner, the forms without adumbilical ridges directly included into *Gansserina gansseri*, while the other properties that are mentioned above were examined for the differentiation of *Gansserina gansseri* and *Globotruncanita angulata* in the forms bearing adumbilical ridges. In this study, like other one involving biostratigraphy, the first occurrence of *Gansserina gansseri* is used in the determination of the biozone. Hence, this form can be observed above the middle parts of the studied section (above the upper part of the *Pseudotextularia elegans* Zone). However, it is also one of the rare forms in the present study.

Occurrence:

From sample AG 137 (*Gansserina gansseri* Zone) to AG 177 (top of the Maastrichtian).

Genus *Globotruncana* CUSHMAN, 1927

Type species: *Pulvinulina arca* CUSHMAN, 1926

Globotruncana aegpytiaca NAKKADY, 1950

Pl. 3, fig 1; Pl. 11, figs. 7, 8

Globotruncana aegpytiaca NAKKADY, 1950, p. 690, pl. 80, fig. 20.

Globotruncana aegpytiaca ROBASZYNSKI et al*.,* 1984, p. 179, pl. 2, figs. 1–6; p. 181, pl. 3, figs. 1–4.

Globotruncana aegyptiaca ÖZKAN and ALTINER, 1984, p. 269, pl. 1, figs. 13-15.

Globotruncana aegyptiaca KELLER, 1988, p. 250, pl.1, fig. 6.

Globotruncana aegyptiaca NORRIS, 1992, p.181, pl. 7, figs. c, d.

Globotruncana aegyptiaca NEDERBRAGT, 1998, p. 399, pl .1, figs. 6, 7; p. 401, pl. 2, fig. 1.

Globotruncana aegyptiaca ÖZKAN-ALTINER and ÖZCAN, 1999, p. 292, pl. 1, fig. 11.

Globotruncana aegyptiaca ARENILLAS *et al.*, 2000. p. 43, pl. 1, fig. 11, 12.

Globotruncana aegyptiaca ROBASZYNSKI *et al.*, 2000. p. 465, p. 12, fig. 1, 2; p. 479, p. 19, fig. 12.

Globotruncana aegyptiaca CHACON et al., 2004, p. 589, fig. 3 E.

Remarks:

This form is one of the important forms, since its first occurrence defines the lower boundary of *Globotruncana aegpytiaca* Zone, which is the lower globotruncanid zone observed in this study. In the lateral view this form resembles *Globotruncana ventricosa* according to the position of its keels. However *Globotruncana aegpytiaca* has lower number of hemispherical chambers. On the other hand, it is differentiated from the other species of *Globotruncana* by having relatively lower number of chambers and having globular chambers. The stratigraphic range of this form continues throughout the Maastrichtian as observed in our samples.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Globotruncana arca CUSHMAN, 1926

Pl. 3, fig 2; Pl. 11, figs. 9, 10

Globotruncana arca CUSHMAN, 1926, p. 23, pl.3, fig.1.

Globotruncana arca ROBASZYNSKI *et al.*, 1984, p. 183, pl. 3, figs. 1–3.

Globotruncana arca KELLER, 1988, p. 250, pl.1, figs. 7, 8, 11.

Globotruncana arca NORRIS, 1992, p. 175, pl. 4, fig. j, k; p. 181, pl. 7, fig. e.

Globotruncana arca NEDERBRAGT, 1998, p. 401, pl .2, fig. 2 (not 3, 4).

Globotruncana arca ROBASZYNSKI *et al.*, 2000. p. 481, p. 20, fig. 4.

Globotruncana arca CHACON et al., 2004, p. 589, fig. 3 F.

Globotruncana arca OBAIDALLA, 2005, p. 217, pl. 2, fig. 1, 2.

Remarks:

It is one of the most abundant species in this study with its very wide imperforate peripheral band and widely spaced keels. By this property, detection of this form is very easy. By the shape of its chambers and the slowly increasing chamber size, *Globotruncana arca* looks like *Globotruncana orientalis,* nevertheless the keels of *Globotruncana orientalis* are more closely spaced with respect to *Globotruncana arca.* This form has a wide stratigraphic range from Campanian to Maastrichtian and it is observed all through the measured section.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Globotruncana bulloides VOGLER, 1941

Pl. 3, fig 3; Pl. 11, fig. 11

Globotruncana linnei (d'Orbigny) subsp. *bulloides* VOGLER, 1941, p. 287, pl. 23, figs. 32-39.

Globotruncana bulloides ROBASZYNSKI *et al.*, 1984, p. 187, pl. 6, figs. 1–4.

Globotruncana bulloides NORRIS, 1992, p.173, pl. 3, figs. a, b.

Globotruncana bulloides ROBASZYNSKI *et al.*, 2000. p. 481, p. 20, fig. 1.

Globotruncana bulloides PREMOLI-SILVA and VERGA, 2004, p. 105, p. 35, figs. 2-4.

Remarks:

This form can be differentiated by its perfect inflated chambers and petaloid appearance of chambers in the spiral side. Double keels are separated widely and parallel in the lateral view. It differs from *Globotruncana linneiana* with the inflated chambers both in spiral and umbilical sides. Its stratigraphic range was determined as from the *Dicarinella asymetrica* Zone to the *Globotruncana falsostuarti* Zone (Upper Santonian-Lower Maastrichtian) (Robaszynski *et al.*, 1984). In the present study, this form is one of the rare forms, mostly smaller than 2% of the sample.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

***Globotruncana dupeublei* CARON et al., 1984**

Pl. 3, fig. 4

Globotruncana dupeublei CARON et al., 1984, pl. 7, fig. 1 a-c.
Globotruncana dupeublei ROBASZYNSKI *et al.*, 1984, p. 189, pl. 7, figs. 1–2.
Globotruncana dupeublei ÖZKAN and ALTINER, 1987, p. 275, pl. 5, fig. 3.
Globotruncana dupeublei ÖZKAN-ALTINER and ÖZCAN, 1999, p. 292, pl. 1, fig. 7.

Globotruncana dupeublei PREMOLI-SILVA and VERGA, 2004, p. 106, p. 36, figs. 1, 2.

Remarks:

This form has the largest number of chambers with 7-9 chambers in its last whorl. The perfect trapezoidal shape of its chambers is also very typical from the spiral side. By these two properties; this form is similar to *Globotruncana falsostuarti*. However, *Globotruncana dupeublei* has only a single keel, whereas *Globotruncana falsostuarti* bears double keels. Its range is the middle and upper parts of Maastrichtian (Robaszynski *et al.*, 1984). In this study, this form is concentrated on the middle parts of the section (from sample AG 132 to AG 152).

Occurrence:

From sample AG 128 (middle parts of the *Globotruncana aegyptiaca* and *Pseudotextularia* zones) to AG 171 (*Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Globotruncana esnehensis NAKKADY, 1950

Pl. 4, fig. 1

Globotruncana arca (Cushman) var. *esnehensis* NAKKADY, 1950, p. 690, pl. 90, figs. 23-26.

Globotruncana esnehensis ROBASZYNSKI *et al.*, 1984, p. 193, pl. 9, figs. 1–4.

Globotruncana esnehensis ÖZKAN and ALTINER, 1987, p. 275, pl. 5, fig. 1, 2, 10.

Globotruncana esnehensis PREMOLI-SILVA and VERGA, 2004, p. 106, p. 36, figs. 3, 4.

Remarks:

The second member of genus *Globotruncana* which is bearing a single keel is *Globotruncana esnehensis.* On the other hand, it differs from *Globotruncana dupeublei* by the less number of its chambers and more asymmetrical lateral view with more convex spiral side. The reason of the classification of this species under genus *Globotruncana* (but not under *Globotruncanita*) is its possession of tegilla instead of portici, like *Globotruncana dupeublei*. The range of this form is through Maastrichtian. Here, it is common in the upper and middle parts of the studied section (throughout the Maastrichtian), while abundance of the form decreases in the Campanian.

Occurrence:

From sample AG 128 (middle parts of the *Globotruncana aegyptiaca* and *Pseudotextularia* zones) to AG 175 (upper parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Globotruncana falsostuarti SIGAL, 1952

Pl. 4, fig. 2

Globotruncana falsostuarti SIGAL, 1952, p. 43, text fig. 46.

Globotruncana falsostuarti ROBASZYNSKI et al., 1984, p. 195, pl. 10, figs. 1–3.

Globotruncana falsostuarti NORRIS, 1992, p. 175, pl. 4, fig. g-i.

Globotruncana falsostuarti ROBASZYNSKI *et al.*, 2000. p. 473, p. 16, fig. 4, 5; p. 479, p. 19, fig. 11.

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

Globotruncana falsostuarti PREMOLI-SILVA and VERGA, 2004, p. 107, p. 37, figs. 1, 2.

Remarks:

This form can be recognized and separated from other forms by its trapezoidal chambers in spiral side, great number of chambers in the last whorl (7-8 chambers), slow increase in the chamber size, double keels which are getting closer in the middle part of the chambers (the most distinctive property) and its biconvex test. Its stratigraphic range is throughout the Maastrichtian. In some of the previous studies including (Robaszynski, 1984), the first appearance of this form marks lower boundary of *Globotruncana falsostuarti* Zone that indicates the start of the Maastrichtian stage. In the samples studied in this thesis, this form is more common in the lower and middle parts of the section (up to the base of the *Racemiguembelina fructicosa* Zone).

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

***Globotruncana insignis* GANDOLFI, 1955**

Pl. 4, fig. 3

Globotruncana rosetta (Carsey) subsp. *insignis* GANDOLFI, 1955, p. 67, pl. 6, figs. 2 a-c.

Globotruncana insignis ROBASZYNSKI et al., 1984, p. 197, pl. 11, figs. 1–3; p 199, pl. 12, figs. 1-3.

Globotruncanita insignis LONGORIA and VON FELDT, 1991, p. 229, pl. 5, figs. 1-8; p. 235, pl. 8, figs. 4, 5.

Globotruncana insignis PREMOLI-SILVA and VERGA, 2004, p. 108, p. 38, figs. 1, 2.

Remarks:

Globotruncana insignis is another debatable form with its resemblance to genus *Globotruncanita* with its single keel. Besides bearing tegilla, which could not be recognized in the studied specimens, it is discriminated form *Globotruncanita angulata* by its more acute peripheral angles, less conical umbilical side and more lobate outline. Its difference from *Globotruncanita pettersi* is its large number of chambers and it can be separated from *Globotruncana dupeublei* and *Globotruncana esnehensis* by its umbilico-convex appearance. The stratigraphic range of *Globotruncana insignis* is from the middle part of the *Globotruncana ventricosa* Zone (middle Campanian) to the end of Maastrichtian (Robaszynski, 1984). In the studied samples, it is mostly rare than 2% and concentrated in the lower and middle part of the section mostly throughout the Campanian.

Occurrence:

From sample AG 123 (lower parts of the *Globotruncana aegyptiaca* and *Pseudotextularia* zones) to AG 174 (upper parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Globotruncana linneiana D'ORBIGNY, 1839

Pl. 4, fig 4; Pl. 11, fig. 12

Rosalina linneiana D'ORBIGNY, 1839, p. 101, pl 5, figs. 10-12.

Globotruncana linneiana ROBASZYNSKI et al., 1984, p. 201, pl. 13, figs. 1–4; p. 203, pl. 14, figs. 1-5.

Globotruncana linneiana ÖZKAN and ALTINER, 1987, p.271, pl. 2, figs. 1 – 3.

Globotruncana linneiana NORRIS, 1992, p.173, pl. 3, figs. c, d; p. 181, pl. 7, fig. a.

Globotruncana linneiana ROBASZYNSKI *et al.*, 2000. p. 465, p. 12, fig. 4.

Globotruncana linneiana PETRIZZO, 2001, p. 854, fig. 9. 6 a-c.

Globotruncana linneiana PREMOLI-SILVA and VERGA, 2004, p. 109, p. 39, figs. 2-4.

Remarks:

It is a very distinctive form with its box-like shape due to very wide double keels and chambers that are not inflated. Its stratigraphic range is from *Dicarinella concavata* Zone (Santonian) to *Gansserina gansseri* Zone (Maastrichtian) (Robaszynski, 1984) and it is common in lower and middle parts of the measured section (up to the middle parts of the *Gansserina gansseri* and *Racemiguembelina fructicosa* zones).

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Globotruncana mariei BANNER and BLOW, 1960

Pl. 4, fig. 5

Globotruncana mariei BANNER and BLOW, 1960, pl. 11, figs.6 a-c.

Globotruncana mariei ROBASZYNSKI et al., 1984, p. 205, pl. 15, figs. 1–6.

Globotruncana mariei ÖZKAN and ALTINER, 1987, p.271, pl. 2, figs. 13 – 15.

Globotruncana mariei PREMOLI-SILVA and VERGA, 2004, p. 110, p. 40, figs. 1-3.

Remarks:

This species also has a low number of chambers. However, it is distinguished by biconvex test from *Globotruncana aegyptiaca* and by the presence of two keels on all chambers from *Globotruncana rosetta*. The stratigraphic range of *Globotruncana mariei* is from *Dicarinella concavata* Zone (Santonian) to *Gansserina gansseri* Zone (Maastrichtian) (Robaszynski, 1984). It is identified mostly in the lower parts of the studied section (mostly along the Campanian).

Occurrence:

From sample AG 124 (lower parts of the *Globotruncana aegyptiaca* and *Pseudotextularia* zones) to AG 175 (upper parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Globotruncana orientalis **EL NAGGAR, 1966**

Pl. 4, fig. 6

Globotruncana orientalis EL NAGGAR, 1966, p. 125, pl. 12, figs. 4 a-d.

Globotruncana orientalis ROBASZYNSKI et al., 1984, p. 207, pl. 16, figs. 1–3; p. 209, pl 17, figs 1-4.

Globotruncana orientalis ÖZKAN and ALTINER, 1987, p.271, pl. 2, figs. 4 – 6.

Globotruncana orientalis NORRIS, 1992, p. 175, pl. 4, fig. a, b.

Globotruncana orientalis ÖZKAN-ALTINER and ÖZCAN, 1999, p. 292, pl. 1, fig. 6.

Globotruncana orientalis ROBASZYNSKI *et al.*, 2000. p. 475, p. 17, fig. 1; p. 481, pl. 20, fig. 7.

Globotruncana orientalis PREMOLI-SILVA and VERGA, 2004, p. 110, p. 40, fig. 4; p. 111, pl. 41, figs. 1, 2.

Remarks:

It is the biconvex species of *Globotruncana* having 5 to 7 chambers in its final whorl with the slow increase in its chamber size in contrast to species with a lower number of chambers. It is separated from *Globotruncana arca* by its more closely spaced keels and its less lobate outline; and from *Globotruncana falsostuarti* by its smaller number of chambers and its parallel keels. In this study, the abundance of this species is relatively higher in the Campanian part of the section.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Globotruncana rosetta CARSEY, 1926

Pl. 4, fig. 7

Globotruncana rosetta CARSEY, 1926, p. 44, pl. 5, figs. 3 a-b.

Globotruncana rosetta ROBASZYNSKI *et al.*, 1984, p. 211, pl. 18, figs. 1–5.

Globotruncana rosetta ÖZKAN and ALTINER, 1987, p.271, pl. 2, figs. 10 – 12.

Globotruncana rosetta PREMOLI-SILVA and VERGA, 2004, p. 111, p. 41, figs. 3, 4.

Remarks:

In this species, the double keels of the form is said to be less developed in the umbilical side and even absent in the final chambers (Robaszynski *et al.*, 1984). However, such an observation hasn’t been made in our samples and they are defined to have very close double keels. The difference of this species with other forms with a low number of chambers (generally 4 to 6), very slightly convex spiral side of *Globotruncana rosetta*. In our samples this form is identified mostly with 5 or 6 chambers in its last whorl and rapidly increasing chamber size. While its stratigraphic range is from *Globotruncana ventricosa* Zone (Upper Campanian) to the end of Maastrichtian, it is mostly observed throughout the Campanian.

Occurrence:

From sample AG 126 (middle parts of the *Globotruncana aegyptiaca* and *Pseudotextularia* zones) to AG 177 (top of the measured section).

Globotruncana ventricosa WHITE, 1928

Pl. 4, fig. 8; Pl. 11, figs.13, 14

Globotruncana canaliculata (REUSS) var. *ventricosa* WHITE, 1928, p. 284, pl. 38, figs. 5 a-c.

Globotruncana ventricosa ROBASZYNSKI *et al.*, 1984, p. 215, pl. 20, figs. 1–3; p. 217, pl. 21, figs. 1-4.

Globotruncana ventricosa CHUNGKHAM and JAFAR, 1998, p. 75, pl. 2, figs. 3-4. *Globotruncana ventricosa* ÖZKAN-ALTINER and ÖZCAN, 1999, p. 294, pl. 2, fig. 6.

Globotruncana ventricosa ROBASZYNSKI *et al.*, 2000. p. 465, p. 12, fig. 3, 5; p. 479, p. 19, fig. 10.

Globotruncana ventricosa PETRIZZO, 2001, p. 854, fig. 9. 4 a-c.

Globotruncana ventricosa CHACON et al., 2004, p. 589, fig. 3 H.

Remarks:

This form resembles *Globotruncana aegyptiaca* by its lateral view with its nearly flat spiral side, the position of its keels and the convexity of the umbilical side. However *Globotruncana ventricosa* has a large number of triangular chambers in its last whorl. The first appearance of this form defines the lower boundary of Middle Campanian *Globotruncana ventricosa* Zone and it ranges up to *Gansserina gansseri* Zone. This form is most common upto the base of the *Racemiguembelina fructicosa* Zone in the measured section.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Genus *Globotruncanita* REISS, 1957

Type species: *Rosalina stuarti* de lapparent, 1918

Globotruncanita angulata TILEV, 1951

Pl. 5, fig. 1; Pl. 11, figs. 15-17

Globotruncanita lugeoni TILEV var. *angulata* TILEV, 1951, p. 46, pl. 3, figs. 13a-c.

Globotruncanita angulata ROBASZYNSKI *et al.*, 1984, p. 221, pl. 23, figs. 1–5.

Globotruncanita angulata NORRIS, 1992, p.169, pl. 1, figs. e, f.

Globotruncanita angulata ROBASZYNSKI *et al.*, 2000. p. 475, p. 17, fig. 2; p. 479, p. 19, fig. 14.

Globotruncanita angulata PREMOLI-SILVA and VERGA, 2004, p. 115, p. 45, figs. 1, 2.

Remarks:

As mentioned before, *Globotruncanita angulata* is one of the problematic forms in taxonomy. Because of the discussion on the presence of adumbilical ridges, this form is confused with *Gansserina gansseri*. In this study, the forms with straight sutures on spiral side (a distinctive property in most of the forms of genus *Globotruncanita)* and the presence of the sutural ridges; hence the presence or absence of the adumbilical ridges isn't a priority in the differentiation of these two forms. A second form that resembles to this species is *Globotruncanita pettersi* and those two forms are discriminated by the higher number of chambers of *Globotruncanita angulata* in its final whorl (generally 6 chambers) and its less lobate outline. This is one of the most abundant species in our samples. Its range is defined by Robaszynski *et al.* (1984) as from the top of *Globotruncana falsostuarti* Zone to the end of Maastrichtian. In this study, this form is common along the *Gansserina gansseri* Zone.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Globotruncanita conica WHITE, 1928

Globotruncana conica WHITE, 1928, p. 285, pl. 38, figs. 7 a-c.

Globotruncanita conica ROBASZYNSKI *et al.*, 1984, p. 227, pl. 26, figs. 1–3.

Globotruncanita conica LONGORIA and VON FELDT, 1991, p. 223, pl. 2, figs. 1-6; p. 237, pl. 9, figs. 12-15; p. 239, pl. 10, fig. 1, 3, 9; p. 241, pl. 11, figs. 11, 16.

Globotruncanita conica CHACON et al., 2004, p. 589, fig. 3 J.

Globotruncanita conica OBAIDALLA, 2005, p. 217, pl. 2, figs. 4, 5.

Remarks:

It is the least common form in abundance that is recognized only in the two samples (AG 133 and AG 142). It can be differentiated by its single keel, its circular outline and conical form because of its highly trochospiral test. The range of this form is Middle to Late Maastrichtian (Robazynski *et al.*, 1984).

Occurrence:

From sample AG 133 (middle parts of the *Gansserina gansseri* and *Pseudotextularia elegans* zones) to AG 142 (top of the Campanian).

Globotruncanita pettersi **GANDOLFI, 1955**

Pl. 5, fig. 2; Pl. 11, figs. 18-20

Globotruncana rosetta (CARSEY) subsp. *pettersi* GANDOLFI, 1955, p. 68, pl.6, figs. 3 a-c.

Globotruncanita pettersi ROBASZYNSKI *et al.*, 1984, p. 233, pl. 29, figs. 1–5.

Globotruncanita pettersi ÖZKAN and ALTINER, 1987, p. 273, pl. 3, figs. 1-3.

Globotruncanita pettersi ÖZKAN-ALTINER and ÖZCAN, 1999, p.294, pl. 2, fig. 5.

Globotruncanita pettersi PREMOLI-SILVA and VERGA, 2004, p. 118, p. 48, figs. 1, 2.

Remarks:

It is the member of genus *Globotruncanita* with its more conical umbilical side, its nearly flat spiral side, its low number of chambers in the last whorl (generally 4) and its lobate outline. Its range has been defined as from *Gansserina gansseri* Zone to the *Abathomphalus mayaroensis* Zone of

Robaszynski *et al.* (1984) and it is noticed in the upper and middle part of the measured section (Uppermost Campanian – Maastrichtian).

Occurrence:

From sample AG 130 (middle parts of the *Gansserina gansseri* and *Pseudotextularia elegans* zones) to AG 177 (top of the measured section).

Globotruncanita stuarti **DE LAPPARENT, 1918**

Pl. 5, fig. 3; Pl. 12, fig. 1

Rosalina stuarti DE LAPPARENT, 1918, p. 11, text-fig. 4, lower 3 figures.

Globotruncanita stuarti ROBASZYNSKI *et al.*, 1984, p. 235, pl. 30, figs. 1–3; p. 237, pl. 31, figs. 1-3.

Globotruncana dupeublei ÖZKAN and ALTINER, 1987, p.269, pl. 1, figs. 1-3.

Globotruncanita stuarti ÖZKAN and ALTINER, 1987, p.273, pl. 3, figs. 4-6.

Globotruncanita stuarti LONGORIA and VON FELDT, 1991, p. 223, pl. 2, figs. 7-12; p. 237, pl. 9, figs. 8-11; p. 241, pl. 11, figs. 8, 13, 14.

Globotruncanita stuarti NORRIS, 1992, p.169, pl. 1, figs. a, b, g; p. 181, pl. 7, fig. j

Globotruncanita stuarti ÖZKAN-ALTINER and ÖZCAN, 1999, p. 292, pl. 1, fig. 8.

Globotruncanita stuarti NEDERBRAGT, 1998, p. 403, pl .3, fig. 2 (not 3, 4).

Globotruncanita stuarti ROBASZYNSKI *et al.*, 2000. p. 467, p. 13, fig. 3; p. 479, p. 19, fig. 8.

Remarks:

This is one of the most characteristic forms with its perfect circular outline, its biconvex test and clearly observed trapezoidal chambers in the spiral side separated by straight sutures joining the spiral suture at right angles. The shape of its chambers set this species apart from *Globotruncanita stuartiformis*. The range of this form is throughout the Maastrichtian. In this study it is rare in abundance, but can be observed in most of the samples.

Occurrence:

From sample AG 121 (lowermost parts of the *Gansserina gansseri* and *Pseudotextularia elegans* zones) to AG 177 (top of the measured section).

Globotruncanita stuartiformis DALBIEZ, 1955

Pl. 5, fig. 4; Pl. 12, figs. 2-6

Globotruncana elevata (BROTZEN) subsp. *stuartiformis* DALBIEZ, 1955, p. 169, text-fig 10 a-c.

Globotruncanita stuartiformis ROBASZYNSKI *et al.*, 1984, p. 239, pl. 32, figs. 1–4.

Globotruncanita stuartiformis ÖZKAN and ALTINER, 1987, p.273, pl. 3, figs. 7-9.

Globotruncanita stuartiformis LONGORIA and VON FELDT, 1991, p. 231, pl. 6, figs. 1-12; p. 237, pl. 9, figs. 1-5; p. 239, pl. 10, figs. 2, 5, 8, 11, 16.

Globotruncanita stuartiformis NORRIS, 1992, p.169, pl. 1, figs. c, d.

Globotruncanita stuarti NEDERBRAGT, 1998, p. 403, pl .3, fig. 3, 4.

Globotruncanita stuartiformis ROBASZYNSKI *et al.*, 2000. p. 467, p.13, fig.2; p. 479, pl.19, fig.6.

Remarks:

This form looks mostly like *Globotruncanita stıuarti*, however its triangular chambers in the spiral side separates those two forms. It is more abundant than *Globotruncanita stuarti* in our samples. The range is this form is from Upper Santonian to the end of Maastrichtian (Robaszynski *et al.,* 1984).

Occurrence:

From sample AG 131 (middle parts of the *Gansserina gansseri* and *Pseudotextularia elegans* zones) to AG 177 (top of the measured section).

Subfamily Abathomphalinae PESSAGNO, 1967

Genus *Abathomphalus* BOLLI, LOEBLICH and TAPPAN, 1957

Type Species: *Globotruncana mayaroensis* BOLLI, 1951

Abathomphalus intermedius BOLLI, 1951

Globotruncana intermedia BOLLI, 1951, pl. 35, figs. 7-9.

Abathomphalus intermedius ROBASZYNSKI *et al.*, 1984, p. 272, pl. 46, figs. 1 a-c.

Abathomphalus intermedius NORRIS, 1992, p.179, pl. 6, figs. k, l.

Abathomphalus intermedius ROBASZYNSKI *et al.*, 2000. p. 479, p. 19, fig. 17.

Abathomphalus intermedius PETRIZZO, 2001, p. 854, fig. 9. 10a-c; p.855, fig. 10.1a-c.

Abathomphalus intermedius PREMOLI-SILVA and VERGA, 2004, p.71, p.1, figs.1-3.

Remarks:

This form is observed in only two of the samples at the uppermost part of the measured section. It is a double-keeled form, however its keels hasn't developed perfectly and can be seen as peripheral band with rugosities. Its lateral view is alike *Globotruncanella pschadae*, however the lateral view of *Abathomphalus intermedius* is characterized by separated double keels. It is distinguished from *Abathomphalus mayaroensis* by its closer keels and biconvex test. The stratigraphic range of this form is from *Gansserina gansseri* Zone to the *Abathomphalus mayaroensis* Zone (Robaszynski *et al.,* 1984); however it has been identified in the middle to upper parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones in this study.

Occurrence:

From sample AG 173 to AG 175 (upper parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Abathomphalus mayaroensis BOLLI, 1951

Pl. 5, fig. 5

Globotruncana mayaroensis BOLLI, 1951, pl. 35, figs. 10-12.

Abathomphalus mayaroensis ROBASZYNSKI *et al.*, 1984, p.272, pl.46, figs.5a-c.

Abathomphalus mayaroensis ÖZKAN and ALTINER, 1987, p.275, pl.4, figs.13-15.

Abathomphalus mayaroensis NORRIS, 1992, p.179, pl.6, figs.m,n; p.181, pl.7, figs.h, i.

Abathomphalus mayaroensis CHUNGKHAM and JAFAR, 1998, p.75, pl.1, figs. 1-2.

Abathomphalus mayaroensis ÖZKAN-ALTINER and ÖZCAN, 1999, p.294, pl.2, fig.7.

Abathomphalus mayaroensis ARENILLAS et al., 2000, p. 43, pl. 1, figs. 13, 14.

Abathomphalus mayaroensis ROBASZYNSKI *et al.*, 2000. p 471, p.15, fig.3, 4.

Abathomphalus mayaroensis PETRIZZO, 2001, p. 855, fig. 10. 2 a-c.

Abathomphalus mayaroensis KAROUI-YAAKOUB et al., 2002,

Abathomphalus mayaroensis CHACON et al., 2004, p. 590, fig. 4 A, B.

Abathomphalus mayaroensis OBAIDALLA, 2005, p. 215, pl. 1, fig. 6.

Remarks:

Abathomphalus mayaroensis is an important form which defines the uppermost part of the Maastrichtian. As it is observed only in four of the studied samples (AG 170, AG 172, AG 173 and AG 174), its rareness becomes a big problem in the biostratigraphical studies of this thesis and caused the description of the second biozonation using the heterohelicids. It can be thought to be similar with *Globotruncana linneiana* due to its rectangular outline from the lateral view, but in contrast to this species, *Abathomphalus mayaroensis* has a slightly convex spiral side and slightly concave umbilical side.

Occurrence:

From sample AG 170 to AG 174 (along the *Abathomphalus mayaroensis* Zone and in the upper parts of the *Pseudoguembelina hariensis* Zone).

Genus *Globotruncanella* REISS, 1957

Type species: *Globorotalia pschadae* KELLER, 1946

Globotruncanella havanensis VOORWIJK, 1937

Pl. 6, fig. 1; Pl. 12, figs. 11, 12

Globotruncana havanensis VOORWIJK, 1937, p. 195, pl. 1, figs. 25, 26, 29.

Globotruncanella havanensis ROBASZYNSKI *et al.*, 1984, p. 267, pl.44, figs.4-6.

Globotruncanella havanensis KELLER, 1988, p. 250, pl.1, fig. 10.

Globotruncanella havanensis NORRIS, 1992, p.171, pl. 2, figs. i.

Globotruncanella havanensis ÖZKAN-ALTINER and ÖZCAN, 1999, p.294, pl. 2, fig. 9.

Globotruncanella havanensis ROBASZYNSKI *et al.*, 2000. p. 481, p. 20, fig. 13.

Globotruncanella havanensis PREMOLI-SILVA and VERGA, 2004, p. 113, p. 43, figs. 1, 2.

Globotruncanella havanensis OBAIDALLA, 2005, p. 217, pl. 2, fig. 6.

Remarks:

This form is differentiated from the other species of this genus that are identified in this study by in having 5 chambers. However, its last chamber is less developed in some of the specimens. The degree of its trochospire is various. This form is very common in most of the samples in this study. It has a range of uppermost Campanian-Maastrichtian and its occurrence defines the lower boundary of the *Globotruncanella havanensis* Zone (Robaszynski *et al.,* 1984). This species is common all along the studied section.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Globotruncanella petaloidea GANDOLFI, 1955

Pl. 6, fig. 2; Pl. 12, fig. 13

Globotruncana (Rugoglobigerina) petaloidea GANDOLFI subsp.
petaloidea GANDOLFI, 1955, p. 52, pl. 3, figs. 13 a-c.
Globotruncanella petaloidea ROBASZYNSKI *et al.*, 1984, p. 267, pl. 44, figs. 1-2.
Globotruncanella petaloidea KELLER, 1988, p. 250, pl.1, figs. 12, 13.
Globotruncanella petaloidea NORRIS, 1992, p.171, pl. 2, figs. j, k.
Globotruncanella petaloidea OBAIDALLA, 2005, p. 215, pl. 1, fig. 5.
Globotruncanella petaloidea PREMOLI-SILVA and VERGA, 2004, p. 114, p. 44, figs. 1, 2.

Remarks:

This form can be identified by having distinctly petaloidal 4 chambers in its last whorl. It has a distinct concavo-convex appearance in the lateral view. *Globotruncanella petaloidea* is also present in most of the samples in this study. The stratigraphic range of the form is throughout the Maastrichtian.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Globotruncanella pschadae KELLER, 1946

Pl. 6, fig. 3; Pl. 12, fig. 14

Globorotalia pschadae KELLER, 1946, p. 99, pl. 2, figs. 4-6.
Globotruncanella pschadae ROBASZYNSKI *et al.*, 1984, p. 267, pl. 44, figs. 7.
Globotruncanella havanensis NEDERBRAGT, 1998, p. 401, pl .2, fig. 5.
Globotruncanella pschadae ROBASZYNSKI *et al.*, 2000. p. 481, p. 20, fig. 14.
Globotruncanella pschadae PREMOLI-SILVA and VERGA, 2004, p. 114, p. 44, figs. 3, 4.

Remarks:

It is the less common form among the other *Globotruncanella* species with abundance mostly smaller than 2%. It is a biconvex form in which the keel formation starts with the row of meridional pustules. However, it can’t be thought as an exact keel. By this property, this form is different than *Abathomphalus intermedius*, which has a similar lateral view with *Globotruncanella pschadae*. The range of the form is from *Gansserina gansseri* Zone to the end of Maastrichtian.

Occurrence:

From sample AG 126 (middle parts of the *Globotruncana aegyptiaca* and *Pseudotextularia* zones) to AG 175 (upper parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Family Rugoglobigerinidae SUBBOTINA, 1959

Genus: *Archaeoglobigerina* PESSAGNO, 1967

Type species: *Archaeoglobigerina blowi* PESSAGNO, 1967

Archaeoglobigerina blowi PESSAGNO, 1967

Archaeoglobigerina blowi PESSAGNO, 1967, p. 316, pl. 59, figs. 5-7.

Archaeoglobigerina blowi ROBASZYNSKI *et al.*, 1984, p. 277, pl. 47, figs. 1-2.

Archaeoglobigerina blowi NORRIS, 1992, p. 173, pl. 3, fig. e.

Archaeoglobigerina blowi ROBASZYNSKI *et al.*, 2000. p. 481, p. 20, fig. 10.

Archaeoglobigerina blowi PREMOLI-SILVA and VERGA, 2004, p. 73, p. 3, figs. 1, 2.

Remarks:

This form resembles *Rugoglobigerina macrocephala* at first sight. However, the pustulose structure of this form separates it from the highly costate *Rugoglobigerina*. It dislikes *Archaeoglobigerina cretacea* in its smaller number of chambers. It has a very wide stratigraphic range from Upper Coniacian to the end of Maastrichtian, however it has been observed only in one of the samples of this study.

Occurrence:

Sample AG 162 (middle parts of the *Gansserina gansseri* and *Racemiguembelina fructicosa* zones).

Archaeoglobigerina cretacea D'ORBIGNY, 1840

Globigerina cretacea D'ORBIGNY, 1840, p. 34.

Archaeoglobigerina cretacea ROBASZYNSKI *et al.*, 1984, p. 277, pl. 47, figs. 3-6.

Archaeoglobigerina cretacea NORRIS, 1992, p. 173, pl. 3, figs. f-h, j (not i).

Archaeoglobigerina cretacea NEDERBRAGT, 1998, p. 399, pl .1, figs. 1, 2.

Archaeoglobigerina cretacea ROBASZYNSKI *et al.*, 2000. p. 471, p. 15, fig. 1.

Archaeoglobigerina blowi PREMOLI-SILVA and VERGA, 2004, p. 74, p. 4, figs. 2-4.

Remarks:

This form has a larger number of chambers and less lobate outline with respect to *Archaeoglobigerina blowi*. On the other hand, it is alike *Rugoglobigerina rugosa* or *Rugoglobigerina hexacamerata* except from non-costate surface. The biggest problem in the classification of these two genera is the distortion of the ornamentation of the forms because of the acid treatment. Since the difference of these two genera is type of surface ornamentations, it is difficult to decide the genera of the specimens. The stratigraphic range of *Archaeoglobigerina cretacea* is from *Dicarinella concavata* Zone to the base of the *Gansserina gansseri* Zone (Robaszynski *et al.*, 1984). However, it has a more restricted range in our section with a small percentage of specimens.

Occurrence:

From sample AG 142 (lower parts of the *Gansserina gansseri* Zone and the upper boundary of the Campanian (*Pseudotextularia elegans* Zone)) to AG 162 (middle parts of the *Gansserina gansseri* and *Racemiguembelina fructicosa* zones).

Genus: *Rugoglobigerina* BRONNIMANN, 1952

Type species: *Globigerina rugosa* PLUMMER, 1927

Rugoglobigerina hexacamerata BRONNIMANN, 1952

Pl. 7, fig.1

Rugoglobigerina reicheli hexacamerata BRONNIMANN, 1952, p. 23, pl. 2, figs. 10-12.
Rugoglobigerina hexacamerata ROBASZYNSKI *et al.*, 1984, p. 283, pl. 49, fig. 8.
Rugoglobigerina hexacamerata KELLER, 1988, p. 252, pl. 2, figs. 16, 17.
Rugoglobigerina hexacamerata NORRIS, 1992, p. 177, pl. 5, fig. a-d.
Rugoglobigerina hexacamerata NEDERBRAGT, 1998, p. 405, pl .4, figs. 1-4.

Remarks:

In this study, the members of genus *Rugoglobigerina* with 6 chambers and nearly flat outline are named as *Rugoglobigerina hexacamerata*. The stratigraphic range of this form is middle to upper Maastrichtian. In our samples, this form isn't as common as most of the other species of this genus.

Occurrence:

From sample AG 120 (base of the measured section) to AG 174 (upper parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Rugoglobigerina macrocephala BRONNIMANN, 1952

Pl. 7, fig. 2; Pl. 12, fig. 7

Rugoglobigerina macrocephala macrocephala BRONNIMANN, 1952, p. 25, pl. 2, figs. 1-3.

Rugoglobigerina macrocephala ROBASZYNSKI *et al.*, 1984, p. 283, pl. 49, fig. 7.

Rugoglobigerina macrocephala KELLER, 1988, p. 250, pl.1, fig. 3.

Rugoglobigerina macrocephala PREMOLI-SILVA and VERGA, 2004, p. 200, p. 130, figs. 1-4.

Remarks:

This form has 4 distinct chambers in which the increase in chamber size is very rapid. The last chamber of the form is approximately as large as the rest of whole test. Its range is middle to upper Maastrichtian (Robaszynski *et al.,* 1984). Here, it is more common in the Late Maastrichtian along the measured section.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Rugoglobigerina milamensis SMITH and PESSAGNO, 1973

Pl. 7, fig. 3; Pl. 12, fig. 8

Rugoglobigerina milamensis SMITH and PESSAGNO, 1973, p. 56, pl. 24, figs. 4-7.

Rugoglobigerina milamensis ROBASZYNSKI *et al.*, 1984, p. 287, pl. 50, fig. 3.

Rugoglobigerina milamensis PREMOLI-SILVA and VERGA, 2004, p. 201, p. 131, fig. 1.

Remarks:

Rugoglobigerina milamensis is the form with highest trochospire among the other members of *Rugoglobigerina*. It has a highly costate surface. The range of the form is middle to upper Maastrichtian. In this study, it is very rare and only observed in some of the samples in the lower part of the section (AG 120, AG 129, AG 132 and AG 136) besides AG 176.

Occurrence:

From sample AG 120 (base of the measured section) to AG 176 (uppermost parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Rugoglobigerina pennyi BRONNIMANN, 1952

Pl. 7, fig. 4

Rugoglobigerina rugosa pennyi BRONNIMANN, 1952, p. 34, pl. 4, figs. 1-3.

Rugoglobigerina pennyi ROBASZYNSKI *et al.,* 1984, p. 287, pl. 50, figs. 1 a-c.

Rugoglobigerina pennyi PREMOLI-SILVA and VERGA, 2004, p. 201, p. 131, figs. 2-4.

Remarks:

This is the most common species of genus *Rugoglobigerina* after *Rugoglobigerina rugosa*. In this study, this from is distinguished with its last chamber directed towards the umbilicus of the specimen, hence it has a higher trochospiral appearance than *Rugoglobigerina rugosa*. Its range is throughout the Maastrichtian except the basal part.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Rugoglobigerina rotundata BRONNIMANN, 1952

Pl. 7, fig. 5

Rugoglobigerina rugosa rotundata BRONNIMANN, 1952, p. 34, pl. 4, figs. 7-9.

Rugoglobigerina rotundata ROBASZYNSKI *et al.,* 1984, p. 287, pl. 50, figs. 2 a-c.

Rugoglobigerina rotundata NORRIS, 1992, p. 177, pl. 5, fig. g.

Rugoglobigerina rotundata CHACON et al., 2004, p. 589, fig. 3 L.

Remarks:

It is another robust species of *Rugoglobigerina*. Its difference from *Rugoglobigerina milamensis* is its lower trochospire and its pustulose surface instead of thick costae. This form is more abundant than *Rugoglobigerina milamensis.* Its range consists of *Gansserina gansseri* and

Abathomphalus mayaroensis Zones. It is more abundant in the Campanian along the studied section.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Rugoglobigerina rugosa **PLUMMER, 1926**

Pl. 7, fig. 6; Pl. 12, figs. 9, 10

Globigerina rugosa PLUMMER, 1926, p. 38, pl. 2, fig. 10 a.
Rugoglobigerina rugosa ROBASZYNSKI *et al.,* 1984, p. 283, pl. 49, figs. 4, 6.
Rugoglobigerina rugosa KELLER, 1988, p. 252, pl. 2, fig. 14.
Rugoglobigerina rugosa NORRIS, 1992, p. 177, pl. 5, fig. h, i; p. 181, pl. 7, fig. b.
Rugoglobigerina rugosa CHACON et al., 2004, p. 590, fig. 4 L.
Rugoglobigerina rugosa OBAIDALLA, 2005, p. 217, pl. 2, fig. 3.

Remarks:

This form is very common throughout the measured section. The strange thing is its permanent disappearance through the *Planoglobulina acervuloinides* Zone. Actually this disappearance is observed in almost all of the species of this genus in this interval. *Rugoglobigerina rugosa* is differentiated form other *Rugoglobigerina* with its flatter outline, 4-5 chambers in its last whorl, rapid increase in the chamber size and absence of the spines (Robaszynski *et al.,* 1984). The stratigraphic range of the form is stated as Campanian and Maastrichtian (Robaszynski *et al.,* 1984) and it is very common all along the measured section.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Superfamily Heterohelicacea CUSHMAN, 1927
Family Heterohelicidae CUSHMAN, 1927
Subfamily Heterohelicinae CUSHMAN, 1927

Genus: *Gublerina* KIKOINE, 1948

Type species: *Gublerina cuvillieri* KIKOINE, 1948

Gublerina acuta DE KLASZ, 1953

Pl. 8, fig. 1

Gublerina acuta DE KLASZ 1953b, p. 246, 247, pl.8, figs. 3a, b.
Gublerina hedbergi BRÖNNIMANN and BROWN 1953, p. 155, text figs. 11,12.
Gublerina acuta NEDERBRAGT 1991, p. 345, pl. 1, figs. 1a, 2.
Gublerina acuta PETRIZZO, 2001, p. 855, fig. 10. 11 a-c.

Remarks:

This form can be differentiated by its widely flaring test and its one or two sets of globular multiserial chamberlets. Its edge view is very thin like in the genus *Laeviheterohelix*; however *Gublerina acuta* is different than this genus by its multiserial chamberlets, its apertures and its ornamented surface with vermicular ornamentations or thin costae. It dislikes the other species of *Gublerina, Gublerina cuvillieri,* by the sharper initial part and by its widely flaring test throughout its side view. Nederbragt (1991) stated the stratigraphic range of this form as from the upper part of the *G. calcarata* Zone to the top of the *A. mayaroensis* Zone. *Gublerina acuta* is a species rarely observed through all other zones except the *Planoglobulina acervuloinides* Zone in this study

Occurrence:

From sample AG 126 (middle parts of the *Globotruncana aegyptiaca* and *Pseudotextularia* zones) to AG 174 (upper parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Gublerina cuvillieri KIKOINE, 1948

Pl. 8, fig. 2

Gublerina cuvillieri KIKOINE, 1948, p. 26, pl. 2, figs. 10a-c.

Gublerina glasessneri BRÖNNIMANN and BROWN 1953, p. 155, 156, text figs. 13, 14.

Gublerina cuvillieri NEDERBRAGT, 1991. p. 345, pl. 1, figs. 3-4b.

Gublerina cuvillieri ARENILLAS *et al.*, 2000. p. 43, pl. 1, fig. 1, 2.

Remarks:

This form can be distinguished form *Gublerina acuta* by its initial chambers that are rapidly increasing in size, so it gains a more globular appearance throughout the initial part of its side view. The stratigraphic range of this form has been determined form the middle part of the *G. gansseri* Zone to the top of the *A. mayaroensis* Zone. In this study, this species is seen in most of the samples.

Occurrence:

From sample AG 121 (lower parts of the *Globotruncana aegyptiaca* and *Pseudotextularia* zones) to AG 176 (upper parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Genus: *Heterohelix* EHRENBERG, 1843

Type species: *Textilaria americana* EHRENBERG, 1843

Heterohelix globulosa EHRENGERG, 1840

Pl. 8, fig. 3; Pl. 13 figs. 2, 3

Heterohelix globulosa EHRENGERG, 1840, p. 135, pl. 4, figs. 2b, 4b, 5b, 7b, 8b.
Guembelina reussi CUSHMAN, 1938, p. 11, pl. 2, figs. 6-9.
Heterohelix globulosa NEDERBRAGT, 1991, p. 347, pl. 2, figs. 1a-2b.
Heterohelix globulosa DE KLASZ *et al.*, 1995, p. 367, pl. 2, fig.3.
Heterohelix globulosa LUCIANI, 2002, p. 312, pl. 1, fig. 7-10.
Heterohelix globulosa OBAIDALLA, 2005, p. 215, pl. 1, fig. 10.

Remarks:

Heterohelix globulosa is the simplest form of the genus *Heterohelix* with its globular chambers. In the description of Nederbragt (1991), it is said that this form may have an initial coiling part, but in the samples of the present study, such an observation hasn't been made. The stratigraphic range of *Heterohelix globulosa* is from Turonian to the top of the Maastrichtian. Here in this study, this form is observed in all of the samples and it is one of the most common forms of this study.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Heterohelix labellosa NEDERBRAGT, 1991

Pl. 8, fig. 4; Pl. 13 figs. 4, 5

Heterohelix labellosa NEDERBRAGT, 1991, p. 347, pl. 2, figs. 4a-c, 3, 5a-b.

Heterohelix labellosa PREMOLI-SILVA and VERGA, 2004, p. 141, p. 71, figs. 1-3.

Remarks:

This form has many different morphotypes with variable chamber shape and strength of costae. In this study *Heterohelix* forms with reniform adult chambers and thinner chamber depth are accepted as the members of this form. While the sides of its juvenile part are widely flaring, sides of the adult part become nearly parallel. Because of the acid treatment, costae of the forms mostly cannot be observed; however the ones strength of the observable costae is variable in this form as defined. Its range is stated as Maastrichtian. In this study, this form is common in all of the samples.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Heterohelix navarroensis LOEBLICH, 1951

Pl. 8, fig. 5

Spiroplecta americana EHRENBERG, 1854, p. 854, pl. 32II, fig. 25.

Heterohelix navarroensis LOEBLICH, 1951, p. 107, 108, pl. 12, figs. 1-3; text fig. 2.

Heterohelix navarroensis KELLER, 1988, p. 252, pl. 2, fig. 5.

Heterohelix navarroensis NEDERBRAGT, 1991, p. 349, pl. 3, figs. 5a-b.

Heterohelix navarroensis LUCIANI, 2002, p. 312, pl. 1, fig. 1.

Remarks:

Heterohelix navarroensis is one of the most specific forms of this genus with its nearly parallel sides. As it is defined with a distinct spiral coil (Nederbragt, 1991), such a planispiral stage hasn't been observed in our specimens. However, it can be distinguished by the semicircular view of its juvenile part through its side view. Most of the specimens of this form are larger among the other heterohelicids. The stratigraphic range of this species is Campanian to Maastrichtian. In this study, *Heterohelix navarroensis* is described in most of the samples

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Heterohelix planata CUSHMAN, 1938

Pl. 8, fig. 6; Pl. 13 fig 6

Heterohelix planata CUSHMAN, 1938, p. 12, 13, pl. 2, figs. 13, 14.

Heterohelix planata NEDERBRAGT, 1991, p. 349, pl. 3, figs. 3-4c.

Heterohelix planata PREMOLI-SILVA and VERGA, 2004, p. 142, p. 72, figs.7-9.

Remarks:

In this form the chamber shape was defined as ovate. However, in our samples the chamber shape can be described as globular to subglobular in side view. Although it can be confused with *Heterohelix globulosa* with this definition, it is differentiated from this form by its edge view which has a thin chamber depth similar with *Heterohelix labellosa*. Thin costae can be seen in some of the forms, while the other's costae were deformed because of the acid treatment. This form has a wide range from the uppermost part of the *D. asymetrica* Zone to the top of the *A. mayaroensis* Zone. Here it is observed in most of the samples and become more abundant in the upper parts of the section.

Occurrence:

From sample AG 120 (base of the measured section) to AG 176 (upper parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Heterohelix punctulata **CUSHMAN, 1938**

Guembelina punctulata CUSHMAN, 1938, p. 13, pl. 2, figs. 15, 16.
Pseudotextularia echevarriai SEIGLIE 1959, p. 59, pl. 3, figs. 2-6.
Heterohelix punctulata KELLER, 1988, p. 252, pl. 2, fig. 10.
Heterohelix punctulata NEDERBRAGT, 1991, p. 349, pl. 3, figs. 6a-b.

Remarks:

This is one of the rare forms mostly observed less than 5% only in some of the samples. It resembles *Heterohelix globulosa* with the subglobular chambers seen in its side view, but in the edge view, the shape of chambers of *Heterohelix punctulata* becomes ovate or rectangular, because this form has chambers that are deeper than wide or high. Like *Heterohelix planata*, the range of this form is also stated as uppermost part of the *D. asymetrica* Zone to the top of the A. mayaroensis Zone (Robaszynski *et al.*, 1984).

Occurrence:

From sample AG 127 (middle parts of the *Globotruncana aegyptiaca* and *Pseudotextularia* zones) to AG 177 (top of the measured section).

Heterohelix semicostata CUSHMAN, 1938

Guembelina semicostata CUSHMAN, 1938, p. 16, pl. 3, figs. 6a-b.

Heterohelix semicostata NEDERBRAGT, 1991, p. 351, pl. 4, figs. 2a-b, 4a-b.

Heterohelix semicostata PREMOLI-SILVA and VERGA, 2004, p. 144, p. 74, figs. 4, 5.

Remarks:

Heterohelix semicostata can be easily differentiated by its compressed appearance form edge view, its widely flaring juvenile part developed into subparallel sides in adult chambers and its costae, which is the strongest among all of the observed *Heterohelix* forms. Its range is uppermost Campanian to lowermost Maastrichtian (Nederbragt, 1991). In this study, this form is more abundant in the Maastrichtian.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Genus: *Laeviheterohelix* NEDERBRAGT, 1991

Type species: *Guembelina pulchra* BROTZEN, 1936

Laeviheterohelix dentata STENESTAD, 1968

Pl. 9, fig. 1

Heterohelix dentata STENESTAD, 1968, p.67, 68, pl. 1, figs. 3-6, 8, 9; pl. 2, figs. 1-3.
Laeviheterohelix dentata NEDERBRAGT, 1991, p. 353, pl. 5, figs. 1-2c.
Heterohelix dentata LUCIANI, 2002, p. 312, pl. 1, fig. 2.

Remarks:

This form can be defined by its smooth surface, which separates the genus from the other heterohelicids, its widely flaring sides, its reniform chambers and its very narrow edge view. The form has an initial spiral coiling part. However, in the studied samples, this coiling cannot be observed in the initial part. The stratigraphic range of this form is Late Campanian to end of the Maastrichtian and in the studied section it is more common in the Middle to Late Maastrichtian.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Laeviheterohelix glabrans CUSHMAN, 1938

Pl. 9, fig. 2

Guembelina glabrans CUSHMAN, 1938, p. 15, pl. 3, figs. 1, 2.
Laeviheterohelix glabrans NEDERBRAGT, 1991, p. 353, pl. 5, figs. 6a-b.
Laeviheterohelix glabrans PREMOLI-SILVA and VERGA, 2004, p.148, pl.78, figs.1, 2.

Remarks:

Laeviheterohelix glabrans is the second species of this genus observed in this study. It is more common than *Laeviheterohelix dentata*, as it is almost recorded in all of the samples. It is differentiated from *Laeviheterohelix glabrans* by its subglobular chambers in the side view (described as lentil-shaped by Nederbragt, 1991). The stratigraphic range of this form is Late Campanian to the end of Maastrichtian. In this study, this form has been identified in a variety of the samples.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Genus: *Planoglobulina* CUSHMAN, 1927

Type species: *Guembelina acervuloinides* EGGER, 1902

Planoglobulina acervuloinides EGGER, 1899

Pl. 9, fig. 3; Pl. 13 fig 9

Guembelina acervuloinides EGGER, 1899, p. 35, pl. 14, fig. 20.

Planoglobulina acervuloinides (Egger) – MARTIN 1972, p. 81, pl. 3, figs. 3-6.

Planoglobulina acervuloinides NEDERBRAGT, 1991, p. 355, pl. 6, figs. 5a-6; p. 357, pl. 7, figs. 1a-b.

Planoglobulina acervuloinides ÖZKAN-ALTINER and ÖZCAN, 1999, p. 292, pl. 1, fig. 9.

Planoglobulina acervuloinides ROBASZYNSKI *et al.*, 2000. p. 481, p. 20, fig. 17.

Remarks:

This form is a *Planoglobulina* species with the biserial part followed by up to 6 sets of multiserial chamberlets. In the specimens observed in this study, the chamberlets are mostly 3-4 sets. Chambers and chamberlets are globular to subglobular. From the edge view, this form is compressed towards its both ends and inflated in the middle part. *Planoglobulina acervuloinides* is defined to be covered by distinct costae. This property distinguishes it from *Planoglobulina riograndensis* which has fine vermicular ornamentation and fine, discontinuous costae. However, in our specimens, the distinct costae that define the form can easily be observed, while costae are disappeared in the others because of the acid treatment. So, it becomes impossible to differentiate these two forms and all of such specimens are named under this species due to its stratigraphic range that has been defined as middle part of *Gansserina gansseri* Zone to top of the *Abathomphalus mayaroensis* Zone. On the other hand, according to the second biozonation described by using heterohelicids, *Planoglobulina acervuloinides* is a form that defines a biozone with the samples between AG 144 and AG 152, which is the lower boundary of the *Racemiguembelina fructicosa* Zone. It is very common within this range, while its abundance decreasing in the upper parts although it doesn’t disappear up to the Cretaceous – Tertiary boundary.

Occurrence:

From sample AG 143 to AG 177 (throughout Maastrichtian)

Planoglobulina carseyae PLUMMER, 1931

Pl. 9, fig. 4; Pl. 13 fig 10

Ventilabrella carseyae PLUMMER, 1931, p. 178, 179, pl. 9, figs. 7-10.
Planoglobulina carseyae KELLER, 1988, p. 250, pl.1, fig. 16.
Planoglobulina carseyae NEDERBRAGT, 1991, p. 357, pl. 7, figs. 2-3.
Planoglobulina carseyae PREMOLI-SILVA and VERGA, 2004, p. 172, pl. 102, fig. 5.

Remarks:

This form has a biserial part followed by only one or two sets of multiserial chamberlets. Both chambers and chamberlets of the form are identified to be globular or reniform as in the original description. In the observations, the similarity of the side view of this form with *Pseudoguembelina hariensis* has been noticed. However, from the edge views these two forms can simply be distinguished. While *Planoglobulina carseyae* has a slowly flaring edge view, the edge view of *Pseudoguembelina hariensis* is compressed towards first and last chambers and inflated in the middle part. The range of this form has been defined as from *Gansserina gansseri* Zone to top of the *Abathomphalus mayaroensis* Zone; it becomes more abundant in the uppermost part of the measured section (along the *Pseudoguembelina hariensis* Zone).

Occurrence:

From sample AG 121 (lower parts of the *Globotruncana aegyptiaca* and *Pseudotextularia* zones) to AG 177 (top of the measured section).

Planoglobulina multicamerata **DE KLASZ, 1953a**

Pl. 9, fig. 35

Ventilabrella multicamerata DE KLASZ, 1953a, p. 230, pl. 5, figs. 1a, b.

Planoglobulina multicamerata NEDERBRAGT, 1991, p. 357, pl. 7, figs. 4-5.

Planoglobulina multicamerata ARENILLAS *et al.*, 2000. p. 43, pl. 1, fig. 3, 4.

Planoglobulina riograndensis ROBASZYNSKI *et al.*, 2000. p. 481, p. 20, fig. 18.

Remarks:

It is one of the most easily recognized species because of its widely flaring test due to its numerous sets of multiserial chamberlets. The chamberlets of this form are smaller with respect to other *Planoglobulina* species.

Occurrence:

From sample AG 128 (midddle parts of the *Globotruncana aegyptiaca* and *Pseudotextularia* zones) to AG 176 (upper parts of the *Abathomphalus mayaroensis* and *Pseudoguembelina hariensis* zones).

Genus: *Pseudoguembelina* BRONNIMANN and BROWN, 1953

Type species: *Guembelina excolata* CUSHMAN, 1926

Pseudoguembelina costulata **CUSHMAN, 1938**

Pl. 9, fig. 6

Guembelina costulata CUSHMAN, 1938, p. 16, 17, pl. 3, figs. 7-9.

Pseudoguembelina costulata NEDERBRAGT, 1991, p. 359, pl. 8, figs. 3-4b.

Pseudoguembelina costulata PREMOLI-SILVA and VERGA, 2004, p. 179, pl. 109, figs. 3-6.

Pseudoguembelina costulata OBAIDALLA, 2005, p. 215, pl. 1, fig. 2.

Remarks:

This form resembles *Heterohelix planata* with its shape of the test and its reniform chambers. *Pseudoguembelina costulata* can be discerned from this form by its accessory apertures and its edge view with the chambers appeared to be pointed towards the initial chambers. Although it has a very wide range from upper part of *Globotruncanita elevata* Zone to the top of the Maastrichtian, it is rare in our samples and only be observed in a few levels (samples AG 140, AG 145, AG 147 and AG 149).

Occurrence:

From sample AG 140 (base of the *Gansserina gansseri* Zone and top of the *Pseudotextularia elegans* Zone) to AG 149 (middle part of the *Gansserina gansseri* Zone and *Planoglobulina acervuloinides* Zone)

***Pseudoguembelina hariensis* NEDERBRAGT, 1991**

Pl. 9, fig. 7; Pl. 13 fig 11

Pseudoguembelina hariensis NEDERBRAGT, 1991, p. 359, pl. 8, figs. 6, 7a-c; p. 361, pl. 9, figs. 1a-b, 2a-b.

Pseudoguembelina hariensis PETRIZZO, 2001, p. 855, fig. 10. 12, 13.

Pseudoguembelina hariensis PREMOLI-SILVA and VERGA, 2004, p. 180, pl. 110, figs. 1-4.

Pseudoguembelina hariensis OBAIDALLA, 2005, p. 215, pl. 1, fig. 3.

Remarks:

This form is the marker species that is used in the heterohelicid biozonation. The biserial part of its test is followed by one or two sets of multiserial chamberlets. As mentioned, it can be distinguished from *Planoglobulina carseyae* with its ecliptic appearance in its edge view. This form has thin, discontinuous costae and it is lacking the accessory apertures. Since the stratigraphic range of this form is the uppermost part of *Abathomphalus mayaroensis* Zone, it is limited only to the uppermost Maastrichtian samples (above sample AG 166).

Occurrence:

From sample AG 166 (top of the *Gansserina gansseri* Zone) to AG 177 (top of the measured section).

Pseudoguembelina palpebra **BRONNIMANN and BROWN, 1953**

Pl. 10, fig. 1

Pseudoguembelina palpebra BRONNIMANN and BROWN, 1953, p.155, text figs. 9, 10.

Pseudoguembelina palpebra KELLER, 1988, p. 252, pl. 2, fig. 11.

Pseudoguembelina palpebra NEDERBRAGT, 1991, p. 361, pl. 9, figs. 5-7b.

Pseudoguembelina palpebra PREMOLI-SILVA and VERGA, 2004, p. 181, pl. 111, figs. 1-6.

Pseudoguembelina palpebra OBAIDALLA, 2005, p. 215, pl. 1, fig. 9.

Remarks:

This form is another rare form of the section. It can be identified with its biserial test that is widely flaring in juvenile part and subparallel in adult part, like in *Heterohelix punctulata* and *Heterohelix semicostata*.

Different than *Heterohelix*, this species have accessory apertures. Another characteristic property of this form is the shape of its terminal chambers. The range of the form is from *Gansserina gansseri* Zone to top of the *Abathomphalus mayaroensis* Zone (Robaszynski *et al.*, 1984).

Occurrence:

From sample AG 129 (midddle parts of the *Globotruncana aegyptiaca* and *Pseudotextularia* zones) to AG 177 (top of the measured section).

Genus: *Pseudotextularia* RZEHAK, 1891

Type species: *Cuneolina elegans* RZEHAK, 1891

Pseudotextularia elegans RZEHAK, 1891

Pl. 10, fig. 2

Cuneolina elegans RZEHAK, 1891, p. 4.
Pseudotextularia elegans KELLER, 1988, p. 250, pl.1, fig. 17.
Pseudotextularia elegans NEDERBRAGT, 1991, p. 363, pl. 10, figs. 1a-2b.
Pseudotextularia elegans ARENILLAS *et al.*, 2000. p. 43, pl. 1, fig. 7, 8.
Pseudotextularia elegans ROBASZYNSKI *et al.*, 2000. p. 481, p. 20, fig. 16.

Remarks:

Pseudotextularia is a genus that can simply be distinguished by its chambers distinctly deeper than wide and high and its compressed side view. The properties that differentiates *Pseudotextularia elegans* from the other species of this genus is its definitely bi-convex test in edge view and the thick, continuous costae which cover its surface. It is an abundant form whose range continues throughout the Maastrichtian.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

***Pseudotextularia intermedia* DE KLASZ, 1953a**

Pl. 10, fig. 3; Pl. 13 fig 12

Pseudotextularia intermedia DE KLASZ, 1953a, p. 231-232, pl. 5, figs. 2a-c.

Pseudotextularia intermedia NEDERBRAGT, 1991, p. 363, pl. 10, figs. 3a-b.

Pseudotextularia intermedia ARENILLAS *et al.*, 2000. p. 43, pl. 1, fig. 5, 6.

Remarks:

Pseudotextularia intermedia is a characteristic form that has two smaller chamberlets on its last chambers. This can be thought as the initial step of proliferation that we examine in the genus *Racemiguembelina*. As its stratigraphic range is mentioned as from *Gansserina gansseri* Zone to top of the *Abathomphalus mayaroensis* Zone, it is most common along the *Planoglobulina acervuloinides* Zone and becomes less abundant towards the upper and lower parts of the section in this study.

Occurrence:

From sample AG 125 (midddle parts of the *Globotruncana aegyptiaca* and *Pseudotextularia elegans* zones) to AG 177 (top of the measured section).

***Pseudotextularia nuttalli* VOORWIJK, 1937**

Pl. 10, fig. 4

Guembelina nuttalli VOORWIJK, 1937, p. 192, pl. 2, figs. 1-9.

Pseudotextularia nuttalli NEDERBRAGT, 1991, p. 363, pl. 10, figs. 4a-b, 6a-b.

Pseudotextularia nuttalli PREMOLI-SILVA and VERGA, 2004, p. 186, pl. 116, figs. 3-5.

Remarks:

Different than *Pseudotextularia elegans*, this form is biconvex in its edge view and its costae are finer. The range of this form is form Coniacian to end of the Maastrichtian (Nederbragt, 1991). In our section, it is seen almost in all of the samples.

Occurrence:

From sample AG 120 (base of the measured section) to AG 177 (top of the measured section).

Genus: *Racemiguembelina* MONTANARO GALLITELLI, 1957

Type species: *Guembelina fructicosa* EGGER, 1902

***Racemiguembelina fructicosa* EGGER, 1899**

Pl. 10, fig. 5; Pl. 13 fig 13

Racemiguembelina fructicosa EGGER, 1899, p. 35, pl. 14, figs. 8, 9, 24.

Racemiguembelina fructicosa KELLER, 1988, p. 250, pl.1, fig. 15.

Racemiguembelina fructicosa NEDERBRAGT, 1991, p. 363, pl. 10, figs. 5a-b.

Racemiguembelina fructicosa ÖZKAN-ALTINER and ÖZCAN, 1999, p. 292, pl. 1, fig. 10.

Racemiguembelina fructicosa ROBASZYNSKI *et al.*, 2000. p. 477, p. 18, fig. 3.

Racemiguembelina fructicosa CHACON et al., 2004, p. 590, fig. 4 M.

Racemiguembelina fructicosa OBAIDALLA, 2005, p. 215, pl. 1, fig. 4.

Remarks:

It is a typical species that the proliferation of the chambers in a three-dimensional plane is recognized on the contrast of other forms in which the multiserial growth develops in two dimensions. The appearance of this form defines the lower boundary of the *Racemiguembelina fructicosa* Zone, which is described within the heterohelicid biozonation. Its range continues up to the end of Maastrichtian. This form is one of the most common forms after the level that it appears.

Occurrence:

From sample AG 152 (middle part of the *Gansserina gansseri* Zone) to AG 177 (top of the measured section).

Racemiguembelina powelli SMITH and PESSAGNO, 1973

Pl. 10, fig. 6

Racemiguembelina powelli SMITH and PESSAGNO, 1973, p. 35-37, pl. 11, figs. 4-12.

Racemiguembelina powelli NEDERBRAGT, 1991, p. 365, pl. 11, figs.1 a-b.

Racemiguembelina powelli KELLER *et al.*, 2002, p. 280, pl. 3, fig.3.

Remarks:

The chambers of this species also show proliferation in three-dimensional plane on the contrast of other forms in which the multiserial growth develops in two dimensions. Its range is same with *Racemiguembelina fructicosa;* however, this form isn't as common as *Racemiguembelina fructicosa* in the samples. The difference of this form is that its multiserial part commonly isn't more than one or two sets and the chamber size of *Racemiguembelina powelli* is larger.

Occurrence:

From sample AG 152 (middle part of the *Gansserina gansseri* Zone and base of the *Racemiguembelina fructicosa* Zone) to AG 177 (top of the measured section).

CHAPTER V

DISCUSSION AND CONCLUSIONS

Regarding to the scope of the study, a Late Cretaceous (Campanian – Maastrichtian) section, which comprises the Cretaceous – Tertiary boundary, has been measured from the Akveren Formation in Bartın, Kokaksu region (NW Anatolia). The aim is to construct the biozonal scheme for the Campanian – Maastrichtian interval, to delineate the Campanian - Maastrichtian and the Cretaceous – Tertiary boundaries and to bring up the environmental responses to the evolution of the Late Cretaceous foraminifers.

First of all, a taxonomic study has been carried out. Here, 16 genera and 58 species have been identified. In the systematic paleontology chapter, the definitions of the forms have not been emphasized, since the detailed definitions have been carried out in the previous studies (Robaszynski et al, 1984; Nederbragt, 1991). However, the species have been compared and the criteria used in distinguishing the forms in this study have been explained.

Campanian - Maastrichtian interval has been studied by many authors in order to construct the biostratigraphy (Robaszynski *et al.,* 1984; Caron, 1985; Chungkham and Jafar, 1998; Robaszynski, 1998; Özkan-Altıner and Özcan, 1999; Sliter, 1999; Robaszynski *et al.*, 2000; Odin *et al.*, 2001; Chacon *et al.*, 2004, Obaidalla, 2005). In these previous studies, the main problem has been to delineate the position of the Campanian – Maastrichtian boundary (Arz and Molina, 2001; Gardin et al., 2001; Küchler et al., 2001; Odin, 2001). Considering all these discussions and different biozonations established for this interval, two different biozonations have been contructed in this study. The first biozonation has been established by using globotruncanids and it consists of three zones; *Globotruncana aegyptiaca* Zone, *Gansserina gansseri* Zone and *Abathomphalus mayaroensis* Zone. Here, the Campanian-Maastrcihtian boundary lies within the *Gansserina gansseri* Zone. However, since the globotruncanid biozone boundaries were not clear in this biozonation because of the rareness of the species that define the zones, a second biozonation has been established by using heterohelicids, which are more abundant through the measured section. This biozonation includes four different planktonic foraminiferal zones, which are *Pseudotextularia elegans* Zone, *Planoglobulina acervuloinides* Zone, *Racemiguembelina fructicosa* Zone and *Pseudoguembelina hariensis* Zone. The heterohelicid biozonation has been established for the first time in Turkey. Here, the Campanian-Maastrichtian boundary has been drawn at the boundary of two zones, namely *Planoglobulina acervuloinides* Zone and *Racemiguembelina fructicosa* Zone. The Cretaceous – Tertiary boundary has been marked with the total disappearance of the Cretaceous forms and occurrence of the small, non-keeled Danian species.

In this study, by considering the Cretaceous paleoceanography and the previously mentioned evolutionary pattern of the planktonic foraminifers as a consequence of the paleoenvironmental conditions (Leckie, 1989; Gasinski, 1997; Premoli-Silva and Sliter 1994 and 1999; Barrera & Savin, 1999; Zeebe, 2001; Petrizzo, 2002; Stüben et al., 2003), the diversity and abundance of the Campanian – Maastrichtian planktonic foraminifers have been examined throughout the measured section. Besides the diversity changes of the genera, changes in relative abundance of each genus have been examined separately. Such a paleoecological study that aims to observe the responses of planktonic foraminifers to the environmental changes has been constructed for the first time in Turkey. The trends in the diversity of the species and genera show a parallelism and there is an increase in diversity of the forms towards the top of the section in terms of both species and genus. The maximum species diversity has been recorded within the *Abathomphalus mayaroensis* globotruncanid zone that is correlated with the *Pseudoguembelina hariensis* heterohelicid zone (sample AG 173) with 44 species and the maximum diversity in terms of genera has been recognized in sample AG 143, which is the base of Maastrichtian, with 16 genera. Here, the maximum generic diversity is correlatable with the global data. On the other hand, the position of the sample that the maximum species diversity has been reached is quite different than the previous studies of Premoli-Silva and Sliter (1994 and 1999) which suggested the maximum species diversity also at the base of the Maastrichtian. However, when we look at for zones that have been separated on the species curve, the mean of species diversities is maximum in the second zone of this curve (Figure 17). In this manner, although we can't see the maximum diversity at the base of the Maastrichtian, its mean value is highest here that is suitable to the global data. Moreover, when we examine the zones in the species and generic diversity curves, we can realize that second and fourth zones in the curves can be correlated with the global regressions of Haq *et al.* (1987) during 71.5 and 70.5 Ma and 67 and 65.5 Ma (Figure 18).

If the responses of ecological changes on planktonic foraminifers are considered, the forms have been grouped as Morphotype 1 (r-strategists), Morphotype 2 (K-strategists) and Morphotype 3 (intermediate r/K strategists) with respect to their tolerance to the environmental changes (Premoli-Silva and Sliter 1994 and 1999). The grouping of the forms with respect to the specific morphological properties has been obviously recognized by using this classification. The Morphotype 1 (r-strategists), the most tolerant, cosmopolitan forms that can adapt to unstable conditions with high nutrient supply (eutrophic waters), is more abundant during Maastrichtian throughout the Gansserina *gansseri* and *Abathomphalus mayaroensis* zones, whereas Morphotype 2 (K-strategists), which can tolerate to oligotrophic conditions such as stable waters with low nutrient content, are more abundant during *Globotruncana aegyptiaca* Zone. Since these morphotypes are tolerant to the specific environmental conditions, we can conclude that the oligotrophic conditions with stable oceans that have low nutrient content were leading during the Campanian stage, whereas the Maastrichtian figures out the occurrence of more eutrophic conditions, i.e. unstable oceans rich in nutrient supply.

Besides this classification, two more arrangements have been done in order to discuss the responses of planktonic foraminifera to the environmental changes. The second arrangement separated the forms under 3 groups, which consist of all heterohelicids, non-keeled coiled forms and keeled trochospiral forms. This arrangement also shows the dominance of heterohelicides during Maastrichtian that reflects the more eutrophic conditions. The last arrangement separates the genera into two as coiled and uncoiled forms. Here, we can observe the dominance of coiled forms during Campanian and dominance of uncoiled forms after the *Racemiguembelina fructicosa* Zone towards the end of Maastrichtian. The basal Maastirichtian doesn’t reflect dominancy.

Considering the effects of lithology on the evolutionary development, the uppermost part of the measured section (the total range of *Pseudoguembelina hariensis* Zone) has been choosen where we can observe a systematic alternation of clayey limestone and marl can be observed. As a result we can see the clear distinction of r- and K-strategists in different lithologies. That is, Morphotype1 (r-strategists) became dominant in clayey limestones, while the Morphotype 2 (K-strategists) were more abundant within the marls along this interval. To a better result, it is suggested to study the lower part of Campanian that isn’t included in this study, where a more systematic lithological alternation is observed.

By clustering our data with respect to species and genus data, we obtain four different clusters due to the abundance of forms. Here the clustering is prepared by using ward method in R program after the logarithmic transformation. Another cluster also shows the grouping of data with respect to time. So by the DCA analysis, we can see that the clusters of our data reflects the time and 3 different clustering can be obtained in terms of stages, globotruncanid biozonation and heterohelicid zonation. This method, which clusters the data by using the statistic programs, has been applied for the first time in Turkey.

To the further studies, it is suggested to examine the lower parts of the Akveren formation, which has already been measured, but not included in the evaluation of this study, in order to find out the effects of the environmental factors in the evolution of the planktonic foraminifers.

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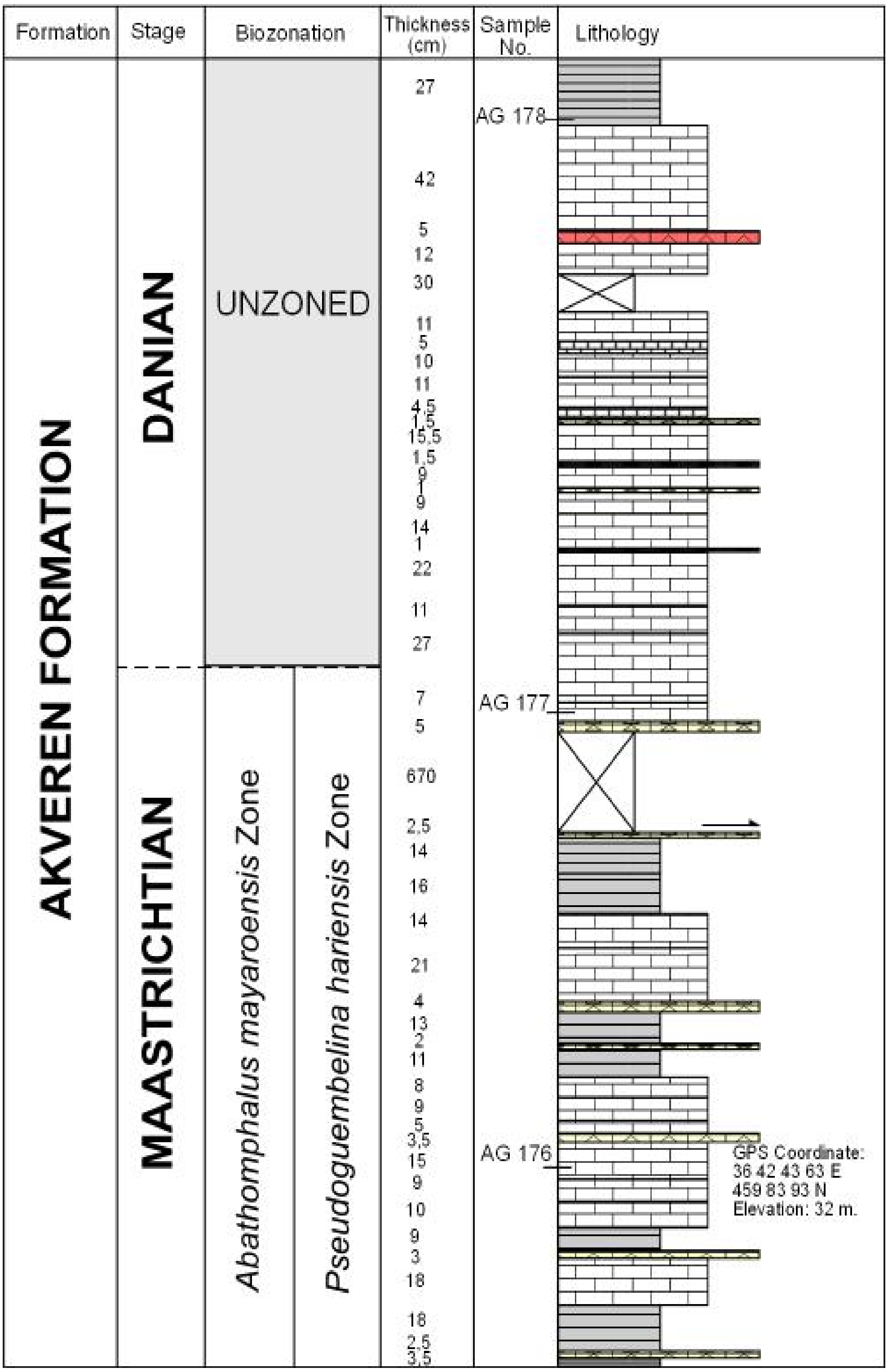
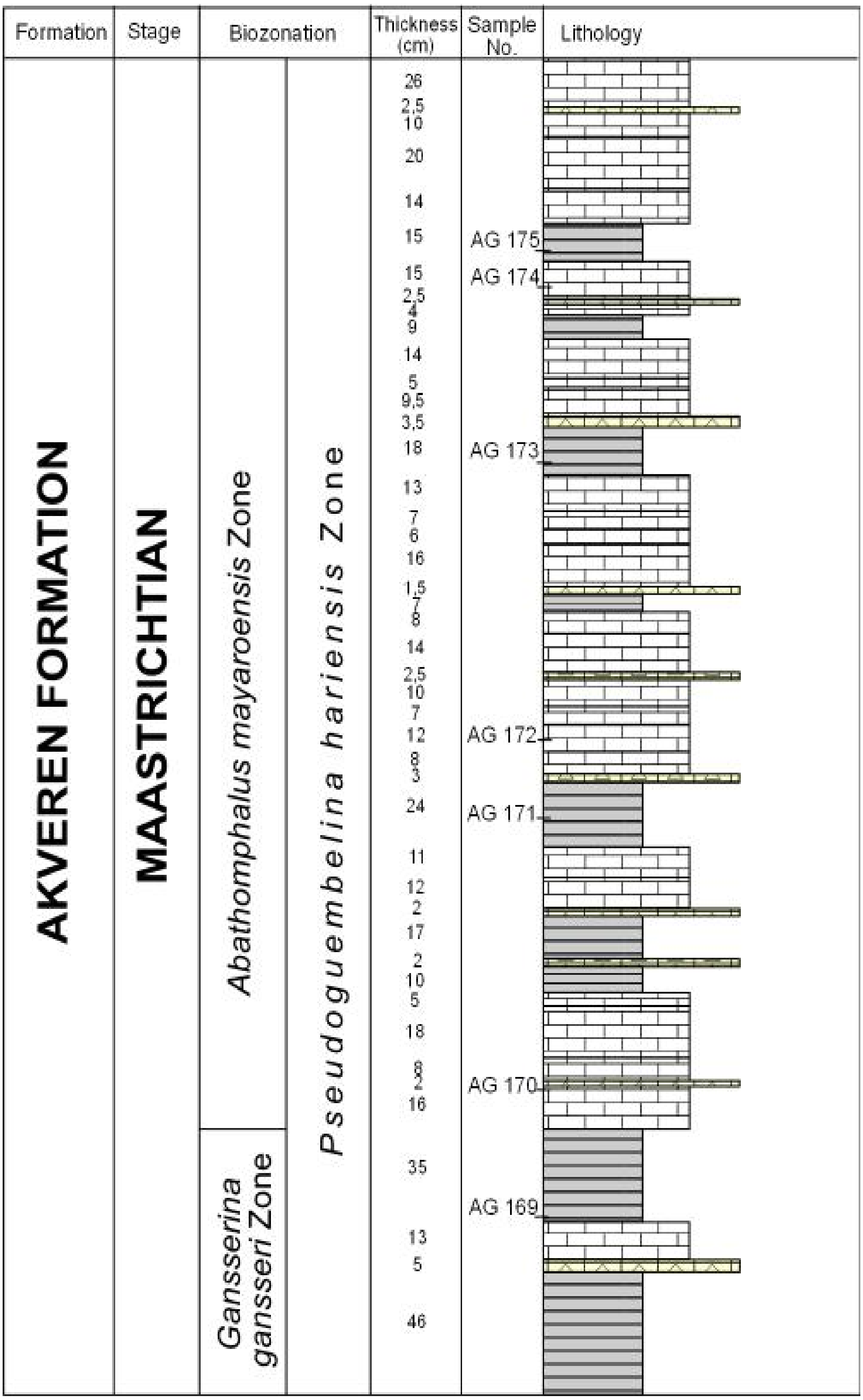
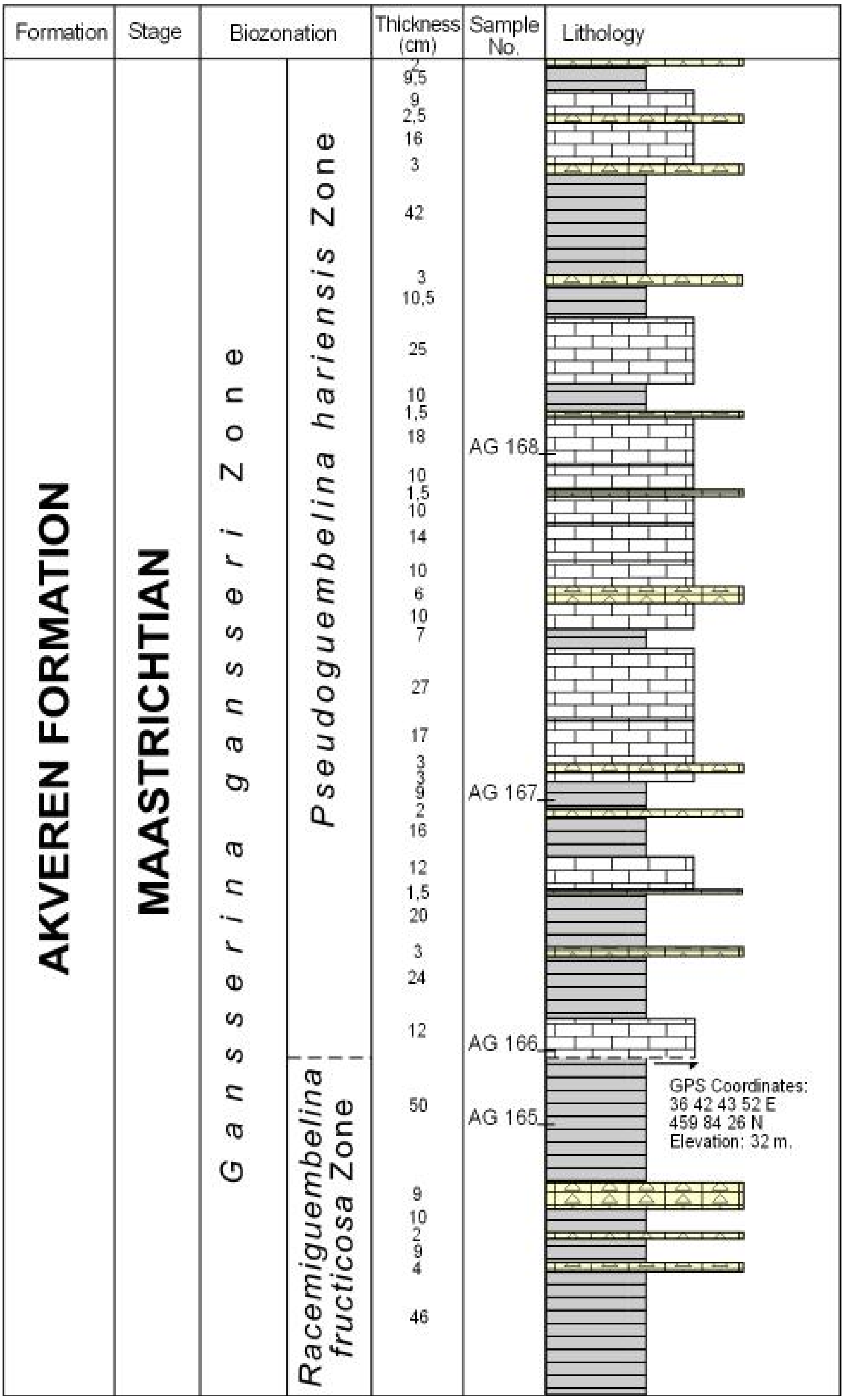
APPENDIX A: DIFFERENT WASHING METHODS USED IN THIS STUDY

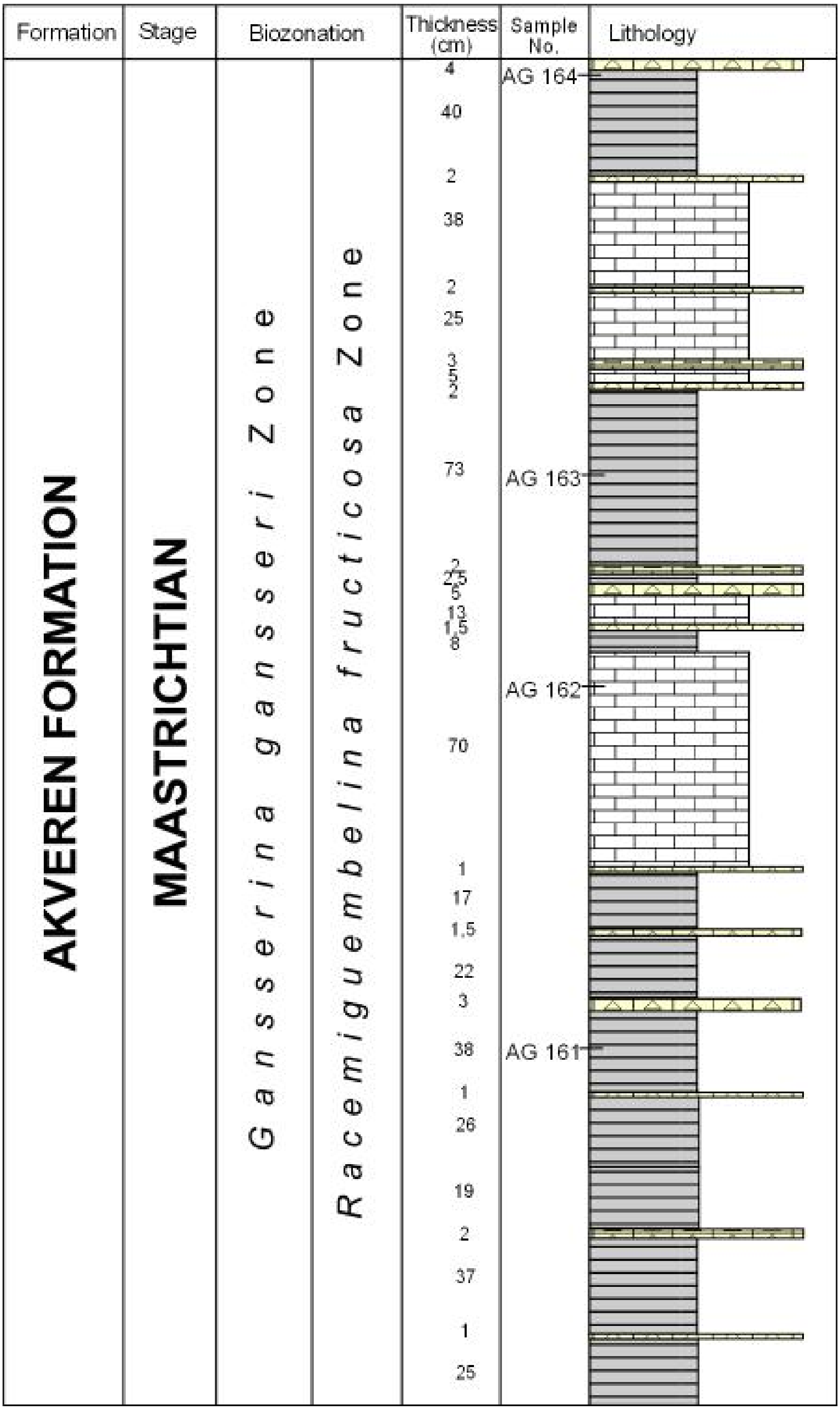
Sample No	Lithology	Thickness (cm)	Method 1	Method 2	Method 3
177	Clayey Limestone	2614	65% Asetic Acid & Sodium polyphosphate	50% Asetic Acid (2 hrs) & Sodium polyphosphate	
176	Clayey Limestone	138	65% Asetic Acid (18 hrs.) & Sodium polyphosphate	50% Asetic Acid (2 hrs) & Sodium polyphosphate	
175	Marl	15	35% H2O2	Calgon treatment	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
174	Clayey Limestone	64	65% Asetic Acid & Sodium polyphosphate	50% Asetic Acid (2 hrs) & Sodium polyphosphate	
173	Marl	113,5	35% H2O2	Calgon treatment	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
172	Clayey Limestone	23	65% Asetic Acid & Sodium polyphosphate	50% Asetic Acid (2 hrs) & Sodium polyphosphate	
171	Marl	100	50% H2O2 & 1 min. Ultrasound	65 % Asetik acid (18 hrs.)	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
170	Clayey Limestone	51,5	65% Asetic Acid & Sodium polyphosphate	50% Asetic Acid (2 hrs) & Sodium polyphosphate	
169	Marl	217	35% H2O2	Calgon treatment	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
168	Clayey Limestone	127,5	65% Asetic Acid & Sodium polyphosphate	50% Asetic Acid (2 hrs) & Sodium polyphosphate	
167	Marl	90,5	35% H2O2 & 1 min. Ultrasound	Calgon treatment	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
166	Clayey Limestone	525	65% Asetic Acid (18 hrs.) & Sodium polyphosphate	50% Asetic Acid (2 hrs) & Sodium polyphosphate	
165	Marl	109	50% H2O2 & 1 min. Ultrasound	65 % Asetik acid (18 hrs.)	50% Asetic Acid (1 hr) & Sodium polyphosphate
164	Marl	153	35% H2O2 & 1 min. Ultrasound	65 % Asetik acid (10 hrs.)	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
163	Marl	104,5	35% H2O2 & 1 min. Ultrasound	65 % Asetik acid (12 hrs.)	50% Asetic Acid (1 hr) & Sodium polyphosphate
162	Marl	98,5	65 % Asetik acid & 1 min. Ultrasound	65 % Asetik acid (6 hrs.)	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
161	Marl	135,5	35% H2O2 & 1 min. Ultrasound	65 % Asetik acid (10 hrs.)	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
160	Marl	131,5	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
159	Clayey Limestone	130	65 % Asetik acid	50% Asetic Acid (2 hrs) & Sodium polyphosphate	
158	Marl	115	35% H2O2	65 % Asetik acid (8 hrs.)	50% Asetic Acid (2 hrs) & Sodium polyphosphate
157	Marl	50	35% H2O2	65 % Asetik acid (4 hrs.)	50% Asetic Acid (2 hrs) & Sodium polyphosphate
156	Marl	114,5	35% H2O2	65 % Asetik acid (8 hrs.)	50% Asetic Acid (2 hrs) & Sodium polyphosphate
155	Marl	127,5	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
154	Clayey Limestone	30	65 % Asetik acid	Calgon treatment	50% Asetic Acid (2 hrs) & Sodium polyphosphate
153	Marl	60,5	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
152	Marl	4410	50% H2O2	Calgon treatment	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
151	Marl	79	35% H2O2	Calgon treatment	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
150	Marl	211	35% H2O2	Calgon treatment	50% Asetic Acid (1 hr) & Sodium polyphosphate
149	Marl	89,5	35% H2O2	Calgon treatment	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
148	Marl	126	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
147	Marl	99,5	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
146	Clayey Limestone	73,5	65 % Asetik acid	50% Asetic Acid (2 hrs) & Sodium polyphosphate	
145	Marl	30	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
144	Clayey Limestone	101	65 % Asetik acid	50% H2O2 & 2 min. Ultrasound	50% Asetic Acid (2 hrs) & Sodium polyphosphate
143	Marl	73	65 % Asetik acid (14 hrs.)	50% H2O2 & 1 min. Ultrasound	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
142	Clayey Limestone	24,5	65 % Asetik acid	50% H2O2 & 1 min. Ultrasound	50% Asetic Acid (2 hrs) & Sodium polyphosphate
140	Marl	75,5	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
139	Marl	123,5	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
138	Marl	94,5	35% H2O2	50% Asetic Acid (1 hr) & Sodium polyphosphate	
137A	Marl	115	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
137	Marl	255,5	35% H2O2	Calgon treatment	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
136	Marl	12	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
135	Marl	159	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
134	Marl	82	50% H2O2 & 2 min. Ultrasound	65 % Asetik acid (18 hrs.)	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
133	Marl	146	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
132	Marl	233,5	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
131	Marl	132	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
130	Clayey Limestone	13	65 % Asetik acid	50% Asetic Acid (2 hrs) & Sodium polyphosphate	
129	Marl	138	35% H2O2	Calgon treatment	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
128	Marl	120	35% H2O2	Calgon treatment	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
127	Marl	153	35% H2O2	50% Asetic Acid (1 hr) & Sodium polyphosphate	
126	Marl	66,5	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
125	Marl	37	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	
124	Clayey Limestone	1103	65 % Asetik acid (18 hrs.)	50% Asetic Acid (2 hrs) & Sodium polyphosphate	
123	Marl	57,5	50% H2O2	Calgon treatment	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate
122	Marl	3	35% H2O2	Calgon treatment	50% Asetic Acid (1 hr) & Sodium polyphosphate
120	Marl	162	35% H2O2	50% Asetic Acid (1,5 hrs) & Sodium polyphosphate	

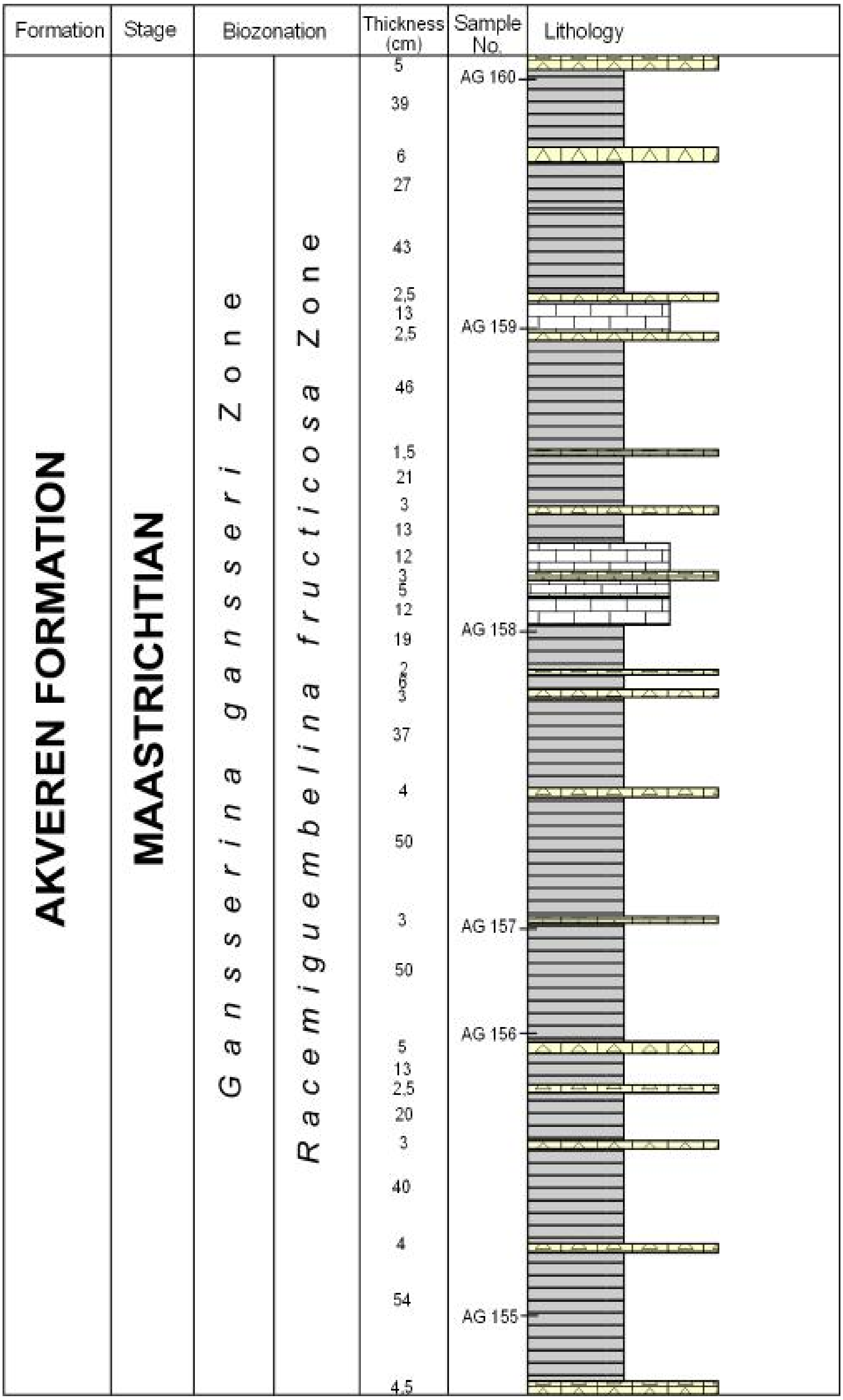
APPENDIX B: DETAILS OF THE MEASURED SECTION

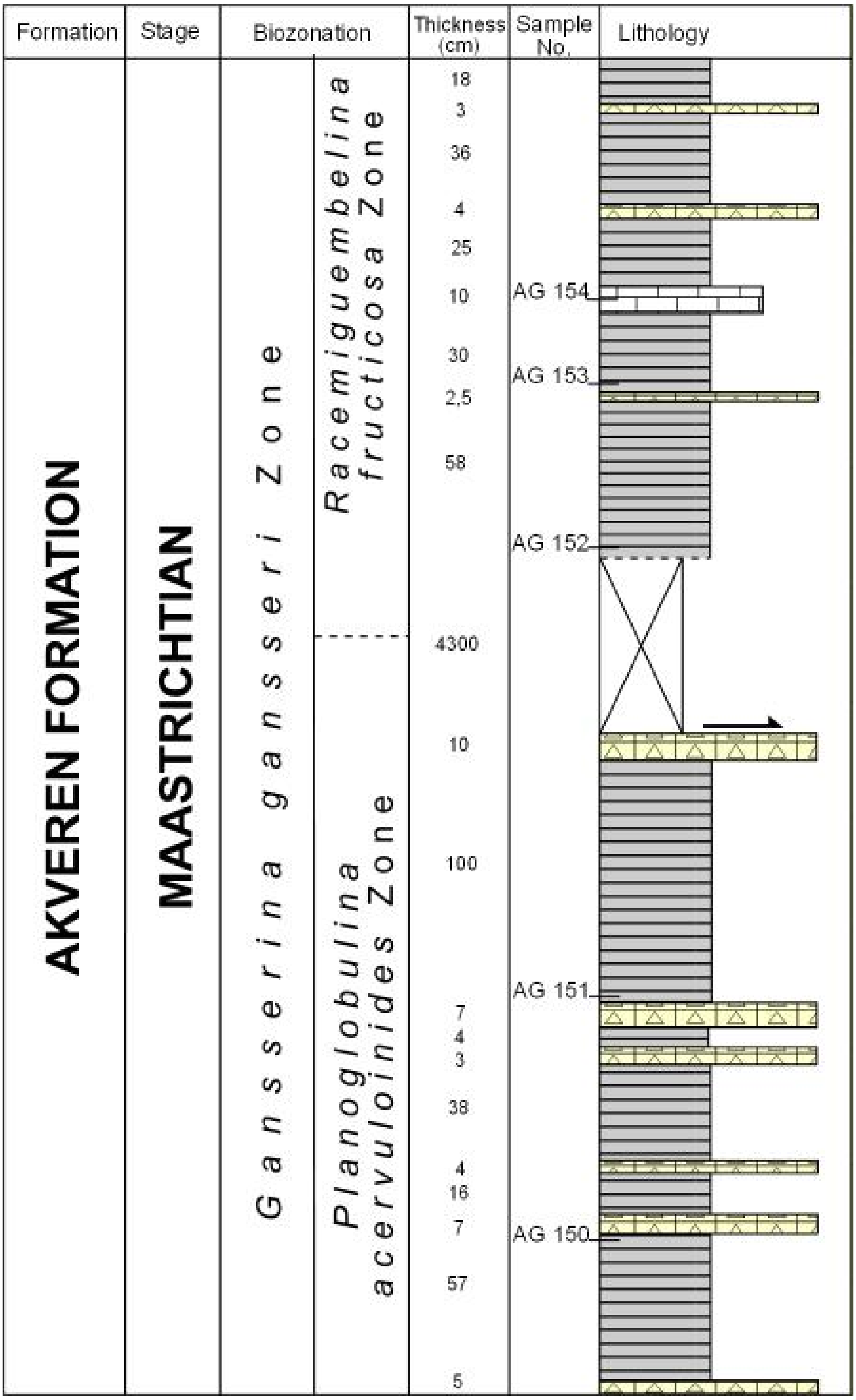


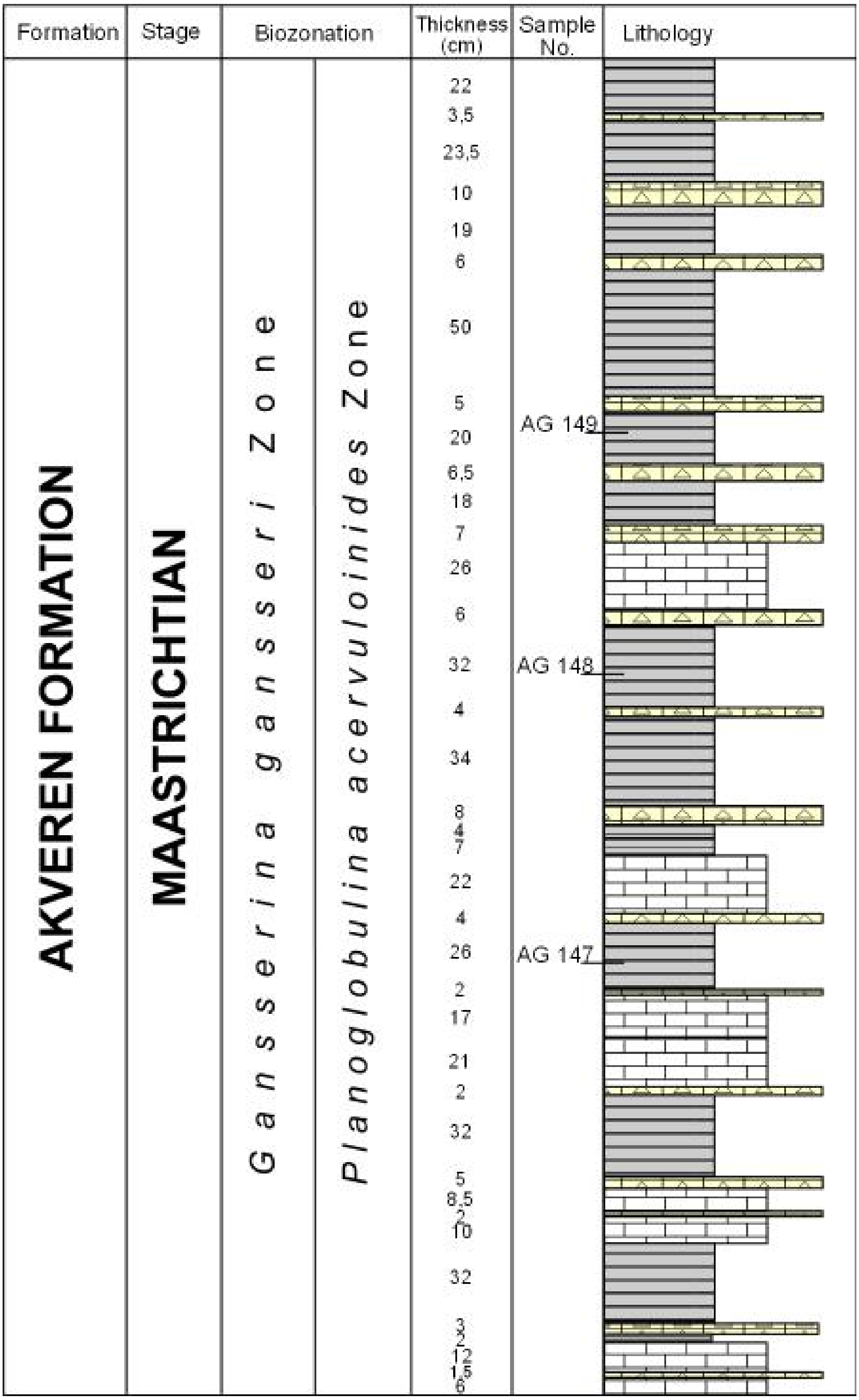

Formation
Stage
Biozonation
Thickness (cm)
Sample No.
Lithology
AKVEREN FORMATION
MAASTRICHTIAN
Abathomphalus mayaroensis Zone
Gansserina gansseri Zone
Pseudoguembelina hariensis Zone
26
2,5
10
20
14
15
15
2,5
4
9
14
5
9,5
3,5
18
13
7
6
16
1,5
7
8
14
2,5
10
7
12
8
3
24
11
12
2
17
2
10
5
18
8
2
16
35
13
5
46
AG 175
AG 174
AG 173
AG 172
AG 171
AG 170
AG 169

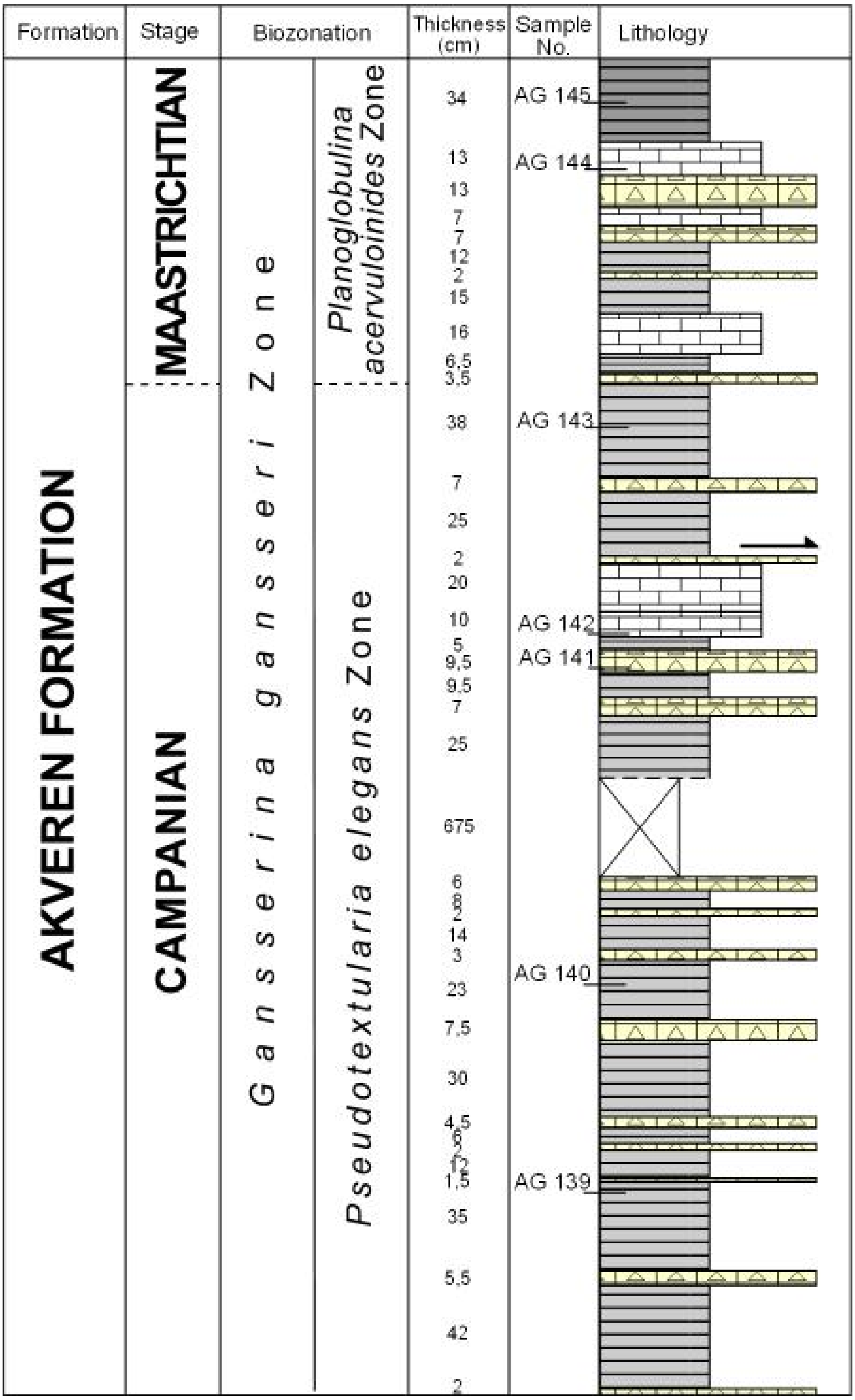

Formation
Stage
Biozonation
Thickness (cm)
Sample No.
Lithology
AKVEREN FORMATION
MAASTRICHTIAN
Gansserina gansseri Zone
Pseudoguembelina hariensis Zone
Racemiguembelina fructicosa Zone
2
9,5
9
2,5
16
3
42
3
10,5
25
10
1,5
18
10
1,5
10
14
10
6
10
7
27
17
3
3
9
2
16
12
1,5
20
3
24
12
50
9
10
2
9
4
46
AG 168
AG 167
AG 166
AG 165
GPS Coordinates:
36 42 43 52 E
459 84 26 N
Elevation: 32 m.

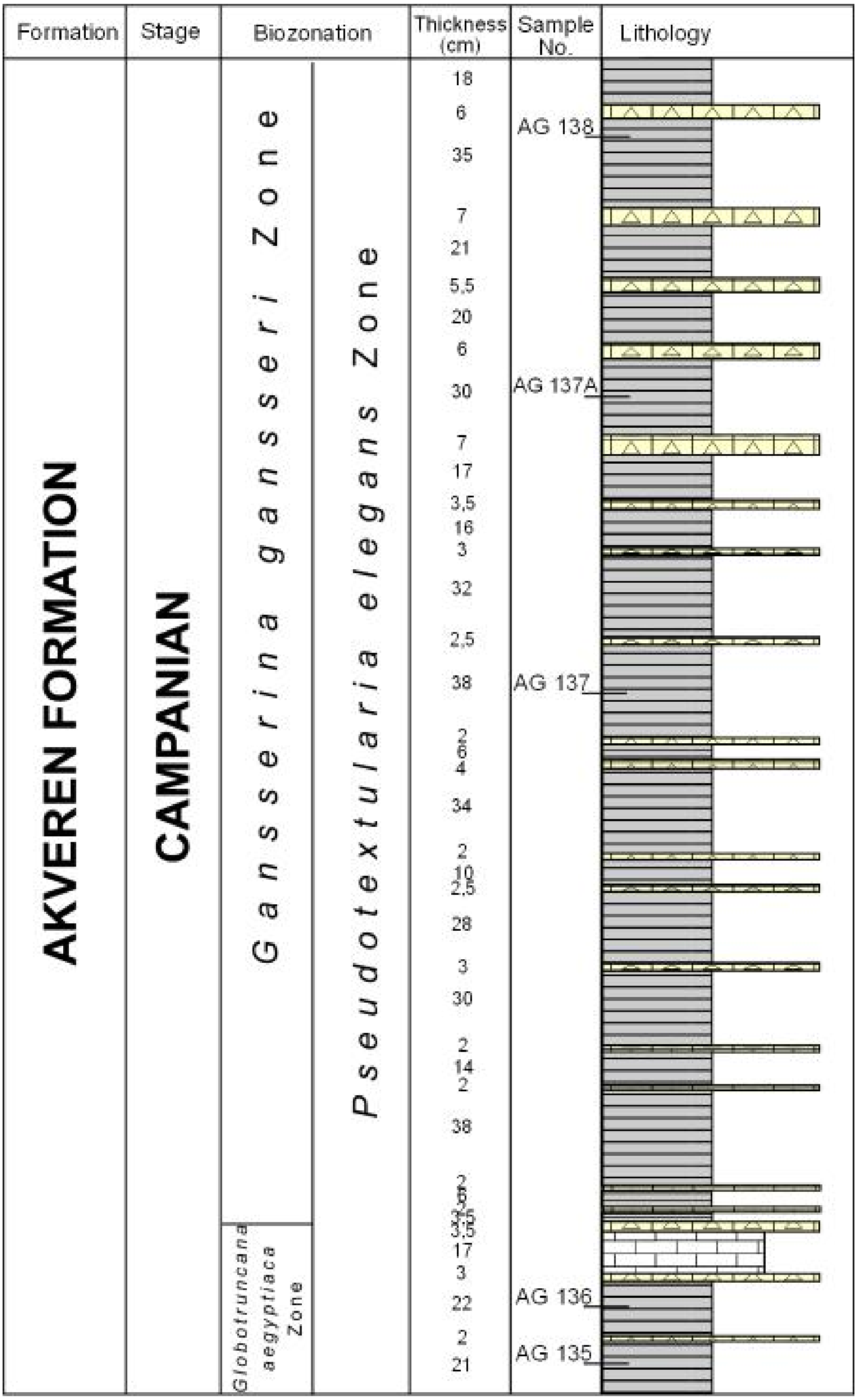

Formation
Stage
Biozonation
Thickness (cm)
Sample No.
Lithology
AKVEREN FORMATION
MAASTRICHTIAN
Gansserina gansseri Zone
Racemiguembelina fructicosa Zone
4
40
2
38
2
25
3
5
2
73
2
2,5
5
13
1,5
8
70
1
17
1,5
22
3
38
1
26
19
2
37
1
25
AG 164
AG 163
AG 162
AG 161

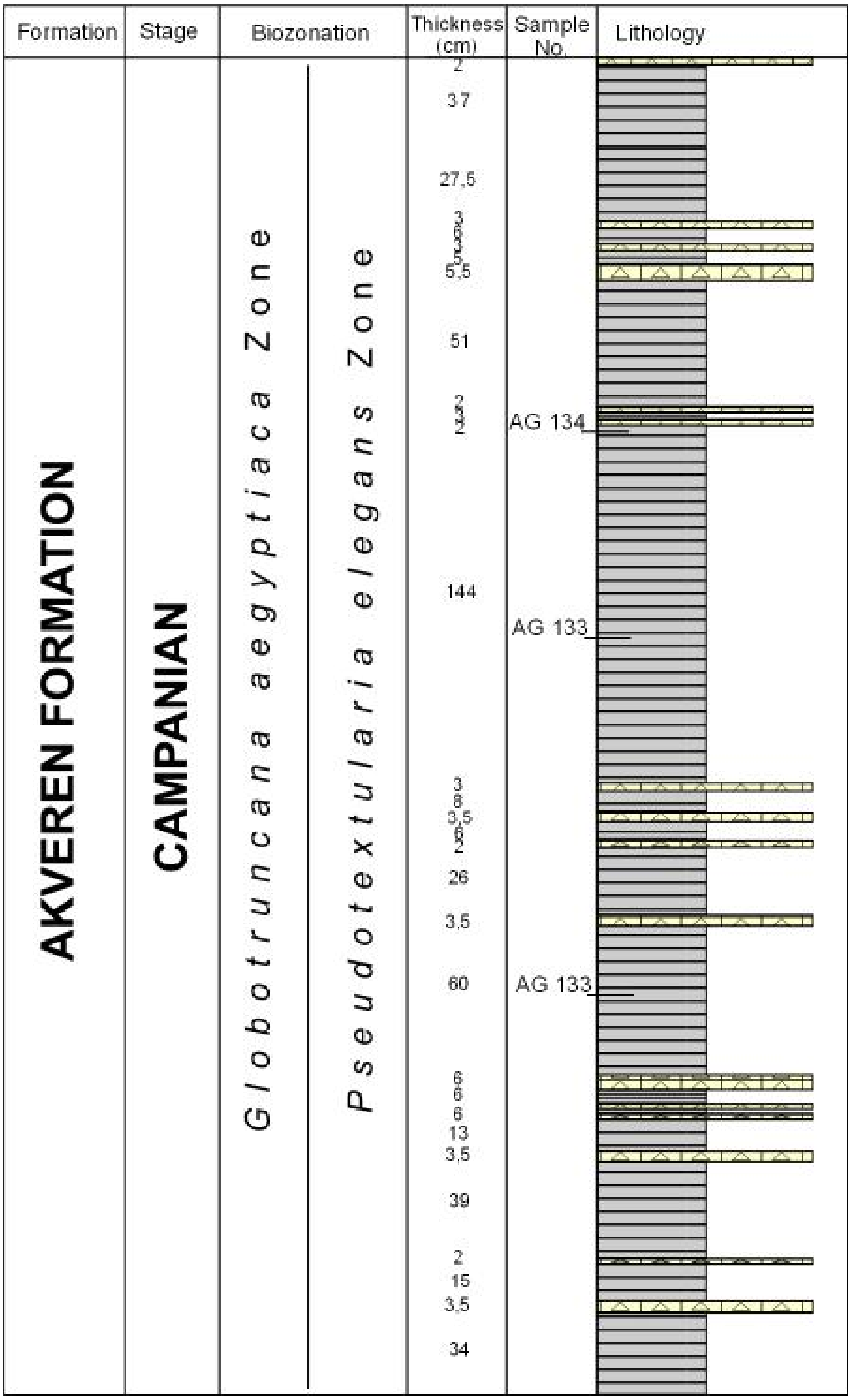

Formation
Stage
Biozonation
Thickness (cm)
Sample No.
Lithology
AKVEREN FORMATION
MAASTRICHTIAN
Gansserina gansseri Zone
Racemiguembelina fructicosa Zone
5
39
6
27
43
2,5
13
2,5
46
1,5
21
3
13
12
3
5
12
19
2
6
3
37
4
50
3
50
5
13
2,5
20
3
40
4
54
4,5
AG 160
AG 159
AG 158
AG 157
AG 156
AG 155

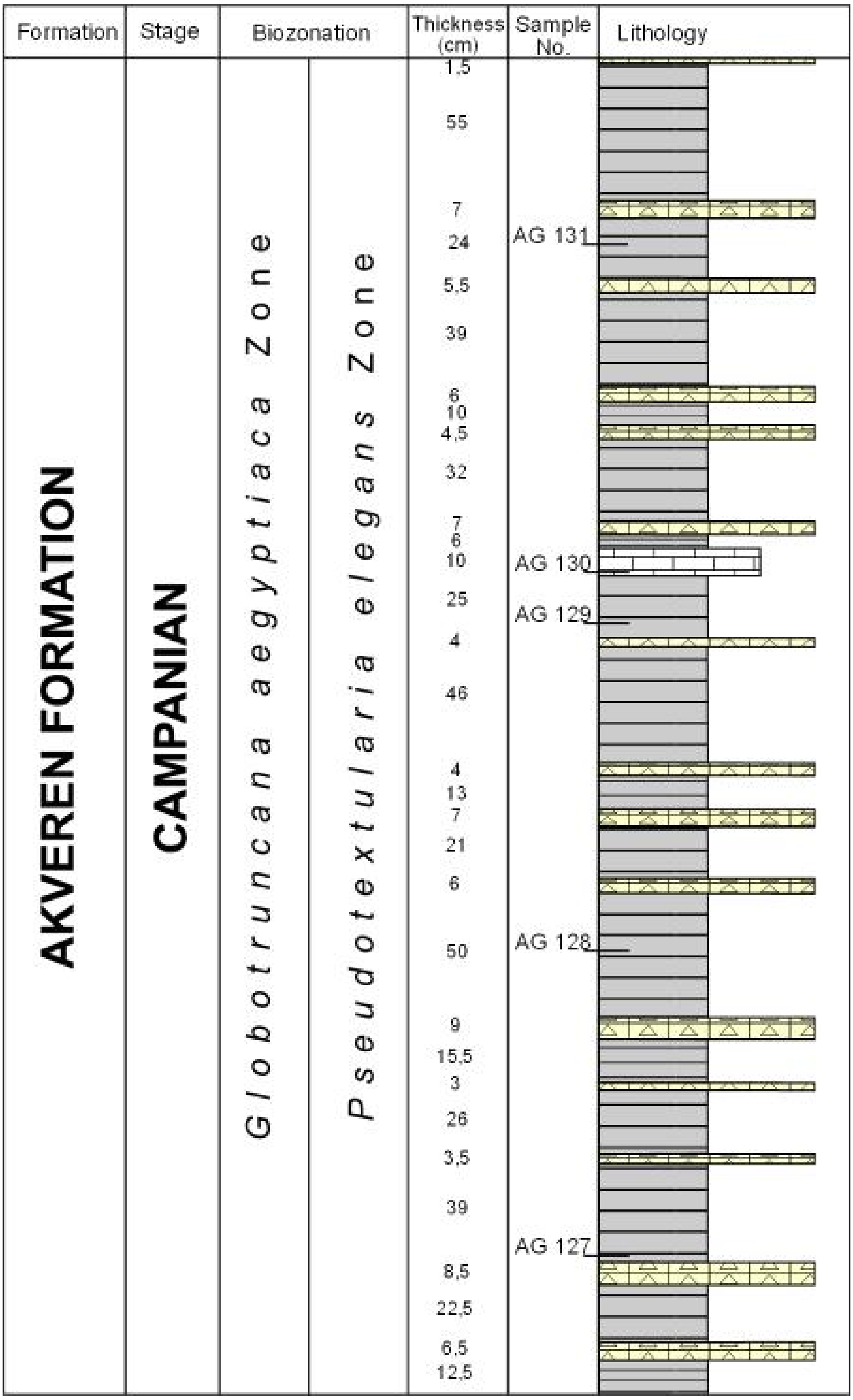

Formation
Stage
Biozonation
Thickness (cm)
Sample No.
Lithology
AKVEREN FORMATION
MAASTRICHTIAN
Gansserina gansseri Zone
Racemiguembelina fructicosa Zone
Planoglobulina acervuloinides Zone
18
3
36
4
25
10
30
2,5
58
4300
10
100
7
4
3
38
4
16
7
57
5
AG 154
AG 153
AG 152
AG 151
AG 150

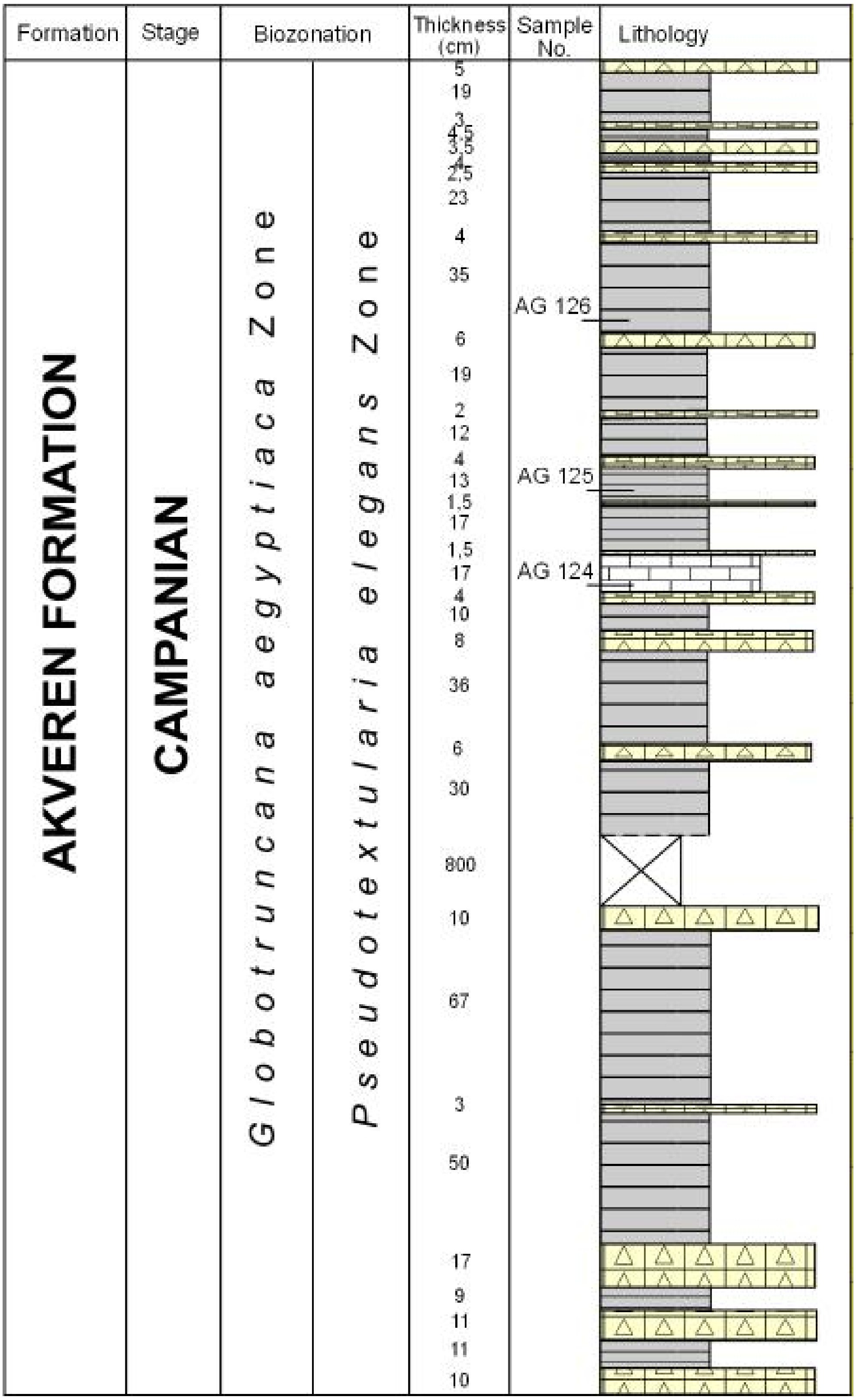

Formation
Stage
Biozonation
Thickness (cm)
Sample No.
Lithology
AKVEREN FORMATION
MAASTRICHTIAN
Gansserina gansseri Zone
Planoglobulina acervuloinides Zone
22
3,5
23,5
10
19
6
50
5
20
6,5
18
7
26
6
32
4
34
8
4
7
22
4
26
2
17
21
2
32
5
8,5
2
10
32
3
2
12
1,5
6
AG 149
AG 148
AG 147

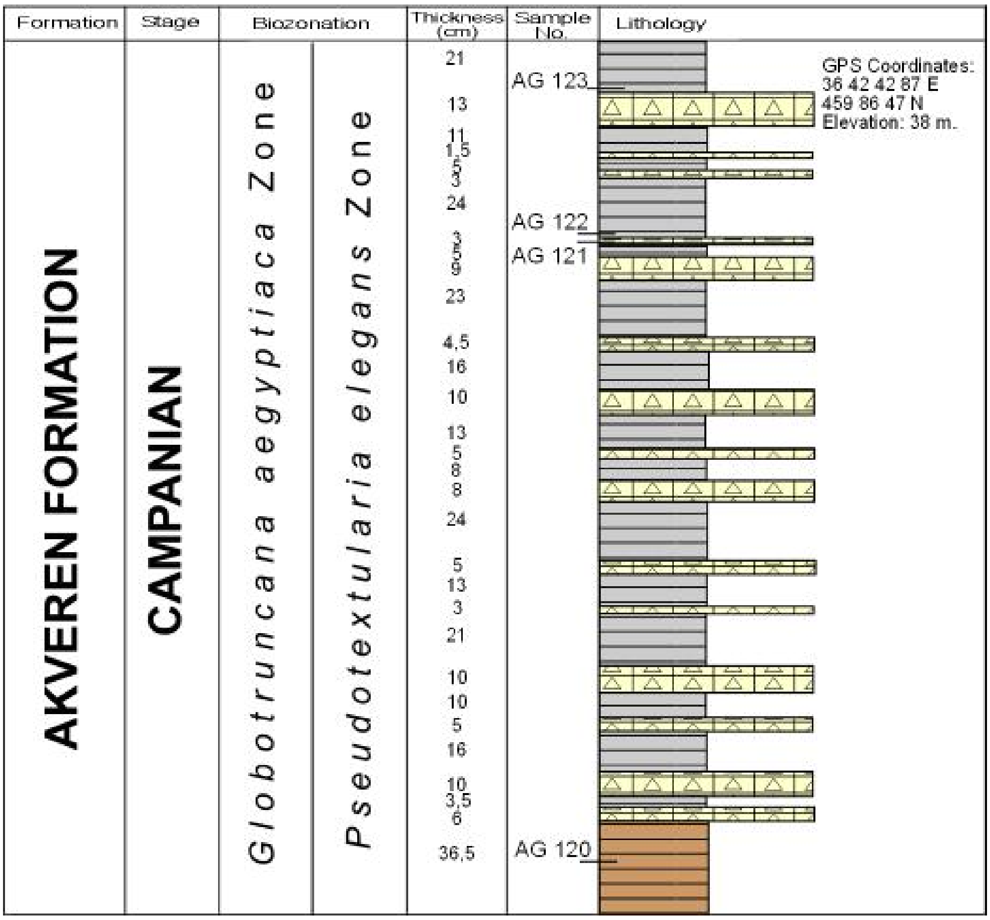

Formation
Stage
Biozonation
Thickness (cm)
Sample No.
Lithology
AKVEREN FORMATION
MAASTRICHTIAN
CAMPANIAN
Gansserina gansseri Zone
Planoglobulina acervuloinides Zone
Pseudotextularia elegans Zone
34
13
13
7
7
12
2
15
16
6,5
3,5
38
7
25
2
20
10
5
9,5
9,5
7
25
675
6
8
2
14
3
23
7,5
30
4,5
6
2
12
1,5
35
5,5
42
2
AG 145
AG 144
AG 143
AG 142
AG 141
AG 140
AG 139


Formation
Stage
Biozonation
Thickness (cm)
Sample No.
Lithology
AKVEREN FORMATION
CAMPANIAN
Gansserina gansseri Zone
Pseudotextularia elegans Zone
Globotruncana aegyptiaca Zone
18
6
35
7
21
5,5
20
6
30
7
17
3,5
16
3
32
2,5
38
2
6
4
34
2
10
2,5
28
3
30
2
14
2
38
2
6
3,5
3,5
17
3
22
2
21
AG 138
AG 137A
AG 137
AG 136
AG 135


Formation
Stage
Biozonation
Thickness (cm)
Sample No.
Lithology
AKVEREN FORMATION
CAMPANIAN
Globotruncana aegyptiaca Zone
Pseudotextularia elegans Zone
2
37
27,5
3
5,5
51
2
3
2
144
3
8
3,5
6
2
26
3,5
60
6
6
6
13
3,5
39
2
15
3,5
34
AG 134
AG 133
AG 133


Formation
Stage
Biozonation
Thickness (cm)
Sample No.
Lithology
AKVEREN FORMATION
CAMPANIAN
Globotruncana aegyptiaca Zone
Pseudotextularia elegans Zone
1,5
55
7
24
5,5
39
6
10
4,5
32
7
6
10
25
4
46
4
13
7
21
6
50
9
15,5
3
26
3,5
39
8,5
22,5
6,5
12,5
AG 131
AG 130
AG 129
AG 128
AG 127


Formation
Stage
Biozonation
Thickness (cm)
Sample No.
Lithology
AKVEREN FORMATION
CAMPANIAN
Globotruncana aegyptiaca Zone
Pseudotextularia elegans Zone
5
19
3
4,5
3,5
4
2,5
23
4
35
AG 126
6
19
2
12
4
13
AG 125
1,5
17
1,5
17
AG 124
4
10
8
36
6
30
800
10
67
3
50
17
9
11
11
10


Formation
Stage
Biozonation
Thickness (cm)
Sample No.
Lithology
AKVEREN FORMATION
CAMPANIAN
Globotruncana aegyptiaca Zone
Pseudotextularia elegans Zone
21
13
11
1,5
5
3
24
3
5
9
23
4,5
16
10
13
5
8
8
24
5
13
3
21
10
10
5
16
10
3,5
6
36,5
AG 123
AG 122
AG 121
AG 120
GPS Coordinates:
36 42 42 87 E
459 86 47 N
Elevation: 38 m.

APPENDIX C: FAUNAL DISTRIBUTION IN MEASURED SECTION

Table 1. Distribution of species throughout the measured section

Sample No	Ab. intermedius	Ab. mayaroensis	Ar. blowi	Ar. cretacea	C. contusa	C. fornicata	C. patelliformis	C. plicata	C. plummerae	C. walfishensis	Ga. gansseri	Globigerinelloides sp.	G. aegyptiaca	G. arca	G. bulloides	G. dupeublei	G. esnehensis	G. falsostuarti	G. insignis	G. linneiana	G. mariei	G. orientalis	G. rosetta	G. ventricosa	Gl. havanensis	Gl. pshadae	Gl. petaloidea	Gt. angulata	Gt. conica	Gt. pettersi	Gt. stuarti	Gt. stuartiformis	Rg. hexacamerata	Rg. macrocephala	Rg. milamensis	Rg. pennyi	Rg. rotundata	Rg. rugosa	Gb. acuta	Gb. cuvilleri	Hx. globulosa	Hx. labellosa	Hx. navarroensis	Hx. planata	Hx. punctulata	Hx. semicostata	Lh. glabrans	Lh. dentata	Pg. acervulinoides	Pg. carseyae	Pg. multicamerata	Psg. costulata	Psg. hariensis	Psg. palpebra	Ps. elegans	Ps. intermedia	Ps. nuttalli	Rc. fructicosa	Rc. powelli
AG 177	0	0	0	0	0	2	1	0	0	0	5	11	24	29	8	0	0	3	0	1	0	4	1	5	3	0	4	1	0	1	1	3	0	8	0	1	3	12	0	0	31	3	12	0	11	8	4	9	15	5	0	0	1	8	24	3	9	17	9
AG 176	0	0	0	0	0	0	0	0	2	0	2	34	7	10	4	0	0	2	0	3	0	5	0	0	0	0	3	3	0	5	5	5	0	8	2	6	7	22	0	2	16	10	16	9	0	10	11	6	11	9	1	0	1	2	44	0	9	8	0
AG 175	2	0	0	0	1	0	3	2	0	0	0	4	4	10	1	0	8	3	0	2	2	8	0	3	1	2	3	1	0	9	0	2	0	18	0	6	27	23	0	0	16	8	2	0	1	10	7	4	21	9	8	0	0	1	18	0	7	31	12
AG 174	0	2	0	0	0	0	0	0	0	0	0	19	1	11	0	0	0	0	2	4	0	0	0	4	0	1	0	0	0	0	1	3	3	8	0	21	12	45	2	0	15	23	6	13	0	17	9	3	8	3	9	0	2	0	22	0	3	22	6
AG 173	1	2	0	0	2	0	1	2	0	2	2	4	4	12	1	0	11	4	0	1	0	6	4	4	8	1	0	6	0	17	4	12	1	3	0	0	6	8	0	1	19	16	14	4	2	16	9	4	31	14	6	0	1	1	6	0	9	18	0
AG 172	0	1	0	0	0	1	0	0	0	0	1	51	4	4	0	0	0	0	0	0	0	5	0	0	3	3	4	4	0	3	0	5	0	0	0	2	0	4	0	0	33	26	9	5	0	39	18	14	11	3	3	0	5	0	12	0	4	16	7
AG 171	0	0	0	0	0	0	0	0	0	0	1	27	0	21	0	2	4	0	0	1	0	12	2	3	2	0	2	9	0	16	3	4	0	3	0	0	0	2	4	5	42	22	7	6	0	12	1	1	14	13	2	0	5	2	11	0	7	32	0
AG 170	0	1	0	0	0	0	0	0	0	0	0	38	9	10	0	0	0	2	0	0	2	0	0	8	4	0	5	5	0	5	0	2	0	8	0	8	0	16	0	4	26	19	12	10	0	9	10	6	16	15	1	0	1	1	7	2	6	13	19
AG 169	0	0	0	0	1	0	5	0	0	0	2	40	6	10	2	0	2	1	0	0	0	6	0	2	6	0	3	0	0	6	1	1	0	2	0	1	0	13	0	11	20	17	17	7	0	18	1	0	14	17	5	0	0	0	14	3	4	18	24
AG 168	0	0	0	0	0	0	0	0	0	0	0	65	1	2	0	0	1	0	0	0	0	0	0	0	0	0	9	4	0	9	0	1	1	8	0	6	0	5	0	4	73	24	10	5	1	30	23	0	0	0	0	0	0	1	10	0	0	3	4
AG 167	0	0	0	0	1	0	0	2	0	0	0	2	1	0	0	0	29	0	0	0	0	0	2	0	0	0	2	4	0	15	0	12	0	1	0	1	5	15	0	20	25	27	11	15	0	11	21	5	11	2	0	0	2	0	25	0	13	17	3
AG 166	0	0	0	0	0	0	0	0	0	0	0	42	1	16	0	0	4	0	0	0	0	10	0	0	3	0	0	0	0	8	0	0	0	9	0	0	0	9	3	0	41	31	10	38	0	29	0	0	5	0	0	0	4	2	4	0	0	21	10
AG 165	0	0	0	0	0	0	0	0	0	0	1	68	12	8	0	0	0	0	0	4	0	0	4	6	0	0	2	2	0	12	2	11	0	4	0	0	0	2	0	4	56	13	16	22	0	19	7	0	0	1	0	0	0	0	1	3	4	8	8
AG 164	0	0	0	0	0	0	0	0	0	0	3	53	9	1	2	0	2	0	0	0	0	1	0	1	1	0	3	1	0	6	0	1	0	7	0	1	1	6	0	12	50	30	11	0	3	10	36	23	0	4	1	0	0	0	8	1	8	4	0
AG 163	0	0	0	0	2	0	3	0	0	1	1	49	5	7	7	0	7	1	0	1	0	3	0	2	0	0	2	3	0	5	3	3	15	3	0	4	0	13	0	0	26	31	14	12	0	14	14	0	3	0	0	0	0	1	26	1	6	9	3
AG 162	0	0	2	1	0	1	0	0	0	2	2	31	4	9	0	3	19	2	0	2	0	13	9	0	13	0	0	13	0	0	0	4	0	0	0	0	0	0	12	0	34	28	3	18	0	4	31	0	5	7	0	0	0	0	14	3	4	5	2
AG 161	0	0	0	9	0	0	3	1	0	1	0	43	3	16	0	3	4	0	0	5	0	0	0	4	0	0	0	4	0	11	11	12	0	9	0	0	1	14	2	0	23	21	7	12	0	21	8	2	0	4	0	0	0	0	9	0	6	26	5
AG 160	0	0	0	4	1	0	0	0	0	0	1	44	10	3	0	1	0	2	0	3	1	2	0	6	11	0	14	2	0	5	2	4	5	5	0	3	0	21	4	5	23	31	14	12	0	7	17	0	4	0	2	0	0	0	8	2	5	9	7
AG 159	0	0	0	1	0	0	0	0	0	0	0	24	7	4	0	0	0	0	0	0	0	6	0	0	14	0	27	3	0	4	0	3	0	0	0	0	0	11	0	3	36	47	16	13	0	19	23	9	0	0	0	0	0	0	17	9	0	3	1
AG 158	0	0	0	0	0	0	2	0	0	3	3	19	36	2	9	0	0	1	0	4	0	0	0	0	5	0	4	0	0	14	3	5	0	0	0	0	0	6	0	12	27	31	16	0	9	17	11	13	0	0	0	0	0	0	16	3	12	14	3
AG 157	0	0	0	1	1	0	1	0	0	1	3	6	0	8	0	3	10	0	0	2	0	0	0	3	3	0	2	7	0	33	4	9	0	2	0	0	0	4	3	0	37	34	16	17	0	21	11	0	1	18	1	0	0	0	11	3	5	16	3
AG 156	0	0	0	0	2	0	2	0	0	1	7	3	37	16	0	0	0	3	0	6	0	9	0	8	7	0	5	22	0	16	2	0	2	2	0	1	0	6	0	9	23	19	12	10	0	13	0	3	0	0	0	0	0	0	15	1	9	21	8
AG 155	0	0	0	0	1	0	4	3	0	1	0	26	17	10	6	0	3	0	0	6	0	3	2	8	1	0	1	15	0	14	0	0	2	0	0	0	0	13	0	4	14	8	9	4	0	15	14	5	0	0	1	0	0	0	21	10	4	41	14
AG 154	0	0	0	0	10	0	5	0	0	0	7	34	3	8	3	0	0	3	0	3	0	3	2	3	8	0	4	14	0	17	0	0	0	0	0	0	0	3	0	8	19	32	11	9	0	8	16	4	4	7	0	0	0	0	18	0	5	22	7
AG 153	0	0	0	0	3	0	0	0	0	8	1	6	11	20	7	0	0	8	0	9	0	10	7	16	7	0	3	2	0	0	0	0	3	5	0	4	1	23	0	12	13	8	8	0	0	1	9	4	0	11	0	0	0	0	17	2	6	41	14
AG 152	0	0	0	1	1	1	0	0	2	0	7	8	3	18	0	4	1	0	6	8	0	7	15	10	0	1	0	33	0	5	1	7	0	0	0	0	0	1	4	15	20	14	6	11	3	11	13	0	0	9	0	0	0	0	23	2	6	14	9
AG 151	0	0	0	0	3	5	12	5	13	0	4	16	2	31	1	1	0	4	0	1	0	0	0	2	3	0	2	26	0	6	0	1	0	2	0	0	0	1	6	0	8	8	7	4	3	9	10	2	34	12	12	0	0	0	25	19	0	0	0
AG 150	0	0	0	0	6	19	9	9	20	0	1	8	2	23	0	3	0	7	4	4	0	10	13	5	5	1	4	12	0	0	0	6	0	0	0	0	0	0	0	3	16	4	7	8	0	5	1	0	28	12	3	0	0	1	19	14	8	0	0
AG 149	0	0	0	0	0	11	1	8	14	2	4	7	2	18	1	3	0	8	8	7	1	4	0	4	10	1	7	33	0	14	1	6	0	0	0	0	0	0	6	1	15	19	4	8	0	6	16	1	4	3	7	4	0	0	16	8	7	0	0
AG 148	0	0	0	0	3	10	13	13	8	0	4	19	4	28	0	5	0	8	0	0	0	0	0	4	8	0	3	24	0	9	2	8	0	2	0	0	0	0	0	4	12	17	0	11	0	6	2	0	21	9	8	0	0	0	22	7	6	0	0
AG 147	0	0	0	0	3	1	15	9	5	1	0	19	6	24	8	1	8	1	0	7	0	3	0	0	15	0	6	15	0	3	1	0	0	0	0	0	0	0	0	4	28	26	11	7	0	10	16	0	10	9	1	1	0	0	11	6	9	0	0
AG 146	0	0	0	0	0	4	5	1	7	0	6	36	9	17	2	0	0	0	0	4	0	0	2	0	4	0	0	12	0	6	2	3	0	0	0	0	0	0	8	0	27	25	14	13	1	18	22	0	7	9	8	0	0	1	17	4	6	0	0
AG 145	0	0	0	0	4	0	8	4	4	0	11	25	1	8	7	4	1	6	0	4	1	5	0	0	8	1	9	20	0	5	0	5	0	3	0	0	0	0	1	0	25	12	3	4	2	13	20	0	23	24	7	2	0	3	7	6	4	0	0
AG 144	0	0	0	0	0	3	4	3	6	0	7	35	16	21	0	0	0	6	8	3	0	12	0	4	1	1	12	20	0	10	0	0	0	1	0	0	0	3	5	0	17	33	10	19	0	4	1	0	9	7	0	0	0	1	12	2	4	0	0
AG 143	0	0	0	1	9	0	21	16	0	4	1	8	4	46	7	4	0	0	0	6	0	0	2	0	3	0	4	4	0	4	2	3	1	0	0	0	0	2	2	1	27	18	2	4	0	6	2	0	7	25	6	0	0	0	24	6	18	0	0
AG 142	0	0	0	1	0	0	2	0	0	0	0	47	0	9	0	3	4	0	0	1	3	5	0	0	3	0	6	12	1	4	1	4	0	0	0	3	0	23	0	0	46	41	4	23	0	9	36	0	0	0	0	0	0	0	5	1	3	0	0
AG 140	0	0	0	0	0	3	17	5	0	5	5	18	2	6	3	3	0	5	1	2	0	9	0	2	2	0	3	5	0	4	0	4	5	5	0	15	20	32	0	1	18	14	13	0	2	0	7	7	0	4	0	1	0	0	32	4	16	0	0
AG 139	0	0	0	0	0	3	18	17	21	5	6	8	0	13	0	4	0	0	2	0	0	9	2	0	4	0	0	19	0	2	5	6	7	0	0	8	2	64	0	0	9	23	0	4	0	0	4	0	0	0	0	0	0	0	23	0	12	0	0
AG 138	0	0	0	0	0	11	7	7	11	1	3	12	2	7	2	7	1	2	0	3	4	0	9	2	2	0	0	8	0	5	2	9	0	4	0	8	12	81	0	0	20	14	1	13	0	0	4	0	0	0	0	0	0	0	19	0	7	0	0
AG 137 A	0	0	0	0	0	9	10	8	6	2	1	24	4	18	6	0	0	0	0	5	0	6	0	0	13	0	12	11	0	3	2	4	0	2	0	5	6	22	0	0	28	27	3	18	0	4	8	0	0	2	1	0	0	0	16	3	11	0	0
AG 137	0	0	0	0	0	15	4	6	3	0	16	51	3	20	0	6	0	3	2	2	4	4	2	1	18	0	8	17	0	8	3	4	0	1	0	0	0	4	0	0	19	14	6	19	0	1	8	0	0	0	4	0	0	0	19	2	3	0	0
AG 136	0	0	0	0	0	3	9	5	11	0	0	0	0	37	0	7	0	15	0	2	0	21	8	9	2	0	0	7	0	0	3	4	6	12	2	11	6	84	0	0	0	9	2	4	1	0	0	0	0	0	0	0	0	0	9	2	9	0	0
AG 135	0	0	0	0	0	24	11	6	9	0	0	1	4	24	1	2	0	18	0	6	11	12	11	0	0	5	0	0	0	0	0	0	0	7	1	18	17	59	0	0	6	11	2	2	0	0	0	0	0	0	5	0	0	0	8	0	19	0	0
AG 134	0	0	0	0	0	8	0	0	9	0	0	0	0	17	0	0	0	24	1	0	0	3	11	0	0	0	4	3	0	0	0	0	0	7	0	0	16	49	21	11	9	14	12	7	0	0	7	0	0	0	3	0	0	0	39	1	24	0	0
AG 133	0	0	0	0	0	14	23	9	5	1	0	19	0	26	2	0	0	9	2	0	0	11	0	8	4	0	1	7	1	3	1	0	0	0	0	9	8	61	0	0	7	9	4	4	0	6	1	0	0	0	0	0	0	0	38	0	7	0	0
AG 132	0	0	0	0	0	1	0	0	6	0	0	9	15	27	6	8	0	9	1	2	0	20	0	19	6	1	0	1	0	0	4	3	3	0	1	9	10	51	0	0	13	21	3	14	1	0	3	0	0	0	2	0	0	0	13	1	17	0	0
AG 131	0	0	0	0	0	0	0	2	0	0	0	18	4	0	8	0	0	0	0	3	0	7	0	2	21	0	22	10	0	10	0	1	0	9	0	11	5	47	0	0	28	29	14	0	0	2	16	11	0	2	0	0	0	0	11	0	7	0	0
AG 130	0	0	0	0	0	1	4	0	0	0	0	22	6	8	9	0	0	3	0	11	0	7	8	6	4	1	7	2	0	7	0	0	0	9	0	5	3	33	4	3	13	48	7	20	0	9	11	4	0	0	0	0	0	0	14	0	11	0	0
AG 129	0	0	0	0	0	7	0	0	2	0	0	28	8	17	1	0	1	7	3	1	14	0	11	0	13	7	7	12	0	0	3	0	14	3	4	0	24	33	2	0	13	19	7	4	0	0	7	0	0	0	0	0	0	2	26	0	0	0	0
AG 128	0	0	0	0	0	0	15	4	0	1	0	16	16	29	12	8	10	11	0	0	0	9	0	0	6	0	0	7	0	0	4	0	4	15	0	14	6	4	0	0	23	24	0	5	0	11	12	0	0	1	3	0	0	0	19	0	11	0	0
AG 127	0	0	0	0	0	7	16	0	0	0	0	33	7	21	0	0	0	5	8	0	5	4	21	0	0	3	2	0	0	0	0	0	0	4	0	2	3	41	0	0	24	37	0	8	1	8	9	0	0	0	0	0	0	0	25	0	6	0	0
AG 126	0	0	0	0	0	0	2	0	2	0	0	12	0	59	0	0	0	15	8	6	9	31	19	0	7	3	6	0	0	0	0	0	0	2	0	3	0	9	5	0	17	51	6	2	0	0	0	13	0	0	0	0	0	0	5	0	8	0	0
AG 125	0	0	0	0	0	14	8	0	0	0	0	9	6	49	0	0	0	9	8	10	0	31	0	12	4	0	4	0	0	0	0	0	0	2	0	0	7	23	0	0	21	43	3	8	0	0	11	3	0	0	0	0	0	0	5	2	8	0	0
AG 124	0	0	0	0	0	3	9	0	0	0	0	14	4	51	3	0	0	19	3	4	5	18	0	8	8	0	6	0	0	0	0	0	0	0	0	0	7	42	0	0	33	19	10	4	0	0	18	0	0	0	0	0	0	0	3	0	9	0	0
AG 123	0	0	0	0	0	0	0	0	0	0	0	22	7	18	23	0	0	4	9	15	0	6	0	8	7	0	4	0	0	0	0	0	0	9	0	8	11	64	0	8	19	16	8	13	0	0	12	0	0	0	0	0	0	0	0	0	9	0	0
AG 122	0	0	0	0	0	0	6	2	0	1	0	25	2	1	6	0	4	9	0	6	0	13	0	5	12	0	1	6	0	0	1	0	9	6	0	16	24	37	0	14	13	24	7	0	0	0	7	6	0	18	0	0	0	0	13	0	6	0	0
AG 120	0	0	0	0	0	2	7	5	0	0	0	22	10	35	9	0	0	6	0	16	0	2	0	13	6	0	3	2	0	0	0	0	4	5	1	11	21	26	0	0	10	19	9	5	0	7	7	5	0	0	0	0	0	0	26	0	6	0	0

Table 2. Distribution of genera throughout the measured section.

Sample No	Lithology	Abathomphalus	Archaeoglobigerina	Contusotruncana	Gansserina	Globigerinelloids	Globotruncana	Globotruncanella	Globotruncanita	Rugoglobigerina	Gublerina	Heterohelix	Laeviheterohelix	Planoglobulina	Pseudoguembelina	Pseudotextularia	Racemiguembelina	Sample No	Stages	Globotruncanid Zonation	Heterohelicoid Zonation
AG 177	Clayey Limestone	0	0	3	5	11	75	7	6	24	0	65	13	20	9	36	26	AG 177	MAASTRICHTIAN	***Abathomphalus mayaroensis* Zone**	***Pseudoguembelina hariensis* Zone**
AG 176	Clayey Limestone	0	0	2	2	34	31	3	18	45	2	61	17	21	3	53	8	AG 176			
AG 175	Marl	2	0	6	0	4	41	6	12	74	0	37	11	38	1	25	43	AG 175			
AG 174	Clayey Limestone	2	0	0	0	19	22	1	4	89	2	74	12	20	2	25	28	AG 174			
AG 173	Marl	3	0	7	2	4	47	9	39	18	1	71	13	51	2	15	18	AG 173			
AG 172	Clayey Limestone	1	0	1	1	51	13	10	12	6	0	112	32	17	5	16	23	AG 172			
AG 171	Marl	0	0	0	1	27	45	4	32	5	9	89	2	29	7	18	32	AG 171			
AG 170	Clayey Limestone	1	0	0	0	38	31	9	12	32	4	76	16	32	2	15	32	AG 170			
AG 169	Marl	0	0	6	2	40	29	9	8	16	11	79	1	36	0	21	42	AG 169		***Gansserina gansseri* Zone**	
AG 168	Clayey Limestone	0	0	0	0	65	4	9	14	20	4	143	23	0	1	10	7	AG 168			
AG 167	Marl	0	0	3	0	2	32	2	31	22	20	89	26	13	2	38	20	AG 167			
AG 166	Clayey Limestone	0	0	0	0	42	31	3	8	18	3	149	0	5	6	4	31	AG 166			
AG 165	Marl	0	0	0	1	68	34	2	27	6	4	126	7	1	0	8	16	AG 165			***Racemiguembelina fructicosa* Zone**
AG 164	Marl	0	0	0	3	53	16	4	8	15	12	104	59	5	0	17	4	AG 164			
AG 163	Marl	0	0	6	1	49	33	2	14	35	0	97	14	3	1	33	12	AG 163			
AG 162	Marl	0	3	3	2	31	61	13	17	0	12	87	31	12	0	21	7	AG 162			
AG 161	Marl	0	9	5	0	43	35	0	38	24	2	84	10	4	0	15	31	AG 161			
AG 160	Marl	0	4	1	1	44	28	25	13	34	9	87	17	6	0	15	16	AG 160			
AG 159	Clayey Limestone	0	1	0	0	24	17	41	10	11	3	131	32	0	0	26	4	AG 159			
AG 158	Marl	0	0	5	3	19	52	9	22	6	12	100	24	0	0	31	17	AG 158			
AG 157	Marl	0	1	3	3	6	26	5	53	6	3	125	11	17	3	19	19	AG 157			
AG 156	Marl	0	0	5	7	3	79	12	40	11	9	77	3	0	0	25	29	AG 156			
AG 155	Marl	0	0	9	0	26	55	2	29	15	4	50	19	1	0	35	55	AG 155			
AG 154	Clayey Limestone	0	0	15	7	34	28	12	31	3	8	79	20	11	0	23	29	AG 154			
AG 153	Marl	0	0	11	1	6	88	10	2	36	12	30	13	3	8	25	55	AG 153			
AG 152	Marl	0	1	4	7	8	72	1	46	1	19	65	13	8	1	31	23	AG 152			
AG 151	Marl	0	0	38	4	16	42	5	33	3	6	39	12	57	1	44	0	AG 151			***Planoglobulina acervuloinides* Zone**
AG 150	Marl	0	0	63	1	8	71	10	18	0	3	40	1	41	3	41	0	AG 150			
AG 149	Marl	0	0	36	4	7	56	18	54	0	7	52	17	14	4	31	0	AG 149			
AG 148	Marl	0	0	47	4	19	49	11	43	2	4	46	2	38	0	35	0	AG 148			
AG 147	Marl	0	0	34	0	19	58	21	19	0	4	82	16	20	1	26	0	AG 147			
AG 146	Clayey Limestone	0	0	17	6	36	34	4	23	0	8	98	22	24	1	27	0	AG 146			
AG 145	Marl	0	0	20	11	25	37	18	30	3	1	59	20	46	13	17	0	AG 145			
AG 144	Clayey Limestone	0	0	16	7	35	70	14	30	4	5	83	1	13	4	18	0	AG 144			
AG 143	Marl	0	1	50	1	8	69	7	13	3	3	57	2	34	4	48	0	AG 143	CAMPANIAN		***Pseudotextularia elegans* Zone**
AG 142	Clayey Limestone	0	1	2	0	47	25	9	22	26	0	123	36	0	0	9	0	AG 142			
AG 140	Marl	0	0	30	5	18	33	5	13	77	1	47	14	4	1	52	0	AG 140			
AG 139	Marl	0	0	64	6	8	30	4	32	81	0	36	4	0	0	35	0	AG 139			
AG 138	Marl	0	0	37	3	12	39	2	24	105	0	48	4	0	0	26	0	AG 138			
AG 137	Marl	0	0	35	1	24	39	25	20	35	0	80	8	3	0	30	0	AG 137			
AG 137	Marl	0	0	28	16	51	47	26	32	5	0	59	8	4	0	24	0	AG 137			
AG 136	Marl	0	0	28	0	0	99	2	14	121	0	16	0	0	0	20	0	AG 136		***Globotruncana aegyptiaca* Zone**	
AG 135	Marl	0	0	50	0	1	89	5	0	102	0	21	0	5	0	27	0	AG 135			
AG 134	Marl	0	0	17	0	0	56	4	3	72	32	42	7	3	0	64	0	AG 134			
AG 133	Marl	0	0	55	0	19	55	5	12	78	0	30	1	0	0	45	0	AG 133			
AG 132	Marl	0	0	7	0	9	107	7	8	74	0	52	3	2	0	31	0	AG 132			
AG 131	Marl	0	0	2	0	18	24	43	21	72	0	73	27	2	0	18	0	AG 131			
AG 130	Clayey Limestone	0	0	5	0	22	58	12	9	50	7	97	15	0	0	25	0	AG 130			
AG 129	Marl	0	0	9	0	28	63	27	15	78	2	43	7	0	2	26	0	AG 129			
AG 128	Marl	0	0	20	0	16	95	6	11	43	0	63	12	4	0	30	0	AG 128			
AG 127	Marl	0	0	23	0	33	71	5	0	50	0	78	9	0	0	31	0	AG 127			
AG 126	Marl	0	0	4	0	12	147	16	0	14	5	76	13	0	0	13	0	AG 126			
AG 125	Marl	0	0	22	0	9	125	8	0	32	0	75	14	0	0	15	0	AG 125			
AG 124	Clayey Limestone	0	0	12	0	14	115	14	0	49	0	66	18	0	0	12	0	AG 124			
AG 123	Marl	0	0	0	0	22	90	11	0	92	8	56	12	0	0	9	0	AG 123			
AG 122	Marl	0	0	9	0	25	46	13	7	92	14	44	13	18	0	19	0	AG 122			
AG 120	Marl	0	0	14	0	22	91	9	2	68	0	50	12	0	0	32	0	AG 120			

APPENDIX D: EXPLANATION OF PLATES

PLATE I

(Scale bar = 100 μm)

Figure 1: *Contusotruncana contusa*; **a.** side view, sample no.: AG 160; **b.** spiral side, sample no.: AG 153

Figure 2: *Contusotruncana fornicata*; **a.** umbilical side, sample no.: AG 133; **b.** side view, sample no.: AG 150; **c.** spiral side, sample no.: AG 133

Figure 3: *Contusotruncana patelliformis*; **a.** spiral side, sample no.: AG 150; **b.** side view, sample no.: AG 150; **c.** umbilical side, sample no.: AG 150

PLATE I

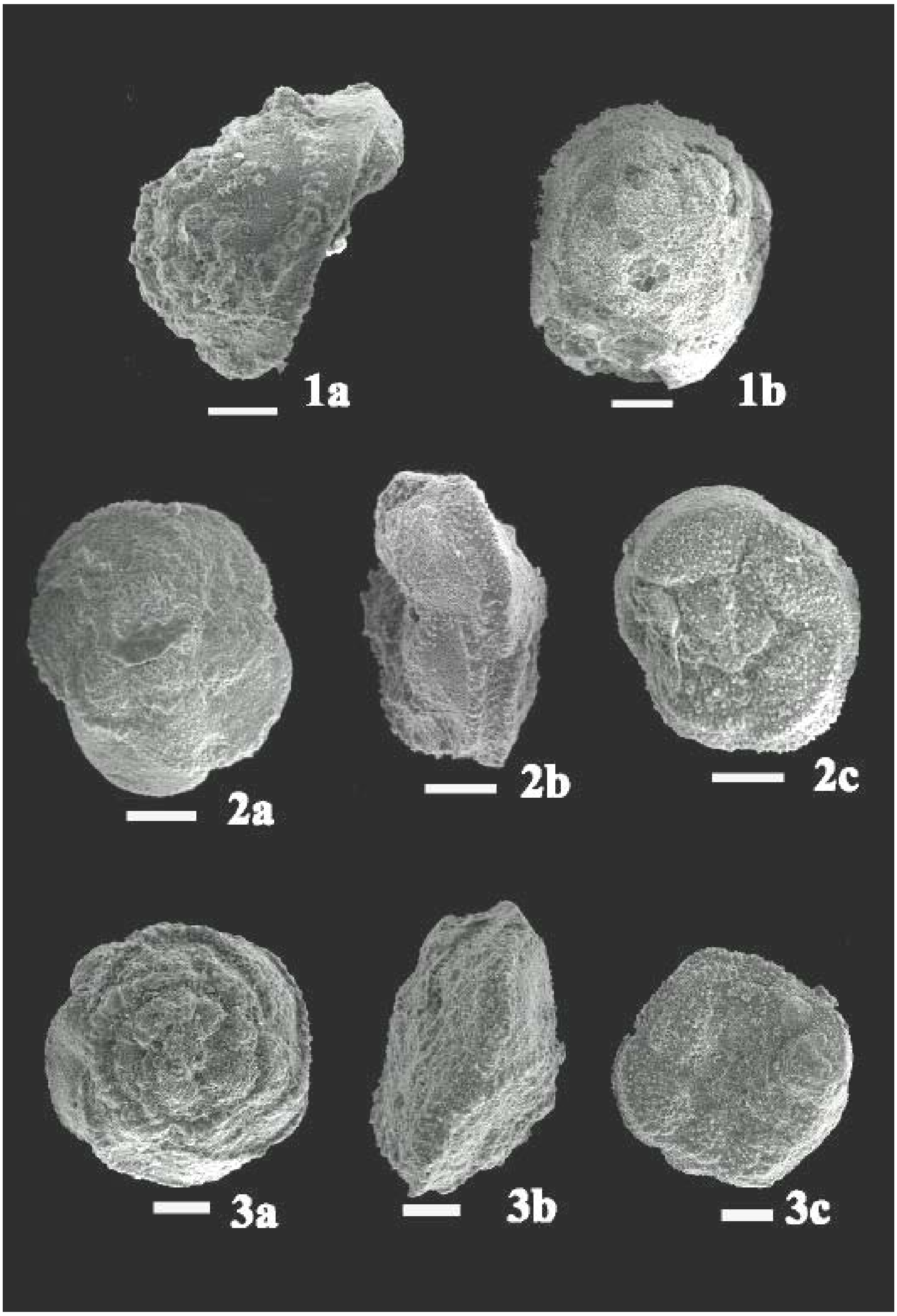


PLATE II

(Scale bar = 100 µm)

Figure 1: *Contusotruncana plummerae*; **a.** spiral side, sample no.: AG 129; **b.** side view, sample no.: AG 129; **c.** umbilical side, sample no.: AG 129

Figure 2: *Contusotruncana walfischensis*; **a.** umbilical side, sample no.: AG 153; **b.** side view, sample no.: AG 153

Figure 3: *Gansserina gansseri*; **a.** spiral side, sample no.: AG 137; **b.** side view, sample no.: AG 149

PLATE II

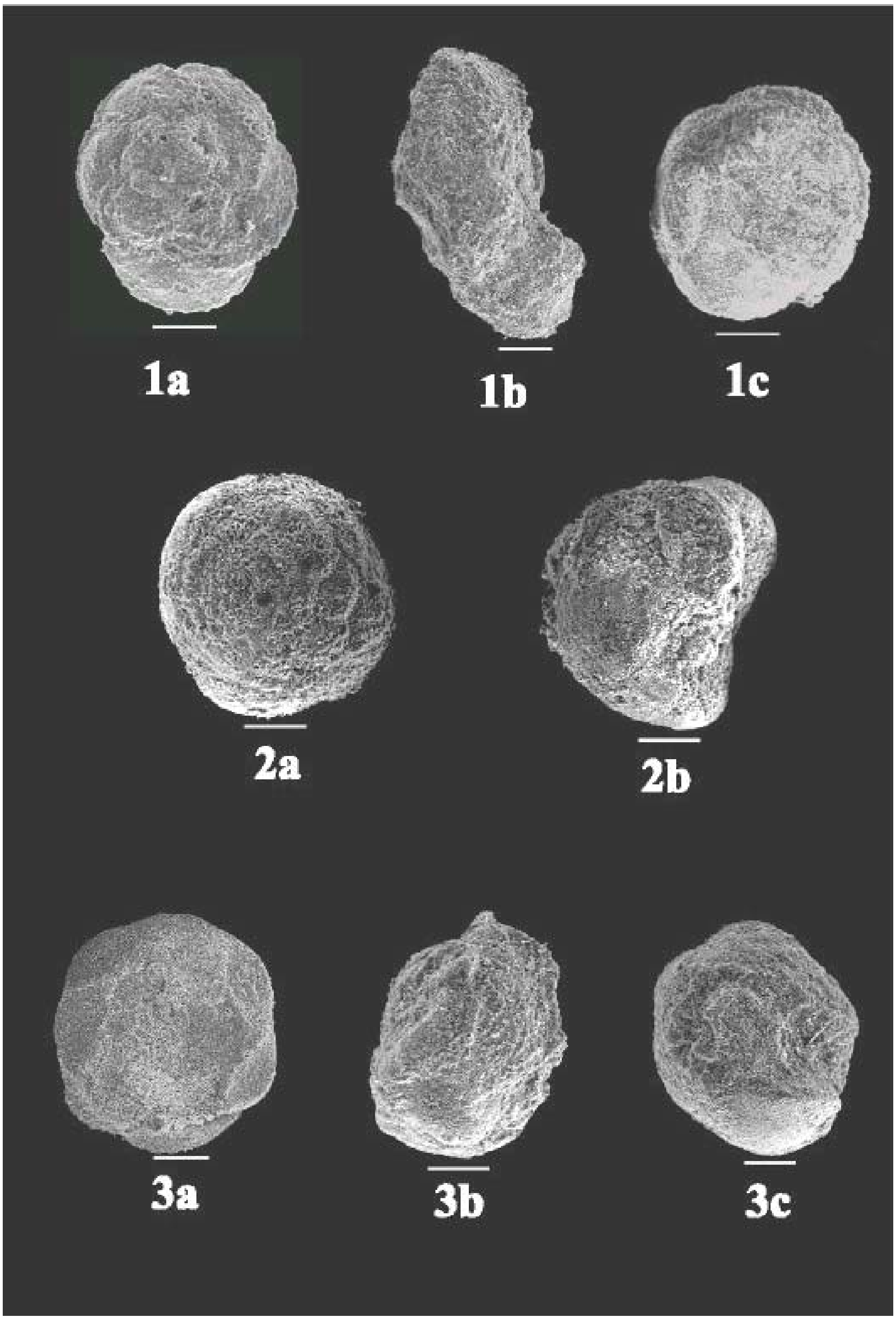


PLATE III

(Scale bar = 100 µm)

Figure 1: *Globotruncana aegyptiaca*; **a.** spiral side, sample no.: AG 127; **b.** side view, sample no.: AG 125; **c.** umbilical side, sample no.: AG 125

Figure 2: *Globotruncana arca*; **a.** spiral side, sample no.: AG 130; **b.** side view, sample no.: AG 123; **c.** umbilical side, sample no.: AG 147

Figure 3: *Globotruncana bulloides*; **a.** side view, sample no.: AG 132

Figure 4: *Globotruncana dupeublei*; **a.** spiral side, sample no.: AG 128; **b.** side view, sample no.: AG 137; **c.** umbilical side, sample no.: AG 128

PLATE III

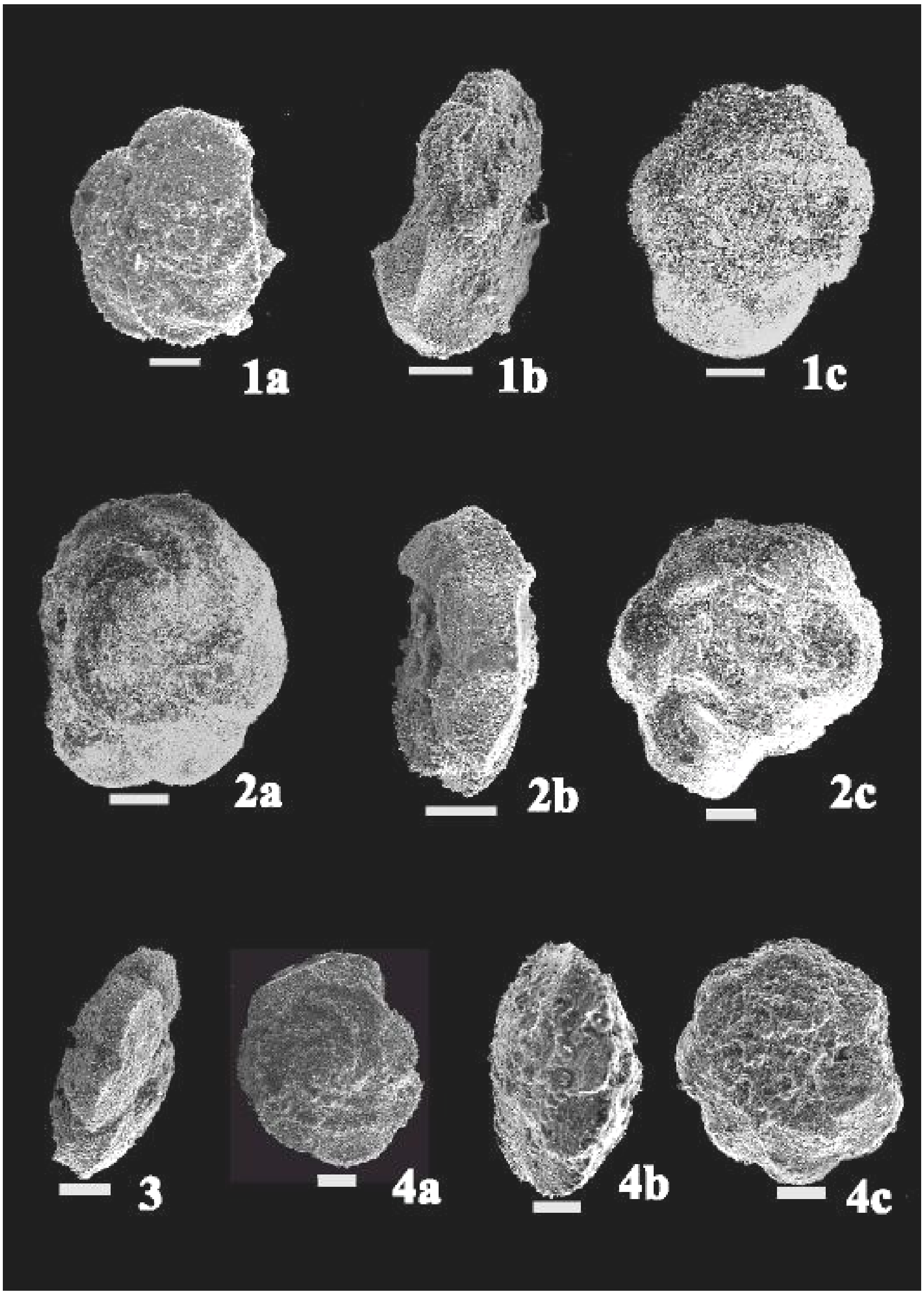


PLATE IV

(Scale bar = 100 μm)

Figure 1: *Globotruncana esnehensis*; side view; sample no.: AG 162
Figure 2: *Globotruncana falsostuarti*; **a.** spiral side, sample no.: AG 134; **b.** side view, sample no.: AG 125; **c.** umbilical side, sample no.: AG 134
Figure 3: *Globotruncana insignis*; side view; sample no.: AG 123
Figure 4: *Globotruncana linneiana*; **a.** spiral side, sample no.: AG 120; **b.** side view, sample no.: AG 123
Figure 5: *Globotruncana mariei*; spiral side; sample no.: AG 137
Figure 6: *Globotruncana orientalis*; **a.** spiral side, sample no.: AG 125; **b.** side view, sample no.: AG 156; **c.** umbilical side, sample no.: AG 125
Figure 7: *Globotruncana rosetta*; **a.** spiral side, sample no.: AG 126; **b.** side view, sample no.: AG 127
Figure 8: *Globotruncana ventricosa*; side view; sample no.: AG 132

PLATE IV

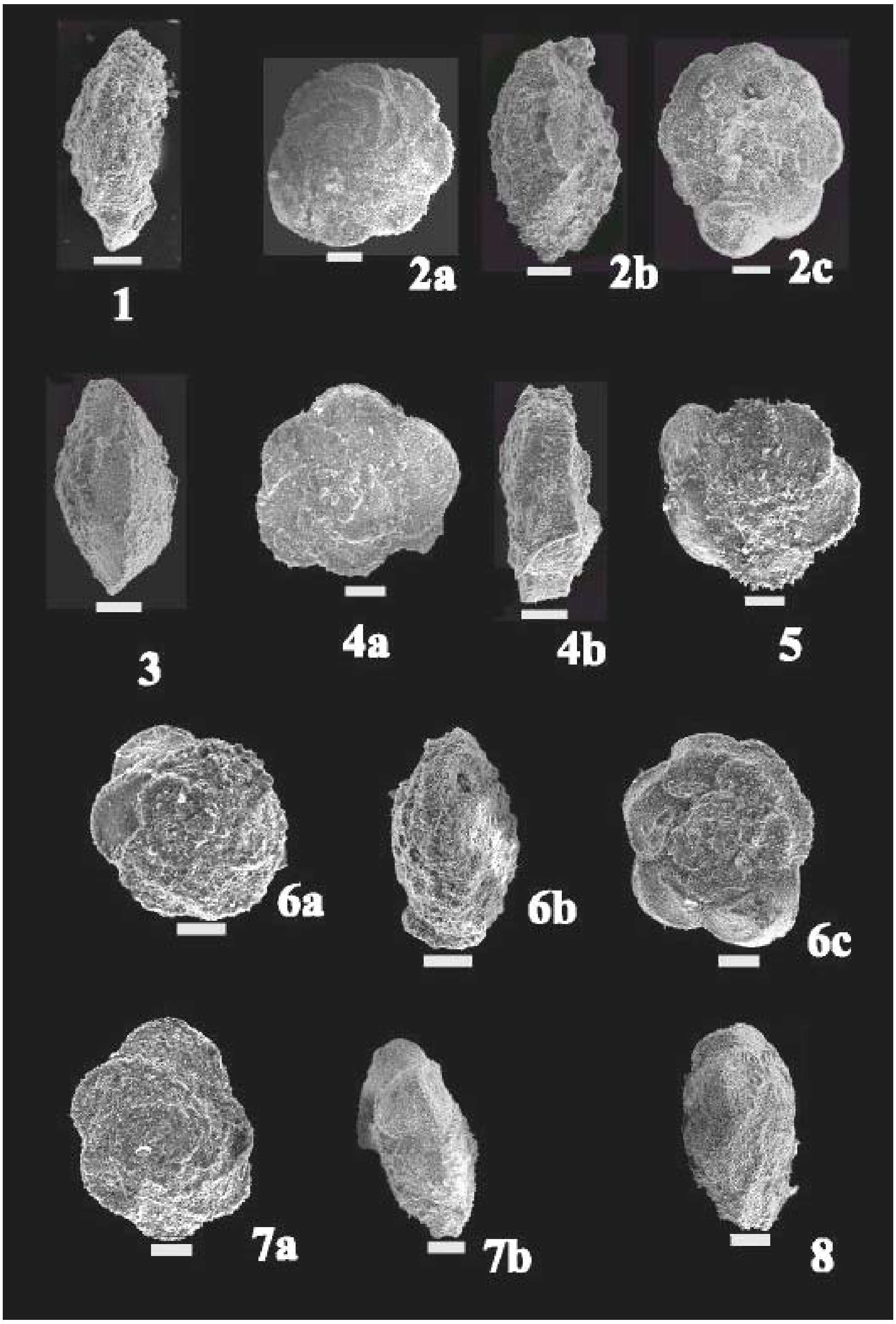


PLATE V

(Scale bar = 100 μm)

Figure 1: *Globotruncanita angulata*; **a.** umbilical side, sample no.: AG 151; **b.** side view, sample no.: AG 133

Figure 2: *Globotruncanita pettersi*; side view, sample no.: AG 149

Figure 3: *Globotruncanita stuarti*; **a.** spiral side, sample no.: AG 137; **b.** side view, sample no.: AG 137

Figure 4: *Globotruncanita angulata*; **a.** side view, sample no.: AG 173; **b.** umbilical side, sample no.: AG 171

Figure 5: *Abathomphalus mayaroensis*; **a.** side view, sample no.: AG 174; **b.** umbilical side, sample no.: AG 173

PLATE V

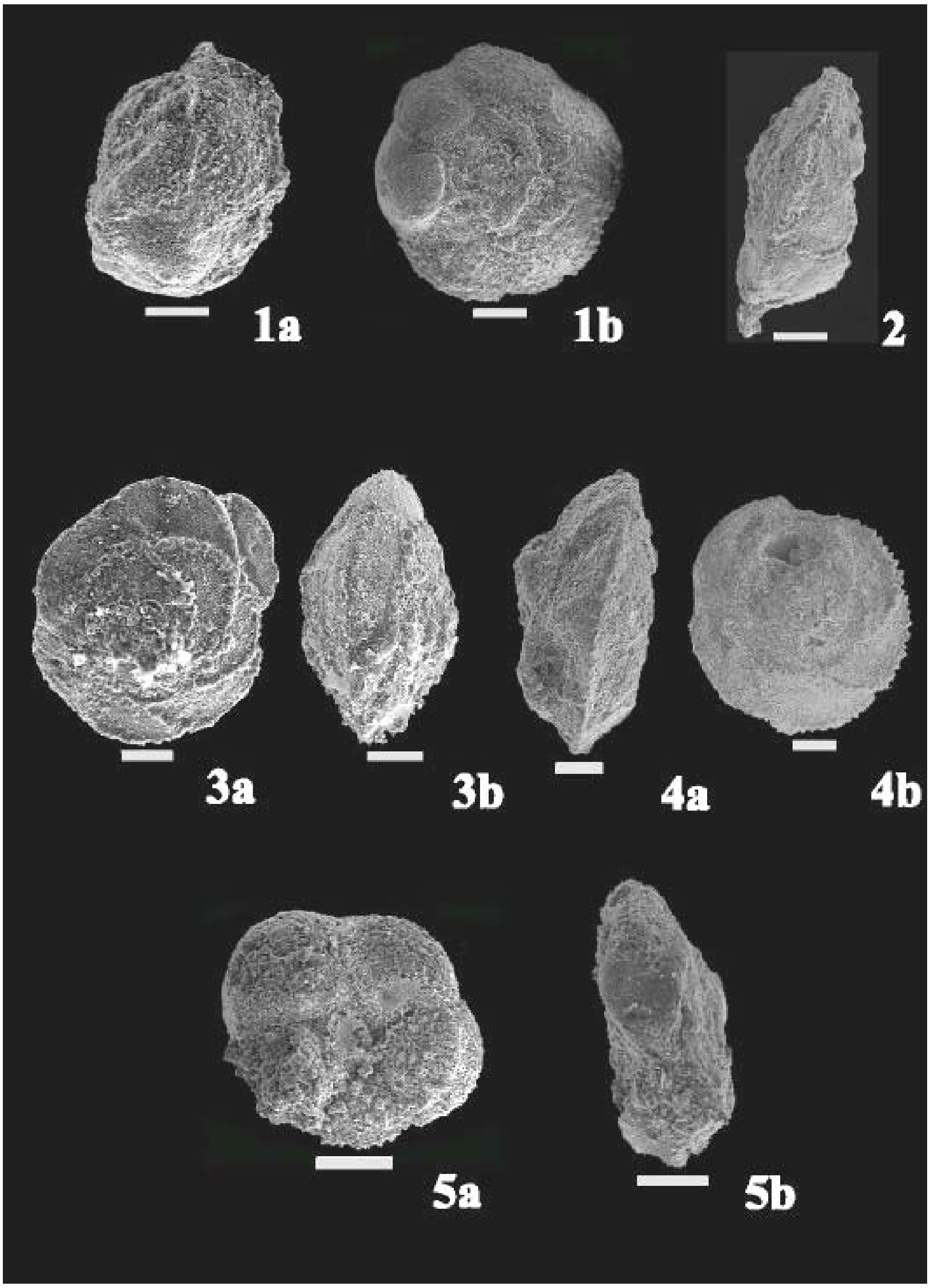


PLATE VI

(Scale bar = 100 μm)

Figure 1: *Globotruncanella havanensis*; **a.** spiral side, sample no.: AG 137; **b.** side view, sample no.: AG 137; **c.** umbilical side, sample no.: AG 137

Figure 2: *Globotruncanella petaloidea*; **a.** spiral side, sample no.: AG 122; **b.** side view, sample no.: AG 159; **c.** umbilical side, sample no.: AG 145

Figure 3: *Globotruncanella pschadae*; **a.** side view, sample no.: AG 173; **b.** umbilical side, sample no.: AG 132

PLATE VI

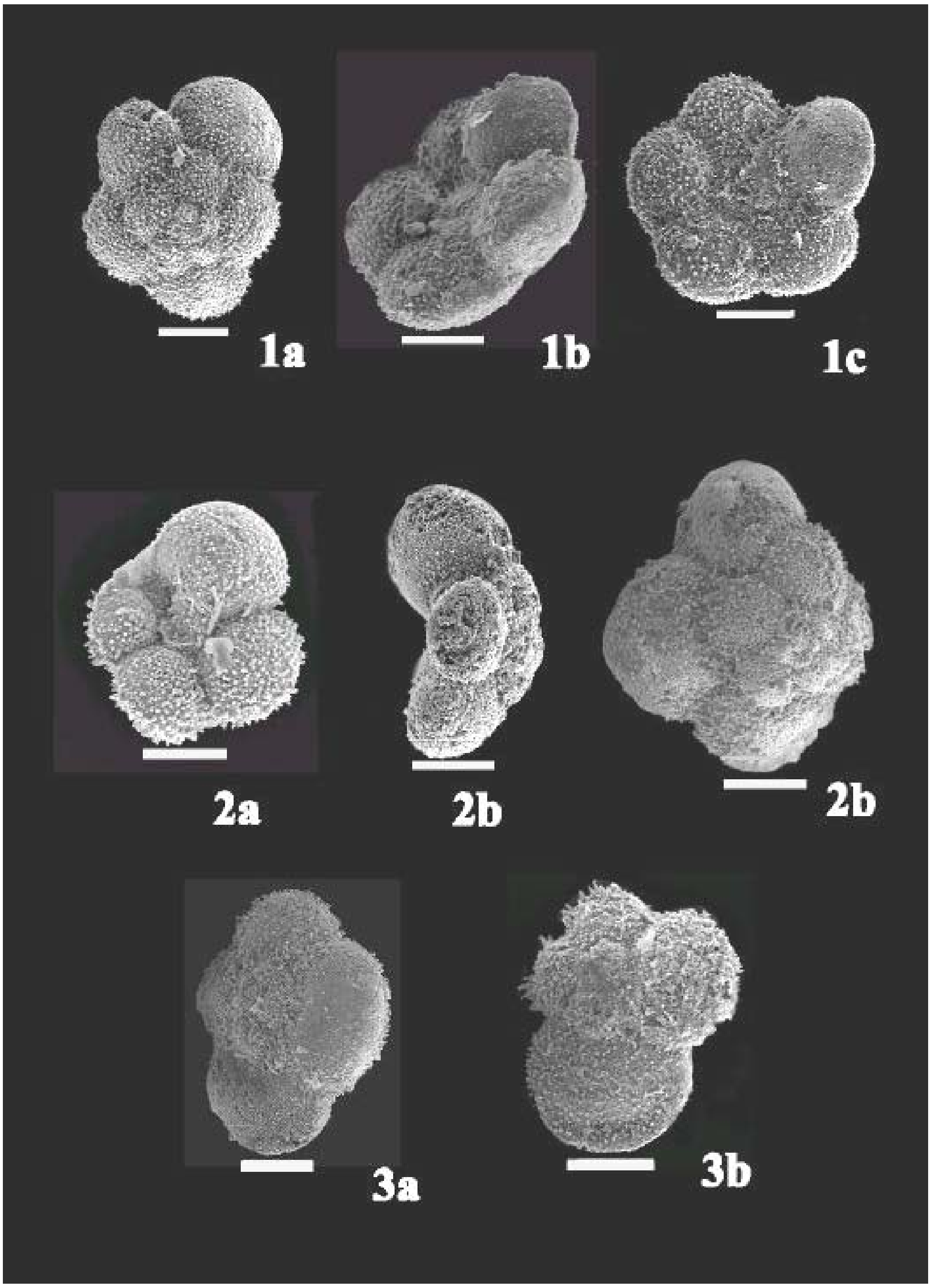


PLATE VII

(Scale bar = 100 µm)

Figure 1: *Rugoglobigerina hexacamerata*; **a.** spiral side, sample no.: AG 122; **b.** side view, sample no.: AG 122

Figure 2: *Rugoglobigerina macrocephala*; umbilical side, sample no.: AG 130

Figure 3: *Rugoglobigerina milamensis*; umbilical side, sample no.: AG 130

Figure 4: *Rugoglobigerina pennyi*; **a.** side view, sample no.: AG 174; **b.** umbilical side, sample no.: AG 135

Figure 5: *Rugoglobigerina rotundata*; side view, sample no.: AG 129

Figure 6: *Rugoglobigerina rugosa*; **a.** spiral side, sample no.: AG 123; **b.** side view, sample no.: AG 129

PLATE VII

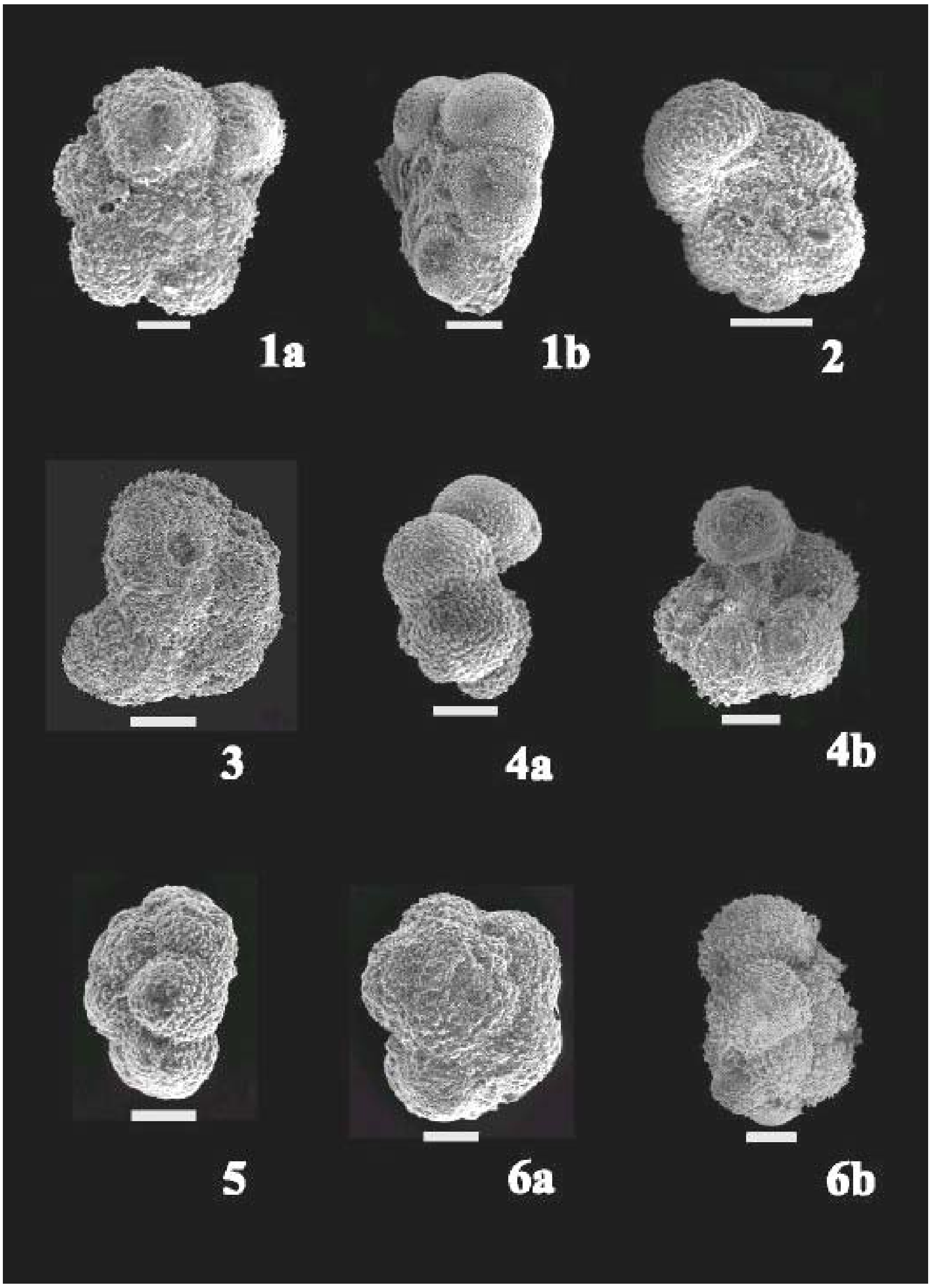


PLATE VIII

(Scale bar = 100 μm)

Figure 1: *Gublerina acuta*; **a, b** sample no.: AG 162

Figure 2: *Gublerina cuvillieri*; sample no.: AG 122

Figure 3: *Heterohelix globulosa*; **a.** sample no.: AG 145, **b.** sample no.: AG 172

Figure 4: *Heterohelix labellosa*; **a.** sample no.: AG 120, **b.** sample no.: AG 177

Figure 5: *Heterohelix navarroensis*; sample no.: AG 120

Figure 6: *Heterohelix planata*; sample no.: AG 169

PLATE VIII

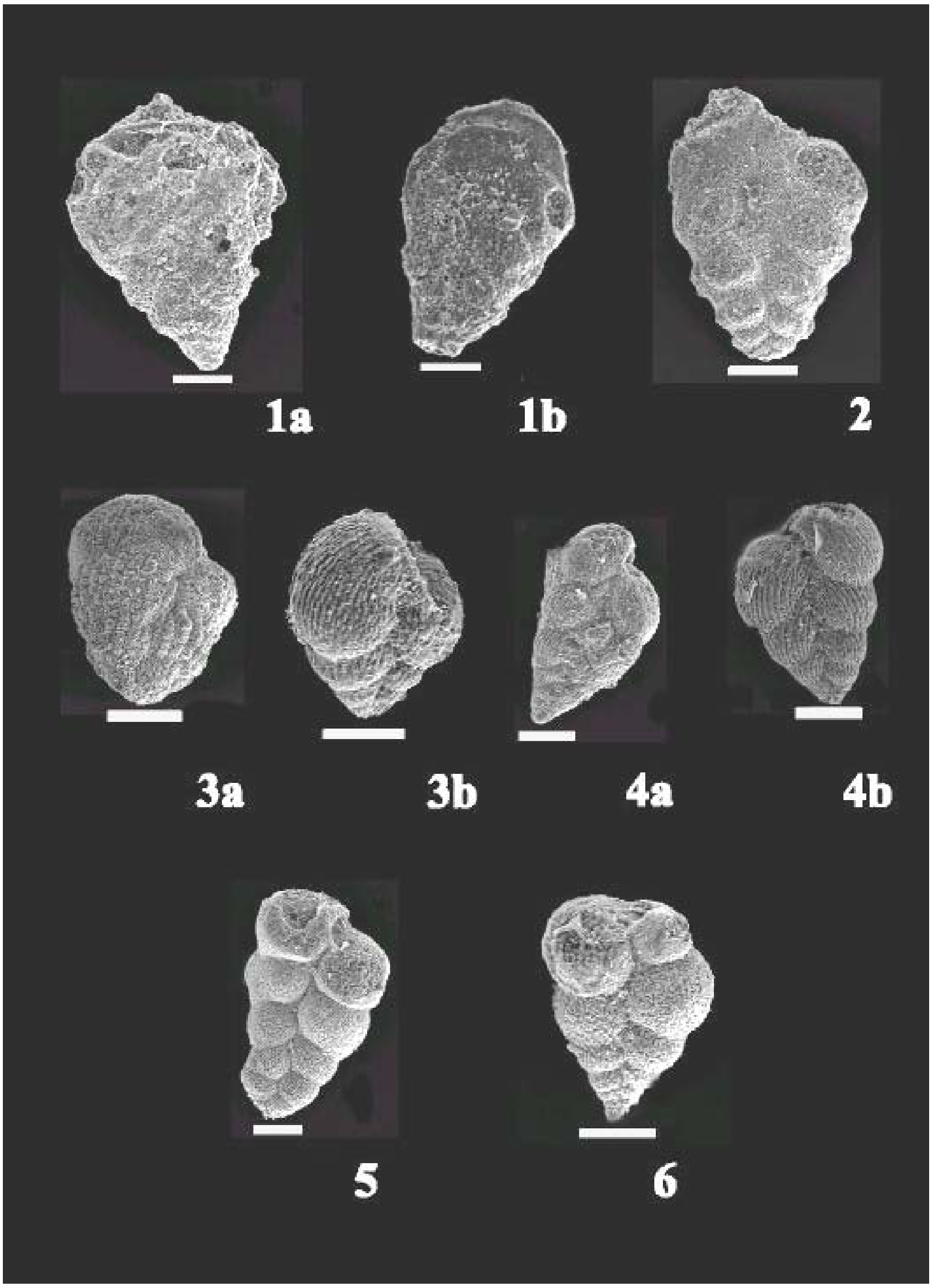


PLATE IX

(Scale bar = 100 µm)

Figure 1: *Laeviheterohelix dentata*; sample no.: AG 158

Figure 2: *Laeviheterohelix glabrans*; sample no.: AG 164

Figure 3: *Planoglobulina acervuloinides*; sample no.: AG 144

Figure 4: *Planoglobulina carseyae*; sample no.: AG 145

Figure 5: *Planoglobulina multicamerata*; sample no.: AG 137

Figure 6: *Pseudoguembelina costulata*; sample no.: AG 147

Figure 7: *Pseudoguembelina hariensis*; **a.** sample no.: AG 172, **b.** sample no.: AG 177

PLATE IX

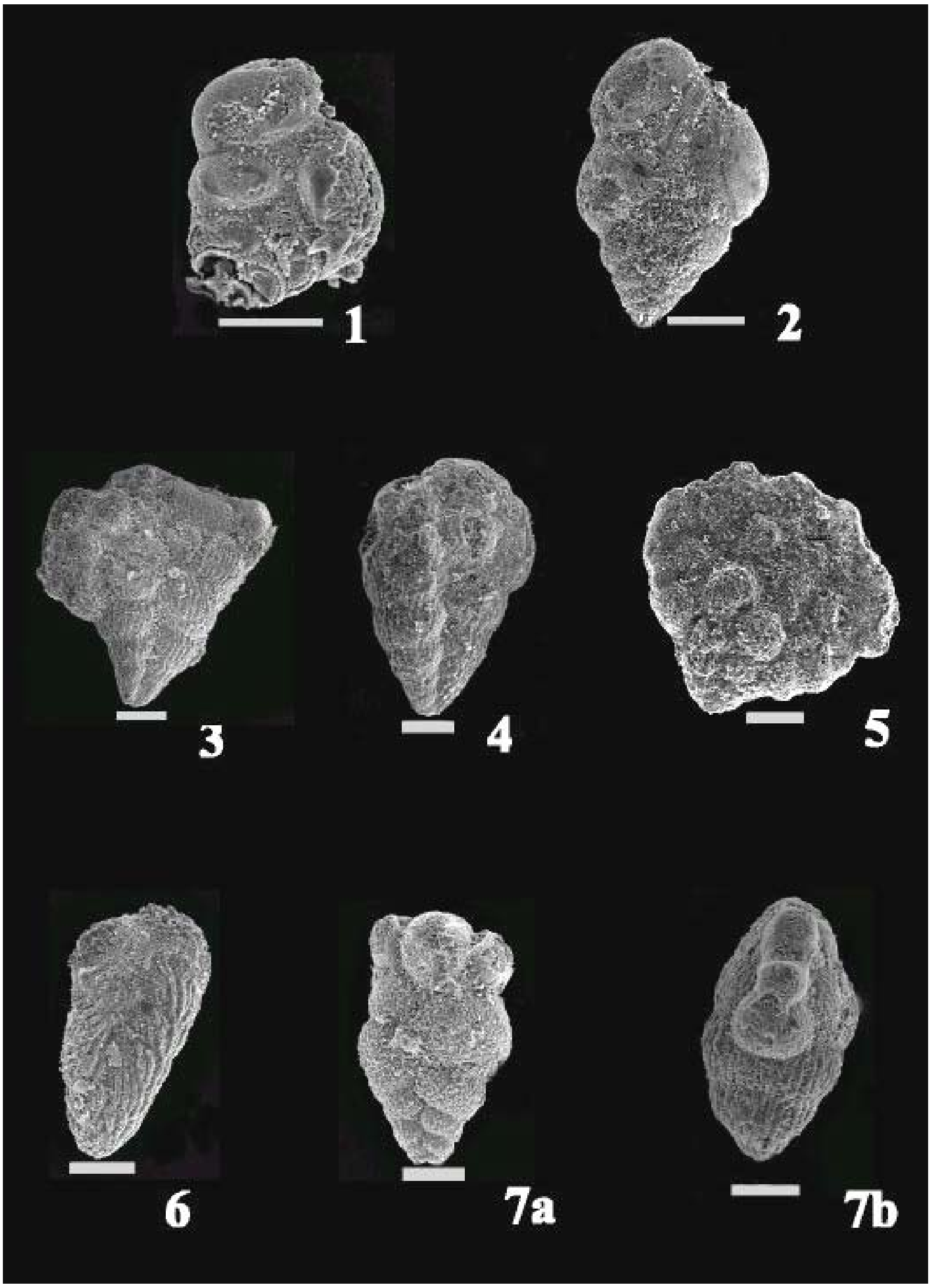


PLATE X

(Scale bar = 100 μm)

Figure 1: *Pseudoguembelina palpebra*; **a.** sample no.: AG 169, **b.** sample no.: AG 175
Figure 2: *Pseudotextularia elegans*; sample no.: AG 176
Figure 3: *Pseudotextularia intermedia*; sample no.: AG 151
Figure 4: *Pseudotextularia nuttalli*; sample no.: AG 152
Figure 5: *Racemiguembelina fructicosa*; sample no.: AG 163
Figure 6: *Racemiguembelina powelli*; sample no.: AG 152

PLATE X

1a

1b

2

3

4

5

6

PLATE XI

Figure 1: *Contusotruncana contusa*; sample no.: AG 158, X40
Figure 2: *Contusotruncana patelliformis*; sample no.: AG 143, X40
Figure 3: *Contusotruncana plicata*; sample no.: AG 137A, X40
Figure 4: *Contusotruncana plicata*; sample no.: AG 142, X40
Figure 5: *Contusotruncana plicata*; sample no.: AG 146, X40
Figure 6: *Contusotruncana walfischensis*; sample no.: AG 158, X40
Figure 7: *Globotruncana aegyptiaca*; sample no.: AG 137A, X40
Figure 8: *Globotruncana aegyptiaca*; sample no.: AG 177, X40
Figure 9: *Globotruncana arca*; sample no.: AG 127, X40
Figure 10: *Globotruncana arca*; sample no.: AG 177, X40
Figure 11: *Globotruncana bulloides*; sample no.: AG 146, X40
Figure 12: *Globotruncana linneiana*; sample no.: AG 127, X40
Figure 13: *Globotruncana ventricosa*; sample no.: AG 127, X40
Figure 14: *Globotruncana ventricosa*; sample no.: AG 162, X40
Figure 15: *Globotruncanita angulata*; sample no.: AG 143, X40
Figure 16: *Globotruncanita angulata*; sample no.: AG 143, X40
Figure 17: *Globotruncanita angulata*; sample no.: AG 152, X40
Figure 18: *Globotruncanita pettersi*; sample no.: AG 143, X40
Figure 19: *Globotruncanita pettersi*; sample no.: AG 146, X40
Figure 20: *Globotruncanita pettersi*; sample no.: AG 146, X40

PLATE XI

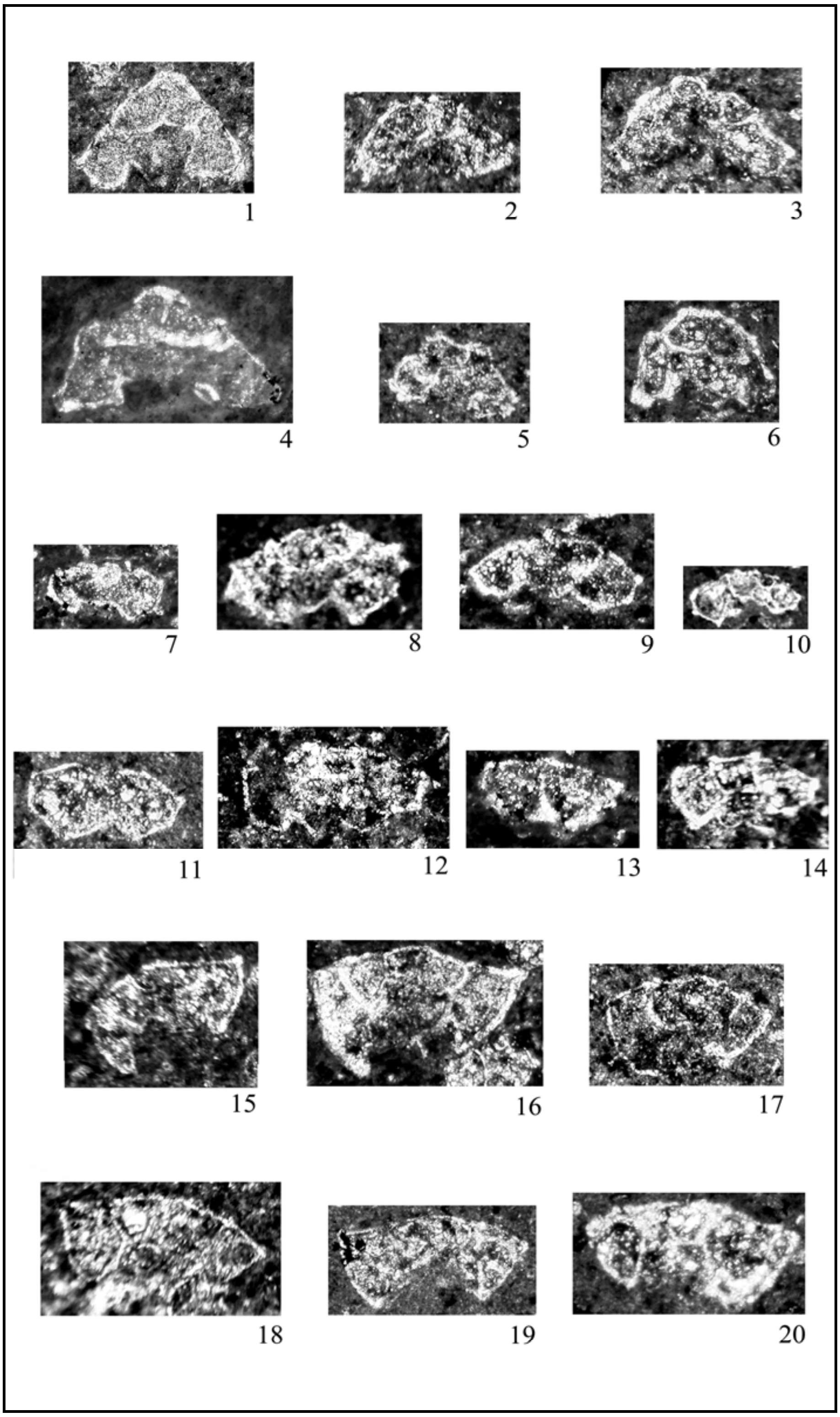
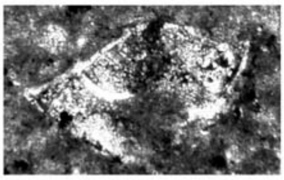


PLATE XII

Figure 1: *Globotruncanita stuarti*; sample no.: AG 151, X40
Figure 2: *Globotruncanita stuartiformis*; sample no.: AG 143, X40
Figure 3: *Globotruncanita stuartiformis*; sample no.: AG 146, X40
Figure 4: *Globotruncanita stuartiformis*; sample no.: AG 163, X40
Figure 5: *Globotruncanita stuartiformis*; sample no.: AG 168, X40
Figure 6: *Globotruncanita stuartiformis*; sample no.: AG 177, X40
Figure 7: *Rugoglobigerina macrocephala*; sample no.: AG 136, X40
Figure 8: *Rugoglobigerina milamensis*; sample no.: AG 136, X40
Figure 9: *Rugoglobigerina rugosa*; sample no.: AG 137A, X40
Figure 10: *Rugoglobigerina rugosa*; sample no.: AG 146, X40
Figure 11: *Globotruncanella havanensis*; sample no.: AG 143, X40
Figure 12: *Globotruncanella havanensis*; sample no.: AG 158, X40
Figure 13: *Globotruncanella petaloidea*; sample no.: AG 137A, X40
Figure 14: *Globotruncanella pschadae*; sample no.: AG 152, X40
Figure 15: *Gansserina gansseri*; sample no.: AG 146, X40
Figure 16: *Gansserina gansseri*; sample no.: AG 163, X40

PLATE XII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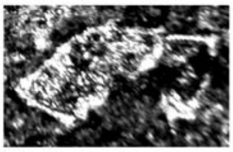
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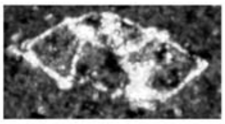
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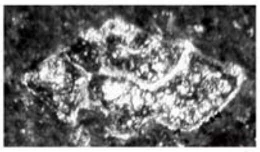
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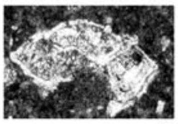
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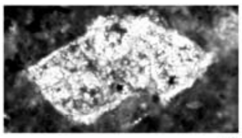
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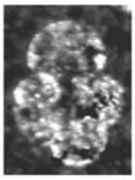
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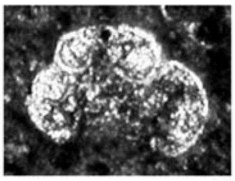
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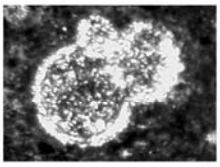
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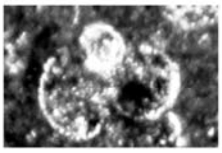
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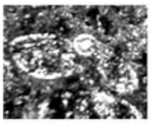
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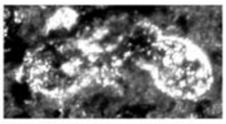
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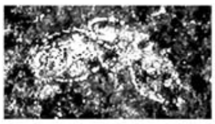
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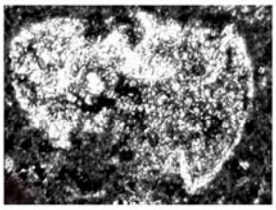
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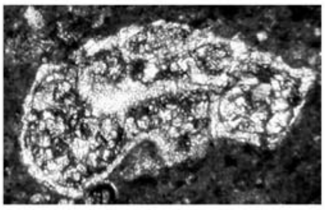
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PLATE XIII

Figure 1: *Heterohelix* sp.; sample no.: AG 137A, X40

Figure 2: *Heterohelix globulosa*; sample no.: AG 143, X40

Figure 3: *Heterohelix globulosa*; sample no.: AG 160, X40

Figure 4: *Heterohelix labellosa*; sample no.: AG 146, X40

Figure 5: *Heterohelix labellosa*; sample no.: AG 169, X40

Figure 6: *Heterohelix planata*; sample no.: AG 162, X40

Figure 7: *Planoglobulina* sp.; sample no.: AG 146, X40

Figure 8: *Planoglobulina* sp.; sample no.: AG 151, X40

Figure 9: *Planoglobulina acervuloinides*; sample no.: AG 177, X40

Figure 10: *Planoglobulina carseyae*; sample no.: AG 143, X40

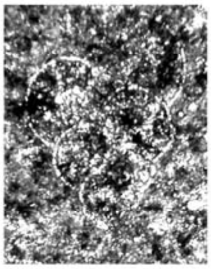
Figure 11: *Pseudoguembelina hariensis*; sample no.: AG 170, X40

Figure 12: *Pseudotextularia intermedia*; sample no.: AG 177, X40

Figure 13: *Racemiguembelina fructicosa*; sample no.: AG 170, X40

PLATE XIII


1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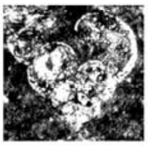
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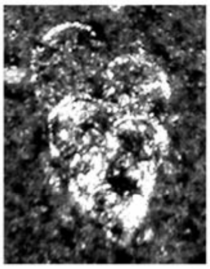
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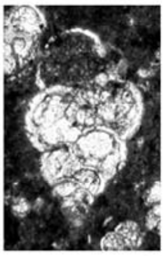
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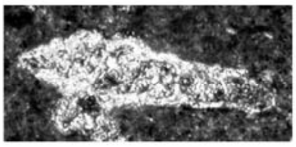
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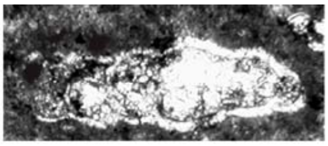
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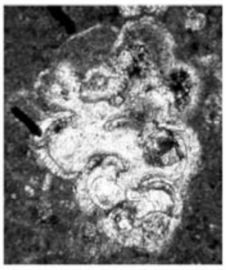
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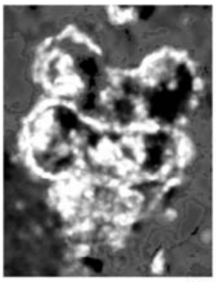
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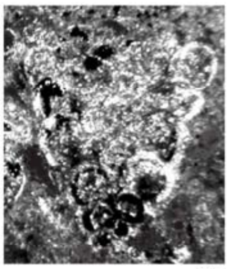
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