TAXONOMY AND BIOSTRATIGRAPHY OF CALPIONELLIDS AND *SACCOCOMA* ACROSS THE JURASSIC-CRETACEOUS BOUNDARY BEDS OF THE ALCI BLOCK: ALACAATLI OLISTOSTROMES, ANKARA, TURKEY

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ABSTRACT

TAXONOMY AND BIOSTRATIGRAPHY OF CALPIONELLIDS AND *SACCOCOMA* ACROSS THE JURASSIC-CRETACEOUS BOUNDARY BEDS OF THE ALCI BLOCK: ALACAATLI OLISTOSTROMES, ANKARA, TURKEY

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The main aim of this study is to determine the exact position of the Jurassic-Cretaceous (the Tithonian-Berriasian) boundary based on the calpionellid species and their biozones within the pelagic limestone block (Alcı Block). To achieve this aim, the stratigraphic section-BA was measured as 59,30 meters throughout the Alcı Block and totally 72 samples were collected for the preparation of the thin sections.

Totally 3 zones and 5 subzones have been designated as *Chitinoidella* Zone (*boneti* Subzone), *Crassicollaria* Zone (*remanei* and *massutiniana* subzones), *Calpionella* Zone (*alpina* and *Remaniella* subzones). Moreover, the “explosion” of *Calpionella alpina* at the base of the Berriasian was used as the criterion for the delineation of the boundary. However, the quantitative analysis (counting method) on calpionellids has been used for the first time in this study in order to obtain more accurate results and the measurements on calpionellids have been illustrated for the morphological comparison.

All microfossil assemblages including microgranular and hyaline calpionellids, small benthic foraminifera and *Saccocoma* Agassiz have been identified by using their morphological/taxonomical features. *Saccocoma* Agassiz was studied at a species level for the first time in Turkey by this study. As a result, *Saccocoma tenella* Goldfuss and *Saccocoma vernioryi* Manni & Nicosia have been identified in detail.

The pelagic limestone block of the Alacaatlı Olistostromes was defined as the basinal deposition based on the dominance of pelagic fossil assemblages, infrequent occurrence of the small benthic foraminifera and frequently observed distal calciturbidites throughout the section. Furthermore, the grey to white, thin to medium bedded limestone-marl alternations with calciturbiditic intercalations throughout the section indicates the Yosunlukbayırı Formation as the origin of this pelagic limestone block.

Keywords: Jurassic-Cretaceous Boundary, Calpionellids, Saccocoma, Alacaatlı Olistostromes, Yosunlukbayırı Formation

ÖZ

ALCI BLOĞU’NUN JURA-KRETASE SINIR TABAKALARINDAKİ CALPIONELLID VE *SACCOCOMA* TAKSONOMİSİ VE BİYOSTRATİGRAFİSİ: ALACAATLI OLİSTOSTROMLARI, ANKARA, TÜRKİYE

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Bu çalışmanın asıl amacı Jura – Kretase (J-K) (Titoniyen – Berriyaziyen) sınırının kalpionellid türleri ve biyozonları kullanılarak Alcı Blok’un pelajik kireçtaşı istifinde belirlenmesidir. Bu amaç doğrultusunda Alcı Blok boyunca toplamda 59,30 metre kalınlığındaki stratigrafik kesit-BA ölçüldü ve ince kesit yaptırılmak üzere 72 örnek toplandı.

Toplamda 3 zon ve 5 alt-zon; *Chitinoidella* (*boneti* altzonu) zonu, *Crassicollaria* (*remanei* ve *massutiniana* alt zonları) ve *Calpionella* (*alpina* ve *Remaniella* alt zonları) zonu belirlendi. Buna ek olarak, Berriyaziyen tabanında gözlemlenen *Calpionella alpina*’nın ani artışı J-K sınırı belirlemek için asıl kriter olarak kullanıldı. Ancak, bu zaman sınırının kesin yerinin belirlenmesi için kalpionellid türleri üzerinde sayısal analiz (sayma metodu) daha kesin sonuçlar elde etmek amacıyla ilk kez bu çalışmada kullanıldı ve alt Berriyezyan’da bulunan bu kalpionellidler üzerinde yapılan ölçümler biçimsel karşılaştırma için çizimlerle gösterildi.

Mikrogranüler ve hiyalin kalpionellidler, küçük bentik foraminiferler ve *Saccocoma* gibi bütün microfosil toplulukları morfolojik özellikler kullanılarak tanımlanmıştır. *Saccocoma* Agassiz tür seviyesinde Türkiye’de ilk defa bu tez çalışmasında yer almıştır. Sonuç olarak *Saccocoma tenella* Goldfuss ve *Saccocoma vernioryi* Manni & Nicosia çalışılan istifte detaylıca belirlenmiştir.

Alacaatlı olistostromlarına ait pelajik kireçtaşı bloğunda pelajik fosil topluluklarının dominant olması, küçük bentik foraminiferlerin çok nadir gözlemlenmesi ve kalsiturbiditli seviyelerin istif boyunca sıklıkla ara katkı şeklinde belirlenmesi derin havza çökelimini işaret etmektedir. Ayrıca gri-beyaz, ince ve orta kalınlıkta kireçtaşı tabakaları ile marn ardalanması ve kalsitürbiditlerin ara katkı şeklinde tekrarlanması bu pelajik kireçtaşı bloğunun kökeninin Yosunlukbayırı Formasyonu olduğunu göstermiştir.

Anahtar Kelimeler: Jura-Kretase Sınırı, Kalpionellidler, Saccocoma, Alacaatlı Olistostromları, Yosunlukbayırı Formasyonu

This thesis is dedicated to my father M. Kenan Akgümüş, to my mother Hülya Akgümüş, to my brother Fatih Akgümüş and his wife Nasiba Akgümüş, and to my fiance Ömer Kapucu.

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INTRODUCTION

1.1. Purpose and Scope

The Jurassic-Cretaceous boundary, also called as the Tithonian-Berriasian boundary, is one of the last Global Stratotype Section and Point (GSSP) tasks of International Commission on Stratigraphy (ICS) due to the fact that it is the most problematic boundary interval in terms of determination and correlation in worldwide. The faunal and depositional differences between the Tethyan and the Boreal realms, the mid-Cretaceous erosion over large areas, the prevalence of non-marine sequences across the boundary, the differentiation in nomenclature, restricted types of index fossils and the discrepencies in their stratigraphic ranges, the lack of important faunal turnover, the intrinsic character of the Berriasian faunas have created an enigma for the Jurassic-Cretaceous boundary interval (Remane, 1991; Wimbledon, 2008). Initially, Fitton (1827) and Brongniart (1829) have tried to positioned the Jurassic-Cretaceous boundary on the upper limit of the Jurassic units. D'Orbigny (1842-51) has studied the Portlandian stage (Fitton, 1827; Brongniart, 1829) and defined the top of *Ammonites giganteus* Sowerby. On the other hand, the Purbeckian has been previously defined by Fitton (1827) and Brongniart (1829). However, it has been laterly understood that it was a diachronic non-marine unit (Allen & Wimbledon, 1991). Because of these problems, the Portladian and the Purbeckian terms are no longer used at the present time. Kilian (1907, 1910), Mazenot (1939), Lyon and Lyon/Neuchatel (1963, 1973) and many other authors have used the ammonite biozonation, i.e. the *jacobi/grandis* zone for the base of Berriasian age. However, this zone could not be used alone to define the Jurassic-Cretaceous boundary. Set &

Kalacheva's (1997) study on the Caucasus, the Crimea, the Russian platform and the western Tethys created more acceptable approach for the correlation of the Tethyan and the Boreal realms while Guzhikov & Eremin (1999) gave a different point of view to the Tithonian-Berriasian boundary by their magnetostratigraphic approach such that the M19n was used as an indicator of the base of the *jacobi*/*grandis* zone and the Jurassic-Cretaceous boundary (Michalik et al., 1990; Housa et al., 1999; Grabowski, 2000, 2006; Wimbledon, 2008). Especially in the Tethyan zonations, magnetic reversals give almost the same results with calpionellids and nannoplankton in respect of the Jurassic-Cretaceous boundary (Ogg & Lowrie, 1986; Channel & Grandesso, 1987; Ogg et al., 1991; Remane, 1991). On the other hand, the calpionellids which are defined as the calcareous microplankton in Tethyan Upper Jurassic-Lower Cretaceous pelagic carbonates (Rehakova & Michalik, 1996) became crucial in the Jurassic-Cretaceous boundary interval studies after Remane (1964, 1969) used calpionellids as index fossils in the stratigraphic studies. These studies lighted the way for more detailed and comprehensive calpionellid studies especially in the Tethyan Realm. The initial standard zonation, which was established by Remane (1963, 1971) and Allemann et al. (1971), has been elaborated and enhanced by other specialists (Borza, 1974, 1984; Trejo, 1975, 1980; Pop, 1976, 1986c, 1989, 1994, 1997b; Bakalova & Ivanova, 1986; Remane et al., 1986; Borza & Michalik, 1986; Altıner & Özkan, 1991; Lakova, 1993; Pop, 1994a; Rehakova, 1995; Rehakova & Michalik, 1997a; Grün & Blau, 1997; Lakova et al., 1999). The pelagic carbonate successions whether they are continuous depositions or the blocks within other units like olistostromes and/or melanges, are excellent locations for calponellid bioevent records of the Jurassic-Cretaceous boundary interval. Today, the "explosion" of *Calpionella alpina* is accepted as one of the standard evidence reflecting the base of Berriasian, the Upper Tithonian-Lower Berriasian boundary (Housa et al., 1999; Wimbledon et al., 2011). Furthermore, the direct correlations between the ammonite and the calpionellid zones imply that the first appearence of *Chitinoidella boneti* represents the base of Late Tithonian while the Late Berriasian time interval is started with the first appearence of the genus *Calpionellopsis* (Lakova & Petrova, 2013). That is, the Jurassic-

Cretaceous boundary studies are generally concentrated on the interval between the first occurrence (FO) of *Chitinoidella boneti* and the FO of the genus *Calpionellopsis*. Besides of ammonites, calpionellids and magnetostratigraphy, calcareous dinoflagellates (Rehakova, 2000; Wimbledon et al., 2011), nannoconids (Özkan-Altıner, 1999) and some benthic foraminifers associated with calpionelids (Altıner & Özkan, 1991) are also used as the fundemental indicators of the Late Jurassic-Early Cretaceous boundary interval.

The main aim of this thesis is to determine the exact position of the Jurassic-Cretaceous time boundary in a pelagic limestone block (Alcı Block) of the Alacaatlı Olistostromes and to provide a potential candidate for a stratotype of this boundary level as a continuous record of both calpionellid bioevents and the sedimentation. For this purpose, this study comprises (1) a detailed analyses on calpionellid bioevents uprising their first occurrences and the variations in the abundance, (2) the biozonations based on calpionellids, (3) the quantitative method for the delineation of the time boundary, (4) the taxonomy of small benthic foraminifera, (5) a detailed study of the *Saccocoma* species, (6) the microfacies analyses carried on the thin sections in order to define the depositional environment of the studied succession and (7) the stratigraphic analyses to control the continuity of the deposition. Although the micropaleontological analyses of this study included calpionellids, small bentic foraminifera and the *Saccocoma* species, the delineation of this time boundary was completely predicated on the calpionellid biozonations. The “explosion” of *Calpionella alpina* was used as the criteria for the determination.

The another crucial point of this thesis is an exhaustive and elaborative study about the *Saccocoma* species. The remains of the genus *Saccocoma* Agassiz (1836) was only defined as the “*Saccocoma* fragments” (rod-like fragments) or “*Saccocoma* sp.” in the Late Jurassic-Early Cretaceous age depositional units (the Soğukçam Limestone, the Günören Limestone) in Turkey by Altıner et al. (1991), Mekik (1994), Atasoy (2017), Okay & Altıner (2007, 2017). Actually, *Saccocoma* Agassiz (1836) was utilized as an index fossil for the Kimmeridgian-Tithonian age (Late Jurassic) in terms of the abundance and the brief temporal distributions within this time interval (Nicosia et al., 1979). The abundance of saccocomids in a distinct interval was also termed as the "*Saccocoma* level" (an informal lithostratigraphic unit) (Nicosia & Parisi, 1979). According to the previous accomplished studies, there are four valid species types of these saccocomids namely; *Saccocoma tenella* (Goldfuss, 1831), *Saccocoma quenstedti* (Doreck & Hess, 2002), *Saccocoma longipinna* (Hess, 2002) and *Saccocoma vernioryi* (Manni & Nicosia, 1984). These species were only studied by isolated skeletal elements extracted from the mud dominated soft rocks. The rock forming quantity of *Saccocoma* was initially recognized in the sample BA-05 during the thin section analyses. However, only thin section views of *Saccocoma* Agassiz (1836) could not be used for the determination of species because of their complex morphological structure such as brachials, wings. Thus, these skeletal elements were extracted from the rock by specific washing methods and they were also photographed by the Scanning Electron Microscope (SEM). In Turkey, saccocomids have not been studied in detail yet. As a result, the second aim of this thesis is to identify the genus *Saccocoma* Agassiz at a level of the species for the first time in Turkey by use of the extracted skeletal elements at the "*Saccocoma* level" of the Late Jurassic-Early Cretaceous age pelagic limestone block.

1.2. Geographic Location of the Study Area

The studied area of this thesis is located on the northwest of Alagöz Village. The Alcı Region is almost 38 km away from Ankara. The studied outcrop is located near to Alagöz subway bridge on the south of İzmir-Ankara road (Fig.1.1). The coordinates of the studied section were mesured as 39.758407 N 32.463344 E.

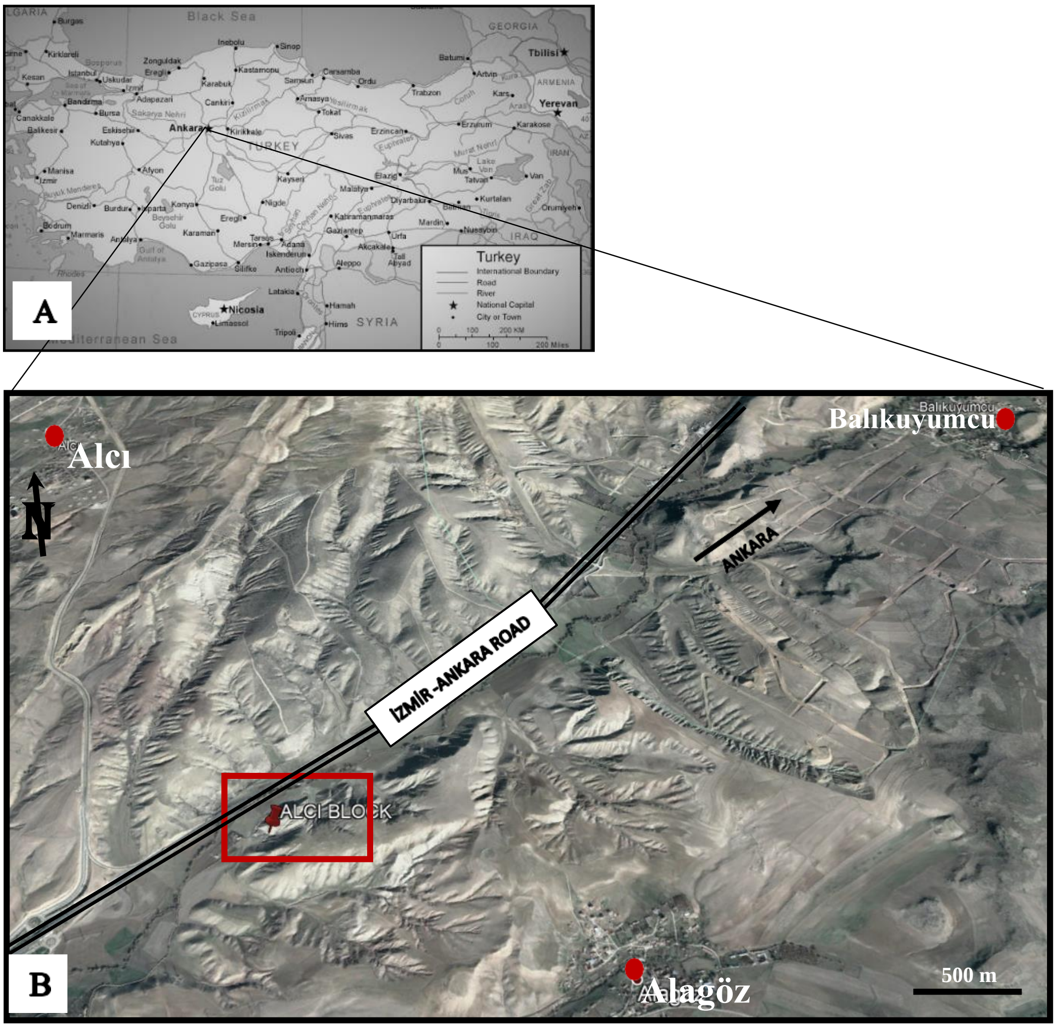


Figure 1.1. A. The map of Turkey; retrieved from www.geology.com, B. Location map of the study area

1.3. Method of Study

This study was carried out in three stages which are the literature survey, the field works and the laboratory works. Fieldworks were repeated five times in order to check the results and detailed measurements for the delineation of an exact position of the Jurassic-Cretaceous time boundary.

The stratigraphic section BA-I was measured as 21,09 meters thick from the bottom of the studied succession to the level represented by the sample BA-15 at the top. The sample BA-16 represents the starting point of the section BA-II which indicates the upper part of the section-BA. This part of the section was measured as 38,21 meters from bottom to top. That is, totally 59,30 meters thick section was measured within the scope of this study. Initially, 55 samples were collected from the whole measured section-BA. However, as more detailed study, additional sampling was carried out between the levels of BA-42, BA-43 and BA-45 in order to detect the exact position of the Jurassic-Cretaceous boundary. Therefore, a total number of 72 samples were collected. All these samples, except the sample BA-33, were prepared as the thin sections for microfacies and micropaleontological analyses. Dunham's (1962) carbonate rock classification and Flügel's (2004) microfacies types of the carbonate rocks were used as a part of the microfacies analyses. Micropaleontological analyses involve the taxonomic classification of microfossils (calpionellids, foraminifera, *Saccocoma*) in the samples in order to determine the stratigraphic ranges of the fossil assemblages. All these thin sections were prepared in the Geological Engineering Department of Middle East Technical University. They were especially used for the determination of the Calpionellid biozones and the exact position of the Jurassic-Cretaceous boundary within the pelagic limestone block. The biozonations were defined by the first (FO) and last (LO) occurrences of the calpionellid species and their relative abundance. On the other hand, the delineation of the Jurassic-Cretaceous boundary was completely predicated on the calpionellid species and the bioevents of the calpionellids.

Besides of these thin sections, the specific washing method was used to extract the skeletal elements of the *Saccocoma* species in especially one sample (BA-05) representing the "*Saccocoma* level" which was recognized by the rock forming quantity of *Saccocoma* Agassiz (1836). The upper and the lower levels of this *Saccocoma*-acme level were also controlled by the same washing methods in order to detect the ranges of the species within the studied succession. The samples were washed by the specific version of the Knitter method (Erk, 1992) which is used to reduce the clay content of the micrites allowing the collection of loose calcareous microfossils. The Knitter method is best choice for the micritic and durable rock types. In that method, the samples are initially crushed into small pieces like a little bit more than a chickpea size and weighed. Generally, acetic acid and chloroform are used in this method. However, I used acetic acid, chloroform and hydrogen peroxide as in different quantities and different combinations except mixing all of these acids at the same time (Table 1.1). A total of 11 different acid combinations and holding periods have been tested in order to extract the skeletal elements of *Saccocoma* Agassiz (1836) as well preserved elements. The dilution of acetic acid and hydrogen peroxide were also changed depending on the mixture type. According to the degree of preservation of the wall material, I determined the most effficient method to applied the whole sample BA-05. Actually, the saccocomids were mostly extracted from mudstones or mud dominated soft samples by using only hydrogen peroxide or boiling with sodium (Hess, 2002; Kroh & Lukeneder, 2009). However, both hydrogen peroxide and acetic acid were used in specific percentages for the sample BA-05 due to the hardness of the rock. These all tested washing methods were listed in the Table 1.1. In consideration of the results, it can be said that the methods including chloroform are not convenient for extracting the morphological elements of *Saccocoma* from the rock. Because, the *Saccocoma* elements were covered by white external layer after using these methods 1, 2, 3 and 10. On the other hand, the methods including acetic acid (%80) caused much glassy appearence of the *Saccocoma* fragments. As a result, the well preserved *Saccocoma* elements were extracted from the rock by using a combination of acetic acid (%50) and hydrogen peroxide (%50) with 24 hr waiting period (the method 6). Moreover, some Late Tithonian age small planktonic foraminifera with well preserved wall structure were also collected from the same investigated sample. These collected isolated elements were analyzed under the stereo-microscope. Totally 310 collected elements were also photographed by the Scanning Electron Microscopy (SEM) in the Metallurgical and Materials Engineering Department of METU in order to identify the species of the *Saccocoma* Agassiz

(1836) and the Late Jurassic age small planktonic foraminifera. All these samples are kept in the paleontology laboratory of the Geological Engineering Department of Middle East Technical University.

Table 1.1. *The washing sample methods for the extraction of Saccocoma elements from the rock.*

Method	Sample amount (gr)	Piece size	Waiting-period (hour)	Acetic acid (%50)	Acetic acid (%80)	Hydrogen peroxide (%50)	Chloroform
1	20	greater than chickpea size	24 hr	✓	—	—	20 ml
2	20	as a green pea size	24 hr	✓	—	—	20 ml
3	25	greater than chickpea size	22 hr	—	✓	—	25 ml
4	25	greater than chickpea size	8 hr	—	✓	✓	—
5	30	coarse size	24 hr	✓	—	✓	—
6	20	greater than chickpea size	24 hr	✓	—	✓	—
7	23	as a green pea size	5 hr	✓	—	✓	—
8	35	coarse size	5 hr	✓	—	✓	
9	20	greater than chickpea size	24 hr	—	—	✓	—
10	20	greater than chickpea size	24 hr	✓	—	—	20 ml
11	20	coarse size	24 hr (renew the acids after 2 hr)	✓	—	✓	—

1.4.Previous Works on the Upper Jurassic-Lower Cretaceous Carbonates of the Sakarya Zone

The geological structure of Turkey is composed of three main units which are the Pontides (Sakarya Block), the Anatolide-Tauride Block including also the Kırsehir Massif and the Southern-East Anatolia (the Arabian Platform) (Fig.1.2). The Sakarya Block of Turkey is surrounded by the Istanbul Zone and the Black Sea on the North and the Kırsehir Block and the Anatolide-Tauride Block on the south. That is, the Pontides are limited between the Black Sea and the Izmir-Ankara-Erzincan Suture.

Sakarya Zone consists of three depositional units namely; the Sakarya Continent previously defined by Şengör and Yılmaz (1981), the Central and Eastern Pontides with the same stratigraphic and tectonical evolution characteristics (Okay & Tüysüz, 1999). The Early Jurassic- Eocene age sequence defined by Tekeli (1981) overlies the highly deformed and partly metamorphosed Triassic subduction-accretion unit which is also called as the Karakaya Complex in the western side of the Sakarya Zone. It includes the Permo-Triassic metabasite-marble-phyllite unit and the exotic Triasic eclogite (Okay & Monie, 1997) and also blueschist lenses (Monod et al., 1996). This sequence also includes conodonts (Kaya & Mostler, 1992), an oceanic seamount (Pickett & Robertson, 1996) or an oceanic intra-arc to fore-arc tectonical setting (Okay et al., 1996) and all of these depositional units are called as the Nilüfer Unit (Kaya & Mostler, 1992). Actually, the Sakarya Zone includes two different basements namely the Hercynian older basement and the Kimmeridgian aged basement which is also called as the Karakaya tectono-stratigraphic unit (the Karakaya Complex). The Hercynian and older basement was mostly observed in the Eastern Pontides while the Karakaya unit was studied from the Biga Peninsula to the Eastern Pontides. The west side of the Sakarya Zone is composed of the Lower-Middle Jurassic continental to shallow marine clastic rocks, the Upper Jurassic- Lower Cretaceous carbonates and also the Upper Cretaceous-Palaeocene volcanic and sedimentary rocks (Okay & Tüysüz, 1999). The Lower Jurassic deposition is located on these basements through all the Sakarya Block as the transgressive succession. The Lower-Middle Jurassic is generally characterized by conglomera, sandstone and shale in the Sakarya Unit and volcanism especially in the Eastern Pontides. The Late Jurassic-Early Cretaceous time interval is represented by the shallow water limestone deposition in the Sakarya Unit while the deep water limestone allocthonous units can be studied in the Central Pontides.

The North-Western Anatolia has been studied since 1934 with numerous explorations (Table 1.2). However, the modern lithostratigraphic nomenclature was applied in 1960's. Granit and Tintant (1960) used the Yediler Limestone, oolithe ferrugineuise and the Bilecik Limestone terms for the sediments representing the Bathonian-Tithonian time interval. Later, Altınlı (1973a, b) used the term Kapıkaya Formation for the equivalent unit of the Bayırköy Formation and the another term Soğukçam Limestone for the deposition belonging to the Early Cretaceous age. The Upper Jurassic- Lower Cretaceous deposits were identified as the Soğukçam Limestone by Yılmaz and others in 1981. This unit has been recognized in the Edremit-Balya, Bursa-Bilecik, Mudurnu-Nallıhan and Aktaş (Gerede)-Sekinindoruk (Çerkeş) sequences in the North-Western Anatolia (Altıner et al., 1991). However, in previous studies, the Upper Jurassic-Cretaceous successions have been identified in the Bilecik Limestone Unit by Altınlı (1965), Eroskay (1965), Altınlı et al. (1970), Altınlı and Saner (1971), Altınlı and Yetiş (1972), Gürpınar (1976), Saner (1978, 1980). The Jurassic-Cretaceous boundary was also studied within the Soğukçam Limestone Unit by Saner (1980) in Göynük and the Mudurnu area, by Yılmaz et al. (1981) in the Bolu-Sakarya and Saner (1980) studied the succession including this time interval in Nallıhan. The Nallıhan Formation was another term used for the description of the succession which inludes the Jurassic- Lower Cretaceous unit around the Nallıhan region. According to the revision of these lithostratigraphic units in the southern part of the North-Western Anatolia by Altıner et al. (1991), the Bilecik Limestone term which had been described several times in the previous studies was replaced by the Bilecik Group. It is composed of two mappable units namely the Taşçıbayırı Formation and the Günören Limestone. The Halılar Formation which was previously described by Rushensky et al. (1980) has been similarly raised to the rank of a group as in the Bilecik Limestone and it has been seperated as the Bağcağız Formation and the Sakarya Formation (Altıner et al., 1991). The pelagic sedimentary sequence overlying the volcano-sedimentary unit of the Mudurnu Formation (Saner, 1980) was initially called as the Soğukçam Limestone by Saner (1980) and Yılmaz et al. (1981). However, the Soğukçam Limestone term was limited only as the Early Cretaceous aged porcellaneous and argillaceous limestones by the study of Altıner et al. (1991). Therefore, the detrital parts consisting of the olistostromes, calciturbidites and also volcanics below the Soğukçam Limestone located in the Mudurnu-Nallıhan-

Beypazarı region were separated as the Yosunlukbayırı Formation and the Kurcalıkdere Formation respectively (Altıner et al., 1991). The Jurassic carbonate studies of Aygen (1956), Kaaden (1957), Gümüş (1964), Aslaner (1965), the "Alancık Formation" of Bingöl et al. (1973) and the "Kocaçaltepe Limestone" of Krushhensky et al. (1980) are currently accepted as the Bilecik Group in the Bakırköy-Günören region. Granit and Tintant (1960) defined the Bilecik Limestone unit, today's the Bilecik Group, and its unconformable relation with the Bayırköy Formation based on the ammonites. In addition to this study, Altınlı (1965), Eroskay (1965), Altınlı et al. (1970), Altınlı & Saner (1971), Altınlı (1973a) and Gürpınar (1976) also accepted the unconformable relation between these two units based on the paleontology and the field studies. However, this bondary is currently accepted as conformable or somewhere paraconformable (Altıner et al., 1991).

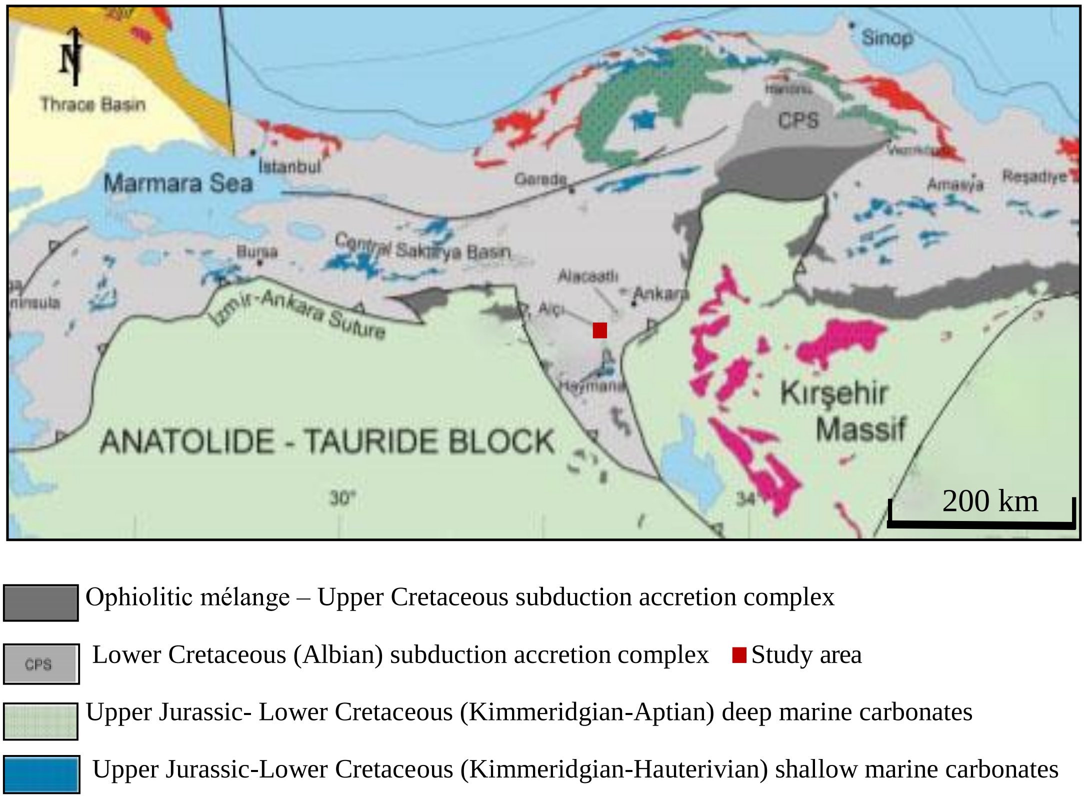
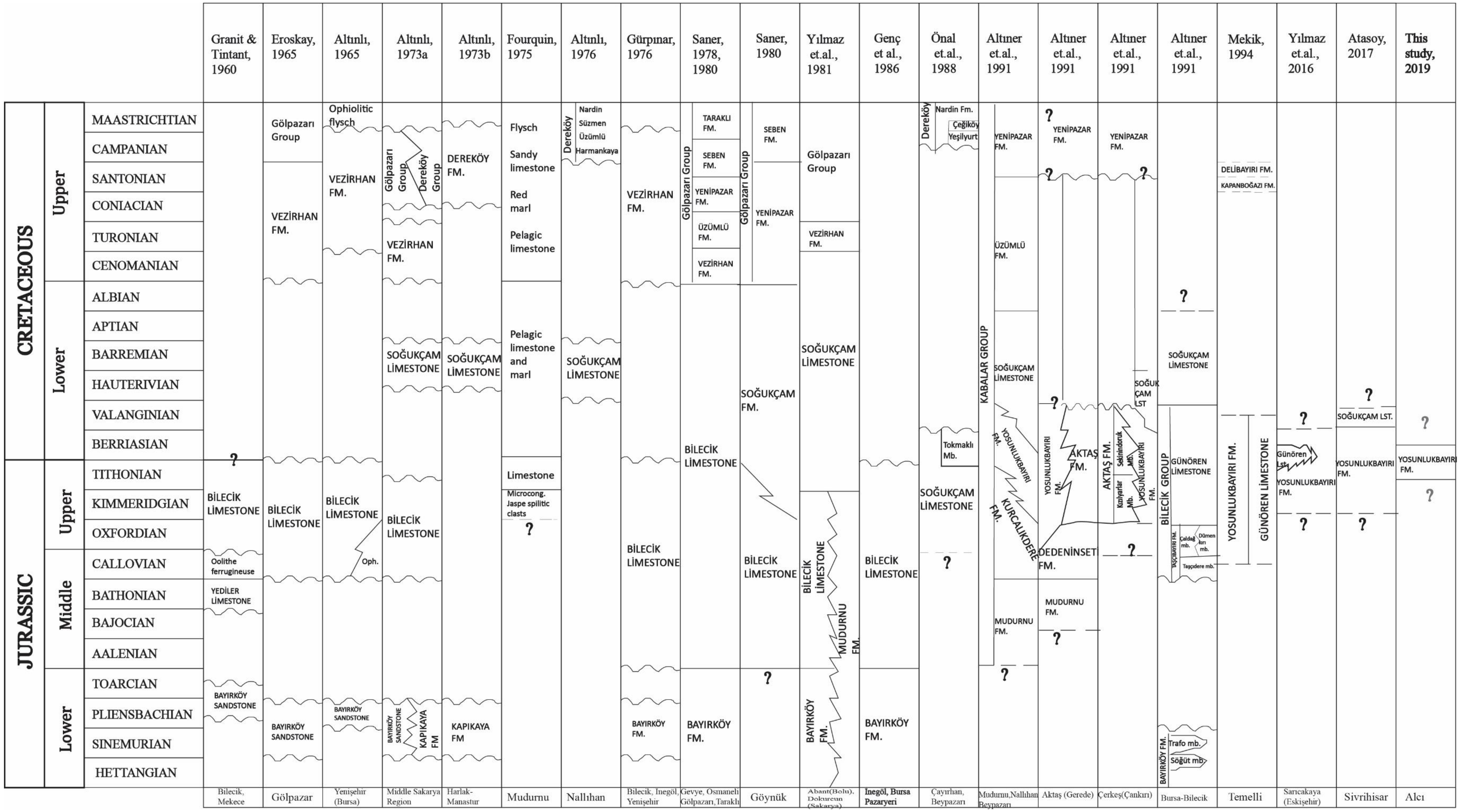


Figure 1.2. The distribution of some Upper Jurassic-Cretaceous sequences within the tectonic unit of Turkey: Pontides (CPS: Central Pontide Supercomplex) (retrieved from; Okay & Altıner, 2017).

In Bakırköy - Günören area, the Günören Limestone represents the Kimmeridgian to Early Hauterivian aged deposits by its variable facies such as white to grey boundstones with stromatoporoid corals, echinoids and bryozoa and grainstones, laminated, intraclastic, oncolitic, bioturbated micritic cream to white limestones, stromatolitic bindstones, mudstones and algal wackestones observed in the lower parts and the medium to thick bedded, partly Nannoconus dominated wackestones and packstones (Altıner et al., 1991). On the other hand, the same Kimmeridgian-Valanginian Günören Limestone unit is characterized by a regressive character with beige to grey fossiliferous limestones consisting of the coral boundstones, oolitic, pebble and pellet rich packstones and grainstones, dasyclad algal wackestones, grey-pinkish limestones rich in oncolites, gastropods and stromatolitic limestone levels with beige to grey micritic and pelletic character in the Kınık area. Within this unit, the Tithonian-Berriasian time interval was detected by the presence of *Charentia* sp., *Everticyclammina* sp., *Reophax* sp., Miliolidae, *Hechtina* sp., *Trocholina* sp., *Clypeina* cf. *jurassica, Tubiphytes morronensis* and *Cayeuxia* sp. Moreover, Altıner et al. (1991) determined the Tithonian-Berriasian time interval pursuant to the presence of *Protopeneroplis trochoangulata* in the Günören Limestone of the Orhaniye (Bursa) area.

The Yosunlukbayırı Formation assigned by Altıner et al. (1991) is characterized by its thin to medium bedded, grey to white argillaceous limestone characteristics with calpionellid rich packstones in the Mudurnu area. The calpionellid content and its diversity indicates the Tithonian-Late Berriasian time interval while the turbidites and the slump structures of the Yosunlukbayırı Formation within this area are related to the tectonically unstable environment (Altıner et al., 1991). In the Nallıhan area, the Yosunlukbayırı Formation term was assigned to argillaceous wackestones, pelletic packstones containing *Chitinoidella* and *Saccocoma,* monotonous fine-grained detrital limestones as calpionellid rich micritic limestones, green sandy packstones with quartz and feldspar grains, bioturbated yellow-grey limestones with echinoid fragments by Altıner et al. (1991). The calpionellid and

Table 1.2. *Lithostratigraphic correlation chart for the formations found in the Upper Jurassic- Lower Cretaceous successions in the Northwestern Pontides.*



foraminifera content detected in this formation such as *Chitinoidella boneti, Tintinnopsella carpathica*, *Crassicollaria* sp., *Ophthalmidium* sp., *Spirillina* sp., *Lenticulina* sp., *Cadosina* sp., *Globochaete alpina*, *Saccocoma*, *Calpionella alpina*, *Calpionella elliptica*, *Remaniella* sp., Ataxophragmiidae, *Dorothia* sp., *Haplophragmides joukowskyi, Montsalevia*? sp., *Meandrospira favrei*, Miliolidae, *Patellina* sp. represents the Tithonian-Early Hauterivian time interval. In the Beypazarı-Çayırhan area, the Yosunlukbayırı Formation includes olistostromal level together with the radiolaria, belemnite and ammonite-rich wackestone and mudstone facies. It represented the basinal facies characteristics in the Oxfordian-Early Tithonian time interval. Transportation and deposition of the detrital material was dominated in the Middle-Late Tithonian and the olistostromes covered the Beypazarı-Çayırhan area. In the Aktaş (Gerede) area, according to the study of Altıner et al. (1991), the Oxfordian-Valanginian age was assigned to the Yosunlukbayırı Formation based upon macro- and microfossils. According to all these olistostromal, calciturbiditic characters and marly levels allow Stow (1986)'s resedimented carbonate facies model application to happen for the Yosunukbayırı Formation and the 'calcidebrite'-'calcilutite-pelagite' terms become applicable for this type of deposition (Altıner et al., 1991).

The Soğukçam Limestone includes the Berriasian - Hauterivian age benthic and the pelagic organisms (calpionellids, globuligerinids etc.), sponge spicule rich wackestones, crinoid rich packstones and grainstones at the lower portions and a typical thin-medium bedded, pink to white porcelaneous limestones which are mainly composed of wackestones rich in radiolaria, *Nannoconus*, planktonic foraminifera such as *Globuligerina* sp., *Globuligerina hoterivica*, *Globigerinelloides ferroelensis, Leupoldina cabri, Hedbergella sigali, Hedbergella delrioensis, Hedbergella planispira, Spirillina* sp., *Patellina* sp., Nodosariidae and *Globochaete alpina* representing the Barremian-Late Aptian age at the upper portions (Altıner, 1991; Altıner et al., 1991). That is, the Soğukçam Limestone overlies the Bilecik Group in many complete successions and indicates the Early Cretaceous age deposition. The

Soğukçam Limestone indicates more stable depositional regime in contrast with the Yosunlukbayırı Formation and this unit is generally associated with the carbonate platform type deposition (Altıner et al., 1991). The carbonate deposition regime can be classified under three time intervals with different sedimentation mechanisms. The first one was the Callovian- Kimmeridgian deposition feeding by olistostromes and breccias. Then, the deposition continued with the calciturbidites, the limestone-marl alternations in the Tithonian-Berriasian time interval. And finally, the Soğukçam Limestone which is characterized as the most stable and quiet period of this carbonate deposition regime took place in the Valanginian-Aptian time interval (Altıner et al., 1991). The Soğukçam Limestone unit was also accepted as the origin of the Upper Jurassic – Lower Cretaceous pelagic limestone blocks dominated within the Alacaatlı Olistostoromes and these blocks are the biggest limestone blocks in the Alcı – Alacaatlı region (Mekik, 1994; Rojay & Süzen, 1997; Okay & Altıner, 2017).

With the perspective on tectonism, it can be said that the Bilecik Carbonate Platform is characterized by its tectonically inactive period in the Late Jurassic-Early Cretaceous time interval (Yılmaz et al., 2016). There was a complete sedimentation as the neritic carbonate facies without any subaerial exposure, gap, erosion or other distinctive features of the nondeposition period. The same characteristics can be observed on the equivalent pelagic deposition within the same time interval. However, the pelagic limestones, which indicate the slope to basin facies overlying the white colored thick bedded platform type carbonate deposition, were accepted as the indicator of the Bilecik carbonate platform drowning in the Hauterivian age (Yılmaz et al., 2016). The drowning has been distinguished by the occurence of the sudden facies change over the oolitic shallow water facies and the entirelly dominant pelagic deposition on the basin without any evidence of platform type deposition. As a part of the correlation for the Tethyan paleogeography and paleoceanography, the Late Hauterivian- Early Barremian platform drowning and overlying anoxic pelagic sedimentation on the Sakarya Zone have been distinguished also in Europe (Föllmi et al., 1994).

Within the scope of paleoceanographic and paleoclimatic studies, Tremolada et al. (2006) determined a cooling in the Late Tithonian and the increasing temperature conditions in the Berriasian time based on the calcareous phytoplankton in contrast with the Weissert & Erba (2004)'s argument of an aridity increase and warming of the North Sea during the Late Tithonian besides the high latitude cooling in the Berriasian. In addition to the numerous sequence stratigraphy and cyclostratigraphy studies about the Jurassic-Cretaceous boundary in all over the world, Haq (2014) defined a major sequence boundary (JTi6,146.2 Ma) near the boundary and the sea level rise trend in the Early Berriasian by short-term curve, although the long-term curve represents a general sea level fall. It is possible to reach a lot of studies about the Late Jurassic-Early Cretaceous successions from platform to basin deposits and their depositional mechanisms. Some of them are Rehakova et al. (1996) of the Penninic Nappe in the Eastern Alps (Austria), Rehakova (2002) in the west Carpathian area (Slovakia), Mandl (2000) in the Northern Calcareous Alps of Austria, Ortner et al. (2008) in the Alpine carbonate margin of the Northwestern Tethys etc. (Yılmaz et al., 2016). Among all these Upper Jurassic-Lower Cretaceous studies, Petrova and others (2012) have been revealed a detailed study on the biostratigraphy and the microfacies of the pelagic carbonates across the Jurassic-Cretaceous boundary of the Stara Planina-Porec Zone in the Eastern Serbia. They have presented calpionellid and calcareous dinoflagellate biozonations including also benthic foraminifera and the carbonate microfacies analyses of the Upper Tithonian-Berriasian pelagic carbonates in order to correlate the Porkovenik, the Rosomac and the Rzana Limestones in Serbia with the Gintsi Formation, the Glozhene and Salash formations in Bulgaria respectively. According to the microfacies analyses on the Rosomac and the Barlya sections, pelagic sedimentation in a deep-water environment was defined as microfossil-bearing mudstone (MF 1), microfossil-bearing clayey mudstone (MF 1a), and microfossiliferous wackestone (MF 2) with calpionellid mudstone and wackestone while *Saccocoma* wackestone (MF 3), bioclast-fossilifeous wackestones (MF 4), peloidal and intraclast-bioclastic grainstones (MF 5), bioclast-intraclastic floatstone (MF 6) and bioclast-intraclastic rudstones (MF 7). The calpionellid and calcareous dinoflagellate zonations gave an opportunity to assign the Late Tithonian- Early Berriasian boundary interval to the Rosomac Limestones (Petrova et al., 2012). The *Chitinoidella* Zone was defined by the *dobeni* Subzone while the *Crassicollaria* Zone was subdivided as the *remanei* and the *massutiniana* subzones. Besides of these, the *Calpionella* Zone was defined as the *alpina*, *Remaniella*, *elliptica* subzones respectively. They determined the deep water conditions with the small benthic foraminifera such as *Patellina turriculata*, *P. subcretacea*, *Paalzowella feifeli seiboldi*, *Spirillina polygyrata*, *S. tenuissima*, *Istriloculina emiliae* and *Moesiloculina danubiana.* Because, Bucur (1992) has defined *Patellina*, *Paalzowella* and *Spirillina* as the fossils representing the deep water depositional settings.

Moreover, the taxonomy, biostratigraphy and paleobiogeography of the calpionellids have been studied since the immemorial time in all over the world. Some of the well known studies are Colom, 1948 ; Remane, 1962, 1963, 1964, 1969a, b, 1971, 1978; Le Hegarat & Remane, 1968; Crescenti, 1969; Allemann et al., 1971, 1975; Catalano & Liguori, 1971; Dodona et al., 1975; Chevalier et al., 1975; Erba & Quadrio, 1987 in the Western and Southern Europe, Brönnimann, 1953; Bonet, 1956; Luterbacher, 1972; Furrazola-Bermudez & Kreisel, 1973; Trejo, 1975, 1976, 1980; Pop, 1976; Jansa et al., 1980; Premoli Silva and McNulty, 1984 in Atlantic and America, Nowak, 1968, 1971; Borza, 1969; Filipescu & Dragastan, 1970; Pop, 1974; Dragastan et al. 1975; Bakalova, 1977 in the Northern and the Eastern Europe, Bozorgnia & Banafti, 1964; Edgell, 1967; Makarieva, 1979 in Asia. The calpionellids have been previously studied in Turkey by Durand Delga and Gutnic (1966), Brönnimann and others (1970), Toker (1976), Poisson (1977), Monod (1977), Fontaine (1981), Burşuk (1981, 1982), Altıner (1988, 1989). The more detailed study about the calpionellid taxonomy, biostratigraphy and the correlation of the calpionellid biozones with the benthic foraminifera has been carried out by Altıner and Özkan (1991) in the region lying to the east of Eskişehir-Adapazarı region and to the west Ankara-Çerkeş in Turkey. The study was mainly concentrated on the deposition with the calpionellid micrites and the calciturbidites. In that study, calpionellids were callibrated with the stratigraphic ranges of the foraminifera species such as the first appearence of *Protopeneroplis trochoangulata* Septfontaine (the Subzone A2, Late Tithonian), *Conicospirillina basiliensis* Mohler (the Kimmeridgian-Early Valanginian calpionellid biozones), *Haplophragmoides joukowskyi* Charollais, Brönnimann & Zaninetti (the Zone C of the Early Berriasian).

1.5. Regional Geological Setting

Ankara region is located in the Sakarya Block which is separated from the southern Anatolide-Tauride Block and the Kırşehir Block by the İzmir-Ankara-Erzincan Suture (Okay & Tüysüz, 1999). This region is mostly known by the melange setting (Bailey & McCallien, 1950, 1953). According to the studies of Boccaletti et al. (1966), Batman (1978), Ünalan (1981), Çapan et al. (1983), Norman (1985) and Koçyiğit (1991) it can be said that these melange setting in the Ankara region can be separated from each other with their stratigraphic ranges and characteristics. The most known of these melanges is called as the Late Triassic age Karakaya Complex including the shallow-water Carboniferous, Permian and Triassic limestone blocks within highly swatted, broken and partly metamorphosed sandstone, shale, graywacke series. The Karakaya Complex located in the Karakaya marginal basin of the northern carbonate platform of Gondwanaland is distinguished by the slightly metamorphosed tectono-sedimentary melange with the mixture of high to low grade metamorphics, ultramafics, recrystallized limestone, radiolarian chert and clastics blocks within a shaley litharenitic matrix (Koçyiğit, 1991). It was also termed as the oldest tectono-statigraphic unit in the Ankara region by Koçyiğit (1991). The Karakaya Complex is overlain by the Early Jurassic aged terrestrial or shallow marine conglomerate, sandstone, shale and the Ammonitico Rosso type facies which are totally called as the Bayırköy Formation (Bremer, 1966; Koçyiğit, 1987; Koçyiğit et al., 1991; Varol & Gökten, 1994; Alkaya & Meister, 1995; Kuznetsova et al., 2003; Deli & Orhan, 2007). The overlying Late Jurassic-Early Cretaceous aged shallow-marine limestones belonging to the Bilecik Group carbonates are unconformably covered by the Berriasian, Albian-Cenomanian and Turonian-Santonian deep-water limestone-breccia successions in the Haymana region (Okay & Altıner, 2016; Okay & Altıner, 2017).

On the other hand, the Late Cretaceous aged ophiolitic melange which is also called as the Ankara Melange (Sarifakioğlu et al., 2014) is mainly composed of basalt, serpantinite, limestone, radiolarian chert blocks of the Triassic, Jurassic and Cretaceous age and contains gabbro, sandstone and shale slices and ophiolitic fragments (Çapan & Buket, 1975; Tankut et al., 1998; Dangerfield et al., 2011; Rojay, 2013; Sarifakioğlu et al., 2014). The Upper Jurassic-Lower Cretaceous limestone blocks and the pelagic limestone blocks, radiolarian chert, serpentinite, pillow basalt and olistostromes form the ophiolitic melange (Koçyiğit & Lünel, 1987). The Greek origin olistostrome term was primarily used by Flores (1955) in order to refer a deposition which is formed by sliding mechanism. Koçyiğit (1979) defined the olistostromes as polygenetic, angular and sometimes pointed blocks swimming in schisty, clayey or sandy matrix. Then, Jackson & Bates (1980) assigned this term to the debris flow consisting of different sized clastics and mud in a complex structure under water. On the other hand, the Alacaatlı Olistostromes has been previously defined as the “Alacaatlı Melange” by Batman and others (1978) in Alacaatlı-Ankara. Then, it was termed as the “limestone block unit” in the Bağlum-Ankara region (Ünalan, 1981). The sedimentary melange term was also assigned to this blocky unit by the study of Koçyiğit (1991), Deli & Orhan (2007), Rojay (2013) in the Alacaatlı and Alcı regions. The ophiolitic melange can be seen in a contact with the Alacaatlı Olistostromes as a secondary discontinuous ophiolitic melange in the Alcı and Bağlum regions. This melange is most specifically composed of red-colored radiolarian chert (the main characteristic feature of the ophiolitic melange in the Alcı region), pelagic limestones, bazalt, rarely phyllite and shallow marine limestone blocks (Okay & Altıner, 2017). Koçyiğit (1991), Rojay and Süzen (1997) and Rojay (2013) have initially defined the contact between the ophiolitic melange and the Alacaatlı Olistostromes as a thrust zone. However, Okay and Altıner (2017) argued that it is a stratigraphic contact rather than a tectonism due to the transition between these identifiable units and debris flows including radiolarian chert and red pelagic limestone fragments in the ophiolitic melange. They also said that the red-colored radiolarian chert and radiolarian biomicritic limestones are observed in both the Alacaatlı Olistostromes and the ophiolitic melange in the Alcı and Bağlum regions as a feature of this stratigraphic contact. Actually, the Bağlum region was determined as the best place for observing the basement of the Alacaatlı Olistostromes as almost lateral contact with the Late Triassic Karakaya Complex or the Liassic Bayırköy Formation by Okay and Altıner (2017).

The Alacaatlı Olistostromes was characterized by the Late Cretaceous olistostorome consisting of Late Jurassic-Early Cretaceous pelagic limestone blocks in silt-clay-marl matrix (Okay & Altıner, 2017) (Fig.1.3). That is, this unit was defined as the matrix-supported olistostromes with %15-20 matrix percentage. The Jurassic-Cretaceous limestones are not seen as a continuous succession around the İzmir-Ankara Suture zone. Instead of that, they come to exist as the limestone blocks within the Alacaatlı Olistostromes (Okay & Altıner, 2017). The limestone block size changes from milimeters to hundred meters and these blocks are found in the olistostromes without any specific arrangement. In the Ballıkuyumcu and the Alacaatlı regions, there are mainly the Callovian-Oxfordian or the Tithonian-Berriasian age limestone blocks with more than hundred meters thickness. The lateral continuity of them generally can not be observed due to slumps and other olistostromal flows.

The stratigraphic sections and a geological map of Okay & Altıner (2017), which was designated from the study of Rojay & Süzen (1997), indicate that large Upper Jurassic- Lower Cretaceous pelagic limestone blocks are located within the Alacaatlı Olistostromes directly overlying the Karakaya Complex in between the Alcı and the Balkuyumcu regions. The Upper Jurassic- Lower Cretaceous pelagic limestone blocks are identified as thin to medium bedded white to grey carbonates including high amount of radiolaria. The origin of these blocks were assumed as the Soğukçam Limestone (Mekik, 1994; Rojay & Süzen, 1997). The large blocks of the Soğukçam Limestone are mainly composed of radiolarian biomicrites, calciturbidites and less amount of chert and shale (Okay & Altıner, 2017). The Alacaatlı olistostromes are directly overlain by the Campanian aged rudistic limestones and the upper volcanogenic sandstone, tuff, basalt sedimentation of the Alcı Formation in the Kargabedir-Balkuyumcu area. These olistostromes composed of the intrabasinal sediments, siltstone, mudstone, sandstone, calciturbiditic deposition in addition to the limestone blocks may be covered by the ophiolitic blocks before the Campanian age rudistic limestones as in the south of Alcı region close to the Ankara-Eskişehir road.

This thesis is mainly concentrated on the Late Jurassic-Early Cretaceous age pelagic limestone block which is also called as the Alcı Block of the Alacaatlı Olistostromes on south of Ankara-Eskişehir road near the Alagöz region (Fig.1.1 and Fig.1.3). The Alcı Block is characterized by the thin to medium bedded limestone and marl alternations and the intercalations of the radiolarian biomicrites and the calciturbidites. The Tithonian- Berrriasian age foraminifera, calpionellids and *Saccocoma* sp., *Globochaete alpina, Belorussiella* sp. were previously used to designate the Late Jurassic- Early Cretaceous age to this pelagic limestone block (Altıner, 1991; Altıner & Özkan, 1991; Okay & Altıner, 2017). Moreover, the Alcı Block was assumed as the smallest limestone block belonging to the Soğukçam Limestone unit with approximately 200 m thickness in the Alcı region (Okay & Altıner, 2017) while the thickness of other limestone blocks changes in between 400 m and 770 m (Altıner & Özkan, 1991; Tunç, 1993; Mekik et al., 1999). The Soğukçam Limestone blocks in the Alcı, Bağlum and Alacaatlı regions were mostly defined as the Early Beriasian aged limestone blocks consisting of *Calpionella alpina, Crassicollaria parvula, Crassicollaria brevis, Remaniella ferasini*. However, the Middle-Late Berriasian aged blocks with *Calpionella elliptica, Calpionella oblonga, Calpionellopsis simplex, Tintinnopsella carpathica, Tintinnopsella longa, Remaniella cadischiana* also exist within the Alacaatlı Olistostromes (Okay & Altıner, 2017).

Besides of these, Mekik (1999) extended the age of the Soğukçam Limestone block in the Alcı region to the Late Valanginian depending on the appearence of *Cadosina* sp. together with *Globochaete alpina* and calpionellids. Furthermore, the calciturbidites between the limestone beds mainly have shallow-water limestone fragments with *Protopeneroplis ultragranulata*, *P. striata*, *Mohlerina basiliensis*, *Crescentiella morronensis*, *Belorussiella* sp., *Charentia* sp., *Nauticulina* sp., *Lenticulina* sp., *Reophax* sp. (Altıner et al., 1991; Okay & Altıner, 2017).

The Alacaatlı Olistostromes are unconformably covered by red micritic limestones and shales with the Santonian age and blue-grey shale, mudstones with the Santonian-Early Campanian age overlie this red micritic limestones in the Alcı region (Mekik, 1994). However, the region was subjected to folding, uplifting and erosion in Campanian. Then, the secondary depositional phase continued within this time interval. In a similar manner, the Alacaatlı olistostomes and the ophiolitic melange of the Alcı region are unconformably covered by clastic deposits such as red colored mudstone, siltstone and conglomerates with the Late Cretaceous age. Blue-grey shales and siltstones which involve gastropods, brachiopods and *Cyclolites* sp. cover the underlying red-colored deposits. They are overlained by white to grey colored, thick-bedded or massive, rudistic limestone with the Maastrichtian age (Koçyiğit & Lünel, 1987; Koçyiğit, 1991; Rojay & Süzen, 1997). But, this age assigned to the rudistic limestone were corrected by Okay & Altıner (2017) as Campanian due to the Ar-Ar analyses on biotites and the appearence of *Pseudosiderolites* sp. in the investigated samples. The Alcı Formation, which is characterized by volcanoclastic sandstone, shale, siltstone, agglomerates, tuff and partly seen rudistic limestone levels, is located on top of the rudistic limestones. Initially, it was defined as the Paleocene age unit (Koçyiğit & Lünel, 1987). However, Okay and Altıner (2017) asserted that the lower part of this formation represents the Campanian age according to the U-Pb analyses.

Within the scope of the tectonism and geological setting, the subduction of the Tethys Ocean took place towards the North under the Pontides located in the northern side during the Late Cretaceous time interval according to the matchup with the study of Okay and Şahintürk (1997). The depositional area of the Alacaatlı Olistostromes was accepted as somewhere located in fore-arc basin more close to the ocean (Rojay & Süzen, 1997) and the deposition have been continued at the same with the oceanic subduction before the Cenral Pontide-Kırşehir Massif collision (Okay & Altıner, 2017). The metamorphism has taken place concurrently in the Kırşehir Massif which is recently located on the eastern side of the İzmir-Ankara Suture (Whitney et al., 2003; Whitney & Hamilton, 2004). However, these two units, the Kırşehir Massif and the Central Pontide, have collided in the Late Masstrichtian-Paleocene resulted in the uplifting and folded structure of the Central Pontide. When the stratigraphic thickness (almost 2km) in a narrow time interval is considered, the tectonism-originated deposition is admissible for the Alacaatlı Olistostromes (Okay & Altıner, 2017). This tectonic evolution can be explained by the deformation based on the entering of oceanic bodies such as the oceanic island arcs, volcanoes, aseismic edges, oceanic plateau, continental pieces (Coffin & Eldholm, 1994; Tetreault & Buiter, 2014) into the subduction trench. In Coniacian, the oceanic crust with an oceanic body subducted under the continental crust of the Pontides and the uplifting on the fore-arc basin, which has been resulted from the oceanic body, caused debris flows onto the Jurassic-Cretaceous pelagic carbonates and the Triassic complex. The debris flow deposition in the direction of the Pontides has been occured as accretionary prism. At the last stage, ohiolitic basalt and chert fragments has been added onto the olistostromal deposition by debris flow and the mechanism has been turned to a normal deposition of the red-micritic limestones and shales overlying the Coniacian succesion (Okay & Altıner, 2017).

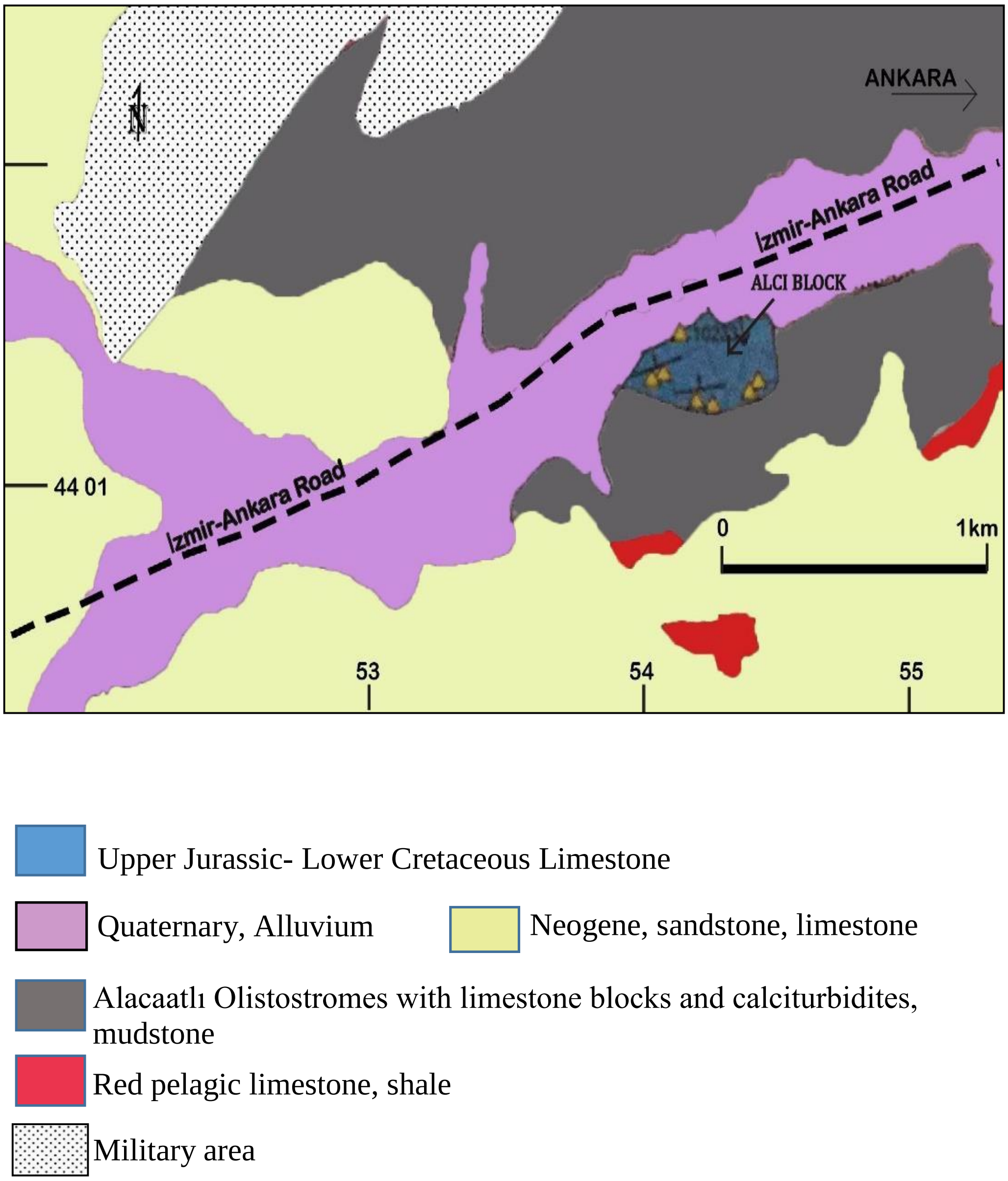


Figure 1.3. Geological map of the Alcı Region (modified from Okay & Altıner, 2017).

CHAPTER 2

STRATIGRAPHY

2.1. Stratigraphic Units

The “olistostrome” term, which comes from the Greek origin as olistostromai (to slide) and stroma (accumulation), was initially used by Flores (1955) in order to describe the accumulation resulted from the sliding. He indicated that olistostromes are not truly bedded except the presence of previously bedded blocks. Then, Boneo (1956) qualified the olistostromes as sedimentary mélange and defined the blocks in the sedimentary mélange with their slump and slide structures. On the other hand, Koçyiğit (1979) defined the olistostrome as swimming of angular, striated or polished blocks in variable size within schisty, clayey and sandy matrix.

The chaotic units of Ankara region were previously introduced as “Ankara Melange” without the separation of the Late Triassic mélange and the Late Cretaceous mélange (Bailey &McCallien, 1950). Then, Yılmaz (1981) and Görür (1984) revealed the differences between the Late Triassic mélange (in the Karakaya Complex) and the Late Cretaceous mélange (in the Anatolian Complex). In addition to these, Şengör & Yılmaz (1981) presented that the Karakaya Complex is restricted within the Sakarya Continent whereas the Anatolian Complex is related with the İzmir-Ankara-Erzincan suture zone. The vertical relations of the Karakaya Complex, the Ankara Group and the Anatolian Complex were described in the generalized stratigraphic section for Ankara region which was prepared by Koçyiğit (1991). According to this study, the Upper Triassic Karakaya Complex is overlain by the Ankara Group including the shallow marine clastics with “Rosso Ammonitico Facies” at the bottom and the sedimentary mélange (Damlaağaçderesi Formation) at the upper part passing into the deep marine fine clastics. In the west of Balıkuyumcu area (Temelli region), Mekik (1994) carried out a master thesis on the blocks of Damlaağaçderesi Sedimentary Melange. This mélange consists of the blocks from the Yosunlukbayırı Formation, the Günören Limestone, the Kapanboğazı Formation and the Güdük Formation. Also, the carbonate blocks were mostly noted as belonging to the Yosunlukbayırı Formation (Mekik, 1994). These units located near the Balıkuyumcu area are belong to the Cretaceous age, so they are younger than the section which is studied within the scope of this thesis.

The Yosunlukbayırı formation term was assigned to the thin-medium bedded, grey-white argillaceous limestones which mainly include mudstones with fine detritics of volcanic origin by Altıner et al. (1991) (Fig.2.1). This formation is limited by the basaltic Kurcalıkdere Formation at the bottom and it is conformably overlain by the porcelaneous Soğukçam limestone at the top. These limestones are also characterized by the presence of chert nodules, quartz and feldspar grains. The thin to medium bedded levels may also represented by calpionellid bearing packstones which are composed of pseudoolitic, oolitic clasts, pellets, coral and echinoid. The cherty limestones of this formation are distinguished by high abundance of radiolarian, sponge spicules, aptychi fragments and echinid fragments (Altıner et al., 1991; Mekik, 1994). The micritic levels of this formation represent very clayey nature. Thick-bedded part of this limestone unit turns into the thin-bedded levels towards upwards including slumps, missing beds and mesoscopic faults (Mekik, 1994). Based on the calpionellid content (Altıner & Özkan, 1991), the Tithonian-Late Berriasian time interval was assigned to this formation. The Yosunlukbayırı Formation indicates the tectonically unstable environment of the Tithonian-Berriasian time interval with the existence of calciturbidites, breccioid levels including calpionellids and the slump structures. This formation was also detected in the Beypazarı- Çayırhan area. It was noted as thin to medium bedded, radiolarian, belemnite and ammonite-rich limestones in wackestone and mudstone facies which continued upwards with a thick turbiditic sequence. The transported clasts of the olistostromal levels were coral boundstones, mudstones, spicule-rich wackestones and *Tubiphytes* bioclasts while the uppermost detritic limestone beds are characterized by *Zoophycus* (Altıner et al., 1991). The Yosunlukbayırı Formation was qualified as the basinal facies of the Oxfordian-Early Tithonian detritic limestones with volcanic materials, clasts and olistoliths derived from carbonate shelf margins. The transformation of detritic materials decreased at the beginning of the Late Tithonian and the Soğukçam Limestone started to precipitate in more stable basinal conditions in the Beypazarı-Çayırhan area (Altıner et al., 1991).

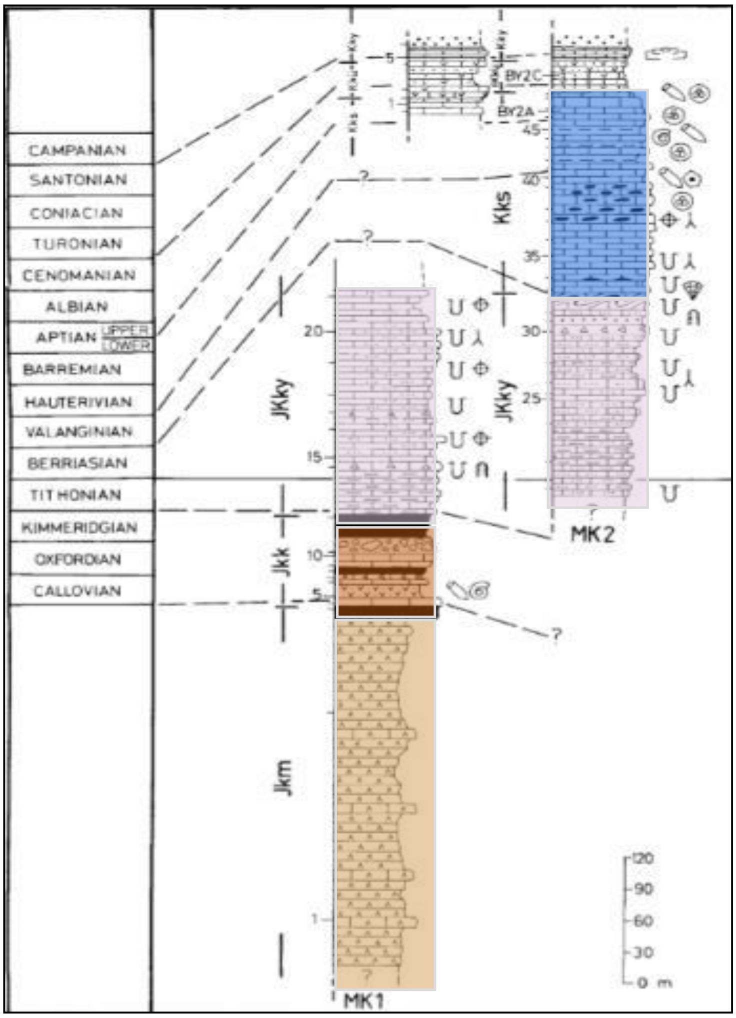


Figure 2.1. MK1 and MK2 measured sections in the Mudurnu area (Jkm: Mudurnu Formation, Jkk: Kurcalıkdere Formation, JKky: Yosunlukbayırı Formation, Kks: The “true Soğukçam Limestone”) (Altıner et al., 1991).

On the other hand, the most common Upper Jurassic- Lower Cretaceous (Tithonian-Berriasian-Valanginian) age pelagic limestone blocks within the Alacaatlı Olistostromes were assumed to be originated from the Soğukçam Limestone as broken and transported large blocks (Mekik, 1994; Rojay & Süzen, 1997; Okay & Altıner, 2017) (Fig.2.2). The large limestone blocks are located in olistostromes with intrabasinal sediments, siltstone, mudstone, sandstone and calciturbidite in the Alcı region. These pelagic limestones are mainly composed of thin to medium bedded, white to grey micritic carbonates with sometimes including chert nodules. The Soğukçam Limestone was defined by the intercalations of calciturbidite or thin shale layers with the pelagic limestone beds in the study of Okay & Altıner (2017).

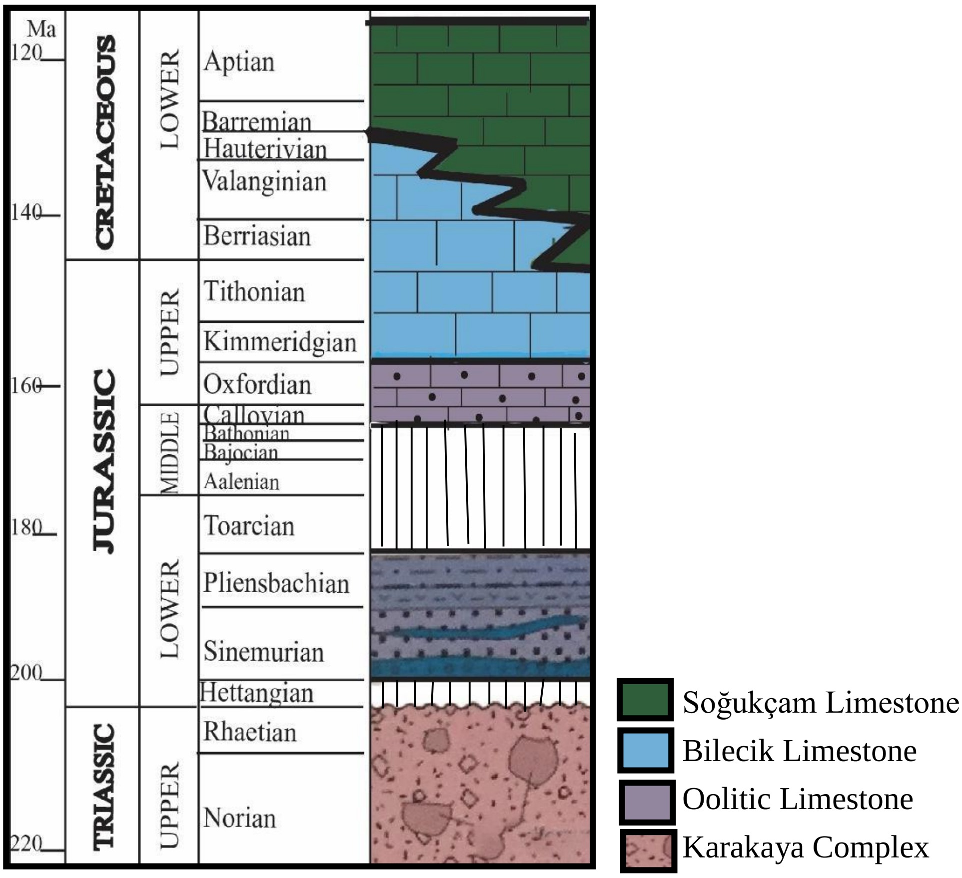


Figure 2.2. Simplified generalized stratigraphic section of the Sakarya Zone (modified from; Okay & Altıner, 2017).

Alcı Block on the south of Ankara-Eskişehir road near Alcı region was previously studied by Okay and Altıner (2017) and they classified the lower part of this block as calciturbidites and laminated carboniferous sandstones intercalated with the radiolarian biomicrites. These levels also include *Saccocoma* sp., *Belorussiella* sp. and *Globochaete alpina* which correspond to the Late Tithonian *Saccocoma* Zone in the study of Altıner (1991). The major part of this block is characterized by the thin to medium bedded radiolarian biomicrites intercalated with the clayey limestones. The calpionellid and the foraminifera content of this part indicate the Tithonian- Early Berriasian age including the Jurassic-Cretaceous boundary interval. Furthermore, the calciturbidites within the Soğukçam Limestone are mainly composed of shallow-marine limestone fragments including the Kimmeridgian-Berriasian age benthic foraminifera and algae such as *Protopeneroplis ultragranulata*, *P. striata*, *Mohlerina basiliensis*, *Crescentiella morronensis*, *Belorussiella sp*., *Charentia* sp., *Nauticulina* sp., *Lenticulina* sp. and *Reophax* sp. (Okay & Altıner, 2017).

The type section of the Soğukçam Limestone was initially introduced by Altınlı (1973b) in the Harlak-Manastır (Soğukçam) area such that this unit was accepted as the Hauterivian-Barremian aged and unconformably overlies the Kapıkaya Formation. However, this unit was also defined as the pelagic Lower Cretaceous aged limestones overlying the Bilecik Group and the limestone unit that overlies diachronously the detrital carbonates of the Upper Jurassic-Neocomian Yosunlukbayırı Formation in the Mudurnu-Nallıhan region (Altıner et al., 1991). In the Mudurnu area, the Soğukçam limestone is characterized by medium bedded, calpionellid and spicule-rich wackestones and *Globochaete* mudstones at the lower part and cherty micritic limestones with abundant Radiolaria and *Nannoconus* turn into a condensed level with belemnites and crinoids towards upwards. The upper part of the Soğukçam Limestone is identified as intercalations of thin to medium bedded limestones in wackestone facies consisting of abundant planktonic foraminifers and belemnites with marls. The uppermost levels, on the other hand, are composed of pinkish colored limestones with abundant planktonic foraminifers. In the Nallıhan area, the succession resembles the unit in the Mudurnu area and these micritic limestones with ammonites, belemnites, brachiopods, planktonic foraminifera and *Nannoconus* also include calciturbiditic levels with terrigenous clastics as intercalations. In the Beypazarı-Çayırhan area, the Soğukçam Limestone is distinguished by thin-thick bedded, white to cream colored micritic limestones of wackestones with abundant calpionellids, Radiolaria, *Nannoconus*, *Zoophycus*, aptychi fragments and belemnites intercalated with the fine turbiditic levels at the lower part. The upper parts are characterized by alteration of medium to thick bedded, beige-cream colored micritic limestones and marls with slump structures. These levels include ammonite, belemnite, aptycus and crinoid-rich levels and mudstone/wackestone facies with *Nannoconus*, sponge spicules, Radiolaria and rare planktonic foraminifera and calpionellids. Calpionellids are dominant in the lower part of the Soğukçam Limestone in contrast with the upper parts and reflect the Upper Tithonian-Valanginian age (Altıner & Özkan, 1991). *Protopeneroplis trochoangulata*, Miliolidae, *Textularia* sp., Ataxophragmiidae, Pseudocyclammina sp., *Spirillina* sp., *Patellina* sp., *Lenticulina* sp., *Tubiphytes morronensis, Cadosina* sp., Calcicphaerulidae and *Globochaete alpina* are benthic foraminifera, algae and *incertae sedis* content of these levels. According to the micro- and macrofossil context, the Late Tithonian-Barremian age was assigned to the formation (Altıner et al., 1991). In Bayırköy- Günören area, the Soğukçam Limestone is characterized by 30-40 cm thick beds with wackestones, packstones and grainstones rich in crinoid, bryozoan and pelagic elements. The unit also includes micritic nodules and a stylolitic breccioid texture defining as the “first condensed sequence” and 10cm thick, yellow to red chert bed overlies this sequence. The “second condensed sequence” is located on top of the chert bed as 80 cm thick limestone beds. The crinoidal, breccioid texture rich in ferrugineous nodules are belong to the lower bed while the upper bed is distinguished by crinoidal packstone and sponge-spicule rich wackestone with a pelagic matrix and hard grounds (Altıner et al., 1991). The overlying levels are identified as thin-medium bedded, pink to white porcelaneous limestones with chert nodules. The wackestones rich in planktonic foraminifera, Radiolaria and *Nannoconus* are found in these porcelaneous limestones.

Unfortunately, there may be an ambiguity between these two formations namely the Yosunlukbayırı Formation and the Soğukçam Limestone due to the independent usage in different studies. In the first instance, the lower part of the Jurassic-Lower Cretaceous succession with a volcano-sedimentary unit in the Mudurnu-Nallıhan-Beypazarı region was named as the Mudurnu Formation (Saner, 1980). In addition to that the pelagic sedimentary sequence of the Late Jurassic-Early Cretaceous age, which overlies this volcano-sedimentary unit, was completely described as the Soğukçam Limestone by Saner (1980) and Yılmaz et al. (1981). However, this unit was rearranged and renamed by Altıner et al. (1991). In this more current study, Altıner et al. (1991) subdivided this pelagic unit into three distinct units as the Soğukçam Limestone, the Yosunlukbayırı Formation and the Kurcalıkdere Formation (Fig.2.1). According to their description, the true Soğukçam Limestone term was restricted to the porcellaneous and argillaceous limestones of Early Cretaceous rather than the whole pelagic unit. Moreover, the underlying detrital parts including olistostromes, volcanics and calciturbidites were seperated as the Kurcalıkdere Formation and the Yosunlukbayırı Formation. The pelagic carbonates with calciturbiditic intercalations of the Yosunlukbayırı Formation overlies the basaltic layers of the Kurcalıkdere Formation in the Mudurnu-Nallıhan-Beypazarı region. The Yosunlukbayırı Formation of the Kabalar Group and the Günören Limestone of the Bilecik Group are also the synchronous units such that the Yosunlukbayırı Formation represents the distal pelagic succession beyond the slope of the carbonate platform while the Günören Limestone is characterized by the platform type deposition.

2.1.1. The Section-BA

The studied section (BA section) was measured as a 59,30 m thick stratigraphic section (Fig. 2.3). A total of 55 samples were collected. In addition to this sampling, the Jurassic-Cretaceous boundary interval (samples BA42 - BA45) resampled in order to delineate the exact position of the boundary. For this purpose, 17 extra samples were collected as 5-10 cm intervals for more detailed sampling. The BA section was actually studied as two parts. The lower part of the section called BA-I corresponds to the lower part of the Yosunlukbayırı Formation with thick calciturbiditic intercalations and the second and upper part of the section (BA-II) represents the upper portion of the same formation including the tapering calciturbiditic levels and the Jurassic-Cretaceous boundary level. Along the whole section BA, ammonites and aptychi were collected as fragments in mass flow part and as an in situ fossil casts or molds in certain argillaceous limestone beds. The ammonites were collected especially from the levels BA-3, 14, 52 during fielwork, however, the other limestone beds with ammonite and aptychi were detected in the field as the levels BA1, BA5, BA7-10, BA19, BA21, BA28.

The section BA-I starts with the sample BA-01 close to the base on the north side of the Alcı Block and its uppermost level was limited by the sample BA-15 (about 21,09 m high from the starting point in studied section) (Fig. 2.4). This lower part of the studied section (BA section) is distinguished by thin to medium bedded, sporadic thick bedded, beige to grey pelagic limestone beds. These limestone beds were later classified as packstones (BA-2, BA-6, BA-7, BA-15) and alternations of wackestones (BA-1, BA-8, BA-14) and some cherty levels by microfacies analyses. Also, the intercalation of calciturbiditic levels (BA-3, BA-10, BA-13) and marls (BA-4, BA-9, BA-11, BA-12) with these biomicrites were designated in this part by these analyses. The thickness of limestone beds varies from 10-20 cm to 70-80 centimeters and it increases towards the upper part of this section. The distal calciturbidites are characterized by thin-bedded (like a few tens of cms), well-developed micritic upper parts, small grained levels with lithoclasts, fossils, ooids, peloids, autochthonous deep-water fossils together with the platform- or slope-derived fossils in micritic matrix detected by microfacies analyses under microscope. The background pelagic sedimentation in the calciturbiditic levels was idefined by calpionellids, calcareous

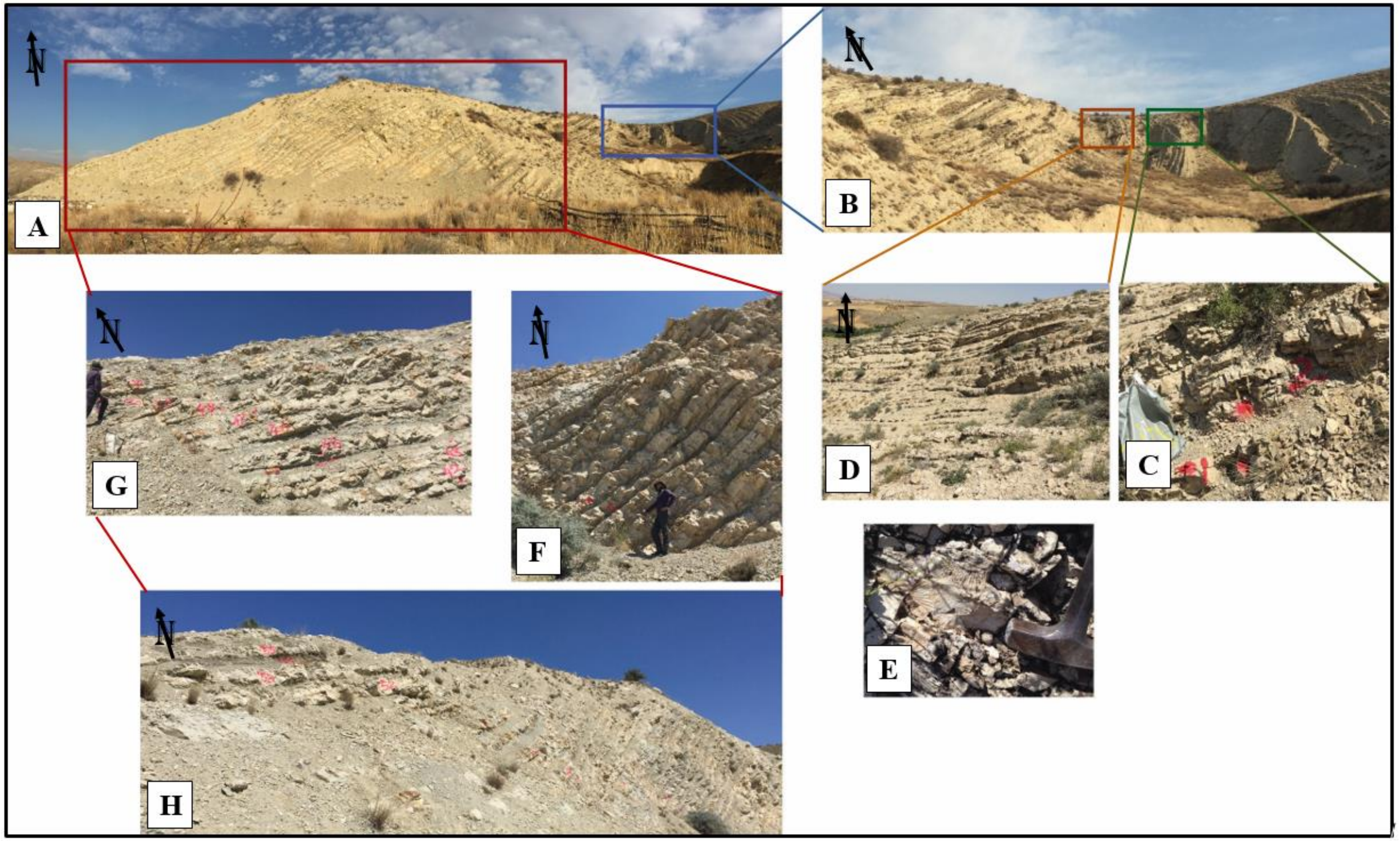


Figure 2.3. The field photos of the studied section BA belongin to the Alcı Block. A) the complete section, B) the southern base parts of the section, C) the starting point of the section, D) thin to medium bedded pelagic limestone of the Yosunlukbayırı Formation, E) ammonites, F) thin to medium bedded pelagic limestone of the Yosunlukbayırı Formation- BAII, G) the upper part of the section, H) the uppermost level of the section (BA-55).

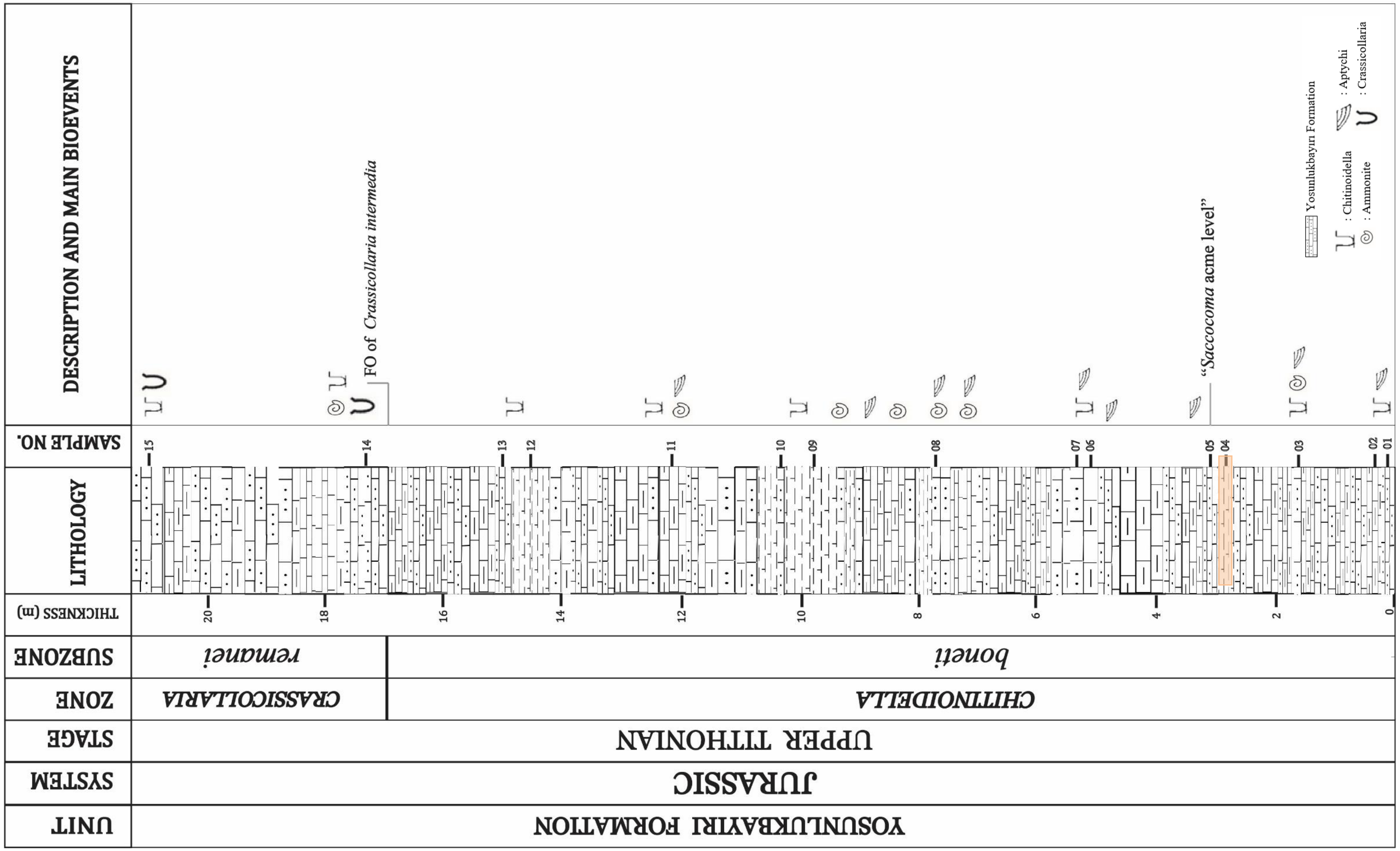


Figure 2.4. Stratigraphic columnar section of BA-I.

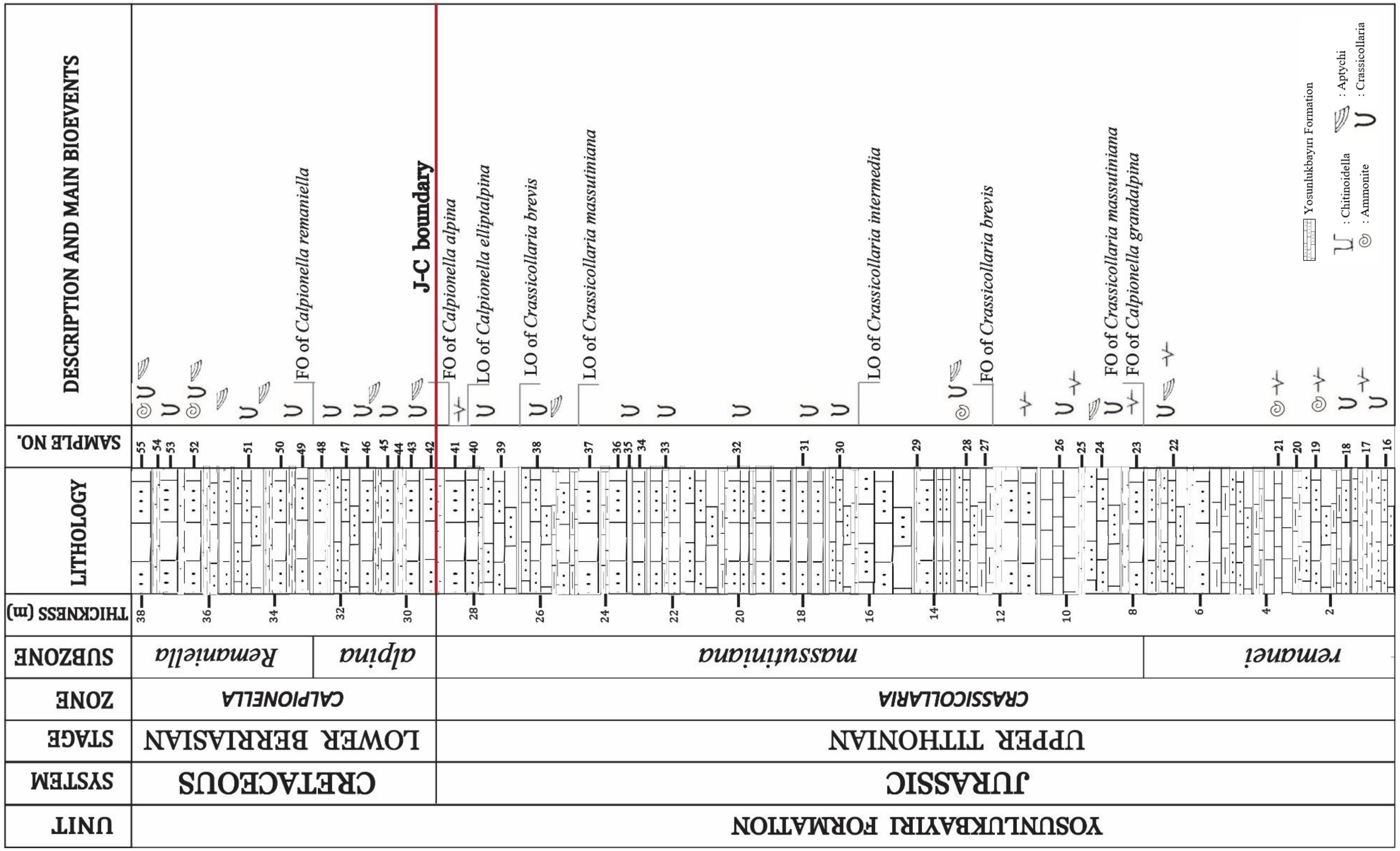


Figure 2.5. Stratigraphic columnar section of BA-II.

dinocyst and calcified radiolarians. The fossil assemblages of these pelagic limestones in the lower part of the section BA were determined as Radiolaria, *Saccocoma* (especially in the sample BA-5), aptychi, globochaete, calcareous dinocyst, rare bryozoan, small benthic foraminifera and *Chitinoidella* and hyaline calpionellids (BA-14 and BA-15).

The upper part of the studied section BA (section BA-II) starts with the level of the sample BA-16 positioned more close to the İzmir-Ankara road (Fig. 2.5). This section was measured as 38,21 meters from bottom to top (BA16 - BA55) and it reflects complete and well-bedded pelagic limestone characteristics especially in the upper parts (from the sample BA-26 to BA-55). The lithological characteristics of the lower section (BA-I) also continue within this part (BA-II). The succession is characterized by thin to medium and partly thick bedded, beige to grey colored pelagic limesone beds and the intercalations of calciturbiditic levels (BA-18, BA-29, BA-34, BA-40, BA-44, BA-46, BA-54) and marls (BA-17, BA-20, BA-25, BA-33, BA-35) in between pelagic limestone beds. Shale was observed by naked eye as interlayers within the limestone represented by the sample BA-26. The thickness of beds varies from 15-20 cm to 110-115 centimeters in the succession. However, the thickness of limestone beds decreases in upward direction. Besides that, the thickness of calciturbiditic levels and the marls sandwiched between the limestone beds also decreases when compared to the section BA-I. Ammonite and aptychi were recognized in some levels as BA-19, BA-21, BA-28, BA-52, also in the weathered part (due to the physical conditions) of the studied section. Hyaline walled calpionellids dominate the fossil context of these pelagic limestone unit at this section. Besides of calpionellids, calcified radiaolaria, calcareous dinocyst, globochaete, *Saccocoma*, bryozoa and rare small benthic foraminifera derived from the slope or platform facies were also identified throughout the BA-II section by thin section analyses. The exact position of the Jurassic-Cretaceous boundary was determined as the level of the sample BA-42 located in upper part of this section. For that purpose, BA-42, BA-43 and BA-45 levels were analyzed in detail with 17 extra samples in 5-

10 cm intervals (Fig. 2.6). The calciturbiditic levels were also observed in this interval. Especially the level represented by the sample BA-43/6^1 is distinguished as laterally continuous distinct red layer. This red layer was later identified as calciturbidites with detrital grains (silt and sand size grains) and some benthic foraminifers derived from the slope or platform facies by thin section analyses. This level is can be explained by the relative sea-level fall in the Early Cretaceous time interval. Moreover, the sample BA-43/3^1 was picked up from very thin (about a few mm) green layer located between the upper two layer of the limestone bed (BA-43) (Fig. 2.6). This sample also includes fine detrital grains and some benthic foraminifera. Vail et al. (1984) generated a sea-level curve for the Jurassic-Early Cretaceous time interval together with the coastal-onlap curve obtained from seismic stratigraphic analysis for the same time interval. According to this study, the eustatic sea-level change is reflected by a sudden decrease within the latest Tithonian- earliest Berriasian time interval.

In conclusion, the lithological characteristics of the whole studied section (the section BA) coincide with the lithology of the Yosunlukbayırı Formation (Altıner et al., 1991). Both the sections BA-I and BA-II are defined as thin to medium bedded, beige to grey pelagic limestone-marl alternations and the intercalations of the calciturbidites in variable thicknesses throughout the studied succession. The porcellaneous limestones of the Soğukçam Limestone unit could not be observed in the Alcı Block. The Alcı Block was previously defined as the pelagic limestone block of the Jurassic-Cretaceous age which was originated from the Soğukçam Limestone in the study of Okay & Altıner (2017). However, the Soğukçam Limestone term was used as the "Soğukçam *sēnsū lātō"* in that study. That is, this term was used as old-general term including the Kurcalıkdere Formation, the Yosunlukbayırı Formation and also the true Soğukçam Limestone. Therefore, it does not mean the true Soğukçam Limestone unit which was limited as the porcellaneous and argillaceous limestones of Early Cretaceous age by Altıner et al. (1991) in the Mudurnu-Nallıhan-Beypazarı region.

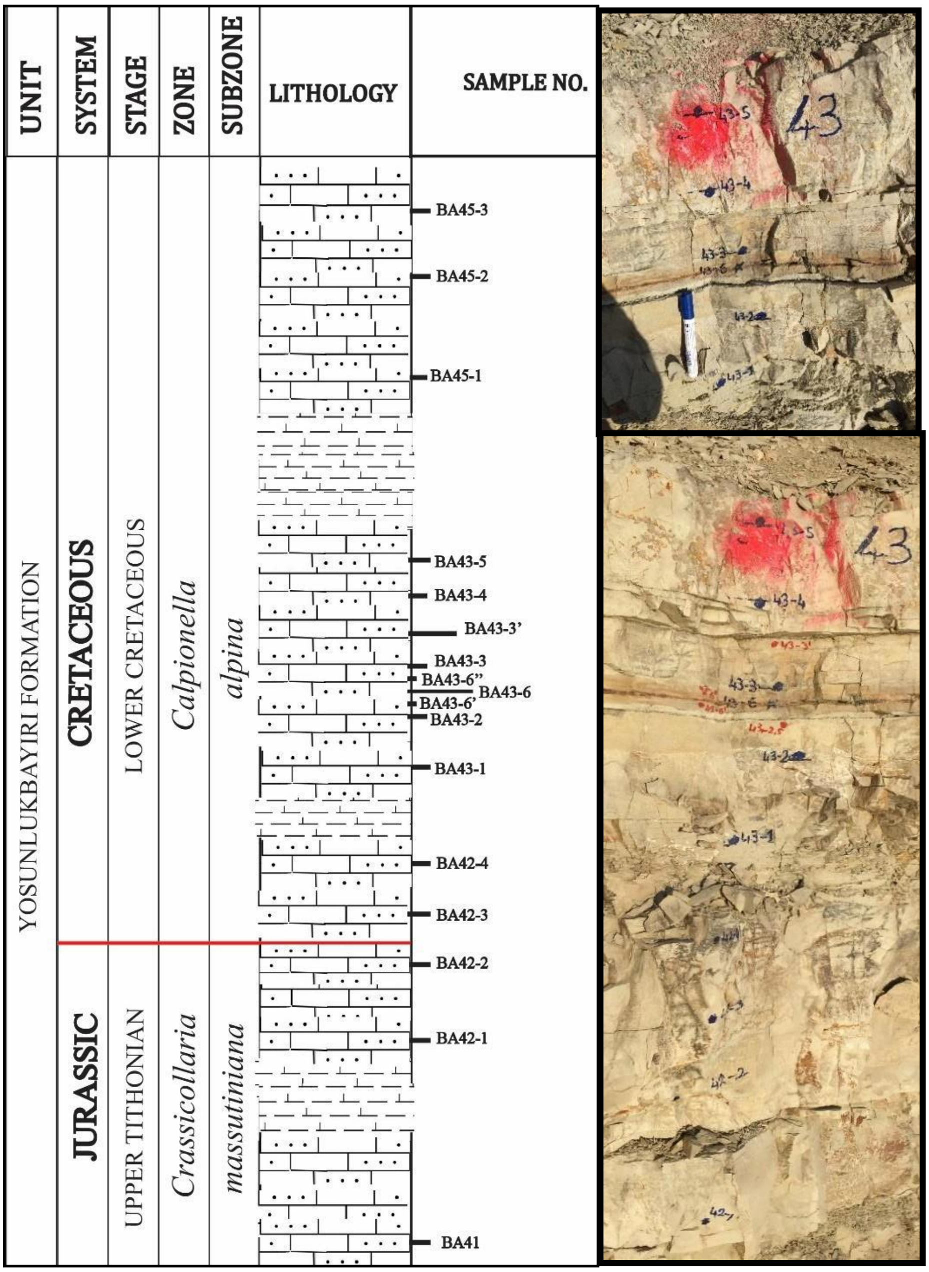


Figure 2.6. Detailed sampling from the interval of the Jurassic-Cretaceous boundary.

2.2. Biostratigraphy

The ICS (International Commision on Stratigraphy) (Cowie et al., 1986) makes the definition of system boundaries with a GSSP (Global Boundary Stratotype Section and Point) obligatory. The GSSP must be chosen as an exact point and the type section that reflects standard characteristics of the selected time interval and the correlation opportunity in worldwide. At this point, the Jurassic-Cretaceous time boundary must also have a widely accepted formal definition as a GSSP. However, it is accepted as the most problematic GSSP task for ICS such that the Cretaceous time still have not been defined by a global boundary definition despite numerous conferences, the International Working Group on the Jurassic-Cretaceous boundary and the Berriasian Working Group activities (Remane, 1991; Cope, 2007; Wimbledon, 2008; Wimbledon et al., 2011). The problems arisen for this boundary interval can be itemized as the lack of significant faunal turnover, the controversial characteristics of the Berriasian faunas, the difficulties in regional, intra-regional and global correlations, differentiation in the biochronologic and the biostratigraphic zones and the zonal boundaries, the differences in the Tethyan and the Boreal realms and the disharmony of nomenclature (Remane, 1991). Tethys was accepted as a first recourse in order to test and apply the boundary criteria because of its high predominance on the Jurassic-Cretaceous boundary markers and the studied areas (Wimbledon et al., 2011). Although the Jurassic-Cretaceous boundary interval is problematic in terms of GSSP, it has a lot of stratigraphic markers reflected by different fossil groups both microfossils and macrofossils together with magnetostratigraphy and cyclostratigraphy. That is, the enigma created on this time boundary interval is actually resulted from the deficiency of a consistent correlation in wordwide. For this purpose, some fossil groups such as especially calpionellids, calcareous nannofossils, calcareous dinoflagellate cysts, ammonites, palynomorphs are used to define the exact position of the boundary. However, magnetostraigraphy can not be used by itself in order to define a boundary because of that it is meaningless and inconsequential for the Boreal Realm. Besides that, nannofossils give exact results for timewise studies but they are rare fossil type. On the other hand, calpionellids may be accepted as a most sufficient, reliable and prevalent boundary marker for Tethys and they are in cooperation with ammonites successfully (Wimbledon et al., 2011). The boundary studies are mainly based on calpionellids and nannoplankton in the Tethyan Realm. However, they are well calibrated with the magnetic reversals ending up with more comprehensive results (Ogg & Lowrie, 1986; Channel & Grandesso, 1987; Ogg et al., 1991). According to the study of Ogg & Lowrie (1986), the base of the *Calpionella* Zone is reflected by the base of CM18 polarity chron. Although magnetostratigraphy seems like an easily accessible and acceptable method for boundary definitions, magnetic reversals require fossil markers, evidences and possible position knowledge in order to locate the exact position of time boundary intervals (Remane, 1991). Wimbledon et al. (2011) summerized the Jurassic-Cretaceous boundary indicators into two groups namely primary markers and secondary markers such that the "explosion" of *Calpionella alpina*, the first appearance datum (FAD) of *Nannoconus steinmannii minor* and *Nannoconus kamptneri minor* and base of M18r (as magnetostratigraphy) are termed as the primary markers while the secondary markers include the base of M19n.1n / M19n.1r, FAD of *Nannoconus wintereri* and *Cruciellipsis cuvillieri*, the base of *Berriasella jacobi* Subzone, FAD of *Warrenia californica*, *Dichadogonyaulax bensonii* and *Apiculatisporis verbitskayae*, the base of *Subcraspedites lamplughi* Zone, the base of *Pseudosubplanites grandis* Zone, the last appearance datum (LAD) of *Dichadogonyaulax pannea*, *Egmontodinium polyplacophorum*, FAD of *Matonisporites elegans* and *Aequitriradites spinulosum*.

The studied section mainly consists of caliponellid, Radiolaria, *Saccocoma* and calcareous dinocysts, *Globochaete alpina*, aptychi, ammonites, small benthic foraminifera in the scope of fossil assemblages. Calpionellids and *Saccocoma* were studied in detail by using thin sections and the washed samples as isolated elements. The biostratigraphical framework is mainly based on calpionellid bioevents in the whole studied succession and the *Saccocoma* species in the sample BA-05.

2.2.1. Calpionellid Biostratigraphy

Calpionellids are the most important constituents in the Upper Jurassic-Lower Cretaceous pelagic carbonates of the Tethyan Realm. They are also marker fossils for precise dating and reliable biostratigraphic correlation with the pelagic carbonates of the Mediterranean Realm (Michalik, 1995; Rehakova & Michalik, 1996; Lakova et al., 1997). The rapid evolution with definable phases, a wide range of bioevents like observable first/last occurrences and the variations of dominant species/genus in the different zones or subzones, the vast geographical distribution, the lack of provincialism in contrast with ammonites, the quantitative abundance and enviable correlations with other micro- or macrofossils make calpionellids fundemental indicators of biostratigraphic correlation and the boundary definition studies (Lakova et al., 1997).

The biostratigraphy, the paleobiogeography and the standard zonations of calpionellids have been previously studied by Colom (1948), Remane (1962, 1963, 1964, 1969a, b, 1971, 1978, 1985, 1986), Le Hegarat & Remane (1968), Crescenti (1969), Allemann et al. (1971, 1975), Catalano & Liguori (1971), Dodona et al. (1975), Peybernes (1975), Chevalier and others (1975), Erba & Quadrio (1987) in Western and Southern Europe; Nowak (1968, 1971), Borza (1969, 1974, 1978, 1979, 1984), Borza & Michalik (1986), Filipescu & Dragastan (1970), Pop (1974, 1976), Bakalova (1977, 1986) in Northern and Eastern Europe; Brönnimann (1953), Bonet (1956), Luterbacher (1972), Furrazola-Bermudez & Kreisel (1973), Trejo (1960, 1972, 1975, 1976, 1980), Pop (1976), Jansa and others (1980), Premoli Silva & McNulty (1984), Adatte et al. (1994, 1996) in Atlantic and Nort & South America locations; Durand Delga (1957), Fares & Lasnier (1971), Memmi & Salaj (1975) in Northern Africa; Bozorgnia & Banafti (1964), Edgell (1967), Makarieva (1979) in Asia. Besides, they were also studied by Durand Delga & Gutnic (1966), Brönnimann and others (1970), Toker (1976), Poisson (1977), Monod (1977), Fontaine (1981), Burşuk (1981, 1982), Altıner (1988, 1989) (Table 2.1). Altıner & Özkan (1991) have also carried out prominent calpionellid studies in Turkey.

Bonet (1956) identified the calpionellids as small planktonic protozoans with hyaline calcitic loricas and assigned them to the Late Tithonian-Valanginian time interval. And then, Trejo (1976) presented the difference between the microgranular calcitic loricas and the hyaline calcitic loricas in order to classify Chitinoidella (Doben, 1963) as another group of calpionellids. Afterwards, Houša (1990) asserted the idea that the hyaline walled calpionellids and the microgranular chitinoidellids actually have same origin. Even, the hyaline ones were originally derived from chitinoidellids with the microgranular calcitic loricas. The first admitted standard calpionellid zonation was revealed by Allemann and others (1971) after the Planktonic Organisms Conference in Rome. This zonation reflects four calponellid zones respectively *Crassicollaria* Zone, *Calpionella* Zone, *Calpionellopsis* Zone and *Calpionellites* Zone from bottom to top. The *Chitinoidella* Zone term was initially used by Enay & Geyssant (1975) (Lakova & Petrova, 2013). Subsequent to the several calpionellid zonation studies in different regions, Remane et al. (1986) compiled these studies and presented another standard subdivision of calpionellid biozonations. These subdivisions are termed as *Chitinoidella* Zone, Zone A (*Crassicollaria* Zone), Zone B and Zone C (*Calpionella* Zone), Zone D (*Calpionellopsis* Zone) and finally Zone E (*Calpionellites* Zone) respectively from the Middle Tithonian to the Early Valanginian time interval. Altıner & Özkan (1991) carried out the study of calpionellid populations, the stratigraphic ranges of calpionellids and their calibrations with the benthic Foraminifera in between the east of Eskişehir-Adapazarı and the west of Ankara-Çerkeş regions. Unlike from Remane (1974, 1985)'s zonal definitons, they have introduced Zone F above the *Calpionellites* Zone in this study. Zone F was described as the last occurence of *Calpionellites darderi* and continued *Tintinnopsella carpathica* in the Valanginian age (Altıner & Özkan, 1991). This supplementation was actually based on the study of Trejo (1975, 1980) which represents the continuity of *Tintinnopsella carpathica* Subzone on top of the *Calpionellites darderi* Subzone.

The Middle-Late Tithonian *Chitinoidella* Zone is subdivided into two subzones namely the *dobeni* and the *boneti* subzones and these microgranular calcitic loricas of *Chitinoidella* and double walled *Praetintinnopsella* are observed later on the *Saccocoma* (pelagic crinoid) rich levels of the Tithonian age (Remane, 1985; Rehakova & Michalik, 1997; Altıner & Özkan, 1991). The *Crassicollaria* Zone (Zone A) starts with the first occurence of hyaline lorica calpionellids such as *Tintinnopsella* and *Crassicollaria* together with the inner hyaline and outer microgranular layered lorica of *Praetintinnopsella* so that the subdivision is called as A1 Subzone of Remane (1974, 1985)'s calpionellid zonations. The Subzone A2 is characterized by abundance of *Crassicollaria intermedia* (Durand Delga), relatively less abundance of *Crassicollaria brevis* (Remane) and *Crassicollaria massutiniana* (Colom), the first appearance of large variety of *Calpionella alpina* (Lorenz), which was later renamed as *Calpionella grandalpina* in recent studies (Petrova et al., 2012; Lakova & Petrova, 2013) and less amount of *Tintinnopsella carpathica.* Moreover, the uppermost subdivision of Zone A is termed as A3 Subzone (Remane 1969a, 1971, 1974, 1985) representing the Late Tithonian age and it is distinguished by the increasing diversity of *Crassicollaria* species like *Cr. intermedia*, *Cr. massutiniana*, *Cr. brevis*, *Crassicollaria parvula* (Remane), common *Calpionella alpina* species and rare *Tintinnopsella carpathica*. However, the predominant form of this subzone is accepted as *Crassicollaria brevis* (Altıner & Özkan, 1991). On the other hand, the Zone B was associated with the Tithonian-Berriasian boundary interval due to the explosion of small sphaerical forms of *Calpionella alpina* (Remane, 1985; Altıner & Özkan, 1991). The Zone B is not only noted for the rapid increase in frequency of *Calpionella alpina* (more than%90), but also characterized by the sudden decrease in abundance of *Crassicollaria brevis* tohether with the other *Crassicollaria* species and the first appearance of *Remaniella ferasini* (Catalano), also transition forms between *Calpionella alpina* and *Calpionella elliptica* Cadisch (Remane, 1985; Altıner & Özkan, 1991). The Zone C represents the Early Berriasian age with a large variety of Tintinnopsella, the first appearance of *Calpionella elliptica,* which was used to define the base of *Calpionella elliptica* Subzone by Catalano & Liguori (1971), and

Remaniella cadischiana (Colom), abundant *Calpionella alpina*, *Remaniella ferasini* (Catalano) and the disappearance of *Crassicollaria parvula* (Remane,1985; Altıner & Özkan, 1991; Adatte et al., 1996). The *Calpionellopsis* Zone (also called Zone D) is limited between the first occurrence of *Calpionellopsis* and the first occurrence of *Calpionellites* and it was subdivided into three distinct subzones respectively Subzone D1, D2 and D3 from bottom to top by Remane (1963, 1985). The first occurrence of *Calpionellopsis simplex* (Colom) refers to the Subzone D1 while the predominance of *Calpionellopsis oblonga* (Cadisch) indicates the Subzone D2. Unlike the other two subzones, Remane (1971, 1974, 1985) distinguished the Subzone D3 as limited within the first occurrence of *Lorenziella hungarica* (Knauer) and *Calpionellites darderi* (Colom). The Berriasian-Valaginian boundary was also located within this subzone. The uppermost part of Remane (1985)'s calpionellid biozonations is termed as the Zone E (*Calpionellites* Zone) with the Early Valanginian age. The first appearance of *Calpionellites darderi* represents the lower boundary of Zone E while the upper boundary is also limited by the last appearance of this species (Remane, 1985; Altıner & Özkan, 1991).

Grün & Blau (1997) have distinguished 6 zones and 19 subzones in terms of the calpionellid taxonomy and biozonation studies. According to this zonal and subzonal division, the *Chitinoidella* Zone starts with the first occurrence of *Chitinoidella dobeni* Borza as the *dobeni* Subzone and it is subdivided into four subzones respectively *dobeni, boneti, bermudezi* and *andrusovi* subzones from bottom to top. Unlike Remane (1985)'s subdivisions, they used the first appearance of *Chitinoidella bermudezi* (Furrazola-Bermudez) as an indicator of the *bermudezi* Subzone while the *andrusovi* Subzone was seperated from the *bermudezi* Subzone by the first occurrence of *Praetintinnopsella andrusovi* (Borza) (Chanell & Grandesso, 1987). The only difference in *Crassicollaria* Zone was new additional *Crassicollaria catalanoi* Subzone located in the uppermost part of this zone. The base of this subzone is contemporary with the base of Subzone A3 (Remane, 1985). However, the content was altered by an addition of the genus *Remaniella* in the upper part of *Crassicollaria*

Zone (Grün & Blau, 1997). They have subdivided the *Calpionella Zone* into three subzones rather than two seperated zones as Zone B and Zone C (Remane, 1985; Altıner & Özkan, 1991). The *Calpionella* Zone term was previously assigned to the level where *Crassicollaria intermedia* became extinct and to the level characterized by the absolute predomination of *Calpionella alpina* (Lorenz) by Catalano and Liguori in 1971. They have seperated Zone C into two distinct units as the *elliptica* Subzone and the *cadischiana* Subzone based upon the first occurrences of *Calpionella elliptica* (Cadisch) and *Remaniella cadischiana* (Colom) respectively. The *Calpionellopsis* Zone was studied under five separate subzones namely *simplex, oblonga, filipescui, murgeanui, dadayi* subzones. These subzones are given names from the first occurrence of their index calpionellid species. According to these subdivisions, the *oblonga* and the *filipescui* subzones coincide with the Subzone D2 while the *murgeanui* Subzone corresponds to the Subzone D3 (Le Hégarat & Remane, 1968; Altıner & Özkan, 1991). Here, the important point is that *Praecalpionellites dadayi* (Knauer) was used as an indicator of the uppermost *dadayi* Subzone and Grün & Blau (1997) presented the differences between *Praecalpionellites dadayi* (Knauer) and *Remaniella cadischiana* (Colom) in terms of metric data, lorica shape and collars. Moreover, the *Calpionellites* Zone was subdivided into the *darderi* Subzone and the *major* Subzone seperately based on the first occcurrences of *Calpionellites* species. Furthermore, Pop (1994b) has previously described the *Tintinnopsella* Zone with the extinction event and the continuity of *Tintinnopsella* and *Remaniella* after this event in a similar vein with Altıner & Özkan (1991)'s study. Grün and Blau (1997) seperated the *Tintinnopsella* Zone into gr. *hungarica* Subzone (*cadischiana* Subzone of Pop (1996)) and gr. *carpathica* Subzone respectively. They associated the gr. *carpathica* Subzone with the Zone F of Altıner & Özkan (1991)'s study.

Reháková & Michalik (1997) have also carried out the comprehensive study of calpionellid evolution and zonation. Their biochronological calpionellid zonation was started in the Middle Tithonian and reached up to the Early Albian including also a barren interval as distinct from the previous biozonations. They defined the

Praetintinnopsella Range Zone restricted within the first occurrence and last occurrence of *Praetintinnopsella andrusovi* which was located between the *Chitinoidella* Interval Zone (Reháková, 1995) and the *Crassicollaria* Interval Zone in the Middle-Late Tithonian age. They also subdivided the *Crassicollaria* Interval Zone (Allemann, 1971) into three distinct units as the *remanei* Range Subzone (A1 Subzone of Remane et al., 1986), the *brevis* Range Subzone (A2 Subzone) and the *colomi* Range Subzone (A3 Subzone) respectively from bottom to top. The *colomi* Subzone was shaped based on the first occurrence of *Crassicollaria colomi* (Doben, 1963) which was already grouped under Remane (1986)'s *intermedia* Subzone and Lakova (1993)'s *massutiniana* Subzone. The difference on the *Calpionella* Interval was the existence of the *ferasini* Interval Subzone started with the first occurrence of *Remaniella ferasini* before the *elliptica* Interval Subzone. The *Calpionellites* Range Zone has same two subdivisions of Grün & Blau (1997)'s study. After the "barren interval" in their calpionellid zonation chart, they defined the *Praecolomiella* Range Zone with the first occurrence of *Praecolomiella trejoi* in Early-Late Aptian. And finally, the *Colomiella* Range Zone was detected by the first occurrence of *Colomiella mexicana* located in the uppermost part of this calpionellid zonation. Reháková & Michalik (1997) determined several changes in the composition of calpionellids' lorica within the scope of calpionellid evolution and they attributed the alterations of lorica to the changes in sea-water chemistry. On the other hand, Lakova and others (1999) concluded the study about bioevents and integrated zonations of calpionellids as almost the same form with Reháková & Michalik (1997) except using the *Crassicollaria massutiniana* Subzone rather than the *Crassicollaria brevis* and the *Crassicollaria colomi* subzones seperately.

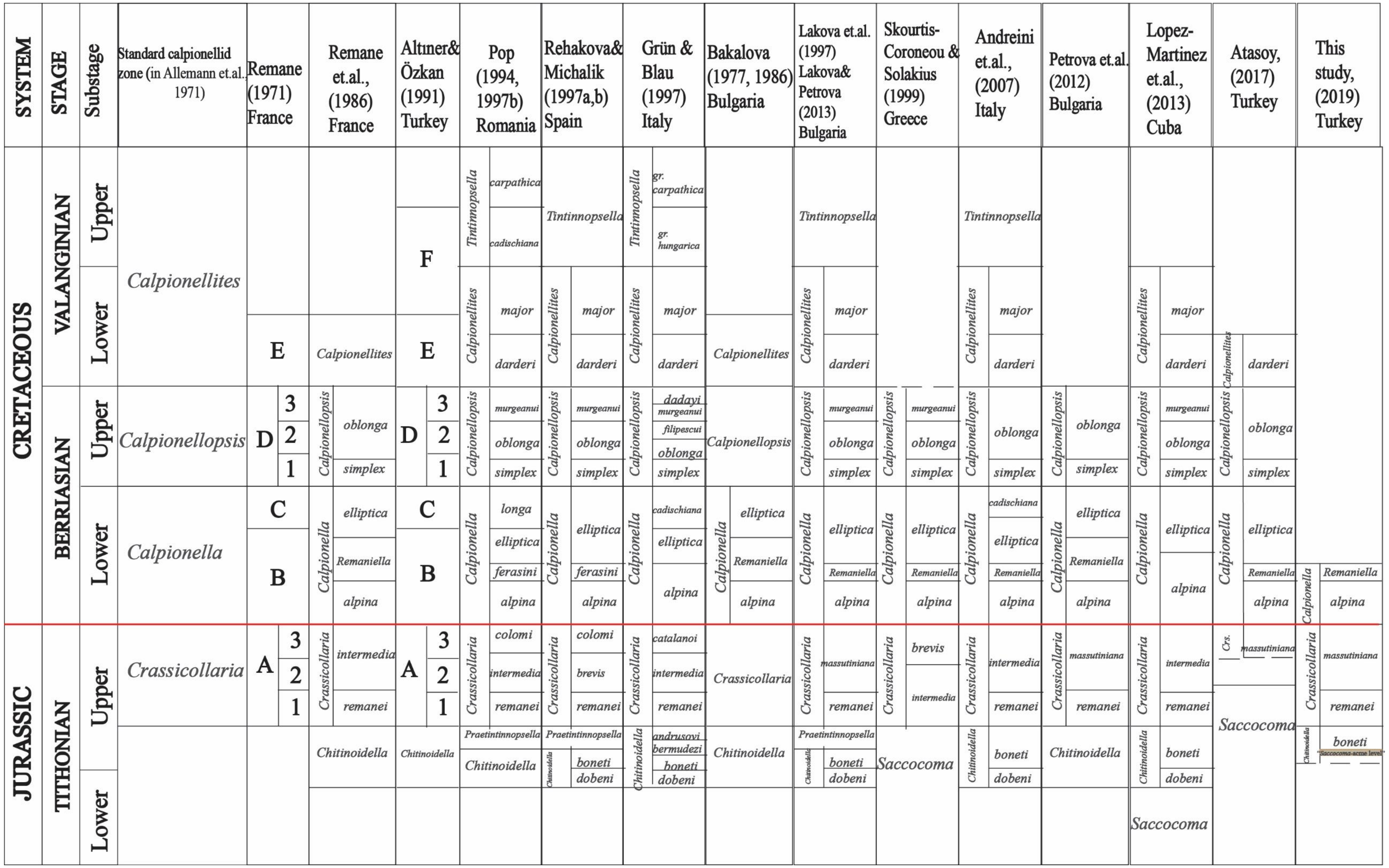
Recently, numerous studies (Lakova et al., 1999, 2007; Petrova, 2009, 2010; Lakova & Petrova, 2013; Pop, 1994, 1997; Reháková & Michalik, 1997a, b; Ivanova et al., 2006; Bakalova, 1997) were focused on the Western Balkan Unit, the Western Carpathians and the Southern Carpathians with respect to the biostratigraphy and calpionellid zonation of the pelagic carbonates in the Upper Jurassic-Lower

Cretaceous boundary interval. Petrova et al. (2012) carried out the biozonation study of the Rosomač pelagic limestones across the Jurassic-Cretaceous boundary in the Eastern Serbia (Stara Planina-Poreć Zone) and obtained almost the same zonation of calpionellids as in the study of Lakova et al. (1999). They also delineate the Tithonian-Berriasian boundary at the base of *Calpionella alpina* Subzone in the same way as previous studies which was represented as the “explosion” of these small spherical calpionellids with hyaline lorica.

Lakova and Petrova (2013) also established a standard calpionellid zonation of the Tethyan Realm in the Western Balkan Unit. The correlation of the calpionellid ranges with ammonites indicated that the base of the Late Tithonian age was pointed out as the first occurrence of *Chitinoidella boneti*. The first occurrence of the genus *Calpionellopsis* was related with the Late Berriasian and the genus *Calpionellites* was restricted within the Early Valanginian age (Lakova & Petrova, 2013). They subdivided the *Crassicollaria* Zone into two subzones respectively; the *Crassicollaria remanei* Subzone and the *Crassicollaria massutiniana* Subzone. The separation between these subzones was pointed as the first occurence of *Calpionella grandalpina* (large spherical calpionellids with hyaline wall). Their *Calpionella* Zone definition was the same with Reháková & Michalik (1997a, b)’s study; however, Lakova and Petrova (2013) used the *C. remaniella* Subzone instead of the *Calpionella ferasini* Subzone. They also accepted the “explosion” of *Calpionella alpina* as an indicator of the Tithoian-Berriasian boundary.

Except for the fact that initial microgranular walled calpionellid forms (chitinoidellids) evolved into more complex forms of calpionellids with hyaline lorica in the Late Tithonian, Michalik et al. (2009) established two distinct morphological changes of hyaline walled calpionellids in the Late Tithonian-Early Berriasian time interval. The first one is distinguished by the replacement of initially occured *Crassicollaria* species of the *remanei* Subzone by the *Crassicollaria brevis* as dominant *Crassicollaria* species. The another critical change within the hyaline calpionellids is a sudden decrease in abundance of *Crassicollaria* species concurrently

Table 2.1. *Calpionellid biozonation correlations of the Late Jurassic-Cretaceous time interval.*



SYSTEM	STAGE	Substage	Standard calpionellid zone (in Allemann et.al. 1971)	Remane (1971) France	Remane et.al., (1986) France	Altıner& Özkan (1991) Turkey	Pop (1994, 1997b) Romania	Rehakova& Michalik (1997a,b) Spain	Grün & Blau (1997) Italy	Bakalova (1977, 1986) Bulgaria	Lakova et.al. (1997) Lakova& Petrova (2013) Bulgaria	Skourtis-Coroneou & Solakius (1999) Greece	Andreini et.al., (2007) Italy	Petrova et.al. (2012) Bulgaria	Lopez-Martinez et.al., (2013) Cuba	Atasoy, (2017) Turkey	This study, (2019) Turkey
CRETACEOUS	VALANGINIAN	Upper	*Calpionellites*			F	*Tintinnopsella* *carpathica* *cadischiana*	*Tintinnopsella*	*Tintinnopsella* *gr. carpathica* *gr. hungarica*		*Tintinnopsella*		*Tintinnopsella*				
		Lower		E	*Calpionellites*	E	*Calpionellites* *major* *darderi*	*Calpionellites* *major* *darderi*	*Calpionellites* *major* *darderi*	*Calpionellites*	*Calpionellites* *major* *darderi*		*Calpionellites* *major* *darderi*		*Calpionellites* *major* *darderi*	*Calpionellites* *darderi*	
	BERRIASIAN	Upper	*Calpionellopsis*	D 3 2 1	*Calpionellopsis* *oblonga* *simplex*	D 3 2 1	*Calpionellopsis* *murgeanui* *oblonga* *simplex*	*Calpionellopsis* *murgeanui* *oblonga* *simplex*	*Calpionellopsis* *dadayi* *murgeanui* *filipescui* *oblonga* *simplex*	*Calpionellopsis*	*Calpionellopsis* *murgeanui* *oblonga* *simplex*	*Calpionellopsis* *murgeanui* *oblonga* *simplex*	*Calpionellopsis* *oblonga* *simplex*	*Calpionellopsis* *oblonga* *simplex*	*Calpionellopsis* *murgeanui* *oblonga* *simplex*	*Calpionellopsis* *oblonga* *simplex*	
		Lower	*Calpionella*	C B	*Calpionella* *elliptica* *Remaniella* *alpina*	C B	*Calpionella* *longa* *elliptica* *ferasini* *alpina*	*Calpionella* *elliptica* *ferasini* *alpina*	*Calpionella* *cadischiana* *elliptica* *alpina*	*Calpionella* *elliptica* *Remaniella* *alpina*	*Calpionella* *elliptica* *Remaniella* *alpina*	*Calpionella* *elliptica* *Remaniella* *alpina*	*Calpionella* *cadischiana* *elliptica* *Remaniella* *alpina*	*Calpionella* *elliptica* *Remaniella* *alpina*	*Calpionella* *elliptica* *alpina*	*Calpionella* *elliptica* *Remaniella* *alpina*	*Calpionella* *Remaniella* *alpina*
JURASSIC	TITHONIAN	Upper	*Crassicollaria*	A 3 2 1	*Crassicollaria* *intermedia* *remanei* *Chitinoidella*	A 3 2 1 *Chitinoidella*	*Crassicollaria* *colomi* *intermedia* *remanei* *Praetintinnopsella* *Chitinoidella*	*Crassicollaria* *colomi* *brevis* *remanei* *Praetintinnopsella* *Chitinoidella* *boneti* *dobeni*	*Crassicollaria* *catalanoi* *intermedia* *remanei* *Chitinoidella* *andrusovi* *bermudezi* *boneti* *dobeni*	*Crassicollaria* *Chitinoidella*	*Crassicollaria* *massutiniana* *remanei* *Praetintinnopsella* *Chitinoidella* *boneti* *dobeni*	*Crassicollaria* *brevis* *intermedia* *Saccocoma*	*Crassicollaria* *intermedia* *remanei* *Chitinoidella* *boneti* *dobeni*	*Crassicollaria* *massutiniana* *remanei* *Chitinoidella*	*Crassicollaria* *intermedia* *remanei* *Chitinoidella* *boneti* *dobeni*	*Crs.* *massutiniana* *Saccocoma*	*Crassicollaria* *massutiniana* *remanei* *Chitinoidella* *boneti* "*Saccocoma*-acme level"
		Lower													*Saccocoma*		

with the “explosion” of small sphaerical *Calpionella alpina* (Michalik et al., 2009). Depending on the studies of the Berriasian Working Group of the International Subcommission on Cretaceous Stratigraphy (ISCS), the base of *Calpionella* Zone and the Jurassic-Cretaceous boundary were determined as the sudden decrease in diversity and appearance of *Crassicollaria* species and the “explosion” of small sphaerical *Calpionella alpina* (Remane, 1985; Remane et al., 1986; Altıner & Özkan, 1991; Lakova, 1994; Pop, 1994, 1997; Grün & Blau, 1997; Rehakova & Michalik, 1997; Lakova et al., 1999, 2007; Petrova, 2009, 2010; Wimbledon et al., 2011; Lakova & Petrova, 2013; Ivanova et al., 2006; Bakalova, 1997).

The biozonations of this study were formed as totally based on calpionellids. Besides these, the abundance of *Saccocoma* Agassiz in the sample BA-05, small benthic foraminifera, calcareous dinocysts, calcified radiolarians, aptychi fragments, ammonites, echinoid spines and algae were also recorded in the studied pelagic limestone block in the Late Jurassic-Early Cretaceous age (Table 2.2). The small planktonic foraminifera were also identified as small biserial foraminifera with welldefined aperture, high-trochospiral, low-trochospiral, planispiral and small microperforated forms in the sample BA-05. These planktonic foraminifera were determined as the *Conogloblugerina* and *Globlugerina* species. *Globuligerina oxfordiana* (Grigelis, 1958) was defined among these extracted small planktonic foraminifera in the sample BA-05. However, these extracted small planktonic formanifera are going to be studied at a species level in subsequent studies. The calpionellid biozonation of this study was represented by the interval between the Late Tithonian age chitinoidellids (calpionellid forms with microgranular wall) and the Early Berriasian age calpionellids (calpionellid forms with hyaline wall) which belong to the *Calpionella* Zone. Calpionellids in the studied samples were generally well preserved and these hyaline forms dominated over the studied section in contrast with the microgranular forms. *Chitinoidella* species were also recorded in the lower part of the studied section. However, they were rare in thin sections and the identification of these species was quite difficult because of their black color and poor preservations.

In this study, three calpionellid zones were well defined; the *Chitinoidella* Zone (with the *boneti* Subzone), the *Crassicollaria* Zone (with the *remanei* and *massutiniana* subzones) and the *Calpionella* Zone (the *alpina* and *remaniella* subzones) respectively. The position of Tithonian-Berriasian boundary was delineated in the sample BA-42 in this study. Moreover, calpionellid ranges within the Late Jurassic-Early Cretaceous time interval in this study were also illustrated by drawings of each calpionellid species on thin section views separately (Fig. 2.7).

2.2.1.1. *Chitinoidella* Zone

Author: Grandesso, 1977.

Description and Remarks:

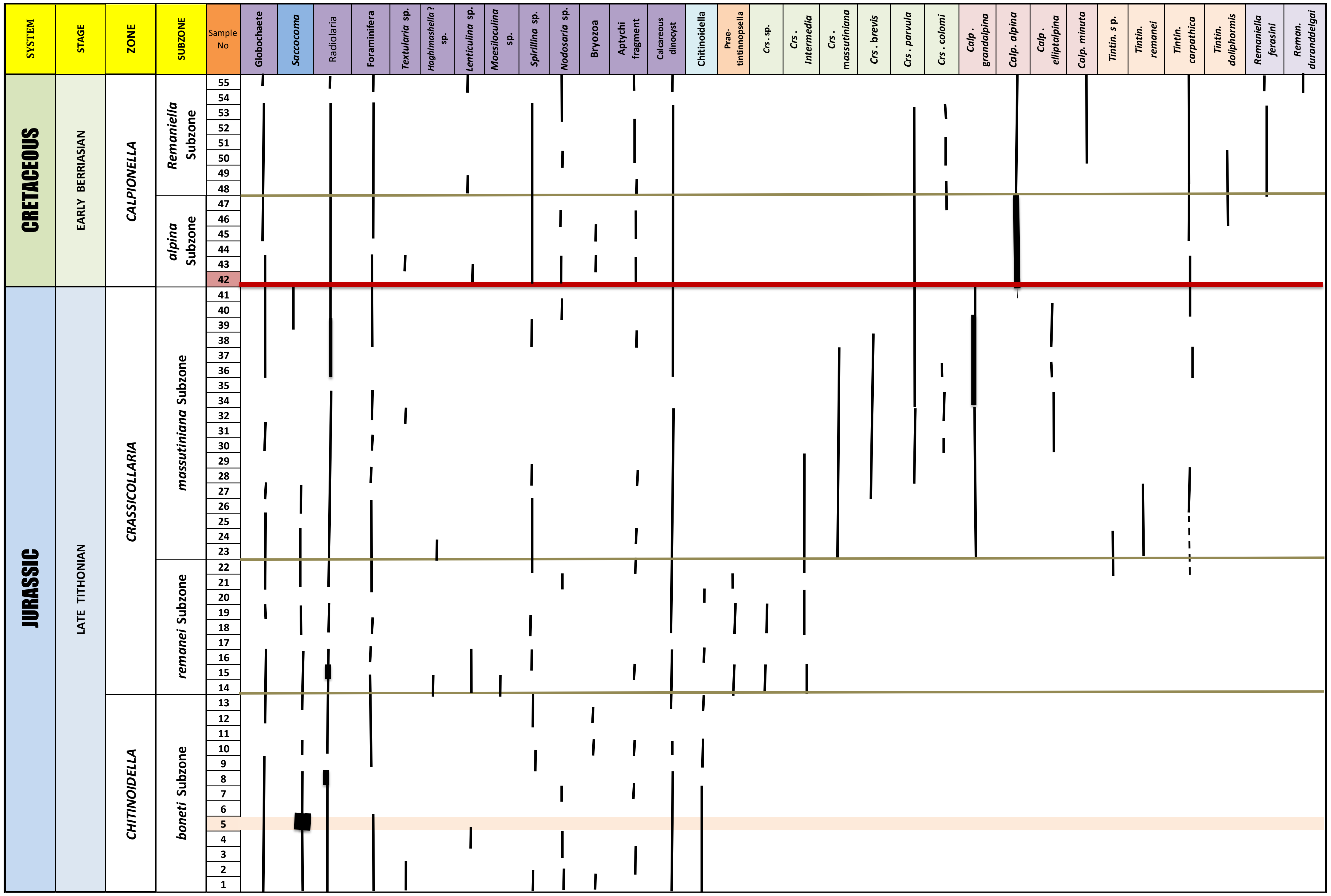
The *Chitinoidella* Zone was defined by Grandesso (1977) and it was subdivided into two subzones namely the *dobeni* Subzone and the *boneti* Subzone (Grandesso, 1977; Borza, 1984). This zone is characterized by the microgranular walled chitinoidellids which are also accepted as ancestors of the calpionellids with hyaline lorica. The Middle-Late Tithonian age was assigned to the *Chitinoidella* Zone. This zone was also identified on top of the pelagic crinoid *Saccocoma* rich levels in the Kozluca and Çayırhan regions in the study of Altıner & Özkan (1991). Chitinoidellids are generally observed as rare and sporadically found forms in thin sections. The black color of the microgranular wall rarifies the identification of these small forms. The upper boundary of the *Chitinoidella* Zone was detected by the first occurrence of hyaline walled calpionellids; crassicollarians.

Stratigraphic Distribution:

In this thesis, chitinoidellids were identified very rarely in the lowermost part of the studied section represented by the samples BA1-13 of the *Chitinoidella* Zone and it continues up to the sample BA-20 renresenting the *remanei* Subzone.

Age: The Middle - Late Tithonian.

Table 2.2. *Fossil range chart of the studied section-BA.*



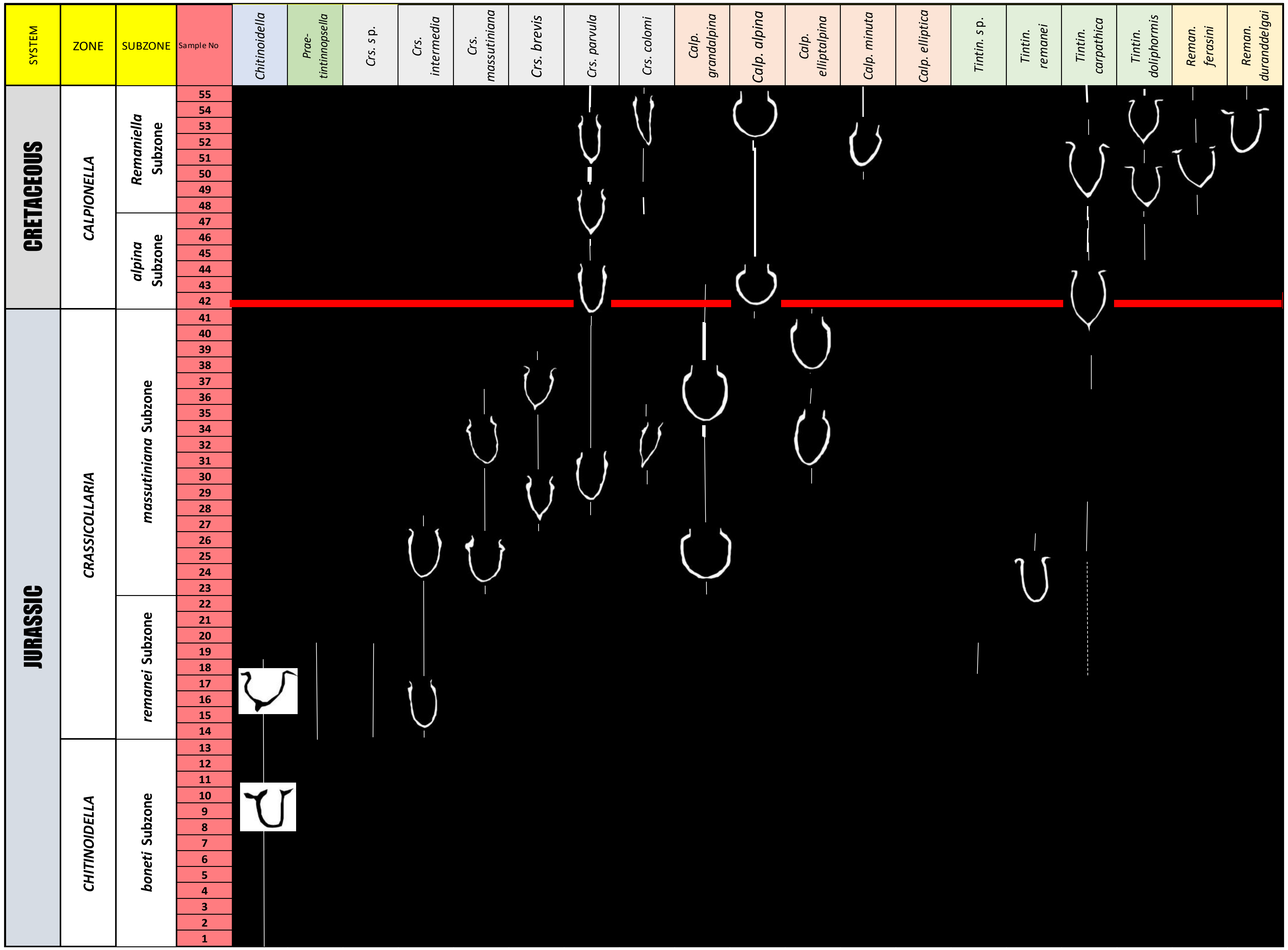


Figure 2.7. The ranges of calpionellid species of the Late Jurassic-Early Cretaceous time interval. All drawings were performed on the real calpionellid individuals in the thin sections of this thesis.

***Boneti* Subzone**

Description and Remarks:

The base of this subzone is identified by the first occurrence of *Chitinoidella boneti* Doben and this species dominates the chitinoidellid assemblage. *Longicollaria insueta*, *Dobenialla cubensis*, *Dobeniella bermudezi*, *Daciella danubica* also occur within this subzone. The subzone was previously recorded by Borza (1984), Borza & Michalik (1986), Rehakova (1995, 2002), Reháková & Michalik (1997a, b), Houša et al. (1999a, b, 2004), Michalik et al. (2009), Pop (1994, 1997b, 1998b), Grün & Blau (1997); Andreini et al. (2007), Lakova et al. (1999), Reháková et al. (2009), Lukeneder et al. (2010), Pruner et al. (2010).

Stratigraphic Distribution:

The *boneti* Subzone was represented as the range between the first occurrence of calpionellids with microgranular lorica (BA-01) and the first occurrence of hyaline walled *Crassicollaria* (BA-13) in this study.

Age: The Late Tithonian.

2.2.1.2. *Crassicollaria* Zone

Author: Alleman et al., 1971.

Description and Remarks:

The *Crassicollaria* Zone (A Zone) was identified by Alleman et al. (1971). The lower boundary of this zone is defined by the first occurrence of calpionellids with hyaline lorica and it is limited by the uppermost level as the “explosion” of *Calpionella alpina*. The *Crassicollaria* Zone represents the Late Tithonian within the studied section. The zone is subdivided as the lower *remanei* Subzone and the upper *massutiniana* Subzone respectively (Lakova et al., 1999; Petrova et al., 2012; Lakova & Petrova, 2013).

Stratigraphic Distribution:

The sample BA-14 was accepted as a starting point of the *Crassicollaria* Zone with the first appearance of hyaline walled *Crassicollaria* sp., *Crassicollaria intermedia* Durand Delga, *Tintinnopsella carpathica* (Murgeanu & Filipescu) together with *Praetintinnopsella andrusovi* Borza and *Chitinoidella boneti* Grandesso. The uppermost limit of the *Crassicollaria* Zone was noted as the sample BA-41 in this study.

Age: The Late Tithonian.

***Remanei* Subzone**

Author: Remane et al., 1986.

Description and Remarks:

The lower subzone of *Crasicollaria* Zone was named by Remane et al. (1986) and it was also called as A1 Subzone of Remane (1963), Le Hégarat & Remane (1968), Altıner & Özkan (1991). Its lower boundary is marked by the first occurrence of *Crassicollaria intermedia* (Durand Delga,1957). *Crassicollaria intermedia* dominates the crassicollarian assemblage of the *remanei* Subzone. *Crassicollaria* sp., *Praetintinnopsella andrusovi*, *Chitinoidella boneti*, *Tintinnopsella* sp., *Tintinnopsella carpathica* and *Tintinnopsella remanei* are also observed as the other members of calpionellid assemblage. The lower boundary of this subzone is also characterised as the transition from microgranular (chitinoidellids) and double walled calpionellids (*Praetintinnopsella*) to hyaline walled forms. So, the samples belonging to the lower part of this subzone contain underrecognised *Crassicollaria* sp. forms due to the fact that these hyaline walled crassicollarians are broken and the lack of collars or upper parts of the lorica make the description impossible. On the other hand, Petrova et al. (2012, from the eastern Serbia) noted that some species of chitinoidellids belonging to the *boneti* Subzone such as *Borziella slovenica*, *Dobeniella bermudezi*, *Chitinoidella elongata* were found as reworked forms within this subzone. Chitinoidellids were seen rarely in this study. However, the range of chitinoidellids reached up to the *remanei* Subzone in this thesis. Besides of calpionellids, the *remanei* Subzone contains calcified radiolarians, globochaetes, calcareous dinocysts, *Saccocoma*, scarce small benthic foraminifera, aptychi fragments and partly bryozoa. Top of the *remanei* Subzone was distinguished by the first occurrance of *Crassicollaria massutiniana* (Colom).

Stratigraphic Distribution:

The samples BA14 and BA-22 of this thesis were assigned to the *remanei* Subzone by the first occurrence of the hyaline walled *Crassicollaria* forms and the pelagic Late Tithonian fossil assemblage. Based on the fossil content, this detected subzone can be correlated with previous studies in Romania (Pop, 1986b, 1994), Slovakia (Reháková & Michalik, 1997a, b; Michalik et al., 2009), Italy (Grün & Blau, 1997; Andreini et al., 2007; Houša et al., 2004), Austria (Rehakova et al., 2009), Bulgaria (Ivanova, 1997; Lakova et al., 1999; Lakova & Petrova, 2013), Serbia (Petrova et al., 2012), Cuba (Pszczólkowski et al., 2005), France (Wimbledon et al., 2013), Turkey (Altıner & Özkan, 1991).

Age: The Late Tithonian.

***Massutiniana* Subzone**

Author: Lakova, 1993.

Description and Remarks:

The *massutiniana* Subzone term was introduced by Lakova (1993) and it was assigned to the calpionellids assemblage occured at the uppermost part of the Tithonian stage just before the Jurassic-Cretaceous boundary. This term involves both A2 and A3 subzones (Remane, 1963; Altıner & Özkan, 1991; Rehakova & Michalik, 1997) and it also reflects the same interval with the *intermedia* Subzone of Remane et al. (1986) and Wimbledon et al. (2013). The lower boundary of this subzone (BA-23) is identified by the first occurrence of *Calpionella grandalpina* Nagy which was also known as a large form or large elongate form of *Calpionella alpina* Lorenz in the studies of Altıner & Özkan (1991) and Reháková & Michalik (1997). *Calpionella alpina* Lorenz was also noted in this subzone (Petrova et al., 2012; Wimbledon et al., 2013; Lakova & Petrova, 2013). The quantitative increase in the number of calpionellids and an observable increase in the diversification of *Crassicollaria* species were characteristic features of the *massutiniana* Subzone (Lakova & Petrova, 2013). According to the calpionellid species within these samples; *Calpionella grandalpina*, *Calpionella alpina*, *Calpionella elliptalpina*, *Tintinnopsella carpathica*, *Crassicollaria intermedia*, *Crassicollaria massutiniana* (Colom), *Crassicollaria brevis* Remane, *Crassicollaria parvula* Remane and *Crassicollaria colomi* Doben formed the calpionellid assemblage of this subzone. At the lower part, *Crassicollaria massutiniana* dominated the subzone while *Crassicollaria brevis*, *Crassicollaria parvula*, *Crassicollaria colomi* and high abundance of *Calpionella grandalpina* indicated the upper part of this subzone. Moreover, *Calpionella elliptalpina* appeared more close to the end of this subzone. *Globochaete*, calcareous dinocyst, calcified radiolarians, echinid spines and calcareous algae were observed almost all samples within this interval. Aptychi fragments were also identified in samples BA-24, BA-28 and BA-38 respectively. The small benthic foraminifera of the *massutiniana* Subzone were noted as *Spirillina* sp., *Nodosaria* sp.

Stratigraphic Distributions:

These specifications correspond to the samples between BA-23 and BA-41 of the studied section. The *massutiniana* Subzone constitutes the major part of studied calpionellid biozonations within this thesis. The calpionellid forms were well-recognized and their ranges in the succession were compatible with the previous studies such as Remane (1963, 1971, 1986), Altıner & Özkan (1991), Lakova (1993), Lakova et al. (1999), Ivanova et al. (2002), Pop (1974, 1994), Reháková & Michalik (1997a, b), Grün & Blau (1997), Skourtsis-Coroneou & Solakius (1999), Houša et al.

(2004), Pszczólkowski et al. (2005), Andreini et al. (2007), Michalik et al. (2009), Rehakova et al. (2009), Pszczólkowski & Myczyński (2010).

Age: The Late Tithonian.

2.2.1.3. *Calpionella* Zone

Author: Allemann et al., 1971.

Description and Remarks:

The Standard *Calpionella* Zone was also introduced by Allemann et al. (1971) as in the *Crassicollaria* Zone. The range of this zone is determined by two distinct calpionellid bioevents so that the lower boundary is maked by the explosion of small sphaerical *Calpionella alpina* while the uppermost level is limited by the FO of *Calpionellopsis simplex* (Colom). The lower boundary of this zone is also accepted as the boundary between the Tithonian and the Berriasian stages (Lyon-Neuchatel Colloquium in 1973 and the 32nd International Geological Congress in Florence in 2004). Two successive bioevents such as the first occurrence of *Remaniella ferasini* (Catalano) / *Remaniella duranddelgai* Pop and the first occurrence of *Calpionella elliptica* Cadisch resulted in the subdivisions of this zone into three subzones; *alpina*, *Remaniella* and *elliptica* subzones respectively from bottom to top.

Stratigraphic Distribution:

The interval between the samples from BA-42 to BA-55 within the studied section was designated as the *Calpionella* Zone on the basis of calpionellid zonation. Moreover, the Jurassic-Cretaceous boundary location was determined as the level represented by the sample BA-42 based on the existence of *Calpionella alpina* “explosion” and the sudden decrease in abundance and diversity of the genus *Crassicollaria*.

Age: The Standard *Calpionella* Zone represents the Early Berriasian age.

Alpina Subzone

Author: Pop, 1974.

Description and Remarks:

This subzone which was restricted between the explosion of *Calpionella alpina* at the bottom and the first occurence of *Remaniella ferasini* (Catalano) as the upper boundary was named by Pop (1974). It indicates the lower part of the *Calpionella* Zone. The most characteristic feature of the subzone is a sudden increase in abundance of *Calpionella alpina* as a predominant species of the calpionellid assemblage within the Early Berriasian Stage. In the studied section, the “explosion” of *Calpionella alpina* was observed in the sample BA-42. At this level, the sample BA-42 was composed of predominantly sphaerical hyaline walled *Calpionella alpina* Lorenz together with the less amount of *Crassicollaria parvula*, *Calpionella grandalpina* and *Tintinnopsella carpathica*. Actually, sphaerical *Calpionella alpina* forms were seen in small quantities as against the genus *Crassicollaria* just before this level (BA-41). However, the starting point of this subzone was assigned to the “explosion” of *Calpionella alpina* species. Therefore, the Jurassic-Cretaceous boundary was identified as the level of sample BA-42 by the existence of dominant *Calpionella alpina*, rare *Crassicollaria parvula*, *Tintinnopsella carpathica* together with calcified radiolarians, globochaete, calcareous dinocyst, scarce small benthic foraminifera and aptychi fragment. *Calpionella grandalpina* did not pass the boundary and it became extinct at the level of the sample BA-42. *Calpionella elliptalpina* Nagy also became extinct within the level of the sample BA-41 just before the Tithonian-Berriasian boundary. *Crassicollaria massutiniana* was also extinct in the Late Tithonian and its range did not reach up to this stage boundary. Therefore, *Crassicollaria parvula* and *Crassicollaria colomi* were exceptional individuals of the genus *Crassicollaria* which were able to pass the boundary. *Crassicollaria parvula* Remane increased in abundance in the lower part of the *alpina* Subzone and it was identified together with *Crassicollaria colomi*, *Tintinnopsella carpathica* and predominant *Calpionella alpina* in between the samples BA-46 and BA-51. Events of increased abundance of *Crassicollaria parvula* occured in some sections were previously recorded as a *Crassicollaria parvula* “acme” zone (“CPAZ”) (Housa et al., 2004; Pruner et al., 2010; Lakova & Petrova, 2013; Wimbledon et al., 2013). In this thesis, the “acme” of *Crassicollaria parvula* was noted as in the sample BA-50. The first occurence of *Tintinnopsella doliphormis* (Colom) was observed in the upper parts of the *alpina* Subzone. On the other hand, globochaete, calcified radiolarians, calcareous dinocyst, *Spirillina* sp., *Lenticulina* sp., *Textularia* sp., ostracods, echinid spines, nodosarids, calcareous algae and aptychi fragments were also identified throughout this subzone. However, *Saccocoma* elements such as brachials or wing-like structures were not clearly observed within the *alpina* Subzone.

Stratigraphic Distribution:

This identified subzone can be correlated with the previous studies as in Turkey (Remane, 1963, 1971; Le Hegarat & Remane, 1968; Cecca et al., 1989; Altıner & Özkan, 1991), in Romania (Pop, 1974, 1986b, c, 1994, 1997b, 1998b), in Serbia (Lakova et al., 2009), in Slovakia (Rehakova, 1995, 2000a; Reháková& Michalik, 1997a, b; Houša et al., 1999a, b; Michalik et al., 2009), in the Western Balkan Unit (Bakalova-Ivanova, 1986; Lakova, 1993; Lakova et al., 1999; Ivanova, 1997; Ivanova et al., 2002; Lakova & Petrova, 2013), in Poland (Pszczólkowski, 1996; Pszczólkowski & Myczyński, 2004; Grabowski & Pszczólkowski, 2006), in Cuba (Pop, 1976; Pszczólkowski & Myczyński, 2010), in Italy (Catalano & Liguori, 1971; Allemann et al., 1975), in Mexico (Trejo, 1980).

Age: The Early Berriasian.

***Remaniella* Subzone**

Author: Pop, 1974.

Description and Remarks:

This subzone was also introduced by Pop (1974) and its lower boundary was fixed by Remane et al. (1986). The first occrrences of *Remaniella ferasini* (Catalano), *Remaniella duranddelgai* Pop and *Remaniella colomi* together with the continued calpionellid taxa of the *alpina* Subzone are distinctive features of the *remaniella* Subzone. The upper boundary of this subzone is defined by the first occurrence of *Calpionella elliptica* Cadisch. This subzone started with the first occurrence of *Remaniella ferasini* within the sample BA-48 and continued with the diversification of *Remaniella duranddelgai*. *Crassicollaria parvula*, *Crassicollaria colomi*, *Calpionella alpina*, *Calpionella minuta*, *Tintinnopsella carpathica*, *Tintinnopsella doliphormis* were also identified together with calcareous dinocysts, calcified radiolarians, *Globochaete alpina*, aptychi fragments, echinid spines, *Spirillina* sp., calcareous algae.

Stratigraphic Distribution:

In this study, the *Remaniella* Subzone was identified at the uppermost part of the studied section which was represented as an interval between the samples BA-48 and BA-55 respectively.

Age: The Early Berriasian.

2.2.2. *Saccocoma* Level

The crinoids are examined under two separated groups which are termed as stalked crinoids and stalkless/stemless crinoids. The evolution of stalkless crinoids has started with osteocrinids in the Triassic age and the genus *Saccocoma* Agassiz (1836) which is classified as the small stemless microcrinoids. Jaekel (1892) described it as “Es ist wohl nicht zu viel gesagt, wenn man die Saccocomiden als den sonderbarsten Typus von Crinoiden bezeichnet…”. *Saccocoma* Agassiz was defined as the strangest and unique among other crinoids in terms of the mode of life which is the most contradictive issue about this genus and the specific morphological features such as the wing like expansions on the brachials (the skeletal elements of the arms), the extremely thin arrow-head shaped radial plates, the lack of a stem on the calyx part (Fig.2.8).

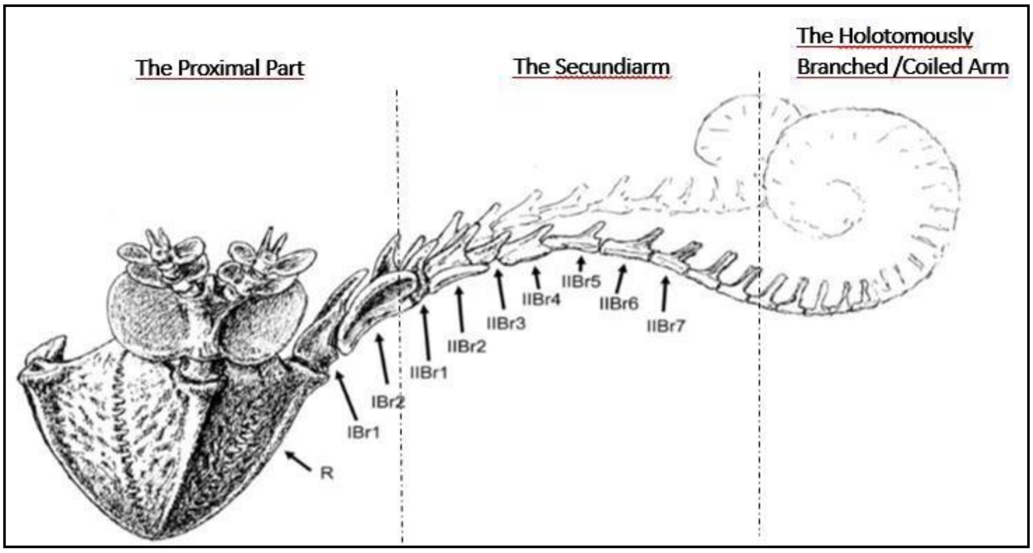


Figure 2.8. Reconstruction of Saccocoma tenella Goldfuss (retrieved from; Brodacki (2006) and Hess & Etter (2011). R: radial, IBr: primibrachial, IIBr: secundibrachial.

Jaekel (1892) initially identified the *Saccocoma* as a swimmer (schwimmplatten) and/or “free-living crinoid” with the ability of upward and downward movements. Jaekel (1892) also indicated the difference between the comatulids and the saccocomids in such a way that comatulids had the articular complexes with ability of wide movements in each direction whereas saccocomids were able to only upward and downward movements as a “free-living crinoid” with their articular complexes. This hypothesis was accepted in many studies such as Seilacher (1985, 2005), Barthel (1990), Keupp & Matyszkiewicz (1997), Hess (1999, 2000, 2002), Seilacher & Hauff (2004), Hess & Etter (2011) based on the accordance with the geodynamic evolution model of the Tethys. Brodacki (2006) reconstructed the functional anatomy model of *Saccocoma* Agassiz including the arrangement and articulations of the proximal brachials (skeletal elements of the arms). The main differences of this model from the former versions (Manni et al., 1997; Hess, 1999) were the positions of arms attached to the cup and the slope of distal facet of the second primibrachial (IBr_2). She also accepted a pelagic life style for the genus *Saccocoma* Agassiz (1836). Hess & Etter (2011) investigated the life and death of *Saccocoma tenella* (Goldfuss) in terms of the biostratinomy, constructional morphology and feeding. *Saccocoma* Agassiz (1836) was considered as a pelagic stakless microcrinoid due to the active "upstream feeding" ability (the Pulsating Funnel Model) (Hess & Etter, 2011). On the other hand; the benthic mode of life of this genus was asserted by Milsom (1994), Milsom & Sharpe (1995), Manni et al. (1997) primarily based on the specific gravity and the absence of a reasonable buoyancy or swimming mechanism. Milsom (1994) also accepted the possibility of swimming ability of *Saccocoma* as an escape mechanism in extreme cases or in the case of current action that lifted crinoid from the substrate.

The genus *Saccocoma* Agassiz (1836) have been mostly identified in the Upper Jurassic pelagic sediments of the Tethyan Realm by Sieverts-Doreck (1955, 1958), Vernioryi (1961, 1962a, 1962b), Pisera & Dzik (1979), Manni & Nicosia (1984), Milsom (1994), Manni et al. (1997), Keupp & Matyszkiewicz (1997), Hess (2000, 2002), Brodacki (2006), Kroh & Lukeneder (2009). The species were also used as index fossils for the Late Jurassic (Kimmeridgian-Tithonian) time interval in terms of the abundance and brief temporal distributions (Nicosia et al., 1979; Manni & Nicosia, 1984; Hess, 2002; Brodacki, 2006; Kroh & Lukeneder, 2009). The abundance of *Saccocoma* restricted in a specific interval was represented by the term "*Saccocoma* level" and it was associated with the Tithonian age (Nicosia & Parisi, 1979). The retrograding spongiolithic phase of the Tethys was also marked by the *Saccocoma* bearing facies in the Upper Jurassic pelagic sediments (Hess, 2002). The rock forming quantity of *Saccocoma* Agassiz (1836) represented by the sample BA-05 was also defined as the "*Saccocoma* level" in the studied succession of the pelagic limestone block (Alcı Block) of the Yosunlukbayırı Formation. The *Saccocoma* Agassiz (1836) were previously studied in the pure, reddish limestone-marl alternations continued with the calpionellid limestones in the Gresten Klippen Belt (Kristan-Tollmann, 1962; Rehakova et al., 1996), in the Northern Calcareous Alps (Flügel, 1967; Holzer, 1968, 1980; Lackschewitz et al., 1989), in the Pieniny Klippen Belt (Pszczólkowski & Myczyński, 2004) and in the Western Carpathian Klippen Belt (Vašiček et al., 1992). The limestone-marl alternation including *Saccocoma* at the lower part and pure limestones at the top dominated with the calpionellid facies in the succession was also studied in the Nutzhof Section of the Gresten Klippen Belt (Kroh & Lukeneder, 2009). The "*Saccocoma level*" was also identified at the lower part of the Late Jurassic-Early Cretaceous age pelagic limestone block (Alcı Block) of the Yosunlukbayırı Formation which is characterized by the limestone-marl alternations with the calciturbiditic intercalations. The *Saccocoma* Agassiz (1836) was investigated in terms of the species and their specific morphological features in this study. For this purpose, the extracted skeletal elements were analyzed by using both microscope views and SEM photographs.

The four valid species of the genus *Saccocoma* Agassiz (1836) are *Saccocoma quenstedti* (Sieverts-Doreck & Hess, 2002), *Saccocoma longipinna* (Hess, 2002), *Saccocoma tenella* (Goldfuss, 1831) and *Saccocoma vernioryi* (Manni & Nicosia, 1984). The stratigraphic ranges of these species were restricted within the Upper Jurassic (Nicosia et al., 1979, Manni & Nicosia, 1984; Hess, 2002; Brodacki, 2006; Kroh & Lukeneder, 2009). *Saccocoma* has been only defined as *Saccocoma* sp. or *Saccocoma* fragments in the *Saccocoma* bearing facies and the *Saccocoma* Zone related with the Yosunlukbayırı Formation or other Late Jurassic-Early Cretaceous aged depositional units (Soğukçam Limestone, Günören Limestone) in Turkey by Altıner et al. (1991), Mekik (1994), Atasoy (2017), Okay & Altıner (2007, 2017). The species of *Saccocoma* Agassiz (1836) were identified and illustrated for the first time in Turkey by this study. For this purpose, *Saccocoma tenella* Goldfuss and *Saccocoma* *vernioryi* Manni & Nicosia were detected in the sample BA-05 taken from the lower part of the studied pelagic limestone block of the Yosunlukbayırı Formation. The simultaneous presence of these two *Saccocoma* species together with *Chitinoidella boneti* in the same sample and the absence of other *Saccocoma* species indicate the Upper Tithonian for the "*Saccocoma* level" in the studied succession. Therefore, *Saccocoma tenella* Goldfuss and *Saccocoma vernioryi* Manni & Nicosia were used as the index fossils for the first time in Turkey.

Moreover, the complete morphological structure of *Saccocoma tenella* Goldfuss was illustrated by the drawing including the skeletal elements (brachials, radial plates and articulations) which were extracted from the sample BA-05 within the scope of this study (Fig. 2.9). This drawing differs from the previous reconstruction of the structure of *Saccocoma tenella* Goldfuss (Brodacki, 2006) by the addition of the distal brachials to the specific layout.

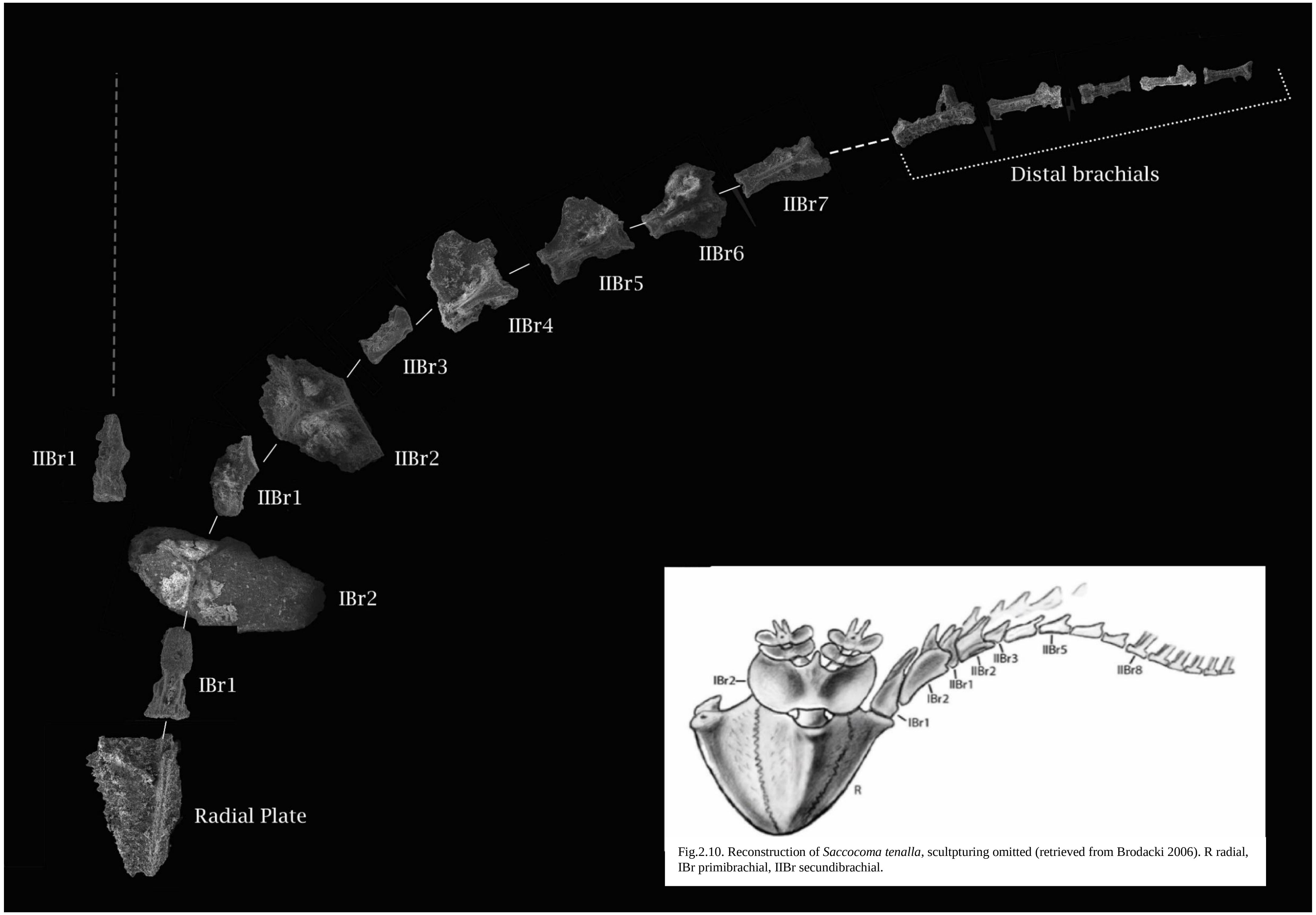


Fig.2.10. Reconstruction of *Saccocoma tenalla*, scultpturing omitted (retrieved from Brodacki 2006). R radial, IBr primibrachial, IIBr secundibrachial.

Figure 2.9. Reconstruction of Saccocoma tenella Goldfuss by using of the extracted brachials, wings and radial plates from the sample BA-05 of this study.

CHAPTER 3

THE JURASSIC-CRETACEOUS BOUNDARY

3.1. The Upper Jurassic-Lower Cretaceous Chronostratigraphy

The chalk sequences in the Swiss French Jura mountains are known as the best places for investigation of the Jurassic aged depositions. The faunal assemblage and the “Laws” of superposition of the Jurassic System were initially studied by William Smith. Then, the term “Terrains Jurassiques”, which also covers the Liassic aged rocks, was first used by Alexander Brongniart (1829) in France. The three-fold segmentation as the lower, middle and upper parts of the Jurassic system was introduced by Leopold von Buch; however, these intervals were named as the Liassic (Black Jurassic), Dogger (Brown Jurassic) and Malm (White Jurassic) by Quenstadt and Albert Oppel. Moreover, the subdivisions of the period into 10 stages in terms of geographical locations of type sections and the results obtained from the previous works was carried out by Alcide d’Orbigny. Only seven of them are still used but they do not retain their initial meaning. In addition to that, Oppel (1856-1858) rearranged the subdivision of d’Orbigny and formed the biostratigraphic zones of the Jurassic in terms of ammonite zones in marginal-marine sections. On the other hand, the chalk sequences were also fundamental unit for the describing of the Cretaceous System as in used by the study of J.J. de Halloy (1822). Actually, it can be deduced from the term “Cretaceous” such that this term is originated from the Latin word “Kreta” (chalk) due to the dominance of chalk deposition within the marine environment during this time interval. Within the scope of the Jurassic-Cretaceous boundary, the base of the Upper Tithonian substage is assumed as a major turnover in ammonite assemblage which corresponds to the first occurrence and diversification of calpionellids in pelagic limestones. This substage was named as Tithonian by Oppel (1865) due to the mythological meaning (Tithon) as the spouse of Eos, the goddess of dawn. Oppel (1865) used this term with poetic trope as in the dawn of the Cretaceous (Gradstein et al., 2012). The lowermost substage of Cretaceous (Berriasian), on the other hand, was defined by Coquard (1871). The term comes from the stratotype located near the village Berrias Ardeche, the southeast France.

At the beginning of the Jurassic-Cretaceous boundary history, Brongniarts (1829) created the Portlandian and the Purbeckian stages before Wimbledon (2007) described the non-marine Purbeck as a "brick wall" in terms of correlation studies. D'Orbigny and Oppel used *Ammonites giganteus* Sowerby in order to define the end of Jurassic. In 1939, Mazenot defined the base of Berriasian by the zone starting with *Berriasella grandis* which later was accepted and applied by Lyon (1963) and Lyon/Neuchatel (1973). Therefore, the *Pseudosubplanites grandis* and *Berriasella jacobi* subzones have been described as markers of the beginning of Cretaceous. Actually, in the Colloque sur la limite Jurassique-Crétacé (1975), the base of the Berriasian has been determined at the base of *Berriasella jacobi* subzone. This decision changed the previous position of the boundary definition as the base of *Pseudosubplanites grandis* (Wimbledon et al., 2011). Therefore, it can be said that the initial Jurassic-Cretaceous boundary interval studies were mostly concentrated on the ammonite biostratigraphy. Still, the *jacobi/grandis* zone are predominantly used to define the base of the Cretaceous age (Hoedemaeker, 1982; Wimbledon et al., 2011). The Tithonian-Berriasian boundary was first assumed as existing within the interval between nannoplankton *Conusphaera mexicana* (Tithonian) and *Nannoconus colomii* Zones (Berriasian) (Ondrejičková et al., 1993). Then, this boundary interval was interpreted as the interval between the first occurrance of *Nannoconus wintereri* and the first occurrance of *Nannoconus steinmanni minor* (Bralower et al., 1989; Michalik et al., 2009). Moreover, the detailed taxonomy of *Nannoconus* species of the Tithonian-Aptian age was studied in terms of the stratigraphic ranges, morphometric measurements, the problematic zonal boundaries of the nannofossil zonation in the studied Yosunlukbayırı and the Soğukçam Limestone formations (Özkan, 1993; Özkan-Altıner, 1996). Furthermore, Michalik et al. (2009) correlated the dominance of nannoconids with the occurance of small globular calpionellid species in the Late Tithonian-Early Berriasian time interval. On the other hand; the radiolarian biozonation was introduced by Pressagno (1977a, b), Baumgartner et al. (1980), Kocher (1981) and Schaaf (1985). Among these studies, Baumgartner (1984, 1987) took a part in the determination of the Jurassic-Cretaceous boundary owing to the biozonation study in the Tethyan region which was identified by nine zones from the Middle Jurassic to the Lower Cretaceous time interval based upon the unitary associations. According to the study, the unitary association (U.A.11), which is also called as Zone D, was assigned to a stratigraphic interval between the uppermost Tithonian and the Upper Berriasian (Baumgartner, 1984, 1987; Ondrejičková et al., 1993). The another fossil assamblage that can be correlated with the calpionellid bioevents and sea level fluctuations is the calcareous dinoflagellates. They were also used in the Jurassic-Cretaceous boundary interval studies. The calcareous dinocyst zaonation was first introduced by Nowak (1968) and it was enhanced reaching up to the Valanginian dinocyst interval zones by many authors including Borza & Michalik (1986), Řehánek & Heliasz (1993), Řehánek & Cecca (1993), Lakova et al. (1999) etc. The current detailed biostratigraphical study as the vertical distribution of the calcareous dinoflagellates in the Late Oxfordian-Late Albian and the direct correlation of these with the calpionellid and the ammonite zonations was carried out by Reháková (2000). The Jurassic-Cretaceous boundary was represented as the first occurrence of the *Stomiosphaerina proxima* Řehánek by Řehánek (1992) and Reháková (2000) also accepted the *proxima* Zone of the Late Tithonian as the Tithonian-Berriasian boundary.

Unfortunately, the delineation of the Jurassic-Cretaceous boundary is quite problematic in contrast to all these historical narrative. The distinct faunal and floral endemism, the debates about the intrinsic nature of the Berriasian faunas, the biogeographic provincialism resulting from the definition of this boundary as the

Purbeckian regression, the lack of mostly accepted fossil biozones and the accurate nomenclature were introduced as the problems of determination and correlation of the Jurassic-Cretaceous boundary by J. Remane (1991). Thanks to the widespread identification of calpionellids in the Tethyan Realm, especially in the areas characterized by the lack of ammonite assemblages, these hyaline walled calcareous microplanktons were accepted as a marker fossil of the Jurassic-Cretaceous boundary by the overwhelming majority of authors as in today (Wimbledon et al., 2011).

3.2. The Jurassic-Cretaceous Boundary in the Studied Section

This section mainly concentrated on how these calpionellids or the calpionellid biozones can be used as a marker of the Jurassic-Cretaceous boundary interval studies and the determination of exact position of this boundary level in the studied area.

The base of *Calpionella alpina* Subzone (Berriasian Working Group, Wimbledon et al., 2011), an acme of the long-ranging *Calpionella alpina* (Houša et al., 1999) and the “explosion” of small globular hyaline walled *Calpionella alpina* at the beginning of the *Calpionella alpina* Subzone (the base of the *grandis* Zone) were used as indicators of the Jurassic-Cretaceous boundary by the majority of authors who studied the Jurassic and the Cretaceous stages (Remane et al., 1986; Remane, 1991; Borza & Michalik, 1986; Altıner & Özkan, 1991; Bucur, 1992; Lakova, 1994; Adatte et al., 1994; Oloriz et al., 1995; Reháková, 1995; Ivanova, 1996; Reháková & Michalik, 1997; Grün & Blau, 1997; Houša et al., 1999; Andreini et al., 2007; Reháková et al., 2009; Petrova et al., 2012). All these studies used almost the same terminology for explanation of the Jurassic-Cretaceous boundary which were noted as “bloom”, “acme” or “explosion” of *Calpionella alpina*. It can be deduced from these terms that the quantitative analysis on the occurrence of the small, globular *Calpionella alpina* forms within the thin section reaches approximately 80-90%. However; the quantitative methods on this specific calpionellid form were not stated clearly within these studies. Therefore, the main aim of this study is to determine the exact position of the Jurassic-Cretaceous boundary based on the counting method on the quantity of *Calpionella alpina* species observed in thin sections which are estimated as in the stage boundary interval.

For that purpose, the calpionellid biozonations were determined and the possible location interval of the Tithonian-Berriasian boundary was limited in terms of the occurrence of small, globular, hyaline walled *Calpionella alpina* within the studied pelagic limestone block. Initially, the boundary interval was detected between the samples BA-41 and BA-42 within the studied section BA. These two samples were selected according to the first occurrence of *Calpionella alpina* or the transition forms between *Calpionella alpina* and *Crassicollaria* (BA-41) and the dominance of small, spherical *Calpionella alpina* over the other fossil assemblages observed in the thin section (BA-42). In order to determine the exact position of the boundary and to prove the “explosion” of *Calpionella alpina*, the quantitative method was applied to the samples BA-41, BA-42/1, BA-42/3, BA-43/1, BA-43/3 and BA-43/5 by counting of all calpionellid forms and full-spherical axial/oblique sections of calpionellids in these thin sections (Table 3.1).

The sample BA-41 was analyzed by quantitative method which was applied as counting of *Calpionella alpina* forms and other hyaline calpionellid forms including also full-spherical axial/oblique sections of calpionellids. There were totally 439 individuals within the one thin section of BA-41 including 86 well-defined *Calpionella alpina*, 60 *Crassicollaria* (especially *Cr. parvula*) forms and 293 full-spherical or nearly elongated axial/oblique sections of calpionellids. The 19,59% of all these forms were distinguished as *Calpionella alpina*; however, this value may reach up to 86,33% by assuming all the spherical axial/oblique sections belong to *C. alpina*. Under these circumstances, the error margin could be high due to a remarkable amount of *Crassicollaria* (13,67%) in this sample. These axial or oblique sections might be related to *Crassicollaria* species. Because of this reason, the limestone bed represented by the sample BA-42 was studied in more detail with 10-25 cm intervals

(BA-42/1, BA-42/2, BA-42/3, BA-42/4 respectively). The possible boundary levels were determined as BA-42/1 and BA-42/3 due to the discernibility of *Calpionella alpina* within the thin sections. BA-42/2 can be classified as radiolarian-packstone due to the dominance of radiolarian forms and BA-42/4 was picked up from the level closer to the upper calciturbiditic level, so it includes high amount of detrital grains.

The same counting method with BA-41 was applied to BA-42/1 and BA-42/3 separately. Totally 1006 calpionellid longitidunal /oblique sections were counted in the sample BA-42/1 and they were seperated as 476 *Calpionella alpina*, 22 *Tintinnopsella*, 16 *Crassicolalia* and 492 full-spherical sections of hyaline calpionellids. This indicates that 47,32% of all calpionellid individuals were distinguished as *C. alpina* and this value may reach up to 96,22% with assuming all spherical axial/oblique sections as *C. alpina*. However, *Crassicollaria parvula* species were still observed in this sample.

Finally, the calpionellid individuals within the sample BA-42/3 were counted and the results indicated that 543 sections belong to *Calpionella alpina* while 471 full-spherical sections, 9 *Tintinnopsella* and only 5 *Crassicollaria* forms were observed in the same thin section. The total number of calpionellid individuals reached up to 1028. It means that 52,82% of the counted individuals were *Calpionella alpina* while *Crassicollaria* forms were represented by only 0,49% within the thin section. Therefore, the possibility of accepting these full-spherical sections as *Calpionella alpina* is quite high due to the obvious difference in the percentage values between these two calpionellid species. Moreover, the size of these full-spherical forms resembles the diameter of the *C. alpina* lorica as in both axial and oblique sections. Nevertheless, *Calpionella alpina*, *Crassicollaria parvula* and the full-spherical forms in the sample BA-42/3 were measured separately as reflecting variable dimensions on the longitudinal section of the loricas (Fig. 3.1). In some cases, for example, in oblique sections without neck part of lorica, *Crassicollaria parvula* may be confused with *Calpionella alpina* or the full spherical forms may cause an indecision. However, the results of measurements reflect that the maximum dimension of full-spherical section on the lorica of *Crassicollaria parvula* reached up to 30 µm. This value may only correspond to the spherical section at the lower part of *Calpionella alpina* lorica. The dimensions changed in between 26-54 µm on the lorica of *Calpionella alpina*. The size of the lorica of *Tintinnopsella* forms are greater than other calpionellids in this level. So, the dimensions were assumed to be greater in this species. The spherical forms, which were included in the counting on the thin section were also measured as 45-47 µm. Thus, these results corroborate the assumption that these full-spherical forms may be axial/oblique sections of *Calpionella alpina*. Therefore, the percentage of *Calpionella alpina* among the calpionellid assemblage reached almost 92% by adding of these full spherical sections (Table 3.1). Thus, the visibly increased total number of calpionellids and the lack of other fossil assemblages refer to the Jurassic-Cretaceous boundary position in the studied pelagic limestone block derived from the Yosunlukbayırı Formation.

Therefore, this counting method provide a more reliable perspective for the term “explosion” or “bloom” of small, spherical *Calpionella alpina* at the base of Berriasian age (the Jurassic-Cretaceous boundary). This method was applied on about 9 cm^2 area of each relevant thin section and the results were evaluated in themselves. The counting on each thin section was also assumed as constant throughout the level represented by the sample. Under the light of these quantitative data, the exact position of the Jurassic-Cretaceous boundary was positioned in between the sample BA-42/1 and BA-42/3 (about 29 m up from the bottom of the section BA-II).

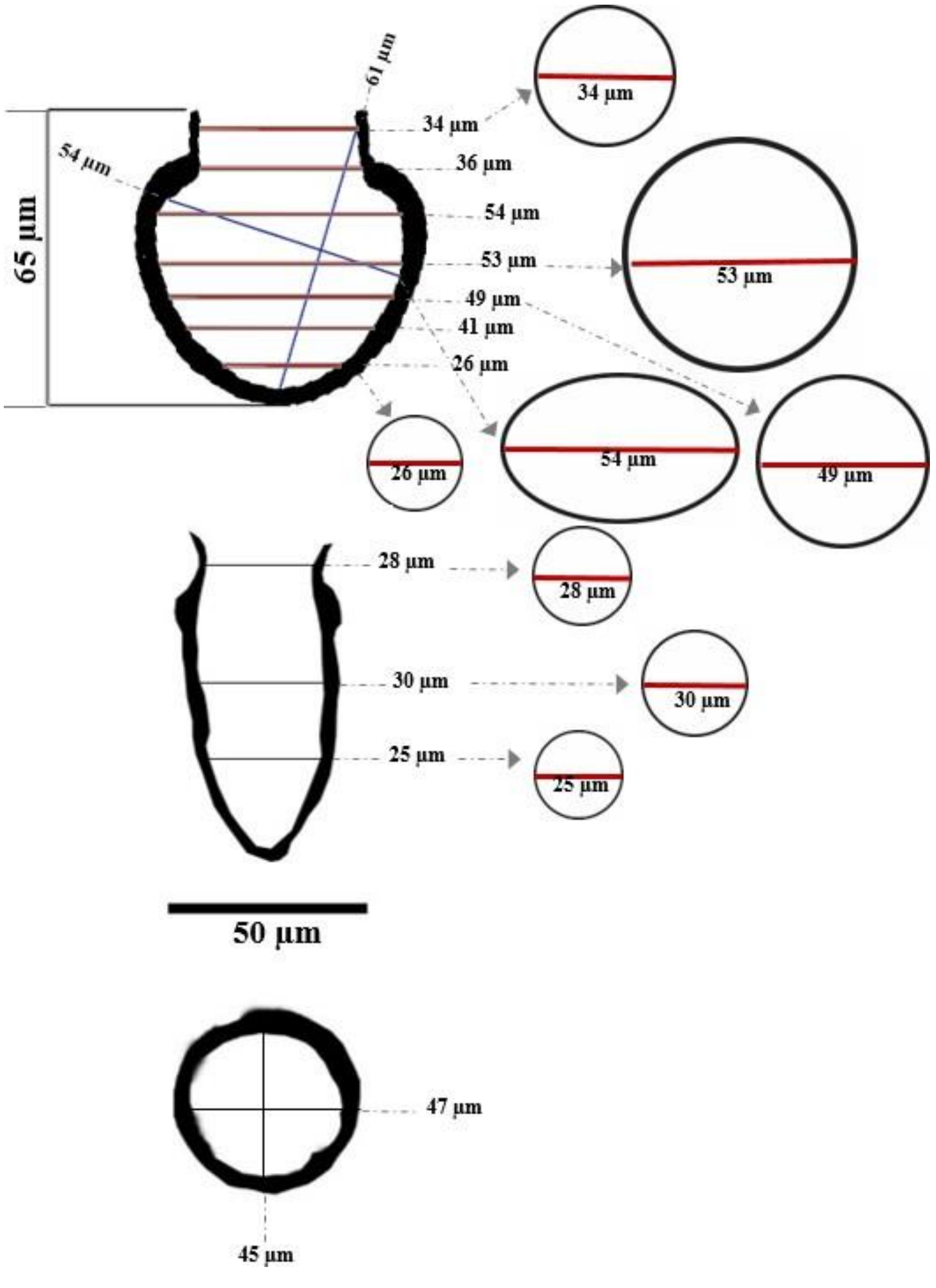


Figure 3.1. Measurements of Calpionella alpina, Crassicollaria parvula and full-spherical section in the sample BA-42/3 representing the Jurassic-Cretaceous boundary level.

Table 3.1. *The quantitative method for the determination of the Jurassic-Cretaceous boundary position at the studied section.*

Sample No	**Examined area in the thin section (cm2)**	**Count of *Calpionella alpina***	**Count of *Crassicollaria***	**Count of full-spherical sections**	**Count of *Tintinnopsella***	**Total count**
BA-43/5	9	511	21	452	11	995
Percentage		**51,36%**	**2,11%**	**45,43%**	**1,10%**	**100%**
BA-43/3	9	447	12	436	4	899
Percentage		**49,72%**	**1,33%**	**48,50%**	**0,44%**	**100%**
BA-43/1	9	221	9	377	7	614
Percentage		**35,99%**	**1,47%**	**61,40%**	**1,14%**	**100%**
BA-42/3	9	543	5	471	9	1028
Percentage		**52,82%**	**0,49%**	**45,82%**	**0,88%**	**100%**
BA-42/1	9	476	16	492	22	1006
Percentage		**47,32%**	**1,59%**	**48,90%**	**2,19%**	**100%**
BA-41	9	86	60	293	0	439
Percentage		**19,59%**	**13,67%**	**66,74%**	**0,00%**	**100%**

Assumptions:

The full spherical axial/oblique section of *Calpionella alpina*: 26 µm – 53 µm

The full spherical axial/oblique section of *Crassicollaria*: 25 µm – 30 µm

Counted full-spherical forms: 45 µm – 47 µm

The Jurassic-Cretaceous boundary was determined as the level represented by the sample BA-42/3 because the counting method indicates both the "explosion" of *Calpionella alpina* and a sudden decrease of the quantity and the diversity of other hyaline walled calpionellids at this level.

CHAPTER 4

MICROFACIES ANALYSES

4.1. Microfacies Types

Microfacies analyses provide crucial clues about the overall history of carbonate rocks such as changes in depositional environment, micro-scale changes in precipitation, the relationship between the depositional patterns and the carbonate sedimentation models etc. These analyses can be accepted as epagoge of the depositional mechanism of the carbonates by using both the sedimentological and paleontological characteristics of the rocks. That is, microfacies types identified in the thin-section analyses help to distinguish the specific depositional environments and the depositional mechanisms. Moreover, the variations in the microfacies types (eg. wackestone, mudstone or packstone) imply both vertical and lateral changes in the depositional environments. The vertical changes may be resulted from regressive or transgressive events based on the relative sea-level changes while the lateral changes may be explained by the changes in water depths, accumulation space and hydrodynamics. Thus, it becomes possible to differentiate local depositional processes and subenvironments within the same lithofacies which resemble each other in the field. For this purpose, the original version of the Dunham classification (Dunham, 1962) and the Folk classification (Folk, 1959, 1962) were used as the limestone classifications based on textural features and the depositional fabrics (Fig. 4.1). The fossil content in thin sections which was studied in terms of taxonomy and biostratigraphy was also evaluated in these analyses. Both classifications include allochthonous limestones (mudstone, wackestone, packstone, grainstone) and autochthonous limestones (boundstone or biolithite). Limestones are grouped as mud-supported or grain-supported and the bioconstruction in these classifications. The Dunham classification (Dunham, 1962) stresses the depositional fabric while the Folk classification (Folk, 1959, 1962) evaluates the hydrodynamic conditions. The dominating groundmass types are considered in both classifications.

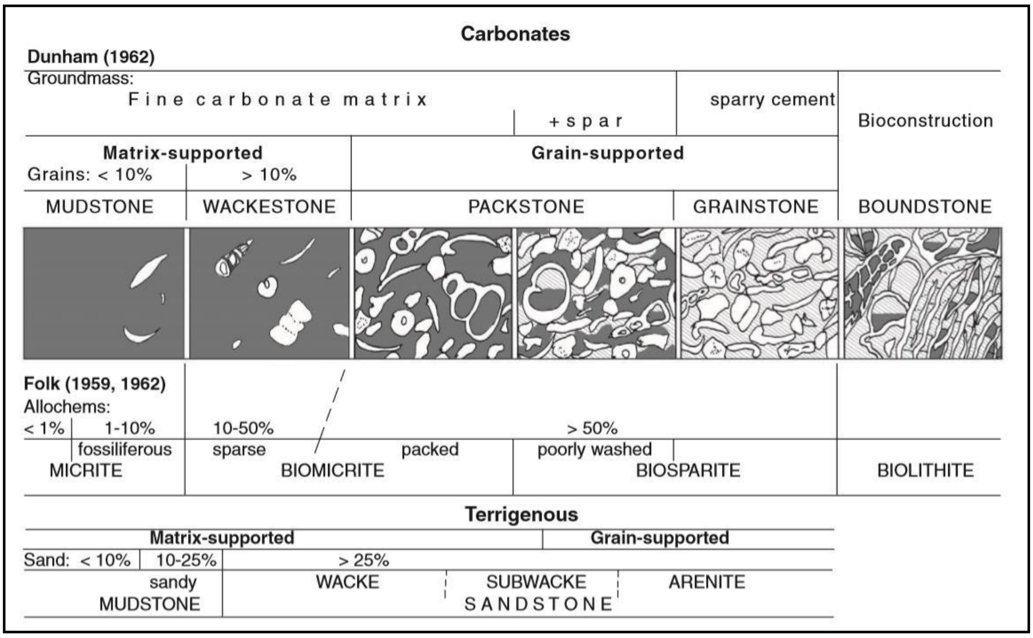


Figure 4.1. Fossiliferous limestone classifications of Dunham (1962) and Folk (1959, 1962).

The Standard Microfacies Types (SMF) concept was needed to understand the similarity in compositional and textural characteristics of the limestone units with different age and analogous depositional environments (Fig. 4.2, Fig. 4.3). Wilson (1975) defined 24 SMF Types in order to differentiate the major facies characteristics of an idealized rimmed carbonate shelf model. The grain types, grain associations, the matrix types, the depositional fabrics, fossil assemblages and the depositional texture types of the rocks were mainly used as description criteria for the Standard Microfacies Types concept. However, this concept may not be adapted to all carbonates. In some instances, there may be discrepancies in microfacies types resulted from the sea-water temperature changes. For example, the microfacies types of cold-water carbonates reflect some differences as the lack of ooids, aggregate grains, the differentiation in skeletal grain mineralogy, texture and weak cementation (Flügel, 2010). So, the initially defined SMF Types (Wilson, 1975) represent the tropical rimmed shelves. The burrowed lime mudstones (deep-shelf margin environments), intraclastic packstones and wackestones in toe-of-slope settings and distally steepened ramp models were not included in this rimmed platform model, they were defined in the Stratigraphic Microfacies Types (Flügel, 2010). The stratigraphic microfacies types depending on the climatic controls, the oceanographic conditions and the evolutionary stages (eg. deep-shelf carbonates in the Jurassic and Late Cretaceous pelagic chalk facies) can be also found in the study of Wilson (1975). Then, the 30 RMF (Ramp Microfacies Types) were established as common microfacies types of the Paleozoic and Mesozoic ramp carbonates from the outer ramp to the carbonate sand shoals and banks (Flügel, 2010).

The microfacies characteristics of the Yosunlukbayırı Formation was designated as thin to medium bedded grey-white argillaceous limestones with fine detrital sediments of volcanic origin, thin to medium bedded calpionellid packstones rich in silt and sand size intraclasts derived from the slope or platform type deposition, radiolarian, belemnite and ammonite-rich thin to medium bedded limestone in wackestone and mudstone facies, limestones with tuffaceous, fine to coarse grained detritals, chert nodules or green tuffaceous material by the study of Altıner et al. (1991) in the Mudurnu-Nallıhan, Beypazarı-Çayırhan areas. The calciturbidites were also identified by silicified packstones with feldspar, quartz, volcanic rock fagments or transported micritic or reefal clasts and some foraminifera (Altıner et al., 1991). Because of the basinal carbonate deposition including abundant calcareous planktons like calpionellids with intercalations of calciturbidites and marls, this formation can be associated with the deep shelf to deep sea or deep water basin of a rimmed carbonate platform model or the outer ramp to basinal depositional environment of the homoclinal ramp model (Flügel, 2010) (Table 4.1).

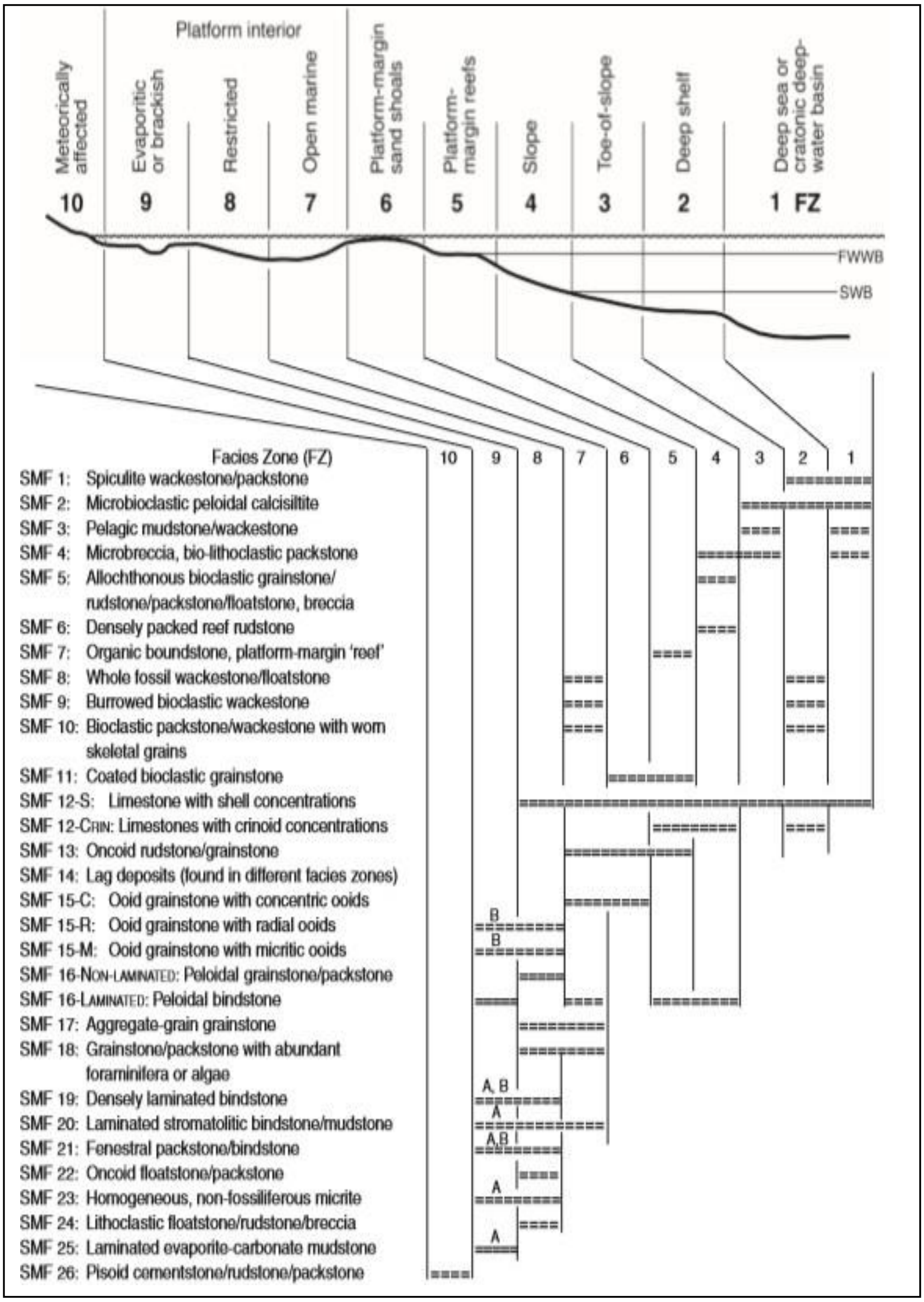


Figure 4.2. Distribution of SMF Types in the Facies Zones (FZ) of the rimmed carbonate platform model; A:evaporitic, B:brackish (Flügel, 2010).

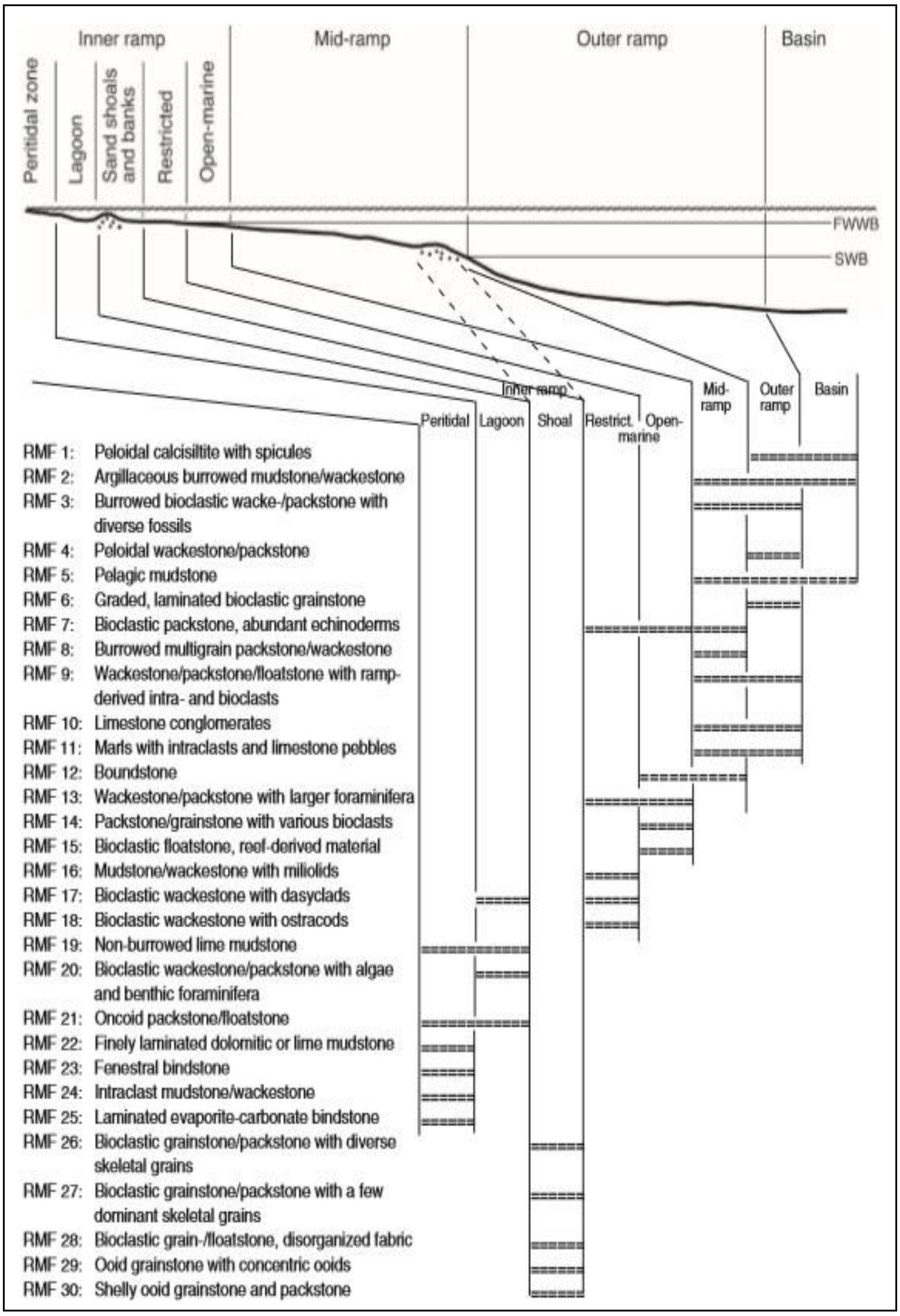


Figure 4.3. Generalized distribution of microfacies types in different parts of a carbonate ramp model (Flügel, 2010).

4.1.1. MF-1: Radiolarian bioclastic wackestone-packstone

The microfacies MF-1 is characterized by marly or argillaceous limestone (wackestone/packstone) with abundant calcified radiolaria, chitinoidellids and rare calpionellids (BA-14), calcified sponge spicules, calcareous algae, *Globochaete alpina*, *Saccocoma* fragments, aptychi fragments, *Spirillina* sp., planktonic foraminifera and rare undefined small planktonic/benthic foraminifera bioclasts within the micritic matrix. The amount of the bioclasts and peloids increase in packstones. This microfacies types are identified in the samples BA-01, BA-02, BA-06, BA-07, BA-14 (Fig. 4.4).

The samples represent the lower part of the Yosunlukbayırı Formation (Altıner et al., 1991) with basinal deep-water environment or deep shelf environment characteristics (Flügel, 2010) based on the textural classification and the fossil assemblages. Within the scope of the Standard Microfacies Types (SMF Types), they match up to the SMF1 and SMF2 representing FZ1 (basinal carbonates), FZ2 (open sea shelf) and also outer ramp in a homoclinal carbonate ramp model (Burchette & Wright, 1992). On the other hand, fine-bioclastic wackestone with sponge spicule of the Late Jurassic in Tabas area/Iran (Fürsich et al., 2003), the pelagic carbonates deposited in deep-marine basins of Late Jurassic Oberalm Formation (Broová et al., 2015), the red-nodular microbioclastic wackestone of the transitional facies between deeper Scheibelberg Limestone and the Adnet Limestones in Northern Calcareous Alps (Bernoulli, 1972; Bernoulli & Jenkyns, 1974), the biomicrites (wackestone to packstone) with abundant *Saccocoma*, *Stomiosphaera moluccana*, *Globochaete alpina*, *Cadosina* sp. and Nodosariidae of the Vigla Formation (Skourtsis & Solakius, 1999), the wackestones with *Saccocoma* and resedimented shallow water debris/fine grained packstones with foraminifera of the Plassen Formation (Gawlick & Schlagintweit, 2006), the peloidal packstone with *Saccocoma*, radiolarian, calpionellids, *Globochaete*, *Cadosina*, *Lenticulina* of the Rosso Ammonitico Unit of the Trapanese Domain (Andreini et al., 2007), the wackestones to packstones of the *Saccocoma* /*Globochaete* microfacies of the Rogoźa Coquina Member (Reháková & Wierzbowski, 2005), the peloidal wackestones with Radiolaria of the Slivnitsa Formation (Ivanova et al., 2008), MF4 with wackestones comprising fine bioclasts and microfossils of the Rosomac Section (Petrova et al., 2012) may be accepted as almost similar microfacies types with the Microfacies 1 of this study in terms of the basinal or the lower slope depositional settings.

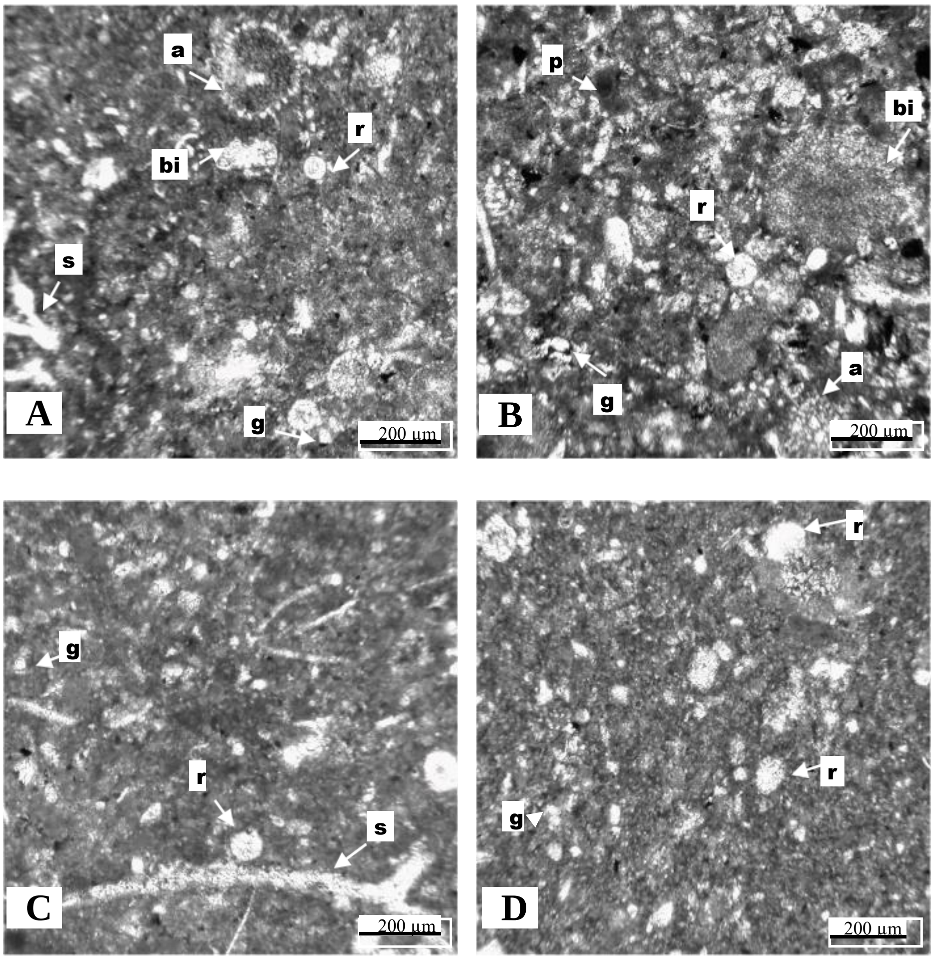


Figure 4.4. MF1: Radiolarian bioclastic wackestone-packstone (4x); A)BA-01, B)BA-02, C)BA-07, D)BA-14; s:Saccocoma, r:radiolarian, a:algae, bi:bioclast, p:peloid, g:Globochaete

4.1.2. MF 2: Radiolarian wackestone to packstone

Especially the lower parts and some intervals in the upper parts of the studied Upper Jurassic-Lower Cretaceous pelagic limestone block were mainly composed of radiolarian dominated wackestones or packstones with rare calpionellids. They can be also called as Radiolarian biomicrites (Folk, 1959, 1962). The microfacies type was distinguished by predominance of the Radiolaria together with calcareous dinocysts, *Globochaete alpina*, sponge spicules, *Saccocoma*, some small benthic foraminifera, echinid spines, bryozoan, aptychi fragments and calcareous algae. The increase in the abundance of Radiolaria resulted in a decrease of the occurrence of calpionellids in these samples. The background where these fossil assemblages were deposited is characterized by micrite. This microfacies type was detected in the samples BA-08, BA-15, BA-21, BA-22, BA-37 (Fig.4.5).

The textural characteristics and the dominant pelagic fossil assemblages indicate the deep basinal facies (FZ1) and the open deep shelf environment (FZ3) represented as SMF3 (Pelagic lime mudstone and wackestone with planktonic microfossils) and SMF3-RAD (radiolarians) as in more detail based on the Standard Microfacies Types (Flügel, 2010). The similar microfacies types were previously detected in the Yosunlukbayırı Formation (Altıner et al., 1991), the radiolarian wackestones and radiolarian packstones of the Jurassic limestones of the Ammonitico rosso and the Adnet facies (Wilson, 1969; Kiessling, 1996), the radiolarian limestone of the Late Jurassic Oberalm Formation (Boorová et al., 2015), the biomicrites with abundant recrystallized Radiolaria (F3A) in the Puerto Pnonnes Section in the northeastern Mexico (Adatte et al., 1996), the radiolarite in the Gulf of Baja California and the Owen basin (De Wever et al., 1994), the radiolarian wackestone to mudstone of the Penninic units (Rehaková et al., 1996), the radiolarites of limestone-chert alterations of the Vigla Formation (Skourtsis & Solakius, 1999) , the radiolarian event in the sample RSV-106 in the western Cuba (Martinez et al., 2013). These microfacies were also reported as the basinal carbonate deposition.

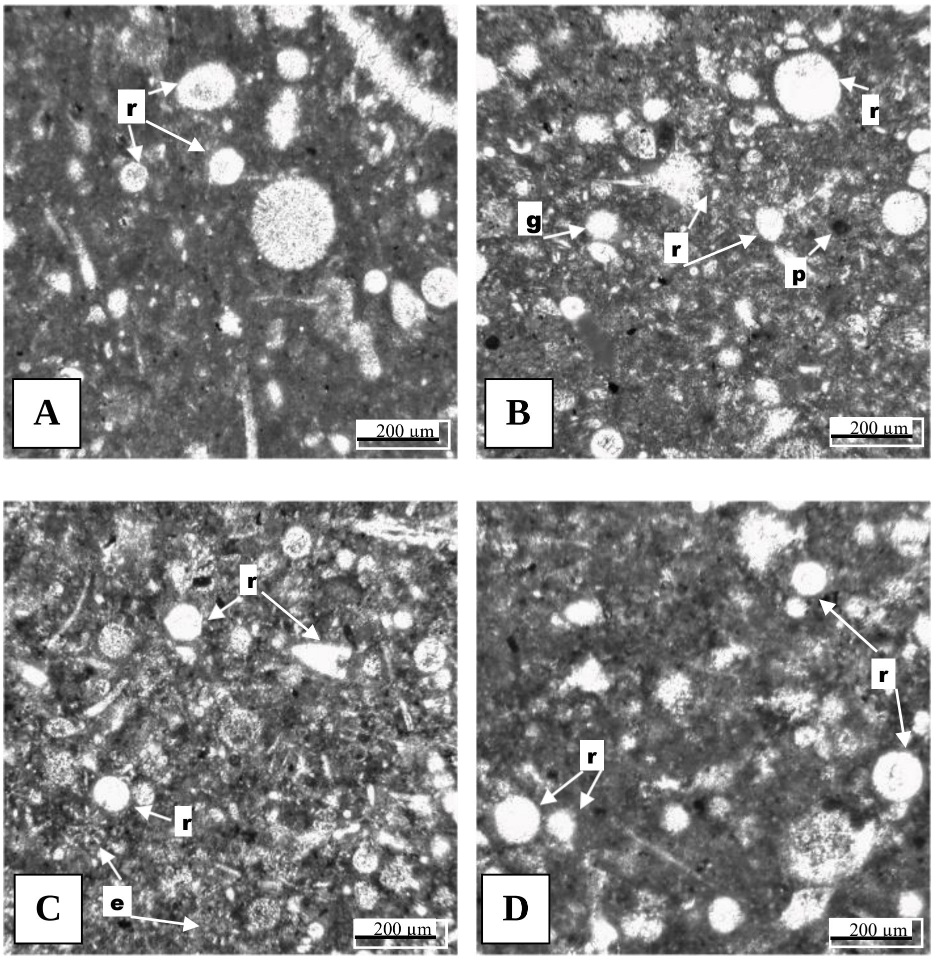


Figure 4.5. MF-2: Radiolarian wackestone to packstone (4x); A)BA-08, B)BA-15, C)BA-22, D)BA-37; r:radiolaria, g:globochaete p:peloid, e:echinid spine

4.1.3. MF 3: Calpionellid-Radiolaria wackestone to pacstone

This microfacies is characterized by the micritic matrix with common to abundant calpionellids and radiolaria together with rare small benthic foraminifera, calcareous dinocysts, *Globochaete alpina*, rare aptychi fragments, echinid spines and pelagic crinoids (*Saccocoma*). The calpionellids and radiolaria terms were used together in the description of this type of microfacies because the occurrence of hyaline walled calpionellids is high. However, they do not dominate the whole fossil assemblages within these levels. The main difference between the MF2 and MF3 is distinguished as an increase in abundance and diversity of the hyaline walled calpionellids. The quantity of the *Saccocoma* elements also decreased in contrast with the lower parts of the succession. These calpionellid and radiolaria dominant microfacies constitute a major part of the studied Jurassic-Cretaceous pelagic limestone succession together with the calpionellid dominated wackestones-packstones (MF4). Moreover, the levels represented by the samples BA-19, BA-24, BA-26, BA-27, BA-30, BA-31, BA-36, BA-38, BA-39, BA-41, BA-43/3, BA-43/6, BA-45/2 were classified under this microfacies type (Fig.4.6).

The textural characteristics and the identified faunal assemblages of these samples indicate the common Mesozoic basinal carbonates (FZ1) and the deep shelf carbonates (FZ2) as well as the outer ramp settings. Within the concept of the Standard Microfacies Types, the MF3 also corresponds to the SMF3 as in the radiolarian wackestone to packstone facies (MF2) (Flügel, 2010). The similar microfacies types of the Jurassic-Cretaceous pelagic limestones were previously identified as the radiolarian-calpionellid microfacies of the Hrušové Section, Western Carpathians (Ondrejičková et al., 1993), the biomicrites (mainly wackestones, rarely packstones) with specimens of *Saccocoma* and a few calpionellids of the Vigla Formation (Skourtsis & Solakius, 1999), the radiolarian-spiculitic-calpionellid microfacies of the Oberalm Formation in the Salzburg area of the Northern Calcareous Alps (Boorova et al., 2015), the biomicrite with equally abundant calpionellids and radiolarians (F4) of the Puerto Pinones Section in the northeastern Mexico (Adette et al., 1996), the microfossiliferous wackestone containing pelagic components into micritic matrix (MF2) in the Stara Planina-Poreč Zone (Petrova et al., 2012), the microfacies of the *elliptica* Subzone mudstone / wackestone of calpionellids, radiolarians and resedimented material of the Sierra de los Órganos in the western Cuba (Martínez et al., 2013).

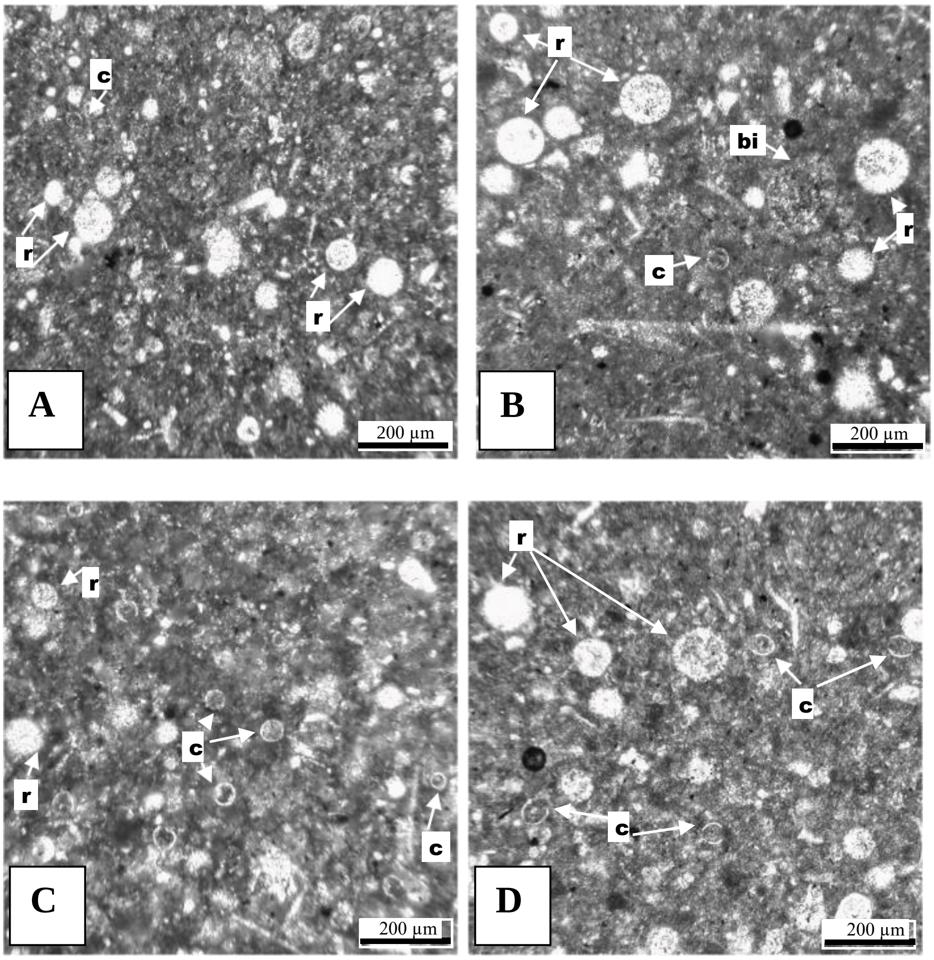


Figure 4.6. MF-3: Calpionellid-Radiolaria wackestone to packstone (4x); A)BA-36, B)BA-39, C)BA-41, D)BA-45/2; c:calpionellid, r:radiolaria, bi:bioclast

4.1.4. MF-4: Calpionellid packstone / Calpionellid biomicrites

Calpionellids dominate the faunal assemblages of the Upper Jurassic- Lower Cretaceous pelagic limestones deposited in the basinal settings and the deep marine environments**.** The calpionellid-rich microfacies with *Globochaete alpina*, calcareous dinocystst, less amount of radiolaria, *Saccocoma*, echinid spines, calcareous algae, aptychi fragments, rare small benthic foraminifera were termed as Calpionellid packstone / Calpionellid biomicrites within the scope of this study. The pelagic fossil assemblages and other grains are preserved in a micritic matrix. The quantity of radiolaria decreases within these levels in contrast with the abundance and diversity of hyaline walled calpionellids. The calpionellid biomicrites were represented by the samples BA-23, BA-28, BA-32, BA-42/1, BA-42/3, BA-43/7, BA-43/8, BA-43/9, BA-47, BA-48, BA-49, BA-50, BA-51, BA-52, BA-53, BA-55 respectively (Fig.4.7). The calpionellid-rich microfacies indicates the open pelagic environments in a global sea-level rise (Haq et al., 1988).

This microfacies type constitutes a major part of the studied section together with the calpionellid-radiolarian wackestone to packstone (MF3) and the recognition of this microfacies as dominant unit within the studied succession strengthens the idea that the depositional environment was the open pelagic deep-water basin (FZ1). The microfacies (MF4) equals to the SMF3 (calpionellid wackestone) of the Standard Microfacies Types (Flügel, 2010). This microfacies may be correlated with the similar microfacies types previously identified as the *crassicollaria-calpionella* microfacies of the Hrušové Section in the Western Carpathians (Ondrejíčková et al., 1993), the biomicrite with abundant calpionellids (F1 and F2) of the La Casita Formation in the northeastern Mexico (Adatte et al., 1996), the Majolica types micrites (Calpionellid, calpionellid-radiolarian wackestone) of the Gresten Zone of the Penninic units in the Northern Calcareous Alps, Austria (Reháková et al., 1996), the calpionellid biomicrites of the Vigla Formation (Skourtsis & Solakius, 1999), the wackestone and mudstone with abundant calpionellids, foraminifers (textulariids, valvulinids) and rare radiolarians, echinoid fragments of the Diesi sections in the Western Sicily (Andreini et al., 2007), the microfossiliferous wackestone (MF2) of the Rosomač Section (Petrova et al., 2012). These microfacies types were also reported as the facies o the deep-water basinal settings.

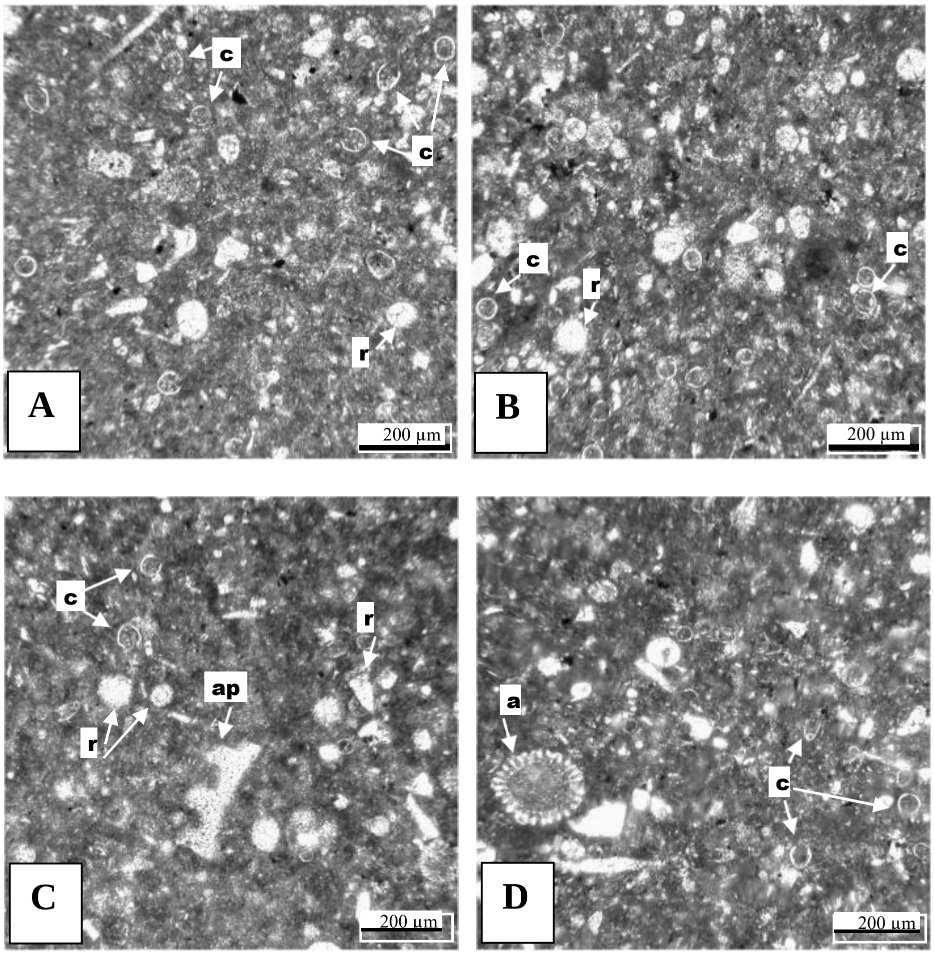


Figure 4.7. MF-4: Calpionellid packstone / Calpionellid biomicrites (4x); A)BA-42/3, B)BA-50, C)BA-52, D)BA-55, a:algae, c:calpionellids, ap:aptychi fragment, r:radiolarian

4.1.5. MF-5: *Saccocoma* packstone

The pelagic microcrinoid (*Saccocoma*) fragments were observed almost all thin sections belonging to the lower and the middle parts of the studied section; however, they were distinguished in small quantities together with calpionellids, radiolarians or other small benthic foraminifera, except the sample BA-05 located at the lower part of the studied succession. The level represented by the sample BA-05 was defined as the “*Saccocoma* level” due to the rock forming quantity of *Saccocoma* and its dominance over radiolaria, calcareous dinocysts, *Globochaete alpina*, chitinoidellids, calcareous algae, echinid spines and other platform derived bioclasts and lithoclasts (Fig.4.8). The background material was micrite. Therefore, the sample was quite sufficient for the extraction of the skeletal elements (brachial, wing-like structure and radial) for detailed taxonomical analyses of the *Saccocoma* species. There was only one sample representing this level and this microfacies type of the studied section. The abundance of *Saccocoma* changed dramatically towards the upper and the lower levels.

According to the textural characteristic and the fossil assemblage, this microfacies type may indicate the Upper Jurassic basin (FZ1), the open-marine shelf (FZ2) or the deep-shelf toe of slope (FZ3) environments depeding on the amount of lithoclasts and bioclasts. The dense crinoid concentrations in limestones (crinoid packstones) were also classified as autochthonous (the open sea shelf-FZ2; the foreslope-FZ4; the mounds-FZ5) and allochthonous (deep shelf margin-FZ3; foreslope-FZ4) in detail (Flügel, 2010). Furthermore, the similar microfacies types were previously identified as the *Saccocoma* wackestone and the *Saccocoma-Globochaete* wackestone of the deep basinal deposits of the Oberalm Formation (Flügel & Fenninger, 1966; Reháková et al., 1996), the biomicrites with specimens of *Saccocoma* in the Vigla Limestone Formation in the western Greece (Skourtsis & Solakius, 1999), the peloidal wackestones and packstones enriched in *Saccocoma*, radiolarians, *Globochaete* of the Rosso Ammonitico Unit in the western Sicily (Andreini et al., 2007), the *Saccocoma* packstone of the Czorsztyn Unit in the West-Carpathian (Reháková, 2000), the wackestone and packstone with abundant *Saccocoma* and echinoid fragments (Calcarenitic / Calcisiltitic limestone of the Upper Kimmeridgian – Lower Tithonian interval) in the Contrada Diesi section in the southwestern Sicily (Marino et al., 2004), the *Saccocoma* wackestones with abundant *Saccocoma* and less amount of calcified radiolarians, sponge spicules and calcareous dinocysts (MF3) of the Gintsi Formation and the Pokrovenik Limestones indicating the deep-water carbonates (Petrova et al., 2012) etc. All these microfacies types were also assigned to the deep-water basinal environments.

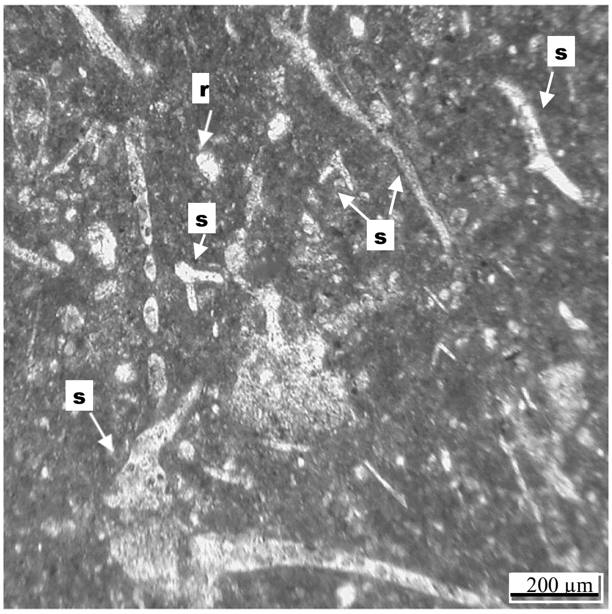


Figure 4.8. MF-5: Saccocoma packstone; BA-05, s:Saccocoma, r:radiolaria

The microfacies of the Yosunlukbayırı Formation was previously studied by Mekik (1994) and she distinguished calpionellid biomicrites with sometimes increasing amount of quartz, feldspar, calcite and micas of detrital origin, radiolarian biomicrites with rare calpionellids, biomicrites with abundant ammonites together with *Globuligerina oxfordiana* and *Globochaete alpina*, and also calcarenite-calcilutite turbiditic facies (Stow, 1985) with pellets, miliolid foraminifera and detrital clasts. Moreover, the microfacies peloidal, bioclastic packstone/bioclastic packstone, bioclastic mudstone, bioclastic/calpionellid/radiolarian wackestone-packstone and bioclastic, lithoclastic, peloidal/lithoclastic, peloidal packstone were asserted as the toe of slope deposition of the Yosunlukbayırı Formation by Atasoy (2017).

4.2. Depositional Environments

The Yosunlukbayırı Formation is defined as a deposition within the open-marine slope to basin environment due to the pelagic limestones with abundant calpionellids and ammonites. In this study, it is described as the basinal deposition close to the slope of carbonate platform (Table 4.1). The unit is distinguished by the intercalations of calciturbidites and breccioid levels with the calpionellid packstones. The presence of calciturbidites and breccioid levels containing calpionellids, slumps, slides and mesoscopic growth faults indicate that the Yosunlukbayırı Formation was formed under a tectonically unstable environment of Tithonian-Berriasian time interval. The Yosunlukbayırı Formation represents more distal characteristics within the marine depositional environment such as the pelagic carbonates with planktonic foraminifera, Radiolaria, ammonites, aptychi fragments, ostracods, free-swimming crinoids; however, it is synchronous with the deposition of carbonate platform as the Günören Limestone in the Bursa-Bilecik region. Therefore, the turbiditic levels of the Yosunlukbayırı Formation are fed by the shelf- or platform-type carbonates during the deposition. The thickness of calciturbiditic levels decreases upwards but these levels are also detected in the upper parts of the studied section. This can be explained by the sea-level fluctuations and changeable amount of the sediment influx towards the basin. Altıner et al. (1991) also noted that transportation and deposition of these detrital materials reached its maximum level in the Middle-Late Tithonian; however, the thickness of calciturbiditic levels decreased in the Late Tithonian times in the Beypazarı-Çayırhan area.

Table 4.1. *The microfacies types of the studied succession.*

Microfacies Types	Definition	Distinctive Feature	Standard Microfacies Types (SMF) (Flügel, 2010)	Facies Zone (FZ) (Flügel, 2010)	Sample No	Depositional Environment
MF1	Radiolarian bioclastic wackestone-packstone	Abundant calcified radiolaria, chitinoidellids and rare calpionellids (BA-14), calcified sponge spicules, calcareous algae, *Globochaete alpina* , *Saccocoma* , aptychi fragments, *Spirillina* sp., bioclasts within the micritic matrix	SMF1 / SMF2	FZ1 , FZ2	BA-01, BA-02, BA-06, BA-07, BA-14	Basinal carbonates
MF2	Radiolarian wackestone to packstone	The predominance of the Radiolaria together with calcareous dinocysts, *Globochaete alpina* , sponge spicules, *Saccocoma* , some small benthic foraminifera, echinid spines, bryozoan, aptychi fragments and calcareous algae.	SMF3-RAD	FZ1, FZ3	BA-08, BA-15, BA-21, BA-22, BA-37	
MF3	Calpionellid-Radiolaria wackestone to pacstone	Abundant calpionellids and radiolaria together with rare small benthic foraminifera, calcareous dinocysts, Globochaete alpina, rare aptychi fragments, echinid spines and pelagic crinoids (Saccocoma)	SMF3	FZ1	BA-19, BA-24, BA-26, BA-27, BA-30, BA-31, BA-36, BA-38, BA-39, BA-41, BA-43/3, BA-43/6, BA54/2	
MF4	Calpionellid packstone / Calpionellid biomicrites	The predominance of calpionellids, *Globochaete alpina* , calcareous dinocystst, less amount of radiolaria,echinid spines, calcareous algae, aptychi fragments, rare small benthic foraminifera	SMF3	FZ1	BA-23, BA-28, BA-32, BA-42/1, BA-42/3, BA-43/7, BA-43/8, BA-43/9, BA-47, BA-48, BA-49, BA-50, BA-51, BA-52, BA-53, BA-55	
MF5	*Saccocoma* packstone	The rock forming quantity of *Saccocoma* , radiolaria, calcareous dinocysts, *Globochaete alpina* , chitinoidellids, calcareous algae, echinid spines and other platform derived bioclasts	SMF3	FZ1 , FZ2	BA-05	

CHAPTER 5

MICROPALEONTOLOGY

Calpionellids, *Saccocoma*, Radiolaria, *Globochaete alpina*, aptychi, calcareous dinocyst, ammonites and some small benthic foraminifera were identified and their ranges were previously indicated by the range chart (Table 2.2) in the Chapter 2 within the scope of this study. However, the determination of the Jurassic-Cretaceous boundary was completely predicated on the calpionellid species and the calpionellid biozonations. In addition to the calpionellid and the benthic foraminifera taxonomy, *Saccocoma* was studied at the level of species for the first time in Turkey.

5.1. Calpionellids

Calpionellids are unilocular calcareous microplankton that are significant for the exhaustive division, precise dating and reliable correlation of the Middle Tithonian to Valanginian aged pelagic carbonates of the Tethyan Realm. Their predominance over the other organisms within this time interval, the rapid evolutionary development steps reflected by distinct bioevents such as the first and last occurences, the high abundance as “acme”, abrupt increases in the relative abundances and their wide geographical distiribution ensure that calpionellids are used as an index fossil of the Jurassic-Cretaceous boundary interval. Below the Aragonite Compensation Depth (ACD), calpionellids are prominent fossil group used in the biochronologic zonation studies of the Jurassic-Cretaceous time interval because these levels are characterized by the lack of ammonites (Grün & Blau, 1997). Nevertheless, the separate correlations by calpionellid’s and ammonite’s zonations almost give the same results for this time interval.

5.1.1. The Evolutionary History

The phylogenetic history of calpionellids was assumed as starting with the sudden appearance of calpionellids with microgranular lorica in the Middle Tithonian (Reháková & Michalik, 1997). Initially, some microfossils of Palaeozoic and Triassic were also assumed as ancestors of calpionellids by Visscher (1970, 1971), Colom (1988) and Eshet (1990). *Chitinoidella dobeni* and *Chitinoidella colomi* Borza (1966) were assumed as ancestors of the hyaline walled *Crassicollaria* species which are characterized by their more or less pronounced swellings below the collars. However, the true calpionellid ancestors are still unknown. Pruner et al. (2009) correlated the first occurrence of chitinoidellids (Middle Tithonian) with the upper *Admirandum* / *Biruncinatum* Ammonite Zone while Benzaggagh et al. (2010) reported as the upper part of the *Ponti* / *Burkhardticeras* Zone (the uppermost Middle Tithonian). The phylogeny of the calpionellids are designated according to the morphology and the differentiation of the wall composition of lorica and collars. Two lineages derived from *Chitinoidella slovenica* were asserted by Borza (1969). The first of them was characterised as the lorica of *Tintinnopsella* species with caudal appendage. This lineage was derived from *Chitinoidella slovenica* and continued as *Chitinoidella boneti*, the double walled *Praetintinnopsella andrusovi* (as a transition form between microgranular chitinoidellids and hyaline calpionellids), *Tintinnopsella remanei*, *Tintinnopsella doliphormis*, *Tintinnopsella carpathica* respectively and it finally reached to deflandronellas and parachitinoidellas in Aptian (Trejo,1972). The second of them evolved into *Calpionella* and *Lorenziella* Knauer & Nagy (1963) species and continued as the Late Aptian *Praecolomiella* towards the hyaline walled Early Albian aged *Colomiella* Bonet (1956). In this context, the first occurrence of the chitinoidellids could not be found in the studied section because the occurrence of calpionellids started with *Chitinoidella boneti* representing the *boneti* Subzone in the Upper Tithonian. However, the phylogenetic steps in calpionellids were put in order as *Chitinoidella* species, *Praetintinnopsella*, *Crassicollaria* species, *Calpionella* species and *Remaniella* respectively.

Lorenz (1902) first identified *Calpionella alpina* as a stratigraphic marker belonging to the foraminifera in the “klippes” of Switzerland. The first description of the calpionellid species was carried out by Cadisch (1932). He named *Calpionella oblonga* for the first time. Then, Colom (1934) described *Calpionella dareri* unlike the previous forms; however, he placed calpionellids into the family Tintinnidae. In 1948, *Crassicollaria massutiniana* was termed as *Calpionella massutiniana* by Colom. The genera *Calpionellites* and *Calpionellopsis* and the genus *Tintinnopsella* were also described by Colom (1948) for the first time. Furthermore, Remane (1962) established the genus *Crassicollaria*; however, he used *Crassicollaria brevis* as the genotype as opposed to Colom (1948). Besides *Crassicollaria brevis,* Remane (1962) brought two new species namely *Crassicollaria parvula* and *Crassicollaria colomi* belonging to the genus *Crassicollaria*. Then, *Crassicollaria colomi,* which was previously defined by Remane (1962), was renamed as *Crassicollaria intermedia* in the study of Doben (1963).

5.1.2. Morphological Features

Calpionellids have the cup-shaped hard part which is also called as lorica. The lorica of calpionellids is composed of the calcite crystals bringing the lorica to microgranular or hyaline characteristics. Calpionellids can be classified by using the differentiations in lorica and collar structures. The microgranular walled chitinoidellids and the hyaline walled calpionellids can be differentiated by colors of the lorica seen under the microscope in the thin section analyses. Chitinoidellids are seen as black colored while the hyaline calpionellids are seen as white. The overall shape of the lorica is used for the determination of the genus while the characteristics of the collars are required for the species specifications. The shape of the lorica changes as ovoid, bell-shaped, spherical, cylindrical or elongated with respect to the genera and the species. For example, within the Early Berriasian *Calpionella* Zone, the initial fully spherical *Calpionella alpina* evolves into the larger and elongated forms of *Calpionella elliptica.* In some forms like the *Tintinnopsella* species, there is a caudal appendage at the bottom of lorica. However, this caudal appendage can not be observed in the *Calpionella* species. Moreover, the bell-shaped *Tintinnopsella carpathica* with distinct caudal appendage evolves into longer and more cylindrical *Tintinnopsella longa* with shortened caudal appendage in Berriasian. The upper part of the lorica is characterized by collars indicating the opening of the hard part. The shape of the collars (cylindrical, funnel-like, bipartite, tripartite) is another crucial morphological feature for the identification of the genus and the species. The genus *Remaniella* is mostly differentiated from the genus *Calpionella* by the bipartite collars within the Standard *Calpionella* Zone in the Early Berriasian. The shoulder occurring between the lorica and the collars is also used as a distinctive feature for *Crassicollaria* species. Furthermore, *Crassicollaria massutiniana* can be mostly distinguished by the swelling structure below the collars on the lorica.

5.1.3. Systematic Paleontology

FAMILY CHITINOIDINELLIDAE Trejo, 1975

Genus *Chitinoidella* Doben, 1963

Chitinoidella boneti Doben, 1963

Pl. 1, Figs. f, i, j, m, n, o, w, x, dd, ee.

1963 *Chitinoidella boneti* n. sp. – Doben, Pl. 6, Figs. 1-5.

1988 *Chitinoidina boneti* Doben – Colom, Fig. 12.1-2.

1991 *Chitinoidina boneti* Doben – Altıner & Özkan, Pl. 3, Figs. 1-2.

1997 *Chitinoidella boneti* Doben – Grün & Blau, Pl. 1, Figs. 1-5.

1999 *Chitinoidella boneti* Doben – Lakova et al., Pl. 1, Fig. 2.

2002 *Chitinoidella boneti* Doben – Reháková, Pl. 2, Figs. 1-4.

2007 *Chitinoidella boneti* Doben – Andreini et al., Pl. 1, Figs. 3-5.

2011 *Chitinoidella boneti* Doben – Reháková et al., Pl. 8, Fig. 1.

2012 *Chitinoidella boneti* Doben – Petrova et al., Fig. 4.14-15.

2013 *Chitinoidella boneti* Doben – Lakova & Petrova, Pl. 1, Figs. 17-18, Pl. 5, Figs. 21-23.

2017 *Chitinoidella boneti* Doben – Petrova et al., Fig. 3.22-24.

Description:

The ovoid to subcylindrical / cylindrical lorica includes a caudal appendage on the aboral side and a large opening surrounded by the collar at the top and the preoral constriction. The lorica is the microgranular calcitic with black color under the light microscope. A length / width ratio is smaller than 1.5. The length dimensions change in between 55-83 µm while the width is measured as 40-50 µm in general. In this study, this species was distinguished by its microgranular lorica, subcylindrical shape with a caudal appendage and divergent collars at the large oral opening.

Remarks:

The species was quite scarce, bad-preserved and difficult to attain in thin sections. However, they were identified by the large opening surrounded by divergent collar and microgranular wall of the lorica.

Occurrence:

The range of this species was defined as the Middle- Late Tithonian (Altıner & Özkan, 1991). These microgranular walled calpionellids with divergent collars were identified in the samples between BA-01 and BA-20. The base of the *boneti* Subzone was defined by the first occurrence (FO) of *Chitinoidella boneti* (Reháková, 2002). Moreover, the appearance of this *Chitinoidella* species directly indicates the base of the *boneti* Subzone in the Middle Tithonian and the range reaches up to the *massutiniana* Subzone in the Late Tithonian.

Chitinoidella elongata Pop, 1997

Pl. 1, Figs. h, s, t.

1969 *Chitinoidella boneti* Doben – Borza, Pl. IXVIII, Fig. 8.

1997 *Chitinoidella elongata* n. sp. – Pop, Fig. 2.3-4.

2002 *Chitinoidella elongata* Pop – Reháková, Fig. 2.5-8.

Description:

The microgranular lorica is characterized by the cylindrical shape with a caudal appendage at the aboral side. The lorica includes outwardly deflected collars at the oral opening. The shape of the lorica resembles the *Chitinoidella boneti*. However, they can be differentiated from each other by the size of the lorica. It changes between 84-105 µm in length and 44-45 µm in width for *Chitinoidella elongata*.

Remarks:

The species was also scarce, bad-preserved and the identification of this species was quite difficult in the micritic matrix. This species was differentiated from

Chitinoidella boneti by the longer length as two times more than *Chitinoidella boneti*.

Occurrence:

It was recognized in the samples BA-02 and BA-07 reflecting the *boneti* Subzone in the Late Tithonian.

Genus *Daciella* Pop, 1998

Daciella danubica Pop, 1998

Pl. 1, Figs. a, b.

1969 *Chitinoidella* sp. – Borza, Pl. IXIX, Fig. 4.

1998 *Daciella danubica* n. sp. – Pop, Fig. 2.14-18.

2002 *Daciella danubica* Pop – Reháková, Fig. 2.17-20.

Description:

The microgranular lorica is small, conical or nearly elongated with a caudal appendage at the aboral side and a swelling below the collars at the oral opening. The collars are short and cylindrical (Reháková, 2002).

Remarks:

The identification of this species was also difficult in the micritic matrix but it was distinguished by the swelling below the collars on the small, conical, microgranular lorica. The size of the lorica was small when it was compared to the other *Chitinoidella* species in the samples of this study.

Occurrence:

It was only recognized in the sample BA-01 with in the *boneti* Subzone representing the Late Tithonian.

Genus *Dobeniella* Pop, 1997

Dobeniella bermudezi (Furrazola-Bermúdez, 1965)

Pl. 1, Figs. z, cc.

1965 *Tintinnopsella bermudezi* n. sp. – Furrazola- Bermúdez, Pl. 1, Figs. 2a-c; Pl. 2, Figs. 6-8; Pl. 3, Fig. 1; Pl. 5, Fig. 2.

1966 *Chitinoidella bermudezi* (Furrazola-Bermúdez) – Borza, Pl. 10, Fig. 11.

1997 *Chitinoidella bermudezi* (Furrazola-Bermúdez) – Grün & Blau, Pl. 1, Fig. 6.

2002 *Dobeniella bermudezi* (Furrazola-Bermúdez) – Reháková, Pl. 3, Figs. 7-9.

2007 *Dobeniella bermudezi* (Furrazola-Bermúdez) – Andreini et al., Pl. 1, Figs. 6a, b; 7a, b.

2012 *Dobeniella bermudezi* (Furrazola-Bermúdez) – Petrova et al., Fig. 4.17.

2013 *Dobeniella bermudezi* (Furrazola-Bermúdez) – Lakova & Petrova, Pl. 1, Figs. 25, 26; Pl. 5, Figs. 27-28.

2017 *Dobeniella bermudezi* (Furrazola-Bermúdez) – Petrova et al., Fig. 4.7-9.

Description:

The bell-shaped, elongated to subcylindrical lorica including a caudal appendage and a composite collar on the large openning shows microgranular wall characteristic. The inner ring of the collars reflects comma- or lens-like form (Pop, 1997). Dimensions are generally recorded as 61-65 µm in length and 40-45 µm in width.

Remarks:

The species was defined as scarce and restricted in the Late Tithonian in the study of Lakova and Petrova (2013). This species was recognized by the thickening of the collars.

Occurrence:

It was identified in the samples BA-11 and BA-16 representing the *boneti* Subzone in the Late Tithonian.

Dobeniella cubensis (Furrazola-Bermúdez, 1965)

Pl. 1, Figs. u, aa, bb.

1965 *Tintinnopsella cubensis* n. sp. – Furrazola-Bermúdez, Pl. 1, Fig. 1a-c; Pl. 2, Figs. 1-5; Pl. 5, Fig. 1.

1966 *Chitinoidella cubensis* (Furrazola-Bermúdez) – Borza, Pl. 10, Fig. 10

1997 *Dobienella bermudezi* (Furrazola-Bermúdez) – Pop, Pl. 2, Figs. 5, 6.

2007 *Dobeniella cubensis* (Furrazola-Bermúdez) – Andreini et al., Pl. 1, Fig. 8a, b.

2013 *Dobeniella* cf. *cubensis* (Furrazola-Bermúdez) – Lakova & Petrova, Pl. 1, Figs. 23-24.

2013 *Dobeniella cubensis* (Furrazola-Bermúdez) – Lakova & Petrova, Pl. 5, Figs. 29-32.

2017 *Dobeniella cubensis* (Furrazola-Bermúdez) – Petrova et al., Fig. 4.10-11.

Description:

The microgranular lorica is bell-shaped and elongated with the composite collar. The collar includes inner ring which is observed as rounded. The length of the lorica changes in between 47-50 µm while 36-40 µm is measured in the width in general.

Remarks:

This species was recognized by the thickening of the collars due to the composite collar characteristic. Although the shape of the lorica of *Dobeniella cubensis* resembles *Dobeniella bermudezi*, the size of *Dobeniella cubensis* was less than the size of *Dobeniella bermudezi*.

Occurrence:

This species type was recognized in the samples BA-07 and BA-13 representing the *boneti* Subzone in the Late Tithonian.

Dobeniella tithonica Borza, 1969

Pl. 1, Fig. d.

1969 *Chitinoidella tithonica* n. sp. – Borza, Pl. IXVII, Figs. 1-2.

1993 *Chitinoidella tithonica* Borza – Lakova, Pl. I, Fig. 3,

1995 *Chitinoidella tithonica* Borza – Reháková, Pl. I, Fig. 5.

1998 *Dobeniella tithonica* Borza – Pop, Pl. I, Figs. 25-26.

2002 *Dobeniella tithonica* Borza – Reháková, Fig. 3.10-12.

Description:

The size of the lorica changes in between 42-54 µm in length and 34-38 µm in width (Reháková, 2002). The lorica includes composite collars with two rings. The outwardly deflected longer ring is located in outer side while the inner one is characterized by short, lens-like structure.

Remarks:

The microgranular lorica was defined as small and bell-shaped microgranular lorica in this study. The aboral part of the lorica was characterized by a caudal appendage.

Occurrence:

The species was identified by its furcate collars in the sample BA-01 indicating the *boneti* Subzone in the Late Tithonian.

FAMILY CALPIONELLIDAE, Bonet 1956

Genus *Crassicollaria* Remane, 1962

Type species: *Crassicollaria brevis* Remane, 1962

Pl. 2, a-s.

1948 *Calpionella elliptica* Cadisch – Colom, Pl. 11, Figs. 65, 71, 78.

1962 *Crassicollaria brevis* n. sp. – Remane, Figs. 19-26; Fig. 35.

1969 *Crassicollaria brevis* Remane – Borza, Pl. IXXIII, Figs. 1-16.

1971 *Crassicollaria brevis* Remane – Remane, Figs. 5-6.

1974 *Crassicollaria brevis* Remane – Pop, Pl. 1, Figs. 10-12; Pl. 2, Figs. 1-3.

1991 *Crassicollaria brevis* Remane – Altıner & Özkan, Pl. 3, Figs. 6-8.

1994 *Crassicollaria brevis* Remane – Mekik, Pl. 54, Figs. 5-9.

1995 *Crassicollaria brevis* Remane – Olóriz et al., Pl. 1, Fig. 9.

1997 *Crassicollaria brevis* Remane – Ivanova, Pl. 2, Figs. 13-15.

1999 *Crassicollaria brevis* Remane – Lakova et al., Pl. 1, Fig. 6.

2007 *Crassicollaria brevis* Remane – Andreini et al., Pl. 1, Figs. 19-20.

2009 *Crassicollaria brevis* Remane – Michalik et al., Fig. 5.5.

2012 *Crassicollaria brevis* Remane – Petrova et al., Fig. 4.28-29.

2013 *Crassicollaria brevis* Remane – Wimbledon et al., Fig. 5.7.

2013 *Crassicollaria brevis* Remane – Lakova & Petrova, Pl. 2, Figs. 2-3; Pl. 6, Figs. 18-19.

2017 *Crassicollaria brevis* Remane – Atasoy, Pl. 1, Figs. a-d.

Description:

The hyaline lorica is small and short with a funnel shaped wide opening which includes collar spreading outward. The massive swelling at the base of the collar is most characteristic features of these species. The species also includes a caudal appendage at the aboral pole.

Remarks:

The species was identified by the swelling at the base of the collar. The lorica is more conical and shorter in comparison with *Crassicollaria intermedia*. On the other hand, the spreading outward collar is used to differentiate these species from *Crassicollaria massutiniana* and *Crassicollaria parvula*. Moreover, the swelling below the collar is used as a distinctive feature when it is compared to small *Tintinnopsella carpathica* of the Late Tithonian.

Occurrence:

The first occurrence of *Crassicollaria brevis* represents the *massutiniana* Subzone of the *Crassicollaria* Zone (the Upper Tithonian). They are also restricted within the *massutiniana* Subzone. *Crassicollaria brevis* disappears before the Jurassic-Cretaceous boundary interval (Lakova & Petrova, 2013). In this study, the range of *Crassicollaria brevis* was determined within the samples between BA-27 and BA-36 (the Late Tithonian).

Crassicollaria intermedia Durand Delga, 1957

Pl. 4, Figs. a-q.

1948 *Calpionella elliptica* Cadisch – Colom, Pl. 11, Figs. 52, 67.

1957 *Crassicollaria intermedia* n. sp. – Durand Delga, Pl. 1, Figs. 2, 4.

1964 *Crassicollaria intermedia* Durand Delga – Remane, Pl. 2, Figs. 19-35; Pl. 5, Figs. 16-17.

1969 *Crassicollaria intermedia* Durand Delga – Borza, Pl. IXXIV, Figs. 1-16.

1970 *Crassicollaria intermedia* Durand Delga – Catalano & Ligouri, Pl. 1, Figs. 1-5.

1971 *Crassicollaria intermedia* Durand Delga – Remane, Pl. 3, Fig. 7.

1991 *Crassicollaria intermedia* Durand Delga – Altıner & Özkan, Pl. 3, Figs. 9-12.

1993 *Crassicollaria intermedia* Durand Delga – Ondrejičková et al., Pl. 1, Fig. 5.

1994 *Crassicollaria intermedia* Durand Delga – Mekik, Pl. 54, Figs. 1-10.

1995 *Crassicollaria intermedia* Durand Delga – Olóriz et al., Pl. 1, Fig. 8.

1997 *Crassicollaria intermedia* Durand Delga – Grün & Blau, Pl. 1, Fig. 10.

2007 *Crassicollaria intermedia* Durand Delga – Andreini et al., Pl. 1, Figs. 28-29.

2009 *Crassicollaria intermedia* Durand Delga – Michalik et al., Fig. 5.3.

2012 *Crassicollaria intermedia* Durand Delga – Petrova et al., Fig. 4.22-24.

2013 *Crassicollaria* aff. *intermedia* Durand Delga – Wimbledon et al., Fig. 5.5.

2013 *Crassicollaria intermedia* Durand Delga – Lakova & Petrova, Pl. 1, Figs. 32-33.

2017 *Crassicollaria* cf. *intermedia* Durand Delga – Petrova et al., Fig. 8.2-3.

2017 *Crassicollaria intermedia* Durand Delga – Atasoy, Pl. 1, Figs. e-h.

Description:

The hyaline lorica is cylindrical with distinct conical aboral pole and a caudal appendage. The collar is initially conical and then shows outward opening. The outward opening of the collars of *Crassicollaria intermedia* is used as a distinctive feature from among the species with cylindrical collar which are *Crassicollaria massutiniana* and *Crassicollaria parvula*. It is characterized by a swollen massive band below the collar.

Remarks:

The species was identified by the swollen massive part just below the collars in this study. The lorica was cylindrical in contrast with the *Crassicollaria brevis*. *Crassicollaria intermedia* is more elongated, cylindrical and scaled-up version of *Crassicollaria brevis*.

Occurrence:

The first occurrence of *Crassicollaria intermedia* represents the *remanei* Subzone of the *Crassicollaria* Zone (the lower part of the Upper Tithonian). It disappears within the *massutiniana* Subzone. Therefore, it does not reach up to the Jurassic-Cretaceous boundary interval (Lakova & Petrova, 2013). In this study, the first occurrence of *Crassicollaria intermedia* was recognized in the sample BA-14 and its range reached up to the sample BA-29. Thus, this species was identified in both the *remanei* Subzone and the lower part of *massutiniana* Subzone respectively (Late Tithonian).

Crassicollaria massutiniana Colom, 1948

Pl. 5, Figs. a-w.

1948 *Crassicollaria massutiniana* n.sp. – Colom, p. 243, Fig. 11.

1964 *Crassicollaria massutiniana* Colom – Remane, Pl. 3, Figs. 17-40.

1969 *Crassicollaria massutiniana* Colom – Borza, Pl. IXXV, Figs. 5-16.

1971 *Crassicollaria massutiniana* Colom – Remane, p. 375, Fig. 10.

1975 *Crassicollaria massutiniana* Colom – Pop, Pl. 1, Fig. 4; Pl. 3, Figs. 14-15.

1991 *Crassicollaria massutiniana* Colom – Altıner & Özkan, Pl. 3, Fig. 13-14.

1993 *Crassicollaria massutiniana* Colom – Ondrejičková et al., Pl. 1, Fig. 4.

1994 *Crassicollaria massutiniana* Colom – Mekik, Pl. 54, Figs. 11-13.

1997 *Crassicollaria massutiniana* Colom – Ivanova, Pl. 2, Fig. 11.

2007 *Crassicollaria massutiniana* Colom – Andreini et al., Pl. 1, Figs. 23-25.

2009 *Crassicollaria massutiniana* Colom – Michalik et al., Fig. 5.4.

2012 *Crassicollaria massutiniana* Colom – Petrova et al., Fig. 4.25-27.

2013 *Crassicollaria massutiniana* Colom – Lakova & Petrova, Pl. 2, Fig. 1; Pl. 5, Figs. 47-48.

2013 *Crassicollaria massutiniana* Colom – Krische et al., p. 39, Figs. E, F.

2013 *Crassicollaria massutiniana* Colom – Wimbledon et al., Fig. 5.4.

2017 *Crassicollaria massutiniana* Colom – Okay & Altıner, Fig. 6.46-47.

2017 *Crassicollaria massutiniana* Colom – Petrova et al., Fig. 8.5.

2017 *Crassicollaria massutiniana* Colom – Atasoy, Pl. 1, Figs. i-o.

Description:

The hyaline lorica is elongated and it includes the conical aboral pole. The collar is cylindrical and observed on a massive swelling. The length of species changes in between 75 and 90 µm while the width is measured as 40-45 µm (Mekik, 1994).

Remarks:

The species was identified by the distinct massive swelling and the cylindrical collars in this study. *Crassicollaria massutiniana* can be differentiated from *Crassicollaria parvula* by the more pronounced massive swelling below the collar and the more conical aboral pole. The size of the lorica is also greater than the size of *Crassicollaria parvula* in general.

Occurrence:

The dominance of *Crassicollaria massutiniana* represents the *massutiniana* Subzone in the uppermost Tithonian. This species was restricted within the *massutiniana* Subzone in this study (in the samples between BA-23 and BA-37). *Crassicollaria massutiniana* disappeared in the uppermost Tithonian before the Jurassic-Cretaceous boundary. However, it was previously defined that *Crs. Massutiniana* reached the upper levels of the Jurassic-Cretaceous boundary in the study of Lakova & Petrova (2013). This may be resulted from the regional variation.

Crassicollaria parvula Remane, 1962

Pl. 6, Figs. a-z.

1948 *Calpionella elliptica* Cadisch – Colom, Pl. 11, Figs. 73-77; 79-81.

1953 *Calpionella elliptica* Cadisch – Brönnimann, Pl. 1, Figs. 23,24.

1962 *Crassicollaria parvula* n. sp. – Remane, p. 20, Figs. 36-46.

1963 *Crassicollaria parvula* Remane – Doben, Pl. 5, Figs. 9-12.

1969 *Crassicollaria parvula* Remane – Borza, Pl. IXXVI, Figs. 1-16.

1971 *Crassicollaria parvula* Remane – Remane, p. 375, Figs. 8-9.

1988 *Crassicollaria parvula* Remane – Colom, Pl. 25, Figs. 9-18.

1991 *Crassicollaria parvula* Remane – Altıner & Özkan, Pl. 3, Figs. 15-20.

1993 *Crassicollaria parvula* Remane – Ondrejičková et al., Pl.1, Fig. 6.

1994 *Crassicollaria parvula* Remane – Mekik, Pl. 54, Figs. 14-18.

1997 *Crassicollaria parvula* Remane – Ivanova, Pl. 2, Fig. 12.

2007 *Crassicollaria parvula* Remane – Andreini et al., Pl. 1, Figs. 21-22.

2009 *Crassicollaria parvula* Remane – Michalik et al., Fig. 5.6.

2012 *Crassicollaria parvula* Remane – Petrova et al., Fig. 4.32-33.

2013 *Crassicollaria parvula* Remane – Lakova & Petrova, Pl. 2, Figs. 4-5; Pl. 5, Fig. 49; Pl. 6, Figs. 20-29.

2013 *Crassicollaria parvula* Remane – Wimbledon et al., Fig. 5.9.

2013 *Crassicollaria parvula* Remane – Martinez et al., Fig. 5E.

2015 *Crassicollaria parvula* Remane – Boorová et al., Fig. 6B.

2017 *Crassicollaria parvula* Remane – Okay & Altıner, Fig. 6.49-50.

2017 *Crassicollaria parvula* Remane – Petrova et al., Fig. 6.10-11; Fig. 8.8-9.

2017 *Crassicollaria parvula* Remane – Atasoy, Pl. 1, Figs. p-ag.

Description:

The hyaline lorica is elongated and bell-shaped. It includes a massive arch shape swelling below the cylindrical collar. However, the swelling is less in compared with *Crassicollaria massutiniana.* The length and width dimensions of the species were previously measured as 65-70 µm in the length and 35-45 µm in the width (Mekik, 1994).

Remarks:

The species was identified by bell-shaped lorica with the arch shape swelling just below the cylindrical collars. *Crassicollaria parvula* may be confused with *Calpionella elliptica* in some oblique sections as in the studies of Colom (1948) and Brönnimann (1953) but the lorica of this species is more elongated and narrower. *Calpionella elliptica* does not have swelling structure below the collar. It may also resemble *Crassicollaria brevis* but the collars of *Crassicollaria parvula* is cylindrical and straight in contrast to *Crs. brevis*.

Occurrence:

The range of this species is quite wide as starting from the *massutiniana* Subzone (the latest Tithonian) to the *simplex* Subzone (the Early-Late Berriasian). It is an exceptional species existing before and later the Jurassic-Cretaceous boundary level together with *Calpionella alpina*. *Crassicollaria parvula* forms the “acme” within the *alpina* Subzone (Lakova & Petrova, 2013). The range of *Crassicollaria parvula* was determined as in the samples between BA-28 and BA-55. It increased the abundance in the level represented by the sample BA-46 (the Early Berriasian). Moreover, the samples BA-50 and BA-55 were also recognized by the increased in the abundance of *Crassicollaria parvula*.

Genus *Tintinnopsella* Colom, 1948

Type species: *Calpionella carpathica* Murgeanu and Filipescu, 1933

Tintinnopsella carpathica Murgeanu and Filipescu, 1933

Pl. 7, Figs. a, c-e, g-h, j, l-n, q-w.

1933 *Calpionella carpathica* n. sp. – Murgeanu & Filipescu, Pl. 1, Figs. 20-23.

1934 *Calpionella carpathica* Murgeanu & Filipescu – Colom, Pl. XXX, Figs. 7-9.

1948 *Tintinnopsella carpathica* Murgeanu & Filipescu – Colom, Pl. 1, Figs. 18-21; Pl. 13, Figs. 1-56.

1953 *Tintinnopsella carpathica* Murgeanu & Filipescu – Brönnimann, Pl. 1, Figs. 13-15.

1962 *Tintinnopsella carpathica* Murgeanu & Filipescu – Remane, p. 10, Fig. 1.

1963 *Tintinnopsella carpathica* Murgeanu & Filipescu – Doben, Pl. 6, Fig. 17.

1964 *Tintinnopsella carpathica* Murgeanu & Filipescu – Remane, Pl. 4, Figs. 1-25; Pl. 5, Figs. 23-25.

1969 *Tintinnopsella doliphormis* Murgeanu & Filipescu – Borza, Pl. IXXX, Figs.1-16.

1971 *Tintinnopsella carpathica* Murgeanu & Filipescu – Remane, p. 375, Figs. 11-12.

1983 *Tintinnopsella carpathica* Murgeanu & Filipescu – Remane, Pl. 1, Figs. 8-9.

1991 *Tintinnopsella carpathica* Murgeanu & Filipescu – Altıner & Özkan, Pl. 2, Figs. 1-12; Pl. 3, Fig. 4.

1993 *Tintinnopsella carpathica* Murgeanu & Filipescu – Ondrejičková et al., Pl. 1, Fig. 10.

1994 *Tintinnopsella carpathica* Murgeanu & Filipescu – Mekik, Pl. 53, Fig. 1-11.

1997 *Tintinnopsella* gr. *carpathica* Murgeanu & Filipescu – Grün & Blau, Pl. 1, Figs. 15-16.

1997 *Tintinnopsella carpathica* Murgeanu & Filipescu – Ivanova, Pl. 2, Figs. 18-19.

2007 *Tintinnopsella carpathica* Murgeanu & Filipescu – Andreini et al., Pl. 1, Figs. 16-18, Pl. 2, Figs. 5, 14-15.

2012 *Tintinnopsella carpathica* Murgeanu & Filipescu – Petrova et al., Fig. 4.19; Fig. 6.14-22.

2013 *Tintinnopsella carpathica* Murgeanu & Filipescu – Lakova & Petrova, Pl. 1, Figs. 35-36; Pl. 2, Fig. 34; Pl. 3, Figs. 41-44; Pl. 4, Figs. 47-49; Pl. 5, Figs. 38-41; Pl. 6, Fig. 32; Pl. 7, Figs. 36-41.

2013 *Tintinnopsella carpathica* Murgeanu & Filipescu – Martinez et al., Fig. 5G.

2013 *Tintinnopsella carpathica* Murgeanu & Filipescu – Wimbledon et al., Fig. 5.3.

2017 *Tintinnopsella carpathica* Murgeanu & Filipescu – Okay & Altıner, Fig. 6.38-40.

2017 *Tintinnopsella carpathica* Murgeanu & Filipescu – Petrova et al., Fig. 6.16-17.; Fig. 8.24-25.

2017 *Tintinnopsella carpathica* Murgeanu & Filipescu – Atasoy, Pl. 3, Figs. d-t.

Description:

The hyaline lorica is ovoid or cylindrical with a minor constriction below the collar. The collar positions perpendicularly outward at the top of the lorica. The conical aboral pole includes a distinct caudal appendage. The genus *Tintinnopsella* includes a wider opening at the top of the lorica in contrast with the species of the genus *Calpionella* and the genus *Crassicollaria*. The dimensions of these species were previously measured as 90-105 µm in the length and 40-55 µm in the width by the study of Mekik (1994).

Remarks:

Tintinnopsella carpathica was initially defined as *Calpionella carpathica* by Murgeanu & Filipescu (1933) and Colom (1934). The species was identified by the size, the perpendicularly outward spreading collars, the distinct caudal appendage and the wide opening at the top of the lorica. It differs from *Tintinnopsella longa* by the smaller size, the shape of the lorica and the presence of a distinct caudal appendage.

Occurrence:

Tintinnopsella carpathica has the longest stratigraphic range among the calpionellid forms. The first occurrence of this species corresponds to the earliest A1 Subzone (Remane, 1985; Altıner & Özkan, 1991) or the lowermost *remanei* Subzone (Petrova et al., 2012) and its range extends to Zone F (Altıner & Özkan) or the *oblonga* Subzone of the *Calpionellopsis* Zone (Petrova et al., 2012). It increases in size and becomes more observable in the Berriasian time interval. In this study, the first occurrence of *Tintinnopsella carpathica* was correspond to the sample BA-26 and it was observed almost in the whole studied section reaching up to the sample BA-55 (the Early Berriasian).

Tintinnopsella doliphormis Colom, 1939

Pl. 7, Figs. k, p.

1939 *Tintinnopsella doliphormis* n. sp. – Colom, Pl.2, Fig. 10.

1948 *Tintinnopsella doliphormis* Colom – Colom, Fig. 11-11.

1988 *Tintinnopsella doliphormis* Colom – Colom, Fig. 21.5-6.

2012 *Tintinnopsella doliphormis* Colom – Petrova et al., Fig. 6.23-24.

2012 *Tintinnopsella doliphormis* Colom – Lakova & Petrova, Pl. 2, Figs. 21-22, Pl. 6, Figs. 33-35.

Description:

The lorica is wide at the middle part and it gradually becomes narrow towards both the aboral end and the oral opening. The characteristic feature of this species is the narrow opening just below the collars. The size of the species was measured as 120-130 µm in length and about 52 µm in width by Colom (1948).

Remarks:

The species was identified by the narrow opening including the the funnel-shaped collars and the subrounded aboral pole in this study. It was recognized as the narrow form of *Tintinnopsella carpathica* without a distinct caudal appendage.

Occurrence:

Tintinnopsella doliphormis was recognized by a few specimens in the samples between BA-46 and BA-50 which was related with the *massutiniana* Subzone (the Late Tithonian).

Tintinnopsella remanei Borza, 1969

Pl. 7, Fig. b.

1969 *Tintinnopsella remanei* n. sp. – Borza, Pl. 80, Figs.7-16.

1991 *Tintinnopsella carpathica* (small form) Murgeanu & Filipescu – Altıner &

Özkan, Pl. 3, Fig. 4.

1993 *Tintinnopsella* cf. *remanei* Borza – Ondrejičková et al., Pl.1, Fig. 3.

1995 *Tintinnopsella remanei* Borza – Oloriz et al., Pl. 1, Fig. 19.

1997 *Tintinnopsella remanei* Borza – Ivanova, Pl. 2, Fig. 16.

1999 *Tintinnopsella remanei* Borza – Lakova et al., Pl. 1, Fig. 3.

2009 *Tintinnopsella remanei* Borza – Michalik et al., Fig. 5.1.

2012 *Tintinnopsella remanei* Borza – Petrova et al., Fig. 4.20-21.

2013 *Tintinnopsella remanei* Borza – Lakova & Petrova, Pl. 1., Fig. 34; Pl. 5, Figs. 42-43.

2013 *Tintinnopsella remanei* Borza – Wimbledon et al., Fig. 5.2.

2017 *Tintinnopsella* cf. *remanei* Borza – Petrova et al., Fig. 8.1.

2017 *Tintinnopsella remanei* Borza – Atasoy, Pl. 3, Figs. a-c.

Description:

The small hyaline lorica includes the funnel-shaped collar spreading outward perpendicularly at the large opening. This species is identified by the lack of a caudal appendage on the subrounded aboral pole and its relatively smaller size of the lorica in contrast with *Tintinnopsella carpathica*.

Remarks:

The species was identified by the smaller size, the funnel-shaped collars at the large opening and the subrounded aboral pole in this study. It was recognized as the smaller form of *Tintinnopsella carpathica* without a distinct caudal appendage. This form was previously noted as *Tintinnopsella carpathica* (small form) by Altıner & Özkan (1991) rather than using a specific species name as *Tintinnopsella remanei*.

Occurrence:

Tintinnopsella remanei was assumed in a restricted range within the *remanei* Subzone in contrast with *Tintinnopsella carpathica*. The first occurrence of this species is identified in the lowermost *remanei* Subzone and it disappears before the *massutiniana* Subzone (Petrova et al., 2012). However, it continued in the *massutiniana* Subzone in the samples of this study. This species could not be recognized in the Jurassic-Cretaceous boundary interval. *Tintinnopsella remanei* was distinguished in the samples between BA-23 and BA-27 which was related with the *massutiniana* Subzone (the Late Tithonian).

FAMILY CALPIONELLIDAE Bonet, 1956

Genus *Calpionella* Lorenz, 1902

Type species: *Calpionella alpina* Lorenz, 1902

Pl. 8, Figs. a-dd.

1902 *Calpionella alpina* n. sp., Lorenz, Pl. 6, Fig. 1.

1948 *Calpionella alpina* Lorenz – Colom, Pl. 11, Fig. 1, Pl. 33, Figs. 3, 13.

1953 *Calpionella alpina* Lorenz – Brönnimann, Pl. 1, Figs. 1-6, 11, 12.

1962 *Calpionella alpina* Lorenz – Remane, Figs. 2-9.

1963 *Calpionella alpina* Lorenz – Doben, Pl. 6, Fig. 11.

1968 *Calpionella alpina* Lorenz – Le Hegarat & Remane, Pl. 6, Figs. 4-10, 18-21; Pl. 8, Figs. 2-5; Pl. 9, Figs. 21-23; Pl. 10, Figs. 2-3.

1970 *Calpionella alpina* Lorenz – Catalano & Ligouri, Pl. 2, Figs. 1-10.

1971 *Calpionella alpina* Lorenz – Remane, Pl. 3, Figs. 1,2; Pl. 1, Fig. 1.

1974 *Calpionella alpina* Lorenz – Pop, Pl. 6, Fig. 15; Pl. 5, Figs. 14-15; Pl. 4, Figs. 1-3; Pl. 3, Figs. 1-4, Pl. 2, Figs. 1-4, Pl. 1, Figs. 14-15.

1984 *Calpionella alpina* Lorenz – Premoli Silva & McNulty, Pl. 6, Figs. 1-2.

1991 *Calpionella alpina* (spherical form) Lorenz – Altıner & Özkan, Pl. 1, Figs. 3-8.

1993 *Calpionella alpina* Lorenz – Ondrejičková et al, Pl. 1, Figs. 8-9.

1994 *Calpionella alpina* Lorenz – Mekik, Pl. 50, Figs. 1-10; Pl. 51, Figs. 1-19.

1996 *Calpionella alpina* Lorenz – Ivanova, Pl. 2, Figs. 1-4.

1996 *Calpionella alpina* Lorenz – Adatte et al., Fig. 8.3.

1997 *Calpionella alpina* Lorenz – Grün & Blau, Pl. 1, Figs. 11-12.

1999 *Calpionella alpina* Lorenz – Lakova et al., Pl. 1, Fig. 9.

2007 *Calpionella alpina* Lorenz – Andreini et al., Pl. 1, Figs. 10-13.

2009 *Calpionella alpina* Lorenz – Michalik et al., Fig. 5.2.

2012 *Calpionella alpina* Lorenz – Petrova et al., Fig. 5.1-7.

2013 *Calpionella alpina* Lorenz – Lakova & Petrova, Pl. 2, Figs. 12-16, Pl. 5, Fig. 52.

2013 *Calpionella alpina* Lorenz – Krische et al., Fig. 12.C, D.

2013 *Calpionella alpina* Lorenz – Wimbledon et al., Fig. 5.10.

2017 *Calpionella alpina* (spheric form) Lorenz – Okay & Altıner, Fig. 6.24-30.

2017 *Calpionella alpina* Lorenz – Petrova et al., Fig. 6.1-3.; Fig. 8.11-13.

2017 *Calpionella alpina* Lorenz – Atasoy, Pl. 2, Figs. f-o, r.

Description:

The lorica of this species is hyaline and spherical including well developed shoulders below the collars. The aboral pole is rounded with the lack of a caudal appendage. The cylindrical collar is short and narrower than the lorica. The size of the lorica was measured as 65 µm in length and 53-54 µm in width in this study. The measurements of the axial sections also varied in between 26-49 µm as smaller towards the aboral and oral sides.

Remarks:

The species was identified by spherical lorica with distinct shoulders below the collars. In some cases, the oblique sections of *Crassicollaria parvula* and small, atypical specimens of *Calpionella alpina* with less observable shoulder may be confused. On the other hand, the certain oblique sections of the longer and elongated *Calpionella elliptica* may be confused with *Calpionella alpina* (Remane, 1985). Remane (1985) asserted that the restricted range of *Calpionella elliptica* and the length to width ratio can be used for the separation. According to the schematic distinction of Remane (1963, 1964), the ratio is more than 1.35 for *Calpionella elliptica* while *Calpionella alpina* indicates the ratio with less than 1.25. Besides of these numeric estimations, the difference between these two species can be distinguished by the thickening on the lorica in the oblique sections in contrast with smooth and uniform thickness of *Calpionella alpina* lorica.

Occurrence:

The explosion (the sudden increase in abundance) of spherical *Calpionella alpina* is mostly accepted as a marker of the base of the Berriasian stage, the Jurassic-Cretaceous boundary. The range of this species indicates the Late Tithonian- Late Berriasian time interval. The Jurassic- Cretaceous boundary (explosion of spherical

Calpionella alpina) was identified in the sample BA-42 within the scope of this study. The fist occurrence of *Calpionella alpina* was detected just before the stage boundary. However, it increased in abundance in the Early Berriasian (in the samples between BA-42 and BA-51).

Calpionella grandalpina Nagy, 1986

Pl. 9, Figs, a-q.

1986 *Calpionella grandalpina* n. sp., Nagy, Pl. 1, Figs. 3, 8.

1988 *Calpionella alpina* Lorenz – Colom, Fig. 13.1.

1991 *Calpionella alpina* (large form) Lorenz – Altıner & Özkan, Pl. 1, Figs. 1-2.

1994 *Calpionella alpina* (large form) Lorenz – Mekik, Pl. 50, Figs. 10-15.

1999 *Calpionella grandalpina* Nagy – Lakova et al., Pl. 1, Fig. 7.

2009 *Calpionella grandalpina* Nagy – Michalik et al., Fig. 5.8.

2012 *Calpionella grandalpina* Nagy – Petrova et al., Fig. 4.37-39.

2013 *Calpionella grandalpina* Nagy – Lakova & Petrova, Pl. 2, Figs. 8-9; Pl. 5, Figs. 53-54; Pl. 6, Fig. 1.

2017 *Calpionella grandalpina* Nagy – Okay & Altıner, Fig. 6.31-32.

2017 *Calpionella grandalpina* Nagy – Petrova et al., Fig. 8.10.

2017 *Calpionella grandalpina* Nagy – Atasoy, Pl. 2, Figs. a-e.

Description:

The species looks like a large form of *Calpionella alpina.* The morphologic characteristics are almost the same except the size of the lorica. The cylindrical collar, well developed shoulder structure below the collars, nearly spherical shape of lorica, rounded aboral pole are morphological features of *Calpionella grandalpina*.

Remarks:

The species was recognized by its large size of the lorica in contrast with the other *Calpionella* and *Crassicollaria* species. In some cases, the oblique or transverse sections of *Calpionella grandalpina* may be confused with *Calpionella alpina* as in the study of Colom (1988). However, these sections include thickening of the wall, so it can be used in the differentiation. Altıner & Özkan (1991) and Mekik (1994) also preferred to use the term "large form of *Calpionella alpina*" in order to indicate *Calpionella grandalpina* in their studies.

Occurrence:

The first occurrence of this species is recognized in the uppermost Tithonian *Crassicollaria* Zone, the *massutininana* Subzone (Petrova et al., 2012; Lakova & Petrova, 2013). *Calpionella grandalpina* is abundant in the *massutiniana* Subzone in contrast with *Calpionella alpina*. Moreover, it also passes the Jurassic-Cretaceous boundary with less abundance and it disappears in lower part of the Early Berriasian the *alpina* Subzone (Lakova & Petrova, 2013). In this study, the first occurrence of *Calpionella grandalpina* was defined in the sample BA-23 and the abundance increased in between the samples BA-34 and BA-40. Moreover, this species did not pass the Jurassic-Cretaceous boundary and it became extinct in the sample BA-41 (the uppermost Tithonian).

Calpionella elliptalpina Nagy, 1986

Pl. 10, Figs. a-k.

1985 “Homeomorphous” *Calpionella elliptica* Cadisch – Remane, Fig. 6, e?

1986 *Calpionella elliptalpina* n. sp., Nagy, Pl. 1, Fig. 4.

1991 “Homeomorph” of *Calpionella elliptica* Cadisch – Altıner & Özkan, Pl. 1, Fig. 19.

1992 *Calpionella elliptica* Cadisch – Tunç, Pl. 2, Fig. 9.

1995 *Calpionella alpina* Lorenz – Olóriz et al., Pl. 1, Fig. 15

1999 *Calpionella elliptalpina* Nagy – Lakova & Petrova, Pl. 1, Fig. 8.

2006 *Calpionella alpina* Lorenz – Grabowski & Pszczólkowski, Fig. 7D.

2007 *Calpionella* sp. – Andreini et al., Pl. 1, Figs. 14-15.

2012 *Calpionella elliptalpina* Nagy – Petrova et al., Fig. 4.40-41.

2013 *Calpionella elliptalpina* Nagy – Lakova & Petrova, Pl. 2, Figs. 10-11; Pl. 6, Fig. 2.

2013 *Calpionella elliptalpina* Nagy – Wimbledon et al., Fig. 5.6.

Description:

Remane (1985) and many authors previously identified this species as the homeomorph of *Calpionella elliptica* in the Latest Tithonian. The term *Calpionella elliptalpina* is more common in the recent studies. The discrimination between *Calpionella grandalpina* and *Calpionella elliptalpina* is quite difficult especially in oblique sections because the oblique sections of *Calpionella grandalpina* may be seem like *Calpionella elliptalpina*. The size of these forms are almost the same.

Remarks:

The species was identified by large and slightly elongated lorica with cyclindrical collars and well developed shoulders below the collars. *Calpionella elliptalpina* may be separated from *Calpionella grandalpina* by the size and the width of the lorica. *Calpionella elliptalpina* is more elongated and narrower form in comparison to *Calpionella grandalpina.* This species was also identified as the "homeomorph" of *Calpionella elliptica* by Remane (1985) and Altıner & Özkan (1991) because of the cyclindrical collars and slightly elongated lorica. However, the collars of *Caliponella elliptica* is longer and the shape of lorica is narrower in comparison to *Calpionella elliptalpina*.

Occurrence:

The ranges of this species can be also used as a distinctive feature such that *Calpionella elliptalpina* has a restricted range within the uppermost Tithonian while the first occurrence of *Calpionella elliptica* indicates the upper part of the Jurassic-Cretaceous boundary (the Early Berriasian). Furthermore, *Calpionella elliptalpina* disappears before the Tithonian - Berriasian boundary (Lakova & Petrova, 2013). In this thesis, *Calpionella elliptalpina* was identified in the samples between BA-30 and BA-40 which correspond to the uppermost Tithonian. It disappeared before the Jurassic-Cretaceous boundary.

Calpionella minuta Houša, 1990

Pl. 11, Figs. a-i.

1985 *Calpionella alpina* (small form) Lorenz – Remane, Fig. 18.3.

1988 *Calpionella alpina* var. *cadischii* Doben – Colom, Fig. 14.11-12.

1991 *Calpionella alpina* (small form) Lorenz – Altıner & Özkan, Pl. 1, Figs. 91-10.

1991 *Calpionella alpina* Lorenz – Tunç, Pl. 3, Fig. 3.

1995 *Calpionella alpina* Lorenz – Olóriz et al., Pl. 1, Fig. 14.

1999 *Calpionella minuta* Houša – Lakova et al., Pl. 1, Fig. 4.

2001 *Calpionella alpina* (small, spherical form) Lorenz – Ciborowski & Kołodziej, Figs. 2,6-9.

2012 *Calpionella minuta* Houša – Petrova et al., Fig. 5.8-10.

2013 *Calpionella minuta* Houša – Lakova & Petrova, Pl. 1, Figs. 17-20; Pl. 3, Fig. 4; Pl. 6, Figs. 8-9.

2013 *Calpionella minuta* Houša – Martínez et al., Fig. 5D.

2017 *Calpionella minuta* Houša – Petrova et al., Fig. 6.8-9.; Fig. 8.14-15.

2017 *Calpionella minuta* Houša – Atasoy, Pl. 2; Figs. p-v.

Description:

Calpionella minuta looks the same with *Calpionella alpina* in terms of the lorica and the collar characteristics except the size of the lorica which is smaller than *Calpionella alpina*. Therefore, the differentiation of these two species is quite relativistic. In previous studies, *Calpionella minuta* was termed as the small form of *Calpionella alpina* (Remane, 1985; Altıner & Özkan, 1991) rather than using a different name. However, the term *Calpionella minuta* is used in recent times after Houša (1990) defined them as another species of the genus *Calpionella* (Lakova et al., 1999; Petrova et al., 2012; Lakova & Petrova, 2013; Martinez et al., 2013).

Remarks:

This species was identified by the small spherical lorica and cyclindrical collars. The shape of the lorica sometimes resembles a lemon. This species was previously identified as "small form of *Calpionella alpina*" (Remane, 1985; Altıner & Özkan, 1991; Ciborowski & Kołodziej, 2001) and *Calpionella alpina* (Tunç, 1991; Olóriz et al., 1995). However, it can be separated from *Calpionella alpina* by its smaller size of the lorica.

Occurrence:

Lakova et al. (1999) identified *Calpionella minuta* as a small degenerative Berriasian form of *Calpionella alpina* and associated the first occurrence of these species as in the upper half of the *Calpionella alpina* Subzone. In this study, *Calpionella minuta* was recognized in the samples between BA50- BA55 in the Lower Berriasian (the *remaniella* Subzone).

Genus *Remaniella* Catalano, 1965

Type species: *Tintinnopsella cadischiana* Colom, 1948

Remaniella ferasini Catalano, 1965

Pl. 12, Figs. a, d, f, h.

1965 *Calpionellites ferasini* n. sp. – Catalano, Pl. 2, Figs. 1-5; Pl. 3, Figs. 5-7.

1969 *Remaniella cadischiana* Colom – Borza, Pl. IXXXI, Fig. 4.

1970 *Remaniella ferasini* Catalano – Catalano & Ligouri, Pl. 3, Figs. 1-5.

1984 *Remaniella dadayi* Knaue – Premoli Silva & McNulty, Pl. 7, Fig. 15.

1986 *Remaniella ferasini* Catalano – Borza & Michalik, Pl. 4, Fig. 4.

1991 *Remaniella ferasini* Catalano – Altıner & Özkan, Pl. 5, Figs. 1-2.

1991 *Remaniella ferasini* Catalano – Tunç, Pl. 3, Fig. 6.

1994b *Remaniella ferasini* Catalano – Pop, Pl. 1, Figs. 5-6.

1994 *Remaniella ferasini* Catalano – Mekik, Pl. 52, Fig. 6.

1996 *Remaniella ferasini* Catalano – Grün & Blau, Pl. 1, Figs. 12-15; Pl. 3, Fig. 7.

1997 *Remaniella ferasini* Catalano – Ivanova, Pl. 2. Fig. 17.

1998 *Remaniella ferasini* Catalano – Reháková, Pl. 1, Figs. 1-2.

1999 *Remaniella ferasini* Catalano – Lakova et al., Pl. 1, Fig. 10.

2004 *Remaniella ferasini* Catalano – Concetta Marino, Pl. 3, Fig. 5.

2007 *Remaniella ferasini* Catalano – Andreini et al., Pl. 1, Figs. 30-31.

2012 *Remaniella ferasini* Catalano – Petrova et al., p. 60, Fig. 5.37-39.

2013 *Remaniella ferasini* Catalano – Lakova & Petrova, Pl. 2, Figs. 23-25; Pl. 6, Figs. 36-41.

2013 *Remaniella ferasini* Catalano – López- Martinez et al., Fig. 6F, G.

2015 *Remaniella ferasini* Catalano – López- Martinez et al., p. 587, Fig. 7H.

2016 *Remaniella ferasini* Catalano – Maalaoui & Zargouni, p. 50, Fig. 4.11.

2017 *Remaniella ferasini* Catalano – Petrova et al., p. 75, Fig. 6.29.; p. 78, Fig. 8.27.

2017 *Remaniella ferasini* Catalano – Atasoy, Pl. 5, Figs. a-f.

Description:

The hyaline lorica is small parabolic with a rounded to conical aboral pole. This species is characterized by a distinct suture between the lorica and bipartite collars. The dimensions are approximately 78 µm in length and 53 µm in width (Mekik, 1994). The collars are almost equal in size and reflect a triangular shape in the longitudinal sections.

Remarks:

The species was identified by the bipartite collars and the suture between the lorica and the collars. The recognition of this species was quite difficult because of the resolution of the microscope. However, the sufficient number of individuals were detected for the specification of the species. This species was completely different from *Calpionella* and *Crassicollaria* species because of the presence of the suture between the lorica and the collars.

Occurrence:

The base of the Early Berriasian *remaniella* Subzone (Remane et al., 1986) was defined by the first occurrence of *Remaniella ferasini* and a sudden decrease in the abundance of calpionellids. In this study, *Remaniella ferasini* was scarcely observed in the range represented by the samples between BA-48 and BA-55. This interval was defined as the *remaniella* Subzone (Early Berriasian) based on the occurrence of this species.

Remaniella duranddelgai Pop, 1996

Pl. 12, Fig. g.

1969 *Remaniella cadischiana* Colom – Borza, Pl. IXXXI, Figs. 2, 3, 5-7.

1991 *Remaniella cadischiana* Colom – Altıner & Özkan, Pl. 5, Fig. 3.

1992 *Remaniella cadischiana* Colom – Bucur, p. 572, Fig. 4o.

1996 *Remaniella duranddelgai* n. sp. – Pop, Pl. 2, Figs. 1-6.

1996 *Remaniella duranddelgai* Pop – Grün & Blau, Pl. 1, Fig. 11.

1997 *Remaniella duranddelgai* Pop – Grün & Blau, Pl. 2, Fig. 9.

1998 *Remaniella duranddelgai* Pop – Reháková, Pl. 1, Figs. 6-7.

2004 *Remaniella duranddelgai* Pop – Concetta Marino, Pl. 3, Fig. 7.

2007 *Remaniella duranddelgai* Pop – Andreini et al., Pl. 2, Figs. 3-6.

2012 *Remaniella duranddelgai* Pop – Petrova et al., Fig. 5.40-43.

2013 *Remaniella duranddelgai* Pop – Lakova & Petrova, Pl. 2, Figs. 26-28; Pl. 3, Fig. 12; Pl. 6, Figs. 42-49.

2013 *Remaniella duranddelgai* Pop – López- Martinez et al., Fig. 6B.

2015 *Remaniella duranddelgai* Pop – Boorová et al., p. 103, Fig. 6D.

2015 *Remaniella duranddelgai* Pop – López- Martinez et al., p. 589, Fig. 8I

2017 *Remaniella duranddelgai* Pop – Atasoy, Pl. 5, Figs. g-i.

Description:

The hyaline lorica is bell-shaped or slightly ovoid. It includes a caudal appendage at the aboral pole. In contrast with *Remaniella ferasini*, *Remaniella duranddelgai* includes bipartite but unequal collars at the top of lorica. The dimensions of the species are 82-90 µm in the length and 46-53 µm in the width (Andreini et al., 2007).

Remarks:

This species was identified by the bipartite collars, the suture between the collars and it was separated from *Remaniella ferasini* by the size of the lorica such that the lorica of *Remaniella duranddelgai* was longer than *Remaniella ferasini* and it was more elongated.

Occurrence:

Remaniella duranddelgai first appears together with *Remaniella ferasini* in the *remaniella* Subzone (Petrova et al., 2012). The last occurrence corresponds to the lower part of the *cadischiana* Subzone. Within the scope of this study, it was recognized in the sample BA-55 (the Early Berriasian).

5.2. Saccocoma

The rock forming quantity of *Saccocoma* Agassiz (1836) in the sample BA-05 was initially recognized by thin section analyses. However, the identification of *Saccocoma* Agassiz (1836) at a level of species could not be possible and reliable by using only thin section views. Therefore, the *Saccocoma* specimens were extracted from the sample BA-05 for more detailed and comprehensive results about the species. The remains of saccocomids were mostly extracted from marls and quite soft rocks by using the hydrogen peroxide, the distilled water, boiling with sodium or even by only scrubbing the weathered rock fragments with water and a brush (Sieverts-Doreck, 1958; Hess, 2002; Brodacki, 2006; Kroh & Lukeneder, 2009). However, the sample BA-05 representing the “*Saccocoma* level” was taken from the relatively firm rock in the studied pelagic limestone block. Thus, 11 different washing methods (different combinations of acetic acid, hydrogen peroxide and chloroform with varying waiting periods) were tried and the most convenient one was chosen as a valid technique for the extraction of the skeletal elements (Table 1.1). All these washing methods were generated for this study in order to extract the elements of *Saccocoma* Agassiz (1836) as well preserved materials for species designation issue. As a result; the combination of acetic acid (50%) together with hydrogen peroxide (50%) with 24 hr waiting period was determined as the best solution for the preservation of elements. Totally, 258 gr sample was used in all these washing trials and 285 gr was washed by the method-6 as a major process. The sieve sizes were chosen as $\geq 63\mu\mathrm{m}$, $\geq 125\mu\mathrm{m}$, $\geq 150\mu\mathrm{m}$, $\geq 250\mu\mathrm{m}$ in the major process while the trials included also the sieve size $106\ \mu\mathrm{m}$ in addition to these sieve sizes used in the major process.

5.2.1. Morphological Features of Saccocoma

Jaekel (1892) revealed the most detailed study about the morphology of *Saccocoma*. *Saccocoma* is composed of three main parts; the proximal part including the calyx without a stem, the secundiarm and the distally coiled arms (Fig.2.8). The calyx, which is also called as a cup, has bowl-shaped structure with a convex base. This part consists of five extremely thin, arrow-head shaped radial plates (R or RR) enclosing the cup-shaped body cavity, five small basals and a minute centrale. The thickness of the cup is used for the separation of the genus *Crassicoma* and the genus *Saccocoma* in such a way that the genus *Crassicoma* Sieverts-Doreck has thick walled cup in comparison with the genus *Saccocoma* Agassiz (Hess, 2002). Each radial plate is convex in shape characterized by the smooth inner surface and the exterior surface with a reticulate ornamentation like the network of anastomosing ridges. The lateral margins of the radials are characterized by a zig-zag suture (Milsom, 1994). The second and major part of *Saccocoma* is composed of well-developed and uniserial 10 arms attached to the calyx. The skeletal elements of the arms are called as brachials which resemble the bones of the human body. The arm structure of *Saccocoma tenella* (Goldfuss, 1831) can be analyzed in three parts namely the proximal part, the secondibrachials and the holotomously branched part. The proximal part consists of only two brachials; the first primibrachial (IBr$_1$) and the second primibrachial (IBr$_2$) respectively. The first primibrachial is characterized by the simple, cylindrical shape with a distinct ligament fossa on the proximal end while the second primibrachial includes large, symmetrical, dish-like lateral wings as dense, porcelain-like structure. IBr$_1$ serves as an attachment between the rest of the arm and the calyx. IBr$_2$ is attached to IBr$_1$ by non-muscular articulation facet whereas IIBr$_2$ is fixed to the first secundibrachial (IIBr$_1$) by a muscular distal articulation facet. The term “articulation facet” indicates the connection surface or the body parts on brachials classified as muscular or non-muscular. Secondly; the secundiarm (secundibrachials) part is composed of approximately seventeen unbranched secundibrachials (Milsom, 1994). The wing-like lateral expansions are positioned in IBr$_2$ and IIBr$_{2,4\text{-}7}$ while the brachials IBr$_1$, IIBr$_1$ and IIBr$_3$ are characterized as the wingless brachials (Milsom, 1994). The wings on brachials may be dish-like or bell shaped depending on the species of *Saccocoma* Agassiz (1836). It is hard to distinguish IIBr$_1$ from IBr$_1$ because of the identical proximal facets and their shapes (Manni & Nicosia, 1984; Brodacki, 2006). The synostosis articulation between IIBr$_3$ and IIBr$_4$ is distinguished by a plane perpendicular to the axis of the arm and the remaining articulations are muscular (Brodacki, 2006). The rest of the arm is nearly horizontal and it has distally coiled structure. Finally, the distal brachials are positioned after the seventh secundibrachial (IIBr$_7$) and they are distinguished by their simple, oblong, cylindrical shapes without lateral expansions.

5.2.2. Saccocoma Taxonomy

The first description and illustration of *Saccocoma* date back to 1730 (Bajer, 1730). Goldfuss (1829) initially assigned *Saccocoma* to the order Comatulida and the species was termed by Agassiz in 1836. Then, d’Orbigny (1852) classified saccocomids in the family Saccocomidae but this family could not be placed in a phylogenetic context. The genus *Saccocoma* Agassiz (1836) is classified in the order Roveacrinida Sieverts- Doreck (1952). The taxonomy, the morphological features, the mode of life and the numerous informal species of the genus *Saccocoma* Agassiz (1836) were previously studied by Sieverts-Doreck (1955, 1958), Verniory (1960, 1961, 1962a, 1962b), Hess (1972, 2002), Nicosia & Parisi (1979), Pisera & Dzik (1979), Holzer & Poltnig (1980), Manni & Nicosia (1984), Milsom (1994), Manni et al. (1997), Brodacki (2006), Kroh & Lukeneder (2009), Hess & Etter (2011) etc. However, a few of these authors used the specific nomenclature for the species of *Saccocoma* Agassiz. Afterwards, some of the informal species were rearranged as the synonymous with *Saccocoma tenella* (Goldfuss, 1831). In the Late Jurassic (Kimmeridgian-Tithonian) time interval, four valid species of the genus *Saccocoma* Agassiz (1836) were determined as *Saccocoma quenstedti* (Sieverts-Doreck & Hess, 2002), *Saccocoma longipinna* (Hess, 2002), *Saccocoma tenella* (Goldfuss, 1831) and *Saccocoma vernioryi* (Manni & Nicosia, 1984) in the chronological order (Brodacki, 2006).

Class Crinoidea Miller, 1821

Subclass Articulata Zittel, 1879

Order Roveacrinida Sieverts-Doreck, 1952

Family Saccocomidae d’Orbigny, 1852

Genus *Saccocoma* Agassiz, 1836

Type species: *Comatula tenella* Goldfuss (1831)

Saccocoma tenella Goldfuss (1831)

Pl. 13, Figs. a-c; Pl. 14, Figs. a-e, g-h; Pl. 15, Figs. a-k, o;

Pl. 16, Figs. a-j, l, m, o, p; Pl. 17, Figs. a-f, k, n-q; Pl. 21, Figs. a-n, p.

1831 *Comatula tenella* sp. nov. – Goldfuss, p. 204, Pl. 62, Fig. 1.

1831 *Comatula pectinate* sp. nov. – Goldfuss, p. 205, Pl. 62, Fig. 2.

1831 *Comatula filiformis* sp. nov. – Goldfuss, p. 205, Pl. 62, Fig. 3.

1892 *Saccocoma tenella* Goldfuss – Jaekel, p. 659-694, Pl. 29, Fig. 6.

1960 *Saccocoma tenella* Goldfuss – Verniory, p. 250-257, Figs. 1-9.

1979 *Saccocoma tenella* Goldfuss – Pisera & Dzik, p. 810-811, Fig. 3a-g; Pl. 1, Figs. 8-9; Pl. 2, Figs. 1-7; Pl. 3, Figs. 1-3.

1980 *Saccocoma tenella* Goldfuss – Holzer & Poltnig, p. 207-215, Fig. 2, Pl. 1, Figs. 1-13; Pl. 2, Figs. 1-16; Pl. 3, Figs. 1-3.

1987 *Saccocoma tenella* Goldfuss – Gluchowski, p. 39-40, Fig. 13: 7-10, Pl. 17, Figs. 1, 4-6; Pl. 18, Figs. 1-5; Pl. 19, Figs. 1-6.

1994 *Saccocoma tenella* Goldfuss – Milsom, Text-Figs. A, B.

2002 *Saccocoma tenella* Goldfuss – Hess, p. 20-21, Figs. 12, 13.

2002 *Saccocoma* cf. *tenella* Goldfuss – Hess, Pl. 9, Figs. 8-13.

2006 *Saccocoma tenella* Goldfuss – Brodacki, p. 264-268, Figs. 3A-E, 4A, B, 5A-D, H, I, 6A, B, E, F, H, I.

2009 *Saccocoma tenella* Goldfuss – Kroh & Lukeneder, p. 390, Fig. 4.

2011 *Saccocoma tenella* Goldfuss – Hess & Etter, Fig. 1.

Description:

The radial plates are thin, convex and arrow-head shaped with distinct zig-zag suture at the lateral margins. The inner surface of the radials is smooth with thin median ridge while the exterior surface is characterized by the network of anastomosing ridges and the pronounced median ridge at the center of the plates. The first primibrachial (IBr$_1$) is simple and cylindrical first element of the arm. It includes distinct ligament fossae on the proximal side while two well-developed muscle fields are positioned on the oral side. The aboral side is characterized by a sloping, non-muscular articulation facet. The second primibrachial (IBr$_2$) is distinguished by two large, symmetrical, dish-like wing structures. The first secundibrachial (IIBr$_1$) and IBr$_1$ resemble each other. The articulation facet of wingless third secundibrachial (IIBr$_3$) is non-muscular and it is almost perpendicular to the axis of arm. IIBr$_3$ resembles IBr$_1$ with its shape and the proximal articulation facet but it is smaller in size. The well-developed wing-like expansions are only positioned in IBr$_2$ and IIBr$_{2, 4\text{-}7}$ respectively and their size become smaller towards the higher order secundibrachials (Jaekel, 1892). IIBr$_8$ and higher order secundibrachials are termed as the distal brachials and they are characterized by elongate, stick-like simple shape with high and flat, paired oral processes.

Remarks:

All radial plates were extracted as broken or small pieces. They probably belong to *Saccocoma tenella* Goldfuss. The sizes of the radial pieces are distinctly greater than the brachials but they are smaller than 7-8 mm as reported in other studies (Gluchowski, 1987; Holzer & Poltnig, 1980). The serrate structure of lateral margins was easily observed in all radial plates. The wingless primi- and secundibrachials (IBr$_1$, IIBr$_1$ and IIBr$_3$) were extracted as well-preserved elements of the arm. The distal brachials were identified with their simple, elongated, stick-like shapes in different sizes. The extracted winged primibrachial and secundibrachials were differentiated from each other by the roundness and the variable sizes of the wings. The size of the wings gradually decreased and they became narrower towards $IIBr_7$ in the investigated materials. The radials of *Saccocoma tenella* Goldfuss differ from *Saccocoma vernioryi* Manni & Nicosia by the lack of spines. *Saccocoma tenella* Goldfuss can be also distinguished from *Saccocoma vernioryi* Manni & Nicosia by dish-like wings on the brachials.

Occurrence:

The first occurrence of *Saccocoma tenella* Goldfuss corresponds to the Lower Tithonian (Brodacki, 2006). Kroh & Lukeneder (2009) defined the range of *Saccocoma tenella* as the Late Kimmeridgian- Late Tithonian time interval based on their study in Austria (2009) which coincides the previous studies such as Milsom (1994, Late Kimmeridgian, Dorset-UK), Verniory (1960, Late Kimmeridgian, France), Jaekel (1892, Early Tithonian, Southern Germany), Brodacki (2006, Early-Middle Tithonian, the Pieniny Klippen Belt- Poland). It is the most common species of *Saccocoma* Agassiz by its longer stratigraphic range. This species was identified in the sample BA-05 representing the Late Tithonian.

Saccocoma vernioryi Manni & Nicosia (1984)

Pl. 16, Figs. n, q; Pl. 17, r-s; Pl. 18, Figs. a-l, n, o, q-s, u-w;

Pl. 19, Figs. a-r; Pl. 20, Figs. b-k, m, o-q, t.

1972 *Saccocoma* sp. – Hess, p. 639, Pl. 2, Figs. 24a, b, c.

1972 Saccocomid non-identifiable element – Hess, p. 639, Pl. 2, Figs. 26a, b.

1979 *Saccocoma* cf. *quenstedti* – Pisera & Dzik, p. 812, Figs. 4a, c, d, e.

1984 *Saccocoma vernioryi* n. sp. – Manni & Nicosia, p. 91-96, Figs. 1-16.

1987 *Saccocoma* cf. *quenstedti* Sieverts-Doreck & Hess – Gluchowski, p. 40-41, Pl. 17, Figs. 2-3, Fig. 13.11.

2006 *Saccocoma vernioryi* Manni & Nicosia – Brodacki, p. 265-268, Figs. 3F-I, 4F, 5G, 6D.

Description:

The radial characteristics are similar with *Saccocoma tenella* Goldfuss except the presence of four spines projecting upward and downward near the bulbous articulation. IBr_1 is characterized by cylindrical and wingless structure with wide and slightly sloping distal articulation surface. Two well-developed, distally diverging grooves are observed in the ventral side and a central articulation pit is observed in the dorsal side. IBr_2 is characterized by the presence of four wings which are grouped as two principal and two secondary wings. The brachial has triangular outline due to these principal and transversal wings. A central adoral groove is positioned in the ventral side (Manni & Nicosia, 1984). $IIBr_3$ is also characterized as wingless secundibrachial with a cylindrical shape as in *Saccocoma tenella* Goldfuss. The winged $IIBr_2$ and $IIBr_4$ are identified by two principal and two transversal secondary wings which are attached to the base of cylindrical body. The higher order secundibrachials also have four wings attached to the cylindrical body. The distal brachials are similar with these parts of *Saccocoma tenella* Goldfuss.

Remarks:

The spines of the radials could not be observed in the investigated materials. It is difficult to differentiate the first primibrachials of *Saccocoma tenella* Goldfuss and *Saccocoma vernioryi* Manni & Nicosia because of the identical structure with the sloping articulation facet. The most characteristic feature of this species is the presence of principal and transversal wings on the brachials. The wings of *Saccocoma vernioryi* Manni & Nicosia are bell-shaped and triangular in outline. Some investigated winged-brachials were classified as *Saccocoma vernioryi* due to the narrow wings, the small brachial size and the nebulous secondary wings. The distal brachials are also identical with *Saccocoma tenella* Goldfuss. The spines on the radials are also identified in the species *Saccocoma quenstedti* (Sieverts-Doreck & Hess, 2002). However, the Kimmeridgian aged *Saccocoma quenstedti* includes two spines on radials with different shape (Vernioryi, 1961; Manni & Nicosia, 1984). This species was identified by the bell-shaped structure of the wings.

Occurrence:

This species was first identified in the Tithonian aged strata of the Central Apennines, Italy (Manni & Nicosia, 1984). Manni & Nicosia (1984) also described the "*Saccocoma* level" in the studied outcrop as intercalations of *Saccocoma tenella* Goldfuss and *Saccocoma vernioryi* Manni & Nicosia. It was previously identified in the Lower-Middle Tithonian aged strata in the Red Rogoznik Coquina, Pieniny Klippen Belt, Poland (Pisera & Dzik, 1979; Brodacki, 2006) and the Deep Sea Drilling Project (Hess, 1972). The Lower- Middle Tithonian age was assigned to the range of *Saccocoma vernioryi* (Manni & Nicosia, 1984). This species was identified in the sample BA-05 belonging to the Tithonian age.

5.3. Benthic Foraminifera

The benthic foraminifera identified in thin sections of the studied Jurassic-Cretaceous pelagic limestone unit were scarcely observed. They were most probably transported from the slope or the shallower part of the carbonate platform.

Order FORAMINIFERIDA Eichwald, 1830

Suborder TEXTULARIINA Delage & Herouard, 1896

Family TEXTULARIIDAE Ehrenberg, 1838

Genus *Textularia* Defrance, 1824

Type species: *Textularia sagittula* Defrance, 1824

Textularia sp.

Pl. 22, Figs. a-h.

The finely agglutinated, biserial tests were termed as *Textularia* sp. in this study. The specimens were composed of semiglobular or nearly rectangular chambers in 4-7 rows. *Textularia* sp. species were recognized intervally in samples representing the Tithonian- Early Berriasian time interval throughout the studied section. This species was observed in the samples BA-01, BA-02, BA-32, BA-43 respectively. They were identified as a few so they would be transported from the shallower part of the carbonate platform by turbidity currents or other transportation mechanism.

Superfamily SPIROPLECTAMMINACEA Cushman, 1927

Family TEXTULARIOPSIDAE Loeblich & Tappan, 1982

Genus *Haghimashella* Neagu & Neagu,1995

Type species: *Haghimashella arcuata* Haeusler, 1890

Haghimashella? sp.

Pl. 22, Figs. i-j.

The free, finely agglitunated test of this species is composed of the uniserial stage following the short early biserial stage with deep oblique sutures. The sutures in the uniserial stage are not perpendicular to the axis of growth. The distinguished specimens in this study were characterized by 2-3 chambers of the uniserial stage following the early biserial stage and they were found in the samples representing the Tithonian age. This species was noted with a question mark because there were only two specimens within the samples BA-14 and BA-23 respectively. These forms were classified as *Haghimashella*? sp. based on the uniserial part after the biserial stage.

Suborder LAGENINA Delage and Herouard, 1896

Superfamily NODOSARICEA Ehrenberg, 1838

Family VAGINULINIDAE Reuss, 1860

Subfamily LENTICULININAE Chapman, Parr and Collins, 1934

Genus *Lenticulina* Lamarck, 1804

Type species: *Lenticulites rotulatus* Lamarck, 1804

Lenticulina sp.

Pl. 23, Figs. a-f.

The wall structure is characterized as calcareous and hyaline. The test is planispiral and involute with a swollen lentil like overall shape. The periphery is pointed. The chambers are broad and triangular shape with increasing in size. *Lenticulina* sp. was recognized intervally in throughout the studied section representing the Tithonian-Berriasian time interval. They were identified by its wall structure, lenticular shape and planispiral involute coiling in this study.

Suborder MILIOLINA Delage and Herouard, 1896

Family HAUERINIDAE Schwager, 1876

Genus *Meosiloculina* Neagu, 1984

Type species: *Quinqueloculina danubiana* Neagu, 1968

Moesiloculina sp.

Pl. 23, Fig. g.

The calcareous, porcelaneous walled test characterizes quinqueloculine type coiling. In transverse sections, carinae like thickening can be observed at the peripheral side of the test. This species was recognized by the pointed chambers at the peripheral side of the test in the sample BA-14 representing the Upper Tithonian.

Family NUBERCULARIDAE Jones, 1875

Subfamily NUBERCULLINELLINAE Jones, 1875

Genus *Hechtina* Bartenstein and Brandt, 1949

Type species: *Hechtina praeantiqua* Bartenstein and Brandt, 1949

Hechtina? sp.

Pl. 23, Figs. h, i.

The calcareous, porcelaneous, imperforate test is subglobular or flattened. The early whorls are irregularly enrolled while the coiling turns to more regular and to the streptospiral type. This species was noted by a question mark because the aperture system and the number of chambers per whorl were not observed in the thin sections. The number of specimens was inadequate for the classification at the species level.

Suborder SPIRILLININA Hohenegger and Piller, 1977

Family SPIRILLINIDAE Reuss and Fristch, 1861

Genus *Spirillina* Ehrenberg, 1843

Type species: *Spirillina vivipara* Ehrenberg, 1843

Spirillina sp.

Pl. 24, Figs. a-l.

The calcareous hyaline walled test is defined as discoidal and bilocular evolute including a spherical proloculus and planispirally coiled, gradually enlarged, undivided tube. The earlies whorls may represent streptospiral coiling. The whorl number generally changes as 4-8 in a complete specimen. The differentiations of the species were noted as changing of coiling type, chamber thickness and arrangement and number of whorls. The axial sections of *Spirillina* were recognized as spherical in thin sections. According to these criteria, different *Spirillina* species were designated such as Spirillina sp.1, Spirillina sp.2, Spirillina sp.3, Spirillina sp.4 respectively.

Spirillina sp.1

Pl. 25, Figs. a-g.

Discoidal, slightly biconcave, planispirally coiled test was characterized as thin and elongated in axial section. The species was distinguished by 5-6 whorls including elongated chambers and narrower prolocular region. The proloculus was not clearly observed in specimens. It was identified in samples BA-22,28,42,45,46,50,51 throughout the studied section.

Spirillina sp.2

Pl. 25, Figs. h-q.

Discoidal test was characterized as initial streptospirally coiled part and later planispirally coiled tube. Thickening of the chamber wall causes a swollen central part unlike *Spirillina* sp.1. The last 3 whorls surrounded this swollen part were clearly observed as planispirally coiling. This species was observed in the samples of the studied section representing a wide range from the *Chitinoidella* Zone (Late Tithonian) to the *Remaniella* Subzone (Early Berriasian).

Spirillina sp.3

Pl. 26, Figs. a-g.

Discoidal, cylindrical test was distinguished by initially streptospirally coiling and later planispirally coiling tube without thickening of the wall around the central part. The chamber height and width were nearly same in last 4 planispirally coiled whorls. *Spirillina* sp.3 was differentiated from *Spirillina* sp.2 by the lack of thickening of the wall around the central part. This form was observed in a wide range represented from the Chitinoidella Zone (Late Tithonian) up to the *Remaniella* Subzone (Early Berriasian).

Spirillina sp.4

Pl. 26, Figs. h-j.

Discoidal, biconcave, planispirally coiled test was distinguished by distinctly enlarging chambers. The chamber width was greater than height in planispirally coiled last 5 whorls. *Spirillina* sp.4 differs from *Spirillina* sp.1 with the growth rate of the chambers in last whorls and distinct biconcave appearance of the test.

Superfamily NODOSARIOIDEA Ehrenberg, 1838

Family NODOSARIIDAE Ehrenberg, 1838

Subfamily NODOSARIINAE Ehrenberg, 1838

Genus *Nodosaria* Lamarck, 1816

Type species: *Nautilus radicula* Linné, 1758

Nodosaria sp.

Pl. 27, Figs. a-n.

The shell is composed of chambers arranged in a straight or gently curved line. The aperture can be observed in the straight forms in thin sections. Some species are composed of only two or three. The form is highly variable in number of segments, the shape and size of the segments and it is also classified according to the presence of ornamentations on the shell. This form could be recognized only at the level of the genus in this study.

CHAPTER 6

DISCUSSION AND CONCLUSION

The main purpose of this thesis is to determine the exact position of the Jurassic-Cretaceous boundary in the pelagic limestone block located on the south of Ankara-Eskişehir road, which is known as the Alcı Block. The specified aim has been achieved by means of the lithostratigraphic and the biostratigraphic studies, the microfacies analyses and the identification of calpionellids, foraminifera and the *Saccocoma* species in terms of their morphological/taxonomical features. However, the delineation of the Jurassic-Cretaceous boundary in the pelagic Alcı Block was completely predicated on the calpionellid species and their biozonations. The "explosion" or "blooms" of the spherical *Calpionella alpina* at the base of the Berriasian, which was previously designated by Remane et al. (1986), Borza & Michalik (1986), Altıner & Özkan (1991), Pop (1994), Adatte et al. (1994), Reháková & Michalik (1997), Grün & Blau (1997), Houša et al. (1999), Andreini et al. (2007), Reháková et al. (2009) and the Berriasian Working Group (WG) of the International Subcommission on Cretaceous Stratigraphy (Wimbledon et al., 2011), was used as the criterion for this aim.

A total of 55 samples were collected from the BA stratigraphic section (59,30 meters) in the Alcı Block. After determining the possible level of the J /K boundary, the 2,08 m thick interval in between the samples BA-41 and BA-45 was resampled on a centimeter scale (about 10 cm interval) and 17 additional samples were collected to obtain a high-resolution biostratigraphy. On the other hand, the "*Saccocoma* level" was detected in thin section analyses as the rock forming quantity of *Saccocoma* in the sample BA-05 representing the Upper Tithonian. The *Saccocoma* species could not be identified by using only thin section views because of their complex morphologic structures such as primibrachials, secundibrachials, distal brachials, wings, radial plates. Therefore, totally 543 gr sample of the BA-05 was washed by using different acid combinations with different waiting periods. The sample BA-05 was quite hard to apply the conventional methods used for the extraction of *Saccocoma* elements from the rock. Thus, 11 different methods were generated for this study in order to extract the skeletal elements of *Saccocoma* Agassiz (1836) as well preserved materials for the species designation issue. These specimens of *Saccocoma* were also photographed by the SEM (Scanning Electron Microscope).

As a result of the studies described above the following findings have been obtained.

1. Unlike the other Jurassic-Cretaceous time boundary studies, the exact position of the Jurassic-Cretaceous boundary was determined by the quantitative method instead of using only the term “explosion” or “blooms” of *Calpionella alpina* at the base of the Berriasian. According to the quantitative analyses, the time boundary was delineated at the level represented by the sample BA-42/3. For this purpose, all *Calpionella alpina*, *Crassicollaria parvula*, *Tintinnopsella* and full-spherical sections of the hyaline calpionellids were counted separately in the samples BA-41, BA-42/1, BA-42/3, BA-43/1, BA-43/3, BA-43/5 and the loricas of these calpionellid species were also measured at different positions on the wall for the comparison. The distinct increase in the percentage of *Calpionella alpina* was recorded in the sample BA-42/3. This quantitative method gave more accurate results about the position of the boundary compared to the visual approach as the term “explosion” or “blooms”.
2. Besides of the detailed calpionellid biozonations, the ranges of microgranular and hyaline calpionellids were represented by drawings of each calpionellid forms via thin section views. Totally 3 calpionellid zones (*Chitinoidella*, *Crassicollaria* and *Calpionella* zones) and 5 subzones

(*boneti*, *remanei*, *massutiniana*, *alpina* and *Remaniella* subzones) were identified in the studied section by means of the first (FO) and the last occurences (LO) of the species.

3. The *Saccocoma* species were identified for the first time in Turkey by this thesis. *Saccocoma* has been only recognized in the thin sections and it was only termed as "*Saccocoma* sp." or "*Saccocoma* fragments" in Turkey. However, it was studied at the level of species by means of the extracted elements of *Saccocoma* specimens in this thesis. The species were identified in the sample BA-05 representing the "*Saccocoma* level" as the rock forming quantity of *Saccocoma*. As a result, two *Saccocoma* species were defined according to the morphological features of the brachials and the wings recognized in the investigated materials. These Tithonian species were *Saccocoma tenella* Goldfuss and *Saccocoma vernioryi* Manni & Nicosia.
4. The complete morphological structure of *Saccocoma tenella* Goldfuss was also drawn as 2-D by using the extracted brachials, wings and radial plates.
5. *Saccocoma tenella* Goldfuss and *Saccocoma vernioryi* Manni & Nicosia were used as the time indicators for the first time in Turkey such that the simultaneous occurrence of these species directly indicates the Late Tithonian age for the investigated level within the Jurassic-Cretaceous age succession of this thesis.
6. The small benthic foraminifera assemblage of the succession includes *Textularia* sp., *Haghimashella*? sp., *Lenticulina* sp., *Moesiloculina* sp., *Hechtina*? sp., *Spirillina* sp., *Nodosaria* sp. These small benthic foraminifera were observed as rare in some calciturbiditic intercalations supporting the idea of the distal calciturbidites.
7. In addition to the field observations on the lithology, the microfacies analysis has been carried out to determine the depositional environment of the studied sequence. Totally 5 microfacies types were recognized in the studied succession by thin section analyses. They are the Radiolarian

bioclastic wackestone-packstone, the Radiolarian wackestone to packstone, the Calpionellid-Radiolaria wackestone to packstone, the Calpionellid packstone and the *Saccocoma* packstone. The boundary was defined in the Calpionellid packstone microfacies (the sample BA-42/3). The grey to white, thin to medium bedded limestone-marl alternations with calciturbiditic intercalations throughout the studied section represent the Yosunlukbayırı Formation as the origin of this pelagic limestone block. The porcellaneous limetones of the Soğukçam Limestone unit could not be observed in this studied section in conrast to the studies carried out in the Mudurnu-Nallıhan-Beypazarı region (Altıner et al., 1991). Although the Alcı Block was previously defined as the pelagic limestone block of the Soğukçam Limestone by Okay & Altıner (2017), the term "Soğukçam Limestone" was used as the "Soğukçam *sēnsū lātō"* in that study. It does not represent the meaning of "the true Soğukçam Limestone". However, the use of term "Soğukçam Limestone" causes a misperception about the lithology of this succession. Because, this pelagic limestone block was completely originated from the Yosunlukbayırı Formation. The studied limestone block of the Alacaatlı Olistostromes was also defined as the distal pelagic deposition (basinal facies) of the carbonate platform (Bilecik Carbonate Platform) based on the dominant pelagic fossil assemblage (calpionellids), infrequent small benthic foraminifera and frequently observed distal calciturbidites throughout the studied section. It was also synchronous with the Günören Limestone which represents the shallow marine deposition of this carbonate platform and the studied succession of the Yosunlukbayırı Formation would be fed by the sediments of the Günören Limestone as in-situ position.

REFERENCES

Adatte, T., Remane, J., Stinnesbeck, W. and Hubberten, H. (1996). Paleoceanographic changes at the Jurassic-Cretaceous boundary in the Western Tethys, northwestern Mexico, *Cretaceous Research, 17*, 671-689.

Alleman, F., Catalano, R., Fares, F. and Remane, J. (1971). Standard calpionellid zonation (Upper Tithonian – Valanginian) of the Western Mediterranean province in: Farinacci, A. (eds.), *Proceedings of the II Planktonic Conference, Roma 1970*, 1337-1340.

Allen, P. & Wimbledon, W.A. (1991). Correlation of NW European Purbeck-Wealden (nonmarine Lower Cretaceous) as seen from the English type-areas, *Cretaceous Research, 12*, 511-526.

Altıner, D. (1991). Microfossil biostratigraphy (mainly foraminifers) of the Jurassic – Lower Cretaceous carbonate successions in north-western Anatolia, Turkey, *Geologica Romana, 27*, 167-213.

Altıner, D. & Özkan, S. (1991). Calpionellid zonation in north-western Anatolia (Turkey) and calibration of the stratigraphic ranges of some benthic foraminifera at the Jurassic – Cretaceous boundary, *Geologica Romana, 27,* 215-235.

Altıner, D., Koçyiğit, A., Farinacci, A., Nicosia, U. and Conti, M.A. (1991). Jurassic – Lower Cretaceous stratigraphy and paleogeographic evolution of the southern part of northwestern Anatolia (Turkey), *Geologica Romana, 27,* 13-80, 36 figs.

Altınlı, İ.E. (1965a). İnegöl havzasının jeolojisi ve hidrojeolojisi, *İ. Ü. Fen. Fakültesi Mecmuası B, 28*(3-4), 173-199.

Altınlı, İ.E. (1965b). Yenişehir havzasının jeolojik ve hidrojeolojik incelenmesi, *İ. Ü. Fen. Fakültesi Mecmuası B, 30*(1-2), 31-51.

Altınlı, İ.E. (1973a). Orta Sakarya jeolojisi, *Cumhuriyet' in 50. yılı Yerbilimleri Kongresi*, *Tebliğler*, 159-191.

Altınlı, İ.E. (1973b). Bilecik Jurasiği, *Cumhuriyet' in 50. yılı Yerbilimleri Kongresi, Tebliğler*, 103-111.

Altınlı, İ.E. (1977). Geology of the Eastern Territory of Nallıhan (Ankara province), *İ. Ü. Fen. Fakültesi Mecmuası B*, *42*, 29-44.

Altınlı, İ.E. & Saner, S. (1971). Bilecik yakın dolayının jeolojik incelenmesi, *İ. Ü. Fen. Fakültesi Mecmuası B, 36*(1-2), 9-21.

Altınlı, İ.E. & Yetiş, C. (1972). Bayırköy – Osmaneli alanının jeolojik incelenmesi, *İ. Ü. Fen. Fakültesi Mecmuası B, 37*(1-2), 1-18.

Andreini, G., Caracuel, J.E. and Parisi, G. (2007). Calpionellid biostratigraphy of the Upper Tithonian - Upper Valanginian interval in Western Sicily (Italy), *Swiss Journal of Geosciences, 100*, 179–198.

Atasoy, S.G. (2017). Foraminiferal and Calpionellid Biostratigraphy, Microfacies Analyses and Tectonic Implications of the Upper Jurassic-Lower Cretaceous Carbonate Platform to Slope Successions in Sivrihisar Region (Eskişehir, NW Turkey), *MSc. Thesis, Middle East Technical University*, 254 p.

Bakalova, D. (1977). La succession a calpionelles de la coupe pres du village de Ginci, Bulgarie du Nord-Ouest. *Comptes rendus de l'Academie bulgare des Sciences*, *30*, 423–426.

Bakalova-Ivanova, D. (1986). Peculiarities of the calpionella zone in Bulgaria, *Acta Geologica Hungarica*, *29,* 89–92.

Banner, F.T. & Desai, D. (1988). A review and revision of the Jurassic – Early Cretaceous Globigerinina, with especial reference to the Aptian assemblages of Speeton (Nowth Yorkshire, England), *J. micropalaeontology*, *7*(2), 143-185.

Basson, P.W. & Edgell, H.S. (1971). Calcareous algae from the Jurassic and Cretaceous fo Lebanon, *Micropaleontology, 17*(4), 411-433.

Batman, B., Kulaksız, S. and Görmüş, S. (1978). A study of the deformational properties of the Jurassic-Cretaceous sequence in the Alacaatlı region (SW Ankara), Turkey, *Yerbilimleri, 4*, 135-152.

Benzaggagh, M., Cecca, F. and Rouget, I. (2010). Biostratigraphic distribution of ammonites and calpionellids in the Tithonian of the internal Prerif (Msila area, Morocco), *Palaontologische Zeitschrift, 84,* 301-315.

Bingöl, E., Akyürek, B., and Korkmazer, B. (1973). Biga yarımadasının jeolojisi ve Karakaya Formasyonu'nun bazı özellikleri, *Cumhuriyet'in 50. yılı, Yerbilimleri Kongresi, Tebliğler*, 70-76.

Blau, J. & Grün, B. (1997). Late Jurassic/Early Cretaceous revised calpionellid zonal and subzonal division and correlation with ammonite and absolute time scales, *Mineralia Slovaca, 29,* 297-300.

Boorovȧ, D., Skupien, P., Vašiček, Z. and Lobitzer, H. (2015). Biostratigraphy of the Lower Cretaceous Schrambach Formation on the classical locality of Schrambachgraben (Northern Calcareous Alps, Salzburg Area), Bulletin of Geosciences, *Czech Geological Survey,* Prague, *90*(1), 89-131.

Borza, K. (1969). Die mikrofazies und mikrofosilien des Oberjuras und der Unterkreide der Klippen-Zone der West-karpatien, *Verlag der Slowakischen Akademie der Wissenschaften,* Bratislava, 302 p.

Borza, K. (1984). The Upper Jurassic-Lower Cretaceous parabiostratigraphic scale on the basis of Tintinninae, Cadosinidae, Stomiosphaeridae, Calcisphaerulidae and other microfossils from the West Carpathians, *Geol. Zborn. Geol. Catpath., 35,* 539-550.

Borza, K. & Michalik, J. (1986). Problems with delimitation of the Jurassic/Cretaceous boundary in the Western Carpathians, *Acta Geologica Hungarica, 29*(1-2), 133-149.

Boudagher - Fadel, M.K., Banner, F.T. and Whittaker, J.E. (with a contribution by M.D. Simmons) (1997). The early evolutionary history of planktonic foraminifera, London, *Chapman & Hall,* 269 p.

Brodacki, M. (2006). Functional anatomy and mode of life of the latest Jurassic crinoid *Saccocoma, Acta Palaeontologica Polonica, 51*(2), 261-270.

Brönnimann, P. (1953). On the occurrence of Calpionellids in Cuba, *Eclogae geol. Helv., 46,* 263-268.

Brönnimann, P. (1965). Microfossils incertae sedis from the Upper Jurassic and Lower Cretaceous of Cuba, *Micropaleontology, 1*(1), 28-51.

Bucur, I.I. (1988). Les foraminiféres du Crétacé inférieur (Berriasien-Valanginien) de la zone de Reşiţa-Moldova Nouă (Carpathes Méridionales, Roumanie), *Remarques biostratigraphiques, Revue de Paléobiologie,* Genéve, *2*(Benthos'86), 379-389.

Bucur, I.I. (1992). Calpionellids and calcispheres from the Upper Jurassic-Lower Cretaceous deposits in the Resita-Moldova Noua zone, Southern Carpathians, *Romania, 13,* 565-576.

Bucur, I.I. & Săsăran, E. (2005). Micropaleontological assemblages from the Upper Jurassic-Lower Cretaceous deposits of Trascău Mountains and their biostratigraphic significance, *Acta Paleontologica Romaniae, 5,* 27-38.

Bucur, I.I., Hoffmann, M. and Kołodziej, B. (2005). Upper Jurassic-Lowermost Cretaceous Benthic Algae from Tethys and the European Platform: A case study from Poland, *Revista Espanola de Micropaleontologia, 37*(1), 105-129.

Burşuk, A. (1981). Aşkale - Bayburt yöresinde (KB Erzurum) calpionellid biyozonları, *Karadeniz Teknik Üniversitesi Yer Bilimleri Dergisi, Jeoloji*, *1*(1), 21-28.

Burşuk, A. (1982). Eight New Species of Calpionellidae from the Late Jurassic-Lower Cretaceous found in the Kop Mountains (Eastern Anatolia, Turkey), *Karadeniz Üniversitesi Yer Bilimleri Dergisi, Jeoloji*, *2*(1-2), 81-86.

Cadisch, J. (1932). Ein Beitrag zum Calpionellen-Problem, *Geologische Rundschau*, *23*, 241-257.

Catalano, R. (1965). Calpionelle di Calabianca (Castellammare, Sicilia), *Atti della Società Toscana di Scienze Naturali* (A), *72*, 1-26.

Colom, G. (1934). Estudio sobre las calpionelas, *Boletin de la Real Sociedad Espaňola de Historia Natural, 34*, 371-391.

Colom, G. (1939). Tintinnidos fósiles (Infusorios oligótricos), *Las Ciencias*, Madrid, *4*(4), 815-825.

Colom, G. (1948), Fossil tintinnids: loricated ınfusoria of the order of the Oligotricha, *J. Paleontol.*, *22*, 233-263.

Colom, G. (1988). Una Revisión Del Grupo De Los Tintínidos (Infusorios Oligotricos, Loricados). La Evolución De Sus Especies En Los Mares Paleozoicos Y Secundarios, *Revista Espanola De Paleontologia*, *3*, 71-104.

Cope, J.C.W. (1991). Ammonite faunas of the ammonitico rosso of the Pontide Mountains, Northern Anatolia, *Geologica Romana*, *27*, 303-325.

Cope, J.C.W. (2008). Drawing the line: the history of the Jurassic – Cretaceous boundary, *Proceedings of the Geologists' Associations, 119*, 105-117.

Deli, A. & Orhan, H. (2007). Stratigraphy of Jurassic-Cretaceous aged deposits outcropping around Alacaatlı-Beytepe village (SW Ankara), Turkey, *Journal of Selçuk University Faculty of Engineering and Architecture, 22*, 61-80.

Derman, A.S. & Sayılı, A. (1995). İnaltı Formation: a key unit for regional geology, in: A. Erler, T. Ercan, E. Bingöl and S. Örçen (eds.), Geology of the Black Sea Region, *General Directorate of Mineral Research and Exploration, and Chamber of Geological Engineers*, Ankara - Turkey, 99-103.

D'Orbigny, A. (1842-1851). Paléontologie Français. Description zoologique et géologique de tous les animaux mollusques et rayonnés fossiles de France, Terrains oolitiques ou jurassiques, I. Céphalopodes, Masson, Paris, 642 p.

D'Orbigny, A. (1852). Cours élémentaire de paléontologie et de géologie stratigraphique, 2, Masson, Paris, 383-847.

Drzewiecki, P.A. & Simó, J.A. (2002). Depositional processes, triggering mechanisms and sediment composition of carbonate gravity flow deposits: examples from the Late Cretaceous of the south-central Pyrenees, Spain, *Sedimentary Geology, 146,* 155-189.

Dunham, R.J. (1962). Classification of carbonate rocks according to depositional texture; in: Ham, W. E., Classification of carbonate rocks, *American Association of Petroleum Geologists, Memoir, 1,* 108-121.

Durand-Delga, M. (1957). Une nouvelle forme de Calpionelles, *Publications du Service géologique de l'Algérie* (nouvelle série), *13*, 165-170.

Flügel, E. (2010). Microfacies of carbonate rocks: analysis, interpretation and application (2nd ed.), *Springer,* Verlag Berlin Heidelberg, 1006 p.

Föllmi, K.B., Weissert, H., Bisping, M. and Funk, H. (1994). Phosphogenesis, carbon-isotope stratigraphy, and carbonate-platform evolution along the Lower Cretaceous northern Tethyan margin, *Geological Society of America Bulletin, 106,* 729-746.

Frau, C., Bulot, L.G., Rehȧkovȧ, D., Wimbledon, W.A.P. and Ilfirm, C. (2016). Revision of the ammonite index species Berriasella jacobi Mazenot, 1939 and its consequence for the biostratigraphy of the Berriasian Stage, *Cretaceous Research*, *66*, 94-114.

Gawlick, H.J. & Schalgintweit, F. (2010). The drowning sequence of Mount Bürgl in the Salzkam-Mergut Area (Northern Calcareous Alps, Austria): evidence for a diachronous Late Jurassic to Early Cretaceous drowning of the Plassen Carbonate Platform, *Austrian Journal of Earth Sciences*, *103*(1), 58-75.

Genç, Ş. (1986). Uludağ – İznik Gölü arasının jeolojisi, *M.T.A. Jeoloji Dairesi Rap. Arşv.*, unpublished report, *243*, 122 p.

Genç, Ş., Selguk, H., Cevher, F., Gözler, Z., Karaman, T., Bilgi, C., and Akgören, F. (1986). İnegöl (Bursa) – Pazaryeri (Bilecik) arasının jeolojisi, *M.T.A. Jeoloji Dairesi Rap. Arşv.*, unpublished report, *255*, 68 p.

Görür, N., Şengör, A.M.C., Akkök, R., and Yılmaz, Y. (1983). Pontidlerde NeoTetis'in kuzey kolunun açılmasına ilişkin sedimentolojik veriler, *Türkiye Jeoloji Kurumu Bülteni*, *26*, 11-19.

Grabowski, J. & Pszczółkowski, A. (2006). Magneto- and biostratigraphy of the Tithonian - Berriasian pelagic sediments in the Tatra Mountains (central Western Carpathians, Poland): sedimentary and rock magnetic changes at the Jurassic/Cretaceous boundary, *Cretaceous Research*, *27*, 398-417.

Granit, Y. & Tintant, H. (1960). Observation préliminaires sur le Jurassique de la region de Bilecik (Turquie), *C. R. Acad. Sc. Paris*, *251*, 1807-1803.

Grün, B. & Blau, J. (1996). Phylogenie, systematik und biostratigraphie der Calpionellidae Bonet, 1956: neue daten aus dem rosso ammonitico superiore und dem biancone (Oberjura/ Unterkreide: Tithon-Valangin) von Ra Stua (Prov., Belluno, Italien), *Revue de Paléobiologie*, *15*(2), 571-595.

Grün, B. & Blau, J. (1997). New aspects of calpionellid biochronology: proposal for a revised calpionellid zonal and subzonal division, *Revue de Paleobiologie*, *16*(1), 197-214.

Gümüş, A. (1964). Contribution a l'étude géologique du secteur septentrional de Kalabak Köy – Eymir Köy (région d'Edremit, Turquie), *M.T.A. Publ., 117*, 1-109.

Haq, B.U., Hardenbol, J. and Vail, P.R. (1988). Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change. In: Wilgus, C.K., Hastings, B.S., Kendall, C.S., Posamentier, H.W, Ross, C.A. and Van Wagoner, J.C. (eds) *Sea-Level Changes: An Integrated Approach, SEPM*, Tulsa, *Special Publications, 42*, 71-108.

Hess, H. (2002). Remains of Saccocomids (Crinoidea: Echinodermata) from the Upper Jurassic of southern Germany, *Stuttgarter Beitr. Naturk., B, 329,* 57 p., 11 pls., 15 figs., Stuttgart.

Hess, H. & Etter, W. (2011). Life and death of *Saccocoma tenella* (Goldfuss), *Swiss Journal of Geosciences, 104,* 99-106.

Hoedemaeker, P.J. (1982). Ammonite biostratigraphy of the uppermost Tithonian, Berriasian and lower Valanginian along the Río Argos (Caravaca, SE Spain), *Scripta Geologica*, *65,* 1-81.

Houša, V., Krs, M., Man, O., Pruner, P. and Vendohova, D. (1999). Correlation of magnetostratigraphy and calpionellid biostratigraphy of the Jurassic/Cretaceous boundary strata in the Western Carpathians, *Geologica Carpathica, 50,* 125–144.

Houša, V., Pruner, P., Zakharov, V. A., Košťák, M., Chadima, M., Rogov, M. A., Slechta, S. and Mazuch, M. (2007). Boreal-Tethyan Correlation of the Jurassic-Cretaceous boundary interval by magneto- and biostratigraphy, *Stratigr. Geol. Correlation, 15,* 297-309.

Ivanova, D. (1997). Upper Jurassic zonation on cadosinids, stomiosphaerids and calpionellids of the Central Forebalkan, Bulgaria, *Geologica Balcanica, 27*(3-4), 33-47.

Ivanova, D. & Kołodziej, B. (2010). Late Jurassic–Early Cretaceous foraminifera from Štramberk-type limestones, Polish Outer Carpathians, *Studia Universitatis Babeş-Bolyai, Geologia, 55*(2), 3-31.

Jenkyns, H.C. (1986). Pelagic environments in: Sedimentary environments and facies (ed. by H. G. Reeding), *Blackewell Scient. Publ.*, (2nd ed), 343-397.

Kırmacı, M.Z. (1992). Alucra – Gümüşhane - Bayburt yörelerindeki (Doğu Pontid Güney Zonu) Üst Jura - Alt Kretase yaşlı Bedirgs Kireçtaşı'nın sedimentolojik incelemesi, *Doktora Tezi, Karadeniz Teknik Üniversitesi Fen Bilimleri Enstitüsü*, Trabzon, 257 s.

Koçyiğit, A. (1979). Çördük Olistostromları, *Türkiye Jeoloji Kurumu Bülteni, 22*, 59-68.

Koçyiğit, A. (1987). Hasanoğlan (Ankara) Yöresinin Tektonostratigrafisi: Karakaya Orojenik Kuşağının Evrimi, *H. Ü. Yerbilimleri, 14*, 269-293.

Koçyiğit, A. & Lünel, A.T. (1987). Geology and Tectonic Setting of Alcı Region, Ankara, *METU Journal of Pure and Applied Sciences, 20*(1), 35-57.

Koçyiğit, A., Özkan, S. and Rojay, B. (1988). Examples from the Forearc Basin Remnants at the Active Margin of Northern Neo-Tethys; Development and Emplacement Ages of the Anatolian Nappe, Turkey, *METU Journal of Pure and Applied Sciences, 21*(1-3), 183-210.

Koçyiğit, A., Altıner, D., Farinacci, A., Nicosia, U., and Conti, M.A. (1991). Late Triassic – Aptian evolution of the Sakarya divergent margin: implications for the opening history of the northern Neo-Tethys in North-Western Anatolia, Turkey, *Estratto da Geologica Romana, 27*, 81-99.

Koçyiğiy, A., & Altıner, D. (2002). Tectonostratigraphic evolution of the North Anatolian Paleorift (NAPR): Hettangian – Aptian passive continental margin of the northern Neo-Tethys, Turkey, *Turkish Journal of Earth Science, 11*, 169-191.

Krajewski, M. & Olszewska, B. (2007). Foraminifera from the Late Jurassic and Early Cretaceous carbonate platform facies of the southern part of the Crimea Mountains, southern Ukraine, *Annales Societatis Geologorum Poloniae,* **77**, 291-311.

Krische, O., Bujtor, L. and Gawlick, H-J. (2013). Calpionellid and ammonite biostratigraphy of uppermost Jurassic to Lower Cretaceous sedimentary rocks from the Leube Quarry (Northern Calcareous Alps, Salzburg, Austria), *Austrian Journal of Earth Sciences*, *106*(1), 26-45.

Kroh, A. & Lukeneder, A. (2009). Crinoids from the Late Jurassic of the Nutzhof section (Lower Austria, Gresten Klippenbelt), *Ann. Naturhist. Mus. Wien*., *110A*, 383-399.

Lakova, I., Stoykova, K., Ivanova, D. (1997). Tithonian to Valanginian bioevents and integrated zonation on calpionellids, calcareous nannofossils and calcareous dinocycts from the Western Balkanides, Bulgaria, *Mineralia Slovaca, 29*, 301-303.

Lakova, I., Stoykova, K. and Ivanova, D. (1999). Calpionellid, nannofossil and calcareous dinocyst bioevents and integrated biochronology of the Tithonian to Valanginian in the Western Balkanides, Bulgaria, *Geologica Carpathica, 50*(2), Bratislava, 131-168.

Lakova, I. & Petrova, S. (2012). Towards a standard calpionellid zonation of the Mediterranean Realm (Tithonian to Valanginian), *Bulgarian Geological Soceity National Conference with international participation "GEOSCIENCES 2012" Abstract*, 89-90.

Lakova, I. & Petrova, S. (2013). Towards a standard Tithonian to Valanginian calpionellid zonation of the Tethyan Realm, *Acta Geologica Polonica, 63*(2), 201-221.

Loeblich, A.R.Jr. & Tappan, H. (1988). Foraminiferal genera and their classification, *von Nostrand Reinhold Company*, New York, 2 volumes, 970 p.

López-Martinez, R., Barragȧn, R. and Rehȧkovȧ, D. (2013). The Jurassic/Cretaceous boundary in the Apulco area by means of calpionellids and calcareous dinoflagellates: An alternative to the classical Mazatepec section in eastern Mexico, *Journal of South American Earth Sciences*, *47*, 142-151.

López-Martinez, R., Barragȧn, R., Rehȧkovȧ, D. and Cobiella-Reguera, J.L. (2013). Calpionellid distribution and microfacies across the Jurassic/Cretaceous boundary in western Cuba (Sierra de los Órganos), *Geologica Carpathica*, *64*(3), 195-208.

López-Martinez, R., Barragȧn, R. and Rehȧkovȧ, D. (2015). Calpionellid biostratigraphy across the Jurassic/ Cretaceous boundary in San José de Iturbide, Nuevo León, northeastern Mexico, *Geological Quarterly*, *59*(3), 581-592.

Manni, R. & Nicosia, U. (1984). *Saccocoma vernioryi* n.sp., A New Saccocomid from The Upper Jurassic of the Central Italy, *Geologica Roma*, *23*, 91-97, 16 figs.

Manni, R., Nicosia, U. and Tagliacozzo, L. (1997). *Saccocoma* as a normal benthonic stemless crinoid: an opportunistic reply within mud-dominated facies, *PALAEOPELAGOS*, *7*, 121-132, Italy.

Marino, M.C., Andreini, G., Baldanza, A., D'Arpa, C., Mariotti, N., Pallini, G., Parisi, G., and Petti, F.M. (2004). Middle Jurassic-Early Cretaceous integrated biostratigraphy (ammonites, calcareous nannofossils and calpionellids) of the Contrada Diesi Section (south-western Sicily, Italy), *Rivista Italiana Di Paleontologia e Stratigrafia*, *110*(1), 357-372.

Matyszkiewicz, J. & Slomka, T. (1994). Organodetrital conglomerates with ooids in teh Cieszyn Limestone (Tithonian-Berriasian) of the Polish Flysch Carpathians and their paleogeographic significance, *Annales Societatis Geologorum Poloniae*, *53*, 211-248.

Mekik, A.F. (1994). An Attempt to Reconstruct the Jurassic-Cretaceous Successions of the Damlaağaçderesi Sedimentary Melange: Stratigraphic and Micropaleontologic Analyses, *MSc Thesis*, *Middle East Technical University*, Turkey, 526 pages.

Mekik, F.A., Ling, H.Y., Özkan-Altıner, S. and Altıner, D. (1999). Preliminary radiolarian biostratigraphy across the Jurassic-Cretaceous boundary from northwestern Turkey, in De Wever, P. and Caulet, J.P. (eds), InterRad VIII, Paris/Bierville 8-13 septembre 1997, *Geodiversitas, 21*(4), 715-738.

Michalík, J., Rehåkovå, D., Halásová, E. and Lintnerova, O. (2009). The Brodno section-a potential regional stratotype of the Jurassic/Cretaceous boundary (Western Carpathians), *Geologica Carpathica*, *60*(3), 213-232.

Michalík, J. & Rehåkovå, D. (2011). Possible markers of the Jurassic/ Cretaceous boundary in the Mediterranean Tethys: a review and state of art, *Geoscience Frontiers, 2*(4), 475-490.

Miík, M., Sotåk, J. and Ziegler, V. (1999). Serpulid worms Mercierella Fauvel, Durandella Dragastan and Carpathiella Nov. Gen. from the Upper Jurassic, Cretaceous and Paleogene of the Western Carpathians, *Geologica Carpathica, 50*(4), 305-312.

Milsom, C.V. (1994). Saccocoma: A Benthic Crinoid From The Jurassic Solnhofen Limestone, Germany, *Palaeontology, 37*(1), 121-129.

Monod, O., Andrieux, J., Gautier, Y. and Kienast, J. R. (1991). Pontides-Taurides relationships in the region of Eskişehir (NW Turkey), *Bulletin of the Technical University İstanbul, 44*, 257-278.

Murgeanu, G. & Filipescu, M.G. (1933). Calpionella carpathica n. sp. dans les Carpathes roumaines, *Notationes Biologicae, 1*(2), 63-64.

Nicosia, U. & Parisi, G. (1979). Saccocoma tenella (Goldfus) – Distribuzione stratigrafica e geografica, *Boll. del. Soc. Pal. Italiana, 18*(2), 320-326.

Ogg, J.G. & Hinnov, L.A. (2012). Cretaceous in: Gradstein, F.M., Ogg, J.G., Schmitz, M.D. and Ogg, G.M. (eds.), The Geologcial Times Scale 2012, 793-853.

Ogg, J.G., Ogg, G.M., and Gradstein, F.M. (2016). A concise geologic time scale, *Elsevier*, 234 p.

Okay, A.I. & Tüysüz, O. (1999). Tethyan sutures of northern Turkey, *Geological Society*, London, Special Publications, *156*, 475-515.

Okay, A.I. & Göncüoğlu, M.C. (2004). The Karakaya Complex: a review of Data and Concepts, *Turkish. Journal of Earth Science, 13*, 77-95.

Okay, A.I., Satır, M. and Siebel, W. (2006). Pre-Alpide Palaeozoic and Mesozoic orogenic events in the Eastern Mediterranean region, In: Gee, D.G. and Sephenson, R.A. (eds.), European lithosphere Dynamics, *Geological Society of London*, *Memoirs*, *32*, 389-405.

Okay, A.I. & Altıner, D. (2016). Carbonate sedimentation in an extensional active margin: Cretaceous history of the Haymana region, Pontides, *International Journal of Earth Sciences*, *105*(7), 2013-2030.

Okay, A.I. & Altıner, D. (2017). Alacaatlı Olistostromları: Ankara'da Alcı ve Bağlum bölgelerinin jeolojisi, Middle East Technical University, unpublished research, *Arazi Gezi Kitapçığı*, 1-41.

Olóriz, F., Caracuel, J.E., Marques, B. and Rodriguez-Tovar, F.J. (1995). Associaciones de tintinoides en facies ammonitico rosso de la Sierrar Norte (Mallorca), *Revista Espaňola de Paleontologia*, 77-93.

Olszewska, B. & Wieczorek, J. (2001). Jurassic sediments and microfossils of the Andrychów Klippes (Outer Western Carpathians), *Geologica Carpathica*, *52*(4), 217-228.

Olszewska B. (2010). Microfossils of the Upper Jurassic – Lower Cretaceous formations of the Lublin Upland (SE Poland) based on thin section studies, *Pol. Geol. Inst. Sp. Pap., 26,* 1–32.

Olszewska B., Matyskiewicz, J., Król, K. and Krajewski, M. (2012). Correlation of the Upper Jurassic-Cretaceous epicontinental sediments in southern Poland and southwestern Ukraine based on thin sections, *Biuletyn Państwowego Instytutu Geologicznego, 453,* 29-80.

Oppel, C.A. (1856-1858). Die Juraformation Englands, Frankreichs und des Südwestlichen Deutschlands, *Württemberger Naturforschende Jahreshefte, 12-14,* 857.

Önal, M., Helvacı, C., İnci, U., Yağmurlu, F., Meriç, E., and Tansel, İ. (1988). Çayırhan, kuzeybatı Ankara kuzeyindeki Soğukçam Kireçtaşı, Nardin Formasyonu ve Kızılçay Grubu'nun stratigrafisis, yaşı, fasiyesi ve depolanma ortamları, *T.P.J.D. bulteni, C/ 1-2,* 152-163.

Özkan, S. (1993). Calcareous nannofossils from the Late Jurassic – Early Cretaceous of northwest Anatolia, Turkey, *Geological Journal, 28,* 295-307.

Özkan, S. (1993a). Calcareous nannofossils and calpionellid biostratigraphy of the Upper Jurassic - Lower Cretaceous in Northwest Anatolia, Turkey, University of London, University College London, *Department of Geological Sciences, Ph.D. Thesis,* 336 p., 28 plates.

Öztürk, A. (1968). Çerkeş – Eskipazar – Gerede bölgesinin jeolojisi, *A. Ü. Fen. Fak., Doktora Tezi,* 193 p.

Petrova, S., Rabrenović, D., Lakova, I., Koleva-Rekalova, E., Ivanova, D., Metodiev, L. and Malešević N. (2012). Biostratigraphy and microfacies of the pelagic carbonates across the Jurassic/Cretaceous boundary in eastern Serbia (Stara Planina-Poreć Zone), *Geologica Balcanica, 41*(1-3), 52-76.

Pleş, G., Bucur, I.I. and Păcurariu, A. (2015). Foraminiferal assemblages and facies associations in the Upper Jurassic carbonates from Ardeu Unit (Metaliferi Mountains, Romania), *Acta Palaeontologica Romaniae, 11*(2), 43-57.

Pleş, G., Mircescu, C.V., Bucur, I.I., and Săsăran, E. (2013). Encrusting microorganisms and microbial sutructures in Upper Jurassic limestones from the Southern Carpathians (Romania), *Facies*, *59*, 19-48.

Pop, G. (1974). Une nouvelle espéce néocomienne de Calpionellidés, Révue roumanie de Géologie, Géophysique, *Géographie*, *18*, 105-107.

Pop, G. (1986). Réflexions sur certaines calpionelles néocomiennes, *D. S. Inst. Geol. Geofiz.*, *3*(70-71), 103-108.

Pop, G. (1994a). Calpionellid evolutive events and their use in biostratigraphy, *Romanian Journal of Stratigraphy*, *76*, 7-24.

Pop, G. (1994b). Systematic revision and biochronology of some Berriasian – Valanginian calpionellids (Genus Remaniella), *Geologica Carpathica*, *45*(6), 323-331.

Pop, G. (1996). Trois nouvelles espéces du genre Remaniella (Calpionellidae Bonet, 1956), *Comptes Rendus de I'Académie des Sciences*, Paris, *332,* 317-323.

Pop, G. (1997). Tithonian to Hauterivian praecalpionellids and calpionellids: bioevents and biozones, *Mineralia Slovaca*, *29*, 304-305.

Pruner, P., Houša, V., Olóriz, F., Košt'ak, M., Krs, M., Man, O., Schanbl, P., Venhodová, D., Tavera, J.M. and Mazuch, M. (2010). High-resolution magnetostratigraphy and biostratigraphic zonation of the Jurassic-Cretaceous boundary strata in the Puerto Escano section (southern Spain), *Cretaceous Research*, *31*, 192-206.

Pszczólkowski, A. (1996). Calpionellid stratigraphy of the Tithonian-Berriasian pelagic limestones in the Tatra Mts (Western Carpathians), *Studia Geologica Polonica, 109,* 103-130.

Pszczólkowski, A., García Delgado, D. and Gil González, S. (2005). Calpionellid and Nannoconid Stratigraphy and Microfacies of Limestones at the Tithonian-Berriasian Boundary in the Sierra Del Infierno (Western Cuba), *Annales Societatis Geologorum Poloniae, 75,* 1-16.

Rehảkovả, D. & Michalik, J. (1997a). Calpionellid associations versus Late Jurassic and Early Cretaceous sea – level fluctuations, *Mineralia Slovaca, 29,* 306–307.

Rehảkovả, D. & Michalik, J. (1997). Evolution and distribution of calpionellids– the most characteristic constituents of Lower Cretaceous Tethyan microplankton, *Cretaceous Research, 18,* 493–504.

Rehảkovả, D. (1998). Calpionellid genus Remaniella Catalano 1956 in Lower Cretaceous pelagic deposits of Western Carpathians, *Mineralia Slovaca, 30,* 443-452.

Rehảkovả, D. (2000). Calcareous dinoflagellate and Calpionellid Bioevents Versus Sea-Level Fluctuations Recorded in the West-Carpathian (Late Jurassic/Early Cretaceous) Pelagic Environments, *Geologica Carpathica, 51*(4), 229-243.

Rehảkovả, D. & Wierzbowski, A. (2005). Microfacies and stratigraphi position of the Upper Jurassic Rogoża coquinas at Rogoźnik, Pieniny Klippen Belt, Carpathians, *Tomy Jurajskie, 3,* 15-27.

Rehảkovả, D., Matyja, B.A., Wierzbowski, A., Schlögl, J., Krobicki, M. and Barski, M. (2011). Stratigraphy and microfacies of the Jurassic and lowermost Cretaceous of the Veliky Kamenets section (Pieniny Klippen Belt, Carpathians, Western Ukraine), *Volumina Jurassica, IX,* 61-104.

Remane, J. (1962). Zur Calpionellen-Systematik, Neus Jahbuch für Geologie und Paläontologie, *Monatshefte, 1,* 8-24.

Remane, J. (1971). Les Calpionells, Protozoaires planctoniques des mers mésogéennes de l'époque secondaire, *Annales Guébhard, 47,* 369-432.

Remane, J. (1974). Les Calpionelles, Cours de 3 éme cycle en Sciences de la Terre, partie II, *Paléontologie*, Univ., Genéve, 58 p.

Remane, J. (1985). Calpionellids, In: Bolli, H. M., Saunders, J. B. and Perch-Nielsen, K. (Eds.): Plankton stratigraphy, *Cambridge Earth Science Series*, *Cambridge University Press,* 555-572.

Remane, J., Bakalova-Ivanova, D., Borza, K., Knauer, J., Nagy, I., Pop, G. and Tardi-Filacz, E. (1986). Agreement on the subdivision of the standard calpionellid zones defined at the II planktonic conferecence, Roma 1970, *Acta Geologica Hungarica, 29,* 5-14.

Remane, J. (1991). The Jurassic – Cretaceous boundary: problems of definition and procedure, *Cretaceous Resarch, 12*, 447-453.

Rojay, B. (1993). Tectonostratigraphy and neotectonic characteristics of the southern margin of Merzifon-Suluova Basin (Central Pontides, Amasya), *PhD. Thesis, Middle East Technical University*, Ankara, 215 p.

Rojay, B. & Süzen, M.L. (1997). Tectonostratigraphic Evolution of the Cretaceous Dynamic Basins on Accretionary Ophiolitic Melange Prism, SW of Ankara Region, *TPJD Bülteni, 9*(1), 1-12.

Rojay, B. & Altıner, D. (1998). Middle Jurassic - Lower Cretaceous Biostratigraphy in the Central Pontides (Turkey): Remarks on Paleogeography and Tectonic Evolution, *Rivista İtaliana di Paleontologia e Stratigrafia, 104*(2), 167-180.

Saner, S. (1978). Geology and the environment of deposition of Geyve – Osmaneli – Gölpazarı – Taraklı area, *İ. Ü. Fen. Fakültesi Mecmuası*, *B, 43*, 63-91.

Saner, S. (1980). Mudurnu – Göynük havzasının Jura ve sonrası çökelim nitelikleriyle paleocoğrafik yorumlaması, *Türkiye Jeoloji Kurumu Bülteni*, *23*, 39-52.

Saner, S., Taner, İ., Aksoy, Z., Saiyako, M., and Bürkan, K.A. (1980). Safranbolu havzasının jeolojik yapısı ve Tersiyer paleocoğrafyası, *Türkiye 5. Petrol Kongresi,* 11-112, Ankara.

Sarg, J.F. (1988). Carbonate sequence stratigraphy in: Wilgus, C.K., Hastings, B. S., Posamentier, H., Wagoner, J.V., Ross, C.A. And Kendall, C.G.St.C. (eds) Sea Level Changes: An Integrated Approach, *SEPM. Special Publicaions, 42,* 155-181.

Sarifakioğlu, E., Dilek, Y. and Sevin, M. (2014). Jurassic-Paleogene intraoceanic magmatic evolution of the Ankara Melange, north-central Anatolia, Turkey, *Solid Earth, 5,* 77-108.

Skompski, S. (1982). The nature and systematic position of the microfossils Globochaete alpina Lombard, 1945, *Aota Geologica Polonica*, Warszawa, *32*(12), 47-59.

Skourtsis-Coroneou, V. and Solakius, N. (1999). Calpionellid zonation at the Jurassic/Cretaceous boundary within the Vigla Limestone Formation (Ionian Zone, western Greece) and carbon isotope analysis, *Cretaceous Research, 20,* 583–595.

Şengör, A.M.C and Yılmaz, Y. (1981). Tethyan evolution of Turkey: plate tectonic approach, *Tectonophysics, 75,* 181-241.

Şengör, A.M.C., Yılmaz, Y. and Sungurlu, O. (1984). Tectonics of the Mediterranean Cimmerides: nature and evolution of the western termination of Paleotethys, *Geological Society, London, Special Publications, 17,* 77-112.

Şengör, A.M.C., Altıner, D., Cin, A., Ustaömer, T. and Hsü, K.J. (1988). Origin and assembly of the Tethyside orogenic collage at the expense of Gondwana Land, *Geological Society, London, Special Publications, 37,* 119-181.

Tekeli, O. (1981). Subduction complex of pre-Jurassic age, northern Anatolia, Turkey, *Geology, 9,* 68-72.

Toker, V. (1976). Stratigraphical studies of the area located between Nallıhan and Bozyaka villages along the Sorgun River, Communications de la Faculté de Sciences de l'Université d'Ankara, C 1, *Géologie, 19,* 1-63.

Trejo, M. (1975). Los Tintinidos mesozoicos de México (Taxonomía y datos Paleobiológicos), *Boletin de la Asociación Mexicana de Geólogos Petroleros, 27*(1012), 329-449.

Trejo, M. (1980). Distribucion estratigrafica de los tintinidos mesozoicos mexicanos, *Rev. Inst. Mex. Pet., 12,* 4-13.

Tremolada, F., Bornemann, A., Timothy, J.B., Koeberl, C. and Schootbrugge, B. (2006). Paleoceanographic changes across the Jurassic/Cretaceous boundary: The calcareous phytoplankton response, *Earth and Planetary Science Letters, 241,* 361-371.

Tunç, M. (1991). Aktaş (Kızılcahamam) yöresinin pelajik kireçtaşlarının biyostratigrafisi, *Türkiye Jeoloji Bülteni, C. 34,* 27-42.

Tunç, M. (1992). Olur (Erzurum) yöresindeki Üst Jura – Akt Kretase yaşlı kireçtaşlarının biyostratigrafisi, *Türkiye Jeoloji Bülteni, C. 35,* 121-130.

Tüysüz, O., Yiğitbaş, E., Yılmaz, Y., Serdar, H.S. (1990). Orta Pontidlerde Üst Jura – Alt Kretase stratigrafisi ve tektonik anlamı, *Türkiye 8. Petrol Kongresi Bildirileri,* 340-350.

Ünalan, G. (1981). Stratigraphy of the “Ankara Melange” southwest of Ankara, Turkey, In: Proceedings of the Symposium on the Central Anatolian Geology, *Türkiye Jeoloji Kurumu*, Ankara, 46-52.

Varol, B. & Kazancı, N. (1981). Nallıhan – Seben (Bolu) bölgesinde Üst Jura - Alt Kretase karbonat istifinin lito- ve biyofasiyes özellikleri, *TJK Bülteni, 24*, 31-38.

Velić, I. (2007). Stratigraphy and palaeobiogeography of Mesozoic benthic foraminifera of the Karst Dinarides (SE Europe*), Geologia Croatica, 60*(1), 1-113.

Weynschenk, R. (1950). Die Jura-mikrofauna und –flora des Sonnwendgebirges (Tirol), *Schlern-Schr*., *83,* 1-32.

Wilson, J.L. (1975). Carbonate facies in geologic history, Springer-Verlag, New York, 471 p.

Wimbledon, W.A.P. (2008). The Jurassic – Cretaceous boundary: an age-old correlative enigma, *Episodes, 31*(4), 423-428.

Wimbledon, W.A.P., Casellato, C.E., Rehåkovå, D., Bulot, L.G., Erba, E., Gardin, S., Verreussel, R.M.C.H., Munsterman, D.K. and Hunt, C.O. (2011). Fixing a basal Berriasian and Jurassic/ Cretaceous (J/K) boundary – is there perhaps some light at the end of the tunnel? *Rivista Italiana di Paleontologia e Stratigrafia, 117*(2), 295-307.

Wimbledon, W.A.P., Reháková, D., Halásová, E., Pszczólkowski, A., Casellato, C.E., Frau, C., Bulot, L.G., Grabowski, J., Sobien, K., Pruner, P., Schnabl, P. and Čížková, K. (2013). An account of the bio- and magnetostratigraphy of the Upper Tithonian-Lower Berriasian interval at Le Chouet, Drôme (SE France), *Geologica Carpathica*, *64*(6), 437-460.

Wimbledon, W.A.P. (2014). Warsaw remarks – Berriasian progress, *Volumina Jurassica, XII* (1), 107-112.

Yılmaz, Y., Tüysüz, O., Gözübol, A.M., and Yiğitbaş, E. (1981). Abant (Bolu) – Dokurcan (Sakarya) arasındaki Kuzey Anadolu Fay Zonunun kuzey ve güneyinde kalan tektonik birliklerin jeolojik evrimi, *İstanbul Üniversitesi Yerbilimleri, 1,* 239-261.

Yılmaz, Y., & Tüysüz, O. (1984). Kastamonu – Boyabat – Vezirköprü - Tosya arasındaki bölgenin jeolojisi (Ilgaz - Kargı masiflerinin etüdü), *MTA Raporu,* 275 p.

Yılmaz, A., Adamia, S., Chabukiana, A., Chkhotua, T. Erdoğan, K., Tuzcu, S. and Karabıyıkoğlu, M. (2000). Structural correlation of the southern Transcaucausus (Georgia) – eastern Pontides (Turkey), In: Bozkuert, E., Winchester, J.A., and Piper, J.A.D. (eds.), Tectonics and magmatism in Turkey and surrounding area, London, *Geological Society, Special Publicaiton, 173*, 171-182.

Yılmaz, İ.Ö., Altıner, D., and, Ocakoğlu, F. (2016). Upper Jurassic-Lower Cretaceous depositional environments and evolution of the Bilecik (Sakarya Zone) and Tauride carbonate platforms, Turkey, *Palaeogeography, Palaeoclimatology, Palaeoecology, 449,* 321-340.

APPENDICES

A. APPENDIX A

PLATE 1

- **a.** *Daciella danubica*, BA-01, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **b.** *Daciella danubica*, drawing from the BA-01, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **c.** *Chitinoidella* sp., BA-01, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **d.** *Dobeniella tithonica*, BA-01, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **e.** *Chitinoidella* sp., BA-01, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **f.** *Chitinoidella boneti*, BA-01, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **g.** *Chitinoidella* sp., BA-01, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **h.** *Chitinoidella elongata*, BA-02, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **i.** *Chitinoidella boneti*, BA-02, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **j.** *Chitinoidella boneti*, drawing from the BA-02, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **k.** *Chitinoidella* sp., BA-03, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **l.** *Chitinoidella* sp., drawing from the BA-03, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **m.** *Chitinoidella boneti*, BA-04, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **n.** *Chitinoidella boneti*, drawing from the BA-04, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

o. *Chitinoidella boneti*, BA-06, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

p. *Chitinoidella* sp., BA-07, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

q. *Chitinoidella* sp., BA-07, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

r. *Chitinoidella* sp., drawing from the BA-07, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

s. *Chitinoidella elongata*, BA-07, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

t. *Chitinoidella elongata*, drawing from the BA-07, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

u. *Dobeniella cubensis*, BA-07, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

v. *Chitinoidella* sp., BA-09, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

w. *Chitinoidella boneti*, BA-09, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

x. *Chitinoidella boneti*, BA-09, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

y. *Chitinoidella* sp., BA-10, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

z. *Dobeniella bermudezi*, BA-11, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

aa. *Dobeniella cubensis*, BA-13, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

bb. *Dobeniella cubensis*, drawing from the BA-13, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

cc. *Dobeniella bermudezi*, BA-16, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation

dd. *Chitinoidella boneti*, BA-16, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation

ee. *Chitinoidella boneti*, BA-16, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation

PLATE 1

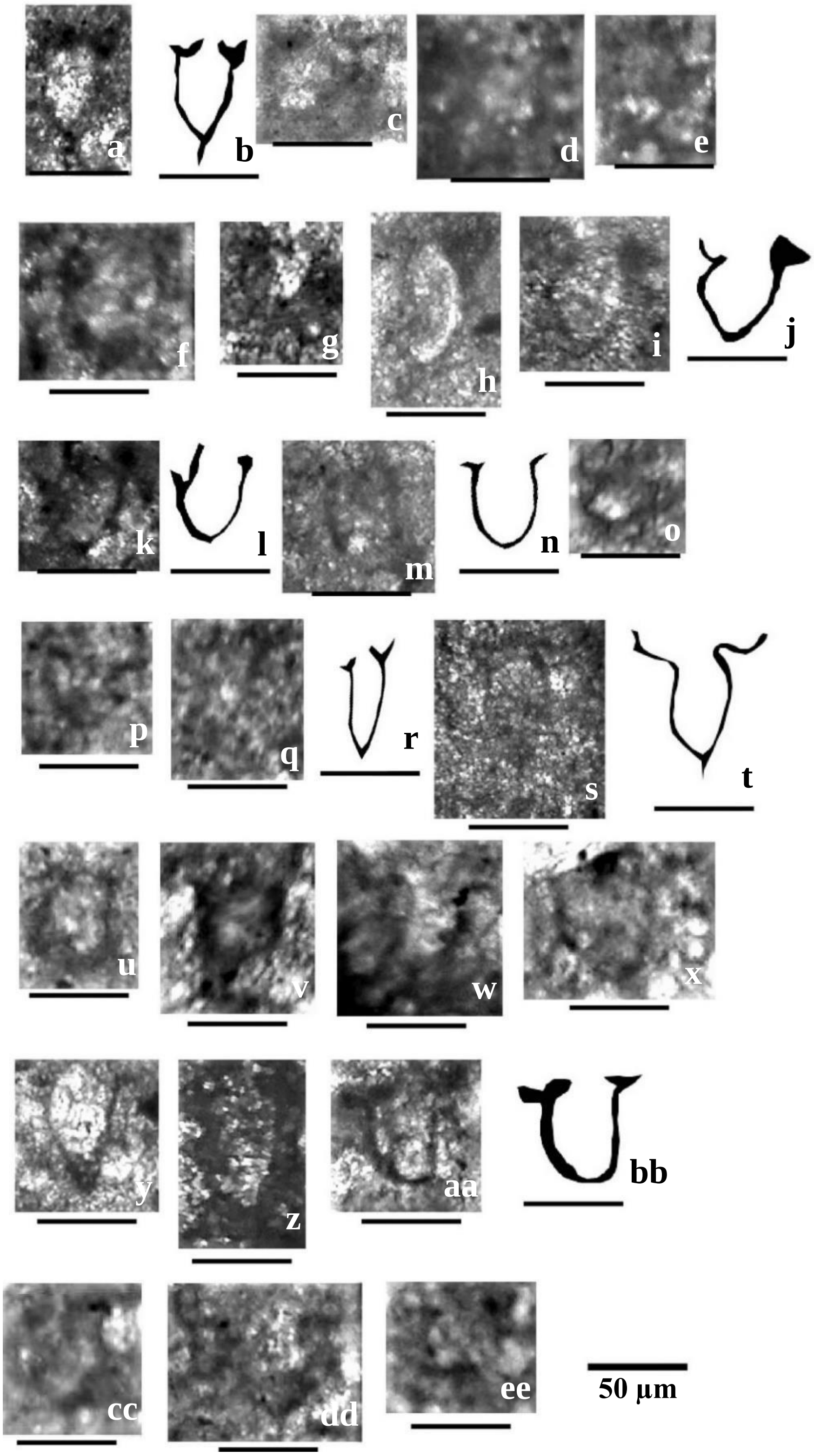


PLATE 2

a. *Crassicollaria brevis*, BA-27, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

b. *Crassicollaria brevis*, BA-28, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

c. *Crassicollaria brevis*, BA-28, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

d. *Crassicollaria brevis*, BA-29, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

e. *Crassicollaria brevis*, BA-29, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

f. *Crassicollaria brevis*, BA-30, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

g. *Crassicollaria brevis*, BA-30, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

h. *Crassicollaria brevis*, BA-30, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

i. *Crassicollaria brevis*, BA-31, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

j. *Crassicollaria brevis*, BA-31, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

k. *Crassicollaria brevis*, BA-32, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

l. *Crassicollaria brevis*, BA-32, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

m. *Crassicollaria brevis*, BA-32, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

n. *Crassicollaria brevis*, BA-32, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

o. *Crassicollaria brevis*, BA-34, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

p. *Crassicollaria brevis*, BA-36, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

q. *Crassicollaria brevis*, BA-36, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

r. *Crassicollaria brevis*, BA-36, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

s. *Crassicollaria brevis*, BA-36, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

PLATE 2

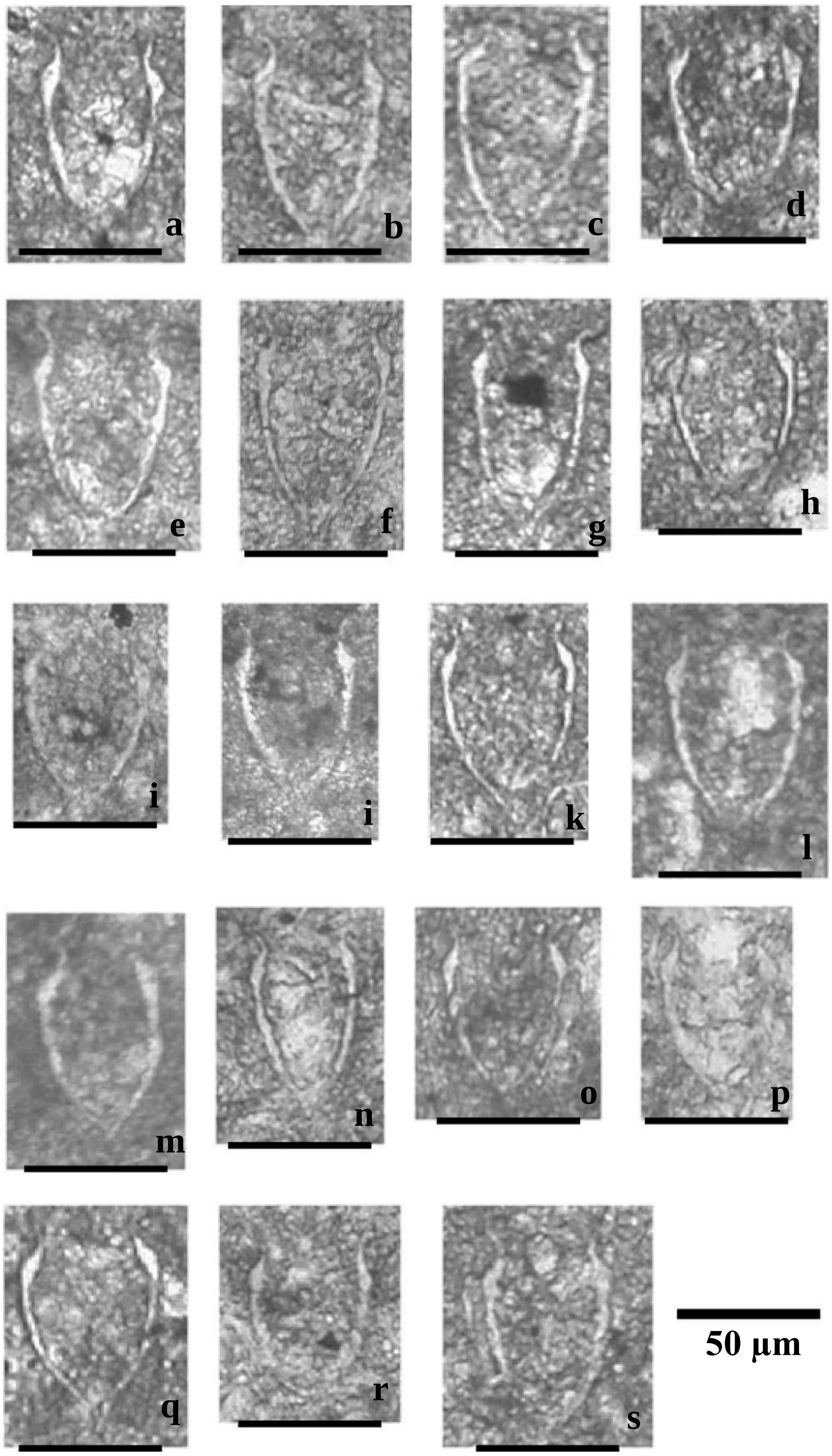


PLATE 3

- **a.** *Crassicollaria colomi*, BA-30, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **b.** *Crassicollaria colomi*, BA-30, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **c.** *Crassicollaria colomi*, BA-32, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **d.** *Crassicollaria colomi*, BA-32, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **e.** *Crassicollaria colomi*, BA-48, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **f.** *Crassicollaria colomi*, BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **g.** *Crassicollaria colomi*, BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **h.** *Crassicollaria colomi*, BA-51, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **i.** *Crassicollaria colomi*, BA-53, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **j.** *Crassicollaria colomi*, BA-55, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **k.** *Crassicollaria colomi*, BA-55, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **l.** *Crassicollaria colomi*, BA-55, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

PLATE 3

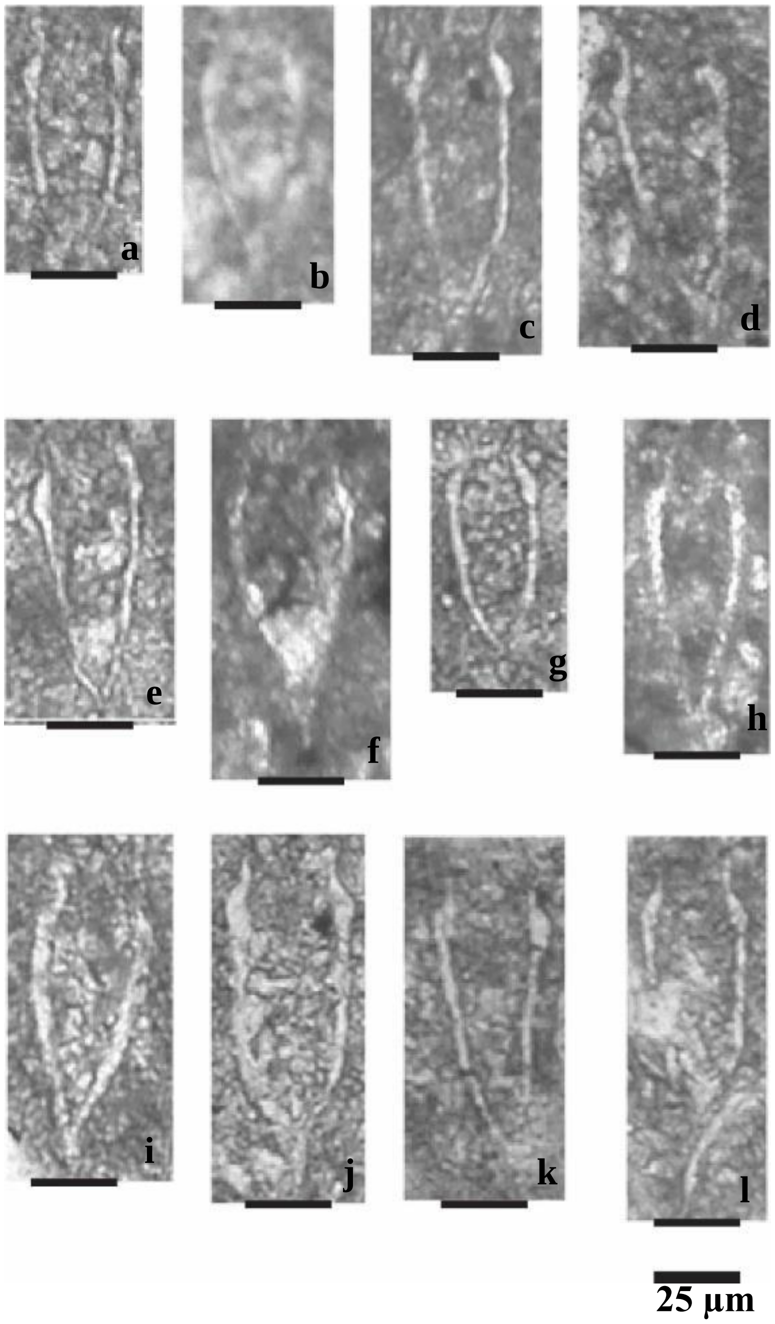


PLATE 4

a. *Crassicollaria intermedia*, BA-14, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation

b. *Crassicollaria intermedia*, BA-14, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation

c. *Crassicollaria intermedia*, BA-18, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation

d. *Crassicollaria intermedia*, BA-19, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation

e. *Crassicollaria intermedia*, BA-20, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation

f. *Crassicollaria intermedia*, BA-22, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation

g. *Crassicollaria intermedia*, BA-23, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

h. *Crassicollaria intermedia*, BA-23, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

i. *Crassicollaria intermedia*, BA-24, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

j. *Crassicollaria intermedia*, BA-25, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

k. *Crassicollaria intermedia*, BA-26, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

l. *Crassicollaria intermedia*, BA-27, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

m. *Crassicollaria intermedia*, BA-27, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

n. *Crassicollaria intermedia*, BA-27, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

o. *Crassicollaria intermedia*, BA-28, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

p. *Crassicollaria intermedia*, BA-28, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

q. *Crassicollaria intermedia*, BA-29, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

PLATE 4

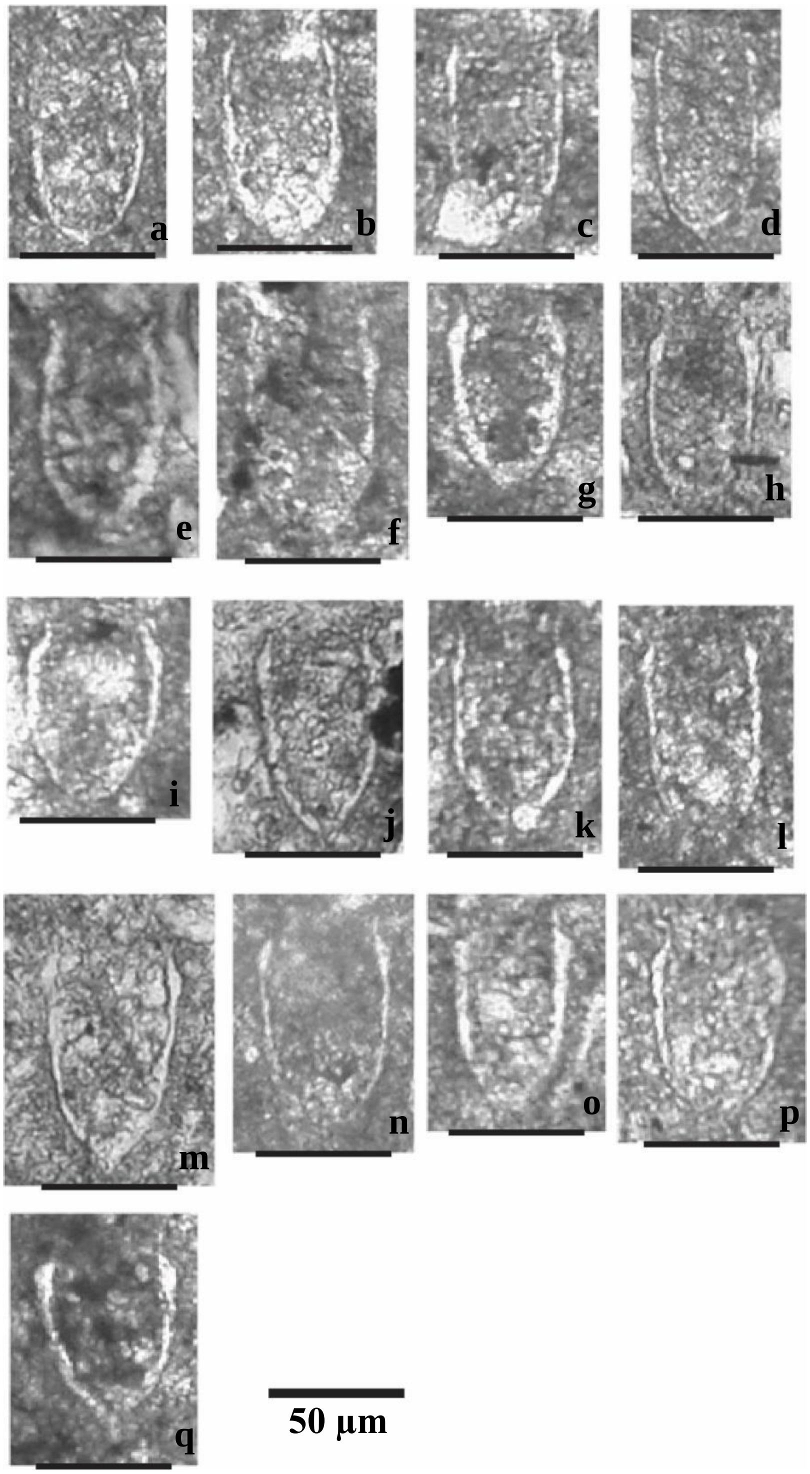


PLATE 5

- **a.** *Crassicollaria massutiniana*, BA-25, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **b.** *Crassicollaria massutiniana*, BA-27, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **c.** *Crassicollaria massutiniana*, BA-28, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **d.** *Crassicollaria massutiniana*, BA-23, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **e.** *Crassicollaria massutiniana*, BA-23, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **f.** *Crassicollaria massutiniana*, BA-24, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **g.** *Crassicollaria massutiniana*, BA-25, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **h.** *Crassicollaria massutiniana*, BA-25, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **i.** *Crassicollaria massutiniana*, BA-25, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **j.** *Crassicollaria massutiniana*, BA-26, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **k.** *Crassicollaria massutiniana*, BA-27, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **l.** *Crassicollaria massutiniana*, BA-27, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **m.** *Crassicollaria massutiniana*, BA-27, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **n.** *Crassicollaria massutiniana*, BA-27, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **o.** *Crassicollaria massutiniana*, BA-28, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

p. *Crassicollaria massutiniana*, BA-28, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

q. *Crassicollaria massutiniana*, BA-28, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

r. *Crassicollaria massutiniana*, BA-29, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

s. *Crassicollaria massutiniana*, BA-29, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

t. *Crassicollaria massutiniana*, BA-32, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

u. *Crassicollaria massutiniana*, BA-32, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

v. *Crassicollaria massutiniana*, BA-32, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

w. *Crassicollaria massutiniana*, BA-32, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

PLATE 5

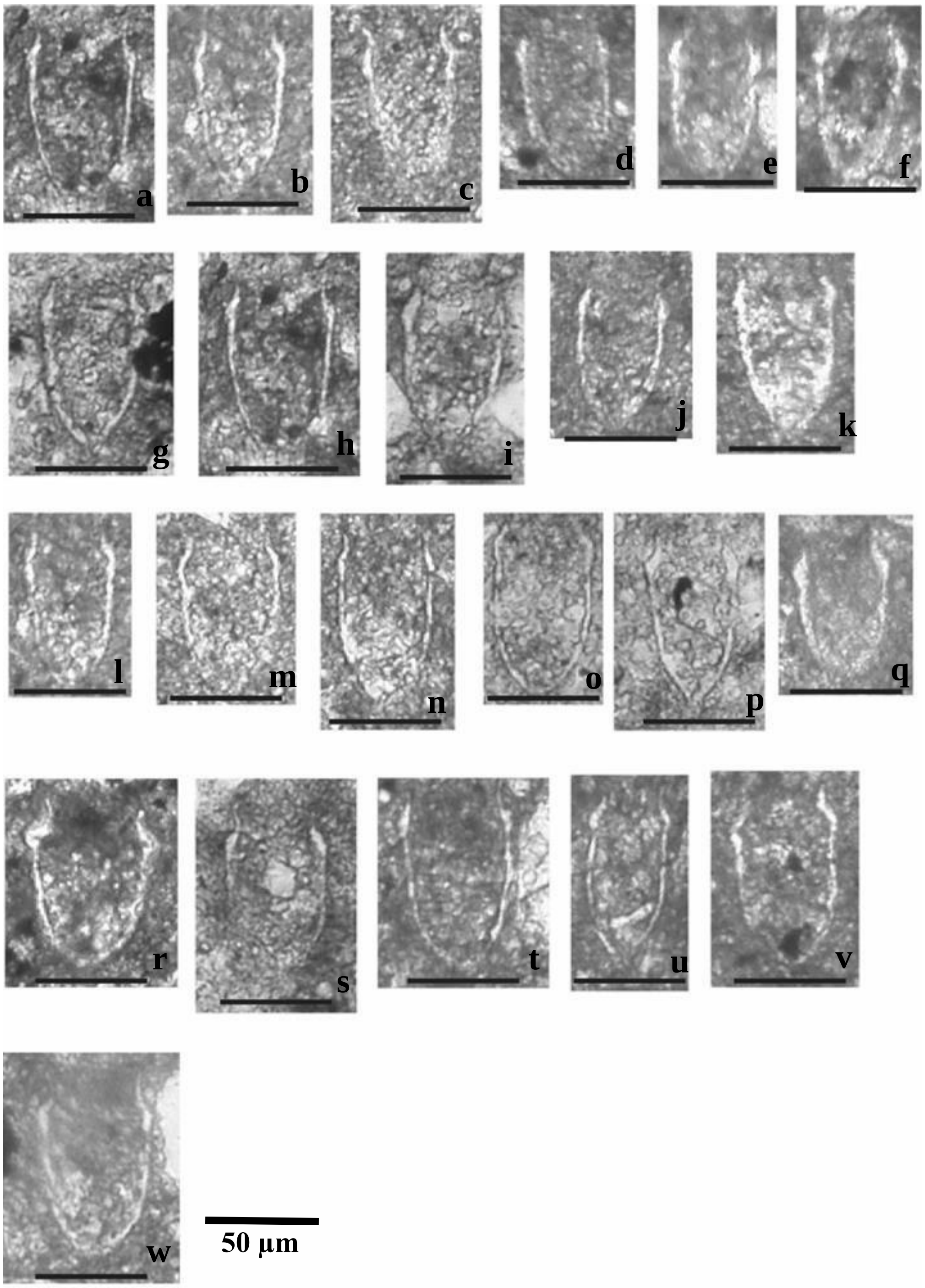


PLATE 6

- **a.** *Crassicollaria parvula*, BA-28, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **b.** *Crassicollaria parvula*, BA-28, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **c.** *Crassicollaria parvula*, BA-32, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **d.** *Crassicollaria parvula*, BA-32, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **e.** *Crassicollaria parvula*, BA-32, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **f.** *Crassicollaria parvula*, BA-34, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **g.** *Crassicollaria parvula*, BA-34, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **h.** *Crassicollaria parvula*, BA-36, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **i.** *Crassicollaria parvula*, BA-39, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **j.** *Crassicollaria parvula*, BA-39, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **k.** *Crassicollaria parvula*, BA-41, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **l.** *Crassicollaria parvula*, BA-47, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **m.** *Crassicollaria parvula*, BA-48, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **n.** *Crassicollaria parvula*, BA-49, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **o.** *Crassicollaria parvula*, BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

p. *Crassicollaria parvula*, BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

q. *Crassicollaria parvula*, BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

r. *Crassicollaria parvula*, BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

s. *Crassicollaria parvula*, BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

t. *Crassicollaria parvula*, BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

u. *Crassicollaria parvula*, BA-51, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

v. *Crassicollaria parvula*, BA-51, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

w. *Crassicollaria parvula*, BA-52, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

x. *Crassicollaria parvula*, BA-53, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

y. *Crassicollaria parvula*, BA-55, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

z. *Crassicollaria parvula*, BA-55, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

PLATE 6

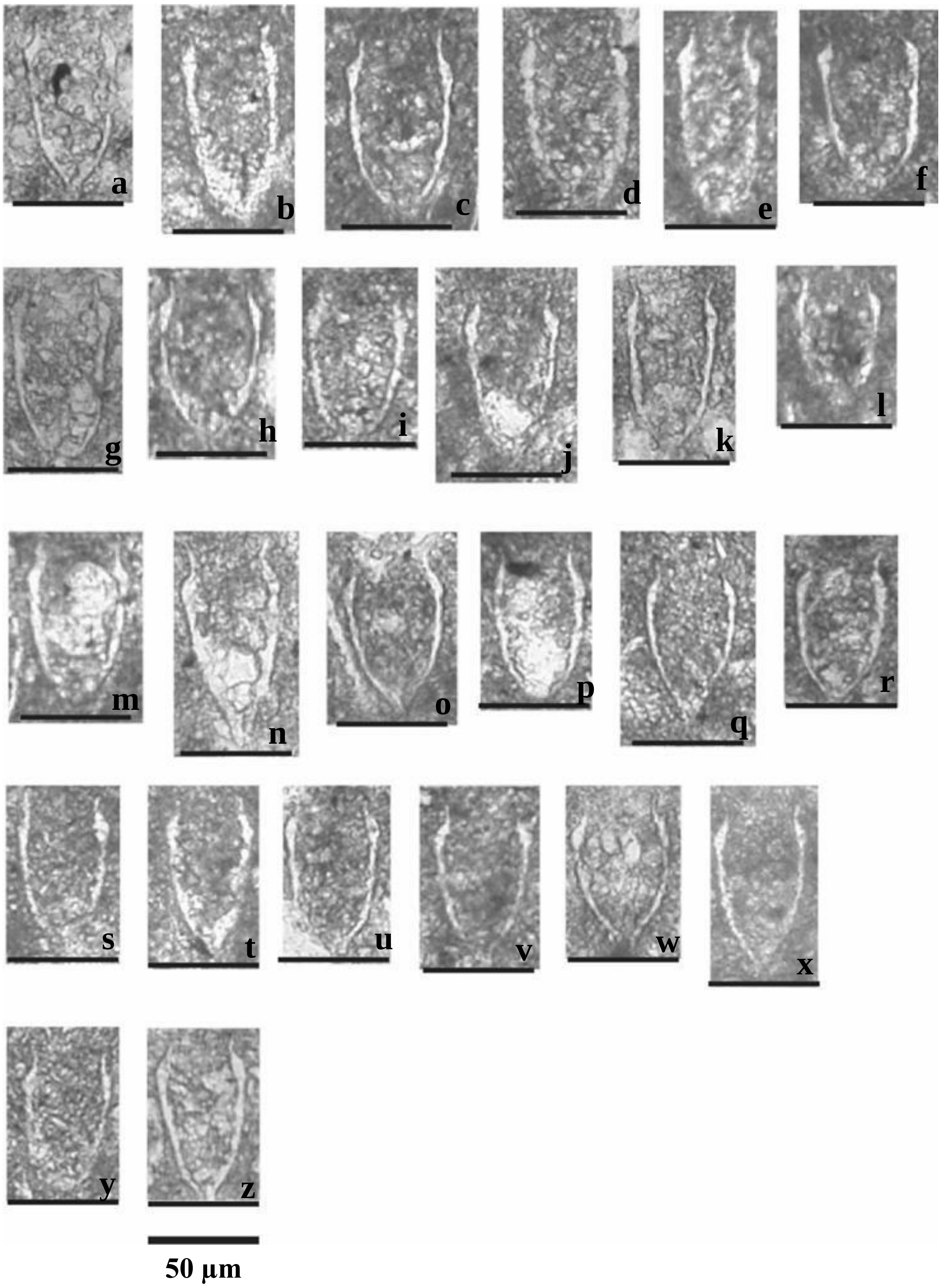


PLATE 7

- **a.** *Tintinnopsella carpathica*, BA-26, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **b.** *Tintinnopsella remanei*, BA-27, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **c.** *Tintinnopsella carpathica*, BA-28, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **d.** *Tintinnopsella carpathica*, BA-28, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **e.** *Tintinnopsella carpathica*, BA-36, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **f.** *Tintinnopsella* sp., BA-40, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **g.** *Tintinnopsella carpathica*, BA-41, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **h.** *Tintinnopsella carpathica*, BA-42, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **i.** *Tintinnopsella* sp., BA-42, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **j.** *Tintinnopsella carpathica*, BA-46, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **k.** *Tintinnopsella doliphormis*, BA-46, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **l.** *Tintinnopsella carpathica*, BA-47, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **m.** *Tintinnopsella carpathica*, BA-47, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **n.** *Tintinnopsella carpathica*, BA-48, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

o. *Tintinnopsella remanei*? , BA-49, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

p. *Tintinnopsella doliphormis*, BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

q. *Tintinnopsella carpathica*, BA-51, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

r. *Tintinnopsella carpathica*, BA-51, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

s. *Tintinnopsella carpathica*, BA-51, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

t. *Tintinnopsella carpathica*, BA-53, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

u. *Tintinnopsella carpathica*, BA-53, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

v. *Tintinnopsella carpathica*, BA-55, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

w. *Tintinnopsella carpathica*, BA-55, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

PLATE 7

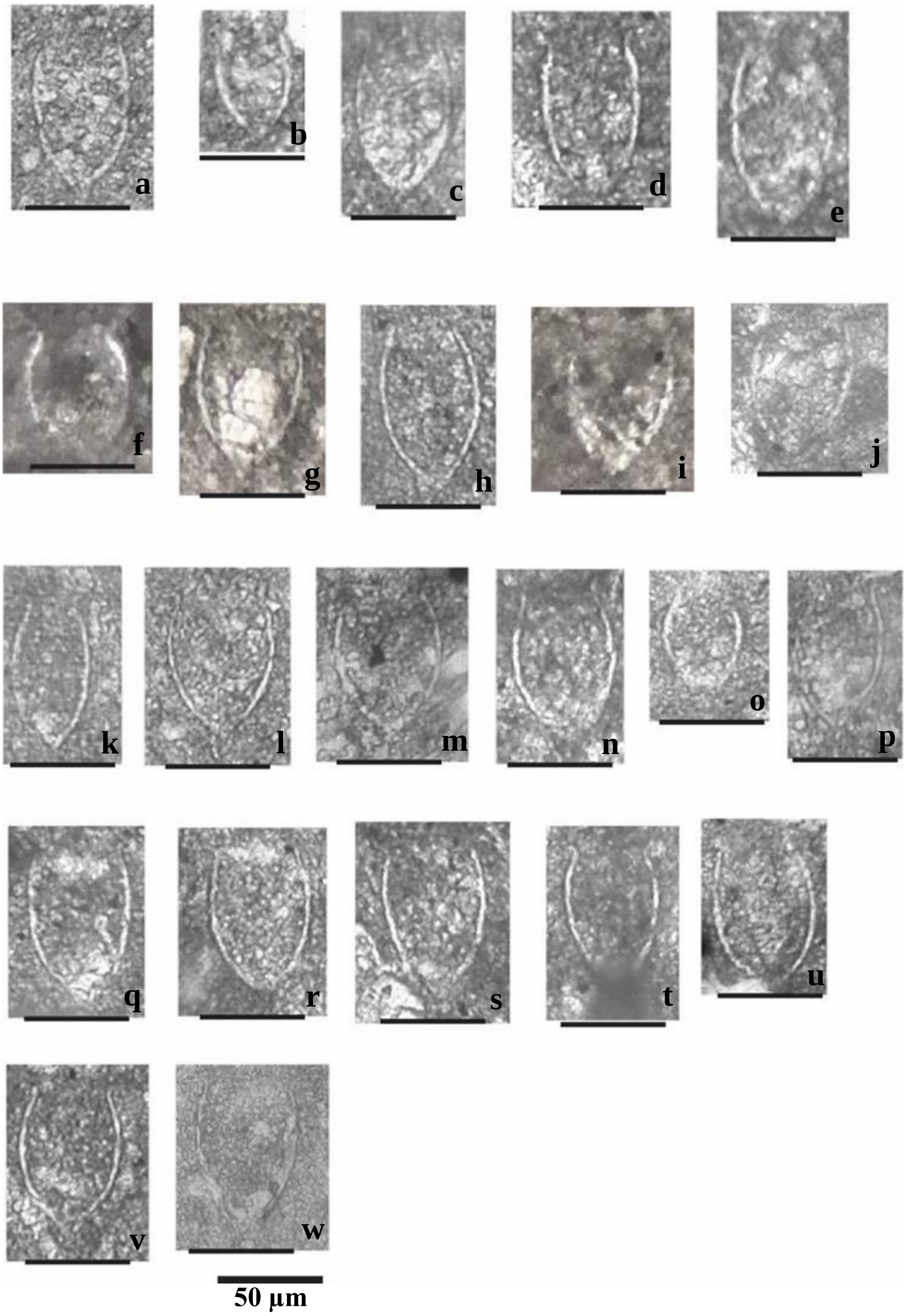


PLATE 8

- **a.** *Calpionella alpina*, BA-41, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **b.** *Calpionella alpina*, BA-41, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **c.** *Calpionella alpina*, BA-41, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **d.** *Calpionella alpina*, BA-42/1, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **e.** *Calpionella alpina*, BA-42/1, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **f.** *Calpionella alpina*, BA-42/2, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **g.** *Calpionella alpina*, BA-42/2, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **h.** *Calpionella alpina*, BA-42/3, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **i.** *Calpionella alpina*, BA-42/3, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **j.** *Calpionella alpina*, BA-42/3, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **k.** *Calpionella alpina*, BA-42/3, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **l.** *Calpionella alpina*, BA-42/4, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **m.** *Calpionella alpina*, BA-43/2, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **n.** *Calpionella alpina*, BA-43/3, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **o.** *Calpionella alpina*, BA-43/3, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

p. *Calpionella alpina*, BA-43/4, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

q. *Calpionella alpina*, BA-43/4, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

r. *Calpionella alpina*, BA-43/5, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

s. *Calpionella alpina*, BA-43/5, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

t. *Calpionella alpina*, BA-45/2, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

u. *Calpionella alpina*, BA-46, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

v. *Calpionella alpina*, BA-47, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

w. *Calpionella alpina*, BA-48, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

x. *Calpionella alpina*, BA-49, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

y. *Calpionella alpina*, BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

z. *Calpionella alpina*, BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

aa. *Calpionella alpina*, BA-52, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

bb. *Calpionella alpina*, BA-53, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

cc. *Calpionella alpina*, BA-55, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

dd. *Calpionella alpina*, BA-55, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

PLATE 8

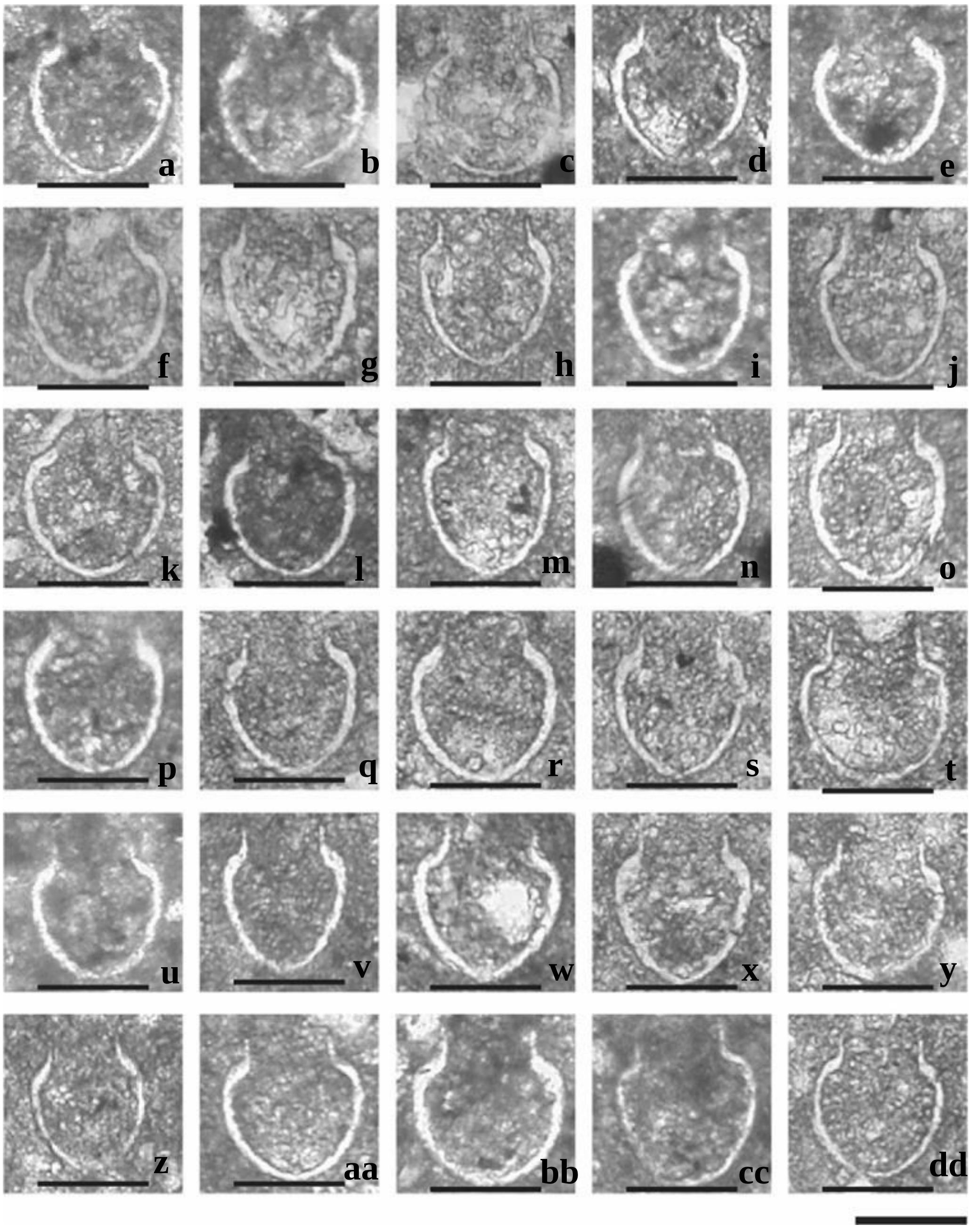


PLATE 9

a. *Calpionella grandalpina*, BA-23, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

b. *Calpionella grandalpina*, BA-24, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

c. *Calpionella grandalpina*, BA-24, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

d. *Calpionella grandalpina*, BA-26, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

e. *Calpionella grandalpina*, BA-26, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

f. *Calpionella grandalpina*, BA-27, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

g. *Calpionella grandalpina*, BA-27, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

h. *Calpionella grandalpina*, BA-30, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

i. *Calpionella grandalpina*, BA-30, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

j. *Calpionella grandalpina*, BA-31, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

k. *Calpionella grandalpina*, BA-31, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

l. *Calpionella grandalpina*, BA-32, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

m. *Calpionella grandalpina*, BA-32, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

n. *Calpionella grandalpina*, BA-34, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

o. *Calpionella grandalpina*, BA-34, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

p. *Calpionella grandalpina*, BA-36, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

q. *Calpionella grandalpina*, BA-39, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

PLATE 9

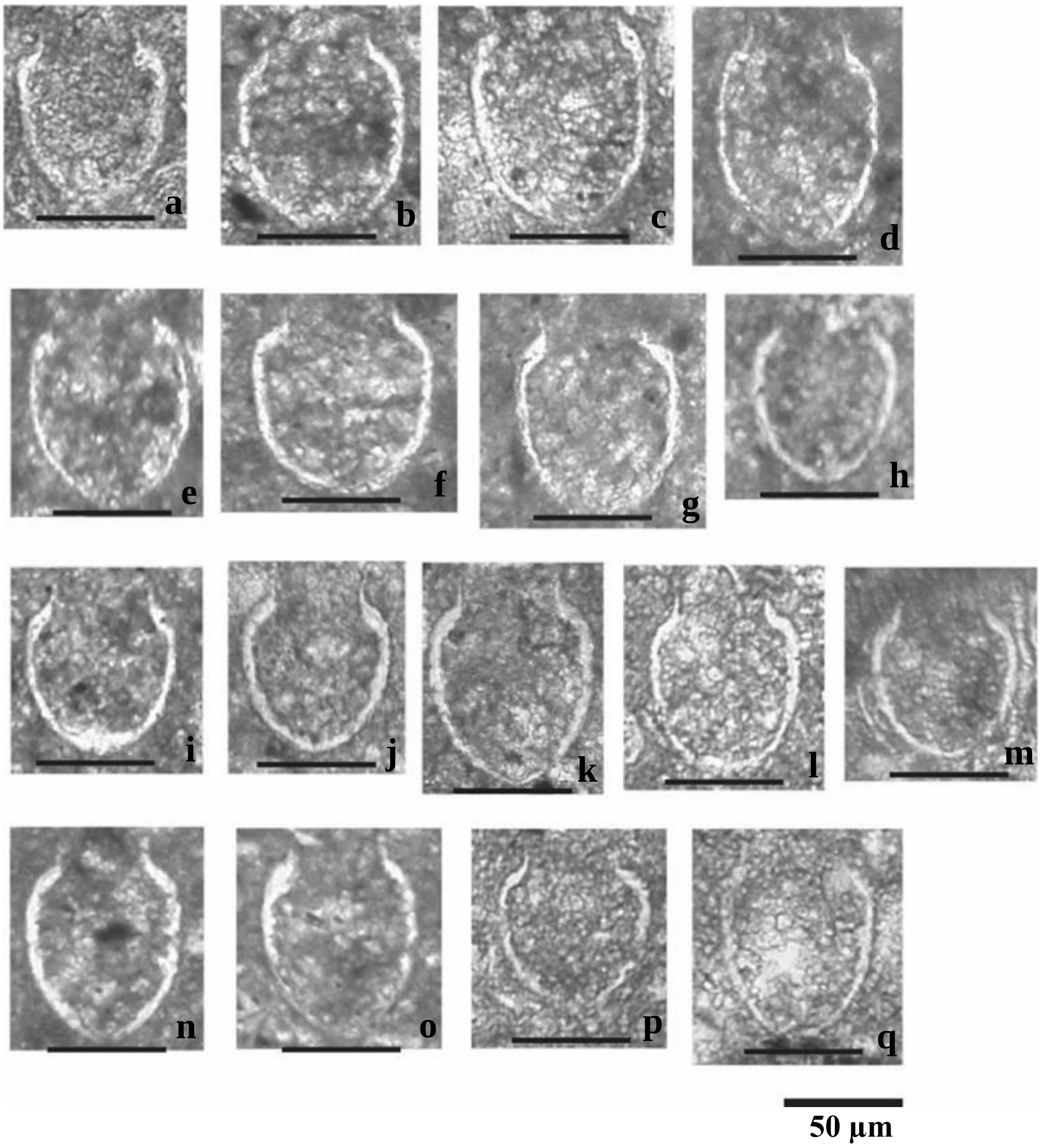


PLATE 10

a. *Calpionella elliptalpina*, BA-25, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

b. *Calpionella elliptalpina*, BA-31, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

c. *Calpionella elliptalpina*, BA-34, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

d. *Calpionella elliptalpina*, BA-36, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

e. *Calpionella elliptalpina*, BA-36, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

f. *Calpionella elliptalpina*, BA-38, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

g. *Calpionella elliptalpina*, BA-38, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

h. *Calpionella elliptalpina*, BA-39, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

i. *Calpionella elliptalpina*, BA-39, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

j. *Calpionella elliptalpina*, BA-40, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

k. *Calpionella elliptalpina*, BA-40, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

PLATE 10

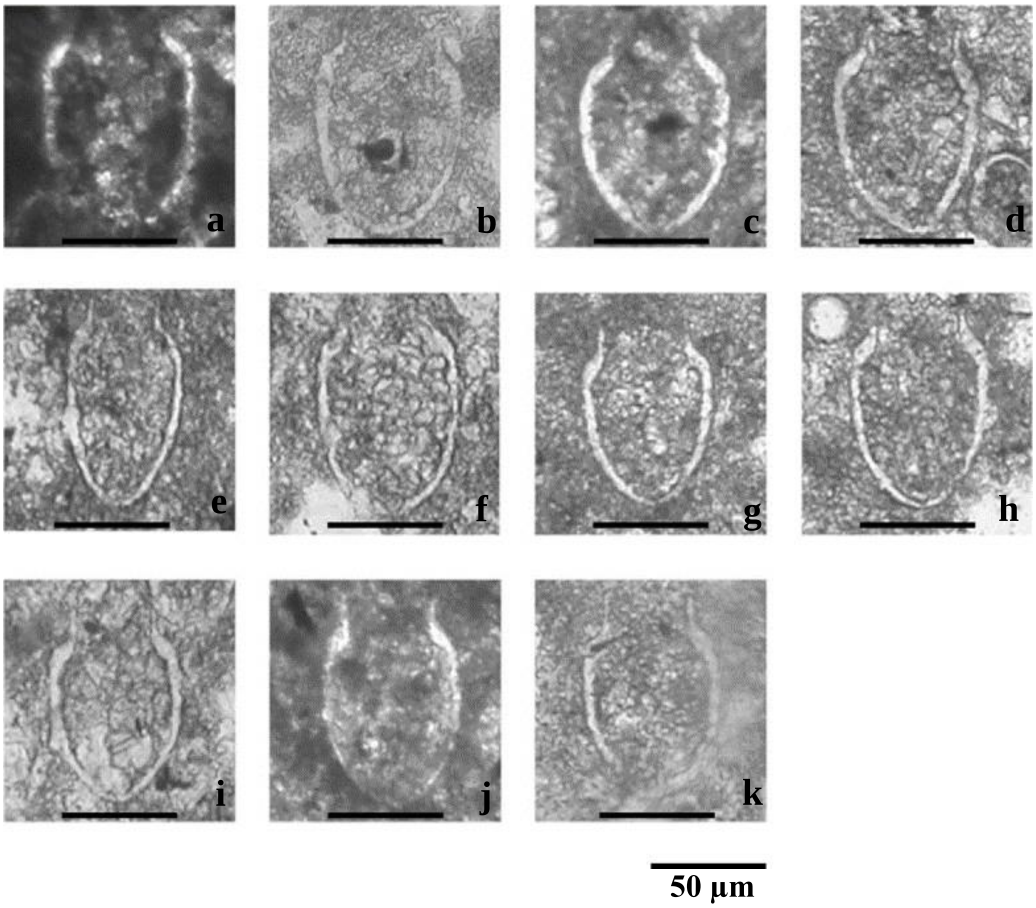


PLATE 11

a. *Calpionella minuta*, BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

b. *Calpionella minuta*, BA-51, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

c. *Calpionella minuta*, BA-51, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

d. *Calpionella minuta*, BA-51, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

e. *Calpionella minuta*, BA-52, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

f. *Calpionella minuta*, BA-52, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

g. *Calpionella minuta*, BA-52, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

h. *Calpionella minuta*, BA-53, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

i. *Calpionella minuta*, BA-55, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

PLATE 11

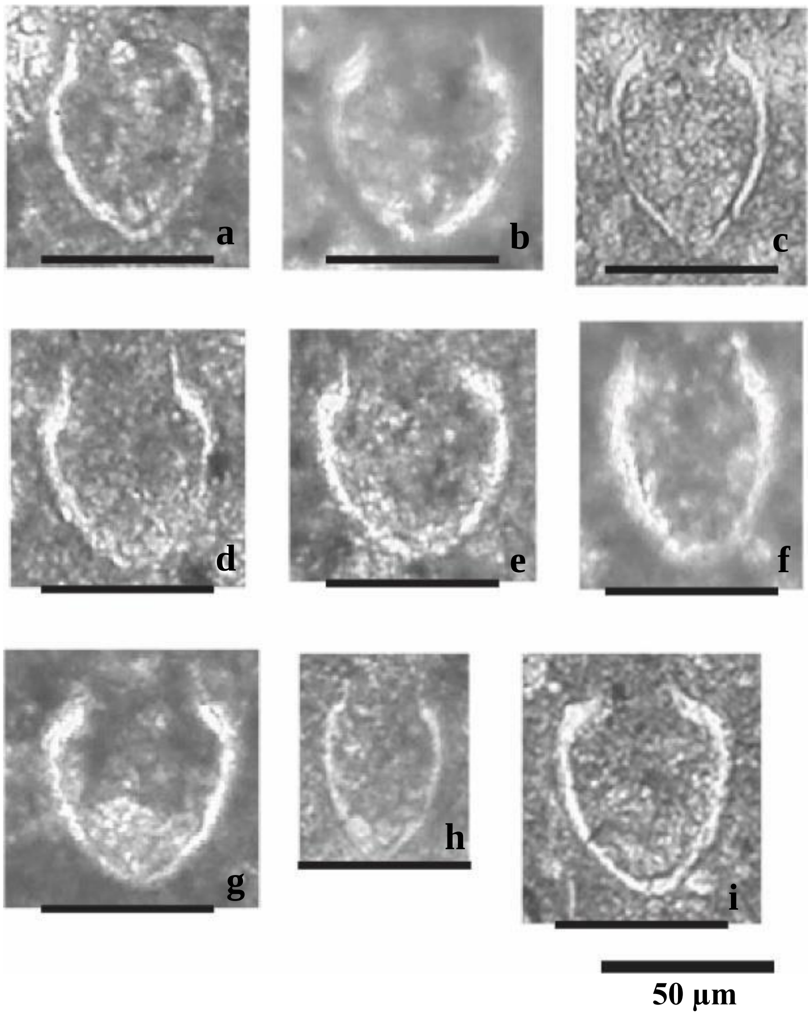


PLATE 12

a. *Remaniella ferasini*, BA-48, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

b. *Remaniella* sp., BA-49, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

c. *Remaniella* sp., BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

d. *Remaniella ferasini*, BA-53, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

e. *Remaniella* sp., BA-53, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

f. *Remaniella ferasini*, BA-55, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

g. *Remaniella duranddelgai*, BA-55, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

h. *Remaniella ferasini*, BA-55, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

PLATE 12

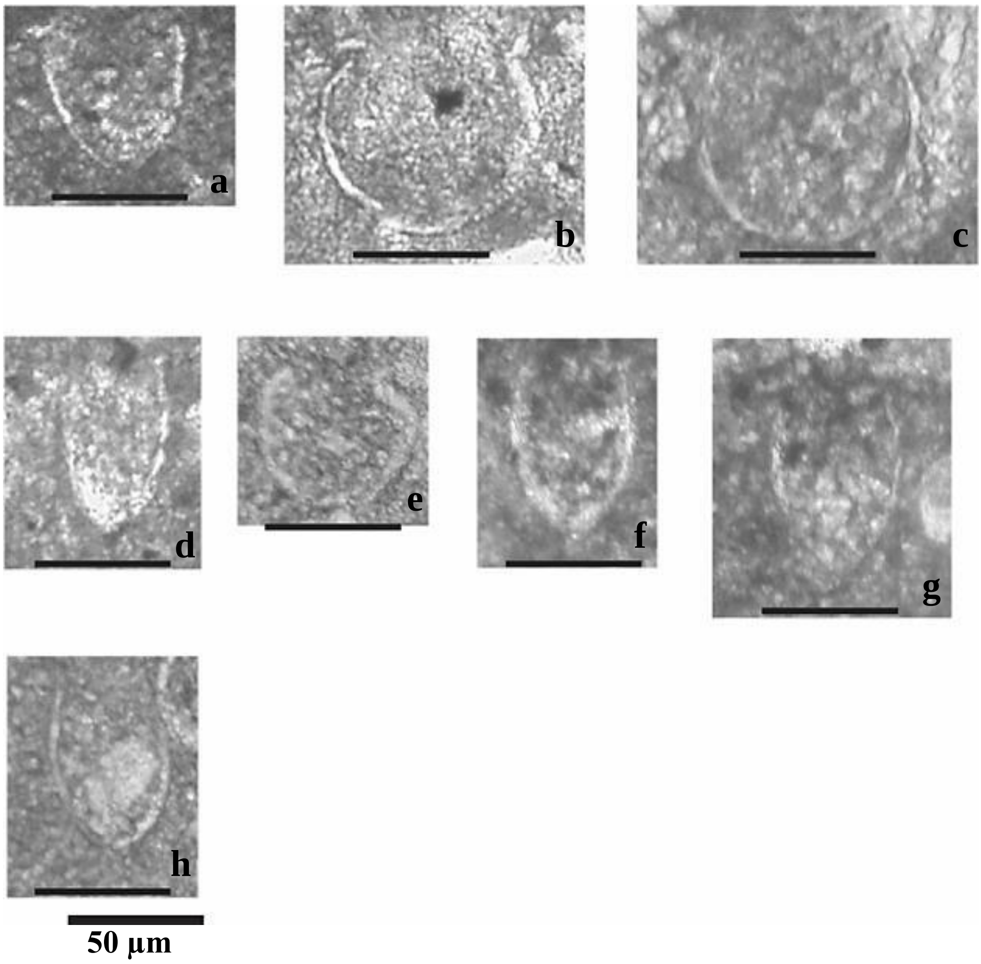


PLATE 13

Radials (RR) of *Saccocoma* Agassiz

a. *Saccocoma tenella* (Goldfuss, 1831), radial plate, BA-05, exterior view, the *Chitinoidella* Zone, Late Tithonian, BA-I section

b. *Saccocoma tenella* (Goldfuss, 1831), radial plate, BA-05, exterior view, the *Chitinoidella* Zone, Late Tithonian, BA-I section

c. *Saccocoma tenella* (Goldfuss, 1831), radial plate, BA-05, exterior view, the *Chitinoidella* Zone, Late Tithonian, BA-I section

d. *Saccocoma* sp. radial plate part, BA-05, the *Chitinoidella* Zone, Tithonian, BA-I section

e. *Saccocoma* sp. radial plate part, BA-05, exterior view, the *Chitinoidella* Zone, Late Tithonian, BA-I section

f. *Saccocoma* sp. radial plate part, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

g. *Saccocoma* sp. radial plate part, BA-05, interior view, the *Chitinoidella* Zone, Late Tithonian, BA-I section

h. *Saccocoma* sp. radial plate part, BA-05, interior view, the *Chitinoidella* Zone, Late Tithonian, BA-I section

i. *Saccocoma* sp. radial plate part, BA-05, exterior view, the *Chitinoidella* Zone, Late Tithonian, BA-I section

PLATE 13

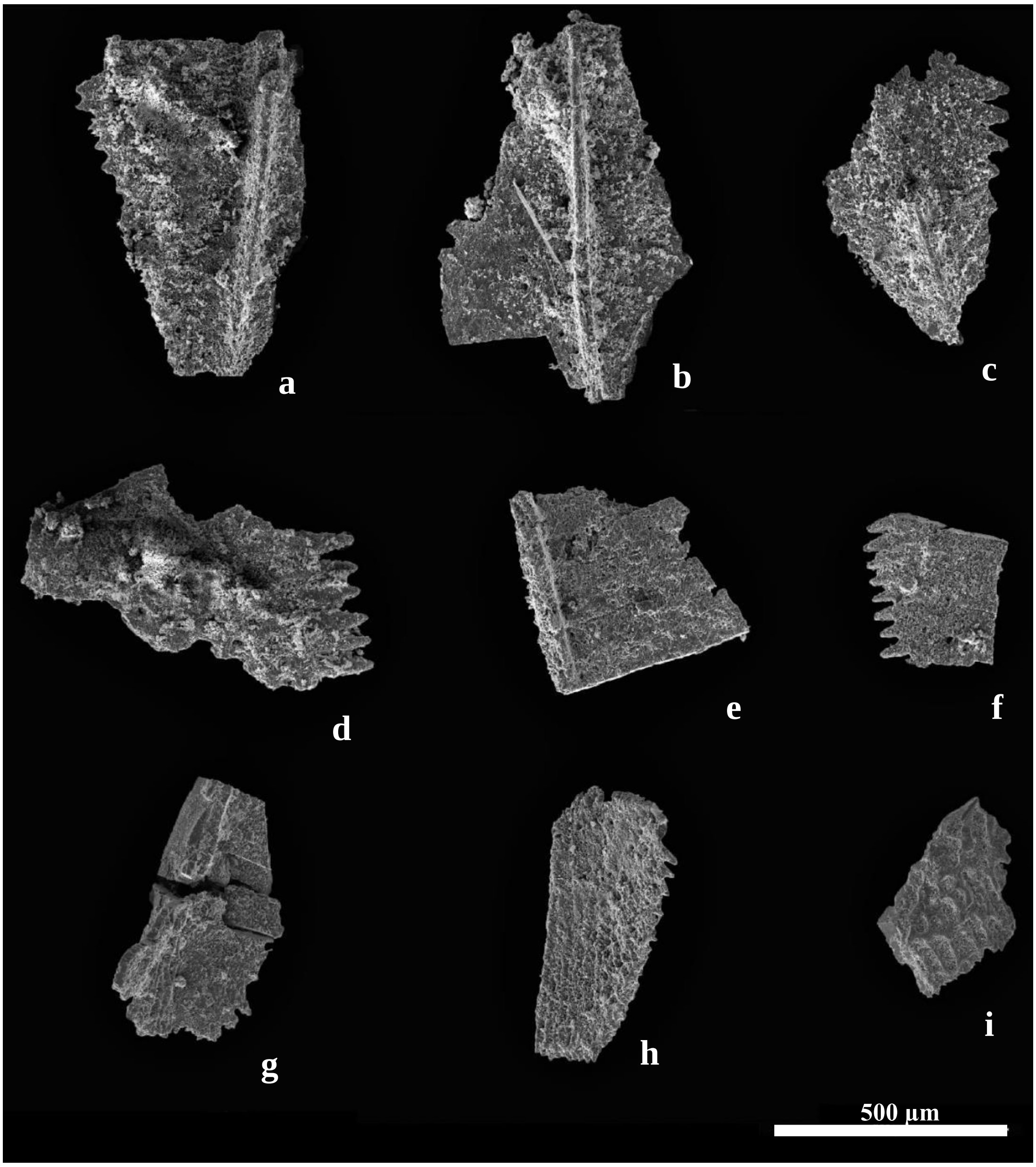


PLATE 14

First primibrachials (IBr$_1$) of *Saccocoma* Agassiz

a. *Saccocoma tenella* (Goldfuss, 1831), IBr$_1$, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

b. *Saccocoma tenella* (Goldfuss, 1831), IBr$_1$, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

c. *Saccocoma tenella* (Goldfuss, 1831), IBr$_1$, oral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

d. *Saccocoma tenella* (Goldfuss, 1831), IBr$_1$, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

e. *Saccocoma tenella* (Goldfuss, 1831), IBr$_1$, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

f. *Saccocoma* sp., IBr$_1$, oral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

g. *Saccocoma tenella* (Goldfuss, 1831), IBr$_1$, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

h. *Saccocoma tenella* (Goldfuss, 1831), IBr$_1$, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

PLATE 14

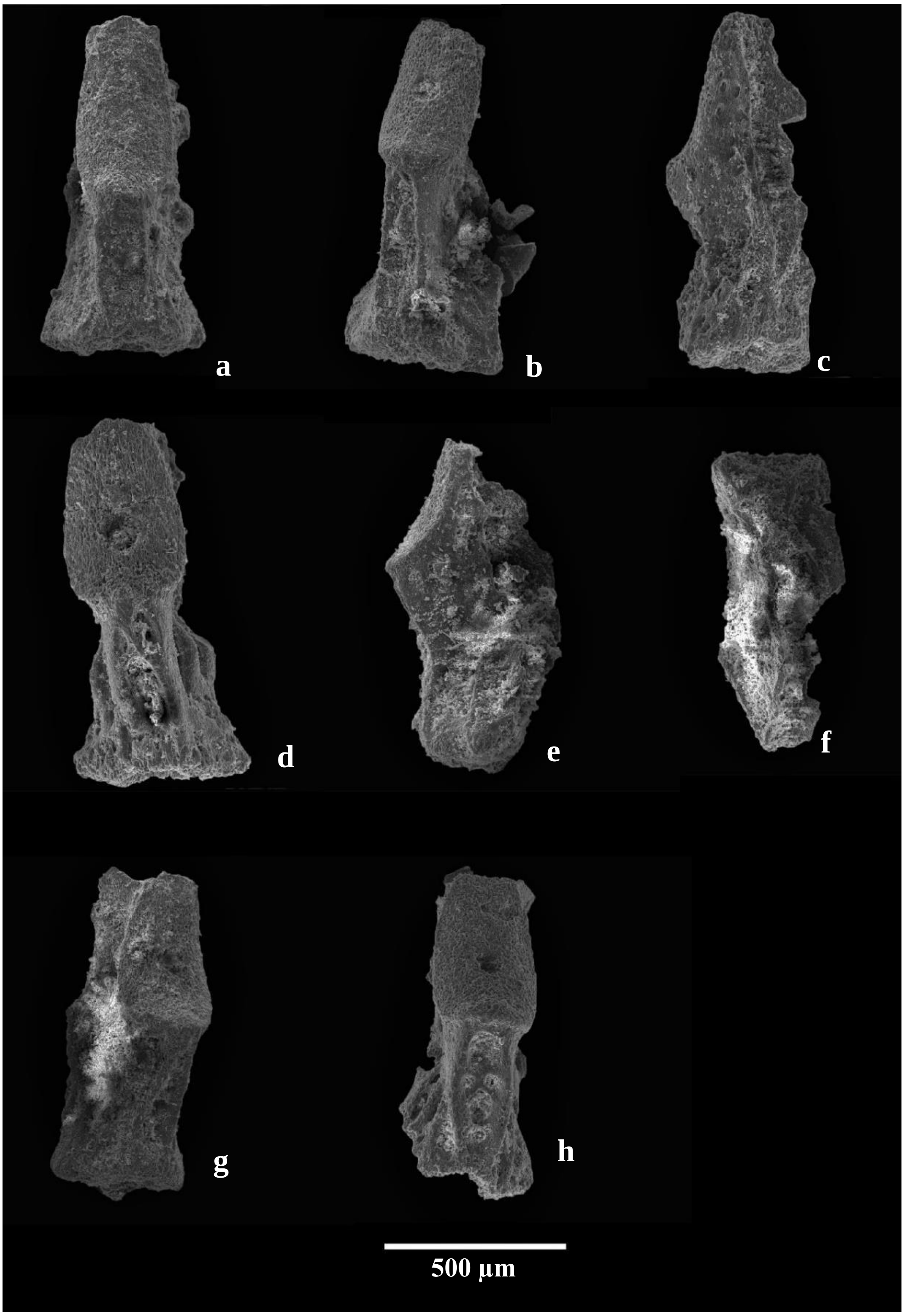


PLATE 15

Secundibrachials (IIBr) of *Saccocoma* Agassiz

- **a.** *Saccocoma tenella* (Goldfuss, 1831), broken second or fourth secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **b.** *Saccocoma tenella* (Goldfuss, 1831), broken second or fourth secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **c.** *Saccocoma tenella* (Goldfuss, 1831), broken second or fourth secundibrachial (IIBr), oral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **d.** *Saccocoma tenella* (Goldfuss, 1831), broken second or fourth secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **e.** *Saccocoma tenella* (Goldfuss, 1831), broken second or fourth secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **f.** *Saccocoma tenella* (Goldfuss, 1831), articular bodyof second or fourth secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **g.** *Saccocoma tenella* (Goldfuss, 1831), articular body of second or fourth secundibrachial (IIBr), BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **h.** *Saccocoma tenella* (Goldfuss, 1831), broken secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Tithonian, BA-I section
- **i.** *Saccocoma tenella* (Goldfuss, 1831), broken secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **j.** *Saccocoma tenella* (Goldfuss, 1831), broken secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **k.** *Saccocoma tenella* (Goldfuss, 1831), broken secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **l.** *Saccocoma* sp., broken secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **m.** *Saccocoma* sp., broken secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **n.** *Saccocoma* sp., broken secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **o.** Saccocoma tenella (Goldfuss, 1831), brokensecond or fourth secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

PLATE 15

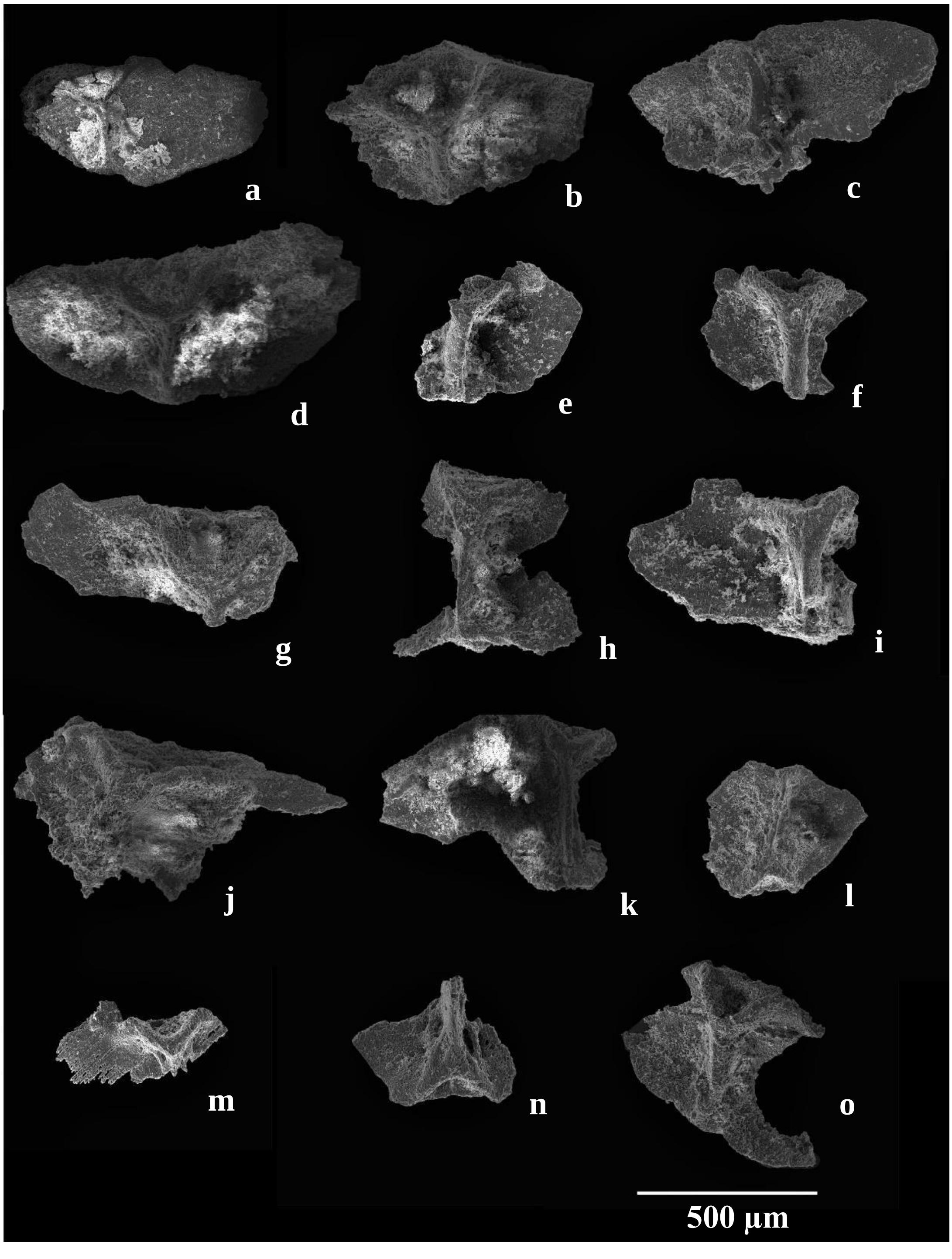


PLATE 16

Secundibrachials (IIBr) of *Saccocoma* Agassiz

a. *Saccocoma tenella*, broken IIBr5, 6 or 7, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

b. *Saccocoma tenella*, probably IIBr$_7$, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

c. *Saccocoma tenella*, probably IIBr5 or 6, oral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

d. *Saccocoma tenella*, probably IIBr5 or 6, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

e. *Saccocoma tenella*, probably IIBr$_6$, oral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

f. *Saccocoma tenella*, broken, probably IIBr$_7$, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

g. *Saccocoma tenella*, broken, probably IIBr5 or 6, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

h. *Saccocoma tenella*, broken secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

i. *Saccocoma tenella*, broken secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

j. *Saccocoma tenella*, broken secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

k. *Saccocoma* sp., broken secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

l. *Saccocoma tenella*, IIBr5, 6 or 7, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

m. *Saccocoma tenella*, IIBr5, 6 or 7, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

n. *Saccocoma vernioryi*, broken secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

o. *Saccocoma tenella*, broken secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

p. *Saccocoma tenella*, broken secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

q. *Saccocoma vernioryi*, broken secundibrachial (IIBr), aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

PLATE 16

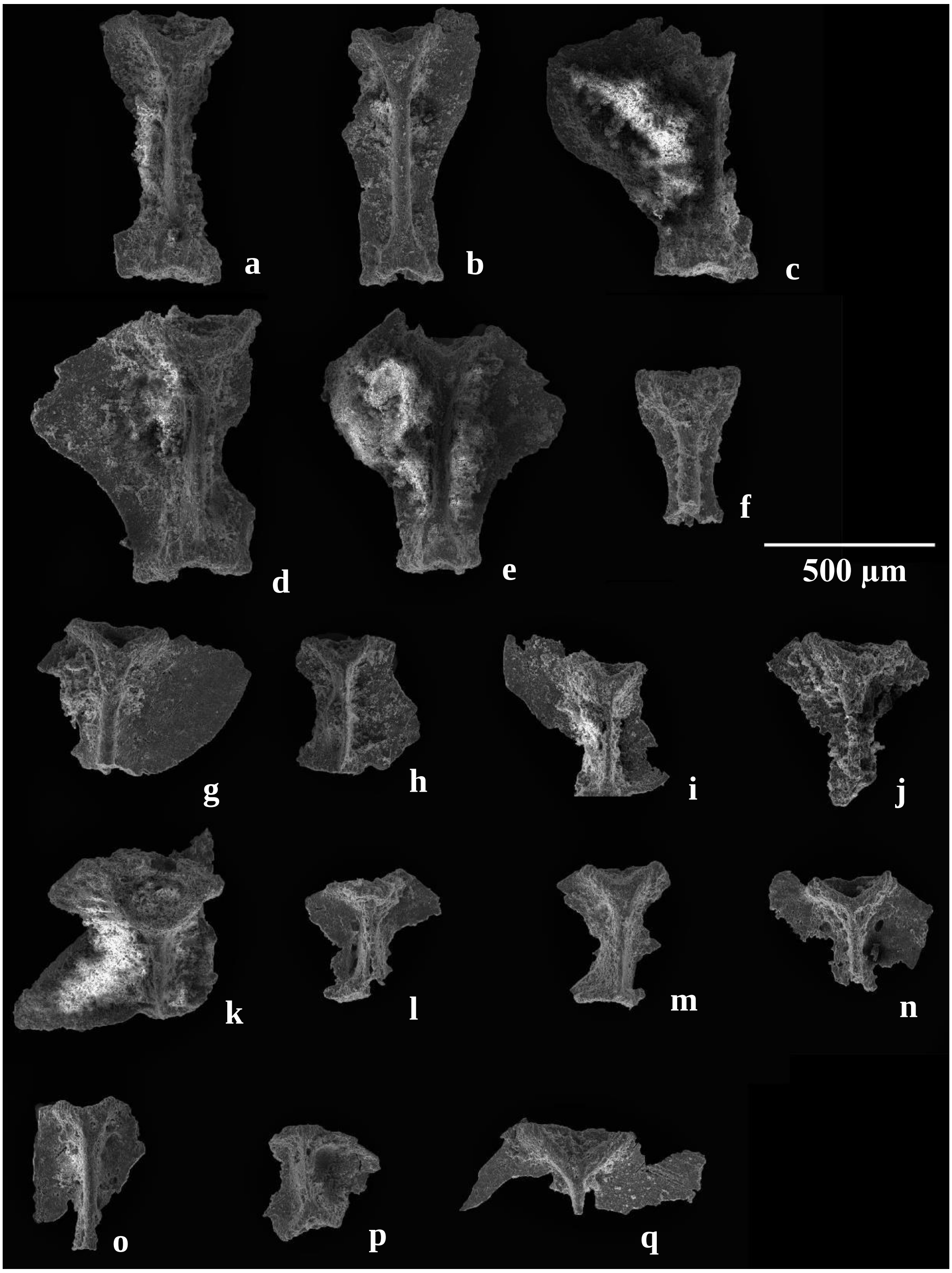


PLATE 17

Secundibrachials (IIBr) of *Saccocoma* Agassiz

- **a.** *Saccocoma tenella*, broken winged-secundibrachial (IIBr), lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **b.** *Saccocoma tenella,* broken winged-secundibrachial (IIBr), lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **c.** *Saccocoma tenella,* broken winged-secundibrachial (IIBr), lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **d.** *Saccocoma tenella,* broken winged-secundibrachial (IIBr), lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **e.** *Saccocoma tenella,* broken winged-secundibrachial (IIBr), lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **f.** *Saccocoma tenella,* broken winged-secundibrachial (IIBr), lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **g.** *Saccocoma* sp., broken secundibrachial (IIBr), lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **h.** *Saccocoma* sp., broken secundibrachial (IIBr), lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **i.** *Saccocoma tenella*?, broken winged-secundibrachial (IIBr), BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **j.** *Saccocoma tenella*?. broken winged-secundibrachial (IIBr), BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **k.** *Saccocoma tenella,* broken wing part (IIBr), BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **l.** *Saccocoma tenella*?, broken winged-secundibrachial (IIBr), lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **m.** *Saccocoma* sp., broken winged-secundibrachial (IIBr), lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **n.** *Saccocoma tenella,* broken wing part (IIBr), BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **o.** *Saccocoma tenella,* broken winged-secundibrachial (IIBr), BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **p.** *Saccocoma tenella,* broken winged-secundibrachial (IIBr), BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **q.** *Saccocoma tenella,* broken winged-secundibrachial (IIBr), BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **r.** *Saccocoma vernioryi*?, broken winged-secundibrachial (IIBr), BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **s.** *Saccocoma vernioryi* ?, broken secundibrachial ? (IIBr), BA-05, *the Chitinoidella* Zone, Late Tithonian, BA-I section

PLATE 17

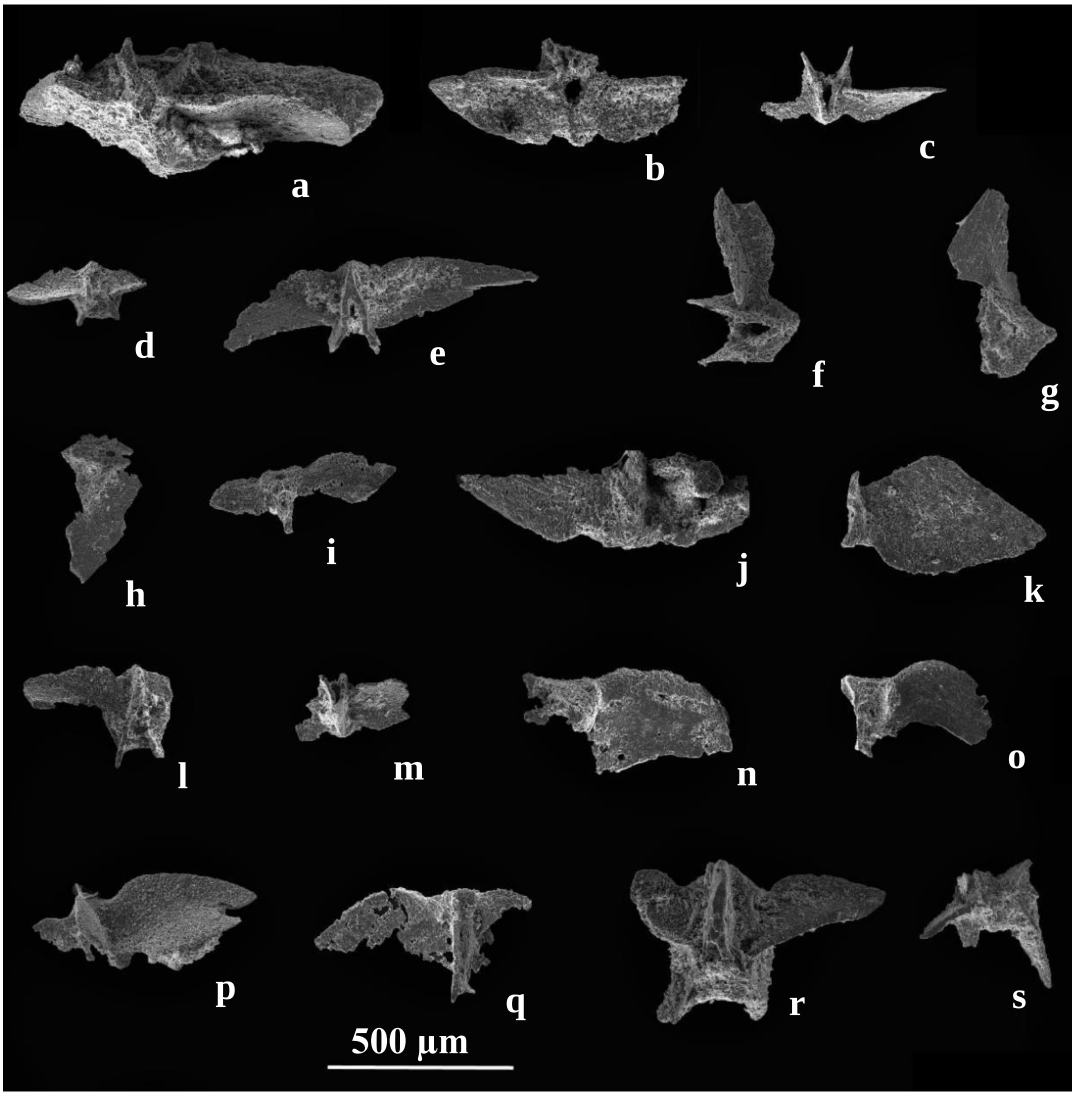


PLATE 18

Brachials of *Saccocoma vernioryi* Manni & Nicosia

a. *Saccocoma vernioryi* (Manni & Nicosia, 1984), primi(IBr) - or secundibrachial (IIBr) wing structure, slightly lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

b. *Saccocoma vernioryi* (Manni & Nicosia, 1984), primi(IBr) - or secundibrachial (IIBr) wing structure, oral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

c. *Saccocoma vernioryi* (Manni & Nicosia, 1984), probably second secundibrachial ($IIBr_2$) wing structure, distal view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

d. *Saccocoma vernioryi* (Manni & Nicosia, 1984), probably second secundibrachial ($IIBr_2$) wing structure, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

e. *Saccocoma vernioryi* (Manni & Nicosia, 1984), primi(IBr) - or secundibrachial (IIBr) wing structure, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

f. *Saccocoma vernioryi* (Manni & Nicosia, 1984), probably second primibrachial (IBr_2) wing structure, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

g. *Saccocoma vernioryi* (Manni & Nicosia, 1984), probably second primibrachial (IBr_2) wing structure, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

h. *Saccocoma vernioryi*? (Manni & Nicosia, 1984), wing structure, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

i. *Saccocoma vernioryi* (Manni & Nicosia, 1984), primi(IBr) - or secundibrachial (IIBr) wing structure, slightly lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

j. *Saccocoma vernioryi* (Manni & Nicosia, 1984), probably second primibrachial (IBr_2) wing structure, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

k. *Saccocoma vernioryi*? (Manni & Nicosia, 1984), wing structure, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

l. *Saccocoma vernioryi* (Manni & Nicosia, 1984), probably articular body of the second primibrachial (IBr_2), wing structure, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

m. *Saccocoma* sp., articular body of the wing structure?, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

n. *Saccocoma vernioryi* (Manni & Nicosia, 1984), wing structure, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

o. *Saccocoma vernioryi* (Manni & Nicosia, 1984), probably IIBr5,6 or 7 wing structure, distal/lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

p. *Saccocoma* sp., wing structure ?, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

q. *Saccocoma vernioryi* (Manni & Nicosia, 1984), wing structure, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

r. *Saccocoma vernioryi* ?(Manni & Nicosia, 1984), probably IIBr5,6 or 7 wing structure, oral/lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

s. *Saccocoma vernioryi* (Manni & Nicosia, 1984), probably second primibrachial (IBr_2) wing structure, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

t. *Saccocoma* sp., wing structure, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

u. *Saccocoma vernioryi*? (Manni & Nicosia, 1984), probably articular body of secundibrachial (IIBr), wing structure, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

v. *Saccocoma vernioryi*? (Manni & Nicosia, 1984), probably secundibrachial (IIBr) wing structure, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

w. *Saccocoma vernioryi?* (Manni & Nicosia, 1984), wing structure, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

PLATE 18

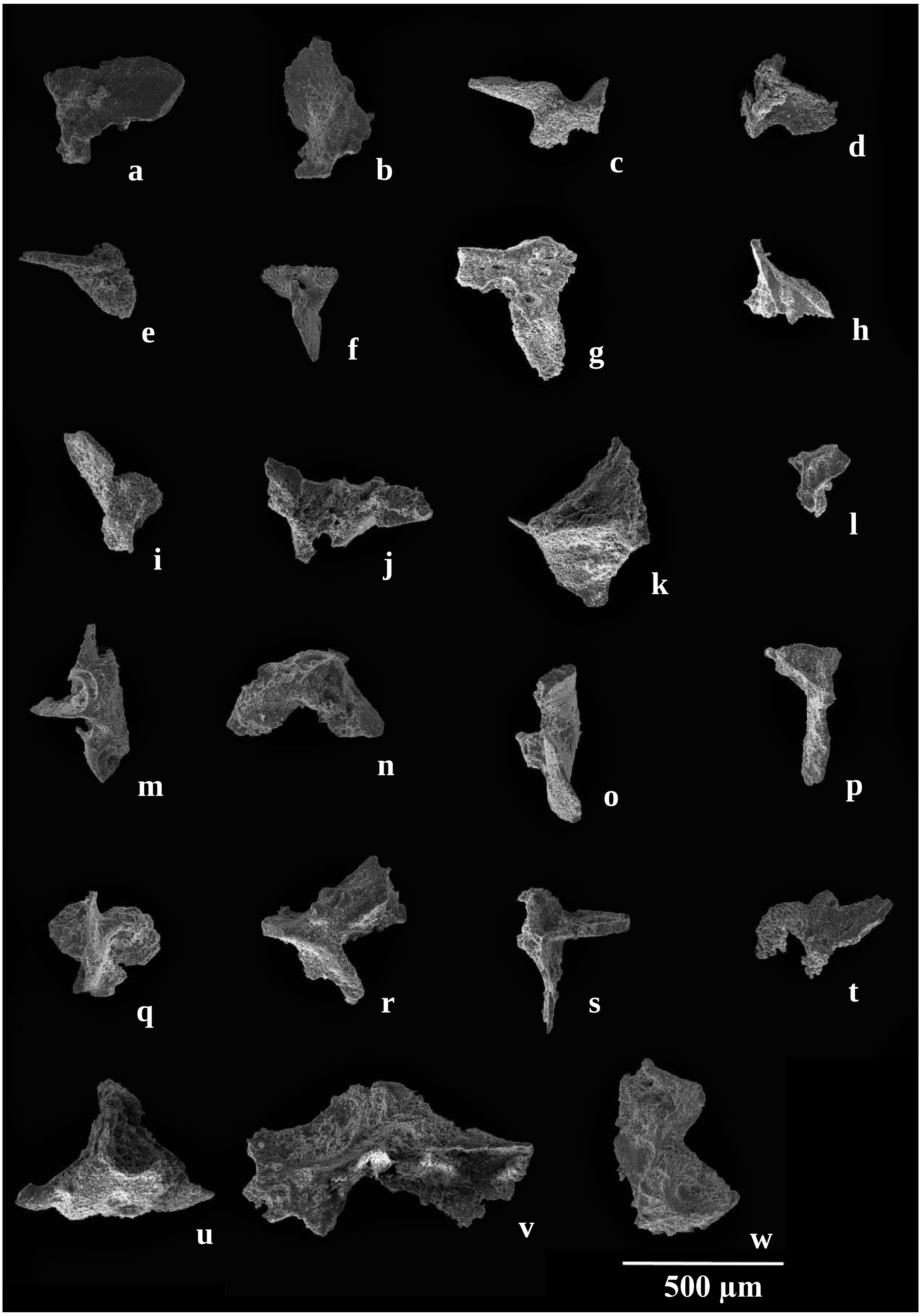


PLATE 19

Brachials of *Saccocoma vernioryi* Manni & Nicosia

a. *Saccocoma vernioryi*? (Manni and Nicosia, 1984), broken wing structure, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

b. *Saccocoma vernioryi*? (Manni and Nicosia, 1984), broken wing structure, slightly lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

c. *Saccocoma vernioryi* (Manni and Nicosia, 1984), probably second primibrachial (IBr$_2$), wing structure, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

d. *Saccocoma vernioryi*? (Manni and Nicosia, 1984), probably second primibrachial (IBr$_2$), wing structure, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

e. *Saccocoma vernioryi* (Manni and Nicosia, 1984), probably second primibrachial (IBr$_2$), wing structure, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

f. *Saccocoma vernioryi* (Manni and Nicosia, 1984), broken part of the secundibrachial IIBr$_{2/4}$, wing structure, aboral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

g. *Saccocoma vernioryi*? (Manni and Nicosia, 1984), probably second primibrachial (IBr$_2$), wing structure, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

h. *Saccocoma vernioryi*? (Manni and Nicosia, 1984), probably broken wing structure, oral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

i. *Saccocoma vernioryi*? (Manni and Nicosia, 1984), articulation facet of the wing like brachial, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

j. *Saccocoma vernioryi*? (Manni and Nicosia, 1984), articulation facet of the wing like brachial, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

k. *Saccocoma vernioryi*? (Manni and Nicosia, 1984), articulation facet of the wing like brachial, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

l. *Saccocoma vernioryi*? (Manni and Nicosia, 1984), articulation facet of the wing like brachial, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

m. *Saccocoma vernioryi*? (Manni and Nicosia, 1984), articulation facet of the wing like brachial, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

n. *Saccocoma vernioryi*? (Manni and Nicosia, 1984), articulation facet of the wing like brachial, BA-05, the *Chitinoidella* Zone, Tithonian, BA-I section

o. *Saccocoma vernioryi*? (Manni and Nicosia, 1984), articulation facet of the wing like brachial, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

p. *Saccocoma vernioryi*? (Manni and Nicosia, 1984), articulation facet of the wing like brachial, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

q. *Saccocoma vernioryi* (Manni and Nicosia, 1984), articulation facet of the wing like brachial, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

r. *Saccocoma vernioryi* (Manni and Nicosia, 1984), broken IIBr5,6 or 7, wing structure, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

PLATE 19

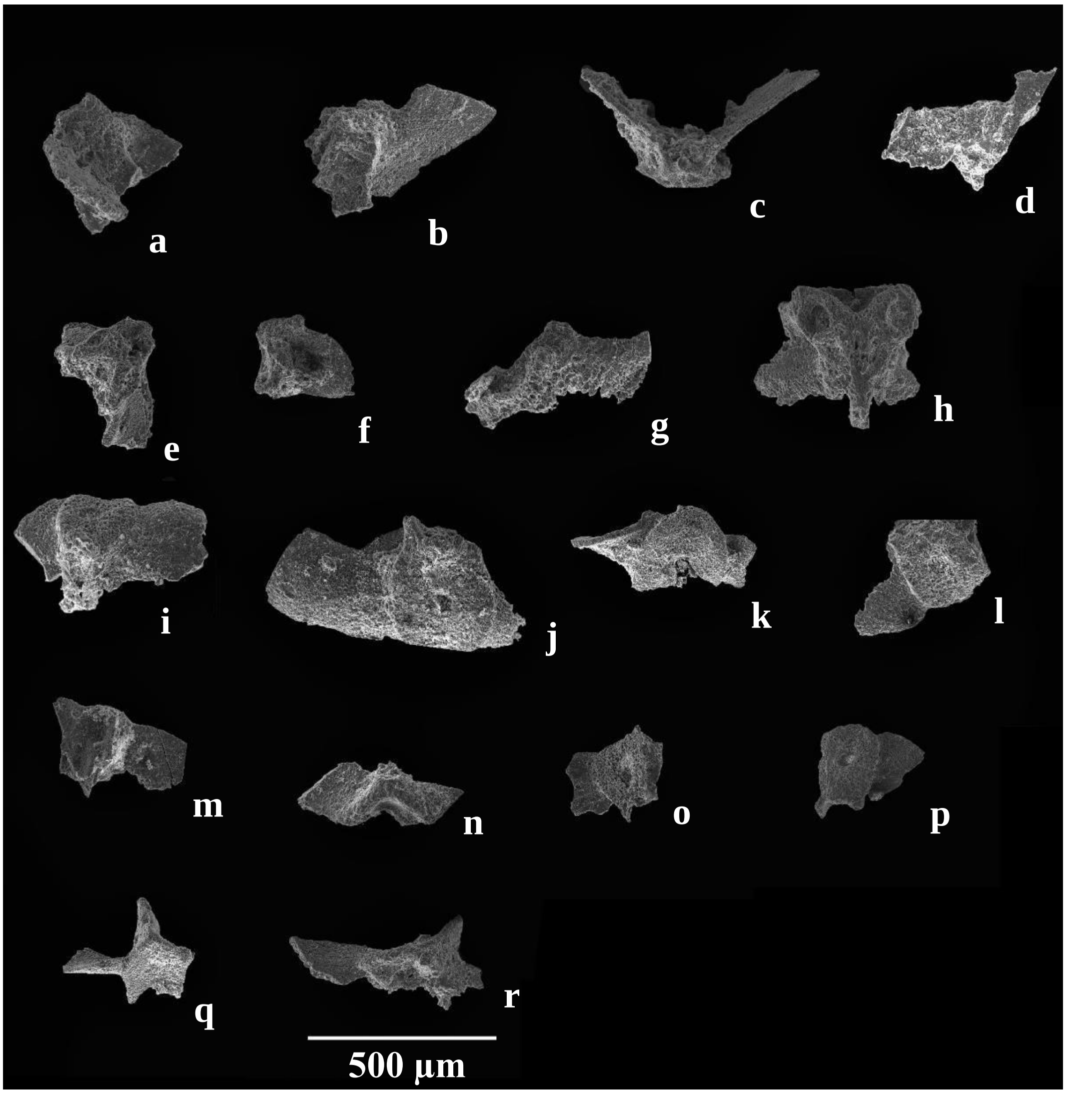


PLATE 20

Brachials of *Saccocoma vernioryi* Manni & Nicosia

- **a.** *Saccocoma* sp., broken articulation body of the brachial, probably wing structure, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **b.** *Saccocoma vernioryi* (Manni and Nicosia, 1984), broken articulation body of the brachial, probably wing structure, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **c.** *Saccocoma vernioryi* (Manni and Nicosia, 1984), broken articulation body of the brachial, probably wing structure, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **d.** *Saccocoma vernioryi* (Manni and Nicosia, 1984), broken articulation body of the brachial, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **e.** *Saccocoma* sp., broken articulation facet of the brachial, probably wing structure, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **f.** *Saccocoma vernioryi*? (Manni and Nicosia, 1984), broken articulation body of the brachial, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **g.** *Saccocoma vernioryi*? (Manni and Nicosia, 1984), broken articulation body of the brachial, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **h.** *Saccocoma vernioryi*? (Manni and Nicosia, 1984), broken articulation body of the brachial, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **i.** *Saccocoma vernioryi*? (Manni and Nicosia, 1984), broken articulation body of the brachial, probably wing structure, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **j.** *Saccocoma vernioryi* (Manni and Nicosia, 1984), broken articulation body of the brachial, probably wing structure, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **k.** *Saccocoma vernioryi*? (Manni and Nicosia, 1984), broken articulation body of the brachial, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section
- **l.** *Saccocoma* sp., broken articulation body of the brachial?, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

m. *Saccocoma vernioryi*? (Manni and Nicosia, 1984), fragment of spines?, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

n. *Saccocoma* sp., broken articulation body of the brachial?, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

o. *Saccocoma vernioryi*? (Manni and Nicosia, 1984), broken articulation body of the brachial, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

p. *Saccocoma vernioryi* (Manni and Nicosia, 1984), secundibrachial wing structure? BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

q. *Saccocoma vernioryi* (Manni and Nicosia, 1984), secundibrachial wing structure ?, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

r. *Saccocoma* sp., probably IIBr$_3$, BA-05, the *Chitinoidella* Zone, Tithonian, BA-I section

s. *Saccocoma* sp., primi- or secundibrachial, undefined, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

t. *Saccocoma vernioryi?* (Manni and Nicosia, 1984), broken articulation body of the brachial, probably wing structure, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

PLATE 20

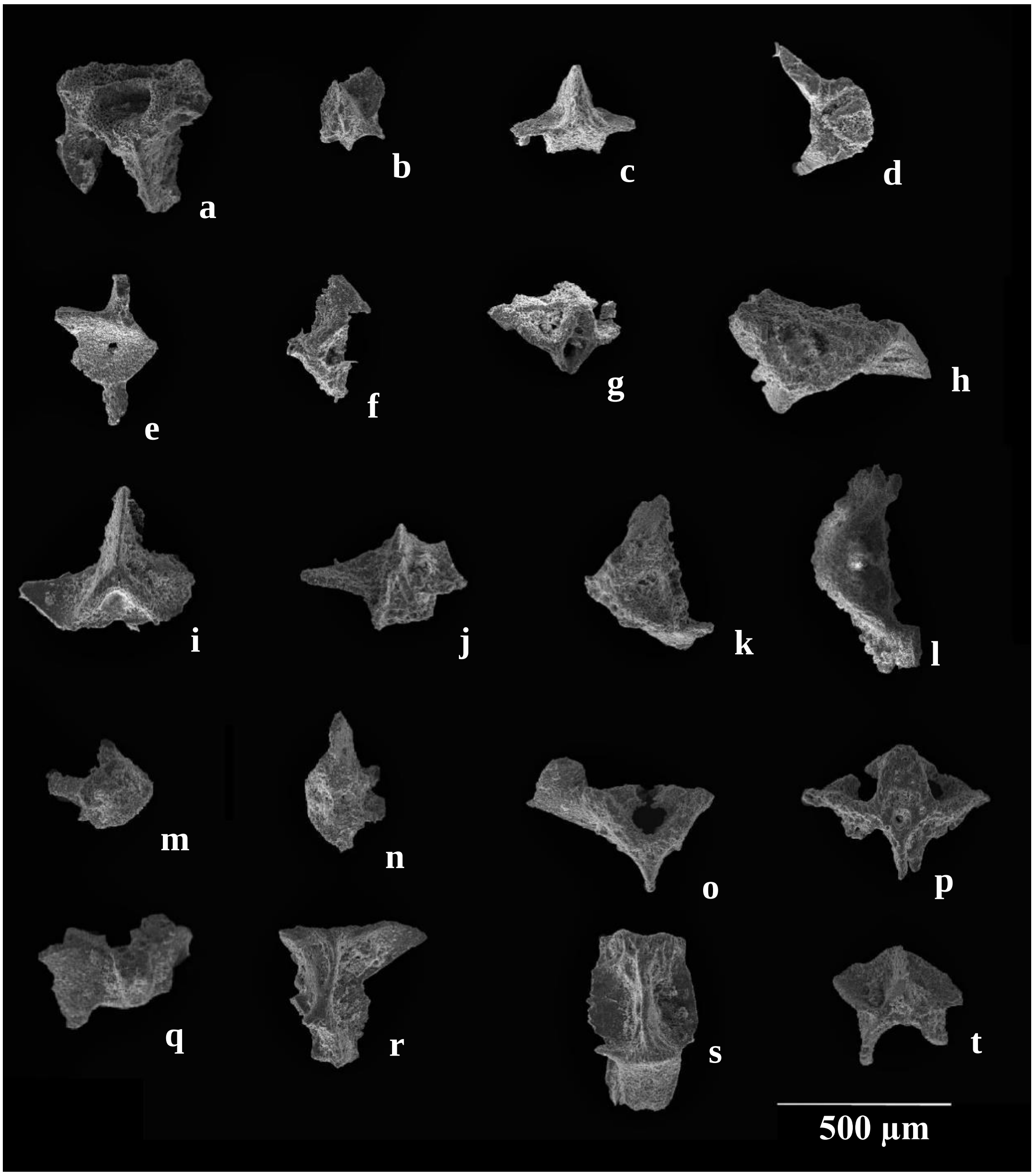


PLATE 21

Distal secundibrachials (IIBr) of *Saccocoma* Agassiz

a. *Saccocoma tenella* (Goldfuss, 1831), $IIBr_3$, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

b. *Saccocoma tenella* (Goldfuss, 1831), IIBr, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

c. *Saccocoma tenella* (Goldfuss, 1831), IIBr, dorsal view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

d. *Saccocoma tenella* (Goldfuss, 1831), IIBr, ventral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

e. *Saccocoma tenella* (Goldfuss, 1831), IIBr, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

f. *Saccocoma tenella* (Goldfuss, 1831), IIBr, ventral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

g. *Saccocoma tenella* (Goldfuss, 1831), IIBr, slightly ventral view, BA-05, the Chitinoidella Zone, Tithonian, BA-I section

h. *Saccocoma tenella* (Goldfuss, 1831), IIBr, ventral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

i. *Saccocoma tenella* (Goldfuss, 1831), IIBr, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

j. *Saccocoma tenella* (Goldfuss, 1831), IIBr, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

k. *Saccocoma tenella* (Goldfuss, 1831), IIBr, ventral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

l. *Saccocoma tenella* (Goldfuss, 1831), IIBr, slightly lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

m. *Saccocoma tenella* (Goldfuss, 1831), broken IIBr, dorsal view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

n. *Saccocoma tenella* (Goldfuss, 1831), IIBr, ventral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

o. *Saccocoma* sp., broken IIBr, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

p. *Saccocoma tenella* (Goldfuss, 1831), IIBr part, lateral view, BA-05, the *Chitinoidella* Zone, Late Tithonian, BA-I section

PLATE 21

PLATE 22

Benthic Foraminifera

Scale Bar: 100 µm

- **a.** *Textularia* sp., BA-01, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **b.** *Textularia* sp., BA-02, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **c.** *Textularia* sp., BA-32, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **d.** *Textularia* sp., BA-43, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **e.** *Textularia* sp., BA-43, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **f.** *Textularia* sp., BA-43, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **g.** *Textularia* sp., BA-43, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **h.** *Textularia* sp., BA-43, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **i.** *Haghimashella*? sp., BA-14, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **j.** *Haghimashella*? sp., BA-23, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

PLATE 22

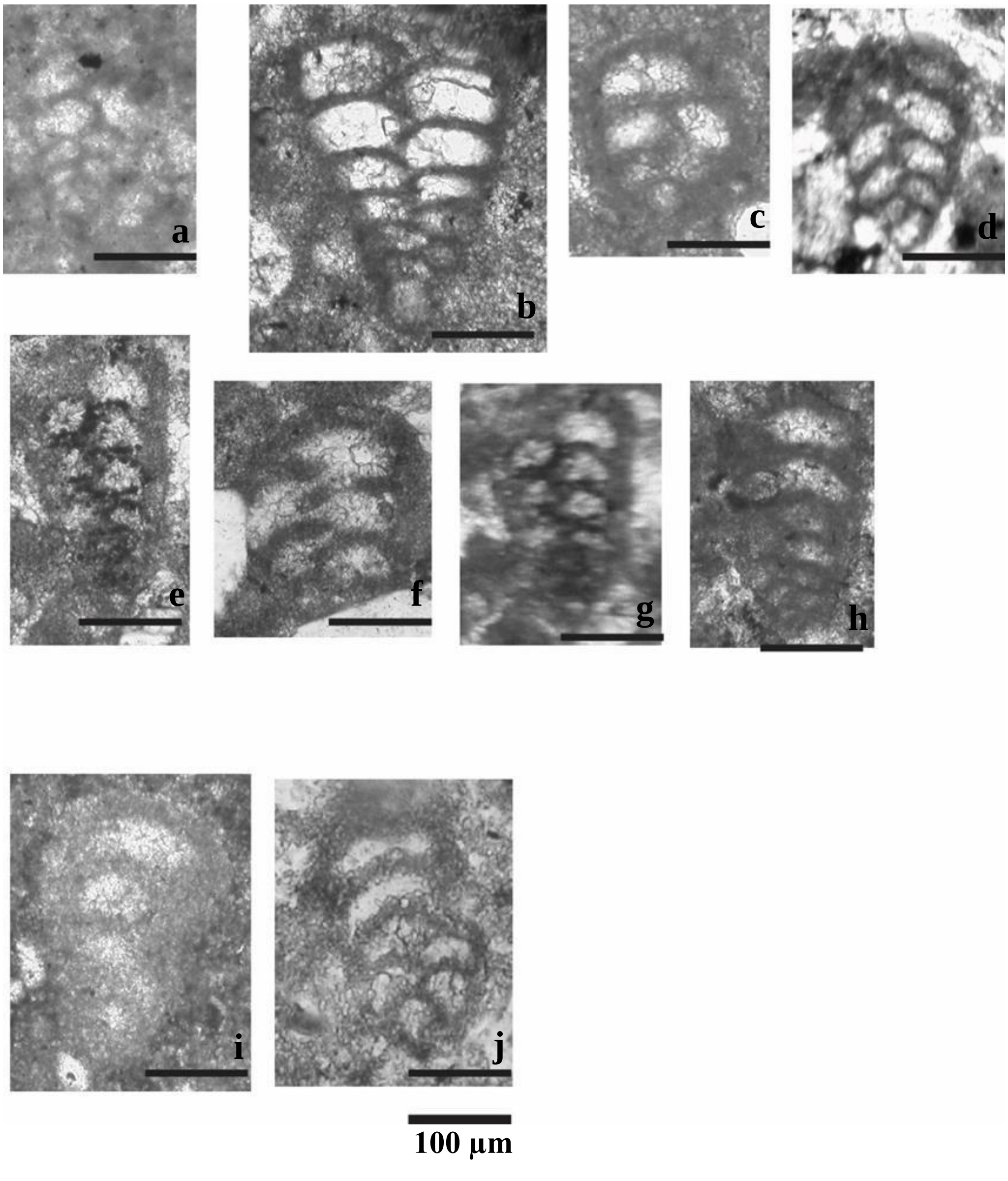


PLATE 23

a. *Lenticulina* sp., BA-04, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

b. *Lenticulina* sp., BA-14, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation

c. *Lenticulina* sp., BA-16, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation

d. *Lenticulina* sp., BA-42, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

e. *Lenticulina* sp., BA-48, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

f. *Lenticulina* sp., BA-55, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

g. *Moesiloculina* sp., BA-14, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation

h. *Hechtina*? sp., BA-43/6, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

i. *Hechtina*? sp., BA-43/6, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

PLATE 23

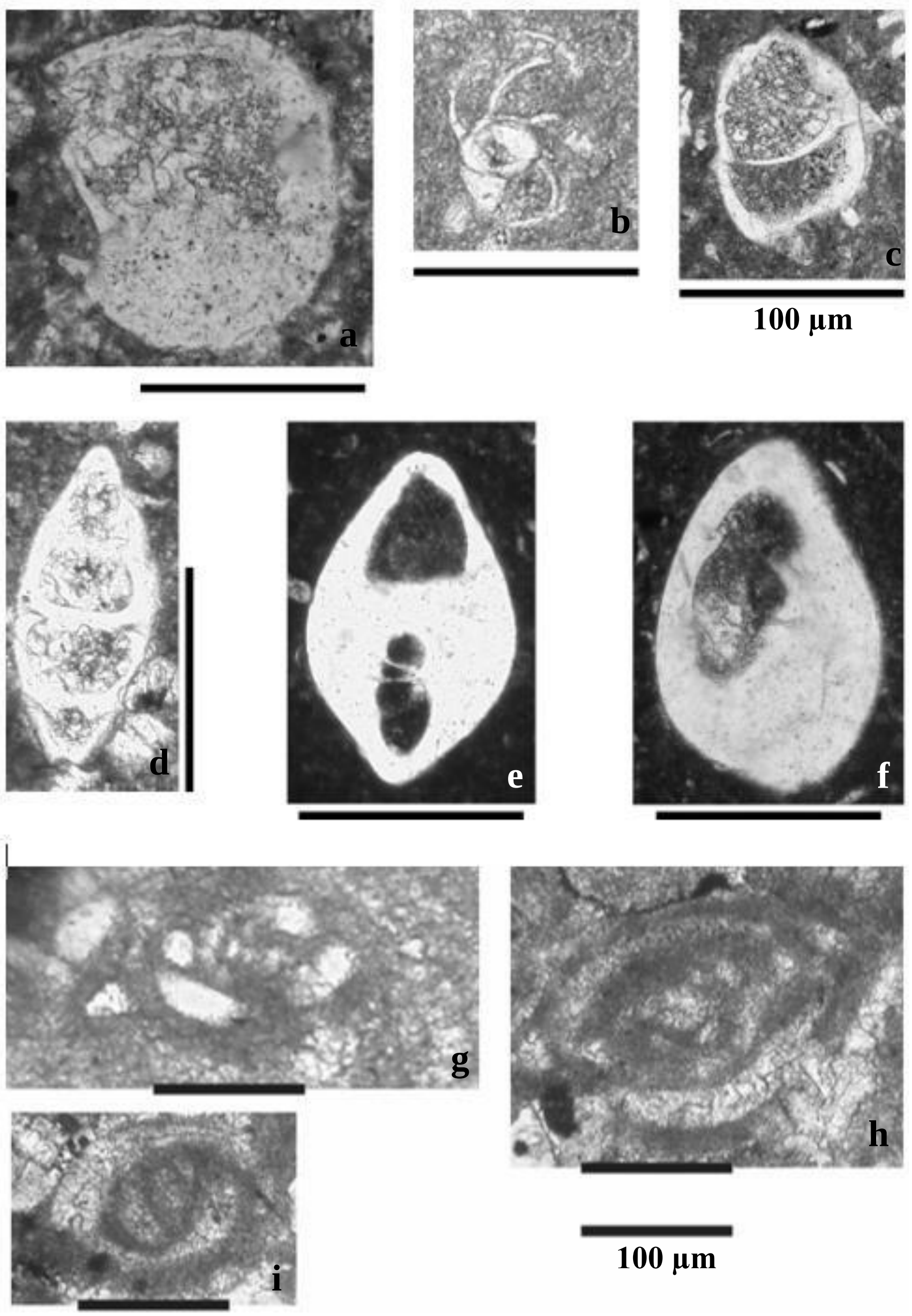


PLATE 24

a. *Spirillina* sp., BA-09, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

b. *Spirillina* sp., BA-12, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation

c. *Spirillina* sp., BA-16, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation

d. *Spirillina* sp., BA-23, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

e. *Spirillina* sp., BA-24, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

f. *Spirillina* sp., BA-39, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

g. *Spirillina* sp., BA-43, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

h. *Spirillina* sp., BA-43, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

i. *Spirillina* sp., BA-42, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

j. *Spirillina* sp., BA-43, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

k. *Spirillina* sp., BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

l. *Spirillina* sp., BA-52, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

PLATE 24

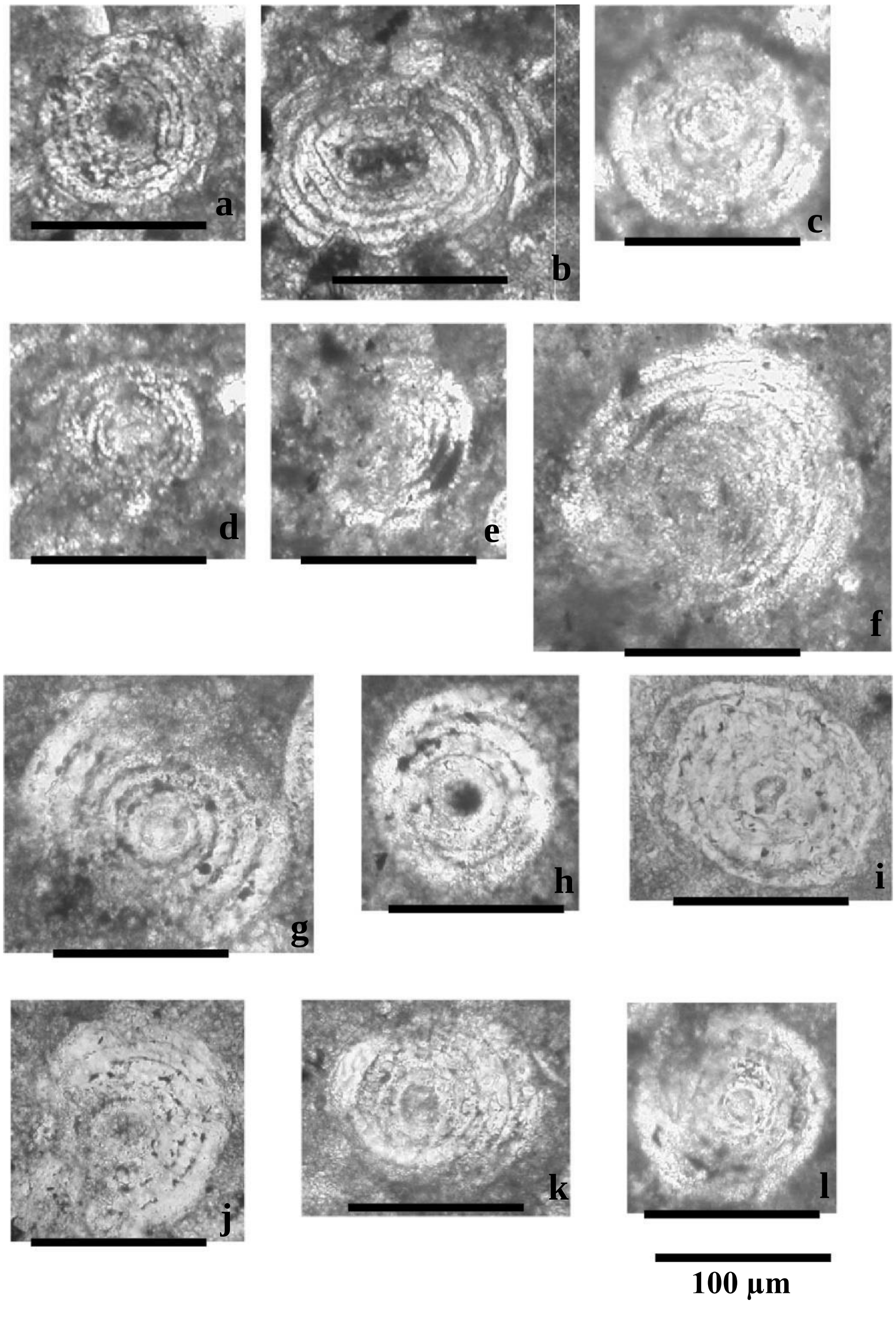


PLATE 25

- **a.** *Spirillina* sp. 1, BA-22, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **b.** *Spirillina* sp. 1, BA-28, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **c.** *Spirillina* sp. 1, BA-42, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **d.** *Spirillina* sp. 1, BA-45, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **e.** *Spirillina* sp. 1, BA-46, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **f.** *Spirillina* sp. 1, BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **g.** *Spirillina* sp. 1, BA-51, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **h.** *Spirillina* sp. 2, BA-01, *boneti* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **i.** *Spirillina* sp. 2, BA-13, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **j.** *Spirillina* sp. 2, BA-18, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **k.** *Spirillina* sp. 2, BA-18, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **l.** *Spirillina* sp. 2, BA-26, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **m.** *Spirillina* sp. 2, BA-38, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation
- **n.** *Spirillina* sp. 2, BA-43, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **o.** *Spirillina* sp. 2, BA-50, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **p.** *Spirillina* sp. 2, BA-51, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation
- **q.** *Spirillina* sp. 2, BA-51, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

PLATE 25

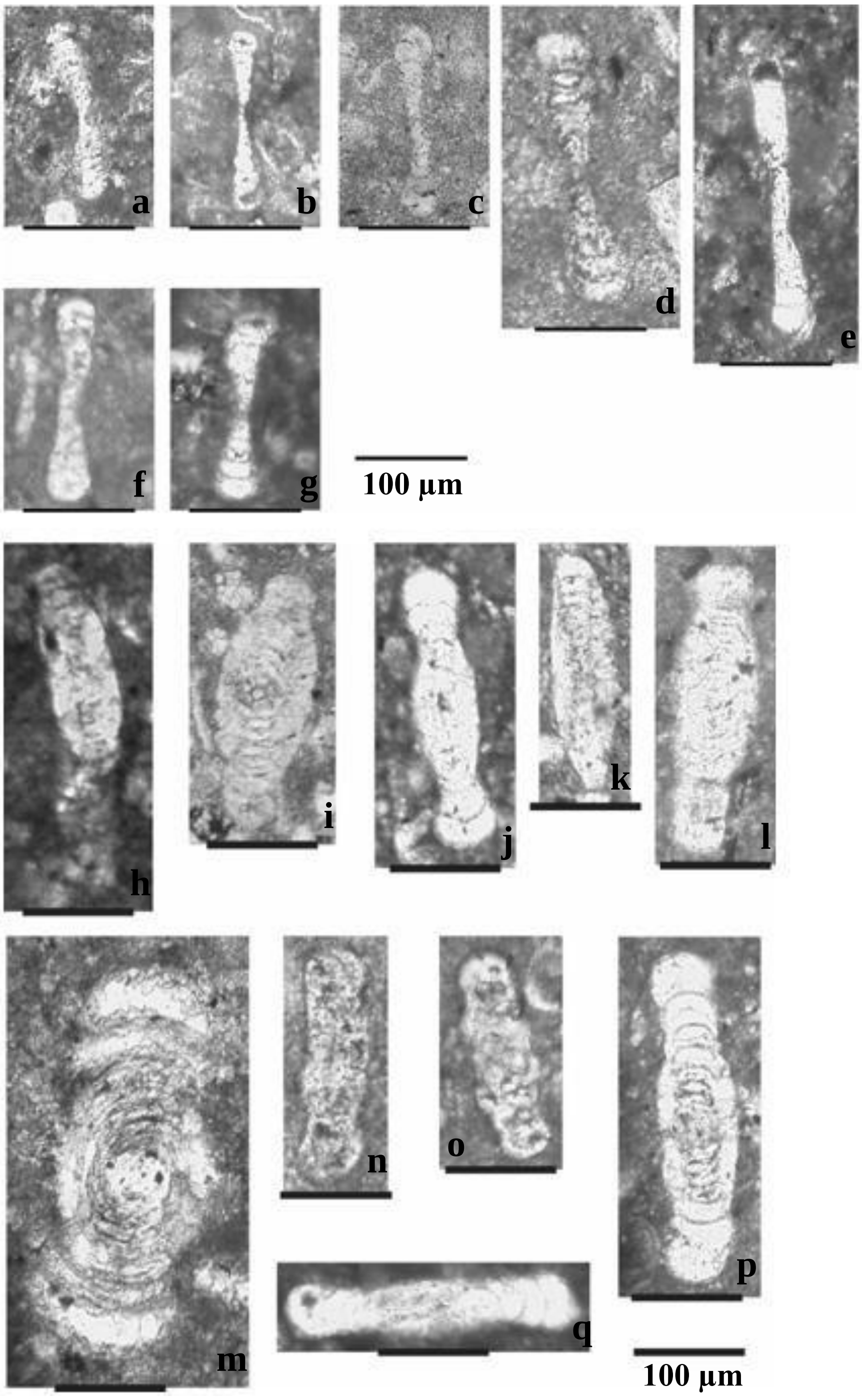


PLATE 26

a. *Spirillina* sp. 3, BA-01, *Chitinoidella* Zone (Late Tithonian), Yosunlukbayırı Formation

b. *Spirillina* sp. 3, BA-01, *Chitinoidella* Zone (Late Tithonian), Yosunlukbayırı Formation

c. *Spirillina* sp. 3, BA-18, *remanei* Subzone (Late Tithonian), Yosunlukbayırı Formation

d. *Spirillina* sp. 3, BA-23, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

e. *Spirillina* sp. 3, BA-42, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

f. *Spirillina* sp. 3, BA-47, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

g. *Spirillina* sp. 3, BA-49, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

h. *Spirillina* sp. 4, BA-25, *massutiniana* Subzone (Late Tithonian), Yosunlukbayırı Formation

i. *Spirillina* sp. 4, BA-45, *alpina* Subzone (Early Berriasian), Yosunlukbayırı Formation

j. *Spirillina* sp. 4, BA-53, *Remaniella* Subzone (Early Berriasian), Yosunlukbayırı Formation

PLATE 26

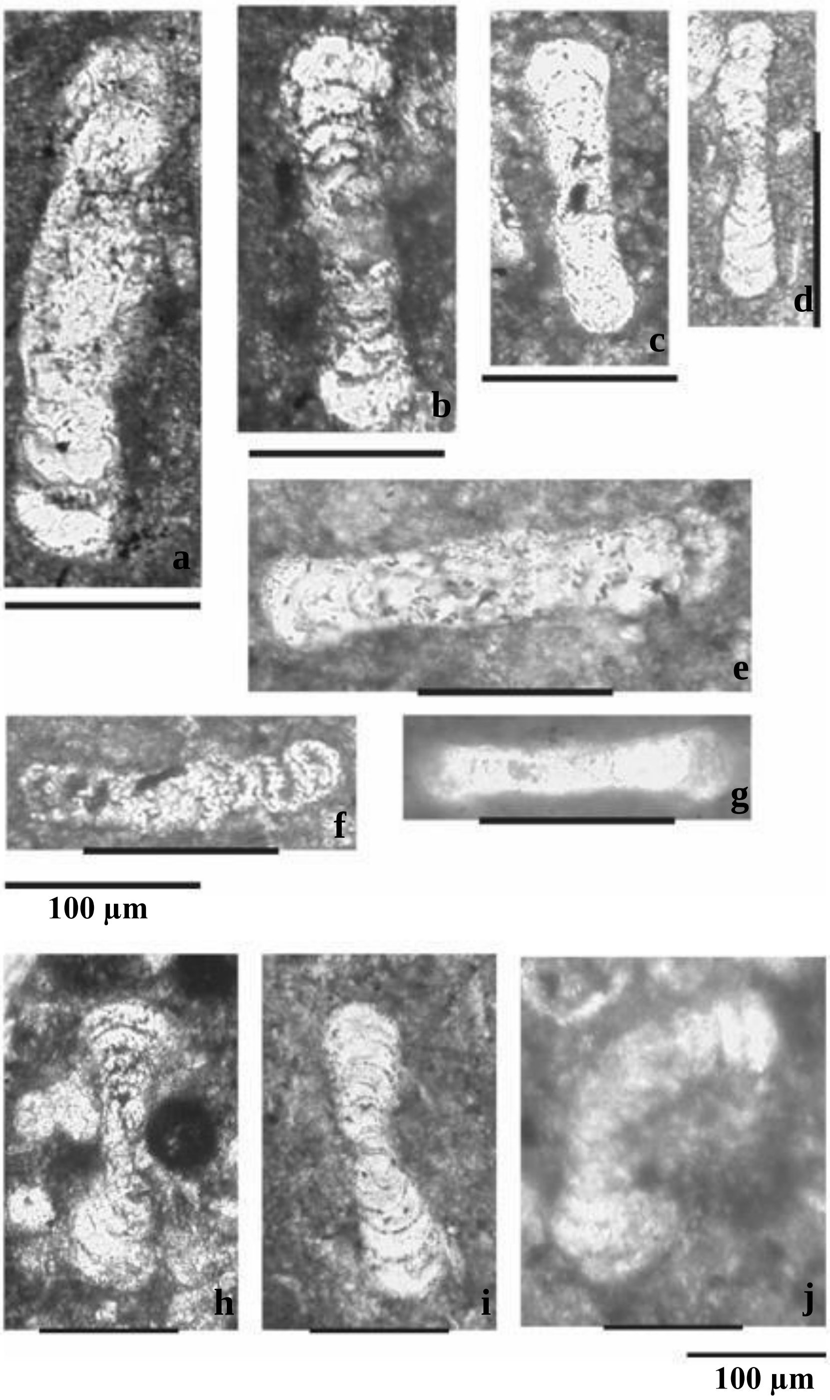


PLATE 27

a. *Nodosaria* sp., BA-01, *boneti* Subzone, Late Tithonian, Yosunlukbayırı Formation

b. *Nodosaria* sp., BA-03, *boneti* Subzone, Late Tithonian, Yosunlukbayırı Formation

c. *Nodosaria* sp., BA-03, *boneti* Subzone, Late Tithonian, Yosunlukbayırı Formation

d. *Nodosaria* sp., BA-07, *boneti* Subzone, Late Tithonian, Yosunlukbayırı Formation

e. *Nodosaria* sp., BA-21, *remanei* Subzone, Late Tithonian, Yosunlukbayırı Formation

f. *Nodosaria* sp., BA-40, *massutiniana* Subzone, Late Tithonian, Yosunlukbayırı Formation

g. *Nodosaria* sp., BA-42, *alpina* Subzone, Early Berriasian, Yosunlukbayırı Formation

h. *Nodosaria* sp., BA-42, *alpina* Subzone, Early Berriasian, Yosunlukbayırı Formation

i. *Nodosaria* sp., BA-43, *alpina* Subzone, Early Berriasian, Yosunlukbayırı Formation

j. *Nodosaria* sp., BA-43, *alpina* Subzone, Early Berriasian, Yosunlukbayırı Formation

k. *Nodosaria* sp., BA-46, *alpina* Subzone, Early Berriasian, Yosunlukbayırı Formation

l. *Nodosaria* sp., BA-50, *Remaniella* Subzone, Early Berriasian, Yosunlukbayırı Formation

m. *Nodosaria* sp., BA-53, *Remaniella* Subzone, Early Berriasian, Yosunlukbayırı Formation

n. *Nodosaria* sp., BA-55, *Remaniella* Subzone, Early Berriasian, Yosunlukbayırı Formation

PLATE 27