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Stratigraphy and Larger Foraminifera of the Eocene Shallow-marine and Olistostromal Units of the Southern Part of the Thrace Basin, NW Turkey

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Abstract: The Eocene marine sequence in the southern part of the Thrace Basin (NW Turkey) involves a variety of platform and deep-marine olistostromal units, the stratigraphy of which have been vigorously debated in the past. A detailed analysis of larger foraminifera in these either foraminifera or foraminifera-coral-coralline algae-dominated platform and associated comparatively deeper-marine units permits us to establish a high-resolution biostratigraphy in the context of shallow benthic zonation (with SBZ zones) of Tethyan Paleogene. The oldest zone (SBZ 5, corresponding to the basal Ypresian) was observed only in olistoliths. An old erosional remnant of a transgressive shallow-marine to basinal sequence (Dişbudak series; late Ypresian–? middle Eocene) was recognized below the regionally most widespread carbonate platform unit, the Soğucak Formation. The Dişbudak sequence, previously considered to belong to the Soğucak Formation and formally introduced recently, contains larger foraminifera, such as orthophragmines, nummulitids and alveolinids in its shallow-marine package referred to SBZ 10 (late Ypresian). The Soğucak Formation, which often exhibits patch reef developments, contains a rich and diverse assemblage of orthophragmines (*Discocyclina*, *Orbitoclypeus* and *Asterocyclina*), nummulitids (reticulate and other *Nummulites*, *Assilina*, *Operculina*, *Heterostegina* and *Spiroclypeus*), and other benthic taxa (*Silvestriella*, *Pellatispira*, *Chapmanina*, *Orbitolina*, *Linderina*, *Gyroidinella*, *Fabiania*, *Halkyardia*, *Eoannularia, Sphaerogypsina, Asterigerina, Planorbulina* and *Peneroplis*). Their assemblages, referred to SBZ 15/16, 17, 18, 19 and 20 Zones, provide a precise tool for recording the history of marine events which resulted in the deposition of the Soğucak Formation during four main periods. Their spatial distribution, recorded as late Lutetian, early Bartonian, late Bartonian and Priabonian, suggests a marine transgression from WSW to ENE. The Çengelli flysch sequence overlying the Soğucak Formation in a limited area to the east of the Gelibolu Peninsula, contains benthic foraminifera, mainly from limestone olistoliths mostly derived from the Soğucak Formation, and also in the turbiditic strata. The assemblages in the olistoliths reveal the existence of various shallow marine limestone sequences ranging in age from late Bartonian to early Priabonian.

Key Words: southern Thrace, benthic foraminifera, biometry, taxonomy, biostratigraphy

Trakya Havzası Güneyi Eosen Sığ-Denizel ve Olistostromal Birimlerinin Stratigrafisi ve Bentik Foraminiferleri (KB Türkiye)

Özet: Trakya Havzası (KB Türkiye) güneyindeki denizel Eosen birimleri stratigrafik konumları tartışmalı platform ve derin-denizel türbiditik ve olistostromal istifleri ile temsil edilir. Havzanın güneyinde, foraminifer ve/veya foraminifer-mercan-kırmızı alg bakımından zengin birimlerde yaptığımız çalışmalar ilk kez bu birimler için yüksek çözünürlü biyostratigrafik bir sistemin oluşturulmasına imkan sağlamıştır. Paleontolojik veriler ve arazi gözlemleri ışığında stratigrafik olarak Soğucak Formasyonu'nun altında daha önce Trakya'da tanımlanmamış erken Geç İpreziyen–? Orta

Eosen yaşlı sığ- ve derin-denizel bir istifin, Dişbudak istifi, varlığı ortaya konmuştur. Önceki çalışmalarda Soğucak Formasyonu içinde değerlendirilen, bu birimin sığ-denizel kısmı SBZ 10'u (erken Geç İpreziyen) temsil eden orthophragmines, nummulitid ve alveolinid grupları içerir. Yama resifi düzeylerinin yaygın olarak gözlendiği Soğucak Formasyonu orthophragmines (*Discocyclina*, *Orbitoclypeus* ve *Asterocyclina*), nummulitid (retikule ve diğer *Nummulites* grupları, *Assilina*, *Operculina*, *Heterostegina* ve *Spiroclypeus*) ve diğer bentik foraminifer grupları (*Silvestriella*, *Pellatispira*, *Chapmanina*, *Orbitolina*, *Linderina*, *Gyroidinella*, *Fabiania*, *Halkyardia*, *Eoannularia, Sphaerogypsina, Asterigerina, Planorbulina* ve *Peneroplis*) içerir. SBZ 15/16, 17, 18, 19 ve 20 sığ bentik zonları temsil eden bu topluluklar birimin çökelimi ile ilgili denizel olayların kronolojisinin oluşturulmasını sağlamış olup dört önemli dönem; Geç Lütesiyen, Erken Bartoniyen, Geç Bartoniyen ve Priaboniyen transgresyon dönemleri ortaya konmuştur. Çengelli fliş istifinin yaygın kireçtaşı olistolitleri (çoğunluğu Soğucak Formasyonu'ndan aktarılma) ve kısmen türbiditik seviyelerinde ise (geç) Bartoniyen ve Priaboniyen grupları tanımlanmıştır.

Anahtar Sözcükler: güney Trakya, bentik foraminifer, biyometri, taksonomi, biyostratigrafi

Introduction

Eocene units, represented mainly by platform carbonates and a flysch sequence containing olistoliths of varying dimensions, can be traced in discontinuous outcrops across the southern part of the Thrace Basin (Figures 1–3). In previous studies, the Eocene platform units were recognized at two stratigraphic levels. The stratigraphically older one, the Başaoğlu carbonates of the Karaağaç Formation, crops out in a single locality in the northern part of the Gelibolu Peninsula. The younger and regionally more widespread Soğucak Formation is traceable throughout the Thrace Basin (Saner 1985; Önal 1986; Sümengen & Terlemez 1991; Siyako & Huvaz 2007) (Figure 4). In this study, we have recognised another shallow marine transgressive sequence below the Soğucak Formation north-east of Şarköy near Doluca Hill. This unit, named the Dişbudak series by Okay *et al.* (2010), is a carbonate-clastic sequence and is quite different from the carbonate blocks of the Çengelli Formation and lithologies of the Soğucak Formation in containing a substantial proportion of clastics. The upper part of the sequence is represented by basinal fine clastics containing a badly preserved pelagic fauna and flora. The Çengelli Formation has not been differentiated and mapped in previous studies and was treated as part of the Soğucak Formation (Şentürk *et al.* 1998b) before Okay *et al.* (2010) provided a detailed map and description of the unit.

The Soğucak Formation is a widely recognized foraminifera- and coral-dominated platform unit and, owing to its well-developed patchy reefs, is a potential reservoir throughout Thrace (Siyako *et al.* 1989; Siyako & Huvaz 2007). Despite its economic potential, a complex biostratigraphic study and information about the correlation of its isolated surface outcrops are completely missing. Most studies were concerned with faunal assemblages in local sections and were far from revealing a basin scale evaluation. Widespread shallow marine limestone outcrops of the Soğucak Formation around Şarköy (Doluca Hill) (Figure 3) were previously considered either to represent the Soğucak Formation, or were regarded as olistoliths in the Çengelli Formation (Saner 1985; Okay & Tansel 1992; Özcan *et al.* 2007a). Recently, Okay *et al.* (2010) have shown that both *in situ* Soğucak Formation (Doluca Hill sequence) and limestones representing the blocks of the Çengelli Formation occur in the same region. The relationship of these limestone outcrops with the surrounding clastic rocks cannot be judged with certainty in all cases mainly due to Miocene cover or tectonic complications. Previous views considering the relationship between the olistostromal unit and the limestone outcrops are discussed in Okay *et al.* (2010).

The olistostromal unit, the Çengelli Formation, formerly investigated under different lithostratigraphic names such as the Korudağ (Sümengen & Terlemez 1991; Şentürk *et al.* 1998b), Ceylan (Siyako 2006) or Çengelli Formation (Okay *et al.* 2010), is made up of turbidite beds with a rhythmic alternation of sandstone and shale and debris flow horizons and olistostromes. Clasts in the mass flows mainly include serpentinite and

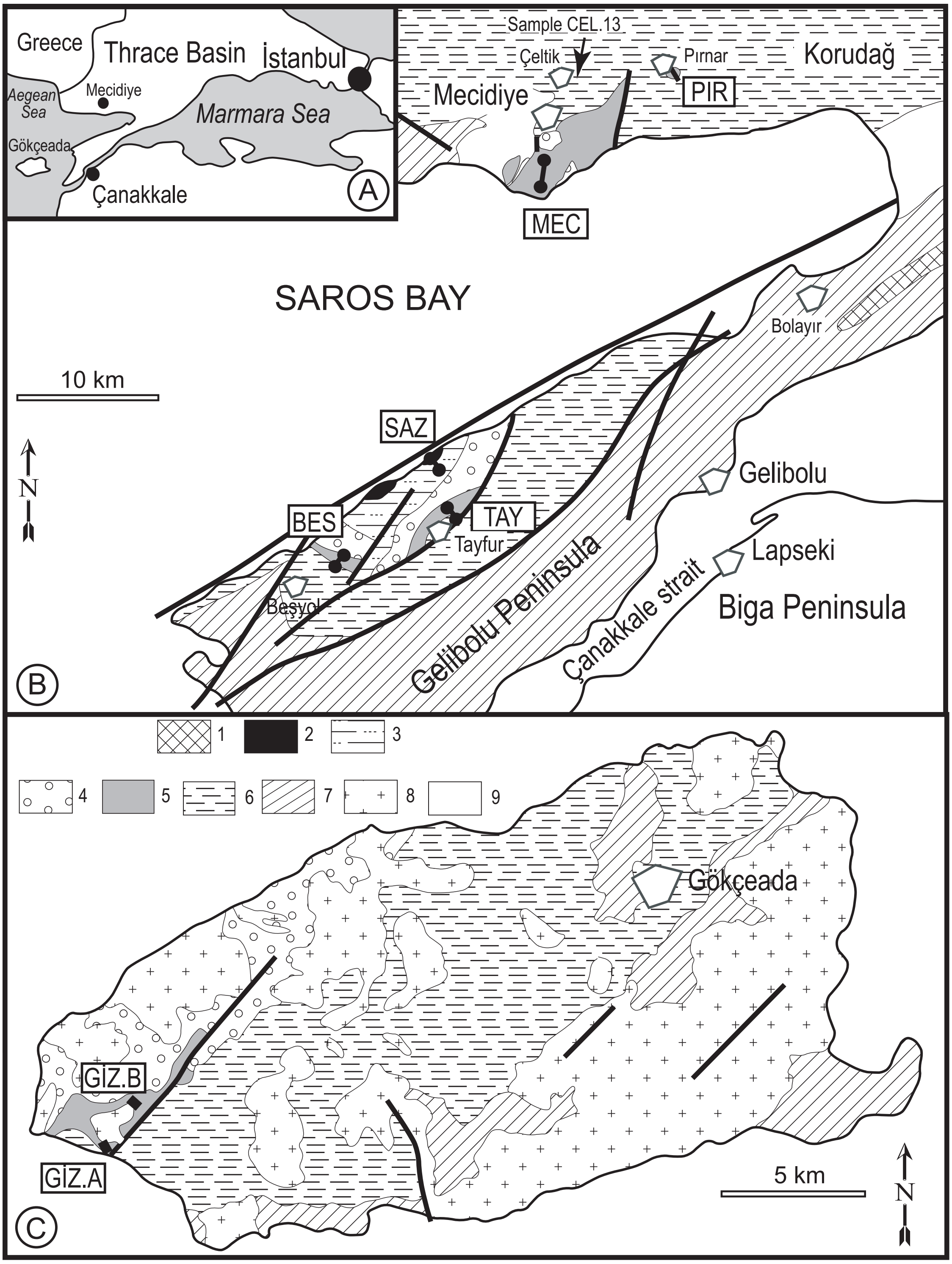


Figure 1. Geological map of the Gelibolu Peninsula **(B)** and Gökçeada **(C)** in the southern part of the Thrace Basin **(A)** and location of stratigraphic sections. Geological maps simplified from Temel & Çiftci (2002), Türkecan & Yurtsever (2002) and Siyako & Huvaz (2007). 1– Ophiolitic units, 2– Lört Limestone, 3– Karaağaç Formation, 4– Fıçıtepe Formation, 5– Soğucak Formation, 6– Keşan and/or Ceylan formations, 7– undifferentiated Miocene and younger units (partly include Oligocene), 8– volcanics, 9– alluvium.

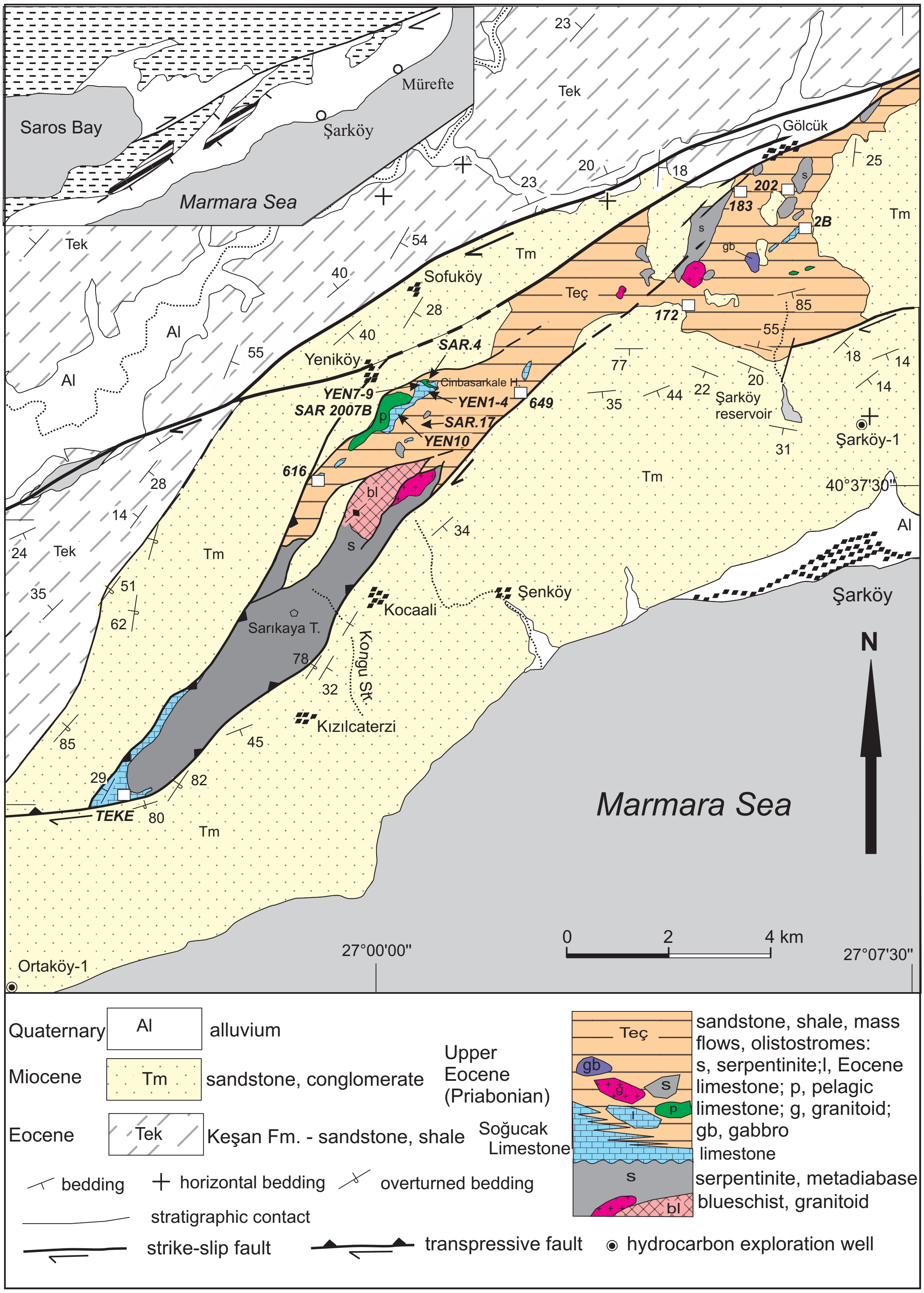


Figure 2. Geological map of the region north and west of Şarköy and location of samples and stratigraphic sections (small boxes). Geological map from Okay *et al.* (2010).

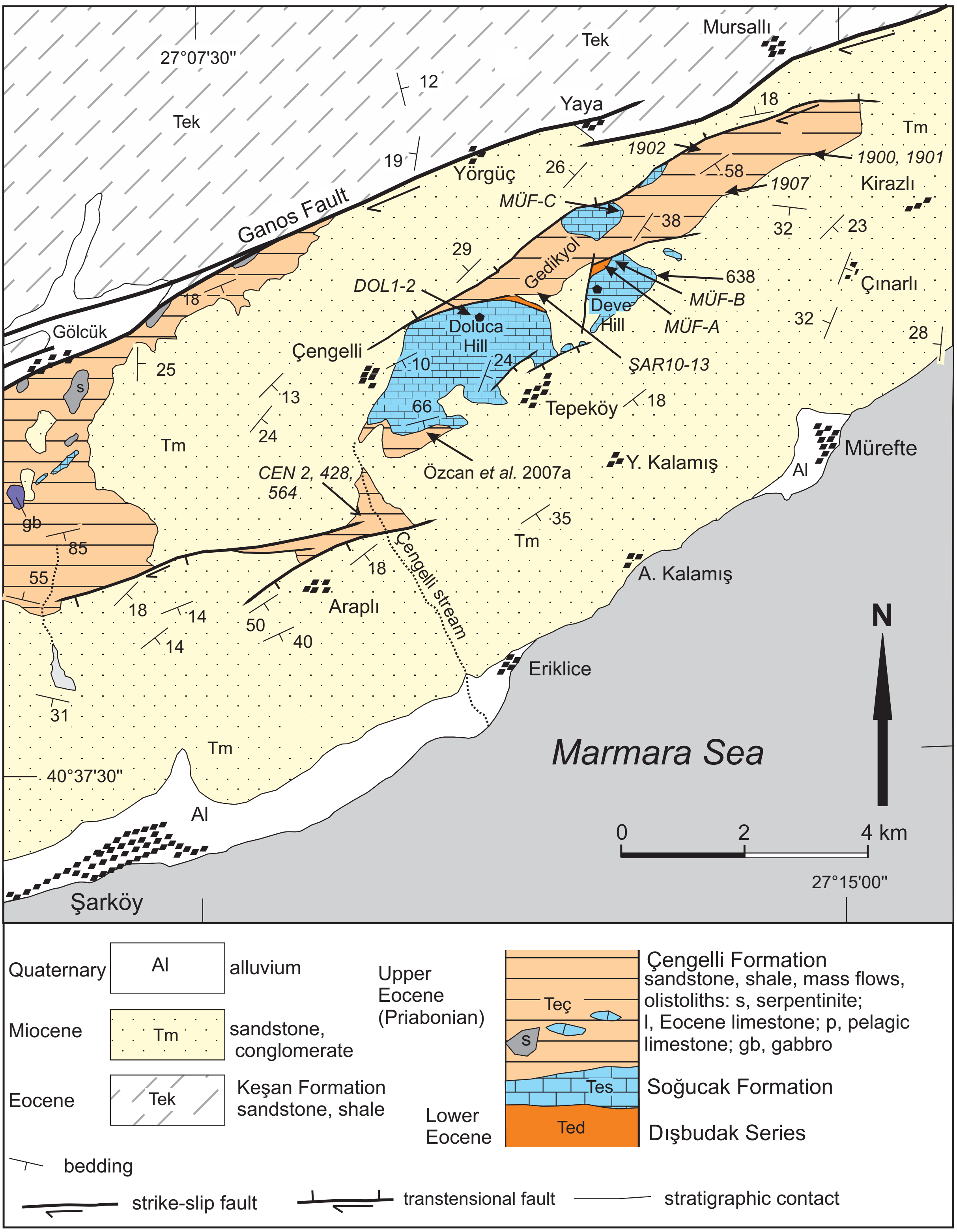


Figure 3. Geological map of the Doluca Hill region northwest of Mürefte and location of samples and stratigraphic sections (small boxes). Geological map from Okay *et al.* (2010).

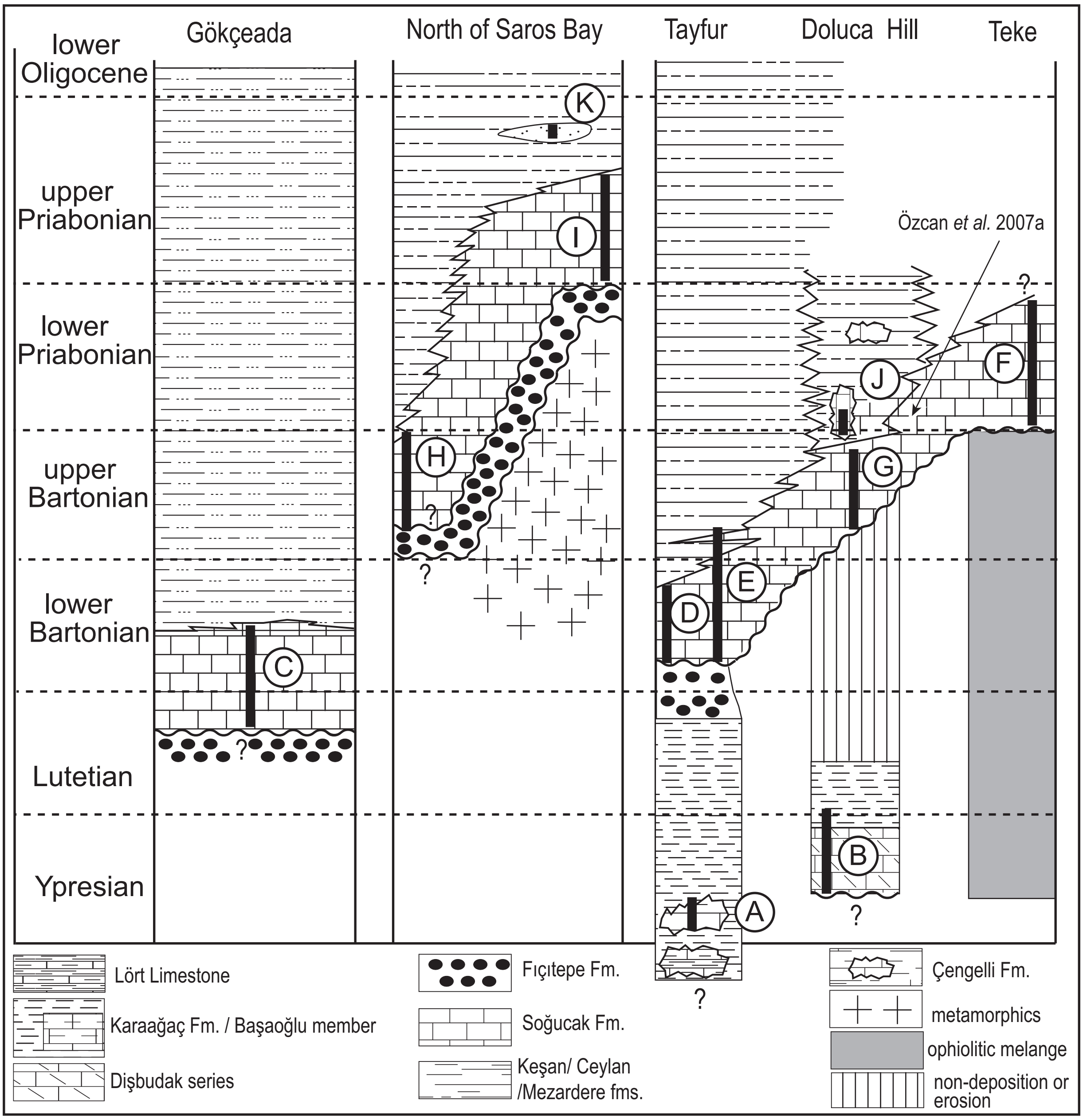


Figure 4. Stratigraphic relations of shallow marine Eocene units in the southern Thrace Basin based on the present study. Bars indicate the stratigraphic intervals of the studied sections/samples; A– SAZ (Sazlimanı), B– MÜF (Mürefte) A, C– GİZ (Gizliliman) A and B, D– TAY (Tayfur), E– BEŞ (Beşyol), F– TEKE (Teke Hill), G–MÜF (Mürefte) B, H– PIR (Pırnar), I– MEC (Mecidiye), J– MÜF (Mürefte) C and YEN (Yeniköy), K– ÇEL (Çeltik). The Lower Priabonian part of the Soğucak Formation studied earlier near Doluca Hill by Özcan *et al.* (2007a) is shown by an arrow.

foraminifera- and coral-dominated limestone (Okay *et al.* 2010). Larger foraminifera occur both in the limestone blocks and in the turbiditic sandstones.

This study is part of the revision of larger foraminifera in the Paleogene shallow marine units in the Thrace Basin. We present here our data from Eocene shallow-marine and associated turbiditic and olistostromal units exposed in the southern part of the Thrace Basin. The description of larger foraminifera and their biostratigraphy from the northern and eastern part of the basin is given in a subsequent paper (Less *et al.* in review). The foraminiferal information on these units is either completely lacking as in the Dişbudak series and Çengelli Formation, or is very poor and includes determinations usually at generic level, thus not permitting a high-resolution biostratigraphic framework (Sümengen & Terlemez 1991; Çağlayan & Yurtsever 1998; Şentürk *et al.* 1998a, b) for the Soğucak Formation. Among these foraminifera, nummulitids (*Nummulites*, *Heterostegina* and *Spiroclypeus*) and some orthophragminid taxa are particularly important since their recently-proposed evolutionary features allow us to subdivide some middle to late Eocene shallow benthic foraminiferal zones into sub-zones (Özcan *et al.* 2007a; Less *et al.* 2008; Less & Özcan 2008). Description of most of the taxa is based on the study of isolated specimens of the above groups recovered from some argillaceous carbonate levels and from thin-sections.

Figured specimens prefixed by 'O/' are stored in the Özcan collection of the Department of Geology, İstanbul Technical University, while those marked by 'E.' are in the Eocene collection of the Geological Institute of Hungary (Budapest).

Abbreviations for biozones: NP– Paleogene calcareous nannoplankton zones by Martini (1971); OZ– Orthophragminid zones for the Mediterranean Paleocene and Eocene (Less 1998a) with correlation to the SBZ zones; P– Paleogene planktic foraminiferal zones by Blow (1969), updated by Berggren *et al.* (1995); SBZ– shallow benthic foraminiferal zones for the Tethyan Paleocene and Eocene (Serra-Kiel *et al.* 1998, with additional sub-zones for SBZ 18 and 19 by Less *et al.* 2008) with correlations to the planktonic and magnetic polarity zones. The correlation of these zonations is shown in Figure 5.

Stratigraphy and Palaeontological Background of the Shallow-marine and Olistostromal Eocene Units in the Southern Thrace

The most complete Eocene sequence in southern Thrace Basin crops out in the northern part of Gelibolu Peninsula along the southern shore of Saros Bay (Figure 4). The lowest observable part of the sequence includes a deep-marine argillaceous carbonate unit containing Late Cretaceous and Early Paleocene planktonic foraminifera (Önal 1986). The stratigraphic position of this unit, just exposed in a limited area, is not clear and it is overlain by a sequence of massive deep-marine marls representing the lower part of the Karaağaç Formation. An outcrop of a 3–5-m-thick shallow marine carbonate sequence (Başaoğlu member of Karaağaç Formation) with a limited lateral extent (about 100–150 m) was observed just above the lower marls of the Karaağaç Formation. This unit, containing a very rich assemblage of nummulitidae and orthophragmines, has been considered to mark an early Eocene transgression. The field observations show a sharp contact between carbonates and marls below and above, suggesting that it is an olistolith in the Karaağaç Formation. The finding of a smaller olistolith in the same area also supports this view. The age of Başaoğlu member was considered to be early Eocene (Önal 1986) and early–middle Eocene (Temel & Çiftci 2002).

Our knowledge about the faunal composition and chronology of the transgressive Eocene sequences comes mainly from the Soğucak Formation, traced in continuous and widespread outcrops across the northern part of the Thrace Basin (Konak 2002; Siyako 2006). The Soğucak Formation can also be traced in discontinuous outcrops in the southern part of the basin in the Biga Peninsula (Siyako *et al.* 1989), in the Gelibolu Peninsula (Önal 1986; Siyako *et al.* 1989; Sümengen & Terlemez 1991; Siyako & Huvaz 2007) and in the islands of Gökçeada and Bozcaada (Temel & Çiftçi 2002; Siyako & Huvaz 2007). It is a platform carbonate unit containing a rich association of benthic foraminifera and other fossil groups, such as corals, molluscs, bryozoans, echinoids and coralline red algae (Daci 1951; Keskin 1966, 1971; Önal 1986; Şentürk *et al.* 1998a, b; Temel & Çiftci 2002). Unlike the lower Eocene units described from Bozcaada in the Aegean Sea (Varol *et al.* 2007) and the Armutlu peninsula (Özgörüş *et al.* 2009), patch-reef carbonates constitute a prominent part of the platform succession. Our data suggest that most shallow marine limestone olistoliths in the Çengelli Formation originated from this unit. Previous studies on the fossil composition of the

Geological time in Ma	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34
Stages	THANETIAN	YPRESIAN: ILERDIAN	YPRESIAN: CUISIAN	LUTETIAN	BARTONIAN	PRIABONIAN																			
Planktic foraminiferal zones (P)	← 4	5	6	7	8	9	10	11	12	13	14	15	16	17											
Calc. nannoplankton zones (NP)	6	7–8	9	10	11	12	13	14	15	16	17	18	19–20	21 →											
Shallow benthic zones (SBZ)	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18a	18b	18c	19a	19b	20				
Orthophragminid zones (OZ)	1a	1b	2	3	4	5	6	7	8a	8b	9	10	11	12	13	14	15	16							

Figure 5. Correlation of orthophragminid biozones with late Paleocene and Eocene planktonic foraminiferal, calcareous nannoplankton and shallow benthic biozones, based on Less *et al.* (2007, 2008) and on Özcan *et al.* (2007a, b), slightly modified. Time scale based on Graciansky *et al.* (1999).

Soğucak Formation in the basinal scale reported rich and diverse foraminiferal taxa belonging to *Nummulites*, *Discocyclina*, *Heterostegina*, *Spiroclypeus*, *Operculina*, *Assilina*, *Glomalveolina*, *Pellatispira*, *Chapmanina*, *Linderina*, *Silvestriella*, *Orbitolites*, *Halkyardia*, *Gyroidinella*, *Fabiania*, *Eoannularia* and *Asterigerina* (Daci 1951; Önal 1986; Şentürk *et al*. 1998a, b). The most comprehensive and systematic foraminiferal data from the Soğucak Formation were presented by Daci (1951), who assigned a Lutetian–Priabonian age to the unit widely exposed west of İstanbul, and by Özcan *et al.* (2007a), who described from the Şarköy section (corresponding to the upper part of the Soğucak Formation from the southern slope of Doluca Hill) an assemblage of early Priabonian larger foraminifera belonging to *Discocyclina*, *Nemkovella*, *Asterocyclina*, *Orbitoclypeus*, *Nummulites*, *Heterostegina*, *Spiroclypeus*, *Assilina* and *Operculina*.

In most studies the Soğucak Formation was regarded as of ‘middle’ Eocene age without a high resolution perspective, although different parts of the unit were referred either to the Lutetian, or Priabonian mainly based on larger foraminifera, molluscs and corals (Keskin 1966, 1971; Önal 1986; Sümengen & Terlemez 1991; İslamoğlu & Taner 1995; Çağlayan & Yurtsever 1998; Şentürk *et al.* 1998a, b; Temel & Çiftci 2002; Siyako & Huvaz 2007). A transgressive shallow marine succession containing Ypresian alveolinids and nummulitids has lately been considered to represent the Soğucak Formation on Bozcaada island by Varol *et al.* (2007). We believe that this marks a much older marine transgression and that the *Alveolina*-dominated ‘Soğucak’ Formation of the authors cannot be correlated with the coral-foraminiferal-algal Soğucak Formation marking a younger inundation event in Thrace. Our data suggest that the unit described from this island may be comparable with the Dişbudak series of Okay *et al.* (2010).

The larger foraminiferal composition of the olistostromal unit, the Çengelli Formation, is not known. In most previous studies, the age of the unit (commonly referred to as the Ceylan or Korudağ Formation) was reported to be late Eocene (Sümengen & Terlemez 1991; Toker & Erkan 1984) or late Eocene–early Oligocene (Çağlayan & Yurtsever 1998). These ages were obtained from correlative units in southern or northern Thrace. In the study area larger foraminifera occur either in turbiditic levels or in the limestone olistoliths of the Çengelli Formation. Okay & Tansel (1992) described some pelagic limestone blocks containing both upper Cretaceous and Paleocene planktonic foraminifera.

Description of the Eocene Shallow-marine and Olistostromal Units and Their Palaeontological Content

Başaoğlu Member of Karaağaç Formation

*Section SAZ (Sazlimanı)***.** This is a limestone unit about 5 m thick exposed only between Saz Limanı and Karaağaç, north of Tayfur village (Section SAZ, UTM coordinates: 0452324, 4475992, Figure 1B). It represents an olistolith in the late Paleocene–early Eocene basinal sequence of the Karaağaç Formation and comprises a rich assemblage of genus *Nummulites* (undetermined in species level) and rare orthophragmines. These (identified only in sample SAZ 46) are represented by *Discocyclina seunesi karabuekensis*, *Nemkovella stockari*, *Orbitoclypeus schopeni neumannae*, *O. munieri* cf.

ponticus, *O. bayani* cf. *bayani*. The first two taxa are characteristic for the OZ 2 Zone while the third one typifies the OZ 3 Zone, although biometrically (Table 2) it is very close to *O. schopeni ramaraoi*, the pylogenetic ancestor, whose range ends in OZ 2. Since *Orbitoclypeus bayani bayani* also starts in OZ 3, the age of the above assemblage can be determined as OZ 2-3, corresponding to the SBZ 4-7 zones. However, since genus *Nummulites* first appears only in the SBZ 5 Zone, the age of this olistolith is thought to cover the SBZ 5-7 Zones, which corresponds to early–middle Ilerdian. Formerly (Serra-Kiel *et al.* 1998) the early Ilerdian was correlated with the late Thanetian. However, the base of the Ilerdian and of the Ypresian proved to be coeval (Pujalte *et al.* (2009a, b), and hence the Sazlimani olistolith is of earliest Ypresian age.

Dişbudak Sequence

Section MÜF (Mürefte) A. The section is a clastic-carbonate sequence about 30 metres thick, exposed due east of Doluca Hill, north-east of Şarköy (Section MÜF.A, UTM coordinates: 0517151, 4505041) (Figures 3 & 6). The lowest part of this highly fossiliferous rock sequence comprises conglomerates and sandstones with a wealth of oysters at its base. This passes upwards into sandstones with intercalated conglomerate horizons, that grade into limy sandstone and/or sandy limestones containing a rich assemblage of *Nummulites, Orbitolina* and alveolinids. These levels are almost devoid of orthophragmines and are interpreted to have been deposited in an inner shelf environment. The top of the profile (sample MÜF A 10) is characterized by a nodular limestone containing a diverse assemblage of nummulitids [among which *Assilina placentula* (Deshayes) predominates], orthophragmines and very sporadic tests of corals (Figure 7) and representing a middle/outer shelf environment. A 10-m-thick siltstone-marl succession was observed to overlie these nodular limestones although the relation between them is not yet fully clear. It is most likely that these fine clastics record a deepening in the depositional environment following the deposition of nodular carbonates. Based on the assemblage presented in Figure 7, the carbonate succession is regarded as early late Ypresian (early

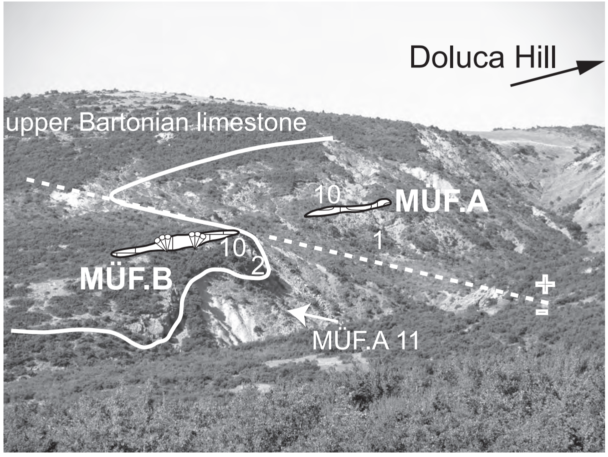


Figure 6. Overview of the Dişbudak sequence (section Mürefte – MÜF.A; upper Ypresian) and the overlying Soğucak Formation (section Mürefte – MÜF.B; upper Bartonian) east of Doluca Hill, looking south from the Çengelli flysch sequence. Limestone lenses denote the nodular limestone level in MÜF.A and coralline algal-coral facies in MÜF.B. Sample MÜF A 11 represents the basinal fine clastics overlying the upper Ypresian nodular limestone of Dişbudak sequence in the downthrown block. Numbers refer to samples.

Cuisian) in age (SBZ 10), although the presence of *D. archiaci* ex. interc. *staroseliensis-archiaci* suggests a transitional position between lower and upper Ypresian (SBZ 9 and 10). Two samples (MÜF A 11 and 1909) representing the fine clastics overlying the nodular limestone have been analysed for calcareous nannoplakton and planktonic foraminifera. Sample MÜF A 11 yielded a calcareous nannoplankton assemblage (Figure 7) among which *Discoaster lodoensis* has the shortest stratigraphic range (NP 12-14) corresponding to a late Ypresian–earliest Lutetian time span. This sample also contains reworked Campanian forms, such as *Eiffellithus turriseiffelli*, *E. eximius*, *Watznaueria barnesae*, *Arkhangelskiella cymbiformis*, *Broinsonia parca* s. l., *Bukryaster hayi* and *Cretarhabdus* sp. Planktonic foraminifera in this sample are quite rare and are only represented by badly preserved *Acarinina primitiva*, which indicates a general early–middle Eocene age. Age data from sample 1909 near Doluca Hill (Figure 3) are controversial. The planktonic foraminiferal assemblage of *Globorotalia bullbrooki*, *G. cerroazulensis cerroazulensis*, *Morozovella spinulosa*, *Globigerina eocaena*, *G. linaperta*, *G. senni*

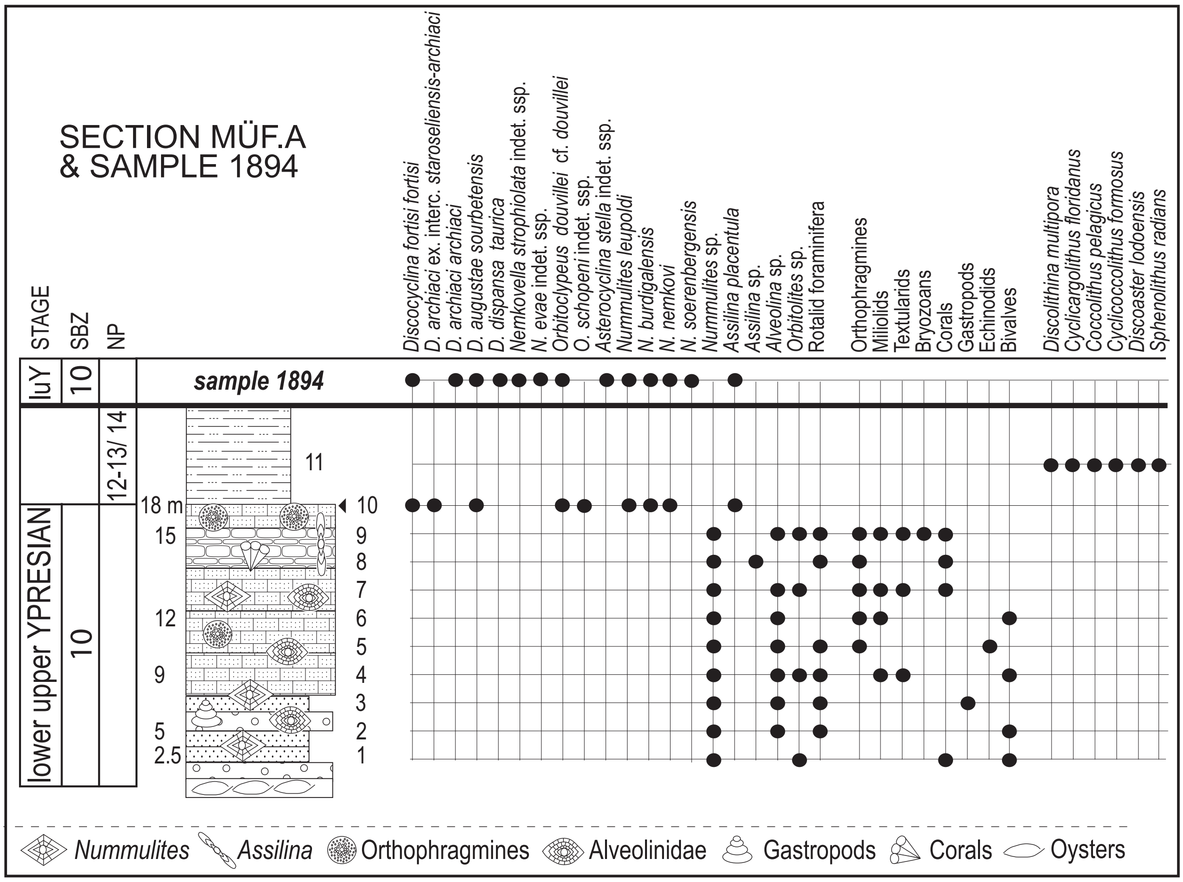


Figure 7. Distribution of benthic foraminifera and other fossil groups in section MÜF (Mürefte) A and sample 1894 (Dişbudak sequence). luY– lower upper Ypresian.

and *Heterolepa dutemplei* is characteristic (based on the appearance of muricate *Globorotalia*) of the early middle Eocene (P 10-12) or, less probably, the youngest (P 9) Ypresian zone. Meanwhile the calcareous nannoplankton (*Coccolithus pelagicus*, *Cruciplacolithus tenuis*, *Chiasmolithus* sp., *Zygrhablithus bijugatus*, *Discoaster multiradiatus*, *D. binodosus*, *D. barbadiensis*, *Sphenolithus moriformis*) indicate the NP 9-10 zones around the Paleocene/Eocene boundary. This sample also contains reworked Cretaceous forms such as *Zeugrhabdotus embergeri*, *Eiffellithus turriseiffeli*, *Cribrosphaerella ehrenbergii*, *Watznaueria barnesae*, *Arkhangelskiella cymbiformis* and *Microrhabdulus* sp. In view of the much younger age given by planktonic foraminifera we think that all the nannoflora of sample 1909 is reworked.

Sample 1894. A spot sample was collected from the shallow marine part of the Dişbudak series immediately east of Doluca Hill (Sample 1894, UTM coordinates: 0516027, 4504475) (Figure 3). It also consisted of argillaceous carbonates and contained almost the same assemblage of nummulitids (with the same predominance of *Assilina placentula*) and orthophragmines as sample MÜF A 10, but also included *Discocyclina archiaci archiaci* (Figure 7), indicating an early late Ypresian (early Cuisian) age (SBZ 10 Zone).

Soğucak Formation

Exposures of the Soğucak Formation can be observed around Gökçeada, Gelibolu Peninsula (Tayfur, Beşyol villages and around Tepe Hill at Sarıkaya Sliver), Şarköy (Doluca Hill) and north of

Saros Bay (Pırnar and Mecidiye villages) (Figures 1–3).

Gökçeada Island (sections GİZ.A and GİZ.B). The Soğucak Formation only crops out in a limited area west of Gökçeada. Two sections, GİZ.A (UTM coordinates: 0386973, 4442620; 0387037, 4442588, Figure 1C) and GİZ.B (UTM coordinates: 0387448, 4443239; 0387011, 4442533, Figure 1C) were sampled near Gizliliman. The lower part of a 47-m-thick section of carbonates in the stratigraphically lower section, GİZ.B, is represented below by coralline red algae and coral-dominated strata, and by foraminifera and coralline algae-dominated horizons at higher levels. Nummulitids occur only in the upper part of the section. The distribution of foraminifera and other fauna and flora is shown in Figure 8. With the absence of diagnostic Bartonian forms, such as *O.* ex. gr. *gomezi* and reticulate *Nummulites*, and its position below the well-described Bartonian part in section GİZ.A, this section is considered to be of late Lutetian age (SBZ 15-16). Section GİZ.A stratigraphically overlying section GİZ.B is represented by a 66-m-thick sequence of limy siltstones, sandstones and limestone beds with abundant larger foraminifera and represents a more distal depositional setting than section GİZ.B. Foraminifera are abundant and diverse at numerous levels. Corals are sporadic and transported. These carbonates are overlain by pelagic marls, but their relationships were not observed because of a fault between the carbonates and overlying marls (Figure 1C). The lower part of the section (samples GİZ A 4-8) is regarded to be of late Lutetian (SBZ 15-16) age, based on the assemblage (Figure 9), containing *Discocyclina pratti montfortensis*, *Asterocyclina stellata adourensis* and lacking *Operculina* ex. gr. *gomezi*. The upper part (samples GİZ A 9-14) of the section is assigned an early Bartonian (SBZ 17) age, based on the first occurrence of *O.* ex. gr. *gomezi* and the presence of characteristic Bartonian taxa such as *Orbitoclypeus douvillei malatyaensis* and *O. haynesi*. The basinal marls of the Ceylan Formation are very rich in calcareous nannoplankton and planktonic foraminifera. A sample (GİZ B 15; UTM coordinates 0388056, 4442442) collected close to section GİZ.B

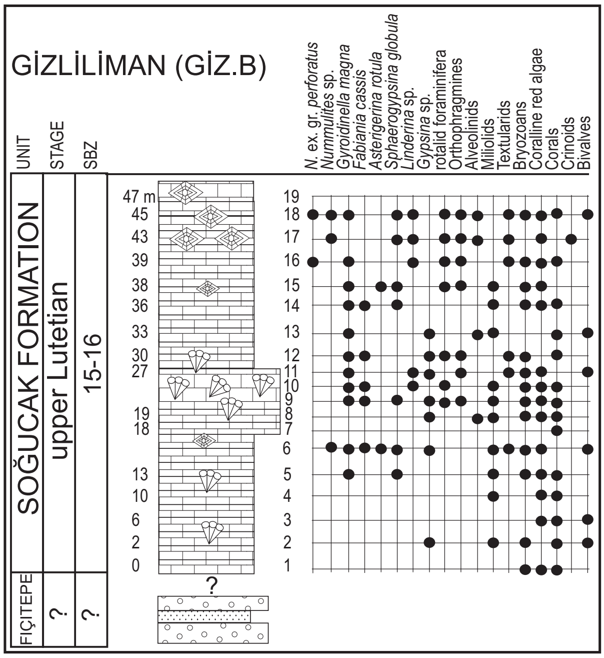


Figure 8. Distribution of benthic foraminifera and other fossil groups in section GİZ (Gizliliman) B (Soğucak Formation).

(but separated very probably by a fault from the platform carbonates) yielded a calcareous nannoplankton assemblage of *Discolithina multipora*, *Isthmolithus recurvus*, *Cyclicargolithus floridanus*, *Reticulofenestra placomorpha*, *R. bisecta*, *Chiasmolithus oamaruensis*, *Coccolithus pelagicus*, *Cyclococcolithus formosus*, *Discoaster* sp., *Sphenolithus moriformis* and *S. predistentus*. The coexistence of *Chiasmolithus oamaruensis*, *Isthmolithus recurvus* and *Cyclococcolithus formosus* suggests a late Eocene (NP 19-20, Priabonian) age for this sample. The same sample yielded a planktonic foraminiferal assemblage of *Globigerina cryptomphala*, *Globigerina eocaena*, and *Globigerinatheka index tropicalis*, suggesting it probably belongs to the lower Upper Eocene *Globigerinatheka semiinvoluta* (P 15) Zone.

Section TAY (Tayfur). This is a clastic-carbonate sequence about 15 metres thick, exposed due south of Tayfur (Section TAY, UTM coordinates: 0455404, 4472526) (Figure 1B). The section is represented by algae and foraminifera (mainly nummulitids, alveolinids and orthophragmines)-dominated

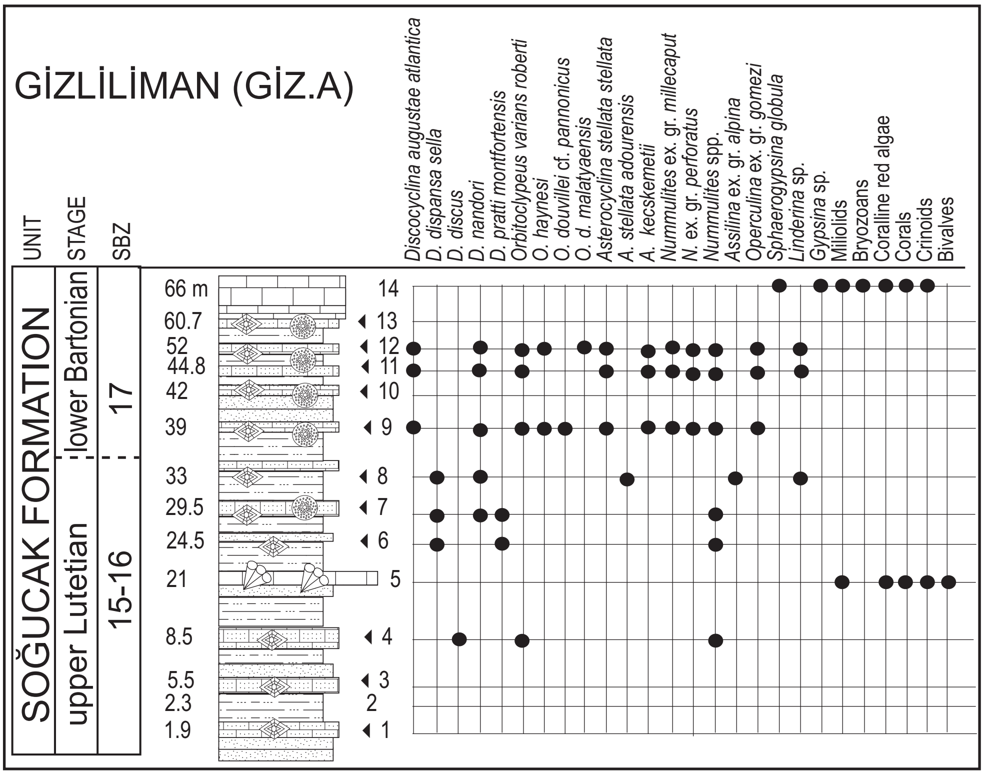


Figure 9. Distribution of benthic foraminifera and other fossil groups in section GİZ (Gizliliman) A (Soğucak Formation).

carbonate levels of the Soğucak Formation and is completely devoid of corals, suggesting an inner shelf depositional setting. These carbonates are in tectonic contact with the overlying pelagic marls. Fossil assemblages (Figure 10), including *Operculina* ex. gr. *gomezi*, but lacking the genus *Heterostegina,* indicate an early Bartonian (SBZ 17) age. Some other larger foraminiferal components, such as *Nummulites biedai,* suggest a somewhat younger age, while others (*Orbitoclypeus varians roberti*) indicate a slightly older age. In summary, the upper part of the Tayfur section most probably belongs to the SBZ 17 Zone.

Section BEŞ (Beşyol). This clastic-carbonate sequence of the Soğucak and Ceylan Formations, about 88 metres thick, is exposed due east of Beşyol village (Section BEŞ, UTM coordinates: 0445329, 4468144, Figure 1B). The lower part of the Soğucak carbonate sequence comprises limestones with bivalves, sporadic nummulitids and corals: their relationship with the clastics of the underlying Fıçıtepe Formation is poorly exposed. The Soğucak Formation is rich in large *Nummulites biedai* (sample BEŞ 8) in the middle and upper parts of the section. The shallow marine carbonates pass upwards into a fine clastic silty-marly sequence with sandstone intercalations containing pelagic fauna and flora. Larger foraminifera occur abundantly only at the transition (sample BEŞ 19) between the carbonates and the overlying fine clastics. The fine clastics yielded a calcareous nannoplankton assemblage of *Cyclicargolithus floridanus*, *Reticulofenestra bisecta, Coccolithus pelagicus*, *C. eopelagicus*, *Cyclicoccolithus formosus*, *Braarudosphaera bigelowi*, *Pemma* sp. and *Sphenolithus moriformis* in sample BEŞ 21, suggesting a middle Eocene age for this part of the section. In these beds planktonic foraminifera are very scarce. The basinal clastics are almost devoid of benthic foraminifera. The top of the profile (samples BEŞ 26 and 27) is characterized by a limestone horizon containing a diverse assemblage of nummulitids and other benthics. This 3-m-thick

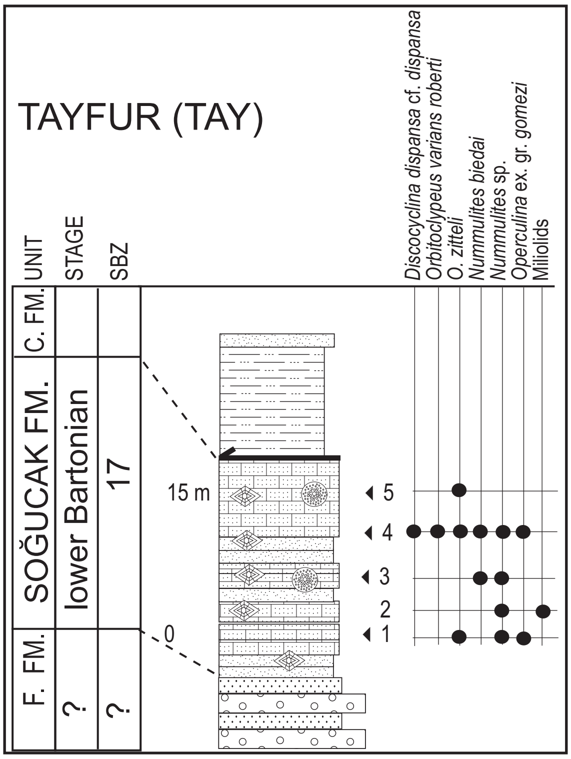


Figure 10. Distribution of benthic foraminifera and other fossil groups in section TAY (Tayfur, Soğucak Formation).

limestone horizon is in turn overlain by more basinal clastics devoid of larger foraminifera. Based on this assemblage (Figure 11), the age of the lower carbonate succession should be similar to that of the shallow marine part of the Tayfur section (see above), i.e. it belongs to the upper part of the SBZ 17 Zone (late early Bartonian). *Heterostegina* (cf. *armenica*) occurs in the upper carbonate level (sample BEŞ 27) suggesting a late Bartonian age (SBZ 18) for it.

Section Teke. This Soğucak Formation carbonate succession approximately 50 metres thick is interpreted as resting unconformably upon the serpentinite of the Sarıkaya sliver (Okay *et al.* 2010). An exposure due west of Teke Hill has been sampled (UTM coordinates: 94978, 91904; 94860, 91959, Figures 2 & 12). The distribution of larger foraminifera (their richest assemblage can be found in sample TEKE 6) and other fossil groups is shown in Figure 13. The abundant occurrence of *Planorbulina*, not recorded in Bartonian blocks in the study area, in the lower to middle parts of sequence, is noteworthy. This part of the carbonates also contains miliolids, bryozoans, echinoids, corals, bivalves and coralline algae. The foraminiferal assemblage (mainly based on the occurrence of *Heterostegina reticulata mossanensis*, *Spiroclypeus sirottii* and *Nummulites fabianii*) confidently indicates the SBZ 19A Sub-zone, and implies an earliest Priabonian age for the Soğucak Formation.

Section MÜF (Mürefte) B. A 19-metres-thick section representing the basal part of Soğucak Formation was measured east of Doluca Hill (MÜF.B, UTM location: 0517306, 4505174, Figure 3). This locality is close to the Dişbudak series (MÜF.A) (Okay *et al.* 2010). The basal part of the profile consists of 11-metre-thick limestones (samples MÜF B 2 to 6) containing an association (Figure 14) in which miliolids are the most common foraminifera. This assemblage indicates an inner shelf depositional environment for the lower part of the sequence. The overlying horizons (samples MÜF B 7-10) contain a more diverse association with different species of *Nummulites*. The single *Heterostegina reticulata* specimen in sample MÜF B 9 has about 9 undivided post-embryonic operculinid chambers, suggesting that it may belong to *H. r. multifida*. Miliolids are rarely identified. The uppermost part of the section is represented by coralline red algae and coral limestone facies containing mainly tests of corals, coralline red algae and scarce miliolids. The aforementioned associations indicate an inner to middle shelf depositional environment for the carbonates. The foraminiferal assemblages just below the coral-algal limestone levels can be assigned to the SBZ 18 Zone (late Bartonian), based on the joint occurrence of *Nummulites biedai*, *N. hormoensis*, highly advanced *N. striatus* and relatively primitive *H. reticulata*.

Section PIR (Pırnar). This is a 108-metres-thick section of carbonates (UTM coordinates: 0470000, 4506590; 0469790, 4506743, Figure 1B) from the Soğucak Formation and overlying deep-marine units

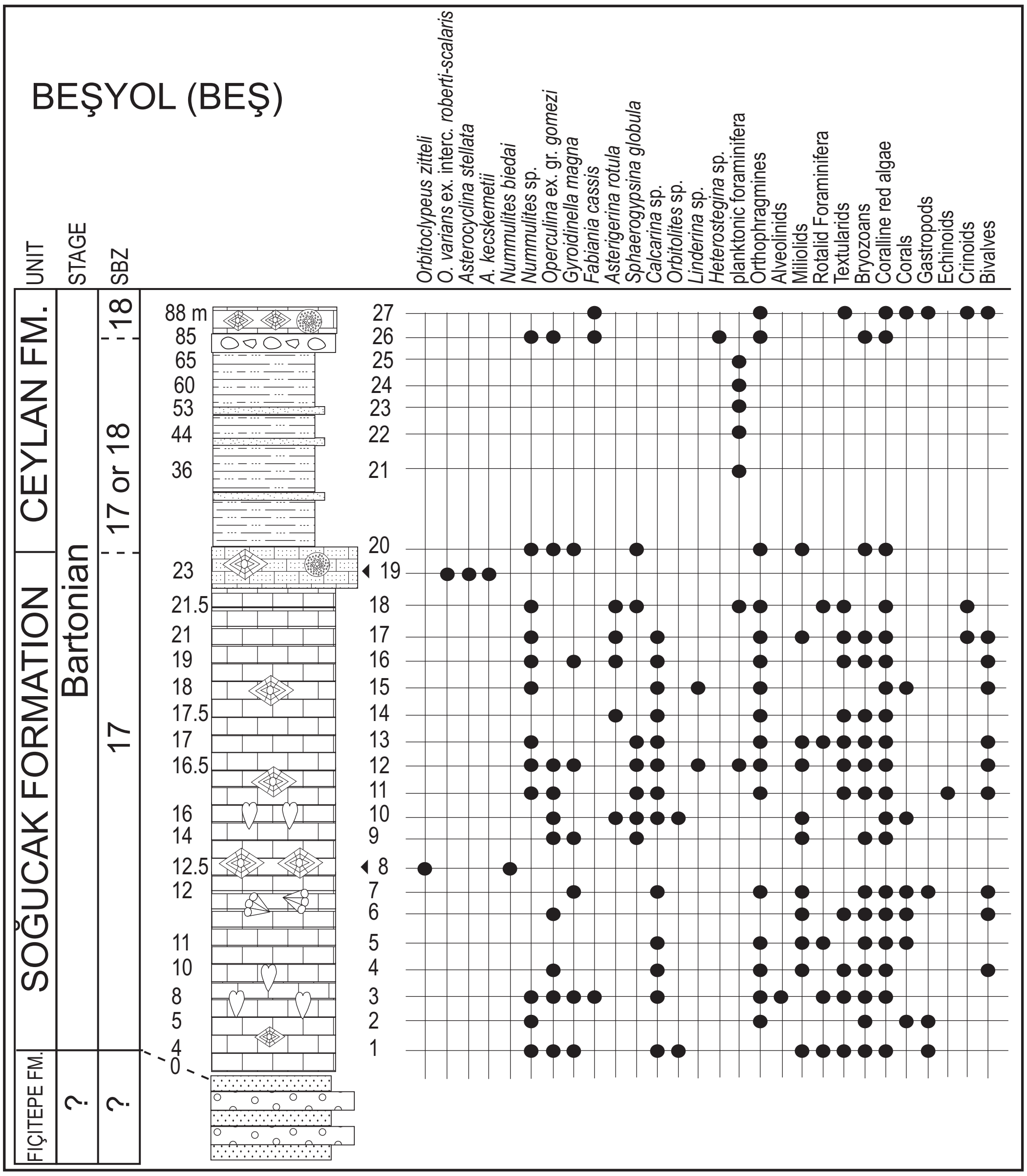


Figure 11. Distribution of benthic foraminifera and other fossil groups in section BEŞ (Beşyol, Soğucak Formation).

(Ceylan/Keşan Formation) exposed close to Pırnar village. The underlying rocks and the lower part of the Soğucak Formation are not exposed in the region. The shallow-marine carbonate sequence is represented throughout the section by foraminifera, coralline algae-foraminifera or coralline algae-coral dominated levels (Figure 15). Miliolids are abundant at some levels in the lower and middle part of the sequence, whereas coral-dominated limestone levels more frequently occur in the upper levels. Larger foraminifera (except for the uppermost levels, where they are the main biogenic contributors) occur only at certain horizons and are mainly represented by *Nummulites*. This part of the section is interpreted to have been deposited in an inner to middle shelf environment. The uppermost part of the section

Figure 12. Overview of the section TEKE (lower Priabonian) from the transgressive Soğucak Formation west of Teke Hill. The locations of two samples are shown.

contains more clastic material and larger foraminifera in rock-forming abundance at some levels. Orthophragmines are more abundant in this part of the section and are accompanied mostly by nummulitids, suggesting more distal platform conditions than the lower part of the section. Based on its assemblage (Figure 15), most of the carbonate succession is regarded as late Bartonian in age, although the lower part of the section with no marker forms may still be early Bartonian. The evolution of the *Heterostegina armenica* lineage, a marker taxon for the early and middle late Bartonian, is nicely observed in the upper part of the section. Based on these, most of the sequence with *H. armenica armenica* but lacking *H. reticulata* can be assigned to an early late Bartonian age (SBZ 18A). The uppermost part of the carbonates, containing *H. armenica tigrisensis* and *H. reticulata* cf. *tronensis,* can already be attributed to the middle late Bartonian (SBZ 18B). *Nummulites lyelli* with large tests of B-forms also occurs here.

The carbonate levels pass up into pelagic marls of the Ceylan/Keşan Formation. A sample (PIR 48A) from the lowest part of these basinal clastics contains a calcareous nannoplankton assemblage of *Cyclicargolithus floridanus*, *Reticulofenestra bisecta*, *R.* cf. *placomorpha*, *Coccolithus pelagicus*, *Cyclococcolithus formosus*, ?*Lanternithus minutus*, *Braarudosphaera bigelowi*, *Discoaster barbadiensis*, *D.* cf. *tani*, *Sphenolithus moriformis* and *S. radians*, suggesting a middle Eocene age (NP 16-17).

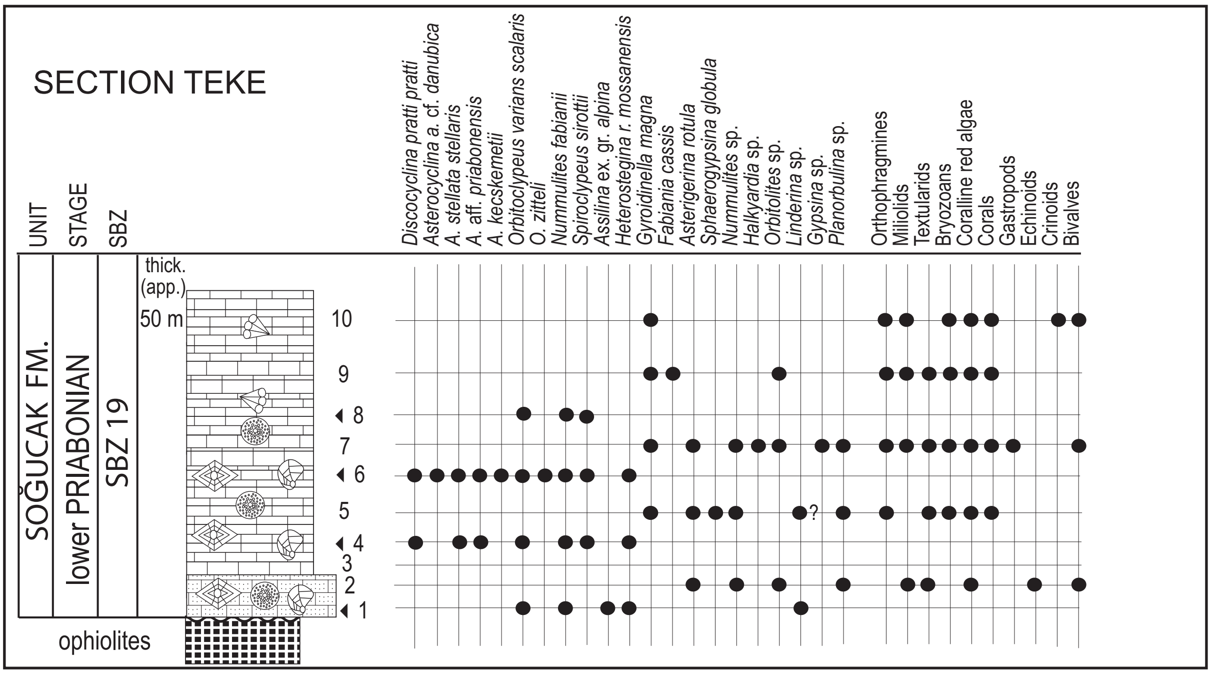


Figure 13. Distribution of benthic foraminifera and other fossil groups in shallow marine carbonates of the Soğucak Formation in section TEKE (Teke Hill).

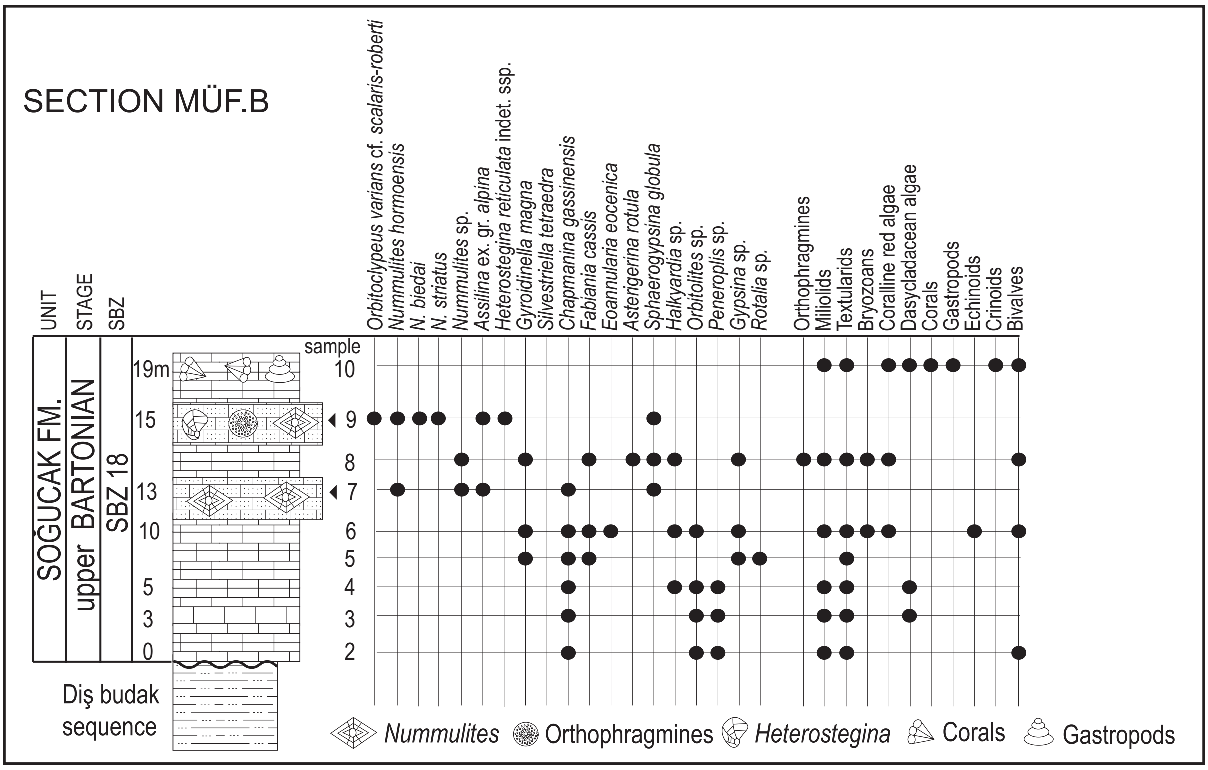
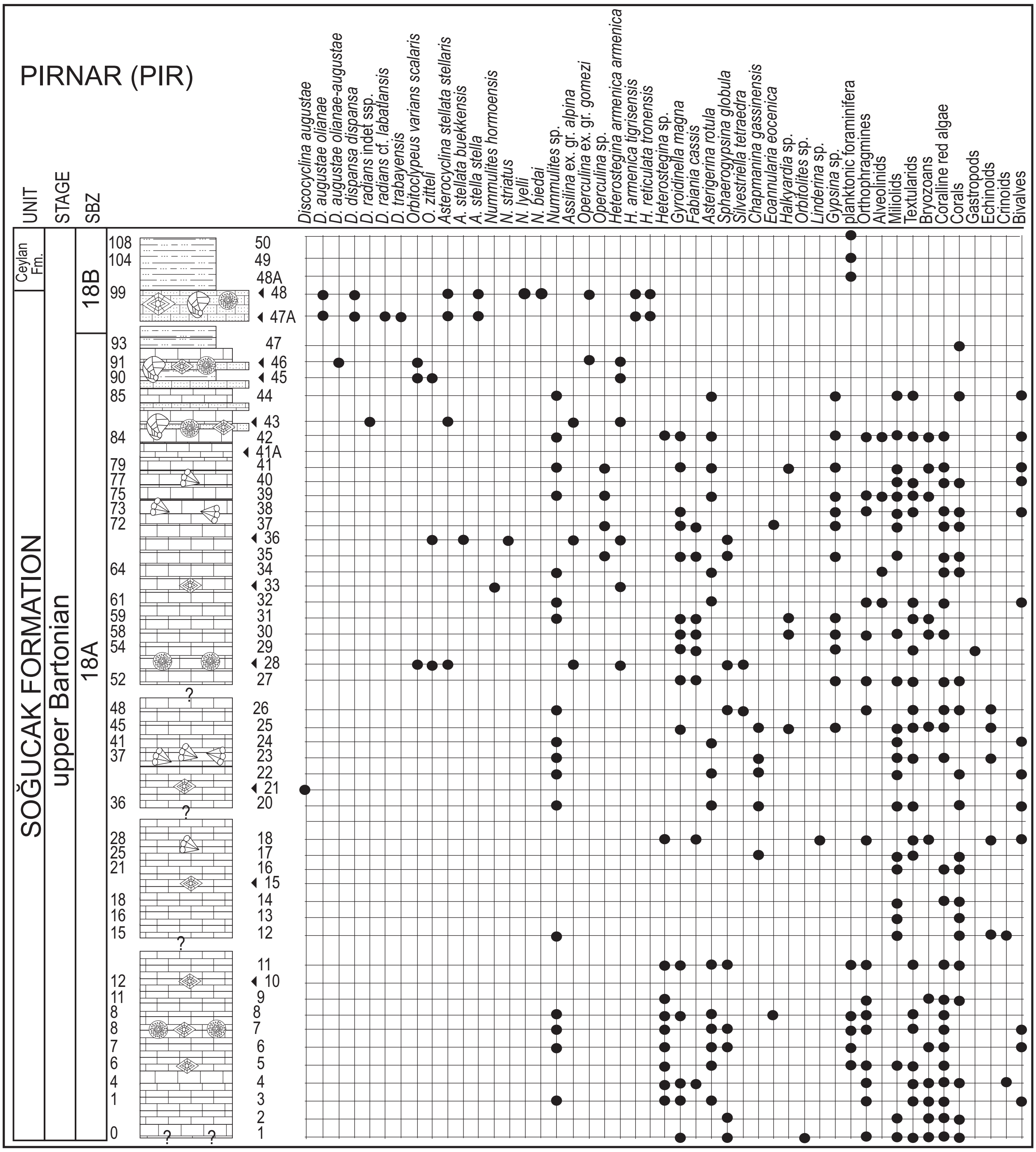


Figure 14. Distribution of benthic foraminifera and other fossil groups in section MÜF.(Mürefte) B (Soğucak Formation).

Samples from Mecidiye Region. The most widespread outcrops of the Soğucak Formation north of Saros Bay are found around Mecidiye (Figure 1B). This unit unconformably overlies the clastics of the Fıçıtepe Formation, which unconformably rests on metamorphic units (Figure 16). The carbonate succession is mainly represented by foraminifera, coralline algae and coral-dominated limestones, suggesting a variety of depositional settings between inner and outer shelf environments. A set of samples from these carbonates were collected from its widespread outcrops near Mecidiye. The commonest larger foraminifera are represented by orthophragmines and heterosteginids (Figure 17). *Nummulites* are very sporadic. Two samples, one collected from the basal part of the Soğucak Formation (sample MEC 40) and the other (sample MEC 41) from the upper part, where the carbonates grade into clastics of the Keşan/Ceylan formation, have yielded free tests of larger foraminifera. Sample MEC 40 contains *Spiroclypeus carpaticus*, a diagnostic late Priabonian (SBZ 20) taxon, although *Heterostegina reticulata* is represented by *H. r.* cf. *mossanensis* (based on few specimens), a marker for the early Priabonian (Figure 17). All samples collected from the lowest part of the section just south of Mecidiye (samples MEC 15-24) contain *Heterostegina gracilis*, a good marker for the late Priabonian (SBZ 20) (Figure 23). Thus, even the lower part of the Soğucak Formation belongs to the late Priabonian. Sample MEC 41 also contains *H. gracilis,* indicating that the upper part of the unit is also of late Priabonian age.

Samples from Doluca Tepe (Şarköy). The outcrops of the Soğucak Formation are widely seen around Doluca Hill, north of Şarköy (Figure 3). Although Özcan *et al.* (2007a) interpreted this large limestone body as a huge olistolith, it has since been reinterpreted as an *in situ* deposit (Okay *et al.* 2010) of the Soğucak Formation, transgressively overlying the lower (–middle) Eocene Dişbudak series. The topmost part of this limestone (samples ŞAR 2, 4 &



Figuer 15. Distribution of benthic foraminifera and other fossil groups in section PIR (Pırnar, Soğucak Formation).

9), gradually passing into the Çengelli Formation, was dated as early Priabonian (SBZ 19A Zone) (Özcan *et al*. 2007a). Two samples from the stratigraphically lower parts of the Doluca Hill limestone (DOL 1 & 2) contain mainly small *Nummulites*, orthophragmines and coralline red algae, suggesting an inner to middle shelf depositional environment, unlike the uppermost part of the sequence, which is dominated by fore-reef talus. The foraminiferal assemblage of the Soğucak

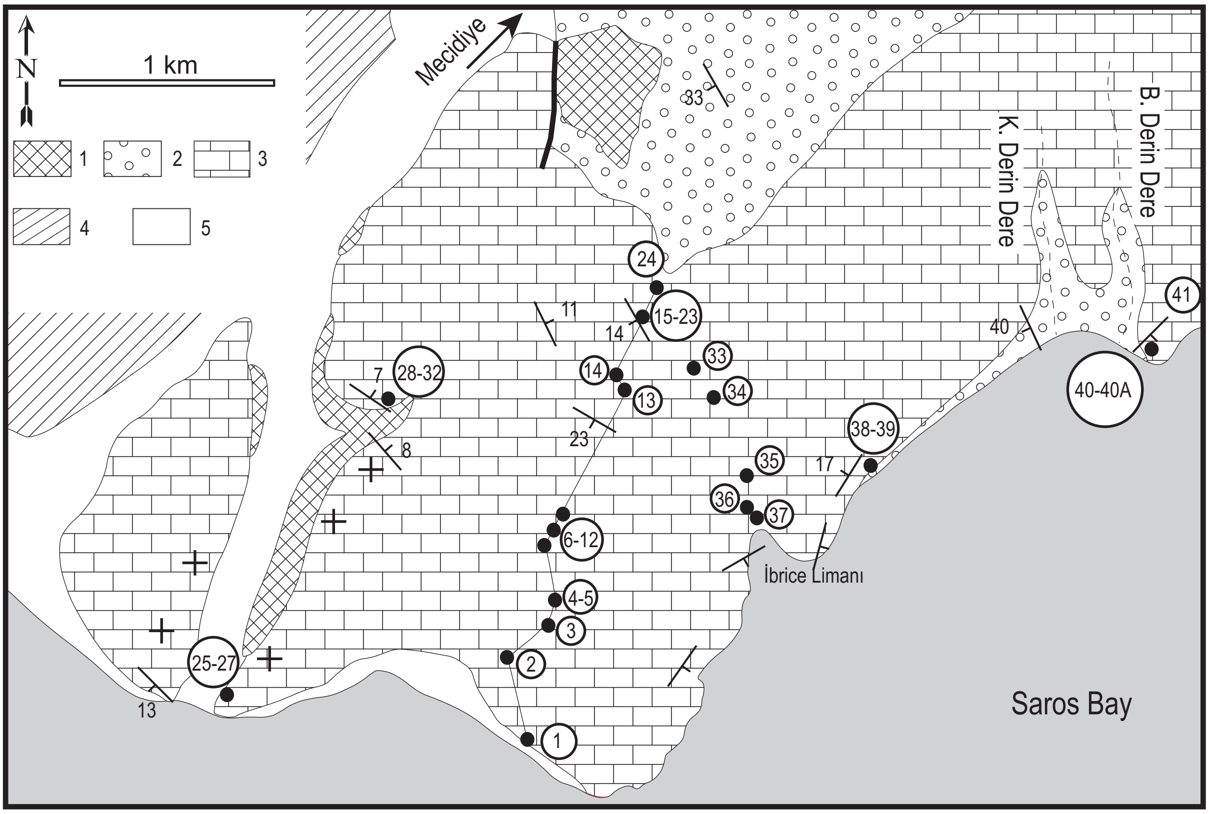


Figure 16. The geological map of Mecidiye region and location of samples. 1– metamorfics, 2– Fıçıtepe Formation, 3– Soğucak Formation, 4– Miocene units, 5– aluvium.

Formation at Doluca Hill and its close vicinity is composed of taxa listed in Figure 18. These samples are assigned to the SBZ 18 or19A Zones (late Bartonian or early Priabonian), based both on the occurrence of *Heterostegina* and the early Priabonian age data from the upper part of the same sequence (Özcan *et al.* 2007a).

Çengelli Formation

The Çengelli Formation can be traced across the southern part of the Thrace Basin from south of Yeniköy in the west to Mürefte in the east (Figures 2 & 3). This unit is not known further west than Yeniköy, where the Paleogene shallow to deep marine carbonates and clastics are prominent parts of the Paleogene sequence. A short description of the studied blocks (olistoliths), turbidite and marl beds is given below.

Olistoliths. The most common blocks in the Çengelli Formation, found in virtually all outcrop areas, are Bartonian–Priabonian. Unlike the mixed clastic-carbonate lithologies of the Dişbudak series, they are composed of white thickly bedded to massive limestone. The sections and samples characterizing these olistoliths are MÜF.C, YEN, 2B, 616, 638 and 1902 (Figures 2 & 3).

Section MÜF (Mürefte) C. A 30-metres-thick section was measured in a large block exposed north of Deve Hill (Figure 3) consisting of monotonous coral and coralline red algal limestone (MÜF.C, UTM coordinates: 0517497, 4505958). Isolated specimens of larger foraminifera can only be obtained from a single level (sample MÜF C 6). The only age-diagnostic group is represented by reticulate *Nummulites,* belonging to *N. hormoensis*, although

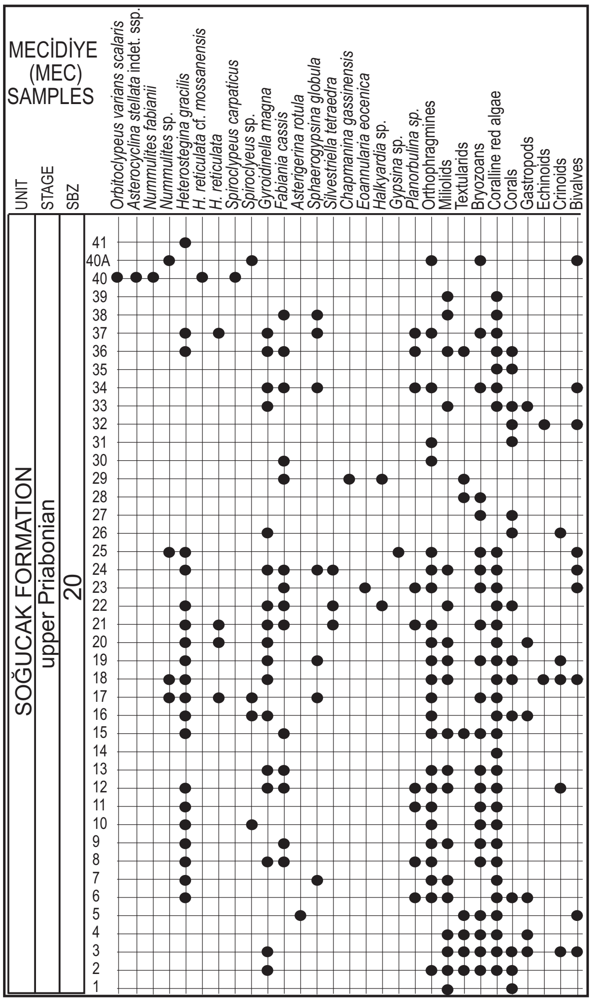


Figure 17. Distribution of benthic foraminifera and other fossil groups in samples from Mecidiye region (samples MEC, Soğucak Formation).

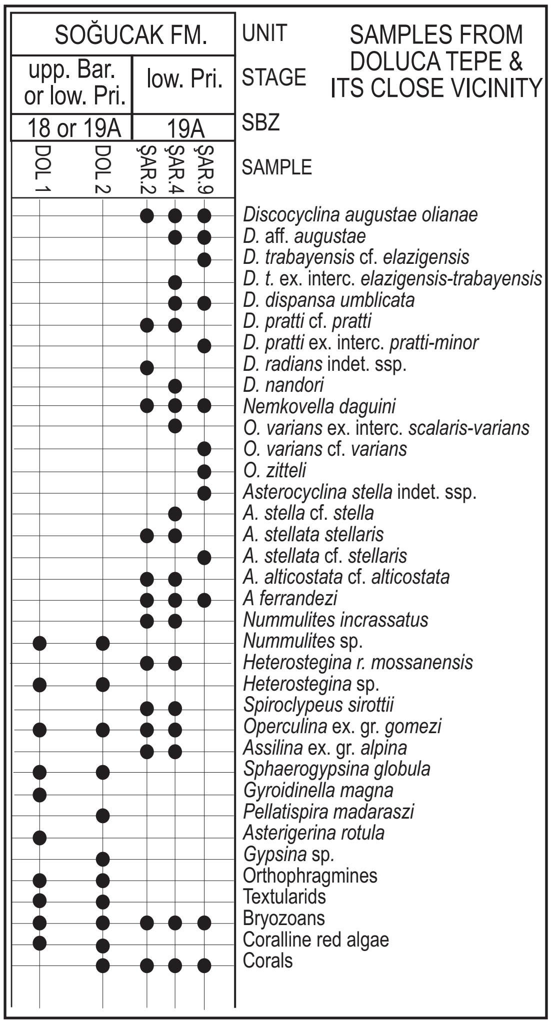


Figure 18. Distribution of benthic foraminifera and other fossil groups in samples DOL 1 and 2 in the lower, and in samples ŞAR 2, 4, 9 (data from Özcan *et al.* 2007a) in the upper part of the Soğucak Formation near Doluca Hill (Şarköy).

very close to *N. fabianii*. The foraminiferal assemblage in the lower part is more diverse and includes taxa listed in Figure 19 (see also for other foraminifera in sample MÜF C 6). Based on the presence of highly advanced *N. hormoensis* and *Heterostegina* sp., the foraminiferal assemblages can be assigned to the uppermost part of the SBZ 18 (late Bartonian) Zone, although a transitional position between SBZ 18 and 19 (early Priabonian) Zones cannot be excluded either.

Samples from Other Olistolits. A set of samples were collected from olistolith outcrops south of Yeniköy (Figure 2), represented mainly by foraminiferal (small-sized *Nummulites*, miliolids and orthophragmines) and coralline algal limestones. The list of foraminifera and other fossil groups from these olistoliths is shown in Figure 20. These groups indicate an inner to outer shelf depositional environment for these blocks.

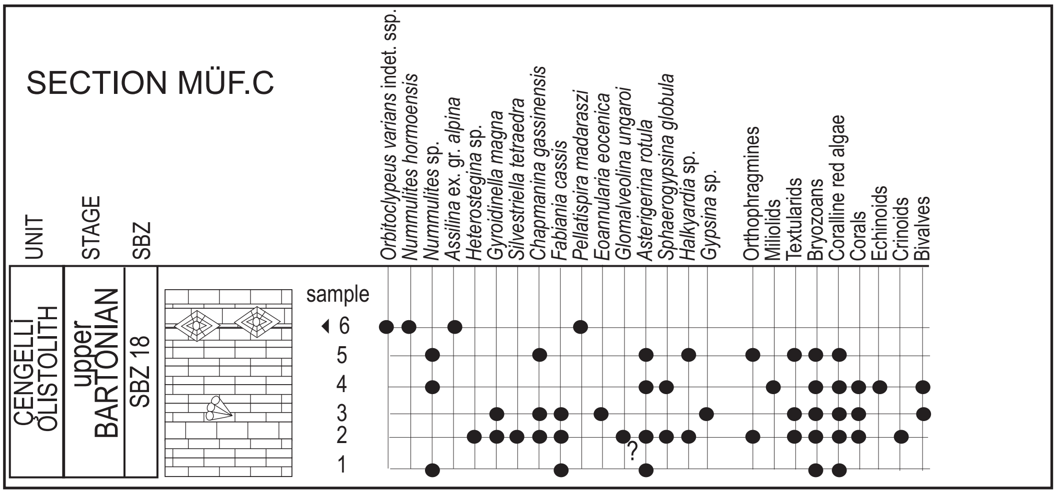


Figure 19. Distribution of benthic foraminifera and other fossil groups in section MÜF (Mürefte) C (olistolith in Çengelli Formation).

A succession 25-metres-thick (samples YEN 1-4, UTM coordinates: 0500905, 4499155, Figure 1) was measured in Eocene limestones at Cinbasarkale Hill. These samples yielded foraminiferal taxa (Figure 20) and, based on the occurrence of *Nummulites fabianii, Heterostegina reticulata mossanensis* and *Asterocyclina ferrandezi* in sample YEN 2, this olistolith was assigned to the SBZ 19A (earliest Priabonian) Sub-zone.

Another nearby olistolith (UTM coordinates: 0500951, 4499494, Figure 21) is a composite block with pink pelagic limestone and chert overlain by 5 metres of Eocene basal conglomerate and limestone. Three samples from this Eocene limestone (YEN 7-9) contain orthophragmines and small-sized *Nummulites* sp. as the dominant biogenic contributors. The occurrence of *Spiroclypeus* confidently establishes the age of the Eocene limestone as Priabonian (SBZ 19–20 Zones). The occurrence of *A. kecskemetii* suggests SBZ 19 rather than 20.

Sample YEN 10 was taken from another limestone block due south of the collecting locality of samples YEN 1–4. Taxa from this sample (Figure 20), and the occurrence of *Spiroclypeus* establish the age of this olistolith as Priabonian (SBZ 19–20 Zones).

Sample 1902, collected due east of Doluca Hill (Figure 3) yielded an association of *Discocyclina pratti*, *D. dispansa*, *D. augustae*, *Orbitoclypeus varians cf. scalaris*, *Heterostegina reticulata reticulata*, and *Pellatispira madaraszi* (Figure 20). The occurrence of *H. r. reticulata* confidently establishes the age of this olistolith as latest Bartonian (SBZ 18C).

Various small olistoliths from the Çengelli Formation were sampled (Samples 2B, 616, 638, Figures 2 & 3). Identified taxa from their faunal and floral composition (Figure 20) do not yield a precise age for these blocks and they can only be referred to Bartonian or Priabonian.

Samples from the Turbidite Beds of the Çengelli Formation. Some turbidite beds of the Çengelli Formation consist of redeposited tests of larger foraminifera and other fossil groups, and do not permit a high-resolution biostratigraphic scheme, since only a few larger foraminifera identified in these beds have a stratigraphic range covering the whole duration of the Bartonian and Priabonian. The distribution of fossil groups in ten levels (samples ŞAR 10, 11, 12, 13, 172, 649, 202, 183 and 428) are shown in Figure 20. Sample 428, representing the uppermost part of the Çengelli Formation (Okay *et al.* 2010), contains mostly coralline red algae, bryozoans and corals and it is

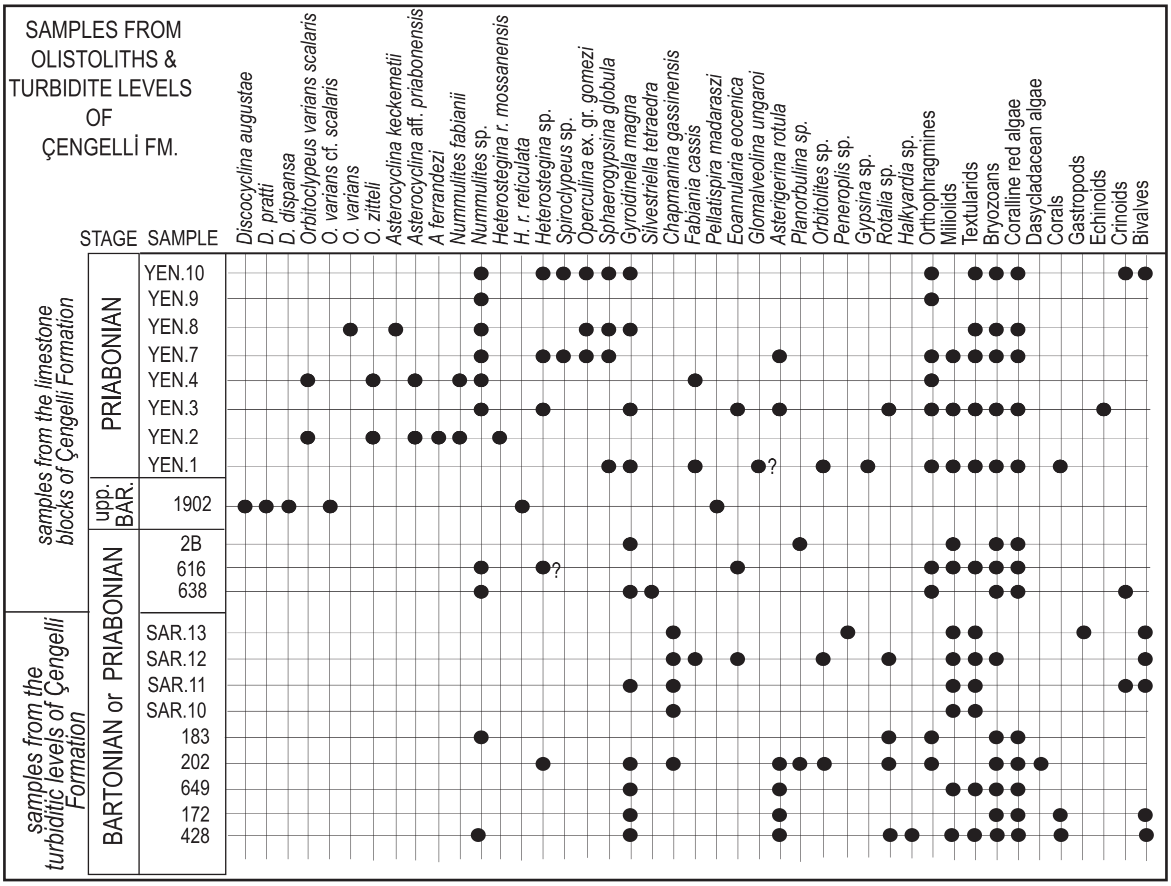


Figure 20. Distribution of benthic foraminifera and other fossil groups in samples from the olistoliths and turbidite levels of the Çengelli Formation.

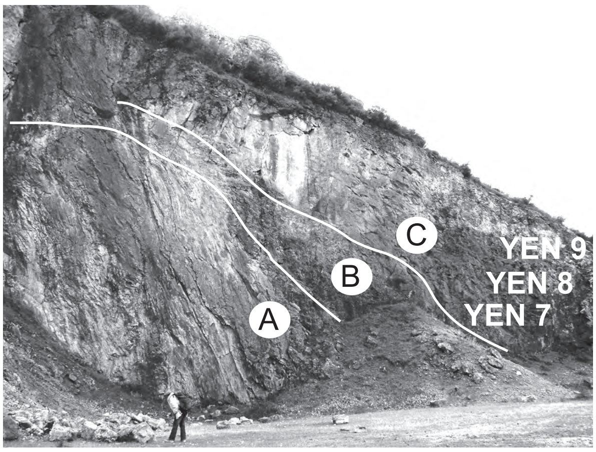


Figure 21. Overview of a composite olistolith in the Çengelli Formation south of Yeniköy. Samples YEN 7-9 represent the lower part of the platform limestone **(C)** above a basal conglomerate **(B)**. These unconformably overlie the red pelagic limestone sequence **(A)**.

very probable that this level is Priabonian, in view of the early Priabonian age data from stratigraphically lower levels (Özcan *et al.* 2007a). Foraminifera in the other samples are not age-diagnostic either, but the occurrence of *Operculina* ex. gr. *gomezi*, *Chapmanina gassinensis*, *Heterostegina* and *Gyroidinella magna* implies a Bartonian or Priabonian age. Some of the turbidite beds of the unit contain reworked late Cretaceous pelagic fauna (mainly Globotruncanidae). Okay & Tansel (1992) presented similar evidence from blocks in the Çengelli Formation.

Samples from the Marls of the Çengelli Formation. Seven samples collected from the marls of the Çengelli sequence to investigate their nannoflora and planktic foraminifera (listed in Figure 22) include

UNIT	ÇENGELLİ FM.						
STAGE	Bartonian-lower Rupelian					upper Eo.-lower Rup.	
NP	16-21			16-22		19-22	
SAMPLE	ŞAR.2007-B	ŞAR.17	ŞAR.4	ÇEN.2	1900	1901	1907
SAMPLES FROM MARLS OF ÇENGELLİ FORMATION							
CALCAREOUS NANNOPLANKTON							
Helicosphaera euphratis Haq					●	●	●
H. compacta Bramlette & Wilcoxon							●
H. intermedia Martini							●
H. seminulum Bramlette & Sullivan							●
Discolithina multipora (Kamptner)					●	●	●
Transversopontis pulcher (Defl.)					●	●	●
Isthmolithus recurvus Defl.						●	●
Cyclicargolithus floridanus (Roth & Hay)	●	●	●	●	●	●	●
Reticulofenestra placomorpha (Kamptner)			●	●	●	●	
R. callida (Perch-Nielsen)						●	
R. bisecta (Hay et al.)	●	●	●	●	●	●	●
R. placomorpha (Kamptner)	●				●		●
Chiasmolithus grandis (Bramlette & Riedel)						●	
C. cf. *grandis* (Bramlette & Riedel)					●		
Chiasmolithus sp. (older type)						●	
Coccolithus pelagicus (Wallich)	●	●	●	●	●	●	●
C. eopelagicus (Bramlette & Riedel)		●			●	●	
Cyclococcolithus formosus Kamptner		●	●		●	●	●
Zygrhablithus bijugatus (Defl.)					●	●	●
Lanternithus minutus Stradner			●				●
Braarudosphaera bigelowi (Gran & Braarud)	●						●
Micrantholithus vesper Defl.						●	●
Discoaster tani Bramlette & Riedel							●
D. cf. *tani* Bramlette & Riedel					●	●	
D. cf. *binodosus* Martini					●		
D. lodoensis Bramlette & Riedel						●	
D. distinctus Martini						●	
D. cf. *distinctus* Martini							●
D. cf. *mirus* Defl.							
D. barbadiensis Tan						●	
D. deflandrei Bramlette & Riedel							●
Sphenolithus radians Defl.						●	●
S. predistentus Bramlette & Wilcoxon						●	●
S. moriformis (Brönn. & Stradner)		●			●	●	●
S. radians Defl.							●
Blackites sp.							●
REWORKED NANNOFOSSILS							
Eiffellithus turriseiffeli (Defl.)					●		
Eiffellithus eximius (Stover)						●	●
Watznaueria barnesae (Black)					●	●	●
Arkhangelskiella sp.						●	●
PLANKTONIC FORAMINIFERA							
Globorotalia bullbrooki (Bolli)						●	
G. cerroazulensis frontosa (Subbotina)					●		
G. cerroazulensis cerroazulensis (Cole)				●			
G. cerroazulensis pomeroli Toumarkine et Bolli				●			
G. cf. c. possagnoensis Toumarkine et Bolli			●				
Globigerina cryptomphala Glaessner					●		●
G. eocaena Gümbel			●	●	●		●
G. corpulenta Subbotina							●
G. hagni Gohrbandt							●
G. linaperta Finlay	●		●	●			
Globigerina sp.	●			●		●	
Globigerinatheka index index (Finlay)							●
G. cf. *luterbacheri* Bolli				●			
Globigerinita martini martini Blow et Banner				●			
Truncorotaloides cf. *rohni* Broennimann et Bermudez	●		●				

Figure 22. Distribution of calcareous nannoplankton and planktonic foraminifera in the marly beds of the Çengelli Formation.

four from near Doluca Hill, where the Çengelli series clearly overlies the Soğucak Limestone. These are (Figure 3) samples 1900, 1901 and 1907 from north-east of Doluca Hill and ÇEN.2 from west of the hill. The calcareous nannoflora from sample 1900 generally indicates the Bartonian NP 16-17 Zones, but the older (lower to middle Eocene) forms such as *Chiasmolithus* cf. *grandis*, *Discoaster* cf. *tani* and *D.* cf. *binodosus* are poorly preserved. Without these forms, most other species belong to the NP 16 to NP 22 Zones, i.e. from Bartonian to lower Rupelian. The assemblage of sample 1901 represents three different ages: (i) Turonian to Campanian, based on the shortest range of *Eiffellithus eximius*, (ii) late Ypresian to earliest Lutetian (NP 12-14), indicated by the shortest range of *Discoaster lodoensis*, (iii) Priabonian to earliest Oligocene (NP 19-22) determined by the range of *Isthmolithus recurvus*. The other marker species for the end of NP 20 or NP 21 (*Discoaster barbadiensis*, *Cyclococcolithus formosus*) may be reworked from older Eocene beds. The above assemblages of three different ages also occur in sample 1907. Its age (NP 19-22, Priabonian to earliest Oligocene) is defined by the range of *Isthmolithus recurvus*. There are reworked older forms from the Cretaceous (Turonian to Campanian with *Eiffellithus eximius*) and from the older (lower to middle ?) Eocene with *Sphenolithus radians*, *Helicosphaera seminulum* and *Discoaster* div. sp. In the poor nannoplankton assemblage of sample ÇEN.2 *Reticulofenestra placomorpha* has the shortest range: NP 16 – NP 22, i.e. Bartonian to lower Oligocene. The age of the rather poor planktic foraminifera from samples 1900 and 1901 is middle Eocene, while those of samples 1907 and ÇEN.2, containing much richer assemblages, span from Bartonian to early Priabonian (P 14-15). To sum up: The Çengelli Formation near Doluca Hill consists of mixed planktonic assemblages, among which the youngest forms approach most reliably the real age of these olistostromal deposits. Therefore, the age of the Çengelli Formation is considered to be middle Priabonian to earliest Rupelian (NP 19-22). This fits with the youngest age (early Priabonian, Özcan *et al.* 2007a) from the underlying Soğucak Limestone.

The other three samples (ŞAR.4, UTM: 0501126, 4499536; ŞAR.17, UTM: 0500825, 4498777 and ŞAR.2007B from the matrix of the olistostrome of samples YEN 7-9 with the same UTM co-ordinates, see above) are from near Yeniköy (Figure 2). They yielded poorer nannoflora, giving an age from Bartonian to earliest Rupelian (NP 16-21), whereas planktonic foraminifera are rare and recrystallized or altogether absent (as in sample ŞAR.17) and give a very uncertain middle Eocene age. Since the presence of *Spiroclypeus* (first appearing in the upper Eocene) in the olistoliths clearly indicates that the matrix cannot be older than Priabonian as well, most of the plankton from the matrix has to be considered as redeposited in this case, too. The upper age of the olistostrome in the Yeniköy region is given by *Cylococcolithus formosus*, last occurring in the NP 21 Zone, approximately marking the Eocene/Oligocene boundary.

Keşan Formation

Larger foraminifera occur very sporadically in the deep marine Keşan (Ceylan) Formation. In southern Thrace, a rather rich assemblage has been discovered only in one locality near Çeltik village (Figure 1B). This sandstone sample (ÇEL 13, UTM coordinates: 06366, 03036) contains *Heterostegina reticulata italica*, the most advanced stage of the species in the Priabonian, *Nummulites budensis*, *Operculina* ex. gr. *gomezi* and *Linderina* sp. This assemblage suggests a middle to late Priabonian (SBZ 19B-20) age for this sample.

Systematic Paleontology

In this section, systematic description of stratigraphically important groups such as orthophragmines and nummulitids (e.g. *Heterostegina*, *Spiroclypeus* and some *Nummulites*) is given. Some comments on the occurrence of other accompanying benthic foraminifera identified in the Çengelli and Soğucak formations are made in the section 'Conclusions'. Some taxa such as *Discocyclina discus*, *D. trabayensis*, *Nemkovella evae* and *N.*

strophiolata, are represented by one single specimen in our material and are therefore not described here. The description of the two *Discocyclina* species, more widely recorded from the northern part of the Thrace Basin, can be found in Less *et al.* (in review), whereas that of the *Nemkovellae* is in Özcan *et al.* (2007b).

Since most of the taxa occurring in our material were described in detail in the last few years, we do not repeat their description here. The most comprehensive data for Western Tethyan *Heterostegina* and *Spiroclypeus,* with their newly proposed taxonomic and phylogenetic scheme, are given in Less *et al.* (2008) and Less & Özcan (2008). A synthesis of diagnostic features of Tethyan orthophragminid families and genera and their qualitative features can be found in Less (1987, 1993), Less *et al.* (2007), Less & Ó. Kovács (2009) and Özcan *et al.* (2007a, b). Additional information with references to more detailed descriptions, geographic and stratigraphic ranges, and the most up-to-date subdivision into subspecies in orthophragmines can be found in Less (1987, 1998a), Less *et al.* (2007), Less & Ó. Kovács (2009), Özcan (2002), Çolakoğlu & Özcan (2003) and Özcan *et al.* (2007a, b). The most up-to-date description of most orthopragminid species discussed below can be found in Özcan *et al.* (2007a); for *Discocyclina archiaci*, *D. fortisi*, *Orbitoclypeus schopeni* and *O. munieri* see Özcan *et al.* (2007b) while for *D. seunesi*, *Nemkovella stockari* and *O. bayani* see Less *et al.* (2007). A shortened description is given for *Orbitoclypeus haynesi* and *Asterocyclina* aff. *priabonensis*, fully described by Samanta & Lahiri (1985) and Less (1987), respectively. A complete description is given only for *O. zitteli*, since this taxon is hardly mentioned since Checchia-Rispoli (1909). A revised stratigraphy of late Paleocene to Priabonian orthophragmines is proposed in Less *et al.* (2007) and Özcan *et al.* (2007a, b). An updated range-chart for the above and other stratigraphically important benthic taxa that cover the late Lutetian to early Rupelian interval is shown in Figure 23. Based on Less *et al.* (2008) the subdivision of reticulate *Nummulites* (*N. fabianii* lineage), spanning from the early Bartonian to the middle Oligocene, is shown in Figure 24.

Principles in the Determination of Orthophragmines and Nummulitids

In the description of orthophragmines we adopted the principles used by Less (1987, 1993) as illustrated in Figure 25A, and explained in the header of Tables 1–3. A synopsis of subspecies identification based on the outer cross-diameter of the deuteroconch (parameter d) is shown in Figure 26. The determination of *Nummulites* is based on both the surface characteristics and the features of the

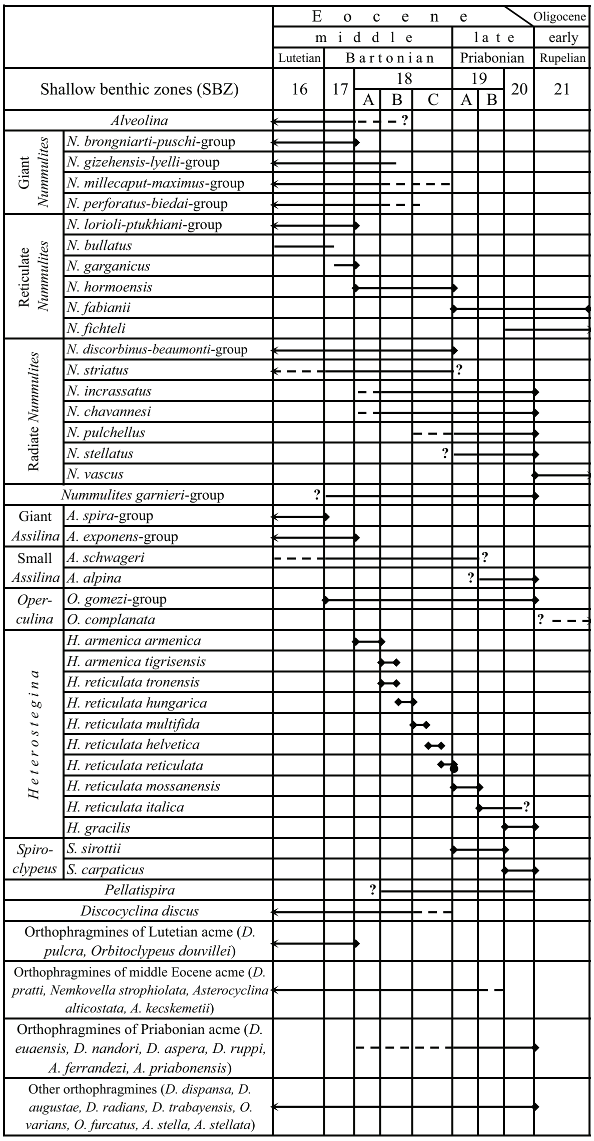


Figure 23. Range-chart for some late Lutetian to early Rupelian larger benthic foraminiferal taxa of the Western Tethys. The subdivision of the stratigraphic scale is not time-proportional (Less *et al.* 2008).

Taxon	P_{mean} (μm)	Surface	Stage	SBZ zone
N. bullatus	65–100	granules, no reticulation	basal Bartonian	early SBZ 17
N. garganicus	100–140	heavy granules + reticulation	early Bartonian to middle late Bartonian	late SBZ 17 to SBZ 18B
N. hormoensis	140–200	heavy granules + umbo + reticulation	late Bartonian	SBZ 18
N. fabianii	200–300	heavy reticulation, weak granules + umbo	Priabonian to early Rupelian	SBZ 19–21
N. fichteli	200–300	weak reticulation to irregular mesh	late Priabonian to late Rupelian	SBZ 20–22A
N. bormidiensis	300–450	irregular mesh	early Chattian	SBZ 22B

Figure 24. Subdivision of the *Nummulites fabianii*-lineage in the Bartonian to early Chattian time-span (Özcan *et al.* 2009). SBZ 21–22B are in the sense of Cahuzac & Poignant (1997).

equatorial section. Based on Drooger *et al*. (1971), Less (1999) introduced a measurement and parameter system to characterize the equatorial section of A-forms that is slightly modified here (Figure 25B). These parameters adopted here are explained in the header of Table 4 (also see Figure 25). The description of *Heterostegina* and *Spiroclypeus* is based on the system introduced by Drooger & Roelofsen (1982) and adopted for Eocene representatives of these genera (Less *et al*. 2008 and Less & Özcan 2008). The explanation of measurements and counts executed in the equatorial section of each megalospheric specimens (Figure 25C) are given in the header of Table 5.

Biometric data are summarized in Tables 1–5. Grouped samples containing almost the same assemblages having similar parameters are evaluated both separately and jointly. However, the subspecific determination of particular species is given for the joint samples on the basis of the total number of specimens. These data are marked always with bold letters. Because of limited space, a complete statistical evaluation with the number of specimens (n°), arithmetical mean and standard error (s.e.) is given only for deuteroconch size (d), the crucial parameter in subspecific determination. Subspecies are determined according to the biometrical limits of subspecies for populations presented in the description of the given species. No subspecies is determined if only a single specimen is available from joint samples. If the number of specimens is two or three, the subspecies is determined as cf. If this number is four or more, however the d_{mean} value of the given population is closer to the biometrical

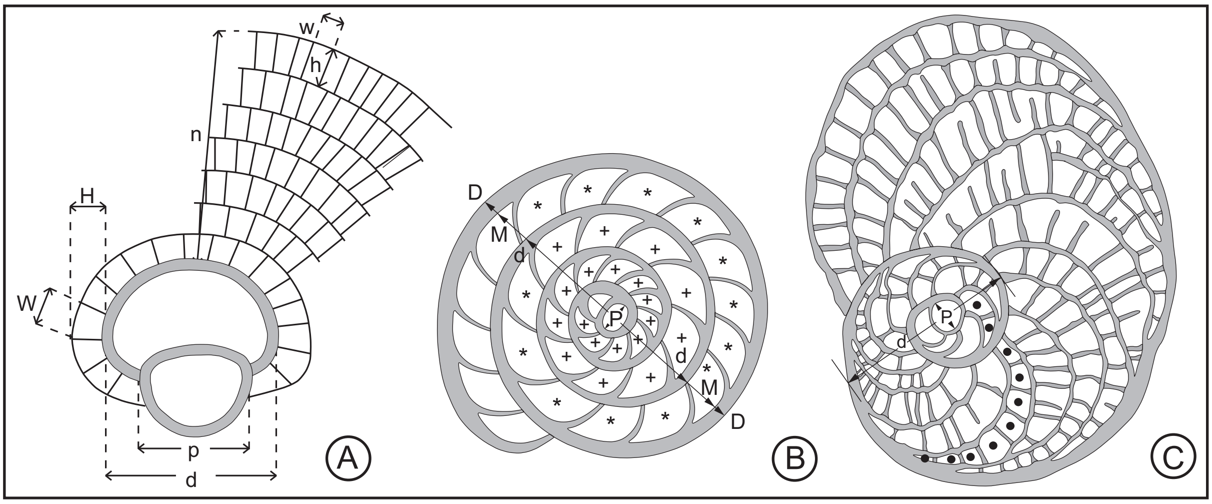


Figure 25. Measurement system for megalospheric larger foraminifera (parameters are explained in the headers of Tables 1 to 5). The parameters for the definition of megalospheric orthophragmines **(A)**, *Nummulites* **(B)**, *Heterostegina* and *Spiroclypeus* **(C)**.

Table 1. Statistical data of *Discoyclina* and *Nemkovella* populations. №: number of specimens, s.e.– standard error.

Parameters		Outer cross-diameter of the embryon					Adauxiliary chamberlets			Equatorial chamberlets			Subspecific determination
		deuteroconch			protoconch		number	width	height	annuli/0.5 mm	width	height	
		d (μm)			p (μm)		N	W (μm)	H (μm)	n	w (μm)	h (μm)	
Species	Sample	№	range	mean±s.e.	range	mean	range	range	range	range	range	range	
Discocyclina seunesi	**SAZ 46**	**6**	**225 – 450**	**341.7 ± 34.9**	**140 – 270**	**203.3**							*karabuekensis*
D. archiaci	**MÜF A 10**	**10**	**280 – 470**	**380.0 ± 19.2**	**150 – 240**	**197.5**	**17–30**	**35–40**	**45–70**	**11–13**	**35–45**	**80–85**	*staroseliensis–archiaci*
	1894	**9**	**380 – 650**	**503.3 ± 29.1**	**170 – 320**	**232.9**	**28–38**	**30–50**	**40–60**	**11–12**	**25–35**	**45–65**	*archiaci*
D. discus	**GIZ A 4**	**1**		**1030.0**		**430.0**							indet. ssp.
D. fortisi	**MÜF A 10**	**28**	**530 – 1040**	**726.3 ± 23.7**	**250 – 630**	**379.4**	**51–63**	**30–50**	**55–80**	**6–9**	**35–45**	**65–100**	*fortisi*
	1894	**21**	**540 – 1005**	**723.8 ± 20.8**	**290 – 520**	**376.7**	**53–61**	**30–50**	**40–85**	**7–9**	**30–50**	**50–75**	*fortisi*
D. augustae	**MÜF A 10**	**8**	**90 – 115**	**106.3 ± 2.8**	**55 – 85**	**66.3**	**10–11**	**15–35**	**15–25**	**16–21**	**20–25**	**70–85**	*sourbetensis*
	1894	**4**	**90 – 125**	**107.5 ± 6.7**	**65 – 85**	**76.7**	**10**	**15–20**	**15–20**	**16–20**	**25–30**	**50–55**	*sourbetensis*
	GIZ A 9+11	**16**	**130 – 215**	**163.1 ± 5.8**	**70 – 110**	**95.4**	**–**	**20–35**	**30–50**	**13–18**	**20–35**	**50–95**	
	GIZ A 9	9	130 – 215	160.0 ± 8.3	70 – 100	92.9	–	20–35	30–50	13–18	20–35	50–90	*atlantica*
	GIZ A 11	7	130 – 190	167.1 ± 7.7	80 – 110	98.3	–	30–35	35–40	15	25–30	95	
	GIZ A 12	**7**	**140 – 190**	**160.7 ± 5.8**	**85 – 115**	**100.0**	**–**	**25–40**	**35–60**	**15**	**25–35**	**50–55**	*atlantica*
	PIR 46	**4**	**195 – 240**	**221.3 ± 9.7**	**100 – 125**	**110.0**	**–**	**–**	**–**	**–**	**–**	**–**	*olianae-augustae*
	PIR 47A+48	**14**	**190 – 225**	**206.1 ± 2.9**	**100 – 130**	**116.3**	**–**	**–**	**–**	**–**	**–**	**–**	
	PIR 47A	3	205 – 225	213.3	110 – 130	120.0	–	–	–	–	–	–	*olianae*
	PIR 48	11	190 – 225	204.1 ± 3.1	100 – 125	115.0	–	–	–	–	–	–	
	1902	**1**		**210.0**		**100.0**							indet. ssp.
D. dispansa	**1894**	**4**	**170 – 250**	**216.3 ± 14.7**	**90 – 125**	**106.3**	**16–20**	**30–35**	**35–45**	**13–16**	**20–25**	**50–70**	*taurica*
	GIZ A 6+7	**4**	**315 – 345**	**331.3 ± 6.0**	**150 – 160**	**155.0**	**–**	**–**	**35–55**	**–**	**–**	**–**	
	GIZ A 6	1		345.0		160.0	–	–	55	–	–	–	*sella*
	GIZ A 7	3	315 – 340	326.7 ± 5.9	150 – 155	153.3	–	30–35	35–50	10–11	–	–	
	GIZ A 8	**9**	**260 – 340**	**311.1 ± 8.1**	**125 – 155**	**141.9**	**–**	**25–45**	**50–70**	**10–12**	**30–40**	**75–90**	*sella*
	TAY 4	**2**	**360 – 535**	**448.0**	**150 – 175**	**162.0**							cf. *dispansa*
	PIR 47A+48	**22**	**320 – 540**	**442.3 ± 10.9**	**150 – 250**	**205.8**	**–**	**–**	**–**	**–**	**–**	**–**	
	PIR 47A	11	320 – 540	444.5 ± 20.0	150 – 240	200.6	–	–	–	–	–	–	*dispansa*
	PIR 48	11	400 – 495	440.0 ± 8.4	150 – 250	210.5	–	30–50	55–75	9–10	30–45	105–110	
	1902	**1**		**295.0**		**170.0**							indet. ssp.
D. pratti	**GIZ A 6+7**	**18**	**325 – 590**	**413.6 ± 15.0**	**110 – 240**	**160.7**	**–**	**35–50**	**55–95**	**9–11**	**30–45**	**90–145**	
	GIZ A 6	15	350 – 590	418.3 ± 16.8	140 – 240	162.1	–	35–50	55–95	9–11	30–45	90–145	*montfortensis*
	GIZ A 7	3	325 – 440	390.0 ± 27.8	110 – 195	155.0	–	35–50	60–95	10–11	30–45	105–130	
	1902	**1**		**450.0**		**150.0**							indet. ssp.
	TEKE 4+6	**11**	**380 – 930**	**531.4 ± 42.8**	**160 – 240**	**200.0**	**33–54**	**30–50**	**70–120**	**6–8**	**25–35**	**100–130**	
	TEKE 4	1		480.0		200.0	41	35–50	100–110	6	20–30	75–100	*pratti*
	TEKE 6	10	380 – 930	536.5 ± 46.8	160 – 240	200.0	33–54	30–50	70–120	6–8	25–35	100–130	
D. trabayensis	**PIR 47A**	**1**		**150.0**		**70.0**	**8**						indet. ssp.
D. nandori	**GIZ A 7**	**1**		**170.0**		**115.0**							
	GIZ A 8	**3**	**130 – 230**	**173.3**	**75 – 100**	**90.0**							
	GIZ A 9+11	**3**	**165 – 245**	**203.3**	**80 – 110**	**95.0**							–
	GIZ A 9	1		165.0		80.0							
	GIZ A 11	2	200 – 245	222.5		110.0							
	GIZ A 12	**12**	**160 – 230**	**202.9 ± 6.4**	**90 – 120**	**103.6**	**–**	**25–50**	**35–65**	**10–12**	**25–40**	**75–130**	
D. radians	**PIR 43**	**1**		**460.0**		**205.0**							indet. ssp.
	PIR 47A	**2**	**360 – 500**	**430.0**	**160 – 210**	**185.0**				**8**			cf. *labatlanensis*
Nemkovella evae	**1894**	**1**		**240.0**		**130.0**	**14**	**30–45**	**45–50**	**13**	**30–35**	**50–65**	indet. ssp.
N. strophiolata	**1894**	**1**		**130.0**		**90.0**	**10**	**25**	**20**	**19**	**30–45**	**50–55**	indet. ssp.
N. stockari	**SAZ 46**	**2**	**95 – 100**	**97.5**	**95 – 105**	**100.0**							–

limit of the given subspecies than 1 s.e. of d_{mean}, we use an intermediate denomination between the two neighboring subspecies. In these cases we adopt Drooger's (1993) proposal in using the notation exemplum intercentrale (abbreviated as ex. interc.).

Order FORAMINIFERIDA Eichwald 1830

Family DISCOCYCLINIDAE Galloway 1928

Genus *Discocyclina* Gümbel 1870

Discocyclina seunesi Douvillé 1922

Figure 27f

In the studied material this species occurs rarely in the Başaoğlu member of the Karaağaç Formation near Sazlimanı and is represented by *D. seunesi karabuekensis* Less & Özcan, which is the most advanced stage of the species in the earliest Ypresian (OZ 2, SBZ 5-6 Zones).

Discocyclina archiaci (Schlumberger 1903)

Figure 27c–e

This taxon, identified only in the Dişbudak series, is represented by two developmental stages. *D. archiaci archiaci* (Schlumberger), identified only in sample 1894 (Figure 27c–d), is a key taxon for the early late Ypresian OZ 5 and 6 Zones corresponding to the SBZ 10 Zone. The *D. archiaci* population in sample MÜF A 10 represents a transitional stage between *D. a. staroseliensis* and *D. a. archiaci*. These specimens were therefore assigned to *D. archiaci* ex. interc. *staroseliensis-archiaci* (Figure 27e).

Table 2. Statistical data of *Orbitoclypeus* populations. №: number of specimens, s.e.– standard error.

Parameters		Outer cross-diameter of the embryon					Adauxiliary chamberlets			Equatorial chamberlets			Subspecific determination
		deuteroconch			protoconch		number	width	height	annuli/0.5 mm	width	height	
		d (µm)			p (µm)		N	W (µm)	H (µm)	n	w (µm)	h (µm)	
Species	Sample	№	range	mean±s.e.	range	mean	range	range	range	range	range	range	
Orbitoclypeus schopeni	**SAZ 46**	**16**	**175 – 270**	**203.4 ± 6.2**	**95 – 130**	**116.0**							*neumannae*
	MUF A 10	**1**		**325.0**		**175.0**		**30–45**	**50–60**	**10**	**30–40**	**105**	indet. ssp.
O. munieri	**SAZ 46**	**3**	**190 – 230**	**215.0**	**100 – 130**	**113.3**				**17–19**	**25–35**		cf. *ponticus*
O. bayani	**SAZ 46**	**2**	**320 – 350**	**335.0**	**170**	**170.0**				**14**	**35–40**		cf. *bayani*
O. douvillei	**MÜF A 10**	**2**	**130 – 205**	**167.5**	**70 – 100**	**85.0**	**14–19**	**25–55**	**25–45**	**15–18**	**20–40**	**55–100**	cf. *douvillei*
	1894	**3**	**140 – 195**	**175.0**	**80 – 95**	**88.3**	**15–20**	**25–30**	**35–45**	**15–16**	**30–40**	**65–100**	cf. *douvillei*
	GIZ A 9	**2**	**510 – 520**	**515.0**	**320 – 335**	**327.5**		**50–80**	**90–130**	**6–7**	**40–50**	**110**	cf. *pannonicus*
	GIZ A 12	**6**	**500 – 740**	**608.3 ± 30.5**	**310 – 420**	**360.0**		**45–75**	**85–120**	**6–7**	**40–75**	**100–220**	*malatyaensis*
O. varians	**GIZ A 4**	**6**	**260 – 310**	**286.7 ± 8.7**	**135 – 160**	**146.0**							*roberti*
	GIZ A 9+11	**23**	**240 – 330**	**287.4 ± 4.5**	**120 – 200**	**157.7**		**25–45**	**30–60**	**12–16**	**30–40**	**40–60**	*roberti*
	GIZ A 9	18	240 – 330	290.6 ± 5.2	135 – 200	162.9		25–45	30–60	13–16	30–40	45–60	
	GIZ A 11	5	255 – 300	276.0 ± 6.8	120 – 150	140.0		30–40	35–55	12–15	30–35	40	
	GIZ A 12	**10**	**260 – 340**	**304.0 ± 8.1**	**150 – 190**	**167.5**							*roberti*
	TAY 4	**13**	**240 – 315**	**272.7 ± 6.2**	**125 – 180**	**147.5**							*roberti*
	BES 19	**4**	**285 – 350**	**316.3 ± 12.0**	**140 – 210**	**167.5**							*roberti–scalaris*
	PIR 28	**4**	**300 – 370**	**348.8 ± 14.2**	**160 – 210**	**180.0**				**11–12**	**30–45**	**50–60**	*scalaris*
	PIR 45+46	**30**	**290 – 590**	**366.8 ± 10.3**	**135 – 330**	**201.5**							*scalaris*
	PIR 45	12	300 – 410	352.5 ± 10.3	150 – 240	189.2							
	PIR 46	18	290 – 590	376.4 ± 15.3	135 – 330	209.7							
	MÜF B 9	**2**	**320 – 330**	**325.0**	**150 – 170**	**160.0**	**30–31**	**30–45**	**40–55**	**10–12**	**30–35**	**45–55**	cf. *scalaris–roberti*
	MÜF C 6	**1**		**365.0**		**200.0**	**29**	**25–45**	**50–65**	**13**	**30–40**	**50–75**	indet. ssp
	1902	**2**	**310 – 395**	**352.5**	**150 – 220**	**185.0**							cf. *scalaris*
	YEN 2+4	**9**	**325 – 385**	**357.8 ± 7.5**	**160 – 200**	**179.4**	**29–32**	**35–65**	**40–85**	**11–13**	**30–40**	**45–65**	*scalaris*
	YEN 2	7	325 – 385	358.6 ± 8.1	160 – 200	180.0	31–32	35–65	40–85	11–13	30–40	45–60	
	YEN 4	2	330 – 380	355.0	175 – 180	177.5	29	35–45	60–65	11	35–40	60–65	
	TEKE 1–8	**30**	**290 – 500**	**372.0 ± 9.7**	**150 – 350**	**202.5**	**30–36**	**25–55**	**40–70**	**9–14**	**25–35**	**40–60**	*scalaris*
	TEKE 1	6	340 – 395	367.5 ± 7.4	190 – 235	209.0	30–32	25–50	50–70	9–14	25–35	40–60	
	TEKE 4	13	290 – 500	383.1 ± 18.1	150 – 350	200.8	32–34	40–45	50–70	12–14	30–35	40–55	
	TEKE 6	10	300 – 430	364.0 ± 15.2	150 – 275	206.1	31–36	25–55	40–65	11–13	25–35	45–55	
	TEKE 8	1		335.0		160.0							
	MEC 40	**19**	**295 – 430**	**359.5 ± 8.8**	**170 – 270**	**211.6**							*scalaris*
O. zitteli	**GIZ A 4**	**6**	**450 – 550**	**509.2 ± 12.5**	**190 – 250**	**217.5**							–
	TAY 1	**7**	**400 – 600**	**502.9 ± 28.5**	**180 – 240**	**206.0**							
	TAY 4+5	**26**	**430 – 630**	**522.9 ± 8.7**	**190 – 340**	**247.6**							
	TAY 4	14	475 – 630	532.5 ± 10.1	220 – 310	259.5							
	TAY 5	12	430 – 610	511.7 ± 14.0	190 – 340	230.7							
	BES 8	**1**		**620.0**		**315.0**							
	PIR 28	**12**	**440 – 605**	**539.6 ± 12.0**	**215 – 330**	**269.4**		**35–45**	**55**	**9–12**	**35–40**	**80–100**	
	PIR 36	**9**	**420 – 640**	**531.1 ± 21.6**	**140 – 300**	**227.5**							
	PIR 45	**1**		**550.0**		**340.0**							
	YEN 2+4	**7**	**490 – 780**	**566.4 ± 37.2**	**235 – 270**	**255.0**	**43–54**	**30–55**	**50–70**	**7–12**	**25–40**	**55–75**	
	YEN 2	3	490 – 580	520.0		270.0	48	30–45	50–65	8–12	25–35	65–75	
	YEN 4	4	490 – 780	601.3 ± 56.5	235 – 260	251.3	43–54	30–55	55–70	7–10	25–40	55–70	
	TEKE 6	**3**	**590 – 710**	**640.0**	**375 – 480**	**415.0**	**46**	**30–50**	**50–75**	**9–10**	**30–40**	**60–90**	
O. haynesi	**GIZ A 9**	**10**	**135 – 200**	**165.0 ± 5.4**	**70 – 90**	**81.5**		**20–35**	**25–35**	**18–23**	**20–30**	**45–65**	–
	GIZ A 12	**18**	**150 – 185**	**169.7 ± 2.5**	**75 – 95**	**84.4**		**25–45**	**25–35**	**19–21**	**25–35**	**45–60**	

Discocyclina fortisi (d'Archiac 1850)

Figure 27a–b

This taxon is represented by *D. fortisi fortisi* (d'Archiac) in the Dişbudak series. It is a key taxon for the early late Ypresian OZ 6 Zone corresponding to the SBZ 10 Zone.

Discocyclina augustae van der Weijden 1940

Figure 27g–m

This taxon is represented in our material by four developmental stages. *D. augustae sourbetensis* Less (OZ 3-8b, OZ 7-13) is identified in the upper Ypresian Dişbudak series (Figure 27g–h), whereas *D. augustae atlantica* Less (OZ 9-12, SBZ 13-16) (Figure 27i–j), *D. augustae* ex. interc. *olianae* Almela & Rios-*augustae* van der Weijden (Figure 27k) and *D. augustae olianae* Almela & Rios (OZ 12-14, SBZ 17-19A) (Figure 27l, m) are found in the Soğucak Formation. The finding of *D. a. atlantica* in the early Bartonian part of the Gizliliman section (samples GİZ A 9-12) means that the range of this subspecies is slightly longer than Özcan *et al.* (2007a) assumed (ending at the Lutetian/Bartonian boundary), and it extends into the early Bartonian (SBZ 17).

Discocyclina dispansa (Sowerby 1840)

Figure 28a–f

This taxon is represented in our material by three developmental stages; *Discocyclina dispansa taurica* Less (OZ 5-8a, SBZ 10-12) in sample 1894 from the Dişbudak series (Figure 28a), *D. dispansa sella* (d'Archiac) (OZ 11-13, SBZ 14-17) (Figure 28b, c) and *D. dispansa dispansa* (Sowerby) (OZ 14, SBZ 18-

Table 3. Statistical data of *Asterocyclina* populations. №: number of specimens, s.e.– standard error.

Parameters		Outer cross-diameter of the embryon					Adauxiliary chamberlets			Equatorial chamberlets			Subspecific determination
		deuteroconch			protoconch		number	width	height	annuli/0.5 mm	width	height	
		d (µm)			p (µm)		N	W (µm)	H (µm)	n	w (µm)	h (µm)	
Species	Sample	№	range	mean±s.e.	range	mean	range	range	range	range	range	range	
Asterocyclina stellata	**GIZ A 8**	**19**	**125 – 170**	**144.2 ± 3.1**	**75 – 105**	**86.7**							*adourensis*
	GIZ A 9+11	**17**	**130 – 230**	**171.2 ± 6.1**	**80 – 120**	**99.4**							*stellata*
	GIZ A 9	7	135 – 230	165.7 ± 11.9	90 – 120	102.9							
	GIZ A 11	10	130 – 200	175.0 ± 5.9	80 – 115	97.0							
	GIZ A 12	**11**	**150 – 170**	**160.9 ± 1.8**	**85 – 115**	**98.6**							*stellata*
	BES 19	**1**		**185.0**		**110.0**							indet. ssp.
	PIR 28	**11**	**185 – 220**	**206.4 ± 3.2**	**115 – 145**	**127.7**							*stellaris*
	PIR 36	**6**	**235 – 250**	**243.3 ± 2.8**	**125 – 160**	**150.0**							*buekkensis*
	PIR 43	**8**	**180 – 230**	**198.8 ± 5.1**	**100 – 130**	**114.3**							*stellaris*
	PIR 47A+48	**10**	**185 – 235**	**213.0 ± 4.9**	**105 – 140**	**128.0**							*stellaris*
	PIR 47A	2	200 – 235	217.5	125 – 140	132.5							
	PIR 48	8	185 – 235	211.9 ± 5.2	105 – 140	126.9							
	TEKE 4+6	**7**	**215 – 245**	**228.6 ± 4.0**	**125 – 150**	**142.9**		**45–110**	**40–60**	**19–24**	**20–30**	**40–65**	*stellaris*
	TEKE 4	4	215 – 245	226.3 ± 5.7	125 – 150	140.0		100–110	50–60	22–24	20–25	40–45	
	TEKE 6	3	220 – 240	231.7	140 – 150	146.7		45–95	40–55	19–20	20–30	60–65	
	MEC 40	**1**		**235.0**		**150.0**							indet. ssp.
A. stella	**1894**	**1**		**130.0**		**70.0**	**8**	**30**	**25**				indet. ssp.
	PIR 47A+48	**13**	**185 – 250**	**220.0 ± 5.6**	**115 – 170**	**141.9**							*stella*
	PIR 47A	3	190 – 240	211.7	135 – 160	143.3							
	PIR 48	10	185 – 250	222.5 ± 6.1	115 – 170	141.5							
A. kecskemetii	**GIZ A 9+11**	**5**	**250 – 315**	**284.0 ± 12.6**	**135 – 185**	**160.0**							–
	GIZ A 9	4	250 – 315	292.5 ± 12.6	135 – 185	163.8							
	GIZ A 11	1		250.0		145.0							
	GIZ A 12	**2**	**250 – 300**	**275.0**	**130 – 170**	**150.0**							
	BES 19	**1**		**305.0**		**150.0**							
	TEKE 6	**1**		**335.0**		**175.0**	**14**	**60**	**50**	**15**	**25**	**35–40**	
A. ferrandezi	**YEN 2**	**3**	**290 – 340**	**310.0**	**220 – 270**	**236.7**	**11–13**	**35–85**	**40–45**	**14–15**	**25–30**	**40–45**	–
A. aff. *priabonensis*	**YEN 2+4**	**17**	**205 – 280**	**227.4 ± 4.2**	**100 – 170**	**137.8**	**11–14**	**30–65**	**30–50**	**13–19**	**20–30**	**35–50**	–
	YEN 2	10	215 – 280	233.0 ± 5.6	100 – 170	140.0	13–14	35–50	30–35	13–14	20–25	45–50	
	YEN 4	7	205 – 240	219.3 ± 4.7	125 – 145	135.0	11–13	30–65	35–50	17–19	25–30	35–45	
	TEKE 4+6	**9**	**195 – 300**	**239.4 ± 9.4**	**130 – 185**	**155.0**	**11–18**	**25–60**	**40–50**	**16–19**	**25–35**	**50–65**	
	TEKE 4	6	220 – 300	249.2 ± 10.9	140 – 185	164.2	14–18	25–45	40–50	16–17	25–35	50–65	
	TEKE 6	3	195 – 245	220.0	130 – 145	136.7	11–13	25–60	45–50	18–19	25–30	50–60	
A. alticostata	**TEKE 6**	**2**	**470 – 500**	**485.0**	**350 – 385**	**367.5**			**85–100**	**10–11**	**30–40**	**100–105**	cf. *danubica*

19a) (Figure 28d–f) from the Soğucak Formation. The two specimens of the species found in the lower Bartonian of the Soğucak Formation in section TAY have been assigned to *D. dispansa* cf. *dispansa*.

Discocyclina pratti (Michelin 1846)

Figure 27n–t

The species is represented by two developmental stages; by *D. pratti montfortensis* Less (OZ 9-12, SBZ 13-16) (Figure 27n-p) and *D. pratti pratti* (Michelin) (OZ 12-14, SBZ 17-19a) (Figure 27q–t) in the Soğucak Formation. The occurrence of *D. pratti pratti* (Michelin) in sample TEKE 6 of early Priabonian age is one of the stratigraphically highest ones.

Discocyclina nandori Less 1987

Figure 27u–x

This species is identified in our material only in the uppermost Lutetian and lower Bartonian Soğucak Formation from Gökçeada (samples GİZ A 7-12, OZ 11-13, SBZ 15-17). This marks a stratigraphically lower occurrence than that indicated in Özcan *et al.* (2007a). However, the Gökçeada specimens with relatively low equatorial chamberlets in the first annuli also show some similarities with *Discocyclina knessae* described from upper Lutetian and the lower Bartonian beds of Hungary (with somewhat smaller embryon than in Gökçeada) by Less (1987). Since the Gökçeada specimens show intermediate characters between *D. nandori* and *D. knessae*, the latter species may appear in synonymy with *D. nandori*, the stratigraphic range of which can be extended from the late Lutetian to the middle Priabonian (OZ 11-15, SBZ 15-19). The sporadic occurrence of this taxon in the lower Priabonian levels of the Soğucak Formation near Şarköy was marked by Özcan *et al.* (2007a).

Discocyclina radians (d'Archiac 1850)

Figure 28g–h

This species is very sporadic in the studied material and only two specimens from the upper Bartonian of

Table 4. Statistical data of *Nummulites* and *Assilina* populations. №: number of specimens, s.e.– standard error.

Parameters		Inner cross-diameter of the proloculus			Outer diameter of the first two whorls			Number of post-embryonic chambers in the first two whorls			Index of spiral opening 3. whorl vs. first 3 whorls		
		P (μm)			d (μm)			E			K=100×(D–d)/(D–P)		
Taxon	Sample	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.
Nummulites hormoensis	PIR 33	9	125 – 215	163.9 ± 9.0	8	935 – 1235	1098 ± 30	8	18 – 23	20.63 ± 0.53	8	33.9 – 37.5	35.22 ± 0.47
	MÜF B 7+9	45	140 – 230	174.0 ± 3.5	45	820 – 1390	1030 ± 17	45	19 – 25	21.42 ± 0.26	45	28.6 – 47.9	35.83 ± 0.44
	MÜF B 7	24	140 – 230	171.7 ± 5.3	24	900 – 1390	1045 ± 25	24	19 – 24	21.08 ± 0.33	24	28.6 – 47.9	36.37 ± 0.71
	MÜF B 9	21	145 – 220	176.7 ± 4.4	21	820 – 1200	1013 ± 20	21	20 – 25	21.81 ± 0.38	21	30.6 – 41.0	35.20 ± 0.47
	MÜF C 6	27	160 – 240	194.8 ± 3.6	22	995 – 1370	1105 ± 19	22	18 – 26	22.68 ± 0.36	22	32.0 – 45.7	35.47 ± 0.60
N. fabianii	YEN 2+4	25	165 – 290	233.8 ± 6.0	24	1025 – 1560	1239 ± 24	24	18 – 24	20.58 ± 0.32	24	27.2 – 36.4	31.92 ± 0.49
	YEN 2	24	165 – 290	234.2 ± 6.3	23	1025 – 1560	1241 ± 25	23	18 – 23	20.43 ± 0.29	23	27.2 – 36.4	31.84 ± 0.50
	YEN 4	1		225.0	1		1190	1		24.00	1		33.68
	TEKE 1–8	52	155 – 305	225.2 ± 4.2	48	890 – 1560	1176 ± 16	49	19 – 26	21.45 ± 0.20	48	27.6 – 38.5	33.46 ± 0.37
	TEKE 1	24	155 – 285	216.9 ± 5.8	21	890 – 1280	1137 ± 22	22	20 – 26	21.45 ± 0.30	21	30.0 – 38.5	34.43 ± 0.50
	TEKE 4	20	185 – 305	236.5 ± 6.3	20	1020 – 1560	1214 ± 26	20	20 – 25	21.45 ± 0.29	20	27.6 – 36.6	32.46 ± 0.60
	TEKE 6	1		210.0	1		1055	1		20.00	1		32.40
	TEKE 8	7	165 – 265	223.6 ± 12.9	6	1105 – 1325	1205 ± 30	6	19 – 25	21.67 ± 0.77	6	30.7 – 36.3	33.56 ± 0.78
	MEC 40	11	220 – 285	245.0 ± 5.9	11	1165 – 1395	1255 ± 21	11	19 – 24	20.73 ± 0.58	11	24.2 – 34.8	30.72 ± 0.78
N. biedai	BES 8	7	750 – 1340	1032.1 ± 74.3	6	2850 – 3420	3050 ± 77	6	21 – 31	25.53 ± 1.26	6	27.6 – 32.4	29.64 ± 0.63
	TAY 3	8	890 – 1320	1048.8 ± 48.8	7	2810 – 3520	3195 ± 89	7	19 – 26	22.71 ± 0.75	7	23.1 – 31.6	28.46 ± 1.02
	TAY 4	10	800 – 1080	949.0 ± 28.6	9	2520 – 3140	2762 ± 67	9	19 – 28	21.89 ± 0.88	9	28.8 – 32.9	30.70 ± 0.42
	MÜF B 9	16	750 – 1500	1042.8 ± 43.6	11	2505 – 3900	3199 ± 117	11	16 – 22	19.91 ± 0.47	11	26.9 – 49.2	35.23 ± 2.12
N. budensis	CEL 13	3	70 – 95	81.7	3	715 – 1325	1017	3	22 – 25	23.67	3	51.1 – 61.4	55.94
N. lyelli	PIR 48	7	860 – 1680	1228.3 ± 100.2									
N. striatus	MÜF B 9	8	385 – 590	498.1 ± 21.8									
Assilina placentula	MÜF A 10	21	135 – 330	243.1 ± 10.5									
	1894	16	215 – 390	279.7 ± 11.8									

Parameters		Third whorl								
		average length of chambers			average shape of chambers			relative width of the spiral cord		
		L=d×π/N (μm)			F=100×(D–d)/(D–d+2d×π/N)			m=100×(D–M)/(D–d)		
Taxon	Sample	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.
Nummulites hormoensis	PIR 33	8	179 – 254	220.2 ± 8.3	8	50.2 – 56.5	53.51 ± 0.67	8	29.5 – 42.4	35.30 ± 1.36
	MÜF B 7+9	45	163 – 268	203.4 ± 3.2	45	46.5 – 66.2	53.93 ± 0.47	45	21.6 – 49.0	33.69 ± 0.82
	MÜF B 7	24	174 – 268	212.1 ± 4.9	24	46.5 – 66.2	53.96 ± 0.77	24	21.6 – 49.0	32.89 ± 1.21
	MÜF B 9	21	163 – 227	193.5 ± 2.8	21	49.9 – 58.8	53.90 ± 0.49	21	24.3 – 43.2	34.61 ± 1.05
	MÜF C 6	22	168 – 269	204.6 ± 4.7	22	50.3 – 64.7	55.01 ± 0.70	22	19.4 – 42.7	31.99 ± 1.18
N. fabianii	YEN 2+4	24	206 – 338	256.1 ± 5.3	24	42.5 – 52.9	47.82 ± 0.54	24	22.5 – 46.7	31.66 ± 1.22
	YEN 2	23	206 – 338	256.5 ± 5.6	23	42.5 – 52.9	47.73 ± 0.55	23	22.5 – 46.7	31.44 ± 1.25
	YEN 4	1		246.0	1		49.90	1		36.73
	TEKE 1–8	48	169 – 291	226.7 ± 3.9	48	44.9 – 58.0	51.34 ± 0.44	48	21.1 – 50.6	35.61 ± 0.93
	TEKE 1	21	175 – 266	225.2 ± 5.8	21	46.9 – 57.3	51.85 ± 0.59	21	27.8 – 50.6	37.13 ± 1.29
	TEKE 4	20	169 – 285	224.0 ± 6.1	20	44.9 – 58.0	51.15 ± 0.72	20	21.1 – 48.6	33.40 ± 1.59
	TEKE 6	1		218.1	1		48.15	1		40.74
	TEKE 8	6	208 – 291	242.7 ± 11.0	6	45.7 – 55.9	50.73 ± 1.32	6	32.8 – 40.9	36.82 ± 1.16
	MEC 40	11	214 – 283	243.9 ± 6.7	11	38.6 – 51.8	47.88 ± 1.10	11	31.8 – 43.5	38.34 ± 1.12
N. biedai	BES 8	6	403 – 524	460.0 ± 20.9	6	44.4 – 55.5	48.56 ± 1.49	6	16.4 – 27.5	22.95 ± 1.67
	TAY 3	7	425 – 614	510.8 ± 23.7	7	36.3 – 49.9	45.39 ± 1.64	7	18.6 – 31.3	23.86 ± 1.38
	TAY 4	9	372 – 521	436.7 ± 16.5	9	44.8 – 51.2	48.17 ± 0.76	9	16.0 – 26.5	22.38 ± 1.10
	MÜF B 9	11	455 – 681	567.4 ± 18.1	11	43.5 – 62.3	50.37 ± 1.70	11	9.9 – 40.8	19.54 ± 2.70
N. budensis	CEL 13	3	148 – 215	174.2	3	75.9 – 78.4	76.88	3	7.4 – 13.4	10.93

the Soğucak Formation (sample PIR 48) have been assigned to *D. radians* cf. *labatlanensis* Less. A single specimen in sample PIR.43 does not permit subspecific designation.

Genus *Nemkovella* Less 1987

***Nemkovella stockari* Less & Özcan 2007**

Figure 28i

This species occurs sporadically in the lower Ypresian Başaoğlu member and this is only its second Tethyan locality. This taxon was originally described from the lower Ypresian of northern central Turkey near Kurucaşile in richer material (Less *et al*. 2007). The associated taxa, and hence the age (OZ 2, SBZ 5-6) of the two localities are very similar.

Table 5. Statistical data of *Heterostegina* and *Spiroclypeus* populations. №: number of specimens, s.e.– standard error.

Parameters		Inner cross-diameter of the proloculus			Outer diameter of the first whorl			Number of post-embryonic pre-heterosteginid chambers			Number of chamberlets in the fourteenth chamber			Subspecific determination
		P (µm)			d (µm)			X			S			
Taxon	Sample	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.	
Heterostegina armenica	**PIR 28**	**12**	**105 – 170**	**146.3 ± 5.1**	**12**	**600 – 1060**	**857 ± 39**	**12**	**15 – 56**	**29.33 ± 2.84**	**12**	**1**	**1.00 ± 0.00**	*armenica*
	PIR 33	**4**	**110 – 180**	**142.5 ± 12.4**	**4**	**640 – 1000**	**850 ± 70**	**4**	**10 – 24**	**15.75 ± 2.84**	**4**	**1 – 3**	**1.75 ± 0.41**	*armenica*
	PIR 36	**14**	**115 – 210**	**161.4 ± 7.2**	**14**	**620 – 1350**	**915 ± 54**	**12**	**3 – 34**	**15.00 ± 2.18**	**12**	**1 – 3**	**1.42 ± 0.22**	*armenica*
	PIR 43	**21**	**110 – 180**	**145.7 ± 4.2**	**15**	**700 – 1160**	**889 ± 32**	**15**	**5 – 22**	**10.80 ± 1.41**	**15**	**1 – 3**	**1.87 ± 0.21**	*armenica*
	PIR 45+46	**17**	**110 – 220**	**159.4 ± 7.8**	**17**	**650 – 1450**	**905 ± 54**	**12**	**4 – 20**	**10.42 ± 1.43**	**17**	**1 – 5**	**1.53 ± 0.25**	
	PIR 45	10	110 – 220	162.0 ± 10.2	10	650 – 1450	935 ± 72	5	4 – 20	10.80 ± 2.36	10	1 – 2	1.10 ± 0.09	*armenica*
	PIR 46	7	120 – 210	155.7 ± 11.9	7	650 – 1310	861 ± 80	7	4 – 17	10.14 ± 1.78	7	1 – 5	2.14 ± 0.51	
	PIR 47A+48	**16**	**125 – 225**	**173.4 ± 7.5**	**16**	**770 – 1210**	**975 ± 32**	**16**	**2 – 10**	**5.63 ± 0.61**	**16**	**1 – 5**	**2.94 ± 0.26**	
	PIR 47A	6	135 – 220	175.8 ± 10.5	6	770 – 1210	1025 ± 55	6	3 – 7	4.83 ± 0.55	6	1 – 3	2.33 ± 0.38	*tigrisensis*
	PIR 48	10	125 – 225	172.0 ± 10.1	10	790 – 1170	945 ± 37	10	2 – 10	6.10 ± 0.89	10	2 – 5	3.30 ± 0.28	
H. reticulata	**PIR 47A+48**	**3**	**95 – 135**	**113.3**	**3**	**510 – 700**	**613**	**3**	**22 – 29**	**26.00**	**2**	**1**	**1.00**	
	PIR 47A	2	95 – 135	115.0	2	510 – 700	605	2	27 – 29	28.00	1		1.00	cf. *tronensis*
	PIR 48	1		110.0	1		630	1		22.00	1		1.00	
	MÜF B 9	**1**		**125.0**	**1**		**790**	**1**		**9.00**	**1**		**3.00**	indet. ssp.
	1902	**9**	**90 – 140**	**116.7 ± 4.8**	**9**	**540 – 870**	**670 ± 32**	**9**	**2 – 6**	**3.56 ± 0.42**	**9**	**3 – 6**	**3.78 ± 0.34**	*reticulata*
	YEN 2	**5**	**110 – 180**	**152.0 ± 11.0**	**5**	**620 – 1000**	**886 ± 62**	**5**	**2 – 3**	**2.20 ± 0.18**	**4**	**4 – 7**	**5.50 ± 0.56**	*mossanensis*
	TEKE 1–6	**23**	**100 – 190**	**144.3 ± 5.2**	**23**	**510 – 1045**	**807 ± 26**	**23**	**1 – 4**	**2.35 ± 0.15**	**21**	**3 – 8**	**4.90 ± 0.27**	
	TEKE 1	1		125.0	1		700	1		3.00	1		3.00	
	TEKE 4	9	105 – 185	149.4 ± 8.9	9	510 – 910	756 ± 39	9	2 – 4	2.44 ± 0.23	8	4 – 6	4.75 ± 0.29	*mossanensis*
	TEKE 6	13	100 – 190	142.3 ± 6.6	13	590 – 1045	851 ± 32	13	1 – 4	2.23 ± 0.19	12	3 – 8	5.17 ± 0.39	
	MEC 40	**4**	**95 – 155**	**118.8 ± 11.4**	**4**	**600 – 800**	**738 ± 40**	**2**	**2 – 3**	**2.50**	**2**	**3**	**3.00**	cf. *mossanensis*
	CEL 13	**12**	**105 – 200**	**142.1 ± 8.7**	**12**	**590 – 1180**	**819 ± 59**	**12**	**1 – 2**	**1.25 ± 0.13**	**12**	**6 – 11**	**8.25 ± 0.43**	*italica*
H. gracilis	**MEC 41**	**1**		**310.0**				**1**		**1.00**				–
Spiroclypeus sirottii	**TEKE 4–8**	**21**	**75 – 145**	**107.1 ± 4.2**	**18**	**420 – 765**	**602 ± 25**	**20**	**1 – 6**	**3.35 ± 0.27**	**19**	**2 – 8**	**4.05 ± 0.29**	
	TEKE 4	3	75 – 95	86.7	3	435 – 610	527	3	4 – 5	4.33	3	3 – 4	3.33	–
	TEKE 6	17	85 – 140	108.5 ± 4.0	14	420 – 765	611 ± 28	16	2 – 6	3.31 ± 0.28	15	2 – 6	3.93 ± 0.24	
	TEKE 8	1		145.0	1		700	1		1.00	1		8.00	
S. carpaticus	**MEC 40**	**6**	**100 – 115**	**108.3 ± 1.9**	**4**	**440 – 670**	**558 ± 41**	**5**	**2**	**2.00 ± 0.00**	**4**	**3 – 4**	**3.75 ± 0.22**	–

Family ORBITOCLYPEIDAE Brönnimann 1946

Genus *Orbitoclypeus* Silvestri 1907

Orbitoclypeus schopeni (Checchia-Rispoli 1908)

Figure 28j, k

In the Başaoğlu member this taxon is represented by *Orbitoclypeus schopeni neumannae* (OZ 3, SBZ 7-8) (Toumarkine) (Figures 28j, k). A single specimen in sample MÜF A 10 is determined at species level. Its biometric data (Table 2) suggest a close relationship to *O. shopeni crimensis* (OZ 5-8b, SBZ 10-13).

Orbitoclypeus munieri (Schlumberger 1904)

Figure 28l, m

This species occurs sporadically in the lowermost Ypresian Başaoğlu member, and is represented by *O. munieri* cf. *ponticus* Less & Özcan (OZ 2-4, SBZ 4-9).

Orbitoclypeus bayani (Munier-Chalmas 1891)

Figures 28n–o

This species occurs sporadically in the lowermost Ypresian Başaoğlu member, and is represented by *O. bayani* cf. *bayani* (Munier-Chalmas) (OZ 3, SBZ 7-8).

Orbitoclypeus douvillei (Schlumberger 1903)

Figure 28p–t

The species is represented in our material by three developmental stages. Based on the principles of subspecies definition, both the two specimens in sample MÜF A 10 and the three ones in sample 1894 (upper Ypresian Dişbudak series) are assigned to *O. douvillei* cf. *douvillei* (Schlumberger) (OZ 4-7, SBZ 8-11) (Figure 28p, q). The assemblages from the lower Bartonian Soğucak Formation in section Gizliliman, GİZ.A are assigned to *O. douvillei* cf. *pannonicus* Less (OZ 11-12, SBZ 14-17) in sample

***Species**/subspecies*	d_{mean} (μm)
Asterocyclina alticostata	
gallica	<275
cuvillieri	275-350
alticostata	350-450
danubica	>450
A. schweighauseri	
n. ssp. Bos d'Arros	<400
schweighauseri	>400
A. stella	
praestella	<150
stella	>150
A. stellata	
adourensis	<150
stellata	150-190
stellaris	190-240
buekkensis	>240
Discocyclina archiaci	
bakhchisaraiensis	<305
staroseliensis	305-390
arhiaci	390-600
bartholomei	>600
D. augustae	
sourbetensis	<145
atlantica	145-180
olianae	180-225
augustae	>225
D. discus	
discus	<1350
adamsi	>1350
D. dispansa	
broennimanni	<160
taurica	160-230
hungarica	230-290
sella	290-400
dispansa	400-520
umbilicata	>520
D. fortisi	
fortisi	<850
simferopolensis	850-1100
anatolica	1100-1450
cairazensis	>1450
D. pratti	
montfortensis	<510
pratti	510-700
minor	>700
D. pulcra	
landesica	<800
pulcra	800-1000
n. ssp. Angoumé	1000-1250
balatonica	1250-1600
baconica	>1600
D. radians	
n. ssp. Caupenne	<240
noussensis	240-300
radians	300-375
labatlanensis	>375

***Species**/subspecies*	d_{mean}
D. seunesi	
seunesi	<250
beloslavensis	250-310
karabuekensis	>310
D. spliti	
polatliensis	<800
spliti	800-1300
ajkaensis	>1300
D. trabayensis	
trabayensis	<125
elazigensis	125-170
vicenzensis	>170
Nemkovella evae	
evae	<260
karitensis	>260
N. strophiolata	
fermonti	<150
strophiolata	150-185
n. ssp. Padragkút	185-230
tenella	>230
Orbitoclypeus bayani	
kurucasileensis	<280
bayani	>280
O. douvillei	
douvillei	<200
yesilyurtensis	200-260
n. ssp. Gibret	260-340
chudeaui	340-425
pannonicus	425-580
malatyaensis	>580
O. furcatus	
palaeofurcatus	<200
n. ssp. Gibret	200-270
rovasendai	270-340
furcatus	>340
O. multiplicatus	
haymanaensis	<310
multiplicatus	310-420
kastamonuensis	>420
O. munieri	
ponticus	<220
munieri	>220
O. schopeni	
ramaraoi	<195
neumannae	195-240
suvlukayensis	240-300
crimensis	300-500
schopeni	>500
O. varians	
portnayae	<165
ankaraensis	165-205
angoumensis	205-255
roberti	255-320
scalaris	320-400
varians	>400

Figure 26. Subspecies limits based on the size of the outer cross-diameter of the deuterococh in orthophragmid taxa.

GİZ.A.9 (Figures 28r-s) and upwards to *O. douvillei malatyaensis* Özcan & Less (OZ 13, late part of SBZ 17) in sample GİZ.A.12 (Figure 28t).

Orbitoclypeus varians (Kaufmann 1867)

Figures 28u–x & 29a–e

The species is recorded both in the Soğucak Formation and in the olistoliths of the Çengelli Formation, and is represented by two developmental stages. *O. varians roberti* (Douvillé) (Figure 28u, v) is identified only in the Soğucak Formation, while *O. varians scalaris* (Schlumberger) (Figures 28w–x & 29a–e) is recorded from both units. Four specimens from the late part of the early Bartonian (SBZ 17) sample BES 19 were assigned to *O. varians* ex. interc. *roberti* (Douvillé) et *scalaris* (Schlumberger), two specimens in the upper Bartonian (SBZ 18) sample MÜF B 9 to *O. varians* cf. *scalaris-roberti,* and the two specimens from the uppermost Bartonian (SBZ 18C) sample 1902 to *O. varians* cf. *scalaris*. In the studied material *O. varians roberti* commonly occurs in upper Lutetian (lower part of section GİZ.A) and lower Bartonian (upper part of section GİZ.A and section TAY) beds. Therefore, its range has to be extended to OZ 11-13 (SBZ 14-17) instead of OZ 11 (SB 14-15) shown in Özcan *et al.* (2007a). *O. varians scalaris* commonly occurs in samples of the PIR (upper Bartonian), TEKE (early Priabonian), sample YEN 2 (earliest Priabonian) and MEC.40 (late Priabonian). The stratigraphic range of this subspecies, too, has to be extended to OZ 12-14 (late SBZ 15 to SBZ 19A) with rare occurrences in OZ 15-16 (SBZ 19B-20) instead of mainly OZ 12 and rare occurrences in OZ 13-14 as defined by Özcan *et al.* (2007a).

Orbitoclypeus zitteli (Checchia-Rispoli 1908)

Figure 29f–h

1908 *Orbitoides* (*Orthopragmina*) *zitteli* n. sp., Checchia-Rispoli, p. 7, 14.

1909 *Orthophragmina zitteli* Checchia-Rispoli, p. 133–134, pl. 7, figs. 3, 4, 19–22, pl. 5, fig. 14.

2007a *Orbitoclypeus* aff. *O. varians* (Kaufmann), Özcan *et al.*, p. 504, pl. 2, fig. 13, text-fig. 15.

Diagnosis. Average-sized, slightly flattened unribbed forms with 'marthae' type rosettes. The rather large embryon is excentrilepidine (very rarely eulepidine). The adauxiliary chamberlets of 'varians' type, are moderately wide and high, as well as the equatorial chamberlets. The annuli are almost circular or very slightly undulated; their growth pattern is of the 'varians' type.

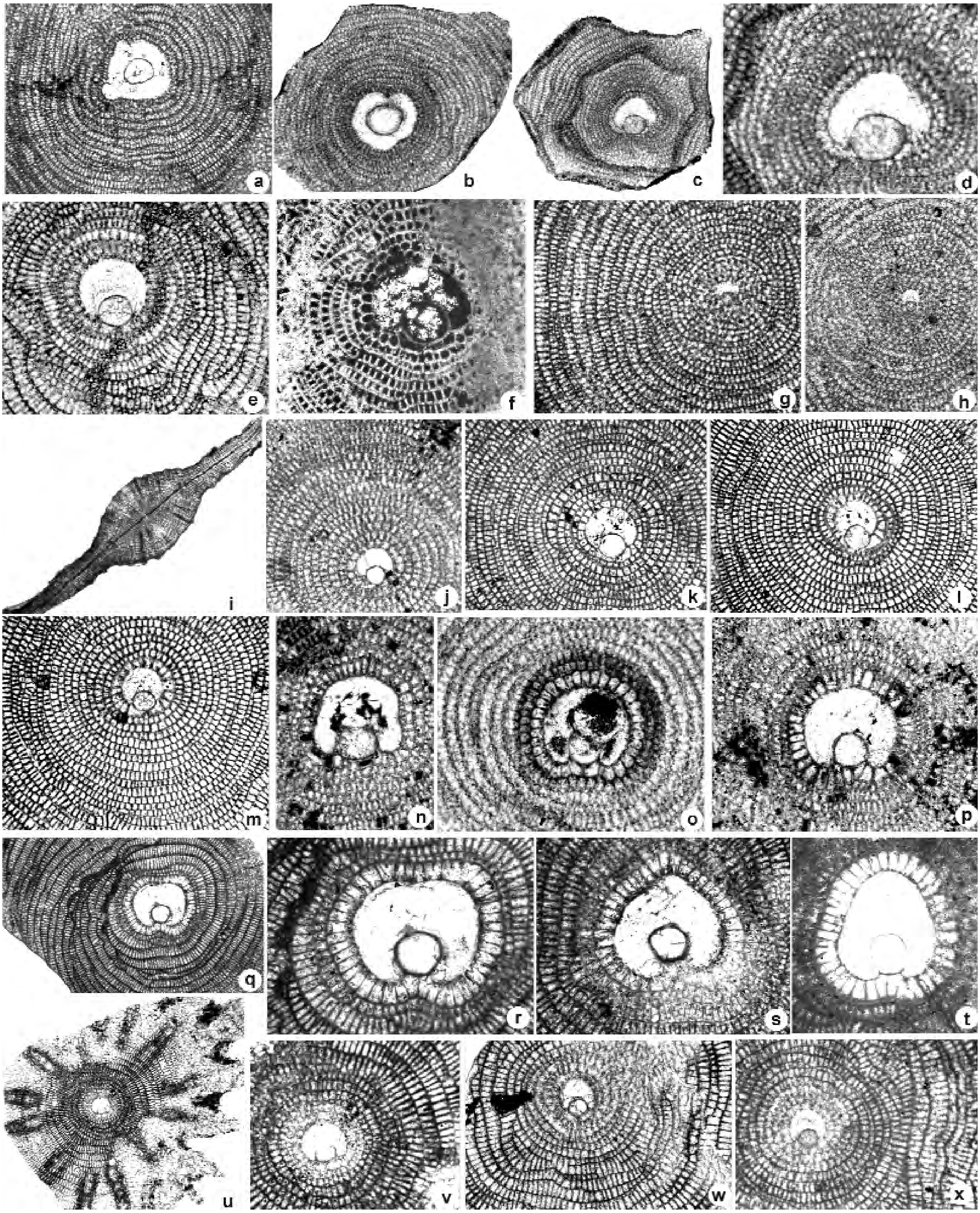


Figure 27.

Description. Medium-sized (3 to 5 mm) slightly flattened forms with no umbo. The rosette is of the 'marthae' type. The granules are of nearly equal size (their diameter varies around 70−170 µm), they are surrounded by 8 to 12 lateral chamberlets. 'B' forms are not yet found.

In the equatorial section of the A-forms the relatively large embryon (p= 150–400 µm, d= 400–750 µm) is mostly excentrilepidine (rarely also eulepidine). The moderately wide (W= 30–50 µm) and moderately high (H= 50–75 µm), 'varians'-type adauxiliary chamberlets are numerous (N= 40–60). Also, the equatorial chamberlets are moderately wide (w= 25–45 µm) and high (h= 60–90 µm, n= 7–12). The cycles are almost circular or only very slightly undulated, their growth pattern is of the 'varians' type.

Microspheric forms are not yet found. In the axial section the height of the embryon is about 270 µm. The equatorial layer is about 70−80 µm thick near the embryon, and keeps its thickness through the periphery. In the lateral layers the chamberlets average 80×30 µm across.

Remarks. Some specimens from samples YEN 2, 4, TEKE 6, TAY 4 and GİZ A 4 have much larger embryons together with much less undulose (or without any undulation) annuli than in the forms assigned to *Orbitoclypeus varians* from the same samples (see Figure 30, in which they clearly form two clusters). Such duality has already been observed in the Keçili samples (eastern Turkey) from the upper Bartonian by Özcan *et al*. (2007a) who called the unusual forms as *O*. aff. *varians*. The specimens with almost regular annuli (without undulation or weakly developed annuli) are here differentiated from those forms with distict undulation of equatorial chamberlets. The latter specimens are attributed to *O. zitteli* (Checchia-Rispoli), which is the only applicable name for these forms, although the lack of protoconch mentioned in the diagnosis of this species by Checchia-Rispoli (1909) clearly has to be abandoned. Beside the Turkish occurrences (see above) and Sicily, based on our unpublished data, this taxon can also be found in lower Bartonian (OZ 13, SBZ 17) beds at Biarritz, rocher de Peyreblanque (SW France). The earliest occurrence of the taxon is in the uppermost Lutetian part of the Gizlimani section (sample GİZ A 4) whereas the latest one is in the lowest Priabonian of Doluca Hill (sample ŞAR 9 in Özcan *et al*. 2007a) (Figure 18), Yeniköy and Teke Hill sections. No real size increase of the deuteroconch can be observed in this time interval; therefore no subspecific subdivision can be applied for *O. zitteli*. Based on the above data the stratigraphic range of this species is latest Lutetian (OZ 12, SBZ 16) to earliest Priabonian (OZ 14, SBZ 19A).

Orbitoclypeus haynesi **(Samanta & Lahiri 1985)**

Figure 29i–n

1985 *Discocyclina haynesi* n. sp. Samanta & Lahiri, p. 262–272, pl. 4, figs. 1–6, pl. 12, figs. 9–14, text figs. 5–7.

Orbitoclypeus haynesi is an unribbed form with 'marthae'-type rosette, small eulepidine embryon, adauxiliary chamberlets of 'varians'-type of average size and shape, plus moderately wide and high equatorial chamberlets arranged into strongly undulated annuli with 'varians'-type growth pattern.

This species was originally described from the middle Eocene Fulra limestone in the Cutch region of India (Samanta & Lahiri 1985). Based on the associated orthophragmines (*Discocyclina dispansa*

Figure 27. **(a–b)** *Discocyclina fortisi fortisi* (d'Archiac), (a) O/MÜF.A.10-5, (b) O/1894-7. **(c–d)** *D. archiaci archiaci* (Schlumberger), O/1894-22. **(e)** *D. archiaci* ex. interc. *staroseliensis* Less- *archiaci* (Schlumberger), O/MÜF.A.10-50. **(f)** *D. seunesi karabuekensis* Less & Özcan, O/SAZ.46-14. **(g–h)** *D. augustae sourbetensis* Less, (g) O/MÜF.A.10-39, (h) O/MÜF.A.10-40, **(i–j)** *D. augustae atlantica* Less, (i) O/GİZ.A.11-29, (j) O/GİZ.A.11-16. **(k)** *D. augustae* ex. interc. *olianae* Almela & Rios-*augustae* van der Weijden, O/PIR.46-25. **(l–m)** *D. augustae olianae* Almela & Rios, (l) O/PIR.48-55, (m) O/PIR.48-54. **(n–p)** *D. pratti montfortensis* Less, (n) O/GİZ.A-7-3, (o) O/GİZ.A.6-3, (p) O/GİZ.A.6-5. **(q–t)** *D. pratti pratti* (Michelin), (q-r) O/TEKE.6-4, (s) O/TEKE.6-3, (t) O/TEKE.6-63. **(u–x)** *D. nandori* Less, (u-v) O/GİZ.A.12-24, (w) O/GİZ.A.12-55, (x) O/GİZ.A.12-56. All A-forms. i: axial section, the others equatorial sections. a-c, i, q, u:×16, the others: ×40.

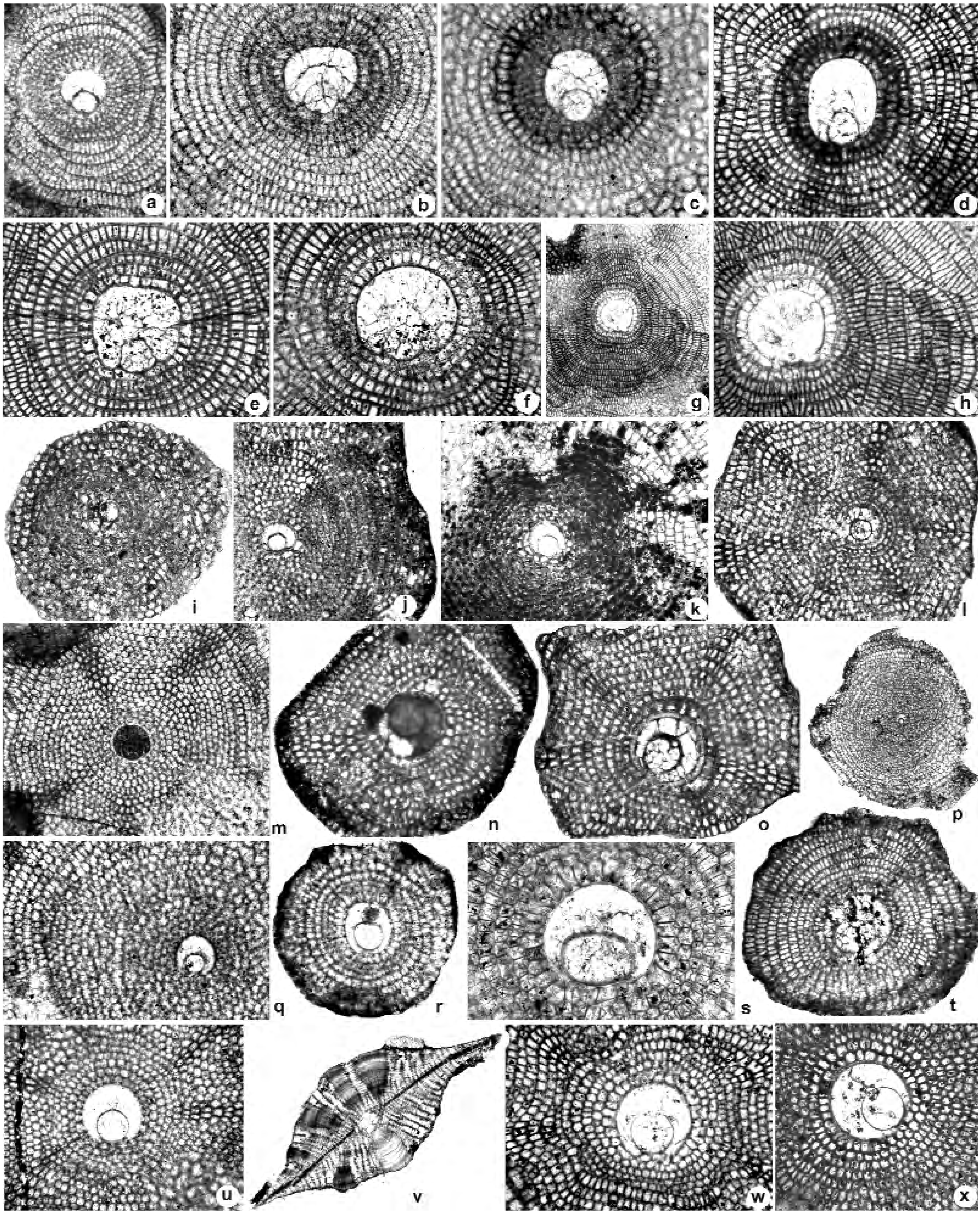


Figure 28.

dispansa, *D. discus adamsi*, *Asterocyclina alticostata alticostata*) topotypic *Orbitoclypeus haynesi* comes from Bartonian beds. Although it was considered as a discocyclinid, the the type of the embryon and the equatorial chamberlets clearly show that it belongs to *Orbitoclypeus*, although microspheric forms have not yet been found. This taxon, identified from the upper part of section GİZ A (lower Bartonian, Soğucak Formation) based especially on its very small embryon and strongly undulated annuli, is recorded first time from the Western Tethys. Since we have also found this species in the upper Bartonian of Akören near Çatalca (Less *et al.* in review), *O. haynesi* is very probably characteristic for the Bartonian (SBZ 17-18).

Genus *Asterocyclina* Gümbel 1870

Asterocyclina stellata (d'Archiac 1846)

Figure 29o–t

The species is represented by four developmental stages recorded in the Soğucak Formation; *A. stellata adourensis* Less (Figure 29o), *A. stellata stellata* (d'Archiac) (Figure 29p), *A. stellata stellaris* (Brünner in Rutimeyer) (Figure 29q–s) and *A. stellata buekkensis* Less (Figure 29t). The stratigraphic position of populations in samples GİZ A 9-12 agrees with that given for *A. s. stellata* (OZ 10-13, SBZ 14-17) by Özcan *et al.* (2007a), as well as in samples PIR 28, 43, 47A, 48 and that of TEKE 4 and 6 given for *A. s. stellaris* (OZ 14-15, SBZ 18-19). The specimens in sample PIR 36 (upper Bartonian) have unusual embryons, bigger than those in both the under- (sample PIR 28) and overlying (samples PIR 43, 47A and 48) upper Bartonian beds. This population is arranged into *A. s. buekkensis* (known from the upper Priabonian OZ 16 corresponding to SBZ 20) and considered as an exception. The occurrence of *A. stellata adourensis* in upper Lutetian–lower Bartonian transitional beds in section GİZ. A (sample GİZ A 8) implies re-evaluation of the stratigraphic range of this taxon, since based on Özcan *et al.* (2007b) this taxon was known only from late Ypresian to early Lutetian (OZ 6-9, SBZ 10-13) beds.

Asterocyclina stella (Gümbel 1861)

Figure 29u–w

This species is very scarce in the upper Ypresian material and a single specimen in sample 1894 is assigned it. Although it cannot be determined at the subspecific level, it greatly resembles *Asterocyclina stella praestella* introduced by Less & Ó. Kovács (2009), and ranging from middle to late Ypresian (from OZ 4 Zone to the early part of 8b corresponding to the SBZ 8–12 zones). It occurs rather abundantly in the upper part of the upper Bartonian PIR section and is represented by *Asterocyclina stella stella* (Gümbel) (OZ 9-15, SBZ 13-19) (Figure 29u–w).

Asterocyclina kecskemetii Less 1987

Figure 29x

Some specimens in samples TEKE 6 (early Priabonian), BEŞ 19 and GİZ A 9 to 12 (all lower Bartonian), were assigned to this species. It ranges from OZ 11 Zone to OZ 14 corresponding to the late SBZ 14 Zone to the SBZ 19A Sub-zone (middle Lutetian to earliest Priabonian). Another early Priabonian occurrence of this species is recorded by Less & Gyalog (2004) from Úrhida (Hungary).

Figure 28. **(a)** *Discocyclina dispansa taurica* Less, O/1894-46. **(b–c)** *D. dispansa sella* (d'Archiac), (b) O/GİZ.A.6-17, (c) O/GİZ.A.7-6. **(d–f)** *D. dispansa dispansa* (Sowerby), (d) O/PIR.47.A-3, (e) O/PIR.47.A-7, (f) O/PIR.47.A-8. **(g–h)** *D. radians* cf. *labatlanensis* Less, O/PIR.48-25. **(i)** *Nemkovella stockari* Less & Özcan, O/SAZ.46-15. **(j–k)** *Orbitoclypeus schopeni neumannae* (Toumarkine), (j) O/SAZ.46-1, (k) O/SAZ.46-22. **(l–m)** *O. munieri* cf. *ponticus* Less & Özcan, (l) O/SAZ.46-16, (m) O/SAZ.46-17. **(n–o)** *O. bayani* cf. *bayani* (Munier-Chalmas), (n) O/SAZ.46-29, (o) O/SAZ.46-31. **(p–q)** *O. douvillei* cf. *douvillei* (Schlumberger), (p) O/MÜF.A.10-37, (q) O/1894-29. **(r–s)** *O. douvillei* cf. *pannonicus* Less, (r) O/GİZ.A.9-10, (s) O/GİZ.A.9-9. **(t)** *O. douvillei malatyaensis* Özcan & Less, O/GİZ.A.12-1. **(u–v)** *O. varians roberti* (Douvillé), (u) O/GİZ.A.9-5, (v) O/GİZ.B.11-28. **(w–x)** *O. varians scalaris* (Schlumberger), (w) O/PIR.45-11, (x) O/PIR.46-5. All A-forms. v: axial section, the others equatorial sections. g, p, r, t,v:×16, the others: ×40.

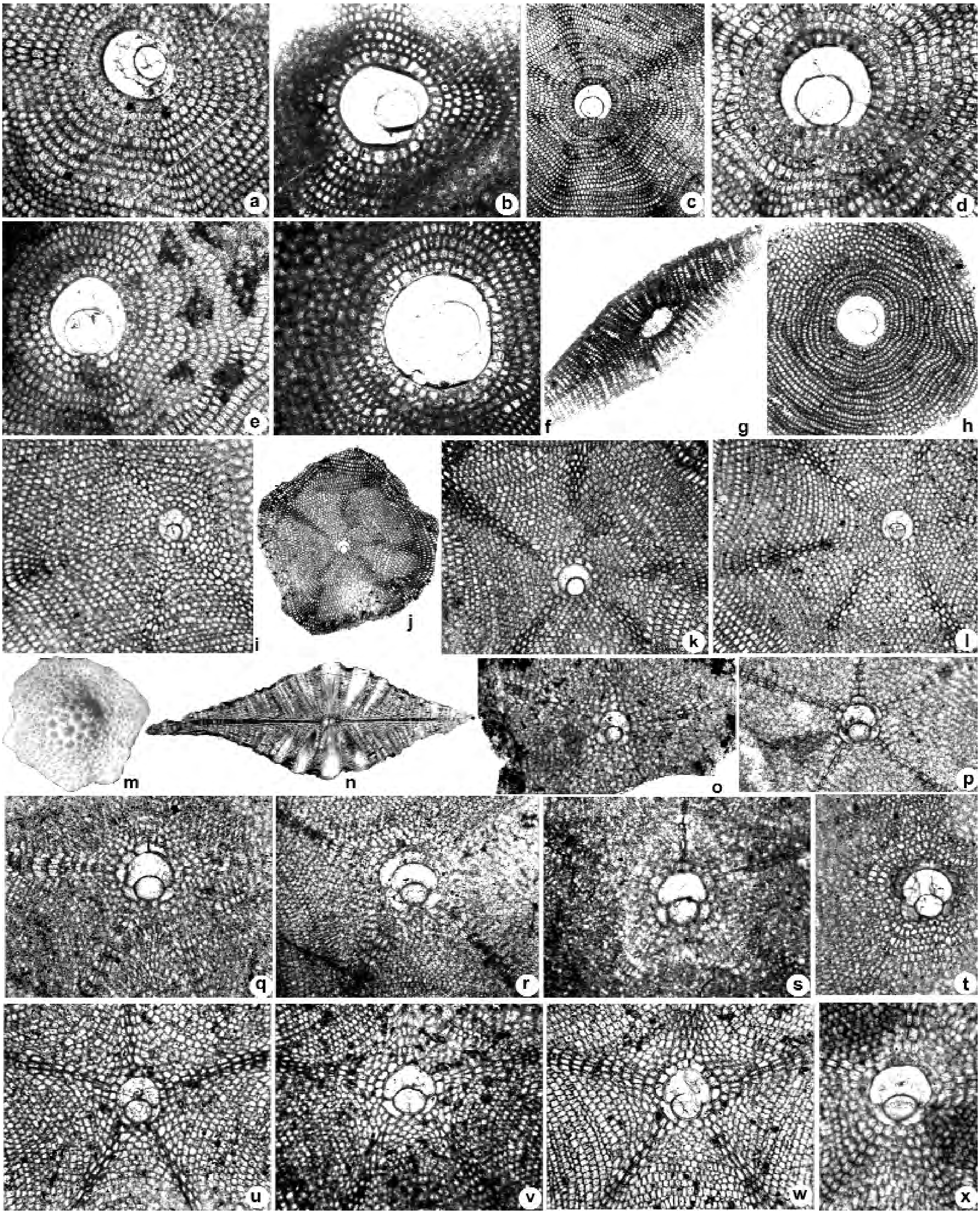


Figure 29.

Asterocyclina ferrandezi **Özcan & Less 2007**

Figure 31d

This species appears in the early Priabonian (OZ 14, SBZ 19A) beds of Soğucak Formation north-east of Şarköy (Özcan *et al.* 2007a). Our record comes from an olistolith (sample YEN 2) of the same age.

Asterocyclina **aff.** ***priabonensis*** **Gümbel 1870**

Figure 31a–c

Some orthophragminid specimens from samples YEN 2, 4 and TEKE 4, 6 lacking any apparent development of ribbing on the external part of the test (a characteristic feature of *Asterocyclina*) but with other internal features identical to *Asterocyclina* have been assigned to this taxon. In terms of embryonic features (i.e. the size of the deuteroconch – Table 3 – and the nephro- to semi-nephrolepidine embryonic arrangement), due to the moderate sharpness of rays and the 'varians'-type adauxiliary chamberlets, these specimens are most comparable with *A. priabonensis* (see in Less 1987), which is characteristic only for the Priabonian (the SBZ 19–20 Zones). The lack of external ribbing may have been caused by ecological factors. According to our taxonomic concept, the ribbing is a diagnostic feature at generic level in *Asterocyclina*, although it is considered to be important only at the species level in other orthophragminid taxa. The development state of ribbing, however, may be highly variable as e.g. in *A. ferrandezi*, the indistinct ribbing of which is one of its characteristic features.

Asterocyclina alticostata **(Nuttall 1926)**

Figure 31e–g

This species, identified only from the basal Priabonian Soğucak Formation in section TEKE, is very scarce in our material, and therefore, based only on two specimens the subspecific level could be determined only as 'cf.' *Asterocyclina alticostata danubica* is a key taxon for the OZ 14 Zone corresponding to the SBZ 18 Zone (late Bartonian) and 19A Subzone (earliest Priabonian).

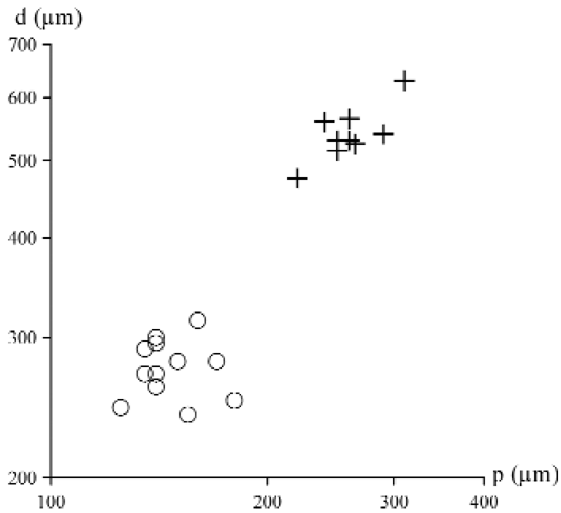


Figure 30. Distribution of *Orbitoclypeus varians* (empty circles) and *O. zitteli* in sample TAY.4 in the p-d (protoconch diameter vs. deuteroconch diameter) bivariate plot.

Family NUMMULITIDAE de Blainville 1827

Genus ***Nummulites*** **Lamarck 1801**

Based on their surface characteristics the representatives of genus *Nummulites* in the studied area can be classified into three categories as follows: *N. hormoensis* and *N. fabianii* belong to the reticulate, *N. burdigalensis*, *N. biedai* and *N. lyelli* to the granulate, while *N. nemkovi*, *N. leupoldi*, *N. soerenbergensis*, *N. striatus* and *N. budensis* to the radiate forms.

Nummulites hormoensis and *N. fabianii* belong to the *N. fabianii* lineage. Numerous populations of this lineage from the Western Tethys, spanning from the

Figure 29. **(a–e)** *O. varians scalaris* (Schlumberger), (a) O/YEN.2-30, (b) O/YEN.2-26, (c–d) O/TEKE.6-32, (e) O/MEC.40-44. **(f–h)** *O. zitteli* Checcia-Rispoli, (f) O/TAY.4-6, (g) O/TAY.1-10, (h) O/TAY.4-7. **(i–n)** *O. haynesi* Samanta & Lahiri, (i) O/GİZ.A.9-2, (j–k) O/GİZ.A.12-45, (l) O/GİZ.A.9-45, (m) O/GİZ.A.12-35, (n) O/GİZ.A.12-75. **(o)** *Asterocyclina stellata adourensis* Less, O/GİZ.A.8-20. **(p)** *A. stellata stellata* (d'Archiac), O/GİZ.A.12-12. **(q–s)** *A. stellata stellaris* (Brünner in Rutimeyer), (q) O/PIR.28-11, (r) O/TEKE.4-20, (s) O/TEKE.6-12. **(t)** *A. stellata buekkensis* Less, O/PIR.36-19. **(u–w)** *A. stella stella* (Gümbel), (u) O/PIR.47.A-23, (v) O/PIR.47.A-24, (w) O/PIR.48-36. **(x)** *A. kecskemetii* Less, O/GİZ.A.9-41. All A-forms. m: external view, n, g: axial sections, the others equatorial sections. m:×10, g-h, j:×16, the others: ×40.

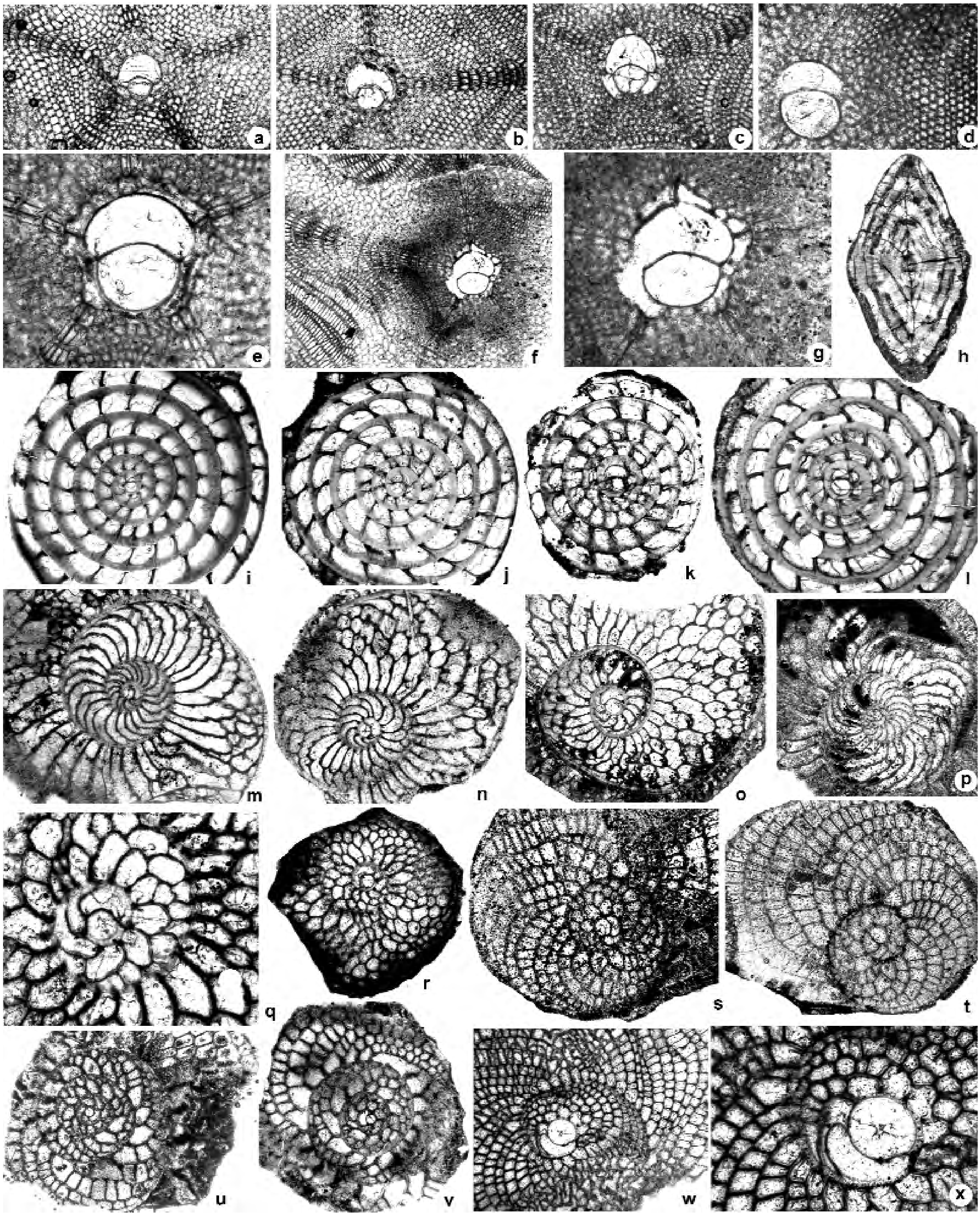


Figure 31.

early Bartonian to the early Chattian, are elaborated and the lineage is revised according to the measurement and parameter system mentioned above. Based on our preliminary communication (Less *et al.* 2006) the lineage is subdivided into species by using the criteria shown in Figure 24. Papazzoni (1998) suggests the biometric boundary between *N.* '*ptukhiani*' (*N. hormoensis* in our interpretation, see there) and *N. fabianii* at P_{mean}= 220 µm where P is the outer height of the proloculus. This value well corresponds to the biometric boundary between the above two species at P_{mean}= 200 µm proposed in Figure 24 where P is the inner cross-diameter of the proloculus.

Nummulites burdigalensis and *N. biedai* belong to the *N. perforatus* group, whereas *N. lyelli* belongs to the *N. gizehensis* group, within which the size increase of the proloculus with time is well documented (Schaub 1981; Serra-Kiel 1984; Less 1998b). A biometric calibration for the middle Eocene representatives of this group is in progress; the preliminary results are used in this work.

According to Schaub (1981) radiate *Nummulites* listed above belong to different lineages distinguishable by using Schaub's typological criteria. The developmental stage within these lineages were also determined by the Schaub (1981) data and by the measurements listed in Less (1998b). For *Nummulites budensis* we use the data in Less (1999).

Nummulites hormoensis Nuttall & Brighton 1931

Figure 31h–j

1931 *Nummulites hormoensis* n. sp., Nuttall & Brighton, p. 53–54, pl. 3, figs. 1–8.

1998 *Nummulites* '*ptukhiani*' Z. D. Kacharava, Papazzoni, p. 161, 164–165, pl. 1, figs. 16–24, pl. 2, figs. 16–21. (cum syn.)

2007a *Nummulites hormoensis* Nuttall & Brighton, Özcan *et al*., pl. 1, figs. 9, 17.

We apply the name of *N. hormoensis* to the immediate ancestral forms of *N. fabianii,* commonly cited as *N. ptukhiani* because of the serious contradictions in the usage of the latter (see details in Papazzoni 1998). Based on Roveda (1970) the topotypical *N. hormoensis* from Somalia fits quite well with the criteria of this taxon in Figure 24. It occurs in great quantity in samples MÜF B 7 and 9 (where associates with characteristic Bartonian taxa such as *N. biedai* and *N. striatus*), in sample PIR 33 (with *Heterostegina armenica armenica*, characteristic for late Bartonian) and also in MÜF C 6. Biometric data of the latter (Table 4) are very close to the biometric boundary between *N. hormoensis* and *N. fabianii*, although this population still belongs to *N. hormoensis* according to the criteria in Figure 24.

Nummulites fabianii (Prever in Fabiani 1905)

Figure 31k–l

1905 *Brugueirea fabianii* n. sp., Prever in Fabiani, p. 1805, 1811.

1998 *Nummulites fabianii* (Prever in Fabiani), Papazzoni, p. 165, 168, pl. 1, figs. 1–15, pl. 2, figs. 1–15. (cum syn.).

Nummulites fabianii can commonly be found in the Soğucak Formation of the TEKE section and in Mecidiye (sample MEC 40) and also in the olistolith of samples YEN 1–4. It occurs with characteristic Priabonian taxa such as *Heterostegina reticulata mossanensis* (in all localities), *Spiroclypeus sirottii* (in the TEKE samples) and *S. carpaticus* (sample MEC 40).

Figure 31. **(a–c)** *Asterocyclina* aff. *priabonensis* Gümbel, (a) O/YEN.2-15, (b) O/YEN.4-10, (c) O/TEKE.4-16. **(d)** *A. ferrandezi* Özcan & Less, O/YEN.2-7. **(e–g)** *A. alticostata* cf. *danubica* Less, (e) O/TEKE.6-10, (f–g) O/TEKE.6-11. **(h–j)** *Nummulites hormoensis* Nuttall & Brighton, (h) O/MÜF.B.9-17, (i) O/MÜF.B.7-2, (j) O/MÜF.B.7-12. **(k–l)** *N. fabianii* (Prever), (k) O/YEN.4-7, (l) O/TEKE.8-7. **(m–n)** *Heterostegina armenica armenica* (Grigoryan), (m) O/PIR.28-38, (n) O/PIR.33-10. **(o)** *H. armenica tigrisensis* Less, Özcan, Papazzoni & Stockar, O/PIR.47.A-15. **(p)** *H. reticulata* cf. *tronensis* Less, Özcan, Papazzoni & Stockar, O/PIR.47.A-19. **(q–r)** *H. reticulata mossanensis* Less, Özcan, Papazzoni & Stockar, (q) O/YEN.2-24, (r) O/YEN.2-3. **(s–t)** *H. reticulata italica* Herb, (s) O/CEL.13-2, (t) O/CEL.13-4. **(u–v)** *Spiroclypeus carpaticus* (Uhlig), (u) O/MEC.40-8, (v) O/MEC.40-12. **(w-x)** *Heterostegina gracilis* Herb, O/MEC.41-1. All A-forms. h: axial section, the others equatorial sections. f, h-p, r-w:×16, the others: ×40.

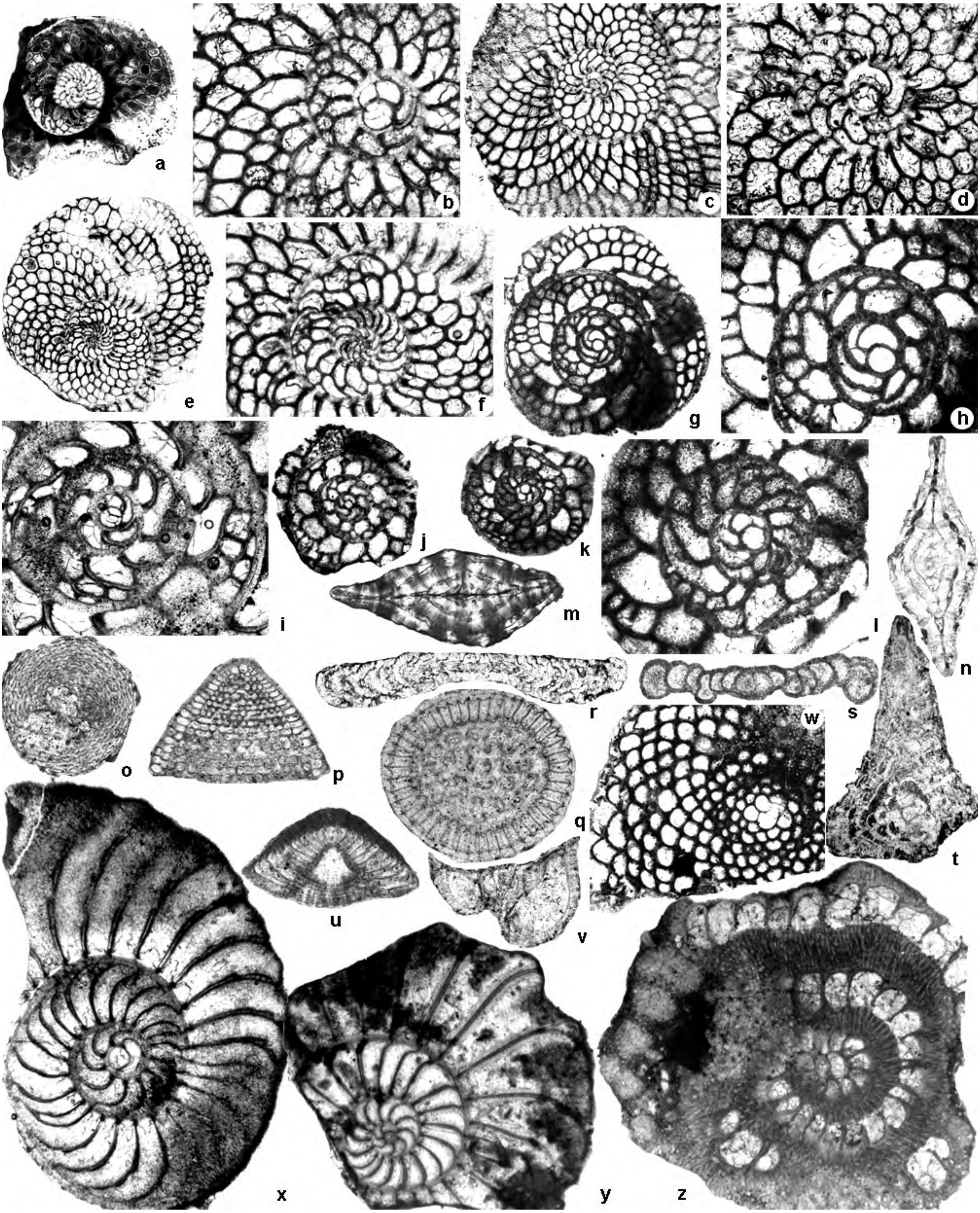


Figure 32.

Nummulites burdigalensis de la Harpe 1926

Figure 33e, f

1926 *Nummulina burdigalensis* n. sp., de la Harpe, p. 71–72.

1981 *Nummulites burdigalensis burdigalensis* de la Harpe, Schaub, pl. 4, figs. 10–12, pl. 5, figs. 1–18, 27–31, 46–51, text-fig. 72, table 2d. (cum syn.)

Nummulites burdigalensis can rarely be found in samples MÜF A 10 and 1894 of early late Ypresian age. The granulation characteristic for this taxon has been found in both generations. The proloculus diameters of two specimens from sample MÜF A 10 are 200 and 290 μm, respectively, correspond very well to the values (200–300 μm) given by Schaub (1981) and measured by Less (1998b) for *N. burdigalensis*, which, according to Serra-Kiel *et al.* (1998), is characteristic for the SBZ 10 Zone of early late Ypresian age.

Nummulites biedai Schaub 1962

Figure 34a–e

1962 *Nummulites biedai* n. sp., Schaub, p. 542, pl. 4, figs. 1–3, text-figs. 7–9.

1981 *Nummulites biedai* Schaub, Schaub, p. 93, pl. 20, figs. 18–25, pl. 21, figs. 1–13, table 3e. (cum syn.)

This taxon commonly occurs in the Soğucak Formation of the Beşyol (sample BEŞ 8), Tayfur (samples TAY 3 and 4) and Mürefte B (samples MÜF B 7 and 9) sections, although in the last one only the A-forms have been found. These populations are identified as *N. biedai,* based on their large mean proloculus diameter (P_{mean}), which exceeds 950 μm for the populations assigned by Schaub (1981) to this taxon (see Less 1998b) from Santa Margarita de Mombuy, Calders (NE Spain) and from Mossano (N Italy). Our own measurements on this taxon from sample Mossano 2 (see in Less *et al.* 2008) show $P_{mean+s.e.}$= 1125±43 μm, which is quite close to the values from our samples (see Table 4), although the proloculus in sample TAY 4 is somewhat smaller. In Mossano (Italy) and in sample MÜF B 9 *N. biedai* co-occurs with rather primitive representatives of the *Heterostegina reticulata*-lineage, and hence surely belongs to the late Bartonian SBZ 18 Zone in accordance with the range of this taxon established by Serra-Kiel *et al.* (1998). In Tayfur and Beşyol, however, *Heterostegina* is lacking but *Operculina* ex. gr. *gomezi* is present. Meanwhile *Orbitoclypeus varians roberti* (in Tayfur) and *O. v. roberti-scalaris* (in Beşyol) also suggest a somewhat older age. The spire of these forms is considerably tighter than in Mürefte (and also from Mossano), and more similar to that of *N. perforatus* from the early Bartonian SBZ 17 Zone. We think, however, that the size of the proloculus is a much more objectively measurable parameter, and therefore, preferable to use in distinguishing *N. perforatus* and *N. biedai*, even though the range of the latter has to be extended at least to the late part of the SBZ 17 Zone.

Nummulites lyelli d'Archiac & Haime 1853

Figure 34f, g

1853 *Nummulites Lyelli* n. sp., d'Archiac & Haime, p. 95, pl. 3, figs. 1a, b, 2.

Figure 32. (**a**) *Heterostegina reticulata reticulata* Rütimeyer, O/1902-15. (**b–f**) *H. reticulata mossanensis* Less, Özcan, Papazzoni & Stockar, (b) O/TEKE.6-22, (c) O/TEKE.6-24, (d) O/TEKE.6-28, (e–f) O/TEKE.6-30. (**g–m**) *Spiroclypeus sirottii* Less & Özcan, (g–h) O/TEKE.6-47, (i) O/TEKE.6-49, (j) O/TEKE.6-52, (k–l) O/TEKE.6-59, (m) O/TEKE.6-56, (**n**) *Spiroclypeus* sp., O/YEN.7-1. (**o**) *Sphaerogypsina globula* (Reuss), O/YEN.10. (**p–q**) *Chapmanina gassinensis* (Silvestri), (p) O/MÜF.B.2, (q) O/MÜF.B.4. (**r**) *Eoannularia eocenica* Cole & Bermúdez, 616. (**s**) *Planorbulina* sp., 2B. (**t**) *Silvestriella tetraedra* (Gümbel), O/MÜF.C-2. (**u**) *Halkyardia* sp., O/MÜF.B.8. (**v**) *Gyroidinella magna* Le Calvez, O/MÜF.B.6. (**w**) *Linderina* sp., O/TEKE.1-30. (**x**) *Operculina* ex. gr. *gomezi* Colom et Bauzá, O/PIR.48-47. (**y**) *Assilina* ex. gr. *alpina* Douvillé, O/MÜF.B.9-20. (**z**) *Pellatispira madaraszi* Hantken, O/MÜF.C.6-8. (**e-f**) B-forms, the others A-forms. m, n– axial, p, r, s, u, v– vertical, q– transversal, the others equatorial sections. a, c, e, g, j-k, m-p, t-v, x-z: ×16, the others: ×40.

1981 *Nummulites lyelli* d'Archiac & Haime, Schaub, p. 116–117, pl. 38, figs. 8–20, table 6e. (cum syn.)

2007a *Nummulites lyelli* d'Archiac & Haime, Özcan *et al.*, pl. 1, fig. 7, table 3.

This taxon has only been found in the uppermost part of the Soğucak Formation in the Pırnar section, in sample PIR 48 where both generations can abundantly be found, although the preservation is rather poor. It co-occurs with *Heterostegina armenica tigrisensis* and *H. reticulata tronensis* as in sample Keçili 11, in E Turkey (Özcan *et al.* 2007a) and in Akören near Çatalca (Less *et al.* in review). This means that the range of *Nummulites lyelli* has to be extended to the beginning of the middle late Bartonian SBZ 18B Subzone, instead of being exclusively within the SBZ 17 Zone as indicated by Serra-Kiel *et al.* (1998).

***Nummulites nemkovi* Schaub 1966**

Figure 33a, b

1966 *Nummulites nemkovi* n. sp., Schaub, p. 297, fig. 2.

1981 *Nummulites nemkovi* Schaub, Schaub, p. 183, pl. 66, figs. 6, 7, 20–31, 36, table 12e. (cum syn.).

Based on their relatively large size, smooth surface and densely spaced, strongly arched chambers these forms (occurring in samples MÜF A 10 and 1894) belong to the *N. distans*-lineage of Schaub (1981). Both generations have been found. According to Schaub (1981) and Less (1998b) both the test diameter of the B-forms (12–16 mm) and also the proloculus diameter of the A-forms (390 and 650 μm on two measured specimens) best fit with the characteristics of *N. nemkovi* from all the members of the *N. distans*-lineage. Based on Schaub (1981) this taxon determines the late part of the SBZ 10 Zone (early late Ypresian).

***Nummulites leupoldi* Schaub 1951**

Figure 33c, d, i

1951 *Nummulites leupoldi* n. sp., Schaub, p. 159, pl. 5, figs. 3–7, text-figs. 206–214.

1981 *Nummulites leupoldi* Schaub, Schaub, p. 122–123, pl. 51, figs. 15–29, table 15b. (cum syn.).

These medium-sized, radiate forms with almost isometric, moderately arched chambers from samples MÜF A 10 and 1894 best correspond to the *Nummulites leupoldi*-lineage of Schaub (1981). Both generations have been found. Based on Schaub (1981) the test diameter of the B-forms (6–10 mm) best fits with the characteristics of *N. leupoldi* from all the members of the *N. leupoldi*-lineage, although the proloculus diameter of the A-forms (140 and 160 μm on two measured specimens) is somewhat smaller than given by Less (1998b). According to Schaub (1981) this taxon defines the late Ypresian SBZ 10–12 Zones.

***Nummulites soerenbergensis* Schaub 1951**

Figure 33g, h

1951 *Nummulites subplanulatus soerenbergensis* n. ssp., Schaub, p. 101, pl. 1, figs. 4–6, text-figs. 37–41.

1981 *Nummulites soerenbergensis* Schaub, p. 139–140, pl. 41, figs. 69–89, text-figs. 90a–p, table 1i. (cum syn.).

Some rather thin, small radiate B-forms with high, densely spaced, moderately arched chambers have been found in sample 1894. They are identified with *N. soerenbergensis*, the most advanced member of the *N. globulus* group, characteristic (Schaub 1981) of the SBZ 9–10 Zones (late early and early late Ypresian).

***Nummulites striatus* (Bruguière 1792)**

Figure 34h–j

1792 *Camerina striata* n. sp., Bruguière, p. 399.

1981 *Nummulites striatus* (Bruguière), Schaub, p. 153–154, pl. 53, figs. 26–31, table 14s. (cum syn.).

This taxon commonly occurs in samples MÜF B 7 and 9 of the basal part of the Soğucak Formation,

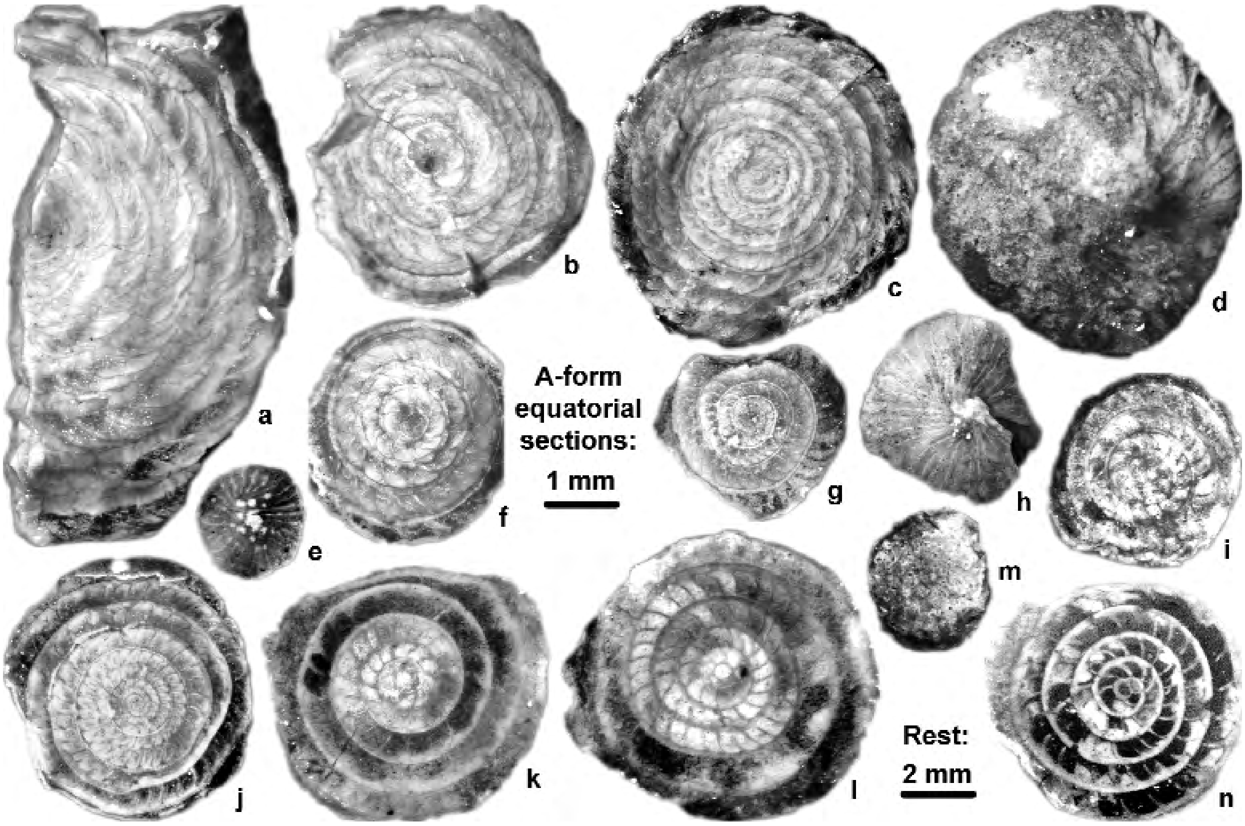


Figure 33. Upper Ypresian nummulitids. (**a, b**) *Nummulites nemkovi* Schaub, (a) E.09.07, (b) E.09.08. (**c, d, i**); *Nummulites leupoldi* Schaub, (c, d) E.09.09., (i) E.09.10.; (**e, f**) *Nummulites burdigalensis* de la Harpe, (e) E.09.11., (f) E.09.12.; (**g, h**) *Nummulites soerenbergensis* E.09.13.; (**j–n**) *Assilina placentula* (Deshayes), (j) E.09.14., (k) E.09.15., (l) E.09.16., (m, n) E.09.17. a, e, g, h, j, k– sample 1894; b–d, f, i, l–n– sample MÜF.A.10. a, c, d, f–h, j– B-forms, the others A-forms; d, f, h, m– external views, the others equatorial sections. a, c, d, f–h, j, m: ×10, the others: ×5.

although only the A-forms have been found. Based on the characteristic surface, on the tight spire and also on the densely spaced, moderately arched chambers, it can safely be identified with *N. striatus*, characteristic for the late Bartonian SBZ 18 and also for the earliest Priabonian SBZ 19A Sub-zone (Serra-Kiel *et al.* 1998). The relatively large proloculus size (see Table 4) is remarkable, although the co-occurrence with *N. biedai* excludes any stratigraphic level above the Bartonian.

Nummulites budensis **Hantken 1875**

Figure 34k

1875 *Nummulites budensis* n. sp., Hantken, p. 74–75, pl. 12, fig. 4.

1999 *Nummulites budensis* Hantken, Less, p. 354, pl. 2, figs. 5, 6, 9, 10. (cum syn.)

This taxon is only identified in Çeltik (sample ÇEL 13) associated with *Heterostegina reticulata italica*, characteristic of the middle to late Priabonian (SBZ 19B-20). As dicussed in Less (1999), *Nummulites budensis* is a characteristic taxon of the same age and can easily be disinguished from the Rupelian *N. bouillei* and from the Chattian *N. kecskemetii*.

Genus *Assilina* d'Orbigny 1839

This genus is represented by large, semi-involute forms of the lower and middle Eocene assigned by Schaub (1981) to the main *A. spira*- and *A. exponens*-

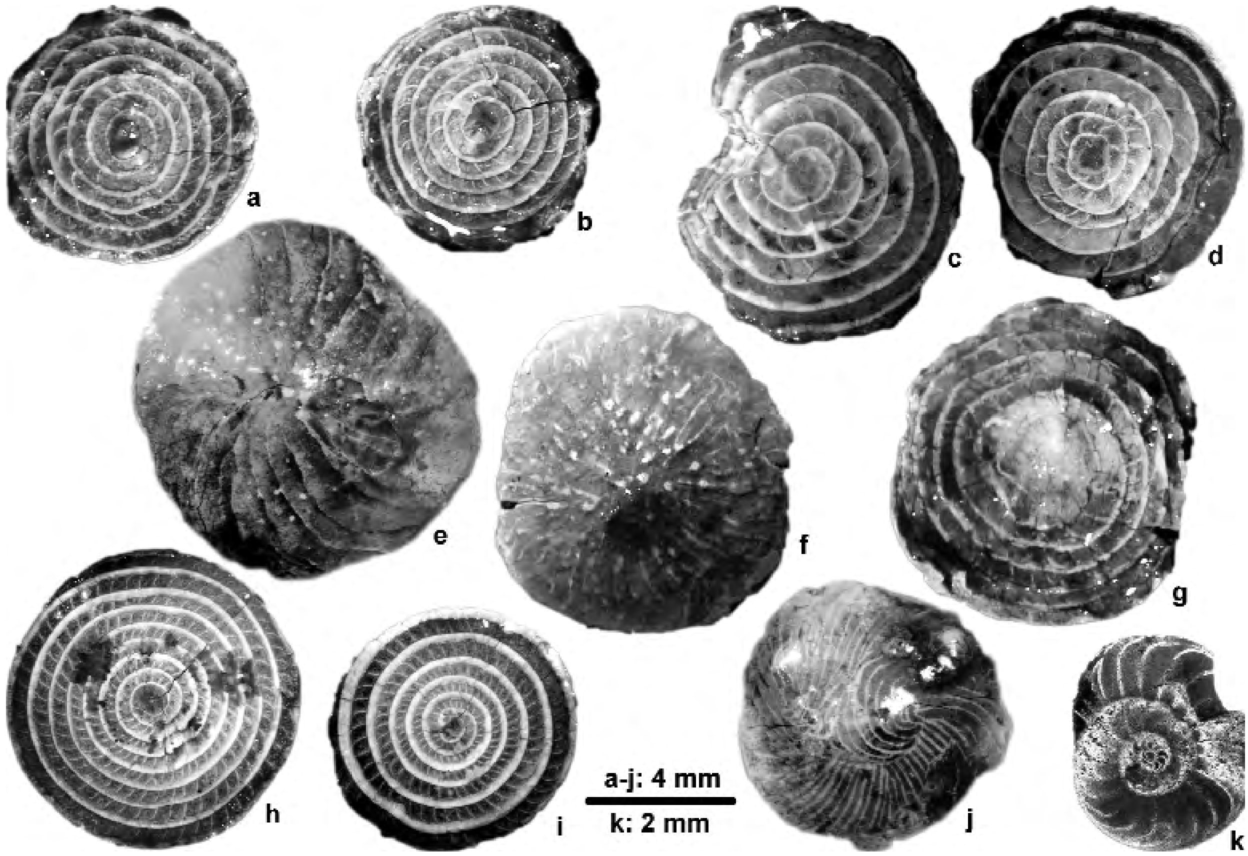


Figure 34. (**a–e**) *Nummulites biedai* Schaub, (a) E.09.18., (b) E.09.19., (c) E. 09.02, (d) E.09.01., (e) E.09.03.; (**f, g**) *Nummulites lyelli* d'Archiac et Haime, E.09.20.; (**h–j**) *Nummulites striatus* (Bruguière), (h) E.09.06., (i) E.09.05., (j) E.09.04.; (**k**) *Nummulites budensis* Hanken, O/CEL.13-8. a– sample TAY.4; b– sample TAY.3; c–e, h, i, j– sample MÜF.B.9; f, g– sample PIR.48; k– sample CEL.13. All A-forms; a–j: ×5, k: ×10. e, f, j: external views, the others equatorial sections.

lineages and to the side-lineage of *A. reicheli*. Based on Romero *et al.* (1999) the evolute forms, formerly called *Operculina alpina*, *O. schwageri*, etc. also belong to the genus *Assilina*. This group needs serious revision. Therefore, they are described jointly under the name of *A.* ex. gr. *alpina*.

Assilina placentula (Deshayes 1838)

Figure 33j-n

1838 *Nummulites placentula* n. sp., Deshayes in Verneuil & Deshayes, p. 69, pl. 6, figs. 8–9.

1981 *Assilina placentula* (Deshayes), Schaub, p. 209–210, pl. 85, figs. 65–70, pl. 86, figs. 1–40, pl. 88, figs. 1–20, text-fig. 115, table 18d–f. (cum syn.).

These forms are abundant in samples MÜF A 10 and 1894, both of early late Ypresian age. We could not distinguish the Schaub (1981) lineages mentioned above in our material. Based on Less (1998b) the mean proloculus diameter of around 250 µm is characteristic for both *Assilina* (*A. placentula* and *A. plana*) from the SBZ 10 Zone (early late Ypresian). The former of the two species names was chosen for our forms because of its priority over the latter one.

Assilina ex. gr. *alpina* (Douvillé 1916)

Figure 32y

These forms occur in almost all samples of the Soğucak Formation. Based on a few specimens a considerable size increase of the inner cross-diameter of the proloculus can be observed. It is 60–70 μm (based on 4 specimens) at about the Lutetian/Bartonian boundary (sample GİZ A 8), 70–120 μm (5 specimens from samples PIR 28, 36 and 43) in the early late Bartonian SBZ 18A Subzone, 120–145 μm (4 specimens from samples MÜF B 9 and MÜF C 6) in the latest Bartonian, whereas around 135 μm (one specimen from sample TEKE 1) in the basal Priabonian SBZ 19A Subzone. This fits with Hottinger (1977) who arranged this group into a single evolutionary lineage starting from *Assilina parva*, followed by *A. schwageri* and ending with *A. alpina*, although the biometric limits between these taxa are not yet established.

Genus *Operculina* d'Orbigny 1826

Operculina ex. gr. *gomezi* Colom et Bauzá 1950

Figure 32x

This taxon is rather abundant in the Bartonian Soğucak Formation (upper part of the GİZ.A section, Tayfur, Beşyol and Pırnar), especially if the descendant genus, *Heterostegina,* is still absent in the lower Bartonian. We think that the first appearance of the *Operculina gomezi* group nearly coincides with the Lutetian/Bartonian boundary (see details in Özcan *et al.* 2007a). Hottinger (1977) assigned the representatives of this group to a single evolutionary lineage starting with *O. bericensis*, followed by *O. roselli* and ending with *O. gomezi*, but did not give their biometric limits. In our material the inner cross-diameter of the proloculus does not show a clear increasing trend and remains in a range between 65 and 130 μm. Very similar forms reappear in the late Priabonian sample ÇEL 13 with proloculus diameter between 70 and 180 μm (5 specimens), although their relationship with *O. gomezi* is not yet clear.

Genus *Heterostegina* d'Orbigny 1826

Based on a wide range of Mediterranean material the Eocene representatives of this genus have recently been revised by Less *et al.* (2008), who arranged them into three species. These are *Heterostegina armenica*, *H. reticulata* and *H. gracilis*; all of which also occur in our material. Here we do not repeat the descriptions by Less *et al.* (2008), only the results are applied.

Heterostegina armenica (Grigoryan 1986)

Figure 31m–o

This species is subdivided (based on the reduction of the number of undivided post-embryonic chambers – parameter X) into two chronosubspecies as follows: *Heterostegina armenica armenica* with $X_{mean} > 8$ and *H. a. tigrisensis* with $X_{mean} < 8$.

The species widely occurs in the Soğucak Formation of the Pırnar (PIR) section where it demonstrates a remarkable development (Table 5) starting from sample PIR 28 up to PIR 48. Moreover, the population in sample PIR 28 is the most primitive representative of the species known so far. The assemblages from sample PIR 28 to PIR 46 belong to *H. a. armenica* (Grigoryan) (Figure 31m, n), representing the early late Bartonian SBZ 18A Subzone while the uppermost populations from samples PIR 47A and 48 belong to *H. a. tigrisensis* Less, Özcan, Papazzoni & Stockar (Figure 31o), marking the middle late Bartonian SBZ 18B Subzone, which is confirmed by the first appearance of *H. reticulata* (represented by *H. r.* cf. *tronensis*), too.

Heterostegina reticulata Rütimeyer 1850

Figures 31p–s & 32a–f

Based on the reduction of undivided post-embryonic chambers (parameter X), Less *et al.* (2008) subdivided the species into seven chronosubspecies as follows: *Heterostegina reticulata tronensis* ($X_{mean} > 17$), *H. r. hungarica* ($X_{mean} = 11–17$), *H. r. multifida* ($X_{mean} = 7.2–11$), *H. r. helvetica* ($X_{mean} = 4.4–7.2$), *H. r. reticulata* ($X_{mean} = 2.8–4.4$), *H. r. mossanensis* ($X_{mean} = 1.7–2.8$) and *H. r. italica* ($X_{mean} < 1.7$).

This species occurs mostly in the Soğucak Formation but also in the olistoliths of samples 1902 and YEN 2 in the Çengelli Formation and in the Keşan Formation, (sample ÇEL 13). The most primitive representatives correspond to *H. reticulata* cf. *tronensis* Less, Özcan, Papazzoni & Stockar (Figure 31p) from the top of the Pirnar section (samples PIR 47A and 48) and mark the middle late Bartonian SBZ 18B Subzone. A more advanced developmental stage, best resembling *H. r. multifida*

(Bieda), however represented by one single specimen, and therefore determined only at the species level, is identified in section MÜF.B. *H. r. multifida* is a key taxon for the latest Bartonian SBZ 18C Sub-zone, as well as the slightly more advanced H. *r. reticulata* Rütimeyer (Figure 32a), found in sample 1902. Most widespread is the occurrence of *H. r. mossanensis* Less, Özcan, Papazzoni & Stockar (Figures 31q, r & 32b–f), which could be identified not only in samples TEKE 4, 6 and YEN 2 but also in the Doluca Hill section (samples ŞAR 2 and 4 in Özcan *et al*. 2007a). This subspecies is a key taxon for the earliest Priabonian (SBZ 19A Sub-zone) in the Western Tethys. Finally *H. r. italica* Herb (Figure 31s, t), the most advanced subspecies, characteristic of SBZ 19B and 20 (middle–late Priabonian), is recorded from sample ÇEL 13.

***Heterostegina gracilis* Herb 1978**

Figure 31w, x

This, easily identifiable species (being a key taxon for the late Priabonian SBZ 20 Zone) is very abundant in the Soğucak Formation of the Mecidiye region. It is found not only in sample MEC 41 from the top of the formation but also in many thin sections from different parts of the limestone.

Genus *Spiroclypeus* Douvillé 1905

According to Less & Özcan (2008) Eocene *Spiroclypeus* in the western Tethys are exclusive to the Priabonian. They are unrelated to the Oligo–Miocene representatives of the genus, and differ from them in having a much tighter spire. The Priabonian forms are classified into two species by using the mean number of undivided post-embryonic chambers (parameter X) as follows: *S. sirottii* Less & Özcan with $X_{mean} < 2.7$, and *S. carpaticus* (Uhlig) with $X_{mean} > 2.7$. Since these species were recently described in Less & Özcan (2008), we do not repeat them here. In the thin sections of the olistolith of samples YEN 7 and 10, *Spiroclypeus* (Figure 32n) could be identified only at the generic level, although based on their tight spire they surely belong to the Priabonian lineage of the genus.

***Spiroclypeus sirottii* Less & Özcan 2008**

Figure 32g–m

This species, marking the early Priabonian SBZ 19 Zone, was previously recorded from the early Priabonian of Doluca Hill (sample ŞAR 4 in Özcan *et al.* 2007a) (Figure 18). We here also document a rich assemblage from the TEKE section, representing the Soğucak Formation.

***Spiroclypeus carpaticus* (Uhlig 1886)**

Figure 31u, v

This species, marking the SBZ 20 Zone of the late Priabonian, is documented from the Soğucak Formation of the Mecidiye region (sample MEC 40).

Conclusions

In the southern part of Thrace Basin, shallow marine Eocene units are observed at many isolated outcrops and a detailed analysis of larger foraminifera from different exposures provides us new taxonomic, biostratigraphic and stratigraphic data that help re-evaluate the Eocene geological evolution of the region (Okay *et al*. 2010).

(1) The oldest shallow marine unit is represented by foraminifera-dominated carbonates (Başaoğlu member of Karaağaç Formation) in the northern part of the Gelibolu Peninsula. The assemblages of orthophragmines, characterized by *Discocyclina seunesi karabuekensis*, *Orbitoclypeus schopeni neumannae*, *O. munieri ponticus*, *O. bayani* cf. *bayani* and *Nemkovella stockari* refer to SBZ 5-6, indicating an earliest Ypresian (basal Ilerdian) age for the unit. This strongly contradicts the previous age assignments, ranging from Cuisian to middle Eocene. This unit, represented by a single small outcrop near Saz Limani, is not *in situ* and represents a block in the lower Eocene basinal sequence of the Karaağaç Formation.

(2) A shallow-marine foraminifera-dominated sequence followed by basinal marls in its upper part, the Dişbudak series has been identified

below the regionally widespread Soğucak Formation. The larger foraminiferal assemblage in the transgressive carbonate-clastic part of the series (section MÜF.A, sample 1894) consists of *Assilina placentula*, *Nummulites burdigalensis*, *N. nemkovi*, *N. leupoldi*, *N. soerenbergensis*, *Discocyclina fortisi fortisi*, *D. archiaci* ex. interc. *staroseliensis-archiaci*, *D. archiaci archiaci*, *D. augustae sourbetensis*, *D. dispansa taurica*, *Orbitoclypeus douvillei* cf. *douvillei*, *O. schopeni*, *Asterocyclina stella*. This association is assigned to SBZ 10 Zone (early Late Ypresian). The deep marine fine clastics overlying the early Late Ypresian beds contain pelagic fauna and flora (samples MÜF A 11 and 1909), indicating the drowning of the platform during the late Ypresian or during the earliest part of the middle Eocene. The shallow marine units representing this time slice are not represented in Thrace but have been described from the island of Bozcaada by Varol *et al.* (2007) and from south-east of the Marmara sea (Özgörüş *et al.* 2009). Varol *et al.* (2009), however, incorrectly assigned the Ypresian shallow marine unit in Bozcaada to the Soğucak Formation. In our view, the unit described from this locality is correlatable with both the Dişbudak series introduced in Okay *et al.* (2010) and the Upper Ypresian shallow marine transgressive sequence introduced by Özgörüş *et al.* (2009). These deposits mark a much older transgressive event in the region.

(3) The Soğucak Formation is characterized mainly by inner, middle to outer shelf carbonates partly composed of patchy coral reefs that developed at quite different stratigraphic levels. Although the most prominent patchy reefs are observed in late Bartonian and Priabonian sequences, such reefs have also developed to a lesser extent in late Lutetian and early Bartonian carbonates around Gökçeada and in the western part of Gelibolu. The coral-dominated levels are closely associated with larger foraminiferal-coralline algae-dominated levels in their lateral and vertical extent. The unit contains a diverse assemblage of larger foraminifera represented by nummulitids, orthophragmines and partly alveolinids. The deposition of this unit is diachronous across southern Thrace and the record of older beds in Gökçeada and western part of Gelibolu suggest a transgression from WSW to ENE.

Our data suggest the following chronology for the deposition of Soğucak carbonates and drowning of the platform:

Late Lutetian phase; recorded only in Gökçeada. This represents by far the oldest event and is not known from other parts of the Thrace Basin. The upper Lutetian to lower Bartonian shallow marine sequence (referred to SBZ 15/16-17 Zones) is overlain by deep marine marls.

Early Bartonian phase; recorded only in the Gelibolu Peninsula. The lower Bartonian shallow marine sequence (SBZ 17) is overlain by deep-marine clastic deposits.

Late Bartonian phase; recorded widely north of Saros Bay and in the eastern extension of the Gelibolu peninsula near Şarköy. It is also widely recognized in the northern part of the Thrace Basin (Less *et al.* in review). A rich and diverse assemblage of larger foraminifera indicates the SBZ 18 Zone. The drowning of the platform is diachronous, ranging from Late Bartonian to Early Priabonian.

Priabonian phase; recorded both in southern and northern Thrace (see also Less *et al.* in review). The Priabonian sequences (SBZ 19 and 20) directly overlie the basement units.

(4) The Çengelli flysch sequence, containing a variety of olistoliths and olistostromal horizons, records deposition in a basinal setting close to extensive platforms developed in NW Turkey during the Priabonian. The exposures of the unit are rather limited in geographic extent and are observed only between Mürefte and Yeniköy south of the Ganos Fault in southern Thrace. Similarly, the outcrops of platform units (Soğucak Formation) are observed only in a limited area in one locality to the west of the study area. The age of the unit has been determined to be Late Eocene (Priabonian) to

early Rupelian, based on the calcareous nannoplankton assemblage identified in marl beds north of Mürefte. The abundance of hyaline larger benthic foraminifera, mainly in the limestone olistoliths of the Çengelli Formation, permits us to understand the relation between these olistoliths and the in-situ platform carbonates, also studied in detail for their foraminiferal inventory. A model explaining the relation of these blocks and platform units in the context of geodynamic evolution of the region is proposed in Okay *et al*. (2010). Benthic foraminifera, most of which are described for the first time from the Eocene units in Thrace here, permits us to draw the following conclusions: Most olistoliths in the Çengelli Formation contain benthic foraminiferal associations, characteristics of either SBZ 18 or 19 (late Bartonian or early Priabonian). The benthic foraminifera in the turbidite beds of the Çengelli Formation are not very diverse and include a few taxa having rather wide stratigraphic ranges from Bartonian to Priabonian. These foraminifera are represented by *Chapmanina gassinensis*, *Gyroidinella magna*, *Asterigerina rotula*, *Planorbulina* sp., *Halkyardia* sp. and *Orbitolites* sp.

In addition to common taxa in Soğucak Formation and Çengelli sequence, a rather diverse assemblage of other groups has also been recognized in these units. These groups are represented by *Chapmanina gassinensis* (Figure 32p–q), *Gyroidinella magna* (Figure 32v), *Eoannularia eocenica* (Figure 32r), *Sphaerogypsina globula* (Figure 32o), *Silvestriella tetraedra* (Figure 32t), *Pellatispira madaraszi* (Figure 32z), *Halkyardia* sp. (Figure 32u), *Orbitolites* sp., *Peneroplis* sp., *Rotalia* sp., *Linderina* sp. (Figure 32w) *Gypsina* sp., and *Planorbulina* sp. (Figure 32s).

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