THANETIAN AND EARLY YPRESIAN ORTHOPHRAGMINES
(FORAMINIFERA: DISCOCYCLINIDAE AND ORBITOCYPEIDAE)
FROM THE CENTRAL WESTERN TETHYS (TURKEY, ITALY AND BULGARIA)
AND THEIR REVISED TAXONOMY AND BIOSTRATIGRAPHY

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Received: February 26, 2007; accepted: July 6, 2007

Key words: Turkey, Italy, Bulgaria, Paleocene, Eocene, Disco
cyclinidae, Orbitocycepidae, Biometry, Biozonation.

Abstract. The rich orthophragminid assemblages from the
upper Thanetian and lower Ypresian of Turkey are discussed together
with the coeval faunas from Spilceco (N Italy) and Beloslav (Bulgaria).
Their taxonomy, evolution and biozonation in the Western Tethys are
revised. Our biometric study is based mainly on a large number of
equatorial sections of megalarval individuals. We present the
emended description of Discocyclina senesi, D. tenuis, Orbitocypeus
multiplicatus, O. hayani and Asteroecyina tanemelii. A new species,
Nemkoella stockani is introduced. The evolutionary lineages of Dis
cocyclina senesi, Orbitocypeus multiplicatus and O. hayani are re
stored for the first time by using the consistent size-increase of the
megalarval embryo that also allowed introducing some new sub
species (Discocyclina senesi beloslavensis, D. s. karabukensis, Orbitocy
peus multiplicatus kastamonuensi, O. hayani kastamonuensi and O.
mutieri mutiensis). By owing the most complete record of Thanetian
and early Ypresian orthophragmines from the Western Tethys (using
also data from SW France and the Crimean Peninsula) we could re
construct their early evolution. The chronostratigraphical position of
some localities was ascertained from planktic and larger benthic for
aminifers, as well as calcareous nannoplankton. In the updated ortho
phragminid zonation (zones are marked by OZ), OZ 1a corresponds to
the early Thanetian, OZ 1b to the middle Thanetian. They are distin
guished on the base of the evolution of Discocyclina senesi. In these
zones, only two unribred species of Discocyclina and Orbitocypeus
each are present. Ribbed Orbitocypeus, and the genera Asteroecyina and
Nemkoella appeared in the redefined OZ 2 zone belonging to the
late Thanetian. Discocyclina archais and D. dispans substituted D.
senesi at about the Paleocene/Eocene boundary. The early Ypresian
can be subdivided into the OZ 3 and 4 zones that can be distinguished
from each other by different developmental stages of simultaneously
running evolutionary lineages such as Discocyclina archais, Orbitocy
peus sdropeii and O. multiplicatus.

Riassunto. Le ricche associazioni a orthophragmine provenien
ti dal Thanetiano superiore e Ypresiano inferiore della Turchia sono
qui discusse unitamente alle faune coeve di Spilceco (N Italia) e Be
oslav (Bulgaria). Ne vengono revisionate la loro tassonomia, evoluzione
e biozonazione nella Tettide Occidentale. Il nostro studio biometrico è
basato soprattutto su un gran numero di sezioni equatoriali di indi
vidui megalarvali. Ne presentiamo le descrizioni emendate di Di
socyclina senesi, D. tenuis, Orbitocypeus multiplicatus, O. hayani e
di Asteroecyina tanemelii. Si introduce inoltre una nuova specie,
Nemkoella stockani. Viene ricostruita per la prima volta la linea evo
lutiva di Discocyclina senesi, Orbitocypeus multiplicatus e O. hayani,
utilizzando il consistente aumento di dimensioni dell’embrione me
galarval, che può avere permesso di individuare alcune nuove sotto
specie (Discocyclina senesi beloslavensis, D. s. karabukensis, Orbitocy
peus multiplicatus kastamonuensi, O. hayani kastamonuensi e O.
mutieri mutiensis). Grazie alla documentazione particolarmente com
pleta delle orthophragmine del Thanetiano e Ypresiano inferiore della
Tettide Occidentale (utilizzando anche dati del SW della Francia e dalla
penisola di Crimea) noi abbiamo potuto ricostruire la loro evoluzione
iniziale. La posizione cronostatigrafica di alcune località è stata de
finita con l’uso dei foraminiferi sia planctonici che bentonici di grandi
dimensioni, così come con il nannoplanto calcareo. Nella zonazione
aggiornata a orthophragmine (le zone sono indicate con il prefisso OZ),
OZ 1a corrisponde al Thanetiano inferiore, OZ 1b al Thanetiano
medio. Esse sono distinte sulla base dell’evoluzione di Discocyclina
senesi. In queste zone, sono presenti solo due specie non costate
Discocyclina e Orbitocypeus. Orbitocypeus costati, i generi Asteroecy
ina e Nemkoella, comparvero nella zona OZ 2 zone, come qui de
finiti, di età Thanetiano superiore. Discocyclina archais e D. di
spansa sostituirono D. senesi intorno al limite Paleocene/Eocene.
L’Ypresiano inferiore può venire suddiviso nelle zone OZ 3 e OZ 4,
distinguibili in base ai diversi stadi di sviluppo delle contemporane
linee evolutive, quali Discocyclina archais, Orbitocypeus sdropeii e
O. multiplicatus.

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Introduction

Orthophragmines (Fig. 1) is an informal collective name for Late Paleocene and Eocene orbitoidal larger foraminifera with almost rectangular equatorial chamberlets. Based on Brönnimann (1945) they are grouped into two systematically independent families that are widespread in the Mediterranean and represented by two genera each. A synoptic summary for distinguishing the four Western Tethyan genera is shown in Fig. 2. Less (1987, 1998) elaborated the recently used orthophragminid taxonomy and stratigraphy for Europe that was successfully integrated into the larger foraminiferal biozonation of the Tethyan Palaeocene and Eocene by Serra-Kiel et al. (1998). For more details see chapter “Review on the recent knowledge on orthophragmines” in Özcan et al. (2007a).

The orthophragminid stratigraphy has been extended and completed to Turkey by Özcan et al. (2001), Özcan (2002), Çolakoğlu & Özcan (2003) and Özcan et al. (2007a, b). In these two latter papers the orthophragminid zonation is updated for the late Ypresian to early Priabonian interval. In this paper we extend this updating into the Thanetian to early Ypresian time-span.

The orthophragmines from several poorly known localities of Thanetian (Karaevi and Kurucagile) and early Ypresian age (Kastamonu, Ağaçkesi and Şile) from northwestern Turkey are closely related to the orthophragmines from Spilecco (N Italy) and Beloslav (Bulgaria) whose main biometrical data are presented in Less (1998). However, the faunas themselves (consisting of new taxa as well) are not yet described systematically. Therefore, these localities are also included because in doing so we may have a much broader and well-established overview on the early evolution of Western Tethyan orthophragmines. This paper is interrelated with the paper dealing with late Ypresian to middle Lutetian orthophragmines from Turkey (Özcan et al. 2007b), since the majority of the profiles is located in basins (the Safranbolu-Karabük, Kastamonu-Boyabat and Haymana-Polatlı Basins and the Şile region) consisting of a succession of Thanetian to

Fig. 1 General architecture of orthophragminids after Pernaya (1974), with smaller modifications. 1. equatorial layer, 2. lateral layers, 3. megaospheric embryo, 4. protoconch, 5. equatorial chamberlets, 6. piles, 7. lateral chamberlets in vertical section, 8. umbo, 9. collar, 10. granules (external parts of piles) on the test surface, 11. lateral chamberlets on the test surface.

Fig. 2 Diagnostic features of Tethyan orthophragminid families and genera. 1. spiral microospheric juvenarium; 2. biserial microospheric juvenarium; 3. equatorial chamberlets with annular stolons; 4. equatorial chamberlets without annular stolons; 5. single equatorial layer; 6. axially subdivided equatorial layer in the ribs; 7. unribbed, flat to discoidal test of circular outline, fine granules and central umbo, varying in size; 8. flat test of circular outline, small central umbo, fine granules, numerous initial and secondary ribs; 9. unribbed, inflated test of circular outline, coarse granules in the center, no distinct umbo; 10. flat test of circular to wavy outline, small central umbo, seven to nine initial ribs, optionally bifurcating at the edges, coarse granules on both the umbo and the ribs; 11. stellate to pentagonal test with distinct, non-bifurcating ribs, coarse granulation, central umbo generally present.
middle Lutetian larger foraminifera. Moreover, the evolution of orthophragmines also crosses the early/late Ypresian boundary.

**Repository:** Figured specimens marked by O are deposited in the Özcan collection in the Geology Department of Istanbul Technical University while those marked by E. are in the Eocene collection of the Geological Institute of Hungary. Some thin sections of Spicello orthophragmines marked by C were lent from the Natural History Museum of Basel.

**Abbreviations for biozones:** NP: Paleogene calcareous nanoplankton zones by Martini (1971); OZ: Orthophragminid zones for the Western Tethyan Paleocene and Eocene by Less (1998) with correlation to the SBZ zones; P: Paleogene planktic foraminiferal zones by Blow (1969) and updated by Berggren et al. (1995); SBZ: Shallow benthic foraminiferal zones for the Tethyan Paleocene and Eocene by Serra-Kiel et al. (1998) with correlation to the planktic and magnetic polarity zones.

**Principles of the determination of orthophragmines and their biometry**

Particular orthophragminid species are separated typologically using some qualitative features (Fig. 3) that are (excepting the type of the rosette) recognizable only in the equatorial section of the A-forms. Therefore, and because they are exceedingly rare, the significance of microporphic forms is subordinate in the specific determination. Most of the species constitute long-living evolutionary lineages with definite internal development that allows their biometric subdivision into artificial subspecies (for theoretical background see Drooger 1993).

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**Fig. 3** - Qualitative features of Tethyan orthophragmines. A: embryo types (suffix "-lepidine" is to be added to each type); B: types of adaxial chamberlets; C: different growth patterns of the equatorial annuli; D: types of rosette (the network of piles and lateral chamberlets on the test surface).

**Fig. 4** - The measurement system of megaslpheric orthophragmines in equatorial section (after Less 1999, modified). See text for explanation.
Biometric features were studied in the equatorial plane of free specimens exposed by either splitting or thin-sectioning. Using the terminology proposed by Less (1987, 1993), eight measurements (in μm) and counts from 709 specimens are used to characterize the taxa, as illustrated in Fig. 4 and listed below:

- p and d: outer diameter of the protoconch and deutoconch perpendicular to their common axis (corresponding to P and D in Less 1987)
- N: number of the adaxial chamberlets (in Fig. 4, N=13)
- H and W: height and width of the adaxial chamberlets (corresponding to H and L in Less 1987)
- n: number of annuli within 0.5 mm distance measured from the deutoconch along the axis of the embryo (corresponding to n25 in Less 1987)
- h and w: height and width of the equatorial chamberlets around the peripheral part of the equatorial layer (corresponding to h and l in Less 1987).

Biometric data are summarized in Table 1. According to Less (1998) subspecies are defined by biometric limits of the population means of parameter “d”, which has been chosen because it is the most easily and objectively measurable quantitative feature and because it reveals the fastest and the least variable evolutionary progress.

Since the orthophragminid fauna of the studied localities is rather diverse and different species can be found in different proportions, we could not reach the sufficient number of preparations for each species from every sample. Therefore, samples close to each other and containing practically the same assemblages with 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 the limited space, a complete statistical evaluation with the number of specimens (n²), arithmetical mean and standard error (s.e.) is given only for deutoconch 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 limit of the given subspecies than one 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.), followed by the names of the two subspecies on either side of the limit and putting that name into the first place to which the assemblage is closer.

**Previous studies on Thanetian to early Ypresian orthophragmines**

In this paper, we adopt the standard stages Thanetian and Ypresian instead of Ilerdian and Cuisien, preferred by Paleogene larger foraminiferal experts (Serra-Kiel et al. 1998). In comparing their chart with that of Hardenbol et al. (1998), it is clear that the Thanetian of the international standard overlaps with the Ilerdian introduced by Hottinger & Schaub (1960), and therefore, the late Thanetian has a different meaning in the two schemes that can be misleading. Thus, instead of early Ilerdian (SBZ 5 and 6) we use late Thanetian in its original sense that includes also the “late Thanetian” (SBZ 4). For the rest of the Ilerdian (SBZ 7-9) we use early Ypresian while Cuisien (SBZ 10-12) is substituted by late Ypresian. According to Serra-Kiel et al. (1998), the early Thanetian corresponds to SBZ 3 from where we have the first orthophragminid record.

In the time when orthophragmines were determined mainly based on their external characteristics, Discocyclina seunesi was widely accepted as a marker for the Paleocene (Douville 1922; Schweighauser 1953; Neumann 1958). However, the internal features of forms described under this name were not really taken into consideration. Therefore, e.g. D. seunesi of the latter two authors are internally different. Not a single form that would be characteristic only for the early Ypresian was commonly accepted.

In the first zonal scheme, presented by Less (1987), the Thanetian-“Ilerdian” has been subdivided into four zones marked by O.1 (Thanetian) and O.2 to 4 (Ilerdian). However, the two older units have only been established based on the re-evaluation of photographs and data from literature. Meanwhile, the two younger units (O.3 and O.4) have been erected based on samples examined mainly from the Bakhchisarai profile of the Crimean peninsula but also from Spileo (N Italy). However, in this latter case only very few specimens have been studied. Bibliographic data of Schlumberger (1904) and Schweighauser (1953) from this site have also been re-evaluated. For some localities of the Northern Corbières and Mont Cayla in France, also bibliographic data were used. Based on this really poor material the existence of ten species has been assumed, two of which (Discocyclina archiaci and Orbitocyclus ramaraoi corresponding recently to O. schopeni) with recognizable evolution serving for the establishment of the above four zones. It is worth noting that Less (1987) assigned Discocyclina seunesi, the widely
<table>
<thead>
<tr>
<th>Specific determination</th>
<th>Horizon</th>
<th>d (μm) range</th>
<th>a</th>
<th>N</th>
<th>H (μm) W (μm) range</th>
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<th>h (μm) w (μm) range</th>
<th>Subspecific determination</th>
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<td>205 - 205 224.5 46.7</td>
<td>46.7</td>
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<td>37 - 16 25 - 50</td>
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<td>205 - 104 200 46.7</td>
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<td><strong>Orbitocyclus multiplicatus</strong></td>
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Tab. 1 - Statistical data of orthopigmid populations (see text for the abbreviation of parameters).

used species name by older authors, erroneously to genus *Orbitocyclus*.

Less (1998) integrated a much wider material for the subdivision of the Thanetian-"Hierian" interval by orthopigmid species. The former O.1 has been subdivided into OZ 1a and 1b based on the evolution of *Discocyclus sevensi* from Beloslav (Bulgaria) presented in detail in this paper. It also allowed re-assigning "sevensi" to *Discocyclus*. In the lower Thanetian from Boussain Mare and Nouts-Oras (both S France), we also could find primitive representatives of the *Orbitocyclus scopeni* (formerly O. ramaraoi) lineage together with *D. sevensi*. In a third sample from S France (Ruisseau de Bec) another *Discocyclus* different from *D. sevensi* has been found and identified as belonging to *D. tenuis*, originally described from Spilecco (N Italy). This taxon was interpreted as the transitional link between *D. sevensi* of OZ 1a and 1b and *D. pseudoaugustae* of OZ 4 and 5. Two evolutionary stages of *D. tenuis* were declared to be the zonal markers of the successive OZ 2
with *D. tenus* n. ssp. Ruiseau de Bec and OZ 3 with *D. tenus tenus*. Unfortunately, this turned out to be a misinterpretation since the Ruiseau de Bec sample contains *Glomalveolina primaeva*, the zonal marker of the early Thanetian SBZ 3. Thus, it is of the same age as the other two French sites mentioned above and are arranged into OZ 1a. This means that the definition of the OZ 2 zone is erroneous in Less (1998). Moreover, the above two subspecies are also too close to each other, and therefore, their separation (based on scarce material) seems to be meaningless as well.

*Discocyclus tenus* was also identified from Gamarde (France) in Less (1998) together with *D. archiaci bakhchisaraiensis* and *D. dispansa braennmanni* described from the *Nummulites crinensis* beds of the Bakhchisarai profile belonging to the same OZ 3 zone. Based on a much wider coeval material than in Less (1987) from Spilecco (N Italy), the morphology of *Orbitolyceus multiplicas* and *O. bayami* could be studied in detail. As a result, the establishment of OZ 3 has been confirmed. This happened also with OZ 4 since the Campo 1 sample (Spain) of Samsó et al. (1990) cited as PYCM1 in Less (1998) appeared to contain practically the same assemblage (*Discocyclus archiaci sterosellensis*, *D. pseudoangustae* and *Orbitolyceus schopeni svolukayensis*) as in the transitional layers of the *Nummulites crinensis* and *Assilmia placentula* beds of the Bakhchisarai profile where O4 of Less (1987) has been established. The fauna of the Campo 1 sample will be described later, together with the Thanetian to early Ypresian assemblages of S France.

Özcan et al. (2001) described the orthophagminid fauna of the Kirkkavak, Karahamzali and Karsak profiles of the Haymana-Polatlı Basin of Central Turkey, that turned out to contain the richest early Thanetian assemblage known so far from the Western Tethys. It co-occurs mostly with *Glomalveolina primaeva*, the zonal marker of SBZ 3, and also with *G. levis* (SBZ 4) in the uppermost part of the Kirkkavak profile. The orthophagminid assemblage contains four different species, *Discocyclus semnesi*, *D. tenus* (described as *Discocyclus* sp. 1), *Orbitolyceus multiplicas* (described as *O. haymanaensis*) and *O. schopeni* (described as *O. neumannae*). The composition of this assemblage also shows that *D. semnesi* and *D. tenus* are not successive but simultaneous taxa. The evolutionary stage of *D. semnesi* is similar to that of the upper samples from Beloslav (Bulgaria), thus these sites can be assigned to OZ 1b.

Çolakoğlu & Özcan (2003) described the orthophagminid fauna from the Sakarya profile of the Haymana-Polatlı Basin. The assemblages from most of the samples could be well correlated with the faunas of OZ 3 and OZ 4 of the Bakhchisarai profile based on the evolution of the *Discocyclus archiaci* and *Orbitolyceus schopeni* lineages. In the uppermost samples, some new lineages appear as well showing a kind of their transition to OZ 5, the lowest orthophagminid zone of the late Ypresian (Cuisian).

Summarizing our recent knowledge on the Thanetian and early Ypresian orthophagmines of the Western Tethys, we can state that the orthophagminid record for this time-span is still rather discontinuous. Especially the late Thanetian orthophagmines have to be re-evaluated and the corresponding OZ 2 zone has to be re-defined.

**Material and localities**

Our samples come from three countries and various sections; a summarizing list of orthophagmines per samples is given in Fig. 5.

**Spilecco (N Italy)**

The classical Spilecco outcrop of the Lessini Mts. between Verona and Vicenza has been described in Less et al. (2000). The rich larger foraminiferal fauna (Gümbel 1870; Munier-Chalmas 1891; Schlumberger 1904; Douvillé 1922; Schweighauser 1953) comes from a 1 to 2 m thick red, tuffaceous marl and limestone (rich in echinoids and brachiopods as well) which is unique in

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**Fig. 5** - Distribution of Thanetian and early Ypresian orthophagminid taxa in the studied sections.
this region. Therefore, our orthophragminid material originating from four different sources can be considered as one single assemblage (Table 1). The first three of the four sources are detailed in Less & Ø. Kovács (1996: 277-278), while the fourth sample was collected by Gy. Less in 2000, at the 5th Meeting of the IGCP Project 393.

The orthophragminid fauna of Spîlceco (Fig. 5) is a key association for the OZ 3 zone. Orbitoidyopsis comprises the overwhelming majority of the assemblage and is represented by the unribbed O. schopeni neumannae and O. multiplicatus multiplicitus together with the ribbed O. munieri ponticus and O. bayani bayani that internally correspond to the above two unribbed forms. Asterochirina taramellii is very rare and Discocyclus tenis is even rarer (it has been found only in the Schweighäuser collection). Planktic data are summarized in Less et al. (2000). According to Barbieri & Medizza (1969) the red marls belong to the lowermost part of P 6 and NP 10 zones. Based on C. A. Papazzoni's data (see Less et al. 2000: 65) the nummulitids need a systematic revision. However, Nummulites baleensis, N. spileccensis, N. oppenheimi, N. perrutus and Assilina castigens can be recognized. This assemblage corresponds to the SBZ 7-8 zones.

Beloslav (Bulgaria)

The Beloslov profile crops out in NE Bulgaria, 20 km W of Varna, and represents the epicontinental facies of the Mesozoic platform. The outcrop, lying in the SW periphery of the settlement near a temporary gypsy camp, is described in detail by Aladzhova-Khrisheva et al. (1983) and Aladzhova-Khrisheva (1984) (Fig. 6). The 6 m thick Thanetian sequence overlies Senonian cherty marls and is followed with another hiatus by the silty Beloslav Formation assigned by Aladzhova-Khrisheva et al. (1983) to the upper Ilerdian (upper part of the lower Ypresian). This latter formation together with the overlying Dikilitas sands (lower Cuisian = lower part of the upper Ypresian) roughly corresponds to the Bakhchisarai beds of the Crimean peninsula, whereas the Alad’n Limestone capping the Beloslav profile corresponds to the base of the Simferopol beds.

We studied the Thanetian part of the profile in detail. It is represented by yellowish-white, somewhat silty, glauconitic limestone rich in biogenic detritus, mainly red algae. The thickness of these beds separated by thin marly intercalations is 20 to 80 cm. Orthophragmines are abundant in the upper part of the sequence while Gryphaea antiqua (according to Belmustakov 1962) and other bivalves are dominating in the lower part. Six samples have been collected by R. Nkov (So- fia) in 1991 from 0, 0.75, 1.5, 2.5, 4 and 6 m measured from the base of the Thanetian limestone. They are marked as Beloslav (BELO) 0, 1, 2, 3, 4 and 5, respectively.

Larger foraminifera are represented exclusively by well-preserved, matrix-free specimens of orthophragmines. All the six samples proved to be monospecific. One single microspheric specimen with discocyclinid juvenarium (Pl. 1, fig. 2) from sample Beloslav 1 has also been found. These forms are identified with D. seuresi described from the Paleocene of Bensse (SW France) and investigated by Less & Ø. Kovács (1996) and Less (1998) also from other Thanetian localities of this region (Boussan Mare, Nouts-Oraas). Discocyclus seuresi, however, shows a peculiar evolution in the Beloslav section. All the quantitative parameters are significantly lower in the lower two samples than in the upper four ones (see Table 1). Therefore, they can be separated into two successive evolutionary stages (subspecies) of the species. Based on the similarity of the quantitative parameters of the lower two populations to the French ones (see above) they are assigned to D. seuresi seuresi, while the upper four populations are separated into the newly described D. s. beloslaviensis. Since these two taxa are zonal markers, the lower two

Fig. 6 - Stratigraphic log of the Beloslav profile according to Aladzhova-Khrisheva et al. (1983) and Aladzhova-Khrisheva (1984). 1. Marl limestone with cherts; 2. red algal limestone; 3. sandy limestone; 4. yellowish, coarse-grained sand; 5. whitish quartzose sand; 6. kumachele; 7. sandy marl; 8. sandy/silty clay; 9. brownish silty sand; 10. nummulite limestone; 11. erosional unconformity; 12. not cropping out.
samples (BELO 0 and 1) belong to the OZ 1a, whereas the upper four (BELO 2-5) to the OZ 1b zone.

Aladžhova-Khrischeva et al. (1983) assigned the Thanetian part of the Beloslav profile to the NP 6 zone; however the same Thanetian beds of the Yunak sequence (15 km SW of Beloslav) belong already to the NP 7 and simultaneously to the P 4 zone according to them. Therefore, the boundaries of the OZ 1a and 1b zones and of the NP 6 and 7 zones may roughly correspond to each other.

Turkey

Our sections (Fig. 7) are located in the Pontides, consisting of several tectonic units, namely the Istanbul and Sakarya zones, separated by the Intra-Pontide sequence. The measuring of the profiles and the sampling was carried out by E. Özcan.

Kurcaşile. In central northern Turkey marine early Tertiary units, referred to as Atbaşi Formation, are known along the Black sea coast between Bartın and Çide regions (Ketin & Gümuş 1963). In this region, relatively deep-water clastic and partly carbonate beds of this unit overlie the Cretaceous succession, which includes substantial amounts of volcanic and volcaniclastic units (Balırgan and Yemişliçay Formations) and deep-marine fine clastic rocks and carbonates of Eocene-Miocene age (Gürsökü Formation). Campanian-Maastrichtian larger foraminifera occur widely in different levels of this latter formation (Özcan & Özkan-Altuner 1999). The Atbaşi Formation is usually devoid of larger foraminifera, except for only few horizons, which contain a rather rich assemblage of orthophragminds. Sample KURUC, collected from a sandstone horizon of this unit in the central part of town of Çide, contains mainly orthophragminds and few indeterminate, small, radiate Nummulites. Their assemblage is listed in Fig. 5. The peculiarity of this very rich association is that the most advanced representatives of the Discocyclina semeni-lineage co-occur with other forms (Nemkovella evae and the three ribbed forms: Orbitolites bayani kurucalseneensis, O. munieri ponticus and Asterocyclina taramellii) for which Kurcaşile and Karævli (see below) are the first known occurrences. This means stratigraphically that this assemblage is younger than OZ 1a, however older than OZ 3, thus it can serve as a base for the re-defined OZ 2. The presence of genus Nummulites indicates that the Kurcaşile site belongs already to the Ilerdian in the sense of Serra-Kiel et al. (1998).

Safranbolu-Karabük Basin. Upper Thanetian to Lutetian shallow-water marine deposits, comprising an approximately 150-m-thick succession of mainly clastics and argillaceous carbonates, transgressively overlie the deformed basement rocks. Safranbolu Formation, the lowermost unit (Fig. 7), contains an association of orthophragminds, nummulitid and alveolinid foraminifera in successive horizons (Koçyiğit 1987). Two sections (Karævli - KARA and Ağakıse - AGA) were sampled from the basin succession (Fig. 8). The upper part of the sequence is described in Özcan et al. (2007b).
Thanetian and early Ypresian orthophragmines from Central Western Tethys

**Karavlı.** The lowermost part of the transgressive Lower Paleogene units of the Safranbolu-Karabük Basin is nicely exposed near Karavlı village, about 11 km to the north of Safranbolu (Fig. 8). This 45-m-thick sequence was measured and sampled along the road from Karavlı to Kırıklar, starting from the basal conglomerate cliffs exposed in Karavlı towards Kırıklar direction. It comprises a 21-m-thick sequence of almost massive, medium- to thick-bedded conglomerates or coarse sandstones at the base, which are wholly devoid of foraminifera. Rare tests of orthophragmines were identified only in the middle part of this unit. Upwards they pass into medium-bedded, very durable coarse sandstones or sandy carbonates with some intercalations of cm-scale silty levels. Larger foraminifera in great quantity first appear in these beds and are mainly represented by small, unidentified nummulitids, operculinids, accompanied by bryozaons, echinoids and rotalids. *Orduella sphaerica* (Fig. 9), described from the Thanetian of Turkey (Sirel 1998), occurs abundantly. Two few cm-thick friable siltstone beds (samples KARA 1 and 2) in this part of the sequence yielded a rich association of orthophragmines (Fig. 5). This assemblage yields the same characteristics as that of the Kurucaşile sample, thus determines the same, emended OZ 2 zone. Upwards, the section grades into more calcareous deposits represented by clayey limestones and fragmental limestones containing *Nummulites* and finally limestones (samples KARA 4-6) with a wealth of echinoid tubes and tests of bivalves. In this interval not any free specimens of foraminifera were identified.

**Ağaçkese.** The outcrop lies near to the mosque of the village of Ağaçkese at the 15 km of the Safranbolu-Eflani road (Fig. 8). The section represents the lower part of the Safranbolu Formation transgressively overlying the Ahmetusta Conglomerate of Cretaceous age in the Safranbolu-Karabük Basin. It comprises a 52-m-thick sequence of mainly coarse clastics with minor amount of silt and carbonates. The sequence starts with a few meters of non-fossiliferous conglomerate and sandstone beds, which are overlain by a sequence of fine and coarse clastics that contains small nummulitids in some levels. Above this, a 1-m-thick, argillaceous carbonate/siltstone bed (sample AĞA 2) containing abundant porcellaneous foraminifera (mainly alveolinids) yielded sporadic free tests of orthophragmines and small *Nummulites*. This part of the section passes upward into carbonates containing mainly *Nummulites* and *Assilina* and rarely orthophragmines, accompanied by miolids, textularids, bryozaons and echinoids. The orthophragminid fauna of sample AĞA 2 listed in Fig. 5 shows great similarity to that of the Spilecco sample, thus it defines the OZ 3 zone.

** règle.** Shallow-marine lower Eocene deposits crop out near the town of Sile, to the east of İstanbul (Fig. 10). The succession is divided into a lower, deep-water chaotic sedimentary unit (called as *Şile Olistostrome*), and an unconformably overlying upper one with shallow-marine nummulitid limestone and clastics (Yuusus-lubayr Formication) of early Lutetian age. This latter is discussed in Özcan et al. (2007b).

The upper part of the *Şile Olistostrome*, which is exposed in a narrow strip along the Black Sea coast, is

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**Fig. 8** - Locality map of the orthophragminid-bearing stratigraphic sections near Kırık and Safranbolu in central northern Turkey (geological map simplified from Saner et al. 1980).

**Fig. 9** - *Orduella sphaerica* Sirel from Karavlı (sample KARA 3), O/KARA 3-4, x 100.
characterized by sandstone beds with marly and silty intercalations and numerous Upper Cretaceous carbonate blocks (Baykal & Önalan 1979). Among the several horizons containing Tertiary larger foraminifera only one olistolithic lense (sample SILE 4) yielded a remarkable quantity of orthophragmines (Fig. 5). The biometric data of genus Orbitoclypeus fit very well with those from Spileco (Italy), thus indicate the OZ 3 zone, although the evolutionary degree of the two Discoecylona species shows a tendency towards OZ 4. Planktonic forms (Table 2) have been studied from two samples taken from the shaly matrix of the olistostrome (SILE 4A laterally interfingerling with SILE 4 and SILE 5 about 2 km to the WSW). The calcareous nannoplankton (studied by M. Balti-Beke) of both samples are clearly mixed, containing even late Cretaceous (but not Maastrichtian) forms, then the Paleocene Helio lithus klempelli (NP 6-8) and finally Ypresian coccoliths among which Discoaster lodoensis (NP 12-14) has the youngest first occurrence. The assemblage of smaller foraminifera (determined by K. Kolláry) is more uniform. Planktonic forms suggest an interval from the middle of the P 6 zone to the top of the P 7 zone which is in accord with the age given by the calcareous nannoplankton but slightly younger than the age based on orthophragmines. This deviation, however, can be explained by the reworking of the orthophragminid assemblage that is confirmed also by the mixed calcareous nannoplankton assemblage.

Kastamonu-Taşköprü Basin. This basin includes a variety of sedimentary and volcanic sequences from the Upper Cretaceous to the Oligocene (Yılmaz et al. 1997). In the vicinity of Kastamonu and Taşköprü, shallow-marine Eocene units unconformably rest upon the Kar gi Massif, which is a tectonic mosaic, composed of various metamorphic, metaophiolite and mélange units (Figs. 5 and 11). Eocene deposits at the close vicinity of Kastamonu are dominated by shallow-marine bio-

<table>
<thead>
<tr>
<th>Sille 4A</th>
<th>Sille 5</th>
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<tbody>
<tr>
<td>Triloculina clypeata (Cushman)</td>
<td>+</td>
</tr>
<tr>
<td>Denticulites beloides (Hillebrand)</td>
<td>+</td>
</tr>
<tr>
<td>Nodosaria latigemata Glämmel</td>
<td>+</td>
</tr>
<tr>
<td>Nodosaria sp.</td>
<td>+</td>
</tr>
<tr>
<td>Dentalina sp.</td>
<td>+</td>
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<tr>
<td>Lingulina sp.</td>
<td>+</td>
</tr>
<tr>
<td>Marginulina exornamentata Bowen</td>
<td>+</td>
</tr>
<tr>
<td>Discorbis sp.</td>
<td>+</td>
</tr>
<tr>
<td>Pleurotomarina sp.</td>
<td>+</td>
</tr>
<tr>
<td>Globorotalia pseudospongiis (Subborina)</td>
<td>+</td>
</tr>
<tr>
<td>Acarinina nitidus (Martin)</td>
<td>+</td>
</tr>
<tr>
<td>A. primitiva (Finlay)</td>
<td>+</td>
</tr>
<tr>
<td>A. solidaeformis angelolus (Boll)</td>
<td>+</td>
</tr>
<tr>
<td>A. solidaeformis solidaeformis (Bohniennann)</td>
<td>+</td>
</tr>
<tr>
<td>Morozovella formosa gracilit (Boll)</td>
<td>+</td>
</tr>
<tr>
<td>Globorotalia linearis Finlay</td>
<td>+</td>
</tr>
<tr>
<td>Cibicides lobatus (Walker and Jacob)</td>
<td>+</td>
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<tr>
<td>Cibicidoids alleni (Plummer)</td>
<td>+</td>
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</tbody>
</table>

Tab. 2 - Smaller foraminifera and calcareous nannoplankton from samples SILE 4A and 5.
up of more or less massive, red to brownish continental conglomerates and sandstones unconformably overlying the Kargı metamorphic massif. This 40 to 50-m-thick clastic unit, with a rapidly changing lateral thickness, is devoid of foraminifera and is overlain by an about 20-m-thick sequence of argillaceous bioclastic limestones, limy sandstones and sandstones. The lowermost few meters of argillaceous limestones, which are extremely rich in alveolinids and Orbilitites sp. (KASC 4) but with rare tests of nummulitids, suggest a low-energy depositional environment of a marine platform. Orthophragmnes are not recorded from these horizons. Further up, bioclastic limestones and calcareous sandstones contain a wealth of nummulitids, to a lesser extent accompanied by orthophragmnes. The orthophragminid assemblage of the two studied samples (KAS C 5 and 7) is listed in Fig. 5 and marks the OZ 3 zone (earliest Ypresian) based on the joint occurrence of Discocyclina archiaci bakhchisaraensis and Orbitocyclus schopeni neumannae.

Upsection, the sequence predominantly comprises massive shales and few sandstone intercalations with a total thickness of about 20 m, succeeded by coarse sandstones and agglomeratic beds of about 5 m in thickness. Sandstones are mainly made up of volcanogenic material. Rare planktonic foraminifera and sporadic tests of transported and fragmented orthophragmminids and nummulitids are recorded. These horizons, from which no matrix-free tests of orthophragminids were recovered, are regarded as deposited in somewhat deeper-water basinal environment. Two volcanogenic sandstone horizons, KAS C 9 and 10, in 4 m interval in the upper part of sequence contain loose tests of orthophragmnes and nummulitids. The orthophragminid assemblage (Fig. 5) marks the OZ 4 zone (late early Ypresian) based on the occurrence of Orbitocyclus schopeni suzukayensis, accompanied by the first appearing O. douvillei. It is worth noting that the evolutionary degree of O. multiplicatus from sample KAS C 10 is considerably higher than that from sites belonging to OZ 3 (Spilecco, sample SILE 4). These forms are introduced in this paper as O. multiplicatus kastamonuensis.

Kastamonu A (KAS A) section. This 30-m-thick exposure of the Boyabat Formation can be found in Kastamonu town, just at the vicinity of the Ceritoğlu primary school in Sarışar district. The road-cut exposure comprises a succession of mudstones and sandy carbonates with intercalations of turbiditic sandstones. Its relation to the under- and overlying units is unknown. A single 40-cm-thick friable sandstone horizon (KAS A 4) in the lower part of the sequence yielded an association of poorly preserved nummulitids and orthophragmnes accompanied by rotalids, alveolinids, bryozoans and echinoid plates, which are interpreted as transported from shallow-water realm. The orthophragminid assemblage contains Orbitocyclus schopeni suzukayensis and very sporadic Discocyclina archiaci indet. sp. Based on the former the sample represents the OZ 4 zone (upper lower Ypresian) as suggested also by the lithological similarity to the upper part of the KAS C section, the samples of which (KAS C 9 and 10) are coeval.

Systematic description of the orthophragmnes

We only give full descriptions for new species and for Discocyclina seuenisi, D. tensis, Orbitocyclus multiplicatus, O. bayani and Asterocyclina taramelli. A short review is given for all the other species covering the most characteristic morphological features, the geographic and stratigraphic range, the references to more detailed descriptions (with the exception of Less 1987, which is common for almost each species), the up-to-date subdivision into subspecies with their biometric limits (mostly according to Less 1998, therefore it is not mentioned separately) and the characteristics (occurrence, evolution and possible deviations) of our material. In the descriptions, characterizing some qualitative features, we adopt the terminology introduced by Less (1987, 1993) and illustrated in Fig. 5.

Only the new subspecies are described separately. Data on figuration, occurrences, biometry and statistics of the other subspecies can be found in the description of the given species and in Table 1, respectively.
Order Foraminiferida Eichwald, 1830
Family Discocyclinidae Galloway, 1928
Genus Discocyclina Gumbel, 1870

Discocyclina seunesi Douvillé, 1922

Diagnosis. Small- to medium-sized, moderately flattened or slightly inflated, unribbed forms. The rosette is mostly of the “Discocyclina” type. The megaspherical embryo is usually eulepidine; the two chambers are moderately small. The arcuate adaxial chambers of the “various” type are few in average in numbers, moderately narrow and low. The equatorial chambers are moderately wide and rather low; their annuli are circular, the growth pattern is of the “various” type.

Description. Small to medium-sized (2-5 mm), moderately flattened or slightly inflated, unribbed forms (Pl. 1, figs. 1, 6). The umbo is rather indistinct. The evenly distributed granules (60 to 100 μm in diameter) are surrounded by 7-10 small lateral chambers, thus the rosette is of the “Discocyclina” type with slight trend towards the “marmatic” type. The protoconch is small- to medium-sized (p = 100-300 μm), relatively large compared to the deuteroconch (d = 180-450 μm). Therefore, the embryo is mostly eulepidine or occasionally tryblio- or excentripleidine. The number of the adaxial chambers is low to average (N = 7-34), they are usually moderately narrow and low, sometimes larger both in width and height (W = 25-80 μm, H = 25-70 μm). Their outer wall is arcuate, and therefore they are of the “various” type. The equatorial chambers are of average width (w = 25-35 μm) and low (h = 30-60 μm, n = 11-20). They bear annular stolons (Pl. 1, figs. 3, 5 and 9) that are not well developed, and thus the equatorial chambers are very slightly hexagonal. The annuli are circular; their growth pattern is of the “various” type. The microspheric juvenarium (Pl. 1, fig. 2) is spiral, characteristic for Discocyclinidae. The number of half-cycles is relatively low, only 6-7. In our material the thickening of the equatorial layer is less significant in the axial section (Pl. 1, fig. 14) than Less (1987: 195).

Remarks. Due to the well-preserved material from Beloslav (Bulgaria), the type of the microspheric juvenarium and the presence of the annular stolon of the equatorial chambers could be recognized, thus this species is assigned to Discocyclina instead of Orbitocyclina as in Less (1987), who based this attribution only on bibliographic data. Although D. seunesi is the most widespread orthophragminid taxon in the Thanetian from France to Turkey, it is far not the only one (see Conclusions), contrary to Less (1987). Its stratigraphic range is restricted to the Thanetian; it can be subdivided into three developmental stages as follows:

\[ D. s. seunesi \quad d_{mean} < 250 \mu m \]
\[ D. s. beloslavensis \quad d_{mean} = 250-310 \mu m \]
\[ D. s. karabukensis \quad d_{mean} > 310 \mu m \]

Discocyclina seunesi beloslavensis n. sp. formally replaces D. seunesi n. sp. Beloslav in Less (1998), however its lower limit is slightly modified to the one (260 μm) proposed originally. Populations of the upper samples of Beloslav (BELO 2-5) are assigned to this taxon as well as D. seunesi described in Ozcan et al. (2001) from the Haymana-Polatlı Basin in Turkey. This taxon seems to characterize the mid-Thanetian OZ 1b orthophragminid zone. Its superposition to the lower Thanetian OZ 1a zone can be observed in the Beloslav profile where the lower two samples (BELO 0 and 1) still contain D. seunesi seunesi. The most advanced representatives of the species belonging to D. s. karabukensis n. sp. have been found in the upper Thanetian OZ 2 zone of Karaevli (samples KARA 1 and 2) and Kuruçasıl (sample KURUC).
**Description** (see also Table 1). Small, moderately flattened, unribbed forms. The embryo is small, eu- to slightly tryblioneplid. The relatively few, "varians" type adaxial chamberlets are low and narrow, their outer wall is arcuate. The equatorial chamberlets are average wide and low, the growth pattern of the annuli is of the "varians" type.

**Remarks.** Discocyclus seunesi seunesi can be distinguished from the other unribbed representatives of the genus (*D. archiaci bakhchisaraitensis, D. furoni, D. dispana taurica, D. d. bangarica, D. augustae augustae*) by its mostly eulepidine embryo and adaxial chamberlets with arcuate outer wall ("varians" type).

**Discocyclus seunesi beloslavensis** n. ssp. Less & Özcan

2001 *Discocyclus seunesi* – Özcan et al., pp. 350, 352, 354, pl. 2, figs. 9-14, pl. 3, figs. 1-6, text-fig. 3B.

**Etymology:** Named after the town of Beloslav (NE Bulgaria), the type locality of the taxon.

**Holotype:** Specimen E.06.92. (Pl. 1, fig. 9).

**Repository:** Geological Institute of Hungary, Budapest.

**Paratypes:** All the other specimens from Beloslav, sample BELO 2, illustrated in Pl. 1, figs. 6-8 and in Fig. 12.

**Type locality:** Beloslav (NE Bulgaria), sample BELO 2.

**Type level:** Middle part of the Thanetian, OZ 1b orthophragminoid zone.

**Diagnosis.** *Discocyclus seunesi* populations with \( \text{d}_{\text{max}} \) ranging between 250 and 310 μm.

**Description** (see also Table 1). Small, moderately flattened, unribbed forms. The embryo is moderately small, in most cases eulepidine. The few to average in numbers, "varians" type adaxial chamberlets are moderately low and narrow, their outer wall is arcuate. The equatorial chamberlets are average wide and low, the growth pattern of the annuli is of the "varians" type.

**Remarks.** *Discocyclus seunesi beloslavensis* can be distinguished from the other unribbed representatives of the genus (*D. archiaci bakhchisaraitensis, D. furoni, D. dispana bangarica, D. d. sella*) by its mostly eulepidine embryo and adaxial chamberlets with arcuate outer wall ("varians" type).

**Discocyclus seunesi karabuekensis** n. ssp. Less & Özcan

2001 *Discocyclus seunesi* – Özcan et al., pp. 350, 352, 354, pl. 2, figs. 9-14, pl. 3, figs. 1-6, text-fig. 3B.

**Etymology:** Named after the city of Karabük, close to the type locality of the taxon in Central Turkey.

**Holotype:** Specimen 0/KARA 21 (Pl. 1, fig. 15).

**Repository:** Geology Department of the Istanbul Technical University.

**Paratypes:** All the other specimens from Karaevli, sample KARA 2, illustrated in Pl. 1, figs. 10, 11, 16 and in Fig. 12.

**Type locality:** Karaevli (Central Turkey), sample KARA 2.
Type level: Upper Thanetian, the OZ 2 orthophragminid zone.
Diagnosis: Discocyclina semnesi population with $d_{\text{mean}}$ exceeding 310 μm.

Description (see also Table 1). Small, moderately flattened, unribbed forms. The embryo is average in size, eulepidine and sometimes excentripleidine. The average in numbers, “variants” type adaxial chamberlets are moderately low and narrow, their outer wall is arcuate. The equatorial chamberlets are average wide and low, the growth pattern of the annuli is of the “variants” type.

Remarks. Discocyclina semnesi karabuekensis can be distinguished from the other unribbed representatives of the genus (D. archiaci staroselensis, D. dispansa sella, D. tenus) by its eu- and excentripleidine embryo and adaxial chamberlets with arcuate outer wall (“variants” type) except for D. tenus that also can be of this type.

Discocyclina archiaci (Schlumberger, 1903)

Discocyclina archiaci is an unribbed form having semi-nephro-, tryblio- and umbilicopledine embryo, moderately wide and average high, ‘archiaci’ type adaxial chamberlets and moderately wide and high equatorial chamberlets with ‘archiaci’ type growth pattern. It is widespread from Spain to Turkey, from the lower Ypresian (OZ 3) up to the lower Lutetian (OZ 8b). Additional data can be found in Ozcan (2002) and Çolakoğlu & Ozcan (2003). Less (1998) ranked the rare D. faroni, D. weijdeni and D. senegalensis with D. archiaci, however in the Turkish material these forms appeared to be separate species (Ozcan et al. 2007b). D. archiaci forms a rather quickly developing evolutionary lineage with four successive subspecies whose biometric limits are considered as follows:

- D. a. bakkhisaraensis $d_{\text{mean}} < 305$ μm
- D. a. staroselensis $d_{\text{mean}} = 305-390$ μm
- D. a. archiaci $d_{\text{mean}} = 390-600$ μm
- D. a. bartholomei $d_{\text{mean}} > 600$ μm

D. archiaci bakkhisaraensis (Pl. 1, figs. 19, 20; Fig. 13) occurs in the lower part of Kastamonu C section representing lowermost Ypresian (OZ 3). The assemblage from sample $\$ile$ 4 is slightly more advanced and can be determined as D. archiaci ex. interc. staroselensis et bakkhisaraensis (Pl. 1, figs. 21-23; Fig. 13), however based on the accompanying fauna the sample still belongs to OZ 3. The single specimen from sample KAS A 4 does not permit determination at sub-specific level.

Discocyclina tenus Douvillé, 1922
Pl. 1, figs 24, 25

1922 Discocyclina tenus Douvillé, p. 87, pl. 4, fig. 9.

1953 Discocyclina tenus Douvillé - Schweighauser, pp. 74-75, pl. 12, fig. 11, text-fig. 47.
2001 Discocyclina sp. 1 - Özcan et al., p. 354, pl. 3, figs. 7-8, text-fig. 3B.

Holotype: Douvillé (1922), pl. 4, fig. 9 (external form), possibly deposited at Université Sorbonne (Paris).

Type locality: Spileco (N Italy).

Type level: Lowermost Ypresian, OZ 3 orthophragminid zone.
The type of the equatorial section of the A-forms: Preparation C.25413/4, deposited at the Naturhistorisches Museum Basel, figured in Schweighauser (1953), pl. 12, fig. 11, and re-figure in Pl. 1, fig. 24.

Diagnosis. Small to medium-sized, flattened, unribbed forms with “Discocyclina” type rosette. The medium-sized embryo is semi-
nephro- to trybirolepidine. The relatively numerous "archiacci-variants" type adaxial auxiliary chamberlets are moderately wide and high like the equatorial chamberlets that are arranged in circular annuli of the "archiacci-variants" type growth pattern.

**Description.** Small to medium-sized (3-6 mm), flattened, unribbed forms with "Discocyclina" type rosette. Externally it cannot be distinguished from the contemporaneous *D. seunesis* and *D. archiacci*. In the equatorial section of the A-forms the medium-sized embryo (p=130-280 μm, d=260-580 μm) is mostly trybioid-, sometimes semi-nephrolepidine. The relatively wide (W=35-60 μm) and high (H=40-100 μm) adaxial auxiliary chamberlets are average to numerous in numbers (N=15-38), their outer wall is more or less arcuate, and of the transitional "archiacci-variants" or the "variants" type. The slightly elongated equatorial chamberlets are moderately wide (w=30-40 μm) and high (h=50-100 μm, n=8-14). The cycles are circular; their growth pattern is of the transitional "archiacci-variants" or the "variants" type. Microspheric specimens have not been found yet. Because of the rarity of the species, the axial section could not be studied yet.

**Remarks.** *Discocyclina tenuis* is a very rare taxon co-occurring in the Thanetian with *D. seunesis* and in the early Ypresian with the less advanced stages of *D. archiacci*. Less (1987) thought it to be invalid, however later he (Less 1998) found a representative population from Risseau de Bec (France) together with *Orbitocyclus schopenii ramaraoi*. It was interpreted as the descendant of *D. seunesis* characterizing the late Thanetian OZ 2 zone. However, later Özcan et al. (2001) recorded it as *Discocyclina* sp. 1 together with an assemblage that contains — according to our revised nomenclature — *D. seunesis beloslavensis*, *Orbitocyclus schopenii ramaraoi* and *O. multiplicatus haymanensis*, thus belonging to the middle Thanetian OZ 1b orthophragminid zone. In this assemblage *D. tenuis* and *D. seunesis* can be fairly well distinguished from each other based on their different embryo (both size and shape) and somewhat different adaxial and equatorial chamberlets. The distinction from the early Ypresian members of the *D. archiacci* lineage is also not too difficult due to the larger embryo, more numerous and slightly arcuate adaxial and more elongated equatorial chamberlets of *D. tenuis*.

Less (1998) proposed to subdivide *D. tenuis* into two developmental stages, however because of its scarce occurrence, by the time being it is better not to segregate the species until finding larger populations.

In our material *D. tenuis* is also very rare. For Spiloco (earliest Ypresian, OZ 3) we could use only the two specimens found in the Schweighauser collection in Basel (which originate from the Douvillé collection, see Schweighauser 1953). One single specimen from Kastamonu, sample KAS C 10 (upper lower Ypresian, OZ 4 zone) has been conditionally assigned to this taxon.

**Discocyclina dispensa** (Sowerby, 1840)

*Discocyclina dispensa* is an unribbed form with a small to medium-sized, semi-nephro- to trybirolepidine embryo, moderately wide and high, "archiacci" type adaxial auxiliary chamberlets and also moderately wide and high equatorial chamberlets. The spiral juvenerium of the microspheric forms is shown in Pl. 1, fig. 28. This early Ypresian to Priabonian taxon (OZ 3-16) is probably the most widespread species with a geographic distribution from Northeastern Spain to the Fiji Islands. Additional information can be found in Less (1999), Özcan (2002) and Özcan et al. (2007a). The biometric subdivision of this rapidly developing species, with its six successive subspecies is as follows:

**D. d. broeniimmanus**

- *d*<sub>mean</sub> < 160 μm

**D. d. taenia**

- *d*<sub>mean</sub> = 160-230 μm

**D. d. hungarica**

- *d*<sub>mean</sub> = 230-290 μm

**D. d. sella**

- *d*<sub>mean</sub> = 290-400 μm

**D. d. dispensa**

- *d*<sub>mean</sub> = 400-520 μm

**D. d. umbilicata**

- *d*<sub>mean</sub> > 520 μm

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**PLATE 2**


7-10: Orbitocyclus hayani (Munier-Chalmas) kuracislenensis n. sp., Kurucakû, upper Thanetian, OZ 2.7: O/KURU-29, 8: O/KURU-3, holotype, 9: O/KURU-30, 10: O/KURU-93.

11: Orbitocyclus hayani (Munier-Chalmas) indet. sp., Karavli, sample KAR 2, upper Thanetian, OZ 2, O/KAR 2-37.

12: Orbitocyclus hayani cf. hayani (Munier-Chalmas), Şile, sample SİLE 4, lowermost Ypresian, OZ 3, O/SİLE 4-6.

13-15: Orbitocyclus hayani hayani (Munier-Chalmas), Spiloco, lowermost Ypresian, OZ 3, topotypes. 13: E.06.148, 14: E.06.149, 15: E.06.146.

16-24: Orbitocyclus munieri (Schlumberger) ponticus n. sp.


25: Orbitocyclus munieri (Schlumberger) cf. ponticus n. sp., Ağakese, sample AĞA 2, lowermost Ypresian, OZ 3, O/AĞA 2-9.

35: Orbitocyclus munieri cf. munieri (Schlumberger), Kastamonu, sample KAS C 10, lower Ypresian, OZ 4, O/KASC 10-38.


5, 6: A-form, axial sections, 40 x; 26: external view, 10 x; 35: B-form, equatorial section, 40 x. All others: A-form, equatorial sections, 40 x.
The population of sample SİLE 4 (OZ 3) is slightly more advanced compared to the accompanying fauna and can be determined as *D. dispansa* ex. interc. *broennmanni-taurica* (Pl. 1, figs. 26-28). The single specimen from Kastamonu, sample KAS C 10 does not allow subspecific determination.

**Genus Nemkovella Less, 1987**

*Nemkovella evae* Less, 1987

*Nemkovella evae* is an unribbed species with a relatively small semi-is to nephrolepidine embryo, low but relatively wide, very diagnostic, arcuate, “various” type adaxial chamberlets and moderately narrow and low equatorial chamberlets with mostly “various” and “architect” types of the growth pattern. A significant increase in cycle height may take place only around the edges. The spiral microsporic juvenile is illustrated in Pl. 1, figs. 32, 33. The earliest occurrence is described here from the upper Thanetian (OZ 2) in Kurucaşile and Karaevli, thus its stratigraphical range is extended back as compared to Less (1998). The evolution of this species is rather slow, thus until now it has not been subdivided into subspecies. However new data (Özcan et al. 2007b) allow us to extend its stratigraphic range up to the middle Lutetian (OZ 10), due to the introduction of *N. evae karitensis*, a more advanced subspecies. The biometric distinction of the two subspecies is considered as follows:

\[ N. e. evae \quad d_{\text{mean}} < 260 \mu m \]
\[ N. e. karitensis \quad d_{\text{mean}} > 260 \mu m \]

In the upper Thanetian and lower Ypresian material from Turkey the species is represented by *N. evae evae* (Pl. 1, figs. 30-33; Fig. 13) from Kurucaşile (KURU, OZ 2) and SİLE, sample SİLE 4 (OZ 3) whereas the single specimen (Pl. 1, fig. 29) from Karaevli, sample KARA 1 (OZ 2) cannot be determined at subspecific level.

**Nemkovella stockare** n. sp. Less & Özcan

Pl. 2, figs 1-6; Fig. 13

**Etymology:** Named in honor of Rudolf Stockar (Lugano), Swiss expert of orthophragmines.

**Holotype:** Preparation O/KURU-76 (Pl. 2, fig. 4).

**Repository:** Geology Department of the Istanbul Technical University.

**Paratypes:** All the other specimens from Kurucaşile illustrated in Pl. 2, figs. 1-5, 6 and in Fig. 13.

**Type locality:** Kurucaşile (Northern Turkey).

**Type level:** Upper Thanetian, OZ 2 orthophragminid zone.

**Diagnosis:** Very small, inflated, unribbed forms. In the very small embryo the protoconch is slightly larger than the deuteroconch, their common wall is straight. The embryo is surrounded by an asymmetrical, quadrilateral neointi. No adaxial chamberlets. The equatorial annuli are circular; the relatively wide and moderately high chamberlets are spatulate in the internal, then distinctly hexagonal in the external cycles. Their growth pattern is of the "various" type. The two lateral layers are well-developed; the lateral chamberlets are relatively high.

**Description.** Very small (1-2 mm), strongly inflated, unribbed forms with coarse granules and "Discocyclina-chudeau" transitional type rosette. The embryo is very small, the protoconch is usually slightly larger (P= 60-105 µm) than the deuteroconch (D= 70-95 µm). Their common wall is straight, thus the type is isolepide to anisolepide. In the quadrilateral neointi the two principal adaxial chambers are large but slightly unequal; they initiate four very short asymmetrical spirals terminating in two closing chambers (40-50 µm in width and 35-45 µm in height). No adaxial chambers can be observed (N= 0). In the second or at least in the third cycle the equatorial chamberlets are already arranged in circular annuli. The relatively wide (w= 30-45 µm) and moderately high (h= 55-65 µm, n= 13-16) chamberlets are arranged in circular annuli from PLATE 3


18: *Orbitochyphus schopeni* (Checchia-Ripolli) cf. *newmani* (Toumarkine), Karaevli, sample KARA 2, upper Thanetian, OZ 2, 0/KARA2-19.


30-32: *Orbitochyphus schopeni* (Checchia-Ripolli) *swedgrenii* Less, Kastamonu, lower Ypresian, OZ 4, 30, 31: sample KAS 1C 30, 0/KASC.10-1, 31: O/KASC.10-8, 32: sample KAS A 4, 0/KASC.4-10.

33: *Orbitochyphus dawesellae* (Schlumberger) indet. sp., Kastamonu, sample KAS C 9, lower Ypresian, OZ 4, 0/KASC.9-19.

5: B-form, equatorial section, 100 x, 6: 26, A-form, external view, 20 x. All others: A-form, equatorial sections, 40 x.
the second or third cycle. They are spatulate in the internal 5 to 7 annuli, then distinctly hexagonal in the external cycles. The growth pattern is of the "varians" type. No microspheric specimens could be found yet. In the axial section (Pl. 2, figs. 5, 6) the embryo is 70 to 90 μm high, the thickness of the equatorial layer increases slightly towards the edges, from 40-50 μm near the embryo to 50-70 μm at the periphery. The lateral septum is thick, the annular one is strongly arcuate. The lateral layers are well-developed, the lateral chamberlets are relatively high (25-30 μm).

**Remarks.** Forms with the above described morphology have been unknown until now from the Tethyan Paleogene. The equatorial characteristics resemble very much to those of *Setta* described by Ferrández-Cañedell (2002). However, the presence of the well-developed, symmetrical lateral layers, rather characteristic for the orthophragminids, does not fit with the diagnosis of *Setta*. The closest orthophragminid taxon is *Nemkovella dagami* with very few adaxial chamberlets and with very similar characteristics in both the equatorial and axial sections. Unfortunately, we could not find microsphere specimens; therefore the assignment of "stockatl" to genus *Nemkovella* is conditional. Its ancestors are unknown, whereas *N. dagami* can be the possible descendant.

Family Orbitoclypeidae Brönnimann, 1946
Genus *Orbitoclypeus* Silvestri, 1907

*Orbitoclypeus multiplicatus* (Gümbel, 1870)

**Emended diagnosis.** Average-sized, inflated, unribbed forms with "marthae" type rosette. The medium-sized to moderately large embryo is excentrilipidene, rarely eulepidene. The numerous, "varians" type adaxial chamberlets are rather wide and average high as well as the equatorial chamberlets. The annuli are usually moderately undulated; the growth pattern is of the "varians" type.

**Emended description.** Relatively small to moderately large (2-5 mm), inflated to strongly inflated, unribbed forms with "marthae" type rosette (Pl. 3, fig. 6). Occasionally the collar can be undulated. In the equatorial section of the A-forms the excentrilipidene (rarely eulepidene) embryo is medium-sized to moderately large (p= 140-400 μm, d= 200-600 μm). The "varians" type adaxial chamberlets are numerous (N= 17-42), rather wide (W= 30-65 μm) and moderately high (H= 40-80 μm). The equatorial chamberlets are also fairly wide (w=30-45 μm), medium high in the internal annuli and somewhat higher in the external ones (h= 50-100 μm, n= 8-15). The annuli are close to circular to slightly undulate with 6-7 waves. Their growth pattern is of the "varians" type. The microsphere juvénarium (Pl. 3, fig. 5) is biserial, characteristic for Orbitoclypeidae. The most diagnostic feature in the axial section is the distinct thickening of the equatorial layer towards the edges. More details can be found in Less (1987: 203) and Özcan et al. (2001: 345-346, under *O. haymanaensis*).

**Remarks.** Gümbel (1872), Schlumberger (1904) and Less (1987) emphasized the undulated collar as the most diagnostic feature of *O. multiplicatus*. The study on the material from Spilecco suggests, however, that this feature is caused by environmental factors since forms with equatorial characteristics similar to those figured by Schlumberger (1904, pl. 4, fig. 18, representing the type of the equatorial section of the A-forms) have rather unwaved collar. Therefore, this feature should be abandoned as a diagnostic one. Based on our material and assigning also *O. haymanaensis* described by Özcan et al. (2001) as a subspecies of *O. multiplicatus*, the geographical range of the species extends from N Italy to Central Turkey whereas stratigraphically it spans from the middle Thanetian (OZ 1b zone) to at least the late early Ypresian (OZ 4) or even to the late early Ypresian (OZ 6/7) based on the finding of one single specimen in Kırklar, sample KIR 9 (see in Özcan et al. 2007b). The considerable material presented in this paper (and in Özcan et al. 2001, see above) allows us to subdivide *O. multiplicatus* into three successive subspecies as defined below:

- *O. m. haymanaensis* \(d_{\text{mean}} < 310 \mu m\)
- *O. m. multiplicatus* \(d_{\text{mean}} = 310-420 \mu m\)
- *O. m. kastamonuensis* n. sp. \(d_{\text{mean}} > 420 \mu m\)

The evolution of the species can be followed in our material. *Orbitoclypeus multiplicatus haymanaensis* occurs both in the middle Thanetian OZ 1b and in the upper Thanetian OZ 2 zone, since it is recorded from Karaevli, sample KARA 1; *O. m. multiplicatus* appears to be restricted to the earliest Ypresian OZ 3 zone and was found in Spilecco and Şile, sample SİLE 4. The poor assemblage from Ağakese, sample AGA 2 can only be determined as *O. m. cf. multiplicatus*. The most advanced stage of the species known so far, *O. m. kastamonuensis*, occurs in Kastamonu, sample KAS C 9, representing the upper part of the lower Ypresian OZ 4 zone. The single specimen from Kurucu şile (Pl. 3, fig. 4, upper Thanetian, OZ 2 zone) and Kastamonu, sample KAS C 7 (Pl. 3, fig. 14, lowermost Ypresian, OZ 3 zone) do not permit any determination at subspecific level.

It is worth noting, however, that the morphology and the evolutionary track of *Orbitoclypeus multiplicatus*, *O. schopeni* and *O. varians* are very similar. These lineages represent three successive waves of genus *Orbitoclypeus* following each other in the above order with significant shift in time. Therefore, the assignment of a given population to any of these three species is based mainly on the accompanying fossils. Moreover, they respectively gave rise to coeval ribbed lineages such as
O. bayani, O. munieri and O. furcatus that are also very similar to each other.

**Orbitocythereus multiplicatus** (Gümbel, 1870)

*haymanaensis* Özcan, Sirel, Özkán-Altiner & Çolakoğlu, 2001

2001 *Orbitocythereus haymanaensis* Özcan et al., pp. 344-345, 347, pl. 1, figs. 1-13, text-fig. 3A.

Holotype, type locality and type level: As given by Özcan et al. (2001: 144).

Emended diagnosis. *Orbitocythereus multiplicatus* populations with \(d_{\text{mean}}\) less than 310 μm.

Remarks. A detailed description of this taxon (for additional data see Tab. 1) is given by Özcan et al. (2001). This taxon (with a modified stratigraphical range, see above) is here integrated into the *multiplicatus* lineage as its less advanced member. *Orbitocythereus multiplicatus haymanaensis* is hardly distinguishable from *O. schopeni sudekbayensis* and *O. varians roberti*, but these two taxa have distinct stratigraphic ranges. Its equatorial chambers can be slightly wider than those of the other two taxa can but this difference is unconvincing.

**Orbitocythereus multiplicatus multiplicatus** (Gümbel, 1870)

1987 *Orbitocythereus multiplicatus* (Gümbel) - Less, pp. 202-203, text-fig. 30g (corr syn.)

Holotype, lectotype, type locality, type level and the type of the equatorial section of the A-forms: As given by Less (1987: 202).

Diagnosis. *Orbitocythereus multiplicatus multiplicatus* populations with \(d_{\text{mean}}\) ranging between 310 and 420 μm.

Description (see also Tab. 1). Average-sized (2.5-4 mm), inflated, unribbed forms with "marthae" type rosette. The embryo is moderately large, in most cases excrinitellipidene. The numerous, "varians" type adaxillary chambers are rather wide and relatively high. The equatorial chambers are also fairly wide and grow from average-sized to somewhat higher towards the edges. The annuli can be slightly undulated; their growth pattern is of the "varians" type.

Remarks. *Orbitocythereus multiplicatus multiplicatus* is hardly distinguishable from *O. schopeni crimenis* and *O. varians scalars*. Its equatorial chambers can be slightly wider than those of the other two taxa, which have different stratigraphical position.

**Orbitocythereus multiplysus** (Gümbel, 1870)

*kastamonuensis* n. ssp. Less & Özcan

Etymology: Named after the city of Kastamonu.

Holotype: Specimen O/KASC 9-11 (Pl. 3, fig. 17).

Repository: Geology Department of the Istanbul Technical University.

Paratypes: All the other specimens from Kastamonu, sample KAS C 9, illustrated in Pl. 3, figs. 10, 15, 16 and in Fig. 14.

Type locality: Kastamonu (Central Turkey), sample KAS C 9.

Type level: Upper lower Ypresian, the OZ 4 orthophragminid zone.

Diagnosis. *Orbitocythereus multiplicatus* population with \(d_{\text{mean}}\) exceeding 420 μm.

Description (see also Tab. 1). Moderately large (3.5 mm), inflated, unribbed forms with "marthae" type rosette. The embryo is fairly large, almost exclusively excrinitellipidene. The numerous, "varians" type adaxillary chambers are rather wide and relatively high. The equatorial chambers are also fairly wide and moderately high. The annuli can be slightly undulated; their growth pattern is of the "varians" type.

Remarks. *Orbitocythereus multiplicatus kastamonuensis* is hardly distinguishable from *O. schopeni crimenis*, *O. schopeni sudekbayensis* and *O. varians varians*. Its equatorial chambers can be slightly wider than those of the other two taxa, which have a different stratigraphical position.

**Orbitocythereus bayani** (Munier-Chalmas, 1891)

Emended diagnosis. Medium-sized, slightly asteroidal or moderately flattened lenticular forms with 5-7 ribs and "marthae" type rosette. The medium-sized embryo is eu- or excrinitellipidene. The "varians" type adaxillary chambers are average in numbers, rather wide and medium high as well as the equatorial chambers. The annuli are distinctly undulated with 5 to 7 waves; the growth pattern is of the "varians" type.

Emended description. Small to medium-sized (2-6 mm), slightly asteroidal or moderately flattened lenticular forms with 5-7 thick, non-bifurcating ribs and "marthae" type rosette. In the equatorial section of the A-forms the eu- or excrinitellipidene embryo is medium-sized (\(p=120-220 \, \mu m\), \(d=200-425 \, \mu m\)). The "varians" type adaxillary chambers are numerous (\(N=16-34\)), rather wide (\(W=35-50 \, \mu m\)) and of middle height (\(H=35-65 \, \mu m\)). The equatorial chambers are also fairly wide (\(w=30-45 \, \mu m\)), moderately low to medium high (\(h=30-80 \, \mu m\), \(n=10-19\)), becoming occasionally high (up to 130 μm) towards the edges. The cycles are distinctly undulated, with 5-7 stronger waves; their growth pattern is of the "varians" type. The microsphericjuvenarium is not yet known. The characteristics of the axial section are described in Less (1987).

Remarks. *Orbitocythereus bayani* is a rather rare taxon known so far only from the upper Thanetian (OZ 2) and lowermost Ypresian (OZ 3) beds of N Italy and Turkey. Based on the close similarity of their characteristics in the equatorial section and also on their
Fig. 14 - Types of embryo and their variation in *Orbitocypris multiplicatus*, *O. schopeni*, *O. munieri* and *Asterocyclus taramellii*. All × 28.
simultaneous evolutionary track, the ribbed *O. bayani* derived most probably from the unribbed *O. multipli-
catus*. *Orbitoclypeus bayani* is very similar to *O. mu-
nieri* (having derived most likely from *O. schopeni*) that
follows it with a considerable shift in time. They are
confused in Less (1987), however separated in Özcan
et al. (2007b) where more details can be found. Based on
our material *O. bayani* can be subdivided into two suc-
cessive subspecies defined below:

O. b. kurucasileensis n. ssp. \(d_{\text{mean}} < 282 \mu m\)
O. b. bayani \(d_{\text{mean}} > 282 \mu m\)

The less advanced developmental stage occurs in
the upper Thanetian (OZ 2) of Kurucasile whereas O. b.
bayani can be found in the lowermost Ypresian (OZ 3)
of Spileco. The single specimen (Pl. 2, fig. 11) from
Karaevi, sample KARA 2 (upper Thanetian, OZ 2)
cannot be determined at subspecific level while the
three specimens from Sile, sample SILE 4 (lowermost
Ypresian, OZ 3) can be determined as O. b. cf. bayani
(Pl. 2, fig. 12).

**Orbitoclypeus bayani** (Munier-Chalmas, 1891)

*kurucasileensis* n. ssp. Less & Özcan

*Pl. 2, figs 7-15; Fig. 13*

**Etymology**: Named after the settlement of Kurucasile, the
type-locality of the taxon.

**Holotype**: Specimen O/KURU-15 (Pl. 2, figs. 8).

**Repository**: Geology Department of the Istanbul Technical
University.

**Paratypes**: All the other specimens from Kurucasile in Pl. 2,
figs. 7, 9, 10 and in Fig. 13.

**Type locality**: Kurucasile (Northern Turkey).

**Type level**: Upper Thanetian, OZ 2 orthophragmaminid zone.

**Diagnosis**: Populations of *Orbitoclypeus bayani* with \(d_{\text{mean}}\) less
than 280 \(\mu m\).

**Description** (see also Table 1). Small (2-4 mm),
slightly asteroidal forms with 5-7 indistinct ribs and
“marthae” type rosette. The moderately small embryo
is mostly eulepidine, sometimes excentrilepidine. The
“varians” type adaxial chamberlets are average in
numbers, moderately wide and medium high. The equa-
torial chamberlets are medium wide and moderately
low. The annuli are significantly undulated with 5-7
waves; their growth pattern is of the “varians” type.

**Remarks**: The other, non-coeval ribbed represen-
tatives of genus *Orbitoclypeus* with similar-sized em-
byron (the less advanced *O. munieri munieri* and *O.
furcatus* n. ssp. Gibert, to be described later) are in most
cases externally flattened and bear distinct ribs that
sometimes bifurcate whereas *O. bayani kurucasileensis*
is mostly asteroidal. However, this difference can only
be observed in fully developed, well-preserved and
adult forms.

**Orbitoclypeus bayani bayani** (Munier-Chalmas, 1891)

*Pl. 2, figs 13-15, Fig. 13*

1891 *Orthophragmina bayani* Munier-Chalmas, pp. 29, 37.
1924 *Orthophragmina bayani* Munier-Chalmas - Schumberger,
pp. 131-132, pl. 4, figs. 21, 22, pl. 5, fig. 25.
1987 *Orbitoclypeus bayani* (Munier-Chalmas) (parim) - Less,
pp. 201-202, pl. 27, fig. 4 (non 5, 6).

**Holotype, Lectotype, type locality and type level**: As given by

**Diagnosis**: *Orbitoclypeus bayani* populations with \(d_{\text{mean}}\) ex-
ceeding 280 \(\mu m\).

**Description** (see also Table 1). Medium-sized (3-6
mm), slightly asteroidal or moderately flattened lenti-
cular forms with 5-7 indistinct ribs and “marthae” type
rosette. The medium-sized embryo is eulepidine or
excentrilepidine. The “varians” type adaxial chamber-
lets are numerous, rather wide and medium high as
well as the equatorial chamberlets. The annuli are dis-
trictly undulated with 5-7 waves; their growth pattern
is of the “varians” type.

**Remarks**: The other, non-coeval ribbed represen-
tatives of genus *Orbitoclypeus* with similar-sized em-
byron (the more advanced *O. munieri munieri, O.
furcatus rovasendas and O. furcatus furcatus*) are in most
cases externally flattened and bear distinct ribs that
sometimes bifurcate whereas *O. bayani bayani* is very
frequently asteroidal. However, this difference only can
be observed in fully developed, well-preserved and
adult forms.

**Orbitoclypeus schopeni** (Checchia-Rispoli, 1908)

*Orbitoclypeus schopeni* is an unribbed species
having “marthae” type rosette (Pl. 3, fig. 26), a small
to relatively large, eu-, tryblio- and excentrilepidine
embryon, narrow or medium wide, low or medium
high “varians” type adaxial chamberlets and also
narrow or medium wide equatorial chamberlets ar-
ranged into circular or slightly undulated annuli with
usually “varians” type growth pattern. The distal margi-
ns of the annular chamberlets are typically arched or
wedge-shaped. It commonly occurs in the orthophrag-
minid assemblages from SW France to India, especially
in the Thanetian and Ypresian. The earliest appearance
is known from the lower Thanetian beds in India and
SW France, with its reported highest occurrence from
late Lutetian (OZ 11) of Padragkut (Hungary) and San
Pancrazio (OZ 12) (Italy). Further information can be
found in Özcan et al. (2001), Özcan (2002) and Çola-
koğlu & Özcan (2003). Due to the rather rapid evolu-
tion of the lineage, especially in the Thanetian and
Ypresian, it can be subdivided into five successive sub-
species:
O. s. ramaraoi  \(d_{\text{mean}} < 195 \, \mu\text{m}\)
O. s. neumannae  \(d_{\text{mean}} = 195-240 \, \mu\text{m}\)
O. s. suevikayensis  \(d_{\text{mean}} = 240-300 \, \mu\text{m}\)
O. s. crimensis  \(d_{\text{mean}} = 300-500 \, \mu\text{m}\)
O. s. schopeni  \(d_{\text{mean}} > 500 \, \mu\text{m}\)

In our upper Thanetian and lower Ypresian material, O. schopeni occurs in many horizons and is represented by three successive developmental stages fitting very well to the stratigraphic ranges given by Less (1998). Orbitocyclus schopeni ramaraoi (Pl. 3, figs. 20-22; Fig. 14) occurs in Kurucaşile (KURUC, OZ 2, upper Thanetian), O. s. neumannae (Pl. 3, figs. 19, 23-29; Fig. 14) in the lowermost Ypresian beds (OZ 3) of Ağäçekese, sample AGA 2, Şile, sample ŞILE 4, Kastamonu, samples KAS C 5 and 7 and Spilecco (SPILE), finally O. s. suevikayensis (Pl. 3, figs. 30-32; Fig. 14) in the upper lower Ypresian beds (OZ 4) of Kastamonu (samples KAS C 9, 10 and KASA 4). Only the small population from the upper Thanetian beds of Kâraveî (sample KARA 2, OZ 2) is slightly more advanced as compared to its inferred age since it can be determined as O. schopeni cf. neumannae (Pl. 3, fig. 18).

Orbitocyclus munieri (Schlumberger, 1904)

Orbitocyclus munieri is a small- to large-sized ribbed form (with 6 to 9 thick ribs, rarely bifurcated) having “martha“ type rosette (Pl. 2, fig. 26), a small- to medium-sized eu- to excentrilopidine (rarely also tryblito- and umbilicopidine) embryo, the adaxial chamberlets are of the “varians“ type, medium wide and high as are the equatorial chamberlets. Microspheeric forms have not been discovered yet. Undulation of the equatorial annuli is very typical. It occurs from SW France to Turkey. Less (1987) described it still under the name of O. bayani. Later (Less & Ö. Kovács 1996; Less 1999), based on the material from Spilecco, the two species were considered as distinct and O. munieri was subdivided into two subspecies. The less advanced of them, informally called earlier as O. munierii n. ssp. Spilecco, is described below under the name of O. munierii ponticus n. ssp. The formal description of the species can be found in Özcan et al. (2007b). Its earliest appearance is from the upper Thanetian (OZ 2) of Kâraveî and Kurucaşile (Turkey), and then it ranges almost until the end of the Ypresian (OZ 8a, the uppermost part of the Sinemorian beds in the Crimean Peninsula). According to Less & Ö. Kovács (1996), its evolution runs parallel with the unribbed O. schopeni. For additional information, see also Özcan (2002), Çolakoglu & Özcan (2003) and Özcan et al. (2007b). The updated nomenclature and subdivision of the lineage is as follows:

O. m. ponticus n. ssp.  \(d_{\text{mean}} < 220 \, \mu\text{m}\)
O. m. munieri  \(d_{\text{mean}} > 220 \, \mu\text{m}\)

Remarks. Orbitocyclus munieri, O. bayani and Asterocyclus taramelli, from the same upper Thanetian (OZ 2) horizon, represent the oldest ribbed orbitocyclus in the Western Tethys. The inferred close phylogenetic relationship of O. munieri to A. taramelli is discussed in the description of the latter. In our material the newly erected O. munieri ponticus occurs both in the upper Thanetian (OZ 2) of Kurucaşile (sample KURUC) and Kâraveî (samples KARA 1 and 2) and in the lowermost Ypresian (OZ 3) of Spilecco. The two specimens from Ağäçekese (AGA 2, OZ 3) are determined as O. munieri cf. ponticus (Pl. 2, fig. 25). The two specimens from the upper part of the Kastamonu C section (samples KAS C 9 and 10, upper early Ypresian, OZ 4) have been referred to O. munieri cf. munieri (Pl. 2, fig. 30). The stratigraphic boundary of the two subspecies may correspond likely to the OZ 3/4 boundary. Although the material is yet insufficient, we think that O. munieri populations with \(d_{\text{mean}}\) ranging between 220 and 300 \(\mu\text{m}\) occur in the OZ 4 and probably also in the OZ 5 zone whereas all the populations with \(d_{\text{mean}}\) exceeding 300 \(\mu\text{m}\) characterize the OZ 6 to 8a zones.

Orbitocyclus munieri (Schlumberger, 1904) ponticus
n. ssp. Less & Özcan
Pl. 2, figs 16-24, 26-29; Fig. 14

Etymology: Named after the Pontides, the mountain range in Northern Turkey where the type locality is located.
Holotype: Specimen O/KURU-103 (Pl. 2, fig. 20).
Repository: Geology Department of the Istanbul Technical University.
Paratypes: All the other specimens from Kurucaşile in Pl. 2, figs. 16-19 and in Fig. 14.
Type locality: Kurucaşile (Northern Turkey).
Type level: Upper Thanetian, OZ 2 orthophragminid zone.
Diagnosis: Populations of Orbitocyclus munieri with \(d_{\text{mean}}\) less than 280 \(\mu\text{m}\).

Description (see also Tab. 1). Small-sized (2-4 mm), moderately flattened forms with 7-9 thick ribs (practically with no bifurcation) and “martha“ type rosette on the surface. The small embryo is of eulespide type. The relatively few adaxial chamberlets of the “varians“ type are moderately narrow and low. The equatorial annuli are strongly undulated with 7-9 waves. The chamberlets are relatively narrow and low, their growth pattern is of the “varians“ type.

Remarks. Orbitocyclus munieri ponticus can be confused with the ribbed O. furcatus n. ssp. Horsarriue (Less 1998, not yet formally described) and having similar type and similar-shaped embryo. Concerning their quantitative parameters they cannot be distinguished from each other in practice although their stra-
tigraphic ranges do not overlap. However, the ribs of *O. furcatus* mostly bifurcate and its annuli are more regularly undulated. In some cases the separation from *Asteroecylma taramelli* can also be difficult. For details see the description of the latter.

**Orbitocyclus douvillei** (Schlumberger, 1903)

Pl. 3, fig. 33

**Orbitocyclus douvillei** is an unribbed species having “chudevi” type rosette, a small to relatively large, eu-, then tryblio- and excentrulepidine embryo, wide and moderately high, “varians” type adiauxiliary chamberlets and wide and moderately high equatorial chamberlets arranged into circular annuli with “varians” type growth pattern. Distal margins of annular chamberlets are typically wedge-shaped. *Orbitocyclus douvillei* occurs sparsely from SW France to Anatolia and Israel. The earliest occurrence is reported here from the lower Ypresian (OZ 4) of Kastamonu. Özcan et al. (2007a) reported its latest occurrence from the lower Bartonian (OZ 13) of Keçili (Turkey). For more information see also Özcan (2002), Çolakoğlu & Özcan (2003) and Özcan et al. (2007a). *Orbitocyclus douvillei* forms a rapidly developing evolutionary lineage with six successive subspecies with the following biometric limits:

\[
\begin{align*}
O. \text{ d. douvillei} & \quad d_{\text{mean}} < 200 \, \mu m \\
O. \text{ d. vesilytrensis} & \quad d_{\text{mean}} = 200-260 \, \mu m \\
O. \text{ d. n. sp. Gibret} & \quad d_{\text{mean}} = 260-340 \, \mu m \\
O. \text{ d. chudevi} & \quad d_{\text{mean}} = 340-425 \, \mu m \\
O. \text{ d. pamoniensis} & \quad d_{\text{mean}} = 425-580 \, \mu m \\
O. \text{ d. malatyaensis} & \quad d_{\text{mean}} > 580 \, \mu m \\
\end{align*}
\]

One single specimen of *O. douvillei* could be detected from Kastamonu, sample KAS C 9, representing the upper lower Ypresian OZ 4 zone. This is the oldest known occurrence of this species that formally cannot be determined at subspecific level, although, based on the very small embryo, it is very close to *O. douvillei* douvillei.

**Genus Asterocyclina** Gümbel, 1870

**Asterocyclina taramelli** (Munier-Chalmas, 1891)

Pl. 2, figs 31-35; Fig. 14

1891 Orthophragmina taramelli Munier-Chalmas, pp. 29, 33, 37.
1904 Orthophragmina taramelli Munier-Chalmas - Schlumberger, p. 131, pl. 6, figs. 41-46, 51, 57.
1935 Asterocyclina taramelli (Munier-Chalmas) (partim) - Schweighauser, pp. 88-90, text-fig. 58 (partim - on the left side).
1955 Asterocyclina stella (Gümbel) (partim) - Schweighauser, pp. 90-91, text-fig. 59 (partim - on the left side).

Holotype, lectotype, type locality and type level: As given by Less (1987: 195) for Asterocyclina stella taramelli.

**Diagnosis.** Small asteroidal forms with 5-7 rays and “matbae” type rosette. The small embryo is nephro- to semi-isolepidine. The few, “varians” type adiauxiliary chamberlets are low and moderately wide. The equatorial chamberlets are narrow and very low, although they may grow high in the peripheries. The annuli – especially in the first cycles – are rather undulating than asteroidal, 5-7 strong waves can be observed. The growth pattern is of the “varians” type.

**Description.** The test is very small to small (1.5-3 mm), asteroidal with 5-7 rays and with no distinct interray areas. The rosette is of the “matbae” type. In the equatorial section of the A-forms the embryo is small (P = 55-115 μm, d = 100-190 μm), nephro- to semi-isolepidine. The “varians” type adiauxiliary chamberlets are few (N = 4-14), relatively wide (W = 30-60 μm) and very low (H = 20-40 μm). The equatorial annuli, especially in the first cycles, are rather undulating than stellate; 5-7 strong waves can be observed. The growth pattern is of the “varians” type. The equatorial chamberlets in the interray areas are narrow (W = 20-35 μm) and very low (20-30 μm, n = 14-25), although they may become high (up to 80-100 μm) in the peripheries. The microspheric juvenarium is not yet known. Because of the scarce occurrence of the species, the axial section could not be studied yet.

**Remarks.** Asterocyclina taramelli is a rather rare species known from France (Aurignac, sample AUR19 in Less 1998) to Turkey from upper Thanetian to lowermost Ypresian beds (OZ 2 and 3). Less (1987) arranged these forms into the A. stella lineage, however later he (Less 1998: 25) separated them. The main difference between the two taxa is in the character of the equatorial annuli that are rather undulating in A. taramelli, and distinctly stellate in A. stella. They are most likely in close phylogenetic relationship and the change between them might have happened at about the boundary of the OZ 3 and OZ 4 zones. In our material A. taramelli occurs in Kuruçálido (upper Thanetian, OZ 2 zone) and in Spilceco (lowermost Ypresian, OZ 3 zone).

No intraspecific evolution could be detected so far in A. taramelli, however our material allows us to infer the ancestry of the species. In the upper Thanetian (OZ 2) from Karamedli and Kuruçálido transitional forms between *Orbitocyclus munieri ponticus* and *A. taramelli* can be observed (Pl. 2, figs. 16, 17, 21, 24, 31, 32). Specimens with eulepidine embryo were referred to *O. munieri ponticus* whereas specimens with nephrolepidine embryo were ranked with *A. taramelli*. These transitional specimens between the two genera suggest that *Asterocyclina* derived most likely from least advanced *Orbitocyclus munieri* in the late Thanetian OZ 2 zone.
### Conclusions and revision of Thanetian to lower Ypresian orthophragminid zones

The rich assemblages of Thanetian to early Ypresian orthophragminid faunas from several Western Tethyan localities significantly increase our knowledge on their taxonomy, evolution and stratigraphy. First of all, the orthophragminid fauna as a whole is uniform from SW France to central Northern Turkey where the record, however, is much more complete, since the evolution of the *Discocyclina seunesi*, *Orbitocyclus multiplicatus* and *O. bayani* lineages can be followed in greater detail than elsewhere. A new species, tentatively placed in *Nemkovella, N. stockari* is described and new evolutionary stages for the lineages of *Discocyclina seunesi* (*D. s. karabuekensis*), *Orbitocyclus multiplicatus* (*O. m. kastamonuensis*), *O. bayani* (*O. b. kurucasileensis*) and *O. munieri* (*O. m. ponticus*) have been introduced. In Turkey (see also Özcan et al. 2001 and Çolakoğlu & Özcan 2003) we could identify the earliest occurrences of *Nemkovella evae*, *Orbitocyclus multiplicatus*, *O. douvillei* and *Asterocyclina taramellii*.

A revision of the assemblages from Beloslav (Bulgaria) and Spilceco (Italy) already attempted by Less (1998) allowed us to reinstate “seunesi” in *Discocyclina* instead of *Orbitocyclus*, as suggested by Less (1987), to introduce a new evolutionary stage (*D. seunesi beloslavensis*) and to revise the species originally described from Spilcecco (*Discocyclina tenusis, Orbitocyclus multiplicatus, O. bayani* and *Asterocyclina taramellii*).

Using a larger dataset than Less (1987, 1998), the five orthophragminid zones of the Thanetian to early Ypresian time-span, introduced in the latter paper, could be updated (Fig. 15) and redefined (in the case of OZ 2). Revised data of Özcan et al. (2001) and Çolakoğlu & Özcan (2003) are also integrated.

According to our present knowledge no orthophragmines are recorded from the Danian SBZ 1 and from the Selanian SBZ 2 zones. The record starts in the early Thanetian SBZ 3 zone whose lower boundary almost coincides with that of the NP 6 zone. For the sake of simplicity the minor age-deviations between the lower boundaries of the above three chronostratigraphical units indicated in Hardenbol et al. (1998) are not taken into consideration.

The oldest calibrated orthophragminid sites (Nouts-Oras and Boussan Mare in the records, see Less 1998, and the two lowest samples from Beloslav) belong to the OZ 1a zone and contain *Discocyclina seunesi seunesi* (the zonal marker) and *Orbitocyclus schopeni*.

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<th>Geological time in Ma</th>
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**Thanetian**

- *Discocyclina seunesi seunesi*
- *D. seunesi beloslavensis*
- *D. seunesi karabuekensis*
- *D. tenusis*
- *D. pseudobugia*
- *D. archiazi bakhchisaraiensis*
- *D. archiazi staraskelemis*
- *D. archiazi archiazi*
- *D. furoni*
- *D. dispans sironimanni*
- *D. dispans tourlaca*
- *D. agustae aboueterein*
- *D. traboeyevis traboyenis*

**Ypresian**

- *Nemkovella evoe evoe*
- *N. stockari*
- *Orbitocyclus schopeni ramaraai*
- *O. schopeni neumannae*
- *O. schopeni savlukayensis*
- *O. schopeni crinensis*
- *O. munieri ponticus*
- *O. munieri munieri*
- *O. multiplicatus haymanorensis*
- *O. multiplicatus multiplicatus*
- *O. multiplicatus kastamonuensis*
- *O. bayani kurucasileensis*
- *O. bayani bayani*
- *O. douvillei douvillei*
- *O. varians pornayae*
- *Asterocyclina taramellii*
- *A. stella n. sp. Horsarrieu*
ramaraoi. This zone can be correlated with the early parts of the P 4 planktic foraminiferal and SBZ 3 shallow benthic zones and practically with the entire duration of the NP 6 calcareous nanoplankton zone based on data from the above localities (see Less & O. Kovács 1996). The presence of *Discocyclina tenus* in the OZ 1a zone is still to be confirmed because the Ruisseau de Bec site (S France) from where the earliest record of this form is known might belong either to the OZ 1a or to the OZ 1b zone based on the joint occurrence of *Globovelina primaeva* and *Orbitolycephtus schopeni ramaraoi*.

The OZ 1b zone can be recognized in the four upper samples from Beloslav and in the Kikkkavak, Karamazali and Kasrak profiles of the Haymana-Polatlı Basin (Özcan et al. 2001). This zone contains *Discocyclina seunesi beloslavensis* (the zonal marker), *Discocyclina tenus*, *Orbitolycepehtus schopeni ramaraoi* and *O. multiplicatus bayanaensis*. The lower boundary with OZ 1a is recognized in the Beloslav section and roughly corresponds to the boundary of NP 6 and 7 zones. Planktic foraminiferal data suggest P 4 zone while larger foraminifera from the Haymana-Polatlı Basin indicate mostly the co-occurrence with *Globovelina primaeva* (the zonal marker of SBZ 3); however *G. levus* (characteristic for SBZ 4) appears in the uppermost part of the Kikkkavak profile. Nevertheless, it is worth noting that *Assulina yetttae*, assigned by Serra-Kiel et al. (1998) to the SBZ 4 zone, is present throughout the Kikkkavak profile, mostly together with *Globovelina primaeva*.

After the reinterpretation of the Ruisseau de Bec site (S France) and its placement into either the OZ 1a or OZ 1b zone, the OZ 2 zone (for the key-locality of which this site had been proposed by Less 1998) has to be re-defined. Fortunately, two localities from Turkey, Kurucaşile and Karaevli contain a representative orthophragminid assemblage, which is clearly intermediate between the fauna of OZ 1b and that of OZ 3 zones. *Discocyclina seunesi karabuekensis* can serve as a zonal marker for the OZ 2 zone, since in OZ 1b this lineage is represented by a less advanced evolutionary stage (*D. seunesi beloslavensis*). However, *D. seunesi* itself is unknown from any higher levels of the Paleogene. In the OZ 2 zone the ribbed orthophragmines (*Orbitolycepehtus bayani*, *O. munierii* and *Asterocyldina taramellii*) and Nemkovella (*N. evae* and *N. stockari* assigned tentatively to this genus) first appear. The distinction between OZ 2 and OZ 3 is also supported by *Orbitolycepehtus schopeni ramaraoi*, *O. multiplicatus bayanaensis* and *O. bayani kuruusilesenis* last occurring in OZ 2, followed by more advanced evolutionary stages (subspecies) of these lineages (species) in OZ 3. The correlation of the two Turkish sites serving as key-localities for OZ 2 with other subdivisions is hampered by the lack of planktonic data. In both localities the genus *Nummulites* occurs suggesting that their age is at least early Lleridian (SBZ 5) that corresponds still to the late Thanetian of Hardenbol et al. (1998). However, the presence of *Ordvella sphaerica* (of Thanetian age according to Sirel 1998) in the Karaevli assemblage suggests a somewhat older age. Since we have much better data for correlating both the underlying OZ 1b and the overlaying OZ 3 zone with other zonations, the intermediate OZ 2 zone is correlated with them mainly depending on data of the neighboring orthophragminid zones. According to Fig. 15 this means that OZ 2 tentatively corresponds to the late Thanetian in the sense of Hardenbol et al. (1998) and to the SBZ 4 to 6 zones.

A relatively rich set of orthophragminid assemblages is available for OZ 3. The relevant localities and samples are Gamard 7 (France, see Less & O. Kovács 1996 and Less 1998), Spilecco (N Italy), the *Nummulites crinemis* beds of the Bakhchisarai section in the Crimean Peninsula (sample CRICR in Less 1998), the lowermost part of the Sakarya section in the Haymana-Polatlı Basin (sample SAK 3 in Çolakoğlu & Özcan 2003), and finally samples S1LE 4, AGA 2 and the lower part of the Kastamonu C section (samples KAS C 5 and 7). After the extinction of *Discocyclina seunesi* new species of the genus appeared in the OZ 3 zone with the first occurrence of *D. archiaci*, *D. dispansa*, *D. augstae* and *D. furonii*. Only the rare *D. tenus* (with somewhat more advanced evolutionary degree) can be followed from the lower levels. The other three genera are represented by the same lineages (with the exception of *Nemkovella stockari*) as in OZ 2, however in three lineages of *Orbitolycepehtus* (*O. schopeni*, *O. multiplicatus* and *O. bayani*) by considerably more advanced evolutionary stages than in the older strata. As a result four taxa, *Discocyclina archiaci bakhchisaraicensis*, *Orbitolycepehtus schopeni neumamae*, *O. multiplicatus multiplicatus* and *O. bayani bayani* seem to be exclusive for OZ 3. In order to correlate OZ 3 zone with other zonal subdivisions, the Kapellos & Schaub (1973) data from Gamarde (NP 9 and SBZ 5) are not taken into consideration, since they contradict those of Sztáros et al. (1998) indicating NP 10, P 6 and SBZ 8 zones. Moreover, if some of Schaub's Gamarde samples come from the Mames de Gan and not from the Mames du Louts (in the interpretation of Sztáros et al. 1998), the age can be extended into NP 11 and to the lower part of NP 12, too. Planktic data from Spilecco (Barbieri & Medizza 1969) suggest most probably P6 and NP 10 zones, respectively, whereas those from the *Nummulites crinemis* beds of the Bakhchisarai profile (Muzilev 1980; Bugrova 1988) indicate the P 6 and NP 11 zones. Data from sample S1LE 4A provide the age of the matrix of the olistostome and give the upper age limit for sample S1LE 4 (an olistolith) as P 6-7 and NP 12. Nummulitid data are rather controversial. The Spilecco red
beds (Less et al. 2000) can be attributed to the SBZ 7-8 zones while the Nummulites crimenis beds of Crimea belong to SBZ 9 based on Schaub (1981). By summarizing these data the age of the OZ 3 zone may correspond to P 6 (and partly P 5), NP 10 (and partly NP 11) and SBZ 7-8 zones.

The orthophragmminid record for the OZ 4 zone is also significant. The relevant localities and samples are the Campo 1 sample (Spain) of Samsó et al. (1990) cited as PYCMI in Less (1998), sample Gamarde 2 (Less & Ó Kovács 1996 and Less 1998), the boundary layers of the Nummulites crimenis and Asilina placentula beds of the Bakchisarai section (sample CRICP in Less 1998), the major part of the Sakarya section in the Haymana-Polatlı Basin (samples SAP 10-19 in Çolakoğlu & Özcan 2003, whereas samples SAP 23-25 are transitional towards OZ 3), and finally the upper part of the Kastamonu C section (samples KAS C 9 and 10). The new taxa in the OZ 4 zone are Discocyclina pseudosaugaena (the forerunner of the D. fortiis lineage), Orbitotyphos dowiellii and Asterocyclina stella. In addition, Discocyclina archiaci, Orbitotyphos schopeni, O. multiplicitatus (and very probably O. musleri, too) are represented by considerably more advanced evolutionary stages (subspecies) than in OZ 3. Based on their widespread occurrence, D. archiaci stenoschelensis and O. schopeni dorekayensis can be considered as markers for OZ 4. Data from sample Campo 1 and from the Crimea can be taken into account in correlating with other zonations, while those from Gamarde have to be eliminated based on the same arguments as for OZ 3. According to Samsó et al. (1990) and Tosquella et al. (1990) the Campo 1 sample belongs to the SBZ 8 and NP 11 zones (J. Serra-Kiel, pers. comm.). Based on the data of Bugrova (1988) and Muzilev (1980), the transitional layers of the "crimenis" and "placentula" beds of the Bakchisarai profile correspond to the P 6 zone and to the boundary of the NP 11 and 12 zones. According to Schaub (1981) these layers correspond to the transition of the SBZ 9 and 10 zones. By summarizing the above data the OZ 4 zone may correspond to the middle part of the P 6 zone, to the most of NP 11 and to the lower part of the NP 12 zones, and finally to the upper part of the SBZ 8 and to the whole SBZ 9 zone.

Here we do not deal with the younger orthophragmminid zones starting with OZ 5 corresponding to the late Ypresin in our interpretation. During this time, the orthophragmminid assemblages became considerably more diverse than in early Ypresian times. They are discussed in Özcan et al. (2007b). Our new results concerning the Thanetian and early Ypresian are synthesized in Fig. 15 including the revised ranges of orthophragmminid taxa.

Acknowledgements. This paper has been supported by the National Scientific Research Fund of Hungary (OTKA, Grants T 02370 and K 60448) and by the Scientific and Technical Council of Turkey (Project TUBITAK-YDADB+CAG 101Y040). We are grateful to R. Nakov (Sofia), L. Hottinger (Basel) and T. Keskeméti (Budapest) for providing material from Beloslav and Spíčko and to A. Pentelényi (Budapest) for some drawings. Thanks are due to the workers of the Natural History Museum of Basel for their kind help in studying Schweighauser's material from Spíčko. The critical remarks of Johannes Pignatti (Rome) and Marcelle BouDagher-Fadel (London) are highly appreciated.

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key: 111-122 (In Turkish with English abstract), Ankara.


