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

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Abstract. The rich orthophragminid assemblages from the upper Thanetian and lower Ypresian of Turkey are discussed together with the coeval faunas from Spilecco (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 megalospheric individuals. We present the emended description of *Discocyclina seunesi*, *D. tenuis*, *Orbitoclypeus multiplicatus*, *O. bayani* and *Asterocyclina taramellii*. A new species, *Nemkovella stockari* is introduced. The evolutionary lineages of *Discocyclina seunesi*, *Orbitoclypeus multiplicatus* and *O. bayani* are restored for the first time by using the consistent size-increase of the megalospheric embryon that also allowed introducing some new subspecies (*Discocyclina seunesi beloslavensis*, *D. s. karabuekensis*, *Orbitoclypeus multiplicatus kastamonuensis*, *O. bayani kurucasileensis* and *O. munieri ponticus*). 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 reconstruct their early evolution. The chronostratigraphical position of some localities was ascertained from planktic and larger benthic foraminifera, as well as calcareous nannoplankton. In the updated orthophragminid zonation (zones are marked by OZ), OZ 1a corresponds to the early Thanetian, OZ 1b to the middle Thanetian. They are distinguished on the base of the evolution of *Discocyclina seunesi*. In these zones, only two unribbed species of *Discocyclina* and *Orbitoclypeus* each are present. Ribbed *Orbitoclypeus*, and the *genera Asterocyclina* and *Nemkovella* appeared in the redefined OZ 2 zone belonging to the late Thanetian. *Discocyclina archiaci* and *D. dispansa* substituted *D. seunesi* 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 archiaci*, *Orbitoclypeus schopeni* and *O. multiplicatus*.

Riassunto. Le ricche associazioni a orthophragmine provenienti dal Thanetiano superiore e Ypresiano inferiore della Turchia sono qui discusse unitamente alle faune coeve di Spilecco (N Italia) e Beloslav (Bulgaria). Ne vengono revisionate la loro tassonomia, evoluzione e biozonazione nella Tetide Occidentale. Il nostro studio biometrico è basato soprattutto su un gran numero di sezioni equatoriali di individui megalosferici. Noi presentiamo le descrizioni emendate di *Discocyclina seunesi*, *D. tenuis*, *Orbitoclypeus multiplicatus*, *O. bayani* e di *Asterocyclina taramellii.* Si introduce inoltre una nuova specie, *Nemkovella stockari.* Viene ricostruita per la prima volta la linea evolutiva di *Discocyclina seunesi*, *Orbitoclypeus multiplicatus* e *O. bayani,* utilizzando il consistente aumento di dimensioni dell'embrione megalosferico, che pure ha consentito di individuare alcune nuove sottospecie (*Discocyclina seunesi beloslavensis*, *D. s. karabuekensis*, *Orbitoclypeus multiplicatus kastamonuensis*, *O. bayani kurucasileensis* e *O. munieri ponticus*). Grazie alla documentazione particolarmente completa delle orthophragmine del Thanetiano e Ypresiano inferiore della Tetide Occidentale (utilizzando anche dati dal SW della Francia e dalla penisola di Crimea) noi abbiamo potuto ricostruire la loro evoluzione iniziale. La posizione cronostratigrafica di alcune località è stata definita con l'uso dei foraminiferi sia planctonici che bentonici di grandi dimensioni, così come con il nannoplancton 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 seunesi.* In queste zone, sono presenti solo due specie non costate *Discocyclina* e *Orbitoclypeus*. *Orbitoclypeus* costati, i generi *Asterocyclina* e *Nemkovella,* comparvero nella zone OZ 2 zone, come qui definita, di età Thanetiano superiore. *Discocyclina archiaci* e *D. dispansa* sostituirono *D. seunesi* intorna al limite Paleocene/Eocene. L'Ypresiano inferiore può venire sudiviso nelle zone OZ 3 e OZ 4, distinguibili in base ai diversi stadi di sviluppo delle contemporanee linee evolutive, quali *Discocyclina archiaci*, *Orbitoclypeus schopeni* e *O. multiplicatus*.

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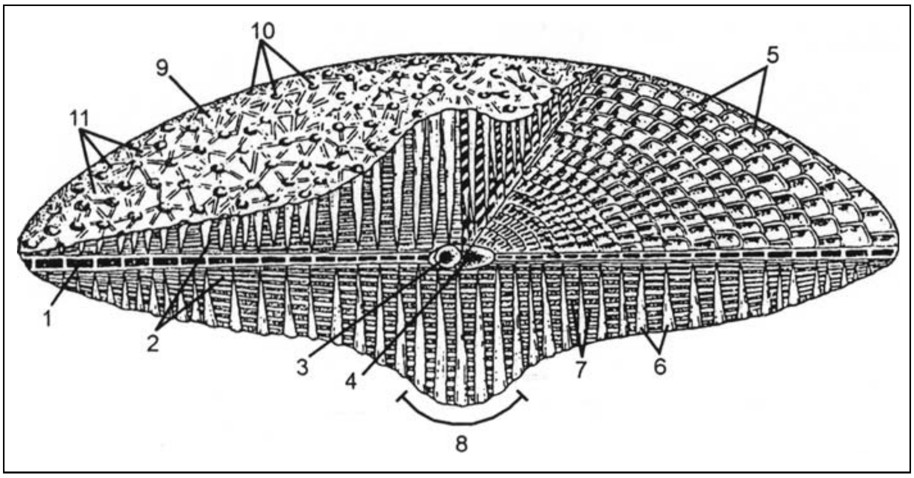


Fig. 1 - General architecture of orthophragminids after Portnaya (1974), with smaller modifications. 1. equatorial layer, 2. lateral layers, 3-4. megalospheric embryon, 3. protoconch, 4. deuteroconch, 5. equatorial chamberlets, 6. piles, 7. lateral chamberlets in vertical section, 8. umbo, 9. collar,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

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 Paleocene 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 (Karaevli and Kurucaşile) and early Ypresian age (Kastamonu, Ağaçkese 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

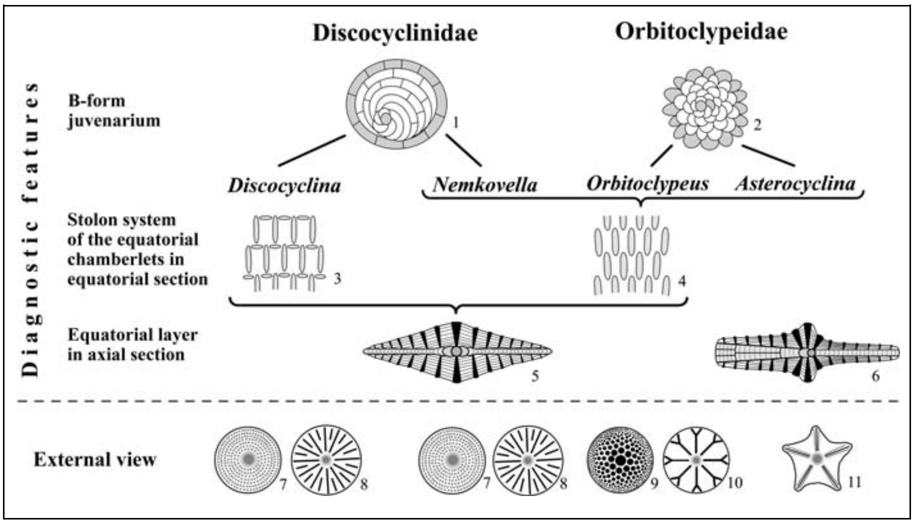


Fig. 2 - Diagnostic features of Tethyan orthophragminid families and genera. 1. spiral microspheric juvenarium; 2. biserial microspheric juvenarium; 3. equatorial chamberlets with annular stolons; 4. equatorial chamberlets without annular stolons; 5. single equatorial layer; 6. axially subdivided equatorial 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 centre, 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.

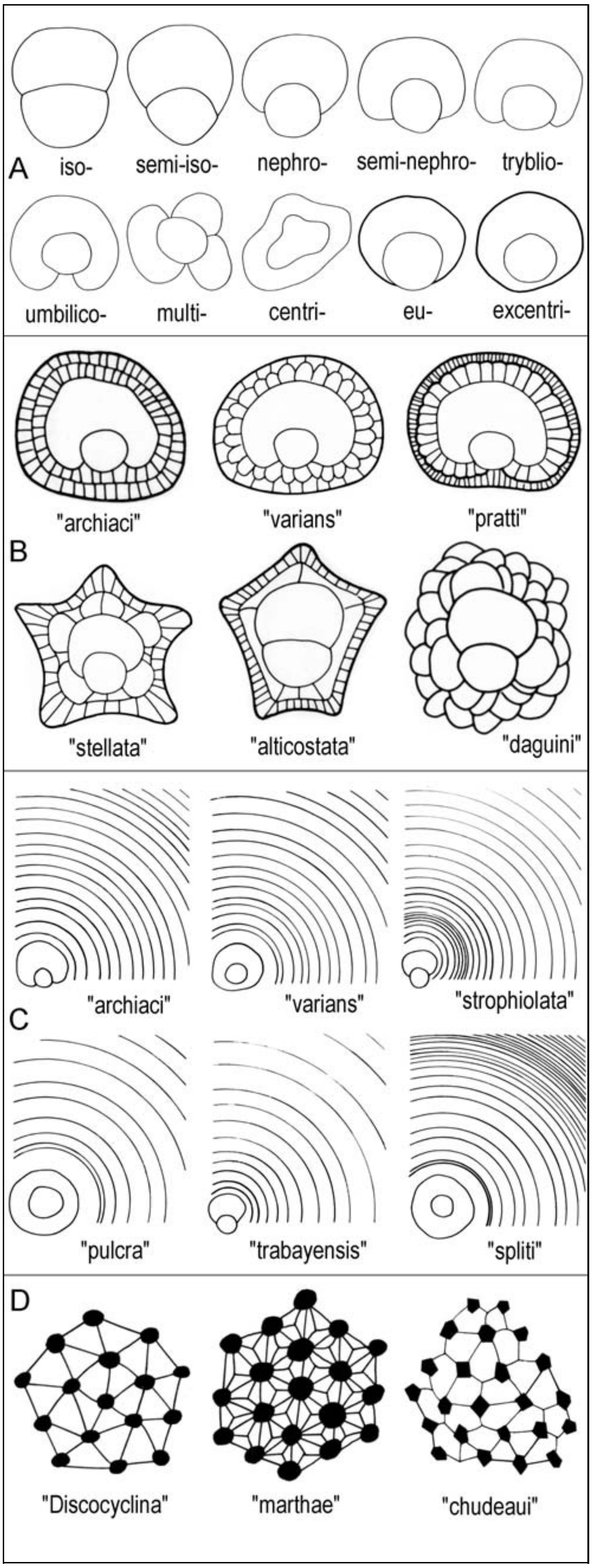


Fig. 3 - Qualitative features of Tethyan orthophragmines. A: embryon types (suffix "-lepidine" is to be added to each type); B: types of adauxiliary chamberlets; C: different growth patterns of the equatorial annuli; D: types of rosette (the network of piles and lateral chamberlets on the test surface).

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 Spilecco orthophragmines - marked by C. - were lent from the Natural History Museum of Basel.

Abbreviations for biozones: NP: Paleogene calcareous nannoplankton 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 microspheric 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).

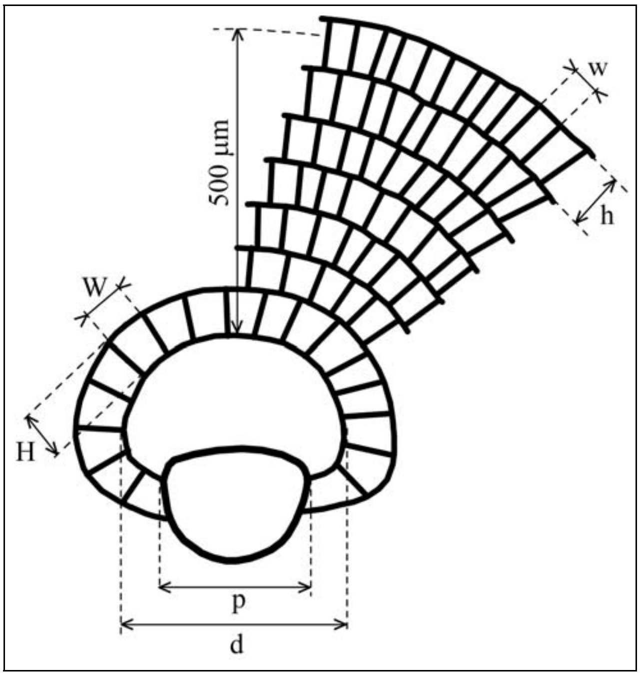


Fig. 4 - The measurement system of megalospheric orthophragmines in equatorial section (after Less 1999, modified). See text for explanation.

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 deuteroconch perpendicular to their common axis (corresponding to P_1 and D_1 in Less 1987)

N: number of the adauxiliary chamberlets (in Fig. 4, N=15)

H and W: height and width of the adauxiliary chamberlets (corresponding to H and L in Less 1987)

n: number of annuli within 0.5 mm distance measured from the deuteroconch along the axis of the embryon (corresponding to $n_{0.5}$ 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 (n°), arithmetical mean and standard error (s.e.) is given only for deuteroconch size (d), the crucial parameter in subspecific determination.

Subspecies are determined according to the biometrical limits of subspecies for populations presented in the description of the given species. No subspecies is determined if only a single specimen is available from joint samples. If the number of specimens is two or three, the subspecies is determined as "cf.". If this number is four or more, however the d_{mean} value of the given population is closer to the biometrical 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 Cuisian, 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 Cuisian (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 (Douvillé 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 Spilecco (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 *Orbitoclypeus 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

Specific determination	Horizon	d (µm) n°	d (µm) range	d (µm) mean±s.e.	p (µm) range	p (µm) mean	N range	H (µm) range	W (µm) range	n range	h (µm) range	w (µm) range	Subspecific determination
Discocyclina seunesi	BELO 0	10	205 – 305	246.5 ± 8.7	115 – 200	156.5	7–16	35–55	35–75	13–17	30–50	25–35	
	BELO 1	27	190 – 305	230.0 ± 4.8	105 – 220	142.6	7–14	25–50	35–75	13–20	25–45	25–35	*seunesi*
	BELO 0+1	**37**	**190 – 305**	**234.5 ± 4.3**	**105 – 220**	**146.4**	**7–16**	**25–55**	**35–75**	**13–20**	**25–50**	**25–35**	
	BELO 2	27	225 – 350	273.3 ± 5.2	110 – 240	165.2	10–19	35–55	35–70	11–16	30–55	25–32	
	BELO 3	20	220 – 365	275.0 ± 6.9	140 – 215	169.0	8–16	40–55	40–80	12–15.5	35–60	27–35	
	BELO 4	4	255 – 305	283.8 ± 10.0	155 – 200	181.2	13–15	40–50	40–60	12–14	35–55	27–32	*beloslavensis*
	BELO 5	23	225 – 345	270.4 ± 6.5	120 – 245	171.1	10–19	40–60	30–75	12–15	35–60	28–35	
	BELO 2–5	**74**	**220 – 365**	**273.4 ± 3.4**	**110 – 245**	**168.9**	**8–19**	**35–60**	**30–80**	**11–16**	**35–60**	**25–35**	
	KURUC	**11**	**225 – 450**	**331.4 ± 19.3**	**125 – 305**	**193.0**	**20–34**	**45–70**	**35–60**	**11–13.5**	**40–55**	**30–35**	*karabuekensis*
	KARA 1	19	245 – 435	328.4 ± 12.6	130 – 225	179.7	16-28	40–60	35–50	13	40–50	30–35	
	KARA 2	42	245 – 450	360.5 ± 8.4	140 – 275	205.9	17–26	40–70	25–60	11–14.5	50–60	30–35	*karabuekensis*
	KARA 1+2	**61**	**245 – 450**	**350.5 ± 7.2**	**130 – 275**	**198.0**	**16–28**	**40–70**	**25–60**	**11–14.5**	**50–60**	**30–35**	
D. archiaci	KAS C 5	3	190 – 310	238.3	95 – 110	102.5	19	35–40	30–35	13–15	45	35	
	KAS C 7	22	205 – 365	272.0 ± 10.0	110 – 190	136.5	13–28	45–80	25–50	10–12	65–140	25–45	*bakhchisaraiensis*
	KAS C 5+7	**25**	**190 – 365**	**268.0 ± 9.8**	**95 – 190**	**132.9**	**13–28**	**35–80**	**25–50**	**10–15**	**45–140**	**25–45**	
	ŞILE 4	**25**	**200 – 435**	**307.4 ± 11.7**	**125 – 210**	**159.5**	**16–31**	**50–85**	**30–45**	**9.5–15**	**45–70**	**30–40**	*staroseliensis–bakhchisaraiensis*
	KAS A 4	**1**		**320.0**		**150.0**							indet. ssp.
D. tenuis	**SPILE**	**2**	**355 – 415**	**385.0**	**200 – 230**	**215.0**	**21–28**	**70**	**45–50**	**8–9**	**60–80**	**35**	–
	KAS C 10	**1**		**580.0**		**280.0**	**38**	**85–110**	**35–50**	**8**	**75**	**25–30**	–
D. dispansa	**ŞILE 4**	**16**	**125 – 195**	**157.8 ± 4.2**	**70 – 110**	**89.4**	**8–14**	**35–45**	**30**	**14–19**	**35–60**	**25–30**	*broennimanni–taurica*
	KAS C 10	**1**		**190.0**		**105.0**							indet. ssp.
Nemkovella evae	**KURUC**	**4**	**175 – 200**	**186.3 ± 4.5**	**130**	**130.0**	**12**	**35–45**	**35–50**	**19**	**50–75**	**35–45**	*evae*
	KARA 1	**1**		**135.0**		**90.0**	**8**			**19.5**			indet. ssp.
	ŞILE 4	**5**	**145 – 185**	**164.0 ± 7.5**	**85 – 115**	**98.0**	**8–11**	**25–35**	**25–35**	**15–18**	**35–45**	**30–35**	*evae*
N. stockari	**KURUC**	**29**	**70 – 95**	**81.4 ± 1.4**	**60 – 105**	**75.7**	**0**	–	–	**13-16**	**55-65**	**30-45**	–
Orbitoclypeus multiplicatus	**KURUC**	**1**		**285.0**		**185.0**							indet. ssp.
	KARA 1	**15**	**250 – 360**	**297.7 ± 8.2**	**140 – 205**	**167.0**	**25–29**	**40–60**	**25–40**	**12**	**45–60**	**30–40**	*haymanaensis*
	AĞA 2	**2**	**260 – 380**	**320.0**	**175 – 215**	**195.0**							cf. *multiplicatus*
	ŞILE 4	**32**	**260 – 420**	**341.4 ± 7.9**	**130 – 255**	**180.5**	**17–39**	**40–65**	**35–50**	**9–13.5**	**50–100**	**35–40**	*multiplicatus*
	SPILE	**12**	**295 – 460**	**392.5 ± 16.4**	**190 – 300**	**238.0**	**19–40**	**40–80**	**40–50**	**8–15**	**50–80**	**35–45**	*multiplicatus*
	KAS C 7	**1**		**370.0**		**200.0**	**34**			**9**			indet. ssp.
	KAS C 9	**10**	**430 – 580**	**497.5 ± 11.6**	**230 – 390**	**283.8**	**32–42**	**45–75**	**30–65**	**9–12**	**50–60**	**30–35**	*kastamonuensis*
O. bayani	**KURUC**	**15**	**200 – 310**	**251.7 ± 8.3**	**125 – 175**	**146.8**	**19–24**	**25–50**	**25–45**	**16–19**	**40–50**	**25–35**	*kurucasileensis*
	KARA 2	**1**		**315.0**									indet. ssp.
	ŞILE 4	**3**	**245 – 420**	**328.3**	**180 – 185**	**182.5**	**24–34**	**45–60**	**35–40**	**10–15**	**30–130**	**30–40**	cf. *bayani*
	SPILE	**29**	**215 – 425**	**332.1 ± 9.4**	**120 – 220**	**171.3**	**18–34**	**40–65**	**38–50**	**9.5–14.5**	**45–75**	**30–45**	*bayani*
O. schopeni	**KURUC**	**18**	**145 – 225**	**185.8 ± 5.7**	**80 – 125**	**106.2**	**13–20**	**30–50**	**25–40**	**13–20**	**50–80**	**25–35**	*ramaraoi*
	KARA 2	**3**	**185 – 245**	**210.0**	**105 – 140**	**122.5**	**19**	**30–35**	**30–40**	**19–22**	**45–50**	**25–40**	cf. *neumannae*
	AĞA 2	**7**	**185 – 230**	**209.3 ± 6.8**	**110 – 150**	**126.7**	**12–15**	**30–35**	**25–35**	**13–18**	**40–60**	**20–30**	*neumannae*
	KAS C 5	12	165 – 290	224.6 ± 11.0	85 – 160	119.0	16–22	25–55	25–45	11–12	80–95	25–35	
	KAS C 7	16	175 – 250	207.2 ± 5.2	85 – 130	107.9	13–22	60	30–45	12–16	55–60	25–50	*neumannae*
	KAS C 5+7	**28**	**165 – 290**	**214.6 ± 5.8**	**85 – 160**	**114.4**	**13–22**	**25–60**	**25–45**	**11–16**	**55–95**	**25–50**	
	ŞILE 4	**25**	**165 – 265**	**210.8 ± 5.0**	**90 – 140**	**112.7**	**12–21**	**30–55**	**25–40**	**13.5–17.5**	**40–80**	**25–35**	*neumannae*
	SPILE	**67**	**165 – 290**	**214.6 ± 3.6**	**95 – 160**	**120.4**	**11–20**	**30–50**	**30–60**	**13–18**	**45–80**	**25–40**	*neumannae*
	KAS C 9	22	195 – 370	277.5 ± 8.4	120 – 185	151.0	13–30	30–40	35–40	11–14	50	25–30	
	KAS C 10	37	230 – 375	288.1 ± 5.6	120 – 205	160.2	20–37	25–50	20–60	12–15	55–90	25–40	*suvlukayensis*
	KAS C 9+10	**59**	**195 – 375**	**284.2 ± 4.8**	**120 – 205**	**157.6**	**13–37**	**25–50**	**20–60**	**11–15**	**50–90**	**25–40**	
	KAS A 4	**13**	**230 – 345**	**279.6 ± 9.8**	**125 – 170**	**144.5**	**25–32**	**30–50**	**25–40**	**11–14**	**50–75**	**25–35**	*suvlukayensis*
O. munieri	**KURUC**	**19**	**155 – 230**	**181.3 ± 4.4**	**90 – 130**	**107.9**	**11–16**	**30–35**	**30–60**	**16–22**	**30–40**	**25–40**	*ponticus*
	KARA 1	6	155 – 200	178.3 ± 7.1	90 – 115	102.5	14–15	25–35	25–40	19	45–50	25–35	
	KARA 2	14	140 – 225	181.8 ± 6.1	85 – 125	104.4	12–18	25–40	25–40	16–21	40–60	25–35	*ponticus*
	KARA 1+2	**20**	**140 – 225**	**180.8 ± 4.8**	**85 – 125**	**103.8**	**12–18**	**25–40**	**25–40**	**16–21**	**40–60**	**25–35**	
	AĞA 2	**2**	**190 – 195**	**192.5**	**110 – 130**	**120.0**	**15**						cf. *ponticus*
	SPILE	**18**	**170 – 235**	**205.0 ± 4.1**	**90 – 130**	**106.8**	**12–17**	**25–40**	**35–50**	**16–18**	**40–70**	**30–35**	*ponticus*
	KAS C 9	1		300.0		175.0		40–50	40				
	KAS C 10	1		260.0		135.0							cf. *munieri*
	KAS C 9+10	**2**	**260 – 300**	**280.0**	**135 – 175**	**155.0**		**40–50**	**40**				
O. douvillei	**KAS C 9**	**1**		**155.0**		**85.0**	**18**			**16**			indet. ssp.
Asterocyclina taramellii	**KURUC**	**3**	**125 – 145**	**135.0**	**75 – 80**	**76.7**	**9–10**	**20–30**	**25–35**	**18–21**	**60–80**	**25–35**	–
	SPILE	**10**	**110 – 190**	**147.0 ± 8.1**	**70 – 115**	**88.9**	**7–14**	**20–40**	**35–60**	**14–25**	**20–30**	**25–35**	–

Tab. 1 - Statistical data of orthophragminid populations (see text for the abbreviation of parameters).

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

Less (1998) integrated a much wider material for the subdivision of the Thanetian-"Ilerdian" interval by orthophragmines. The former O.1 has been subdivided into OZ 1a and 1b based on the evolution of *Discocyclina seunesi* from Beloslav (Bulgaria) presented in detail in this paper. It also allowed re-assigning "*seunesi*" to *Discocyclina*. In the lower Thanetian from Boussan Mare and Nouts-Oraas (both S France), we also could find primitive representatives of the *Orbitoclypeus schopeni* (formerly *O. ramaraoi*) lineage together with *D. seunesi*. In a third sample from S France (Ruisseau de Bec) another *Discocyclina* different from *D. seunesi* 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. seunesi* 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. tenuis* n. ssp. Ruisseau de Bec and OZ 3 with *D. tenuis tenuis*. Unfortunately, this turned out to be a misinterpretation since the Ruisseau 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.

Discocyclina tenuis was also identified from Gamarde (France) in Less (1998) together with *D. archiaci bakhchisaraiensis* and *D. dispansa broennimanni* described from the *Nummulites crimensis* 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 *Orbitoclypeus multiplicatus* and *O. bayani* 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 (*Discocyclina archiaci staroseliensis*, *D. pseudoaugustae* and *Orbitoclypeus schopeni suvlukayensis*) as in the transitional layers of the *Nummulites crimensis* and *Assilina placentula* beds of the Bakhchisarai profile where O.4 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 orthophragminid fauna of the Kırkkavak, Karahamzalı 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 Kırkkavak profile. The orthophragminid assemblage contains four different species, *Discocyclina seunesi*, *D. tenuis* (described as *Discocyclina*. sp. 1), *Orbitoclypeus multiplicatus* (described as *O. haymanaensis*) and *O. schopeni* (described as *O. neumannae*). The composition of this assemblage also shows that *D. seunesi* and *D. tenuis* are not successive but simultaneous taxa. The evolutionary stage of *D. seunesi* 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 orthophragminid 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 *Discocyclina archiaci* and *Orbitoclypeus schopeni* lineages. In the uppermost samples, some new lineages appear as well showing a kind of their transition to OZ 5, the lowest orthophragminid zone of the late Ypresian (Cuisian).

Summarizing our recent knowledge on the Thanetian and early Ypresian orthophragmines of the Western Tethys, we can state that the orthophragminid record for this time-span is still rather discontinuous. Especially the late Thanetian orthophragmines 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 orthophragmines 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

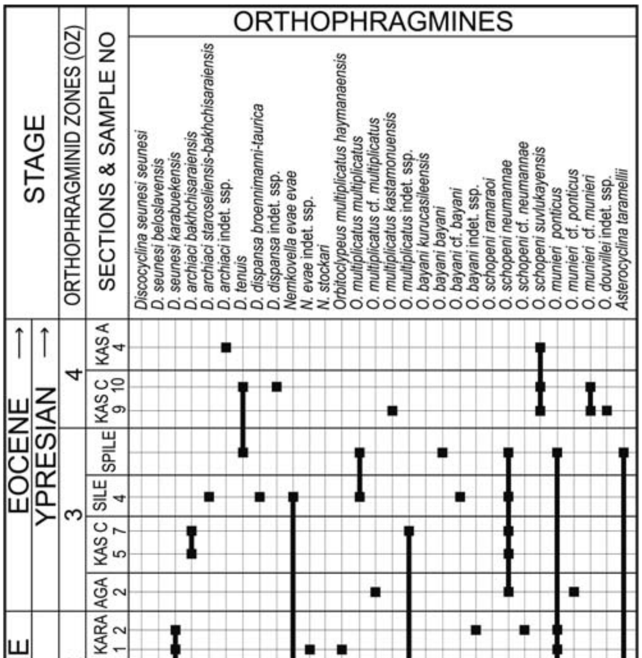


Fig. 5 - Distribution of Thanetian and early Ypresian orthophragminid taxa in the studied sections.

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 & Ó. 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 Spilecco (Fig. 5) is a key association for the OZ 3 zone. *Orbitoclypeus* comprises the overwhelming majority of the assemblage and is represented by the unribbed *O. schopeni neumannae* and *O. multiplicatus multiplicatus* together with the ribbed *O. munieri ponticus* and *O. bayani bayani* that internally correspond to the above two unribbed forms. *Asterocyclina taramellii* is very rare and *Discocyclina tenuis* is even rarer (it has been found only in the Schweighauser 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 bolcensis*, *N. spileccensis*, *N. oppenheimi*, *N. pernotus* and *Assilina custugensis* can be recognized. This assemblage corresponds to the SBZ 7-8 zones.

Beloslav (Bulgaria)

The Beloslav profile crops out in NE Bulgaria, 20 km W of Varna, and represents the epicontinental facies of the Moesian platform. The outcrop, lying in the SW periphery of the settlement near a temporary gypsy camp, is described in detail by Aladzhova-Khischeva et al. (1983) and Aladzhova-Khrischeva (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-Khrischeva et al. (1983) to the upper Ilerdian (upper part of the lower Ypresian). This latter formation together with the overlying Dikilitash 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. Nakov (Sofia) 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. seunesi* described from the Paleocene of Bénesse (SW France) and investigated by Less & Ó. Kovács (1996) and Less (1998) also from other Thanetian localities of this region (Boussan Mare, Nouts-Oraas). *Discocyclina seunesi*, 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. seunesi seunesi*, while the upper four populations are separated into the newly described *D. s. beloslavensis*. Since these two taxa are zonal markers, the lower two

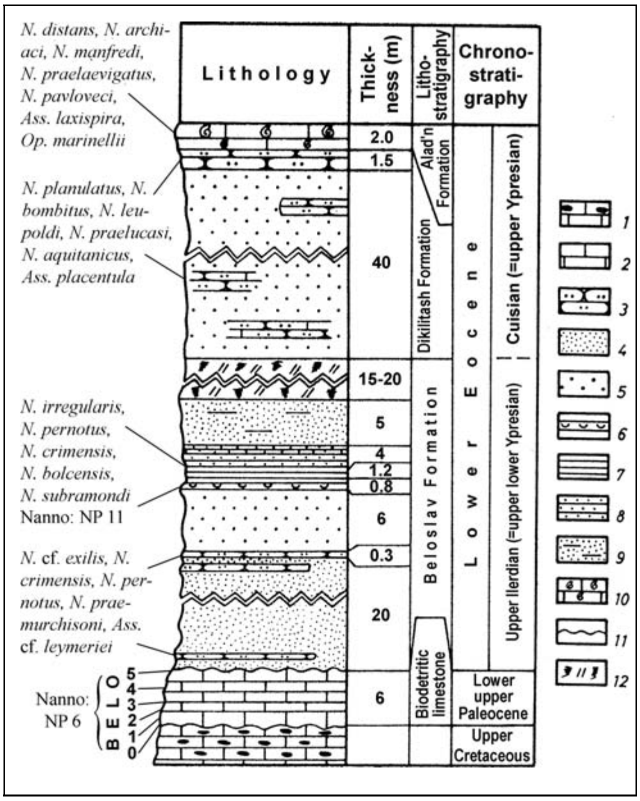


Fig. 6 - Stratigraphic log of the Beloslav profile according to Aladzhova-Khrischeva et al. (1983) and Aladzhova-Khrischeva (1984). 1. Marly limestone with cherts; 2. red algal limestone; 3. sandy limestone; 4. yellowish, coarse-grained sand; 5. whitish quartzose sand; 6. lumachelle; 7. sandy marl; 8. sandy/silty clay; 9. brownish silty sand; 10. nummulitic 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.

Aladzhova-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 İstanbul and Sakarya zones, separated by the Intra-Pontide suture. The measuring of the profiles and the sampling was carried out by E. Özcan.

Kurucaşile. In central northern Turkey marine early Tertiary units, referred to as Atbaşı Formation, are known along the Black sea coast between Bartın and Cide regions (Ketin & Gümüş 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 volcanoclastic units (Baldıran and Yemişliçay Formations) and deep-marine fine clastic rocks and carbonates of Campanian Maastrichtian age (Gürsökü Formation). Campanian-Maastrichtian larger foraminifera occur widely in different levels of this latter formation (Özcan & Özkan-Altıner 1999). The Atbaşı Formation is usually devoid of larger foraminifera, except for only few horizons, which contain a rather rich assemblage of orthophragminids. Sample KURUC, collected from a sandstone horizon of this unit in the central part of town of Cide, contains mainly orthophragmines and few indeterminable, 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 seunesi*-lineage co-occur with other forms (*Nemkovella evae* and the three ribbed forms: *Orbitoclypeus bayani kurucasileensis*, *O. munieri ponticus* and *Asterocyclina taramellii*) for which Kurucaşile and Karaevli (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 Kurucaşile 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 orthophragmines, nummulitid and alveolinid foraminifera in successive horizons (Koçyiğit 1987). Two sections (Karaevli - KARA and Ağaçkese - AĞA) were sampled from the basin succession (Fig. 8). The upper part of the sequence is described in Özcan et al. (2007b).

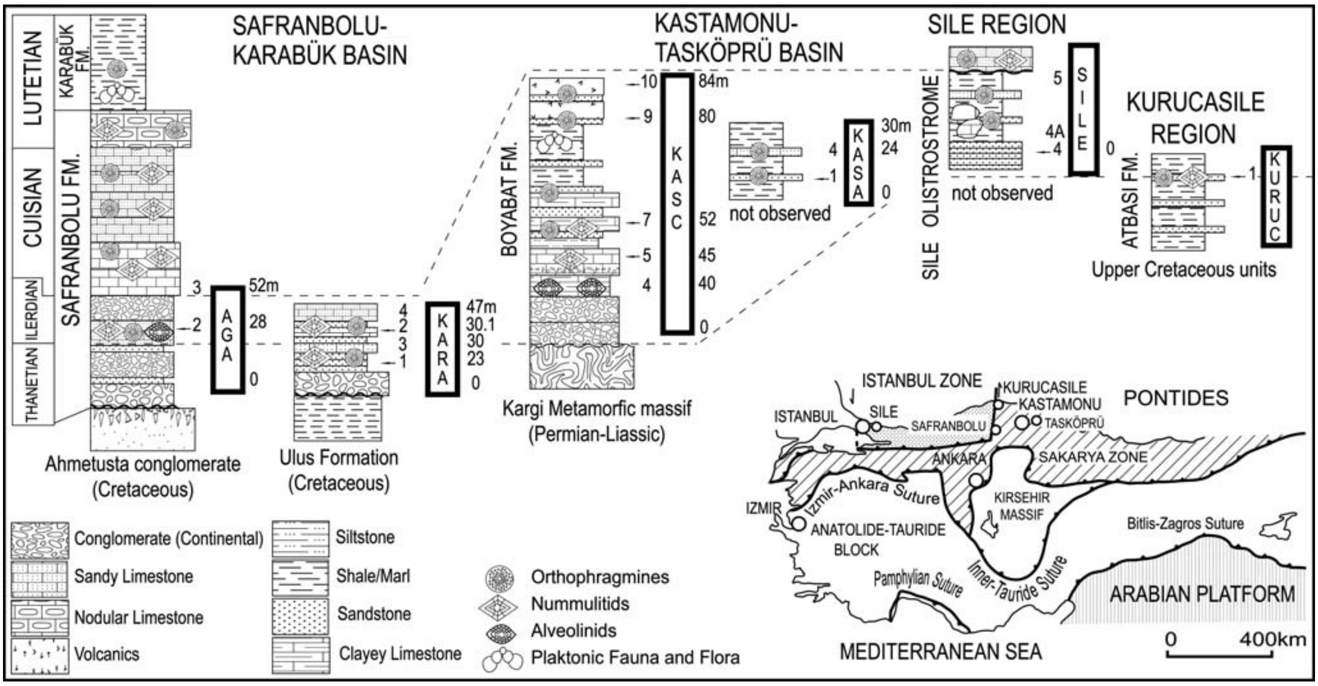


Fig. 7 - Synthetic stratigraphic sections of the sedimentary succession in Central and Northern Turkey and position of the studied stratigraphic intervals (tectonic map simplified from Okay et al. 2001). The horizons with loose tests of orthophragmines are shown by arrow.

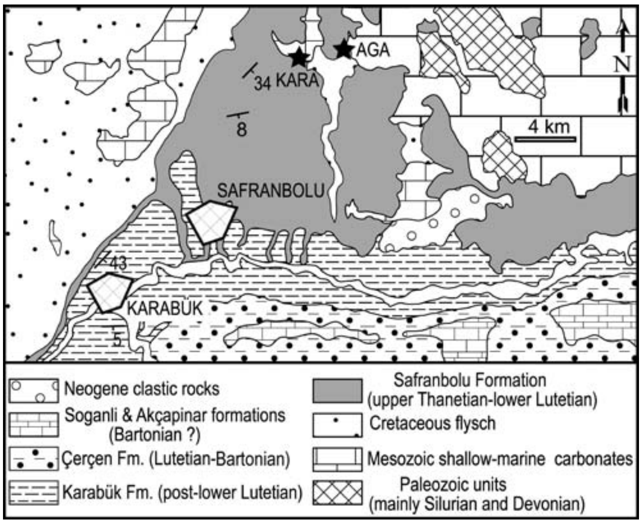


Fig. 8 - Locality map of the orthophragminid-bearing stratigraphic sections near Karabük and Safranbolu in central northern Turkey (geological map simplified from Saner et al. 1980).

Karaevli. The lowermost part of the transgressive Lower Paleogene units of the Safranbolu-Karabük Basin is nicely exposed near Karaevli village, about 11 km to the north of Safranbolu (Fig. 8). This 45-m-thick sequence was measured and sampled along the road from Karaevli to Kırıklar, starting from the basal conglomerate cliffs exposed in Karaevli 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 bryozoans, echinoids and rotaliids. *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 miliolids, textularids, bryozoans 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.

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

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

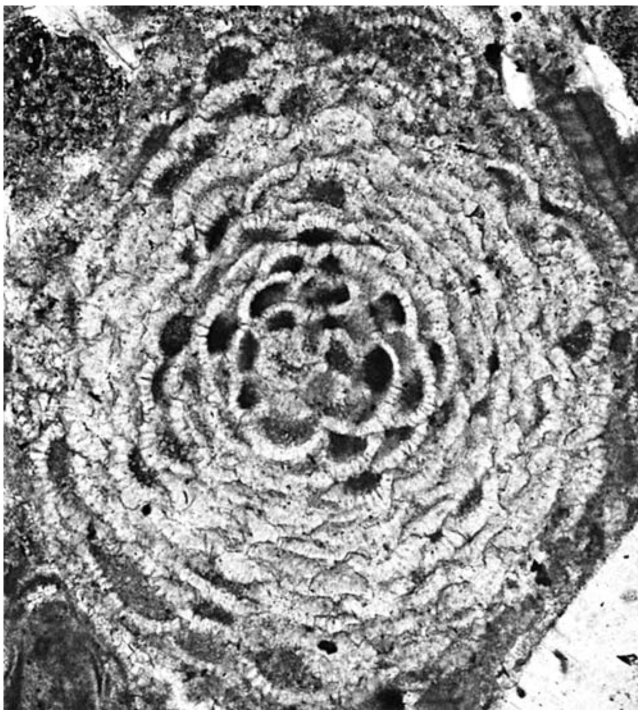


Fig. 9 - *Orduella sphaerica* Sirel from Karaevli (sample KARA 3), O/KARA.3-4, × 100.

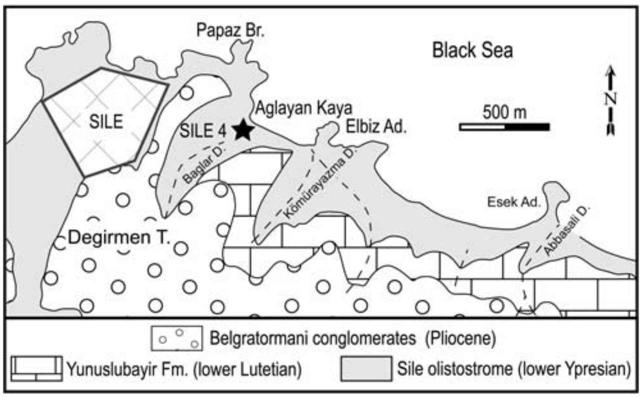


Fig. 10 - Locality map of the samples collected in the close vicinity of Şile (İstanbul). Geological map simplified from Baykal & Önalan (1979).

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 ŞİLE 4) yielded a remarkable quantity of orthophragmines (Fig. 5). The biometric data of genus *Orbitoclypeus* fit very well with those from Spilecco (Italy), thus indicate the OZ 3 zone, although the evolutionary degree of the two *Discocyclina* 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 (ŞİLE 4A laterally interfingering with ŞİLE 4 and ŞİLE 5 about 2 km to the WSW). The calcareous nannoplankton (studied by M. Báldi-Beke) of both samples are clearly mixed, containing even late Cretaceous (but not Maastrichtian) forms, then the Paleocene *Heliolithus kleinpelli* (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. Kollányi) 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 Kargı 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-

Smaller foraminifera	Şile 4A	Şile 5
Tritaxia alpina (Cushman)	+	+
Dorothia beloides Hillebrandt	+	
Nodosaria latejugata Gümbel	+	
Nodosaria sp.	+	
Dentalina sp		+
Lenticulina sp.	+	+
Marginulina enbornensis Bowen	+	+
Discorbis sp.	+	
Plectofrondicularia sp.		+
Globorotalia pseudotopilensis (Subbotina)	+	
Acarinina nitida (Martin)	+	+
A. primitiva (Finlay)	+	+
A. soldadoensis angulosa (Bolli)		+
A. soldadoensis soldadoensis (Brönnimann)	+	+
Morozovella formosa gracilis (Bolli)	+	
Globigerina linaperta Finlay	+	+
Cibicides lobatulus (Walker and Jacob)		+
Cibicidoides alleni (Plummer)		+
Calcareous nannoplankton		
Transversopontis pulcher (Defl.)	few	few
Discolithina sp.		few
Zygodiscus sp.		1–2
Blackites div. sp.	1	rare
Lophodolithus nascens Bramlette et Sullivan		3
Zygrhablithus bijugatus (Deflandre)	1	1
Coccolithus pelagicus (Wallich)	rare	few
Cyclococcolithus formosus Kamptner	1–2	1–2
Chiasmolithus solitus (Bramlette et Sullivan)	1	
Ch. consuetus (Bramlette et Sullivan)		1
Heliolithus kleinpelli Sullivan		1
Discoaster barbadiensis Tan		1
D. multiradiatus Bramlette et Riedel	1	2
D. lodoensis Bramlette et Riedel	1	few
D. cf. *deflandrei* Bramlette et Riedel	1	
Tribrachiatus orthostylus (Shamrai)	2	few
Braarudosphaera bigelowi (Gran et Braarud)	1–2	1
Sphenolithus anarrhopus Bukry et Bramlette	1	
Micrantholithus vesper Deflandre		1–2
Reworked Cretaceous taxa:		
Chiastozygus sp.	1	
Zeugrhabdotus embergeri (Noël)		1
Eiffellithus eximius (Stover)	1–2	1
Watznaueria barnesae (Black)	few	rare
Arkhangelskiella sp.		1
Microrhabdulus sp.		1

Tab. 2 - Smaller foraminifera and calcareous nannoplankton from samples ŞİLE 4A and 5.

clastic limestones and fine clastics, overlain by a prominent shaly succession which includes substantial amounts of volcanic and volcaniclastic units, known as Boyabat Formation. The lowermost part of this unit, with a thickness of about 80 m, contains a rich association of nummulitids and alveolinids, and several horizons with orthophragmines. In the same region a few horizons in the lowermost portion of the overlying shales and volcaniclastics were also found to contain nummulitids and orthophragmines. Two sections (KAS C and KAS A) discussed below contain early Ypresian orthophragmines.

Kastamonu C (KAS C) section. This 84-m-thick sequence of the Boyabat Formation is exposed about 2 km to the west of Kastamonu. At the bottom, it is made

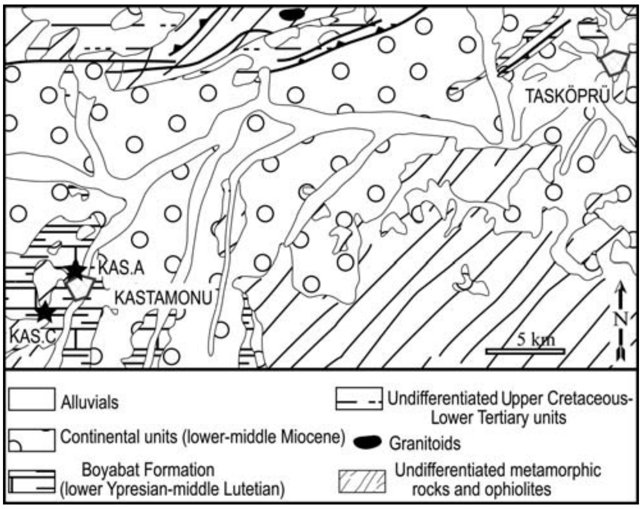


Fig. 11 - Locality map of the orthophragminid foraminifera-bearing sections near Kastamonu (map after the "Geological map of Turkey", Sinop sheet in 1:500,000 scale, 2002).

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 *Orbitolites* sp. (KASC 4) but with rare tests of nummulitids, suggest a low-energy depositional environment of a marine platform. Orthophragmines are not recorded from these horizons. Further up, bioclastic limestones and calcareous sandstones contain a wealth of nummulitids, to a lesser extent accompanied by orthophragmines. 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 bakhchisaraiensis* and *Orbitoclypeus 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 orthophragminids 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 orthophragmines and nummulitids. The orthophragminid assemblage (Fig. 5) marks the OZ 4 zone (late early Ypresian) based on the occurrence of *Orbitoclypeus schopeni suvlukayensis*, 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 ŞİLE 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 Saraçlar 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 orthophragmines accompanied by rotalids, alveolinids, bryozoans and echinoid plates, which are interpreted as transported from shallow-water realm. The orthophragminid assemblage contains *Orbitoclypeus schopeni suvlukayensis* and very sporadic *Discocyclina archiaci* indet. ssp. 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 orthophragmines

We only give full descriptions for new species and for *Discocyclina seunesi*, *D. tenuis*, *Orbitoclypeus multiplicatus*, *O. bayani* and *Asterocyclina taramellii*. 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. 3.

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* Gümbel, 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 megalospheric embryon is usually eulepidine; the two chambers are moderately small. The arcuate adauxiliary chamberlets (of the "varians" type) are few to average in numbers, moderately narrow and low. The equatorial chamberlets are moderately wide and rather low, their annuli are circular, the growth pattern is of the "varians" 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 chamberlets, thus the rosette is of the "Discocyclina" type with slight trend towards the "marthae" type. The protoconch is small- to medium-sized (p= 100-300 µm), relatively large compared to the deuteroconch (d= 180-450 µm). Therefore, the embryon is mostly eulepidine or occasionally tryblio- or excentrilepidine. The number of the adauxiliary chamberlets 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 "varians" type. The equatorial chamberlets 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 chamberlets are very slightly hexagonal. The annuli are circular; their growth pattern is of the "varians" 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).

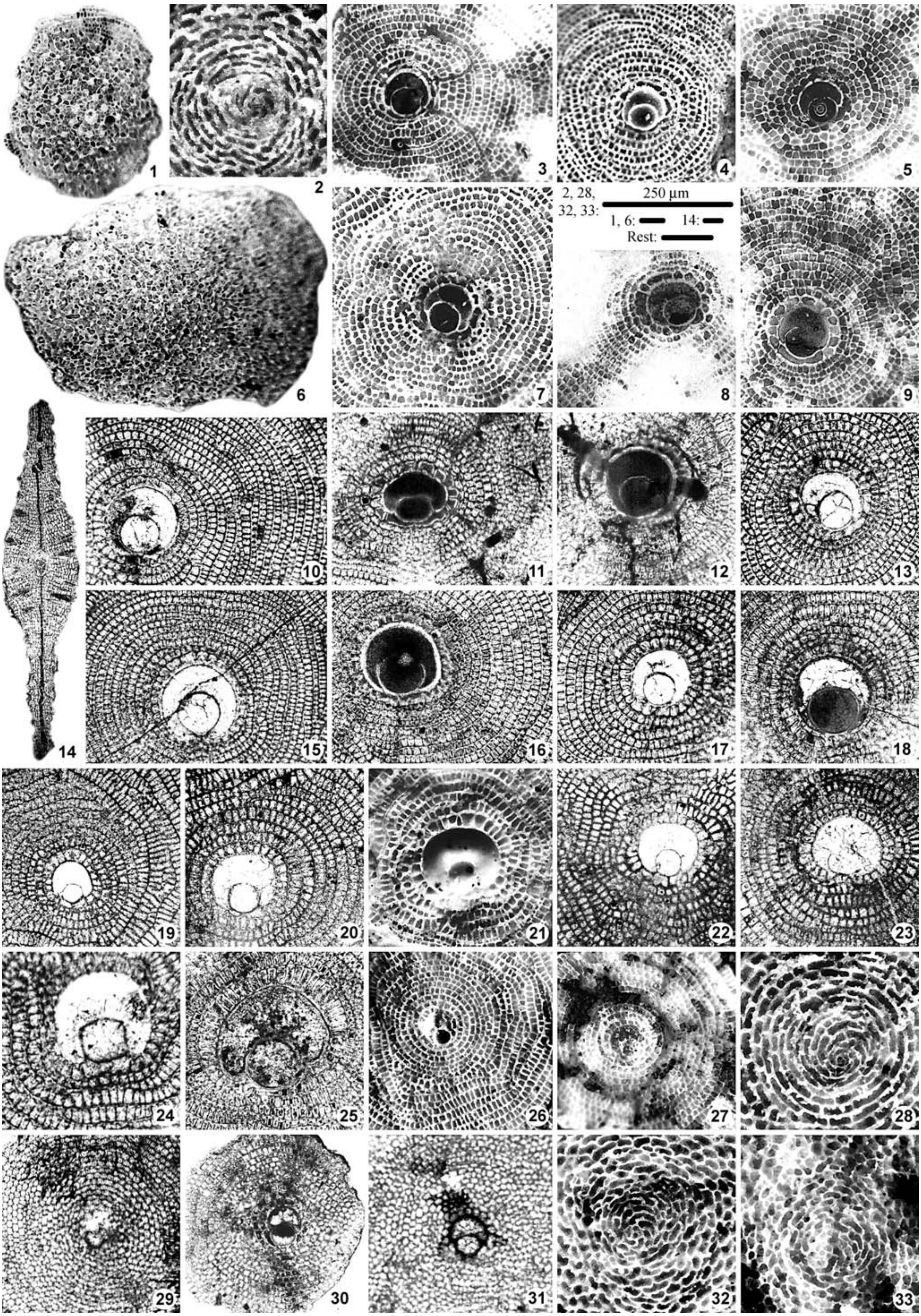
Remarks. Due to the well-preserved material from Beloslav (Bulgaria), the type of the microspheric juvenarium and the presence of the annular stolon of the equatorial chamberlets could be recognized, thus this species is assigned to *Discocyclina* instead of *Orbitoclypeus* as in Less (1987), who based 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	d_{mean} < 250 µm
D. s. beloslavensis	d_{mean} = 250-310 µm
D. s. karabuekensis	d_{mean} > 310 µm

Discocyclina seunesi beloslavensis n. ssp. formally replaces *D. seunesi* n. ssp. 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 Özcan 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. karabuekensis* n. ssp. have been found in the upper Thanetian OZ 2 zone of Karaevli (samples KARA 1 and 2) and Kurucaşile (sample KURUC).

PLATE 1

1-5: *Discocyclina seunesi seunesi* Douvillé, Beloslav, sample BELO 1, lower Thanetian, OZ 1a. 1: E.06.72., 2: E.06.87., 3: E.06.85., 4: E.06.82., 5: E.06.83.
6-9: *Discocyclina seunesi* Douvillé *beloslavensis* n. ssp., Beloslav, middle Thanetian, OZ 1b. 6, 8, 9: sample BELO 2; 6: E.06.73., 8: E.06.95., 9: E. 06.92., holotype; 7: sample BELO 3, E.06.97.
10-18: *Discocyclina seunesi* Douvillé *karabuekensis* n. ssp., upper Thanetian, OZ 2. 10-12, 14-16: Karaevli: 10, 11, 15, 16: sample KARA 2: 10: O/KARA.2-25, 11: O/KARA.2-60, 15: O/KARA.2-1, holotype, 16: O/KARA.2-8; 12: sample KARA 1: O/KARA.1-20; 14: sample KARA 5, O/KARA.5-3; 13, 17, 18: Kurucaşile: 13: O/KURU-53, 17: O/KURU-58, 18: O/KURU-50.
19, 20: *Discocyclina archiaci* (Schlumberger) *bakhchisaraiensis* Less, Kastamonu, sample KAS C 7, lowermost Ypresian, OZ 3. 19: O/KASC.7-44, 20: O/KASC.7-24.
21-23: *Discocyclina archiaci* (Schlumberger) ex. interc. *staroseliensis* Less et *bakhchisaraiensis* Less, Şile, sample ŞİLE 4, lowermost Ypresian, OZ 3. 21: O/ŞİLE.4-45, 22: O/ŞİLE.4-102, 23: O/ŞİLE.4-115.
24, 25: *Discocyclina tenuis* Douvillé. 24: Spilecco, lowermost Ypresian, OZ 3, C.25413/4; 25: Kastamonu, sample KAS C 10, lower Ypresian, OZ 4, O/KASC.10-39.
26-28: *Discocyclina dispansa* (Sowerby) ex. interc. *broennimanni* Less et *taurica* Less, Şile, sample ŞİLE 4, lowermost Ypresian, OZ 3. 26: O/ŞİLE.4-26, 27: O/ŞİLE.4-48, 28: O/ŞİLE.4-19.
29: *Nemkovella evae* Less indet. ssp., Karaevli, sample KARA 1, upper Thanetian, OZ 2, O/KARA.1-35.
30-33: *Nemkovella evae evae* Less. 30, 31: Kurucaşile, upper Thanetian, OZ 2; 30: O/KURU-27, 31: O/KURU-26. 32, 33: Şile, sample ŞİLE 4, lowermost Ypresian, OZ 3, 32: O/ŞİLE.4-55, 33: O/ŞİLE.4-75.
1, 6: A-form, external views, 20×; 2, 28, 32, 33: B-form, equatorial sections, 100×; 14: A-form, axial section (slightly off-center), 16×. All others: A-form, equatorial sections, 40×.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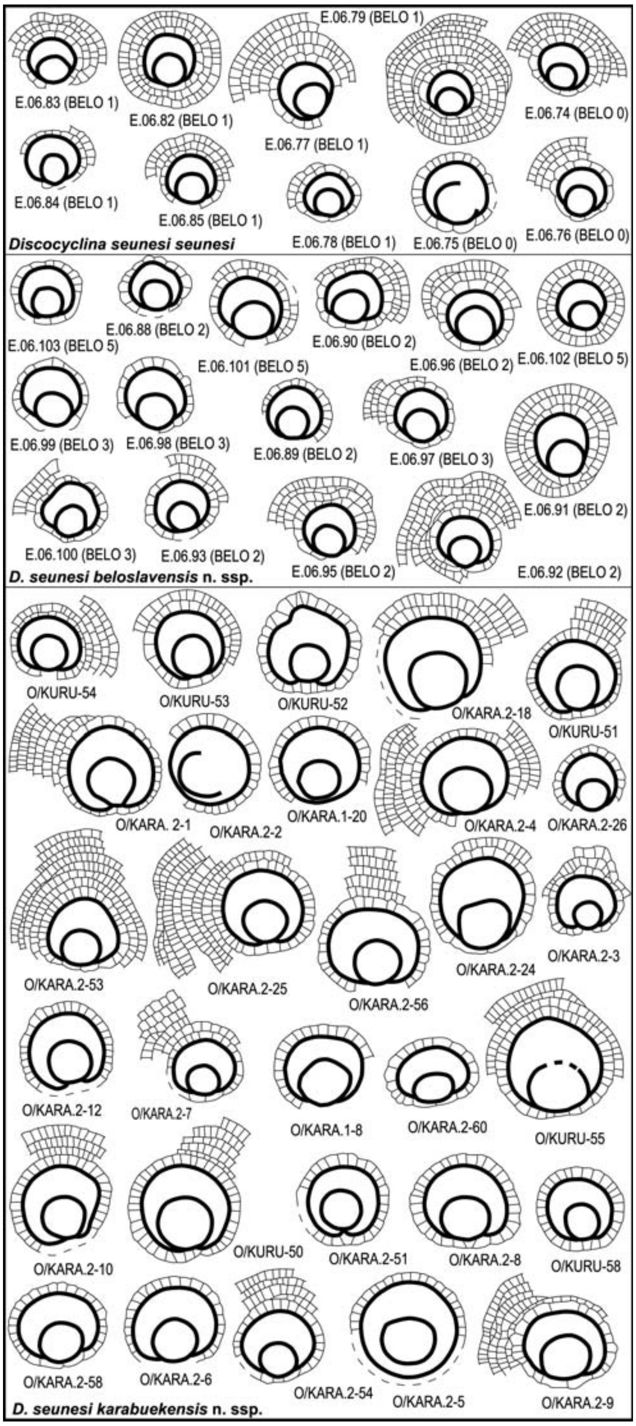


Fig. 12 - Types of embryon and their variation in *Discocyclina seunesi*. All ×28.

Discocyclina seunesi seunesi Douvillé, 1922

Pl. 1, figs 1-5; Fig. 12

1922 *Discocyclina seunesi* Douvillé, pp. 64-65, pl. 4, figs. 1-4, text-figs. 1, 6, 15.

1958 *Discocyclina seunesi* Douvillé (partim) - Neumann, pp. 109-110, pl. 23, figs. 1-7, pl. 25, fig. 2, text-fig. 34.

Holotype, type locality, type level and the type of the equatorial section of A-forms: As given by Less (1987: 195).

Diagnosis. *Discocyclina seunesi* populations with d_{mean} less than 250 µm.

Description (see also Table 1). Small, moderately flattened, unribbed forms. The embryon is small, eu- to slightly trybliolepidine. The relatively few, "varians" type adauxiliary 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. *Discocyclina seunesi seunesi* can be distinguished from the other unribbed representatives of the genus (*D. archiaci bakhchisaraiensis*, *D. furoni*, *D. dispansa taurica*, *D. d. hungarica*, *D. augustae augustae*) by its mostly eulepidine embryon and adauxiliary chamberlets with arcuate outer wall ("varians" type).

Discocyclina seunesi beloslavensis n. ssp. Less & Özcan

Pl. 1, figs 6-9; Fig. 12

2001 *Discocyclina 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 orthophragminid zone.

Diagnosis. *Discocyclina seunesi* populations with d_{mean} ranging between 250 and 310 µm.

Description (see also Table 1). Small, moderately flattened, unribbed forms. The embryon is moderately small, in most cases eulepidine. The few to average in numbers, "varians" type adauxiliary 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. *Discocyclina seunesi beloslavensis* can be distinguished from the other unribbed representatives of the genus (*D. archiaci bakhchisaraiensis*, *D. furoni*, *D. dispansa hungarica*, *D. d. sella*) by its mostly eulepidine embryon and adauxiliary chamberlets with arcuate outer wall ("varians" type).

Discocyclina seunesi karabuekensis n. ssp. Less & Özcan

Pl. 1, figs 10-18; Fig. 12

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

Holotype: Specimen O/KARA.2-1 (Pl. 1, fig. 15).

Repository: Geology Department of the İstanbul 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 seunesi* population with d_{mean} exceeding 310 μm.

Description (see also Table 1). Small, moderately flattened, unribbed forms. The embryon is average in size, eulepidine and sometimes excentrilepidine. The average in numbers, "varians" type adauxiliary 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. *Discocyclina seunesi karabuekensis* can be distinguished from the other unribbed representatives of the genus (*D. archiaci staroseliensis*, *D. dispansa sella, D. tenuis*) by its eu- and excentrilepidine embryon and adauxiliary chamberlets with arcuate outer wall ("varians" type) except for *D. tenuis* that also can be of this type.

Discocyclina archiaci (Schlumberger, 1903)

Discocyclina archiaci is an unribbed form having semi-nephro-, tryblio- and umbilicolepidine embryon, moderately wide and average high, 'archiaci' type adauxiliary 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 Özcan (2002) and Çolakoğlu & Özcan (2003). Less (1998) ranked the rare *D. furoni*, *D. weijdeni* and *D. senegalensis* with *D. archiaci*; however in the Turkish material these forms appeared to be separate species (Özcan 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. bakhchisaraiensis	d_{mean} < 305 μm
D. a. staroseliensis	d_{mean} = 305-390 μm
D. a. archiaci	d_{mean} = 390-600 μm
D. a. bartholomei	d_{mean} > 600 μm

D. archiaci bakhchisaraiensis (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 Şile 4 is slightly more advanced and can be determined as *D. archiaci* ex. interc. *staroseliensis* et *bakhchisaraiensis* (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 subspecific level.

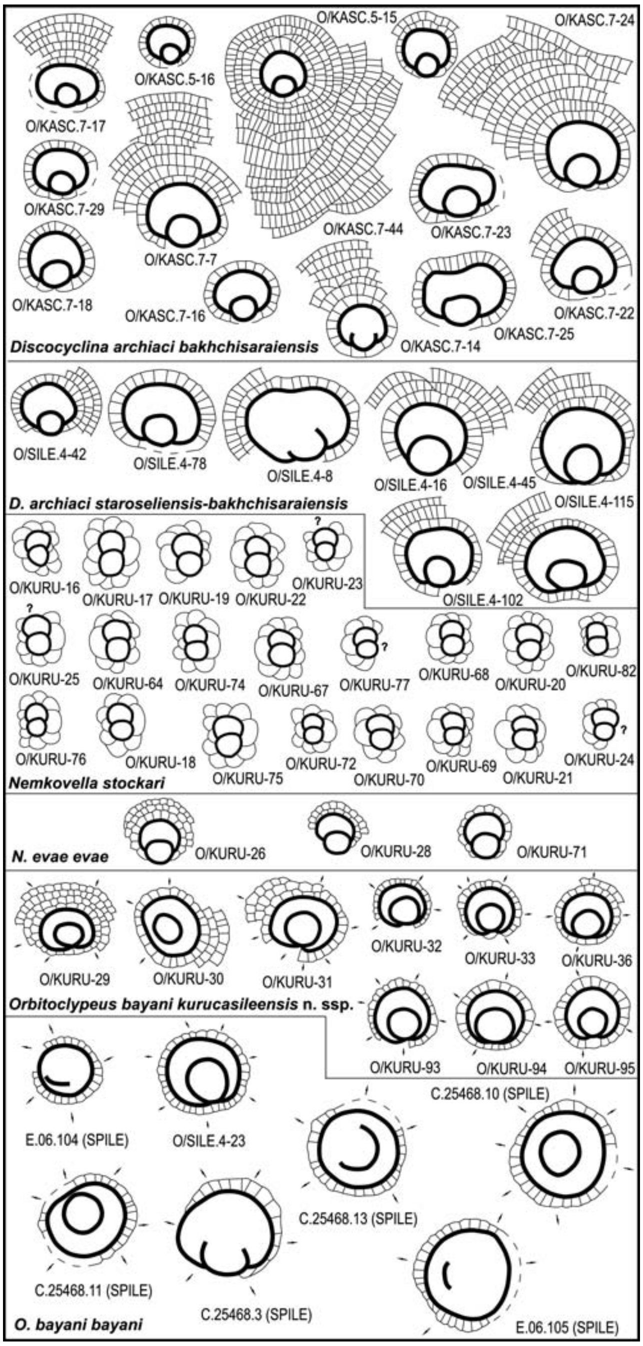


Fig. 13 - Types of embryon and their variation in *Discocyclina archiaci* (×28), *Nemkovella evae* (×28), *N. stockari* (×40) and *Orbitoclypeus bayani* (×28).

Discocyclina tenuis Douvillé, 1922

Pl. 1, figs 24, 25

1922 *Discocyclina tenuis* Douvillé, p. 87, pl. 4, fig. 9.

1953 *Discocyclina tenuis* 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: Spilecco (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-figured in Pl. 1, fig. 24.

Diagnosis. Small to medium-sized, flattened, unribbed forms with "Discocyclina" type rosette. The medium-sized embryon is semi-nephro- to trybliolepidine. The relatively numerous "archiaci-varians" type adauxiliary chamberlets are moderately wide and high like the equatorial chamberlets that are arranged in circular annuli of the "archiaci-varians" 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. seunesi* and *D. archiaci*. In the equatorial section of the A-forms the medium-sized embryon (p= 130-280 µm, d= 260-580 µm) is mostly tryblio-, sometimes semi-nephrolepidine. The relatively wide (W= 35-60 µm) and high (H= 40-100 µm) adauxiliary chamberlets are average to numerous in numbers (N= 15-38), their outer wall is more or less arcuate, and of the transitional "archiaci-varians" or the "varians" 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 "archiaci-varians" or the "varians" 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. seunesi* and in the early Ypresian with the less advanced stages of *D. archiaci*. Less (1987) thought it to be invalid, however later he (Less 1998) found a representative population from Ruisseau de Bec (France) together with *Orbitoclypeus schopeni ramaraoi*. It was interpreted as the descendant of *D. seunesi* 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. seunesi beloslavensis*, *Orbitoclypeus schopeni ramaraoi* and *O. multiplicatus haymanaensis*, thus belonging to the middle Thanetian OZ 1b orthophragminid zone. In this assemblage *D. tenuis* and *D. seunesi* can be fairly well distinguished from each other based on their different embryon (both size and shape) and somewhat different adauxiliary and equatorial chamberlets. The distinction from the early Ypresian members of the *D. archiaci* lineage is also not too difficult due to the larger embryon, more numerous and slightly arcuate adauxiliary 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 Spilecco (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.

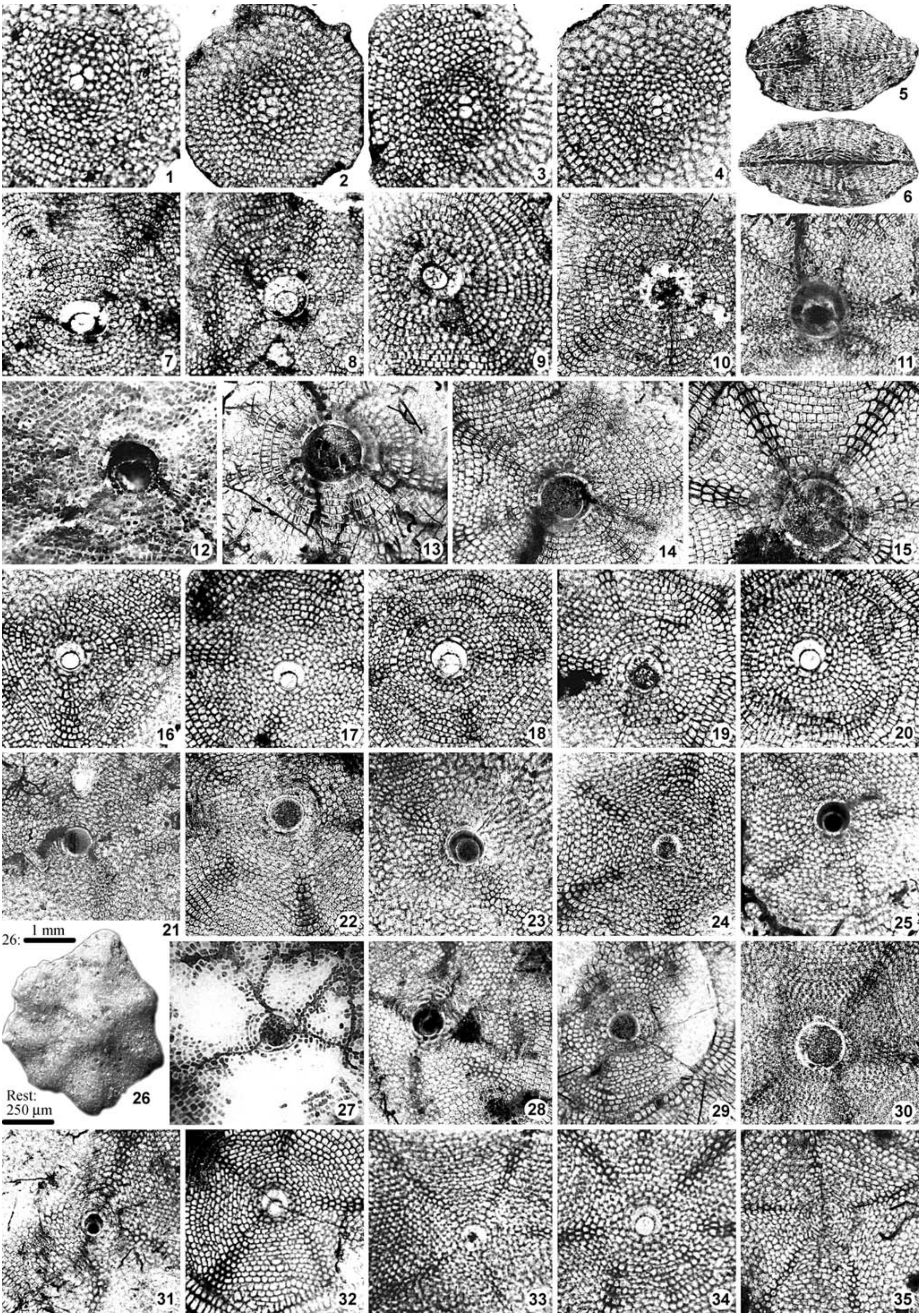
Discocyclina dispansa (Sowerby, 1840)

Discocyclina dispansa is an unribbed form with a small to medium-sized, semi-nephro- to trybliolepidine embryon, moderately wide and high, "archiaci" type adauxiliary chamberlets and also moderately wide and high equatorial chamberlets. The spiral juvenarium 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. broennimanni	d_{mean} < 160 µm
D. d. taurica	d_{mean} = 160-230 µm
D. d. hungarica	d_{mean} = 230-290 µm
D. d. sella	d_{mean} = 290-400 µm
D. d. dispansa	d_{mean} = 400-520 µm
D. d. umbilicata	d_{mean} > 520 µm

PLATE 2

1-6: *Nemkovella stockari* n. sp., Kurucaşile, upper Thanetian, OZ 2. 1: O/KURU-17, 2: O/KURU-74, 3: O/KURU-22, 4: O/KURU-76, holotype, 5: O/KURU-84, 6: O/KURU-62.
7-10: *Orbitoclypeus bayani* (Munier-Chalmas) *kurucasileensis* n. ssp., Kurucaşile, upper Thanetian, OZ 2. 7: O/KURU-29, 8: O/KURU-33, holotype, 9: O/KURU-30, 10: O/KURU-93.
11: *Orbitoclypeus bayani* (Munier-Chalmas) indet. ssp., Karaevli, sample KARA 2, upper Thanetian, OZ 2, O/KARA.2-37.
12: *Orbitoclypeus bayani* cf. *bayani* (Munier-Chalmas), Şile, sample ŞİLE 4, lowermost Ypresian, OZ 3, O/ŞİLE.4-6.
13-15: *Orbitoclypeus bayani bayani* (Munier-Chalmas), Spilecco, lowermost Ypresian, OZ 3, topotypes. 13: E.06.148., 14: E.06.149., 15: E.06.146.
16-24, 26-29: *Orbitoclypeus munieri* (Schlumberger) *ponticus* n. ssp. 16-20: Kurucaşile, upper Thanetian, OZ 2; 16: O/KURU-97, 17: O/KURU-90, 18: O/KURU-100, 19: O/KURU-101, 20: O/KURU-103, holotype. 21-24: Karaevli, upper Thanetian, OZ 2; 21: sample KARA 1, O/KARA.1-13; 22-24: sample KARA 2; 22: O/KARA.2-41, 23: O/KARA.2-50, 24: O/KARA.2-33; 26-29: Spilecco, lowermost Ypresian, OZ 3. 26: E.06.114., 27: E.06.112., 28: E.06.140., 29: E.06.141.
25: *Orbitoclypeus munieri* (Schlumberger) cf. *ponticus* n. ssp., Ağaçkese, sample AĞA 2, lowermost Ypresian, OZ 3, O/AĞA.2-9.
30: *Orbitoclypeus munieri* cf. *munieri* (Schlumberger), Kastamonu, sample KAS C 10, lower Ypresian, OZ 4, O/KASC.10-38.
31-35: *Asterocyclina taramellii* (Munier-Chalmas). 31, 32: Kurucaşile, upper Thanetian, OZ 2. 31: O/KURU-49, 32: O/KURU-47. 33-35: Spilecco, lowermost Ypresian, OZ 3, topotypes. 33: C.27459/3, 34: C.27459/2, 35: E.06.152.
5, 6: A-form, axial sections, 40 ×; 26: external view, 10 ×; 35: B-form, equatorial section, 40 ×. All others: A-form, equatorial sections, 40 ×.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26: 1 mm
Rest: 250 µm
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The population of sample ŞİLE 4 (OZ 3) is slightly more advanced compared to the accompanying fauna and can be determined as *D. dispansa* ex. interc. *broennimanni-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-iso to nephrolepidine embryon, low but relatively wide, very diagnostic, arcuate, "varians" type adauxiliary chamberlets and moderately narrow and low equatorial chamberlets with mostly "varians" and "archiaci" types of the growth pattern. A significant increase in cycle height may take place only around the edges. The spiral microspheric juvenarium 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 $d_{mean} < 260$ µm
N. e. karitensis $d_{mean} > 260$ µm

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 Şile, sample ŞİLE 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 stockari 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 İstanbul Technical University.

Paratypes: All the other specimens from Kurucaşile illustrated in Pl. 2, figs. 1-3, 5, 6 and in Fig. 13.

Type locality: Kurucaşile (Northern Turkey).

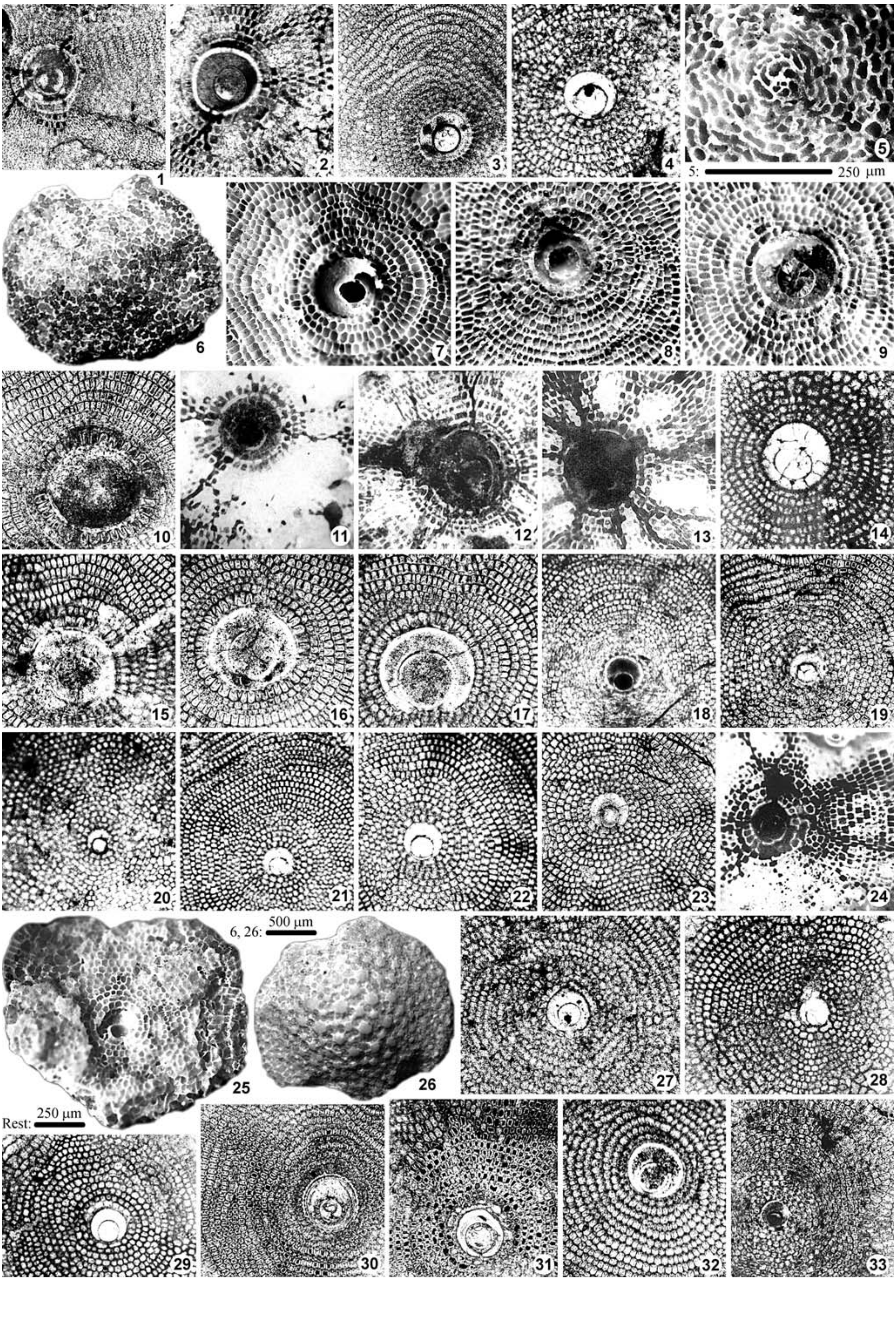
Type level: Upper Thanetian, OZ 2 orthophragminid zone.

Diagnosis. Very small, inflated, unribbed forms. In the very small embryon the protoconch is slightly larger than the deuteroconch, their common wall is straight. The embryon is surrounded by an asymmetrical, quadriserial nepiont. No adauxiliary 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 "varians" 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-chudeaui" transitional type rosette. The embryon 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 isolepidine to anisolepidine. In the quadriserial nepiont the two principal adauxiliary 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 adauxiliary 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

1-3: *Orbitoclypeus multiplicatus* (Gümbel) *haymanaensis* Özcan, Sirel, Özkan-Altiner et Çolakoğlu, Karaevli, sample KARA 1, upper Thanetian, OZ 2, 1: O/KARA.1-16, 2: O/KARA.1-24, 3: O/KARA.1-9.
4, 14: *Orbitoclypeus multiplicatus* (Gümbel) indet. ssp. 4: Kurucaşile, upper Thanetian, OZ 2, O/KURU-61; 14: Kastamonu, sample KAS C 7, lowermost Ypresian, OZ 3, O/KASC.7-3.
5-9, 11-13: *Orbitoclypeus multipicatus multiplicatus* (Gümbel), lowermost Ypresian, OZ 3. 5-9: Şile, sample ŞİLE 4; 5: O/ŞİLE.4-56, 6: O/ŞİLE.4-53, 7: O/ŞİLE.4-97, 8: O/ŞİLE.4-59, 9: O/ŞİLE.4-98. 11-13: Spilecco, topotypes; 11: E.06.111, 12: E.06.110., 13: E.06.109.
10, 15-17: *Orbitoclypeus multiplicatus* (Gümbel) *kastamonuensis* n. ssp., Kastamonu, sample KAS C 9, lower Ypresian, OZ 4; 10: O/KASC.9-18, 15: O/KASC.9-26, 16: O/KASC.9-23, 17: O/KASC.9-11, holotype.
20-22: *Orbitoclypeus schopeni* (Checchia-Rispoli) *ramaraoi* (Samanta), Kurucaşile, upper Thanetian, OZ 2. 20: O/KURU-13, 21: O/KURU-8, 22: O/KURU-2.
18: *Orbitoclypeus schopeni* (Checchia-Rispoli) cf. *neumannae* (Toumarkine), Karaevli, sample KARA 2, upper Thanetian, OZ 2, O/KARA.2-19.
19, 23-29: *Orbitoclypeus schopeni* (Checchia-Rispoli) *neumannae* (Toumarkine), lowermost Ypresian, OZ 3. 19: Ağaçkese, sample AĞA 2, O/AĞA.2-2. 23, 24: Spilecco (Italy), 23: E.06.128., 24: E.06.119. 25, 26, 29: Şile, sample ŞİLE 4; 25: O/ŞİLE.4-28, 26: O/ŞİLE.4-54, 29: O/ŞİLE.4-106. 27, 28: Kastamonu; 27: sample KAS C 5, O/KASC.5-9; 28. sample KAS C 7, O/KASC.7-37.
30-32: *Orbitoclypeus schopeni* (Checchia-Rispoli) *suvlukayensis* Less, Kastamonu, lower Ypresian, OZ 4. 30, 31: sample KASC.10; 30: O/KASC.10-1, 31: O/KASC.10-8. 32: sample KAS A 4, O/KASA.4-10.
33: *Orbitoclypeus douvillei* (Schlumberger) indet. ssp., Kastamonu, sample KAS C 9, lower Ypresian, OZ 4, O/KASC.9-19.
5: B-form, equatorial section, 100×; 6, 26: A-form, external view, 20×. All others: A-form, equatorial sections, 40×.


1
2
3
4
5
5: 250 µm
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
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22
23
24
6, 26: 500 µm
25
26
27
28
Rest: 250 µm
29
30
31
32
33

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 embryon is 70 to 90 µm high, the thickness of the equatorial layer increases slightly towards the edges, from 40-50 µm near the embryon 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 *Setia* described by Ferràndez-Cañadell (2002). However, the presence of the well-developed, symmetrical lateral layers, rather characteristic for the orthophragmines, does not fit with the diagnosis of *Setia*. The closest orthophragminid taxon is *Nemkovella daguini* with very few adauxiliary chamberlets and with very similar characteristics in both the equatorial and axial sections. Unfortunately, we could not find microspheric specimens; therefore the assignment of "*stockari*" to genus *Nemkovella* is conditional. Its ancestors are unknown, whereas *N. daguini* 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 embryon is excentrilepidine, rarely eulepidine. The numerous, "varians" type adauxiliary 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 excentrilepidine (rarely eulepidine) embryon is medium-sized to moderately large (p= 140-400 µm, d= 200-600 µm). The "varians" type adauxiliary 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 microspheric juvenarium (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 (1870), 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 early late Ypresian (OZ 6/7) based on the finding of one single specimen in Kırıklar, 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_{mean} < 310 µm
O. m. multiplicatus	d_{mean} = 310-420 µm
O. m. kastamonuensis n. ssp.	d_{mean} > 420 µm

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 ŞİLE 4. The poor assemblage from Agaçkese, sample AĞA 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 Kurucaşile (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.

Orbitoclypeus multiplicatus (Gümbel, 1870) **haymanaensis** Özcan, Sirel, Özkan-Altiner & Çolakoğlu, 2001

Pl. 3, figs 1-3; Fig. 14

2001 *Orbitoclypeus 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: 344).

Emended diagnosis. *Orbitoclypeus multiplicatus* populations with d_{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 *O. multiplicatus* lineage as its less advanced member. *Orbitoclypeus multiplicatus haymanaensis* is hardly distinguishable from *O. schopeni suvlukayensis* and *O. varians roberti*, but these two taxa have distinct stratigraphic ranges. Its equatorial chamberlets can be slightly wider than those of the other two taxa can but this difference is unconvincing.

Orbitoclypeus multiplicatus multiplicatus (Gümbel, 1870)

Pl. 3, figs 5-9, 11-13; Fig. 14

1987 *Orbitoclypeus multiplicata* (Gümbel) - Less, pp. 202-203, text-fig. 30g (*cum 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. *Orbitoclypeus multiplicatus* populations with d_{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 embryon is moderately large, in most cases excentrilepidine. The numerous, "varians" type adauxiliary chamberlets are rather wide and relatively high. The equatorial chamberlets 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. *Orbitoclypeus multiplicatus multiplicatus* is hardly distinguishable from *O. schopeni crimensis* and *O. varians scalaris*. Its equatorial chamberlets can be slightly wider than those of the other two taxa, which have different stratigraphical position.

Orbitoclypeus multiplicatus (Gümbel, 1870) **kastamonuensis** n. ssp. Less & Özcan

Pl. 3, figs 10, 15-17; Fig. 14

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. *Orbitoclypeus multiplicatus* population with d_{mean} exceeding 420 μm.

Description (see also Tab. 1). Moderately large (3-5 mm), inflated, unribbed forms with "marthae" type rosette. The embryon is fairly large, almost exclusively excentrilepidine. The numerous, "varians" type adauxiliary chamberlets are rather wide and relatively high. The equatorial chamberlets are also fairly wide and moderately high. The annuli can be slightly undulated; their growth pattern is of the "varians" type.

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

Orbitoclypeus 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 embryon is eu- or excentrilepidine. The "varians" type adauxiliary chamberlets are average in numbers, rather wide and medium high as well as the equatorial chamberlets. 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 excentrilepidine embryon is medium-sized (p= 120-220 μm, d= 200-425 μm). The "varians" type adauxiliary chamberlets are numerous (N= 16-34), rather wide (W= 35-50 μm) and of middle height (H= 35-65 μm). The equatorial chamberlets are also fairly wide (w= 30-45 μm), moderately low to medium high (h= 30-80 μm, 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 microspheric juvenarium is not yet known. The characteristics of the axial section are described in Less (1987).

Remarks. *Orbitoclypeus 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

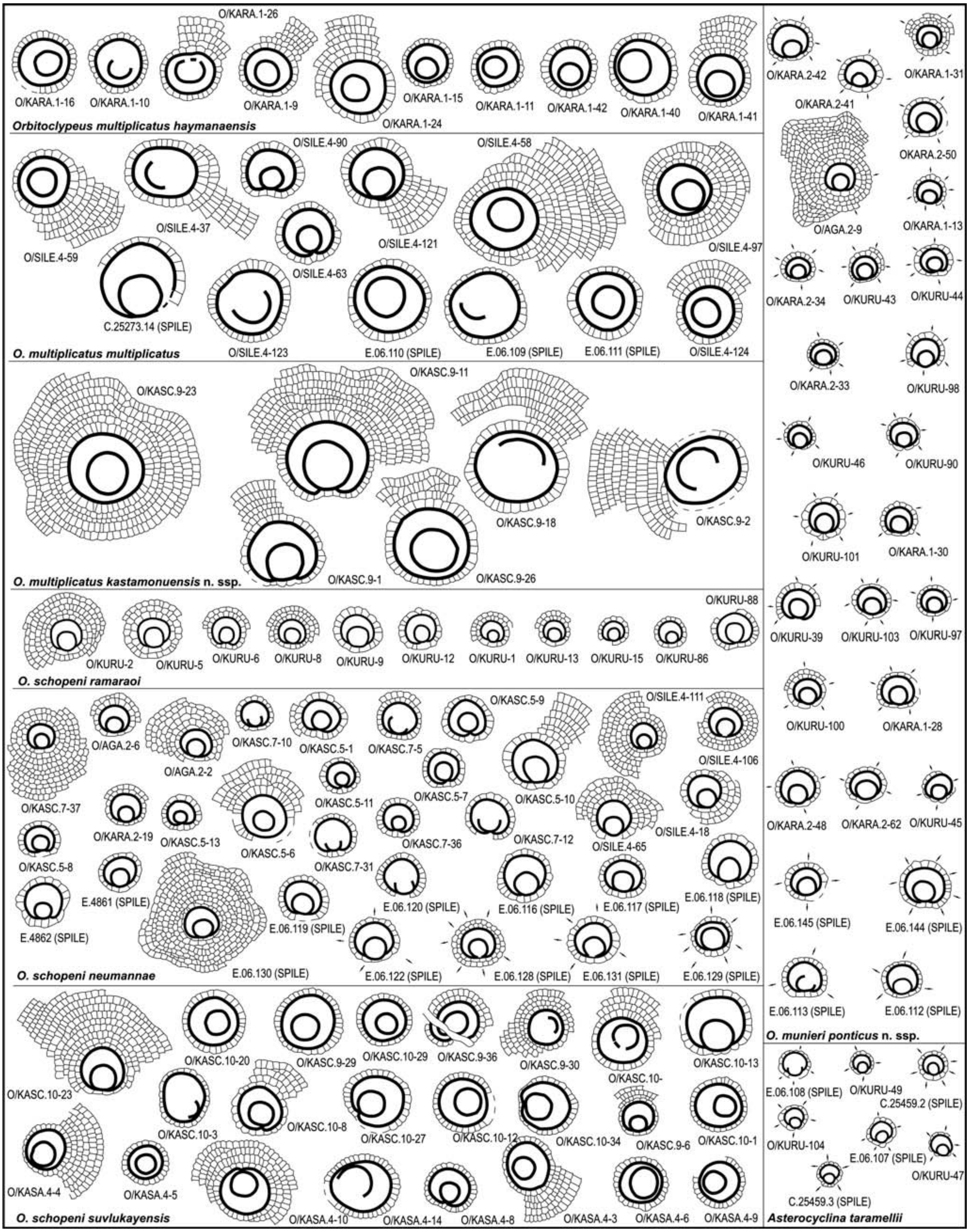

Fig. 14 - Types of embryon and their variation in *Orbitoclypeus multiplicatus*, *O. schopeni*, *O. munieri* and *Asterocyclina taramellii*. All ×28.

simultaneous evolutionary track, the ribbed *O. bayani* derived most probably from the unribbed *O. multiplicatus*. *Orbitoclypeus bayani* is very similar to *O. munieri* (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 successive subspecies defined below:

O. b. kurucasileensis n. ssp. $d_{mean} < 280$ µm
O. b. bayani $d_{mean} > 280$ µm

The less advanced developmental stage occurs in the upper Thanetian (OZ 2) of Kurucaşile whereas *O. b. bayani* can be found in the lowermost Ypresian (OZ 3) of Spilecco. The single specimen (Pl. 2, fig. 11) from Karaevli, sample KARA 2 (upper Thanetian, OZ 2) cannot be determined at subspecific level while the three specimens from Şile, sample ŞİLE 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 7-10; Fig. 13

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

Holotype: Specimen O/KURU-33 (Pl. 2, figs. 8).

Repository: Geology Department of the Istanbul Technical University.

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

Type locality: Kurucaşile (Northern Turkey).

Type level: Upper Thanetian, OZ 2 orthophragminid zone.

Diagnosis. Populations of *Orbitoclypeus bayani* with d_{mean} less than 280 µm.

Description (see also Table 1). Small (2-4 mm), slightly asteroidal forms with 5-7 indistinct ribs and "marthae" type rosette. The moderately small embryon is mostly eulepidine, sometimes excentrilepidine. The "varians" type adauxiliary chamberlets are average in numbers, moderately wide and medium high. The equatorial 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 representatives of genus *Orbitoclypeus* with similar-sized embryon (the less advanced *O. munieri munieri* and *O. furcatus* n. ssp. Gibret, 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.

1904 *Orthophragmina bayani* Munier-Chalmas - Schlumberger, pp. 131-132, pl. 4, figs. 21, 22, pl. 5, fig. 23.

1987 *Orbitoclypeus bayani* (Munier-Chalmas) (partim) - Less, pp. 201-202, pl. 27, fig. 4 (non 5, 6).

Holotype, Lectotype, type locality and type level: As given by Less (1987: 195).

Diagnosis. *Orbitoclypeus bayani* populations with d_{mean} exceeding 280 µm.

Description (see also Table 1). Medium-sized (3-6 mm), slightly asteroidal or moderately flattened lenticular forms with 5-7 indistinct ribs and "marthae" type rosette. The medium-sized embryon is eulepidine or excentrilepidine. The "varians" type adauxiliary chamberlets are numerous, rather wide and medium high as well as the equatorial chamberlets. The annuli are distinctly undulated with 5-7 waves; their growth pattern is of the "varians" type.

Remarks. The other, non-coeval ribbed representatives of genus *Orbitoclypeus* with similar-sized embryon (the more advanced *O. munieri munieri*, *O. furcatus rovasendai* 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 adauxiliary chamberlets and also narrow or medium wide equatorial chamberlets arranged into circular or slightly undulated annuli with usually "varians" type growth pattern. The distal margins of the annular chamberlets are typically arched or wedge-shaped. It commonly occurs in the orthophragminid 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 Padragkút (Hungary) and San Pancrazio (OZ 12) (Italy). Further information can be found in Özcan et al. (2001), Özcan (2002) and Çolakoğlu & Özcan (2003). Due to the rather rapid evolution of the lineage, especially in the Thanetian and Ypresian, it can be subdivided into five successive subspecies:

O. s. ramaraoi $d_{mean} < 195$ µm
O. s. neumannae $d_{mean} = 195\text{-}240$ µm
O. s. suvlukayensis $d_{mean} = 240\text{-}300$ µm
O. s. crimensis $d_{mean} = 300\text{-}500$ µm
O. s. schopeni $d_{mean} > 500$ µm

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). *Orbitoclypeus 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 Ağaçkese, sample AĞA 2, Şile, sample ŞİLE 4, Kastamonu, samples KAS C 5 and 7 and Spilecco (SPILE), finally *O. s. suvlukayensis* (Pl. 3, figs. 30-32; Fig. 14) in the upper lower Ypresian beds (OZ 4) of Kastamonu (samples KAS C 9, 10 and KAS A 4). Only the small population from the upper Thanetian beds of Karaevli (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).

Orbitoclypeus munieri (Schlumberger, 1904)

Orbitoclypeus munieri is a small- to large-sized ribbed form (with 6 to 9 thick ribs, rarely bifurcated) having "marthae" type rosette (Pl. 2, fig. 26), a small- to medium-sized eu- to excentrilepidine (rarely also tryblio- and umbilicolepidine) embryon, the adauxiliary chamberlets are of the "varians" type, medium wide and high as are the equatorial chamberlets. Microspheric 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 & Ó. Kovács 1996; Less 1998), 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. munieri* n. ssp. Spilecco, is described below under the name of *O. munieri 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 Karaevli and Kurucaşile (Turkey), and then it ranges almost until the end of the Ypresian (OZ 8a, the uppermost part of the Simferopolian beds in the Crimean Peninsula). According to Less & Ó. Kovács (1996), its evolution runs parallel with the unribbed *O. schopeni*. For additional information, see also Özcan (2002), Çolakoğlu & Özcan (2003) and Özcan et al. (2007b). The updated nomenclature and subdivision of the lineage is as follows:

O. m. ponticus n. ssp. $d_{mean} < 220$ µm
O. m. munieri $d_{mean} > 220$ µm

Remarks. *Orbitoclypeus munieri*, *O. bayani* and *Asterocyclina taramellii*, from the same upper Thanetian (OZ 2) horizon, represent the oldest ribbed orbitoclypeids in the Western Tethys. The inferred close phylogenetic relationship of *O. munieri* to *A. taramellii* 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 Karaevli (samples KARA 1 and 2) and in the lowermost Ypresian (OZ 3) of Spilecco. The two specimens from Ağaçkese (AĞA 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_{mean} ranging between 220 and 300 µm occur in the OZ 4 and probably also in the OZ 5 zone whereas all the populations with d_{mean} exceeding 300 µm characterize the OZ 6 to 8a zones.

Orbitoclypeus 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 İstanbul 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 *Orbitoclypeus munieri* with d_{mean} less than 280 µm.

Description (see also Tab. 1). Small-sized (2-4 mm), moderately flattened forms with 7-9 thick ribs (practically with no bifurcation) and "marthae" type rosette on the surface. The small embryon is of eulepidine type. The relatively few adauxiliary 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. *Orbitoclypeus munieri ponticus* can be confused with the ribbed *O. furcatus* n. ssp. Horsarrieu (Less 1998, not yet formally described) and having similar type and similar-shaped embryon. Concerning their quantitative parameters they cannot be distinguished from each other in practice although their stratigraphic 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 *Asterocyclina taramellii* can also be difficult. For details see the description of the latter.

Orbitoclypeus douvillei (Schlumberger, 1903)

Pl. 3, fig. 33

Orbitoclypeus douvillei is an unribbed species having "chudeaui" type rosette, a small to relatively large, eu-, then tryblio- and excentrilepidine embryon, wide and moderately high, "varians" type adauxiliary 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. *Orbitoclypeus 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). *Orbitoclypeus douvillei* forms a rapidly developing evolutionary lineage with six successive subspecies with the following biometric limits:

O. d. douvillei	$d_{mean} < 200$ µm
O. d. yesilyurtensis	$d_{mean} = 200\text{-}260$ µm
O. d. n. ssp. Gibret	$d_{mean} = 260\text{-}340$ µm
O. d. chudeaui	$d_{mean} = 340\text{-}425$ µm
O. d. pannonicus	$d_{mean} = 425\text{-}580$ µm
O. d. malatyaensis	$d_{mean} > 580$ µm

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 embryon, it is very close to *O. douvillei douvillei*.

Genus *Asterocyclina* Gümbel, 1870

Asterocyclina taramellii (Munier-Chalmas, 1891)

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

1891 *Orthophragmina taramellii* Munier-Chalmas, pp. 29, 33, 37.

1904 *Orthophragmina taramellii* Munier-Chalmas - Schlumberger, p. 131, pl. 6, figs. 41-46, 51, 57.

1953 *Asterocyclina taramellii* (Munier-Chalmas) (partim) - Schweighauser, pp. 88-90, text-fig. 58 (partim - on the left side).

1953 *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 taramellii*.

Diagnosis. Small asteroidal forms with 5 -7 rays and "marthae" type rosette. The small embryon is nephro- to semi-isolepidine. The few, "varians" type adauxiliary 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 "marthae" type. In the equatorial section of the A-forms the embryon is small (p= 55-115 µm, d= 100-190 µm), nephro- to semi-isolepidine. The "varians" type adauxiliary 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 taramellii* is a rather rare species known from France (Aurignac, sample AURI9 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. taramellii*, 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. taramellii* occurs in Kurucaşile (upper Thanetian, OZ 2 zone) and in Spilecco (lowermost Ypresian, OZ 3 zone).

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

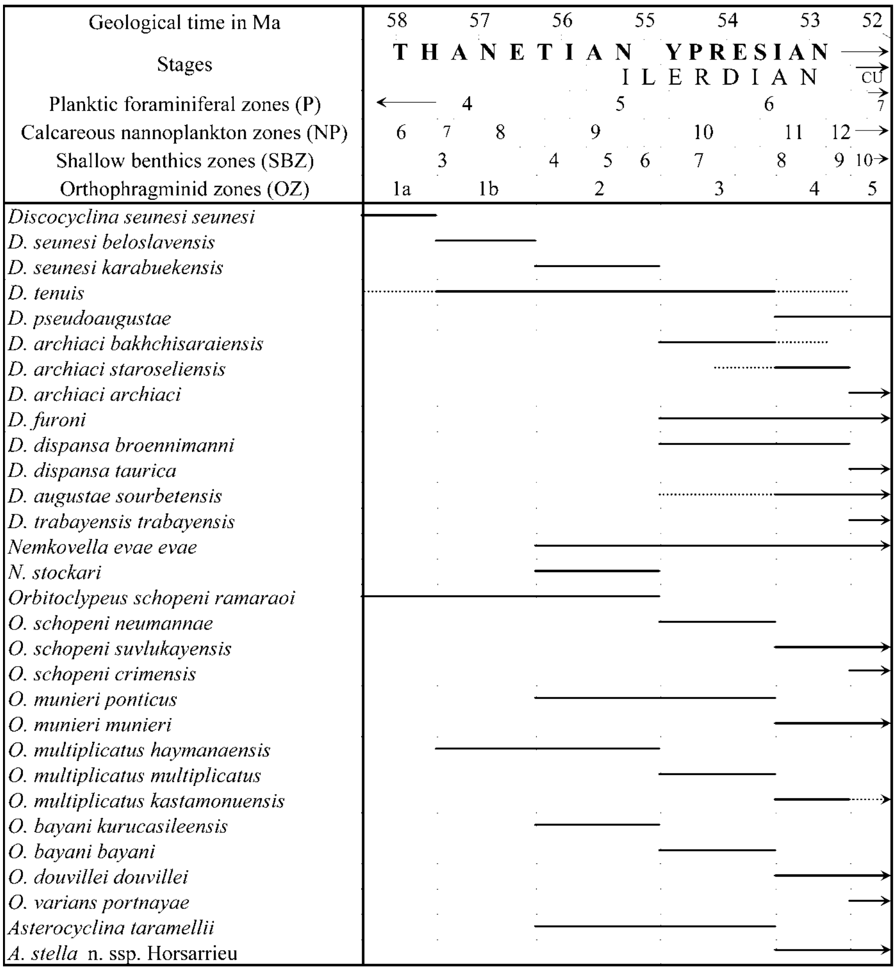

Fig. 15 - Updated range-chart for Thanetian to early Ypresian orthophragminid taxa. Dashed lines indicate uncertain occurrence. The time scale and the mutual relationship of stages and zonal subdivisions (other than that of the orthophragmines) are based on Hardenbol et al. (1998). CU: Cuisian.

Conclusions and revision of Thanetian to lower Ypresian orthophragminid zones

The rich assemblages of Thanetian to early Ypresian orthophragmines 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*, *Orbitoclypeus 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*), *Orbitoclypeus 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*, *Orbitoclypeus multiplicatus*, *O. douvillei* and *Asterocyclina taramellii*.

A revision of the assemblages from Beloslav (Bulgaria) and Spilecco (Italy) already attempted by Less (1998) allowed us to reinstate "*seunesi*" in *Discocyclina* instead of *Orbitoclypeus*, as suggested by Less (1987), to introduce a new evolutionary stage (*D. seunesi beloslavensis*) and to revise the species originally described from Spilecco (*Discocyclina tenuis*, *Orbitoclypeus 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 Selandian 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-Oraas and Boussan Mare in S France, 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 *Orbitoclypeus schopeni* *ramaraoi*. This zone can be correlated with the early parts of the P 4 planktic foraminiferal and SBZ 3 shallow benthics zones and practically with the entire duration of the NP 6 calcareous nannoplankton zone based on data from the above localities (see Less & Ó. Kovács 1996). The presence of *Discocyclina tenuis* 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 *Glomalveolina primaeva* and *Orbitoclypeus schopeni ramaraoi*.

The OZ 1b zone can be recognized in the four upper samples from Beloslav and in the Kırkkavak, Karahamzalı and Karsak profiles of the Haymana-Polatlı Basin (Özcan et al. 2001). This zone contains *Discocyclina seunesi beloslavensis* (the zonal marker), *Discocyclina tenuis*, *Orbitoclypeus schopeni ramaraoi* and *O. multiplicatus haymanaensis*. 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 *Glomalveolina primaeva* (the zonal marker of SBZ 3); however *G. levis* (characteristic for SBZ 4) appears in the uppermost part of the Kırkkavak profile. Nevertheless, it is worth noting that *Assilina yvettae*, assigned by Serra-Kiel et al. (1998) to the SBZ 4 zone, is present throughout the Kırkkavak profile, mostly together with *Glomalveolina 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 (*Orbitoclypeus bayani*, *O. munieri* and *Asterocyclina 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 *Orbitoclypeus schopeni ramaraoi*, *O. multiplicatus haymanaensis* and *O. bayani kurucasileensis* 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 Ilerdian (SBZ 5) that corresponds still to the late Thanetian of Hardenbol et al. (1998). However, the presence of *Orduella 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 overlying 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 Gamarde 7 (France, see Less & Ó. Kovács 1996 and Less 1998), Spilecco (N Italy), the *Nummulites crimensis* 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 ŞİLE 4, AĞA 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. augustae* and *D. furoni*. Only the rare *D. tenuis* (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 *Orbitoclypeus* (*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 bakhchisaraiensis*, *Orbitoclypeus schopeni neumannae*, *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 Sztrákos et al. (1998) indicating NP 10, P 6 and SBZ 8 zones. Moreover, if some of Schaub's Gamarde samples come from the Marnes de Gan and not from the Marnes du Louts (in the interpretation of Sztrákos 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 crimensis* beds of the Bakhchisarai profile (Muzilev 1980; Bugrova 1988) indicate the P 6 and NP 11 zones. Data from sample ŞİLE 4A provide the age of the matrix of the olistostrome and give the upper age limit for sample ŞİLE 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 crimensis* 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 orthophragminid 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 PYCM1 in Less (1998), sample Gamarde 2 (Less & Ó. Kovács 1996 and Less 1998), the boundary layers of the *Nummulites crimensis* and *Assilina placentula* beds of the Bakhchisarai section (sample CRICP in Less 1998), the major part of the Sakarya section in the Haymana-Polatlı Basin (samples SAK 10-19 in Çolakoğlu & Özcan 2003; whereas samples SAK 23-25 are transitional towards OZ 5), 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 pseudoaugustae* (the forerunner of the *D. fortisi* lineage), *Orbitoclypeus douvillei* and *Asterocyclina stella*. In addition, *Discocyclina archiaci*, *Orbitoclypeus schopeni*, *O. multiplicatus* (and very probably *O. munieri*, too) are represented by considerably more advanced evolutionary stages (subspecies) than in OZ 3. Based on their widespread occurrence, *D. archiaci staroseliensis* and *O. schopeni suvlukayensis* 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 "*crimensis*" and "*placentula*" beds of the Bakhchisarai 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 orthophragminid zones starting with OZ 5 corresponding to the late Ypresian in our interpretation. During this time, the orthophragminid 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 orthophragminid taxa.

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