

Late Ypresian to Middle Lutetian Orthophragminid Record From Central and Northern Turkey: Taxonomy and Remarks on Zonal Scheme

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Abstract: Orthophragmines are one of the commonest larger foraminifera in the late Paleocene–Eocene shallow-marine deposits of Turkey. Following several common lineages, such as *Discocyclina archiaci*, *Orbitoclypeus schopeni* and *O. multiplicatus*, a major turnover in the orthophragminid composition – both in diversity and abundance – is observed to occur around the early–late Ypresian boundary. This is manifested in the first appearance/dominance of such important lineages like *Discocyclina augustae*, *D. fortisi*, *Nemkovella strophiolata*, *Orbitoclypeus douvillei*, *O. varians*, *O. furcatus*, *Asterocyclina stellata* and *A. alticostata* simultaneously with the disappearance of *O. multiplicatus* and other forms. These and their successors, ranging up at least to the middle Lutetian, have been studied and statistically evaluated in the equatorial sections of their megalosferic forms. The identified forms are categorized into evolutionary lineages, in which different developmental stages are distinguished by biometrically defined subspecies. Based mainly on the Turkish record, the evolutionary track of several little known western Tethyan lineages could be completed and redescribed in the late Ypresian to middle Lutetian interval. Also introduced and newly established are four new subspecies; two new subspecies of *Discocyclina*, *D. fortisi anatolica* n. ssp. and *D. spliti polatliensis* n. ssp. from the late Ypresian and early Lutetian respectively, one subspecies of *Nemkovella*, *N. evae karitensis* n. ssp. and one of *Orbitoclypeus*, *O. varians ankaraensis* n. ssp., from middle and early Lutetian, respectively. An emended diagnosis of *O. munieri* is also given. As a result, the taxonomy of western Tethyan orthophragmines has been updated and the stratigraphic distribution of some taxa is rearranged. The definition of some previously assigned orthophragminid zones (OZ 7, 8a and 8b) were completed and simultaneously recalibrated in the context of the shallow benthic zonation of the Tethyan Early Paleogene.

Key Words: Turkey, Eocene, Discocyclinidae, Orbitoclypeidae, Biometry, Evolution, Zonation

Orta ve Kuzey Türkiye'deki Geç Yiprezyen–Orta Lütesyen Orthophragminidleri: Taksonomi ve Geliştirilmiş Zonasyon

Özet: Orthophragminidler Türkiye'de Geç Paleosen–Eosen sığ-denizel birimlerde yaygın olarak bulunan iri bentik foraminifer gruplarından bir tanesini temsil eder. *Discocyclina archiaci*, *Orbitoclypeus schopeni* ve *O. multiplicatus* gibi stratigrafik önemi olan erken Yiprezyen gruplarını takiben, orthophragminid çeşitlilik ve bolluğunda erken–geç Yiprezyen sınırı dolaylarında önemli bir değişim gözlenmektedir. Bu *Discocyclina augustae*, *D. fortisi*, *Nemkovella strophiolata*, *Orbitoclypeus douvillei*, *O. varians*, *O. furcatus*, *Asterocyclina stellata* ve *A. alticostata* gibi bazı türlerin ilk ortaya çıkışı ve *O. multiplicatus* ve diğer bazı formların stratigrafik kayıtdan yok olması ile tanımlanır. Bu ve filojetik olarak Orta Eosen dönemine kadar devam eden gruplar megalosferik bireylerin ekvatoryal kesitlerinde çalışılmış ve istatistiksel olarak değerlendirilmiştir. Çalışılan formlar, filojetik gelişim aşamalarına bağlı olarak, biyometrik tanımlanan alttürler altında sınıflandırılmışlardır. Batı Tetis'de geç Yiprezyen–orta Lütesyen döneminde az bilinen bazı grupların evrimsel basamakları tanımlanmış ve yeni dört alttür tariflenmiştir. Geç Yiprezyen ve erken Lütesyen'de iki yeni *Discocyclina*, *D. fortisi anatolica* n. ssp. ve *D. spliti polatliensis* n. ssp., orta Lütesyen'de yeni bir *Nemkovella*, *N. evae karitensis* n. ssp. ve erken Lütesyen'de yeni bir *Orbitoclypeus*, *O. varians ankaraensis* n. ssp., tanımlanmış olup *O. munieri*'nin tür tanımı yenilenmiştir. Buna bağlı olarak Batı Tetis Orthophragminid Zonasyonu ve bazı grupların stratigrafik dağılımı yeniden düzenlenmiş, orthophragminid zonlarının (OZ 7, 8a ve 8b) tanımı verilmiş ve Tetis Erken Paleojen sığ-denizel bentik zonasyonu ile denştirilmiştir.

Anahtar Sözcükler: Türkiye, Eosen, Discocyclinidae, Orbitoclypeidae, Biyometri, Evrim, Zonasyon

Introduction

The marine lower Paleogene sedimentary sequences of Turkey record the Neotethyan evolution of several tectonic components of the eastern segment of Mediterranean Alpides (Şengör & Yılmaz 1981). These sequences are characterized by a variety of both shallow and deep-marine carbonate-clastic units that contain typical Mediterranean fauna (Sirel 1998, 2003; Özcan *et al.* 2001, 2007). The larger benthic foraminifera in the shallow-marine parts of these marine deposits mainly include nummulitids, orthophragmines and alveolinids that are usually associated in many stratigraphic sections (Dizer 1953, 1964, 1968; Sirel 1992, 1998). Although Turkish orthophragmines, traditionally attributed to the genus *Discocyclus*, were frequently cited in some reports and publications, their taxonomy and stratigraphic potential remained obscure partly because of insufficient knowledge of the group in other regions of the Tethys. Thus, despite their widespread known occurrence, the correlation of Turkish neritic Eocene sections with European marine stages was mostly based on nummulitids and alveolinids that gained high index value in intercontinental correlations during the second half of last century (Hottinger 1960, 1977; Drobne 1977; Schaub 1981).

The preliminary systematic studies of Turkish orthophragmines follow the stratigraphic conclusions made after the establishment of Early Paleogene shallow benthic zonation of the Mediterranean Tethys by Serra-Kiel *et al.* (1998) and the first biostratigraphic scheme of Tethyan orthophragminids by Less (1998a). Several continuous profiles in the Haymana-Polatlı Basin, proposed as reference sections for the early Thanetian and Ypresian of Turkey, proved to contain rather diverse assemblages of the genera *Discocyclus*, *Nemkovella*, *Orbitoclypeus* and *Asterocyclus* that show peculiar similarities to their counterparts known from the peri-Mediterranean region (Özcan *et al.* 2001; Özcan 2002; Çolakoğlu & Özcan 2003). Moreover, new developmental stages of several lineages (*Discocyclus fortisi*, *Orbitoclypeus multiplicatus*, and *O. douvillei*) were also described, providing an improved stratigraphic framework for them in Tethyan deposits. Their widespread occurrence in loosely cemented carbonate sediments and stratigraphic potential in age determinations led to a more throughout survey of orthophragmines based on a large number of

stratigraphic profiles, from which the frequently accompanying nummulitids were also partly sampled. These sections correspond usually to the shallow-marine parts of lower Thanetian to lower Priabonian deposits known from several basins in the Pontides and Anatolide-Tauride block. Ample material from numerous horizons, hence, provides us with a better understanding of the taxonomy and stratigraphic distribution of this group in Tethys. Our recent data from this material also permit us to define the new evolutionary stages of several lineages, and enhance the precision of their proposed biostratigraphy in western Tethys. In this context, the taxonomy and revised zonal scheme of late Lutetian to early Priabonian orthophragminids can be found in Özcan *et al.* (2007). The Thanetian–early Ypresian orthophragminids, together with several other localities in Italy and Bulgaria, are presented in Less *et al.* (in press). We here deal with the stratigraphic interval from the late Ypresian to the middle Lutetian, during which a major diversification and proliferation occurs. The material was collected from eight profiles in the Safranbolu-Karabük Basin (sections Kırıklar – KIR, Safranbolu – SAF, Küpler – KÜP, Karıt – KARI), Kastamonu-Taşköprü Basin (sections Kastamonu B – KASB, Taşköprü – TAŞ), the Haymana-Polatlı Basin (section Çayraz – ÇAY) and one locality in northern Turkey: Şile (section ŞİLE).

All figured specimens, marked by *O/*, are deposited in the Özcan collection of the Geology Department in İstanbul Technical University.

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

Stratigraphy of the Late Ypresian to Middle Lutetian Orthophragmines: A Review

Instead of Ilerdian and Cuisian preferred mostly by Paleogene larger foraminiferal experts (Serra-Kiel *et al.* 1998), we prefer to use the standard stages for the sake of better understanding by a wider public. Therefore, Cuisian (SBZ 10–12) is replaced by late Ypresian.

When orthophragmines were determined mainly on the basis of their external characteristics (Schlumberger 1903, 1904; Douvillé 1922; Schweighauser 1953; Neumann 1958), no single form that would be characteristic only for the late Ypresian or early–middle Lutetian was commonly accepted. The time-interval discussed in the present paper was subdivided into six units by Less (1987) in the first preliminary scheme of orthophragmines based on their internal characteristics. The zones 0.5 to 7 were attributed to the late Ypresian (=‘Cuisian’) while 0.8 to 10 to the whole Lutetian. This first system was based on a rather scarce material that included in the discussed time-span the Bakhchisarai section in the Crimean Peninsula (0.5–8) and isolated sites in SW France (Gan and Horsarrieu – 0.6, Saint-Barthélémy, maisonave – 0.8, Couches de Nousse – 0.9 and Angoumé – 0.10) as the most important key-localities with reasonable (i.e. containing at least two lineages) orthophragminid fauna. Meanwhile the possible subdivision of 0.8 was already forecast. The main role in subdividing especially the Cuisian to early Lutetian time-span was placed on the *Discocyclusina archiaci-discus* and *D. pseudoaugustae-fortisi-stratiemanuelis* lineages.

Less (1998a) presented the first real zonal system for the orthophragmines based on more extensive material. In this zonation the zones are marked by OZ, although their numbers correspond to the previous preliminary system, and Zone 8 was subdivided into the Zones 8a and 8b. On one hand, he incorporated some important localities from SW France (Gan, Berdoulou – OZ 5, Bos d’Arros – OZ 6, the uppermost part of the Horsarrieu marl-pit – OZ 6/7, Caupenne, Jeangazé – OZ 8b, Gibret, église – completing the OZ 9 of Couches de Nousse), although they are not yet described in detail, while on the other hand, Fermont’s (1982) material from the Ein Avedat section in Israel (OZ 8a to 8b) was re-evaluated in Utrecht. Statistical data from these localities can be found in Less (1998a).

Based on a more thorough correlation of these zones with planktonic and nummulitid zones, the early/middle Eocene boundary has been slightly adjusted from the OZ 7/8a boundary to about the middle of the OZ 8a zone, since the top of the Simferopolian beds in the Crimean Peninsula belongs to the base of the NP 14 zone (Kapellos 1973), corresponding to the latest Ypresian, whereas at Saint-Barthélémy, maisonave basal Lutetian *Nummulites* can be found (Schaub 1981). This solution,

however, conflicted with the data from Caupenne, Jeangazé (belonging to the OZ 8b zone) that, according to Kapellos & Schaub (1973) contains latest Cuisian nummulitids and calcareous nannoplankton. Similarly, the bulk of the Ein Avedat section still belongs (according to the planktonic foraminiferal – Benjamini 1995b, and calcareous nannoplankton – Moshkovitz 1995 data) to the late Ypresian. Recently we decided that these latter data are more relevant than those from Saint-Barthélémy since according to Less (1998b) the developmental stage of the *Nummulites perforatus*-group from here indicates the latest Ypresian ($P_{\text{mean}\pm\text{s.e.}} = 346.3\pm 4.8 \mu\text{m}$ based on 4 specimens of *N. gallensis*) rather than the basal Lutetian, and no other data are known. This means that, taking into account our new results, the Ypresian/Lutetian boundary falls within the OZ 8b zone. The Lutetian/Bartonian boundary has also been adjusted, first (Less 1998a) to the OZ 11/12 boundary and then to within the OZ 12 zone (Özcan *et al.* 2007). Consequently, the OZ 10 zone corresponds roughly to the middle Lutetian.

Özcan (2002) detailed the orthophragmines from the lower part of the Çayraz section and from the neighboring Yeşilyurt section in the Haymana Basin, following a nice succession of the *Discocyclusina fortisi* and *Orbitoclypeus douvillei* lineages. Firstly he showed that it had a much longer evolution than Less (1987, 1998a) supposed, and then described a new developmental stage *D. fortisi cairazensis*, characteristic for the late Cuisian as well as the newly described *O. douvillei yesilyurtensis*. He arranged the assemblages into four groups characterizing the OZ 5, OZ 6, OZ 6/7 and OZ 7/8a? zones, respectively. We now consider that, based on the consistent evolution of the *D. fortisi* lineage confirmed by our new data, the upper samples can be subdivided into two groups belonging already to the OZ 8a and 8b zones, respectively. Samples YEŞ 128, ÇAY 14 and 17 contain the less advanced *D. fortisi anatolica* (separated from *D. fortisi cairazensis* in this paper) that (together with *O. douvillei yesilyurtensis*) marks the OZ 8a zone whereas samples ÇAY 18 and 21 consist of the essential *D. fortisi cairazensis* indicating already the OZ 8b zone.

Biometry of Orthophragmines and Principles of Their Subspecific Determination

Biometric features of the orthophragmines were studied in thin-sections, prepared through the equatorial plane of

free specimens. Using the terminology proposed by Less (1987, 1993), eight measurements (in μm) and counts from 610 specimens are used to characterize the taxa, as illustrated in Figure 1, tabulated and listed below:

p and d : outer diameter of the protoconch and deutoconch perpendicular to their common axis (corresponding to P_1 and D_1 in Less 1987)

N : number of the adauxiliary chamberlets

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 deutoconch along the axis of the embryo (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 Tables 1 and 2. Grouped samples 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 limited space, a complete statistical evaluation with the number of specimens (n°), arithmetical mean and standard error (s.e.) is given only for deutoconchal 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 1 s.e. of d_{mean} , we use an intermediate denomination between the two neighboring subspecies. In these cases we adopt Drooger's (1993) proposal in using the notation *exemplum intercentrale* (abbreviated as ex. interc.), followed by the names of the two subspecies on either side of the limit and putting first the name which the assemblage is closer to.

Determination of Some Nummulitids

The nummulitid larger foraminifera of the *Nummulites perforatus* group in some horizons of Safranbolu (SAF 9), Çayraz (ÇAY 28A, 36A and 37A), Boyabat (TAŞ 1, 2, 4 and 5) and Yunuslubayır (ŞİLE 8A) formations were studied in split specimens. By applying the biometric methods to successive *N. perforatus* populations, we could observe that the inner cross-diameter of the proloculus of the megalospheric forms (P) steadily increases with time; hence, it gives the opportunity for the biometric approach to be successfully applied. The ongoing work of the third author of this paper presently permits us a tentative correlation of different developmental stages of the group with shallow benthic zonation. In the recent state of the work, the specific names of Schaub (1981) cannot be used any longer, just as the biometry-based revised names cannot be applied yet. Therefore, based on the data of Serra-Kiel (1984) and Less (1998b) we suggest that populations of the *N. perforatus*-group with P_{mean} : 300 to 450 μm tentatively characterize the SBZ 11–12 zones (upper late Ypresian according to our terminology), those between 450 and 600 μm the SBZ 13 (early Lutetian), finally those

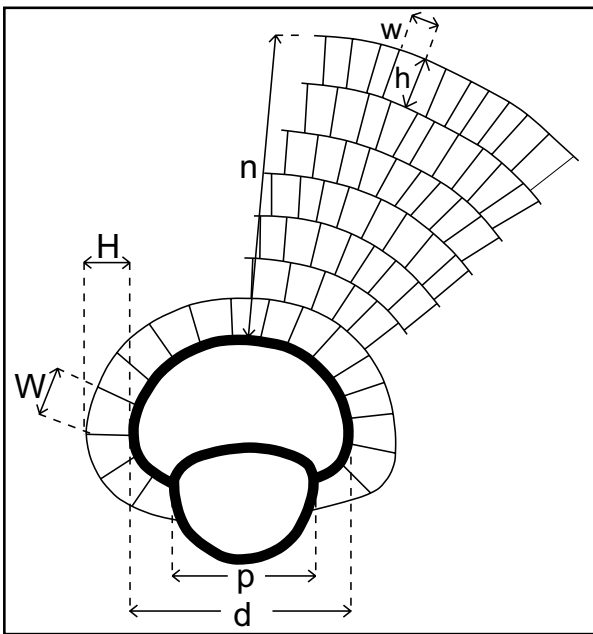


Figure 1. Quantitative parameters for the definition of megalospheric orthophragminids in equatorial sections. See text for explanation.

Table 1. Statistical data of discocyclusid populations (see the text for the abbreviations of parameters).

	Horizon	d (µm)		p (µm)		N	H (µm)	W (µm)	n	h (µm)	w (µm)	
		n°	range	mean±s.e.	range							mean
<i>Discocyclusina archiadi</i>	KIR 7	1		555.0		225.0	37	60 - 70	35 - 55	8	60	20 - 40
	KIR 8	11	440 - 760	573.6 ± 26.9	210 - 350	264.4	35 - 51	65 - 75	25 - 40	7 - 13	55 - 65	20 - 45
	KIR 7+8	12	440 - 760	572.1 ± 24.7	210 - 350	260.5	35 - 51	60 - 75	25 - 55	7 - 13	55 - 65	20 - 45
	KIR 9	1		560.0		230.0				11		
	KÖP 10	14	450 - 750	611.8 ± 18.2	215 - 290	247.8	30 - 40	50 - 75	35 - 60	9 - 11	40 - 45	35 - 40
<i>D. senegalensis</i>	KAS B 1	5	440 - 760	624.0 ± 61.1	200 - 345	268.8	30	60 - 85	30 - 50	7 - 10	65 - 85	30 - 40
	ŞİLE 8	9	600 - 1005	796.7 ± 40.7	190 - 410	286.7	49 - 55	50 - 120	40 - 70	6 - 8	60 - 65	40 - 50
	ÇAY 28	5	420 - 775	542.0 ± 59.1	115 - 330	225.0	20 - 28	80 - 105	35 - 75	6 - 7	60 - 120	35 - 60
	ÇAY 33	1		520.0		260.0		90 - 125	50 - 75	7	65 - 75	40 - 50
<i>D. weijdeni</i>	KIR 7	1		680.0		300.0		75	40 - 50	6	40 - 50	25 - 30
	KIR 8	2	480 - 755	617.5		310.0	40	75 - 100	40 - 55	6 - 6.5	105	30 - 40
	KIR 7+8	3	480 - 755	638.3	300 - 310	305.0	40	75 - 100	40 - 55	6 - 6.5	105	25 - 40
<i>D. furoni</i>	KIR 7	1		225.0		130.0	27	65	30 - 35	12	50	20 - 25
	KIR 8	1		225.0		120.0	21			13		
	KIR 7+8	2	225	225.0	120 - 130	125.0	21 - 27	65	30 - 35	12 - 13	50	20 - 25
	KIR 10	1		250.0		155.0	23					
<i>Discocyclusina sp.</i>	KARI 1	2	480 - 550	515.0		260.0	35	60 - 80	30 - 55	9	55 - 90	30 - 50
<i>D. fortisi</i>	KIR 8	6	860 - 1095	975.8 ± 30.5	435 - 750	598.3		45 - 55	25 - 55	6 - 9	85 - 90	25 - 35
	KIR 9	16	600 - 905	754.1 ± 23.8	260 - 585	388.2	59 - 60	45 - 80	35 - 65	7 - 10	40 - 100	25 - 60
	KIR 10	1		890.0		490.0						
	KIR 9+10	17	600 - 905	762.1 ± 23.7	260 - 585	395.0	59 - 60	45 - 80	35 - 65	7 - 10	40 - 100	25 - 60
	KÖP 5	21	675 - 1160	923.3 ± 29.0	250 - 575	465.4	42 - 78	40 - 100	35 - 60	6 - 8		
	KÖP 8	11	780 - 1330	1076.8 ± 52.8	440 - 650	538.1		65 - 100	45 - 65	6 - 8	55 - 65	35 - 50
	KÖP 9	27	700 - 1460	1106.9 ± 29.6	350 - 885	548.2	54 - 82	50 - 100	40 - 55	6 - 8	60 - 75	25 - 45
	KÖP 8+9	38	700 - 1460	1098.2 ± 26.1	350 - 885	545.2	54 - 82	50 - 100	40 - 65	6 - 8	55 - 75	25 - 50
	KAS B 1	4	1000 - 1325	1171.3 ± 76.0				55 - 80	30 - 50	6 - 8	90 - 95	35 - 40
	SAF 1	10	900 - 1450	1202.0 ± 52.4	445 - 830	679.3	67 - 72	60 - 100	40 - 60	6 - 9	55	25 - 45
	SAF 8	16	940 - 1500	1225.6 ± 45.8	375 - 630	505.0		65 - 105	35 - 75	5 - 8	55 - 60	35 - 55
	SAF 9	7	780 - 1640	1307.1 ± 98.5		610.0	80 - 97	60 - 120	35 - 70	5 - 7	50 - 75	30 - 50
	SAF 8+9	23	780 - 1640	1250.4 ± 44.5	375 - 630	522.5	80 - 97	60 - 120	35 - 75	5 - 8	50 - 75	30 - 55
	ÇAY 28	2	1040 - 1925	1482.5				100 - 125	60 - 70	5	70 - 105	40 - 50
	ÇAY 32	6	1090 - 2000	1580.0 ± 133.5				65 - 110	40 - 60	5 - 6	80	40 - 50
ÇAY 33	10	1040 - 2000	1644.3 ± 69.6	505 - 940	685.0		100 - 120	50 - 85	5 - 6	55 - 80	30 - 50	
ÇAY 35	20	1400 - 2660	1968.0 ± 73.6	560 - 780	682.0	>80	60 - 120	50 - 90	4 - 5	45 - 65	30 - 45	
<i>D. spliti</i>	SAF 8	1		485.0				40 - 50	30 - 45	12	45 - 75	35 - 40
	ÇAY 28	23	360 - 860	591.1 ± 22.5	210 - 360	271.1	36 - 53	55 - 70	30 - 70	6 - 13	40	25 - 40
	ÇAY 32	3	590 - 800	726.7				70 - 90	30 - 55	7 - 10	50 - 70	30 - 35
	ÇAY 33	14	500 - 900	650.7 ± 28.9	230 - 360	295.0	37 - 44	60 - 75	30 - 70	7 - 11	35 - 40	25 - 45
	ÇAY 35	1		680.0						9		
	TAŞ 4	16	1000 - 1590	1235.6 ± 41.5	450 - 900	611.4	>69	75 - 120	50 - 75	6 - 8	65 - 75	40 - 50
	TAŞ 7	10	940 - 1575	1226.0 ± 63.6	475 - 870	685.0	54 - 69	100 - 135	45 - 80	6 - 7	50 - 65	30 - 55
<i>D. augustae</i>	KIR 8	8	105 - 155	130.6 ± 5.5	55 - 100	77.5	10 - 11	20 - 30	25 - 35	17 - 20	45 - 60	15 - 25
	KIR 9	1		115.0		75.0		30		19	40	25 - 35
	KIR 10	9	100 - 150	125.6 ± 4.8	60 - 85	75.6	8 - 12	25 - 35	25 - 35	16 - 20	65 - 90	20 - 25
	KIR 9+10	10	100 - 150	124.5 ± 4.4	60 - 85	75.5	8 - 12	25 - 35	25 - 35	16 - 20	40 - 90	20 - 35
	KÖP 10	11	115 - 150	130.0 ± 3.0	75 - 90	80.7	10 - 13	35 - 40	25 - 35	15 - 18	45 - 65	20 - 35
	KAS B 1	1		120.0		80.0	11	35		18		
	ÇAY 28	22	110 - 175	130.0 ± 2.9	65 - 100	81.2	8 - 14	25 - 35	20 - 30	13 - 17	70 - 90	25 - 40
	KARI 1	5	130 - 175	146.0 ± 7.1	80 - 100	88.0	11					
<i>D. dispansa</i>	KIR 8	2	200	200.0	100	100.0	18 - 19	40 - 45	25 - 35	14 - 17	85	25 - 35
	ÇAY 28	1		215.0		110.0	19			16		
	KÖP 10	1		100.0		65.0	7			17		
<i>D. trabayensis</i>	ÇAY 28	2	90 - 110	100.0	50 - 70	60.0	6	20 - 25	20 - 25	20	50 - 65	25 - 30
	KARI 1	2	115 - 130	122.5	70 - 85	77.5	10	20 - 25	25 - 40	19	100 - 120	20 - 25
<i>D. pratti</i>	TAŞ 7	2	270 - 450	360.0	120 - 190	155.0	21 - 32			7.5		
<i>Nemkovella evae</i>	KIR 7	1		195.0			12			13		
	KIR 8	1		200.0		110.0	14	35	35 - 45	18	40 - 45	25 - 30
	KIR 7+8	2	195 - 200	197.5		110.0	12 - 14	35	35 - 45	13 - 18	40 - 45	25 - 30
	KIR 9	9	170 - 270	210.6 ± 11.7	100 - 170	128.9	9 - 15	35 - 50	30 - 55	13 - 15	50 - 150	25 - 50
	KIR 10	9	150 - 205	182.2 ± 5.7	95 - 130	108.9	8 - 14	35 - 45	30 - 40	12.5 - 16.5	50 - 120	25 - 45
	KIR 9+10	18	150 - 270	196.4 ± 7.3	95 - 170	118.9	8 - 15	35 - 50	30 - 55	12.5 - 16.5	50 - 150	25 - 50
	ÇAY 28	18	205 - 400	301.4 ± 14.8	110 - 220	158.2	9 - 20	50 - 75	25 - 50	9 - 14	90	30 - 45
KARI 1	17	225 - 395	290.9 ± 10.8	130 - 225	170.0	11 - 17	55 - 75	40 - 55	10 - 12	80 - 110	30 - 50	
<i>N. strophiolata</i>	KIR 7	2	130 - 140	135.0	85 - 90	87.5	7 - 8	25	25 - 35	18	55 - 95	25 - 40
	KIR 8	14	110 - 175	145.7 ± 3.8	80 - 120	94.6	7 - 11	25	30 - 45	15 - 19	35 - 70	25 - 45
	KIR 7+8	16	110 - 175	144.4 ± 3.5	80 - 120	93.8	7 - 11	25	25 - 45	15 - 19	35 - 95	25 - 45
	KIR 9	1		155.0		90.0	7	30	40 - 45	17.5	85	25 - 40
	KÖP 10	2	135 - 145	140.0		90.0	7 - 8			19		
<i>Nemkovella sp.</i>	KÖP 10	1		530.0		240.0	26	75 - 85	50 - 75	8	90 - 110	30 - 50
	ÇAY 32	1		500.0		300.0	21	45 - 50	35 - 65	11	55 - 100	35 - 40

Table 2. Statistical data of orbitoclypeid populations (see the text for the abbreviations of parameters).

Specific determination	Horizon	d (µm)			p (µm)		N	H (µm)	W (µm)	n	h (µm)	w (µm)	Subspecific determination
		n°	range	mean±s.e.	range	mean							
<i>Orbitoclypeus douvillei</i>	KIR 8	6	140 - 175	159.2 ± 4.5	80 - 100	90.8	14 - 17	25 - 35	25 - 40	14 - 15	85	25 - 30	<i>douvillei</i>
	KIR 9	14	135 - 200	160.7 ± 4.0	70 - 110	85.4	13 - 18	25 - 35	20 - 30	13 - 17	45 - 190	25 - 55	<i>douvillei</i>
	KIR 10	15	135 - 185	151.0 ± 3.9	70 - 110	86.8	10 - 16	25 - 40	20 - 35	12 - 17.5	50 - 170	25 - 45	
	KIR 9+10	29	135 - 200	155.7 ± 2.9	70 - 110	86.1	10 - 18	25 - 40	20 - 35	12 - 17.5	45 - 190	25 - 55	<i>douvillei</i>
	KÖP 5	12	150 - 190	170.8 ± 3.8	80 - 95	86.8	14 - 18	30 - 40	20 - 40	13 - 16	60 - 135	30 - 40	
	KÖP 9	1		185.0									indet. ssp.
	KÖP 10	13	165 - 220	192.3 ± 4.4	80 - 115	101.5	13 - 17	30 - 40	30 - 35	13	100 - 125	30 - 40	<i>douvillei</i>
	KAS B 1	1		175.0			18	30 - 35	25 - 35	17	75	25 - 40	indet. ssp.
	SAF 1	1		205.0			22						indet. ssp.
	KARI 1	2	340 - 445	392.5	180 - 200	190.0	23 - 24	50 - 85	40 - 60	10	55 - 80	30 - 45	<i>cf. chudeaul</i>
<i>O. multiplicatus</i>	KIR 9	1		590.0		350.0	40	35 - 40	40 - 55	8	120	25 - 50	indet. ssp.
<i>O. schopeni</i>	KIR 7	3	270 - 345	310.0	150 - 225	181.7	20 - 24	55 - 75	30 - 50	10 - 12	65 - 100	25 - 35	<i>ex. interc. suvlukayensis-crimensis</i>
	KIR 8	8	230 - 385	280.6 ± 21.9	125 - 180	145.0	17 - 29	50	25 - 35	11 - 15	40 - 60	25 - 35	
	KIR 7+8	11	230 - 385	288.6 ± 17.1	125 - 225	158.8	17 - 29	50 - 75	25 - 50	10 - 15	40 - 100	25 - 35	
	KÖP 5	8	225 - 340	275.0 ± 12.9	110 - 145	120.0	22 - 36	40 - 55	25 - 35	11 - 15	40	30 - 35	<i>suvlukayensis</i>
	KAS B 1	2	320 - 370	345.0						11 - 12			<i>cf. crimensis</i>
	SAF 1	5	290 - 375	328.0 ± 13.6	125 - 155	135.0	32 - 39	45 - 60	20 - 40	12 - 13	45 - 50	35 - 40	<i>crimensis</i>
<i>O. munieri</i>	KIR 7	5	285 - 380	338.0 ± 42.7	175 - 195	190.0	31 - 33	35 - 45	30 - 40	16 - 19	30 - 40	25 - 30	<i>munieri</i>
	KIR 8	17	260 - 430	332.9 ± 9.8	125 - 215	168.5	32 - 44	45 - 50	25 - 45	11 - 14	50 - 115	25 - 35	
	KIR 7+8	22	260 - 430	334.1 ± 8.3	125 - 215	173.5	31 - 44	45 - 50	25 - 45	11 - 19	30 - 115	25 - 35	
<i>O. varians</i>	KIR 10	3	115 - 150	130.0	75 - 80	76.7	9 - 11	25 - 30	30 - 35	18 - 19	45 - 50	25 - 45	<i>cf. portnayae</i>
	ÇAY 28	20	165 - 230	189.3 ± 3.7	85 - 130	103.0	14 - 17	35	30	14 - 15	60	25 - 30	<i>ankaraensis</i>
<i>Asterocyclina alticostata</i>	KIR 7	1		235.0		160.0							<i>gallica</i>
	KIR 8	24	160 - 255	220.0 ± 4.2	130 - 205	165.8		45 - 60	50 - 175	13 - 16	40 - 50	25 - 40	
	KIR 7+8	25	160 - 255	220.6 ± 4.1	130 - 205	165.5		45 - 60	50 - 175	13 - 16	40 - 50	25 - 40	
	KIR 9	1		190.0		140.0							
<i>A. schweighauseri</i>	KÖP 10	3	400 - 700	503.3	270 - 290	280.0		50 - 70	40 - 75	8	60	25 - 30	<i>cf. schweighauseri</i>
	ÇAY 28	1		500.0		335.0							indet. ssp.
<i>A. stellata</i>	KIR 8	9	100 - 125	114.4 ± 2.7	60 - 75	68.3	2 - 7	25	70	22 - 25	25 - 35	20 - 25	<i>adourensis</i>
	KIR 9	5	105 - 130	117.0 ± 4.2	70 - 80	72.5		25	45	23 - 24	25 - 30	25 - 35	<i>adourensis</i>
	KÖP 10	7	130 - 160	140.7 ± 3.4	80 - 95	86.3		20 - 45	25 - 35	21 - 23	25 - 35	20 - 30	<i>adourensis</i>

between 600 and 800 µm the SBZ 14–16 (middle–late Lutetian). Although these results will be published later separately, the most important biometric results are summarized in Table 3. Nummulitids other than the *N. perforatus* group, which are determined by following Schaub’s (1981) typological taxonomical concept.

Table 3. Statistical data of the *Nummulites perforatus* group and *N. pratti*.

Taxon	Sample	n°	Proloculus diameter (P) in mm	
			Range	Mean ± s.e.
<i>Nummulites perforatus</i> - group	SAF 9	14	250 - 450	323.6 ± 16.1
	ŞİLE 8A	29	400 - 650	547.9 ± 13.3
	ÇAY 28A	21	430 - 730	576.2 ± 19.9
	ÇAY 36A	12	540 - 760	646.7 ± 20.1
	ÇAY 37A	25	520 - 850	703.6 ± 18.0
	TAŞ 1	26	400 - 590	497.3 ± 10.8
	TAŞ 2	22	500 - 740	620.5 ± 14.8
	TAŞ 4	19	620 - 980	782.1 ± 25.0
	TAŞ 5	21	600 - 880	723.8 ± 18.1
	<i>N. pratti</i>	KIR 7	18	460 - 680

Regional Geological Setting and Description of Sections

Turkey is situated at the collisional boundary between Gondwana and Laurasia and its mountain ranges

constitute the easternmost segment of the Mediterranean Alpine chain (e.g., Şengör & Yılmaz 1981; Okay & Tüysüz 1999; Okay *et al.* 2001). The present tectonic regime follows the closure of the oceanic branches of Neotethys, which began to open in the Triassic and closed during the Late Cretaceous and Eocene. The final assembly of continental units is discussed under three tectonic units (Figure 2); the Pontides in the north, the Tauride–Anatolide Platform and the Arabian Plate in the south. The Eocene sections studied here for orthophragmines and other related foraminifera are confined to the Pontides, where shallow-marine Eocene sequences are better developed and preserved. It consists of several tectonic units, namely the İstanbul and Sakarya zones, separated by the Intra-Pontide suture (Şengör & Yılmaz 1981; Okay *et al.* 2001).

Safranbolu-Karabük Basin

Upper Thanetian to Lutetian shallow-marine deposits, comprising an approximately 150-m-thick succession of mainly clastic rocks and argillaceous carbonates, transgressively overlie deformed basement rocks. The Safranbolu Formation, the lowermost unit, contains an association of orthophragmines, nummulitid and

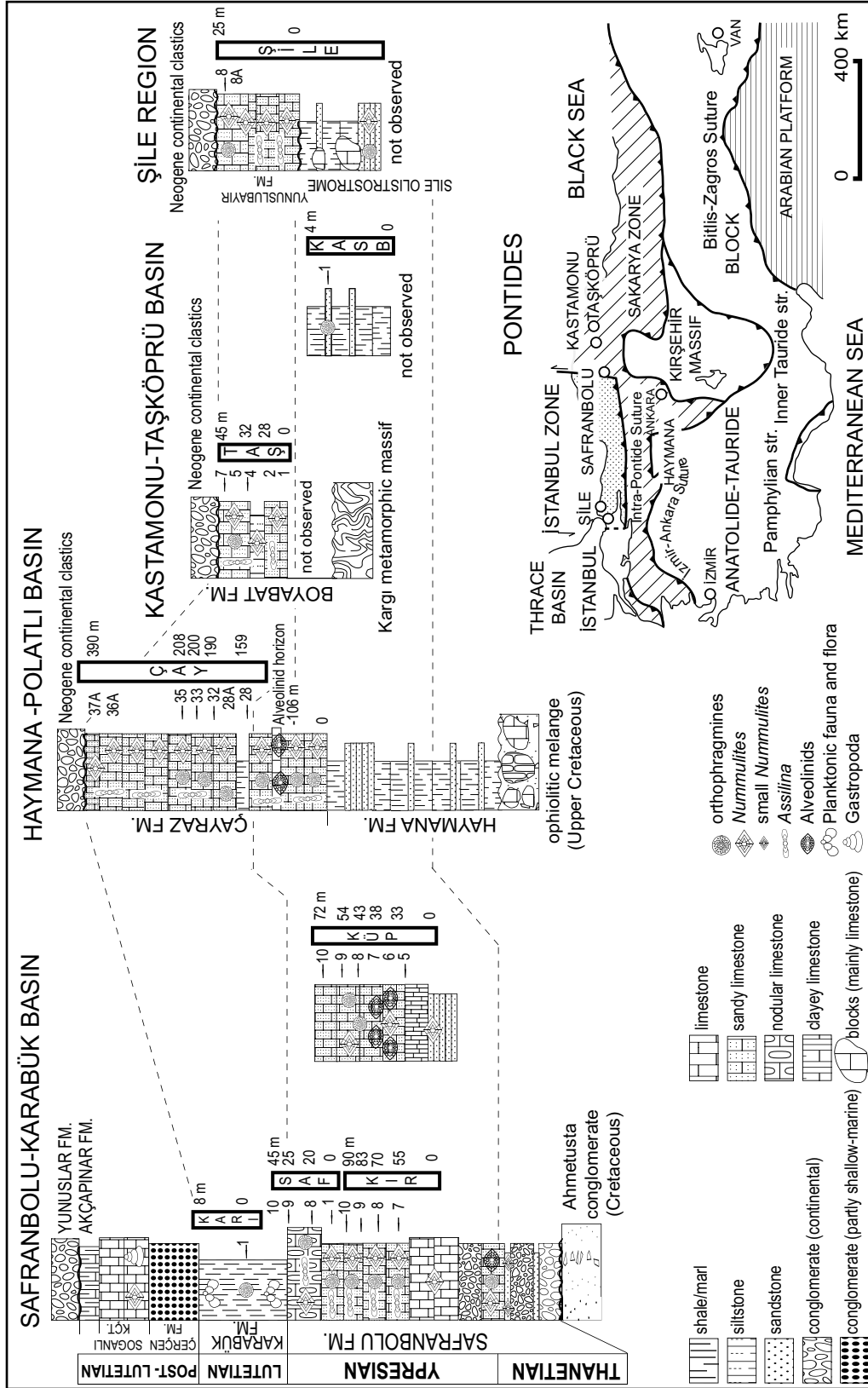


Figure 2. Synthetic stratigraphic sections of the sedimentary succession in central and northern Turkey and position of the studied stratigraphic intervals (tectonic map simplified from Okay et al. 2001). The horizons with free tests of orthophragmines are shown by arrows.

alveolinid foraminifera in different proportions in successive horizons (Koçyiğit 1987) (Figure 2). It is overlain by a thick (varying from 450 to 1500 m, Saner *et al.* 1980) succession of massive shales, siltstones and sandstones/conglomerates of the Karabük Formation. These clastic rocks, interpreted as a fluvio-deltaic complex (Güven 1980), however, contain mainly pelagic fossils and sporadic tests of transported nummulitids and orthophragmines in their lower part. Four sections (Kırıklar– KIR, Safranbolu– SAF, Küpler– KÜP and Karıt– KARI) were sampled from the basin succession (Figure 3). A brief stratigraphic account of each section is given below.

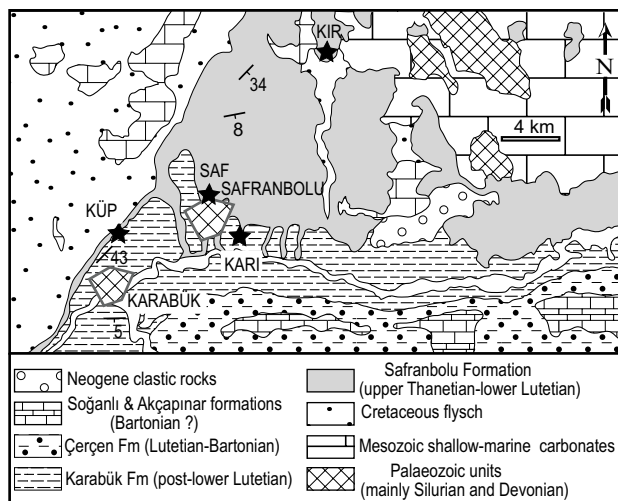


Figure 3. Locality map of the orthophragminid-bearing stratigraphic sections in the close vicinity of Karabük and Safranbolu in central northern Turkey (geological map simplified from Saner *et al.* 1980).

Kırıklar Section (KIR)– This 90-m-thick sequence of the Safranbolu Formation is located along the road from Safranbolu to Eflani between km 14 and 15 km, near Kırıklar village (Figures 2 & 3). The lower, 50-m-thick sequence is composed of thin- to medium-bedded, durable argillaceous limestone or limestones containing mainly miliolids, bryozoans, echinoids and scarce larger foraminifera (*Nummulites*, *Assilina* and orthophragmines). The upper, 40-m-thick part of the section comprises siltstones and/or sandstones with subordinate carbonates and contains a wealth of larger foraminifera dominated by *Nummulites* and orthophragmines. Some horizons (KIR 7 and KIR 8) are wholly made up of their tests, especially of *Nummulites*

pratti (see also Table 3). In this portion of the profile four horizons, two of them from the lower (KIR 7 and 8) and two of them from upper levels (KIR 9 and 10) have been investigated for orthophragmines. These assemblages, listed in Figure 4, are assigned to the early–middle part of the late Ypresian. Some forms like *Discocyclus archiaci* (though close to the upper biometric limit of the subspecies), *D. fortisi fortisi* (from sample KIR 9), *Orbitoclypeus schopeni* ex. interc. *suvlukayensis-crimensis*, *O. douvillei douvillei* and *Asterocyclus stellata adourensis*, both of the latter with rather small embryos, suggest the OZ 6 zone. Meanwhile *D. fortisi simferopolensis* (from sample KIR 8), *Nemkovella strophiolata fermonti* with rather large embryo and *A. alticostata gallica* indicate instead the OZ 7 zone. According to Less's (1998b) data, the proloculus size of *Nummulites pratti* is also more characteristic for the middle rather than early Cuisian (late Ypresian). By bearing the characteristics of both orthophragminid zones and considering also the unusual decrease of parameter 'd' of the *D. fortisi*-lineage between samples KIR 8 and 9 in superposition (passing also the subspecies limit between *D. f. simferopolensis* and *D. f. fortisi*), the age of samples KIR 7 to 10 can be determined to fall between the boundary of the OZ 6 and 7 zones.

Küpler Section (KÜP). This 72-m-thick sequence of the Safranbolu Formation was measured and sampled 200 m due west of Küpler village, which is about 1.5–2.0 km north of Karabük (Figures 2 & 3). The basal part of the sequence consists of sandstones and conglomerates, which are almost devoid of fauna. The middle part is characterized by the dominance of mostly friable limy sandstones or sandy limestones containing mainly miliolids, alveolinids, and scarce nummulitids and orthophragmines. The genus *Orbitolites* is quite abundant. In some horizons alveolinids are in rock-forming quantity (KÜP 6 and 7). In the upper portion of the sequence, where sandy limestone and limestones alternate with sandstone beds, a rather rich association of orthophragmines occurs. The orthophragminid composition of four horizons (KÜP 5, 8, 9 and 10) is shown in Figure 4. KÜP 5 can be referred to as about the boundary of OZ 6/7 zones because of the joint occurrence of *Discocyclus fortisi simferopolensis* characteristic for OZ 7 and *Orbitoclypeus schopeni suvlukayensis* previously known only from older layers (mainly OZ 4). Meanwhile

O. douvillei douvillei occurs in both the OZ 6 and 7 zones. Samples KÜP 8, 9 and 10 are significantly younger. *Discocyclus fortisi* ex. interc. *simferopolensis-anatolica* from the two lower samples indicates the transition between the OZ 7 and 8a zones, while some forms from sample KÜP 10 (*D. archiaci* ex. interc. *bartholomei-archiaci* and *Orbitoclypeus douvillei douvillei*, close to the

upper limit of the subspecies) suggest the OZ 7 zone and others (*Asterocyclina stellata adourensis* close to its upper biometric limit and *A. schweighauseri* cf. *schweighauseri*) indicate a rather younger age. To sum up, placing these three upper samples at about the boundary of the OZ 7 and 8a zones seems to be a reasonable compromise.

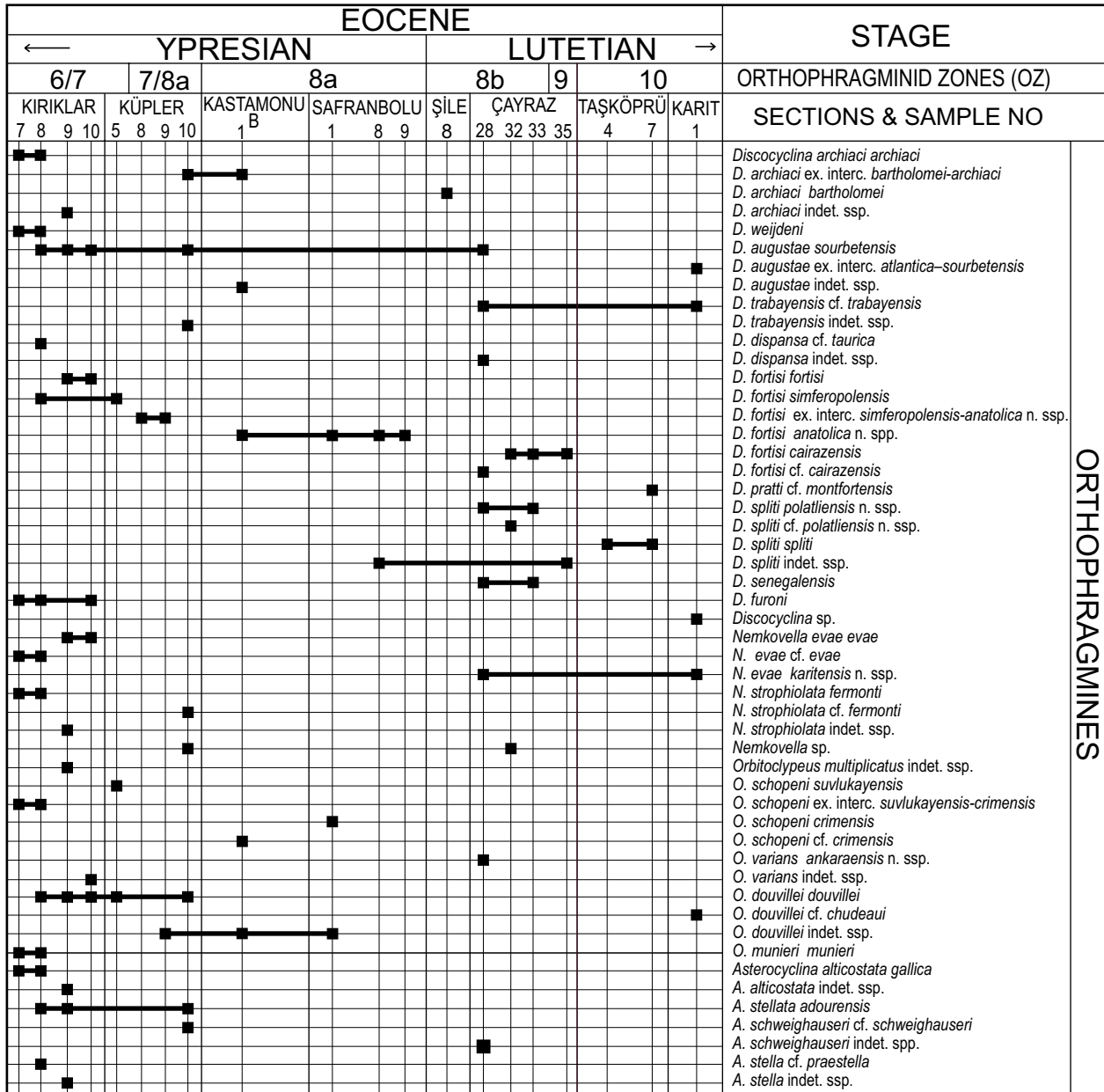


Figure 4. Distribution of late Ypresian–middle Lutetian orthophragmines in the studied sections.

Safranbolu Section (SAF). The section is located on a small hill in the centre of Safranbolu town on the main road to Eflani (Figure 3). The profile, about 30 m thick, exposes the upper part of Safranbolu Formation, which is overlain by the basinal siliciclastic rocks of the Karabük Formation (Figure 2). The lower part comprises a 20-m-thick sequence of massive, friable limy siltstones, which contain nummulitids, alveolinids and orthophragminids (SAF 1). These pass upwards into thick-bedded to massive, partly friable nodular carbonate and limy claystone/siltstone horizons, which attain a thickness of about 15 m. The whole section is characterized by abundant nummulitids (*Nummulites perforatus*-group, *N. laevigatus*-group, *N. tauricus*, *Assilina maior*) and some alveolinids. The evolutionary degree of the *N. perforatus*-group in sample SAF 9 corresponds to the latest Ypresian SBZ 12 zone. Three horizons (SAF 1, 8 and 9) contain orthophragminid specimens represented predominantly by *Discocyclus fortisi* (Figure 4). The orthophragminid assemblages in all three samples can be referred to zone OZ 8a, based on the common occurrence of *D. fortisi anatolica* n. ssp. and *O. schopeni crimensis*, identified only in the lowermost sample. Two marly horizons at the lower part of Karabük Formation (KIR 10 A and B) yielded the following calcareous nannoplankton assemblage (determined by Mrs. M. Báldi-Beke); KIR 10A contains *Coccolithus pelagicus* (Wallich) and *Pemma rotundum* Klumpp and KIR 10B contains an association of *C. pelagicus* (Wallich) *C. eopelagicus* (Bramlette et Riedel) *Cyclococcolithus formosus* Kamptner, *Cyclicargolithus floridanus* (Roth et Hay), *Chiasmolithus medius* Perch-Nielsen, *Discoaster barbadiensis* Tan, *Braarudosphaera bigelowi* (Gran et Braarud), *Micrantholithus flos Deflandre*, *Sphenolithus radians* Deflandre *Pemma* sp., and *Discolithina* sp. These horizons can be referred to NP 15 (middle Lutetian) based on the occurrence of *Ch. medius* in KIR 10B. It is worth noting that *Nummulites dufrenoyi*, considered by Schaub (1981) as a zonal marker of the 'Barrizian' (Bartonian), can be identified neither in all studied profiles from the Safranbolu region, the type locality of the species, nor in the neighboring regions. Owing to the above nannoplankton data, the presence of Bartonian larger Foraminifera in the town of Safranbolu, where d'Archiac & Haime (1853) described the above *Nummulites*, is hard to imagine.

Karit Section (KARI). This section is located on the main road from Safranbolu to Kastamonu at km 1.5, about 2.0 km north of Karit village (Figure 3). The profile, about 8 m thick, represents the lower part of the basinal Karabük Formation (Figure 2). This road cut section comprises a sequence of massive mudstones, containing a horizon of nummulitids and orthophragmines (sample KARI 1, the orthophragminid inventory is listed in Figure 4), and a redeposited pebbly horizon in its upper part. The orthophragminid assemblage marks zone OZ 10 (middle Lutetian) based on the rather advanced developmental stage of *Orbitoclypeus douvillei* (*O. d. cf. chudeaui*) and *Nemkovella evae* (*N. e. karitensis* n. ssp.).

Kastamonu-Boyabat Basin

The Kastamonu-Boyabat Basin includes a variety of sedimentary and volcanic sequences continuous from the Upper Cretaceous to the Oligocene (Yılmaz *et al.* 1997). However, in the Kastamonu and Taşköprü regions, shallow-marine Eocene units, unconformably rest upon the Kargı Massif, which is a tectonic mosaic of various metamorphic, metaophiolite and mélange units (Figures 2 & 5). Eocene deposits near Kastamonu are dominated by shallow-marine bioclastic limestones and fine clastics, overlain by a prominent shaly succession which includes substantial amounts of volcanic and volcanoclastic rocks, termed the Boyabat Formation. The lowest part of this unit, about 80 m thick, contains a rich association of nummulitids and alveolinids, and there are several horizons with orthophragmines throughout the section. In the same region a few horizons in the lowest portion of the overlying shales and volcanoclastics were also found to contain nummulitids and orthophragmines. East of Kastamonu near Taşköprü, another shallow-marine unit containing nummulitids and orthophragmines crops out. These deposits, also referred to as the Boyabat Formation in the literature, contain a younger faunal association and record another shallowing in the Lutetian.

Kastamonu B Section (KASB). This is a 4-m-thick road-cut exposure of the Boyabat Formation just along the street where the teachers' guest house is situated in Kastamonu. The succession, representing a small part of the upper shaly unit, comprises mudstones rich in pelagic fauna and turbiditic sandstone beds with badly preserved

nummulitids and orthophragmines. The orthophragminid assemblage of sample KAS B 1 (Figure 4) marks most probably zone OZ 8a, based on the joint occurrence of *Discocyclus fortisi anatolica* n. ssp., *D. archiaci* ex. interc. *bartholomei-archiaci* and *Orbitoclypeus schopeni* cf. *crimensis*, although the number of specimens is very limited.

Taşköprü Section (TAŞ). In Taşköprü region, about 45 km northeast of Kastamonu, Eocene shallow marine units, with an observable thickness of about 45 m, are exposed along the road from Taşköprü to Boyabat, at the Taşköprü-Boyabat-Kastamonu road junction (Figures 2 & 5). The lower boundary of the unit in the Taşköprü section is not observed but its unconformable relation with the Kargı Massif is inferred from the regional geology. In the lower portion of the section, a 28-m-thick sequence is represented mainly by medium-bedded, sandy bioclastic limestones containing nummulitid foraminifera (*Nummulites laveigatus* and *N. perforatus* groups) in rock-forming quantity in many horizons. Orthophragminids are not observed in these levels. The middle 4-m-thick calcareous siltstone horizon is succeeded by a nummulitid bioclastic sequence of sandy carbonates and siltstones containing representatives of the *Nummulites perforatus*- and *Assilina exponens*-groups. The *Nummulites perforatus*-group, studied in samples TAŞ 1, 2, 4 and 5, shows a peculiar development

throughout the section (Table 3). Based on these data the bottom of the section (TAŞ 1) corresponds to the early Lutetian SBZ 13 zone, whereas the upper samples represent at least the middle–upper Lutetian SBZ 14–16 zones. Orthophragminid foraminifera are only confined to few beds in the upper part of the section (TAŞ 4 and 7). In sample TAŞ 4 the orthophragmines are monospecific and represented by *Discocyclus spliti spliti*. The upper sample contains both *Discocyclus spliti spliti* and *D. pratti* cf. *montfortensis*. These forms indicate most probably the OZ 10 zone for the upper part of the shallow-marine succession.

Haymana-Polatlı Basin

The Haymana-Polatlı Basin in central Anatolia is an accretionary type of fore-arc basin formed by the destruction of the Neotethys during the Late Cretaceous to Middle Eocene time interval (Koçyiğit 1991). The Paleocene to middle Eocene part of the basin sequence is characterized by the abundance and diversity of nummulitids and partly alveolinids. Orthophragmines are locally abundant and are found in rock-forming quantities in some horizons (Özcan 2002; Özcan *et al.* 2001; Çolakoğlu & Özcan 2003). The Çayraz Formation, the highest stratigraphic unit of the Tertiary succession, is a thick (locally up to 500 m) shallow-marine carbonate-clastic unit; it conformably overlies the basinal siliciclastic rocks of the Eskipolatlı Formation and is unconformably overlain by Neogene sediments. Çiner *et al.* (1996) subdivided the Çayraz Formation into two (lower and upper) shelf systems, characterized by the repetition of marls and nummulitic horizons ('nummulitic banks' of the authors). The orthophragminid assemblage of the lower shelf system, delimited by underlying basinal clastic rocks at its lower boundary and by an *Alveolina*-rich horizon (horizon with alveolinids at 106 m, Figure 2) at its upper part, has already been presented by Özcan (2002). Özcan referred it to zones OZ 5-8a (late Ypresian), although, according to our recent interpretation samples ÇAY 18 and 21 with *Discocyclus fortisi*-assemblages, with d_{mean} over 1450 μ m corresponding to the redefined *D. f. cairazensis*, belong already to the OZ 8b zone. The succeeding upper carbonate package of the Çayraz Formation (the interval between 106 and 390 m) corresponds to the 'Upper Çayraz' section.

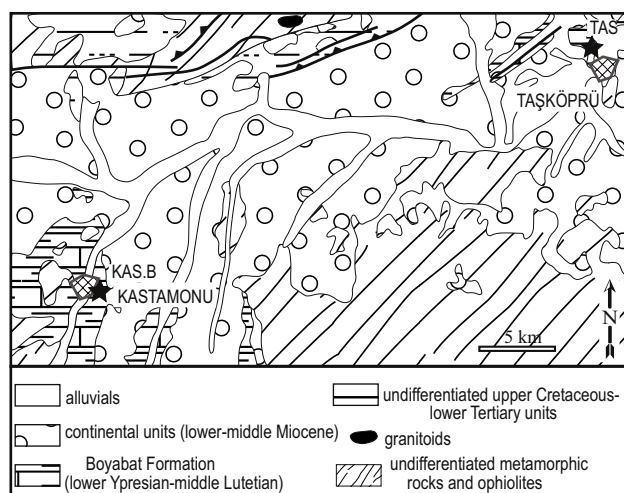


Figure 5. Locality map of the orthophragminid foraminifera-bearing sections in the close vicinity of Kastamonu and Taşköprü (geological map simplified from 1:500 000 scale 'Geological map of Turkey' Sinop Sheet, 2002).

Upper Çayraz Section (ÇAY). This 284-m-thick sequence of the upper part of the Çayraz Formation was sampled along the hill towards Hasanfaki Tepe, to the north of the road from Çayraz to Yeşilyurt, just few hundred meters to the east of Çayraz village (Haymana, Ankara) (Figures 2 & 6). The base comprises a 25-m-thick sequence of more or less massive, marl-siltstone and sandstone unit, devoid of larger foraminifera above the alveolinid horizon (at 106 m). This is directly overlain by a 259-m-thick monotonous succession of medium- to thick-bedded carbonate beds with intervening siltstone and mudstone horizons. The argillaceous carbonate beds contain nummulitids in rock-forming quantity. Orthophragmines can only be encountered in the lower part of the sequence (samples ÇAY 28, 32, 33 and 35) and were not identified in the upper part of the section. Three horizons (ÇAY 28A, 36A and 37A) have been sampled to study the developmental stage of *N. perforatus* (Table 3). These horizons correspond to samples 10 (= 28A), 16 (= 36A) and 18 (= 37A) of the Çayraz section as drawn by Sirel (1992). According to the field-trip guide in 1992, sample 18 is the type locality of *N. lehneri* belonging to the *N. perforatus*-group. This species is considered as a zonal marker for SBZ 13 (early Lutetian) of Serra-Kiel *et al.* (1998), although the representatives of the *N. perforatus*-group of this age (from other localities) have significantly smaller proloculus dimensions (cf. Less 1998b). In eliminating this nomenclature, based strictly on average protoconch diameters (Table 3), ÇAY 28A corresponds to the SBZ 13 zone, while the other two populations to SBZ 14/15. The orthophragminid assemblage of ÇAY 28, (Figure 4), is referred to zone OZ

8b (latest Ypresian to early Lutetian), based on the joint occurrence of *Discocyclus fortisi* cf. *cairazensis*, *D. spliti polatliensis* n. ssp., *D. senegalensis*, *Nemkovella evae karitensis* n. ssp. and *Orbitoclypeus varians ankaraensis* n. ssp. According to nummulitid data (see above) and also from the presence of *N. evae karitensis* sample ÇAY 28 belongs to the earliest Lutetian rather than the latest Ypresian. The assemblages in ÇAY 32 and 33 are referred to zone OZ 8b (early Lutetian) based on the joint occurrence of *Discocyclus fortisi cairazensis*, *D. spliti polatliensis* n. ssp. and *D. senegalensis*. Finally, sample ÇAY 35 contains considerably more advanced *D. f. cairazensis* than the lower samples; therefore it corresponds already to zone OZ 9. It is worth noting that the age of at least the middle and upper parts of the Çayraz section is, based on the orthophragmines, significantly younger than suggested by Hottinger (1960), Sirel & Gündüz (1976), Schaub (1981) and Sirel (1992), based on alveolinids and nummulitids. Meanwhile our ages are very close to those given by Dizer (1968).

Şile Region

Shallow-marine lower Eocene deposits crop out near the town of Şile, east of İstanbul (Figures 2 & 7). The succession is divided into a lower, rather deep-water chaotic sedimentary unit, and an upper unconformable shallow-marine nummulitid carbonate and clastic unit (Baykal & Önal 1979). The upper unconformable unit, named the Yunuslubayır Formation, is about 25 meters thick and contains a wealth of nummulitids (*Nummulites laevigatus*, *N. perforatus* and *Assilina spira*-groups) and

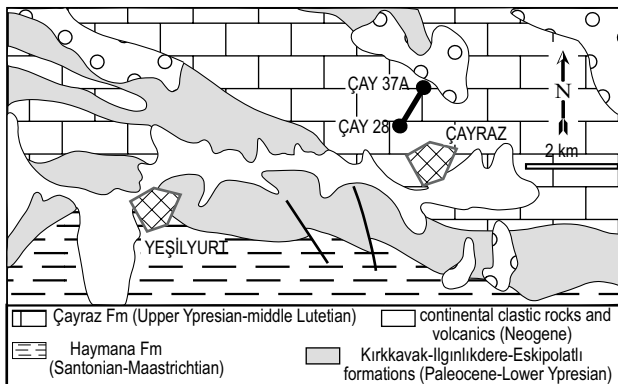


Figure 6. Locality map of the Çayraz section near Çayraz (Haymana, Ankara) (geological map simplified from Ünal *et al.* 1976).

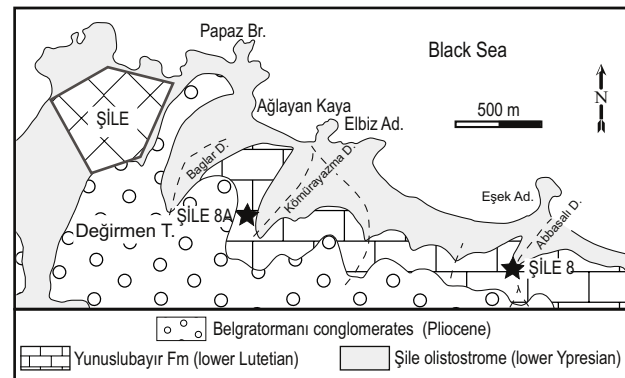


Figure 7. Locality map of the samples collected in the close vicinity of Şile (İstanbul) (geological map simplified from Baykal & Önal 1979).

sporadic tests of orthophragminids in its uppermost levels (ŞİLE 8A and 8 respectively). Orthophragminids at this level are monospecific and represented by the most advanced *D. archiaci bartholomei* known so far. The evolutionary degree of *Nummulites*, belonging to the *N. perforatus*-group from sample ŞİLE 8A (Table 3) corresponds to the early Lutetian SBZ 13 zone. By synthesizing the above data, the Lutetian part of the OZ 8b zone seems to be the most probable age of these beds.

Systematic Part

We only give full descriptions for *Orbitoclypeus munieri* (confused in Less 1987 with *O. bayani*) and for the new subspecies. 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 each species), the up-to-date subdivision into subspecies with their biometric limits (mostly according to Less 1998a, therefore it is not mentioned separately) and the characteristics (occurrence, evolution and possible deviations) of the Turkish material. In the descriptions, in characterizing some qualitative features, we adopt the terminology introduced by Less (1987, 1993).

Only the new subspecies and *Discocyclina spliti spliti* 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 Tables 1 and 2, respectively.

Order FORAMINIFERIDA Eichwald 1830

Family DISCOCYCLINIDAE Galloway 1928

Genus *Discocyclina* Gümbel 1870

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 a common orthophragminid taxon known from at least Spain to Turkey. It first appears in the early Ypresian (OZ 3), and then spreads until the early Lutetian (zone OZ 8b). Additional information on the species can

be found in Özcan (2002) and Çolakoğlu & Özcan (2003). Less (1998a) ranked the rare *D. furoni*, *D. weijdeni* and *D. senegalensis* with *D. archiaci*; although in the Turkish material the validity of these taxa has been strengthened (for reasons see the description of the actual taxon). *D. archiaci* forms a rapidly evolving lineage with four successive subspecies whose biometric limits are considered as follows:

<i>D. a. bakhchisaraiensis</i>	$d_{\text{mean}} < 305 \mu\text{m}$
<i>D. a. staroseliensis</i>	$d_{\text{mean}} = 305\text{--}390 \mu\text{m}$
<i>D. a. archiaci</i>	$d_{\text{mean}} = 390\text{--}600 \mu\text{m}$
<i>D. a. bartholomei</i>	$d_{\text{mean}} > 600 \mu\text{m}$

The species can be arranged in two groups. However, the one with smaller embryon is (rather unfortunately) cut by the biometric boundary between *D. archiaci archiaci* and *D. a. bartholomei*. This limit should very probably be lowered from 600 μm to 540 μm by gathering more data in the future. Meanwhile, the assemblages from samples KIR 7–8 of early–middle late Ypresian age (OZ 6/7) have to be determined as *D. archiaci archiaci* (Figures 8i & 9) whereas those from sample KÜP 10 are of middle late Ypresian age (OZ 7/8a) and those from sample KAS B 1 are very probably of latest Ypresian age (OZ 8a) as *D. archiaci ex. interc. bartholomei-archiaci* (Figures 8j & 9). The assemblage from sample ŞİLE 8 represents the most advanced *D. archiaci bartholomei* (Figures 8k–m & 9) known so far and, considering also nummulitid data, belongs to the Lutetian part of the OZ 8b zone.

Discocyclina augustae van der Weijden 1940

Discocyclina augustae is an unribbed form having a very small to small, semi-iso- to nephrolepidine embryon, narrow and low, 'archiaci'-type adauxiliary chamberlets and also narrow and relatively low equatorial chamberlets mostly with 'strophiolata'-type growth pattern. Geographically distributed from NE Spain to India, it first appears in the early Ypresian (OZ 3), but only becomes common from the beginning of the late Ypresian and then spreads until the very end of the Priabonian. Additional information on *D. augustae* can be found in Less (1999), Rasser *et al.* (1999), Özcan (2002) and Çolakoğlu &

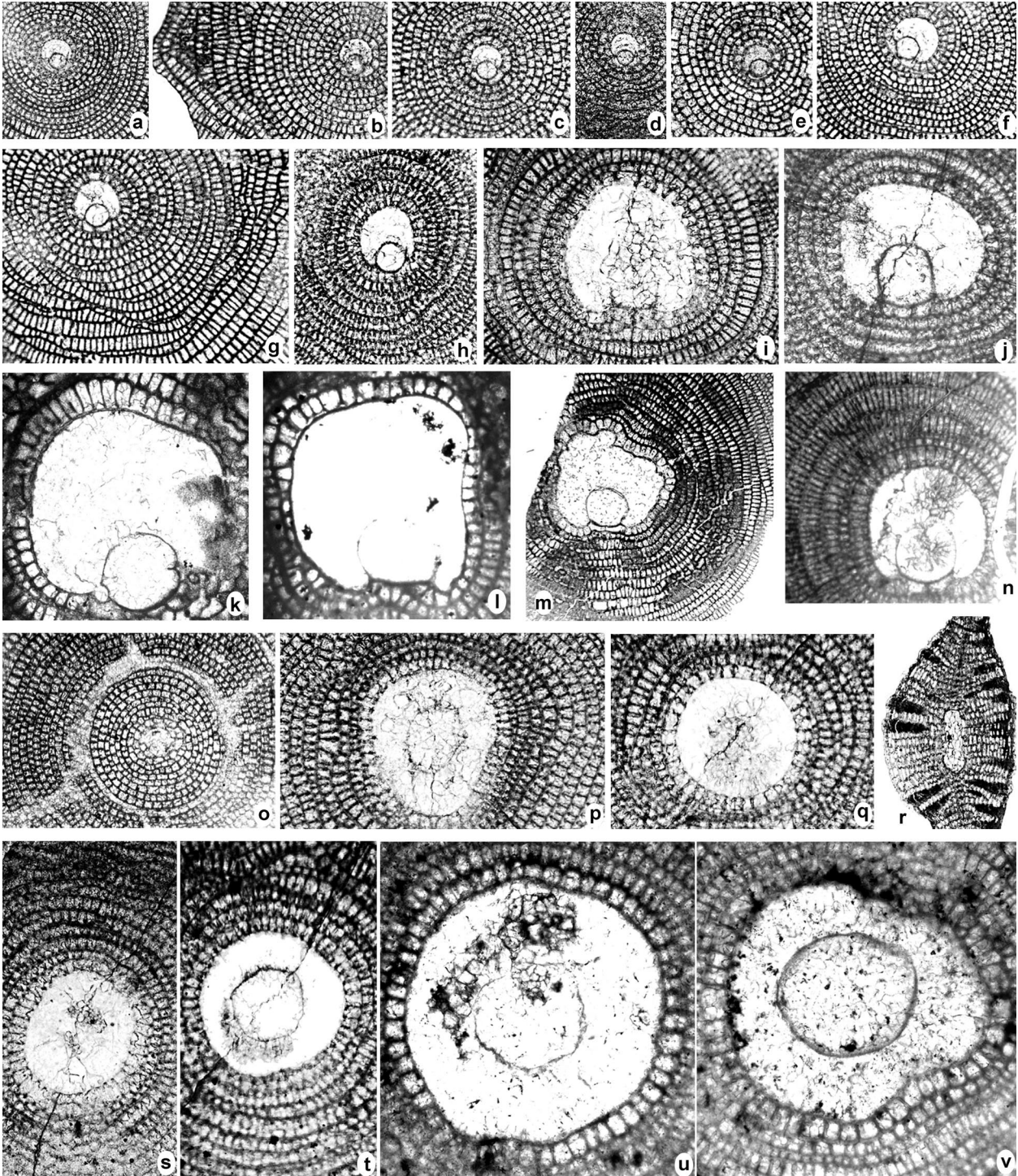


Figure 8. (a–d) *Discocyclusina augustae* van der Weijden *sourbetensis* Less, (a) O/KIR 8-25, (b) O/KIR 10-32, (c) O/ÇAY 28-1, (d) O/KÜP.10-44. (e) *D. augustae* van der Weijden ex. interc. *atlantica-sourbetensis* Less, O/KARI 1-27. (f–g) *D. dispansa* (Sowerby) cf. *taurica* Less, (f) O/KIR 8-103, (g) O/KIR 8-102. (h) *D. furoni* Samanta, O/KIR 7-11. (i) *D. archiaci archiaci* (Schlumberger), O/KIR 8-107. (j) *D. archiaci* (Schlumberger) ex. interc. *bartholomei-archiaci* (Schlumberger), O/KÜP 10-70. (k–m) *D. archiaci bartholomei* (Schlumberger), (k) O/ŞİLE 8-9, (l) O/ŞİLE 8-1, (m) O/ŞİLE 8-4. (n) *D. weijdeni* Less, O/KIR 8-50. (o) *D. cf. trabayensis* Neumann, O/ÇAY 28-52. (p–t) *D. spliti* Butterlin et Chorowicz *polatliensis* n. ssp., (p) O/ÇAY 28-14, holotype, (q) O/ÇAY 28-62, (r) O/ÇAY 33-10, (s) O/ÇAY 33-1, (t) O/ÇAY 28-56. (u–v) *D. spliti spliti* Butterlin et Chorowicz, (u) O/TAŞ.4-1, (v) O/TAŞ 4-9. All A-forms, r: vertical, the others equatorial sections, m, r: x17, the others: x40.

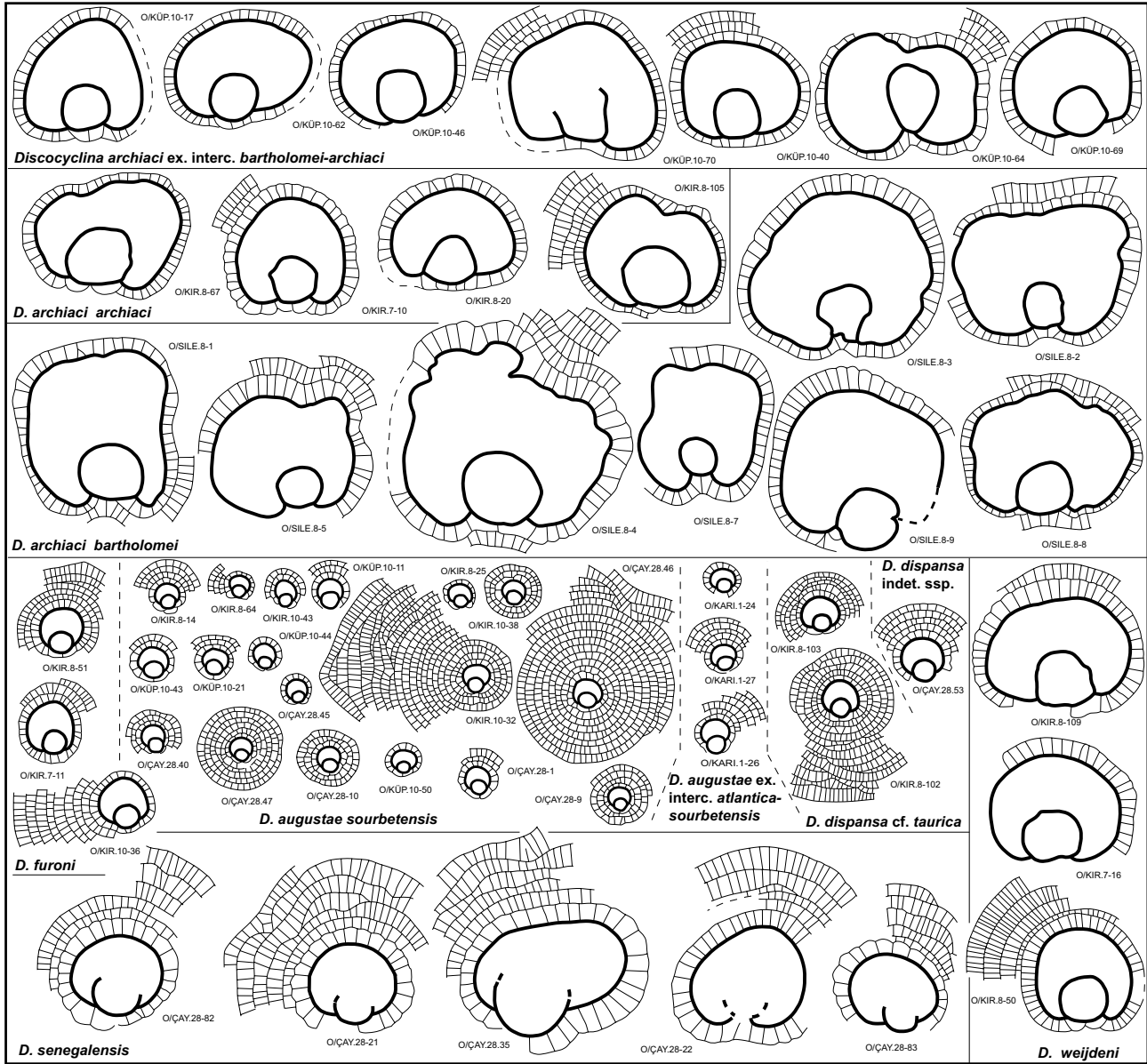


Figure 9. Types of embryo and their variation in *Discocyclina archiaci*, *D. augustae*, *D. dispansa*, *D. furoni*, *D. senegalensis* and *D. weijdeni*. All $\times 28$.

Özcan (2003). The species forms a rather slowly developing evolutionary lineage with four subspecies listed below:

<i>D. a. sourbetensis</i>	$d_{\text{mean}} < 145 \mu\text{m}$
<i>D. a. atlantica</i>	$d_{\text{mean}} = 145\text{--}180 \mu\text{m}$
<i>D. a. olianae</i>	$d_{\text{mean}} = 180\text{--}225 \mu\text{m}$
<i>D. a. augustae</i>	$d_{\text{mean}} > 225 \mu\text{m}$

Two developmental stages are described: *D. augustae sourbetensis* (Figures 8a–d & 9) in the late Ypresian of Kırıklar (OZ 6/7), and Küpler (OZ 7/8a) and in the earliest Lutetian of Çayraz, sample ÇAY 28 (OZ 8b), whereas *D. augustae ex. interc. atlantica-sourbetensis* (Figures 8e & 9) is in the middle Lutetian of Kart (OZ 10). Our data, based on the specimens from ÇAY 28, indicate that the stratigraphic range of *D. a. sourbetensis* should be slightly modified by extending its upper boundary upward to include zone OZ 8b (or maybe even OZ 9).

Discocyclina fortisi (d'Archiac 1850)

Discocyclina fortisi is an unribbed species having a large to giant centrilepidine (rarely excentrilepidine) embryo, numerous, wide and high, 'archiaci' (rarely also 'archiacipratti') type adauxiliary chamberlets and relatively wide and high equatorial chamberlets with 'archiaci'-type growth patterns. Sometimes the equatorial chamberlets in the external annuli are significantly lower than those in the internal cycles, and in this case, the growth pattern is of 'spliti'-type. Geographically it is known to extend from SW France to Turkey.

Less (1987, 1998a) considered *D. pseudoaugustae* (mostly with multilepidine embryo) characteristic for the OZ 4 and 5 zones as the precursor form of *D. fortisi* ranging from OZ 6 only to OZ 7 (however with two successive subspecies, 'fortisi' and 'simferopolensis') and passing into *D. stratiemanuelis* (with 'pratti'-type adauxiliary chamberlets) characteristic for OZ 8a. Özcan's (2002) data from the lower part of the Çayraz section significantly modified the extension of the species upward by describing a more advanced developmental stage (*D. fortisi cairazensis*) with giant embryo from the uppermost Ypresian (zones OZ 8a and 8b according to our recent interpretation). Later, Çolakoğlu & Özcan (2003) found a single specimen in the uppermost beds of Sakarya at about the early/late Ypresian boundary (zone OZ 4/5). This discovery should extend the range of the species downwards, but it has to be treated with some caution because of its unique manner and because *D. pseudoaugustae* characteristic for this age can occasionally bear centrilepidine embryo, too. Our new data from Turkey allow further upwards extension of the stratigraphic range of the species since it also occurs in the upper part of the Çayraz section demonstrating giant embryo sizes and coexisting with the most primitive evolutionary stage of *D. spliti* (*D. spliti polatliensis* n. ssp.). Based on a considerable data set from Çayraz, Safranbolu and Kastamonu, Özcan's (2002) *D. fortisi cairazensis* can be further subdivided. By reserving its type locality, however modifying the diagnosis (see below), it is restricted to zones OZ 8b and 9, while the newly erected *D. fortisi anatolica* is characteristic for OZ 8a. To sum up, *D. fortisi* forms a nicely developing evolutionary lineage (extending questionably from zone OZ 4/5, and surely from OZ 6 to at least OZ 9) with four successive subspecies listed below:

<i>D. f. fortisi</i>	$d_{\text{mean}} < 850 \mu\text{m}$
<i>D. f. simferopolensis</i>	$d_{\text{mean}} = 850\text{--}1100 \mu\text{m}$
<i>D. f. anatolica</i> n. ssp.	$d_{\text{mean}} = 1100\text{--}1450 \mu\text{m}$
<i>D. f. cairazensis</i>	$d_{\text{mean}} > 1450 \mu\text{m}$

Discocyclina fortisi is, perhaps, the most common orthophragminid species in the Ypresian and early Lutetian of Turkey. Its occurrence with very large to giant embryonic apparatus is documented here for the first time. Five developmental stages are described: *D. f. fortisi* from the upper samples of Kırıklar (KIR 9–10; OZ 6/7, Figures 10b–c & 11), *D. f. simferopolensis* from the lower samples of Kırıklar (KIR 7–8; OZ 6/7, Figures 10d–f & 11) and Küpler (KÜP 5; OZ 6/7), *D. f. ex. interc. simferopolensis-anatolica* from the middle samples of Küpler (KÜP 8, 9; OZ 7/8a, Figures 10g–h & 11), *D. f. anatolica* n. ssp. in the late Ypresian of Kastamonu B and Safranbolu (OZ 8a, Figures 10i–k & 11) and *D. f. cairazensis* in the early Lutetian of Çayraz (OZ 8b for ÇAY 32 and 33 and probably OZ 9 for ÇAY 35, Figures 10l–m & 11). It is worth noting that in this latter sample the embryo size is the largest of all orthophragmines recorded so far in the western Tethys. As with *D. spliti* the advanced *D. fortisi* (*D. f. anatolica* and *D. f. cairazensis*) can be found separately from the other orthophragmines, it occurs rather with the representatives of the *Nummulites perforatus*-group; thus they seem to have been accommodated in shallower marine niches.

Based on our new data from the Kırıklar section, it is clear that the stratigraphic ranges of *D. fortisi fortisi* and *D. f. simferopolensis* strongly overlap at about the boundary of the OZ 6 and 7 zones, and therefore, neither of them can be considered any longer as zonal marker for these zones. With the introduction of *D. f. anatolica* n. ssp. some populations from the middle part of the Çayraz and Yeşilyurt sections (samples ÇAY 14, 17 and YEŞ 128 in Özcan 2002) have to be re-arranged to this developmental stage. Consequently, they should belong to the OZ 8a zone. Simultaneously, the uppermost populations of the Çayraz section (ÇAY 18 and 21) belong to *D. f. cairazensis* and determine (probably the latest Ypresian part of) the OZ 8b zone. It is worth noting the lack of *D. stratiemanuelis* in the latest Ypresian of Turkey.

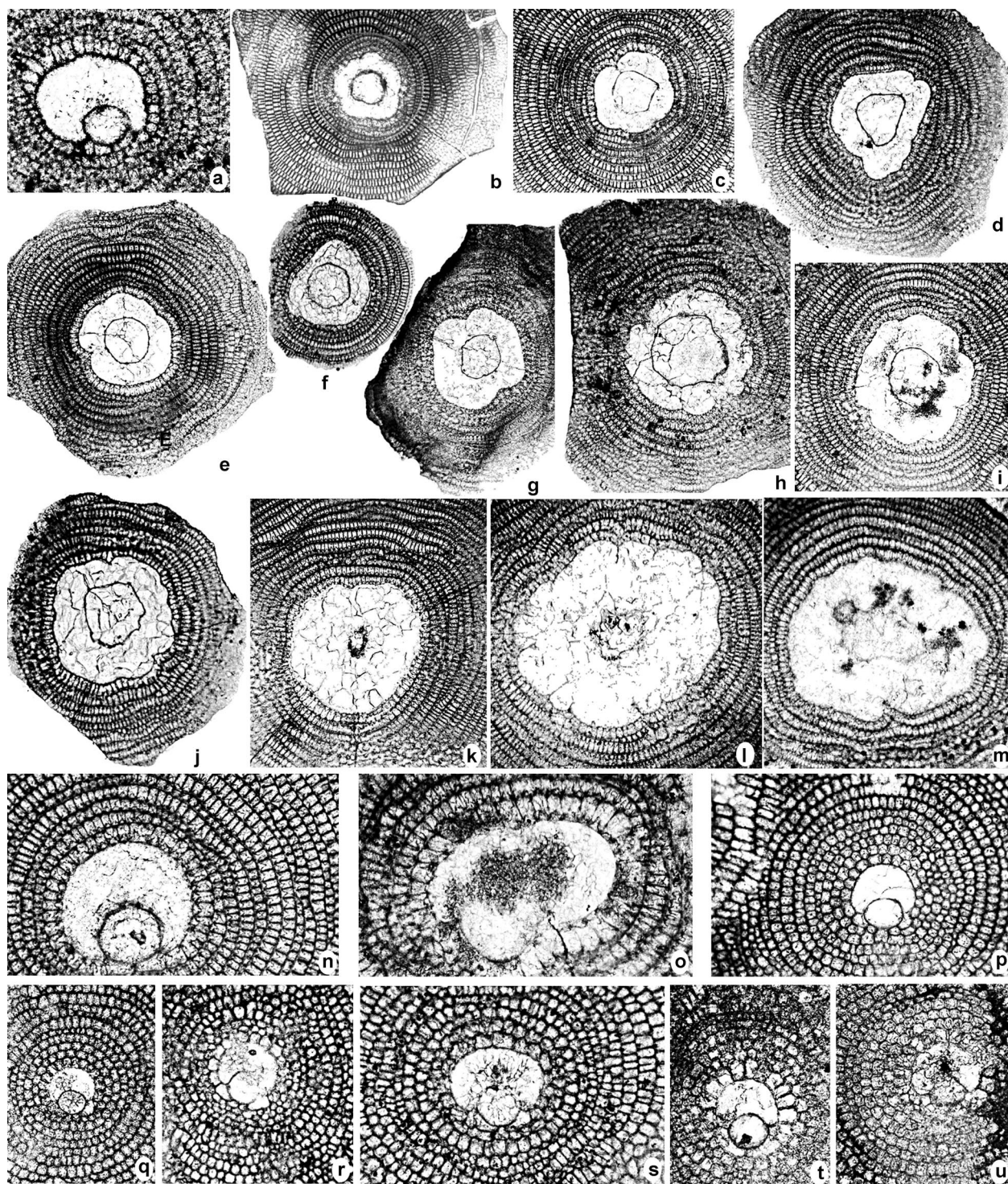


Figure 10. (a) *Discocyclusina pratti* (Michelin) cf. *montfortensis* Less, O/TAŞ 7-1. (b-c) *D. fortisi fortisi* (d'Archiac), (b) O/KIR 9-15, (c) KIR 8-31. (d-f) *D. fortisi* (d'Archiac) *simferopolensis* Less, (d) O/KÜP 5-42, (e) O/KÜP 5-21, (f) O/KIR 8-98. (g-h) *D. fortisi* (d'Archiac) ex. interc. *simferopolensis* Less-*anatolica* n. ssp., (g) O/KÜP 8-10, (h) O/KÜP 9-23. (i-k) *D. fortisi* (d'Archiac) *anatolica* n. ssp., (i) O/SAF 8-1, (j) O/SAF 9-5, holotype, (k) O/SAF 8-14. (l-m) *D. fortisi* (d'Archiac) *cairazensis* Özcan, (l) O/ÇAY 35-21b, (m) O/ÇAY 33-6. (n) *Discocyclusina* sp., O/KARI 1-19. (o) *D. senegalensis* Abrard, O/ÇAY 28-35. (p-r) *Nemkovella evae evae* Less, (p) O/KIR 9-43, (q) O/KIR 9-1, (r) O/KIR 9-42. (s-u) *N. evae* Less *karitensis* n. ssp., (s) O/ÇAY 28-108, (t) O/KARI 1-7, (u) O/KARI 1-6, holotype. All equatorial sections of A-forms, b-m:×17, the others: ×40.

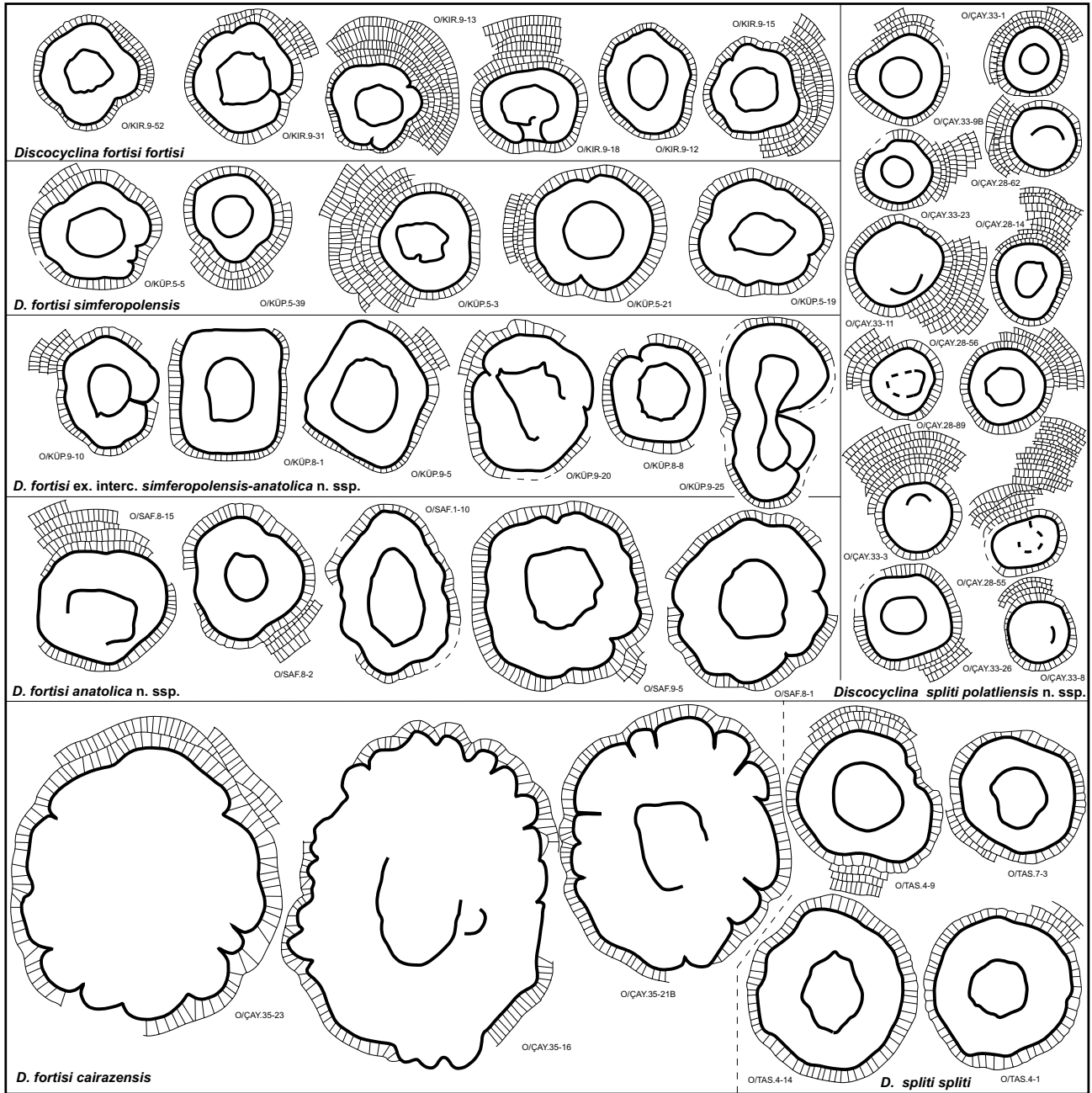


Figure 11. Types of embryo and their variation in *Discocyclusa fortisi* and *D. spliti*. All $\times 20$.

Since Özcan (2002) reported it from the lower part of the Yeşilyurt section belonging to early late Ypresian (OZ 5-6), this latter species cannot be considered any longer as the straight offspring of *D. fortisi*: rather these two species run parallel in the late Ypresian.

Discocyclusa fortisi (d'Archiac 1850) *anatolica* n. ssp. Özcan et Less

Figures 10i-k & 11

partim 2002 *Discocyclusa fortisi* (d'Archiac, 1850) *cairazensis* n. ssp., Özcan, p. 82–83, pl. 4, fig. 9.

Etymology. From Greek Anatole, that means 'sunrise' or 'East'.

Holotype. Specimen O/SAF 9-5 (Figures 10j & 11).

Paratypes. All the other specimens from sample SAF 9 assigned to the same taxon in Figure 11.

Depository. Geology Department of İstanbul Technical University.

Type Locality. Safranbolu (Karabük, central Turkey), sample SAF 9, upper part of Safranbolu Formation.

Type Level. late Ypresian, zone OZ 8a.

Diagnosis. *D. fortisi* populations with d_{mean} ranging between 1100 and 1450 μm .

Description (see also Table 1). Medium- to large-sized (up to 9 mm), thick inflated forms. The large embryo invariably presents excentri- to mainly centri-lepidine configuration. The adauxiliary chamberlets are numerous, and are of 'archiaci'-type. The equatorial chamberlets are typically rectangular in shape, relatively wide and moderately high. Their growth pattern is mostly of the 'archiaci', rarely of the transitional 'archiaci-spliti' type. In this latter case the equatorial annuli are lower in the external than in the internal annuli.

Remarks. Among the unribbed forms that have similar-sized and type embryo, *Discocyclus spliti spliti* and *D. s. ajkaensis* have lower equatorial chamberlets, especially in the external annuli, therefore their growth pattern is distinctly of the 'spliti'-type. *D. stratiemanuelis*, *D. pulcra* n. ssp. Angoumé (to be introduced later) and *D. p. balatonica* possess 'pratti'-type adauxiliary chamberlets and 'pulcra'-type growth pattern. The equatorial chamberlets of *D. pulcra* are also significantly narrower and higher than those of *D. fortisi anatolica*.

Discocyclus spliti Butterlin et Chorowicz 1971

Discocyclus spliti is an unribbed species having a moderately large to large centrilepidine (rarely slightly excentrilepidine) embryo, and numerous, moderately wide and high, 'archiaci'-'pratti'-type adauxiliary chamberlets. The equatorial chamberlets are relatively wide; in the internal annuli relatively high, although in the external cycles they are significantly lower, making a characteristic 'spliti' or at least transitional 'archiaci'-'spliti'-type growth pattern. The characteristics of the vertical section are described in Less (1987) and illustrated in Figure 8r. Since this figure illustrates the

less advanced *D. spliti polatliensis* n. ssp., the height of the embryo is only about 170 μm . The species is known to occur only from a few localities in Hungary, Croatia and Turkey. The earliest occurrence of the species in the Tethys is known from the upper Ypresian beds (zone OZ 8a) from Safranbolu in central Turkey and the last occurrence from the late Lutetian of Ajka, Hungary (OZ 11). Based on our new material the evolutionary lineage of *D. spliti*, formerly with two subspecies, can be extended downwards by introducing *D. s. polatliensis* n. ssp. The up-to-date subdivision of the species into three successive subspecies with their biometric limits is listed below:

<i>D. s. polatliensis</i> n. ssp.	$d_{\text{mean}} < 800 \mu\text{m}$
<i>D. s. spliti</i>	$d_{\text{mean}} = 800\text{--}1300 \mu\text{m}$
<i>D. s. ajkaensis</i>	$d_{\text{mean}} > 1300 \mu\text{m}$

Discocyclus spliti polatliensis, associated with *D. fortisi cairazensis*, is described from the early Lutetian of Çayraz (zones OZ 8b and 8b-9). Its occurrence in late Ypresian is suggested based on a single specimen in sample SAF 8 of the Safranbolu section. A further advanced developmental stage of the species, *D. spliti spliti*, is described from middle Lutetian of Taşköprü (zone OZ 10). It is worth noting that – like the advanced *D. fortisi* (*D. f. anatolica* and *D. f. cairazensis*) – *D. spliti* can be found mostly separately from the other orthophragmines: it occurs rather with the representatives of the *Nummulites perforatus*-group, thus it seems to have been accommodated in shallower marine niches.

Discocyclus spliti Butterlin et Chorowicz 1971 *polatliensis* n. ssp. Özcan et Less

Figures 8p–t & 11

Etymology. Named after Polatlı town, close to the type-locality of the taxon in the Haymana-Polatlı Basin, central Turkey.

Holotype. Specimen O/ÇAY 28-14 (Figures 8p & 11).

Paratypes. All the other specimens assigned to the same taxon from sample ÇAY 28 in Figure 11.

Depository. Geology Department of İstanbul Technical University.

Type Locality. Çayraz (Haymana, Ankara, central Turkey), lower part of the 'Upper Çayraz' section.

Type Level. early Lutetian, OZ 8b.

Diagnosis. *Discocyclusina spliti* populations with d_{mean} less than 800 μm .

Description (see also Table 1). Medium-sized (up to 7 mm), thick inflated forms (Figure 8r). The embryo invariably presents excentric- to mainly centric-lepidine configuration; the two chambers are moderately large. The adauxiliary chamberlets are numerous, and are of the transitional 'archiaci'-'pratti'-type. The equatorial chamberlets are rectangular in shape, moderately wide and typically low, especially in the external annuli.

Remarks. The new taxon is associated with *Discocyclusina fortisi cairazensis* in the early Lutetian horizons of the Çayraz section. It is distinguished from the latter by having a much smaller embryo and very characteristic low equatorial chamberlets (Figure 11). *Discocyclusina spliti spliti* differs from *D. fortisi fortisi* with similar-sized and -shaped embryo by having lower equatorial chamberlets, especially in the external annuli that resulted in the characteristic 'spliti'-type growth pattern.

Discocyclusina spliti spliti Butterlin et Chorowicz 1971

Figures 8u–v & 11

1971 *Discocyclusina archiaci* (Schlumberger) *spliti* n. ssp., Butterlin et Chorowicz, p. 267–271, pl. 1, figs. 1–11.

1987 *Discocyclusina spliti spliti* Butterlin et Chorowicz, Less, p. 149, text-fig. 26y.

Emended Diagnosis. *Discocyclusina spliti* populations with d_{mean} ranging between 800 and 1300 μm .

Remarks. Based on five figures from the original description by Butterlin & Chorowicz (1971) $d_{\text{mean}\pm\text{s.e.}}$ of the topotypes from Konjsko village near Split (Croatia) equals 954 ± 106 μm while in the case of the Hungarian population from Ajka, Jókai-akna, 'perforatus' beds (sample JOKAI in Less 1998a) these values are 1028 ± 28 μm based on 22 specimens. In both these samples *D. spliti spliti* is the only orthophragminid larger Foraminifera associated with large *Nummulites* (of the 'perforatus' and 'millecaput' groups) and *Assilina exponens*. The situation in the upper levels of the Taşköprü section (samples TAŞ 4 and 7) is quite similar, although here *D. spliti spliti* is slightly more advanced

than the two other populations mentioned above, and in the upper sample it coexists with rare *D. pratti* cf. *montfortensis*, too. The evolutionary degree of the *N. perforatus*-group is also similar in Taşköprü (see Table 3) and in Ajka ($P_{\text{mean}} \pm \text{s.e.} = 862 \pm 34$ μm based on 18 specimens). These values correspond to the middle-upper Lutetian (SBZ 15–16). Since in the late Lutetian OZ 11 zone of Ajka (Hungary) we have already the more advanced *D. spliti ajkaensis* associated with other orthophragmines, the stratigraphic range of *D. spliti spliti* approximately corresponds to the middle Lutetian OZ 10 zone.

Discocyclusina senegalensis Abrard 1956

Discocyclusina senegalensis is an unribbed species with moderately large nephro-, tryblio- and umbilico-lepidine embryo, high and wide very diagnostic, arcuate, 'varians' to 'pratti'-type adauxiliary chamberlets and moderately high and relatively wide equatorial chamberlets with 'pratti'-type growth pattern. Because of its rarity there are no indications of its internal evolution. Less (1998a) thought it to be synonymous with *D. archiaci bartholomei*, but our data from Turkey (Figures 9 & 10o) rather strengthen the segregation of the two taxa.

Remarks. *Discocyclusina senegalensis* is distinguished from *D. archiaci bartholomei* in having arcuate, 'varians' to 'pratti'-type adauxiliary chamberlets whose number, therefore, is significantly lower.

Discocyclusina dispansa (Sowerby 1840)

Discocyclusina dispansa is an unribbed form with a small to medium-sized, semi-nephro- to tryblio-lepidine embryo, moderately wide and high, 'archiaci'-type adauxiliary chamberlets and also moderately wide and high equatorial chamberlets. This species is probably the most widespread orthophragminid taxon with a geographic distribution extending from NE Spain to the Fiji Islands. It first appears in the earliest Ypresian (zone OZ 3), and becomes abundant at the beginning of late Ypresian and then extends to the upper part of the Priabonian, with a quite rapid evolutionary lineage with six successive subspecies. Additional information can be found in Less (1999) and Özcan (2002). The recent biometric subdivision of the species, with its successive subspecies is as follows:

<i>D. d. broennimanni</i>	$d_{\text{mean}} < 160 \mu\text{m}$
<i>D. d. taurica</i>	$d_{\text{mean}} = 160\text{--}230 \mu\text{m}$
<i>D. d. hungarica</i>	$d_{\text{mean}} = 230\text{--}290 \mu\text{m}$
<i>D. d. sella</i>	$d_{\text{mean}} = 290\text{--}400 \mu\text{m}$
<i>D. d. dispansa</i>	$d_{\text{mean}} = 400\text{--}520 \mu\text{m}$
<i>D. d. umbilicata</i>	$d_{\text{mean}} > 520 \mu\text{m}$

Since *D. dispansa* is extremely sporadic in our upper Ypresian and lower–middle Lutetian localities, no further taxonomic and stratigraphic conclusions can be made. Specimens from sample KIR 8 (zone OZ 6/7, Figures 8f–g & 9) are attributed to *D. dispansa* cf. *taurica* whereas the one single specimen from sample ÇAY 28 (zone OZ 8b) does not allow any subspecific determination.

Discocyclusina furoni Samanta 1968

Discocyclusina furoni is an unribbed form with moderately small nephrolepidine embryo, moderately wide and low ‘archiaci’-type adauxiliary chamberlets and moderately wide and low equatorial chamberlets of ‘archiaci’-type growth pattern. Specimens having nephrolepidine embryo configuration and ‘archiaci’-type adauxiliary chamberlets and annuli growth pattern were assigned to this species based mainly on the considerably smaller embryo dimensions than those of the associated *D. archiaci*. Therefore, Less (1998a) correlated some populations with *D. archiaci bakhchisaraiensis* and *D. a. archiaci*. One single specimen each in three samples from Kırıklar (KIR 7, 8 and 10, Figures 8h & 9) differs so much from the associated *D. archiaci* that we rather separate them. It cannot be excluded that the rare *Discocyclusina* sp. from sample KARI 1 from Karit of middle Lutetian age represents the evolutionary offspring of *D. furoni*. However, because of the scarcity of our material we cannot make any further taxonomic conclusions.

Discocyclusina weijdeni Less 1987

The unribbed *Discocyclusina weijdeni* was erected by Less (1987) from Horsarrieu (SW France, zone OZ 6), and differentiated from the accompanying, and otherwise very similar *D. archiaci* specimens, mainly based on the shape of equatorial chamberlets, which are conspicuously elongated in radial direction. The validity of *D. weijdeni*

was, however, lately questioned by Less (1998a) who considered the taxon as being synonymous with *D. archiaci*, following the argument that the increasing water-depth favours the elongation of chamberlets. In our material from Kırıklar three specimens having almost the same embryonic configuration and dimensions as the accompanying *D. archiaci archiaci*, but bearing conspicuously high, elongated equatorial chamberlets, have been assigned to this taxon (Figure 8n). Due to their very similar embryonic dimensions, the divergence in the interpretation of *D. weijdeni* and *D. archiaci* fortunately does not cause any bias in the biostratigraphical evaluation.

Discocyclusina trabayensis Neumann 1955

D. trabayensis is an unribbed species having a very small, iso- to nephro-lepidine embryo, very low, relatively wide, peculiar ‘varians’-type adauxiliary chamberlets and narrow equatorial chamberlets with ‘trabayensis’-type growth pattern. It is a rather sporadic taxon geographically distributed from SW France to Turkey. The earliest occurrence is known from the late Ypresian (zone OZ 5) and then it spreads until the very end of the Eocene becoming quite abundant only in the upper Priabonian. It forms an evolutionary lineage – developing very slowly in the early and middle Eocene, but accelerating in the Priabonian – with three successive subspecies. More information can be found in Özcan *et al.* (2007), who give the biometric subdivision of the lineage as follows:

<i>D. t. trabayensis</i>	$d_{\text{mean}} < 125 \mu\text{m}$
<i>D. t. elazigensis</i>	$d_{\text{mean}} = 125\text{--}170 \mu\text{m}$
<i>D. t. vicenzensis</i>	$d_{\text{mean}} > 170 \mu\text{m}$

Discocyclusina trabayensis is extremely sporadic in our material and only very few specimens in ÇAY 28 (zone OZ 8b) from the Çayraz Formation and KARI 1 (zone OZ 10) from the Karabük Formation were attributed to *D. trabayensis* cf. *trabayensis* (Figure 8o).

Discocyclusina sp.

Two discocyclusinid specimens, in KARI 1 (zone OZ 10, Figure 10n), with deuteroconch dimensions of 480 and

550 μm , respectively, cannot be attributed to any of the known lineages of genus *Discocyclusina*. However, we suggest (tentatively because of the very scarce material) that they represent the late descendants of *D. furoni*.

Genus *Nemkovella* Less 1987

Nemkovella strophiolata (Gümbel 1870)

Nemkovella strophiolata is an unribbed species with a small semi-iso- to nephro-lepidine embryo, low but relatively wide, very diagnostic, arcuate, 'varians'-type adauxiliary chamberlets and moderately narrow and low equatorial chamberlets with 'strophiolata'-type growth pattern. The characteristics of the vertical section are described in Less (1987) and illustrated in Figure 12d (note the coarseness of the piles). It occurs in orthophragminid assemblages from Southwestern France to Anatolia. The earliest occurrence is known from zone OZ 6, then it becomes more abundant in the middle Eocene and can be followed until the early Priabonian (boundary of OZ 14 and 15 zones), forming a rather slowly but steadily developing evolutionary lineage with four successive subspecies. Additional information of *N. strophiolata* can be found in Özcan (2002) and Çolakoğlu & Özcan (2003). Subspecies limits are as follows:

<i>N. s. fermonti</i>	$d_{\text{mean}} < 150 \mu\text{m}$
<i>N. s. strophiolata</i>	$d_{\text{mean}} = 150\text{--}185 \mu\text{m}$
<i>N. s. n. ssp. Padragkút</i>	$d_{\text{mean}} = 185\text{--}230 \mu\text{m}$
<i>N. s. tenella</i>	$d_{\text{mean}} > 230 \mu\text{m}$

The most primitive developmental stage of the species, *N. s. fermonti*, could be identified from the lower part of Safranbolu Formation, from samples KIR 7 and 8 (Kırıklar late Ypresian, zone OZ 6/7, Figures 12b–d & 13). The single specimen found in the upper part of the same unit, in sample KIR 9 (OZ 6/7), does not permit any subspecific designation. A single population referred to *N. s. cf. fermonti* is also described from a stratigraphically higher horizon (zone OZ 7/8a) of the Küpler section.

Nemkovella evae Less 1987

Nemkovella evae is an unribbed species with a relatively small semi-iso to nephro-lepidine embryo, 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 described in Less (1987) and illustrated in Figure 12e. The vertical section of the species is illustrated in Figure 12a for the first time. The height of the protoconch and deuteroconch is about 80 and 110 μm . The equatorial layer is about 35 μm thick throughout the ontogeny and does not widen at all. The lateral chamberlets are 25–35 μm in height. The earliest occurrence is known from the late Thanetian OZ 2 zone in Kurucaşile and Karaevli in Turkey. The evolution of this species is rather slow, thus until now it has not been subdivided into subspecies. However, our new data (see below) permit its stratigraphic range to extend up to the middle Lutetian (zone OZ 10), simultaneously with the introduction of a more advanced developmental stage (subspecies). This also necessitates the formal separation of *Nemkovella evae evae* on the subspecific level. The biometric limit of the two subspecies is considered as follows:

<i>N. e. evae</i>	$d_{\text{mean}} < 260 \mu\text{m}$
<i>N. e. karitensis</i> n. ssp.	$d_{\text{mean}} > 260 \mu\text{m}$

The less advanced developmental stage of the species, *N. e. evae*, is identified from late Ypresian levels of the Safranbolu Formation at Kırıklar. The newly described *N. e. karitensis*, corresponding to the more advanced evolutionary stage of the species, occurs in the early Lutetian of Çayraz (sample ÇAY 28, zone OZ 8b) and in the middle Lutetian of Karit (zone OZ 10).

Nemkovella evae evae Less 1987

Figures 10p–r, 12e & 13

1987 *Nemkovella evae* n. sp., Less, p. 184–187, pl. 23, figs. 1–7, 9–12; pl. 24, figs. 1–4, text-fig. 29a (with synonymy).

2002 *Nemkovella evae* Less 1987, Özcan, p. 84–85, pl. 1, fig. 3, text fig. 3B.

Holotype, type locality and type level. As given by Less (1987, p. 186) for *Nemkovella evae*.

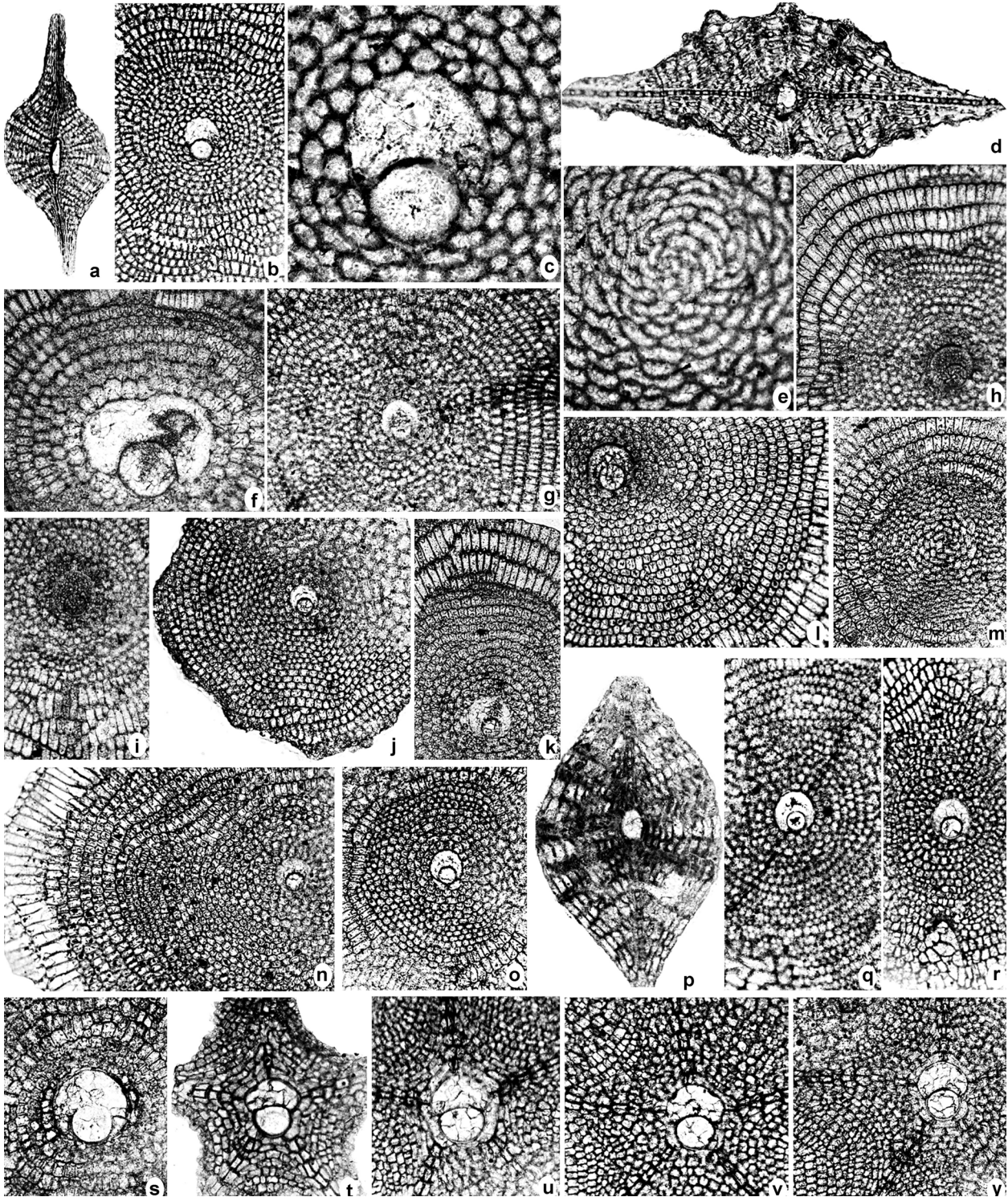


Figure 12. (a) *Nemkovella evae* Less *karitensis* n. ssp., O/KARI 1-31. (b-d) *N. strophiolata* (Gümbel) *fermonti* Less, (b-c) O/KIR 8-71, (d) O/KIR 8-9. (e) *N. evae evae* Less, O/KIR 9-5. (f) *Nemkovella* sp., O/KÜP.10-26. (g-i) *Orbitoclypeus varians* (Kaufmann) *ankaraensis* n. ssp., (g) O/ÇAY 28-26, holotype, (h) O/ÇAY 28-24, (i) O/ÇAY 28-27. (j) *O. varians* (Kaufmann) cf. *portnayae* Less, O/KIR 10-23. (k-r) *O. douvillei douvillei* (Schlumberger), (k) O/KÜP 10-10, (l) O/KIR 9-38, (m) O/KÜP 10-55, (n) O/KIR 9-48, (o) O/KIR 10-13, (p) O/KIR 10-10, (q) O/KÜP 5-25, (r) O/KIR 8-74. (s) *O. douvillei* cf. *chudeaui* (Schlumberger), O/KARI 1-18. (t-y) *Asterocyclina alticostata* (Nuttall) *gallica* Less, (t) O/KIR 8-84, (u) O/KIR 8-82, (v) O/KIR 7-15, (y) O/KIR 8-15. (e, m) B-forms, the others are A-forms; a, d, p: vertical, the others are equatorial sections, a:×17, the others:×40.

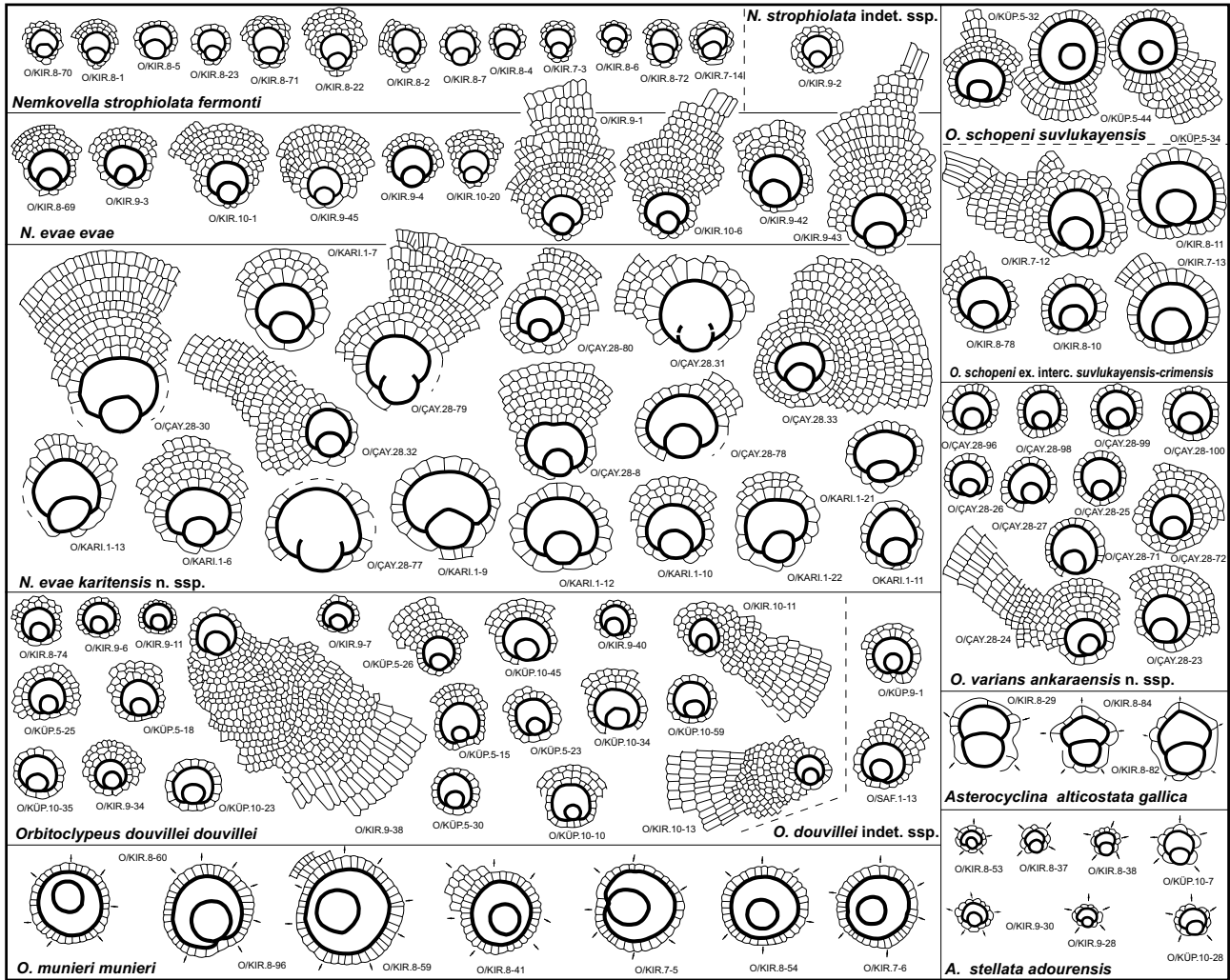


Figure 13. Types of embryo and their variation in *Nemkovella strophiolata*, *N. evae*, *Orbitoclypeus douvillei*, *O. schopeni*, *O. varians*, *O. munieri*, *Asterocyclina alticostata* and *A. stellata*. All $\times 28$.

Diagnosis. *Nemkovella evae* populations with d_{mean} less than 260 μm .

Description (see also Table 1). As given by Less (1987, p. 186) for *Nemkovella evae*.

Remarks. The formal separation of *N. evae evae* on the subspecific level became necessary because of the introduction of *N. e. karitensis*. Its characteristics including the differential diagnosis are the same as those of *N. evae* in Less (1987).

Nemkovella evae Less 1987 *karitensis* n. ssp. Özcan et Less

Figures 10s–u, 12a & 13

Etymology. Named after Karit village, close to the type locality of the taxon near Safranbolu.

Holotype. Specimen O/KARI 1-6 (Figure 10u).

Paratypes. All the other specimens attributed to the same taxon from Karit in Figure 13.

Depository. Geology Department of İstanbul Technical University.

Type Locality. Sample KARI 1, around Karit village (Safranbolu, Karabük, central Turkey).

Type Level. middle Lutetian, zone OZ 10.

Diagnosis. *N. evae* populations with d_{mean} exceeding 260 μm

Description (see also Table 1). Small- to medium-sized (up to 3 mm), flat, centrally inflated forms. The relatively small- to medium-sized embryo invariably presents nephrolepidine configuration. The arcuate adauxiliary chamberlets of the 'varians'-type are relatively few. The equatorial chamberlets are relatively wide and low; their growth pattern is of the 'varians'-type with possible transitions to the 'archiaci', 'strophiolata' and 'trabayensis' types.

Remarks. Since this taxon bears the largest embryo of all the unribbed *Nemkovella*, it can hardly be confused with any other forms. Less (1998a) already detected the possible presence of the more advanced subspecies of *N. evae* from Israel (samples Is 399 and 407 of Fermont 1982). These levels are at a higher stratigraphic level than those with the less advanced *N. evae* (samples Is 199 to 366), and, according to Moshkovitz (1995), belong to the earliest Lutetian NP 14b zone. Our two new populations are also Lutetian (sample ÇAY 28 from the base, and KARI 1 from the middle part), so the stratigraphic range of the taxon seems to be restricted to the earliest to middle Lutetian.

Nemkovella sp.

Two specimens clearly belonging to genus *Nemkovella*, one from Küpler, sample KÜP 10 (zone OZ 7/8a, Figure 12f), with a deuteroconch dimension of 530 µm, and another one from Çayraz, sample ÇAY 28 (zone OZ 8b), with a deuteroconch dimension of 500 µm, can not be assigned to any of the known lineages of this genus.

Family ORBITOCYPEIDAE Brönnimann 1946

Genus *Orbitocypeus* Silvestri 1907

Orbitocypeus douvillei (Schlumberger 1903)

Orbitocypeus douvillei is an unribbed species having 'chudeaui'-type rosette, a small to relatively large, eu-, then tryblio- and excentrilepidine embryo, wide and moderately high, 'varians'-type adauxiliary chamberlets and also wide and moderately high equatorial chamberlets arranged into circular annuli with 'varians'-type growth pattern. Distal margins of annular chamberlets are typically wedge-shaped. The biserial juvenarium of the microspheric forms (characteristic for Orbitocypeidae) is shown in Figure 12m. The

characteristics of the vertical section are described in Less (1987, see also the description of *Orbitocypeus chudeaui*) and illustrated in Figure 12p. *Orbitocypeus douvillei* occurs, though only less dominantly in orthophragminid assemblages ranging from SW France to Anatolia and Israel. The earliest appearance is known from the early Ypresian (zone OZ 4) in the Kastamonu region of Turkey. Özcan *et al.* (2007) reported its highest occurrence from the early Bartonian (zone OZ 13) of Keçili (Turkey). For more information see also Özcan (2002) and Çolakoğlu & Özcan (2003). *Orbitocypeus douvillei* forms a rapidly developing evolutionary lineage with six successive subspecies with the following biometric limits:

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

In our material *O. douvillei*, together with *O. schopeni*, is the commonest orbitocypeid taxon. Two developmental stages are described. *O. d. douvillei* occurs in the late Ypresian of Kırıklar (samples KIR 8, 9 and 10, all zone OZ 6/7) and Küpler (sample KÜP 5, zone OZ 6/7 and KÜP 10, 7/8a) (Figures 12k–r & 13), where the last population is significantly more advanced than the other ones. On the other hand, the rather advanced *O. douvillei* cf. *chudeaui* could be found in the middle Lutetian (zone OZ 10, Figure 12s) of Karit. The single specimens from samples KÜP 9, KAS B 1 and SAF 1 could not be identified in subspecific level.

Orbitocypeus schopeni (Checchia-Rispoli 1909)

Orbitocypeus schopeni is an unribbed species having a 'marthae'-type rosette, a small to relatively large, eu-, tryblio- and excentrilepidine embryo, 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 orthophragminid assemblages ranging 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 (zone OZ 11) of Padragkút (Hungary) and San Pancrazio (zone OZ 12) (Italy). Further information can be found in Özcan *et al.* (2001), Özcan (2002) and Çolakoğlu & Özcan (2003). This taxon can be subdivided into five successive subspecies with the biometric limits listed below:

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

The species occurs in several horizons and can be arranged into two groups. Populations with d_{mean} less than $300 \mu\text{m}$ are known from the late Ypresian OZ 6/7 zone of Küpler (sample KÜP 5, determined as *O. schopeni suvlukayensis*, Figures 13 & 14f) and Kırıklar (samples KIR 7 and 8, determined as *O. schopeni ex. interc. suvlukayensis-crimensis*, Figures 13, 14g, h). This means that the stratigraphic range of *O. schopeni suvlukayensis* extends at least up to the end of the OZ 6 zone. Populations with considerably larger embryos are recorded from the latest Ypresian OZ 8a zone; from sample SAF 1 of Safranbolu (*O. schopeni crimensis*, Figures 14i, j) and from sample KAS B 1 of Kastamonu (*O. s. cf. crimensis*).

***Orbitoclypeus varians* (Kaufmann 1867)**

Orbitoclypeus varians is an unribbed form with a 'marthae'-type rosette, small- to medium-sized excentric to eulepidine embryo, adauxiliary chamberlets of 'variens'-type with average size and shape and also moderately wide and high equatorial chamberlets arranged into undulated annuli with 'variens'-type growth pattern. *O. varians* is one of the most common and widely distributed orthophragminid taxa from Spain to Armenia. The earliest occurrence is known from the late Ypresian (OZ 5 zone) of the Haymana-Polatlı Basin in Turkey

(Özcan 2002). However, it becomes abundant only at the beginning of Lutetian and then continues until the very end of the Priabonian, forming a rapidly evolving lineage with six successive subspecies. Further information can be found in Less (1999), Özcan (2002) and Özcan *et al.* (2007). The informal name of *O. varians* n. ssp. Caupenne is replaced here by *O. v. ankaraensis* n. ssp., adopting the same biometric limits. The updated subdivision of the lineage, following the above modification, is as follows:

<i>O. v. portnayae</i>	$d_{\text{mean}} < 165 \mu\text{m}$
<i>O. v. ankaraensis</i> n. ssp.	$d_{\text{mean}} = 165\text{--}205 \mu\text{m}$
<i>O. v. angoumensis</i>	$d_{\text{mean}} = 205\text{--}255 \mu\text{m}$
<i>O. v. roberti</i>	$d_{\text{mean}} = 255\text{--}320 \mu\text{m}$
<i>O. v. scalaris</i>	$d_{\text{mean}} = 320\text{--}400 \mu\text{m}$
<i>O. v. varians</i>	$d_{\text{mean}} > 400 \mu\text{m}$

The most primitive developmental stage of the species, *O. v. cf. portnayae*, is identified from late Ypresian levels of the Safranbolu Formation of Kırıklar, sample KIR10 (zone OZ 6/7, Figure 12j). A more advanced evolutionary stage, the newly erected *O. v. ankaraensis*, is described from the earliest Lutetian (zone OZ 8b) of Çayraz, sample ÇAY 28.

***Orbitoclypeus varians* (Kaufmann 1867) *ankaraensis* n. ssp. Özcan et Less**

Figures 12g–i & 13

Etymology. Named after Ankara, close to the type locality of the taxon near Çayraz (Haymana).

Holotype. Preparation O/ÇAY 28-26 (Figure 12g).

Paratypes. All the other specimens of the same taxon in Figure 13.

Depository. Geology Department of İstanbul Technical University.

Type Locality. Sample ÇAY 28, around Çayraz village (Haymana, central Turkey).

Type Level. earliest Lutetian, zone OZ 8b.

Diagnosis. *Orbitoclypeus varians* populations with d_{mean} ranging between 165 and $205 \mu\text{m}$

Description (see also Table 2). Small-sized (up to 2–3

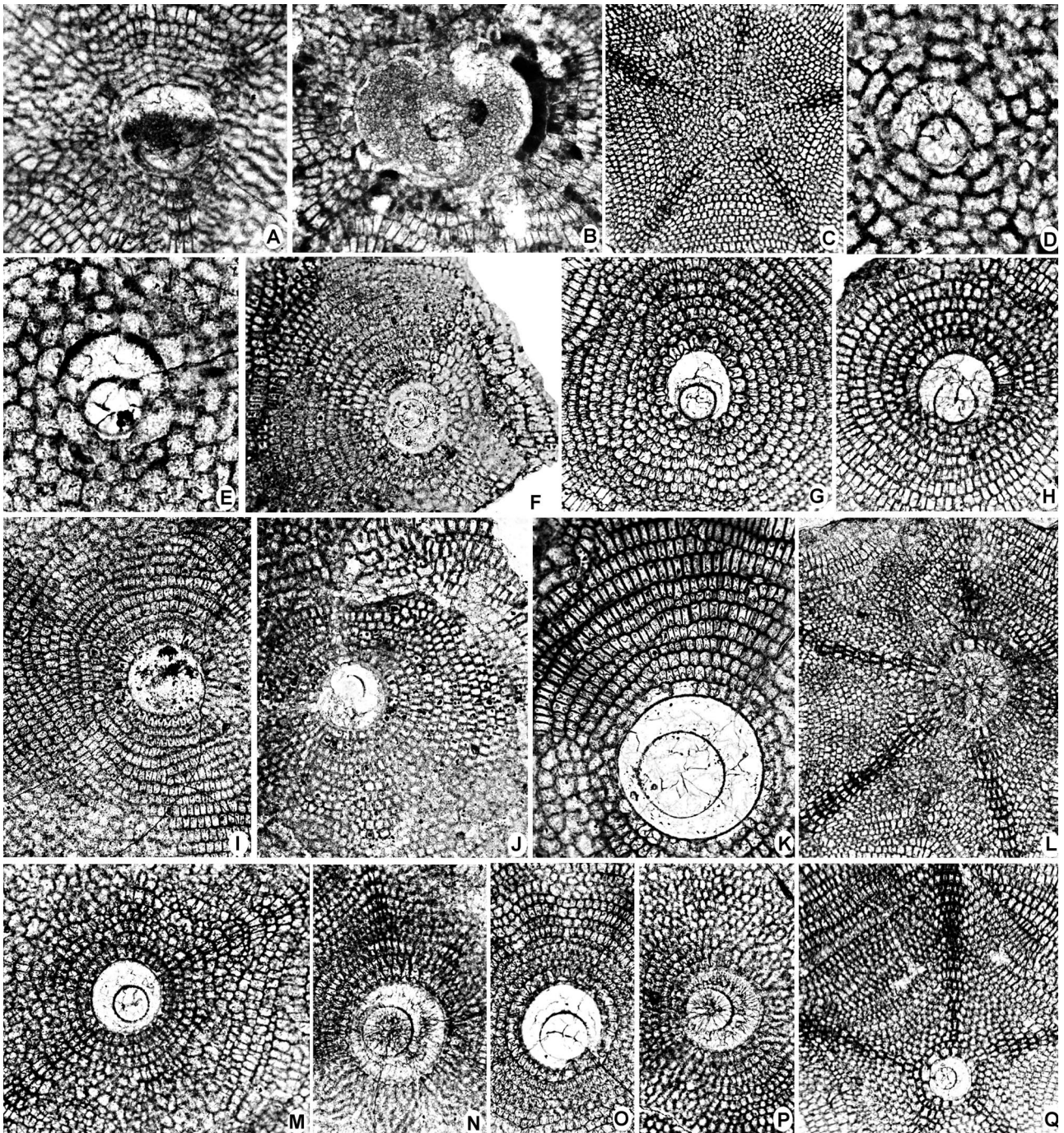


Figure 14. (a-b) *Asterocyclus schweighauseri* cf. *schweighauseri* Less, (a) O/KÜP 10-65, (b) O/KÜP 10-66. (c-e) *A. stellata* (d'Archiac) *adourensis* Less, (c-d) O/KIR 8-55, (e) O/KIR 9-27. (f) *Orbitoclypeus schopeni* (Checchia-Rispoli) *suvlukayensis* Less, O/KÜP.5-44. (g-h) *O. schopeni* (Checchia-Rispoli) ex. interc. *suvlukayensis-crimensis* Less, (g) O/KIR 7-12, (h) O/KIR 7-13. (i-j) *O. schopeni* (Checchia-Rispoli) *crimensis* Less, (i) O/SAF 1-7, (j) O/SAF 1-17. (k) *O. multiplicatus* (Gümbel) indet. ssp., O/KIR 9-49. (l-p) *O. munieri munieri* (Schlumberger), (l) O/KIR 7-6, (m) O/KIR 8-41, (n) O/KIR 8-59, (o) O/KIR 8-96, (p) O/KIR 7-5. (q) *O. furcatus* (Rüttimeyer) indet. ssp., O/KIR 8-94. All equatorial sections of A-forms, All: $\times 40$.

mm), inflate forms with a 'marthae'-type rosette. The eulepidine embryo is small. The adauxiliary chamberlets are of 'varians'-type, they are low in numbers, narrow and low. The equatorial chamberlets are low and narrow, but may rapidly grow long on the edges forming 'trabayensis'-type growth pattern of the annuli in this case (otherwise it is of the 'varians'-type). Sometimes gentle undulation of the cycles with 6–7 waves can be observed.

Remarks. This developmental stage of *O. varians* was first found in Caupenne, Jeangazé (sample CAUPE in Less 1998a) and informally called as *O. varians* n. ssp. Caupenne. Our specimens from Çayraz, sample ÇAY 28 bear very similar characteristics; only the undulation is less significant than in the Caupenne specimens. Very probably, the depositional depth of the latter site was somewhat deeper than in Çayraz which is reflected also in the specific composition of the accompanying larger foraminiferal fauna. At the same time, based on the evolutionary degree of the associated fossils, the two samples mark the same, OZ 8b orthophragminid zone. *Orbitoclypeus varians ankaraensis* can be confused with other representatives of the genus having similar-sized embryo. *O. schopeni ramaraoui* and *O. schopeni neumannae* can be very similar, but their accompanying fauna, due to the quite different stratigraphic level, is totally different. The distinction from *O. douvillei douvillei* can be made based on the "chudeaui" type rosette of the latter.

Orbitoclypeus munieri (Schlumberger 1904)

Diagnosis. Small- to large-sized, mostly flattened forms with 6 to 9 ribs and with a 'marthae'-type rosette. The embryo is eu- to excentrilepidine, the two chambers are small to medium sized. The adauxiliary chamberlets are of the 'varians'-type, medium wide and high as well as the equatorial chamberlets. The annuli are definitively undulated, their growth pattern is of the 'varians' type.

Description. Small- to large-sized (2 to 12 mm) mostly flattened forms with distinct umbo varying from 1 to 2 mm in diameter. From the umbo 6 to 9 thick radial ribs are developed. Between them interrib areas are formed. Some additional ribs may also start to develop in the interrib area. The ribs may branch irregularly into two towards the edges. The rosette is of the 'marthae' type. The granules are the biggest on the umbo (their diameter

varies around 100 µm), whereas on the interrib areas they are quite fine (30 to 50 µm). Each granule is surrounded by 9 to 12 lateral chamberlets. The 'B' forms are two to three times bigger than the 'A' forms.

In the equatorial section of the A-forms the small to medium-sized embryo ($p=90\text{--}260\ \mu\text{m}$, $d=150\text{--}520\ \mu\text{m}$) is eu- to excentrilepidine (rarely also tryblio- and umbilicolepidine). The narrow to moderately wide ($W=25\text{--}60\ \mu\text{m}$) and low to moderately high ($H=30\text{--}80\ \mu\text{m}$), "varians" type adauxiliary chamberlets are few to numerous in numbers ($N=12\text{--}44$). Also the equatorial chamberlets are narrow to moderately wide ($w=25\text{--}45\ \mu\text{m}$) and low to high, sometimes very high towards the edges ($h=50\text{--}120\ \mu\text{m}$, $n=10\text{--}22$). The cycles are significantly undulated with 6 to 9 waves; their growth pattern is of the "varians" type.

We have not yet found forms with well-preserved microspheric juvenarium. The axial section is characterised based on Neumann's (1958) figure (pl. 33, fig. 5). The height of the embryo is about 150 to 200 µm (taking into consideration Neumann's incorrect magnifications – see Less 1987, p. 54). The equatorial layer is about 50 µm thick near the embryo, but the periphery is not shown. The lateral layer is thick, the annular one is slightly arcuate. In the lateral layers the chamberlets are 60–35 µm big on the average.

Remarks. These forms are described in Less (1987) as *Orbitoclypeus bayani*. However, after examining a relatively large material (see in Less *et al.* in press) from the uppermost Thanetian and lower Ypresian beds from Spilecco (N Italy, the type locality of *O. bayani*) and Turkey (Kurucaşile, Karaevli, Kastamonu and Şile), it became clear that there exist two unribbed *Orbitoclypeus*, *O. multiplicatus* with a larger embryo and *O. schopeni* (described as *O. ramaraoui* in Less 1987) with a smaller one and two ribbed *Orbitoclypeus* that correspond to the two unribbed forms. Of the ribbed forms *O. bayani* has the larger embryo and corresponds to *O. multiplicatus*.

The other ribbed form corresponds to the unribbed *O. schopeni* and, consequently, it must have a name different from *O. bayani*. For these forms three names could have been adapted. Of these, the internal morphology of '*decoratus*' has never been figured, '*patellaris*' cannot be used for the reasons discussed in detail in Less (1987, p. 250). However, '*munieri*', the third adaptable name can well be used for these forms because it is figured from its

topotypical layers (Marne à *Xanthopsis*) by Neumann (1955) and there are no serious contradictions in its usage. It is worth noting that later she (Neumann 1958) changed the name of these forms to '*patellaris*' and used incorrect magnifications (see in detail in Less 1987, p. 54), although this has no effect on the validity of the name '*munieri*'. These forms were later studied from the Marne à *Xanthopsis* of Horsarrieu by Less & Ó. Kovács (1996) and Less (1998a) who restored the name '*munieri*', but did not describe it formally.

On the basis of their internal similarity and similar stratigraphical position, *Orbitoclypeus munieri* with ribs might have been derived from *O. schopeni* without ribs. In some cases (Spilecco, Kurucaşile, Karaevli) these two taxa can be found together. The parallel evolution of these two species during the latest Thanetian and Ypresian is very similar to that of the unribbed *O. varians* and the ribbed *O. furcatus* in the late Ypresian to Priabonian (see in Less & Ó. Kovács 1996). Therefore, one can conclude that the ribbing of the genus *Orbitoclypeus* is only an ecological phenomenon. However, until further evidence is obtained, ribbed *Orbitoclypeus* are considered as separate species.

The ample material from France, Turkey and northern Italy presented in Less (1998a), Less *et al.* (in press) and in this paper allows us to establish the *O. munieri*-lineage and subdivide it into two subspecies as defined below (*O. m. ponticus* n. ssp. to be described in Less *et al.* in press substitutes the informal name of *Orbitoclypeus munieri* nov. ssp. Spilecco in Less 1998a).

O. m. ponticus n. ssp. $d_{\text{mean}} < 220 \mu\text{m}$

O. m. munieri $d_{\text{mean}} > 220 \mu\text{m}$

The stratigraphic boundary of the two subspecies probably corresponds to the zone OZ 3/4 boundary. Although we have not enough material yet we think that *O. munieri* populations with d_{mean} ranging between 220 and 300 μm occur in the OZ 4 zone and probably also in the OZ 5 zone whereas the populations with d_{mean} exceeding 300 μm can be found in the OZ 6 to 8a zones. Based on their similar morphology in Kurucaşile and Karaevli *Orbitoclypeus munieri* gave rise very probably to *Asterocyclina taramellii* (see in detail in Less *et al.* in press). Probably the last representatives of the *O. munieri*-lineage are described by Portnaya 1974 (as

Actinocyclina munieri) from the uppermost part of the Simferopolian beds of the Crimean Peninsula corresponding to the latest Ypresian. Unfortunately, the internal morphology of these forms is not known yet.

In the upper Ypresian of Turkey, *Orbitoclypeus munieri* is represented by *O. m. munieri* from the lower part of Safranbolu Formation in Kırıklar, samples KIR 7 and 8 (OZ 6/7).

Orbitoclypeus munieri munieri (Schlumberger 1904)

Figures 13, 14l–p

1904 *Orthophragmina munieri* nov. sp., Schlumberger, p. 125, pl. 3, fig. 12.

?1904 *Orthophragmina decorata* nov. sp., Schlumberger, p. 124–125, pl. 3, fig. 11.

1955 *Actinocyclina munieri* (Schlumberger), Neumann, p. 131–132, pl. 6, fig. 6; pl. 7, figs. 4, 6, 7.

1958 *Actinocyclina patellaris* (Schlotheim), Neumann, p. 123–125, pl. 33, figs. 1, 2, 4–6, text-fig. 42.

1987 *Orbitoclypeus bayani* (Munier-Chalmas) (partim), Less, p. 203–205, pl. 27, figs. 5, 6 (non 4!).

2002 *Orbitoclypeus munieri munieri* (Schlumberger), Özcan, p. 86, pl. 3, figs. 11, 12; pl. 4, figs. 1–4, text-fig. 5A.

Holotype. Not given by the author of the taxon.

Lectotype. Schlumberger 1904, pl. 3, fig. 12, depository: École de Mines (Paris) – marked out by us.

Type Locality. Sainte-Colombe (Landes, SW Aquitaine, France).

Type level. Not specified (in our opinion the lower part of the upper Ypresian (the SBZ 10 and OZ 6 zones).

The Type of the Equatorial Section of the A-forms. Neumann 1955, pl. 7, fig. 6. (repeated in Neumann 1958: pl. 33, fig. 6. under the name of *Actinocyclina patellaris* with incorrect magnification), Doazit (Landes, SW), Marne à *Xanthopsis* (the same as of the type locality), lower Lutetian by Neumann 1955, 1958, in our opinion the lower part of the upper Ypresian (the SBZ 10 and OZ 6 zones).

Depository. not given, presumably Université de Paris.

Diagnosis. *Orbitoclypeus munieri* populations with d_{mean} exceeding 220 μm .

Description (see also Table 2). Medium- to large-sized (4–12 mm), moderately flattened forms with 7–9-thick ribs (sometimes with additional ribs in the interrib area) and a 'marthae'-type rosette on the surface. The medium-sized embryo is mostly of excentrilepidine type. The rather numerous adauxiliary chamberlets of the 'varians'-type are moderately wide and high. The equatorial annuli are strongly undulated with 7–9 waves. The chamberlets are moderately wide and high (sometimes very high at the peripheries), their growth pattern is of the 'varians' type.

Remarks. Among the ribbed forms with similar type and similar-sized embryo *Orbitoclypeus munieri munieri* can be very easily confused with *O. bayani bayani*, *O. furcatus rovasendai* and *O. furcatus furcatus*. The external shape of *O. bayani bayani* is very frequently asteroidal (that is never so with *O. munieri munieri*); its internal morphology is a little different, i.e. the equatorial chamberlets are somewhat wider and longer. The ribbing of *O. furcatus* is much more regular than that of the *O. munieri*, i.e. there are no ribs starting from the interrib area and all ribs bifurcate practically simultaneously. The internal morphology of *O. furcatus* is slightly more delicate, i.e. the equatorial chamberlets are somewhat narrower and also the undulation of the equatorial annuli is more definite. However, in both cases these differences are very slight. Due to the difference in the stratigraphical level of the compared forms their accompanying fauna is totally different, and this may help in distinguishing them.

Orbitoclypeus multiplicatus

Average-sized, inflates, unribbed forms with a 'marthae'-type rosette. The medium-sized to moderately large embryo is in most cases excentrilepidine, rarely eulepidine. The numerous, 'varians'-type adauxiliary chamberlets are rather wide and of average height as are the equatorial chamberlets. The annuli are usually moderately undulated; the growth pattern is of the 'varians' type.

One single specimen assigned to *O. multiplicatus* (with no formal subspecific determination) is identified from the lower part of the Safranbolu Formation in sample Kırıklar, KIR 9 (zone OZ 6/7, Figure 14k). It represents an evolutionarily advanced stage of the species, and belongs most probably to *O. multiplicatus kastamonuensis* n. ssp. introduced in Less *et al.* (in press).

Genus *Asterocyclina* Gümbel 1870

Asterocyclina stellata (d'Archiac 1846)

Asterocyclina stellata is a star-shaped form usually with five rays and a 'marthae'-type rosette. It has a small semi-iso- to nephro-lepidine embryo, few, wide and low, 'stellata'-type adauxiliary chamberlets and also narrow and low equatorial chamberlets arranged into asteroidal annuli with 'strophiolata'-type growth pattern. It is the most common *Asterocyclina* from Northeastern Spain to Assam (India) or maybe even to Indonesia. The earliest occurrence is known from the early late Ypresian (zone OZ 6); but it becomes dominant from the middle Eocene and ranges up to the end of the Priabonian forming a rather slowly developing, though quite reliable evolutionary lineage, with four successive subspecies. Further information can be found in Less (1999) and Özcan *et al.* (2007). The biometric limits of subspecies are considered as follows:

<i>A. s. adourensis</i>	$d_{\text{mean}} < 150 \mu\text{m}$
<i>A. s. stellata</i>	$d_{\text{mean}} = 150\text{--}190 \mu\text{m}$
<i>A. s. stellaris</i>	$d_{\text{mean}} = 190\text{--}240 \mu\text{m}$
<i>A. s. buekkensis</i>	$d_{\text{mean}} > 240 \mu\text{m}$

Asterocyclina stellata occurs in several horizons of the Safranbolu Formation and is represented only by *A. stellata adourensis* in the late Ypresian (Figures 13, 14c–e), although the populations from Kırıklar, samples KIR 8 and 9 (zone OZ 6/7) are significantly less advanced than that of sample KÜP 10 from Küpler, representing the OZ 7/8a zone.

Asterocyclina alticostata (Nuttall 1926)

Asterocyclina alticostata is a star-shaped species usually with five to seven rays and a 'chudeau'-type rosette. It has a medium-sized to relatively large isolepidine embryo, very few, very wide and moderately low, 'alticostata'-type adauxiliary chamberlets and also wide and moderately high equatorial chamberlets arranged into asteroidal annuli with 'strophiolata'- or 'varians'-type growth pattern. It occurs in the orthophragminid assemblages from SW France to Israel and Kutch (India). The earliest occurrence is recorded below from Kırıklar

(samples KIR 7 to 9) representing early late Ypresian (zone OZ 6/7). *Asterocyclina alticostata* forms a steadily developing, reliable evolutionary lineage extending up to the early Priabonian (to about the boundary of the OZ 14/15 zones). The biometric limits of the four successive subspecies are delimited as follows:

<i>A. a. gallica</i>	$d_{\text{mean}} < 275 \mu\text{m}$
<i>A. a. cuvillieri</i>	$d_{\text{mean}} = 275\text{--}350 \mu\text{m}$
<i>A. a. alticostata</i>	$d_{\text{mean}} = 350\text{--}450 \mu\text{m}$
<i>A. a. danubica</i>	$d_{\text{mean}} > 450 \mu\text{m}$

In our material the population of samples KIR 7–8 (zone OZ 6/7) belongs to *A. a. gallica* (Figures 12t–y & 13), but it shows some primitive features even within the limits of the subspecies. At about half of the forms the adauxiliary chamberlets are still not fully developed and represent the transitional ‘varians–alticostata’-type (Figures 12t, v & 13). The one single specimen from sample KIR 9 cannot be determined in the subspecific level.

Asterocyclina schweighauseri Less 1987

Asterocyclina schweighauseri is an asteroidal form with 6–8 rays with very limited interray areas and a ‘chudeau’-type rosette. It has a medium-sized to relatively large embryo, very wide and medium high ‘varians–alticostata’-type adauxiliary chamberlets. The 6 to 8 rays are rather irregular; the chamberlets in the interray areas are wide and medium high. The growth pattern of the annuli is of the transitional ‘varians–strophiolata’-type. Based on rather scattered data, *A. schweighauseri* is known from France, Turkey and Israel. The first appearance is recorded from the late early Ypresian of Bos d’Arros in SW France (zone OZ 6), and extends to the middle (?) Lutetian of Montfort (zone OZ 9–10). Despite the rare data, *A. schweighauseri* can be subdivided into two subspecies with the following biometric limits:

<i>A. s. n. ssp. Bos d’ Arros</i>	$d_{\text{mean}} < 400 \mu\text{m}$
<i>A. s. schweighauseri</i>	$d_{\text{mean}} > 400 \mu\text{m}$

In our material *A. schweighauseri* is extremely rare. The three specimens from Küpler, sample KÜP 10 (zone OZ 7/8a) can be determined as *A. schweighauseri* cf. *A. schweighauseri* (Figures 14a, b) whereas the one single specimen from the basal Lutetian of Çayraz, sample ÇAY 28 (zone OZ 8b) cannot be determined at the subspecific level.

The Orthophragminid Stratigraphy of the Late Ypresian to Early Lutetian Time-interval: Updated Zonation

The late Paleocene is marked conventionally in Turkey, as elsewhere in western Tethyan realm, by the first appearance of orthophragmines. Being already very widespread in the early Ypresian shallow-marine realms (Less *et al.* in press), their main diversification starts from the late Ypresian (SBZ 10, zone OZ 5–6) with the first appearance/abundance of such stratigraphically significant lineages as *Discocyclina augustae*, *D. fortisi*, *Nemkovella strophiolata*, *Orbitoclypeus douvillei*, *O. varians*, *O. furcatus*, *Asterocyclina stellata* and *A. alticostata* simultaneously with the disappearance of *O. multiplicatus* and *O. bayani*. Characteristic early Ypresian lineages like *D. archiaci*, *D. fortisi*, *N. evae*, *O. schopeni* and *O. munieri* are quite common still in the upper Ypresian, however they disappeared gradually in the early Lutetian (SBZ 13–14, zone OZ 8b–9), simultaneously with the appearance of *D. pratti*, *D. pulcra* and *D. radians* (see also Özcan *et al.* 2007).

The assemblages of late Ypresian to early Lutetian orthophragmines from Turkish localities significantly increased our knowledge on the taxonomy, evolution and stratigraphy of the group in this time-interval. It can be stated that the orthophragminid fauna as a whole is almost uniform in a huge area stretching from SW France to Central Turkey where the record, however, is a little bit different, since the evolution of the *Discocyclina fortisi*, *D. spliti*, *Nemkovella evae*, *N. strophiolata*, *Orbitoclypeus douvillei*, *O. varians* and *Asterocyclina alticostata* lineages can be followed in more detail than in the territories to the northwest. New evolutionary stages of some formerly established evolutionary lineages such as *Discocyclina fortisi* (*D. f. anatolica*), *D. spliti* (*D. s. polatliensis*), *Nemkovella evae* (*N. e. karitensis*) and *O. varians* (*O. v. ankaraensis*) have been introduced here. They follow the formerly erected *D. fortisi cairazensis*

and *O. douvillei yesilyurtensis* described in Özcan (2002). In the Turkish localities we could identify the earliest occurrences of some species (*Discocyclusa spliti*, *Nemkovella strophiolata*, *Orbitoclypeus varians* and *Asterocyclusa alticostata*) known so far. In contrast, such species as *D. dispansa* (otherwise quite abundant in the Ypresian to middle Lutetian of the Western Tethys), *D. weijdeni*, *D. senegalensis*, *D. furoni* and *A. schweighauseri* are very rare and recorded in only a few horizons. Some other taxa, such as *D. pulcra*, *D. radians* and stratigraphically less significant European taxa like *D. knessae*, *D. kingae*, *D. aquitanica*, *D. aaroni*, *N. rota*, *N. bodrakensis*, *N. daguini*, *O. koehlerii*, and *O. marthae*, have not been recorded.

By governing a much richer set of orthophragminid assemblages than it was possible for Less to review (1987) and even (1998a), the first five (OZ 5 to 8b) of the seven orthophragminid zones of the late Ypresian to middle Lutetian time-span, introduced in the latter paper, can be updated and their correlation to the standard stages redefined. It is based on the most complete distribution chart of orthophragmines known so far and presented in Figure 15. Revised data from Özcan (2002) are also integrated. Our material from the OZ 9 and 10 zones is rather poor; thus we cannot add any significant surplus to our knowledge in this respect.

The orthophragminid record from zone OZ 5 is still somewhat scarce. The relevant localities are the *Assilina placentula* beds from the Crimean Peninsula (except for their lowest and highest parts), marked as CRIPA and CRIPU in Less (1998a); Dikilitash (DIKIL) in Bulgaria, Gan-Berdoulou (GANBD) in France and the upper part of the Eskipolatlı Formation in the Yeşilyurt section (samples YEŞ 80 and 87) described by Özcan (2002). Its lower boundary within the late early Ypresian OZ 4 zone is characterized by the replacement of *Discocyclusa archiaci staroseliensis* by *D. a. archiaci* and *D. dispansa broennimanni* by *D. d. taurica*. *Orbitoclypeus varians* is recorded first also from this zone. Formerly (Less 1998a) thought that *O. schopeni suvlukayensis* was also substituted by *O. s. crimensis*, but the Turkish data indicate instead that they coexist both here and in the OZ 6 zone. The last occurrences of *Discocyclusa pseudoaugustae* can be found in the OZ 5 zone. It was replaced by *D. fortisi* at about the boundary with the OZ 6 zone, and the unique data from Sakarya that seem to contradict this statement are discussed in the description of *D. fortisi*. *Discocyclusa 'stratiemanuelis'* reported by

Özcan (2002) from samples YEŞ 80 to 91 needs further examination. In order to correlate with other subdivisions we can use data from the Crimea and Gan, Berdoulou. An exact correlation of the Çayraz and Yeşilyurt sections of Özcan (2002) with the profiles of Hottinger (1960) and Sirel & Gündüz (1976) from the same region is not possible. According to Muzilev (1980) and Bugrova (1988) the *Assilina placentula* beds in the Bakhchisarai section correspond to the P 6–7 and to the NP 12 zones whereas P 7 and NP 12 zones are assigned by Sztrákó et al. (1998) for Gan, Berdoulou. Based on Schaub (1981) both localities and the Dikilitash sands (Aladzhovala-Khrischeva 1984) belong to the SBZ 10 zone.

The orthophragminid record from the overlying OZ 6 zone is richer. The relevant sites from SW France belonging to this zone are Gan, Tuilerie (GANTU in Less 1998a), Bos d'Arros (BOSDA) and the main body of the Sourbet marl-pit in Horsarrieu (HORSA). In the Haymana-Polatlı Basin the lowest part of the Çayraz Formation (samples ÇAY 5, 7, 9 and YEŞ 91, 92, 95), while in the Bakhchisarai section the transitional layers of the local Bakhchisarai and Simforopol stages (CRIPN in Less 1998a) can be assigned to this zone. The lower boundary is marked by the proliferation of some lineages, such as, *Discocyclusa fortisi* (substituting *D. pseudoaugustae*) and *Orbitoclypeus douvillei* lineages and also the first occurrence of the *D. pulcra*, *Nemkovella strophiolata*, *Asterocyclusa stellata* and *A. schweighauseri*. The upper boundary with the OZ 7 zone is defined by the replacement of *D. archiaci archiaci* by *D. a. bartholomei* and *D. fortisi fortisi* by *D. f. simferopolensis*. These two changes (like also the one from *Orbitoclypeus schopeni suvlukayensis* to *O. s. crimensis*), however, mutually overlap, as reflected in the rich orthophragminid assemblages of the topmost part of the Horsarrieu marl-pit (HORSX in Less 1998a) and also in Kırıklar (samples KIR 7 to 10) and Küpler (only in sample KÜP 5). These latter sites and their fauna are discussed at the description of these localities. Therefore, these sites (consisting also of the first record of the *Asterocyclusa alticostata* and *Orbitoclypeus furcatus* lineages) are attributed to about the transition of the OZ 6 and 7 zones as well as sample YEŞ 112 (of Özcan 2002) containing *Discocyclusa fortisi* ex. interc. *simferopolensis-fortisi*. The NP 12 zone has been reported from most of these sites (from Gan and Horsarrieu by Kapellos & Schaub 1973; from Bakhchisarai by Muzilev 1980), only Bos d'Arros

Geological time in Ma	53	52	51	50	49	48	47	46	45	44	43
Stages	← Y P R E S I A N				L U T E T I A N →						
Planktic foraminiferal zones (P)	← ILERD		C U I S I A N			10		11			12 →
Calcareous nannoplankton zones (NP)	← 11	12		13	14		15			16 →	
Shallow benthic zones (SBZ)	← 8	9	10		11	12	13		14		15 →
Orthophragminid zones (OZ)	4	5	6	7	8a	8b	9	10		11	
<i>Discocyclina archiaci staroseliensis</i>											
<i>D. archiaci archiaci</i>											
<i>D. archiaci bartholomei</i>											
<i>D. discus discus</i>											
<i>D. discus adamsi</i>											
<i>D. senegalensis</i>											
<i>D. weijdeni</i>											
<i>D. furoni</i>											
<i>D. pseudoaugustae</i>											
<i>D. fortisi fortisi</i>											
<i>D. fortisi simferopolensis</i>											
<i>D. fortisi anatolica</i>											
<i>D. fortisi cairazensis</i>											
<i>D. stratiemanuelis</i>											
<i>D. spliti polatiensis</i>											
<i>D. spliti spliti</i>											
<i>D. spliti ajkaensis</i>											
<i>D. pulcra landesica</i>											
<i>D. pulcra pulcra</i>											
<i>D. pulcra</i> n. ssp. Angoumé											
<i>D. pulcra balatonica</i>											
<i>D. augustae sourbetensis</i>											
<i>D. augustae atlantica</i>											
<i>D. knessae</i>											
<i>D. dispansa broenimanni</i>											
<i>D. dispansa taurica</i>											
<i>D. dispansa hungarica</i>											
<i>D. dispansa sella</i>											
<i>D. kingae</i>											
<i>D. radians</i> n. ssp. Caupenne											
<i>D. radians noussensis</i>											
<i>D. radians radians</i>											
<i>D. trabayensis trabayensis</i>											
<i>D. aquitana</i>											
<i>D. aaroni</i>											
<i>D. pratti montfortensis</i>											
<i>Nemkovella evae evae</i>											
<i>N. evae karitensis</i>											
<i>N. rota</i>											
<i>N. katoae</i>											
<i>N. strophiolata fermonti</i>											
<i>N. strophiolata strophiolata</i>											
<i>N. strophiolata</i> n. ssp. Padragkút											
<i>N. bodrakensis</i>											
<i>N. daguini</i>											
<i>Orbitoclypeus douvillei douvillei</i>											
<i>O. douvillei yesilyurtensis</i>											
<i>O. douvillei</i> n. ssp. Gibret											
<i>O. douvillei chudeaui</i>											
<i>O. douvillei pannonicus</i>											
<i>O. multiplicatus kastamonuensis</i>											
<i>O. koehleri</i>											
<i>O.</i> n. sp. Horsarrieu											
<i>O. schopeni suvlukayensis</i>											
<i>O. schopeni crimensis</i>											
<i>O. schopeni schopeni</i>											
<i>O. muniere muniere</i>											
<i>O. varians portnayae</i>											
<i>O. varians ankaraensis</i>											
<i>O. varians angoumensis</i>											
<i>O. varians roberti</i>											
<i>O. furcatus</i> n. ssp. Horsarrieu											
<i>O. furcatus</i> n. ssp. Gibret											
<i>O. furcatus rovasendai</i>											
<i>O. marthae</i>											
<i>Asterocyclina stella</i> n. ssp. Horsarrieu											
<i>A. stella stella</i>											
<i>A. stellata adourensis</i>											
<i>A. stellata stellata</i>											
<i>A. sirelli</i>											
<i>A. kecskemetii</i>											
<i>A. schweighauseri</i> n. ssp. Bos d'Arros											
<i>A. schweighauseri schweighauseri</i>											
<i>A. alticostata gallica</i>											
<i>A. alticostata cuvillieri</i>											

Figure 15. Updated range-chart for late Ypresian to middle Lutetian orthophragminid taxa. Dashed lines indicate uncertain occurrence. The time scale and the relationship of stages and zonal subdivisions (other than that of the orthophragmines) to each other are based on Hardenbol *et al.* (1998).

was assigned to NP 13 by Kapellos & Schaub (1973). The planktic foraminifera in the Crimea belong to the P 7 zone based on Bugrova (1988) whereas in Gan and Bos d'Arros to the P 8 zone according to Sztrákos *et al.* (1998). Based on Schaub (1981) all the French and Crimean sites represent still the SBZ 10 zone. Our measurements of *Nummulites pratti* from Kırıklar, however, indicate rather the SBZ 11 but this is in accord with the transitional position of this locality. Unfortunately, we could not reflect all these details in Figure 15 without destroying its internal proportions synthesized by Hardenbol *et al.* (1998).

The data from the next, OZ 7 zone are poorer probably because of its short duration reflected in Figure 15. Without considering the localities showing transitional character between OZ 6 and 7 (discussed above) or between OZ 7 and 8a (see later), only the assemblages from upper part of the *Nummulites nemkovi* and from the lower part of the *N. distans* beds (both belonging to the local Simferopolian stage and marked as CRINU and CRIDL in Less 1998a) from the Bakhchisarai profile fit exactly with the determination of this zone. The lower boundary is defined by the appearance of *Discocyclina archiaci bartholomei* (substituting *D. a. archiaci*) and *D. fortisi simferopolensis* (instead of *D. f. fortisi*) whereas the upper boundary is redefined here. In Less (1998a), *D. fortisi simferopolensis* has been assigned as an exclusive taxon for the OZ 7 zone. The author interpreted that this taxon represents the final developmental stage of *D. fortisi* and suggested that in the overlying OZ 8a zone it is replaced by *D. stratiemanuelis*. Our new data reveal that this latter lineage can be followed into far younger levels and *D. stratiemanuelis* is only a side-branch of this lineage. Therefore, it is worth assigning the first appearance of *D. fortisi anatolica* (substituting *D. f. simferopolensis*) as a marker for the boundary between the OZ 7 and 8a zones, together with that of *Orbitoclypeus douvillei yesilyurtensis* (substituting *O. d. douvillei*). As a result, the first appearance of *D. stratiemanuelis* does not necessarily coincide with the change from *D. fortisi simferopolensis* to *D. f. anatolica*. Thus, the orthophragminid assemblage from the upper part of the *Nummulites distans* beds of the Bakhchisarai profile (CRIDU in Less 1998a, containing *D. stratiemanuelis*) can be attributed to both the OZ 7 and OZ 8a zones, since no other decisive taxa can be found. As a compromise we put

it provisionally into the boundary of the above two zones as well as the assemblages from the upper part of the Küpler section (samples KÜP 8 to 10) discussed in detail at the description of the locality. For the samples CRINU and CRIDL planktic foraminiferal data by Bugrova (1988) indicate the P 7–8 zones, the calcareous nannoplankton detects about the boundary of the NP 12 and 13 zones according to Muzilev (1980). Schaub (1981) places these beds to about the boundary of the SBZ 10 and 11 zones. The upper part of the *Nummulites distans* beds (sample CRIDU) corresponds to the P 9, NP 13 and SBZ 11 zones according to the same authors.

The relevant sites belonging to the successive OZ 8a zone are Saint-Barthélémy, maisonnavé (STBAR in Less 1998a) in France, samples ÇAY 14, 17 and YEŞ 128 from the Haymana-Polatlı Basin, described by Özcan (2002), the re-studied and re-evaluated samples IS 187, 199 and 221 from the Ein Avedat section of Israel described by Fermont (1982) and samples SAF 1, 8 and 9 from Safranbolu discussed in this paper. The two decisive taxa, *Discocyclina fortisi anatolica* and *Orbitoclypeus douvillei yesilyurtensis* seem not only to appear in the beginning of the OZ 8a zone but also to disappear at its end having been replaced by *D. fortisi cairazensis* and *O. douvillei* n. ssp. Gibret, respectively. The upper boundary is marked also by other phyletic changes listed in the discussion of the OZ 8b zone. The first, though unique record of the *Discocyclina spliti* lineage is known from Safranbolu, sample SAF 8. The OZ 8a zone was formerly (Less 1998a) interpreted as crossing the Ypresian/Lutetian boundary, based on the erroneous evaluation of data from Saint-Barthélémy, maisonnavé. However, these data appeared to be quite poor and indicate rather the Ypresian age of this locality (see details in the introductory review). For the correlation only the Israeli data are really useful. The samples listed above belong to the lower part of the P 9 zone according to Benjamini (1995b). Romein (1979) puts sample IS 187 into the NP 12 whereas the other two samples into the NP 13 zone. Moshkovitz (1995) locates this boundary a little higher, placing it between samples IS 199 and IS 221 (corresponding roughly to samples 88110 and 88113 in Benjamini 1995a). However, according to Hardenbol *et al.* (1998) P 9 and NP 12 do not overlap. It is possible, that *Tribrachiatulus orthostylus* (whose last occurrence marks the boundary of the NP 12 and 13 zones) is re-sedimented in samples IS 187 and

199 (resedimentation is common throughout the Ein Avedat section according to Fermont 1982) causing the bias between the ages given by the two planktic groups. Thus, we accept in this case the planktic foraminiferal age. It is in accord with the nummulitid data by Schaub (1995) detecting the SBZ 11 zone.

Several orthophragminid localities fall within the OZ 8b zone. These are Caupenne, Jeangazé (CAUPE in Less 1998a) in France; the larger foraminifera-bearing lower part of the local Bodrakian stage in the Bakhchisarai section (CRIBO), the re-studied and re-evaluated samples IS 273, 276, 278, 335, 336, 366, 382, 399 and 40 from the Ein Avedat section of Israel described by Fermont (1982); samples ÇAY 18, 21, 28, 32 and 33 from the Haymana-Polatlı Basin (the first two are described in Özcan 2002, the last three in this paper); and finally sample ŞİLE 8 from Şile, also discussed in the recent paper. The lower boundary is defined by the transition of (1) *Discocyclina fortisi ankaraensis* to *D. f. cairazensis*, (2) *D. dispansa taurica* to *D. d. hungarica*, (3) *Nemkovella strophiolata fermonti* to *N. s. strophiolata*, (4) *Orbitoclypeus douvillei yesilyurtensis* to *O. douvillei* n. ssp. Gibret, (5) *O. varians portnayae* to *O. v. ankaraensis*, and (6) probably also *O. furcatus* n. ssp. Horsarrieu to *O. furcatus* n. ssp. Gibret. Ribbed forms of genus *Discocyclina* (*D. kingae*, restricted to this zone and *D. radians*, continuing up to the end of the Eocene) occur first in this zone, and the common occurrence of *D. spliti* also starts from OZ 8b. Two other phyletic changes seem to have happened within the OZ 8b zone, *Nemkovella evae evae* has been replaced by *N. e. karitensis* while *Asterocyclina stella praestella* was replaced by *A. s. stella*. Both transitions are quite rapid as the change can be followed in the Ein Avedat section, between samples IS 366–382 and IS 399, and may correspond to the Ypresian/Lutetian boundary. Since we do not discuss in detail the younger orthophragminid zones in this paper, the upper boundary of the OZ 8b zone is also defined here. It is characterized by the sudden shift from *Discocyclina archiaci* to *D. discus*, by the first appearance of *D. pratti* and by the more or less common occurrence of *D. pulcra*. Phylogenetic transitions of (1) *D. augustae sourbetensis* to *D. a. atlantica*, (2) *D. radians* n. ssp. Caupenne to *D. r. noussensis* and (3) *Orbitoclypeus varians ankaraensis* to *O. v. angoumensis* seem to have happened also at about the boundary of the OZ 8b and OZ 9 zones. Very probably the most advanced developmental stage of *Discocyclina fortisi* (*D. f.*

cairazensis with d_{mean} exceeding 1800 μm) known so far also represents already the OZ 9 zone (this stage is present in sample ÇAY 35, very close to samples with advanced representatives of the *Nummulites perforatus* group, for more details see the description of the Upper Çayraz section).

The OZ 8b zone seems to cross the early/middle Eocene boundary based on both the planktic and benthic data. In this respect the Ein Avedat section provides the most reliable data, although planktic Foraminifera in the given interval belong according to Benjamini (1995b) uniformly to the “*Sphaeroidinellopsis*” *senni* zone corresponding to the transition between the P 9 and P 10 zones, and thus have an intermediate position between Ypresian and Lutetian. Both Romein (1979) and Moshkovitz (1995) indicate that the lower samples (IS 273 to 278, according to Moshkovitz also IS 336 corresponding to sample 88120 of Benjamini 1995a) still belong to the NP 13 zone. Schaub (1995) located the middle/upper Cuisian boundary (= SBZ 11/12) just below sample 88120. The interval between samples IS 336 (or according to Moshkovitz IS 366 corresponding to samples 88130 and 88132 of Benjamini 1995a) and about IS 390 (= 88133 of Benjamini 1995a) belongs to the NP 14a while the uppermost samples (IS 399 and 407 of Fermont 1982 or 88134–88136 of Benjamini 1995a) to the NP 14b zone. The NP 14a/b boundary corresponds not only to the Ypresian/Lutetian boundary but also to the change in the orthophragminid fauna characterized by the appearance of *Nemkovella evae karitensis* and *Asterocyclina stella stella*. Schaub (1995) assigned all samples of the Ein Avedat section above sample 88120 into the late Cuisian corresponding to the SBZ 12 zone. Fortunately, both the NP 14a and 14b zones are defined by first occurrence data, therefore resedimentation in these cases could not affect the age determination. The calcareous nannoplankton from the other localities indicate the same NP 14 zone as determined for Caupenne, Jeangazé by Kapellos & Schaub (1973) and for the ‘Bodrakian’ stage of the Bakhchisarai section by Muzilev (1980). Planktic foraminiferal data are known only from this latter site, Bugrova (1988) still detected the P 9 zone. Based on nummulitids Schaub (1981) arranged the locality of Caupenne, Jeangazé to SBZ 12 (uppermost Ypresian) whereas our data on the developmental degree of the *Nummulites perforatus* group (see Table 3) indicate the early Lutetian age (SBZ 13) of samples ÇAY 28 from

Çayraz (containing *Nemkovella evae karitensis*, too), and ŞİLE 8 from Şile.

To sum up, the OZ 8b orthophragminid zone probably includes both the uppermost part of the Ypresian (represented by samples IS 273 to 382 from the Ein Avedat section in Israel, by the 'Bodrakian stage' of the Crimea and by the Caupenne, Jeangazé site from SW France) and the lowest part of the Lutetian (presented in samples IS 399 and 407 in Ein Avedat, in samples at least from ÇAY 28 in Çayraz and in the samples from the upper part of the Şile profile).

Our material from the higher part of the Lutetian is rather poor, and therefore we cannot discuss the OZ 9 and 10 zones in as much detail as in the lower zones. Based on available data from Turkey we can add to our previous knowledge that very probably the most advanced *Discocyclus fortisi cairazensis* (recorded from Çayraz, sample ÇAY 35) is characteristic already for the OZ 9 zone (see above). For the OZ 10 zone the presence of *Nemkovella evae karitensis* and *Discocyclus spliti spliti* can be added to what is presented in Less (1987, 1998a). The age of the samples is confirmed also by other data. In the case of Karit, sample KARI 1, the calcareous

nannoplankton from the nearly corresponding sample of KIR 10B detects the NP 15 zone while in the case of Taşköprü, samples TAŞ 4 and 7 the developmental degree of the associated *Nummulites perforatus* group (see Table 3) agrees well with our data.

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