

## ORTHOPHRAGMINID FORAMINIFERAL ASSEMBLAGES FROM AN ILLERDIAN- EARLY CUISIAN REFERENCE SECTION (SAKARYA SECTION, HAYMANA-POLATLI BASIN, CENTRAL ANATOLIA-TURKEY)

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**Key-words:** biostratigraphy, Orthophragminid foraminifera, *Discocyclina*, *Orbitoclypeus*, *Nemkovella*, *Asterocyclina*, biometry, middle-late Ilerdian/early Cuisian, central Anatolia, Turkey.

**Abstract.** The Sakarya section represents a highly fossiliferous part of the Haymana- Polatlı Basin succession (central Anatolia), consisting of mainly nummulitid, alveolinid and orthophragminid foraminifera. This section formerly proposed to serve as a reference section for early Ilerdian-early Cuisian Shallow Benthic Zones in Turkey by the 'Early Paleogene working group' was studied for its orthophragminid foraminifera, and a sequence of populations has been subjected to biometric analysis of the embryo and equatorial chamberlets. *Discocyclina*, which occurs throughout the section, is mainly represented by primitive specimens of *Discocyclina archiaci*; *D. archiaci bakhchisaraiensis* and *Discocyclina* sp.1 in the lowermost part, which is regarded as of middle Ilerdian age (orthophragminid zone 3). Upwards, different developmental stages of *D. archiaci*; transitional developmental stages of *D. archiaci bakhchisaraiensis-staroseliensis* and *D. archiaci staroseliensis* are accompanied sporadically by unribbed *Orbitoclypeus*, *O. schopeni suvlukayensis* and *Discocyclina* sp.1. This part of the section is regarded as middle-late Ilerdian in age (orthophragminid zone 4). A more diverse assemblage, represented by *Nemkovella*, *Asterocyclina*, ribbed and unribbed *Orbitoclypeus* accompanied by different *Discocyclina* species occurs in the uppermost part, which is thought to represent the transitional late Ilerdian-early Cuisian orthophragminid zones (orthophragminid zones 4/5). In these horizons, *N. strophiolata fermonti*, *N. evae*, primitive developmental stages of *D. augustae sourbetensis*, *O. douvillei douvillei*, *D. fortisi fortisi*, *A. stella* and *O. munieri munieri* are accompanied by *D. archiaci staroseliensis*, transitional developmental stages of *D. archiaci staroseliensis-archiaci*, *O. schopeni suvlukayensis* and *Discocyclina* sp. 2. Biometric data allow refinements with respect to the stratigraphic ranges of some discocyclinid and orbitoclypeid foraminifera. This paper records the first descriptions of orthophragminids from the middle-late Ilerdian/early Cuisian marine deposits of Turkey.

**Riassunto.** La sezione Sakarya rappresenta una porzione altamente fossilifera nell'ambito della successione del Bacino di Haymana- Polatlı (Anatolia Centrale), soprattutto ricca in nummulitidi, alveolinidi e orthophragminidi (Foraminifera). Questa sezione fu proposta formalmente dal 'Early Paleogene Working Group' come sezione di riferimento per la zonazione dei bentonici di acque basse dell' Ilerdiano inferiore-Cuisiano inferiore in Turchia. La sezione è stata studiata per quanto concerne i foraminiferi orthophragminidi ed una successione di popolazioni è stata valutata secondo l'analisi biometrica

delle camerette embrionali ed equatoriali. Il genere *Discocyclina*, distribuito lungo tutta la sezione, è rappresentato nella parte più bassa principalmente da esemplari primitivi di *Discocyclina archiaci*, *D. archiaci bakhchisaraiensis* e *Discocyclina* sp.1. Questa porzione viene considerata di età Ilerdiano medio (zona a orthophragminidi No.3). Verso l'alto, stadi di sviluppo diversi di *D. archiaci*; stadi di sviluppo transizionali di *D. archiaci bakhchisaraiensis-staroseliensis* e *D. archiaci staroseliensis* sono sporadicamente accompagnati da *Orbitoclypeus* non costolati, *O. schopeni suvlukayensis* e da *Discocyclina* sp.1. Questa parte della sezione è considerata di età Ilerdiano medio-superiore (zona a orthophragminidi No. 4). Una associazione più diversificata, costituita da *Nemkovella*, *Asterocyclina*, *Orbitoclypeus* costolati e non costolati, accompagnati da specie di *Discocyclina* diverse, caratterizza invece la parte superiore. Questa parte viene considerata come rappresentare la transizione tardo Ilerdiano- Cuisiano inferiore (zone a orthophragminidi No. 4/5). In questi orizzonti, *N. strophiolata fermonti*, *N. evae*, stadi di sviluppo primitivi di *D. augustae sourbetensis*, *O. douvillei douvillei*, *D. fortisi fortisi*, *A. stella* e *O. munieri munieri* sono accompagnati da *D. archiaci staroseliensis*, stadi di sviluppo transizionali di *D. archiaci staroseliensis-archiaci*, *O. schopeni suvlukayensis* e *Discocyclina* sp. 2. I dati biometrici consentono di affinare ulteriormente la distribuzione stratigrafica di alcuni foraminiferi discocyclinidi and orbitoclypeidi. Questo articolo contiene la prima descrizione di orthophragminidi da depositi marini della Turchia di età Ilerdiano medio-superiore sino a Cuisiano inferiore.

### Introduction

The terms 'orthophragminae' or 'orthophragminid foraminifera' are informally used for late Paleocene and Eocene larger foraminifera each characterized by a test comprising a median equatorial layer and lateral chamberlets developed on either side of this layer (Brönnimann 1951; Less 1987 and 1998 and Ferrández-Cañadell 1998a). Orthophragminid foraminifera consist of two systematically independent families, namely Discocyclinidae and Orbitoclypeidae that are completely different in their microspheric juvenaria (Ferrández-Cañadell 1998b). Mesogean orthophragminids comprise the genera *Discocyclina*, *Orbitoclypeus*, *Nemkovella*, and *Asterocyclina*, most of the species and/or subspecies of

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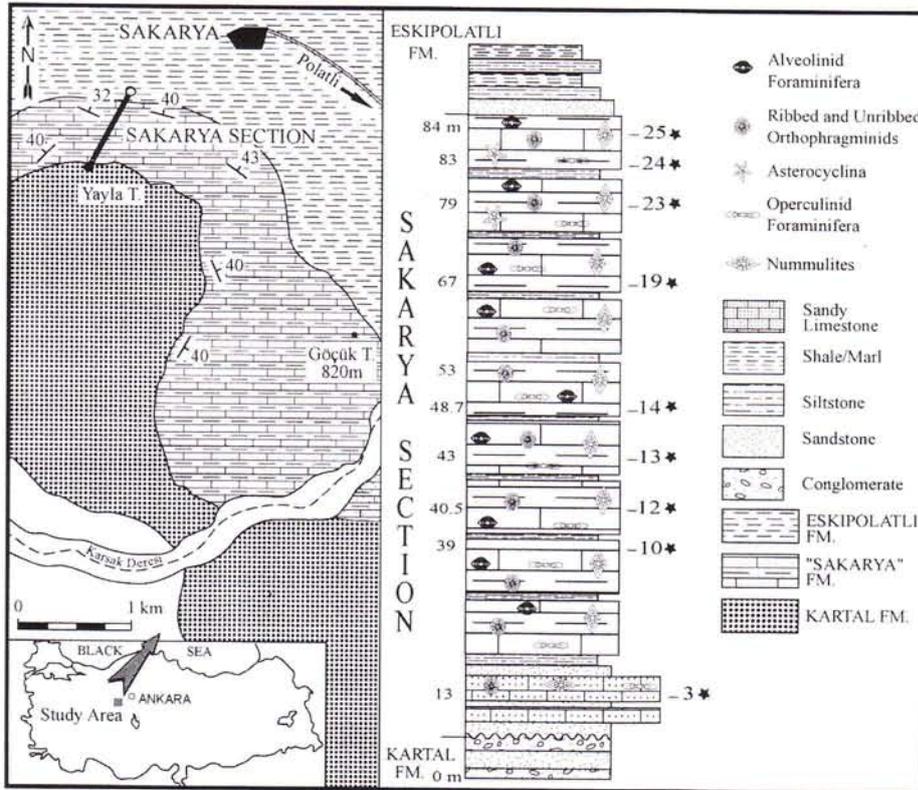


Fig.1 - Stratigraphy of the Sakarya (SAK) section in the vicinity of Sakarya village (Polatlı, central Anatolia, Turkey). Stars and numbers on the right of each section refer to sample numbers and horizons studied for orthophragminids.

which were originally described from the Mediterranean region and Crimean peninsula and some from Indian localities. Previous studies were mainly focused on the taxonomy (see Less 1987 for a more complete record of previous studies) as well as on the morphostructure of the orthophragminids (Brönnimann 1941, 1946a and b, 1951; Neumann 1972; Ferrández-Cañadell et al. 1992 and Ferrández-Cañadell 1998a and b). Biostratigraphic zonation of shallow marine Tethyan Paleocene and Eocene deposits using orthophragminids in the last decades has allowed the recognition of sixteen orthophragminid zones corresponding to twenty Shallow Benthic Zones (SBZ), established in the time span ranging from Thanetian to the end of Eocene (Serra-Kiel et al. 1998). The philosophy of this zonation bases the biometric subdivision of lineages on quickly evolving parameters observed only in the equatorial layer of the test.

Systematic treatment of Anatolian orthophragminids in equatorial sections was initiated by Özcan et al. (2001a and b) and Özcan (2002) following recognition that only poor information on the orthophragminids in Turkey was available and the realization of their potential for developing biostratigraphic subdivision of Tethyan deposits (Less 1987, 1998; Serra-Kiel et al. 1998). In the content of this study, six stratigraphic sections representing Thanetian, Ilerdian-early Cuisian and Cuisian-early Lutetian reference sections from the Haymana-Polatlı Basin (central Anatolia) were sampled. One of these, the Sakarya section, represents an extremely fossiliferous shallow-water succession pro-

posed to be a reference section for the Ilerdian-early Cuisian (Shallow Benthic Zones 5 to 10) by the 'Early Paleogene working group' (IGCP n. 286) (Serra-Kiel et al. 1998). This section, previously studied for its alveolinids and nummulitids, revealed faunal assemblages characteristic of the Ilerdian and it is only the uppermost part of the section, which was reported to represent early Cuisian (Sirel 1975, 1992). Since, the Shallow Benthic Zones (SBZ) proposed for the Tethyan Paleogene are characterized on the basis of the association of several taxa (Serra-Kiel et al. 1998), the Sakarya (SAK) section, with its fairly well-known alveolinid and nummulitid fauna, was considered of great importance. The present study essentially aims to describe the orthophragminid foraminifera from the Sakarya section in their equatorial and vertical sections, and to document their biometric features.

#### Geological/Paleontological background

The material was sampled from the so-called Sakarya (SAK) section of the late Cretaceous- middle Eocene forearc sequence of the Haymana-Polatlı Basin succession (Koçyigit 1991), which includes extremely fossiliferous shallow-water beds (Fig. 1). This section, measured and sampled about 10 km south of the town of Polatlı, near Sakarya village (central Anatolia, Ankara), records a transgressive phase over continental coarse clastics and contains abundant free specimens of orthophragminids. In the Polatlı region, the early Paleo-

gene part of the Haymana-Polatlı Basin succession includes mainly continental clastics of the Kartal Formation and shallow-marine clastic-carbonate units of the Kirkkavak and 'Sakarya' Formations. The Kartal Formation is described as a thick-unit, whose thickness is in excess of 400 m and comprises continental red beds. This unit, which is devoid of benthic foraminifera, is regarded as of early Paleocene age based on foraminifera identified only in the uppermost part of the unit (Sirel 1975; Ünalán et al. 1976). The Kartal Formation is unconformably overlain either by the Kirkkavak Formation with typical Thanetian benthic foraminifera or the 'Sakarya' Formation, which contains Ilerdian-early Cuisian fauna. The Kirkkavak Formation, whose thickness is in the excess of 100 m, is represented by friable siltstone, sandstone, conglomerate and local argillaceous carbonate horizons in its lower part and passes upward into carbonate-rich units, mainly friable shale/siltstone, sandstone and limestone. In its uppermost part, a thick 'algal limestone' horizon, composed of mainly massive argillaceous limestone, represents the final phase of shallow-water sedimentation in the region. An assemblage of *Discocyclina seunesi*, *Discocyclina* sp.1, *Orbitoclypeus neumannae* and a new species of *Orbitoclypeus*, *O. haymanaensis* n. sp. was described from this unit (Özcan et al. 2001a, b). The foraminifera associated with these orthophragminids are represented by *Glomalveolina primaeva*, *Glomalveolina* cf. *levis*, *Glomalveolina* cf. *pilula*, *Operculina heberti*, *Vania anatolica*, *Assilina yvettae*, *Miscellanea yvettae*, *Mississippina* ? *binkhorsti*, *Valvulina* ? sp., *Quinqueloculina* ? sp., *Coskinolina* sp., *Rotalia* sp. and *Pseudolacazina* sp. This succession, considered to be of Thanetian age (Sirel 1975, 1976a and b, 1998; Özcan et al. 2001b), passes upward into basinal, planktonic fauna-bearing horizons.

In the same region, a few km west of this locality, around Sakarya village, continental red beds of the Kartal Formation are unconformably overlain by the shallow-marine succession of Sakarya section. However, the faunal assemblages of this fossiliferous section are completely different than that of the Kirkkavak Formation.

This 84 m-thick succession is represented by siltstone-sandstone intercalations containing sporadic occurrences of nummulitid foraminifera immediately overlying the red beds of the Kartal Formation (Fig. 1). These horizons are succeeded by medium-to thick-bedded carbonate-rich beds, which contain abundant free specimens of orthophragminids accompanied by alveolinid and nummulitid foraminifera. In some levels, the foraminifera are in rock-forming quantities. These levels are interrupted by thin- to medium-bedded horizons made up of mainly clastic material. Up in the succession, the regime of shallow-water sedimentation ended with subsidence in the basin and basinal conditions began. This part of the succession has been treated either as the Kirkkavak Formation (Ünalán et al. 1976) or left unnamed as in Sirel (1975), who first described in detail the lithostratigraphic units cropping out in the region, with their nummulitid and alveolinid foraminifera. In this study, this part of the succession was informally treated as the 'Sakarya' Formation. Sirel (1975, 1976a, b) identified *Alveolina cucumiformis* Hottinger, 1960, *Nummulites exilis* Douvillé, 1919, *N. solitarius* de la Harpe, 1883 in the lowermost part of the same section. Upward in the succession, this is followed by an assemblage of *A. ellipsoidalis* Schwager, 1883, *A. avellana* Hottinger, 1960, *A. aragonensis* Hottinger, 1960, *A. pasticillata* Schwager, 1883, *A. minervensis* Hottinger, 1960, *A. cucumiformis* Hottinger, 1960, *A. leupoldi* Hottinger, 1960, and in the following horizons by an assemblage of *A. decipiens* Schwager, 1883, *A. subpyrenaica* Leymerie, 1846, *A. ilderdensis* Hottinger, 1960, *A. sakaryaensis* Sirel, 1975, *N. ataticus* Leymerie, 1846 and *N. murchisoni* (Rüttimeyer, 1850). The uppermost part of this section was reported to contain *A. polatliensis* Sirel, 1975, *A. ilderdensis* Hottinger, 1960, *A. rotundata* Hottinger, 1960, *A. subpyrenaica* Leymerie, 1846 and *N. ataticus* Leymerie, 1846. Sirel (1976a) also reported and illustrated *A. oblonga* d'Orbigny, 1826 and *N. planulatus* (Lamarck, 1804) from the uppermost part of the same section, and considered the section to range in age from early Ilerdian to early Cuisian.

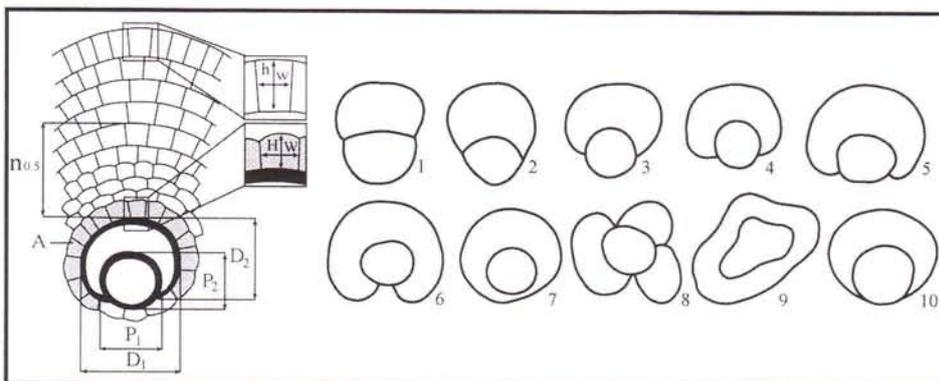


Fig.2 - Parameters for the definition of embryo and equatorial chamberlets in orthophragminids. See explanation in the text. Types of embryo; 1- isolepidine, 2- semi-isolepidine, 3- nephrolepidine, 4- semi-nephrolepidine, 5- trybliolepidine, 6- umbilicolepidine, 7- excentriolepidine, 8- polyolepidine, 9- centriolepidine, 10- eulepidine (redrawn from Less 1987).

### Description of orthophragminid foraminifera.

The present work is based on the thin-sectioning of megalospheric orthophragminid specimens in equatorial and partly vertical sections. For the quantitative description of embryos and other features related to their equatorial layers, we adopt the terminology proposed by Less (1987) (Fig. 2).

P1 and P2: outer diameter of protoconch perpendicular and parallel to P-D axis, D1 and D2: outer diameter of deutoconch perpendicular and parallel to P-D axis, A: number of auxiliary chamberlets directly arising from the deutoconch (adauxiliary chamberlets), n0.5: number of annuli within 0.5mm distance measured from the deutoconch along P-D axis, H and W: height and width of the equatorial chamberlets in the first annulus, h and w: height and width of the equatorial chamberlets around the peripheral part of the equatorial layer. We here present the data related to P1 and D1, their ranges and means; A, its range; n0.5, its range; and H, W, h and w, and their ranges

(Table 1). In the text, the diameters of protoconchs and deutoconchs are designated by P and D, corresponding to P1 and D1, and Dmean stands for the population average of D1. For different configurations of embryos, we adopt the terminology of Less (1987) (Fig. 2).

In taxonomy, we basically follow the concepts of 'lineages' proposed by Less (1987 and 1998), and define our taxa in terms of species/subspecies rank. Statistical data related to the parameters for each population are presented in Table 1. In the correlation of Ilerdian and Cuisian stages with Shallow Benthic Zones (SBZ) and orthophragminid zones, we adopt the scheme proposed by Serra-Kiel et al. (1998).

Nine stratigraphic horizons (SAK 3, 10, 12, 13, 14, 19, 23, 24 and 25), sampled from the Sakarya section, contain abundant free specimens of orthophragminid foraminifera (Fig. 1). *Discocyclina* occurs throughout the entire section. In the lowermost 39 m of the section,

TAXON	Horizon	N	P1			D1				A Range	n0.5 Range	H Range	W Range	h Range	w Range
			Min	Max	Mean	Min	Max	Mean	s.d.						
<i>D. archiaci bakhchisaraiensis</i>	SAK 3	20	105	215	134.2	220	350	278.5	41.3	17-24	11-15	35-65	25-50	55-100	25-55
<i>D. archiaci staroseliensis</i>	SAK 12	8	150	200	162.5	280	400	337.5	42.76	22-37	12	50-70	30-40	-	-
	SAK 14	10	125	215	161.0	230	380	312.0	50.62	19-28	8-17	45-90	30-50	45-100	25-50
	SAK 24	19	125	260	175.5	250	480	340.5	58.80	20-38	11-12	50-75	20-50	75-85	25-40
	SAK 25	20	115	225	169.0	225	525	328.2	71.03	19-33	8-15	45-80	25-50	65-100	25-45
<i>D. archiaci bakhchisaraiensis-staroseliensis</i>	SAK 10	13	120	210	149.5	230	365	304.6	55.43	20-31	11-13	45-75	25-65	65-75	30-40
	SAK 13	18	105	200	143.8	200	455	296.6	64.74	18-43	9-13	55-70	20-50	-	-
	SAK 19	9	125	180	147.7	230	350	298.8	41.06	19-25	10-13	35-75	25-50	75	30-50
<i>D. archiaci staroseliensis-archiaci</i>	SAK 23	8	150	265	189.3	295	620	395.6	104.7	24-38	9-11	50-75	30-50	85-110	30-50
<i>D. fortisi fortisi</i>	SAK.25	1	-	-	325.0	-	-	650.0	-	49	7	85	40-50	75	30-45
<i>D. augustae sourbetensis</i>	SAK 24	1	-	-	65.0	-	-	95.0	-	-	-	-	-	-	-
	SAK 25	12	60	100	79.5	100	150	121.6	15.35	7-13	16-20	20-30	20-30	50-80	20-30
<i>Discocyclina</i> sp.1	SAK 3	1	-	-	120.0	-	-	195.0	-	17	13	60	40	85-90	30-45
	SAK13	1	-	-	100.0	-	-	175.0	-	19	-	-	-	-	-
<i>Discocyclina</i> sp.2	SAK 24	2	-	-	275.0	605	610	607.5	3.54	38-40	-	70	50	-	-
	SAK 25	2	400	510	455.0	885	910	897.5	17.68	46-47	7	50-110	30-50	85	35-45
<i>N. evae</i>	SAK 24	1	-	-	110.0	-	-	185.0	-	14	-	40	35	-	-
<i>N. strophiolata fermonti</i>	SAK 24	5	90	115	101.1	135	165	147.0	12.55	9-10	16-18	25-30	30-50	50-95	30-40
	SAK 25	3	85	100	91.6	125	150	136.6	12.58	9-10	17-18	25-30	30-40	70	30-40
<i>O. schopeni suvlukayensis</i>	SAK 10	2	145	180	162.5	275	305	290.0	21.21	35	14	50-55	25-40	70-105	30-40
	SAK 12	5	130	185	146.2	230	310	267.0	32.33	23-28	10-14	40-50	30-35	-	-
	SAK 13	1	-	-	175.0	-	-	300.0	-	-	-	-	-	-	-
	SAK 14	2	105	155	130.0	200	310	255.0	77.78	18-30	10	50-70	30-45	60	35-45
	SAK 19	9	120	140	128.3	220	290	254.4	22.42	25-29	10-12	45-65	25-50	80-120	35-50
	SAK 23	3	105	110	107.5	190	270	221.6	42.52	18-28	12	30-40	30-40	90	35
	SAK 24	4	105	145	131.6	220	325	270.0	37.53	24-32	-	40-55	20-45	80-105	30-40
SAK 25	2	160	160	160.0	225	340	282.5	81.32	-	-	70-75	35-40	-	-	
<i>O. douvillei douvillei</i>	SAK 23	1	-	-	70.0	-	-	125.0	-	10	18	25-30	25-30	75	35
	SAK 25	1	-	-	80.0	-	-	155.0	-	11	18	25	25-30	175	35-40
<i>O. munieri munieri</i>	SAK 25	2	155	185	170.0	320	330	325.0	7.07	32	-	50-55	30-45	-	-
<i>O. cf. munieri</i>	SAK 25	1	-	-	100.0	-	-	175.0	-	19	-	-	-	-	-
<i>A. stella</i>	SAK 23	4	70	85	76.2	115	120	116.2	2.5	7	-	-	-	-	-
	SAK 24	2	80	85	82.5	125	130	127.5	3.53	7-8	-	-	-	-	-
	SAK 25	3	75	85	80.0	130	135	131.6	2.89	-	-	-	-	-	-

Tab.1 - Numeric data for orthophragminids (see the text for the explanation for abbreviations).

orthophragminids are represented only by the genus *Discocyclina*. Unribbed specimens of *Orbitoclypeus* were first encountered in sample SAK 10. Between samples SAK 10 and 19, in the 39-67-m interval, unlike *Discocyclina*, *Orbitoclypeus* specimens are extremely scarce. A remarkable increase both in diversity and abundance of orthophragminids is observed with sample 19, which contains a comparatively rich association of unribbed *Orbitoclypeus* specimens and *Discocyclina*. The most diverse assemblages, represented by *Nemkovella*, *Asterocyclina*, ribbed and unribbed *Orbitoclypeus* accompanied by *Discocyclina*, occur in an interval between samples SAK 23 and 25 representing the uppermost part of the Sakarya section. Descriptions of the orthophragminid taxa are given below.

Order Foraminiferida Eichwald, 1830  
 Family Discociclynidae Galloway, 1928  
 Genus *Discocyclina* Gumbel, 1870

***Discocyclina archiaci*** (Schlumberger, 1903)  
***bakhchisaraiensis*** Less, 1987

Pl. 2, fig.10, Fig. 4 (specimens from SAK 3)

?1972 *Discocyclina archiaci* (Schlumberger, 1903), Samuel et al., p. 161-162, pl. 47, fig. 4.

1987 *Discocyclina archiaci* (Schlumberger, 1903) *bakhchisaraiensis* n. ssp., Less, p. 130-131, pl. 1, figs. 1-6, text figs. 26a, b; 27a.

**Description.** Each embryo is characterized by a protoconch, measuring from 105 to 215 microns and a larger deutoconch measuring from 220 to 350 microns (Table 1) and presents a mainly semi-nephrolepidine

configuration. A few specimens are characterized by embryos, most close to nephrolepidine and trybliolepidine configurations (Fig. 4, SAK 3-2). Aduaxiliary chamberlets are comparatively high and wide (H: 35-65 microns, W: 25-50 microns) with almost flat to slightly arcuate outer parts. Their number varies from 17 to 24. The discocyclinid population in SAK 3, with  $D_{\text{mean}} = 278.5$  microns, is attributed to a primitive stage of *D. archiaci* after Samuel et al. (1972) and Less (1987 and 1998) and its biometric features are most similar to *D. archiaci bakhchisaraiensis*, considering the subspecies limit of  $D_{\text{mean}} < 305$  microns set by Less (1998).

**Remarks.** The SAK 3 population with  $D_{\text{mean}} = 278.5$  microns represents the most primitive developmental stage of *D. archiaci* in the Haymana-Polatlı Basin succession. Its biometric features are most close to those of *D. archiaci bakhchisaraiensis* populations (Crimean peninsula-CRIOS:  $D_{\text{mean}} = 275.0$  and CRICR:  $D_{\text{mean}} = 282.9$  microns; France, Gamarde-GAMA7: 303.1 microns) described from orthophragminid-zone 3 (middle Ilerdian) (Less 1998).

***Discocyclina archiaci*** (Schlumberger, 1903)

***bakhchisaraiensis*** Less, 1987

***D. archiaci*** (Schlumberger, 1903)

***staroseliensis*** Less, 1987

Pl. 2, figs. 2-5, 8, fig. 4 (specimens from SAK 10 and 13)  
 and 5 (specimens from SAK 19)

1972 *Discocyclina archiaci* (Schlumberger, 1903), Samuel et al., p.

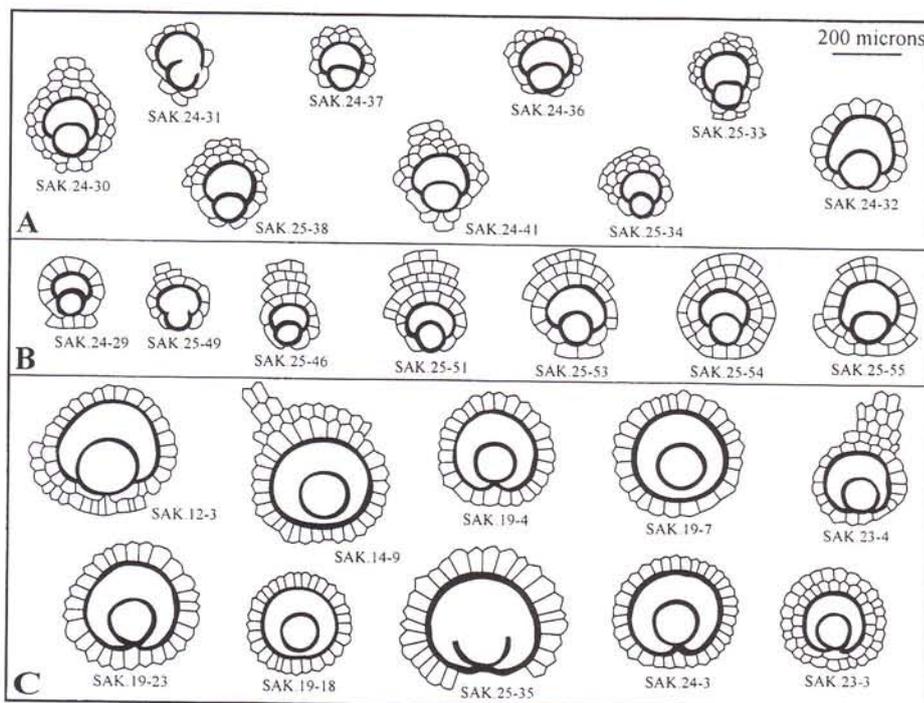


Fig.3 - Megalospheric embryo, early chamberlets and their variation in A- *N. strophiolata* (Gumbel, 1868) *fermonti* Less, 1987 (SAK 24-30, 31, 37, 36, 41; SAK 25-34, 33, 38) and *N. evae* Less, 1987 (SAK 24-32), B- Primitive developmental stage of *D. augustae* van der Weijden, 1940 *sourbetensis* Less, 1987, C- *O. schopeni* (Cecchia-Rispoli, 1908) *svulukayensis* Less, 1987.

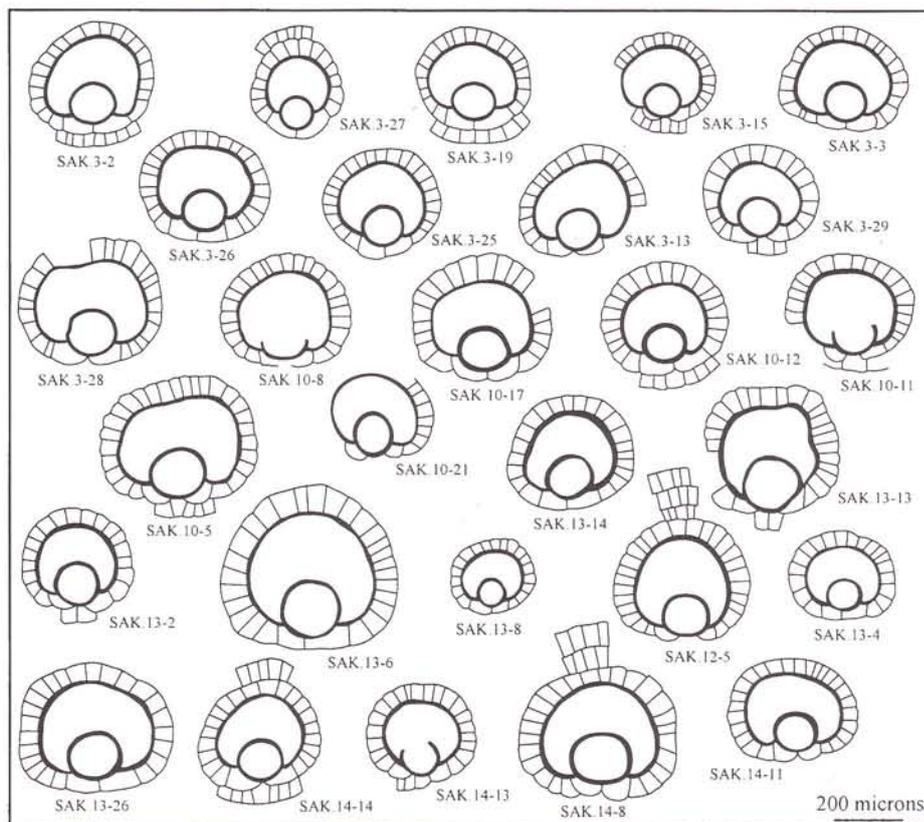


Fig.4 - Megalospheric embryo, early chamberlets and their variation in *D. archiaci* (Schlumberger, 1903) *bakhchisaraiensis* Less, 1987 (specimens from sample SAK 3 other than SAK 3-27, which belongs to *Discocyclusina* sp. 1), transitional developmental stages of *D. archiaci* (Schlumberger, 1903) *bakhchisaraiensis* Less, 1987 and *D. archiaci* (Schlumberger, 1903) *staroseliensis* Less, 1987 (specimens from SAK 10 and 13), and *D. archiaci* (Schlumberger, 1903) *staroseliensis* Less, 1987 (specimens from SAK 12 and 14)

- 161-162, pl. 47, fig. 4.  
 1987 *Discocyclusina archiaci* (Schlumberger, 1903) *bakhchisaraiensis* n. ssp., Less, p. 130-131, pl. 1, figs. 1-6, text fig. 26a, b, 27a.  
 1987 *Discocyclusina archiaci* (Schlumberger, 1903) *staroseliensis* n. ssp., Less, p. 131-132, pl. 1, figs. 7-12, text fig. 26c.

**Description.** *Discocyclusina* specimens in SAK 10, 13 and 19 are characterized by embryos presenting mostly semi-nephrolepidine (Pl. 2, fig. 8) and sporadically trybliolepidine configurations. The diameter of the protoconchs, measure from 120 to 210, 105 to 200 and 125 to 180 microns, and deuteroconchs measure from 230 to 365, 200 to 455 and 230 to 350 microns, respectively (Table 1). Aduaxiliary chamberlets are comparatively high and wide (H: 35-75 microns, W: 20-65 microns) with almost flat to slightly arcuate outer parts. The number of adauxiliary chamberlets varies from 18 to 43. These populations, with  $D_{\text{mean}} = 304.6$ , 296.6 and 298.8 microns, are ascribed to primitive developmental stages of *D. archiaci*; transitional developmental stages of *D. archiaci bakhchisaraiensis*- *D. archiaci staroseliensis* considering the subspecies limit  $D_{\text{mean}} = 305$  microns proposed by Less (1998) to differentiate both taxa.

**Remarks.** Biometric aspects of *D. archiaci staroseliensis* populations are known from the Crimean peninsula (CRICP:  $D_{\text{mean}} = 351.3$  microns) from the Pyrenees (Campo-PYCM1:  $D_{\text{mean}} = 309.0$  and Aurignac-AUR12:  $D_{\text{mean}} = 356.9$  microns), and from France (Gamarde-GAMA2:  $D_{\text{mean}} = 331.6$  microns) (Less 1998). SAK 10, 13 and 19 populations with  $D_{\text{mean}} =$

304.6, 296.6 and 298.8 microns, respectively, represent a stage transitional between advanced *D. archiaci bakhchisaraiensis* and primitive *D. archiaci staroseliensis*, described from orthophragminid zones 3 to 4 (middle-middle/late Ilerdian) (Less 1998).

***Discocyclusina archiaci* (Schlumberger, 1903) *staroseliensis* Less, 1987**

Pl. 2, figs. 6-7, 9, Fig. 4 (specimens from SAK 12 and 14) and 5 (specimens from SAK 24 and 25)

- 1972 *Discocyclusina archiaci* (Schlumberger, 1903), Samuel et al., p. 161-162, pl. 47, fig. 4.  
 1987 *Discocyclusina archiaci* (Schlumberger, 1903) *staroseliensis* n. ssp., Less, p. 131-132, pl. 1, figs. 7-12, text fig. 26c.

**Description.** In SAK 12, 14, 24 and 25, embryos of *Discocyclusina* specimens are characterized by a protoconch, measuring from 150 to 200, 125 to 215, 125 to 260 and 115 to 225 microns and a larger deuteroconch, measuring from 280 to 400, 230 to 380, 250 to 480 and from 225 to 525 microns, respectively (Table 1). These specimens present trybliolepidine and semi-nephrolepidine embryonic configurations. Aduaxiliary chamberlets are comparatively high and wide (H: 45-90 microns, W: 20-50 microns) with almost flat to slightly arcuate outer parts. The number of adauxiliary chamberlets vary from 19 to 38. These populations with  $D_{\text{mean}} = 337.5$ , 312.0, 340.5 and 328.2 microns, respectively, are attributed to *D. archiaci staroseliensis* considering the subspecies limit

$D_{mean}$  = 305-390 microns set by Less (1998).

**Remarks.** The stratigraphic range of *D. archiaci staroseliensis* was reported to be middle- late Ilerdian (orthophragminid zone 4) and *D. archiaci archiaci* with  $D_{mean}$  = 390-600 microns is considered to be a typical early Cuisian (orthophragminid zone 5-6) chronospecies (Less 1998). The uppermost part of Sakarya section (SAK 23, 24 and 25) is considered to be of late Ilerdian/early Cuisian age (orthophragminid zone 4/5) on the basis of the orthophragminid foraminiferal associations. *D. archiaci* specimens in SAK 24 and 25 have lower values for deuteroconch diameter than those described from orthophragminid zone 5, corresponding to the early Cuisian (Less 1998). These *D. archiaci* specimens are also more primitive than *D. archiaci archiaci* (YEŞ 80:  $D_{mean}$  = 427.3 microns; YEŞ 91:  $D_{mean}$  = 408.0 microns; YEŞ 95:  $D_{mean}$  = 422.5 microns) described from the early Cuisian part (orthophragminid zones 5 and 6) of the Cuisian/early Lutetian reference section in the Haymana-Polatlı Basin (Özcan 2002).

**Discocyclina archiaci** (Schlumberger, 1903)

**staroseliensis** Less, 1987

**D. archiaci archiaci** (Schlumberger, 1903)

Fig. 5 (specimen from SAK 23)

- 1903 *Orthophragmina archiaci* n. sp., Schlumberger, p. 277, pl. 8, figs. 5, 6?, 11.
- 1958 *Discocyclina archiaci* (Schlumberger), Neumann, p. 81-84, pl. 1, figs. 1-2, 3(?), 4-8, text fig. 20.

- ?1972 *Discocyclina archiaci* (Schlumberger, 1903), Samuel et al., p. 161-162, pl. 47, fig. 4.
- 1987 *Discocyclina archiaci archiaci* (Schlumberger), Less, p. 132-133, pl. 1, fig. 13, pl. 2, figs. 1-2, 6, pl. 3, figs. 1-2, 8-9, 12, text fig. 26d.
- 1987 *Discocyclina archiaci* (Schlumberger, 1903) *staroseliensis* n. ssp., Less, p. 131-132, pl. 1, figs. 7-12, text fig. 26c.

**Description.** In SAK 23, *Discocyclina* embryos are characterized by a protoconch, measuring from 150 to 265 microns, and a deuteroconch, measuring from 295 to 620 microns (Table 1) and present either trybliolepine or nephrolepine configurations. Aduaxiliary chamberlets are comparatively high and wide (H: 50-75 microns, W: 30-50 microns) with almost flat to slightly arcuate outer parts. Their number varies from 24 to 38. This population, with  $D_{mean}$  = 395.0 microns, represents a further stage in *D. archiaci* and is attributed to transitional developmental stages of *D. archiaci staroseliensis-archiaci*.

**Remarks.** The *D. archiaci* population in SAK 23 represents the most advanced developmental stage of the species in the upper part of the Sakarya section, and its biometric features are most similar to those of transitional stages of *D. archiaci staroseliensis-archiaci*, considering the subspecies limit  $D_{mean}$  = 390 microns set by Less (1998) to differentiate both taxa. It should be noted that *D. archiaci* specimens in this horizon, which are thought to represent orthophragminid zones 4/5 (corresponding to late Ilerdian-early Cuisian transition) in the studied section, have lower values for deuteroconch diameter considering the corresponding parame-

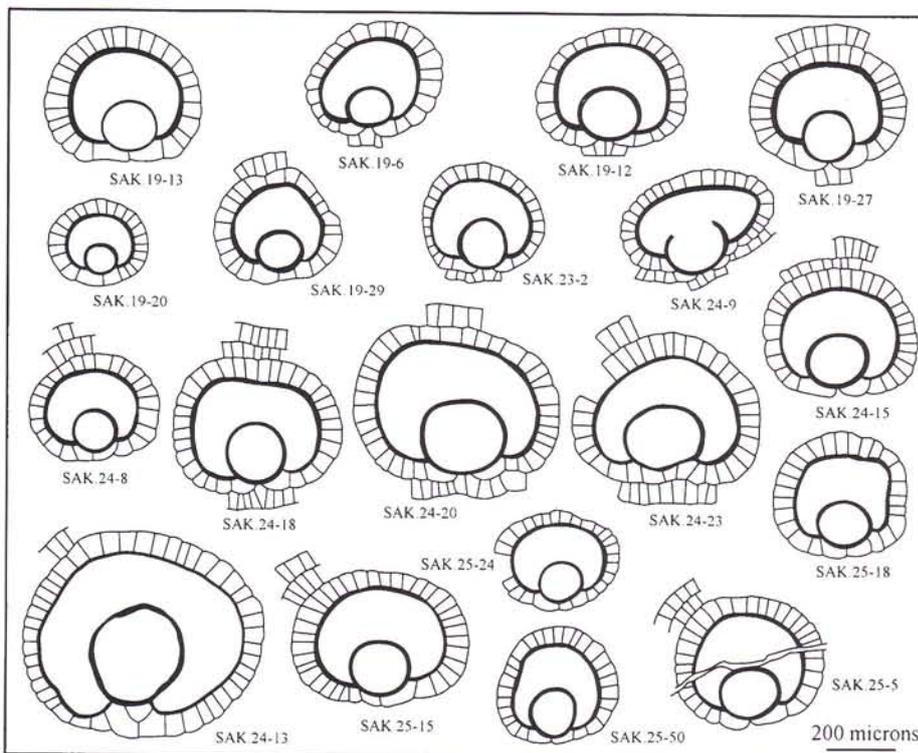


Fig.5 - Megalospheric embryo, early chamberlets and their variation in transitional developmental stages of *D. archiaci* (Schlumberger, 1903) *bakhchisaraiensis* Less, 1987 and *D. archiaci* (Schlumberger, 1903) *staroseliensis* Less, 1987 (specimens from SAK 19), transitional developmental stages of *D. archiaci* (Schlumberger, 1903) *staroseliensis* Less, 1987 and *D. archiaci archiaci* (Schlumberger, 1903) (specimens from SAK 23), *D. archiaci* (Schlumberger, 1903) *staroseliensis* Less, 1987 (specimens from SAK 24 and 25 other than SAK 24-13) and *Discocyclina* sp. 2 (specimen SAK 24-13).

ters reported from the early Cuisian (orthophragminid zone 5) for *D. archiaci archiaci* by Less (1998).

**Discocyclina augustae** van der Weijden, 1940

**sourbetensis** Less, 1987

Pl. 1, figs. 6-11, Fig. 3B

- 1987 *Discocyclina augustae* van der Weijden, 1940 *sourbetensis* n. ssp., Less, p. 152-153, pl. 9, figs. 7, 9-12, pl. 10, fig. 1, text fig. 27f.  
 2002 *Discocyclina augustae* van der Weijden, 1940 *sourbetensis* Less, 1987, Özcan, p. 80, pl. 1, figs. 11-12 (?), pl. 2, fig. 1-3, text fig. 3C.

**Description.** Some of the discocyclinid specimens sectioned in SAK 24 and 25 are characterized by a small protoconch, measuring from 60 to 100 microns, and a slightly larger deutoconch measuring from 100 to 150 microns (Table 1) and present nephrolepidine-semi-isolepidine configurations. Adauxiliary chamberlets are low and narrow (H: 20-30 microns, W: 20-30 microns) with almost flat outer parts ('archiaci type'), and their number varies from 7 to 13. In the early part of the equatorial layer, the chamberlets are typically square, low (n0.5: 16-20), and in the later ontogenetic stage, they progressively grow higher toward the peripheral part of the test, and are typically rectangular in shape. The height of the peripheral chamberlets may reach up to 80 microns (Pl. 1, figs. 10, 11).

**Remarks.** Less (1998) describes two coevolving species from Cuisian strata: *D. augustae sourbetensis* with  $D_{\text{mean}} < 145$  microns and *D. dispansa taurica* with  $D_{\text{mean}} = 160-230$  microns having similar internal and outer features but differentiated mainly by the size of embryo. In Ilerdian beds, the existence of *D. augustae* is deduced from only a single specimen identified in an horizon corresponding to orthophragminid zone 3. Since the diameter of the deutoconch for both species are very close, distinction of these species seems to be rather difficult (Özcan 2002). The specimens in SAK 24 and 25 are very similar to those *D. augustae* specimens described from the early Cuisian of France (orthophragminid zone 5) (Gan: Berdoulou- GANBD:  $D_{\text{mean}} = 120.0$  microns), and more primitive than those described from orthophragminid zone 6 from France (Tuilerie- GANTU:  $D_{\text{mean}} = 140.8$  microns Bos'Arros- BOSDA:  $D_{\text{mean}} = 135.0$  microns and Horsarrieu- HORSAs:  $D_{\text{mean}} = 130.0$  microns) (Less 1998). Since no orthophragminid foraminiferal data is available from the uppermost Ilerdian (upper part of orthophragminid

zone 4= SBZ-9), a comparison cannot be made. The biometric aspects of these specimens are also more primitive than those described from the early Cuisian part of Cuisian reference sections (orthophragminid zones 5-6): Yeşilyurt-YEŞ ( $D_{\text{mean}} =$  ranging between 127.5 and 147.5 microns) and Çayraz- ÇAY (ÇAY 5:  $D_{\text{mean}} = 143.3$  microns) in the Haymana-Polatlı Basin (Özcan 2002). The diameter of embryos and the number of adauxiliary chamberlets of *D. augustae* specimens in our material fit the sub-species limits ( $D_{\text{mean}} < 165$  microns) set for *D. augustae sourbetensis*.

**Discocyclina fortisi fortisi** (d'Archiac, 1850)

Pl. 2, fig. 11.

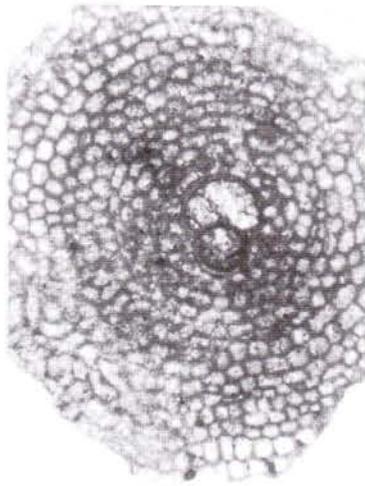
- 1850 *Orbitolites fortisii* n. sp., d'Archiac, p. 404, pl. 8, figs. 10-12.  
 1987 *Discocyclina fortisi fortisi* (d'Archiac), Less, p. 145-146, pl. 7, figs. 8-9, text fig. 26s.  
 2002 *Discocyclina fortisi fortisi* (d'Archiac), Özcan, p. 82, pl. 4, figs. 5-6, 11, text fig. 5B.

**Description.** Only one Discocyclinid specimen in the uppermost part of the section yielded a conspicuously large embryo of centrilepidine configuration; that is, the wall of the deutoconch encompasses the whole of the protoconch. The diameter of the protoconch is about 325 microns and that of the deutoconch about 650 microns (Table 1). Adauxiliary chamberlets are comparatively high and wide (H: 85 microns, W: 40-50 microns) with flat outer parts, and their number is about 49. The height of the following cycles does not change or barely increases toward the periphery.

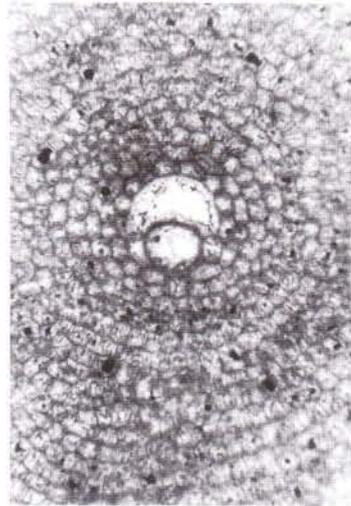
**Remarks.** *D. fortisi* is a diagnostic and most abundant discocyclinid species for the Cuisian in the Haymana-Polatlı Basin succession (Özcan 2002), and it first appears in orthophragminid zone 6 corresponding to early Cuisian (Less 1998). Only one specimen, with  $D = 650$  microns, is thought to represent a primitive developmental stage of the species and is attributed to primitive *D. fortisi fortisi*. This taxon yielded similar values for deutoconch size to those described in the early Cuisian part of the Yeşilyurt-YEŞ and Çayraz-ÇAY sections ( $D_{\text{mean}} =$  YEŞ 91: 652.1; YEŞ 92: 805.0; YEŞ 95: 736.6, ÇAY 5: 544.0, ÇAY 7: 628.3 and ÇAY 9: 820.0 microns) from the Haymana-Polatlı Basin (Özcan 2002). However, in these horizons, *D. fortisi* is very common. The uppermost part of the Sakarya section possibly corresponds to the stratigraphic horizons in which *D. fortisi* first appears in the stratigraphic record.

PLATE 1

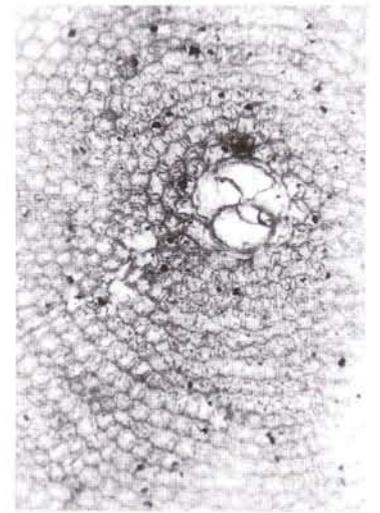
1-5) *Nemkovella strophiolata* (Gümbel, 1868) *fermonti* Less, 1987. 1-3, 5) equatorial section: 1) sample SAK 25-33. 2) sample SAK 24-30. 3) sample SAK 24-41. 5) sample SAK 25-34. 4 -vertical section, sample SAK 24-38. 6-11) Primitive developmental stage of *Discocyclina augustae* van der Weijden, 1940 *sourbetensis* Less, 1987, equatorial section: 6, 8) sample SAK 25-51. 7) sample SAK 25-54. 9-10) sample SAK 25-53. 11) sample SAK 25-49. 1-5, 7-9 x75; 6, 10-11 x28.



1



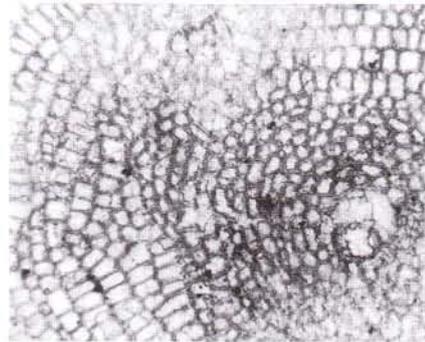
2



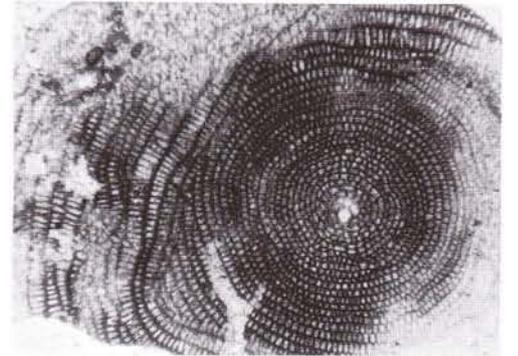
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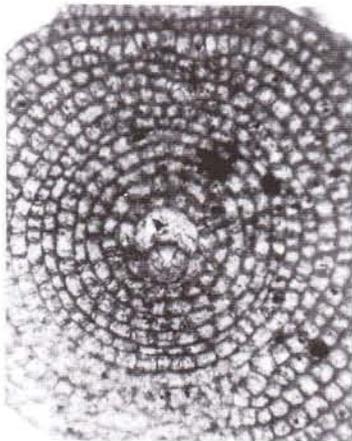
4



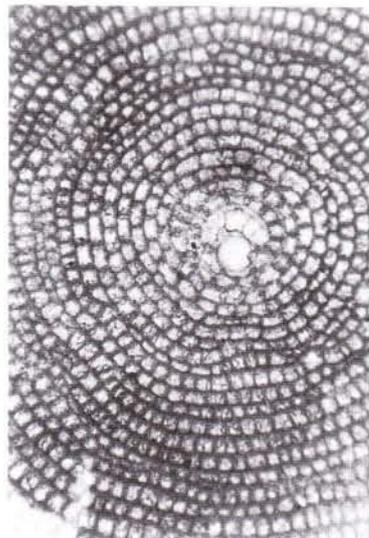
5



6



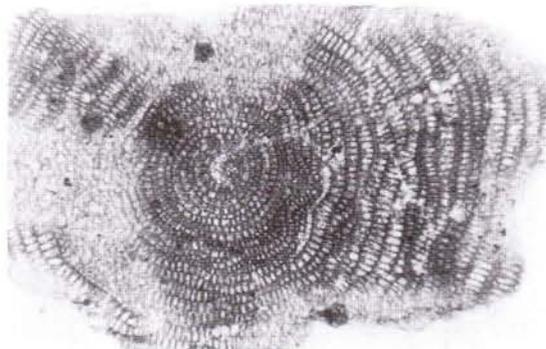
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**Discocyclina** sp. 1

Pl. 2, fig.1

Several specimens in SAK 3 and 13 have rather small embryos (D= varying from 175 to 195 microns) with nephrolepidine configurations. These specimens are differentiated from *D. archiaci* in having rather small embryos, in which the protoconchs are in a more eccentric position with respect to the deuterococonchs.

**Discocyclina** sp. 2

Text fig. 5 (specimen SAK 24-13)

Some specimens in the uppermost part of the Sakarya section have a rather large embryo with an embryonal configuration most similar to the umbilicolepidine type. The large protoconch (P=varying between 275 and 510 microns) is almost enveloped by the deuterococonch (D= varying from 605 to 910 microns). These specimens, having completely different embryos from *D. archiaci*, are attributed provisionally to *Discocyclina* sp.2.

Genus *Nemkovella* Less, 1987**Nemkovella strophiolata** (Gümbel, 1868)**fermonti** Less, 1987

Pl. 1, figs. 1-5, Fig. 3A.

1987 *Nemkovella fermonti* n. sp., Less, p. 187-188, pl. 24, figs. 5-6, text fig. 29b.

2002 *Nemkovella strophiolata* (Gümbel, 1868) *fermonti* Less, 1987, Özcan, p. 84, pl. 1, figs. 1-2, 4-7, text fig. 3A.

**Description.** Embryos are small, and of semi-isolepidine-nephrolepidine configuration. In SAK 24, the diameter of the protoconch varies from 90 to 115 microns and that of the deuterococonch from 135 to 165 microns (Table 1). In SAK 25, these parameters range between 85 and 100 microns and 125 and 150 microns, respectively. Adauxiliary chamberlets are few in number (A: 9-10), and typically low and wide (H: 25-30 microns, W: 30-50 microns). Outer parts of these chamberlets are typically arcuate or wedge-shaped. Some adjacent chamberlets in the second or third annuli do not have a common wall and very much resemble the chamberlets in late Cretaceous *Orbitoides*. The chamberlets are very low in the early part (n0.5: 16-18), high and narrow in late stages (H: up to 95 microns and w:

30-40 microns), and are typically hexagonal.

**Remarks.** Less (1987 and 1998) described *N. fermonti* from late Cuisian - early Lutetian sections (orthophragminid zone 8a) in the Crimea and France (CRIDU:  $D_{\text{mean}}=146.0$  and Saint-Barthélémy-STBAR:  $D_{\text{mean}}=148.3$  microns, respectively), and from the middle part of the Cuisian section (orthophragminid zone-7) in France (Horsarrieu-HORSX:  $D_{\text{mean}}=130.7$  microns). *Nemkovella* specimens in SAK 24 and 25, with  $D_{\text{mean}}=147.0$  and 136.6 microns, respectively, are attributed to *N. strophiolata fermonti* considering the limit  $D_{\text{mean}} < 150$  microns set for this species by Less (1998). However, considering that the upper part of the Sakarya section, which belongs to orthophragminid zones 4/5, the lower limit for the stratigraphic range of this species must be lowered to at least the lower part of the Cuisian (orthophragminid zone 5). The same species was also reported from beds in the Haymana-Polatlı Basin succession (Özcan 2002), that are characterized by an early Cuisian (orthophragminid zone 6) orthophragminid foraminiferal association. Since no data is present from the uppermost part of the Ilerdian, and no record of the taxon was proposed so far from the Ilerdian, a comparison cannot be made.

**Nemkovella evae** Less, 1987

Fig. 3A (Specimen SAK 24-32)

1987 *Nemkovella evae* n. sp.- Less, p. 184-187, pl. 23, figures 1-7, 9-12; pl. 24, figures 1-4, text figure 29a.

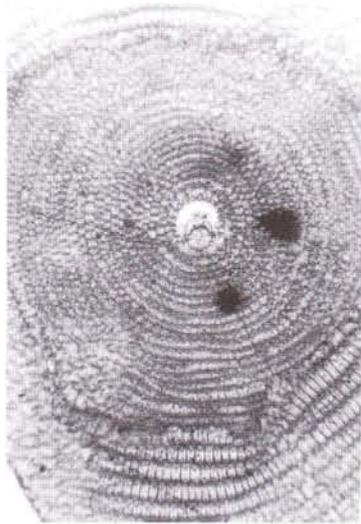
2002 *Nemkovella evae* Less, 1987- Özcan, p. 84-85, pl. 1, figure 3, text figure 3B.

**Description.** Only a single embryo of nephrolepidine configuration, characterized by a small protoconch, measuring about 110 microns, and a larger deuterococonch, measuring about 185 microns (Table 1), was sectioned from the uppermost part of this section. Adauxiliary chamberlets are arcuate or typically truncated arcuate in their outer parts. The number of adauxiliary chamberlets is about 14.

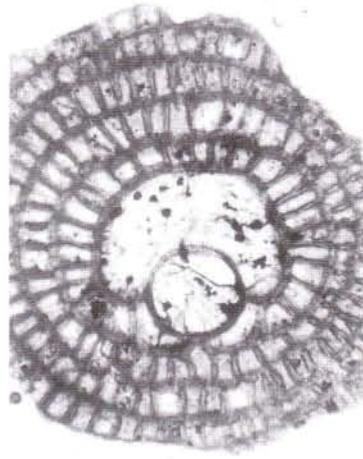
**Remarks.** Less (1998) presented the biometric aspects of *N. evae* over a wide stratigraphic interval, from Ilerdian to Lutetian (orthophragminid zones 3 to 9). In our material, *Nemkovella* specimen having a large embryo and comparatively high adauxiliary chamberlets were ascribed to *N. evae*, following that author.

## PLATE 2

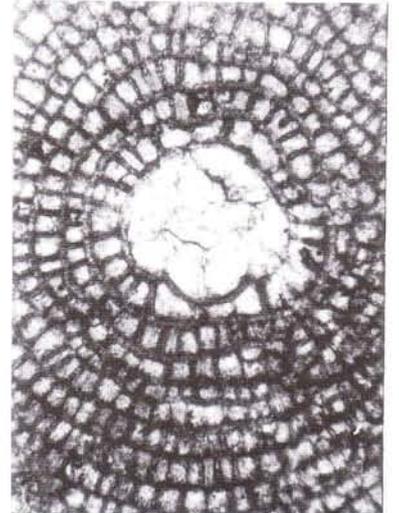
1) *Discocyclina* sp.1, equatorial section: sample SAK 3-27. 2-5, 8, Transitional developmental stages of *Discocyclina archiaci* (Schlumberger, 1903) *bakhchisaraiensis* Less, 1987 and *Discocyclina archiaci* (Schlumberger, 1903) *staroseliensis* Less, 1987, equatorial section: 2) sample SAK 19-27. 3) sample SAK 19-29. 4) sample SAK 13-26. 5) sample SAK 13-2. 8) sample SAK 13-7. 6-7, 9) *Discocyclina archiaci* (Schlumberger, 1903) *staroseliensis* Less, 1987. 6, 7) equatorial section: 6) sample SAK 14-14. 7) sample SAK 25-15. 9) vertical section: sample SAK 25-8. 10) *Discocyclina archiaci* (Schlumberger, 1903) *bakhchisaraiensis* Less, 1987, vertical section: sample SAK 3-22. 11) Primitive developmental stage of *Discocyclina fortisi fortisi* (d'Archiac, 1850), equatorial section: sample SAK 25-22 2-8 x75; 1, 9-11 x28.



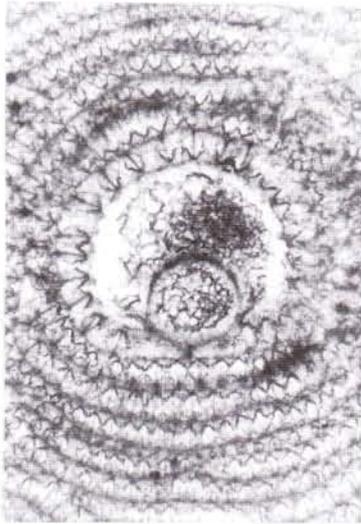
1



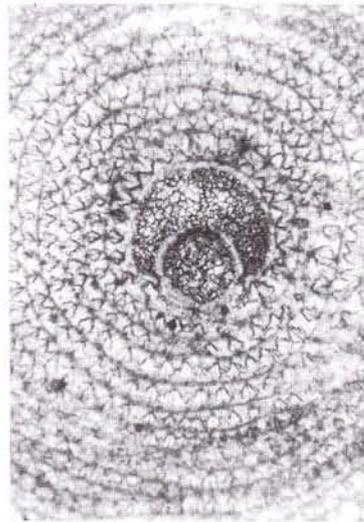
2



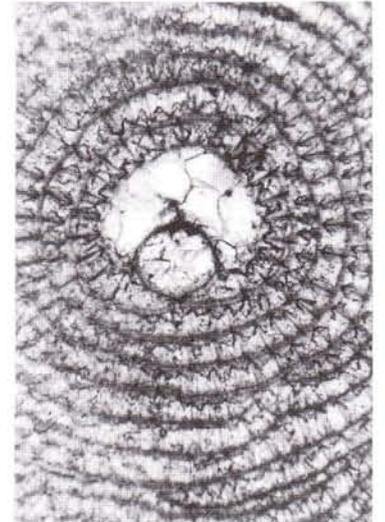
3



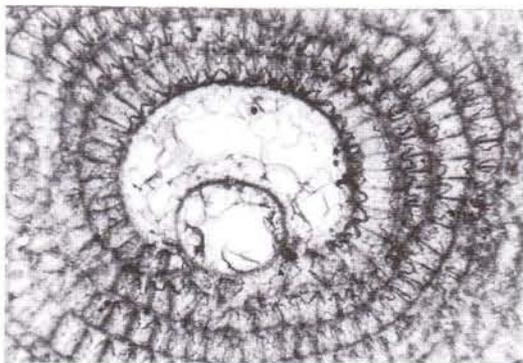
4



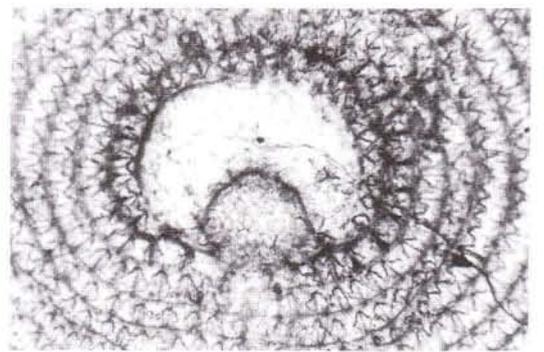
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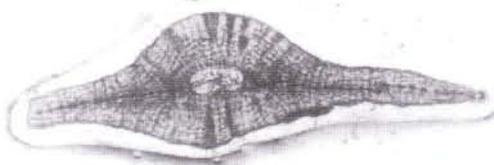
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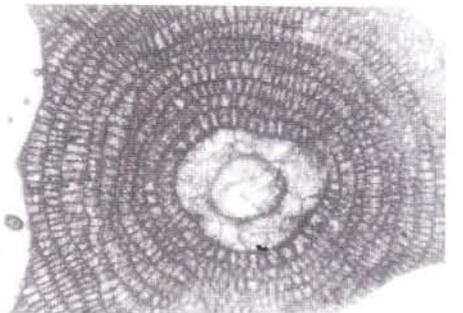


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10

11



Family Orbitoclypeidae Brönnimann, 1946

Genus *Orbitoclypeus* Silvestri, 1907

***Orbitoclypeus douvillei douvillei*** (Schlumberger, 1903)

Pl. 3, fig.11

- 1903 *Orthophragmina douvillei* n. sp., Schlumberger, p. 283-284, pl. 9, figs. 21-24.  
 1958 *Discocyclina douvillei* (Schlumberger) 1903- Neumann, p. 92-93, pl. 11, figs. 4-9, text fig. 26B.  
 1987 *Orbitoclypeus douvillei* (Schlumberger) 1903- Less, p. 205-206, pl. 27, figs. 7-9, text figs. 30i-k.  
 2002 *Orbitoclypeus douvillei douvillei* (Schlumberger) 1903- Özcan, p. 84-85, pl. 2, figs. 10-12, pl. 3, fig. 6, text fig. 4B.

**Description.** Embryos are small, and characterized, in only two specimens, by spherical protoconchs measuring from 70 to 80 microns, deuteroconchs measuring from 125 to 155 microns, and eulepidine configurations. The distal parts of the equatorial chamberlets in the first and successive annuli are typically arcuate or wedge-like. 10-11 chamberlets arising directly from the deuteroconch are observed. Equatorial chamberlets, which are usually 25-30 microns high around the embryo, rapidly grow long and may range up to 175 microns toward the peripheral part of equatorial layers.

**Remarks.** *O. douvillei* is known from lower Cuisian- middle Lutetian (orthophragminid zone 6 to 9) of the Mediterranean region (Less 1998 and Özcan 2002). However, the presence of this taxon in the middle Ilerdian (orthophragminid zone 3) also has been proposed (personal comm. with Dr. Less) from Spilecco (Italy) material. Although few in number, the specimens in SAK 23 and 25 with D: 125.0 and 155.0 microns respectively, are attributed to the primitive developmental stages of *O. douvillei douvillei* (Schlumberger 1903), considering the subspecies limit  $D_{\text{mean}} < 200$  microns set by Less (1998). The deuteroconch diameters of these specimens are lower than those measured from *O. douvillei douvillei* specimens from the lower part of Cuisian Çayraz (ÇAY) section (Haymana-Polatlı Basin, Özcan 2002), which corresponds to orthophragminid zone 6.

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

***suvlukayensis*** Less 1987

Pl. 2, figs. 1-5, 10

- 1987 *Orbitoclypeus ramaraoui* (Samanta), 1967 *suvlukayensis* n. ssp., Less, p. 199, pl. 26, figs. 3-4, text fig. 30d.  
 2002 *Orbitoclypeus schopeni* (Cecchia-Rispoli, 1908) *suvlukayensis*

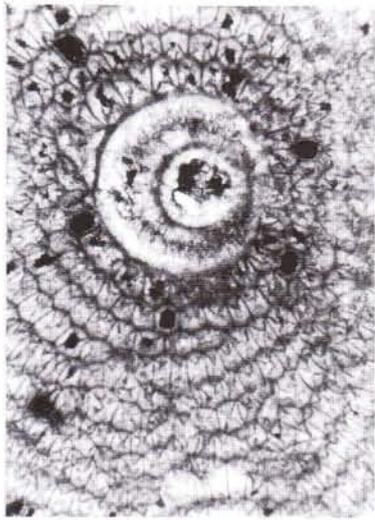
Less, 1987, Özcan, p. 85-86, pl. 2, figs. 7-9, text fig. 4C.

**Description.** Unribbed *Orbitoclypeus* specimens, which occur in most parts of the studied section, consist of an embryonic apparatus with an almost spherical protoconch and spherical to sub-spherical deuteroconch. Three types of configurations have been identified. In some of the specimens, the deuteroconch envelopes the protoconch with a restricted surface of contact, or embryonic chambers have no common wall and the protoconch is in an eccentric position. In the others, the embryos have trybliolepidine configuration. The diameters of the protoconchs vary from 105 to 185 microns and the diameters of the deuteroconchs vary from 190 to 340 microns (Table 1). SAK 10, 12, 14, 19, 23, 24 and 25 populations have mean D values of 290.0, 267.0, 300.0, 255.0, 254.4, 221.6, 270.0 and 282.5 microns, respectively. The distal parts of equatorial chamberlets in the first and successive annuli are typically arcuate or wedge-like. Chamberlets in the first annulus are numerous, and vary from 18 to 35 in number. Equatorial chamberlets, which are usually 30-75 microns high around the embryo, may be as high as 120 microns toward the periphery.

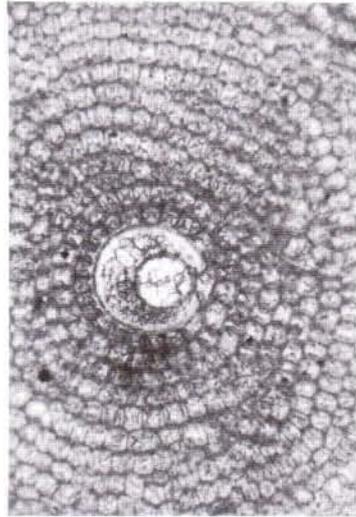
**Remarks.** Unribbed orbitoclypeid specimens with trybliolepidine-excentriplepidine configurations are very common in late Thanetian, Ilerdian, and Cuisian horizons of the Haymana-Polatlı basin succession (Özcan et al. 2001a, b; Özcan 2002). Less (1998) established the biometric identification of *O. schopeni suvlukayensis* in the late Ilerdian (orthophragminid zone 4) with the subspecies limit  $D_{\text{mean}} = 240-300$  microns, and *O. schopeni crimensis* in the Cuisian and Lutetian (orthophragminid zones 5-9?), and assigned the limits of  $D_{\text{mean}} = 300-(390)-(500)$  microns. *Orbitoclypeus* specimens in SAK 10, 12, 14, 19, 23, 24 and 25 with  $D_{\text{mean}} = 290.0, 267.0, 300.0, 255.0, 254.4, 221.6, 270.0$  and 282.5 microns, respectively, are attributed to *O. schopeni suvlukayensis* following the limits set by Less (1998) for this taxon. Considering the faunal assemblages in SAK 23, 24 and 25, represented by *D. augustae sourbetensis*, *N. strophiolata fermonti*, *O. douvillei douvillei* and *D. fortisi fortisi*, these horizons are considered to represent orthophragminid zones 4/5, corresponding to the late Ilerdian/early Cuisian transition. The same taxon studied in the lower Cuisian part of the Çayraz section from the Haymana-Polatlı Basin revealed similar values for diameters of deuteroconchs ( $D_{\text{mean}}$ : varying between

PLATE 3

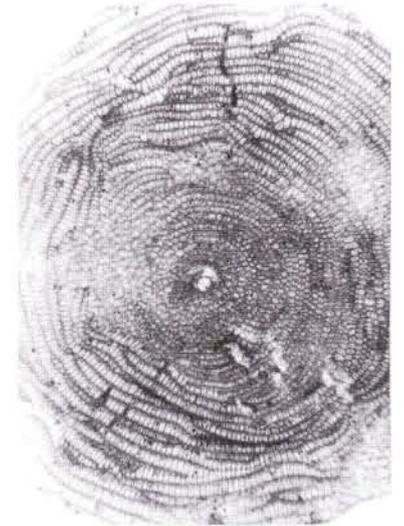
1-5, 10) *Orbitoclypeus schopeni* (Cecchia-Rispoli, 1908) *suvlukayensis* Less, 1987. 1-5) equatorial section: 1) sample SAK 14-9. 2) sample SAK 23-3. 3-4) sample SAK 23-4. 5) sample SAK 12-1. 10) vertical section: sample SAK 19-24. 6) *Orbitoclypeus munieri munieri* (Schlumberger, 1904). equatorial section: sample SAK 25-48. 7-8) *Orbitoclypeus* cf. *munieri* (Schlumberger, 1904). equatorial section: sample SAK 25-11. 9) *Asterocyclina stella* (Gümbel, 1861). Equatorial section: Sample SAK 23-15. 11) Primitive developmental stages of *Orbitoclypeus douvillei douvillei* (Schlumberger, 1903). equatorial section: sample SAK 23-14. 1-2, 4, 7, 11 x75; 3, 8 x19; others x28.



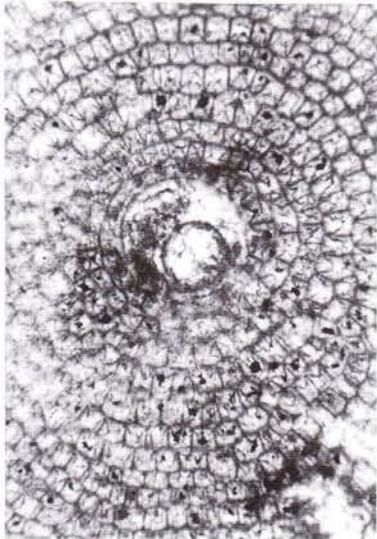
1



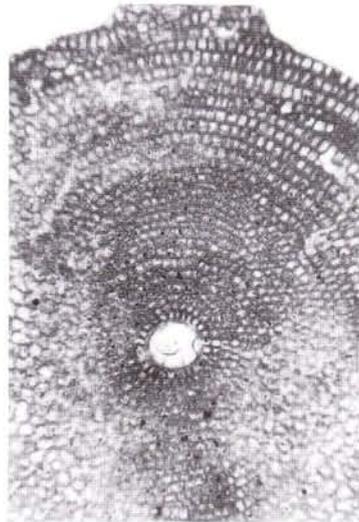
2



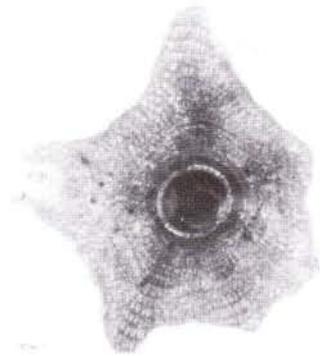
3



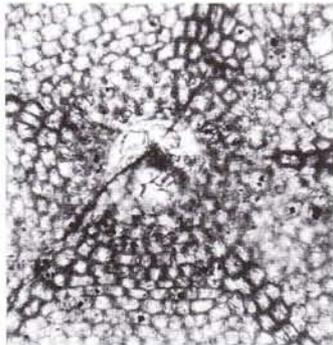
4



5



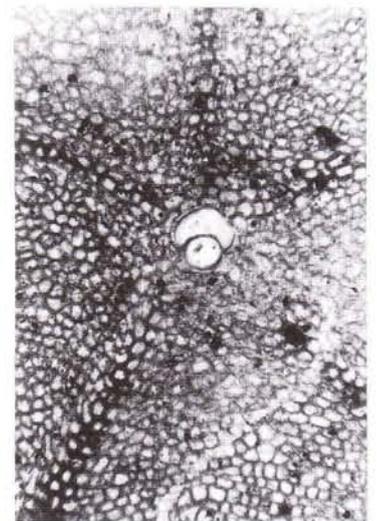
6



7



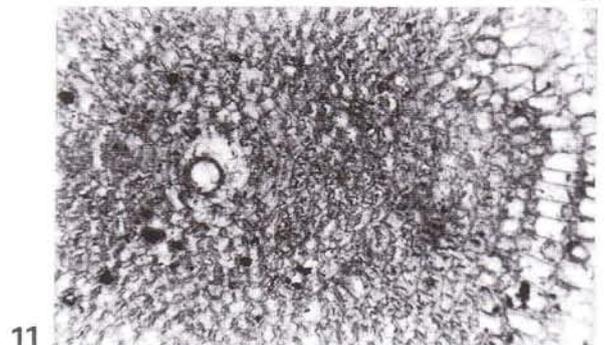
8



9



10



11

254.4 and 282.5 microns). Thus, the upper limit for the stratigraphic range of this subspecies requires its elevation to the lower part of the Cuisian as indicated by Özcan (2002).

***Orbitoclypeus munieri munieri* (Schlumberger, 1904)**

Pl. 3, figs. 6-8

- 1904 *Orthophragmina munieri* n. sp., Schlumberger, p. 125, pl. 3, fig. 12.  
 1987 *Orbitoclypeus bayani* (Munier-Chalmas, 1891), Less, p. 203, pl. 27, figs. 5-6.  
 2002 *Orbitoclypeus munieri munieri* (Schlumberger, 1904), Özcan, p. 86-87, pl. 3, figs. 11-12, pl. 4, figs. 1-2, text fig. 5A.

**Description.** Embryos are characterized by spherical protoconchs measuring from 155 to 185 microns and almost spherical deutoconchs measuring from 320 to 330 microns (Table 1), and present invariably excentrilepidine configurations. Except for the early stage, annuli are strongly undulated in the ribs. The distal parts of the equatorial chamberlets in the first and successive annuli are typically arcuate or wedge-like. The number of adauxiliary chamberlets counted in only one specimen is about 32. One five-ribbed specimen with a small eulepidine embryo ( $D=175$  microns) was also sectioned (Pl. 3, figs 7-8).

**Remarks.** In the Haymana- Polatlı Basin succession, six to eight ribbed *Orbitoclypeus* specimens having comparatively large embryos of mainly excentrilepidine configuration and several four- five? -ribbed specimens with small, eulepidine embryos are known from the early Cuisian part of the Çayraz section (Özcan 2002). Our specimens from the upper part of the Sakarya section with typically excentrilepidine configuration were attributed to *O. munieri munieri* (Schlumberger) 1904 considering the limits ( $D_{\text{mean}} > 280$  microns) set by Less (1998) for this taxon. The five-ribbed specimen with a small, eulepidine embryo was provisionally attributed to *O. cf. munieri*.

Genus *Asterocyclina* Gümbel, 1868

***Asterocyclina stella* (Gümbel, 1861)**

Pl.3, fig.9

- 1987 *Asterocyclina stella* (Gümbel, 1861) *taramellii* (Munier-Chalmas, 1891)- Less, p. 230-231, pl. 36, figs. 7-13, text figs. 32a-b.

**Description.** Embryos are characterized by protoconchs measuring from 70 to 85 microns and deutoconchs measuring from 115 to 135 microns (Table 1), and are of semi-isolepidine- nephrolepidine configuration. Except for the early stage, annuli are asteroidal with five rays. The number of adauxiliary chamberlets is low and varies between seven and eight. In one specimen, the rays, which are well developed in equatorial

section, were not observed externally.

**Remarks.** Less (1998) subdivided his *A. stella* lineage, creating *A. taramellii* and *A. stella* lineages, which are differentiated from each other by the stage of development of the rays. The rays in our specimens are fairly well-developed and sharp in equatorial section. These specimens having rather low values for the diameter of deutoconchs (SAK 23, 24 and 25:  $D_{\text{mean}} = 116.2, 127.5$  and  $131.6$  microns, respectively) represent primitive stages of *A. stella* (in the sense of Less 1998), and possibly the first representatives of the taxon; *Asterocyclina stella* n. ssp. Horsarrieu (Less 1998).

**Discussion**

The middle-late Ilerdian/early Cuisian Sakarya section with its orthophragminid foraminiferal assemblages as presented herein constitutes the most eastern locality along the eastern part of the Mediterranean Tethys from which a set of biometric data has been presented from stratigraphically successive horizons. A comparison of the inventory of orthophragminid foraminifera (with their biometric features) from the Sakarya section with those mainly from the northern, eastern Mediterranean region and the Crimean peninsula reveals peculiar similarities. However, although abundant, the orthophragminid foraminiferal diversity in the lower (only monospecific) and middle part of the section is low. A kind of discrepancy also arises in the determination of the late Ilerdian-early Cuisian boundary.

The lowermost horizon of the section (SAK 3) with the most primitive *D. archiaci* population ( $D_{\text{mean}} = 278.5$  microns) is considered to be middle Ilerdian in age (orthophragminid zone 3) following the biometric features of *D. archiaci bakhchisaraiensis* populations described from orthophragminid zone 3 in the Crimean peninsula (CRIOS:  $D_{\text{mean}} = 275.0$  and CRICR:  $D_{\text{mean}} = 282.9$  microns) (Less 1998). In successive beds (samples SAK 10, 12, 13, 14 and 19, in the 39-67 m interval of the sequence), orthophragminid foraminifera are represented by different developmental stages of *D. archiaci* and *O. schopeni suvlukayensis*. Although a general increase in  $D_{\text{mean}}$  values for deutoconch size in this interval is not followed, the *D. archiaci* specimens in these populations, with fluctuation values for deutoconch size ( $D_{\text{mean}} = 304.6, 337.5, 296.6, 312.0$  and  $298.8$ ), represent a higher developmental stage for *D. archiaci*, compared to the underlying horizon. These populations were ascribed to transitional developmental stages of *D. archiaci bakhchisaraiensis-staroseliensis* or to *D. archiaci staroseliensis*, following the biometric subspecies limit  $D_{\text{mean}} = 305$  micron to differentiate *D. archiaci bakhchisaraiensis* and *D. archiaci staroseliensis* (Less 1998). The *Orbitoclypeus* specimens, which most-

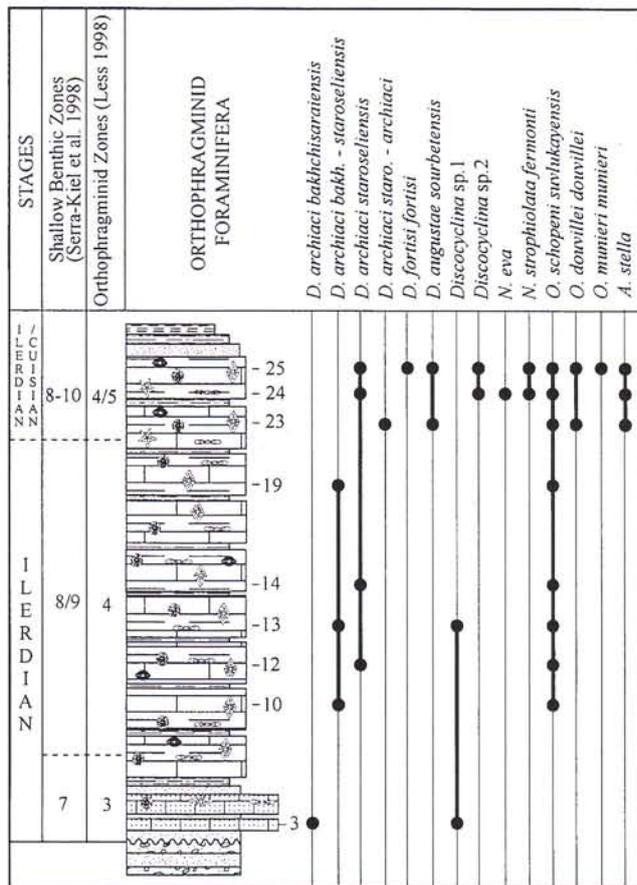


Fig.6 - Stratigraphic distribution of orthofofragminid species/subspecies identified in the Sakarya section.

ly present umbilicolepidine and excentrilepidine embryos, do not show a remarkable increase in deutoconch size in this interval and were attributed to *O. schopeni svvlukayensis*. The biometric values for the deutoconch size of this subspecies ( $D_{\text{mean}}=254.4-300.0$  microns) fit very well with those *O. schopeni svvlukayensis* populations described from the lower part of orthofofragminid zone 4 (middle-late Ilerdian).

In the uppermost part of the section (SAK 23, 24 and 25), with almost the same depositional conditions, a sudden proliferation of orthofofragminid foraminifera represented by *N. strophiolata fermonti*, *N. evae*, primitive developmental stages of *D. augustae sourbetensis*, *O. douvillei douvillei*, *D. fortisi fortisi*, *A. stella* and *O. munierti munierti* are accompanied by *D. archiaci staroseliensis*, and transitional developmental stages of *D. archiaci staroseliensis-archiaci*, *O. schopeni svvlukayensis* and *Discocyclus* sp. 2. are observed. Although this foraminiferal association is usually known from the Cuisian (mainly early/middle Cuisian), it is rather difficult to determine the Ilerdian-Cuisian boundary in the Sakarya section. These horizons are rather considered to represent the Ilerdian/Cuisian transition, rather than a specific age designation of Cuisian, following the below arguments.

a- The biometric values of *Discocyclus archiaci*

specimens in samples SAK 23, 24 and 25 with  $D_{\text{mean}}=395.6, 340.5$  and  $328.2$  microns (ascribed to *D. archiaci staroseliensis* and transitional developmental stage of *D. archiaci staroseliensis-archiaci*), respectively, are lower than those reported from the early Cuisian (orthofofragminid zones 5-6) by Less (1987 and 1998). *D. archiaci archiaci* is considered to be a characteristic subspecies of the early Cuisian by Less (1998). The *D. archiaci* populations thus far reported from early Cuisian beds have mean deutoconch values higher than 400 microns. Similarly, the mean deutoconch values of associated *O. schopeni svvlukayensis* in our material are lower than those populations known from the early Cuisian (reported to be higher than 300 micron by Less 1998). However, *O. schopeni svvlukayensis* associated with *D. archiaci archiaci* in early Cuisian part of the Yeşilyurt-YEŞ and Çayraz-ÇAY sections from the Haymana-Polatli Basin (Özcan 2002) have lower values than  $D=300$  microns. Thus, in agreement with the lack of orthofofragminid data from the uppermost part of the Ilerdian in the literature, it seems that it would be better to raise the upper limit of the stratigraphic range of *O. schopeni svvlukayensis* to early Cuisian.

b- The existence of *D. augustae* and *O. douvillei* in the uppermost samples cannot be argued with confidence for Cuisian age designation for these levels for several reasons. First, so far no orthofofragminid data have been presented that represent the upper part of orthofofragminid zone 4, which corresponds to SBZ 9 below the early Cuisian, so there is a gap for orthofofragminid data from the uppermost Ilerdian. Second, although *D. augustae* is well-known from the early Cuisian as the oldest by now, a single specimen of this species also was reported in orthofofragminid zone 3 (middle Ilerdian) (GAMA7 population of Less 1998). Additionally, several specimens ascribed to *O. douvillei* occur in a middle Ilerdian horizon, which corresponds to orthofofragminid zone 3 (Spilecco-SPILE population in Italy, personal comm. with Dr. Gy. Less, 2002). This implies the existence of possible roots for these taxa in older horizons than what is known in the literature.

c- *N. strophiolata fermonti* is known by far only from orthofofragminid zone 7 (middle Cuisian) as the oldest. The existence of this subspecies in association with primitive developmental stages of *D. augustae* and *O. fortisi* requires the lowering of its lower stratigraphic limit to an interval indicating late Ilerdian/early Cuisian as also deduced from its presence in the early Cuisian horizons of the YEŞ and ÇAY sections from the Haymana-Polatli Basin (Özcan 2002).

*Asterocyclus* specimens, identified only in the upper part of the section, reveal well-developed, sharp rays in equatorial sections. These specimens, with  $D=115-135$  microns, possibly are the first representatives of *A. stella* n. ssp. Horsarrieu Less, 1998, which has

not yet been formally described by Less (1998).

### Summary and Conclusion

The Sakarya section is a well-known sequence in central Anatolia, proposed as a reference-section for the 'Ilerdian-early Cuisian' Shallow Benthic Zones (Serra-Kiel et al. 1998) because of its continuous sedimentary record for this time period and the abundance of larger foraminifera. This section contains abundant free specimens of orthophragminid foraminifera, which belong to different lineages and developmental stages of *Discocyclina*, *Nemkovella*, *Orbitocypeus* and *Asterocyclina* (Fig. 6) accompanied by nummulitid and alveolinid foraminifera. The identified taxa closely resemble orthophragminids described from the Mediterranean and Crimean regions. Most of the taxa, presented with their biometric characteristics for equatorial sections, constitute the first descriptions of orthophragminids from the middle-late Ilerdian/early Cuisian marine deposits of Turkey.

The lowermost part of the 'Sakarya' Formation (sample SAK 3) contains only *Discocyclina* specimens with semi-nephrolepidine configuration. The trybliolepidine embryo configuration is rarely observed. This population, with  $D_{\text{mean}} = 278.5$  microns, represents the most primitive developmental stage of *D. archiaci* in the studied section and was attributed to *D. archiaci bakhchisaraiensis*, indicating orthophragminid zone 3 (middle Ilerdian, in the sense of Serra-Kiel et al. 1998). In this horizon, a specimen with a comparatively small nephrolepidine embryo was ascribed to *Discocyclina* sp. 1.

Upward in the section, in addition to *Discocyclina*, sparse occurrences of unribbed *Orbitocypeus* specimens are noted between SAK 10 and 19. In these levels (SAK 10, 12, 13, 14 and 19), *Discocyclina* specimens have mostly semi-nephrolepidine and partly nephrolepidine and trybliolepidine embryo configurations. These populations, with  $D_{\text{mean}} = 304.6, 337.5, 296.6, 312.0$  and  $298.8$  microns, were attributed either to transitional developmental stages of *D. archiaci bakhchisaraiensis*-*staroseliensis* or to *D. archiaci staroseliensis*. *D. archiaci* in these horizons is accompanied by sparse occurrences of *Discocyclina* sp. 1 and unribbed *Orbitocypeus* specimens having excentrilepidine and trybliolepidine/umbilicolepidine embryonal configurations. *Orbitocypeus* populations with  $D_{\text{mean}} = 290.0, 267.0, 300.0, 255.0$  and  $254.4$  microns are attributed to *O. schopeni suvlukayensis*. This part of the section is considered to represent orthophragminid zone 4 (middle-late Ilerdian, in the sense of Serra-Kiel et al. 1998).

The uppermost part of the Sakarya section (SAK 23, 24 and 25) contains a more diverse assemblage of abundant *Discocyclina*, but sporadic *Nemkovella*, *Orbitocypeus* and *Asterocyclina*. *Discocyclina* is represented by comparatively advanced developmental stages

of *D. archiaci*; *D. archiaci staroseliensis* (SAK 24 and 25:  $D_{\text{mean}} = 340.5$  and  $328.2$  microns, respectively) and transitional stages of *D. archiaci staroseliensis-archiaci archiaci* (SAK 23:  $D_{\text{mean}} = 395.6$  microns). In these levels, discocyclinid specimens with comparatively small (SAK 25:  $D_{\text{mean}} = 121.6$  microns) nephrolepidine-semi-isolepidine and, large centrilepidine embryo (a single specimen with  $D = 650$  microns) were attributed to primitive developmental stages of *D. augustae soubetensis* and *D. fortisi fortisi*, respectively. Several discocyclinid specimens, which are characterized by large (SAK 24 and 25:  $D_{\text{mean}} = 607.5$  and  $897.5$  microns, respectively) umbilicolepidine-type embryos were attributed to *Discocyclina* sp. 2. *Nemkovella* is represented by *N. strophiolata fermonti*, which possesses a small (SAK 24 and 25:  $D_{\text{mean}} = 147.0$  and  $136.6$  microns, respectively) embryo with semi-isolepidine-nephrolepidine configuration and *N. evae*, characterized by a larger (only a single specimen, with  $D = 185.0$  microns) embryo. *Orbitocypeus* includes both ribbed and unribbed varieties. Unribbed *Orbitocypeus* is represented by *O. schopeni suvlukayensis*, which has an excentrilepidine-trybliolepidine/umbilicolepidine-type embryo (SAK 24 and 25:  $D_{\text{mean}} = 270.0$  and  $282.5$  microns, respectively) and *O. douvillei douvillei*, having a small ( $D = 125.0$  and  $155.0$  microns) eulepidine embryo. Ribbed *Orbitocypeus* specimens, having excentrilepidine-trybliolepidine embryos (SAK 25:  $D_{\text{mean}} = 325$  microns), were attributed to *O. munieri munieri*. In SAK 25, one five-ribbed specimen with a comparatively small eulepidine embryo ( $D = 175$  microns) was provisionally ascribed to *O. cf. munieri*. Asteroidal orthophragminid foraminifera with typically five rays, and having of small embryos (SAK 23, 24 and 25:  $D_{\text{mean}} = 116.2, 127.5$  and  $131.6$  microns) of semi-isolepidine and nephrolepidine configuration, were attributed to *A. stella*. This part of the section is considered to be transitional late Ilerdian-early Cuisian in age (orthophragminid zone 4/5). Our data indicate that both *D. archiaci* and *O. schopeni suvlukayensis* specimens, which are thought to represent orthophragminid zone 4/5, in the uppermost part of the studied section have lower values for deuteroconch diameter. This discrepancy was also reported for *O. schopeni suvlukayensis* from the early Cuisian part of the Çayraz Formation (Özcan 2002). This implies the extension of the stratigraphic range for the upper limit of *D. archiaci staroseliensis* and *O. schopeni suvlukayensis* to the early Cuisian (possibly orthophragminid zone 5). *N. strophiolata fermonti* was previously reported from orthophragminid zones 7 and 8a (middle-late Cuisian-early Lutetian) (Less 1998). Identification of this taxon in our material in association with a typical late Ilerdian/early Cuisian assemblage also requires the extension of the lower range of the stratigraphic distribution of this taxon to at least the Ilerdian/Cuisian boundary.

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