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Revised chrono-biostratigraphy of Lower Miocene deposits of the Eastern Mediterranean (SW Turkey), based on calcareous nannofossils

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Abstract

Lower Miocene deposits of the Güneyce Formation formerly described as the Elmalı Formation of Lutetian-Burdigalian age are located near the villages of Gökçebağ (Burdur) and Yakaören (Isparta), (southwestern Turkey), Eastern Mediterranean, and overlie the pre-Neogene tectonostratigraphic units of the Isparta Angle. The purpose of this study is to discuss new biostratigraphic data calibrated to originally classified nannofossil records. Three Early Miocene nannofossil biozones, NN1 - *Triquetrorhabdulus carinatus* Zone, NN2 - *Discoaster druggii* Zone and NN3 – *Sphenolithus belemnos* Zone, were defined in clastic sediments of the Güneyce Formation. In addition, one Lutetian biozone, NP16 – *Discoaster tanii nodifer* Zone, was recognized in the remaining outcrops of the Isparta Formation unconformably underlying the Güneyce Formation.

Nannofossil assemblages of shallow marine deposits in the Güneyce Formation contain high amounts of reworked (Palaeogene and Cretaceous) specimens. New biostratigraphic data and sedimentary features of the Güneyce Formation clastics indicate shallow marine deposition and the beginning of the transgression, spreading over an erosional surface on the ophiolitic melange and Cretaceous to Eocene marine successions rising to the west of the region.

Keywords: Aquitanian, Burdigalian, biostratigraphy, calcareous nannofossils, marine deposits, geologic map

1. INTRODUCTION

The Cretaceous to Neogene marine successions are in the northern, western and eastern parts of the Isparta Angle. Within the context of the regional stratigraphy, sedimentology and tectonic evolution, many studies were carried out by GUTNIC et al. (1979), KARAMAN (1990, 1994), YAĞMURLU (1994), ŞENEL (1997), GÖRMÜŞ & ÖZKUL (1995), GÖRMÜŞ et al. (2001, 2004), POISSON et al. (2003) and ROBERTSON et al. (2003). There are problems concerning the geological mapping, age of sedimentation and environmental interpretation of Palaeogene and Neogene sediments in the region. In previous studies the marine clastics and the carbonate rock series of the studied area were mainly described as Eocene flysch by GUTNIC et al. (1979), the Kayıköy Formation (Eocene) by YAĞMURLU (1994), Isparta flysch (Eocene) by GÖRMÜŞ & ÖZKUL (1995), the Elmalı Formation (Lutetian to Burdigalian) by ŞENEL (1997) and Yavuz Flysch (Eocene) by POISSON et al. (2003). Clastic and carbonaceous deposits, belonging to the Güneyce Formation in the studied area, were interpreted by BARRIER & VRIELYNCK (2008) as the Derinçay Formation corresponding to platform or shallow shelf carbonate or terrigenous clastics, deposited at the back-arc basin or on the low-land margin of the active subduction zone placed in the Eastern Mediterranean Basin. The scope of the study is to provide new biostratigraphic data from the sediments of the Isparta and the Güneyce formations for the new geologic map. The proposed new Lower Miocene marine clastics of the Güneyce Formation, which extend in the northern part of the Isparta Angle, are significant for the Eastern Mediterranean geology.

2. GEOLOGICAL SETTING

There are two different geological interpretations on the stratigraphy of the Palaeogene and Neogene marine sequences and their structural constructions related to the study area. The accepted former (and common) view is that the Eocene marine sedimentary successions (Elmalı Formation) were overthrust by the ophiolitic melange (Gökçebağ Melange) after the Early Miocene (Fig. 1). However, the results of this study show that there are two angular unconformable marine successions, the Isparta Formation (Lutetian) and the Güneyce Formation (Early Miocene), overlying the ophiolitic melange (Fig. 2). In the region, the Yavuz Flysch (GUTNIC et al., 1979), was described as marine carbonate and clastics deposited during the Paleocene to Eocene (Lutetian interval) and the second succession, the Elmalı Formation (ŞENEL, 1997), was described as marine shelf clastics deposited during the Lutetian or ranging from the Lutetian to the Burdigalian. According to GÖRMÜŞ et al. (2001), the studied Güneyce Formation comprises six lithological units from the bottom to the top: (1) mudstone dominated facies (muddy facies); (2) sandstone dominated facies (sandy facies); (3) olistostrome facies; (4a) rhythmic sandstone-mudstone facies; (4b) carbonate facies; (5) sandstone facies and (6) coarse clastics-conglomerates facies. In this area, there are particularly clastic facies 1 to 4a. The overlying units of the investigated area are Plio-Quaternary volcanics and Quaternary alluvium or colluvial fan deposits.

3. MATERIAL AND METHODS

In this study, 35 samples of various grain-sized clastic or carbonate rocks such as marls, mudstones, sandstones or limestones were collected and examined from 17 locations within the three measured stratigraphic sections. All the study material obtained from YAVUZLAR (2015) is preserved in the General Geology Laboratory of Suleyman Demirel University. The three stratigraphic sections, Necibin Tepe, Arapdere and Abidinoğlutaşı Tepe were researched in the field (Fig. 3). The sedimentary succession

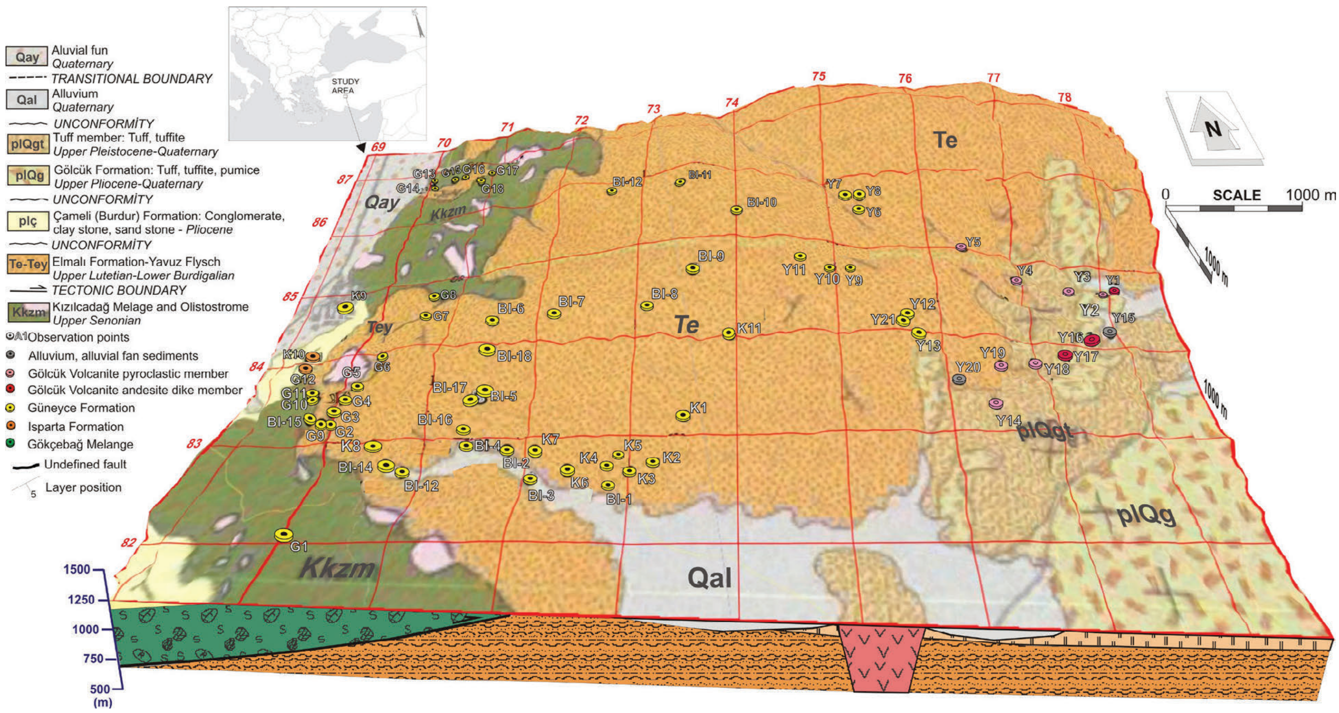

Figure 1. A new detailed version of the map, built on the existing geologic maps (GUTNIC et al., 1979, ŞENEL, 1997).

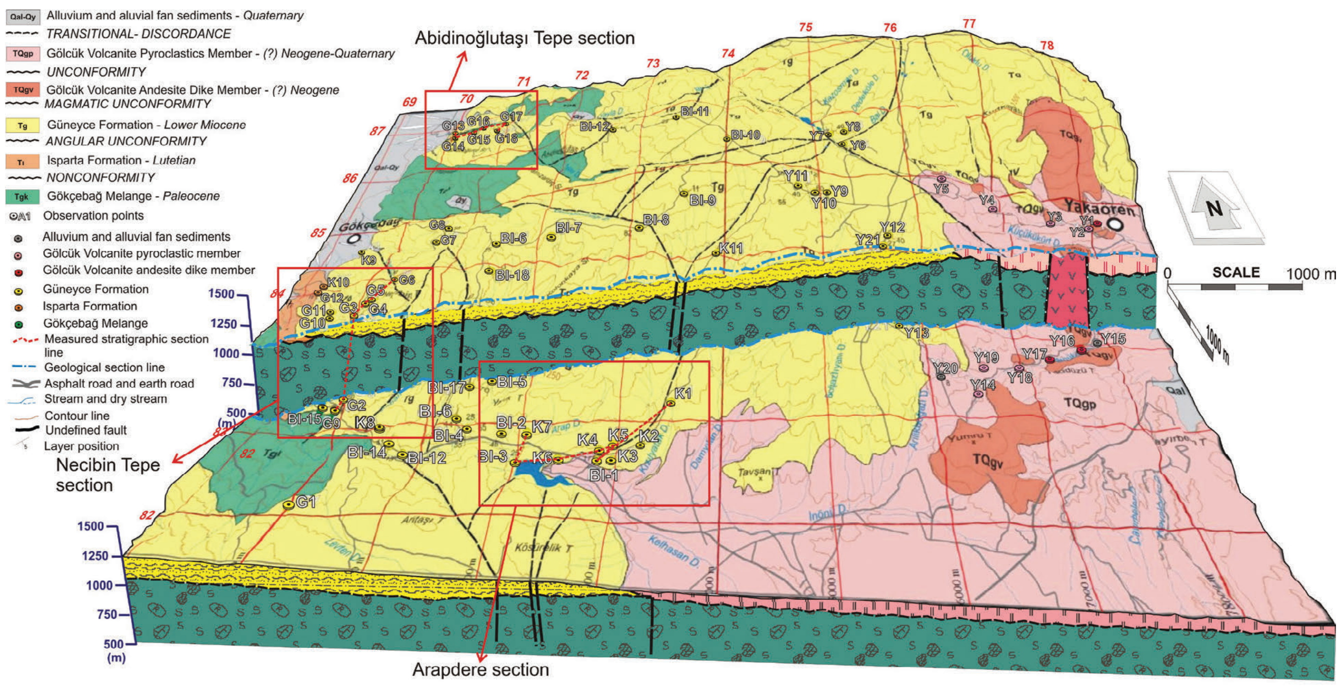

Figure 2. A new geologic 3D map was built based on nannofossil biostratigraphy (emended from YAVUZLAR & SAGULAR, 2016).

of the Güneyce Formation begins with terrestrial deposits including gypsum and coal-bearing sandy-mudstones, and continues with rhythmic sandstone and mudstone/marl alternations including sand-dominated levels. Clastic rock packages seen are partially similar to the depositional facies 1-4a of GÖRMÜŞ et al. (2001).

3.1. Stratigraphic sections

The Necibin Tepe stratigraphic section (Figs. 3 A, 4) belongs to the first sedimentary levels of the Güneyce Formation overlying the ophiolitic melange. In the lower part of the succession (up to 44 m), there are sandy mudstones with sandstone interbeds of sandy facies of the Güneyce Formation, followed by dolomitic limestone lenticular beds within the muddy marine sedimentation. In addition, these levels include lense-shaped gypsum and coal intercalations that could belong to very shallow olistostrome facies. Above sixty metres, there is a shallow marine sandstone and mudstone alternation in the upper part of the succession belonging to the rhythmic sandstone-mudstone facies of the Güneyce Formation. In the Necibin Tepe section, a transgression

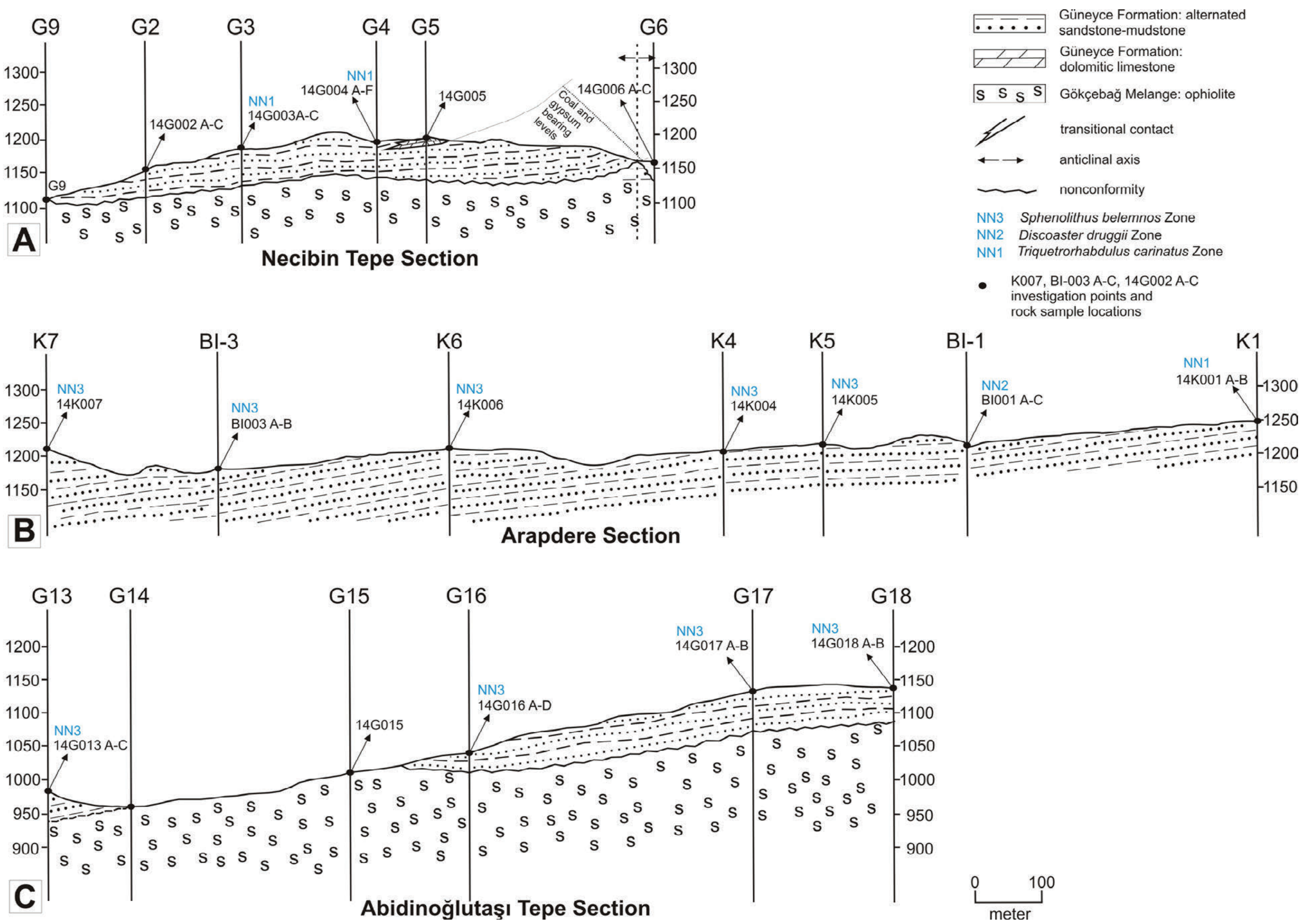

Figure 3. Measured stratigraphic sections in the Güneyce Formation: **A.** Necibin Tepe stratigraphic cross section, **B.** Arapdere stratigraphic cross section, **C.** Abidinoğlutaşı Tepe stratigraphic cross section (emended from YAVUZLAR & SAGULAR, 2017).

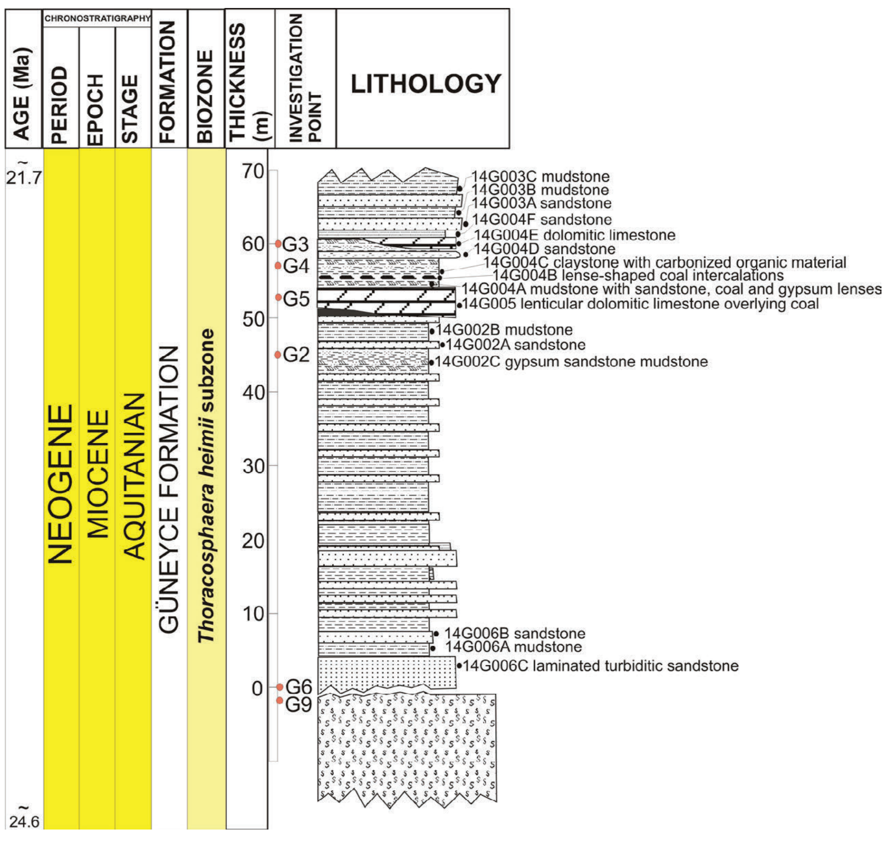

Figure 4. Lithostratigraphy of the Necibin Tepe section.

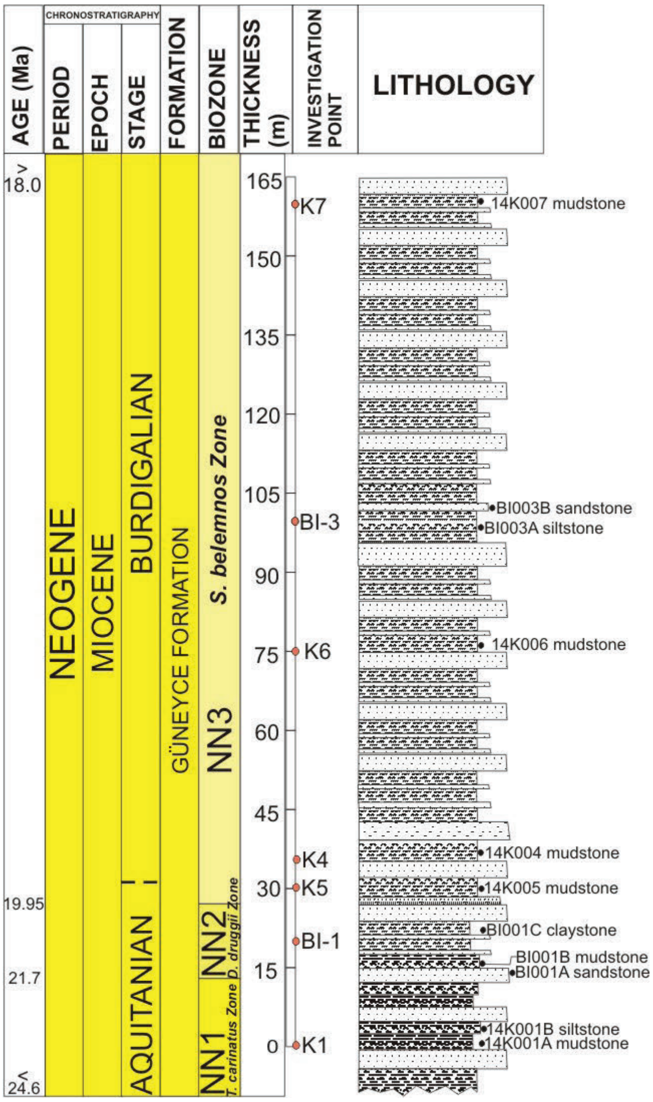

Figure 5. Lithostratigraphy of the Arapdere section.

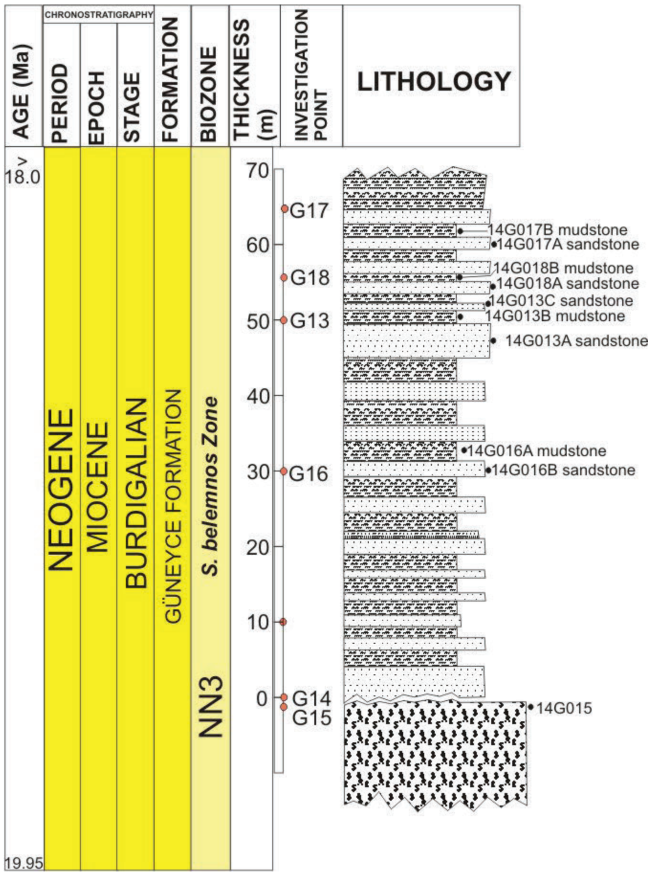

Figure 6. Lithostratigraphy of the Abidinoğlutaşı Tepe section.

resulted in deposition of shallow marine sediments on top of terrestrial sedimentary rocks and facies of the succession.

The Arapdere stratigraphic section (Figs. 3 B, 5) belongs to the middle levels of the Güneyce Formation following the sediments of Necibin Tepe section. Here, sediments and facies of the succession exhibit the rhythmic alternations of mudstones and sandstones representing shallow marine sedimentation.

The Abidinoğlutaşı Tepe stratigraphic section (Figs. 3 C, 6) belongs to the rhythmic sandstone-mudstone facies of the Güneyce Formation, overlies the ophiolitic melange and coincides with the sediments of the Arapdere section. The sedimentary successions and facies of this section also include mudstone and sandstone rhythmic alternation representing shallow marine sedimentation.

3.2. Investigation methods

The standard nannofossil preparation method was used without applying any concentration or cleaning process and taxonomic

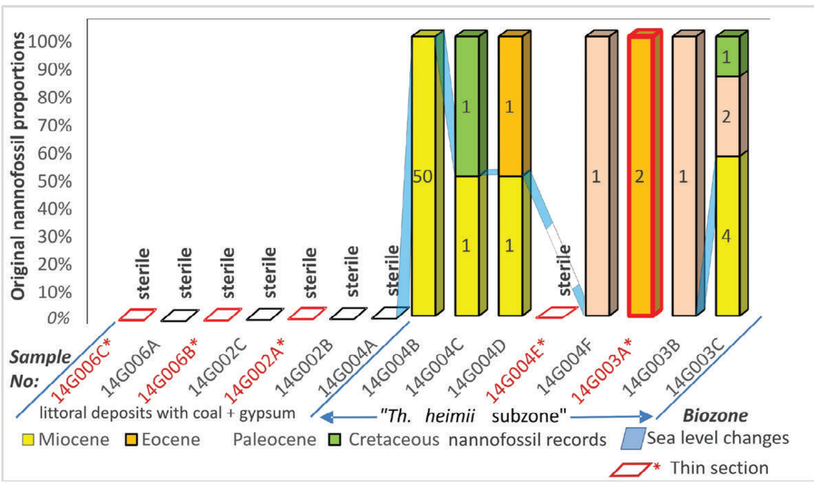

Figure 7. Distribution of original nannofossil percentages in the Necibin Tepe section (* indicates nannofossil data in thin section).

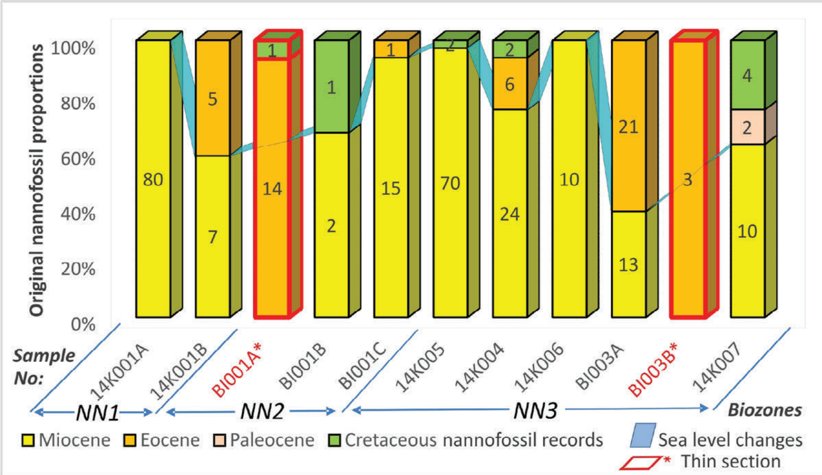

Figure 8. Distribution of original nannofossil percentages in the Arapdere section (*indicates nannofossil data in thin section).

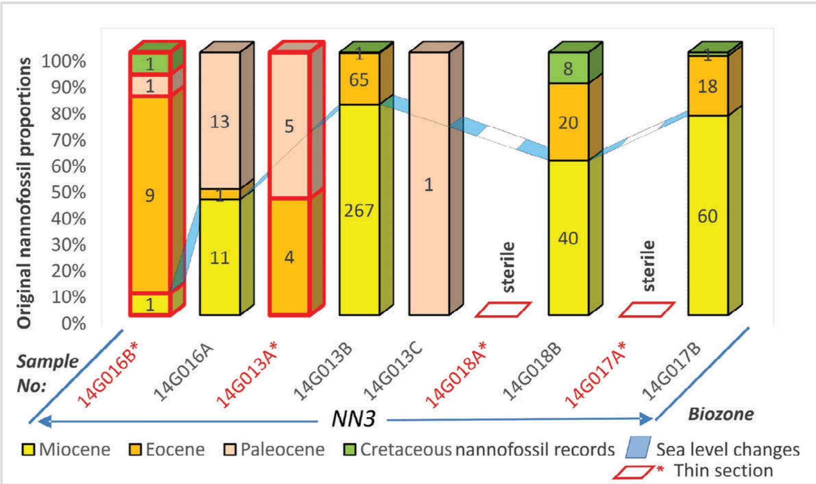

Figure 9. Distribution of original nannofossil percentages in the Abidinoğlutaşı Tepe section (* indicates nannofossil data in thin section).

concepts were followed PERCH-NIELSEN (1985a), BOWN & YOUNG (1998). Analyses were carried out by polarized light microscopes at x2500 magnification, using a Nikon Optiphot-Pol and Leica DM2700 P, at the Department of Geology, Suleyman Demirel University. For each smear slide, nannofossil specimens were counted in 200 fields of view and the identified species were separated into two groups as autochthonous and reworked taxa.

In addition, thinned (20-25 microns) petrographic sections were prepared from coarse grained rock samples such as sandstone and limestone (SAGULAR, 2003a, 2003b). Nannofossil records within lithoclasts or within the matrix in thin-sections of a sandstone are considered to be mainly reworked sedimentary grains. The nannofossils within intraclasts or within the calcite cement of a calcarenite or limestone could be coeval with sedimentation (synsedimentary). Nannofossil records observed in lithoclasts are considered as reworked from extrabasin sources whereas those in intraclasts are considered as removed from elsewhere within the basin. Whereas, fossil data found in matrix or cement are considered either reworked or resedimented. Thus, the autochthonous or reworked nannofossil assemblages and their sedimentological properties were determined in both nannofossil smear-slides and thin-sections. The results of the laboratory determinations were correlated with field observations and previous studies.

MELINTE (2005), WADE & BOWN (2006) used the nannofossil population as an indicator of sea level changes. SAGULAR (2003b) described another method based on reworked nannofossil data, where the reworked specimen proportions are used as an indicator of sea level changes in coastal environments. The method which SAGULAR (2003b) described is applied in this study.

4. RESULTS

4.1. Nannofossil biostratigraphy

Four nannofossil biozones according to MARTINI's (1971) zonation were identified (Fig. 10).

4.1.1. *Discoaster tani nodifer* Zone (NP16)

Definition: The last occurrence (LO) of *Rhabdolithus gladius* to the LO of *Chiasmolithus solitus*

Authors: HAY et al. (1967), emend. MARTINI (1970)

Age: Lutetian, Middle Eocene

Type locality: The NP16 Zone covers the Isparta Formation observed in only a few outcrops within the investigated area (south of Gökçebağ Village, west of the investigated area, Fig. 2).

Remarks on assemblage: The LO of *Chiasmolithus solitus* in the upper part of the zone and the first occurrence (FO) of *Reticulofenestra umbilicus* and LO *Blackites inversus* at the base

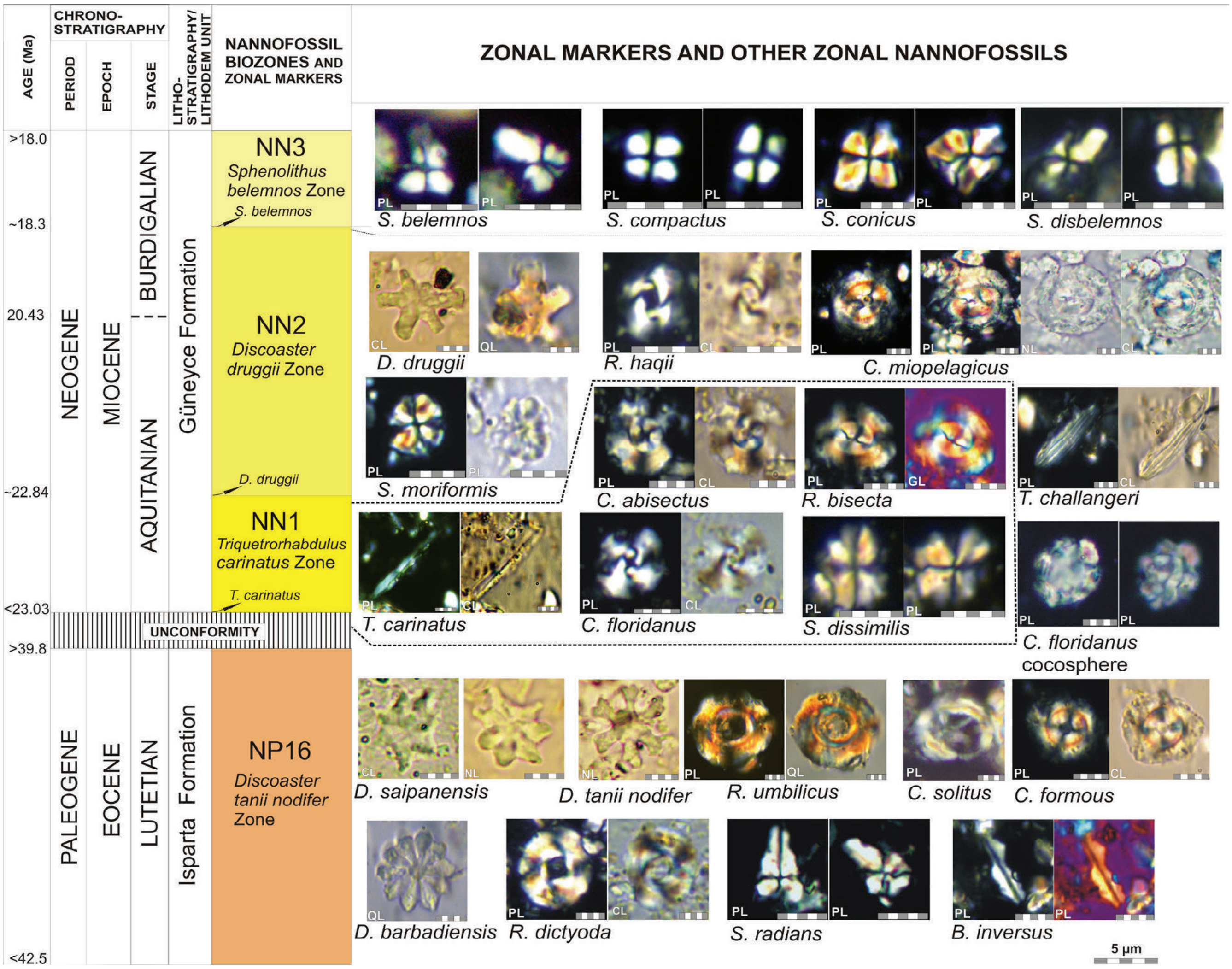

Figure 10. Biozones and marker nannofossils of the Isparta and the Güneyce formations.

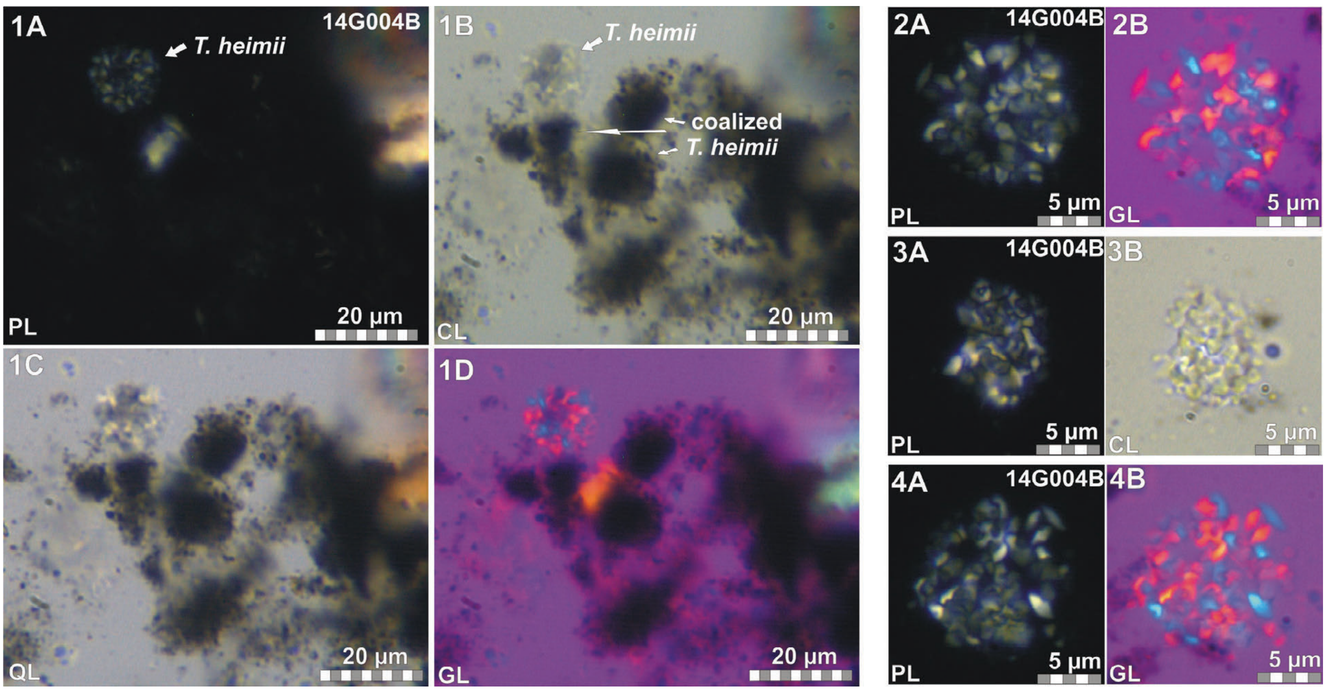

Figure 11. Smear slide images of dinoflagellate cysts in sample 14G004B:1A-D) *T. heimii* and coalized *Thoracosphaera* spp. (*T. heimii* ?); 2-4) *T. heimii* (PL: polarized light, CL: phase contrast, QL: with quartz wedge, GL: with gypsum wedge).

Table 1. List of calcareous nannofossil species distribution, counts and percentages in the Necibin Tepe section (* indicates thin section nannofossil data).

Zone	SPECIES	S. compactus	S. moriformis	T. heimii	∑ coeval Lower Miocene	% autochtonous	R. hesslandii	S. moriformis	T. saxea	∑ Eocene	% reworked Eocene	M. murus	W. barnesiae	∑ Cretaceous	% reworked Cretaceous
Triquetrorhabdulus caritanus Zone (NN1)	14G003A*			1	1	33	1	1		2	67				
	14G003B								1	1	100				
	14G003C	1	1	2	4	57			2	2	29		1	1	14
	14G004B			50	50	100									
	14G004C			1	1	50						1		1	50
	14G004D			1	1	50			1	1	50				
	14G004E*							STERILE							
	14G004F								1	1	100				
	14G002A*							STERILE							
	14G002B							STERILE							
	14G002C							STERILE							
	14G006A							STERILE							
	14G006B*							STERILE							
	14G006C*							STERILE							

(BOWN & NEWSAM 2017, PERCH-NIELSEN 1985) is noticed in the assemblage with *D. saipanensis*, *D. tanii nodifer*, *R. dictyoda* and *S. radians* and *B. inversus*.

4.1.2. *Triquetrorhabdulus carinatus* Zone (NN1)

Definition: LO of *Helicosphaera recta* and/or *Sphenolithus ciperoensis* to the FO of *Discoaster druggii*

Authors: BRAMLETTE & WILCOXON (1967), emend. MARTINI & WORSLEY (1970)

Age: Aquitanian, Early Miocene

Type locality: The base of the Arapdere section

Remarks on assemblages: The LO of *Cyclicargolithus abisectus* is observed in the assemblage with *T. caritanus*, *C. floridanus*, *Reticulofenestra bisecta*, *Sphenolithus dissimilis*. In this zone, the presence of *S. moriformis*, *S. compactus* and *T. heimii* were observed in samples from the Necibin Tepe section. In the Arapdere section the following species were identified: *C. miopelagicus*, *C. pelagicus*, *C. abisectus*, *C. floridanus*, *R. bisecta*, *R. gelida*, *R. producta*, *S. compactus*, *S. dissimilis*, *S. moriformis* and *T. carinatus*.

4.1.3. *Discoaster druggii* Zone (NN2)

Definition: FO of *Discoaster druggii* to the LO of *Triquetrorhabdulus carinatus*.

Authors: MARTINI & WORSLEY (1970)

Age: Aquitanian to Burdigalian, Early Miocene

Table 2. List of calcareous nannofossil species distribution, counts and percentages in the Arapdere section (* indicates thin section nannofossil data).

BIOZONE	SAMPLES	B. bigelowii	C. miopelagicus	C. pelagicus	C. abisectus	C. floridanus	D. druggii	R. bisecta	R. gelida	R. haqii	R. minuta	R. producta	S. compactus	S. dissimilis	S. moriformis	T. heimii	T. carinatus	∑ coeval Lower Miocene	% autochtonous	B. bigelowii	C. eopelagicus	C. pelagicus	D. barbadiensis	D. kuepperi	E. ovalis	R. hesslandii	S. moriformis	Z. bijugatus	∑ reworked Eocene	% reworked Eocene	T. saxea	∑ reworked Paleocene	% reworked Paleocene	Micula sp.	M. murus	M. staurophora	∑ reworked Cretaceous	% reworked Cretaceous
NN3	14K007					2				6					2			10	62												2	2	14	4			4	25
	BI003A	1		2				4			2		4					13	38	1	14	4			2				21	62								
	BI003B*																						1				2		3	100								
	14K006			2		2		2				2			1	1		10	100																			
	14K004		2	2		6		2					4	2	6			24	75		2		2				2		6	19					2		2	6
	14K005		12		6	15		8		5				2	22			70	97															2			2	3
NN2	BI001A*																			2		1		1		1	9		14	93						1	1	7
	BI001B		1	1														2	67																	1	1	33
	BI001C			1		1	1	1		1		3	1	1	3			13	87						1			1	2	13								
NN1	14K001A		2	6	3	12		18	2			6	2	11	16		2	80	100																			
	14K001B					2				2			2		1			7	58				2		2		1		5	42								

Type locality: Arapdere section

Remarks on assemblages: *Discoaster druggii*, *Reticulofenestra haqii*, *Coccolithus miopelagicus* and *Sphenolithus moriformis* are present. Apart from the samples of the measured section, *Triquetrorhabdulus challengeri* were identified in the mudstone spot sample BI016D.

4.1.4. *Sphenolithus belemnos* Zone (NN3)

Definition: LO of *Triquetrorhabdulus carinatus* to LO of *Sphenolithus belemnos*

Authors: BRAMLETTE & WILCOXON (1967)

Age: Burdigalian, Early Miocene

Type locality: Arapdere section and Abidinoğlutaşı Tepe section

Remarks on assemblages: *Sphenolithus belemnos*, *S. disbelemnos*, *S. compactus* and *S. conicus* are considered as marker species in this zone.

4.2. Assemblage composition

4.2.1. Necibin Tepe section

In this section fourteen samples were studied and half of them were sterile. The following species were identified: *Sphenolithus*

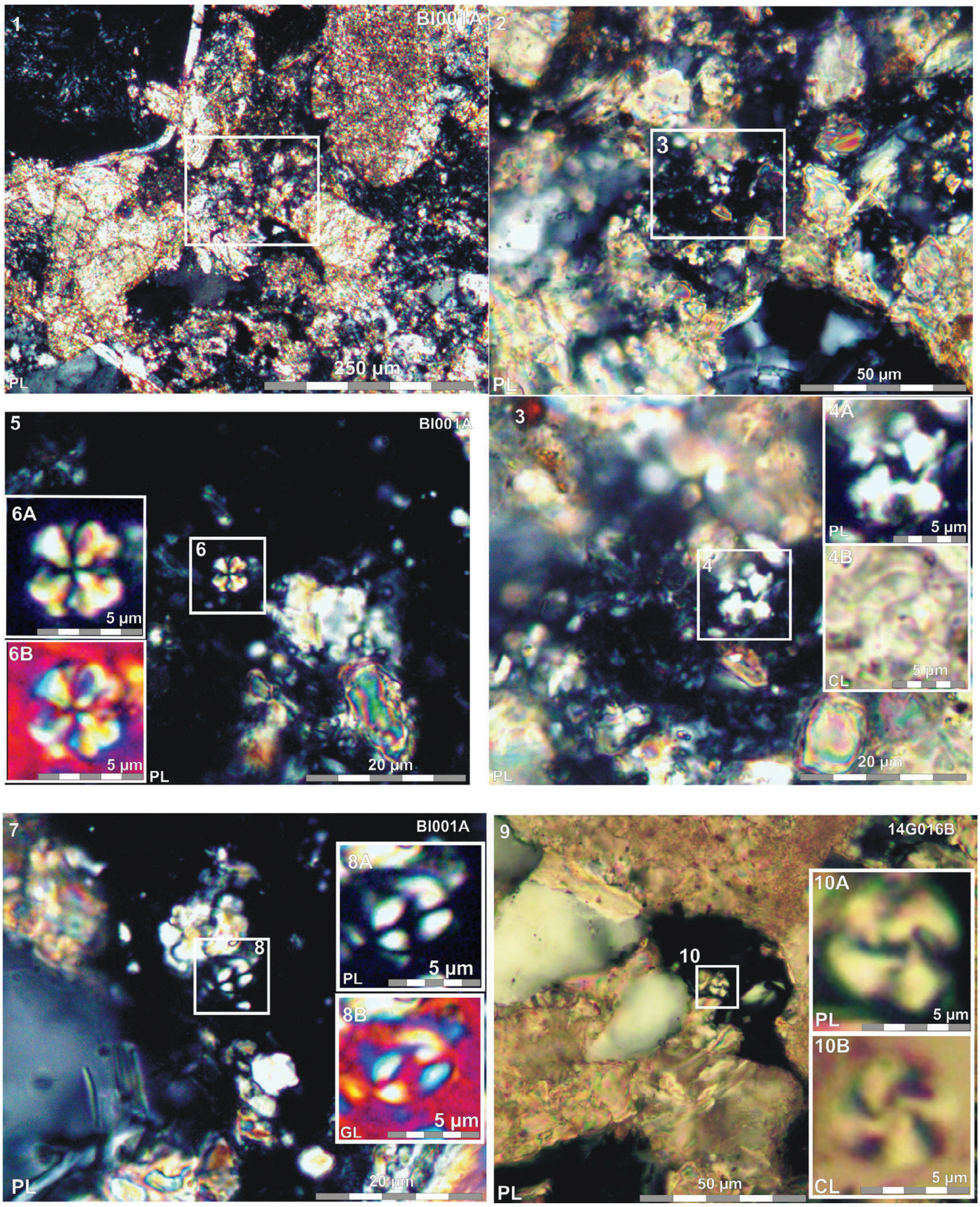

Figure 12. Thin section images with reworked nannofossil taxa in the matrix of sandstones 1-4) *R. hesslandii,* (Arapdere section, sample BI001A) 5-6) *S. moriformis,* (Arapdere section, sample BI001A), 7-8) *C. pelagicus* (Arapdere section, sample BI001A), 9-10) *C. floridanus* (Abidinoğlutaşı Tepe section, sample 14G0013A) (PL: polarized light, CL: phase contrast, QL: with quartz wedge, GL: with gypsum wedge).

Table 3. List of calcareous nannofossil species distribution, counts and percentages in the Abidinoğlutaşı Tepe section (* indicates thin section nannofossil data).

BIOZONE	SPECIES	*C. miopelagicus*	*C. pelagicus*	*C. abisectus*	*C. floridanus*	*D. druggii*	*R. bisecta*	*R. haqii*	*S. belemnos*	*S. disbelemnos*	*S. conicus*	*S. compactus*	*S. dissimilis*	*S. moriformis*	*T. heimii*	∑ coeval Lower Miocene	% autochtonous
NN3	14G017A*	STERILE															
	14G017B	1	12	3	1		5	18	1	1	1	11		6		60	76
	14G018A*	STERILE															
	14G018B	3	6		3	3	3		3			8	5	5		39	59
	14G013A*																
	14G013B	24	64		32		40	1	1	1		9	10	84		266	80
	14G013C*																
	14G016A											3			8	11	44
	14G016B*				1											1	8

BIOZONE	SPECIES	*C. solitus*	*C. formosus*	*C. pelagicus*	*D. lodoensis*	*D. mohleri*	*D. saipanensis*	*E. robusta*	*E.* cf. *subpertusa*	*P. inversus*	*R. dictyoda*	*S. moriformis*	*S. radians*	*S. spiniger*	*Z. bijugatus*	∑ reworked Eocene	% reworked Eocene	*T. saxea*	∑ reworked Paleocene	% reworked Paleocene	*C. obscurus*	*L. cayeuxii*	*M. murus*	*M. staurophora*	*W. barnesiae*	∑ reworked Cretaceous	% reworked Cretaceous	Ascidian spicule
NN3	14G017A*	STERILE																										
	14G017B			4			5			3	3	2	2	3		18	23							1		1	1	5
	14G018A*	STERILE																										
	14G018B			3		8	3			3		3			1	21	29					3			5	8	12	3
	14G013A*	1										3				4	44	5	5	56								
	14G013B		3	16							10	20		16		65	20						1			1	0	
	14G013C*																	1	1	100								
	14G016A				1											1	4	13	13	52								
	14G016B*			3				1	1			4				9	76	1	1	8	1					1	8	1

compactus, *S. moriformis* and *Thoracosphaera heimii*. Almost half of the assemblage contains reworked specimens from the Eocene: *Reticulofenestra hesslandii*, *T. saxea* and from the Cretaceous: *Micula murus* and *Watznaueria barnesiae* (Table 1).

Above 60 m in the section, deposits turn to the 4a rhythmic sandstone-mudstone facies of the Güneyce Formation defined in calcareous nannofossil NN1, NN2 and NN3 zones at the Arapdere section. Below 60 m in the section, sediments contain only very sparse Miocene *Sphenolithus compactus*, the first appearance of which is also observed in the NN1 Zone (PERCH-NIELSEN (1985) and AUBRY (1989)) in the autochthonous nannofossil assemblage with 33 to 67% reworked nannofossils from the Cretaceous and 33 – 100% from the Lutetian (Fig. 7). This section is very close to the Arapdere section (Fig. 2) and it is positioned at the base of the Arapdere section.

4.2.2. Arapdere section

From a total of eleven samples, two were thin-sections and contain reworked nannofossil taxa. These samples contain: *Braarudosphaera bigelowii*, *Coccolithus miopelagicus*, *C. pelagicus*, *Cyclicargolithus abisectus*, *C. floridanus*, *Discoaster druggii*, *Reticulofenestra bisecta*, *R. gelida*, *R. haqii*, *R. minuta*, *R. producta*, *S. compactus*, *S. dissimilis*, *S. moriformis*, *T. heimii* and *T. carinatus.* The reworked assemblage from the Eocene contains: *B. bigelowii*, *C. eopelagicus*, *C. pelagicus*, *Discoaster barbadiensis*, *D. kuepperi*, *E. ovalis*, *R. hesslandii*, *S. moriformis*, *Z. bijugatus*. *T. saxea* is determined as reworked from the Paleocene. The reworked Cretaceous nannofossils are *Micula* sp., *M. murus* and *M. staurophora* (Table 2).

In the samples of the Arapdere section, the NN1 zone contains 28% autochthonous and 72% reworked nannofossils. The NN2 zone contains from 50 to 60% autochthonous and 40 to 50% reworked forms. The NN3 zone includes 58 to 98% autochthonous forms and between 2 and 42% reworked nannofossil taxa (Fig. 8).

4.2.3. Abidinoğlutaşı Tepe section

Of nine samples studied, five were thin sections and two were sterile smear slides. The autochthonous species are *C. miopelagicus*, *C. pelagicus*, *C. floridanus*, *D. druggii*, *R. bisecta*, *R. haqii*, *Sphenolithus belemnos*, *S. disbelemnos*, *S. compactus*, *S. conicus*, *S. dissimilis*, *S. moriformis*, *T.heimii*. The reworked species are as follows from the Eocene: *Chiasmolithus solitus*, *Coccolithus formosus*, *C. pelagicus*, *Discoaster lodoensis*, *D. mohleri*, *D. saipanensis*, *Ericsonia robusta*, *E. subpertusa*, *Pyrocyclus inversus*, *Reticulofenestra dictyoda*, *S. moriformis*, *S. radians*, *S. spiniger* and *Z. bijugatus.* Paleocene taxa include: *T. saxea* and from the Cretaceous, the following were determined: *Calculites obscurus*, *Lucianorhabdus cayeuxii*, *M. murus*, *M. staurophora* and *Watznaueria barnesiae*. In samples 14G017B, 14G018B and 14G016B ascidian spicules were observed (Table 3).

The autochthonous species belonging to the NN3 zone display percentages from 50 to 73% and reworked species comprise 27 to 50% of the assemblage (Fig. 9).

5. DISCUSSION

5.1. Biostratigraphy and palaeoecology

Previous studies in this region were undertaken by GÖRMÜŞ et al. (2001) who first identified the NN1 and NN2 zones. The NN1 Zone was defined by the presence of: *C. floridanus*, *C. abisectus*, *C. pelagicus*, *Discoaster deflandrei*, *D. bisectus*, *Helicosphaera obliqua*, *S. conicus*, *S. compactus*, *S. dissimilis* and *Z. bijugatus*. The NN2 Zone was defined by the presence of *Discoaster drug-*

gii, *D. deflandrei*, *C. floridanus*, *C. abisectus*, *Calcidiscus* sp, and *S. dissimilis*. These zones are very diverse and were determined in relatively deeper marine environments than presented here.

In this region, the NN3 zone was first described by HEPDENİZ & SAGULAR (2009), defined by the presence of *Triquetrorhabdulus carinatus*, *Discoaster* cf. *druggii*, *Sphenolithus belemnos*, *Dictyococcites perplexus*, *Pyrocyclus* cf. *orangensis*, *Reticulofenestra haqii*, *Sphenolithus compactus*, *Sphenolithus conicus*, *Coccolithus miopelagicus*.

A general distinction of autochthonous and reworked nannofossil taxa allows the definition of depositional and paleoenvironmental characteristics and leads to more reliable sedimentary and stratigraphic interpretations, especially for a fluctuating and unfavourable coastal environment (SAGULAR, 2003a, b). In this type of environment, marine deposits, such as the Güneyce Formation, generally contain very low amounts of autochthonous nannofossil assemblages. Reworked nannofossil assemblages are predominant in the sediments of the Güneyce Formation (Tables 1, 2 and 3). While autochthonous nannofossils display percentages between 33 and 100%, the reworked taxa account for between 6 and 100% of the assemblage composition. Based on the generally very high percentages of reworked taxa in the assemblages the Güneyce Formation can be interpreted as representing a very shallow marine environment (Figs. 7, 8 and 9).

The calcareous nannofossil assemblages of the Güneyce Formation, are dominated by the *Sphenolithus* genus, as being more common in lower latitudes, preferring warm and shallow waters than open ocean (PERCH–NIELSEN 1985b). According to WEI

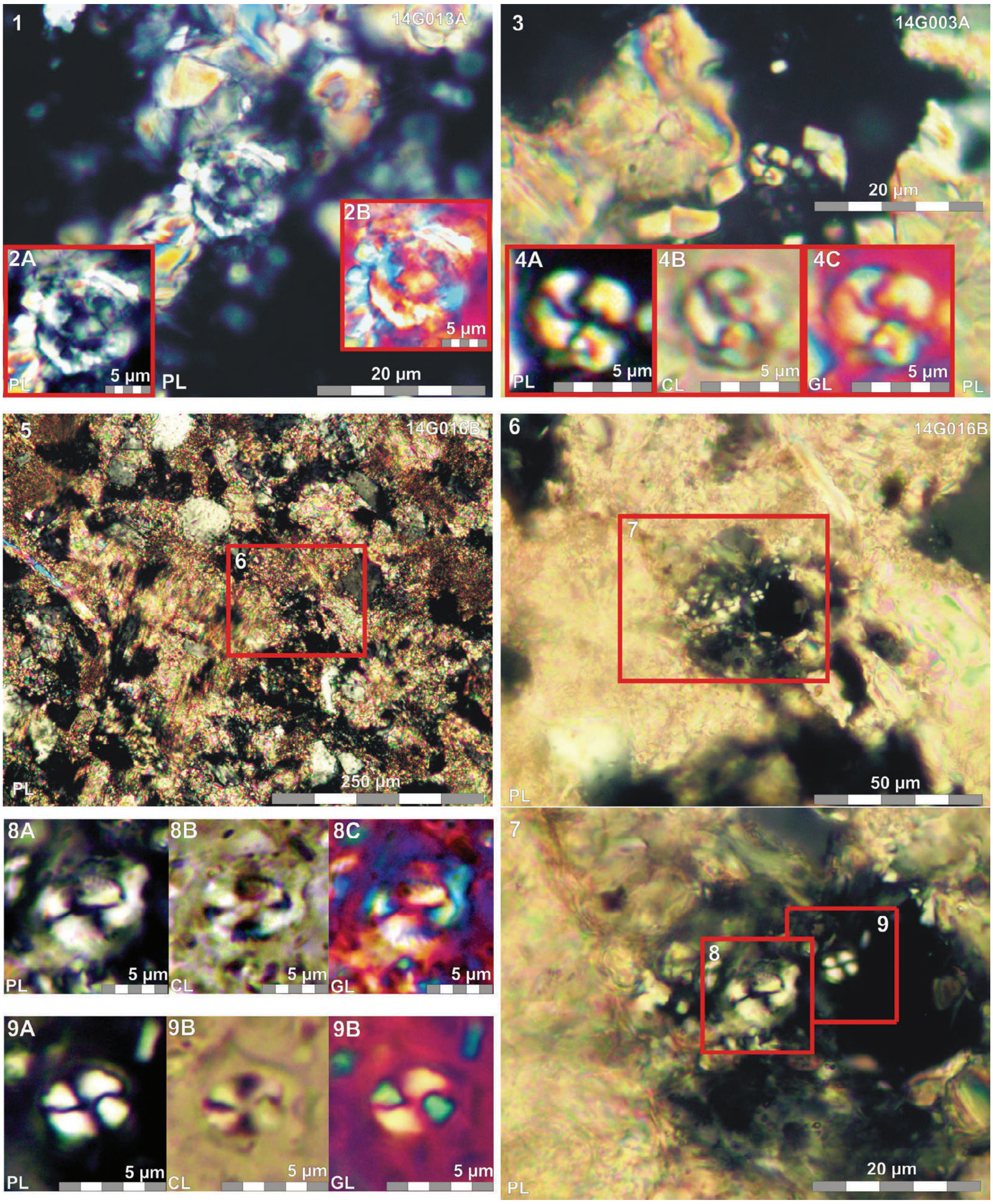

Figure 13. Thin section images of sandstones with reworked nannofossil taxa 1-2) *C. solitus* in lithoclast (Abidinoğlutaşı Tepe section, sample 14G0013A), 3-4) *R. hesslandii* in matrix (Necibin Tepe section, sample 14G003A); 5-8) *C. pelagicus* in matrix, and 5-7 & 9) *C. pelagicus* in matrix (Abidinoğlutaşı Tepe section, sample 14G013A) (PL: polarized light, CL: phase contrast, QL: with quartz wedge, GL: with gypsum wedge).

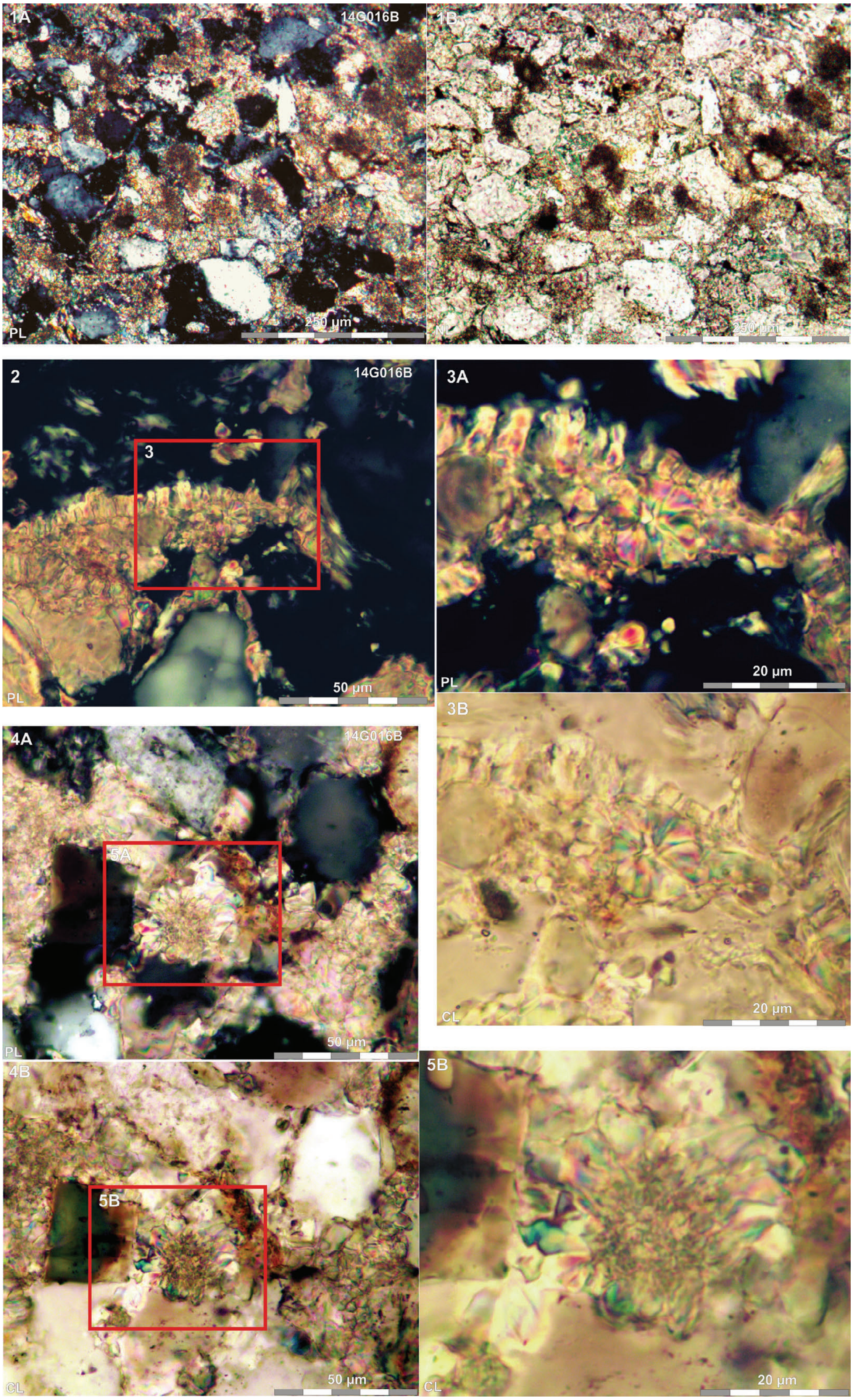

Figure 14. Thin section images of sedimentary structures in sandstone sample 14G0016B of the Abidinoğlutaşı Tepe section 1) General view of the sandstone, 2-3) Isopachous rim cement and ascidian spicule enclosed in intergranular sparry calcite cement of an intertidal sandstone, 4-6) Neomorphic fibrous fine crystalline spherulite FLÜGEL (1982).

& WISE (1990) sphenolith diversity is higher in equatorial sites, being less diverse in the mid-latitude areas. Only *S. moriformis* existed in the high-latitude sites. Within the whole asemblage, 150 individuals were counted and *S. moriformis* is presented here as the most abundant species. Based on the work of the aforementioned authors *Sphenolithus* spp. abundance and diversity indicate a shallow marine environment of the mid-latitudes.

5.2. Necibin Tepe section

The clastic levels in approximately the first 44 m of the section have no nannofossil data due to a prevailing terrestrial or shoreline environment (Figure 4, Table 1). From 44 m - 60 m, the presence of gypsum and microalgal (derived from dinoflagellate cysts) sapropelic coal lenses can be observed in the muddy levels of the succession. Due to the presence of such coal (Fig. 11) and gypsum lenses in the samples of the Necibin Tepe section, it is considered that the Early Miocene sedimentation was started in terrestrial and continued to occur in a littoral environment (Fig. 7). Besides, nannofossil data indicate the NN1 biozone, this section includes the beginning of the Early Miocene sedimentation of the Güneyce Formation.

5.3. Arapdere section

Depending on the original distribution of nannofossil assemblages within the Miocene to Cretaceous (Table 2), the Arapdere section represents transgressive shallow marine sediment levels in the Güneyce Formation. They include beach sediments or shoreline sandstones representing shallow marine environments such as littoral, tidal or the offshore-transitional zone or clastic shelf and contain mudstones with low coeval nannofossil contents. The distribution of autochthonous and reworked nannofossils in rock samples indicate sea level fluctuations in the Early Miocene shoreline transgression (Figs. 8 and 12).

5.4. Abidinoğlutaşı Tepe section

According to the nannofosil records of the Abidinoğlutaşı Tepe section, autochthonous nannofossil species decrease from the bottom levels and then become dominant again in the upper parts of the section (Fig. 9, Table 3). The interpretation of this section is that the sediments of these levels represent shallow marine depositional environments. Additionally, the presence of ascidian spicules in the samples 14G017B, 14G018B and 14G016B (Table 3) can be considered as an indicator of a shallow environment (VAN NAME, 1945). From the bottom to the top of the section, the transgressive character and sea level fluctuations continue throughout. The proportions of autochthonous and reworked nannofossil assemblages in the samples of the Abidinoğlutaşı Tepe section indicate a generally transgressive trend with unstable sea level change observed in a very shallow coastal environment during the Burdigalian after the beginning of the Miocene (Figs. 9, 13 and 14).

Based on the new results, in addition to previous studies in the southern part of Isparta (GÖRMÜŞ et al., 2001; HEPDENİZ & SAGULAR, 2009), the marine carbonate and clastics of the Isparta Formation were deposited during the Lutetian and the shallow marine shelf clastics of the Güneyce Formation were deposited during the Lower Miocene.

6. CONCLUSIONS

The following nannofossil biozones are represented in this study: the NP16 - *Discoaster tanii nodifer* Zone, which was defined in the Isparta Formation and three zones in the Lower Miocene: the NN1 - *Triquetrorhabdulus carinatus* Zone, NN2 - *Discoaster druggii* Zone and NN3 - *Sphenolithus belemnos* Zone in the Güneyce Formation. Based on the high amount of reworked nannofossil species the Güneyce Formation was probably deposited in a shallow marine environment.

The map of the study area was refined and two marine clastic sedimentary units were revised and described (the Isparta and Güneyce Formations). An Ophiolitic melange (Gökçebağ melange) was illustrated in regional maps in former studies as having been thrust over all the sedimentary sequence, in this study the map is modified according to the presented results. Marine clastic sediments unconformably overlie the ophiolitic melange. In addition, the 3D geologic map of the study area is revised and presented here.

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LIST OF CALCAREOUS NANNOFOSSIL TAXA

Miocene Nannofossil Taxa:

Coccolithus miopelagicus BUKRY
Cyclicargolithus abisectus (MÜLLER) WISE
Cyclicargolithus floridanus (ROTH & HAY) BUKRY
Discoaster druggii BRAMLETTE & WILCOXON
Reticulofenestra bisecta (HAY, MOHLER & WADE) ROTH
Reticulofenestra haqii BACKMAN
Reticulofenestra minuta ROTH
Reticulofenestra producta (KAMPTNER) WEI & THIERSTEIN
Reticulofenestra pseudoumbilicus (GARTNER) GARTNER
Sphenolithus belemnos BRAMLETTE & WILCOXON
Sphenolithus compactus BACKMAN
Sphenolithus conicus BUKRY
Sphenolithus disbelemnos FORNACIARI & RIO
Sphenolithus dissimilis BUKRY & PERCIVAL
Sphenolithus moriformis (BRONNIMANN & STRADNER) BRAMLETTE & WILCOXON
Thoracosphaera heimii (LOHMANN) KAMPTNER
Triquetrorhabdulus carinatus MARTINI
Triquetrorhabdulus challengeri PERCH-NIELSEN

Palaeogene Nannofossil Taxa:

Blackites inversus (BUKRY & BRAMLETTE) BOWN & NEWSAM
Chiasmolithus gigas (BRAMLETTE & SULLIVAN) RADOMSKI
Chiasmolithus solitus (BRAMLETTE AND SULLIVAN) LOCKER
Coccolithus eopelagicus (BRAMLETTE & RIEDEL) BRAMLETTE & SULLIVAN
Coccolithus formosus (KAMPTNER) WISE
Coccolithus pelagicus (WALLICH) SCHILLER
Discoaster barbadiensis TAN
Discoaster deflandrei BRAMLETTE & RIEDEL
Discoaster kuepperi STRADNER
Discoaster lodoensis BRAMLETTE & RIEDEL
Discoaster mohleri BRAMLETTE & PERCIVAL
Ericsonia robusta (BRAMLETTE & SULLIVAN) EDWARDS & PERCH-NIELSEN
Discoaster saipanensis BRAMLETTE & RIEDEL
Ericsonia subpertusa HAY & MOHLER
Reticulofenestra dictyoda (DEFLANDRE IN DEFLANDRE & FERT) STRADNER
Reticulofenestra gelida (GEITZENAUER) BACKMAN
Reticulofenestra hesslandii (HAQ) ROTH
Sphenolithus moriformis (BRONNIMANN & STRADNER) BRAMLETTE & WILCOXON
Sphenolithus radians DEFLANDRE
Sphenolithus spiniger BUKRY
Thoracosphaera heimii (LOHMANN) KAMPTNER
Thoracosphaera saxea STRADNER
Zygrhablithus bijugatus (DEFLANDRE) DEFLANDRE

Mesozoic Nannofossil Taxa:

Calculites obscurus (DEFLANDRE) PRINS & SISSINGH IN SISSINGH
Lucianorhabdus cayeuxii DEFLANDRE
Micula VEKSHINA
Micula murus (MARTINI) BUKRY
Micula staurophora (GARDET) STRADNER
Thoracosphaera heimii (LOHMANN) KAMPTNER
Watznaueria barnesiae (BLACK) PERCH-NIELSEN