Bulletin of the Mineral Research and Exploration

http://bulletin.mta.gov.tr

Drilling and core data from the Gulf of Gemlik (SE Sea of Marmara): Holocene fauna and flora assemblages

Engin MERİÇ[a], Zeki Ü. YÜMÜN[b], Atike NAZİK[c*], Enis K. SAGULAR[d], M. Baki YOKEŞ[e], Yeşim BÜYÜKMERİÇ[f], Ayşegül YILDIZ[g] and Gülin YAVUZLAR[d]

[a]*Moda Hüseyin Bey Sokak No: 15/4, 34710 Kadıköy, İstanbul, Turkey*
[b]*Namık Kemal University, Çorlu Faculty of Engineering, Department of Environmental Engineering,59860, Çorlu, Tekirdağ, Turkey*
[c]*Çukurova University, Faculty of Engineering, Department of Geological Engineering, 01330, Balcalı, Adana, Turkey*
[d]*Süleyman Demirel University, Faculty of Engineering and Architecture, Department of Geological Engineering,32260 Çünür, Isparta, Turkey*
[e]*AMBRD Doğa Bilimleri, Hanımefendi Sokak 160/6 34384 Şişli, İstanbul, Turkey*
[f]*Bülent Ecevit University, Faculty of Engineering, Department of Geological Engineering, 67100 Zonguldak, Turkey*
[g]*Aksaray University, Faculty of Engineering, Department of Geological Engineering, 68100 Aksaray, Turkey*

Research Article

Keywords:
Foraminifer, Ostracod, Mollusc, Nannoplankton, Diatome, Gemlik Gulf

ABSTRACT

This study was conducted to determine fauna and flora assemblages of Holocene sequences from Gemlik Gulf (SE Marmara Sea) and to obtaine their similarities and differences between the assemblages of Gemlik and İzmit Bays. Total of 201 dark gray colored, fine to medium grained sandy clay samples were studied. In the drilled samples, 22 genera and 38 species were identified from the foraminifera characterizing the infralittoral zone. 40 genera and 58 species of foraminifera characterizing the upper circalittoral zone were identified. In addition, Black Sea originated Ammonia parasovica was found for the first time in cores taken from Gemlik Gulf. Nannofossil species characterizing the open-shallow marine environment *Emiliania huxleyi*, *Reticulofenestra parvula*, *Coronosphaera* spp., *Syracosphaera* spp., *Helicosphaera* spp. beside *Gephyrocapsa oceanica*, small *Gephyrocaps*a spp., S*cyphosphaera porosa* were obtained. A total of 27 genera and 37 species from ostracods were defined in the samples from gulf. Moreover, the quite abundant mollusc assemblage characterizing the shallow marine environment and fewer genera and species of diatoms were identified. The studied sequence is represented by NN21 *Emiliania huxleyi* biozone at the Holocene. Foraminifers and ostracods of the Gemlik Gulf are observed as Mediterranean-Aegean Sea originated assemblages. The mollusc shows the shallow marine community.

Received Date: 26.09.2018
Accepted Date: 03.04.2019

1. Introduction

The study area is the Gulf of Gemlik located in southeast of Marmara Region (Figure 1). In order to reveal information about the Black Sea-Marmara-Mediterranean connection, many studies have been carried out both with marine and non-marine data obtained from the drilling and bottom sediments in the Sea of Marmara and the Gulf of Gemlik (Meriç, (1995); Görür et al. (1997); İslamoğlu and Chepalyga, (1998); Çağatay et al. (2000, 2003, 2009); Aksu et al. (1999, 2002); Yaltırak and Alpar, (2002); Sperling et al. (2003); Kerey et al. (2004); Mudie et al. (2004); Meriç et al. (2005, 2009, 2018); Chepalyga (2007); Hiscott et al. (2007); Yanko-Hombach et al. (2007); McHugh et al. (2008); Marret et al. (2009); İslamoğlu, (2002, 2009); Brückner et al. (2010); Vidal et al. (2010); Gasperini et al. (2011); Nazik et al. (2011); Mertens et al. (2012); Taviani et al. (2014); Vardar et al. (2014); Filikçi et al. (2017).

Citation Info: Meriç, E., Yümün, Z. Ü., Nazik, A., Sagular, E. K., Yokeş, M. B., Büyükmeriç, Y., Yıldız, A., Yavuzlar, G. 2020. Drilling and core data from the Gulf of Gemlik (SE Sea of Marmara): Holocene fauna and flora assemblages. Bulletin of the Mineral Research and Exploration. 161, 121-149. https://doi.org/10.19111/bulletinofmre.581537

** Corresponding author: Atike NAZİK, anazik@cu.edu.tr*

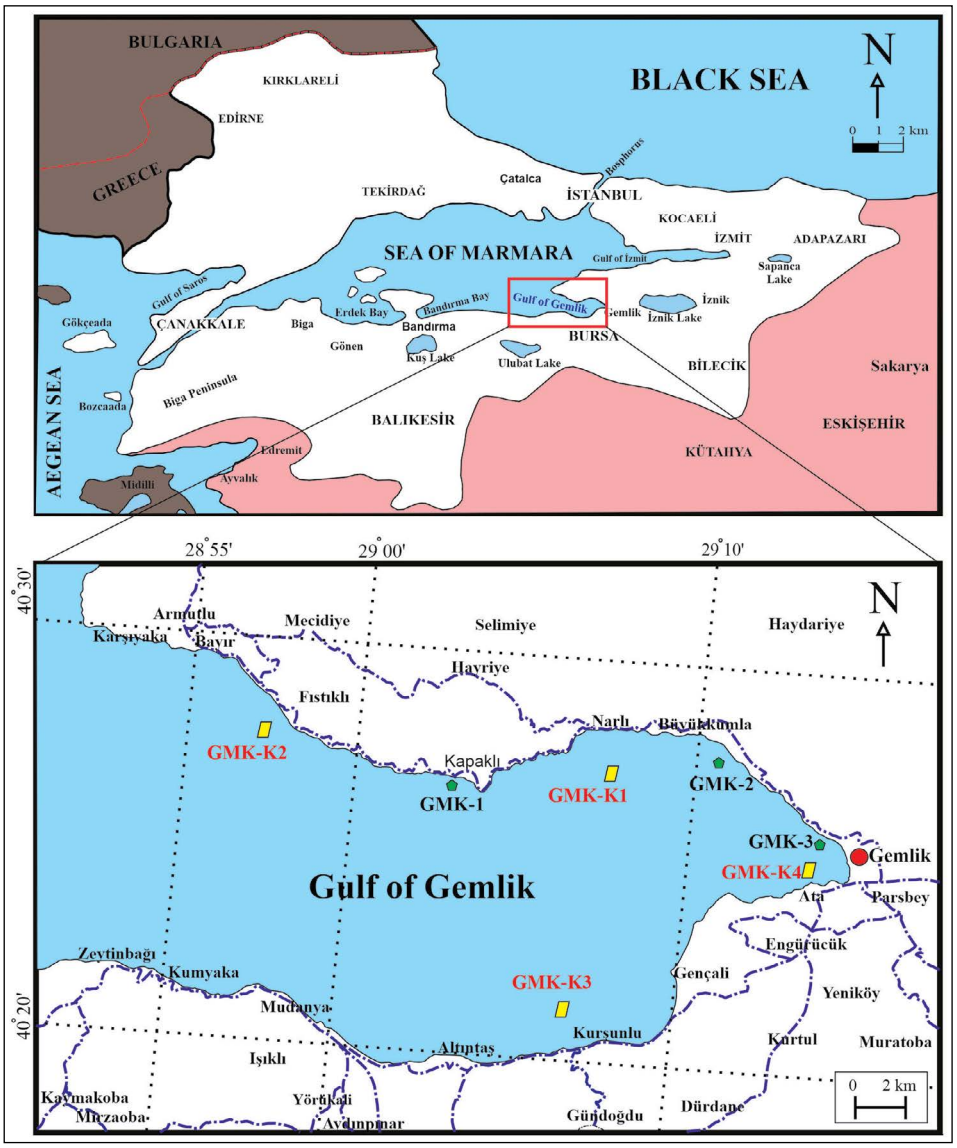


Figure 1- Location map of drilling and cores taken from the Gulf of Gemlik (GMK drilling, GMK-K core locations).

In this study, the foraminifer, ostracod, mollusc, nannoplankton and diatom assemblages in the deposits identified in three drilling holes (GMK-1, GMK-2, GMK-3) from the northeast and east of the Gulf of Gemlik and 4 cores taken from its north, northeast and southeast (GMK-K1, GMK-K2, GMK-K3, GMK-K4) were studied and compared with the Mediterranean-Marmara-Black Sea assemblages in order to reveal similarities and differences.

When previous studies carried out in the region are compared, the foraminifer, ostracod and mollusc faunas of the Sea of Marmara, and also the nannoplankton and diatom assemblages from the deep sediments of the Gulf of Gemlik, as indicated by the present study, are considered to be richer compared to those reported by Meriç et al. (2005).

2. Material and Methods

Sediment samples used in this study were taken from 3 drillings carried out in north, northeast and southeast of the Gulf of Gemlik (GMK-1, GMK-2, GMK-3) (Figures 1-3). Samples come from 4 cores ranging from between 0,70-1,00 m in length. These were collected from the north, northeast and southeast of the bay (GMK-K1, GMK-K2, GMK-K3, GMK-K4) during summer 2015 (Figures 1-4, 5 and table 1). The drilling samples mostly consist of blackish gray, clayey and sandy gravel, medium-grained sandy and

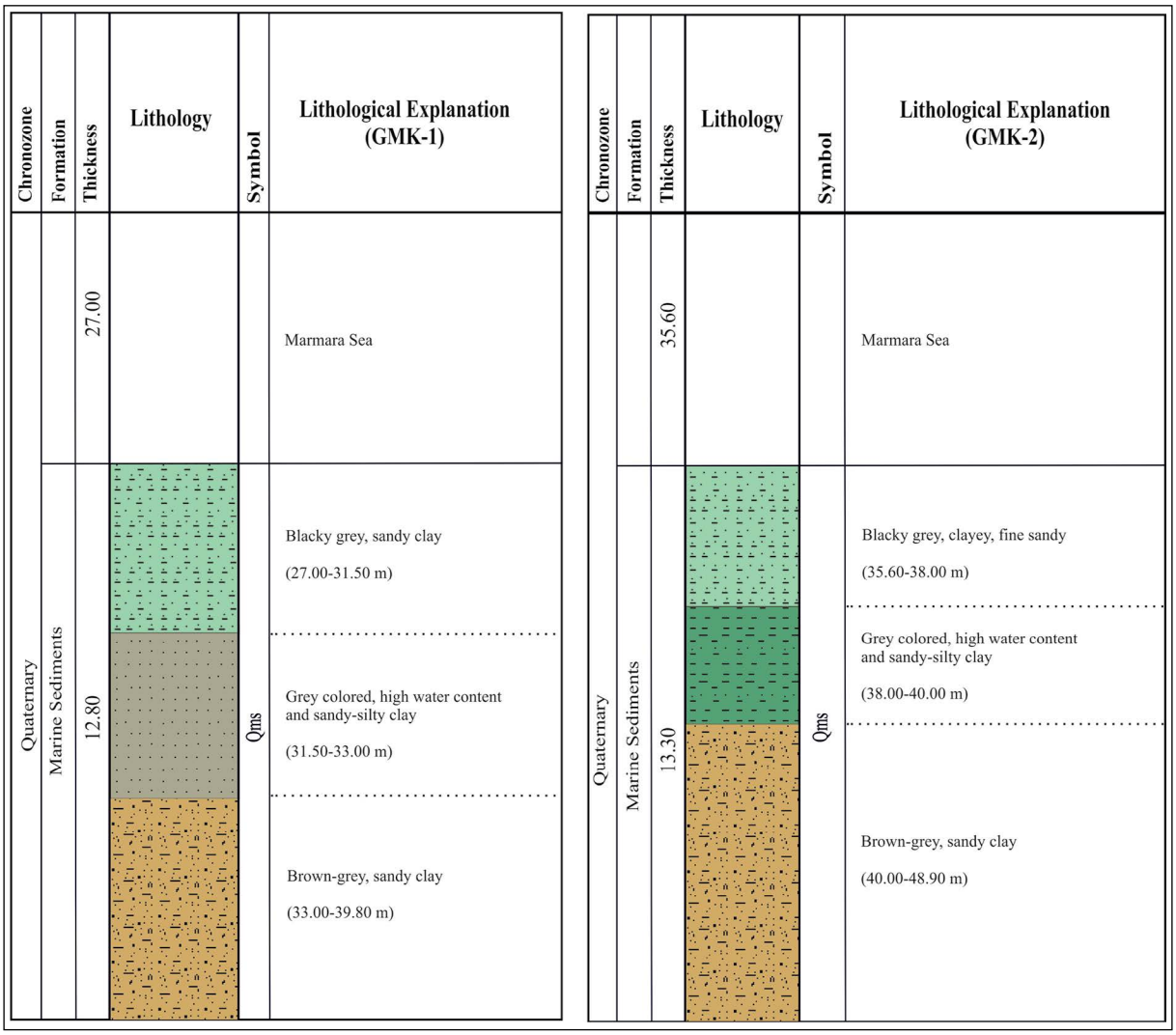


Figure 2- The columnar section of the locations in which drilling samples were taken in the Gulf of Gemlik (GMK-1, water depth 27,00 m and GMK-2, water depth 35,60 m) (not to scale).

silty clay with mollusc shells. The core samples are dark gray, fine sand (with high water content), silty and sandy clay units.

A total of 201 samples were studied as follows: 150 samples (with 10 cm intervals) from the cores of GMK-1 and GMK-2, 14 samples from GMK-3 drilling (with 20 cm intervals) and 37 samples taken from 4 cores (with 10 cm intervals).

To identify foraminifer, ostracod and molluscs, 10% hydrogen peroxide was added to wet sediment samples weighing 5 g, and then left for 24 hours. Afterwards, the samples were washed through a 0.063 mm sieve with pressurized water, allowed to dry in a 50 °C oven and further sieved through 2.00, 1.00, 0.500, 0.250, 0.125 mm size sieves and then examined under a binocular microscope.

The nannofossil smear-slides were prepared by the traditional method, as summarized by Perch-Nielsen (1985*a, b*). Preparations were examined under the light microscope with the help of 100x magnification oil-immersion objective lens and 10x ocular magnification (using the traditional method) and displayed by using approximately 40x magnification with an intermediate lens+digital camera. Imaging under polarized (PL), normal (NL), contrast (CL) light was as used by Perch-Nielsen (1985*a, b*) for microscope studies. In addition, the imaging methods under PL using a gypsum wedge (GL) was employed as suggested by Reinhardt (1972) and Romein (1979). Also, imaging

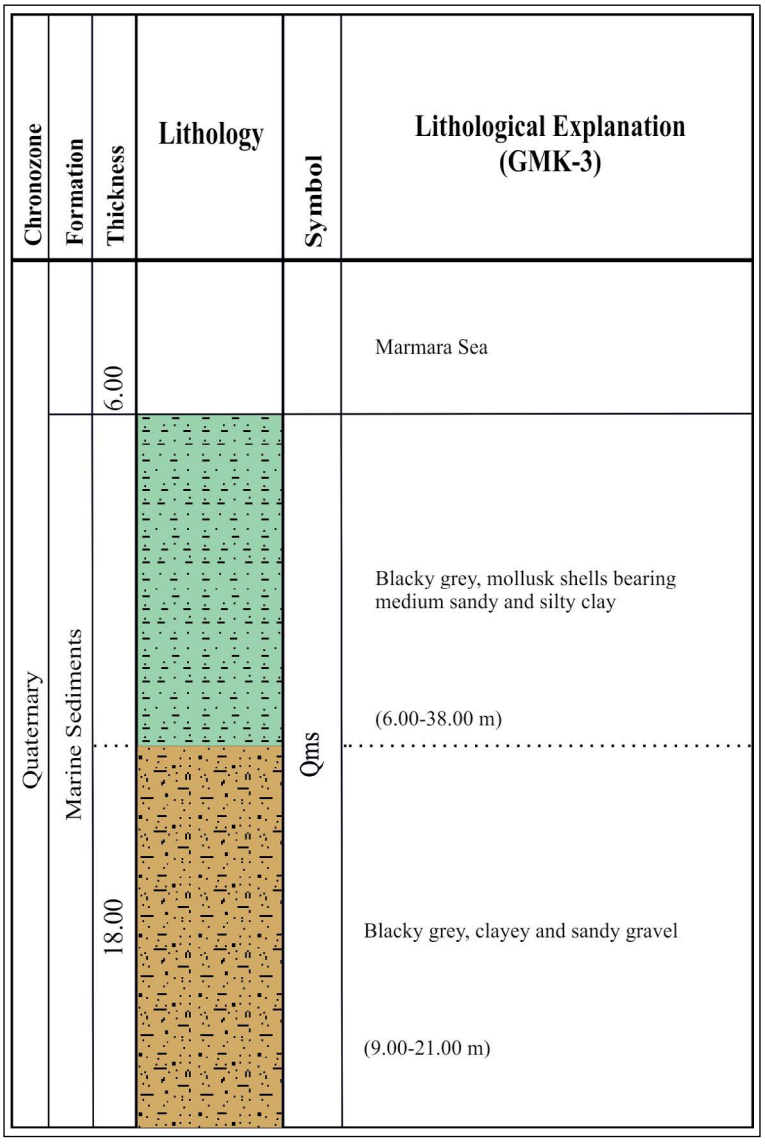


Figure 3- The columnar section of locations in which drilling samples in the Gulf of Gemlik were taken (GMK-3, water depth: 6 m) (not to scale).

under PL was carried out using a quartz wedge (QL), as recommended by Sagular (2009). Selected images of the nannofossil species identified are shown in plate 1.

Samples taken from the drilling holes for diatom analysis were first cleaned by using 10% HCl at the Department of Geological Engineering of the Faculty of Engineering in Aksaray University; this material was then prepared for paleontological study by mounting on a slide using entellan and a coverglass. The preparations were examined under 1600x magnification using a polarizing microscope and an oil-immersion objective with a Leica DM 2500 P. The fossil diatom genera and species were then identified and photographed (Plate 2)

3. Micro and Macro Faunal Findings

3.1. Foraminifera

In the samples from GMK-1, GMK-2 and GMK-3, a total of 22 genera and 39 species were identified as follows: *Textularia bocki* Höglund, *Adelosina cliarensis* (Heron-Allen and Earland), *A. mediterranensis* (Le Calvez and Le Calvez), *Spiroloculina dilatata* d'Orbigny, *S. excavata* d'Orbigny, *S. ornata* d'Orbigny, *Siphonaperta*

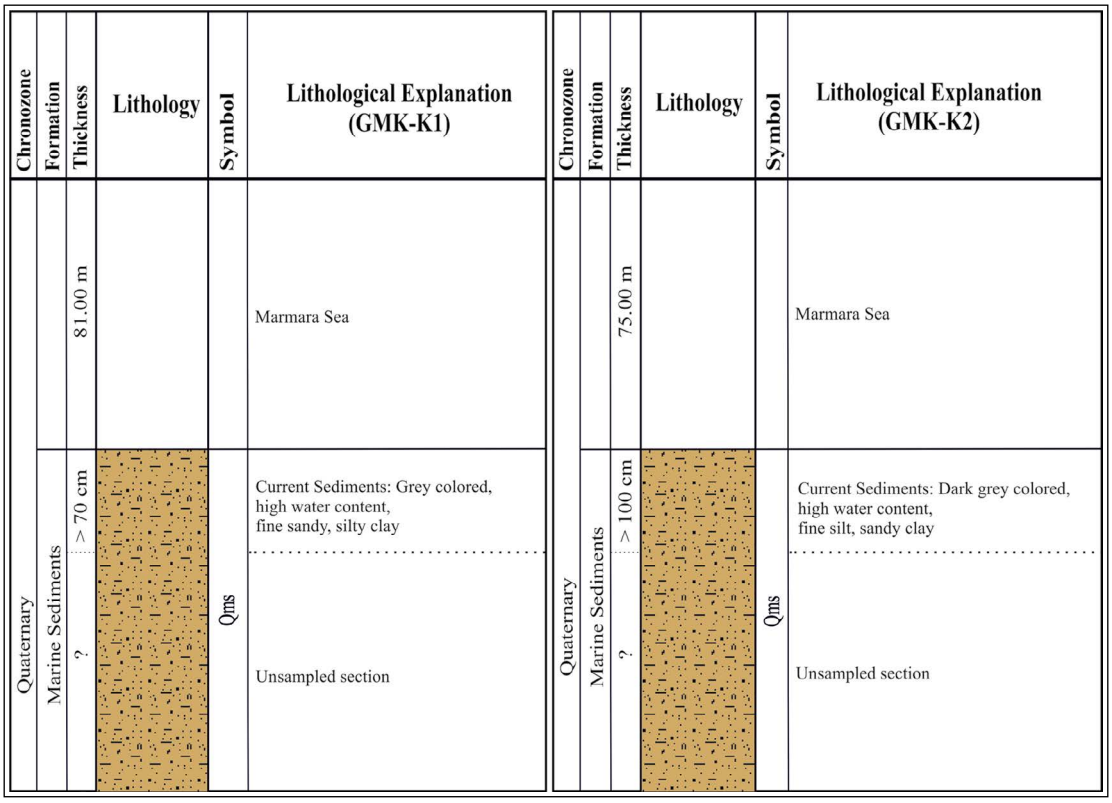


Figure 4- The columnar section of locations in which core samples in the Gulf of Gemlik were taken (GMK-K1, water depth 81,00 m and GMK-K2, water depth 75,00 m) (not to scale).

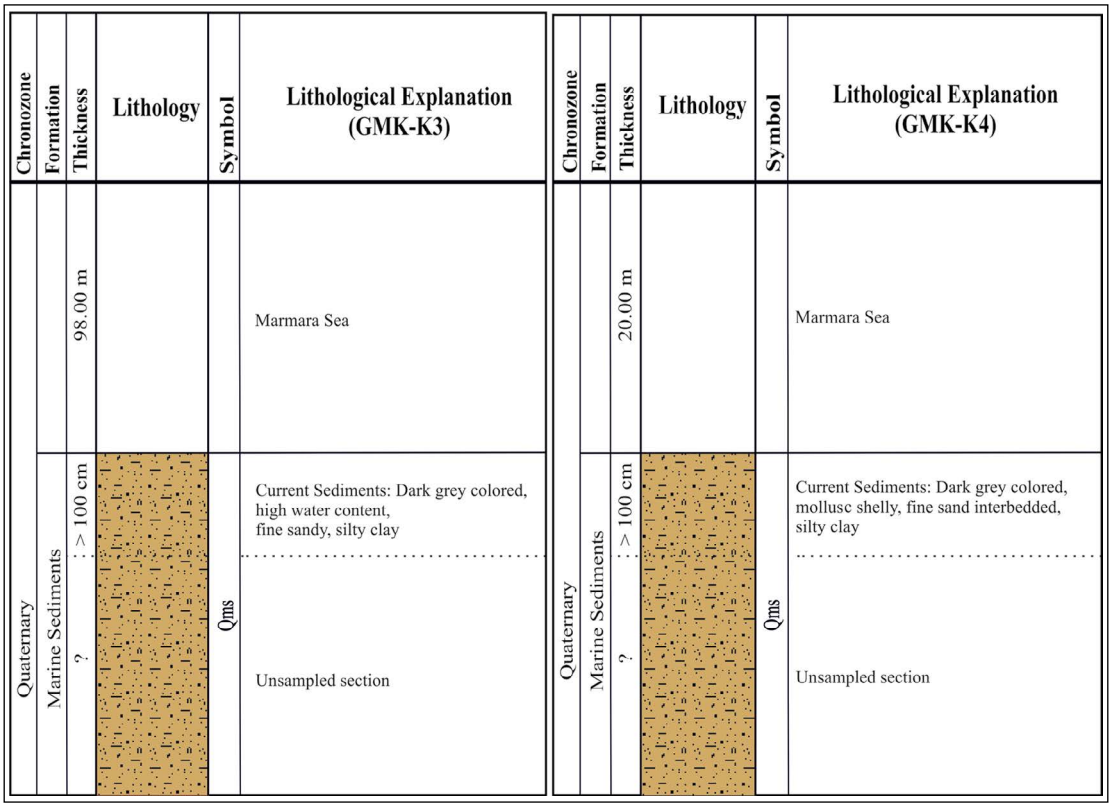


Figure 5- The columnar section of locations in which core samples in the Gulf of Gemlik were taken (GMK-K3, water depth 98,00 m and GMK-K4, water depth 20,00 m) (not to scale).

Table 1- Coordinates and other specifications of drilling and core locations.

Borehole and Cores	GMK-1: GS-84 6 Degree Coordinates		Water Depth	Sample Length
	Longitude	Latitude	(m)	(m)
GMK-1	666899.00 d E	4480487.00 m N	27,00	12,80
GMK-2	677320.00 d E	4480755.00 m N	35,60	13,30
GMK-3	682561.00 d E	4477768.00 m N	6,00	3,00
GMK-K1	672101.00 d E	4481326.00 m N	81,00	0,70
GMK-K2	658957.00 d E	4481138.00 m N	75,00	1,00
GMK-K3	669332.26 d E	4471289.16 m N	98,00	1,00
GMK-K4	681950.40 d E	4477270.34 m N	20,00	1,00

aspera (d'Orbigny), *Cycloforina contorta* (d'Orbigny), *C. rugosa* (d'Orbigny), *Massilina secans* (d'Orbigny), *Quinqueloculina bidentata* d'Orbigny, *Q. disparilis* d'Orbigny, *Q. jugosa* Cushman, *Q. lamarckiana* d'Orbigny, *Q. seminula* (Linné), *Miliolinella elongata* Kruit, *M. subrotunda* (Montagu), *Pseudotriloculina laevigata* (d'Orbigny), *P. oblonga* (Montagu), *P. rotunda* (d'Orbigny) *Triloculina marioni* Schlumberger, *Lagena laevis* (Montagu), *Polymorphina* sp., *Globobulimina affinis* (d'Orbigny), *Valvulineria bradyana* (Fornasini), *Rosalina bradyi* Cushman, *Lobatula lobatula* (Walker and Jacob), *Planorbulina mediterranensis* d'Orbigny, *Asterigerinata mamilla* (Williamson), *Nonion depressulum* (Walker and Jacob), *Ammonia compacta* Hofker, *A. parkinsoniana* (d'Orbigny), *Porosononion subgranosum* (Egger), *Elphidium advenum* (Cushman), *E. complanatum* (d'Orbigny), *E. crispum* (Linné), *E. depressulum* Cushman, *E. jenseni* (Cushman), *E. macellum* (Fichtel and Moll).

In contrast, in the samples from GMK-K1, GMK-K2, GMK-K3 and GMK-K4, a total of 40 genera and 58 species were found, namely: *Ammodiscus planorbis* Höglund, *Eggerelloides scabrus* (Williamson), *Bigenerina nodosaria* d'Orbigny, *Textularia bocki* Höglund, *T.* cf. *pala* Czjek, *Adelosina cliarensis* (Heron-Allen and Earland), *Spiroloculina excavata* d'Orbigny, *S. tenuiseptata* Brady, *Siphonaperta aspera* (d'Orbigny), *Cycloforina contorta* (d'Orbigny), *C. tenuicollis* (Wiesner), *Quinqueloculina seminula* (Linné), *Biloculinella depressa* (Wiesner), *B. wiesneri* (Le Calvez and Le Calvez), *Miliolinella subrotunda* (Montagu), *Pseudotriloculina laevigata* (d'Orbigny), *P. rotunda* (d'Orbigny), *Pyrgo elongata* (d'Orbigny), *P. inornata* (d'Orbigny), *Triloculina tricarinata* d'Orbigny, *Sigmoilinita costata* (Schlumberger), *S. edwardsi* (Schlumberger), *S. tenuis* (Czjcek), *Sigmoilopsis schlumbergeri* (Silvestri), *Dentalina inornata* d'Orbigny, *Neolenticulina peregrina* (Schwager), A*mphicoryna scalaris* (Batsch), *Lagena strumosa* Reuss, *Brizalina alata* (Seguenza), *B. spathulata* (Williamson), *Cassidulina carinata* Silvestri, *Rectuvigerina phlegeri* Le Calvez, *Bulimina aculeata* d'Orbigny, *B. costata* d'Orbigny, *B. elongata* d'Orbigny, *B. marginata* d'Orbigny, *Globobulimina affinis* (d'Orbigny), *G. pseudospinescens* (Emiliani), *Reussella spinulosa* (Reuss), *Fursenkoina acuta* (d'Orbigny), *Valvulineria bradyana* (Fornasini), *Discorbinella bertheloti* (d'Orbigny), *Hyalinea balthica* (Schröter), *Planorbulina mediterranensis* d'Orbigny, *Asterigerinata mamilla* (Williamson), *Nonion depressulum* (Walker and Jacob), *Nonionella turgida* (Williamson), *Chilostomella mediterranensis* Cushman and Todd, *Gyrodinoides lamarckiana* (d'Orbigny), *Aubignyna perlucida* (Heron-Allen and Earland), *Ammonia compacta* Hofker, *A. parasovica* Stshedrina and Mayer, *A. parkinsoniana* (d'Orbigny), *Porosononion subgranosum* (Egger), *Elphidium complanatum* (d'Orbigny), *E. crispum* (Linné), *E.* cf. *incertum* (Williamson), *E. macellum* (Fichtel and Moll) (Table 2). These genera and species were identified by using Meriç et al. (1995, 2005); Sakınç, (2008); Meriç et al. (2014). In total, 77 species were observed in the drillings and cores.

3.2. Ostracods

Ostracods were found in 82 samples of GMK-1, GMK-2, GMK-3 and 37 samples of GMK-K1, GMK-K2, GMK-K3, GMK-K4, in which a total of 27 genera and 37 species were identified (Table 3), according to Van Morkhoven (1963); Breman (1975); Bonaduce et al. (1975); Yassini (1979); Athersuch et al. (1989); Guillaume et al. (1985); Tunoğlu (1999, 2002); Şafak (1999); Guernet et al. (2003).

Table 2- The foraminifer contents of boreholes and cores.

FORAMINIFERA	BOREHOLES			CORES			
	GMK-1	GMK-2	GMK-3	GMK-K1	GMK-2	GMK-3	GMK-4
Ammodiscus planorbis Höglund				*		*	
Eggerelloides scabrus (Williamson)							*
Bigenerina nodosaria d'Orbigny				*	*		
Textularia bocki Höglund		*		*		*	
Textularia cf. *pala* Czjek				*	*	*	
Adelosina cliarensis (Heron-Allen and Earland)		*			*		
Adelosina mediterranensis (Le Calvez and Le Calvez)		*					
Spiroloculina dilatata d'Orbigny	*						
Spiroloculina excavata d'Orbigny	*	*		*	*	*	
Spiroloculina ornata d'Orbigny		*					
Spiroloculina tenuiseptata Brady				*	*	*	
Siphonaperta aspera d'Orbigny	*	*				*	
Cycloforina contorta (d'Orbigny)	*	*	*				*
Cycloforina rugosa (d'Orbigny)	*						
Cycloforina tenuicollis (Wiesner)				*			
Massilina secans (d'Orbigny)	*	*	*				
Quinqueloculina bidentata d'Orbigny	*						
Quinqueloculina disparilis d'Orbigny	*		*				
Quinqueloculina jugosa Cushman	*						
Quinqueloculina lamarckiana d'Orbigny		*					
Quinqueloculina seminula (Linné)	*	*	*	*	*	*	*
Biloculinella depressa (Wiesner)						*	
Biloculinella wiesneri (Le Calvez and Le Calvez)				*	*	*	
Miliolinella elongata Kruit		*					
Miliolinella subrotunda (Montagu)	*				*		
Pseudotriloculina laevigata (d'Orbigny)	*	*				*	
Pseudotriloculina oblonga (Montagu)	*		*				
Pseudotriloculina rotunda (d'Orbigny)	*						*
Pyrgo elongata (d'Orbigny)				*			
Pyrgo inornata (d'Orbigny)				*			
Triloculina marioni Schlumberger	*						
Triloculina tricarinata d'Orbigny				*			
Sigmoilinita costata (Schlumberger)					*		
Sigmoilinita edwardsi (Schlumberger)					*		
Sigmoilinita tenuis (Czjcek)					*	*	
Sigmoilopsis schlumbergeri (Silvestri)						*	
Dentalina inornata d'Orbigny						*	
Neolenticulina peregrina (Schwager)				*			
A*mphicoryna scalaris* (Batsch)				*	*		
Lagena laevis (Montagu)	*						
Lagena strumosa Reuss				*	*		
Polymorphina sp.	*						
Brizalina alata (Seguenza)				*	*	*	
Brizalina spathulata (Williamson)				*	*	*	*
Cassidulina carinata Silvestri				*	*	*	
Rectuvigerina phlegeri Le Calvez				*	*	*	
Bulimina aculeata d'Orbigny				*	*	*	
Bulimina costata d'Orbigny						*	

Table 2- continued.

Bulimina elongata d'Orbigny				*	*	*	
Bulimina marginata d'Orbigny				*	*	*	
Globobulimina affinis (d'Orbigny)	*			*	*	*	
Globobulimina pseudospinescens (Emiliani)						*	
Reussella spinulosa (Reuss)						*	
Fursenkoina acuta (d'Orbigny)					*		
Valvulineria bradyana (Fornasini)		*		*	*	*	
Rosalina bradyi Cushman	*						
Discorbinella bertheloti (d'Orbigny)				*	*	*	
Hyalinea balthica (Schröter)				*	*	*	
Lobatula lobatula (Walker and Jacob)	*	*	*				
Planorbulina mediterranensis d'Orbigny		*		*			
Asterigerinata mamilla (Williamson)	*					*	
Nonion depressulum (Walker and Jacob)	*						*
Nonionella turgida (Williamson)				*	*	*	
Chilostomella mediterranensis Cushman and Todd				*	*	*	
Gyrodinoides lamarckiana (d'Orbigny)				*	*	*	
Aubignyna perlucida (Heron-Allen and Earland)							*
Ammonia compacta Hofker	*	*	*		*		*
Ammonia parasovica Stshedrina and Mayer							*
Ammonia parkinsoniana (d'Orbigny)	*	*	*				*
Porosononion subgranosum (Egger)			*				*
Elphidium advenum (Cushman)	*		*				
Elphidium complanatum (d'Orbigny)	*	*	*		*		*
Elphidium crispum (Linné)	*	*	*				*
Elphidium depressulum Cushman	*	*					
Elphidium cf. *incertum* (Williamson)					*		*
Elphidium jenseni (Cushman)	*						
Elphidium macellum (Fichtel and Moll)	*		*				*

When the boreholes and cores were compared to each other in terms of the Gulf of Gemlik ostracod community, it was found that the number of genera and species are richer in the drilling samples of GMK-1 and GMK-2 and the core samples of GMK-K2 and GMK-K4 (Table 3). When the drilling locations are considered, it is observed that the northern and eastern parts of the bay are rich in ostracod fauna, similar to the ostracod fauna found in the bottom sediments of the Gulf of Gemlik, as emphasized by Meriç et al. (2005).

The ostracod community found in this study was compared with the ostracod communities in the Aegean islands, the Adriatic Sea, Algeria, Sea of Marmara (Gökçeada-Bozcaada-Çanakkale), the southern Marmara shelf, the Western Black Sea, and the İzmir, Edremit and Gemlik gulfs as reported by Nazik (2001), Meriç et al. (2002, 2005, 2008), Parlak and Nazik (2016), and in the studies mentioned above. There are numerous similarities in genera and species, with *Carinocythereis carinata* (Roemer), *Hiltermannicythere turbida* (Mueller), *H. Rubra* (Mueller), *Costa edwardsii* (Roemer), *Pterygocythereis jonesii* (Baird), *Palmoconcha agilis* (Ruggieri), *Cytheridea acuminata* (Bosquet) species being widespread. In addition, *Loxocauda pellucida* (Mueller), which is known from the Mediterranean, Aegean and Marmara Seas (from Pliocene to the Recent), was found only in the core samples. *Ilyocypris bradyi* Sars, indicative of fresh water inflow, was found at depths of 6,00-6,20 m; i.e. in the topmost part of the GMK-3 drilling. *Heterocypris salina* (Brady) was found at higher levels of the core of GMK-K4 drilling at depths of 20,10-20,20 m. As a result, it was inferred that the ostracod community obtained from the Gulf of Gemlik drillings and cores can be equated with the ostracods of Mediterranean-Aegean seas.

Table 3- The ostracod content of boreholes and cores.

OSTRACODA	BOREHOLES			CORES			
	GMK-1	GMK-2	GMK-3	GMK-K1	GMK-K2	GMK-K3	GMK-K4
Cytherella alvearium Bonaduce, Ciampo and Masoli		*			*		
Carinocythereis carinata (Roemer)	*	*					*
Carinocythereis rhombica Stambolidis	*	*					*
Aurila arborescens (Brady)			*				
Aurila convexa (Baird)		*					
Tyrrenocythere amnicola (Sars)							*
Hiltermannicythere rubra (Mueller)	*						*
Hiltermannicythere turbida (Mueller)	*						*
Pterygocythereis jonesii (Baird)	*	*					*
Cytheretta judaea (Brady)	*				*		
Costa batei (Brady)					*		
Costa edwardsii (Roemer)	*	*		*	*	*	*
Costa tricostata (Reuss)		*					
Callistocythere intricatoides (Ruggieri)	*						*
Callistocythere pallida (Mueller)	*						
Cyprideis torosa (Jones)	*		*				
Cytheridea acuminata (Bosquet)	*	*		*			*
Leptocythere sp.	*	*					
Leptocythere multipunctata (Seguenza)							*
Urocythereis crenulosa (Terquem)	*		*		*		
Buntonia sp.					*		
Semicytherura acuta Mueller	*						
Semicytherura incongruens (Mueller)	*	*					
Semicytherura inversa (Seguenza)	*						*
Paracytheridea depressa Mueller	*				*		
Cytheropteron sp.				*			
Palmoconcha agilis (Ruggieri)	*	*		*	*		*
Loxoconcha bairdi Mueller	*						
Loxoconcha stellifera Mueller	*	*	*		*		
Sagmatocythere versicolor (Mueller)					*		
Loxocauda pellucida (Mueller)				*		*	
Cushmanidea turbida (Mueller)	*	*			*		*
Pontocypris rara Mueller	*	*		*			
Argilloecia sp.					*		
Xestoleberis dispar (Mueller)	*						*
Heterocypris salina (Brady)							*
Ilyocypris bradyi Sars			*				

3.3. Nannoplanktons

The studies were carried out on mud/ unconsolidated mudstone samples from GMK-1, GMK-2, GMK-3 drillings and GMK-K1, GMK-K2, GMK-K3 and GMK-K4 cores. In general, the nannofossil assemblages including: *Gephyrocapsa oceanica,* small *Gephyrocapsa* spp.*, Scyphosphaera porosa* are present, in addition to *Emiliania huxleyi, Reticulofenestra parvula, Coronosphaera* spp.*, Bylosphaera* spp.*, Helicosphaera* spp. characterize an open-shallow marine environment. Biostratigraphic evaluation of this group allowed NN21 *Emiliania huxleyi* biozone to be determined. According to these data, Holocene marine deposition occurred.

In addition, both synsedimentary and reworked nannofossil assemblages, and their representative biozones and environmental characteristics were determined in mud samples belonging to the boreholes

and cores of the Gulf of Gemlik. In these stratigraphic interpretations, the data related from other coeval fossils, such as dinoflagellate cysts, ascidian spicules, diatom and sponge spicules were also used (see Table 4 and Plate 1). Some synsedimentary (Holocene) nannofossil species were simply reported as "coccospheres".

In mud samples of the GMK-1 drilling, 18 nannofossil species were observed, of which 12 are "synsedimentary", 5 of them "reworked from Cenozoic rocks" and a single one is "reworked from Cretaceous rocks". In these samples, 4 dinoflagellate cysts (*Thoracosphaera* spp.) were recognized, 2 of them are "synsedimentary" and the other 2 are "reworked" (Table 4). In mud samples from the GMK-2 drilling, 39 nannofossil species were recorded, of which 16 species are "synsedimentary", 20 of them were "reworked" from Cenozoic units, which of them are recorded as 3 dinoflagellate species, 2 are "synsedimentary" and 1 "reworked" (*Thoracosphaera* spp.) (Table 4) is. Finally, in the mud samples of the GMK-3 drilling, 15 nannofossil species were observed, 2 of them were "synsedimentary", 8 of them were reworked from the Cenozoic and 5 of them were reworked from the Cretaceous. Two "synsedimentary" dinoflagellate cysts (*Thoracosphaera* spp.) were also distinguished (Table 4). As shown in Table X, the nannofossil assemblages *Syracosphaera* spp. and *Coronosphaera* spp., in addition to *Emiliania huxleyi, Reticulofenestra parvula*, indicate the presence of the NN21 *Emiliania huxleyi* Zone. It is concluded that the sediments, excluding *Gephyrocapsa omega* individuals in the GMK-1 and GMK-2 drillings, represent shallow-open sea deposition during the Holocene period (Varol and Houghton, 1996; Young, 1998; Young et al., 2014). Although, there are few nannofossils in the samples from the GMK-3 drilling, the abundance

Table 4- The nannofossils assemblage and biostratigraphical distribution of boreholes and cores.

ORIGINAL CLASSIFICATION	CHRONOZONE	BIOZONE	Nannofossil species	BOREHOLES			CORES			
				GMK-1	GMK-2	GMK-3	GMK-K1	GMK-K2	GMK-K3	GMK-K4
SYNSEDIMENTARY	HOLOCENE	NN21 *Emiliania huxleyi* Zone	*Alisphaera* sp. (Gran and Braarud)		*					
			Anthosphaera sp. "coccosphere"		*					
			Braarudosphaera bigelowii (Gran and Braarud)	*	*		*	*	*	
			Cocolithus pelagicus (Wallich)				*		*	
			Coronosphaera binodata (Kamptner)	*	*		*	*	*	
			Coronosphaera mediterranea Lohmann	*	*		*	*	*	*
			Dictyococcites antarcticus Haq	*						
			Dictyococcites productus (Kamptner)	*	*		*	*	*	*
			Emiliana huxleyi (Lohmann)	*	*	*	*	*	*	*
			Emiliana huxleyi (Lohmann) "coccosphere"		*			*	*	*
			küçük *Gephyrocapsa* sp.		*			*	*	
			Gphyrocapsa oceanica Kamptner				*		*	
			Helicosphaera carteri (Wallich)	*	*		*	*	*	
			Helicosphaera hyalina Gaarder	*	*			*	*	
			Helicosphaera wallichii (Lohmann)				*	*		
			Papposphaera sp. Tangen "coccosphere"		*					
			Pontosphaera japonica (Takayama)		*		*			
			Pseudoemiliana lacunosa ovata (Kamptner)				*			
			Reticulofenestra parvula (Okada and McIntyre)	*	*	*	*	*	*	*
			Rhabdosphaera clavigera Murray and Blackman	*	*		*			
			Syracosphaera histrica Kamptner	*			*		*	
			Syracosphaera pulchra Lohmann	*	*		*	*	*	*
			Thoracosphaera granifera Fütterer	*	*	*	*	*	*	*
			Thoracosphaera tuberosa Kamptner	*	*	*	*	*		

Table 4- continued.

REWORKED	PALEOGENE-NEOGENE	?	*Arkhangelskiella specillata* Vekshina		*					
			Blackites spinosus (Deflandre and Fert)				*			
			Chiasmolithus grandis (Bramlette and Riedel)							*
			Clausicoccus fenestratus (Deflandre and Fert)		*					
			Cocolithus miopelagicus Bukry							*
			Cocolithus pelagicus (Wallich)	*	*	*				*
			Cruciplacolithus tenuis (Stradner)	*						
			Cyclicargolithus floridanus (Roth and Hay)	*	*		*			
			Dictyococcities hesslandii (Haq)		*	*	*	*	*	
			Dictyococcites scrippsae Bukry and Percival		*					
			Discoaster gemmifer Stradner							*
			Discoaster saipanensis Bramlette and Riedel			*				
			Ericsonia formosa (Kamptner)		*	*		*		
			Micrantolithus basquensis Martini		*					
			Neococcolithus dubius (Deflandre)		*					
			Pemma sp. Klumpp		*					
			Pontosphaera obliquipons (Deflandre)					*		
			Pontosphaera pectinata (Bramlette and Sullivan)	*	*					
			Prinsius martinii (Perch-Nielsen)			*				
			Reticulofenestra dictyoda (Deflandre)		*					
			Reticulofenestra gelida (Geitzenauer)					*		
			Reticulofenestra haqii Backman		*		*	*		
			Reticulofenestra hampdanensis Edwards			*				
			Reticulofenestra lockeri Müller				*	*		
			Reticulofenestra minuta Roth		*					
			Reticulofenestra minutula (Gartner)		*				*	
			Reticulofenestra pseudoumbilicus (Gartner)	*	*		*	*	*	*
			Scyphosphaera globulata Bukry and Percival		*					
			Sphenolithus abies Deflandre				*			
			Sphenolithus moriformis (Bronnimann and Stradner)		*	*				*
			Sphenolithus radians Deflandre		*	*				*
			Thoracosphaera heimii Lohmann	*	*		*	*		
			Toweius crassus (Bramlette and Sullivan)							*
	UPPER CRETACEOUS	?	*Aspidolithus parcus parcus* (Stradner)			*				
			Braarudosphaera bigelowii (Gran and Braarud)			*				
			Braarudosphaera discula Bramlette and Riedel					*		
			Cribrosphaerella ehrenbergii (Arkhangelsky)				*			
			Cyclagelosphaera reinhardtii (Perch-Nielsen)				*			
			Ellipsogelosphaera britannica (Stradner)							*
			Ellipsogelosphaera ovata (Bukry)						*	
			Microrhabdulus attenuatus Deflandre					*		
			Micula decussata Vekshina							
			Micula staurophora (Gardet)			*				
			Prediscosphaera cretacea (Arkhangelsky)			*			*	*
			Quadrum gartneri Prins and Perch-Nielsen							*
			Rhomboaster cuspis Bramlette and Sullivan					*		
			Stradneria crenulata Bramlette and Martini				*			
			Thoracosphaera saxea Stradner	*			*			
			Watznaueria barnesae Black	*	*	*	*	*	*	*

of dinoflagellate cysts such as *Thoracosphaera* spp. (*Th. granifera, Th. tuberosa*) that represent shallow-sea conditions indicates that the deposition, which generally represents the Holocene, records a steadily deepening marine environment. Although there are no nannofossils at some levels (as specified in the tables for the drilling samples), the presence of dinoflagellate cysts such as *Thoracosphaera* spp., which represent a shallow-marine setting (*Th. granifera*), suggests that there has been at least one short-period decrease in sea level during the Holocene.

In the mud samples of the GMK-K1 core, 18 nannofossil species were determined, of which 15 are "synsedimentary" and 3 are from Cenozoic and Cretaceous rocks, which of them are recorded as 3 dinoflagellate species (Thoracosphaera spp.), 2 of them are "synsedimentary" and 1 of them is "reworked" (Table 4). In the mud samples from the core GMK-K2 , 23 nannofossil species are "reworked", of which 12 are "synsedimentary", 11 are from the Cenozoic and Cretaceouss, which of them are recorded as 3 dinoflagellate species), 2 of them are "synsedimentary" and 1 of them is "reworked" (*Thoracosphaera* spp). Also, in mud samples from core GMK-K3 core, 20 nannofossil species are present, of which 14 are "synsedimentary", and 6 were reworked from the Cenozoic and Cretaceous. In addition, q 1 "synsedimentary" dinoflagellate species (*Thoracosphaera granifera*) was observed. In the mud samples of GMK-K4, 18 nannofossil species occur, of which 6 are "synsedimentary" and 12 were "reworked" from the Cenozoic and Cretaceous (Table 4).

In addition to an abundance of Emiliania huxleyi and Reticulofenestra parvula in the mud samples from GMK-K2 (75,00-76,00 m) and GMK-K3 (98,00 - 99,00 m), two deepest cores in Gemlik Bay, the existence of *Gephyrocapsa oceanica* and small *Gephyrocapsa* species (survivors after extinction of *Gephyrocapsa omega)* indicate that marine sedimentation began at the base of Holocene.

3.4. Diatoms

The number of genera and species of diatoms in the drilling and core samples is very small. In the drilling of GMK-2, *Stephanodiscus lucens* Hustedt occurs at 39,00-39,10 m also, *Perissonoe cruciata* (Janisch and Robenhorst) Andrews and Stocizel at 41,00-41,10 and 41,40-41,50 m. In the drilling of GMK-3, *Eunotia sp*. occurs at 7,20-7,40 m and *Campylodiscus echeneis* Ehrenberg at 8,20-8,40 m. (Plate 2). Between these, *Stephanodiscus lucens* is a planktonic freshwater form commonly found in the high-temperature waters. *Perissonoe cruciata* (Janisch and Robenhorst) is a warm-water form, which is common in marine, littoral environments. *Eunotia sp.* is common in waters with both low and high temperatures, and is also a benthic (epiphytic, epilitic) fresh water form; it is common in low-nutrient (oligosaprobic) waters, which have both low and high water temperatures (oligotropic, eutropic) and pH>7 (alkaline). *Campylodiscus echeneis* Ehrenberg is generally a marine form (Krammer-Lange Bertalot, 1988, 1991; Soinien and Könönen, 2004; Round et al., 2007; Lerin and Cambra, 2007; Lange Bertalot et al., 2011; Krizmanici et al., 2015).

In terms of the diatom flora, *Stenopterobia* sp., which is a cosmopolitan form, occurs in the cores of GMK-K3 between 98,30-98,40 m and 98,60-98,70 m, and individuals belonging to the same genus rarely occur at 21,90-22,00 m in GMK-K4 (Krammer, Lange-Bertalot, 1988 and URL) (Plate 2).

Stephanodiscus lucens Hustedt and *Eunotia* sp., which are encountered in small numbers amongst the diatom assemblages in the drilling samples, are freshwater forms and are likely to have been transported to the environment by rivers. *Perissonoe cruciata* (Janisch and Robenhorst) and *Campylodiscus echeneis* Ehrenberg are marine forms. Especially, *Perissonoe cruciata* (Janisch and Robenhorst) represents both a marine environment and a littoral warm-water environment.

The diatom species and genera described in boreholes and cores are widespread throughout the Holocene.

3.5. Molluscs

The drilled samples contain very rich gastropod and bivalve assemblages. In drilled samples of GMK-1, GMK-2, GMK-3, there is a rich community of gastropod, namely: *Gibbula albida* (Gmelin), *G. rarilineata* (Michaud*), Phorcus mutabilis* (Philippi), *Bittium latreillii* (Payraudeau), *B. reticulatum* (da Costa), *B. submammillatum* (de Rayneval and

Ponzi), *Turritella communis* Risso, *Similiphora similior* (Bouchet and Guillemot), *Epitonium clathrus* (Linné), *Melarhaphe neritoides* (Linné), *Rissoa auriformis* Pallary, *R. splendida* Eichwald, *Pussilina inconspicua* (Alder), *P. lineolata* (Michaud), *P. marginata* (Michaud), *Alvania geryonia* (Nardo), *Obtusella intersecta* (S. Wood), *O. macilenta* (Monterosato), *Hydrobia acuta* (Draparnaud), *Hyala vitrea* (Montagu), *Euspira intricata* (Donovan), *Tritia pygmaea* (Lamarck), *Clathromangelia strigilata* Pallary, *Sorgenfreispira brachystoma* (Philippi), *Mangelia scabrida* Monterosato, *Mangelia* sp., *Raphitoma* sp., *Eulimella acicula* (Philippi), *Parthenina juliae* (de Folin), *Megastomia conoidea* (Brocchi), *Odostomia megerlei* (Locard), *Ondina crystallina* Locard, *Turbonilla acutissima* Monterosato, *Retusa leptoeneilema* (Brusina,), *R. minutissima* (Monterosato), *R. obtusa* (Montagu), *Cylichna cylindracea* (Pennant) (Table 5a), and bivalves which are; *Nucula hanleyi* Winckworth, *N. sulcata* Bronn, *Lembulus pella* (Linné), *Mytilus galloprovincialis* Lamarck, *Musculus subpictus* (Cantraine), *Modiolula phaseolina* (Philippi), *Ostrea edulis* Linné, *Ctena decussata* (O. G. Costa), *Lucinella divaricata* (Linné), *Myrtea spinifera* (Montagu), *Kurtiella bidentata* (Montagu), *Acanthocardia paucicostata* (G. B. Sowerby II), *Parvicardium scriptum* (Bucquoy, Dautzenberg and Dollfus), *Papillicardium papillosum* (Poli), *Spisula solida* (Linné), *S. subtruncata* (da Costa), *Abra prismatica* (Montagu), *Atlantella pulchella* (Lamarck), *Timoclea ovata* (Pennant), *Gouldia minima* (Montagu), *Pitar mediterraneus* (Aradas and Benoit), *P. rudis* (Poli), *Ruditapes decussatus* (Linné), *Corbula gibba* (Olivi),

Table 5a- The mollusc content of the drillings.

MOLLUSCA		BOREHOLES		
		GMK-1	GMK-2	GMK-3
GASTROPODA	*Gibbula albida* (Gmelin)	*		*
	Gibbula rarilineata (Michaud)			*
	Phorcus mutabilis (Philippi)		*	
	Bittium latreillii (Payraudeau)	*	*	*
	Bittium reticulatum (da Costa)	*		*
	Bittium submammillatum (de Rayneval and Ponzi)	*	*	*
	Turritella communis Risso	*	*	
	Similiphora similior (Bouchet and Guillemo)	*		
	Epitonium clathrus (Linnaeus)	*		
	Melarhaphe neritoides (Linnaeus)	*		
	Rissoa auriformis Pallary		*	*
	Rissoa splendida Eichwald	*	*	*
	Pussilina inconspicua (Alder)	*	*	
	Pusillina lineolata (Michaud)	*	*	*
	Pusillina marginata (Michaud)	*		
	Alvania geryonia (Nardo)	*		
	Obtusella intersecta (S. Wood)	*	*	
	Obtusella macilenta (Monterosato)	*		
	Hyala vitrea (Montagu)		*	
	Hydrobia acuta (Draparnaud)	*		
	Euspira intricata (Donovan)	*	*	*
	Tritia pygmaea (Lamarck)	*	*	
	Tritia reticulata (Linnaeus)			*
	Sorgenfreispira brachystoma (Philippi)	*		
	Clathromangelia strigilata Pallary		*	
	Mangelia scabrida Monterosato	*	*	
	Raphitoma sp.	*	*	
	Eulimella acicula (Philippi)	*	*	
	Parthenina juliae (de Folin)	*		

Table 5a- continued.

GASTROPODA	*Megastomia conoidea* (Brocchi)		*	*
	Odostomia megerlei (Locard)	*	*	
	Turbonilla acutissima Monterosato	*		
	Retusa leptoeneilema (Brusina)	*		
	Retusa obtusa (Montagu)	*	*	
	Cylichna cylindracea (Pennant)	*	*	
BIVALVIA	*Nucula hanleyi* Winckworth		*	
	Nucula sulcata Bronn	*		
	Lembulus pella (Linnaeus)	*	*	*
	Musculus subpictus (Cantraine)	*		
	Modiolula phaseolina (Philippi)	*	*	*
	Ostrea edulis Linnaeus			*
	Ctena decussata (O. G. Costa)	*		
	Lucinella divaricata (Linnaeus)	*	*	*
	Myrtea spinifera (Montagu)	*	*	
	Kurtiella bidentata (Montagu)	*	*	
	Acanthocardia paucicostata (G. B. Sowerby II)	*		
	Parvicardium scriptum (Bucquoy, Dautzenberg and Dollfus)	*	*	*
	Papillicardium papillosum (Poli)	*		
	Spisula solida (Linnaeus)	*	*	
	Spisula subtruncata (da Costa)	*		
	Abra prismatica (Montagu)		*	
	Atlantella pulchella (Lamarck)	*	*	
	Timoclea ovata (Pennant)	*	*	
	Gouldia minima (Montagu)	*	*	*
	Pitar mediterraneus (Aradas and Benoit)	*		
	Pitar rudis (Poli)	*		
	Ruditapes decussatus (Linnaeus)	*		
	Corbula gibba (Olivi)	*		
	Hiatella arctica (Linnaeus)	*		
	Hiatella rugosa (Linnaeus)			*

Hiatella arctica (Linné), *H. rugosa* (Linné) were found (Table 5a) (Cossignani et al., 2011; Scaperrotta et al., 2009-2015) (Plates 3 and 4).

When the cores of GMK-K1, GMK-K2, GMK-K3 and GMK-K4 are considered in terms of mollusc assemblages; i.e. the following bivalves were identified: *Kelliella miliaris* (Philippi), *Spisula subtruncata* (da Costa), *Parvicardium exiguum* (Gmelin), *Loripes dentatus* (Defrance), *Timoclea ovata* (Pennant), *Corbula gibba* (Olivi), *Abra* sp., from gastropods; *Turritella communis* Risso, *Alvania cimicoides* (Forbes), *Panthenina intersincta* (J. Adams), *Bittium reticulatum* (de Costa), *Ecrobia* cf. *maritima*, *Rissoa* sp., *Turbonilla* sp.; the scaphopod, *Dentalium* sp. was also observed (Table 5b). The above assemblage is Holocene and characterizes a shallow-marine environment. Owing to the partial fossilization of the shells, they are considered to be of Early Holocene age (Nevesskaja, 1965, 1974; Perna, 2003; Nielsen et al., 2006; Taviani et al., 2014; Çağatay et al., 2015; Büyükmeriç, 2016).

4. Discussion and Conclusion

As a result of the studies, it is understood that the foraminifer assemblage of the Gulf of Gemlik was under the influence of the Mediterranean-Aegean Sea communities. It is remarkable that there is a great difference between the samples from the drilling and the cores in terms of the number of genera and species. Although, a total of 22 genera and 38 species, characterizing the infra-littoral zone in drilling samples were identified, 40 genera and 58 species were observed, which characterize the circa-littoral zone in the cores. In addition, to observing large

Table 5b- The mollusc content of core samples.

MOLLUSCA	CORES			
	GMK-K1	GMK-K2	GMK-K3	GMK-K4
Kelliella miliaris (Philippi)	*	*	*	*
Spisula subtruncata (da Costa)		*	*	*
Parvicardium exiguum (Gmelin)		*		*
Loripes dentatus J.L.M. Defrance				*
Timoclea ovata (Pennant)				*
Corbula gibba Olivi				*
Abra sp.				*
Turritella communis Risso		*		
Alvania cimicoides (Forbes)		*		
Parthenina interstincta (J. Adams)				*
Bittium reticulatum (da Costa)				
Ecrobia cf. *maritima* (Milaschewitsch)	*			
Rissoa sp.		*		
Turbonilla sp.				*
Dentalium sp.	*			

number of species of Black Sea origin, *Ammonia parasovica* in samples from GMK-K4, taken from the eastern part of the gulf, is another notable feature for the study area, and is the first record of this species in the Gulf of Gemlik. The same genus and species were encountered at different levels of the drillings of KS-2, S-5 and S-3, carried out in the Gulf of İzmit (Meriç et al., 1995). It is thought that this species of Black Sea origin continued its life in the Gulf of Gemlik after the Gulf of İzmit in Holocene. Both the boreholes and the core samples have a very rich fauna in terms of the ostracod assemblage. The ostracod assemblage of the boreholes and the core samples resembles each other. *Loxocauda pellucida*, which is known in the Mediterranean, Aegean and Marmara Seas, was encountered only in core samples. The ostracod genera and species identified belong to typical Mediterranean-Aegean Sea fauna.

The nannofossil assemblage in which *Emiliania huxleyi, Reticulofenestra parvula, Gephyrocapsa oceanica, Scyphosphaera porosa* species are present in the boreholes and cores, characterize an open shallow-marine environment, typical of the Holocene period, including the NN21 *Emiliania huxleyi* biozone in the samples studied. The nannoplankton community is richer than in terms of the number of genera and species in the Gulf of İzmit.

Although the drilling boreholes and cores represent a sparse community in terms of the diatom flora, its actual presence in the eastern Gulf of Gemlik is first emphasized by this study. When compared, it observed that there is a great difference between the diatom assemblage of the Gulf of Gemlik and that of the İznik Lake. The presence of fresh-water diatoms and ostracods in some boreholes and drilling samples also suggests that there was fresh water outflow to the marine Gulf of Gemlik at certain times.

The mollusc assemblage on the other hand includes characteristic Mediterranean genera and species. According to the data obtained, the Gulf of Gemlik remained under Mediterranean influence during the Holocene period. A remarkable feature is the great abundance of *Turritella communis in a* mud-rich environments between 27,10 to 40,00 m in GMK-1 and also between 35,10-40,80 m in the GMK-2 drilling. This shows that the life conditions were suitable in the Gulf of Gemlik for this species. This is the only species that adapted itself to the ambient low-oxygen conditions in the gulf. When all of the microfossil and the macrofossil findings were evaluated, it was determined that the Gulf of Gemlik assemblage is typical of the Mediterranean-Aegean Sea community during the Holocene period.

Acknowledgements

The authors would like to thank to Aynur Yümün (Yümün Mühendislik A.Ş.) for providing the drilling and core samples for this study. The authors are also thankful to Prof. Muhittin Görmüş (A.U.), Assoc. Prof. Burçin Aşkım Gümüş and an unknown referee who made significant contributions with their supportive criticism and suggestions during the revision of this article. Also, we would like to thank to Prof Alastair Robertson (The University of Edinburgh) who linguistically improved of last version of the manuscript.

References

Aksu, A.E., Hiscott, R.N., Yaşar, D. 1999. Oscillating Quaternary water levels of the Marmara Sea and vigorous out- £ow into the Aegean Sea from the Marmara Sea-Black Sea drainage corridor. Marine Geology 153, 275-302.

Aksu, A.E., Hiscott, R.N., Kaminski, M.A., Mudie, P.J., Gillespie, H., Abrajano, T., Yaşar, D. 2002. Last Glacial-Holocene paleoceanography of the Black Sea and Marmara Sea: stable isotopic, foraminiferal and coccolith evidence. Marine Geology 190, 119-149.

Athersuch J., Horne D.J., Whittaker J.E. 1989. Marine and brackish water ostracods. In Kermack D.M., Barnes R.S.K.(Ed.), Synopses of the British Fauna (New Series) 43, 345p.

Breman, E. 1975. The distribution of ostracodes in the bottom sediments of the Adriatic Sea. Vrije Universiteit te Amsterdam, Krips Repro, Meppel, 165 p.

Brückner, H., Kelterbaum, D., Marunchak, O., Porotov, A., Vott, A. 2010. The Holocene sea level story since 7500 BP - Lessons from the Eastern Mediterranean, the Black and the Azov Seas. Quaternary International 225, 160-179.

Bonaduce G., Ciampo G., Masoli M. 1975. Distribution of Ostracoda in the Adriatic Sea. Pubblicazioni della Stazione Zoologica di Napoli 40, 304 p.

Büyükmeriç, Y. 2016. Postglacial flooding of the Marmara Sea (Turkey): Molluscs and sediments tell the story. Geo-Marine Letters 36, 4, 307-321.

Chepalyga, A.L. 2007. The Late Glacial great flood in the Ponto-Caspian basin. In:Yanko-Hombach, V., Gilbert, A.S., Panin, N., Dolukhanov, P.M. (Ed.), The Black Sea Flood Question. Springer, Dordrecht, 119-148.

Cossignani, T., Ardovani, R., Micali, P., Tisselli, M., Cossignani, V., Cecalupo, A. 2011. Malacologia Mediterranea: Atlante delle Conchiglie del Mediterraneo. L'Informatore Piceno, Cupra Marittima, Italy, 536 p.

Çağatay, M.N., Görür, N., Algan, O., Eastoe, C., Tchapalyga, A., Ongan, D., Kuhn, T., Kuşçu, I. 2000. Late Glacial-Holocene palaeoceanography of the Sea of Marmara: timing of connections with the Mediterranean and the Black Seas. Marine Geology 167, 191-206.

Çağatay, M.N., Görür, N., Polonia, A., Demirbağ, E., Sakınç, M., Cormier, M.-H.,Capotondi, L., McHugh, C., Emre, Ö., Eriş, K. 2003. Sea level changes and depositional environments in the Izmit Gulf, eastern Marmara Sea, during thelate glacial-Holocene period. Marine Geology 202, 159-173.

Çağatay, M.N., Eris¸ , K., Ryan, W.B.F., Sancar, U., Polonia, A., Akcer, S., Biltekin, D., Gasperini, L., Görür, N., Lericolais, G., Bard, E. 2009. Late Pleistocene-Holocene evolution of the northern shelf of the Sea of Marmara. Marine Geology 265, 87-100.

Çağatay, M. N., Wulf, S., Sancar, Ü., Özmaral, A., Vidal, L., Henry, H., Appelt, O., Gasaperini, L. 2015. The tephra record from the Sea of Marmara for the last ca. 70 ka and its palaeoceanographic implications. Marine Geology 361, 96-110.

Filikçi, B., Eriş, K.K., Çağatay, N., Sabuncu, A., Polonia, A. 2017. Late glacial to Holocene water level and climate changes in the Gulf of Gemlik, Sea of Marmara: evidence from multi-proxy data. Geo-Marine Letters 37, 501-513.

Gasperini, I., Polonia, A., Çağatay, M. N., Bortoluzzi, C., Ferrante, V. 2011. Geological slip rates along the North Anatolian Fault in the Marmara Region. Tectonics, 30, TC6001.

Görür, N., Çağatay, M.N., Sakınç, M., Sumengen, M., Senturk, K., Yaltirak, C., Tchapalyga, A. 1997. Origin of the Sea of Marmara as deducted from the Neogene to Quaternary paleogeographic evolution of its frame, Int. Geol. Rev., 39, 342–352, doi:10.1080/00206819709465276.

Guernet, C., Lemeille, F., Sorel, D., Bourdillon, C., Berge-Thierry C., Manakou, M. 2003. Les ostracodes et le Quaternaire d'Aigion (golfe de Corinth, Grèce). Revue de Micropaleontologie 46, 73–93.

Guillaume, M.C., Peypouquet, J.P. et Tetart, J. 1985. Quaternaire et actuel. Atlas des Ostracodes de France, Ed: H.J. Oertli. Bulletin des centres de recherches exploration-production Elf-Aquitaine Mémoire 9, 337-377.

Hiscott, R.N., Aksu, A.E., Mudie, P.J., Kaminski, M.A., Abrajano, T., Yaşar, D., Rochon, N. 2007. The Marmara Sea gateway since ~16 Ky BP: non-catastrophic causes of palaeoceanographic

events in the Black Sea at 8.4 and 7.15 Ky BP. In:Yanko-Hombach, V., Gilbert, A.S., Panin, N., Dolukhanov, P.M. (Ed.), The Black Sea Flood Question. Springer, Dordrecht, 89-117.

İslamoğlu, Y. 2002. Neoeuxinian-Holocene molluscan fauna of the southern part of the Marmara Sea between Gemlik and Bandırma Bay (NW Turkey). Yılmaz, A. (Ed.). Oceanography of the Eastern Mediterranean and Black Sea, Similarities and Differences of Two Interconnected Basins. TÜBİTAK Publishers (ISBN: 975-288-451-2), Ankara, 953-960.

İslamoğlu, Y. 2009. Middle Pleistocene bivalves of the İznik lake basin (Eastern Marmara, NW Turkey) and a new paleobiogeographical approach. International Journal of Earth Sciences 98, 1981-1990.

İslamoğlu, Y., Chepalyga, A.L. 1998. The environmental changes determined with Molluscan assemblages during the Neoeuxinian-Holocene stages in the Sea of Marmara. Geological Bulletin of Turkey 41, 55-62.

Kerey E., Meriç, E., Tunoğlu, C., Kelling, G., Brenner, R.L., Doğan, A.U. 2004. Black Sea–Marmara Sea Quaternary connections: new data from the Bosphorus, Istanbul, Turkey. Palaeogeography, Palaeoclimatology, Palaeoecology 204, 3-4, 277-295.

Krammer, K., Lange-Bertalot, H. 1988. Bacillariophyceae. 2. Teil: Bacillariophyceae, Gustav Fischer Verlag, Band 2-2, Stuttgart, 611 p.

Krammer, K., Lange-Bertalot, H.1991. Bacillariophyceae. 3. Teil: Centrales, Fragilariaceae, Gustav Fischer Verlag, Band 2-3, Stuttgart, 599 p.

Krizmaniči, J., Ilıċ, M., Vidakoviči, D., Simiči, G.S., Petrovii, J., Cvetanovi, K. 2015. Diatoms of the Dojkinci River (Stara Planina Nature Park, Serbia). Acta Botanica Croatica 74, 2, 317– 331.

Lange Bertalot, H., Bak, M., Witkowski, A., Tagliavent, N. 2011. Eunotia and some related genera. Diatoms of Europe 6. Koeltz Scientific Books, Königstein.

Lerin, R., Cambra, J. 2007. Distribution and taxonomic notes of Eunotia Ehrenberg 1837 (Bacillariophyceae) in rivers and streams of Northern Spain. Limmetica 26, 2, 415-434.

Marret, F., Mudie, P., Aksu, A., Hiscott, R.N. 2009. A Holocene dinocyst record of a two-step transformation of the Neoeuxinian brackish water lake into the Black Sea. Quaternary International 197, 72-86

McHugh, C.M.G., Gurung, D., Giosan, L., Ryan, W.B.F., Mart, Y., Sancar, U., Burkle, L., Çağatay, M.N. 2008. The last reconnection of the Marmara Sea (Turkey) to the World Ocean: a paleoceanographic and paleoclimatic perspective. Marine Geology 255, 64-82.

Meriç, E. 1995. İstanbul Boğazı öncesinide Marmara Denizi-Karadeniz bağlantısının İzmit Körfezi-Sapanca Gölü-Sakarya Vadisi boyunca gereçekleştiğinin ön bulguları. Meriç, E. (Ed.). İzmit Körfezi Kuvaterner İstifi. İstanbul, 295-301.

Meriç, E., Yanko, V., Avşar, N. 1995. İzmit Körfezi (Hersek Burnu-Kaba Burun) Kuvaterner istifinin foraminifer faunası, Meriç, E. (Ed.). İzmit Körfezi Kuvaterner İstifi. İstanbul, 105-151.

Meriç, E., Avşar, N., Nazik, A. 2002. Bozcaada (Kuzey Ege Denizi) bentik foraminifer ve ostrakod faunası ile bu toplulukta gözlenen yerel değişimler, Yerbilimleri (Geosound) 40-41, 97-120.

Meriç, E., Avşar, N., Nazik, A., Alpar, B., Yokeş, B., Barut, İ. F., Ünlü, S. 2005. Gemlik Körfezi yüzey çökellerinin foraminifer, ostrakod ve mollusk faunası, foraminifer kavkılarında gözlenen morfolojik anomaliler ile bölgenin sedimentolojik, hidrokimyasal ve biokimyasal özellikleri. Maden Tetkik ve A*rama* Dergisi 131, 21-48. Ankara.

Meriç, E., Avşar, N., Tunoğlu, C., Nazik, A., Yokeş, B., Barut, İ.F., Yücesoy-Eryılmaz, F., Tuğrul, B., Görmüş, M., Öncel, M.S., Orak, H., Kam, E. ve Dinçer, F. 2008. Harmantaşı Mevkii (Saros Körfezi-Kuzey Ege Denizi) deniz içi kaynakları çevresinde foraminifer ve ostrakod topluluğuna bu alandaki çevresel koşulların etkisi. Maden Tetkik ve Arama Dergisi 136, 63-84.

Meriç, E., Nazik, A., Avşar, N., Alpar, B., Ünlü, S., Gökaşan, E. 2009. Marmara Denizi-Karadeniz su bağlantısında İzmit Kanalı'nın varlığının delilleri: İznik Gölü (Bursa-KB Türkiye) güncel sedimanlarının paleontolojik açıdan değerlendirilmesi. İstanbul Üniversitesi Yerbilimleri Dergisi 22, 1, 1-19.

Meriç, E., Avşar, N., Yokeş, M.B., Dinçer, F. 2014. Atlas of Recent benthic foraminifera from Turkey. Micropaleontology 60, 3-4, 188 p.

Meriç, E., Nazik, A., Yümün, Z. Ü., Büyükmeriç, Y., Avşar, N., Yıldız, A., Sagular, E. K., Koral, H., Gökaşan, E. 2018. Fauna and flora of drilling and core data from the İznik Lake: The Marmara and the Black Sea connection. Quaternary International 486, 156-184.

Mertens, K.N., Bradley, L.R., Takano, Y., Mudie, P.J., Marret, F., Aksu, A.E., Hiscott, R.N., Verleye, T.J., Mousing, E.A., Smyrnova, L.L., Bagheri, S., Mansor, M., Pospelova, V., Matsuoka, K. 2012. Quantitative estimation of Holocene surface salinity variation in the Black Sea using dinoflagellate cyst process length. Quaternary Science Reviews 39, 45-59.

Mudie, P.J., Rochon, A., Aksu, A.E., Gillespie, H. 2004. Late glacial, Holocene and modern dinoflagellate cyst assemblages in the Aegean-Marmara-Black Sea corridor: statistical analysis and re-interpretation of the early Holocene Noah's Flood hypothesis. Review of Palaeobotany and Palynology 128, 143-167.

Nazik, A. 2001. Ostracode faunas of bottom sediments from the continental shelf, South Marmara Sea, NW Turkey and their comparision with other shelf environments in the Mediterranean and Aegean regions. Geological Journal 36, 2, 111-123.

Nazik, A., Meriç, E., Avşar, N., Ünlü, S., Esenli, V., Gökaşan, E. 2011. Possible waterways between the Marmara Sea and the Black Sea in the late Quaternary: evidence from ostracod and foraminifer assemblages in lakes İznik and Sapanca. Geo-Marine Letters, 31, 2, 75-86.

Nevesskaja, L. A. 1965. Late Quaternary bivalve molluscs of the Black Sea, their systematics and ecology. Trudy Paleontologičeskogo Instituta, Akademiya Nauk SSSR 105, 390 p.

Nevesskaja, L. A. 1974. Molluscan shells in deep-water sediments of Black Sea. Degens E.T., Ross, D.A. (Ed.). The Black Sea-geology, chemistry and biology. American Association of Petroleum Geologists Memoir 20, 349-352.

Nielsen. J. K., Hanken, N-M., Nielsen, J. K., Haansen, K. S. 2006. Biostratigraphy and palaeoecology of the marine Pleistocene ofRhodes, Greece: Scleractinia, Serpulidae, Mollusca and Brachiopoda. Bulletin of Geosciences 80, 3,173-196.

Parlak, D., Nazik, A. 2016. Akdeniz (Antalya Körfezi) ve Ege Denizi (Ayvalık ve Kuşadası) ostrakodları ve biyocoğrafik dağılımı, Maden Tetkik Arama Dergisi 152, 63-65.

Perch-Nielsen, K. 1985*a*, Mesozoic calcareous nannofossils. Bolli, H. M., Saunders, J. B., Perch-Nielsen, K. (Ed.). Plankton Stratigraphy, Cambridge Earth Sciences Series, 329-426.

Perch-Nielsen, K. 1985*b*. Cenozoic calcareous nannofossils. Bolli, H. M., Saunders, J. B., Perch-Nielsen, K. (Ed.). Plankton Stratigraphy, Cambridge Earth Sciences Series, 427-554.

Perna, R. L. 2003. The Quaternary deep-sea protobranch fauna from the Mediterranean: composition, depth-related distribution and changes. Bollettino Malacologico 39, 1-4, 17-34.

Reinhardt, P. 1972. Coccolithen. Kalkiges nannoplankton seit jahmillionen. Neue Brehm Bücherei 453, 1-99.

Romein, A. J. T. 1979. Lineages in early paleogene calcareous nannoplankton. Utrecht Micropaleontological Bulletins 22, 1-231.

Round, F.E., Crawford, R.M., Mann, D.G. 2007. The Diatoms Biology and morphology of the Genera. Cambridge University Press, 747p.

Sagular, E.K. 2009. Fossil didemnid ascidian spicule records in the Plio-Quaternary marine clastics of the Antalya basin (Eastern Mediterranean) and their stratigraphic calibration to new nannofossil data. Geosciences Journal 13, 2, 121-131.

Sakınç, M. 2008. Marmara Denizi Bentik Foraminiferleri: Sistematik ve Otoekoloji. İstanbul Teknik Üniversitesi Rektörlüğü, İstanbul, 1638, 129 s.

Scaperrotta, M., Bartolini, S., Bogi, C. 2009-2015. Accrescimenti - Stadi di accrescimento dei Molluschi marini del Mediterraneo - Stages of growth of marine molluscs of the Mediterranean Sea, Vol. I-VI.

Sperling, M.R., Schmiedl, G., Hemleben, C., Emeis, K.C., Erlenkeuser, H., Grootes, P.M. 2003. Black Sea impact on the formation of eastern Mediterranean sapropel S1?Evidence from the Marmara Sea. Palaeogeography, Palaeoclimatology, Palaeoecology 190, 9-21.

Soininen, J., Könönen, K. 2004. Comparative study of monitoring South-Finnish rivers and streams using macroinvertebrate and benthic diatom community structure. Aquatic Ecology 38, 63-75.

Şafak, Ü. 1999. Recent ostracoda assemblage of the Gökçeada-Bozcaada-Çanakkale region, Yerbilimleri/Geosound 35, 149-172.

Taviani, M., Angeletti, L., Çağatay, M. N., Gasperini, L., Polonia, A., Wesselingh, F. P. 2014. Sedimentary and faunal signatures of the post-glacial marine drowning of the Pontocaspian Gemlik "Lake" (Sea of Marmara). Quaternary International 345, 11-17.

Tunoğlu, C. 1999. Recent ostracoda association in the Sea of Marmara, NW Turkey. Yerbilimleri 21, 63-87.

Tunoğlu, C. 2002. Karadeniz'in İstanbul Boğazı çıkışı ile Zonguldak ve Amasra kıyı alanlarında Güncel Ostrakod topluluğu. Yerbilimleri 26, 27-43.

URL,http//craticula.ncl.ac.uk/EADiatomKey/html/Stenopterobia.html

Van Morkhoven, F.P.C.M. 1963. Post Palaeozoic Ostracoda. Elsevir Amsterdam, (2), 478 pp.

Vardar, D., Öztürk, K., Yaltırak, C., Alpar, B., Tur, H. 2014. Late Pleistocene–Holocene evolution of the southern Marmara shelf and sub-basins: middle

strand of the North Anatolian fault, southern Marmara Sea, Turkey. Marine Geophysical Researches 35, 69-85.

Varol, O., Houghton, S.D. 1996. A review and classification of fossil didemnid ascidian spicules. Journal of Micropalaeontology 15, 135-149.

Vidal, L., Menot, G., Joly, C., Bruneton, H., Rostek, F., Çagatay, M.N., Major, C., Bard, E. 2010. Hydrology in the Sea of Marmara during the last 23 ka: implications for timing of Black Sea connections and sapropel deposition. Palaeoceanography 25, 1-16.

Yaltırak, C., Alpar, B. 2002. Evolution of the middle strand of North Anatolian Fault and shallow seismic investigation of the southeastern Marmara Sea (Gemlik Bay). Marine Geology 190, 307-327.

Yanko-Hombach, V.V., Gilbert, A.S., Dolukhanov, P., 2007. Controversy over Noah's flood in the Black Sea: geological and foraminiferal evidence from the shelf. Yanko-Hombach, V., Gilbert, A.S., Panin, N., Dolukhanov, P.M. (Ed.), The Black Sea Flood Question. Springer, Dordrecht, 149-203.

Yassini, l. 1979. The littoral system ostracodes from the Bay of Bou, İsmail, Algeries, Algeria: Revista Espanola de micropaleontologica, vol. XI, num. 3, 353-416.

Young, J.R. 1998. Neogene. Bown, P.R. (Ed.), Calcareous Nannofossil Biostratigraphy. British Micropalaeontological Society Publications Series. Chapman and Hall, London, 225-265.

Young, J.R., Bown P.R., Lees J.A. (Ed.) 2014. Nannotax3 website. International Nannoplankton Association. 21 Apr. 2014. URL: http://ina.tmsoc.org/Nannotax3.

PLATES

PLATE 1

Holocene nannofossil species found in drill and core samples of the Gemlik Bay (PL: polarized light, NL: normal light, CL: contrast light, GL: with gypsum wedge, QL: with quartz wedge; letter and number order on the upper left corner: drilling number and rock sampling depth, linear scale: 5 μm):

1. *Emiliania huxleyi*,

2. *Helicosphaera carteri*,

3. *Helicosphaera hyalina*,

4. *Syracosphaera histrica*,

5. *Braarudosphaera bigelowii*,

6. *Coronosphaera mediterranea*,

7. *Emiliania huxleyi*,

8. *Dictyococcites productus*,

9. *Reticulofenestra parvula*,

10. *Rhabdosphaera clavigera*,

11. *Thoracosphaera granifera*,

12. *Anthosphaera* sp.,

13. *Syracosphaera pulchra*,

14. *Gephyrocapsa oceanica*,

15. *Scyphosphaera porosa*,

16. *Coccolithus pelagicus*,

17. *Bonetia acuta* "Ascidian spicule",

18. *Reticulofenestra dictyoda* "reworked",

19. *Thoracosphaera tuberosa*,

20. *Pontosphaera pectinata* "reworked",

21. *Scyphosphaera globulata.*

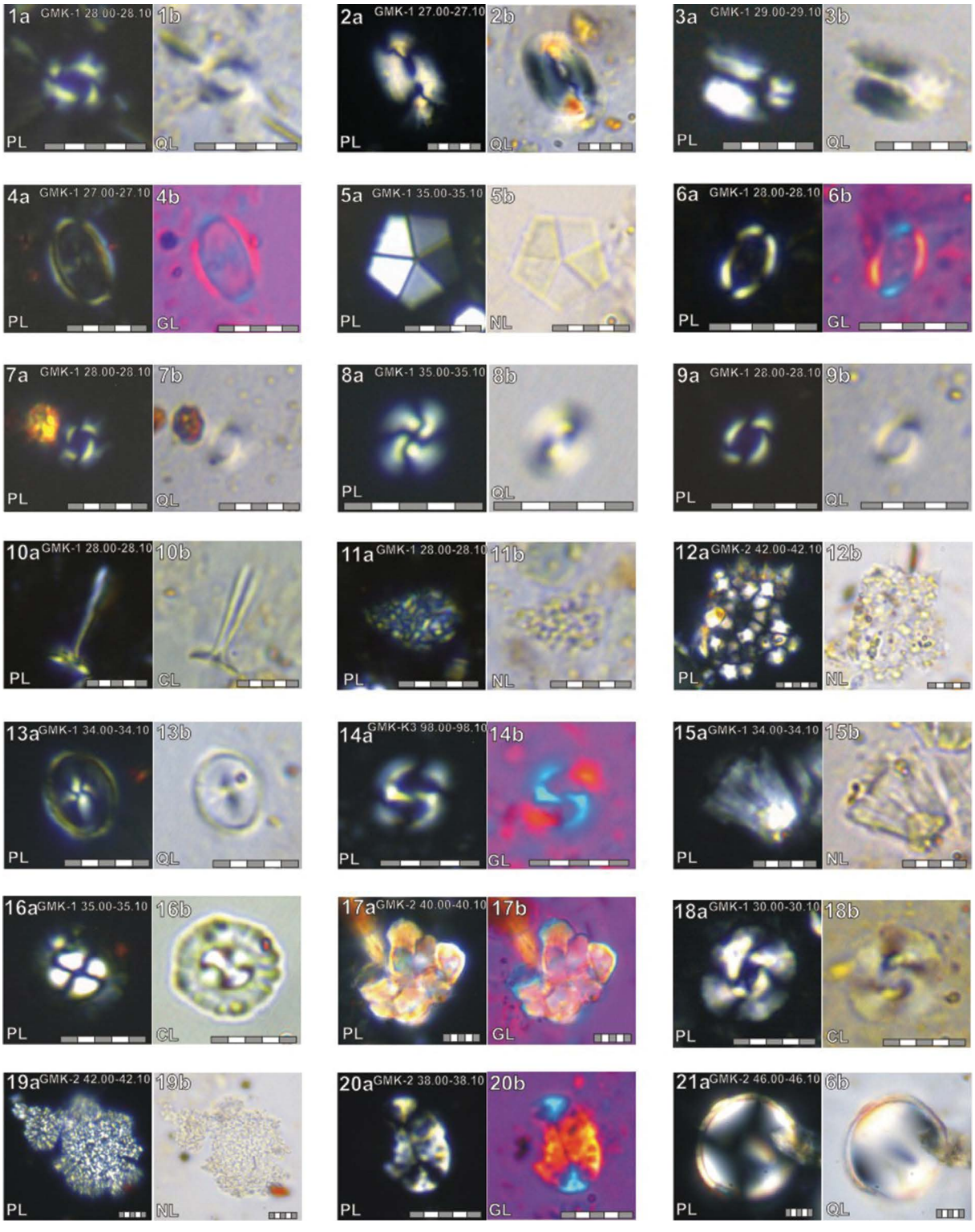

1a GMK-1 28.00-28.10
PL
1b
QL
2a GMK-1 27.00-27.10
PL
2b
QL
3a GMK-1 29.00-29.10
PL
3b
QL
4a GMK-1 27.00-27.10
PL
4b
GL
5a GMK-1 35.00-35.10
PL
5b
NL
6a GMK-1 28.00-28.10
PL
6b
GL
7a GMK-1 28.00-28.10
PL
7b
QL
8a GMK-1 35.00-35.10
PL
8b
QL
9a GMK-1 28.00-28.10
PL
9b
QL
10a GMK-1 28.00-28.10
PL
10b
CL
11a GMK-1 28.00-28.10
PL
11b
NL
12a GMK-2 42.00-42.10
PL
12b
NL
13a GMK-1 34.00-34.10
PL
13b
QL
14a GMK-K3 98.00-98.10
PL
14b
GL
15a GMK-1 34.00-34.10
PL
15b
NL
16a GMK-1 35.00-35.10
PL
16b
CL
17a GMK-2 40.00-40.10
PL
17b
GL
18a GMK-1 30.00-30.10
PL
18b
CL
19a GMK-2 42.00-42.10
PL
19b
NL
20a GMK-2 38.00-38.10
PL
20b
GL
21a GMK-2 46.00-46.10
PL
6b
QL

PLATE 2

Diatom species found in drill and core samples from the Gulf of Gemlik.

1. Stenopterobia sp., a) GMK-K3, 98,30-98,40 m, b). GMK-K3, 98,60-98,70 m, c) GMK-K4, 21,90-22,00 m.

2. Eunotia sp., GMK-3, 07,20-07,40 m.

3. Campylodiscus echeneis, GMK-3, 08,20-08,40 m.

4. Stephanodiscus lucens, GMK-2, 39,00-39,10 m.

5. Perissonoe cruciata, a. GMK-2, 41,00-41,10 m, b. GMK-2, 41,40-41,50 m.

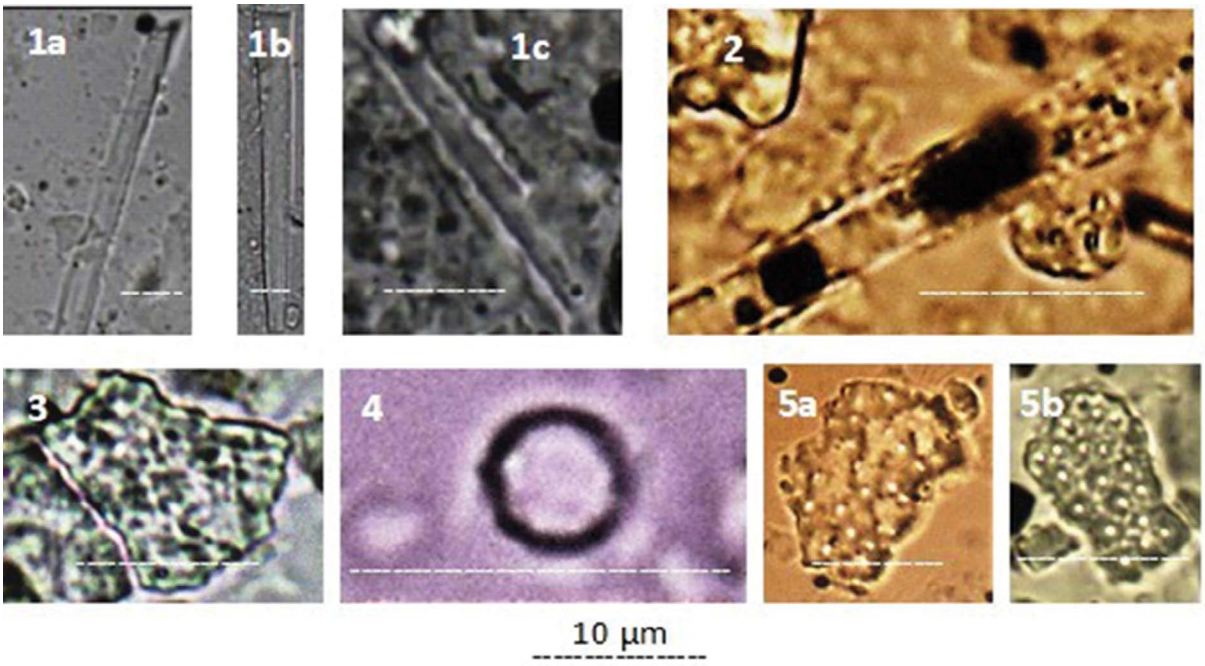

1a
1b
1c
2
3
4
5a
5b
10 µm

PLATE 3

Gastropod species found in drill samples from the Gulf of Gemlik.

1. *Phorcus mutabilis*, Gemlik-2, 40,20-40,30 m.

2. *Gibbula albida* Gemlik-1, 31,40-31,50 m.

3. *Melarhaphe neritoides*, Gemlik-1, 34,30-34,50 m.

4. *Rissoa splendida*, Gemlik-2, 38,00-38,10 m.

5. *Rissoa auriformis*, Gemlik-3, 07,20-07,40 m.

6. *Pussilina inconspicua*, Gemlik-2, 40,50-40,60 m.

7. *Pusillina lineolata*, Gemlik-1, 29,90-30,00 m.

8. *Pusillina marginata*, Gemlik-1, 30,50-30,60 m.

9. *Hyala vitrea*, Gemlik-2, 41,10-41,20 m.

10. *Euspira intricata*, Gemlik-1, 29,90-30,00 m.

11. *Epitonium clathrus*, Gemlik-1, 30,20-30,30 m.

12. *Similiphora similior*, Gemlik-1, 33,70-33,80 m.

13. *Bittium latreillii*, Gemlik-1, 33,50-33,60 m.

14. *Bittium reticulatum*, Gemlik-3, 07,20-07,40 m.

15. *Bittium submammillatum*, Gemlik-3, 06,40-06,60 m.

16. *Turritella communis*, Gemlik-2, 35,50-35,60 m.

17. *Tritia pygmaea*, Gemlik-1, 34,50-34,60 m.

18. *Sorgenfreispira brachystoma*), Gemlik-1, 35,10-35,20 m.

19. *Mangelia scabrida*, Gemlik-1, 34,00-34,10 m.

20. *Clathromangelia strigilata*, Gemlik-2, 35,50-35,60 m.

21. *Megastomia conoidea*, Gemlik-3, 06,20-06,40 m.

22. *Ondina crystallina*, Gemlik-2, 46,40-46,50 m.

23. *Eulimella acicula*, Gemlik-2, 41,80-41,90 m.

24. *Turbonilla acutissima*, Gemlik-1, 33,40-33,50 m.

25. *Parthenina juliae*, Gemlik-1, 37,60-37,70 m.

26. *Odostomia megerlei*, Gemlik-1, 34,60-34,70 m.

27. *Retusa leptoeneilema*, Gemlik-1, 34,70-34,80 m.

28. *Retusa obtusa*, Gemlik-1, 29,90-30,00 m.

29. *Cylichna cylindracea*, Gemlik-1, 30,30-30,40 m.

(Scale = 1 mm)

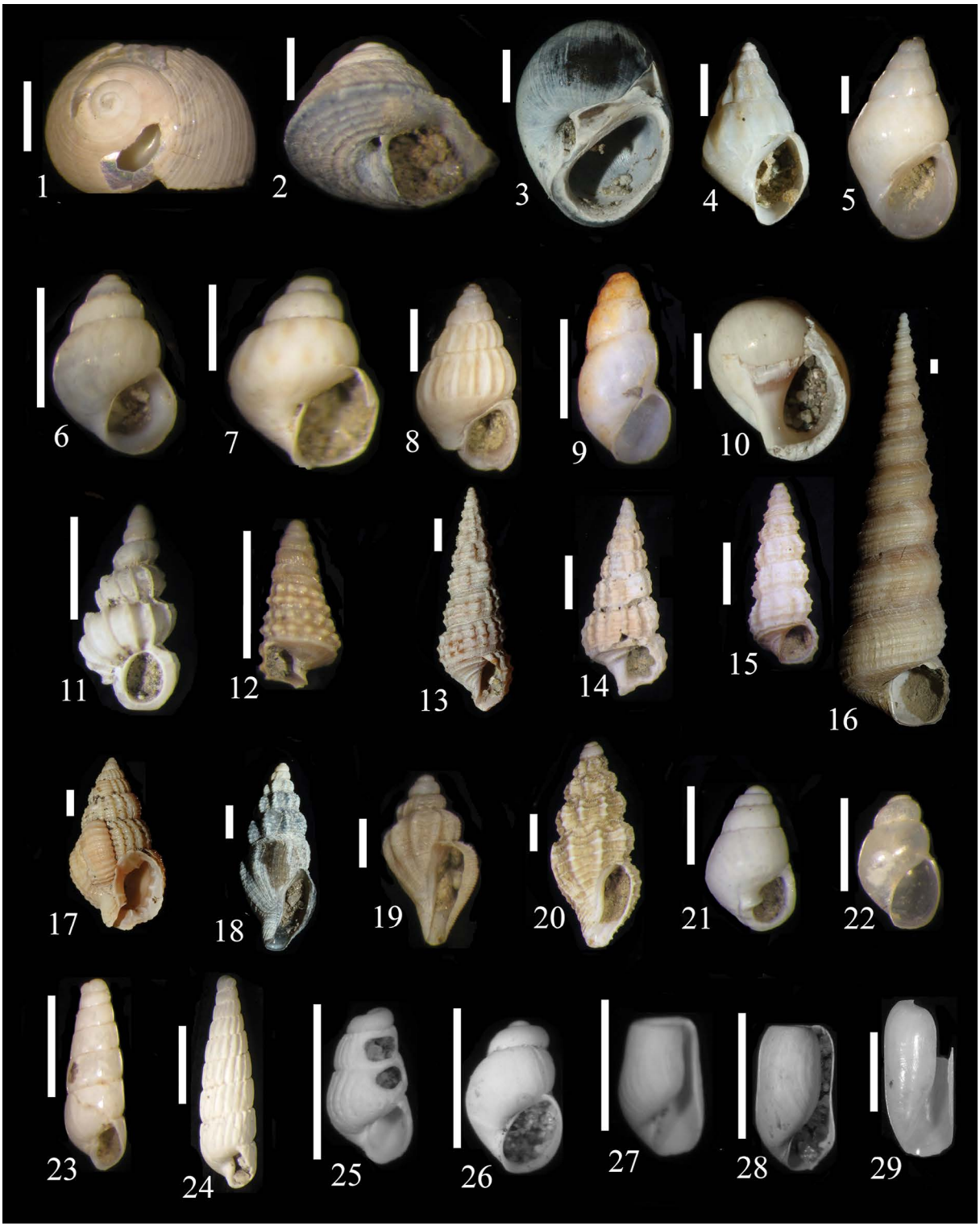

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29

PLATE 4

Bivalve species found in drill samples from the Gulf of Gemlik.

1. *Nucula hanleyi*, Gemlik-2, 42,00-42,10 m.

2. *Nucula sulcata*, Gemlik-1, 35,00-35,10 m.

3. *Lembulus pella*, Gemlik-2, 39,20-39,30 m.

4. *Mytilus galloprovincialis*, Gemlik-3, 08,80-09,00 m.

5. *Ostrea edulis*, Gemlik-3, 06,20-06,40 m.

6. *Musculus subpictus*, Gemlik-1, 29,00-29,10 m.

7. *Modiolula phaseolina*, Gemlik-2, 44,60-44,70 m.

8. *Ctena decussata*, Gemlik-1, 34,00-34,10 m.

9. *Lucinella divaricata*, Gemlik-1, 28,10-28,20 m.

10. *Myrtea spinifera*, Gemlik-1, 27,80-27,90 m.

11. *Kurtiella bidentata*, Gemlik-1, 28,80-28,90 m.

12. *Acanthocardia paucicostata*, Gemlik-1, 27,90-28,00 m.

13. *Parvicardium scriptum*, Gemlik-1, 27,70-27,80 m.

14. *Papillicardium papillosum*, Gemlik-1, 3,30-33,40 m.

15. *Spisula solida*, Gemlik-2, 36,80-36,90 m.

16. *Spisula subtruncata*, Gemlik-1, 34,10-34,20 m.

17. *Abra prismatica*, Gemlik-2, 37,70-37,80 m.

18. *Atlantella pulchella*, Gemlik-1, 32,80-32,90 m.

19. *Timoclea ovata*, Gemlik-1, 27,80-27,90 m.

20. *Gouldia minima*, Gemlik-1, 33,60-33,70 m.

21. *Pitar mediterraneus*, Gemlik-1, 34,20-34,30 m.

22. *Pitar rudis*, Gemlik-1, 34,20-34,30 m.

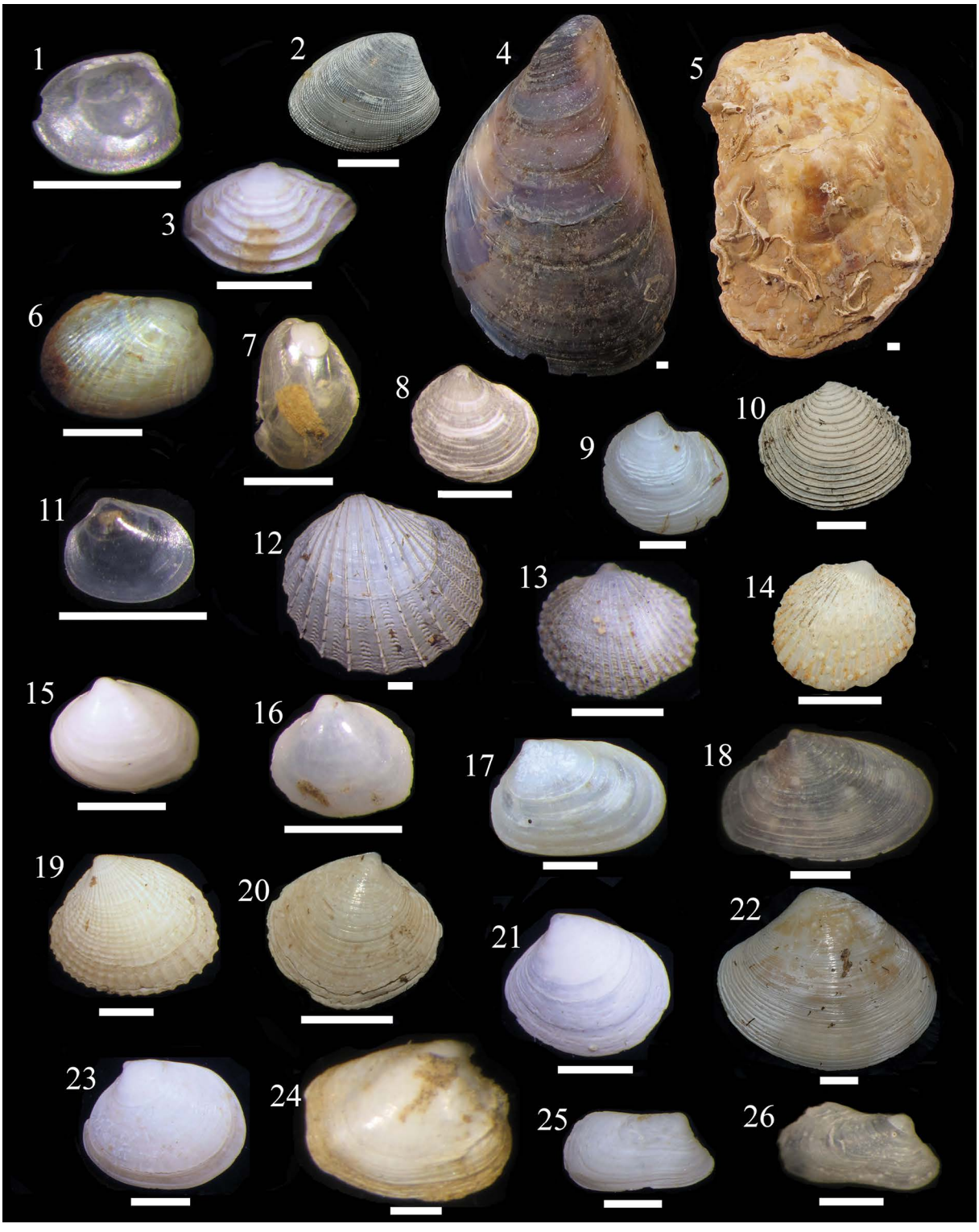
23. *Ruditapes decussatus*, Gemlik-1, 34,20-34,30 m.

24. *Corbula gibba*, Gemlik-2, 42,10-42,20 m.

25. *Hiatella arctica*, Gemlik-1, 33,40-33,50 m.

26. *Hiatella rugosa*, Gemlik-3, 6,40-6,60 m.

(Scale = 1 mm)


1
2
4
5
3
6
7
8
10
9
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26