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## Ecology of benthic foraminifera of the eastern Aegean Sea coasts

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### Abstract

The aim of this study was to determine the distribution of benthic foraminifera in some field of the Turkish Aegean coasts have been investigated and the effects of ecological changes observed on these fauna in 2009-2014 period. Sediment samples from Alibey and Maden Islands (Balıkesir), Kuşadası (Aydın), Çeşme Ilıca Bay (Izmir) and northwestern coast of Karaburun Peninsula (Izmir) have been analysed. Similarities, as well as dissimilarities were observed between the assemblages from different locations. The Red Sea originated alien foraminifer *Amphistegina lobifera* Larsen was found to form a very dense population around the south and west part of a submarine spring water in Kuşadası, where as it was replaced by *Ammonia compacta* Cushman and *Elphidium crispum* (Linné) assemblages on the northern and eastern parts. *Euthymonacha polita* (Chapman) has been first recorded in Kuşadası and it is also abundant in the Ilıca Bay. The Red Sea originated *Coscinospira acicularis* (Batsch) has also been first recorded in the Mediterranean from Ilıca Bay. Presence of the individuals with colored tests indicates the presence of heavy metals in spring waters. Aberrant aperture morphologies observed in some of the *Vertebralina striata* d'Orbigny individuals attracts attention. Therefore, abundance of individuals with colored tests, morphological deformities or togetherness, as well as the Red Sea originated species have indicated the special environmental and ecological conditions around the submarine springs. The main reasons for these ecological changes are salinity changes, the presence of heavy metals, thermal springs and cold-water springs. It is noteworthy that there is a different benthic foraminiferal living due to physical and chemical changes in the regions where different ecological conditions develop around the submarine thermal / cold water springs observed in these coastal regions.

**Keywords:** Alibey and Maden Islands (Ayvalık, W-TR coasts), Benthic Foraminifer, Ecological Factors, Ilıca Bay, Karaburun Peninsula, Gulf of Kuşadası.

### Introduction

Morphological differences have been observed in the tests of benthic foraminifers from recent sediment samples collected at different locations and depths on the Turkish Aegean and Levantine coast (Meriç et al., 2002, 2003b, 2009b). Alterations in the ecological conditions have been found to be the main reason causing these kinds of morphological abnormalities. Besides the studies performed by researchers from various countries, in our previous studies also we have shown that extreme salinity, rapid changes in salinity, presence of heavy metals and trace elements, both thermal and cold water submarine springs and the chemical compositions of the submarine spring waters in karstic regions are suggested to be the main factors which cause changes ecological conditions (Nigam et al., 2006; Meriç et al., 2003a, b, 2009a, b, c, 2010, 2012a, b; Okuş et al., 2004, 2006, 2010; Yokeş et al., 2014; Simav, et al., 2015; Meriç et al., 2016; Demir et al., 2016; Gazioglu, 2018; Duman et al., 2019).

Our recent studies conducted on the eastern Aegean Sea coasts of revealed similarities and dissimilarities in the foraminiferal assemblages from located around Alibey and Maden islands, Çeşme Ilıca Bay (Izmir), northwestern coast of Karaburun Peninsula and Gulf of Kuşadası (Figure 1 a-d). The Aegean Sea coast of Turkey, both in the sea and near-shore areas include hot and cold-water outlets (Çağlar, 1946; Başkan & Canik, 1983). In addition, a large number of mineral deposits are known to exist in the region. Therefore, mineral deposits in the underground or the mineral concentration of ground water was carried to the sea by various rivers to the benthic foraminifera and trace elements survived an impact on coastal areas provide a well-known fact (Yalçın et al., 2008; Meriç et al., 2009b). Numerous hot water springs are found around Gulf of Kuşadası.

The thermal mineral waters have a temperature range of 19-64 oC (Figure 1d) (Yenal et al., 1974; Barut et al., 2004). In Doganbey Cape (Seferihisar), there are terrestrial as well as submarine springs, of which the

temperatures range between 66-70oC. The variations observed in the concentrations of the elements are noteworthy. The concentration of Br is much above the average values reported for earth's crust (2.5 mg/l), sandstone (1 mg/l) and limestone (6.2 mg/l) (Turekian & Wedepohl, 1961; Mason & Moore, 1982). Even though trace level of heavy metals that have been disposed into the natural environment due to human activities, in time

they accumulate in soil, water, sediments as well as in plants and animals. Inspired by a study done in the western part of Greenland (Elberling et al., 2003) a similar research was carried out in the present study basing upon the samples of the cores cut at the seafloor stations located around Alibey and Maden islands (Figure 1a) (Meriç et al., 2009c, 2017).

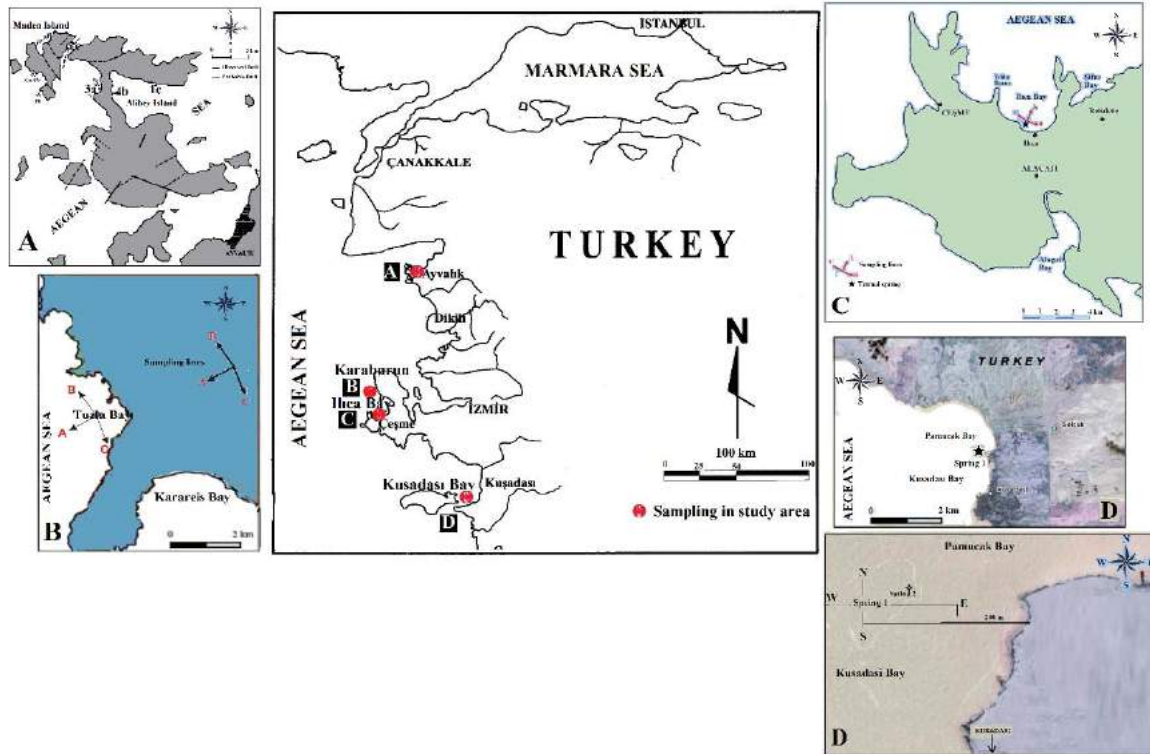


Fig. 1. Location map of study areas.

Those islands are located along southern coast of the Gulf of Edremit which is NE extension of Aegean Sea. Part of the recent sediments deposited in study area is red-brown in color. Coloured tests and morphological disorders related to *Peneroplis* are interesting occurrences to notify. The test views of foraminifera also include various abnormal individuals in the second locality Karaburun Peninsula (Figure 1b) (Meriç et al., 2012b). Transported of heavy metals and trace elements to marine environment in the northern part of the Karaburun Peninsula (Figure 1b) were related to Karareis mercury mine bedrock and numerous fault systems, NE-SW partly, NW-SE, N-S (Çakmakoğlu & Bilgin, 2006). A rich foraminifer assemblages were observed around a submarine spring located 200 m of the shore in Pamucak Bay (Kuşadası, Aydın) (Figure 1d), at a depth of 12.40 m. The temperature of the springs was 19.6 oC (Yokeş et al., 2014). The Red Sea species, *Amphistegina lobifera* Larsen was found to be the dominant species on the southern and western part of the spring.

Another such thermal water as submarine spring water which is located at a depth of 2.50 m on Yıldız Cape, Ilıca Bay (Çeşme-Izmir) (Figure 1c) was investigated for its recent benthic foraminifera assemblages. The thirty-eight surface sediment samples have been collected on 3 transects.

The Pacific Ocean and the Red Sea originated benthic foraminifera were abundantly observed (Meriç et al., 2012a).

The distribution pattern of the species, site specific abundance of Indo-Pacific originated ones, the presence of morphological abnormalities in test structure together with color formation were found to be noteworthy (Meriç et al., 2010, 2011, 2012a, b). Known that like it is observed on the land, the submarine springs and spas found on the Aegean coasts create special ecological conditions which cause the formation of benthic foraminifer assemblages different than observed in other locations. Different living conditions were occurred around thermal spas in submarine spring waters in according structure fault lines (Meriç et al., 2003a, b, 2012a; Yalçın et al., 2008).

The aim of this study was to evaluate by the effects of physical, chemical and radioactive properties of the environmental conditions on the foraminiferal assemblages, by means of abnormal individuals with colored tests and/or morphological deformity, abundance pattern, individuals with abnormal togetherness and aliens species around Alibey and Maden islands (Ayvalık), NE and SW Karaburun Peninsula, Ilıca Bay and Gulf of Kuşadası.

## Material and Methods

Sediment samples were manually collected by a plastic shovel during SCUBA diving in locations of Karaburun Peninsula (İzmir), Ilica (Çeşme) and Gulf of Kuşadası, and at distances of 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90 and 100 m in lines. Of total 90 samples taken on 07.11.2008, 45 were taken from the SW part of Karaburun Peninsula (Karaburun-I) on lines A (210°), B (125°) and C (290°), and 45 further samples were taken (Figure 1b, Table 1).

Thirty-eight sediment samples were collected around the submarine spring water in the Ilica Bay in November 2008 (Figure 1c, Table 1). Taking the center of this spring as the starting point (coordinates: 0444185 E and 4240949 N) three transect lines were determined with different angles set (Line A 210°, Line B 120° and Line C 292°). In the first 50 m from the spring, sediment samples were collected at each 5 m distance and at each 10 m distance between 50-100 m. But because of a jetty, samples could not be obtained on line A after 40 m of distance. The spring temperature was measured as 28.4°C. A total of eleven cores were taken at four stations located north of the Alibey Island (3 sites) and east of the Maden Island (Figure 1a, Table 1). The cores were split longitudinally into two halves. One-half of each core was used for microfaunal investigation. The foraminifera samples were taken every 2 cm. Two cm sampling interval is applied for benthic foraminifer investigations.

For paleontological analyses in all sampling five grams of wet sediment samples were weighed and 10% hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) was added for 24 hours. Then these samples were washed by pressurized water in a 0.063 mm mesh size sieve. Remaining coarser residues in the sieve were dried in an oven at 50°C temperature. The dried samples were progressively sieved through 2.00, 1.00, 0.500, 0.250, 0.125 mm mesh sizes (Babin, 1980; Bignot, 1985) and then examined under binocular microscope in order to determine characteristics of the fauna. Almost all the samples contained *Amphistegina lobifera* Larsen individuals 0.50 mm - 1.00 mm in size. Although a rich foraminifer fauna was observed over the 0.25 mm and 0.125 mm mesh sized sieve, *Amphistegina lobifera* Larsen individuals were very scarce.

For laboratory analyses of the samples that in Alibey and Maden islands, in Karaburun Peninsula and in Ilica Bay (Çeşme) were performed elemental chemical analysis conducted in CNAEM (Cekmece Nuclear Research and Training Center) by Wavelength Dispersive X-ray Fluorescence (WDXRF) Spectrophotometry. Recordings of the solid, liquid and gas samples were obtained at ppm level and bbp level was reached when pre-enrichment was done. Quantitative and qualitative analysis of the elements between Boron (B) and Uranium (U) were performed using X0 ray tube, various crystals (LiF220, PX10, GeIII-C, PE 202-C), two receptors, collimators with various

sizes and characteristics and by a computer program. Before analysis, samples were ground to 200 mesh size and dried in desiccator. 12g of dried sample was mixed with 3g of wax, placed in 40mm mold and pelleted under 35 ton of pressure. Electron microprobe quantitative analysis was performed by computer controlled JEOL-733 electron microprobe instrument and online ZAFM quantitative analysis program.

In the Gulf of Kuşadası of spring water was measured at it was center and four vertical lines were set on south, north, east and west directions (Figure 1d, Table 1). A total of 45 sediment samples were collected at around the submarine spring water from different points on the lines in Kuşadası-Pamucak Bay (Figure 1d, Table 1). The spring water was located 200 m of the coast at 12.4 m depth and its temperature was 19.6°C. Temperature and depth of the seawater were manually measured on the Gulf of Kuşadası samples. Seawater samples taken for the quality and quantity of phytoplankton cells were transferred to 1000 ml capacity PVC containers and fixed with borax buffered formaldehyde (10 ml/l) and transferred to Istanbul University Institute of Marine Sciences and Management, Biology Laboratory in 24 hours. The Hg values were measured in Shimadzu 6701 AAS Hydride Unit in Istanbul University Institute of Marine Sciences and Management, Marine Chemistry Laboratory.

For heavy metal and trace element (Al, Si, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Hg ve Pb) analysis water sample was collected in 0.5 l polyethylene bottle containing 2ml HCl. The analyses were done in Çukurova University, Faculty of Engineering and Architecture, Department of Geology, Geochemistry Laboratory. Since the sample was liquid, it is directly used for the analysis with Atomic Absorbance Spectrophotometer 700. For As and Hg readings, the elements were reduced with sodium borohydride before measurement. Hg readings were measured in Shimadzu 6701 AAS Hydride Unit in Istanbul University Institute of Marine Sciences and Management, Marine Chemistry Laboratory. The spring water was frozen without adding any preservatives and sent to TÜBİTAK MAM Institute of Chemistry and Environment laboratory as quick as possible for nutrient analysis. N, P, Si, NH<sub>3</sub>, total nitrogen and total phosphate analysis were measured by autoanalyser.

## Results

### Benthic Foraminifer Assemblages

The foraminifer assemblage found around Maden and Alibey islands (Ayvalık) is composed of 29 genera and 52 species (systematics after Loeblich & Tappan, 1988) (Appendix 1). Foraminiferal assemblages observed in the study area is not rich as the assemblages that have been encountered in the other studied areas in eastern Aegean coastline.

Table 1. Line, distance, depth and water temperature measurements and the distribution of *Amphistegina lobifera* Larsen individuals among sediment samples from Kuşadası.

	Line	Horizontal distance	Side	Depth (m)	Water temperature (°C)	Number of <i>Amphistegina lobifera</i>
KUŞADASI	A	From spring	From spring	12.4	19.6	305
	A	5 m	South	11.1	17.5	262
	A	10 m	South	9.7	17.5	627
	A	15 m	South	9.2	17.5	753
	A	20 m	South	9.5	17.5	866
	A	25 m	South	10.5	17.5	1072
	A	30 m	South	11.3	17.5	368
	A	35 m	South	12.3	17.5	154
	A	40 m	South	12.5	17.5	116
	A	45 m	South	13.7	17.5	185
	A	50 m	South	14.9	17.5	93
	B	5 m	North	8.9	17.5	76
	B	10 m	North	8.5	17.5	71
	B	15 m	North	8.7	17.5	30
	B	20 m	North	9.0	17.5	41
	B	25 m	North	10.1	17.5	16
	B	30 m	North	10.9	17.5	18
	B	35 m	North	12	17.5	34
	B	40 m	North	13.1	17.5	20
	B	45 m	North	14.2	17.5	9
	B	50 m	North	20.1	17.5	5
	C	5 m	West	9.1	17.5	1954
	C	10 m	West	9.3	17.5	303
	C	15 m	West	11.3	17.5	639
	C	20 m	West	12.8	17.5	374
	C	25 m	West	14.7	17.5	242
	C	30 m	West	17.3	17.5	72
	C	35 m	West	17.9	17.5	55
	C	40 m	West	18.2	17.5	65
	C	45 m	West	22.3	17.5	12
	D	5 m	East	12.8	17.5	153
	D	10 m	East	11.9	17.5	44
	D	15 m	East	12.1	17.5	149
	D	20 m	East	11.5	17.5	161
	D	25 m	East	14.4	17.5	121
	D	30 m	East	15.3	17.5	77
	D	35 m	East	15.9	17.5	127
	D	40 m	East	18.1	17.5	109
	D	45 m	East	19.1	17.5	8
	D	50 m	East	19.5	17.5	1
D	60 m	East	19.4	17.5	2	
D	70 m	East	19.1	17.5	1	
D	80 m	East	20.2	17.5	0	
D	90 m	East	20.1	17.5	0	
D	100 m	East	20.2	17.5	3	

Table 2. Line, distance, depth and water temperature measurements and the distribution of *Amphistegina lobifera* Larsen individuals among sediment samples from Karaburun-I, Ayvalık and Çeşme-İlica.

	Line	Horizontal distance	Side	Depth (m)	Water temperature (°C)	Number of <i>Amphistegina lobifera</i>
KARABURUN -I	A	5	Southwest	1	17.8	6
	A	10	Southwest	1.1	17.6	6
	A	15	Southwest	1.8	17.6	7
	A	20	Southwest	2.5	17.6	15
	A	25	Southwest	3.2	17.2	16
	A	30	Southwest	3.8	17.2	12
	A	35	Southwest	4.9	17	88
	A	40	Southwest	6.6	17	69
	A	45	Southwest	7.6	16.8	76
	A	50	Southwest	9.1	16.8	61
	A	60	Southwest	11.8	16.8	92
	A	70	Southwest	13.9	16.8	27
	A	80	Southwest	15.3	16.7	19
	A	90	Southwest	17.5	16.7	4
	A	100	Southwest	19.3	16.7	1
	B	5	Northwest	1	17.6	1
	B	10	Northwest	1	17.6	0
	B	15	Northwest	1	17.6	5
	B	20	Northwest	1	17.6	8
	B	25	Northwest	1	17.4	1
	B	30	Northwest	1.2	17.2	1
	B	35	Northwest	1.2	17.2	4
	B	40	Northwest	1.2	17.2	2
	B	45	Northwest	1.4	17	4
	B	50	Northwest	1.4	17	0
	B	60	Northwest	1.6	17	3
	B	70	Northwest	2	17	2
	B	80	Northwest	1.9	17	1
	B	90	Northwest	2.3	17	0
	B	100	Northwest	2.4	17	0
	C	5	Southeast	1.2	17.2	3
	C	10	Southeast	1.4	17.1	3
	C	15	Southeast	1.7	17.1	3
	C	20	Southeast	2	17.1	15
	C	25	Southeast	2.3	16.9	7
	C	30	Southeast	2.3	16.9	11
	C	35	Southeast	2.4	16.9	32
	C	40	Southeast	2.5	16.9	30
	C	45	Southeast	2.7	16.9	25
C	50	Southeast	3.1	16.9	7	
C	60	Southeast	3.4	16.9	6	
C	70	Southeast	3.5	16.9	26	
C	80	Southeast	3.1	16.9	5	
C	90	Southeast	2.9	16.9	8	
C	100	Southeast	2.7	16.9	4	
AYVALIK	Core 1c			1.66-1.68		1
ÇEŞME-İLİCA						0

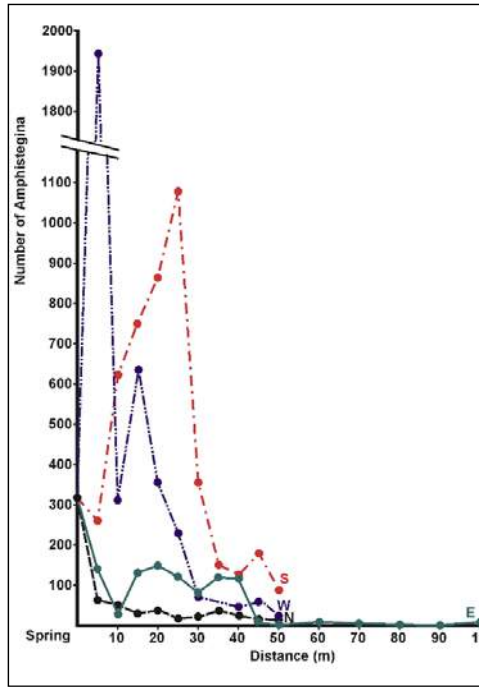


Fig. 2. The quantitative distribution pattern of *Amphistegina lobifera* Larsen sampled by east, west, north, and south directions from around the Pamucak Bay (Kuşadası) submarine water spring.

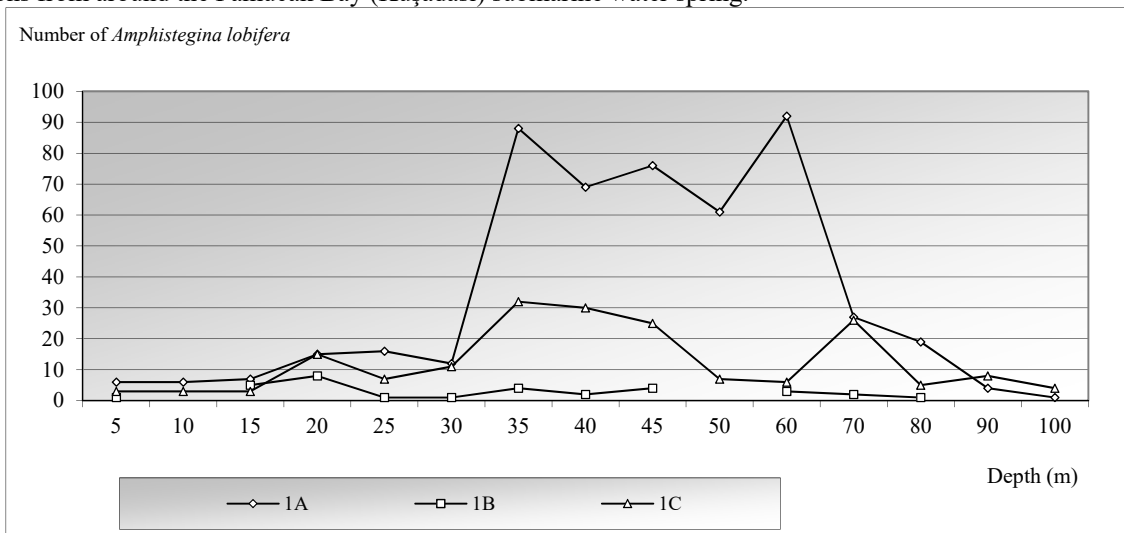


Fig. 3. The quantitative distribution pattern of *Amphistegina lobifera* Larsen sampled by directions from around the Karaburun A, B, C lines. (from Meric et al., 2012b).

In forty-five samples collected from SW of Karaburun Peninsula 48 genera and 84 species were observed (Appendix 2). The thirty-eight samples collected around the submarine spring water in Çeşme-Ilica Bay were found to contain 45 genera and 80 species of foraminifera (Appendix 3), including 10 genera and 10 species of Indo-Pacific origin; (*Nodophthalmidium antillarum* (Cushman), *Spiroloculina antillarum* d'Orbigny, *Triloculina fichteliana* d'Orbigny, *Euthymonacha polita* (Chapman), *Coscinospira acicularis* (Batsch), *Monalysium acicularis* (Batsch), *Peneroplis arietinus* (Batsch), *Amphisorus hemprichii* Ehrenberg, *Cymbaloporetta plana* (Cushman), *Amphistegina lobifera* Larsen) (Table 2, Plates 1-4; linear scale: 100 micron). A rich foraminiferal fauna was observed in Gulf of Kuşadası (Appendix 4) and

analyzed of 45 sediment samples revealed the presence of 59 genera and 103 species.

Evaluation of Alien Species, Abnormal Species with Colored Tests or Morphological Deformities or Togetherness in the Study Areas

The foraminifer assemblages showing abnormal features, such as colored tests, morphological deformities or togetherness, in Ayvalık-Alibey Maden islands which was identified beside the normal benthic foraminifer assemblage in cores (Figure 1a, 1c, 2c and 3a) is composed predominantly of *Lobatula lobatula* (Walker and Jacob), *Ammonia compacta* Hofker, *A. parkinsoniana* (d'Orbigny), *Challengerella bradyi* Billman, Hottinger and Oesterle, *Elphidium complanatum* (d'Orbigny), *E*

*crispum* (Linné); and while in core 4b *Peneroplis pertusus* (Forskal) and *P. planatus* (Fichtel and Moll) were the abundantly observed abnormal individuals. Additionally, a few specimens of *Spiroloculina angulata* (d'Orbigny),

*Cibicidella variabilis* (d'Orbigny) were found to display features similar to the abovementioned ones. A single individual of *Amphistegina lobifera* Larsen has been only observed in core (1 c) (Table 2).

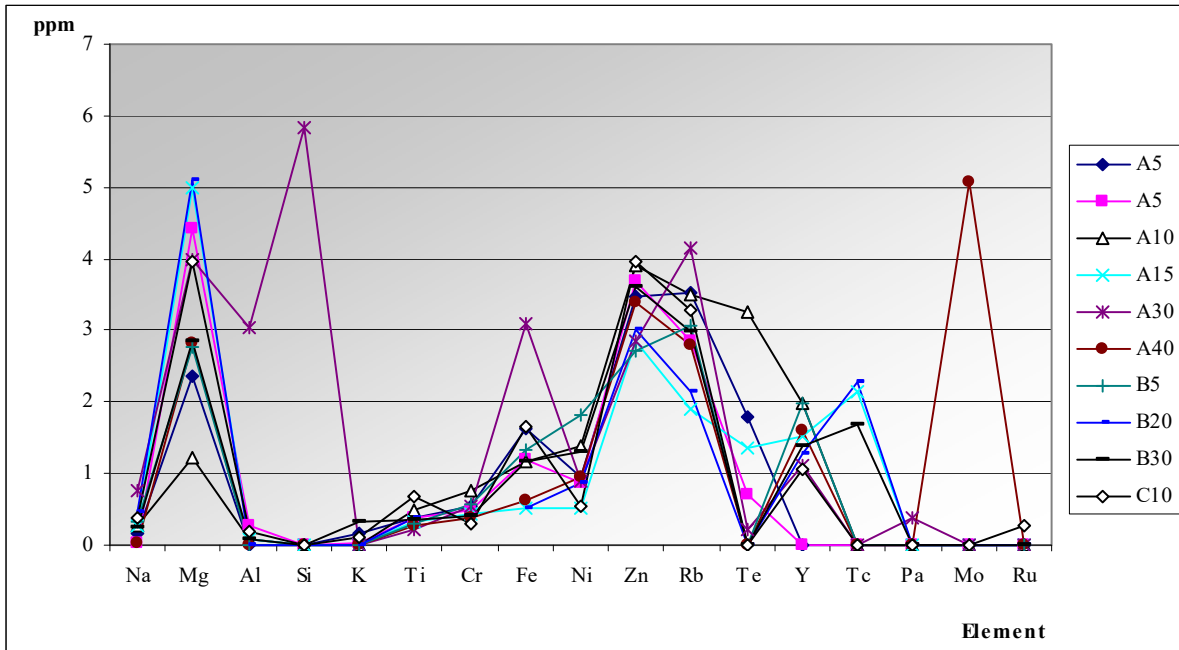


Fig. 4. Distribution of chemical analyses in coloured tests of *Peneroplis planatus* (Fichtel and Moll) in Ilıca Bay.

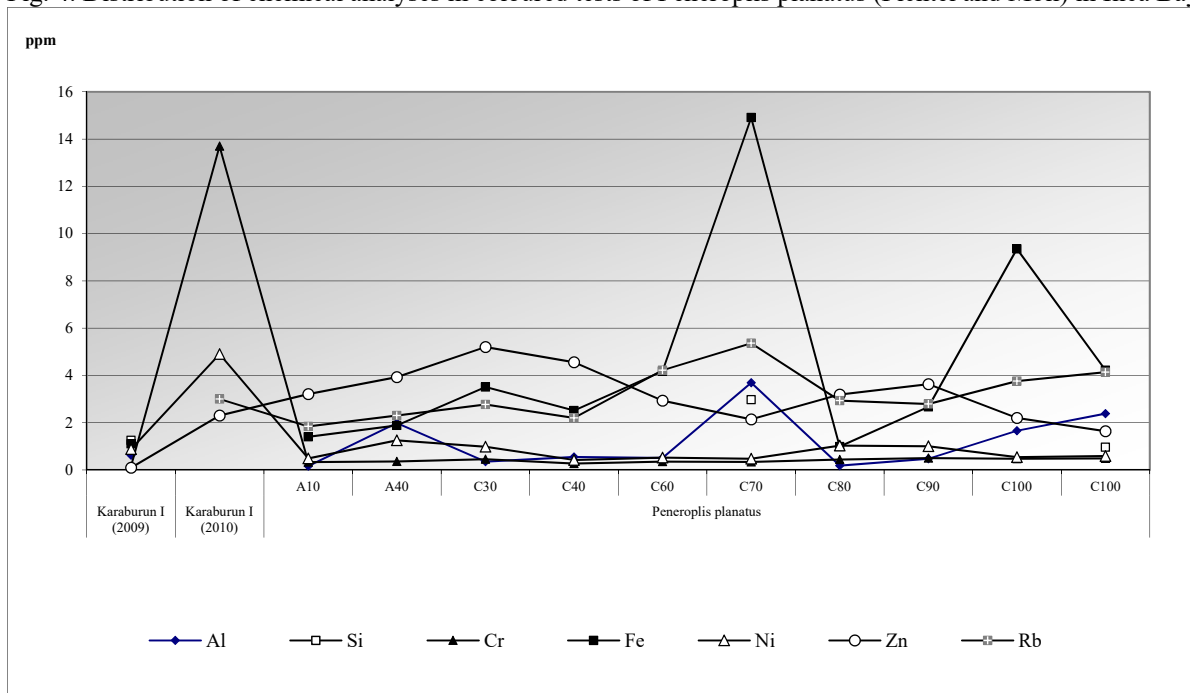


Figure 5. Distribution of heavy metal and trace elements in coloured tests of *Peneroplis planatus* in some samples and seawater in Karaburun.

Ilıca Bay (Çeşme-Izmir) was investigated for recent benthic foraminifer assemblage. The thirty-eight surface sediment samples have been collected on 3 transects. The Pacific Ocean and the Red Sea originated benthic foraminifera were abundantly observed. However *Amphistegina lobifera* Larsen specimens did not observed (Table 2). The identified species were *Nodopthalmidium antillarum* (Cushman), *Spiroloculina antillarum* d'Orbigny, *Triloculina* cf. *fichteliana* d'Orbigny, *Euthymonacha polita* (Chapman), *Coscinospira*

*acicularis* (Batsch), *Peneroplis arietinus* (Batsch), *Amphisorus hemprichii* Ehrenberg, *Sorites orbiculus* Ehrenberg, *Cymbaloporeta plana* (Cushman). Beside these species, *Peneroplis arietinus* (Batsch), *Spiroloculina antillarum* d'Orbigny, *Triloculina* cf. *fichteliana* d'Orbigny and *Cymbaloporeta plana* (Cushman) which were recorded on the SW coasts of Antalya were also found in this region. *Euthymonacha polita* (Chapman) which was first recorded (Meriç et al., 2010) in Gulf of Kuşadası is also abundant in Ilıca Bay.



This observation shows a northward spread of this species. *Coscinospira acicularis* (Batsch) is a SW Pacific originated species which is also found in Gulf of Aqaba, north of Red Sea. It is a typical immigrant species inhabiting the Ilica Bay. This is the first record of this species both for the Mediterranean and for Aegean Sea.

Major differences in foraminiferal assemblages have been observed between the eastern and western coasts on the northern part of the Karaburun Peninsula. In contrast to the rich fauna of the western coast (Table 2), a poor assemblage was found on the eastern coast, which is located in the Gulf of İzmir. A great difference in population sizes have also been observed in *Amphistegina lobifera* Larsen assemblages found on the Aegean coasts of Karaburun Peninsula and Gulf of İzmir. These individuals were in core 1a in range of 30-70 m (Figure 3). In the frame work of this study, 67 foraminifer species were identified. The most abundant species were *Ammonia tepida* Cushman, *Elphidium crispum* (Linné), *Ampicoryna scalaris* (Batsch), *Nonionella turgida* (Williamson) and *Nonion depressulum* (Walker and Jacob). Highest heavy metal pollution was observed in the inner part of the Gulf, where least number of foraminifera species observed.

It was found that all the samples in Gulf of Kuşadası included *Amphistegina lobifera* Larsen specimens with

0.50-1.00 mm sizes. A considerable amount of foraminifer specimens was observed over the 0.250 and 0.125 mm sieves, however the amount of *Amphistegina lobifera* Larsen individuals was very low. Abnormal abundance of *Amphistegina lobifera* Larsen specimens observed on the south and west of the study area is noteworthy. It shows variable distribution in the sampling locations according the direction and distance to the submarine spring water (Figure 2). The diatom analysis revealed that there is diverse and rich community of diatoms around and near this springs (Meriç et al., 2009b, 2015, 2016, 2018). Benthic foraminifer species feed on diatoms, suggesting that the abundance of diatoms may serve as an important food source for *Amphistegina lobifera* Larsen. An increase as observed in *Elphidium crispum* (Linné) and *Ammonia compacta* Hofker populations as *Amphistegina lobifera* Larsen populations decrease. The abundance of *Coscinospira hemprichii* Ehrenberg, *Peneroplis planatus* (Fichtel and Moll), *Lobatula lobatula* (Walker and Jacob), *Cibicides variabilis* (d'Orbigny) individuals have with abnormal test morphologies, and observed in *Spiroloculina angulosa* Terquem individuals have a double apertures in the study is noteworthy (Yokeş et al., 2014).

Geochemical Characteristics of the Sediments and *Peneroplis planatus* (Fichtel and Moll) Tests from the Study Area.

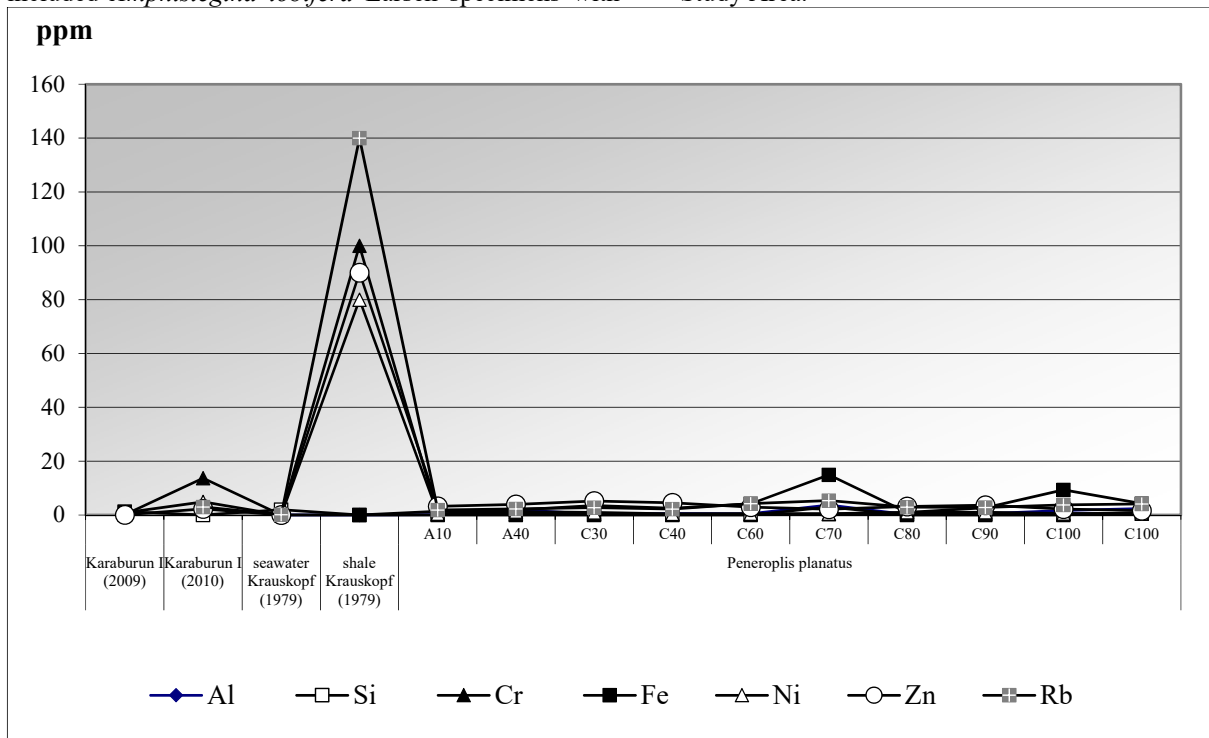


Figure 6. Distribution of heavy metal and trace elements in coloured tests of *Peneroplis planatus* in some samples and seawater in Karaburun, Krauskopf (1979) comparison with reference values for seawater and shale.

Heavy metal and trace element analysis of the colored *Peneroplis planatus* (Fichtel and Moll) samples from Çeşme-Ilica Bay showed that Ti, Cr, Te and Y had the highest values in Station A10; Na, Al, Si, Fe, Rb and Pa in A30; Mo in A40; Ni and Y in B5; Mg and Tc in B20; K in B30; Zn and Ru in C10. The geochemical content of the tests were compared to the water sample from the

Çeşme-Ilica Bay and it was found that Ti, Cr and Fe were higher in tests. When the results were compared to Krauskopf (1979) seawater reference values, high values of Mg, Al, Si, (in A30), Ti, Cr, Fe, Ni, Zn, Rb and Y attracts attention. Al, Si, Fe and Mo (A40) values were found to be higher compared to Krauskopf (1979) shale reference. Another interesting finding was the presence of

Pa (A30), Mo (A40) and Ru (C10) in only one sediment sample (Bergin et al., 2006; Meriç et al., 2012a).

Microprobe analysis of normal specimens of *Peneroplis planatus* (Fichtel and Moll) tests from the Çeşme-İlica Bay (samples A10, A15, A30, A40, B5, B20, B30 and C10) revealed that Mg, Si, Fe, Zn, Rb, Y, Tc and Mo concentrations content of the tests were not uniform in all samples (Figure 4). Mg and Tc had the highest values in A5 and B20, as Si, Fe and Rb in A30, Mo in A40. Of the elements with the lowest values, Al and Si were recorded in all tests except A30 and K was recorded in all tests except B30 (Meriç et al., 2012a, b, c). Microprobe analysis of *Peneroplis planatus* tests from Station I'in Karaburun (samples A10, A40, C30, C40, C60, C70, C80, C90 and C100) showed that the elements with the highest values were Ni in A40; Zn in C30; Zn in C70; Al, Fe and Rb in C70; Cr in C90 (Figure 5). Elements with lowest values were Al and Rb in A10; Mn and Ni in C40, Fe in C80; Zn in C100 (Meriç et al., 2012 b). In general, Zn in C30; Fe in C70 and C100 were the highest values. When geochemical findings of test analysis compared with Karaburun water sample and Krauskopf (1979) seawater reference values, Al, Cr, Fe, Zn and Rb were found to be higher. Al, Fe and Rb were higher compared to the Krauskopf (1979) shale reference (Figure 6).

*Amphistegina lobifera* Larsen is abundantly found around the two submarine springs in the Gulf of Kuşadası, which is located on the south of İlica Bay. It is also recorded on the NW coasts of the Karaburun Peninsula which is north to the study area. However, *Amphistegina lobifera* Larsen is absent in the İlica Bay, which constitutes the most important finding of this study. Si, Mg and Mo concentrations were found to be high in the tests of some of the colored *Peneroplis planatus* (Fichtel and Moll) individuals. But, rare earth elements, such as, Tc, Pa, Ru and Mo were observed in tests obtained from some sampling points.

## Discussion and Conclusion

Along the Turkish Aegean coast, alien benthic foraminifer species have been observed around the submarine springs. However, abundance of individuals with colored tests, morphological deformities and togetherness, as well as the origin of alien species suggests the presence of special environmental as well as ecological conditions around the spring water, different from the other parts of Turkish coasts. *Peneroplis arietinus*, *Cymbaloporeta plana* and *Amphisorus hemprichii* are observed very abundant in the Gulf of İlica and on SW coasts of Turkey. *Sorites orbiculus* also were observed commonly along the coast of SW Turkey.

The identified species are *Nodophthalmidium antillarum* (Cushman), *Spiroloculina antillarum* d'Orbigny, *Triloculina fichteliana* d'Orbigny, *Euthymonacha polita* (Chapman), *Coscinospira acicularis* (Batsch), *Peneroplis arietinus* (Batsch), *Amphisorus hemprichii* Ehrenberg, *Sorites orbiculus* Ehrenberg, *Cymbaloporeta plana* (Cushman). Besides, *Peneroplis arietinus* (Batsch), *Spiroloculina antillarum* d'Orbigny, *Triloculina*

*fichteliana* d'Orbigny and *Cymbaloporeta plana* (Cushman), which have been previously recorded from southwestern Antalya were also recorded in the İlica Bay (Meriç et al., 2012a).

The presence of hot water submarine spring water is a common characteristic of Kuşadası Pamucak Bay and Çeşme-İlica Bay. The Pacific and Red Sea originated alien benthic foraminifer species can reach these spots with various ways and not only survive around these springs, but also show south to north expansions (Meriç et al., 2010, 2011). In each three locations Peneroplid and Hauerinid individuals with colored tests were found. Peneroplid individuals with abnormal test morphology were also abundant in these locations. Pacific originated *Euthymonacha polita* (Chapman) has been first recorded in the Mediterranean Sea from Kuşadası-Pamucak Bay. On the northern and eastern parts of the Pamucak Bay the populations of alien species decreases and the assemblages of *Ammonia compacta* Cushman and *Elphidium crispum* (Linné) become dominant.

The abnormal togetherness of *Vertebralina striata* d'Orbigny and *Coscinospira hemprichii* Ehrenberg was also observed in Pamucak Bay. In previous studies togetherness of *Peneroplis pertusus* and *P. planatus*, *Peneroplis planatus* and *Coscinospira hemprichii*, *Peneroplis pertusus* and *Coscinospira hemprichii* have been observed (Meriç et al., 2008b, c, 2012c).

On the other hand, *Amphistegina lobifera* Larsen which was abundantly found in Kuşadası-Pamucak Bay (Figure 2) and on west coast of Karaburun Peninsula was not observed in other locations. In Pamucak Bay, 1954 individuals were recorded in 5 gr of sediment, whereas 92 individuals were found in the 46 sediment samples from northwest Karaburun Peninsula, only a single specimen was found in the 17 sediment samples from Dilek Peninsula and none was found in İlica Bay.

*Euthymonacha polita* (Chapman) has been first recorded on Turkish coastline from Gulf of Kuşadası and it was abundantly observed in İlica Bay. The finding of an established population of *Coscinospira acicularis* (Batsch), which is found in Gulf of Aqaba (Red Sea), constituted the first record of this species from the Aegean Sea, as well as from the Mediterranean (Meriç et al., 2008a). The abundance foraminifer specimens with colored tests and conjoined twins of *Peneroplis planatus* (Fichtel and Moll)- *Peneroplis pertusus* (Forskal), abnormal aperture morphology observed in some *Vertebralina striata* d'Orbigny individuals are also characteristics of the region.

Atlantic originated benthic foraminifer *Iridia diaphana* Heron-Allen and Earland, Red Sea / Pacific originated benthic species *Nodophthalmidium antillarum* (Cushman), *Triloculina fichteliana* d'Orbigny, *Euthymonacha polita* (Chapman), *Peneroplis arietinus* (Batsch), *Sorites orbiculus* Ehrenberg, *S. variabilis* Lacroix, *Cymbaloporeta plana* (Cushman) *C. squamosa* (d'Orbigny) and *Amphistegina lobifera* Larsen were found on the northwest coasts of Karaburun Peninsula.

*Amphistegina lobifera* Larsen was the most abundant of all (Meriç et al., 2012b). Although a submarine spring was not located in the study area, the presence of many fault lines found in the vicinity suggests that there might be water exits on the sea floor.

A typical Mediterranean foraminifer fauna was observed around the investigated submarine spring. *Ammonia compacta* Hofker and *Elphidium crispum* (Linné) were found to be the highly dominating species on the eastern line. On the other hand, the observation of Indo-Pacific originated species *Quinqueloculina* sp. C, *Triloculina* sp. A, *Euthymonacha polita* (Chapman), *Pyramidulina catesbyi* (d'Orbigny), *Brizalina simpsoni* (Heron-Allen and Earland), *Amphistegina lessonii* d'Orbigny for the first time on the Turkish coastline is noteworthy. *Amphistegina lessonii* d'Orbigny was previously reported from northwest of Crete Island (Hollaus and Hottinger, 1997) and Andros Island in the Middle Aegean Sea (Triantaphyllou et al., 2005, 2012; Langer et al., 2012). Besides, *Haddonina* sp. and *Cymbaloporetta plana* (Cushman), which are abundant on the southwestern coast of Turkey, *Iridia diaphana* Heron-Allen and Earland which is recorded in Ayvalık (North Aegean), were represented in the sediment with few individuals. *Nodopthalmidium antillarum* (Cushman) which was known from Gulf of Iskenderun and *Adelosina carinata-striata* Wiesner which was rarely observed on the Aegean coasts were found to be abundant in the study area.

The chemical compositions show that these thermal springs have carbonated sulphated waters with high Na, K and Mg concentrations and carbonate hardness exceeds 50%. Alkaline elements (Na, K) have higher values compared to the alkaline earth elements (Ca, Mg). Na, Ca and K are the most abundant cations, where is the most abundant anions are Cl, HCO<sub>3</sub> and SO<sub>4</sub>, suggesting that the waters are coming through limestones. These thermal waters have radioactive characteristics. Total alpha and total beta Rn<sup>222</sup> values are higher in Kemerli, Kuşadası Spring and Cumalı. Total alpha values are ranging between 0.50±5.07(6)-4.57±27.23 (5) Bq/l, whereas total beta values are found to be 2.29±5.11 (2)- 22.19±26.61 (1) Bq/l (Yokeş et al., 2014).

As a result, the environmental conditions created by the submarine springs on the Eastern Aegean coasts affect the benthic foraminifers. Abundance of individuals with colored tests and Red Sea originated benthic species suggests the presence of environmental and ecological conditions special to the vicinity of the spring. Physical (temperature, salinity, pH, depth of submarine spring water), properties of chemical concentrations and radioactivity levels of the submarine spring waters play a role in the formation of the foraminiferal assemblages.

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## Appendix 1

Maden and Alibey islands- Ayvalık (Balıkesir, NE Aegean Sea):

*Rhabdammina abyssorum* Sars, *Iridia diaphana* Heron-Allen and Earland, *Eggerelloides scabrus* (Williamson), *Textularia bocki* Höglund, *Vertebralina striata* d'Orbigny, *Nubecularia lucifuga* Defrance, *Adelosina cliarensis* (Heron-Allen and Earland), *A. duthiersi* Schlumberger, *A. mediterraneensis* (Le Calvez J. and Y.), *A. partschi* (d'Orbigny), *A. pulchella* d'Orbigny, *Spiroloculina angulata* d'Orbigny, *S. angulosa* Terquem, *S. antillarum* d'Orbigny, *S. depressa* d'Orbigny, *S. excavata* d'Orbigny, *S. ornata* d'Orbigny, *Siphonaperta agglutinans* (d'Orbigny), *S. aspera* (d'Orbigny), *Cycloforina contorta* (d'Orbigny), *C. villafranca* (Le Calvez J. and Y.), *Lachlanella undulata* (d'Orbigny), *L. variolata* (d'Orbigny), *Massilina secans* (d'Orbigny), *Quinqueloculina berthelotiana* d'Orbigny, *Q. bidentata* d'Orbigny, *Q. disparilis* d'Orbigny, *Q. jugosa* Cushman, *Q. lamarckiana* d'Orbigny, *Q. laevigata* d'Orbigny, *Q. seminula* (Linné), *Miliolinella dilatata* (d'Orbigny), *M. labiosa* (d'Orbigny), *M. semicostata* (Wiesner), *M. subrotunda* (Montagu), *M. webbiana* (d'Orbigny), *Pseudotriloculina laevigata* (d'Orbigny), *P. oblonga* (Montagu), *P. rotunda* (d'Orbigny), *P. sidebottomi* (Martinotti), *Pyrgo anomala* (Schlumberger), *Triloculina marioni* Schlumberger, *T. plicata* Turquem, *T. schreiberiana* d'Orbigny, *Wellmanellina striata* (Sidebottom), *Sigmolinita costata* (Schlumberger), *Parrina bradyi* (Millet), *Coscinospira hemprichii* Ehrenberg, *Laevipeneroplis karreri* (Wiesner), *Peneroplis pertusus* (Forskal), *P. planatus* (Fichtel and Moll), *Sorites orbiculus* Ehrenberg, *Polymorphina* sp. 1 and 3, *Neoepionides bradyi* (Le Calvez), *Neoconorbina terquemi* (Rzehak), *Rosalina bradyi* Cushman, *R. globularis* d'Orbigny, *Conorbella imperatoria* (d'Orbigny), *Lobatula lobatula* (Walker and Jacob), *Planorbulina mediterraneensis* d'Orbigny, *Cibicides variabilis* (d'Orbigny), *Acervulina inhaerens* Schultze, *Sphaerogypsina globula* (Reuss), *Asterigerinata mamilla* (Williamson), *Amphistegina lobifera* Larsen, *Nonion depressulum* (Walker and Jacob), *Ammonia compacta* Hofker, *A. parkinsoniana* (d'Orbigny), *A. tepida* Cushman, *Challengerella bradyi* Billman, Hottinger and Oesterle, *Cribolephidium poeyanum* (d'Orbigny), *Porosonion subgranosum* (Egger), *Elphidium aculeatum* (d'Orbigny), *E. advenum* (Cushman), *E. complanatum* (d'Orbigny), *E. crispum* (Linné), *E. depressulum* Cushman, *E. macellum* (Fichtel and Moll) and *Elphidium* sp.

## Appendix 2

Karaburun Peninsula:

*Iridia diaphana* Heron-Allen and Earland, *Rhabdammina abyssorum* Sars, *Eggerelloides scabrus* (Williamson), *Textularia bocki* Höglund, *Vertebralina striata* d'Orbigny, *Wiesnerella auriculata* (Egger), *Nodophthalmidium antillarum* (Cushman), *Nubecularia lucifuga* Defrance, *Adelosina carinata-striata* Wiesner, *A. cliarensis* (Heron-Allen and Earland), *A. duthiersi* Schlumberger, *A. mediterraneensis* (Le Calvez J. and Y.), *Spiroloculina angulosa* Terquem, *S. depressa* d'Orbigny, *S. excavata* d'Orbigny, *S. ornata* d'Orbigny, *Siphonaperta agglutinans* (d'Orbigny), *S. aspera* (d'Orbigny), *Cycloforina contorta* (d'Orbigny), *C. villafranca* (Le Calvez J. and Y.), *Lachlanella undulata* (d'Orbigny), *L. variolata* (d'Orbigny), *Massilina gualteriana* (d'Orbigny), *M. secans* (d'Orbigny), *Quinqueloculina berthelotiana* d'Orbigny, *Q. bidentata* d'Orbigny, *Q. disparilis* d'Orbigny, *Q. lamarckiana* d'Orbigny, *Q. seminula* (Linné), *Q. vulgaris* d'Orbigny, *Miliolinella elongata* Kruij, *M. semicostata* (Wiesner), *M. subrotunda* (Montagu), *M. webbiana* (d'Orbigny), *Pseudotriloculina laevigata* (d'Orbigny), *P. oblonga* (Montagu), *P. rotunda* (d'Orbigny), *P. sidebottomi* (Martinotti), *Pyrgo elongata* (d'Orbigny), *Triloculina* cf. *bermudezi* Acosta, *T. fichteliana* d'Orbigny, *T. marioni* Schlumberger, *T. plicata* Terquem, *T. schreiberiana* d'Orbigny, *Sigmolinita costata* (Schlumberger), *S. edwardsi* (Schlumberger), *Articulina carinata* Wiesner, *Euthymonacha polita* (Chapman), *Laevipeneroplis karreri* (Wiesner), *Peneroplis arietinus* (Batsch), *P. pertusus* (Forskal), *P. planatus* (Fichtel and Moll), *Sorites orbiculus* Ehrenberg, *S. variabilis* Lacroix, *Polymorphina* sp.3, *Reussella spinulosa* (Reuss), *Eponides concameratus* (Williamson), *Neoepionides bradyi* Le Calvez, *Neoconorbina terquemi* (Rzehak), *Rosalina bradyi* Cushman, *R. obtusa* d'Orbigny, *Pararosalina* cf. *dimorphiformis* McCulloch, *Pararosalina* sp., *Conorbella imperatoria* (d'Orbigny), *Discorbinella bertheloti* (d'Orbigny), *Cibicides advenum* (d'Orbigny), *Lobatula lobatula* (Walker and Jacob), *Planorbulina mediterraneensis*

d'Orbigny, *Cibicidella variabilis* (d'Orbigny), *Cymbaloporeta plana* (Cushman), *C. squamosa* (d'Orbigny), *Sphaerogypsina globula* (Reuss), *Asterigerinata mamilla* (Williamson), *Amphistegina lobifera* Larsen, *Nonion depressulum* (Walker and Jacob), *Ammonia compacta* Hofker, *A. parkinsoniana* (d'Orbigny), *A. tepida* Cushman, *Challengerella bradyi* Billman, Hottinger and Oesterle, *Criboelphidium poeyanum* (d'Orbigny), *Porosonion subgranosum* (Egger), *Elphidium aculeatum* (d'Orbigny), *E. advenum* (Cushman), *E. complanatum* (d'Orbigny), *E. crispum* (Linné), *E. depressulum* (Cushman).

### Appendix 3

#### Çeşme-Ilica Bay:

These are *Textularia bocki* Höglund, *Spirillina vivipara* Ehrenberg, *Vertebralina striata* d'Orbigny, *Nodopthalmidium antillarum* (Cushman), *Nubecularia lucifuga* Defrance, *Adelosina carinata-striata* Wiesner, *A. cliarensis* (Heron-Allen and Earland), *A. mediterraneensis* (Le Calvez J. and Y.), *Spiroloculina angulosa* Terquem, *S. antillarum* d'Orbigny, *S. ornata* d'Orbigny, *Siphonaperta agglutinans* (d'Orbigny), *S. aspera* (d'Orbigny), *Cycloforina contorta* (d'Orbigny), *C. villafranca* (Le Calvez J. and Y.), *Lachlanella variolata* (d'Orbigny), *Massilina gualteriana* (d'Orbigny), *M. secans* (d'Orbigny), *Quinqueloculina berthelotiana* d'Orbigny, *Q. bidentata* d'Orbigny, *Q. jugosa* Cushman, *Q. laevigata* d'Orbigny, *Q. lamarckiana* d'Orbigny, *Q. seminula* (Linné), *Miliolinella elongata* Kruit, *M. labiosa* (d'Orbigny), *M. subrotunda* (Montagu), *M. webbiana* (d'Orbigny), *Pseudotriloculina laevigata* (d'Orbigny), *P. oblonga* (Montagu), *P. rotunda* (d'Orbigny), *P. sidebottomi* (Martinotti), *Triloculina bermudezi* Acosta, *T. fichteliana* d'Orbigny, *T. marioni* Schlumberger, *T. schreiberiana* d'Orbigny, *Sigmoilinita costata* (Schlumberger), *S. edwardsi* (Schlumberger), *Articulina carinata* Wiesner, *Parrina bradyi* (Millet), *Euthymonacha polita* (Chapman), *Coscinospira acicularis* (Batsch), *C. hemprichii* Ehrenberg, *Laevipeneroplis karreri* (Wiesner), *Peneroplis arietinus* (Batsch), *P. pertusus* (Forsk.), *P. planatus* (Fichtel and Moll), *Amphisorus hemprichii* Ehrenberg, *Sorites orbiculus* Ehrenberg, *Polymorphina* sp.3, *Polymorphina* sp.5, *Polymorphina* sp.7, *Brizalina spatulata* (Williamson), *Reussella spinulosa* (Reuss), *Neoeponides bradyi* Le Calvez, *Gavelinopsis praegeri* (Heron-Allen and Earland), *Neoconorbina terquemi* (Rzehak), *Rosalina bradyi* Cushman, *R. globularis* d'Orbigny, *Pararosalina* cf. *dimorphiformis* McCulloch, *Planoglabratella opercularis* (d'Orbigny), *Cyclocibicides vermiculatus* (d'Orbigny), *Lobatula lobatula* (Walker ve Jacob), *Planorbulina mediterraneensis* d'Orbigny, *Cibicidella variabilis* (d'Orbigny), *Cymbaloporeta plana* (Cushman), *C. squamosa* (d'Orbigny), *Miniacina miniacea* (Pallas), *Asterigerinata mamilla* (Williamson), *Nonion depressulum* (Walker and Jacob), *Ammonia compacta* Hofker, *A. parkinsoniana* (d'Orbigny), *A. tepida* Cushman, *Challengerella bradyi* Billman, Hottinger and Oesterle, *Criboelphidium poeyanum* (d'Orbigny), *Porosonion subgranosum* (Egger), *Elphidium aculeatum* (d'Orbigny), *E. advenum* Cushman, *E. complanatum* (d'Orbigny), *E. crispum* (Linné) and *E. depressulum* (Cushman).

### Appendix 4

#### Gulf of Kuşadası:

*Lagenammina fusiformis* (Williamson), *Iridia diaphana* Heron-Allen and Earland, *Haddonina* sp., *Eggerelloides advenum* (Cushman), *E. scabrus* (Williamson), *Textularia bocki* Höglund, *T. truncata* Höglund, *Cornuspira foliacea* Philippi, *Vertebralina striata* d'Orbigny, *Nodopthalmidium antillarum* (Cushman), *Nubecularia lucifuga* Defrance, *Adelosina carinata-striata* Wiesner, *A. cliarensis* (Heron-Allen and Earland), *A. duthiersi* Schlumberger, *A. mediterraneensis* (Le Calvez J. and Y.), *A. partschi* (d'Orbigny), *A. pulchella* d'Orbigny, *Spiroloculina angulosa* Terquem, *S. depressa* d'Orbigny, *S. dilatata* d'Orbigny, *S. excavata* d'Orbigny, *S. ornata* d'Orbigny, *Siphonaperta agglutinans* (d'Orbigny), *S. aspera* (d'Orbigny), *S. dilatata* (Le Calvez J. and Y.), *S. irregularis* (d'Orbigny), *Hauerina diversa* Cushman, *Cycloforina contorta* (d'Orbigny), *C. villafranca* (Le Calvez J. and Y.), *Lachlanella undulata* (d'Orbigny), *Massilina gualteriana* (d'Orbigny), *M. secans* (d'Orbigny), *Quinqueloculina berthelotiana* d'Orbigny, *Q. bidentata* d'Orbigny, *Q. disparilis* d'Orbigny, *Q. jugosa* Cushman, *Q. laevigata* d'Orbigny, *Q. lamarckiana* d'Orbigny, *Q. limbata* d'Orbigny, *Q. seminula* (Linné), *Quinqueloculina* sp. C, *Miliolinella semicostata* (Wiesner), *M. subrotunda* (Montagu), *M. webbiana* (d'Orbigny), *Pseudotriloculina laevigata* (d'Orbigny), *P. oblonga* (Montagu), *P. rotunda* (d'Orbigny), *Triloculina affinis* d'Orbigny, *T. bermudezi* Acosta, *T. marioni* Schlumberger, *T. plicata* Terquem, *T. schreiberiana* d'Orbigny, *T. tricarinata* d'Orbigny, *Triloculina* sp. A, *Sigmoilinita costata* (Schlumberger), *S. edwardsi* (Schlumberger), *Sigmoilopsis schlumbergeri* (Silvestri), *Parrina bradyi* (Millet), *Euthymonacha polita* (Chapman), *Laevipeneroplis karreri* (Wiesner), *Peneroplis pertusus* (Forsk.), *P. planatus* (Fichtel and Moll), *Sorites orbiculus* Ehrenberg, *S. variabilis* Lacroix, *Laevidentalina inflexa* (Reuss), *Lenticulina cultrata* (Montfort), *Pyramidulina catesbyi* (d'Orbigny), *Polymorphina* sp. 1, 2, 3, *Brizalina simpsoni* (Heron-Allen and Earland), *B. spatulata* (Williamson), *Bulimina elongata* d'Orbigny, *Reussella spinulosa* (Reuss), *Fursenkoina acuta* (d'Orbigny), *Valvulineria bradyana* (Fornasini), *Eponides concameratus* (Williamson), *Neoeponides bradyi* Le Calvez, *Gavelinopsis praegeri* (Heron-Allen and Earland), *Neoconorbina terquemi* (Rzehak), *Rosalina bradyi* Cushman, *R. floridensis* (Cushman), *R. globularis* d'Orbigny, *Conorbella imperatoria* (d'Orbigny), *Discorbinella bertheloti* (d'Orbigny), *Cibicides advenum* (d'Orbigny), *Lobatula lobatula* (Walker and Jacob), *Cyclocibicides vermiculatus* (d'Orbigny), *Planorbulina mediterraneensis* d'Orbigny, *Cibicidella variabilis* (d'Orbigny), *Cymbaloporeta plana* (Cushman), *Sphaerogypsina globula* (Reuss), *Asterigerinata mamilla* (Williamson), *Amphistegina lessonii* d'Orbigny, *A. lobifera* Larsen, *Nonion depressulum* (Walker and Jacob), *Astronionion stelligerum* (d'Orbigny), *Ammonia compacta* Hofker, *A. parkinsoniana* (d'Orbigny), *A. tepida* Cushman, *Challengerella bradyi* Billman, Hottinger and Oesterle, *Criboelphidium poeyanum* (d'Orbigny), *Porosonion subgranosum* (Egger), *Elpidium aculeatum* (d'Orbigny), *E. advenum* (Cushman), *E. complanatum* (d'Orbigny), *E. crispum* (Linné), *E. depressulum* Cushman, *E. macellum* (Fichtel and Moll).

Plate 1.



Plate 2.

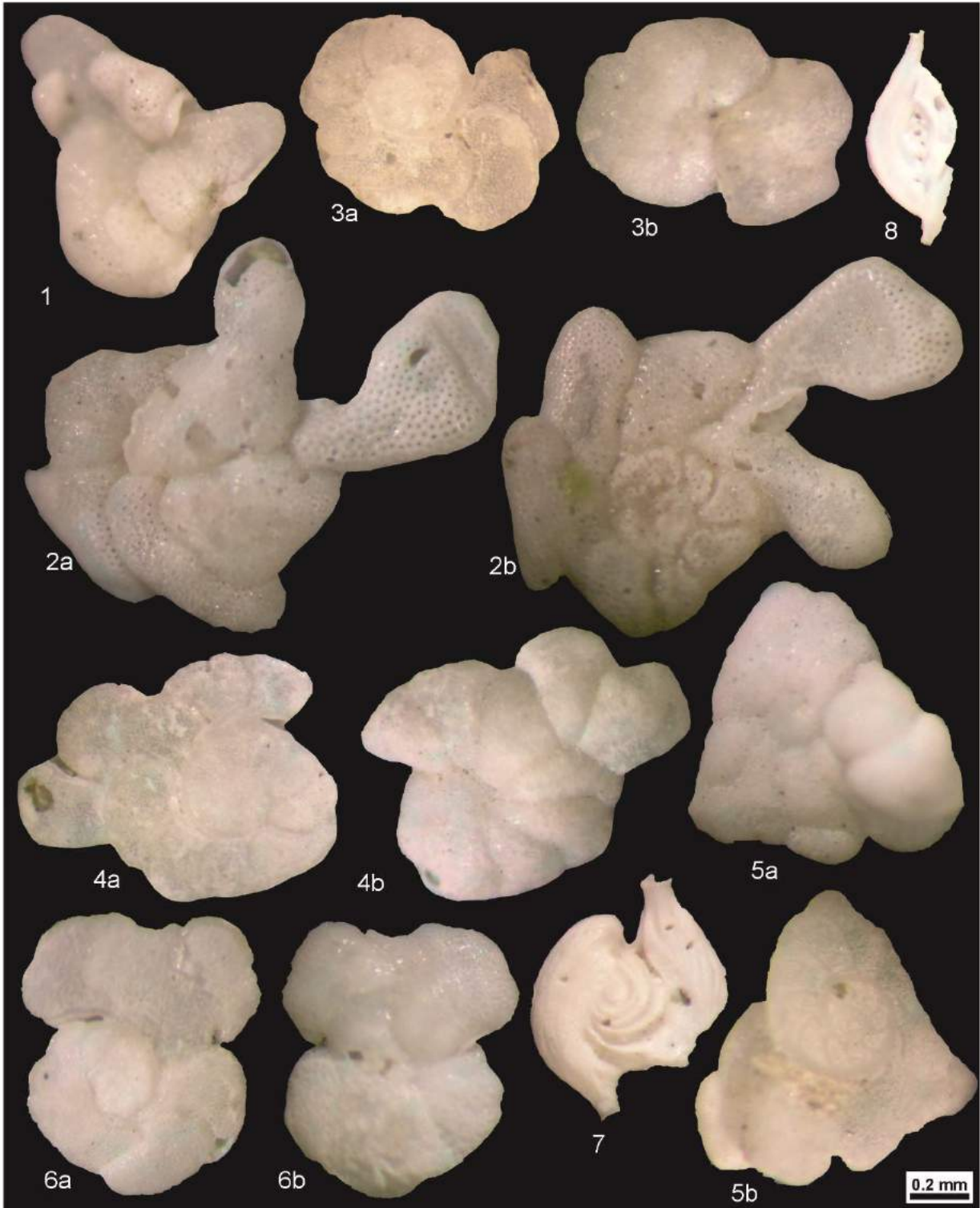




Plate 3.

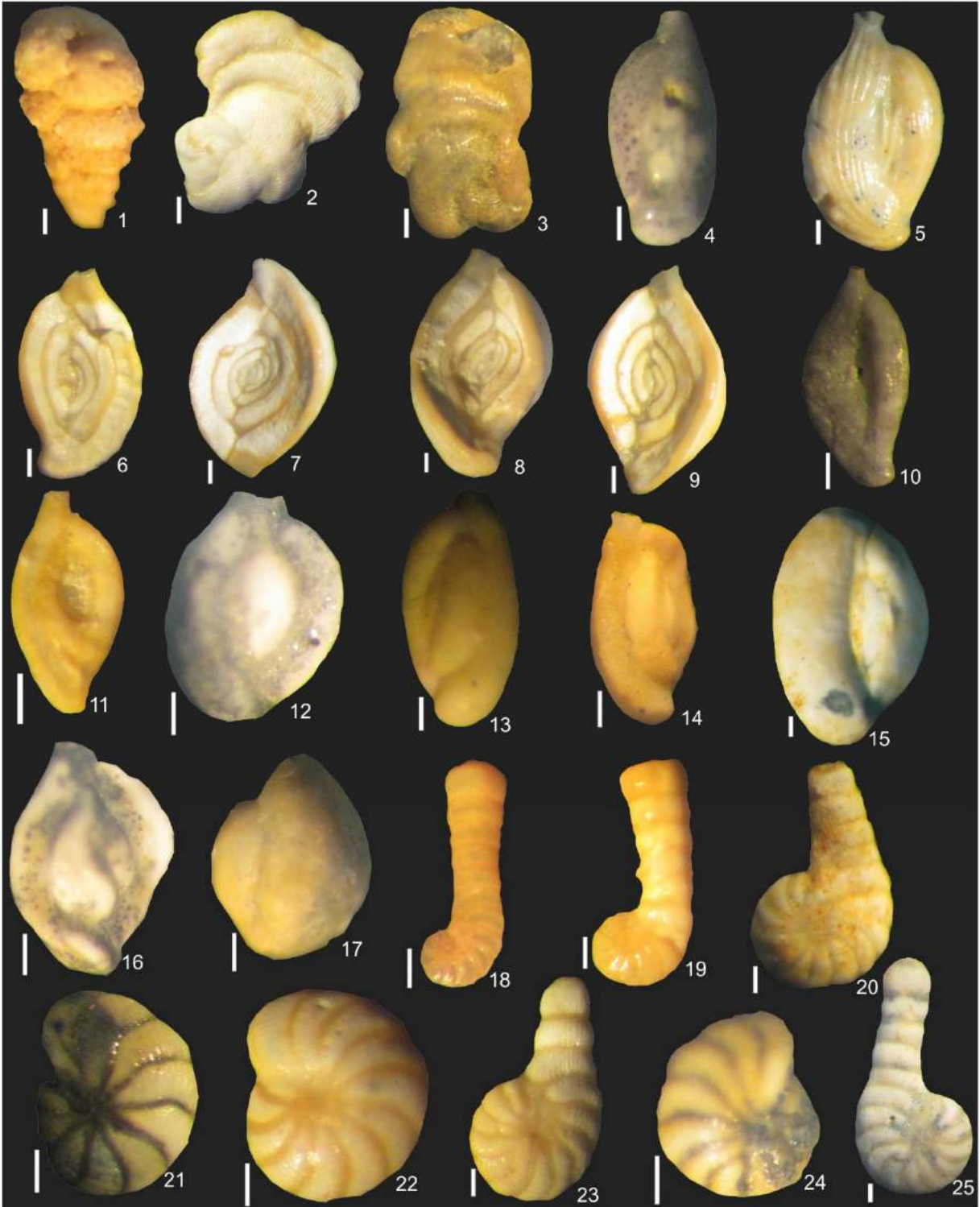


Plate 4.

