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A multi disciplinary overview of factors controlling on meiofauna assemblages around Maden and Alibey islands in Ayvalik (Balikesir, Eastern Aegean Sea)

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A B S T R A C T

In coastal parts of the study areas, heavy metals containing ground water flows along the faults and fractures and reaches at sea. In these contaminated waters, morphologically abnormal individuals of the affected meiofauna (benthic foraminifera, ostracod, mollusc) can be found. Three cores were taken from the seafloor in the four separate stations that are located in NW of Ayvalık village, around Alibey and Maden islands, and one core of each three core groups was studied in order to investigate the aforementioned morphological affects on the recent meiofauna, which have been inhibited in those contaminated waters. Lead, manganese, hematite and limonite deposits with small reserves were present in Alibey, Maden and Küçük (Small) Maden islands. Morphological changes and coloring were observed in tests of large number of *Peneroplis*, *Lobatula*, *Ammonia* and *Elphidium* samples collected from these areas. This observation vindicates impact of heavy metals onto the foraminifera assemblages. Heavy metals and other chemical and radioactive elements found in the surrounding country side have been naturally transported into the adjacent sea water during the past and present. The aim of this study is to figure out the effects of the chemical and radioactive elements, which were carried from the land on the meiofaunal (benthic foraminifera, ostracod and mollusc) assemblages.

1. Introduction

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. Those islands are located along southern cost of the Gulf of Edremit which is northeastern extension of Aegean Sea (Fig. 1).

Part of the Recent sediments deposited in study area is red-brown in color. They contain plenty of benthic foraminifera tests with red-brown, yellow, orange and dark gray colors, or with mixture of those colors. *Peneroplis pertusus* (Forskal) and *P. planatus*

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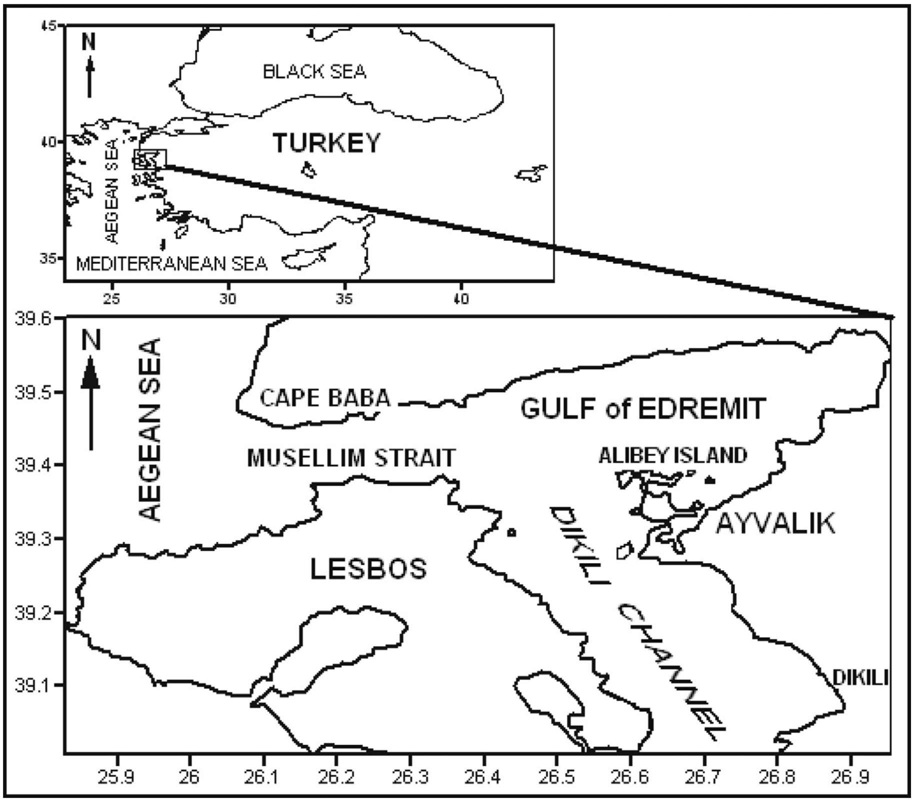


Fig. 1. Location map of the investigation area.

(Fichtel and Moll) are the abnormally abundant members of existing biota. In this assemblage, another noteworthy feature is abundance of benthic foraminifera especially *Peneroplis* tests displaying extreme morphological disorders. The recent sediments consist of light gray sands in the other studied areas, and a small number of partly colored or colorless benthic foraminifera are observed in the upper levels (Meriç et al., 2012a,b; Barut et al., 2013; Yümün et al., 2016). *Ammonia compacta* Hofker, *A. parkinsoniana* (d'Orbigny), *Challengerella bradyi* Billman, Hottinger and Oesterle, *Elphidium complanatum* (d'Orbigny) and *E. crispum* (Linné) are the dominant species in this assemblage. Although benthic foraminifera found in those studied locations also display interesting shape deformations, however these morphological features are less remarkable than the deformation displayed by the aforementioned benthic foraminifera.

Presence of ostracods in these Recent sediments reveals occurrence of different conditions in the site of deposition. Observed genera and species are small in number in the reddish-colored sands; hence the genera and species are diversified and abundant in the gray sands. These observed differences in both abundance and diversity of the foraminifera under consideration suggest that ecological conditions had locally and periodically changed in the studied area. The mollusc fauna exhibits a parallel tendency to the foraminifera and ostracod assemblage. Molluscs are rarely found in the red-brown sands while they are common to abundantly in the gray sands.

Rarity versus extreme abundance of the recent plant remains in the different layers is another feature that was observed in the studied sediments. For example, in a 0.45 m long 1c core; plant remains are rare in 0.00–0.16 m interval, extremely abundant in 0.16–0.32 m interval and they are reduced in numbers in 0.32–0.45 m interval. In both 2c and 3a cores; the plant remains are abundant in entire 0.00–0.45 m interval. However this throughout abundance is not observed in a 0.52 m long core 4b. Water depths (subsea elevations) measured at the coring stations is as follows: 4b (0.80 m), 1c (1.50 m), 3a (2.70 m) and 2c (8.00 m).

Presence of the economic mineral deposits with small reserves at various locations in both Maden and Alibey islands are reported in some of the previous studies. The volcano sedimentary sequence, which was deposited from Middle-Upper Miocene to younger period, is a typical depression fill. The topographic depression is the extension of a larger NW trending structural feature which is called the Dikili-Ayvalık Depression. In this area, polymetallic ore dykes are found along approximately NNE trending fault and fractures that had been developed in the alkaline basaltic volcanic rocks (Dora and Savaşçın, 1980). Among these ore minerals lead has a primary place, and limonite, hematite and manganese oxides are the minerals with lesser economic importance (Dora and Savaşçın, 1980; Akyürek, 1989).

Some aquatic plants and diatoms were used as biomarkers by Padinha et al. (2000) and Fisher et al. (1981) respectively, in order to identify marine contaminators. Benthic foraminifera abundantly present in marine environment, therefore they are very important group of organisms to be used studying changes occur in the environmental conditions. Their sensitivity to environmental changes has long been reported in relevant publications (*i.e.* Murray, 1991). To some extent, preservation of morphologic and textural properties of shells and tests deposited in sediments for a long time is a unique feature. Therefore, they have been reliable biomarkers up against both natural (Murray, 1991) and artificial (Nagy and Alve, 1987; Alve, 1995; Yanko et al., 1999) contaminators. Oil wastes, agricultural chemicals and heavy metals in waters had played active role in those reported morphological deformations (Ellisson et al., 1986; Nagy and Alve, 1987; Alve, 1995; Samir and El-

Din, 2001). Heavy metal content in tests of the individuals displaying morphological defects is found significantly higher than the individuals of normal population (Yanko et al., 1999; Alve and Olsgard, 1999; Samir and El-Din, 2001).

This study was conducted with the aim of revealing the quantitative and qualitative nature of the biological effects of human and natural heavy metals in the environment. The presence of heavy metal, trace elements and radioactive properties from the well known mining deposits as Cu–Pb, Fe–Mn and Pb in the region to seawater mixed were studied to determine the influence of meiofauna (benthic foraminifer, ostracod and mollusc) assemblages.

1.1. Geographical setting of the study area

The study area lies in between 39º00′00″–39º60′00″ latitude north and 25º90′00″–26º90′00″ longitude east (Fig. 1). The area framed by these geographical coordinates can be divided into three main geographic regions such as the Gulf of Edremit, Müsellim Strait and Dikili Channel (SHOD, 1994a).

Gulf of Edremit is located to the north of Ayvalık town, and displays a triangular shape in the map view. The gulf is surrounded by the prominent geographic features such as Alibey Island, Lesbos Island, Cape Baba and Akçay town (Fig. 1). Topography of the land which surrounds the eastern margin of the gulf is almost low as the sea level. This topographic depression continues in the triangular shape area which is called as the Edremit-Burhaniye-Havran triangle. Topography of northerly boarding land of the gulf rises steeply behind a narrow coastal strip transforming into the Mount Ida massif. This massif strikes E-W direction and extends from Cape Baba to city of Balıkesir. Southern coastline of the gulf generally strikes northwest-southeast direction. It is more indented than the northern coastline. Large to small islands are present along southern coast of the gulf near to Ayvalık town and surroundings (SHOD, 1994b).

The prevailing wind directions are north and northeast in the region. The average annual wind speed is about 5.4 knots. The average annual temperature is 16.4 °C. Annual average rainfall is 783.6 mm in the Gulf of Edremit (379.4 mm in winter, 20.3 mm in summer) (Meteorology Bulletin, 1984). The streams with steep slopes are present, and they discharge a considerable amount of water during the rainy seasons. In addition to Havran Creek, the other two important running waters of the Madran Creek and Bakır Creek are also discharged into the Gulf of Edremit. There are fresh water springs at the seabed near to Akçay town. Existence of thermal springs which were controlled by the tectonic features at various points of the region has also been reported (Meriç et al., 2003a).

1.2. Coastal land and sea floor topography of the region

Morphology of the study area was affected by geological development of the region. The E-W striking graben system which was developed in the Western Anatolia had controlled morphology of the region (Dewey and Şengör, 1979; Şengör, 1980; Şengör et al., 1985; Turgut, 1987; Mascle and Martin, 1990; Eryılmaz, 1996). A fault plane strikes parallel to the coast between the Cape Baba and Akçay town seems to control the coastal topography between the Cape Baba and Akçay town. The cliff making topography is also seen between Akçay town and Alibey Island. Large to small sized submarine fans (deltas) had developed along this cliff making coast. A submarine valley aligned east-west direction and extending across entire Gulf of Edremit is the prominent submerged topographical feature in the region. An abrasion platform has developed along the eastern shore of Alibey Island. Alluvial plains and beaches developed on the seafloor fills are the geographical features observed in the Dikili Channel and along the shore which extends between Cape Eğribucak and Dikili town.

Water depth increases up to 110.00 m to the north of Lesbos (Lesbos) Island. However it gradually decreases in the eastern end of the Gulf of Edremit towards Akçay town. The Müsellim reefs are adjacent to a deep through which lies between Lesbos Island and Cape Sivrice.

The land topography displays steep slopes to the north of the Gulf of Edremit, and keeps this character towards the shore. These steep slopes create a submerged topographic low (through) which strikes east-west direction. To the south, there are many large to small islets, remnant rocks, but causing sudden shallows around the Alibey Island which is located at offshore area of Ayvalık town. To the north of Dikili Channel water depth is less than 60 m between Dikili town and Lesbos Island (Eryılmaz, 1996, 2003; Eryılmaz and Yücesoy-Eryılmaz, 1998; 2001, 2004; SHOD, 1994a; b) (Fig. 2).

1.3. Oceanographic characteristics of the region

Although no difference is found between extreme and average temperature values measured in the bottom waters, hence seasonal temperature differences are observed in surface waters of the Gulf of Edremit. The seasonal thickness variations in the surface water layer can be monitored. These values are as follows; around 10.00 m thick in spring (May) and 30.00 m thick in summer (July). Average temperatures of the surface waters are; 15.5 °C in spring (May), 22.5 °C in summer (July), 20.8 °C in fall (September) and 13.03 °C in winter (February). Average temperatures of the bottom waters by season are; 14.8 °C in spring (May), 16.0 °C in summer (July), 16.1 °C in fall (September) and 12.36 °C in winter (February). Seasonal temperature averages of the surface waters of the Dikili Channel are; 16.39 °C, in spring (May), 23.76 °C in summer (July), 21.61 °C, in fall (September), 13.97 °C, in winter (February). The temperature averages of the bottom waters are reported as follows; 14.24 °C in spring (May), 15.77 °C in summer (July), 15.26 °C in fall (September), 13.39 °C in winter (February) (SHOD, 1988, 1995).

No significant salinity difference is measured between deep and shallow waters of the Gulf of Edremit in all seasons. However, several salinity differences are observed at some depths of the gulf due to increase and decrease of the fresh water influx, as well as the currents caused by occurred temperature differences in the gulf waters. Salinities measured in the Gulf of Edremit waters are as follows; in spring (May) at surface 38.84–39.04‰, at 30.00 m depth

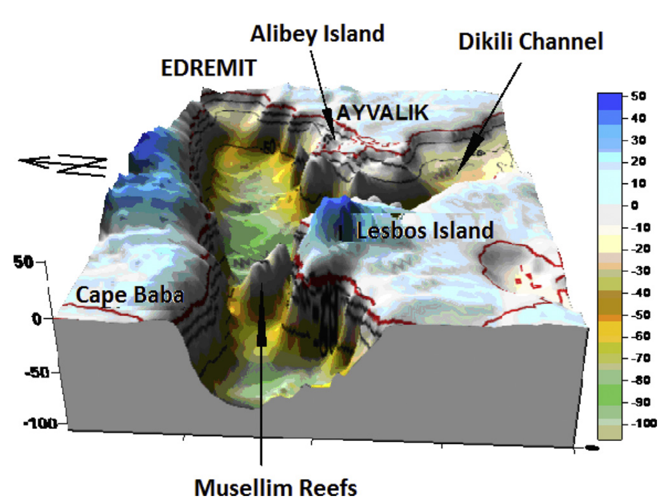


Fig. 2. 3D Bathimetric display of the study area (sighting from Cape Baba, depths in m).

38.9–39.08‰; in summer (July); at surface 39.08–39.26‰, at 30.00 m depth ‰38.95–39.08; in fall (September); at surface 38.97–39.15‰, at 30.00 m depth 38.87–39.01‰; in winter (February), at surface 38.58–39.21‰, at 30.00 m depth 38.63–39.23‰.

Absence of any prominent current system in the region has been concluded basing upon the current measurement surveys done in the Gulf of Edremit. Generally, the observed regional currents are generated by temperature, salinity and density differences occur in the gulf waters because of the meteorological factors. The ordinary regional currents are caused by water bodies having density differences. These differences especially occur when the fresh water discharge of the Havran Creek and other running waters are seasonally increased.

The Dikili Channel lies between the Gulf of Edremit to the north and the gulfs of İzmir and Çandarlı to the south. The waters of those gulfs would move and be forced to pass through the channel by the effective meteorological events in the region. The channel is a passage way between those gulfs. Therefore movements of the water mass from north to south or vise versa could be controlled by prevailing wind directions and/or seasonal density fluctuations in the waters. In addition, the fresh water currents which flow opposite directions of overall water mass movements are also seen in the Gulf of Dikili. Likewise, the counter clockwise and clockwise costal currents are generated by the northerly and southerly blowing winds respectively.

1.4. Evaluation of recent sedimentation in the study area

In the Gulf of Edremit, average and highest gravel fraction weights found in the recent sediments are 2.4% and 14.4% respectively. Average volume of the sand is 24.5% while the maximum and minimum of the sand fractions weight are 72.6% and 0.5% respectively in the total sedimentary column. Calculated sand fractions in the samples collected from the Dikili Channel are as follows: average 61.2%, max. 89.5%, min. 16.4%. The silt size grains have an average of 32.5% in the studied sediment samples. They reached at a 72.5% maximum in the samples collected from the Gulf of Edremit. The lowest silt fraction value of 2.5% was found in the samples collected from the Dikili Channel sampling station. The regional distribution of silt size grains in the Gulf of Edremit is; average 43.66%, max. 72.5%, min. 13.9%. Hence clay contents in the total sediments are as follows: min. 6.9%, max. 59.4% and average 29.5%. Calculated clay fraction figures of the samples collected in the Dikili Channel are; average 9.4%; max. 21.3% and min. 3.9%. The max. value (92%) of the coarse grain size material composed of gravels and coarse sands which was observed in a sample collected from the Dikili Channel, whilst min. value (0.58%) of the coarse grain size material was calculated in the sample collected from the deepest sampling station located in the Gulf of Edremit. Maximum of the gravel + sand fractions is 79.1% and found in the sample collected from the Gulf of Edremit.

The mud which is composed of the grains having diameters smaller than 0.063 mm (silt + clay size particles) displays an average value of 53%, hence maximum of mud content in the recent sediment samples collected in the studied area is 99.4%. Regional distribution of mud in the Gulf of Edremit is found as follows: average is 73.1%, 99% and 20.9% are measured max. and min. values respectively. The averaged value of the mud fraction calculated in the samples collected from the Dikili Channel is 30.8%, while min. and max. values are 7.45 and 80% respectively. This reveals that the mud is basically composed of silt fraction in this region (Yücesoy-Eryilmaz et al., 2002a,b, 2004, 2006; Esenli et al., 2005). Statistical work such as cumulative curve plots and skewness (SkF) calculations which are based on the grain-size (phi diameter) analysis of the studied samples indicated that depositional period in the region was not long enough for accomplishment of textural maturity of the accumulated grains. In event, most of them are classified as poorly and very poorly sorted grains (Table 1, Fig. 3 after Folk, 1974).

Distribution of grain size based units defined in recent sediments is displayed in a 1/100 000 scale map (Fig. 3). In the region, coarse grained sandy and gravelly sediments occupy coastal shoals, while deep-sea areas hosted silty, clayey and muddy sediments. However, gravel, sandy gravel, gravelly sand and gravelly muddy sand bodies are present along the shores but they are found in very limited areas as very narrow bands. Therefore displaying of those units in this scale map has not been possible. The sandy deposits by definition are composed of sand, gravelly muddy sand, muddy sand and silty sand. They are gathered under the “Sand” and displayed as single unit in the map under consideration. The “Silty” units contain silt, sandy and clayey silt components. The “Mud” unit is seen as mud or sandy mud facies. Clayey materials are accumulated in the troughs usually deeper than 80.00 m. Biogenic fraction of the sediments is composed of whole shells, shell fragments and various plant remains. This organic debris is found in the limited areas which lie on the coastal shoals of the region where the sun light could penetrate.

Quartz is main mineral of the sand and gravel size grains. Plagioclase is significant mineral in the silt size detritus. Igneous and volcanic rock fragments, mica, chlorite are the prominent components in these sediments. Smectite, calcite are found abundantly or rarely in the studied samples. Volume of the compositional components could vary, but they keep mineralogical homogeneity in the sampled sediments. Terrigeneous (land derived) grains represent the geological out-crops that they have been derived. Propagation of shells and algae in northeast of Ayvalik town is under influence of the local factors (Yücesoy-Eryılmaz et al., 2002a,b, 2004, 2006; Esenli et al., 2005).

In the study area, recent sedimentation was investigated basing upon grain size analysis data of the collected sediment samples. Accordingly, sand prevails in near-shore areas of the Gulf of Edremit, silty sand is replaced by clayey silt, silty clay and finally mud due to progressive reduction of grain size as the water depth has gradually increased. Shells (*i.e.* carapaces or tests) are found in some of the sediments deposited in the northwesterly located areas of Ayvalik town. Center of the Gulf of Edremit has been filled by silty clay and mud. Sand and silty sand are the major sediment types around Alibey Island (Fig. 3).

1.5. Formation of ore minerals in Maden and Alibey islands

Poly-metallic ore veins are seen along the NNE trending fault and fractures which were formed in the Middle-Upper Miocene aged alkaline basaltic volcanic rocks of Maden and Alibey islands (Savaşçın and Güleç, 1992). Ore veins or alternative massive quartz veins are also common in Maden Island. Solitary and thicker veins (Dykes) were split into dendritic veinlets rising from deeper horizon to the surface. The length of veins varies between 10.00 and 800.00 m. The dykes with their present attitude exhibit a typical

Table 1
Skewness values based on grainsize analysis.

SkF	Skewness
+1.0–+0.30	Highly skewed to fine grain
+0.30–+0.10	Skewed to fine grain
+0.10–−0.10	Symmetrical
−0.10–−0.30	Skewed to coarse grain
−0.30–−1.0	Highly Skewed to coarse grain

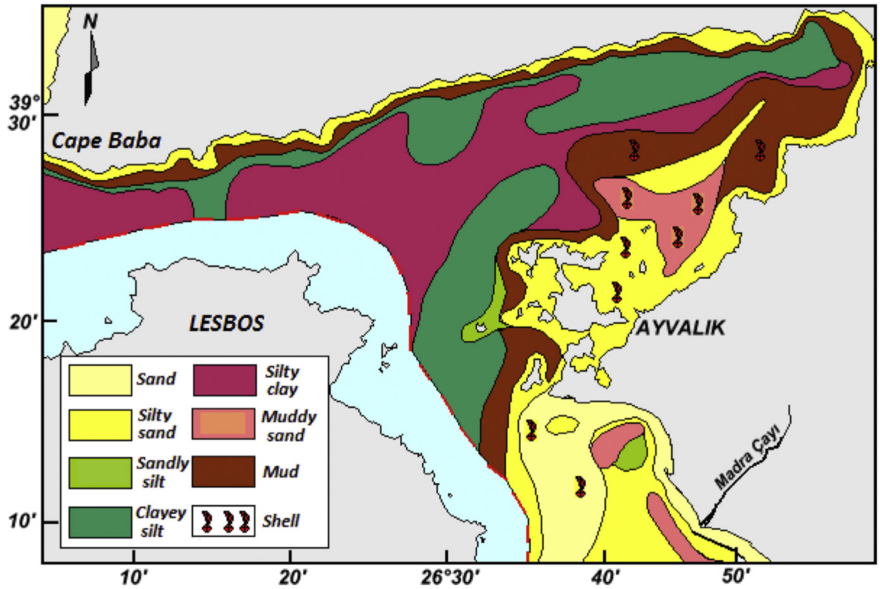


Fig. 3. Map of recent sediments distribution in Gulf of Edremit (after Eryılmaz and Yücesoy-Eryılmaz, 2004; Yücesoy- Eryılmaz and Yücesoy-Eryılmaz, 2001).

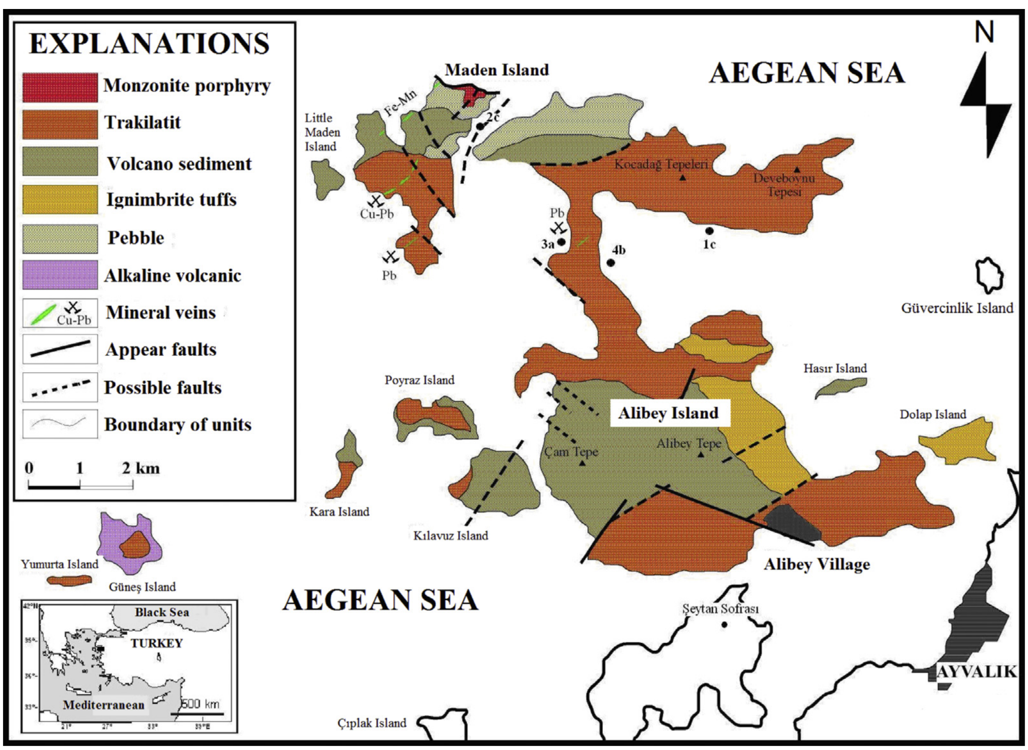


Fig. 4. Geological Map of Alibey and Maden Island (vicinity of Ayvalik) (modified after Dora ve Savaşçın, 1980).

fan-shaped fault and fracture fillings that were formed by extensional tectonic events (Fig. 4).

In Alibey Island ore bearing dykes display only a few traces at the surface. Mineralized coatings consisting limonite and manganese oxides (pyrolusite and psilomelane) are seen in the 0.10–0.40 m wide and 5.00–30.00 m long brecciated fractures. Host rock is an altered alkaline volcanite. Contrary to rare surfaced occurrences of the ore bearing veins, abandoned facilities such as the large management buildings, smelting furnace, properly built wells and large piles of rust, prove that the mining activity was conducted many years in the island. Probably when mining had to be done below the sea-level, occurred technological problems had caused abandonment mining activity in the island. Ore minerals such as galena, limonite, hematite and manganese oxides are observed in the weathered tailings. Gangue is fracture filling fine crystalline quartz.

A NNE-SSW striking major dyke extends almost entire length of Maden Island. In this dyke, ore bearing parts are seen as lenses having lengths up to 9.50 m and widths varying 1.00–4.00 m. The dyke as a whole is a widening and narrowing brecciated fault zone which displays typical sausage structures. Primary chalcopyrite, pyrite and galena minerals are found in the galleries which were dug down to a depth of 25.00 m. Chalcocite and covellite are seen in the cementation zone; malachite, azurite, hematite, limonite, anglesite and sericite minerals are observed in the oxidation zone. Quartz is the dominant gangue mineral. Calcite, siderite, barite, and epidote are the additional gang minerals. In the secondary dykes that lie at 40.00–60.00 m east of the major dyke and striking opposite direction; galenite and sphalerite are the dominant and rare ore minerals respectively. Coarse crystalline galena mineral contains silver up to 80 g in per ton. Silver (Ag) is settled in the lattice of galena crystals (Dora, 1967). Poly-metallic ore veins are also found in alkaline volcanic rocks of Maden Island. Hence the massive quartz veins hosting Fe and Mn oxides could be encountered in the volcano-sedimentary rocks. A vague zoning is seen in between the ore bearing and ore sterile dykes.

Late alkaline volcanism was generally sterile in terms of ore mineralization in Western Anatolia. However the young alkaline intrusions had controlled ore mineral generation in many places (Ovacık area, Yılmaz et al., 2006; Yamanlar area, Sayılı and Gonca, 1999; Efemçukuru area, Oyman et al., 2000; Bodrum area, Pişkin and Bertrand, 1980, etc.). Therefore would be the most realistic approach concluding that the monzonitic dykes (quartz latite) were responsible for existing mineralization in Alibey and Maden islands (Dora and Savaşçın, 1980). Ore minerals are observed at periphery of the skarn development (formation of epidote, diopside, and amphibolite feldspars minerals) in the volcano-sedimentary rocks, and in the youngest fault and fracture systems. Basing upon the temperature measurement of the fluid inclusions formed in the quartz crystals (Yağcı, 1981), it is possible to conclude that the mineralization had happened during the 350 °C hot high hydrothermal stage which followed the skarn development. The galena ore contains very low tenure of silver (Ag) and no gold (Au) due to the high temperatures subjected during early or late mineralization.

2. Materials and methods

The two hundred sixty five seafloor surface sediment samples were used in this study. An orange-peel type grab sampler was used for collecting those samples. Grain size analysis of the collected samples was carried out using standard laboratory techniques (Folk, 1974; Lewis, 1984; Muller, 1967). The weight of grain sizes and grain size classes of analyzed sedimentary particles were calculated using the methods given in Folk (1974). A total of eleven (11) cores were taken by penetrating a corer into seafloor at the four (4) stations which are located as follows: three (3) sites in the north of Alibey Island, and one site in the east of Maden Island (Fig. 4). Those core samples were stored until laboratory analyses commenced. In the laboratory, the holders were cut opened splitting the core column longitudinally in to two halves. One half of the each studied core was used for sedimentary analysis, while the other half was utilized for faunal investigation. Two (2) cm sampling interval is applied for faunal investigations.

Three cores were taken from sea floor in the four separate stations that are located in NW of Ayvalik village, around the Alibey, Maden and Kucuk Maden islands, and one core of each three core groups was studied in order to investigate the aforementioned morphological affects on the recent and fossil benthic foraminifera, which have been inhibited in these contaminated waters. However one of the three cores cut in the stations 3 was failed to be recovered.

10% Hydrogen peroxide (H2O2) was added in to each 2 cm long sediment section, and this mixture left alone for 24 h. 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 and 0.125 mm mesh size sieves, and then examined under binocular microscope in order to determine characteristics of the fauna. No organisms other then molluscs, a few foraminifers and ostracods were found in the coarser fractions held by 2.00 and 1.00 mm mesh size sieves. Foraminifers and ostracods contained in fraction of the sediment held by 0.500 mm mesh size sieve were also small in numbers. Three (3) cores were taken at the coring stations numbered as 1, 2 and 4 and, two (2) cores at the station numbered 3. Recovered lengths of those cores were as follows; core 1c = 0.45 m, core 2c = 0.42 m, core 3a = 0.45 m and core 4b = 0.52 m (Table 2).

All of the taken core samples are composed of sand size material. Therefore their granulometric properties were determined by using the Sieve Analysis Method. The sample dried at 105 °C temperature is put in upper most sieve of the set which is a combination of 5 sieves and one round pan at the bottom, called the receiver pan. The sieves are arranged from with coarsest to finest mesh (opening) as follows; 2 mm, 1 mm, 0.5 mm, 0.125 mm, 0.063 mm. The set is capped and put in/on a shaker. Then the set is shaken and sieved for 10 min. At the end of this period, the dried sample which is put in the top sieve with largest opening (2 mm) would be sieved through the succeeding sieves with gradually reducing openings. Then the each sieve is removed one by one, and the contained grains are poured on a white paper sheet (having standard size and weight) and weighted separately. Weights of sieve contents are recorded in the representative grain size column. Contained grain size groups of a sample are calculated using the formula which is given below (Galehouse, 1971; Mcmanus, 1988).

$$\% \, n = (\text{weight of n size sample} \, / \, \text{initial weight of total sample}) * 100 \quad (1)$$

Chemical analyses were applied to the sediment samples dried at 50 °C temperature. Heavy metal (Cu, Co, Ni, Cr, Zn, Fe and Mn) contents of samples selected from 34 levels were measured by the two succeeding steps of chemical analyses. At first, these samples were dissolved using specific methods (Chester and Hughes, 1967; Agemian and Chau, 1976; Anonymous, 1986; Loring, 1987; Loring and Rantala, 1988) and then these solutions were torched by air-acetylene flame, the resultant colors spectrums were analyzed using a Shimadzu AA-6701-F atomic absorption spectrophotometer. The geochemical evaluation was done in accordance with the results of these analyses.

Analysis of radioactivity as total alpha and total beta measurements were done in Çekmece Nuclear Research and Training Centre, Department of Measurement and Instrumentation, Laboratory of Radioactivity Measurement and Analysis Unit. Measurements for a total of 52 sediment samples taken from the four cores were carried out using a Berthol Lb 770 Low Level Counter device. Measurement uncertainty is in the range of $\pm 2\ \sigma$. The total uncertainty that would occur during background correction, self-absorption correction, counting and preparation of sample for counting was calculated. Accordingly, the total uncertainty at 95% confidence in the range of $\pm 2\ \sigma$.

Table 2
Length, water depth and coordinates of the cores cut in the study area.

Name of core	Latitude	Longitude	Water Depth (m)	Core Length (m)
1c	39.350 E	26.650 N	−1.5	0.45
2c	39.353 E	26.578 N	−8	0.42
3a	39.374 E	26.602 N	−2.7	0.45
4b	39.345 E	26.625 N	−0.8	0.52

3. Results

3.1. Sedimentological properties of the core samples

Cores 1c, 2c, 3a and 4b are 0.45 m, 0.42, 0.45 and 0.52 m long, respectively. The cores were split into two halves in the laboratory, and their lithological properties were described. The sedimentary column in core 1c is composed of brownish grey sand (0.00–0.20 and 0.32–0.45 m) and dark grey sand with dense plants remains (0.20–0.32 m). Whole and broken bivalve shell fragments are present at 0.00–0.20 and 0.32–0.45 m intervals in the core column (Fig. 5). Cores 2c and 3a show similar lithological properties. The uppermost 0.00–0.30 m parts of these cores consist of light grey sand with marine shells (Fig. 5), which is followed by dark grey sand with abundant plant grains. This sand unit continues downward until 0.42 m in core 2c and 0.40 m in core 3a. Core 4b is composed of rusty brown sand with whole and broken shell fragments. Sediments in this core show homogeneous distribution of sand and shell fragments.

3.2. The distribution of grain size in core samples

Vertical change in grain size along the sedimentary column of the cores collected at four stations (1c, 2c, 3a and 4b) is illustrated in Fig. 6.

3.2.1. Core 1c

The grain size based distribution of the compositional constituents in core 1c is portrayed as ranges, and they are: gravel 0.2–20.10%, sand 79.6–100% and mud <2.3% (Fig. 6). The average percentages of the grain size classes calculated in a total of 23 samples from the core 1c are as follows; 4.07% for gravel, 95% for sand. Highest percentages measured for gravel and sand grains are found in the 0.14–0.16 and 0.00–0.40 m intervals respectively, whereas the lowest gravel and sand values are measured in intervals 0.06–0.08 and 0.14–0.16 m respectively. In addition, the gravel fraction is not observed in the 0.00–0.06 and 0.08–0.12 m intervals of core 1c. Examination of gravel fraction under binocular-microscope revealed that the fraction is composed of 5% rock fragments and 95% benthic organisms such as pelecypoda (90%) and gastropods (10%).

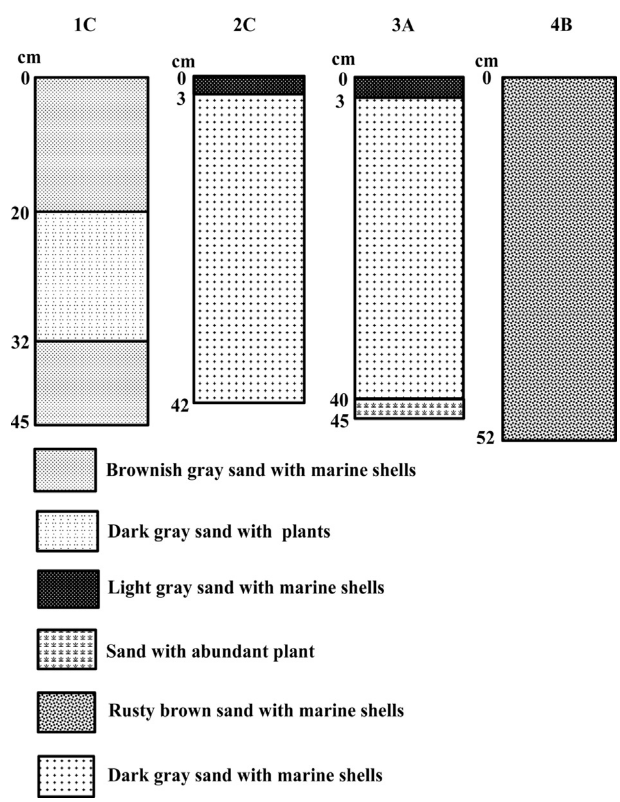


Fig. 5. Lithological identification of cores 1c, 2c, 3a and 4b.

3.2.2. Core 2c

Result of grain size analysis of the 22 samples is summarized as follows: min. value of gravel fraction is 0.03% and observed in 0.26–0.28 and 0.32–0.34 m intervals. Sand is the dominant fraction in the sample taken from 0.02 to 0.04 m interval. The maximum weight of gravel fraction is 9.5% and found in the 0.02–0.04 m interval; average of gravel fraction is 2.5%. Sand content of the samples analyzed along entire core column changes in between 89.5 and 97.9%; hence the average is 94.5%. In core 2c, the lowest mud content is 0.5%, and found in 0.02–0.04 m interval, and 8% is the highest mud content and found in 0.38–0.40 m interval. Analysis of those 22 samples indicated that average of mud fraction in entire core column is 3%.

3.2.3. Core 3a

Result of grain size analysis of the 22 samples is displayed along the core column as lithological units composed of gravel, sand and mud intervals (Fig. 5). Calculated average of gravel size material in the studied samples is 4.6%, whereas the observed minimum and maximum weights of the gravel fraction and their sampling intervals are 0.2% (0.42–0.45 m) and 15.6% (0.06–0.08 m) respectively. In this core, 82.8% is lowest sand fraction content which is measured in 0.06–0.08 m interval. 97.7% is highest sand fraction that is found in 0.42–0.45 m interval. Calculated average of sand fraction for all studied intervals is 92.20%. Mud content is less than 6.5%; all over the core column, hence calculated average of mud fraction is 3.2%.

3.2.4. Core 4b

Grain size analysis of the samples taken all over core 4b was resulted in that the entire core column is represented by fine-sand fraction (Fig. 6).

3.3. Faunal properties

In this study, examined microfauna and macrofauna include benthic foraminifers, ostracods and pelecypods, gastropods respectively.

3.3.1. Benthic foraminifer assemblages

The foraminifer assemblage found in this region includes 29 genera and 52 species. Following publications were used as references during identification process of the selected samples: Cimerman and Langer, 1991; Hatta and Ujiie, 1992; Hottinger et al., 1993; Sgarrella and Moncharmont-Zei, 1993; Loeblich and Tappan, 1994; Avşar, 1997, 2002; Avşar and Meriç, 2001; Avşar and Ergin, 2001; Avşar et al., 2001; Meriç and Avşar, 2001; Meriç et al., 1995, 2002a, 2002b, 2003a, 2003b, 2004a, 2004b; 2005; Kaminski et al., 2002. Foraminifer assemblages observed in the study area is not reach as the assemblages that have been encountered in the other studied areas in eastern Aegean coast line. Systematically identified genera and species (Loeblich and Tappan, 1988) in this assemblage are as follows: *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),

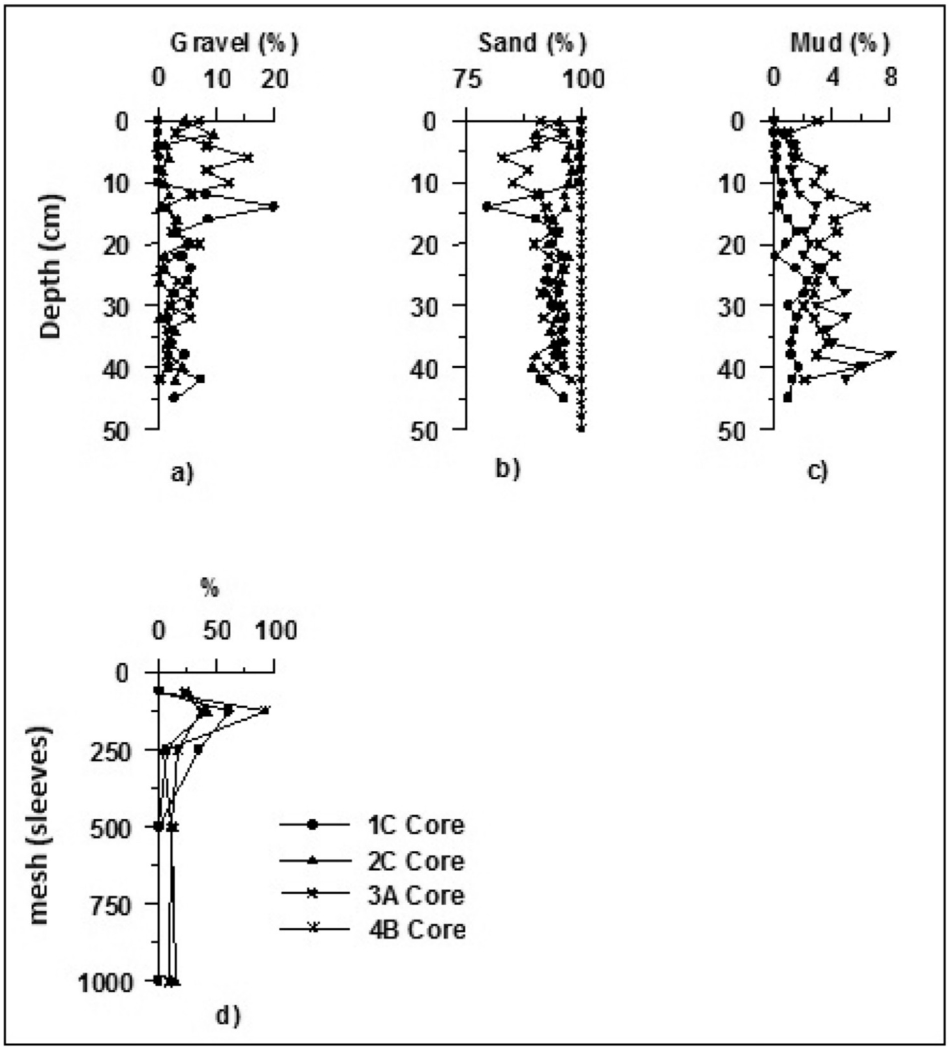


Fig. 6. Distribution of gravel % (a), sand % (b), mud % contents in cores and classification of sand size fraction with depth through four core profiles.

A. duthiersi Schlumberger, *A. mediterranensis* (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* Terquem, *T. schreiberiana* d'Orbigny, *Wellmanellinella striata* (Sidebottom), *Sigmoilinita 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, *Neoeponides bradyi* (Le Calvez), *Neoconorbina terquemi* (Rzehak), *Rosalina bradyi* Cushman, *R. globularis* d'Orbigny, *Conorbella imperatoria* (d'Orbigny), *Lobatula lobatula* (Walker and Jacob), *Planorbulina mediterranensis* d'Orbigny, *Cibicidella 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, *Cribroelphidium poeyanum* (d'Orbigny), *Porosononion 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. (Plate 1–5).

3.3.2. Abnormal foraminifer assemblages

The assemblage of abnormal foraminifers which was identified beside the normal benthic foraminifer assemblage in cores 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); while in core 4b *Peneroplis pertusus* (Forskal) and *P. planatus* (Fichtel and Moll) were the observed abnormal individuals. Additionally *Spiroloculina angulata* (d'Orbigny), *Cibicidella variabilis* (d'Orbigny) were identified as a small number of individuals that display features similar to the abovementioned ones (Plate 2, 3).

Plate 1. 1. *Peneroplis pertusus* (Forskal), Core 4b, 2–4 cm, Ayvalık; 2. *Peneroplis pertusus* (Forskal), Core 4b, 4–6 cm, Ayvalık; 3. *Peneroplis pertusus* (Forskal), Core 4b, 6–8 cm, Ayvalık; 4. *Peneroplis planatus* (Fichtel and Moll), Core 4b, 8–10 cm, Ayvalık; 5. *Peneroplis planatus* (Fichtel and Moll), Core 4b, 10–12 cm, Ayvalık; 6. *Peneroplis pertusus* (Forskal), Core 4b, 10–12 cm, Ayvalık; 7. *Peneroplis pertusus* (Forskal), Core 4b, 12–14 cm, Ayvalık; 8. *Peneroplis planatus* (Fichtel and Moll), Core 4b, 14–16 cm, Ayvalık; 9. *Peneroplis pertusus* (Forskal), Core 4b, 16–18 cm, Ayvalık; 10. *Peneroplis pertusus* (Forskal), Core 4b, 16–18 cm, Ayvalık; 11. *Peneroplis pertusus* (Forskal), Core 4b, 18–20 cm, Ayvalık; 12. *Peneroplis pertusus* (Forskal), Core 4b, 22–24 cm, Ayvalık; 13. *Peneroplis pertusus* (Forskal), Core 4b, 24–26 cm, Ayvalık; 14. *Peneroplis pertusus* (Forskal), Core 4b, 24–26 cm, Ayvalık; 15. *Peneroplis planatus* (Fichtel and Moll), Core 4b, 28–30 cm, Ayvalık; 16. *Peneroplis pertusus* (Forskal), Core 4b, 34–36 cm, Ayvalık; 17. *Peneroplis planatus* (Fichtel and Moll), Core 4b, 40–42 cm, Ayvalık.

3.3.3. Ostracod assemblages

The Recent sediment samples selected from the cores include a different ostracod assemblage that has likely been affected by existing ecological conditions in the inhibited environment. In this ostracod assemblage (19 genera and 22 species) is identified and listed according to Hartman and Puri 1974, and World Ostracoda Data Base (http://www.marinespecies.org/ostracoda/). The identification of the species are used reference publications as: Van Morkhoven, 1963; Sissingh, 1972, Hartman and Puri, 1974; Breman, 1975; Yassini, 1979, Bonaduce et al., 1979; Guillaume et al., 1985; Oertli, 1985; Nazik, 1994, 2001, Şafak, 1999; Tunoğlu, 1999, 2002, Meriç et al., 2005. The ostracod assemblage is pointed an epineritic environment in this study.

Some of them are known as Mediterranean and Atlantic originated. Such as: *Neonesidea corpulenta* (Mueller), *Aurila convexa* (Baird), *Jugosocythereis prava* (Baird), *Carinocythereis antiquata* (Baird), *C. carinata* (Roemer), *Costa batei* (Brady), *Basslerites berchoni* (Brady), *Semicytherura inversa* (Seguenza), *Loxoconcha rhomboidea* (Fischer), *Neocytherideis fasciata* (Brady and Robertson), *Cushmanidea elongata* (Brady) and *Neonesidea frequens* (Mueller). The other species are only observed in Mediterranean region. Such as: *Triebelina raripila* (Mueller), *Cytherelloidea beckmanni* Barbeito-Gonzalez, *Cytherelloidea sordida* (Mueller), *Aurila arborescens* (Brady), *Carinocythereis rhombica* Stambolidis, *Hiltermannicythere rubra* (Mueller), *Hiltermannicythere turbida* (Mueller), *Cytheretta adriatica* Ruggieri, *Cytheretta judaean* (Brady), *Callistocythere intricatoides (*Ruggieri), *Urocythereis crenulosa* (Terquem), *Acanthocythereis hystrix* (Reuss), *Paracytheridea depressa* Mueller, *Loxoconcha stellifera* Mueller, *Xestoleberis communis* Mueller, *Xestoleberis dispar* Mueller, *Pontocypris acuminata* (Mueller) (Parlak and Nazik, 2016). They have a calcified carapace and a high preservational capacity. No abnormalities of ostracod carapace morphology are not observed in any samples according to ambient conditions in this study.

Plate 2. 1. *Peneroplis pertusus* (Forskal), Core 4b, 42–44 cm, Ayvalık; 2. *Peneroplis planatus* (Fichtel and Moll), Core 4b, 46–48 cm, Ayvalık; 3. *Peneroplis pertusus* (Forskal), Core 4b, 48–50 cm, Ayvalık; 4. *Peneroplis pertusus* (Forskal), Core 4b, 48–50 cm, Ayvalık; 5. *Peneroplis pertusus* (Forskal), Core 4b, 48–50 cm, Ayvalık; 6. *Peneroplis pertusus* (Forskal), Core 4b, 50–52 cm, Ayvalık; 7. *Quinqueloculina* cf. *seminula* (Linné), Core 1c, 8–10 cm, Ayvalık; 8. *Lobatula lobatula* (Walker and Jacob), Core 1c, 12–14 cm, Ayvalık; 9. *Lobatula lobatula* (Walker and Jacob), Core 1c, 16–18 cm, Ayvalık; 10. *Challengerella bradyi* Billman, Hottinger and Oesterle, Core 1c, 18–20 cm, Ayvalık. 11. *Peneroplis planatus* (Fichtel and Moll)-*Coscinospira hemprichii* Ehrenberg unity. External view, Core 3a, 0–2 cm, Ayvalık; 2. *Peneroplis pertusus* (Forskal)-*Coscinospira hemprichii* Ehrenberg unity. External view, Core 3a, 2–4 cm, Ayvalık; 13. *Peneroplis planatus* (Fichtel and Moll)-*Coscinospira hemprichii* Ehrenberg unity. External view, Core 2c, 2–4 cm, Ayvalık; 14. *Elphidium crispum* (Linné). External view, Core 2c, 2–4 cm, Ayvalık;15. *Lobatula lobatula* (Walker and Jacob). External view, umblical side, Core 2c, 6–8 cm, Ayvalık; 16. *Massilina secans* (d'Orbigny). External view, Core 2c, 8–10 cm, Ayvalık.

3.3.4. Mollusc assemblages

Thirty seven (37) genera and sixty five (65) species of gastropods were found to in the studied core samples. The publications used for identification of the species are as follows: Nordsieck, 1968, 1969, 1972, 1977; Giannuzzi Savelli et al., 1994, 1996, 1999, 2003. Total of identified species was in accordance with the typical littoral fauna of the Turkish coasts of the Northern Aegean Sea (Öztürk and Çevik, 2000; Demir, 2003). However, species totals display significant variations in the different cores. The majority of the species observed in the samples of cores 1c, 2c and 3a were 40 and 34 species, respectively. Only 10 species were found in the samples of core 4b. *Bittium* spp. are found as a dominating species in all of the core samples and almost in every analysed layer.

The systematically identified species in the present study are as follows: *Smaragdia viridis* (Linné), *Diadora graeca* (Linné), *Scissurella costata* D'Orbigny, *Gibbula adansoni* (Payraudeau), *G. albida* (Gmelin), *G. varia* (Linné), *Jujubinus exasperatus* (Pennant), *J. striatus* (Linné), *Tricolia pullus pullus* (Linné), *T. speciosa* (von Mühlfeldt), *T. tenuis* (Michaud), *Cerithium vulgatum* Bruguière, *Bittium jadertinum* (Brusina), *B. latreillii* (Payraudeau), *B. reticulatum* (Da Costa), *Turritella communis* Risso, *T. turbona* Monterosato, *Eatonia celata* (Monterosato), *Rissoa auriformis* Pallary, *R. auriscalpiareum* (Linné), *R. labiosa* (Montagu), *R. monodonta* Philippi, *R. scurra* (Monterosato), *R. splendida* Eichwald, *Alvania cancellata* (Da Costa), *A. carinata* (Da Costa), *A. cimex* (Linné), *A discors* (Allan), *A. geryonia* (Nardo), *A. littoralis* (Nordsieck), *A. mamillata* Risso, *Manzonia crassa* (Kanmacher), *Obtusella intersecta* (Wood S.W.), *O. macilenta* (Monterosato), *Pusillina inconspicua* (Alder), *P. lineolata* (Michaud), *P. marginata* (Michaud), *P. parva* (Da Costa), *P. philippi* (Aradas and Maggiore), *Circulus tricarinatus* (Wood), *Truncatella subcylindrica* (Linné), *Calyptera chinensis* (Linné), *Crepedula ungiformis* Lamarck, *Natica stercusmuscarum* (Gmelin), *Monophorus perversus* (Linné), *Epitonium linctum* (De Boury and Monterosato), *Vitreolina philippi* (De Rayneval and Ponzi), *Hexaplex trunculus* (Linné), *Muricopsis*

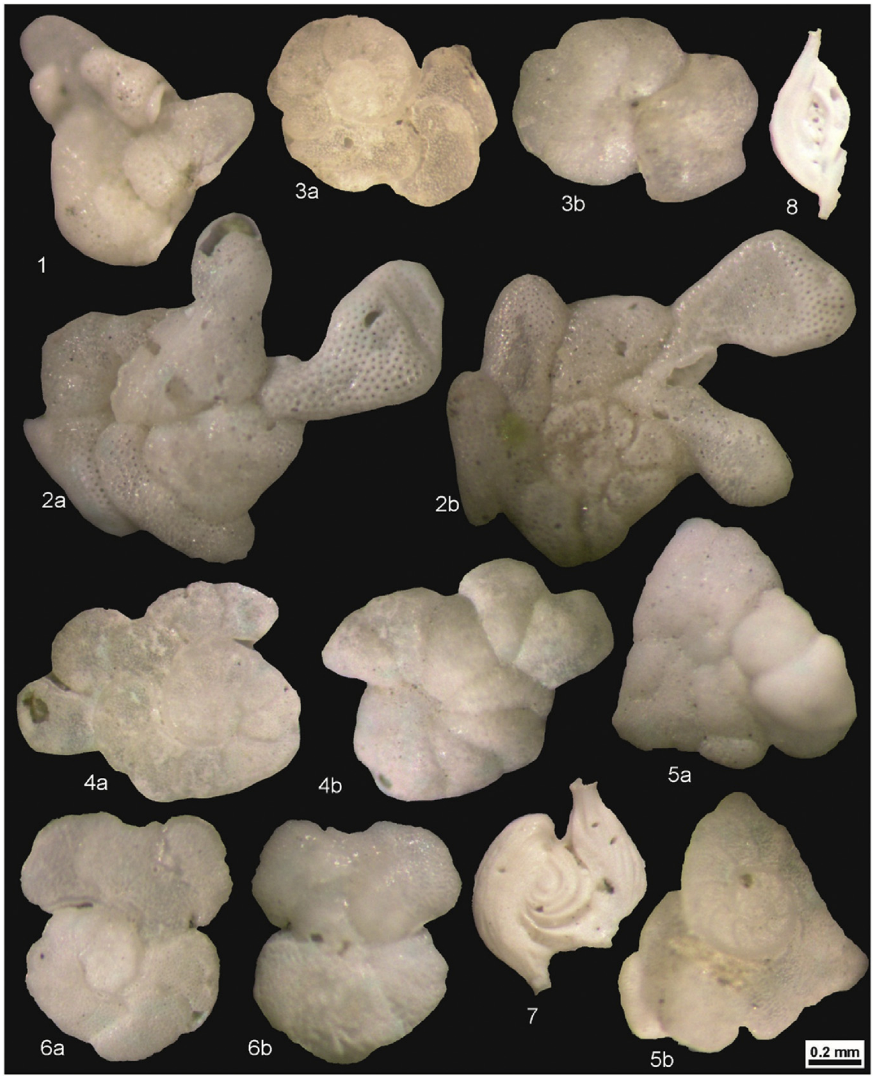


Plate 3. 1. *Cibicidella variabilis* (d'Orbigny). External view, umblical side, Core 2c, 10–12 cm, Ayvalık; 2. *Cibicidella variabilis* (d'Orbigny). External views, a, umblical side and b, spiral side, Core 2c, 18–20 cm, Ayvalık; 3. *Lobatula lobatula* (Walker and Jacob). External views, a, spiral side and b, umblical side, Core 2c, 10–12 cm, Ayvalık; 4. *Lobatula lobatula* (Walker and Jacob). External views, a. spiral and b, umblical sides, Core 2c, 30–32 cm, Ayvalık; 5. *Lobatula lobatula* (Walker and Jacob). External views, a, umblical and b, spiral sides, Core 2c, 32–34 cm, Ayvalık; 6. *Lobatula lobatula* (Walker and Jacob). External views, a, spiral and b, umblical sides, Core 2c, 34–36 cm, Ayvalık; 7. *Adelosina mediterranensis* (Le Calandz J. and Y.). External view, Core 2c, 10–12 cm, Ayvalık; 8. *Spiroloculina angulosa* Terquem. External view, Core 2c, 20–22 cm, Ayvalık.

cristata (Brocchi), *Ocinebra aciculata* (Lamarck), *Chauvetia brunnea* (Donovan), *Cyclope neritae* (Linné), *C. pellucida* Risso, *Vexillum tricolor* (Gmelin), *Granulina clandestina* (Brocchi), *G. occulta* (Monterosato), *Conus mediterraneus* Hwass in Bruguière, *Bela nebula* (Montagu), *Mangelia scabrida* Monterosato, *M. smithii* (Forbes), *Raphitoma linearis* (Montagu), *Anisocycla nitidissima* (Montagu), *Cylichnina laevisculpta* (Granata-Grillo), *C. umbilicata* (Montagu), *Pyrunculus minutissimus* (Monterosato).

The bivalvia fauna found in the studied core samples was poorer than the known fauna of the Northern Aegean coast of Turkey (Öztürk and Çevik, 2000; Demir, 2003). The sample 4b displays the poorest diversity of species, and it is represented by only 5 species. The species diversity varies between the samples, and each sample has a different dominant species. The 26 genera and 32 species were identified in the present study. The reference publications used in the identification stage are as follows: Giannuzzi Savelli et al., 2001 and Nordsieck, 1969. The species were *Nucula nucleus* (Linné), *Striarca lactea* (Linné), *Modiolarca subpicta* (Cantraine), *Musculus costulatus* (Risso), *Modiolus barbatus* (Linné), *Limatula subauriculata* (Montagu), *Loripes lacteus* (Linné), *Lucinella divaricata* (Linné), *Anodontia fragilis* (Philippi), *Myrtea spinifera* (Montagu), *Lucinoma boreale* (Linné), *Glans trapezia* (Linné), *Cardita aculeata* (Poli), *Acanthocardia tuberculata* (Linné), *Parvicardium exiguum* (Gmelin), *P. minimum* (Philippi), *P. roseum* (Lamarck), *P. scabrum* (Philippi), *Plagiocardium papillosum* (Poli), *Tellina donacina* Linné, *T. distorta* Poli, *Donax trunculus* Linné, *Psammobia costulata* Turton, *Abra alba* (Wood W.), *A. longicallus* (Scacchi), *A. prismatica* (Montagu), *Venus casina* Linné, *Chamelea gallina* (Linné), *Gouldia minima* (Montagu), *Pitar rudis* (Poli), *Irus irus* (Linné), *Hiatella rugosa* (Linné).

3.4. Evaluation gypsum crystals

Abundant gypsum crystals were observed in 0.28–0.45 m interval of core 3a which is one of the four examined cores in the present study (Plate 5). Contemporaneous formation of gypsum crystals around tests, shell, etc. of the different groups of living organisms is an interesting observation. Especially gypsum crystals

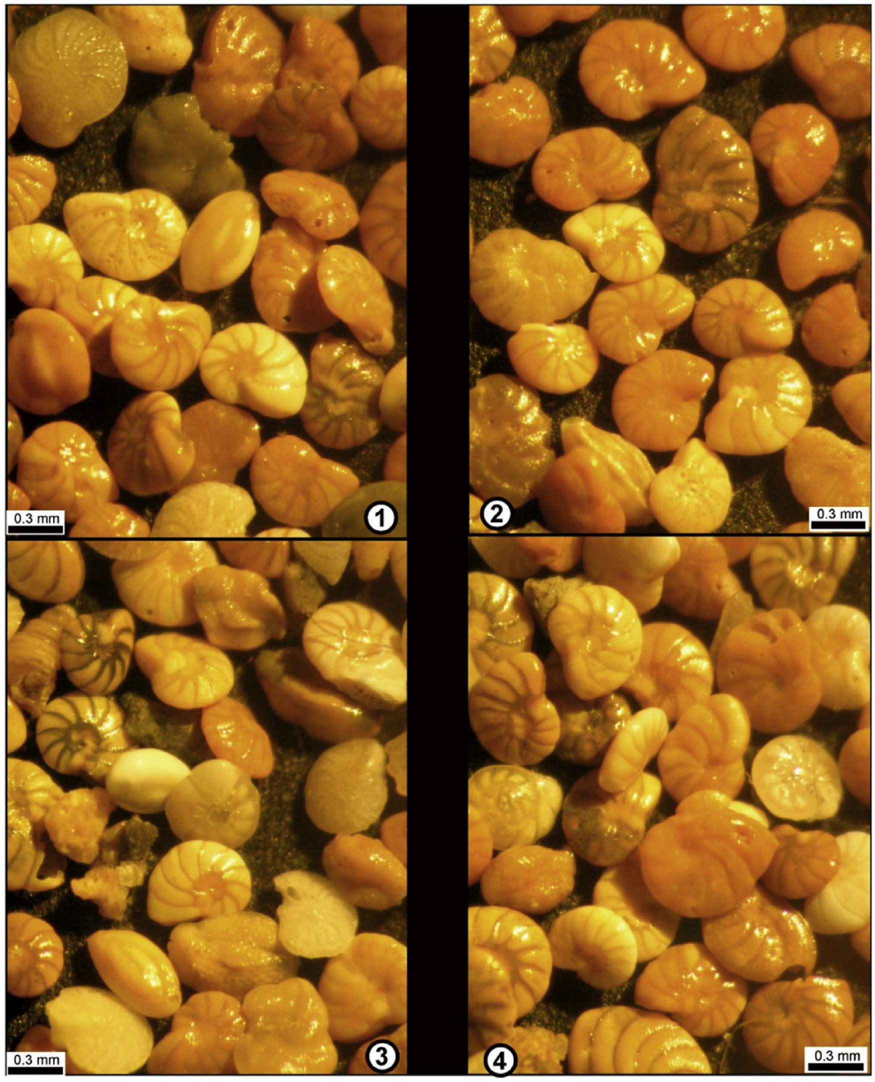


Plate 4. 1. General view, Core 4b, 0–2 cm, Ayvalık; 2. General view, Core 4b, 2–4 cm, Ayvalık; 3. General view, Core 4b, 4–6 cm, Ayvalık; 4. General view, Core 4b, 6–8 cm, Ayvalık.

developed on *the Ammonia compacta, Elphidium complanatum, Bittium* sp. tests and *Posidonia* plants are the important and different feature in the region. This suggests occurrence of a near past hydrothermal mineralization phase in this area/areas.

General properties, mineralogical difference occurred laminas of the gypsum crystals, and the responsible environmental causes of the differences observed in the gypsum samples examined in 0.28–0.45 m interval of core 3a would be explained as follows: No significant difference is seen between the samples. Varying abundance and size of the gypsum crystals, presence of gypsum twins, nonexistence of foreign material inclusions in the crystals, but existence of the selenite (transparent gypsum) crystals were the prominent differences observed in the studied samples.

Lithological properties of core 3a are; 0.03–0.40 m interval is represented by a dark brown sand layer with whole shells and shell fragments. In the underlying 0.40–0.45 m interval lithology changes into different sand containing abundant plant remains. The gypsum crystals do not show any significant change in despite of the aforementioned lithological change in the core column. Distribution of changes in contained gypsum crystals in the recent sedimentary column was investigated. The size variation, twinning, coexisting organism, twinning and idiomorphism and organic matter contents in the gypsum crystals are comparatively investigated in some papers (*i.e.* Krauskopf and Bird, 1995). In the present study idiomorphism (euhedral crystalization) is found adversely propotional to the organic matter content of the gypsum crystals as exhibited in Fig. 7. Tweening also displays similar adverse relation with the organic matter content in the gypsum crystals (Fig. 7). These specified changes in the gypsum crystals are also exhibited in Table 3.

In the examined gypsum crystals, any significant mineralogic or genetic diference was not found. Therefore it has been concluded that changes occured in either environmental conditions or in site of deposition were not significant. However some local and minör environmental changes are considered to be active basing upon observed diference in the crystal size and the twinning ratio of the examined gypsum crystals. In event, the biologic constituents are low in 0.32–0.34 m interval, but high in 0.38–0.45 m interval. Lessen biological particles in the overlying sedimentary unit (32–34) suggests that the relatively higher concentration of Ca and SO4 ions in the depositional environment would restrict proliferation of the organism in this layer. In addition, a relatively sharp interface, which is seen in between the two sedimentary units described as unit “B” sand with relatively abundant gypsum

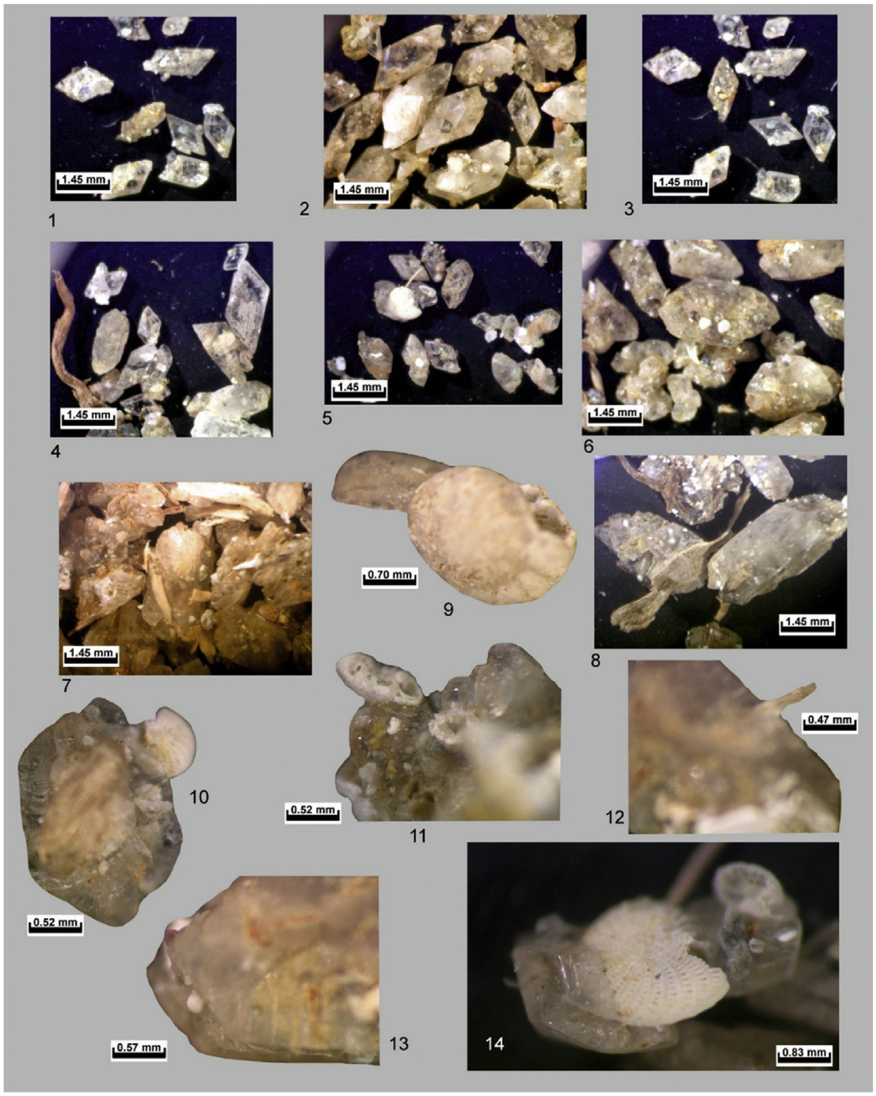


Plate 5. Fig. 1. Gypsum crystals. Core 3a, 28–30 cm, Ayvalık; Fig. 2. Gypsum crystals. Core 3a, 30–32 cm, Ayvalık; Fig. 3. Gypsum crystals. Core 3a, 30–32 cm, Ayvalık; Fig. 4. Gypsum crystals. Core 3a, 32–34 cm, Ayvalık; Fig. 5. Gypsum crystals. Core 3a, 34–36 cm, Ayvalık; Fig. 6. Gypsum crystals. Core 3a, 38–40 cm, Ayvalık; Fig. 7. Gypsum crystals. Core 3a, 40–42 cm, Ayvalık; Fig. 8. Gypsum crystals. Core 3a, 42–45 cm, Ayvalık; Fig. 9. Gypsum crystal on the *Challengerella bradyi* Billman, Hottinger and Oesterle test. Core 3a, 40–42 cm, Ayvalık; Fig. 10. Gypsum crystal around of the *Elphidium crispum* (Linné) test. Core 3a, 40–42 cm, Ayvalık; Fig. 11. Gypsum crystal around of the *Challengerella bradyi* Billman, Hottinger and Oesterle test. Core 3a, 40–42 cm, Ayvalık; Fig. 12. The piece of the *Posidonia* in the Gypsum crystal. Core 3a, 40–42 cm, Ayvalık; Fig. 13. Tests of foraminifer in the Gypsum crystal. Core 3a, 40–42 cm, Ayvalık; Fig. 14. Gypsum crystal around of the *Elphidium crispum* (Linné) test. Core 3a, 34–36 cm, Ayvalık.

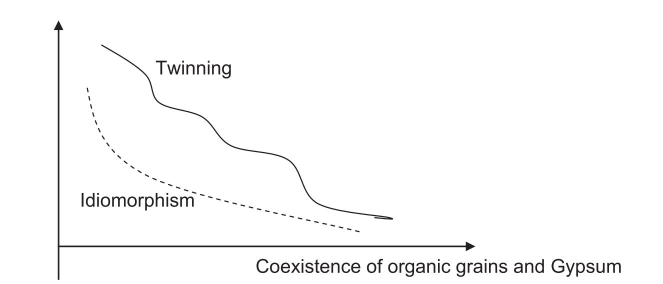


Fig. 7. Idiomorphism and twinning frequency of the gypsum crystals against the organic matter content.

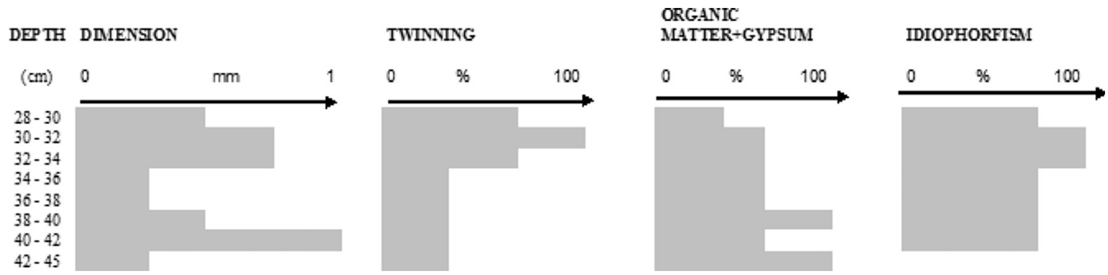
crystals, and unit "A" sand with abundant organisms might witness existence of at least one frequently repeated rhythmic "ABAB" (or cyclic to some other workers) system in the site of deposition.

Reduction in numbers of twin and euhedral gypsum crystals when shell + gypsum coexistence is increased supports this cyclic deposition idea. Presence of nested gypsum crystals bearing shells may indicate a high sulfur input to the depositional environment during their life span. Influx of the hot hydrothermal fluids likely with high metal content during early and/or final stage of deposition might cause such a "gypsum + shell" coexistence. Presence of ore minerals (*i.e.* Pb, Fe, Cu, and Mn) around the study area supports this interpretation.

3.5. Radioactivity properties of the sediments

Fifty two (52) pieces of sediment samples collected from the examined cores were used to measure total alpha and total beta counts. The total alpha and total beta counts are graphically exhibited in Fig. 8a and b displays of respectively. In core 1a, total alpha counts vary in the range of 265–376 Bq/kg values, hence total beta counts are ranged in between 502 and 603 Bq/kg values. In core 2a, total alpha and total beta values display ranges of 217–615

Table 3
Frequency of variation in properties of the gypsum crystals at depth.



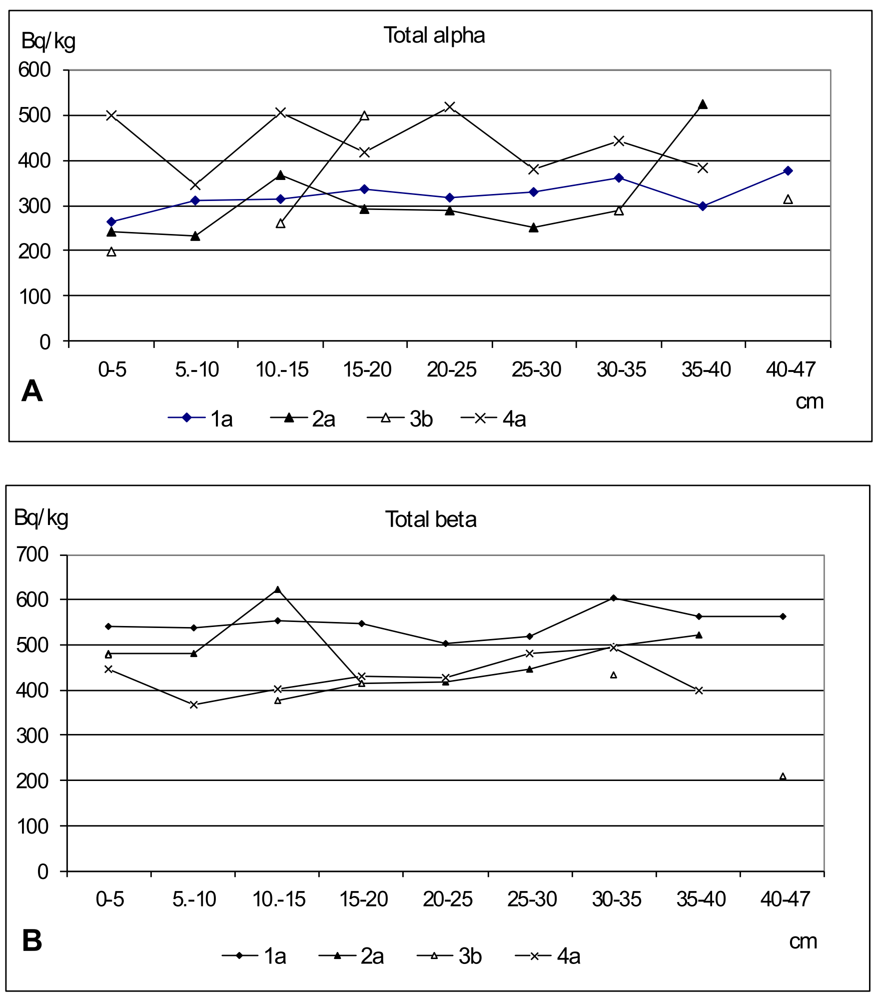


Fig. 8. a. Depth versus total alpha count distribution in cores; b. Depth versus total beta count distribution in cores.

Bq/kg, and 377–632 Bq/kg respectively. In core 3b, total alpha counts are in between 199 and 660 Bq/kg and total beta counts are 158–556 Bq/kg values. In core 4a, total alpha counts vary in between 346 and 519 Bq/kg values, while total beta counts are found in 368–494 Bq/kg range.

Lowest and the highest total alpha counts are measured in core 3b. The lowest and highest total beta counts are measured in cores 3b and 2a respectively. Higher total alpha counts measured intervals in each core are as follows: core 1a, in 0.30–0.35 m interval; core 2a, in 0.05–0.10 m, 0.10–0.15 m, 0.15–0.20 m, 0.25–0.30 m and 0.35–0.40 m intervals; core 3b, in 0.30–0.45 m interval; core 4a, in 0.30–0.35 m interval. Abundant gypsum crystals are observed in 0.28–0.45 m interval of core 3a. The high total alpha and total beta counts measured samples were taken from 0.30 to 0.35 m and 0.40–0.45 m intervals of the nearby core 3b respectively. Distribution of total alpha and total beta counts measured in the cores is as follows: the highest values of total alpha counts are reached at 0.35–0.40 m and 0.15–0.20 m intervals in 2a and 3b cores respectively, while the higher counts in core 4a displays fluctuating values measured in 0.00–0.05, 0.10–0.15, 0.20–0.25 m intervals. In core 2a, highest total beta is measured in 0.10–0.15 m interval.

3.6. Chemical properties of the sediments

Heavy metal (Cu, Co, Ni, Cr, Zn, Fe and Mn) analysis was done in the sediment samples selected from 34 intervals of the four (4) cores cut at the seafloor stations located around Maden and Alibey islands (Fig. 4). The cores with an average of 0.45 m length were examined being divided into 0.05 m thick intervals (segments). Comparison of heavy metal contents of the cores giving the peaked elements in parentheses (Cu, Co, Ni, Cr, Zn, Fe and Mn) beside the core number are as follows; *e.g.*, core 1b (Fe), core 2a (Cr), core 3b (Zn and Cu). Mn, Fe and Co contents are prominent in core 4a. In other words Fe and Mn concentrations in core 4a are higher than others. Fe has an average of 1.5% in the other cores. However calculated average of Fe is increased up to 2.3% in core 4a (Table 4).

Increment of calculated average up to 2.3% in core 4a would be affected by the different environmental conditions that caused higher precipitation of Fe in the sediments. Assuming that higher mud content might cause the higher Fe values due to high clay fraction in usual muddy sediments would be eliminated because of contained high volume of shells in the sediment. In addition, averaged value of Mn is 900 ppm in core 4a, hence Mn average is around only 280 ppm in the other three cores. This significant difference found in the cores which were cut at the relatively nearby seafloor stations, can be caused by the locally controlled environmental conditions. In core 4a, Co value is also higher than values found in the other cores. The differences (6 ppm–17 ppm) seen in Co values are not as high as high as found in Mn and Fe contents of the other cores. The lowest Ni and Cu contents were also determined in core 4a, while overall distribution of these elements is similar in the other three cores.

Zn displays a variable distribution in each core. However in 3b core, Zn is higher than the others. Cr is found a little higher in 2a core than the others. Lowest values are measured in 3b core.

Nevertheless Cr displays a regular distribution in all cores. In 4a core, Fe and Mn contents are significantly higher than the other three cores. This is the most prominent property to be considered in the heavy mineral analysis results. Beyond this solitary core, over all heavy metal contents of the studied cores are lower than normal marine sediments. However, when reducing impact of the present rich organic (skeletal) particles on to fine grained material that likely contains the heavy metal particles in the analyzed recent sediment samples is considered, measured heavy metal values in the recent sediment samples would be accepted as relatively significant concentrations.

In the study area, increments in contents of the heavy metals (Zn and Mn) (except Fe) in different intervals of the analyzed cores can be considered higher than the Zn and Mn contents reported in Krauskopf (1979). Higher contents of Zn measured in all cores are in the rage of (90.3–338.5 ppm). In addition, the maximum Co value (16.5 ppm) which is measured in 0.15–0.20 m interval of core 4a is close to the shale values of Krauskopf (1979).

3.7. The chemical properties of foraminifer tests

SEM/EDS analyzes were performed to the 16 samples of normal and abnormal colored, and colorless tests of *Massilina secans*

Table 4
Metallic element analyses of the samples of the cores cut around Ayvalık, Alibey and Maden islands.

cm	Co (ppm)	Ni (ppm)	Cu (ppm)	Cr (ppm)	Zn (ppm)	Fe (%)	Mn (ppm)
Core 1b							
0–5	10.9	8.5	8.4	19.0	57.7	1.8	315.2
5–10	12.2	5.9	9.8	18.8	41.8	2.0	300.6
10–15	12.5	12.5	10.4	29.4	152.4	2.2	302.9
15–20	11.4	10.0	9.5	26.8	70.7	1.9	302.4
20–25	11.1	7.1	9.8	20.0	83.4	2.0	298.1
25–30	11.9	6.9	11.1	19.9	57.4	2.1	294.9
30–35	10.8	11.0	9.6	27.0	121.2	2.0	285.4
35–40	11.7	6.4	11.4	18.2	46.5	2.0	294.4
40–47	11.2	5.7	9.8	17.8	37.0	2.0	285.5
0–5	7.9	8.8	12.8	30.7	23.4	1.5	325.6
5–10	7.6	9.1	10.5	28.1	90.3	1.5	291.6
10–15	6.9	7.5	8.4	26.3	120.8	1.3	266.4
Core 2a							
15–20	7.0	8.5	7.8	26.4	144.3	1.3	266.8
20–25	7.3	9.7	10.3	29.8	105.7	1.4	323.2
25–30	7.2	9.3	9.9	27.3	51.7	1.4	302.1
30–35	7.7	13.7	13.3	32.3	19.6	1.6	343.8
35–42	7.6	14.5	15.0	30.6	88.2	1.6	517.7
0–5	8.3	6.9	8.0	14.2	173.2	1.2	228.7
5–10	8.9	8.2	9.2	14.7	196.7	1.3	242.4
10–15	9.6	6.0	10.8	15.0		1.3	227.2
15–20	9.6	9.6	34.3	15.7	190.2	1.4	223.3
20–25	9.3	11.5	11.1	17.1	57.5	1.5	223.3
Core 3b							
25–30	10.2	13.1	13.2	20.7	54.2	1.7	235.3
30–35	9.1	9.0	12.4	15.3	100.5	1.5	261.0
35–40	9.9	12.4	10.7	16.0	338.5	1.4	284.6
40–45	9.5	10.6	9.5	15.1	114.4	1.7	266.3
0–5	14.2	9.7	8.5	24.7	130.8	2.3	945.8
5–10	14.7	4.4	8.1	20.6	42.3	2.3	969.7
10–15	15.3	5.5	8.2	21.3	61.0	2.4	955.0
15–20	16.5	4.9	7.8	22.4	53.1	2.4	951.4
Core 4a							
20–25	15.4	5.4	8.7	21.9	56.7	2.3	829.1
25–30	14.1	4.4	7.6	20.2	32.9	2.2	754.1
30–35	14.0	5.2	8.2	20.8	38.9	2.2	764.3
35–40	12.9	4.5	6.9	19.3	59.3	2.2	698.1

(d'Orbigny), *Peneroplis pertusus* (Forskal), *P. planatus* (Fichtel and Moll), *Lobatula lobatula* (Walker and Jacob), *Ammonia compacta* Hofker which were collected from different depths of 2c, 3a and 4b cores. The list of the analyzed samples is displayed in a table (Table 5).

In the microprobe analyzes of tests of the 16 benthic foraminifer which were sampled from various depths of 2c, 3a and 4 b cores; C, O, Ne, Na, Mg, Al, Si, K, Ca, Fe, Mn, Zn, Ni, Rb, Tc, Cd, Rh, Te, Ho, Fr, Ra, Np, Pu, Pa, and U elements were found. Some of the elements are found in only one sample. Mn element is encountered in the colorless, abnormal *Massilina secans* test sampled in 0.08–0.10 m interval of 2c core; Ni, Ho, Rh, Fr, Np elements were found in the colorless, abnormal *Ammonia compacta* test sampled in 0.24–0.26 m interval of 3a core.

Mn element is also found in the colored normal *Peneroplis planatus* test sampled in 0.04–0.06 m interval, and Cd element is found in the colored, abnormal *Peneroplis planatus* tests sampled in 0.08–0.10 m interval of 4b core.

As it is displayed in Fig. 9; the elements found in highest levels in all tests are C, O, Ca, Na, Mg and Te. The Si element was found in the *Lobatula lobatula* and *Ammonia compacta* tests and the *Ammonia compacta* test in 2c and 3a cores respectively (Fig. 9a–c).

Fe element found in the tests of foraminifer genera and the core numbers been sampled for the microprobe analyses are as follows; *Ammonia compacta* (2c), *Peneroplis pertusus* (3c), *Ammonia compacta* (4b) (Fig. 9d, e). The highest value of Mn element was found in the *Peneroplis planatus* test in normal color, while the highest Zn value was found in the colorless test of *Lobatula lobatula* which was sampled in 2c core.

Some differences are observed when results of geochemical analyses done in the sediment samples of the cores compared with results of the similar analyses done in colored/colorless, normal/abnormal tests of the foraminifers sampled from the same cores. In the sediment analyses the highest Fe value (1.7%) was found in 0.25–0.30 m interval of 3b core while the highest Fe value (1.51%) was measured in the test of *Ammonia compacta* which was sampled in 0.24–0.26 m interval of 3a core. The highest value (967.7 ppm) of Mn element was measured in 0.05–0.10 m, interval of 4a core, hence the highest Mn value was found in the test of *Peneroplis planatus* which was sampled in 0.04–0.06 m interval of core 4b. Zn element is reached at the highest value (144.3 ppm) in 0.15–0.20 m interval of 2a core, hence the highest Zn value is found in 0.40–0.42 m interval of 2c core. Ni element is found only in the test of *Ammonia compacta* which was sampled in 0.24–0.26 m interval of 3a core, and it reached at the highest value (13.1 ppm) in 25–30 m interval of 3b core.

4. Conclusion and discussion

Recent sedimentation in the study area is investigated basing upon the grain size analysis data obtained from the seafloor samples. Accordingly, in the Gulf of Edremit sediments of coastal areas are represented by sand (S), silty sand (siS). In normal course of sedimentation, the grain size of the clastics is progressively decreased where water depth is gradually increased, thus the fine-very fine grained sediments such as clayey silt (clS), silty clay (siCL) and mud (M) have been deposited in the study area. The recent sediment samples of the Gulf of Edremit are dominantly composed of mud (M) and mud with lesser amounts of mixed sands and gravels.

Those would be symbolized as follows: gravelly sandy mud (gsM), gravelly mud (gM) and sandy mud (sM). A few sand dominant sediments such as gravelly muddy sand (gmS) and muddy sand with lesser gravels ((g)mS) were also sampled in the study area.

Bioclastics (grains made of mollusc shells, ostracod carapaces and foraminifer tests) sediments are seen place to place in the northwest of Ayvalık around Alibey and Maden islands. “Silty clay and mud” and “sand and silty sand” are the dominant sediment types found in central parts of the Gulf of Edremit and around the Alibey Island respectively (Fig. 4). Most of the Dikili Channel samples are composed of sand dominant sediments such as muddy sand with lesser gravels ((g) mS), gravelly and muddy sand (gmS). However a few mud dominant sediments such as gravelly mud (gM) and sandy mud with lesser gravels were sampled in the Dikili Channel.

According to the statistical parameters such as Mz (graphic mean), Sf (graphic standard deviation), Ski (graphic skewness), Kg (graphic Kurtosis) calculated from the cumulative grain size distribution curves of the sediment samples, the current depositional regime is interpreted to be a rapid deposition is active in this region, and influx of fast but less transported grains has been dominant rather than a sedimentation under normal marine conditions. The skeletal grains (mollusc shells, ostracod carapaces and foraminifer tests) are abundant in the sandy and gravelly units of the study area. However, skeletal materials are found extremely abundant in some points of the study area. Observed abundance of the skeletal grains in the marine areas especially located in the

Table 5
Micoprob analysis applied Normal-abnormal, colored-colorless bentic foraminifers.

Name of core	Sample No.	Depth (cm)	Benthic Foraminifers	Colour		Colourless	
				Normal	Abnormal	Normal	Abnormal
2c	1	6–8	*Lobatula lobatula*				X
2c	2	8–10	*Massilina secans*				X
2c	3	40–42	*Lobatula lobatula*				X
2c	4	0–2	*Ammonia compacta*				X
2c	5	4–6	*Peneroplis planatus*				X
2c	6	2–4	*Peneroplis planatus*			X	
3a	15	24–26	*Ammonia compacta*				X
3a	16	34–36	*Ammonia compacta*			X	
4b	7	4–6	*Peneroplis planatus*	X			
4b	8	6–8	*Peneroplis planatus*	X			
4b	9	18–20	*Peneroplis pertusus*	X			
4b	10	24–26	*Peneroplis pertusus*	X			
4b	11	8–10	*Peneroplis planatus*		X		
4b	12	10–12	*Peneroplis planatus*		X		
4b	13	22–24	*Peneroplis planatus*		X		
4b	14	48–50	*Peneroplis pertusus*		X		

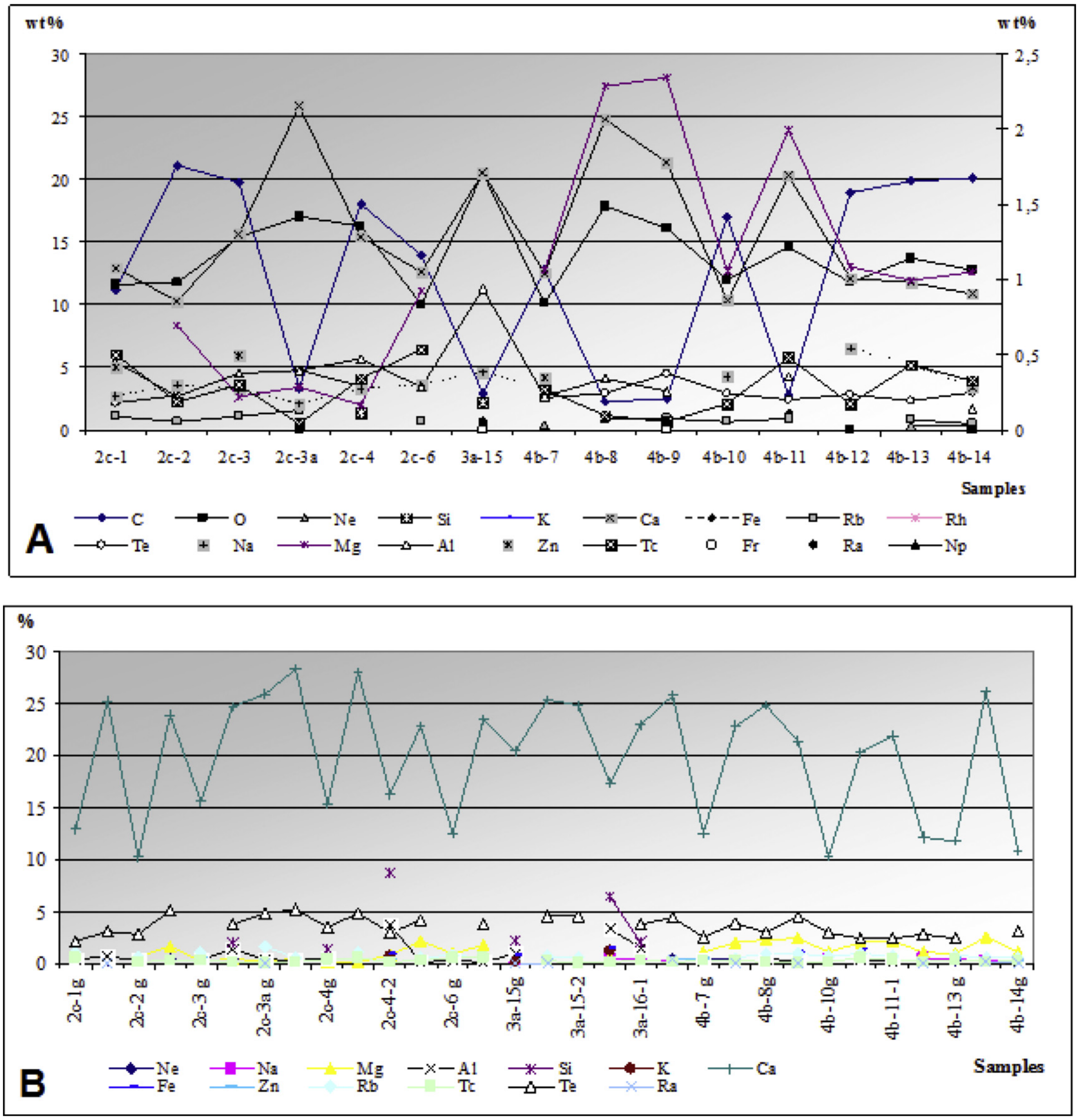


Fig. 9. a, b, c, d, e. Distribution by microprobe analysis of the chemical elements of abnormal benthic foraminifera individuals.

northwest of Ayvalik town, and shallow parts of the Dikili Channel is under the influence of local factors such as bathymetry, currents, temperature and salinity.

Quartz is the major mineral in sand and gravel-sized material. Quartz is also a significant mineral in silt-sized material together with Plagioclase (albite) mineral. Their mutual existence is adversely proportional to each other. Feldspar and mica minerals are observed abundantly in the sand and gravel-sized material. Quartz is a dominant mineral in thin sections of silt and clay-sized material 27% is the calculated average value of the total carbonates found in 71 studied sedimentary samples. Calculated averages of total carbonates in the Dikili Channel and the Gulf of Edremit samples are 41% and 15.4% on respectively. Although the highest carbonate contents are found in the Dikili Channel samples, the total carbonate data display no concordance with the grain size distribution in this region. This could be due to existing different depositional conditions in the region.

Terrigenous grains are land-derived materials and their content depends on geological formations cropped out at the land surface. In general, grain sizes of the sediments are controlled by the initial grain sizes of the disintegrated geological formations, as well as the distance, medium and mechanism of transportation and travelled distance to the site deposition. For example; in the study area fine grained material has likely been transported by the small streams in to the site of deposition hence the large fragments were derived from the steep sea-cliffs where the bed-rock was abraded by the severe and repeated wave actions. There is less interaction between the land having different morphological features and the recent sediments deposited in the study area. The major cause of this is the submarine topography. The Müsellim Strait lies in between the Cape Baba being extension of Anatolian Land and Lesbos Island, and it is an important submarine link in between the Gulf of Edremit and northern Aegean Sea. The Müsellim Reefs cause a major submarine obstruction in the narrowest part of the strait thus connection of the Gulf of Edremit to open marine waters is significantly restricted. Only link is possible through a narrow channel extending along the northeast-southwest striking fault plane. The sediments below −50.00 m depth could not pass through −30.00 m deep threshold in the Dikili Channel and would not affect the sedimentation in the Gulf of Edremit. Additionally the currents are

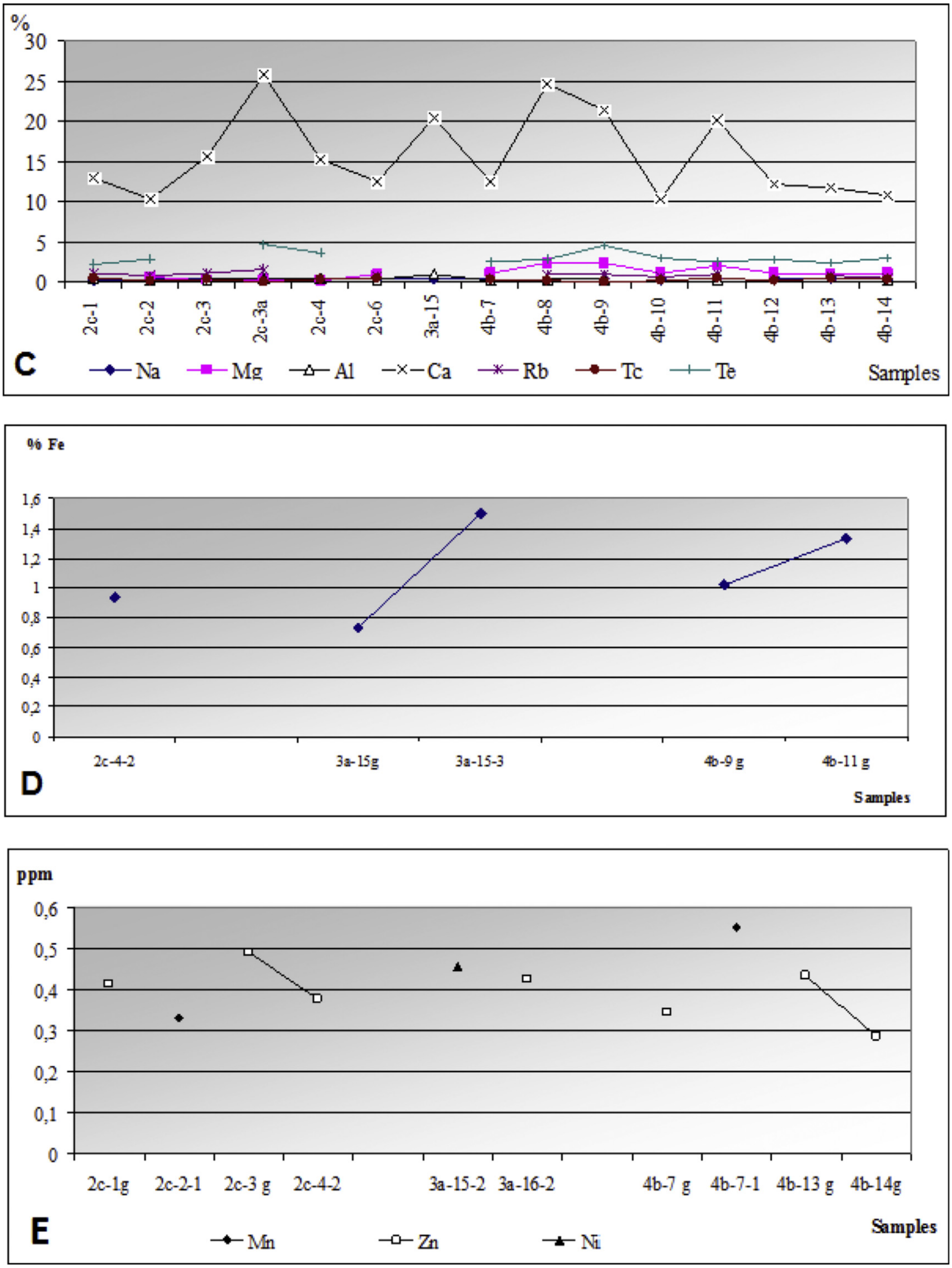


Fig. 9. (*continued*).

also limited in the Gulf of Edremit. Therefore the gulf displays restricted basin characteristics in the region.

All of the four studied cores were cut from the seafloor stations which are located nearby the economic mineral deposits, and each of them displays different properties. In a 0.45 m long 1c core, 22 samples were examined. Although some mollusc shells are found, the material held by the sieve with 2 mm mesh openings mostly contains the gastropod shells. Materials of the 8 samples held by 1 mm mesh opening sieve, contain foraminifers such as *Massilina secans, Coscinospira hemprichii, Rosalina bradyi, Lobatula lobatula, Ammonia compacta, Elphidium complanatum and E. crispum*, and ostracod is found in one sample only. However, foraminifers are common but ostracods are rare organism found in the sediment fraction held in 0.5 mm mesh sieve. Ostracods are found in 17 out of 21 samples. Plenty of foraminifers and ostracods are found in the fraction held by 0.250 mm mesh sieve.

In the samples of this core, common presence of the intact ostracod shells, abundant existence of *Posidonia* (sea grass) at all levels of 1c core indicate that calm conditions supporting prolific plant life during deposition of the studied sedimentary sequence have been dominant in the region. Likewise, the abundance of large foraminifers in this area reveals excessive CaCO3 influx to the depositional environment.

Similarly 22 samples were taken from a 0.45 m long 3a core. The recent sediments contain a rich fauna of pelecypods, gastropods, ostracods and foraminifers. Over 1 mm sized foraminifers such as *Massilina secans, Laevipeneroplis karreri, Ammonia compacta, A. parkinsoniana, Challengerella bradyi* have been observed in the 21 out of 22 samples selected from core 3a. The over 0.5 mm sized fraction of all 22 sediment samples contains foraminifera but only 13 samples contain ostracods. The sediment fraction held above 0.250 mm sieve is rich at foraminifers and ostracods as the other coarser fractions. Apart from these features, the recent sediments sampled in 0.28–0.45 m interval of core 3a, contain plenty of gypsum crystals. Development of gypsum crystals on the tests of different kinds of foraminifers during their life span is an interesting phenomenon.

Especially presence of these gypsum crystals on *Ammonia compacta, Elphidium complanatum* and *Bittium* sp. tests is a remarkable feature for the region. Again, observed formation of gypsum crystals on the *Posidonia* that lived on sea floor in the recent past demonstrates the similar features. This crystallization event reveals existence of the penec on temporaneous hydrothermal spring(s) in the site of deposition. Similar features were also observed in the Golden Horn in Turkey (Istanbul), in the Holocene sediments (Meriç et al., 2003a,b, 2007; Önal, 2004), and in the Gulf of Izmit, in the Middle-Late Pleistocene sediments (Meriç and Suner, 1995; Suner and Meriç, 2001). The all observed gypsum crystals in core 3a are transparent. This is the most important feature documented in the present study. Nevertheless gypsum crystals observed in the Golden Horn display similar features (transparent), the gypsum crystals found in the Gulf of Izmit are opaque.

Abundance of benthic foraminifers with larger and colored tests in this core indicates a considerable influx of hydrothermal fluids during recent sedimentation in the marine area lies between NW of the Alibey and Maden islands. Likewise this situation was observed in nearby work areas (Meriç et al., 2012a,b).

The mapped probable faults around the seafloor coring stations (Fig. 4) would support the aforementioned hypothesis. Core 4b is the last examined core, and presents a type of sediment different than the other cores. A total of 26 samples were analyzed in this 0.52 m long core. The fractions of this core which were held on the sieves with 2 and 1 mm mesh openings contain very few pelecypods and gastropods, and in only one sample of this core; *Peneroplis planatus*, *Elphidium crispum* genera were observed in the over 1 mm sieve fraction.

Abundant populations of the foraminifers were found in both sieves with 0.5 and 0.250 mm mesh openings. All individuals of the foraminifer assemblage dominated by *Coscinospira hemprichii, Peneroplis pertusus and P. planatus*, are reddish brown, orange, yellow and partly dark gray in color. The recent sediments consisting of reddish colored fine sand contains very few genera and species of the pelecypods, gastropods and ostracods than others sand units. It is concluded that these individuals displaying abnormal morphological distortions were affected by the heavy metals contaminations to the sea water due to reaching heavy metal bearing solutions likely derived from the existing mineral deposits within the vicinity and moved (flew) along the faults and fractures. Another interesting feature in this core is inexistence of *Posidonia* plants which are common in the other 3 cores.

1c, 2c and 3a cores, the dominant species are *Lobatula lobatula, Ammonia compacta, A. parkinsoniana, Challengerella bradyi, Elphidium complanatum* and *E. crispum*, while *Peneroplis pertusus, P. planulatus* are the dominant genera and species in core 4b. Abnormal morphologic distortions observed in individuals belonging to this genus and species are not equivalent to those observed in 1c, 2c, and 3a cores. However, in these 3 cores, the common morphologic abnormalities can be observed in the tests of numerous individuals.

In conclusion, observed morphologic distortions and coloring in the tests of various benthic foraminifers gathered from all four cores are considered to be caused by the existing metallic mineral deposits and thermal springs discharging at many different points in the Alibey and Maden islands. While common morphologic abnormalities are observed in foraminifer tests, ostracods are not affected by ambient conditions and no morphological abnormalities are not observed in their shells.

Lowest and the highest total alpha counts are measured in core 3b. The lowest and highest total beta counts are measured in cores 3b and 2a respectively. Abundant gypsum crystals are observed in 0.28–0.45 m interval of core 3a. The high total alpha and total beta counts measured samples were taken from 0.30 to 0.35 m and 0.40–0.45 m intervals of the nearby core 3b respectively. Distribution of total alpha and total beta counts measured in the cores is as follows: the highest values of total alpha counts are reached at 0.35–0.40 m and 0.15–0.20 m intervals in 2a and 3b cores respectively.

In the study area, increments in contents of the heavy metals (Zn and Mn) (except Fe) in different intervals of the analyzed cores can be considered higher than the Zn and Mn contents reported in Krauskopf (1979). Higher contents of Zn measured in all cores are in the rage of (90.3–338.5 ppm). In addition, the maximum Co value (16.5 ppm) which is measured in 0.15–0.20 m interval of core 4a is close to the shale values of Krauskopf (1979).

Geochemical evaluation of sediments and benthic foraminifera tests supports the published conclusions stating that the metallic elements could have been derived from the mines and mineral deposits and igneous rocks and brought into the depositional environment (Apaydın and Ersen, 1981). Finding some elements in only one kind test sample is an interesting observation. The source of these elements is controversial and might be controlled by an anthropogenic (human) activity. These elements may also be provided by the geological formations rich in these elements and cropping out as the coastal lands.

The gypsum crystals observed in the 3a core by due to thermal formation (Plate 5, Figs. 1–14) with the reddish colors in the foraminifera and mollusc shells at some levels that show that the hot water effect makes of the shells smother.

The ostracod fauna of the recent sediments also varied between stations. The reddish brown sediments included a smaller number of genera and species, however, the gray sediments contained a diverse and rich fauna. The diversity of the mollusc fauna was in accordance with the foraminifer and ostracod faunas. Only a few species were found in the reddish brown sediments, but the gray sediments were rich in mollusc species.

In the framework of this study, small reserves of lead, manganese, hematite and limonite were found around the stations on Alibey, Maden and Küçük Maden Islands. A part of the recent sediments were found to be reddish brown in color and they contained reddish brown, yellow, orange and dark gray colored foraminifera (or foraminifera colored with a combination of these) in large quantities, mainly *Peneroplis pertusus (*Forskal) and *P. planatus* (Fichtel ve Moll). Morphologically abnormal Peneroplis individuals were very frequently observed.

In the other areas investigated, the sediments were found to be composed of light gray sand and there was a very small amount of partially colored or uncolored individuals. Although morphologically abnormal individuals were observed in these sediments, they were less attractive than the samples from other locations (Meriç et al., 2012a,b).

In general, it has not possible to distinguish between the results of natural and partially human-induced effects on foraminifera. However, the natural impact of this area on the mineral deposits is more than environmental impact. It was thought that abnormalities in *Peneroplis pertusus, P. planatus, Lobatula lobatula, Ammonia compacta, Challengerella bradyi, Elphidium complanatum* and *E. crispum* could be used as bioindicators for contamination from mineral deposits around Alibey and Maden islands.

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