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Alien foraminifers of the northern and northeastern coastlines of Cyprus Island

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ABSTRACT

The study area covers the northern coasts of Cyprus from the Güzelyurt Gulf to the Gazimağusa Gulf. This study was carried out in order to reveal the presence of the alien foraminifera, which are widely distributed in the Eastern Mediterranean particularly *Amphistegina lobifera* in the study area, and the effects of trace elements on faunal assemblages (foraminifera, ostracod and mollusc). The bottom sediment samples were taken from eighteen different points and depths, the faunal assemblages were examined, and the sediment distribution map of the studied area was made by ICP-MS analysis and geochemical evaluations. 30 genera and 48 species of foraminifera have been identified, of which 9 species belonging to 6 genera are the alien foraminifera. These are: *Spiroloculina angulosa, S. antillarum, Hauerina diversa, Coscinospira hemprichii, Peneroplis pertusus, P. planatus, Amphisorus hemprichii, Sorites orbiculus* and *Amphistegina lobifera*. Amphistegina lobifera was observed to be abnormally abundant in most of the samples. This foraminiferal assemblage of Red Sea origin constitutes a poor assemblage compared to the alien assemblages in Turkish Mediterranean coastal areas. It has been determined that the ostracod and mollusc genera and species found in the same samples belong to the typical Mediterranean and Aegean Sea community.

1. Introduction

Data revealing the presence of large number of alien species and their origins have been unpublished in several studies concerning benthic foraminiferal assemblages in the Mediterranean and Aegean coasts of Turkey (Meriç et al., 2008*a*, 2015*a*, *b*, 2016, 2018 *a*, *b*, Yokeş et al., 2014). In these studies, it was observed that the diversity of alien foraminifera on the Aegean coasts was higher than those obtained in the studies conducted on the Mediterranean coasts. Alien foraminifera such as *Spiroloculina antillarum*, *Coscinospira hemprichii*, *Peneroplis pertusus*, *P. planatus*, *Sorites orbiculus*, *Astacolus insolithus*, *Siphonina tubulosa*, *Amphistegina lessonii*, *A. lobifera*, which were found in the Middle Pleistocene-Holocene sediments of Turkey, are accepted to have reached Eastern Mediterranean via Suez Canal (Meriç et al., 2018*a*). In addition, it was also stated in these studies that the alien foraminifera have increased

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populations in the areas with hot springs. This study was carried out to determine the sediment distribution, faunal content (benthic foraminifers, ostracods and molluscs) and trace elements of the bottom sediments in samples from the northern coasts of Cyprus, located in the Eastern Mediterranean, and also to investigate test coloration in alien foraminifera. In addition, alien foraminifera observed in the Mediterranean and the Aegean coasts of Turkey were compared in terms of assemblages and the coloration characteristics of their tests.

2. Material and Methods

In the study area, paleontological samples were collected from 0.10-40.00 m depths from 18 points in northern and northeastern coasts of the island in 2019 summer (Figure 1, Table 1). Microorganism analyses in sediment samples were performed according to Babin (1980) and Bignot (1985). 5 g of dry samples weighed and 10% H_2O_2 was added, kept for 24 hours, and subsequently washed in a 0.063 mm sieve with pressurized water, dried in a 50 ºC oven, and were further sieved in 2.00, 1.00, 0.500, 0.250, 0.125 mm sieves. These samples were examined under a binocular microscope and the benthic foraminifera, ostracods and molluscs it contained were separated (Table 2-4).

Seasonal physical parameters of sea water were evaluated in-situ by using CTD (temperature, salinity and depth) device and current meters. Current velocity and directions were measured at three different depths (surface, middle and bottom) for a short time.

In addition, 563 recent sediment samples collected from the sea floor of the Northern Cyprus coasts via Orange-peel and other samplers were analyzed according to their grain size distribution. Sieve and pipette analysis methods were applied to these samples, the results were classified in triangular diagram (Wentworth, 1922; Folk, 1974), and a sediment distribution map of the region at 1: 50,000 scale was prepared according to the grain size.

In the study, the grain size content of 18 samples in which paleontological data were evaluated were determined by using the methods proposed by Galehouse (1971) and McManus (1991) (gravel, sand, silt and clay amounts). Gravel- and sand-size materials were determined by sieve analysis, and silt- and clay-size materials were determined by particle size analyzer (sedigraph method).

The geochemical analyzes of sediments were carried out at İstanbul Technical University by ICP-MS (Inductively Coupled Plasma Mass Spectrometer). Trace elements including Cd, Ce, Cs, Dy, Er, Eu, Ga, Gd, Ho, In, La, Lu, Nd, Pr, Rb, Sm, Tb, Tl, Tm, Y, Yb, Th, U were measured.

3. Oceanography and Recent Sediment Distribution of the Marine Space Between Girne and Gazimağusa

Kyrenia (Girne) is located in the north of Beşparmak Mountains which extend from Zafer Cape (Karpass) to Koruçam Cape (Kormacit) in the east. The coasts generally extend in the E-W direction and are quite indented, protruding. The shores of Güzelyurt Bay, from Koruçam Cape to Gemikonağı (Yedidalga Beach), have a rather flat and arc-shaped appearance. The Beşparmak Mountains with steep-slopes, which played an important role in shaping the coast, extend parallel to the shore at approximately 4-6 km far from the coast. There are many riverbeds that cut the steep slopes of these mountains. This steep topography continues with the same slope up to 200 meters deep of the sea. The slope of the land topography increases again in the section from Yeşilyurt to Gemikonağı. In this mountainous region, which constitutes the northern slopes of the Troodos Mountains, rivers flow through deep and relatively long valleys and reach the sea (Figure 1).

Famagusta (Gazimağusa) Bay is the marine space between Zeytin Cape and Poyraz Cape (Ayili Cape) in the east of Cyprus Island. Karpass mountainous region, which does not exceed 400 m in elevation, is located at the north of this area. In the south of the mountainous region, wide flatlands where Boğaz town is also located, with less than 100 m height as the continuation of Nicosia Plain are located. Although there are stream beds in places in this region, there is no river discharging waters into the bay. Due to factors such as the drought, the flatness of the stream beds and evaporation, the waters collected by precipitation cannot reach the sea (Figure 1).

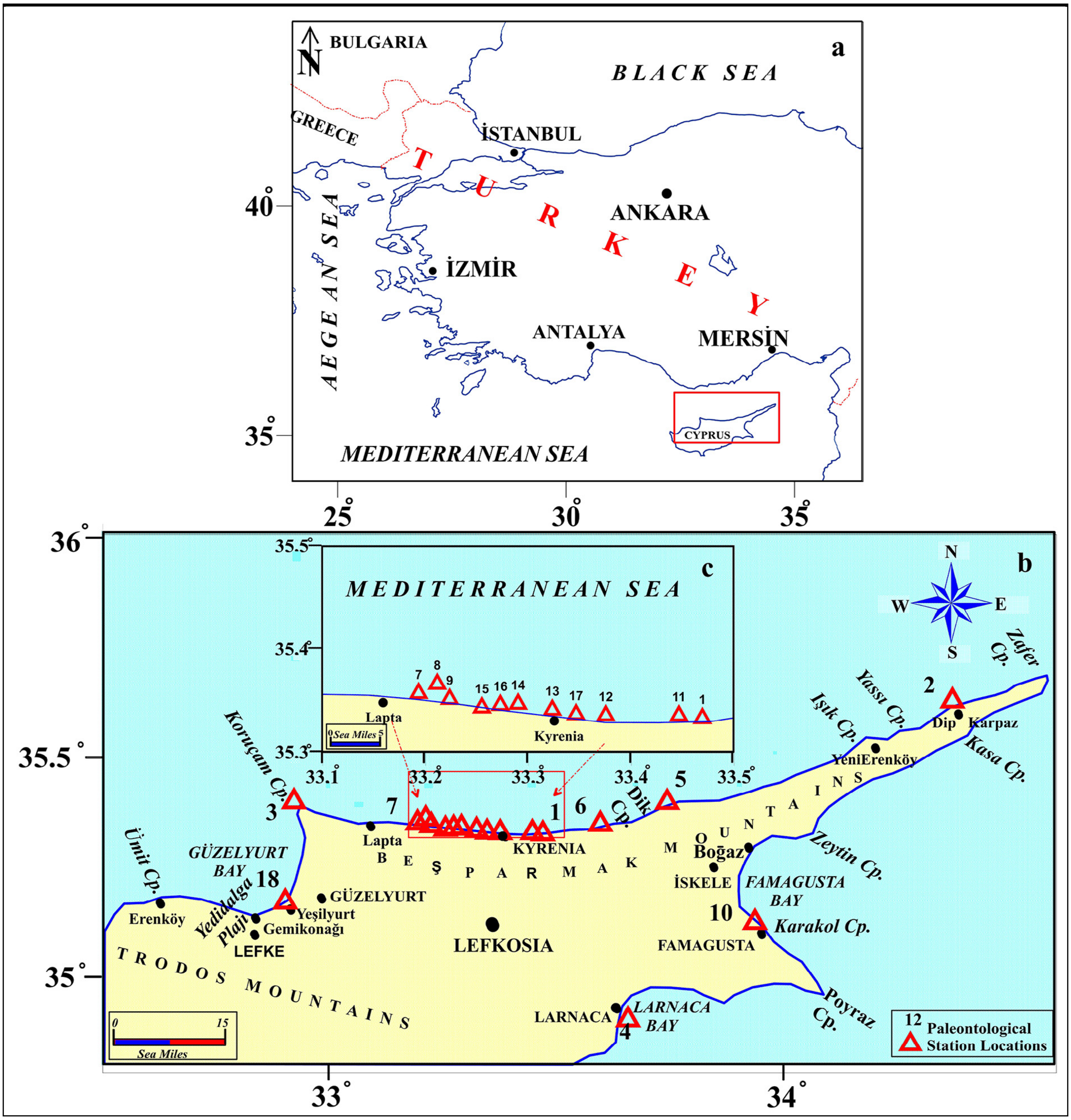

Figure 1- Location map ; a) general view, b) locations of the studied samples and c) locations of paleontological samples in detail. (Cp.: Cape).

3.1. Coastal and Sea Bottom Topography

The slope of the bottom topography is less in the Güzelyurt Bay which is located in the northern part of Cyprus Island. In this region, contour lines (isobaths) become denser towards the west. The 200 m depth curve is 5.5 km distant in the west of Koruçam Cape, 13 km in the middle of Güzelyurt Bay, and 3 km distant in the west of Gemikonağı Village. Sea floor inclination, starting to increase as from the north of Gemikonağı, is at the highest value in the region that is the seaward extension of the Troodos Mountains in the west. The sea bottom topography in the Kyrenia (Girne) Region changes in concordance with the land structure on land. Inclination of the sea bottom topography in the section eastward from Koruçam Cape up to a depth of 500 meters, varies between 4.5-9.0%. However, in this area there are regions which has an inclination of more than 10% in places (Figure 2a) (TR-341, 2007; TR-342, 2014; TR-343, 2017; TR-344, 2012; Özhan, 1988; Eryılmaz and Yücesoy Eryılmaz, 2003; Report 1 (1987), Report 2 (1988), Report 3 (1990), Report

Table 1- Depths of the paleontological sampling and coordinates of the stations.

SAMPLE STATIONS	LATITUDE	LONGITUDE	DEPTH (m)
1	35.33264	33.46905	1.0
2	35.62875	34.37109	5.0
3	35.40415	32.92118	2.0
4	34.9179	33.65669	40
5	35.40266	33.74286	0.1
6	35.35401	33.59583	0.1
7	35.35682	33.19328	7.0
8	35.36594	33.21136	25
9	35.35118	33.2235	0.1
10	35.13519	33.93623	1.0
11	35.33516	33.44621	0.1
12	35.33532	33.37515	0.1
13	35.34071	33.32322	0.1
14	35.34659	33.2899	0.1
15	35.3449	33.27534	0.1
16	35.3454	33.27273	0.1
17	35.33633	33.34624	0.1
18	35.18084	32.90192	0.1

4 (1991), Report 5 (1992); http://users.metu.edu.tr/kktctntm/KKTC_tarihi/ adacogr. html).

The sea bottom topography in the Famagusta (Gazimağusa) Region changes in concordance with the land topography. Although the inclination of the sea bottom is very low in the east of the region, it suddenly increases off the Poyraz Cape, in the east of the Boğaz town. While the sea depth of 500 meters around Famagusta (Gazimağusa) is reached 9 km off the coast, this depth is 3.5 km off Poyraz Cape. The inclination decreases again, off the Kurnyalı, east of the Poyraz Cape (Ayili). In this section, there are places reached a depth of 200 meters at a distance of 13 km.

A gently inclined bottom topography (2-2.5%) is observed between Famagusta (Gazimağusa) and the Strait up to a water depth of 50 meters. This inclination decreases further at shallower parts than 20 meters. There are wide beaches on the shores of these aforementioned shallow slopes (Figure 2a, b) (TR-341, 2007; TR-342, 2014; TR-343, 2017; TR-344, 2012; Eryılmaz and Yücesoy Eryılmaz, 2003; Report 1, 1987; Report 2, 1988; Report 3, 1990; Report 4, 1991; Report 5, 1992).

3.2. Physical and Chemical Properties of Sea Water

3.2.1. Temperature

In the Güzelyurt Bay-Kyrenia (Girne) Region of Cyprus, seasonal water temperature varies according to the depth. In spring it is 17.50-18.55 °C at the surface, 17.51-17.56 °C at a depth of 50 meters, and in the summer 28.17-29.14 °C at the surface, 18.09-20.20 °C at a depth of 50 meters. In the autumn it is 21.12-22.06 °C at the surface and 19.41-21.90 °C at a depth of 50 meters, while in the winter it varies between 16.60-17.42 °C at the surface and 16.25-17.24 °C at a depth of 50 meters (Figure 3a) (Eryılmaz, 2004).

In the Cyprus-Famagusta (Gazimağusa) region, the seasonal temperature distributions of water (Figure 4a) were measured as 17.03-17.61 °C at the surface in the spring season, and 16.54-17.41 °C at a depth of 50 meters. In summer it varies between 27.98-29.13 °C at the surface, 18.33-19.12 °C at a depth of 50 meters, and in the autumn 21.19-21.57 °C at the surface, 20.86-21.42 °C at a depth of 50 meters. In the winter, it changes between 16.53-17.75 °C at the surface, and 16.56-17.51 °C at a depth of 50 meters (Figure 4a) (Eryılmaz, 2004).

3.2.2. Salinity

In the measurements made in Güzelyurt Bay and Kyrenia (Girne) Region, salinity values at surface and 50-meter water depth were determined as follows. In the spring, it is 39.02-39.40‰ at the surface, 38.98-39.40‰ at 50 meter-depth, and in the summer, it is 39.01-39.26‰ at the surface, 38.82-39.07‰ at 50 meter-depth. In the autumn, it is between 39.05-39.22‰ at the surface and 38.89-39.23‰ at 50 meter-depth. In the winter, these values were determined as 38.62-39.02‰ at the surface and 38.82-38.97‰ at 50 meter-depth (Figure 3b) (Eryılmaz, 2004).

Salinity values determined in the Famagusta (Gazimağusa) Bay are as follows: in the spring, 38.97-39.32‰ at the surface, 38.97-39.34‰ at 50 meter-depth; in the summer, 38.95-39.21‰ at the surface, 38.82-39.10‰ at 50 meter-depth; in the autumn, 38.94-39.36‰ at the surface, 39.02-39.55‰ at 50 meter-depth; in the winter, 38.57-39.09‰ at the surface, 38.78-38.99‰ at 50 meter-depth (Figure 4b) (Eryılmaz, 2004).

Table 2- Distributions of benthic foraminifera by stations.

FORAMINIFERA	STATIONS																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Spiroplectinella sagittula				*														
Bigenerina nodosaria												*	*					
Textularia bocki			*	*	*	*	*	*				*	*		*	*		
Textularia conica				*	*							*	*					
Patellina corrugata				*														
Nubecularia lucifuga				*						*		*						
Adelosina cliarensis				*			*			*		*		*				
Adelosina duthiersi			*	*														
Adelosina mediterranensis				*		*				*		*				*		
Adelosina partschi			*						*									
Adelosina pulchella						*												
Spiroloculina angulata														*				
Spiroloculina angulosa												*						
Spiroloculina antillarum				*			*					*		*				
Spiroloculina depressa					*													
Spiroloculina excavata				*								*						
Spiroloculina tenuiseptata				*								*						
Hauerina diversa							*					*						
Cycloforina contorta				*														
Massilina secans												*						
Quinqueloculina bidentata												*						
Quinqueloculina disparilis										*								
Quinqueloculina jugosa										*								
Quinqueloculina lamarckiana												*						
Quinqueloculina seminula	*						*					*		*	*		*	
Miliolinella subrotunda										*								
Pseudotriloculina laevigata				*						*		*						
Triloculina marioni				*		*				*		*		*				
Triloculina tricarinata														*				
Sigmoilinita costata				*		*												
Sigmoilinita edwardsi										*								
Coscinospira hemprichii		*					*		*	*		*				*		
Laevipeneroplis karreri			*															
Peneroplis pertusus		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Peneroplis planatus		*	*			*	*				*					*		
Amphisorus hemprichii										*		*						
Sorites orbiculus		*	*				*					*	*					
Amphicoryna scalaris				*														
Rosalina bradyi				*								*		*				*
Rosalina floridensis												*						
Lobatula lobatula				*				*				*	*					
Cyclocibicides vermiculatus												*						
Planorbulina mediterranensis				*														
Miniacina miniacea								*										
Amphistegina lobifera	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*
Ammonia tepida																		*
Porosononion subgranosum							*											
Elphidium crispum				*						*			*					

Table 3- Distributions of ostracods by stations.

OSTRACODA	STATIONS				
	2	4	5	10	12
Acantocythereis hystrix		*			
Aurila convexa		*	*		*
Bosquetina carinella		*			
Cytheretta judaea					*
Cytherois sp.					*
Ekpontocypris prifera		*			
Jugosocythereis prava	*	*			
Loxoconcha bairdi		*			
Loxoconcha gibberosa		*			
Neonesidea corpulenta		*			*
Neonesidea formosa	*	*			*
Cushmanidea elongata					*
Urocythereis crenulosa	*	*		*	*
Xestoleberis communis		*			
Xestoleberis depressa		*			

3.2.3. Current Systems

The current system seen in the study area develops in accordance with the circulation system of the Eastern Mediterranean (Figure 5). Based on the results of seasonal current measurements in the Güzelyurt Bay (Figure 6) and the Kyrenia (Girne) Region (Figure 7), the surface currents are generally from east to west. However, some variable currents occur in the shallower waters depending on local winds and coastal morphology (Eryılmaz, 1998, 2004; Eryılmaz and Yücesoy Eryılmaz, 2002; Millot and Taupier-Letage, 2005; Meriç et al., 2018*c*; Report 1, 1987; Report 2, 1988; Report 3, 1990; Report 4, 1991; Report 5, 1992).

According to the results of seasonal short-term flow measurements in Famagusta (Gazimağusa) Region (Figure 8), surface currents are generally from south to north as a result of the average flow velocity and directions, in concordance with the circulation system

Table 4- Distributions of molluscs by stations.

MOLLUSCA		STATIONS							
		3	6	13	12	10	7	4	8
Gastropoda	*Jujubinus exasperatus*							*	
	Homalopoma sanguineum							*	
	Tricolia pullus	*							*
	Cerithium scabridum	*							
	Bittium latreillii	*	*			*	*	*	*
	Bittium reticulatum	*	*			*	*		*
	Cerithidium submammillatum	*						*	
	Turritella communis							*	
	Epithonium sp.					*			
	Rissoa similis	*	*						
	Pusillina lineolata	*					*		*
	Setia sp.			*			*		
	Alvania amati								*
	Alvania cimex		*		*		*		
	Alvania lanciae	*							
	Truncatella subcylindrica			*					
	Strombus persicus	*							
	Mangelia cf. angelinae	*							
	Parthenina interstincta					*			
	Parthenina suturalis					*	*		
	Turbonilla multilirata	*							
	Turbonilla pusilla		*						
Bivalvia	*Ctena decussata*								*
	Glans trapezia							*	

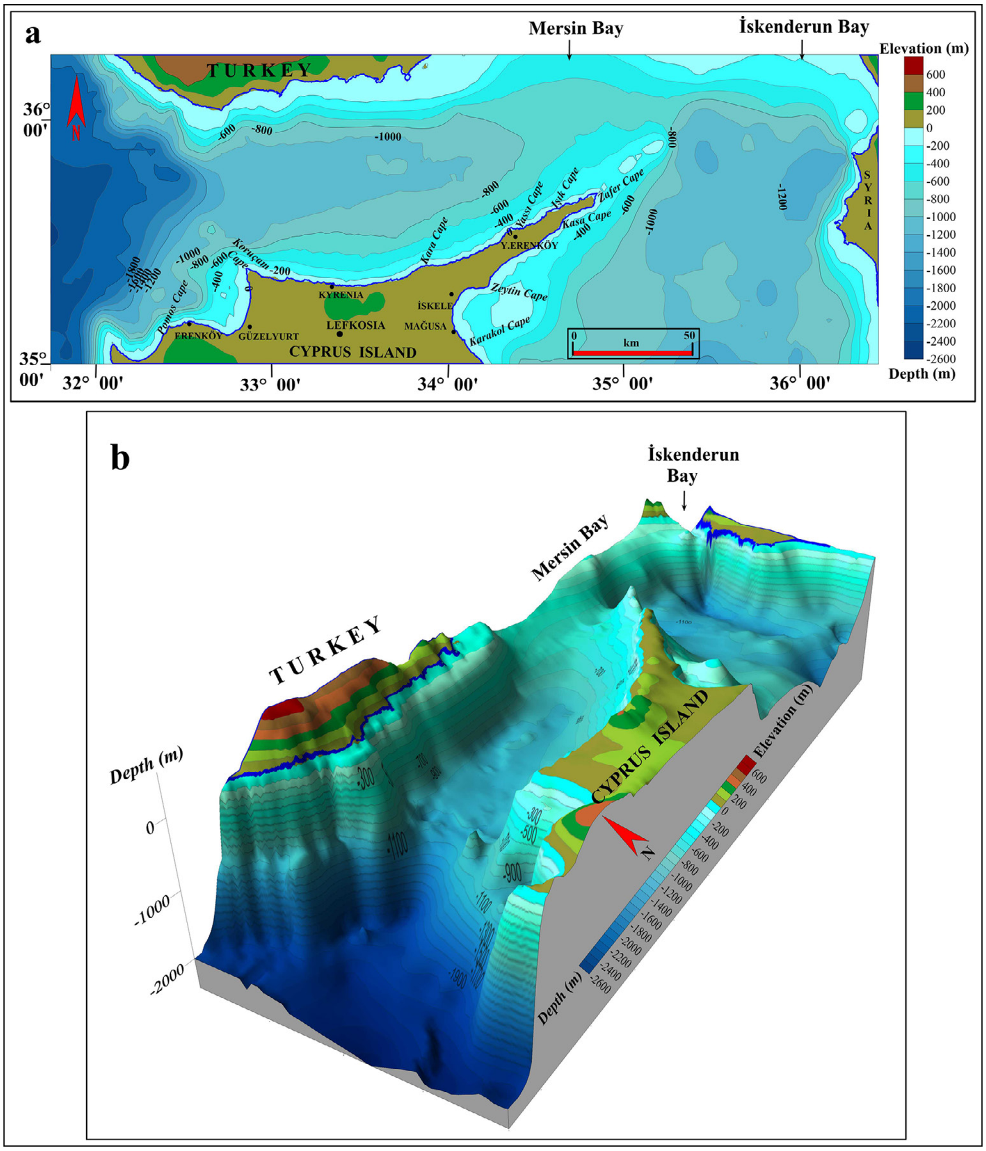

Figure 2- Bathymetry map and block diagram; a)Bathymetry map of the northern part of Cyprus and eastern Mediterranean, b) 3D bathymetry and morphological view of the northern part of Cyprus and the Eastern Mediterranean (depths in meters) (TR-341, 2007; TR-342, 2014; TR-343, 2017; TR-344, 2012; Eryılmaz, 2004).

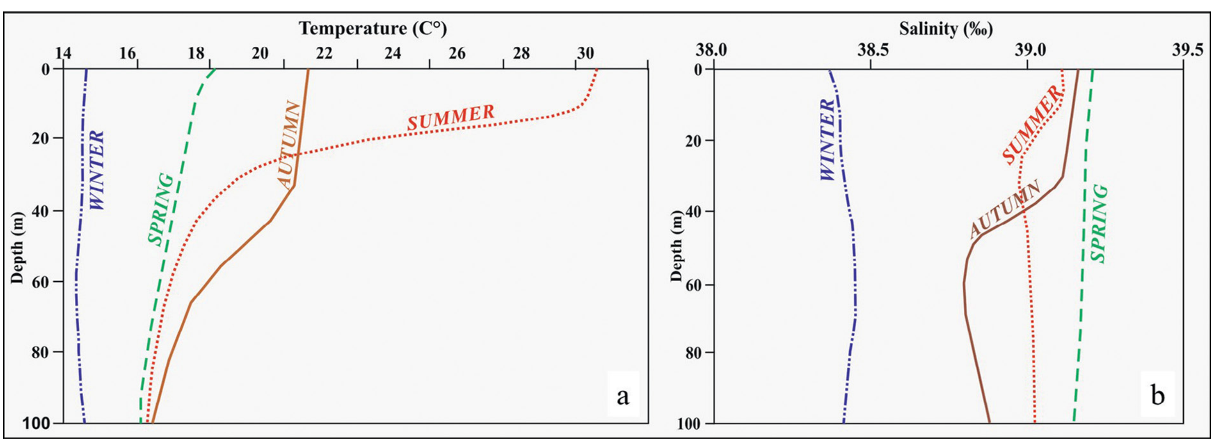

Figure 3- a) Seasonal average temperatures of Güzelyurt Bay-Kyrenia (Girne) Region, b) seasonal average salinity values (Eryılmaz, 2004).

of the Eastern Mediterranean (Figure 5). However, some variable currents occur in the shallower waters depending on local winds and coastal morphology (Eryılmaz, 1998, 2004; Eryılmaz and Yücesoy Eryılmaz, 2002; Millot and Taupier-Letage, 2005; Meriç et al., 2018*c*; Report 1, 1987; Report 2, 1988; Report 3, 1990; Report 4, 1991; Report 5, 1992).

3.3. Distribution of bottom sediments

Various coast types are observed in the Kyrenia (Girne) Region. The region to the east of Koruçam Cape is under the influence of northern winds. This region is of the high coastal type and inclination of the bottom topography is high. For this reason, wave erosion is effective on the coast, creating cliff-type coasts there. On the other hand, in areas with soft rock assemblages, an indented, protruding coastline occurred due to further erosion by the wave effect. Less eroded places extend towards the sea like a headland. Sandy pocket beaches were formed between the headlands. On the coasts in Koruçam and around, the dominant wave direction is west and northwest, and the land topography in this region consists of low coasts. Flat lands consisting of materials carried by streams were eroded by the sea and formed the low coasts. As the waves carried all the material it could carry to the offshores, only gravels larger than 5 cm left on the shore. As a result of the erosion of the mountainous land on the coasts to the west of the Güzelyurt Bay, seaside cliffs occurred. Small pocket beaches are observed between the high coasts. Gravels and blocks of various sizes are scattered in the sea in front of the eroded rocky shores (Figure 9) (Kırca and Eryılmaz, 1987, 1989, 1997; Eryılmaz and Kırca, 1998; Eryılmaz and Yücesoy Eryılmaz, 2002, 2003, 2019; Eryılmaz et al., 2002; Eryılmaz, 2004; Özhan, 1988; Report 1, 1987; Report 2, 1988; Report 3, 1990; Report 4, 1991; Report 5, 1992).

In the bottom sediments in the Kyrenia (Girne) Region, grain size decreases from the coast towards the offshore. There are sandy deposits in small-scale bays and pocket beaches in the coastal area between Koruçam Cape and Zafer Cape. Scree, as gravels and blocks, is commonly seen on the headlands and in the shallow-marine parts of the high coast. From 3-4 meter-depth of the sea towards the open sea, as a narrow strip parallel to the shore, first sand and then silty sand fields are seen. Sand and silty sand fields are spread over a wider area between Mutlu Cape and Koruçam Cape. After sandy silt, there is a narrow strip of sandy muddy field. After that, the bottom is completely muddy. The initial depth of muddy areas in the region is generally 200 meters. However, also in shallower areas in places, mud is observed (Figure 9) (Eryılmaz, 2004).

In the Güzelyurt Bay, coastal and near-coast areas are gravelly. As moving away from the coast, sand, silty sand, sandy silt and sandy mud sorting is seen. After that, there are muds covering large areas. The gravelly ground forming a 5-10 meter strip around the coastline of the Güzelyurt Bay could not be drawn on the map (Figure 9) (Eryılmaz, 2004). Coastal forms in Famagusta (Gazimağusa) Bay are in concordance with the inclination of the sea bottom topography at near-coast. High coasts as in form of the cliff are seen around Poyraz Cape and in the south of Karakol Cape which are exposed to wave movements. The coasts outside

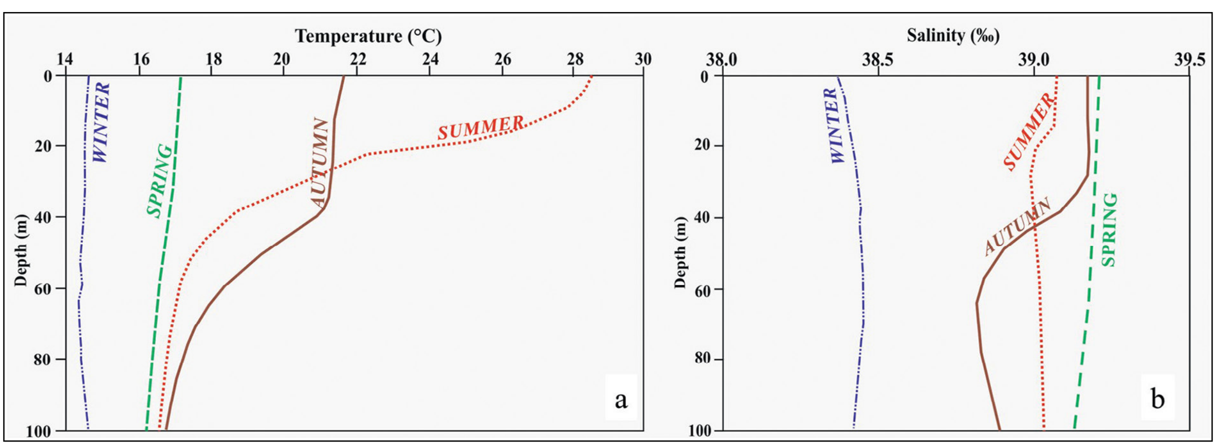

Figure 4- a) Seasonal average temperatures of Famagusta (Gazimağusa) Bay, b) seasonal average salinity values (Eryılmaz, 2004).

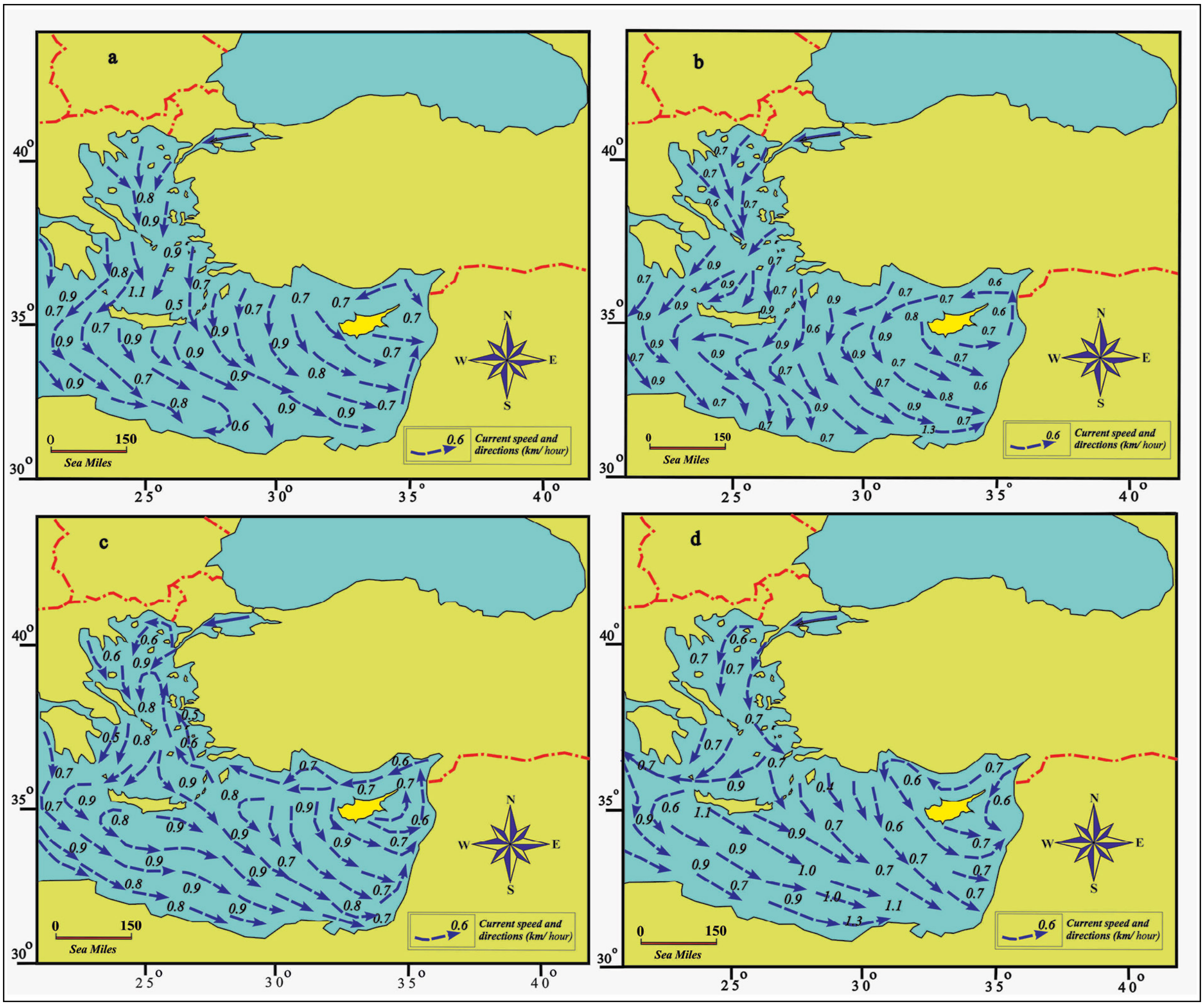

Figure 5- Eastern Mediterranean general current systems; a) spring, b) summer, c) autumn, d) winter (Eryılmaz, 1998, 2004; Eryılmaz and Yücesoy Eryılmaz, 2002; Millot and Taupier-Letage, 2005; Meriç et al., 2018*b*; Report 1, 1987; Report 2, 1988; Report 3, 1990; Report 4, 1991; Report 5, 1992).

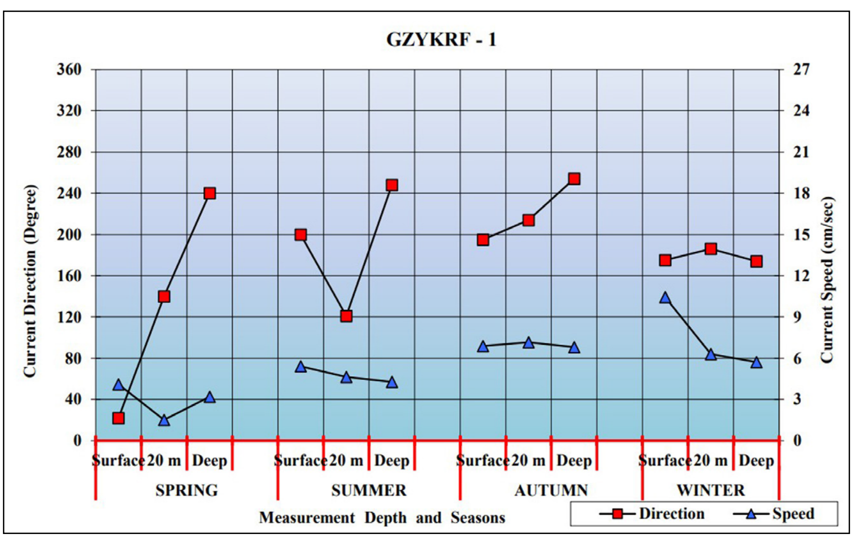

Figure 6- Recent, speeds and directions of the current in Güzelyurt Bay (Eryılmaz, 2004).

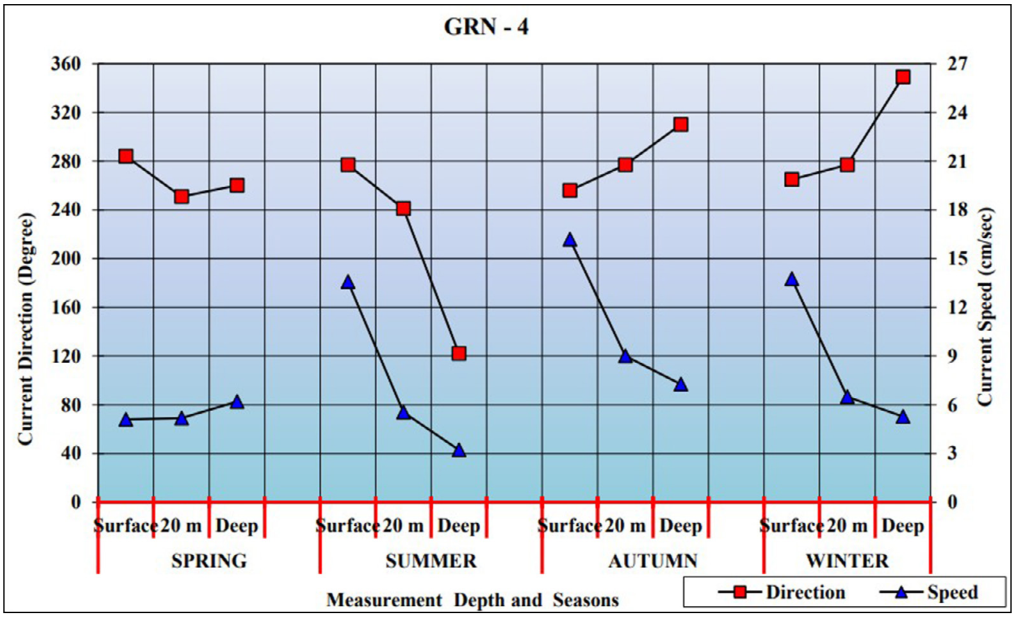

Figure 7- Recent, speeds and directions of the current in Kyrenia (Girne) Region (Eryılmaz, 2004).

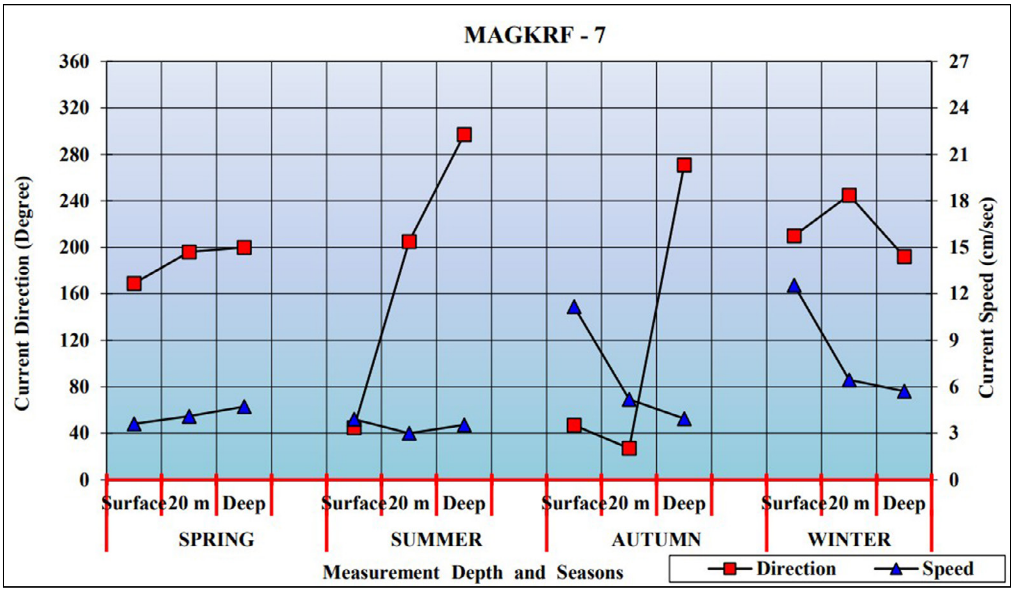

Figure 8- Recent, speeds and directions of the current in Famagusta (Gazimağusa) Bay (Eryılmaz, 2004).

these regions are low coasts that are completely sandy beaches. Small scale indentations are not common in the bay. In the Famagusta (Gazimağusa) Region, a distinct array of materials is observed, depending on the depth, from the coast towards the offshore. The bottom feature extending in the form of sandy beaches on the shore offers a spread up to a depth of 20 meters. Bottom sediment distribution is observed in silty sand and sandy silt feature up to a depth of 50 meters, and a sandy mud feature from 50 to 100 meters. Deeper marine sections contain mud. Streams, reaching the sea from the land, only transport a small amount of water during rainy times, due to their irregular regimes they are not featured to change the general sedimentation pattern of the bay. Terrestrial pebbles are found at the mouths of the creeks in places. In the Güzelyurt Gulf and the Kyrenia (Girne) Region, in Karpass Cape - Güzelyurt Bay, there are thin strips of clay and clayey materials after a depth of 200 m (Figure 9) (Kırca and Eryılmaz, 1987, 1989, 1997; Eryılmaz and Kırca,

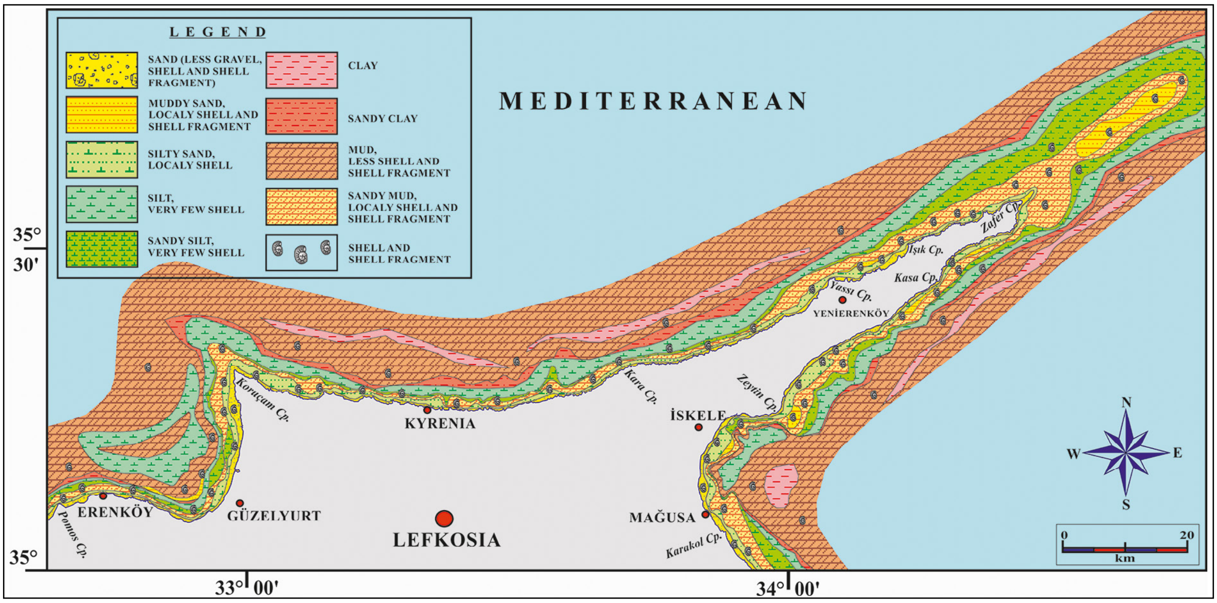

Figure 9- Recent sediment distribution in the northern part of Cyprus (Kırca and Eryılmaz, 1987, 1989, 1997; Eryılmaz and Kırca, 1998; Eryılmaz and Yücesoy Eryılmaz, 2002, 2003, 2019; Eryılmaz et al., 2002; Eryılmaz, 2004) (Cp.: Cape).

1998; Eryılmaz and Yücesoy Eryılmaz, 2002, 2003, 2019; Eryılmaz et al., 2002; Eryılmaz, 2004; Özhan, 1988; Report 1, 1987; Report 2, 1988; Report 3, 1990; Report 4, 1991; Report 5, 1992).

4. Findings

4.1. Benthic Foraminiferal Assemblage

Benthic foraminifers of 18 young sediments obtained from different points and depths were identified based on Meriç et al. (2008*a*, *b*) and Meriç et al. (2018*b*, *c*). 30 genera and 48 species of benthic foraminifers were determined. These are: *Spiroplectinella sagittula*, *Bigenerina nodosaria*, *Textularia bocki*, *T. conica*, *Patellina corrugata*, *Nubecularia lucifuga*, *Adelosina cliarensis*, *A. duthiersi*, *A. mediterranensis*, *A. partschi*, *A. pulchella*, *Spiroloculina angulata*, *S. angulosa*, *S. antillarum*, *S. depressa*, *S. excavata*, *S. tenuiseptata*, *Hauerina diversa*, *Cycloforina contorta*, *Massilina secans*, *Quinqueloculina bidentata*, *Q. disparilis*, *Q. jugosa*, *Q. lamarckiana*, *Q. seminula*, *Miliolinella subrotunda*, *Pseudotriloculina laevigata*, *Triloculina marioni* Schlumberger, *T. tricarinata* d'Orbigny, *Sigmoilinita costata*, *S. edwardsi*, *Coscinospira hemprichii*, *Laevipeneroplis karreri*, *Peneroplis pertusus*, *P. planatus*, *Amphisorus hemprichii, Sorites orbiculus*, *Amphicoryna scalaris*, *Rosalina bradyi*, *R. floridensis*, *Lobatula lobatula*, *Cyclocibicides vermiculatus*, *Planorbulina mediterranensis*, *Miniacina miniacea*, *Amphistegina lobifera*, *Ammonia tepida*, *Porosononion subgranosum, Elphidium crispum* (Table 2). These species have the characteristics of Aegean Sea and Mediterranean fauna.

Individuals with colorful test were found in the samples collected from the station no 7, 10 and 12, as observed in the specimens from the Mediterranean and the Aegean coasts of Turkey. Among them, the most dominant species is *Peneroplis pertusus*. In *Amphistegina lobifera*, coloration is almost absent, as observed in Turkish Mediterranean coasts.

4.2. Ostracod Assemblage

6 of the 18 samples (2, 4, 5, 10, 12, 13) collected from the region contain ostracods. In identification of ostracods, Van Morkhoven (1963), Hartmann and Puri (1974), Bonaduce et al. (1975), Breman (1975), Yassini (1979), Guillaume et al. (1985), Athersuch et al. (1989), Zangger and Malz (1989), Mostafawi and Matzke-Karasz (2006), Joachim and Langer (2008), and MarBEF Data System (http://www.marbef.org/data/) were used. 12 genera and 15 species were identifed as follows: *Acantocythereis hystrix*, *Aurila convexa*, *Bosquetina carinella*, *Cytheretta judaea*, *Cytherois* sp., *Ekpontocypris prifera*, *Jugosocythereis*

prava, *Loxoconcha bairdi*, *Loxoconcha gibberosa*, *Neonesidea corpulenta*, *Neonesidea formosa*, *Cushmanidea elongata*, *Urocythereis crenulosa*, *Xestoleberis communis* and *X. depressa*. It was observed that the stations 4 and 12 have high diversity in genera and species (Table 3).

The determined species are known as common species also in the Mediterranean, Aegean Coasts, Adriatic Sea, Marmara and Turkish coasts.

4.3. Mollusc Assemblage

Regarding the Mollusc community, no individual of macroscopic size was found in the samples. In samples 3, 4, 6, 7, 8, 10, 12 and 13, the obtained individuals with microscopic size were bivalves and gastropods, representing a Mediterranean assemblage with quite a large number of *Jujubinus exasperatus, Homalopoma sanguineum*, *Tricolia pullus*, *Cerithium scabridum*, *Bittium latreillii*, *B. reticulatum*, *Cerithidium submammillatum*, *Turritella communis*, *Epithonium* sp., *Rissoa similis*, *Pusillina lineolata*, *Setia* sp., *Alvania amati*, *A. cimex*, *A. lanciae*, *Truncatella subcylindrica*, *Strombus persicus*, *Mangelia* cf. *angelinae*, *Parthenina interstincta*, *P. suturalis*, *Turbonilla multilirata*, *T. pusilla*, *Ctena decussata*, *Glans trapezia* specimens (Table 4) (Cossignani et al., 2011; Scaperrotta et al., 2009-2015).

4.4. Grain Size Content Findings

Grain size classification gives important data on geo-statistical identification of sediment, strength of sediment supplier and investigation of sedimentation environment (Sarı et al., 2014 and 2016). In addition, it is known that as the grain size of the sediment decreases, the surface area increases and stores more heavy metals in the sediment (Hallı et al., 2014). For these reasons, grain size is one of the most important features of lithogenic sediment, and its classification is given in Table 5.

While gravel and sand content were determined in all of the 18 surface samples taken from the Northern Cyprus coastline, silt and clay content was determined in only two samples and given as percentage in Table 6. Since the mud (silt + clay) content in 16 samples was below 2.5%, the silt and clay separation could not be made in these samples. According to the findings, gravel, sand, mud (silt + clay), silt and clay contents range between 0 - 42.20%, 53.78 - 99.49%, 0.40 - 8.57%, 2.60 - 8.14% 0.43 - 1.43%, respectively (Table 6 and Figure 10).

In the study area, while the gravel content was more than 4% in samples 1, 4, 5, 6, 8 and 13; no gravel detected in the samples 9, 11, 12, 14 and 17. In samples 2, 3, 7, 10, 15, 16 and 18, the gravel content is less than 1% (Table 6). The average gravel content in the study area was calculated as 5.66%.

In the sediments which grain size analysis was performed on, the highest sand content was measured in sample 16 taken between the coasts of Kyrenia (Girne) and Lapta, and the lowest in sample 13 taken from the Kyrenia (Girne) coast. The average sand content in the study area was calculated as 92.85%. As the result of the sieve analysis this was concluded; samples 8 and 13 are very coarse sand-dominated; samples 3, 4, 7, 10, 16 are coarse sand-dominated; samples 1, 2, 5, 6, 11, 14, 15, 18 are medium sand-dominated and samples 9, 12 and 17 are fine sand-dominated (Table 6).

Due to the low mud content in the samples of the study area, silt and clay contents were separated in 2 samples. While the silt content in the sample no 4 is 8.14, it is 2.60 in the sample no 13. The clay contents in these samples are 0.43 and 1.43, respectively (Figure 10).

Table 5- Classification of lithogenic sediments based on grain size (Folk, 1980).

Grain diameter Millimeter (mm)	Grain diameter Micrometer (µm)	Grain diameter Phi (Φ)	Wentworth Size Class
64-2	>2000	< -1	Gravel
2.0-0.063	2000 - 63	(-1) - 4.0	Sand
0.063-0.002	63-3.9	4.0 - 8.0	Silt
<0.02	<3.9	> 8	Clay

Table 6- Statistical distribution of grain size parameters of Northern Cyprus coastal sediments.

Sample	Gravel (%)	Sand (%)						Mud (%)	Silt (%)	Clay (%)
		Total sand (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)			
1	9.26	89.33	13.45	22.87	50.19	2.82	0.00	1.4		
2	0.18	98.46	0.10	3.93	48.84	45.56	0.02	1.36		
3	0.57	98.38	14.29	66.37	17.42	0.26	0.06	1.05		
4	4.10	87.32	30.47	34.38	12.64	7.03	2.81	8.57	8.14	0.43
5	9.23	89.41	19.54	21.80	40.56	7.48	0.11	1.36		
6	7.31	92.27	10.14	33.82	46.57	1.73	0.00	0.42		
7	0.33	98.93	1.28	61.42	27.53	8.05	0.10	0.75		
8	25.50	73.86	41.51	29.93	2.07	0.11	0.13	0.64		
9	0.00	99.08	0.00	0.00	33.34	65.46	0.37	0.92		
10	0.84	98.57	5.54	78.86	13.73	0.32	0.12	0.60		
11	0.00	99.38	0.00	0.00	41.19	57.86	0.26	0.62		
12	0.00	97.62	0.52	2.55	37.58	56.13	0.84	2.38		
13	42.19	53.78	24.99	17.38	9.26	1.58	0.43	4.03	2.60	1.43
14	0.00	99.44	0.33	29.09	67.48	2.53	0.00	0.56		
15	1.29	98.17	0.99	8.75	85.11	3.33	0.00	0.54		
16	0.11	99.49	0.10	64.55	33.07	1.73	0.10	0.40		
17	0.00	99.16	0.00	0.29	32.19	65.94	0.74	0.84		
18	0.92	98.64	0.82	4.04	69.65	24.14	0.00	0.44		
Minimum	0.00	53.78	0.00	0.00	2.07	0.11	0.00	0.40		
Maximum	42.19	99.49	41.51	78.86	85.11	65.94	2.81	8.57		
Mean	5.66	92.85	9.12	26.67	37.13	19.56	0.34	1.49		

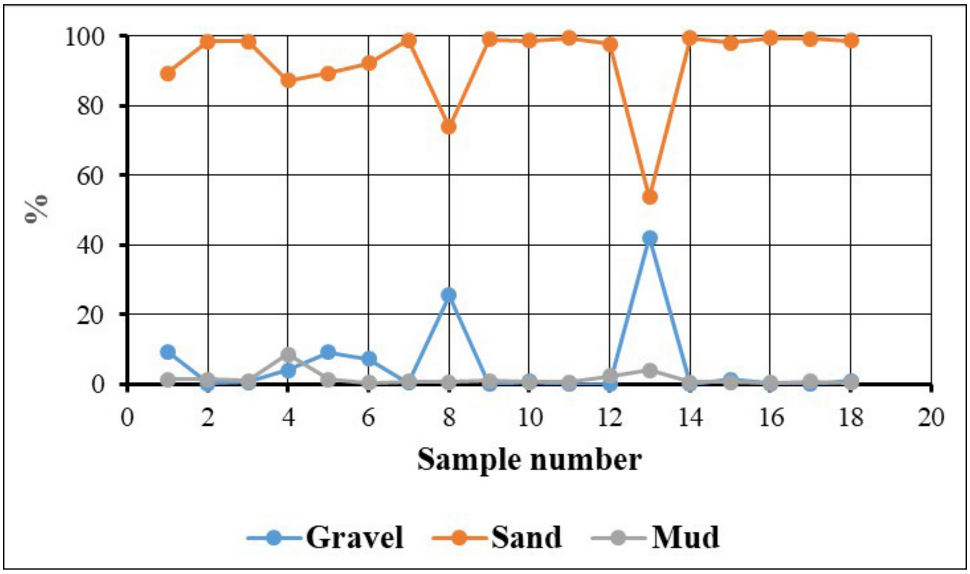

Figure 10- Percentage distribution of gravel, sand and mud.

4.5. Evaluation of Geochemical Analysis

In ICP-MS analyzes of sediments (Ce, Cs, Dy, Er, Eu, Gd, Ho, La, Lu, Nd, Pr, Rb, Sm, Tb, Tm, Y, Yb), the distribution of rare earth elements was measured lower than the earth's crust and the shale threshold values (Krauskopf, 1979) (Figures 11 and 12). While the distribution of elements versus sediments is parallel, only Y differs (Figure 13). Again in sediments, distribution of the elements among themselves is in the way that Rb> Ce> La> Y> Nd> Gd> Dy (Figure 13).

In the evaluation of the geochemical analysis of sediments, Ga and Tl elements were not detected. Cd, the toxic element, are lower than the threshold value (Krauskopf, 1979) in samples 5, 11, 12, 13, 14 and 17, while no data were obtained from the others. While in

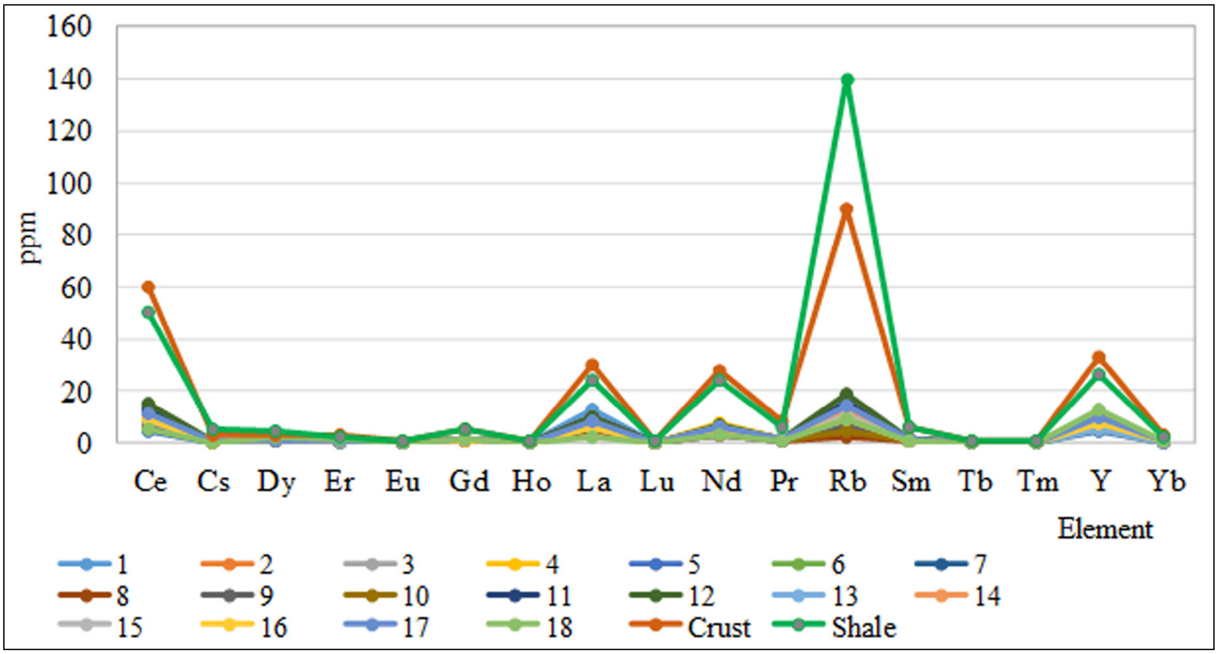

Figure 11- Comparison of the trace element distributions in the study area to those in the earth's crust and shale values (Krauskopf, 1979).

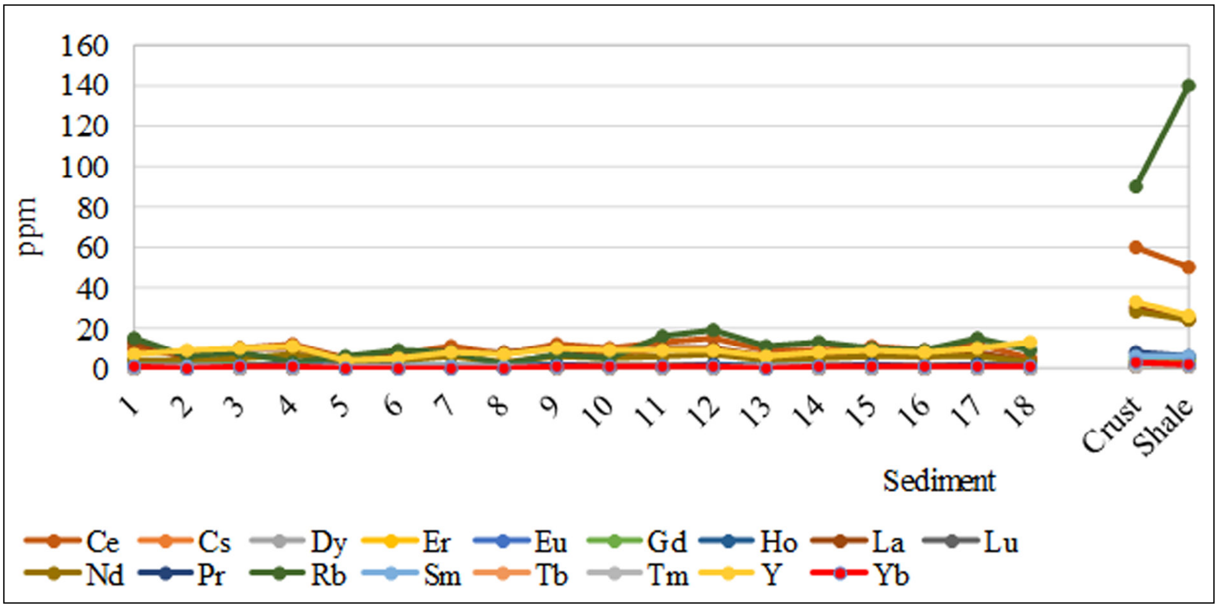

Figure 12- Comparison of the trace element distributions in sediments to those in the earth's crust and shale values (Krauskopf, 1979).

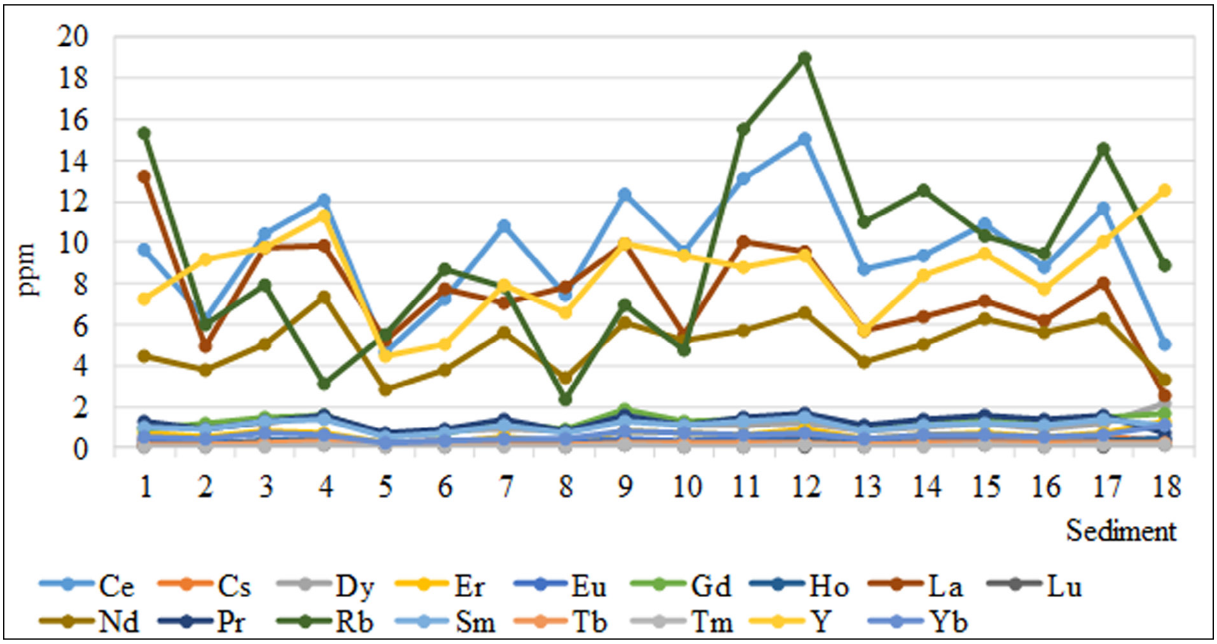

Figure 13- Distribution of the trace elements in sediments.

is lower than the threshold value in samples 4 and 9, data was not obtained in the others (Table 7). U, one of the radioactive elements, was found as higher than the earth's crust but lower than shale in samples no 4, 5, 6, and 13, and lower than the threshold values in other sediments (Figure 14).

Considering the trace elements in the samples which geochemical analysis conducted on, this can be seen that no trace element, except Sr, could exceed 0.1% in concentration. The relatively high Sr content suggests that the rocks might be carbonates deposited in the shelf environment. Negative anomaly of Ce and relatively high Ni values indicate a sedimentation that occurs in a shallow marine or shelf environment. The presence of elements that are expected to have higher concentrations in terrestrial units such as Pb, Zn, Ba at very low concentrations indicates that the terrestrial input is at minimum degree during sedimentation. The fact that the Mn element is below the detection limits of the analyzer also strengthens the argument that the samples do not belong to deep marine sediments.

5. Results

Spiroloculina angulosa, *S. antillarum*, *Hauerina diversa*, *Coscinospira hemprichii*, *Peneroplis pertusus*, *P. planatus*, *Amphisorus hemprichii, Sorites orbiculus* and *Amphistegina lobifera*, which constitute the foraminiferal assemblage identified in this study carried out on the Northern Cyprus coasts, are the alien foraminifera and are of Red Sea origin. *Amphistegina lobifera* was abnormally abundant compared to the other foraminifera. It has been determined that, this assemblage constitutes a poor alien foraminifera assemblage in comparison with those obtained in study (Meriç et al., 2008*a*; 2018*b*) conducted in the Mediterranean coasts in Turkey. Foraminiferal individuals with colored tests, of which *Peneroplis pertusus* is the dominant species, were found at stations 7, 10 and 12 from the samples studied.

It was determined that the obtained ostracod and mollusc genera and species were similar to the typical Mediterranean and Aegean Sea community and that there is no abnormality in their tests.

Sample no 4, in which individuals of foraminifera, ostracod, gastropod and bivalve are observed, is characterized by high ratio of very coarse sand, very fine sand, mud and silt. In sample no 8, which includes individuals of foraminifera, gastropod and bivalves, very coarse sand is in the highest ratio, medium and fine sand is the lowest. Foraminifera, ostracod and gastropod individuals were found in sample no 10, which has the highest coarse sand ratio, and low fine sand and mud ratio. In sample no 12, in which foraminifera has a high abundance, ostracod and

Table 7- Geochemical analysis results of sediments (ND: no data; *Krauskopf, 1979).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Earth's crust*	Shale*
Cd	ND	ND	ND	ND	0.099	ND	ND	ND	ND	ND	0.039	0.036	0.075	0.147	ND	ND	0.127	ND	0.2	0.3
Ce	9.645	6.289	10.376	12.075	4.649	7.222	10.782	7.42	12.383	9.573	13.136	15.03	8.695	9.389	10.895	8.736	11.65	5.006	60	50
Cs	0.445	0.241	0.239	0.204	0.202	0.296	0.278	0.182	0.324	0.218	0.423	0.519	0.443	0.381	0.387	0.3	0.487	0.292	3	5
Dy	0.953	0.962	1.164	1.581	0.51	0.786	0.945	0.803	1.434	1.103	1.062	1.206	0.835	1.027	1.233	0.907	1.214	2.105	3.00	4.30
Er	0.671	0.5	0.769	0.693	0.206	0.259	0.553	0.272	0.847	0.734	0.61	0.873	0.462	0.634	0.673	0.509	0.67	1.253	2.80	2.70
Eu	0.329	0.237	0.298	0.328	0.197	0.295	0.287	0.262	0.401	0.337	0.439	0.394	0.287	0.296	0.317	0.279	0.327	0.429	1.20	1.10
Ga	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	15.00	19.00
Gd	0.909	1.148	1.5	1.565	0.594	0.72	1.192	0.901	1.868	1.264	1.428	1.492	0.96	1.211	1.343	1.187	1.52	1.65	5.40	5.20
Ho	0.178	0.14	0.302	0.341	0.089	0.15	0.223	0.164	0.259	0.265	0.275	0.3	0.148	0.201	0.232	0.188	0.287	0.381	1.20	1.20
In	ND	ND	ND	0.019	ND	ND	ND	ND	0.007	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.10	0.10
La	13.157	4.929	9.709	9.848	5.266	7.687	7.066	7.784	9.95	5.518	10.04	9.595	5.729	6.343	7.126	6.151	8.039	2.494	30.00	24.00
Lu	0.047	0.077	0.104	0.095	0.021	0.061	0.088	0.037	0.137	0.084	0.075	0.073	0.062	0.087	0.111	0.062	0.074	0.167	0.50	0.60
Nd	4.484	3.749	4.99	7.369	2.854	3.784	5.594	3.411	6.136	5.249	5.698	6.533	4.123	5.05	6.319	5.622	6.264	3.337	28.00	24.00
Pr	1.315	0.885	1.336	1.585	0.67	0.883	1.381	0.832	1.605	1.12	1.484	1.665	1.084	1.371	1.587	1.368	1.596	0.701	8.20	6.10
Rb	15.277	6.004	7.958	3.13	5.519	8.73	7.787	2.346	6.961	4.725	15.541	18.93	11.02	12.544	10.335	9.437	14.535	8.843	90.00	140.00
Sm	0.959	0.912	1.265	1.343	0.564	0.681	1.08	0.666	1.27	1.103	1.245	1.452	0.77	1.088	1.216	1.129	1.339	1.097	6.00	5.80
Tb	0.141	0.139	0.205	0.287	0.106	0.131	0.168	0.128	0.228	0.221	0.186	0.246	0.093	0.215	0.246	0.2	0.224	0.276	0.90	0.90
Tl	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.50	1.00
Tm	0.027	0.053	0.078	0.111	0.039	0.075	0.081	0.021	0.1	0.078	0.085	0.09	0.059	0.047	0.129	0.077	0.09	0.141	0.50	0.50
Y	7.289	9.151	9.719	11.263	4.445	5.065	7.874	6.548	9.924	9.39	8.826	9.401	5.677	8.369	9.431	7.694	10.01	12.573	33.00	26.00
Yb	0.519	0.429	0.747	0.642	0.213	0.291	0.385	0.411	0.79	0.744	0.641	0.682	0.452	0.58	0.603	0.524	0.592	1.127	3.40	2.20
Th	1.015	0.48	0.954	0.529	0.473	0.58	0.876	0.414	0.855	0.669	1.121	1.31	1.016	0.693	0.812	0.75	1.086	0.311	7.20	12.00
U	0.891	1.367	0.912	1.849	2.789	2.52	0.841	1.1	1.091	1.064	0.997	1.017	1.916	1.183	1.097	1.292	1.139	0.357	1.80	3.70

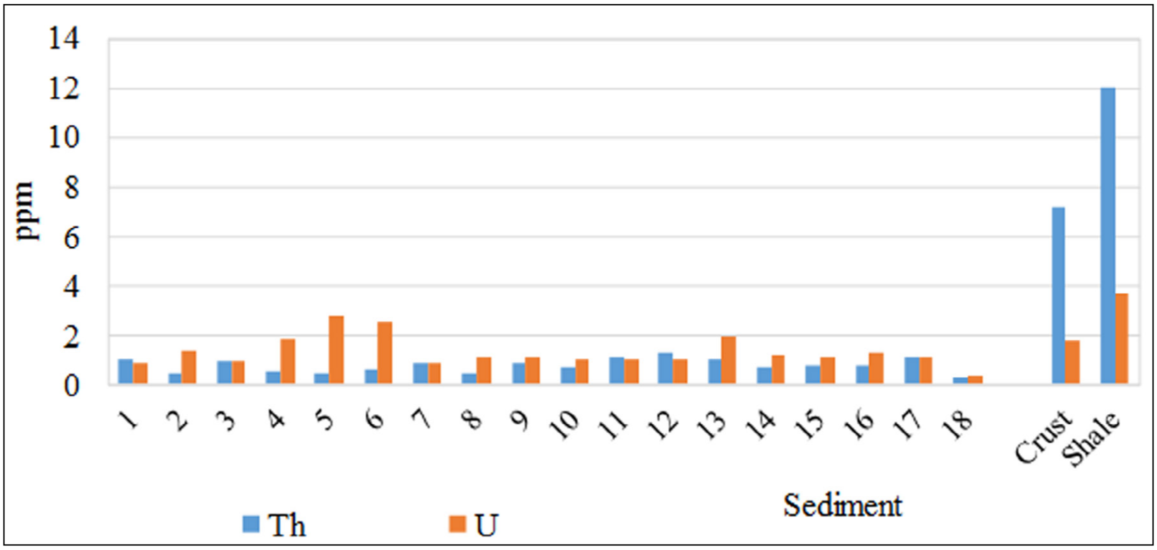

Figure 14- Comparison of the radioactive element distributions in the study area to those in the earth's crust and shale values (Krauskopf, 1979).

gastropod are also present, gravel is in the lowest ratio and fine sand is high. In sample 13, which includes foraminifera and gastropod individuals, medium sand is low and clay is in high ratio. Samples of 9, 11, 14, 15, 16, 17 and 18 containing only foraminifera individuals have low gravel and high sand ratio.

There are industrial raw materials and natural structures such as sand and gravels in the foothills of the Beşparmak Mountains in Nicosia, gypsum in the Güngör region and manganese in Beylerbeyi (close to the station number 1 and 11). While high quality marble found in Lapta (close to station number 7-12) of Kyrenia (Girne), high quality marble, manganese and brick raw materials are present in the İskele region (close to station number 10). There are minerals such as pyrite, zinc and copper in the foothills of the Troodos Mountains among the most important industrial raw materials and natural building materials of Southern Cyprus, natural building materials such as marble, sand and gravel are also known. In the north, compared to the south, there are mostly industrial raw materials such as manganese, copper and high-quality marble (Diner, 2012). It was stated that there is gypsum in Kaleburnu of Iskele in Famagusta (Gazimağusa) Bay (close to sediment area 10), manganese in Balalan Village, Ziyamet (between sediments no 2 and 5), high quality marbles in Yedikonuk and Büyükkonuk (close to the sediment no 5) (Diner, 2012). In Southern Cyprus, especially in the Troodos Mountains, Paphos and Limassol, zinc, pyrite, gravel, sand is found, while presence of copper, zinc and sand are known in the Katodris region (Diner, 2012).

The coasts between Lefke and Dipkarpaz where the sampling was carried out are Quaternary terrace and alluvium. Quantitative distribution of genera and species with regard to foraminifera, ostracod and mollusc (gastropod and bivalve) content of sediments is shown in Figure 15. While benthic foraminifera were observed in all sediments, ostracods in samples 2, 4, 5, 10, 12; gastropods in samples 3, 4, 6, 7, 8, 10, 12, 13, and bivalves (only one in each) were found in samples 4 and 8. While foraminifera were found in samples 1, 11, 14-18, all micro and macro fauna individuals were observed in only sample 4. While diversity of foraminifera in genera and species is high in samples 4, 7, 10 and 12; ostracod is high in sample 4 and gastropod in sample 3. No relationship between trace and radioactive elements and abundance of faunal individuals in sediments is seen (Figures 16 and 17).

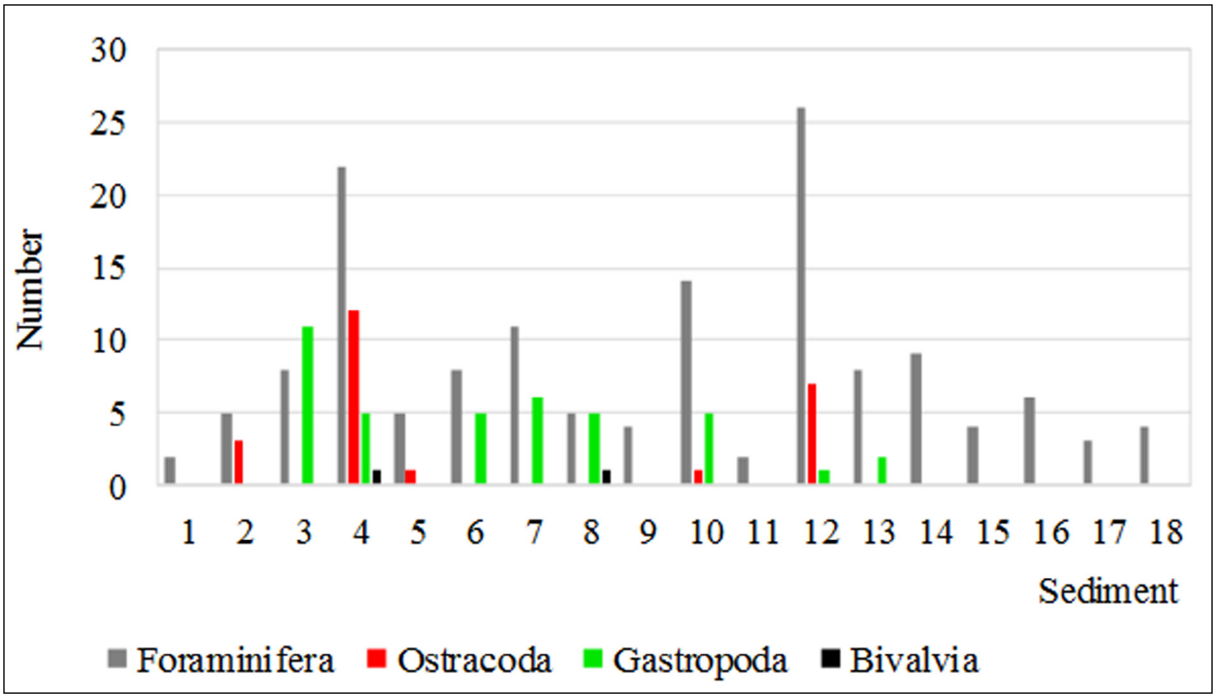

Figure 15- Quantitative distribution of fauna in sediments of the study area.

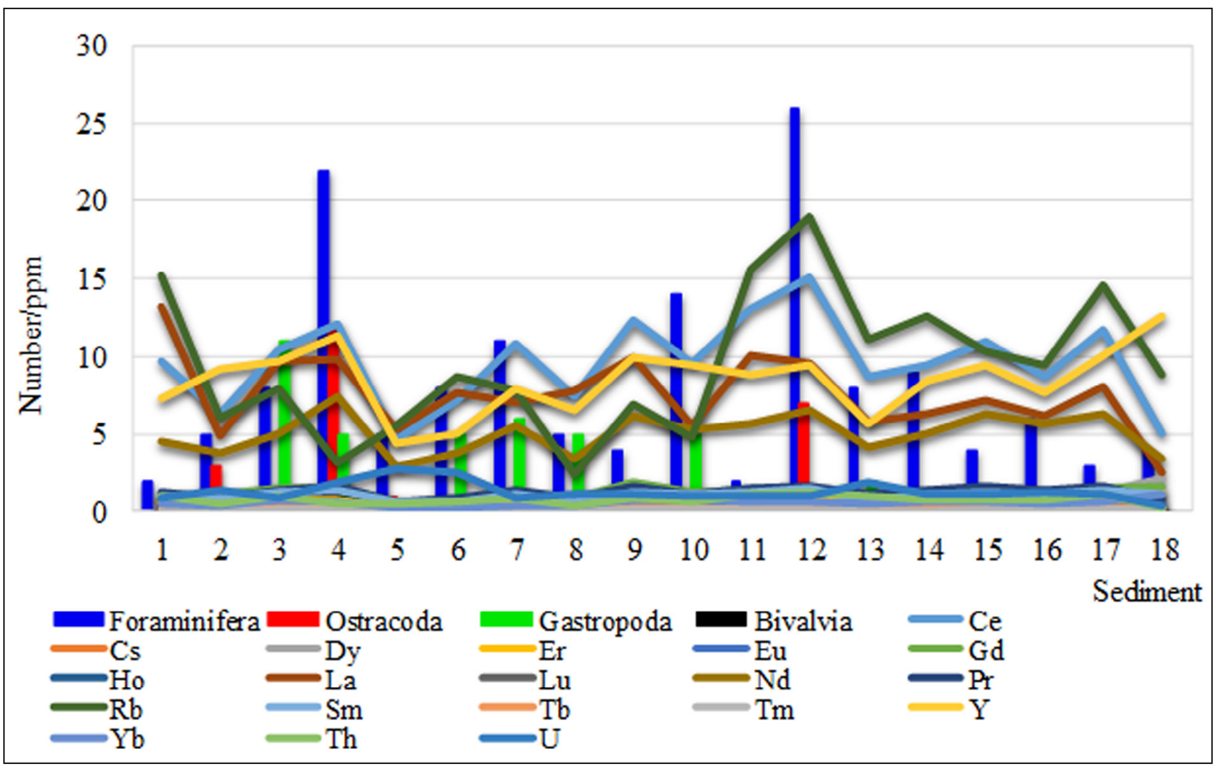

Figure 16- Quantitative distribution of trace elements and fauna in sediments of the study area.

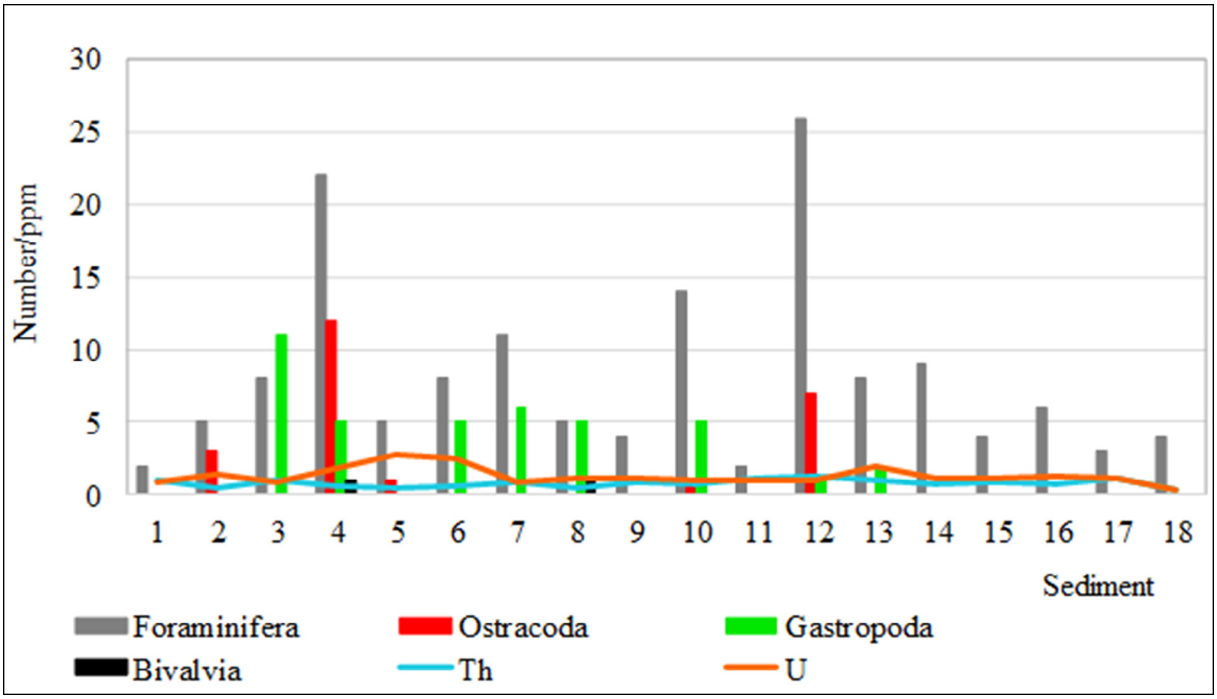

Figure 17- Quantitative distribution of radioactive elements and fauna in sediments of the study area.

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