GEOLOGY AND GEOCHEMISTRY OF RECENT SEDIMENTS FROM THE NORTHEASTERN MEDITERRANEAN BASIN

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ŞAKİR ÇAĞAN TUNÇ

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Approval of the thesis:

GEOLOGY AND GEOCHEMISTRY OF RECENT SEDIMENTS FROM THE NORTHEASTERN MEDITERRANEAN BASIN

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Şakir Çağan Tunç

ABSTRACT

GEOLOGY AND GEOCHEMISTRY OF RECENT SEDIMENTS FROM THE NORTHEASTERN MEDITERRANEAN BASIN

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The present study mainly aims to indicate the origin and distribution of the recent sediments collected from the northeastern Mediterranean shelf by means of clarifying the textural and chemical compositions of these sediments in the light of prevailing physical, chemical, biological and geological processes. In this scope, grain size compositions and various geochemical properties such as carbonate, organic carbon and heavy metal (Fe, Mn, Cr, Ni, Zn, Cu, Co) content have been obtained in forty-five grab samples distributed at depths from 12 m. to 330 m.

Recent sediments represent a wide variety of sediment types (sandy gravel to mud) and are generally characterized by their relatively high mud contents with varying silt and clay fractions. However, due to the presence of high biogenic material, several coarse-grained sediment patches with high $CaCO_3$ contents occur in the studied area. The organic carbon contents of the sediments, except the coastal sediments polluted by the waters carried by perennial rivers, mostly reflect the normal marine production of organic matter.

The variations in the metal contents of the northeastern Mediterranean recent sediments can be satisfactorily explained in terms of the variations in texture (fine-grained or coarse-grained) or genetic type (terrigenous or biogeneous dominance) of the sediments. The Fe, Mn, Cu, Zn and Co concentrations generally indicate consistency with the average distribution of these elements in the earth`s crust. However, noticeably high Ni and Cr concentrations are mainly related to the weathering products of the ultrabasic-basic rock series and associated ore deposits in Taurus and Amanous Mountains. The high amounts of siliciclastic material carried by perennial rivers cause a masking effect on the heavy metal concentrations of the Seyhan – Berdan deltaic sediments. Furthermore, significant and positive correlations between the low heavy metal and high $CaCO_3$ contents suggest the considerable dilution effect of the coarse-grained carbonate components on the measured element concentrations in the sediments.

Key Words: sediment, grain size, heavy metal, carbonate, organic carbon, northeastern Mediterranean

ÖZ

KUZEYDOĞU AKDENİZ GÜNCEL SEDİMANLARININ JEOLOJİSİ VE JEOKİMYASI

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Bu çalışmanın temel amacı Kuzeydoğu Akdeniz kıta sahanlığından alınan güncel sedimanların yapısal ve kimyasal kompozisyonlarını bölgeye hakim fiziksel, kimyasal, biyolojik ve jeolojik koşullar ışığında inceleyerek, bu sedimanların kökenlerini ve dağılımlarını belirlemektir. Bu kapsamda, çalışma sahasında farklı derinliklerden toplanan 45 yüzey sedimanı (12 – 330 m) örneğinin tane boyu kompozisyonları ve karbonat, organik karbon ve ağır metal (Fe, Mn, Cr, Ni, Zn, Cu, Co) içerikleri belirlenmiştir.

İncelenen örneklerin sediman tipleri kumlu çakıldan çamura kadar geniş bir çeşitlilik gösterir. Bununla birlikte, güncel sedimanlar çoğunlukla farklı miktarlarda kil ve silt boyutunda malzeme içeren çamur ile temsil edilir. Yüksek biyojenik malzeme içeriğine bağlı oluşmuş karbonatça zengin iri taneli sedimanlar çalışma sahasında lokal olarak gözlenmektedir. Nehirler tarafından kirletilen deltayik sedimanlar haricinde, sedimanlarda ölçülen organik karbon değerleri denizlerdeki normal organik üretim koşullarını yansıtmaktadır.

Kuzeydoğu Akdeniz güncel sedimanlarının ağır metal içerikleri genellikle sedimanların tane boyu içeriğindeki (iri taneli, ince taneli) ya da sedimanı oluşturan malzemenin kökenindeki (karasal, biyojenik) değişimlere bağlı olarak farklılıklar gösterir. Fe, Mn, Cu, Zn ve Co konsantrasyonları çoğunlukla bu metallerin yerkabuğunda bulunma miktarlarına yakın seviyelerdedir. Sedimanlarda gözlenen yüksek Cr ve Ni değerleri Toros ve Amanos dağlarında bulunan bazik-ultrabazik kayaçlardan ve maden yataklarından aşınan malzelerin nehirler yoluyla denize taşınmasının bir sonucudur. Seyhan – Berdan delta sisteminde ölçülen düşük metal derişimleri, bu nehirler ile taşınan ince taneli malzemelerin oluşturduğu maskeleme etkisi ile ilişkilidir. Ayrıca kaba taneli çökellerin ağır metal içerikleri, bu çökellerdeki yüksek karbonat derişiminin neden olduğu seyrelme etkisinden ötürü düşük oranlarda gözlenmiştir.

Anahtar Kelimeler: sediman, tane boyu, ağır metal, karbonat, organik karbon, kuzeydoğu Akdeniz

To My Parents

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1. INTRODUCTION

Sediments are deposits which keep record of the pollution history. Metals are one of the pollutant class which toxic to living organisms. Virtually every element has been detected in seawater. Those present at concentrations less than 50 μmol/kg are called as minor and those which concentrations are below 0.05 μmol/kg are termed as trace elements (Bruland, 1983). Trace elements don't affect the salinity of seawater as their concentrations are too low. However, many trace metals have important function as micronutrients and play an important role in biological enzyme systems. The chemical cycle of many of these trace metals are controlled by redox reactions. Some of their important functions and features of trace metals are:

- They compose the bulk of the earth crust (e.g. Al, Fe, Ti, and Si)
- They can be used as micronutrients (e.g. Fe, Mn, Zn, Mo, Cd, Ni, Ba, Cu, and V)
- They are key participants in redox reactions (e.g. Fe, Mn, Re, V, Mo, U, Ag)
- Some of them are toxic to living organisms at even low concentrations (e.g. Pb, Cr, Cd, Hg)
- Most of them are tracers and carry information about ocean processes (e.g. mixing, scavenging, and pollution)

Certain trace metals may help clarification of the mechanisms by which organic carbon-rich deposits and petroleum source rocks are formed (e.g.; Pedersen *et al*., 1992; Calvert and Pedersen, 1993), and to constrain models of paleocean anoxia (Emerson and Huested, 1991; Hasting, 1994; Morford and Emerson, 1999) and paleoproductivity (Rosenthal *et al*., 1995; Nameroff *et al*., 2004).

It has been established from numerous investigations that sediments deposited in marine environments, particularly at coastal areas near industrial and urban areas, are reliable recorders of both natural and anthropogenic impacts.

The Turkish coastal marine waters, especially the area investigated in this study (Figure 1.1), are environments where both anthropogenic activities and geochemical anomalies are expected to interact with each other (Ergin and Yemenicioğlu, 1997).

Many studies deal with the surface sediments of the northeastern Mediterranean have been published until now. Mange-Rajetzky (1983), Ediger (1991), Bodur and Ergin (1992), Okyar and Ediger (1997), Ediger *et al*. (2002) established the sedimentation patterns and sediment dispersal of the studied area.

Shaw and Bush (1978), Bodur and Ergin (1988), Sanın *et al*. (1992), Ediger *et al*. (1997) studied the mineralogy and geochemistry of the surface sediments of the Mersin Bay, whilst Kapur *et al*. (1989), Kazan (1994) and Ergin *et al*. (1996, 1998) focused on the sediments of İskenderun Bay. The distribution and origin of the saprogenic sediments of the Cilicia Basin are studied by Shaw and Evans (1984).

Quaternary seismic stratigraphy of the sediments of the area has been studied by Aksu *et al*. (1992a), Ergin *et al*. (1992) and Okyar *et al*. (2005). Origin and tectonic evolution of the northeastern Mediterranean is implemented by Özhan (1988), Garfunkel (1998, 2004), Robertson (1998), Ergün and Oral (2000), Koral *et al*. (2001), Over *et al*. (2004), Ergin *et al*. (2004), Aksu *et al*. (1992a, 1992b, 2005a, 2005b, 2005c).

Heavy metal levels in tissues of various living organisms (fish, crustacea, mussel) in the study area are represented by Balkas *et al*. (1982), Yılmaz *et al*. (1998), Yılmaz (2003), Kalay *et al* (2004), Çelik and Oehlenschlager (2005), Türkmen *et al*. (2005).

Although all this studies clearly indicate the provenance and dispersal of the sediments, the knowledge on geochemical properties of the surface sediments is limited with the time interval that these studies carried on. Since the industrial activities increase and two busy international harbors and petroleum terminals (Baku-Tiflis-Ceyhan; Kerkük-Ceyhan) are located in the region, the study area can be considered as a polluted hot spot. In addition, due to the existence of dynamic oceanographic and tectonic conditions, recent sediments of the region need to be kept under investigation continuously.

The main objective of this study is to clarify the origin of the surface sediments and indicate the factors controlling the heavy metal distribution in the light of prevailing physical, chemical, biological and geological processes. This study is intended to not only be a complimentary to the other studies, but also indicate the modern conditions of surface sediments by focusing on the distribution of grain size, carbonate, organic carbon and heavy metals in the surface sediments collected. In addition, this study includes the determination of possible associations of various heavy metals, texture and other geochemical parameters of the recent sediments.

In this scope, the general characteristics of the study area are discussed in this chapter for better understanding the origin and spatial distribution of the northeastern Mediterranean surface sediments.

1.1. HYDROGRAPHY OF THE STUDY AREA

The study area is located in the south coasts of Turkey, northeastern Mediterranean and comprises two main submarine depocentres (Mersin Bay and İskenderun Bay) with the area stays between these bays (Figure 1.1). The region under investigation covers an area approximately 7600 km^2.

1.1.1. Bathymetry

The overall bottom topography of the studied area shows an asymmetric pattern; deepest in the southwest and gradually shallowing towards the northeast (Figure 1.1).

The shelf of the Mersin Bay gradually widens, from 8.4 km near the Göksu River delta to 43 km off the Seyhan River delta due to the higher sediment supply from the rivers of Seyhan and Tarsus than Göksu and Lamas rivers. The southwest shelf of the bay, between the mouths of Göksu and Lamas rivers, has a relatively steep slope (2.5^o) from 0 to 50 m depth and it becomes more gentle offshore (~0.8^o), between 50 and 200 m depth. Near Erdemli, the sea-floor has a slope of approximately 1^o between coastline and 50 m, of 0.6^o between the 50 – 200 m contours. Between Erdemli and the eastern edge of the Mersin Bay, the sea-floor has a gentler slope of 0.3^o from coastline to 50 m depth and flattens to 0.4^o between the 50 – 200 m depths. The water depths in İskenderun Gulf are generally less than 100 m. The depths increase from the relatively shallow inner part to the mouth of the gulf where it joins to the northeastern Mediterranean shelf region. The bathymetry varies irregularly along the north – south direction and the gulf is much deeper and has pronounced depth variations in its southern part.

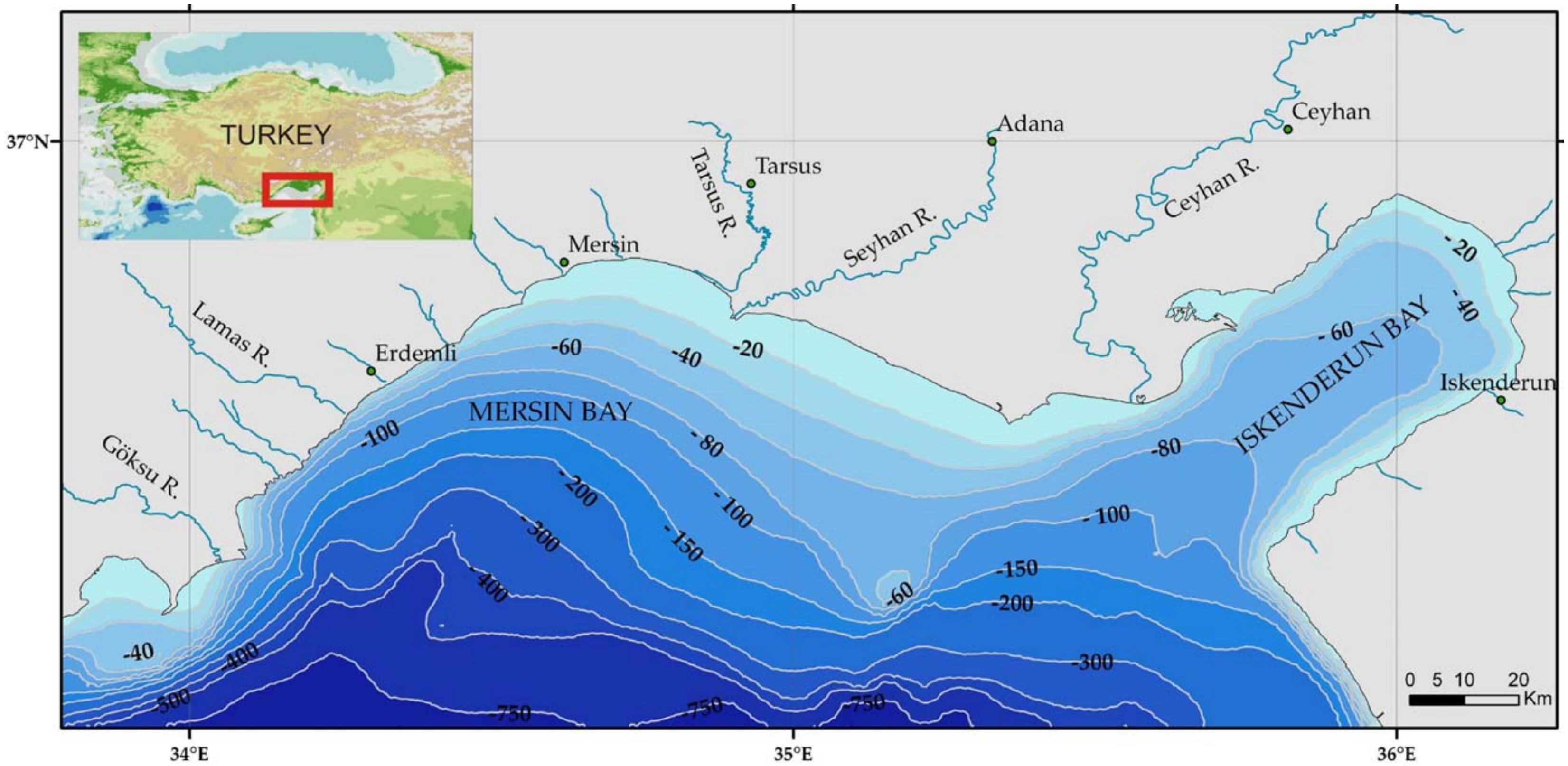


Figure 1. 1 Location map and bathymetry of the study area

1.1.2. Coastal Morphology

From west to east, the surrounding coastline area can be divided into four regions: the Göksu Delta; the Erdemli – Mersin coastal plain; delta plain of the Adana Basin; and the coastal plains of the Gulf of İskenderun (Figure 1.2; Evans, 1971).

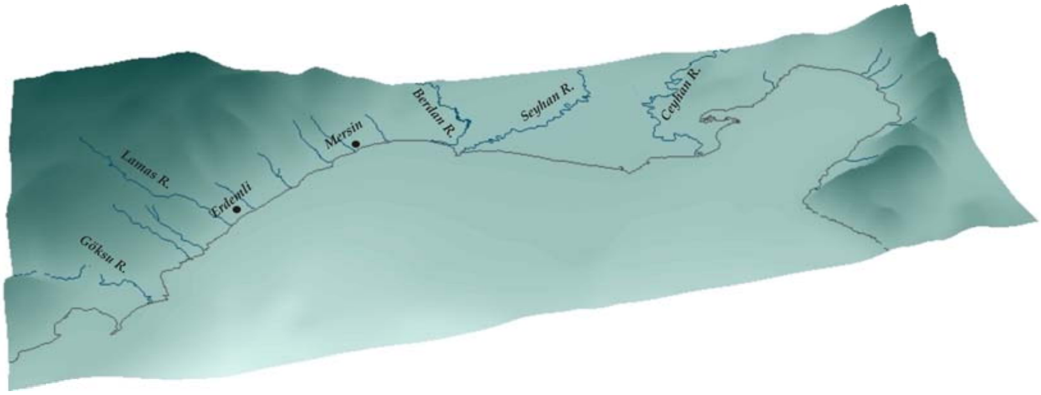


Figure 1. 2 Coastal morphology of the study area

The Göksu River emerges from the mountains and crosses its wide coastal plain to form a delta, which is wave-dominated and surrounded by broad beaches including some small lagoons and oxbow lakes, and enters the sea in the southeastern part of the delta. The beach sediments are composed of similar material to the river bed and include coarse sands and gravelly sands (Evans, 1971).

From the eastern part of the Göksu Delta to a point near Erdemli, Miocene rocks crop out at the coast forming sea cliffs. Coastal rivers, other than Lamas River, only flow for short periods and small beaches are present between rocky areas and where this ephemeral streams reach the sea. The beaches in this region are composed of sands and gravels (Evans, 1971).

From Erdemli to the east of Mersin City, the mountains recede slightly from the coast and there occurs a narrow coastal plain. This plain is crossed by a series of ephemeral streams flowing only in winter and spring and formed by a complex of alluvial fans that composed of conglomerates with various types of particles (Evans, 1971).

In the coastal area east of Mersin City, the mountains and the fans at their foot swing inland to the northeast and the wide coastal plain of the Adana Basin intervenes between the mountains and sea (Figure 1.3; Evans, 1971). This Basin is bounded landward by three prominent and slightly tilted terraces (Erinç, 1978) and seaward by a network of complex coastal dunes and beach ridges (Russell, 1954). Seyhan River occupies the central and western portions of the delta plain and shows well developed meandering. The shoreline of the plain between Mersin and the southwest of Karataş is sandy and is formed of beaches backed by dunes (Evans, 1971).

The Ceyhan River, occupying the easternmost portion of the delta plain, has built a prominent delta complex exhibiting several typical lagoons, marshes, delta mouths in the north of the İskenderun Bay (Russel, 1954; Bal and Demirkol, 1987). In contrast, to the south and east, the gulf is surrounded by narrow coastal plains flanked by a high topography where ephemeral rivers enter the gulf (Ergin *et al*., 1998.).

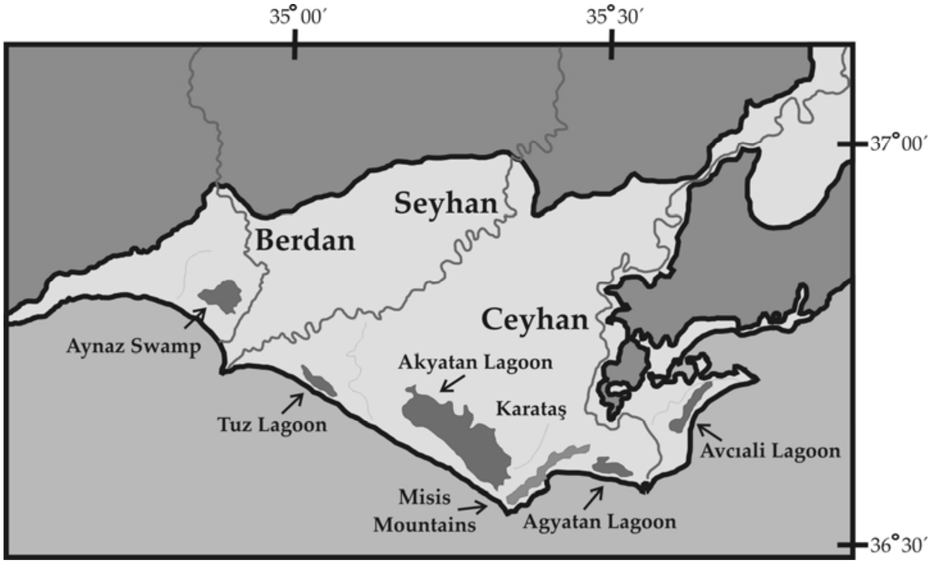


Figure 1. 3 Delta plain of the Adana Basin and the location of the abandoned channels and coastal lagoons and swamps (after Aksu, 1992a)

1.1.3. Water Circulation

The Mediterranean Sea is a mid-latitude semi-enclosed sea or nearly isolated oceanic system and comprises two approximately equal size basins (Figure 1.4; Robinson *et al*., 2001). The circulation pattern of the Mediterranean Sea is mainly characterized by climate and bathymetry of the region. The water output from the basin by evaporation is more than double the input by precipitation and run-off. This inequality produce an outflow of saline warm Mediterranean water (MW) in the lower layer across the Gibraltar Strait and a surface inflow of less saline Atlantic water (AW) (Krijgsman, 2002). The open sea waters entering the Mediterranean Sea extend eastwards at surface, south of the Island of Crete and reach the coast of Israel where they turn northwards. They flow into İskenderun and Cilicia Basins by passing east of Cyprus (Figure 1.5; Hecht, 1986; Özsoy *et al*., 1989).

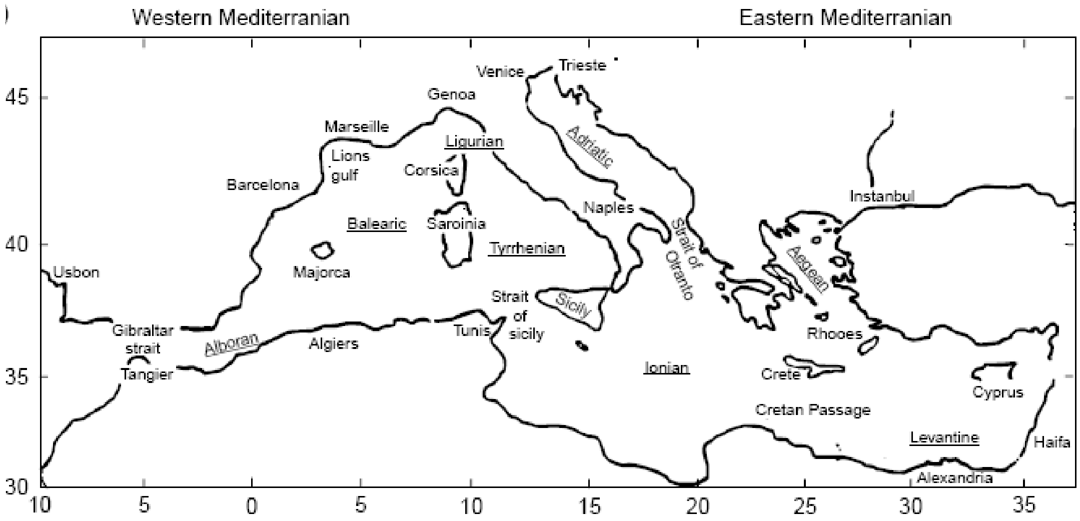


Figure 1. 4 The Mediterranean Sea geography and the major basins and straits (Robinson, 2001)

Figure 1. 5 Circulation pattern in the Mediterranean Sea (1a: LPC Current, 1b: Gulf of Lyon Gyre, 1c: Western Corsica Current, 2: Northward Tyrrenian current and gyres, 3: Gibraltar – Atlantic current system, 4: Rhodes Gyres, 5: Western Cretan Cyclone, 6: Western Ionian Cyclonic Gyre, 7: Syrte Gyre, 8: Anticyclonic System of the southeastern Levantine Basin, 9: Asia minor current, 10: Lera-Petra Gyre, 11: Pelops Gyre, 12: Southern Adriatic Cyclonic Gyre, 13: Western Adriatic Coastal Gyre, 14: Western Ionian Anticyclonic Gyre (from Pinardi et al., 2004)

The northwesterly flowing open sea currents and local winds affect the circulation pattern in İskenderun Bay (Figure 1.6; İyiduvar, 1986). The open sea waters enter the gulf from the northwest and create clockwise and anticlockwise water transport during summer (İyiduvar, 1986; Latif *et al*., 1989). The circulation system which is observed during summer months starts to change in autumn. During the winter months, open sea waters enter the gulf from the south – southwest and move further into the gulf along the coast (İyiduvar, 1986). General circulation pattern comprises two main gyres (anticyclonic and cyclonic) with variable rotation and extend (Latif *et al*., 1989).

Figure 1.7 shows the developed eddies during the spring and early summer due to the frontal instabilities of the shelf waters in Mersin Bay. The general pattern of water movement in the Mersin Bay is characterized by a cyclonic circulation of a dominant westerly flowing shelf current system (Lacombe and Tchernia, 1972; Ünlüata *et al*., 1978). However, several minor anticyclonic and cyclonic circulation systems, which may extend to the shelf edge, are produced by local winds and coastal morphology (Collins and Banner, 1978).

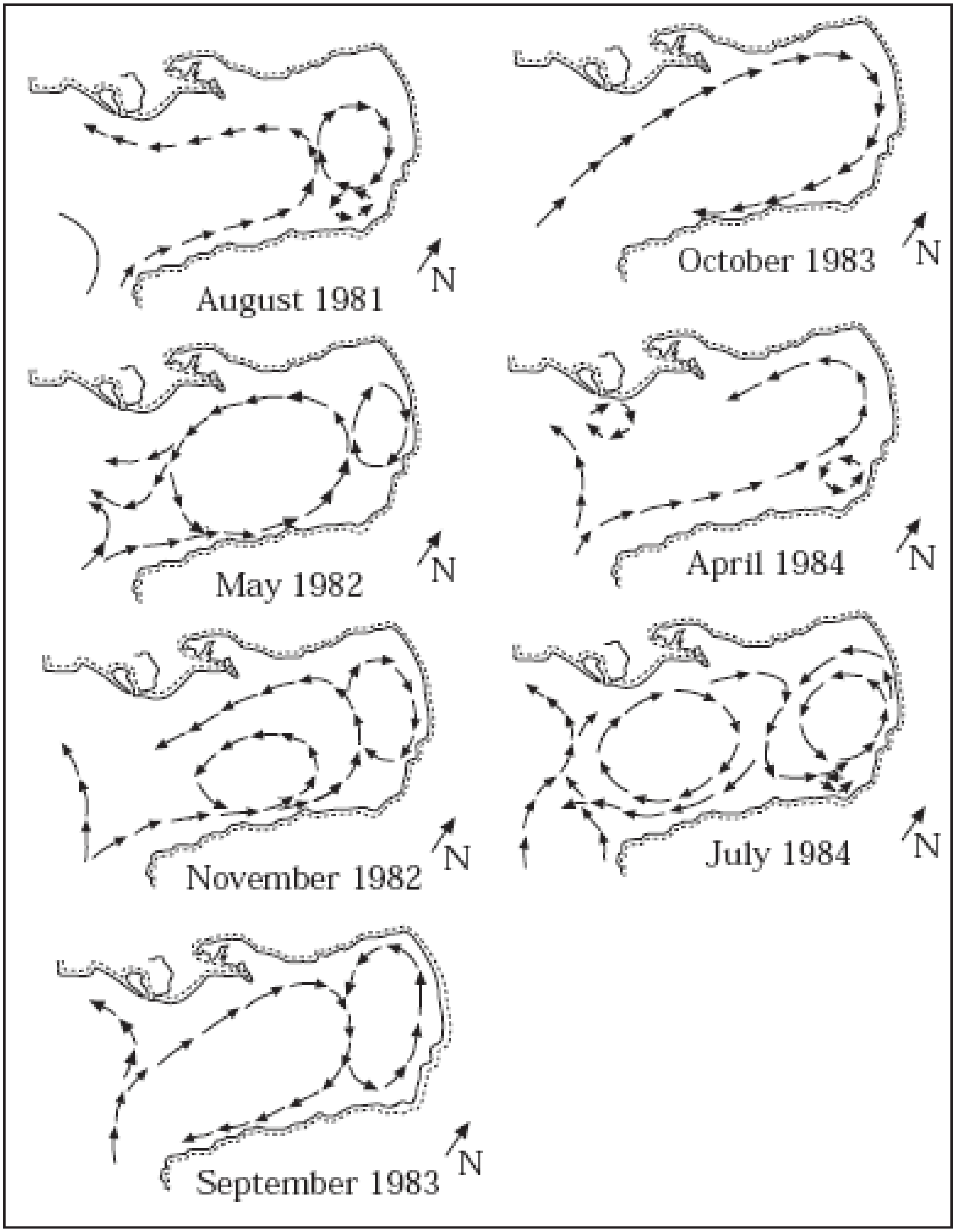


Figure 1. 6 Surface circulation patterns in the Gulf of İskenderun (İyiduvar, 1986)

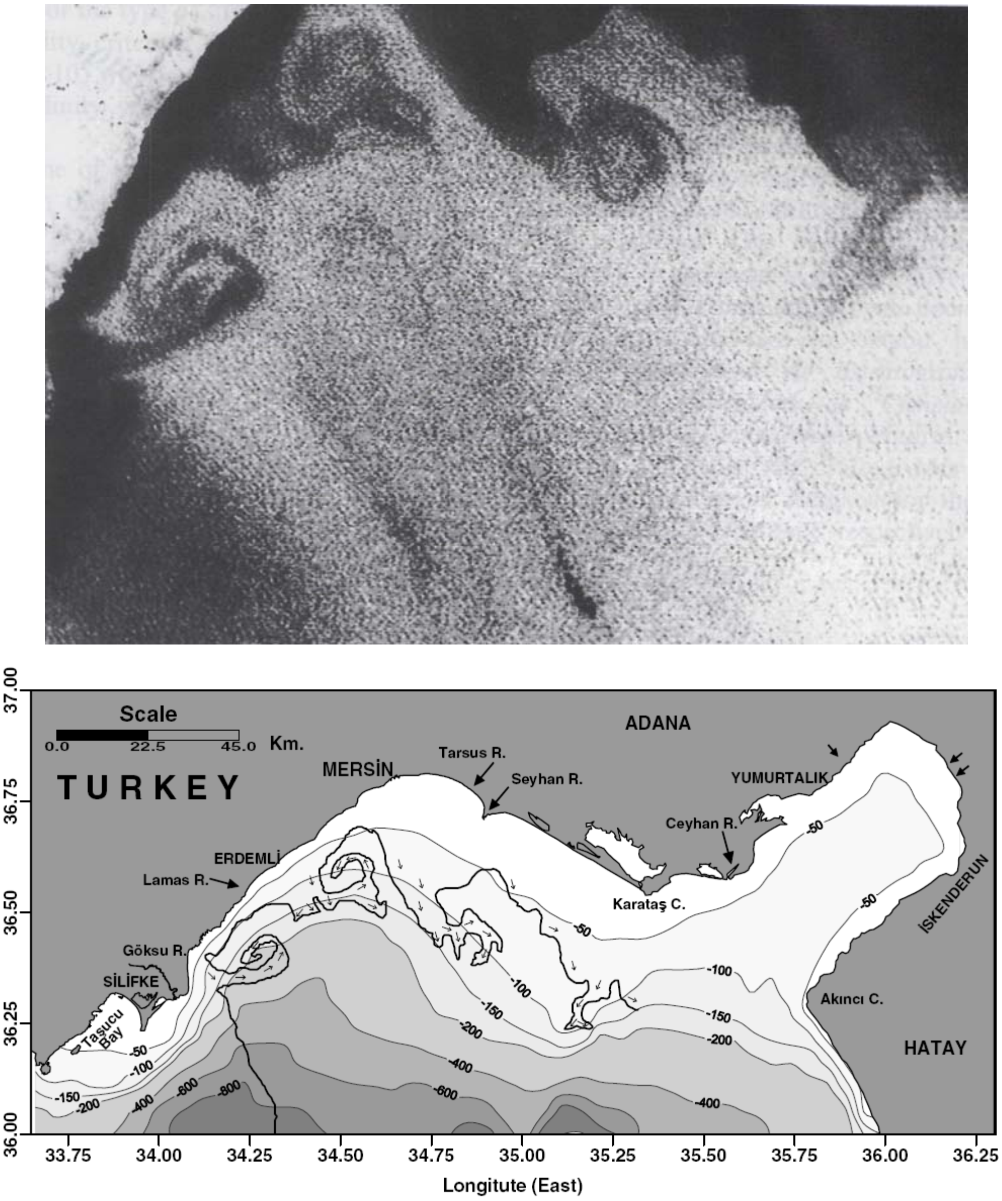


Figure 1. 7 Contrast-enhanced satellite (LANDSAT, band 4 (visible) image of a section of the southern Turkish coastline (Silifke in the southwest, towards Mersin). High turbidity inshore waters and flow features are shown dark, against the lighter low turbidity offshore waters (after Evans *et al.*, 1995) and Interpretation of the satellite image (after Ediger and Evans, 2007)

1.1.4. Climate

The sea-land breezes and the westerly wind system effects the prevailing meteorological conditions in the eastern Mediterranean (Özsoy, 1981). In summer (from April to October), the wind direction along the southern coasts of Turkey is dominantly from the southwest, whilst northwesterly and northeasterly winds are dominant in winter (from November to March) (Meteorological Bulletin, 1970; Ataktürk, 1980).

A "Mediterranean Climate" that is hot dry in summers and mild wet in winters dominates in the southern coast of Turkey (Evans, 1971).

In Mersin and vicinity area, the air temperature varies between 10 ^{o}C in January and 30 ^{o}C in July. The average rainfall and mean humidity are approximately 600 mm/year and 70 %, respectively (Meteorological Bulletin, 1970).

İskenderun bay receives a considerable rainfall, because of the dominant westerly winds which cause an increase in the rate of precipitation. The average rainfall in İskenderun and Dörtyol is about 785 mm/year and 1082 mm/year, respectively.

1.1.5. Rivers and Drainage Areas

Five perennial rivers (Göksu, Lamas, Berdan, Seyhan, and Ceyhan) and several ephemeral rivers drain into the study area. Drainage areas and water flow monitoring stations of EIE (General Directorate of Electrical Power Resources Survey and Development Administration) are shown in Figure 1.8 and annual water discharge values of the stations are given in Table 1.1.

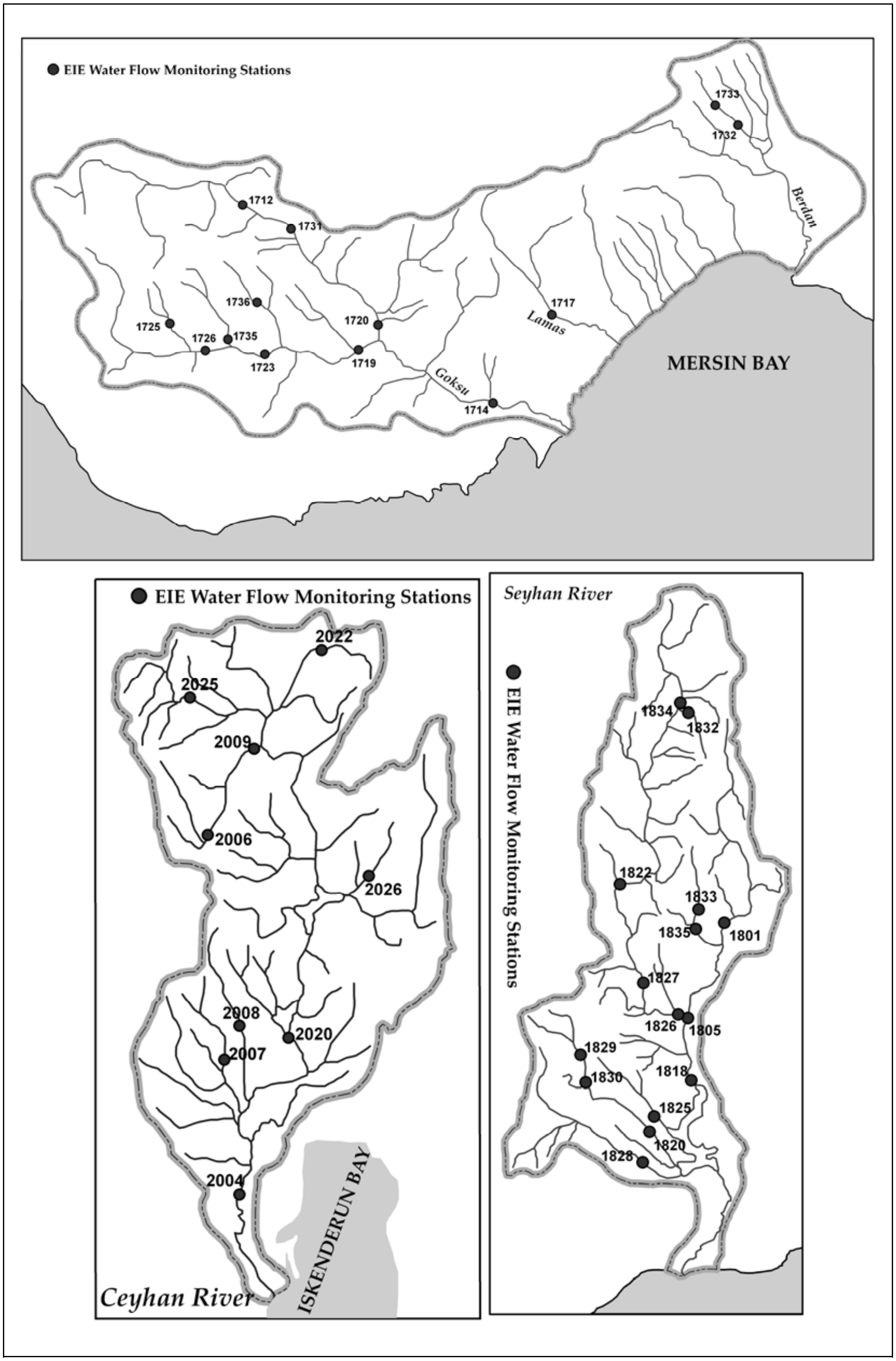


Figure 1. 8 Drainage areas of the rivers draining into the study area and water flow monitoring stations of EIE (2003)

Table 1. 1 Annual water discharge of monitoring stations of EIE

Monitoring Station (EIE, 2003)	Drainage Area (EIE, 2003)	Annual Discharge (million m^3)(EIE, 2003)
1712	Mediterranean Rivers	716
1714	Mediterranean Rivers	2628
1717	Mediterranean Rivers	130
1719	Mediterranean Rivers	1202
1720	Mediterranean Rivers	1097
1721	Mediterranean Rivers	677
1723	Mediterranean Rivers	1119
1725	Mediterranean Rivers	111
1726	Mediterranean Rivers	932
1729	Mediterranean Rivers	53.3
1730	Mediterranean Rivers	429
1731	Mediterranean Rivers	882
1732	Mediterranean Rivers	569
1733	Mediterranean Rivers	124
1735	Mediterranean Rivers	77.5
1736	Mediterranean Rivers	31.4
1801	Seyhan River	876
1805	Seyhan River	1845
1818	Seyhan River	4337
1820	Seyhan River	360
1822	Seyhan River	604
1825	Seyhan River	268
1826	Seyhan River	1888
1827	Seyhan River	799
1828	Seyhan River	363
1829	Seyhan River	153
1830	Seyhan River	198
1832	Seyhan River	55.2
1833	Seyhan River	154
1834	Seyhan River	235
1835	Seyhan River	280
2004	Ceyhan River	5249
2006	Ceyhan River	248
2007	Ceyhan River	405
2008	Ceyhan River	256
2009	Ceyhan River	354
2020	Ceyhan River	3826
2022	Ceyhan River	101
2025	Ceyhan River	235
2026	Ceyhan River	5.98

Göksu River drains a basin of 10.065 km^2 with an annual discharge of 2628 x 10^6 m^3 and an annual sediment yield of 2539 x 10^3 t. Lamas River drains a basin of 1005 km^2 with an annual discharge of 130 x 106 m^3. Berdan River drains a basin of 1426 km^2 with an annual discharge of 1057 x 106 m^3. The annual sediment yield of the river is 129 x 10^3 t. Seyhan River drains a basin of 19352 km^2 with an annual discharge of 5063 x 10^6 m^3 and an annual suspended sediment yield of 5185 x 10^3 t. Ceyhan River drains a basin of 20.466 km^2 with an annual discharge 5249 x 10^6 m^3. The annual sediment yield of Ceyhan is 5462 x 10^3 t (Table 1.2 ; Figure 1.9).

Table 1. 2 Surface area of drainage basins and sediment and water discharge rates of the perennial rivers draining into the study area

Rivers	Drainage Area (km^2) (EIE, 2003)	Annual Sediment Load(ton) (EIE, 1984)	Annual Water Discharge (m^3) (EIE, 2003)
Göksu	10065	2539 x 10^3	2628 x 10^6
Ceyhan	20466	5462 x 10^3	5249 x 10^6
Seyhan	19352	5185 x 10^3	5063 x 10^6
Berdan	1426	129 x 10^3	1057 x 10^6
Lamas	1005	-	130 x 10^6

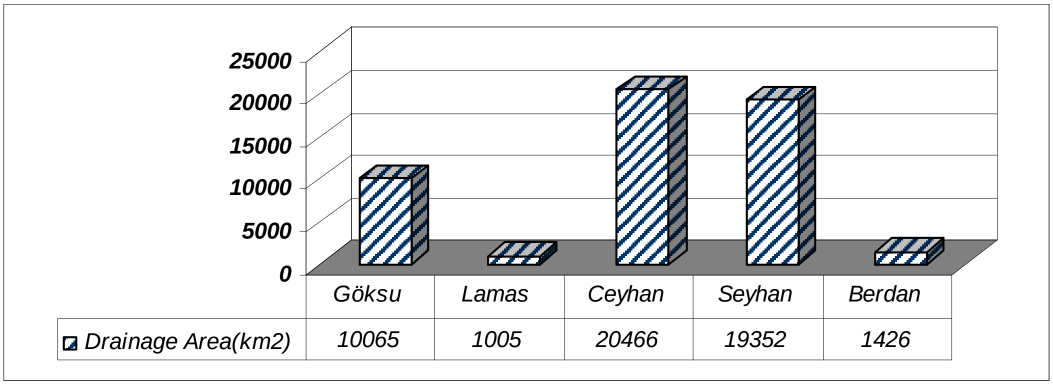


Figure 1. 9 Drainage areas of the rivers draining into the studied area (EIE, 2003)

The perennial rivers (Ceyhan, Seyhan, Göksu, Lamas, Berdan) are the main siliciclastic sediment suppliers into the study area. The maximum discharge of the rivers usually occurs in April, when the snow melts in the nearby mountains, whilst the minimum discharge occurs in June – December. Annual water and sediment supply percentages are shown in Figure 1.10.

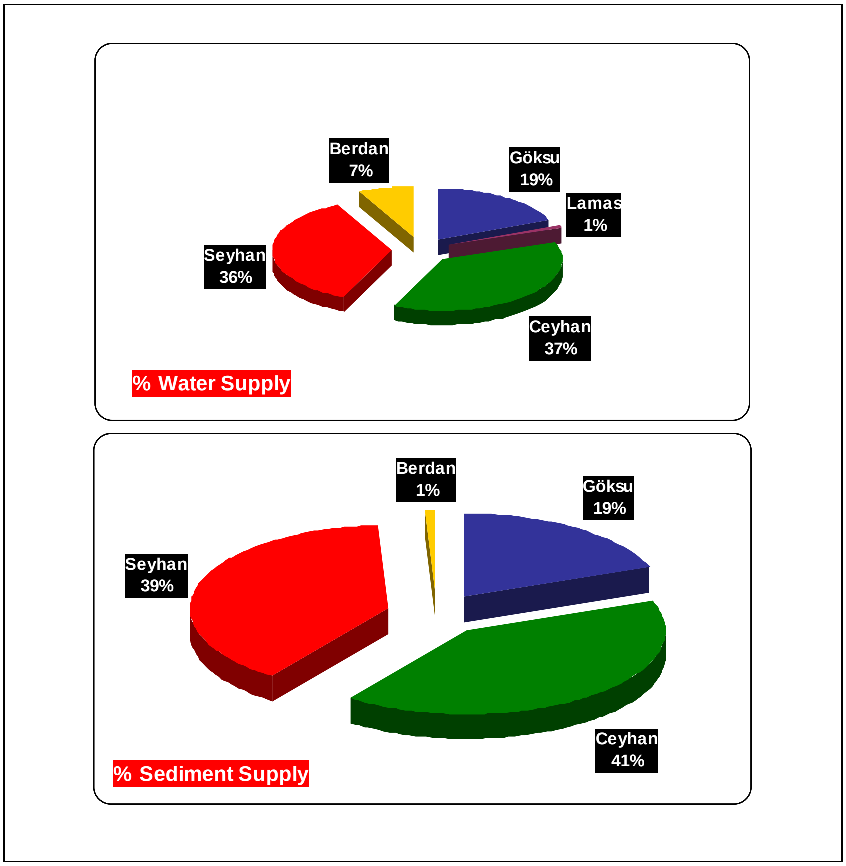


Figure 1. 10 Annual water and sediment supply percentages carried by perennial rivers into the study area (EIE, 2003)

1.2. TECTONIC SETTING OF THE STUDY AREA

The last phase of collision between the African and Eurasian plates, especially the displacements of the smaller Arabian, Syrian, Anatolian and Aegean microplates, acts as the primary role on the tectonic framework of the eastern Mediterranean (Figure 1.11; Aksu *et al.*, 1992b). The collision between the Arabian/Syrian and Eurasian plates along Bilis-Zagros Suture Zone (BZZ) causes the Aegean-Anatolian "microplate" to move westwards along the strike-slip faults (Şengör and Yılmaz, 1981). Depending on tectonic motions, the dextral North Anatolian Fault (NAF), the sinistral East Anatolian Fault (EAF) and subsidiary faults, such as the Ecemiş and Sungurlu Faults occur (Figure 1.11). The Hellenic Arc (HA) and Pliny-Strabo Trench (PST) in the west, the Cyprus Arc (CA) and Amanos Fault in the east delineate the boundary between the Anatolian and African plates. The sinistral Dead Sea Transform Fault (DSF) represents the boundary between the African and Arabian plates (Aksu *et al.*, 1992b).

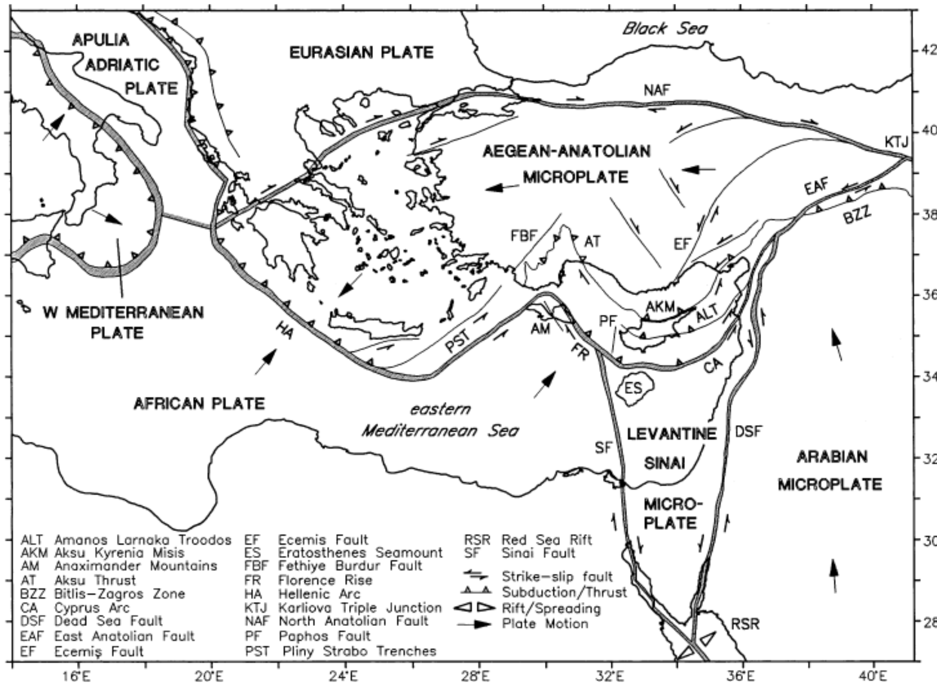


Figure 1. 11 Simplified tectonic map of the eastern Mediterranean Sea and surrounding area, compiled from Şengör and Yılmaz (1981), Hancock and Barka (1981), Jongsma *et al*. (1985, 1987), Dewey *et al*. (1986), Mascle *et al*. (2000), Zitter *et al*. (2003) and Salamon *et al*. (2003) (From Aksu *et al*., 1992b)

The study area is located at the edge of the Aegean-Anatolian microplate, in the southwest of the Africa/Arabia/Anatolia triple junction (Dewey *et al*., 1986) and includes two genetically related basins: Inner Cilicia Basin and İskenderun basin. The structural framework of the study area is controlled by NE-trending fault zones: Ecemiş, Amanos and Misis-Girne Faults (Figure 1.12). Ecemiş is a NE-SW trending sinistral strike-slip fault system and is mainly represented by horst-graben structures (Özer *et al*., 1974). Similarly, the Middle-Late Miocene Amanos Fault, NE-trending strike-slip fault zone, exhibits horst-graben structures with considerable vertical throws (Perinçek and Çemen, 1990; Perinçek and Eren, 1990). The pre-Miocene Misis-Girne thrust belt separates the offshore region between Cyprus and Turkey into two NE-trending basins: Cilicia Basin in the west and İskenderun basin in the east (Figure 1.12; Aksu, 1992b). The Misis Mountains (Kelling *et al*, 1987) and Girne Mountains (Robertson and Dixon, 1984) are the extensions of the thrust belt on land.

The Inner Cilicia Basin is characterized by EW trending extensional imbricate fan that comprises of listric normal faults include a 20 km wide north-dipping in the south and a 40 km south-dipping in the north (Aksu *et al*., 1992b).

The İskenderun Basin is bounded by the Misis lineament in the northwest. The sinistral Amanos Fault borders the southeastern margin of the Amanos Mountains. To the southwest, 1 – 2 km wide zone of SW-dipping listric normal faults separate İskenderun Bay from Latakia Basin. Two sets of steep normal faults comprise of NE- and N-trending faults exist within the basin (Figure 1.12).

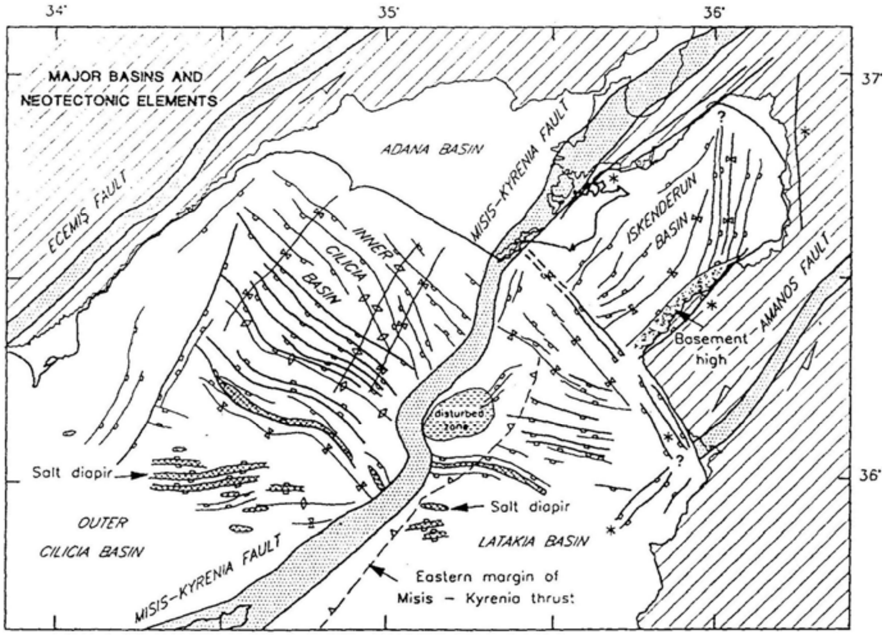


Figure 1. 12 Tectonic map of the study area, showing Ecemiş, Amanos and Misis-Girne Faults, major faults with ticks at downthrows and major salt diapers and ridges, and anticlinal (◇) and basinal (⋈) axes. Faults with * are from Perinçek and Çemen (1990) (From Aksu *et al*., 1992b)

1.3. GEOLOGIC SETTING OF THE STUDY AREA AND COASTAL REGION

The northeastern Mediterranean basins (Adana, Cilicia, İskenderun and Latakia) evolved since Middle-Late Miocene due to an intraplate extension related to displacements around the triple junction (Şengör *et al*., 1985; Dewey *et al*., 1986).

Studies carried out by Schmidt (1961), Biju-Duval *et al*. (1977), Yalçın and Görür (1984) and Görür (1985) in Adana, Cilicia and İskenderun Basins show that >1000 m thick Lower Miocene siliciclastics overlain by 500 – 1000 m thick Messinian evaporites unconformable cover a pre-Miocene orogenic belt. And, Plio-Pleistocene deltaic successions with various thicknesses (300 – 2000 m) deposited on the evaporitic serie.

The study area has been subjected to various orogenic movements since the Paleozoic time. The Taurus Mountains located in the northeastern coast of the study area, were mainly formed during the Tertiary Alpine Orogeny. On the hinterland of the Mersin area, the lithologies exposed compose mainly of sedimentary rocks (Figure 1.13). Paleozoic carbonate and clastic rocks reflect the shallow marine environments, whilst Lower Triassic limestone – mudstone - marl sequences indicate tidal flat environments (Figure 1.13; Tekeli and Göncüoğlu, 1984). Jura – Cretaceous neritic limestone sequences were deposited during the Upper Jurassic transgression (Figure 1.13; Tekeli and Göncüoğlu, 1984). Ophiolitic melange sequences settled in the basin during Senonian (Upper Cretaceous) (Figure 1.13; Erendil, 1984). Clastic rocks such as conglomerates, sandy limestones, marls, sandy marls and sandstones were deposited in the Tertiary. Miocene limestones crop out widely in northwestern coast of the study area disconformably overlie all the older formation along the coast (Figure 1.13; Pampal and Kurtman, 1984). The Plio-Quaternary deposits composed of terrace deposits, alluvium, slope debris, alluvial fans show their minimum thickness on the western coasts of Mersin Bay where Miocene basement rocks outcrop. Towards the wide fluvial plains of the Tarsus and Seyhan rivers, the thickness of the Plio-Quaternary deposits` increase up to 1250 m (Schmidt, 1961).

The Adana Basin covers the northeastern coasts of the Mersin Bay and is nestled between the Taurus Mountains to the north and west and the Misis high in the east. Geologic evolution of the basin is studied by Özer *et al*. (1974), Yalçın and Görür (1984), Görür (1985) and Burton-Ferguson *et al*. (2005) and summarized below.

The Adana Basin exhibits approximately 6000 m thick sedimentary succession from Miocene to Recent (Burton-Ferguson *et al.*, 2005). Paleozoic - Mesozoic deformed rocks of Taurus and Misis Mountains and ophiolitic series constitute the basement of the Adana Basin.

A 300 meter thick conglomerate – sandstone – siltstone succession related to SE-trending transgression deposited on the basement during Late Miocene (Figure 1.13). Limestones with 100 – 350 m thick overlie these layers and reflect the shallow marine environment. The major sedimentation in Adana Basin occurs in Langhian – Serravallian and neritic limestones overlaid by 3000 m thick siliciclastic turbidities and deep sea shale (Figure 1.13). The regression period started in Early Tortanian ends with the occurrence of 100 – 900 m thick evaporitic series in Messinian. 400 – 450 m thick neritic limestone, sandstone and shale deposited in the basin during Pliocene with the effect of a new transgression period. A wide part of the basin is covered by Quaternary units (alluvium, travertine, etc) deposited on the Late Tertiary sequences (Figure 1.13). The thickness of the Quaternary units shows variety from region to region.

Şengör *et al*. (1985) and Kelling *et al*. (1987) suggested that the geological evolution of NE-SW trending İskenderun Basin is related to Neogene convergence and strike-slip movements along the East Anatolian and Dead Sea Fault complexes.

The geological formations outcropping in the coastal hinterland of the İskenderun Bay have been reported by Aslaner (1973), Tolun and Pamir (1975), Kozlu (1987). NE-trending Early Paleozoic formations comprise shale-slatephyllites, micro-conglomerate-quartz sandstones, grey-black dolomitize limestone and clayey limestone-shale, quartzite crop out at the northern corner of the bay. The Early Mesozoic series are characterized by conglomeratic sandstone-quartzite and crystallized gray limestone, brecciated dolomitic limestone formations (Figure 1.13). Cretaceous is represented by two different formations. Sedimentary series comprise gray-black dolomitic limestones and gravel conglomerate, detritic fossiliferous clayey limestone.

The ophiolitic succession (up to 3000 m thick) composed of various basic (mainly gabbroic, amphibolites, diabase and basalt) and ultrabasic (mainly dunit, harzburgite and serpantinite) rocks (Figure 1.13). Magmatic rocks outcropped in the area comprise a potentially important source of some heavy metals. Compositions of the major elements in the upper continental crust are shown in Table 1.3. Tertiary is represented by the Paleocene limestones, the Lutetian cherty, gray limestone, nodular limestone series, the Miocene conglomerate, sandstone, limestone and marl formations and the Pliocene porous conglomerate, sandstone, clay and tuffaceous limestone beds. Depending on the prograding delta complexes, Quaternary, including ancient and recent alluvial, cemented, angular rubbish breccia poor cemented conglomerate with angular and rounded pebbles, sands and clay, is widespread in the area.

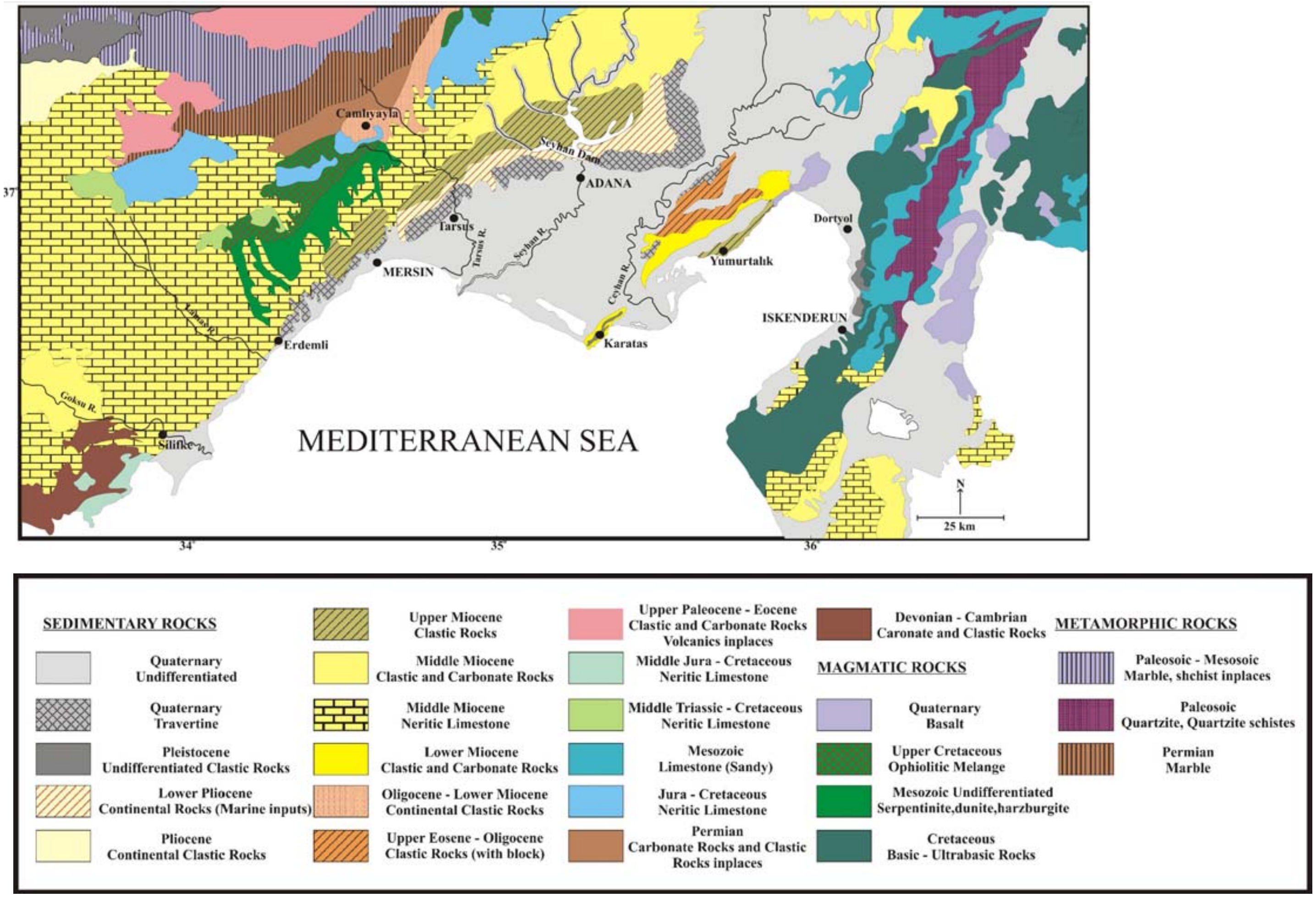


Figure 1. 13 Geologic map of the area surrounding study area (modified from MTA, 2002)

Table 1. 3 Composition of the 16 different elements in the upper continental crust

Elements	Units	T&M	Wedepohl
Al	%	8.04	7.74
Ti	ppm	3000	3117
V	ppm	60	53
Cr	ppm	35	35
Mn	ppm	600	527
Fe	%	3.5	3.09
Co	ppm	10	11.6
Ni	ppm	20	18.6
Cu	ppm	25	14.3
Zn	ppm	71	52
Mo	ppm	1.5	1.4
Ag	ppb	50	55
Cd	ppb	98	102
Ba	ppm	550	668
Pb	ppm	20	17
U	ppm	2.8	2.5

T&M: Taylor and McLennan (1985, 1995), Wedepohl: Wedepohl (1995)

2. MATERIALS AND METHODS

Surface sediment samples were collected by using a Dietz LaFond grab sampler which collects top 10 cm. The sediment samples were subjected to grain size analyses and chemical (carbonate, organic carbon and heavy metal) analyses. The complete analyses scheme is shown in a flow chart in Figure 2.1.

2.1. SAMPLING OF THE SURFACE SEDIMENTS

During the study at sea, a Global Positioning System (GPS) was used to determine the location of the sampling site. The depth values at each sediment samples were taken was determined by an echo sounder system that is mounted to the research vessel, R/V Bilim.

A total of forty-five surface sediments, from bottom were taken between the depths of 12 meters to a depth of 330 meters, with a Dietz LaFond grab (Figure 2.2) during January 2007 cruise of R/V Bilim of Institute of Marine Sciences / METU in the northeastern Mediterranean Sea. The locations of the sediment samples used in the study are shown in Figure 2.3. Their coordinates and depths are listed in Table 2.1. After the collection of sediment samples, they were immediately placed into plastic bags and kept frozen until their analyses in the laboratory.

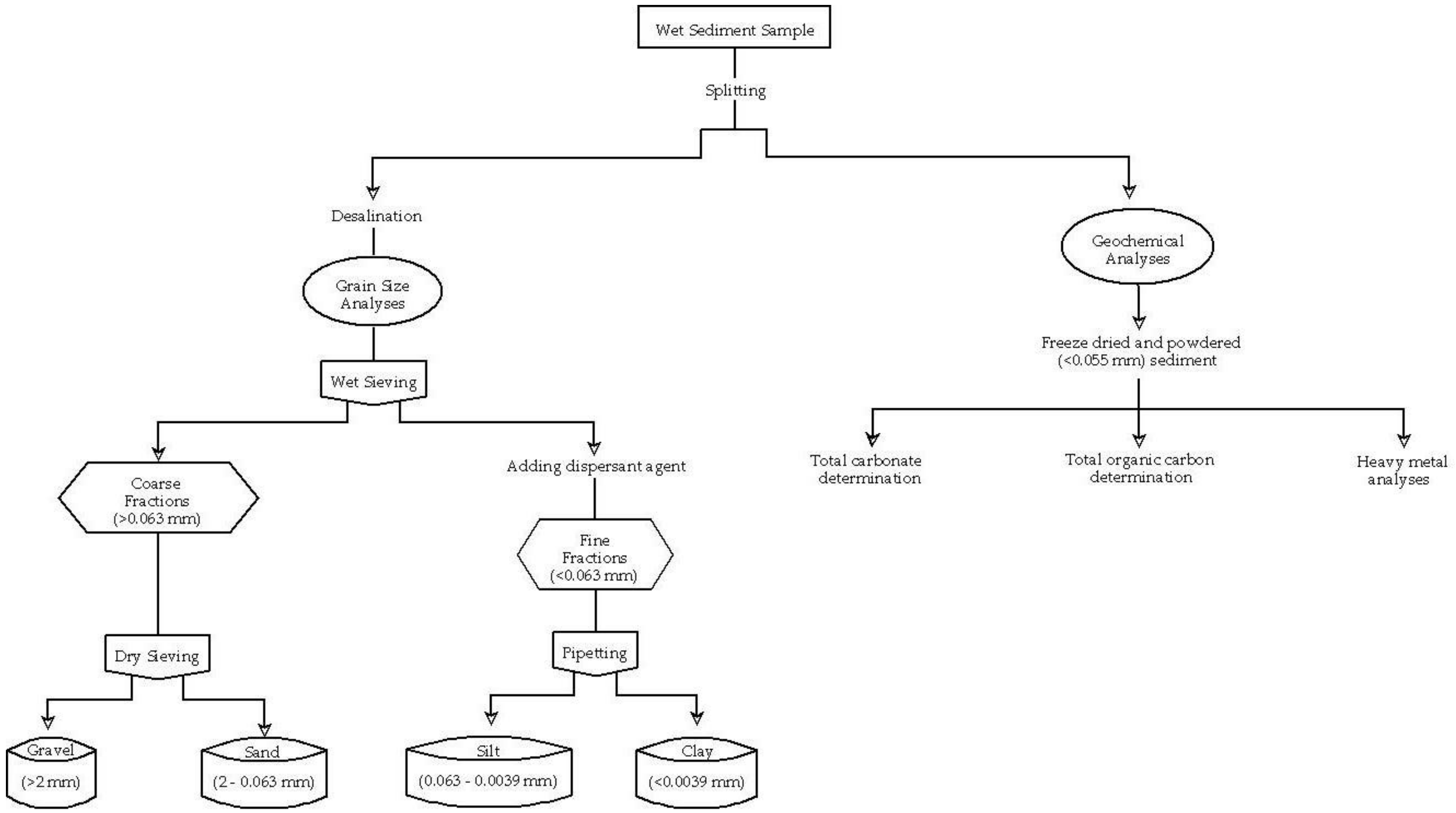


Figure 2. 1 Flow chart of sediment analyses

Figure 2. 2 Dietz LaFond grab sampler

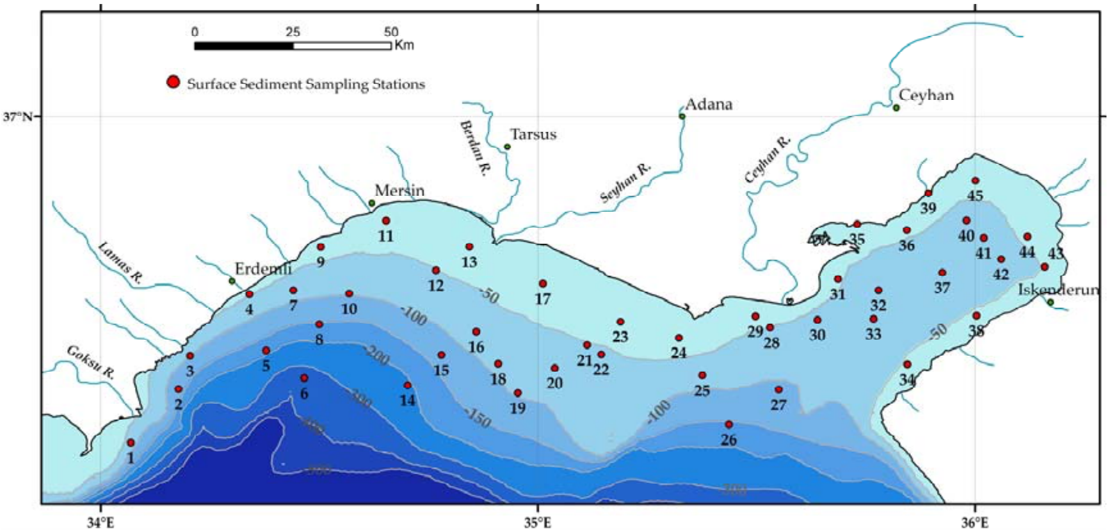


Figure 2. 3 Location map of the surface sediment samples

Table 2. 1 Locations of the sediment sampling stations in the study area

Station	Longitude	Latitude	Depth
1	34.06867	36.24767	65
2	34.17767	36.371	159
3	34.20417	36.44817	112
4	34.34	36.59	30
5	34.37833	36.46033	202
6	34.4655	36.39667	330
7	34.44033	36.59917	88
8	34.5	36.52067	168
9	34.50317	36.69883	30
10	34.56817	36.59133	100
11	34.65267	36.75967	18
12	34.76667	36.64517	50
13	34.84317	36.69917	20
14	34.702	36.38	206
15	34.77917	36.44983	133
16	34.859	36.50367	85
17	35.01133	36.6145	20
18	34.90933	36.42967	93
19	34.95417	36.36233	101
20	35.0385	36.41967	74
21	35.1125	36.47283	58
22	35.14483	36.451	61
23	35.18883	36.52667	24
24	35.32267	36.4895	24
25	35.37617	36.4025	89
26	35.43717	36.2895	150
27	35.55083	36.36983	102
28	35.53117	36.51283	51
29	35.49783	36.539	15
30	35.63967	36.53067	69
31	35.6865	36.62483	40
32	35.77917	36.59917	65
33	35.768	36.533	79
34	35.84533	36.42817	50
35	35.7305	36.75167	12
36	35.844	36.7375	45
37	35.92517	36.63983	70
38	36.00333	36.5405	48
39	35.8935	36.82283	17
40	35.9805	36.76017	56
41	36.02017	36.71983	64
42	36.05983	36.67067	68
43	36.15933	36.65317	56
44	36.12	36.72267	50
45	36.00117	36.85217	42

2.2. LABORATORY PROCEDURES

The laboratory works comprised of grain size analyses (wet/dry sieving, pipetting) and geochemical analyses (carbonate, organic carbon, heavy metal) were described in the following chapters.

2.2.1. Grain Size Analyses

Grain size analyses were performed by using wet/dry sieving and pipetting methods according to the standard laboratory procedures outlined by Folk (1974). The grain size distribution in each sediment sample was grouped into four categories as follows; gravel (>2 mm), sand (2 – 0.063 mm), silt (0.063 – 0.0039) and clay (<0.0039 mm) (Figure 2.4).

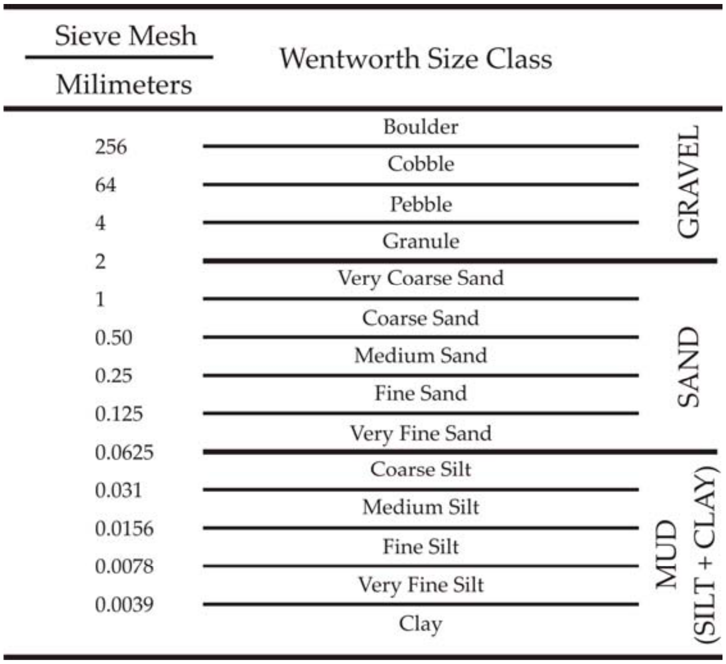


Figure 2. 4 Grain Size Scales (modified from Folk, 1974)

For grain size determination, wet sediment samples (approximately 50 gr) were placed into beakers and filled with 100 ml distillated water. This mixture was then stirred vigorously and let stand for a while. In order to prevent flocculation between the grains and to provide salt-free sediment sample, this procedure repeated at least three times.

Representative subsamples were separated into coarse and fine fractions by means of wet – sieving with a 0.063 mm sieve by using distillated water. The mud material (silt + clay) passing through 0.063 mm sieve was transferred into a cylinder for pipette analysis. The coarse material (gravel + sand) retained on the sieve (0.063 mm) was transferred to the evaporation pot and let stand overnight for drying in an oven at about 105 ^{O}C. During the dry – sieving, the coarse fractions are divided to two fractions: gravel and sand by using 2 mm sieve.

The mud fraction comprised of silt (0.063 – 0.0039 mm) and clay (<0.0039 mm) was determined by using the pipette method. The principle of the pipette method is based on the "Stokes Law" which is expressed simply as ;

$V = c \times d^2$

Where ;

V = The settling velocity

d = Particle size (mm)

c = Constant equaling

$c = [(\mu s - \mu f)g] / 18v$

Where ;

μs = Particle density

μf = Fluid density

g = Acceleration of gravity

v = Fluid viscosity (Folk, 1974)

The mud fraction (silt and clay) that passes through the 0.063 mm sieve was transferred to a 1000 ml measuring cylinder. The suspension in the cylinder was diluted to 1000 ml and then allowed to stand for 24 hours. Withdrawal intervals of pipette analyze are shown in Figure 2.5. The suspension was stirred one minute before the first withdrawal. Twenty seconds after stirring, a pipette was inserted to 20 cm depth and exactly 20 ml of suspension withdrawn and transferred in a beaker. The suspension was evaporated and the dried mud was weighed. The weight of mud multiplied by 50 gave the weight of mud in the total sample. After 2 hours 3 minutes from stirring, 20 ml suspension withdrawn from 10 cm depth and evaporated. The dried material was weighed and multiplied by 50 represented the weight of silt in the total mud.

The textural classification of the sediment samples was defined by a triangular diagram showing the distributions of relative proportions of gravel, sand and mud (Figure 2.6).

		Diameter (mm)	Withdrawal Depth (cm)	Withdrawal Volume (ml)	Withdrawal Time After Stirring
SILT	First Withdrawal	0.0625	20	20	20s
		0.031	10	20	1m 56s
		0.0156	10	20	7m 44s
		0.0078	10	20	31m 00s
CLAY	Second Withdrawal	0.0039	10	20	2h 03m 00s
		0.0020	5	20	4h 06m 00s
		0.00098	5	20	16h 24m 00s

Figure 2. 5 Withdrawal intervals of pipette analysis for silt / clay separation (modified from Folk, 1974)

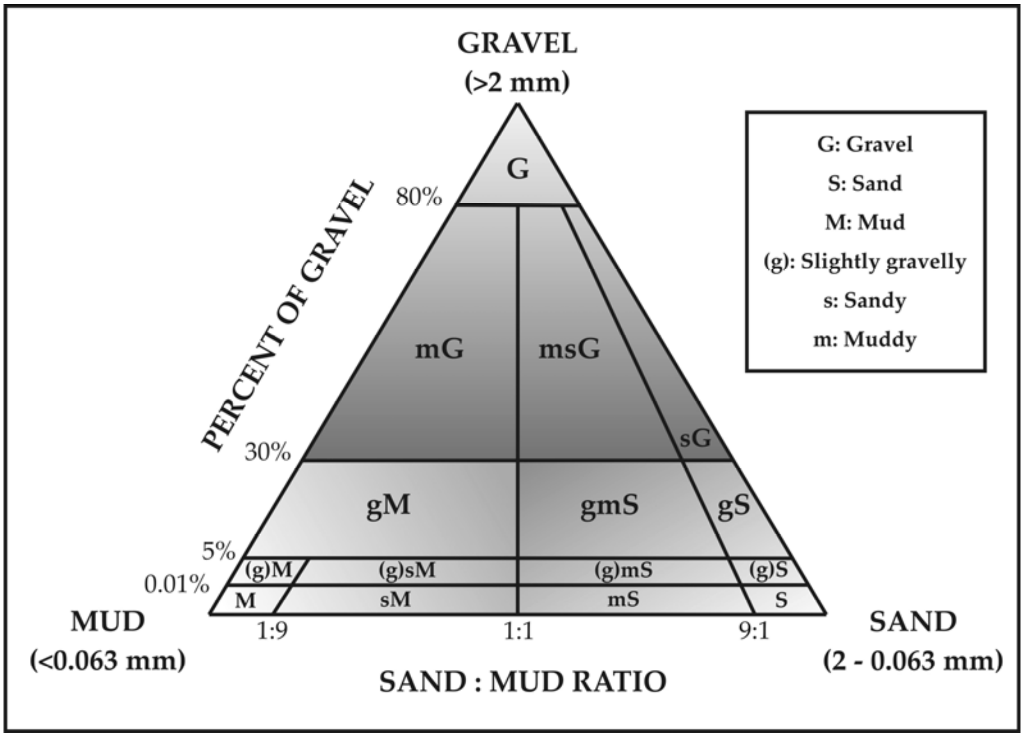


Figure 2. 6 Triangular diagram for sediment classification (modified from Folk, 1974)

2.2.2. Geochemical Analyses

In order to determine the geochemical properties of the surface sediments, approximately 100 gr of subsample was dried in freeze-dry system and powdered down to a grain size less than 0.055 mm in diameter by using agate mortar and pestle.

2.2.2.1. Carbonate Determination

The total carbonate contents of the sediment samples were determined by gasometrical method which is a modified "Scheibler" system (Muller, 1967; Figure 2.7). This method is based on the volumetric determination of CO_2 released by acidification of the oven-dried and pre-weighed samples with HCl solution.

In this method, 0.3 gr of powdered sediment sample (S) was reacted with 10 ml of 10% HCl solution (A) in a closed glass bottle. CO_2 released from the reaction between the HCl acid and the carbonate present in the sample generates an excess pressure which forces the water (W) to rise up in the scaled columnar barometric tube.

$$CaCO_3 + 2HCl \rightleftharpoons CaCl_2 + CO_2 + H_2O$$

The percentages of $CaCO_3$ were calculated by comparing the read-off value of water level (WL) in the barometric tube and that obtained from pure $CaCO_3$ (standards) with known quantities.

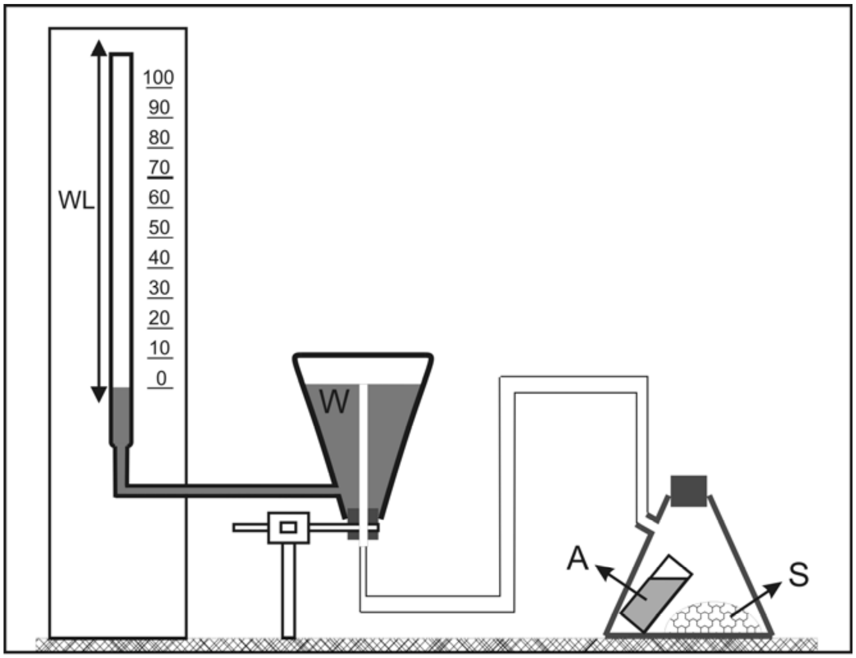


Figure 2. 7 A modified Scheibler apparatus designed by Ediger for determination of $CaCO_3$ contents in sediments (Ediger, 1991)

2.2.2.2. Heavy Metal Analyses

The total concentrations of heavy metals (Fe, Mn, Cr, Ni, Zn, Co, Cu) in the surface sediments were determined by using a flame atomic absorption spectrometer.

A microwave digestion system is used for digestion of the sediment subsamples. Approximately 0.4 gr of powdered sediment sample were treated in closed Teflon tubes with 10 ml hydrofluoric acid (HF) in combination with 3 ml aqua regia in order to decompose the samples. The use of HF is essential because it is the only acid that completely dissolves the silicate lattices and releases all the metals. The material in Teflon tubes were placed into the microwave oven and oven run for 5 minutes with 100% power.

In addition to the sediment samples, two IAEA – 433 reference materials and two blanks were digested for each set to control the validity and precision of the digestion method.

2.2.2.3. Organic Carbon Analyses

The analytical method for the quantitative determination of organic carbon is based on the complete and instantaneous oxidation of the sample by “high temperature flash combustion”, using a Thermo Finnigan Flash EA 1112 Series elemental analyzer. The total organic and inorganic substances were converted to combustion products in a tin capsule in the presence of O_2 gas. The resulting combustion gas mixture were sent to a chromatographic column with the help of a carrier inert gas (Helium) where they are separated and put in order with respect to their retention periods. There they were detected by a thermoconductive detector which gives an output signal proportional to the concentration of the individual components of the mixture.

3. RESULTS

3.1. GRAIN SIZE COMPOSITION OF THE SURFACE SEDIMENTS

The surface sediments of the study area show various sediment textures ranging from sandy gravel to mud (Figure 3.1 and Table 3.1). Sediment types such as; slightly gravelly mud, slightly gravelly sand, slightly gravelly muddy sand, slightly gravelly sandy mud, mud, gravelly muddy sand, gravelly mud, muddy sandy gravel and muddy sand were determined according to the triangular diagram showing the distributions of relative proportions of gravel, sand and mud fractions.

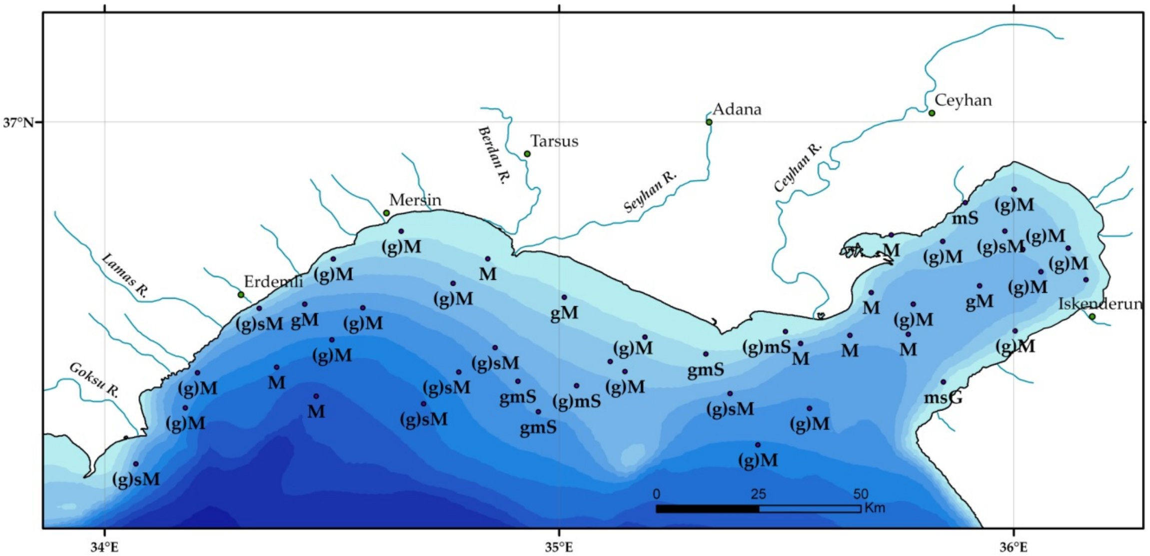


Figure 3. 1 Textural classification of the surface sediments in the study area

Table 3. 1 Grain size composition and textural classification of the surface sediments

Station No	Gravel (%)	Sand (%)				Silt (%)	Clay (%)	Mud (%)	Sediment Texture
		Coarse	**Medium**	**Fine**	**Total**				
1	4.2	10.3	8.2	14.2	32.7	29.6	33.5	63.0	(g)sM
2	0.1	0.2	0.2	1.9	2.3	42.5	55.1	97.7	(g)M
3	0.2	1.4	0.9	1.3	3.6	37.7	58.5	96.2	(g)M
4	0.0	1.1	2.5	37.4	41.0	43.7	15.3	59.0	(g)sM
5	0.0	0.2	0.2	0.7	1.1	33.8	65.1	98.9	M
6	0.0	0.5	1.0	3.4	4.9	35.7	59.4	95.2	M
7	10.1	11.9	7.4	7.3	26.6	25.3	38.0	63.3	gM
8	0.2	0.1	0.2	0.9	1.2	38.6	60.0	98.6	(g)M
9	1.2	0.8	0.6	5.0	6.4	49.8	42.6	92.4	(g)M
10	0.0	0.1	0.2	0.8	1.1	36.9	62.0	98.9	(g)M
11	0.4	0.5	0.6	6.0	7.1	58.2	34.3	92.4	(g)M
12	2.0	0.6	0.2	0.4	1.2	38.9	57.9	96.7	(g)M
13	0.0	0.2	0.1	0.6	0.9	61.8	37.3	99.0	M
14	0.0	0.4	0.5	10.0	10.9	33.6	55.5	89.1	(g)sM
15	0.0	0.4	0.8	9.0	10.2	35.2	54.6	89.7	(g)sM
16	3.9	12.5	6.5	16.0	35.0	29.2	31.9	61.1	(g)sM
17	6.2	1.8	1.1	4.1	7.0	58.2	28.6	86.9	gM
18	5.9	25.8	11.6	17.8	55.2	16.6	22.3	39.0	gmS
19	6.6	40.1	20.6	19.3	80.0	4.6	8.8	13.5	gmS
20	2.2	7.0	19.7	41.5	68.2	23.8	5.8	29.5	(g)mS
21	0.1	0.3	0.2	1.2	1.7	58.6	39.6	98.2	(g)M
22	0.2	0.5	0.4	1.6	2.5	53.1	44.2	97.4	(g)M
23	1.5	4.6	3.7	23.7	32.0	52.2	14.3	66.5	(g)sM
24	22.8	15.8	10.2	17.8	43.8	25.4	8.0	33.3	gmS
25	3.3	6.4	3.5	5.3	15.2	37.3	44.2	81.5	(g)sM
26	0.0	0.2	0.2	1.4	1.8	41.6	56.6	98.2	(g)M
27	0.5	0.6	0.5	1.5	2.6	37.4	59.5	97.0	(g)M
28	0.0	0.0	0.2	0.5	0.7	57.9	41.4	99.3	M
29	0.1	2.1	0.5	61.1	63.7	28.8	7.4	36.3	(g)mS
30	0.0	0.0	0.0	0.0	0.0	42.9	57.1	99.9	M
31	0.0	0.0	0.1	0.6	0.7	56.2	43.1	99.2	M
32	0.0	0.1	0.1	0.2	0.4	77.8	21.8	99.6	(g)M
33	0.0	0.1	0.1	0.3	0.5	29.9	69.6	99.4	M
34	34.6	15.8	8.4	11.7	35.9	12.5	17.0	29.6	msG
35	0.0	0.2	0.1	5.2	5.5	66.3	28.2	94.5	M
36	0.1	0.2	0.1	0.4	0.7	50.0	49.2	99.2	(g)M
37	6.3	2.2	0.9	2.1	5.2	28.8	59.7	88.5	gM
38	0.1	0.5	0.6	5.0	6.1	59.9	33.9	93.7	(g)M
39	0.0	0.3	0.6	62.0	62.9	27.4	9.7	37.1	mS
40	1.9	4.0	3.9	7.3	15.2	28.0	54.9	82.8	(g)sM
41	0.1	0.3	0.2	0.6	1.1	98.0	0.8	98.9	(g)M
42	0.1	0.3	0.3	1.0	1.6	94.0	4.3	98.4	(g)M
43	0.1	0.3	0.2	0.6	1.1	46.1	52.7	98.8	(g)M
44	0.3	0.7	0.8	4.6	6.1	41.6	52.0	93.6	(g)M
45	0.2	0.4	0.2	0.6	1.2	55.3	43.3	98.5	(g)M

The distribution of grain size ranges between 0% to 35% gravel, <1% to 80% sand, 4% to 98% silt and 1% to 70% clay along the study area (Table 3.1). Figure 3.2 shows the grain-size distribution for each station.

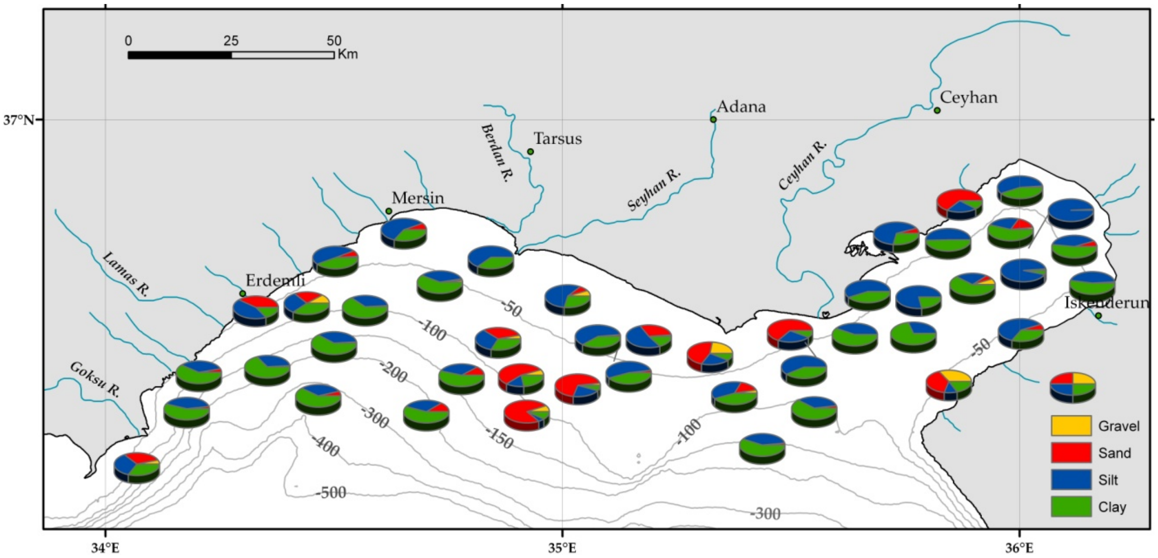


Figure 3. 2 Pie charts showing the grain-size distribution for each station

The gravel contents are mostly less than 1% in the study area. High gravel percentages are found at two stations which are mainly composed of biogenic constituents: In the southwestern corner of Iskenderun Bay (35%) and in the western part of the Ceyhan Delta (23%) (Figure 3.3).

The surface sediments are dominantly composed of sand fraction (55% - 80%) in the southeastern part of Mersin Bay between 50 and 100 m. contours (Figure 3.4). The sediments in this area contain high amounts of remains of biogenic organisms. Furthermore, three other distinct sandy patches are found among the study area: an ephemeral deltaic area in the northern corner of İskenderun

Bay (63%), Erdemli coastal sediments (41%) and Karataş Cape coastal sediments (64%). The major part of the sand fractions of the surface sediments consist of fine sand fractions (125 – 250 microns) at most stations (Figure 3.5). However, the sediments with high $CaCO_3$ contents include high percentages of coarse and medium sand fractions (250 – 2000 microns)

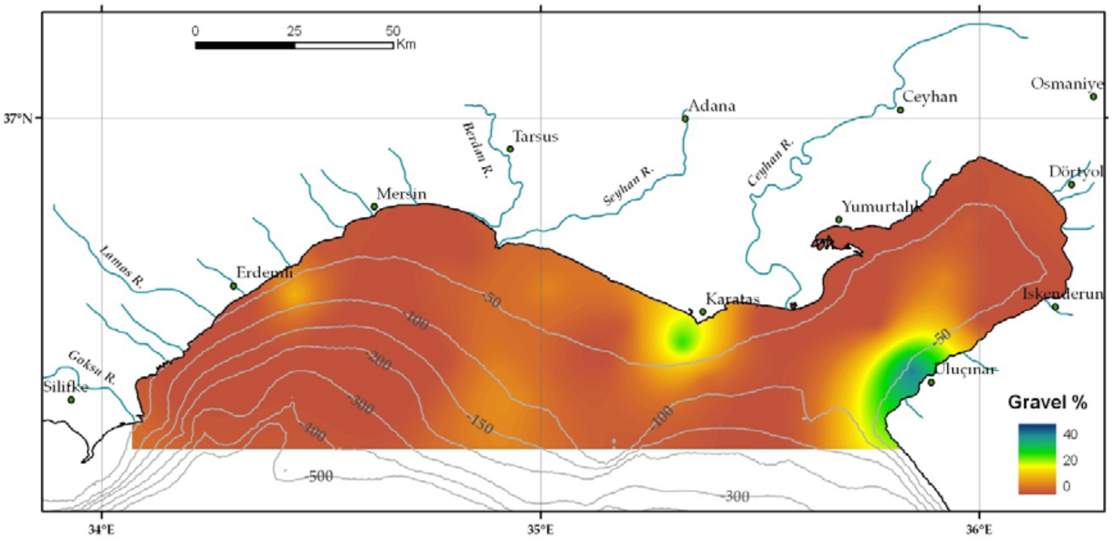


Figure 3. 3 Spatial distribution of the gravel fractions of the surface sediments

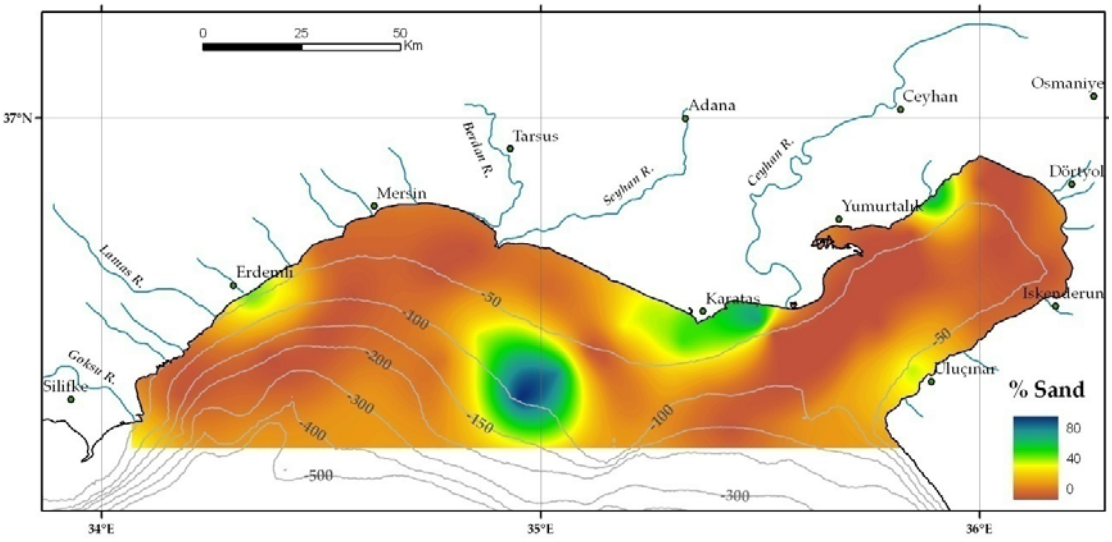


Figure 3. 4 Spatial distribution of sand fractions of the surface sediments

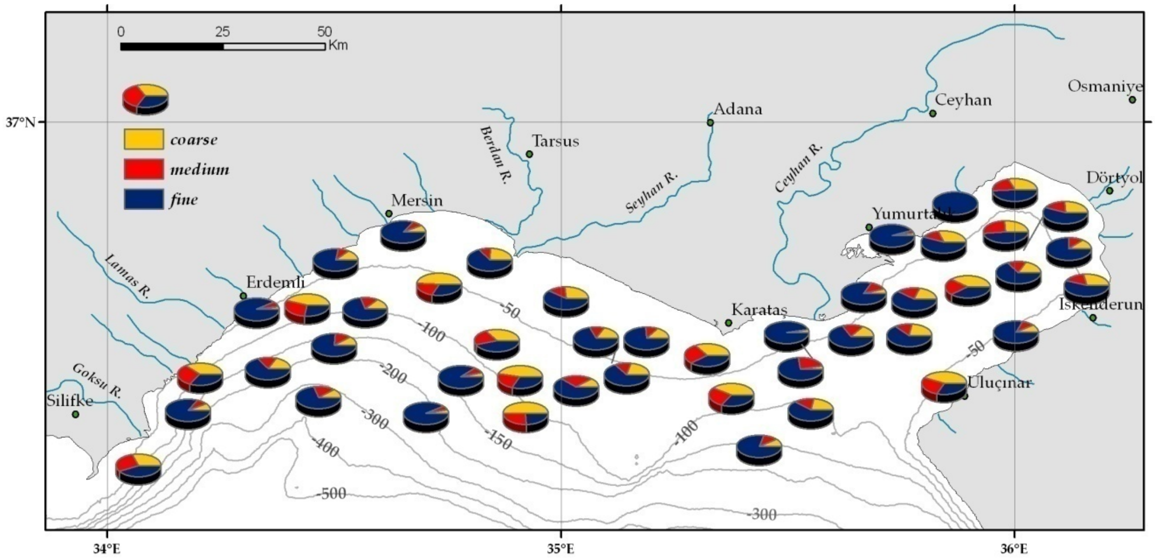


Figure 3. 5 Pie chart showing the coarse, medium and fine sand percentages in total sand fractions

High silt percentages (50% – 62%) are found between 0 – 50 m bathymetric contours along the northeastern coasts of Mersin Bay from Mersin City to Karataş Cape (Figure 3.6). Towards the western-southwestern part of the bay, silt contents decrease with respect to the increase of the clay content. The highest silt percentages are observed in southeastern İskenderun Bay (94% – 98%). There is an apparent decrease in silt contents towards southeastern corner of the gulf which is represented by coarse-grained sediments.

Except the biogenic sandy patch in the southeastern corner of Mersin Bay, the clay contents of the studied sediments (1% - 70%) are generally low in near-shore areas and high in offshore (Figure 3.7).

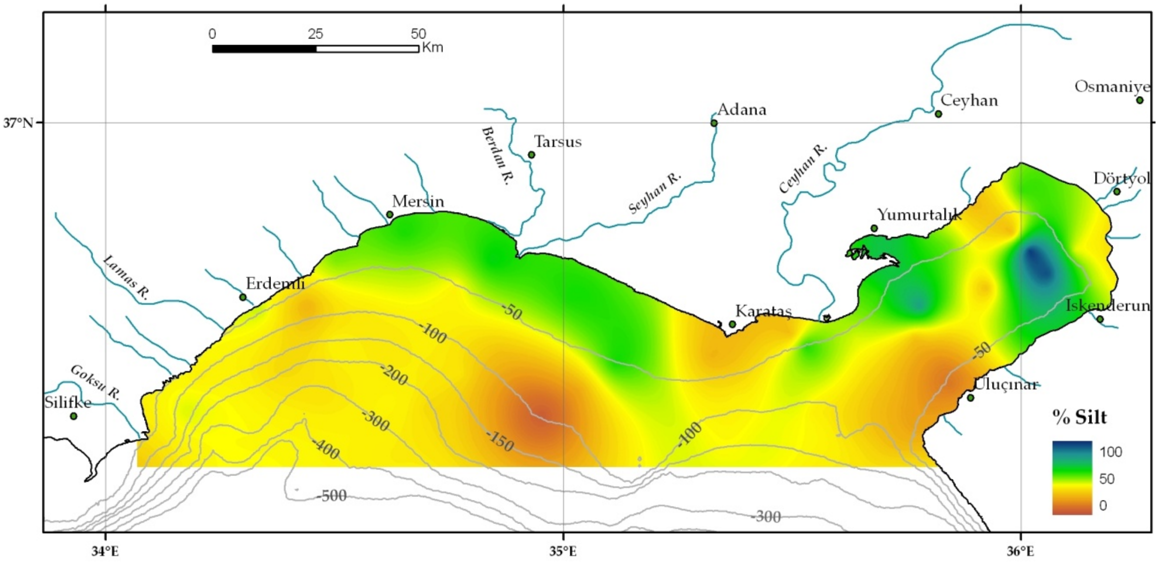


Figure 3. 6 Spatial distribution of silt fractions of the surface sediments

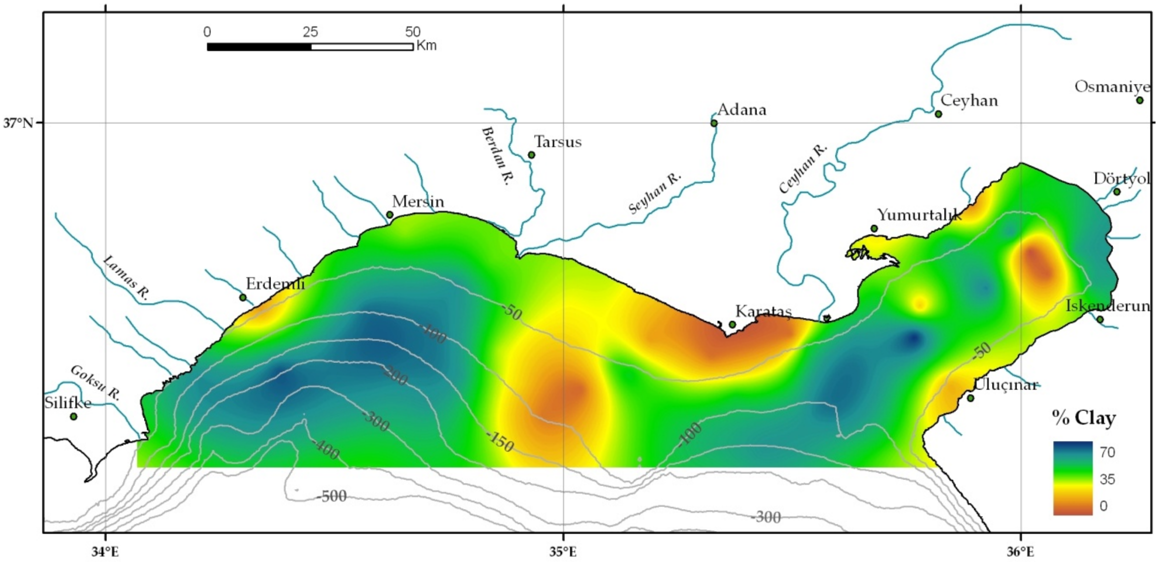


Figure 3. 7 Spatial distribution of clay fractions of the surface sediments

3.2. CHEMISTRY OF THE SURFACE SEDIMENTS

3.2.1. $CaCO_3$ Contents of the Surface Sediments

The total calcium carbonate ($CaCO_3$) content of the surface sediments in the region varies from 21% to 75% (Table 3.2; Figure 3.8) with the average of 34%. The major part of the sediments, especially muddy sediments, contains 20% to 30% $CaCO_3$. The highest carbonate percentages are found in the southern corner of İskenderun Bay and in the southeastern part of Mersin Bay due to the high organism shell accumulation (Figure 3.8). In addition, there is an apparent carbonate enrichment in the coastal sediments off Karataş Cape.

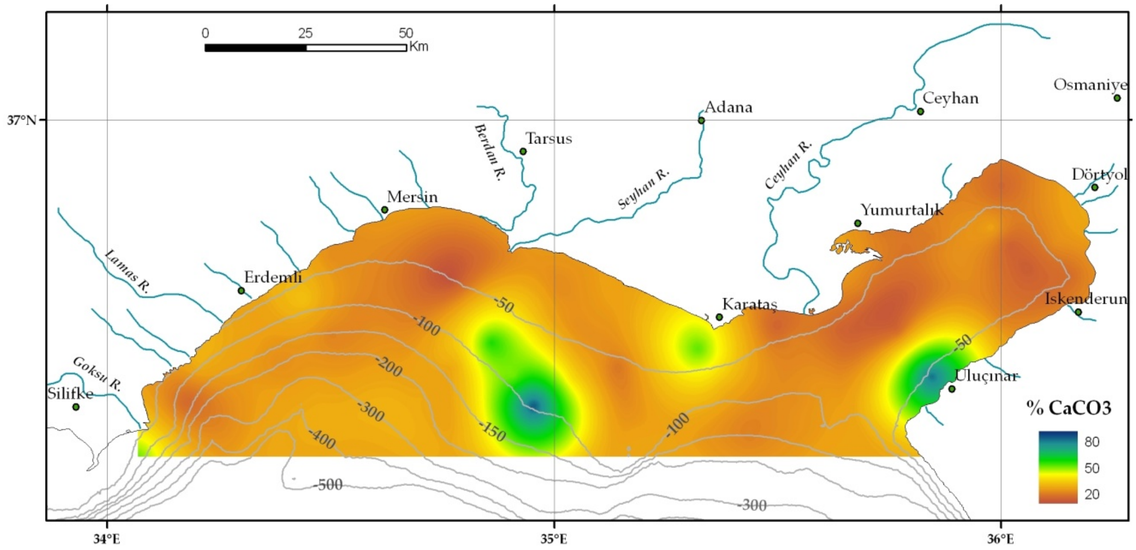


Figure 3. 8 CaCO3 contents of the surface sediments in the study area

Table 3. 2 Calcium carbonate and organic carbon contents of the surface sediments

Station	$CaCO_3$ (%)	Organic C (%)
1	50.6	0.32
2	24.0	0.29
3	33.3	0.41
4	31.9	0.12
5	29.4	0.01
6	32.5	0.43
7	36.2	1.51
8	28.1	0.49
9	29.1	0.68
10	28.2	0.29
11	29.7	3.55
12	19.4	0.05
13	25.3	2.14
14	33.1	0.40
15	33.7	n/a
16	54.5	0.73
17	29.3	12.03
18	49.6	0.05
19	75.7	n/a
20	40.9	2.99
21	29.7	1.49
22	26.5	6.56
23	34.0	1.06
24	51.0	n/a
25	34.6	0.43
26	28.0	0.08
27	29.5	0.58
28	27.7	0.23
29	23.0	10.28
30	23.1	3.48
31	27.7	0.24
32	21.7	0.98
33	23.6	0.03
34	73.0	0.14
35	26.9	0.86
36	27.0	0.72
37	29.0	0.65
38	29.3	0.36
39	28.1	0.86
40	31.7	1.13
41	22.7	0.66
42	22.1	0.93
43	25.2	0.69
44	29.2	0.29
45	23.4	1.41

3.2.2. Organic Carbon Contents of the Surface Sediments

Total organic carbon contents of the surface sediments of the northeastern Mediterranean vary regionally from 0.01% to 12% with the average of 1.4% (Table 3.2; Figure 3.9). The highest organic carbon concentrations (3.55% - 12.03%) were found along the eastern coasts of Mersin Bay, extending from Mersin City to the Ceyhan River Delta. Especially, sediments in the east of the Seyhan River (12.03%) and the deltaic sediments accumulated in the west of Ceyhan River (10.28%) contain high percentages of organic carbon.

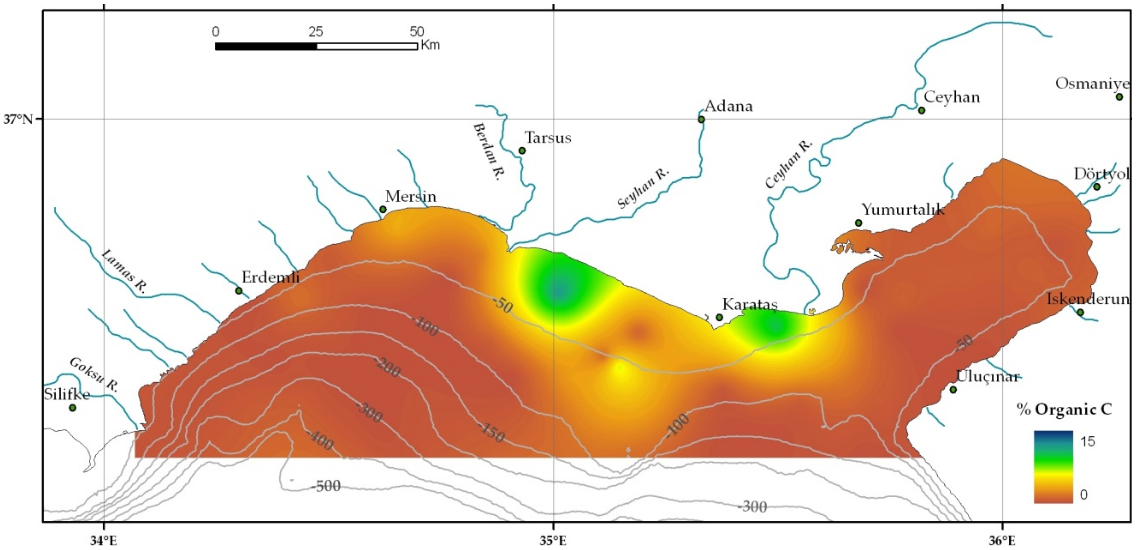


Figure 3. 9 Organic carbon contents of the surface sediments in the study area

3.2.3. Heavy Metal Contents of the Surface Sediments

Results obtained from the heavy metal analyses of the sediments are given in Table 3.3 and Figure 3.10 – 3.16.

Table 3. 3 Heavy metal concentrations in the sediments

Stations	**Fe (%)**	**Co (ppm)**	**Mn (ppm)**	**Ni (ppm)**	**Zn (ppm)**	**Cu (ppm)**	**Cr (ppm)**
1	2.16	11.21	411.94	124.65	50.76	19.33	70.72
2	3.50	17.07	552.03	235.60	73.57	28.52	217.56
3	3.37	17.47	587.15	237.02	69.42	25.79	247.44
4	3.02	9.25	682.67	499.57	34.54	20.06	227.70
5	4.76	3.79	708.00	265.23	55.79	32.64	245.98
6	4.39	4.03	1517.70	223.66	45.63	34.32	198.89
7	2.97	2.89	574.59	394.85	67.86	29.03	56.25
8	3.13	1.19	648.04	339.93	77.96	29.45	54.81
9	3.92	4.63	628.21	452.34	46.51	27.62	252.73
10	4.05	2.74	647.69	218.98	57.44	27.27	169.26
11	3.62	10.18	827.74	327.24	81.78	29.84	131.31
12	3.37	8.73	898.15	344.75	65.56	26.15	124.07
13	2.92	2.86	513.90	234.46	46.58	30.11	171.93
14	3.36	4.54	849.11	201.91	48.74	29.06	114.44
15	2.62	0.24	584.93	166.02	76.56	26.69	174.54
16	1.95	3.95	524.34	190.99	65.67	19.57	79.51
17	2.75	4.70	605.79	258.97	58.23	25.26	112.52
18	2.02	0.41	535.56	32.61	40.52	21.39	144.75
19	0.46	0.75	562.98	48.16	24.96	9.00	25.74
20	1.98	1.14	565.43	91.22	48.02	13.48	84.43
21	2.91	4.87	688.97	223.22	80.12	24.11	157.91
22	2.75	2.67	627.39	191.86	69.36	28.53	238.37
23	2.15	4.31	652.07	173.92	38.77	18.11	94.18
24	1.85	1.86	576.97	79.43	74.79	13.82	91.76
25	3.18	3.91	696.52	225.55	51.16	29.93	196.86
26	3.46	4.75	716.03	222.42	56.48	31.61	163.36
27	2.92	1.59	641.41	434.94	49.09	32.94	216.99
28	3.17	1.76	677.64	310.69	56.38	28.75	165.45
29	2.48	1.58	729.07	104.09	286.89	13.47	127.04
30	3.36	2.29	628.50	145.32	88.49	35.89	137.73
31	3.17	1.80	639.29	200.16	68.97	29.32	133.47
32	3.19	2.69	768.15	203.96	114.45	37.48	214.07
33	3.23	2.29	752.74	396.29	66.81	35.13	155.35
34	1.22	2.05	443.97	506.91	23.08	17.81	138.45
35	2.89	4.01	675.77	138.03	50.87	29.22	107.88
36	2.96	1.71	671.75	315.38	52.97	27.66	167.38
37	3.22	2.33	750.16	373.26	63.28	27.49	163.29
38	2.93	2.50	625.62	563.64	59.24	22.63	252.51
39	2.17	4.94	757.42	116.74	33.8	18.69	97.70
40	2.69	6.84	748.93	294.79	61.75	31.37	161.68
41	3.34	5.97	720.61	343.25	59.56	30.52	180.05
42	3.41	6.99	696.20	378.63	67.49	32.57	175.31
43	3.10	9.22	660.87	525.80	55.92	32.41	200.59
44	3.13	6.65	711.56	433.20	54.11	28.39	188.22
45	2.73	6.57	700.55	546.52	52.32	26.59	247.21

3.2.3.1. Iron (Fe)

The total Fe concentrations in the study area are ranging between 0.45% to 4.76% with the average value of 2.9% (Table 3.3; Figure 3.10). Low Fe values (0.46% - 1.85%) are measured in the coarse-grained patches of the studied area. The western Mersin Bay sediments contain the highest Fe values (>4%) along the study area.

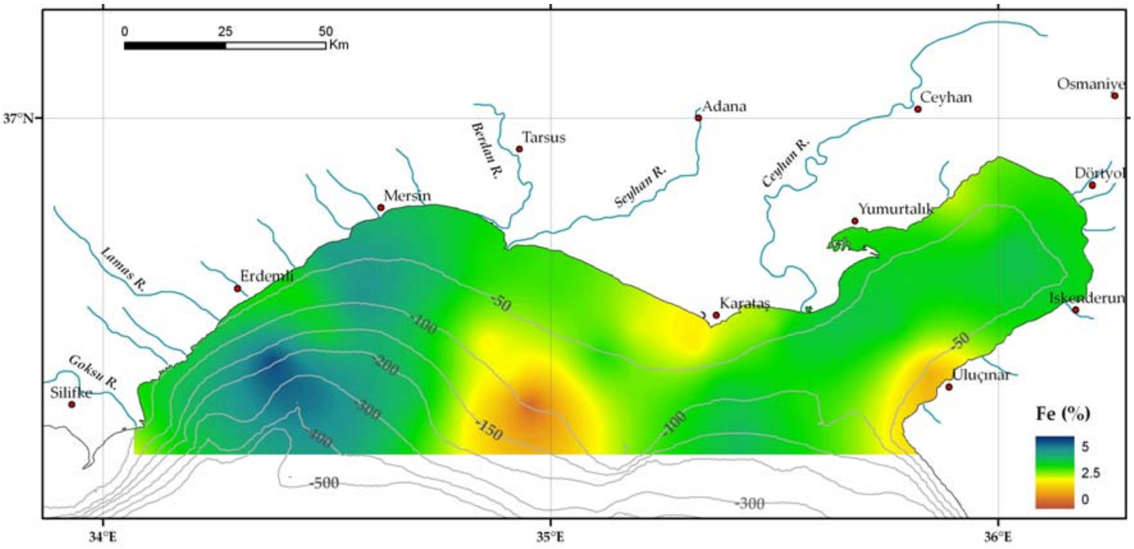


Figure 3. 10 Spatial distribution of Fe concentrations of the surface sediments

3.2.3.2. Manganese (Mn)

The total Mn concentrations of the surface sediments in the study area are ranging between 411 ppm and 1517 ppm with an average value of 675 ppm (Table 3.3; Figure 3.11). The overall high Mn concentrations were found in an offshore station of western Mersin Bay and coastal sediments off Mersin City. The Mn concentrations of the sediments accumulated in other parts of the study area generally ranged from 600 ppm to 800 ppm.

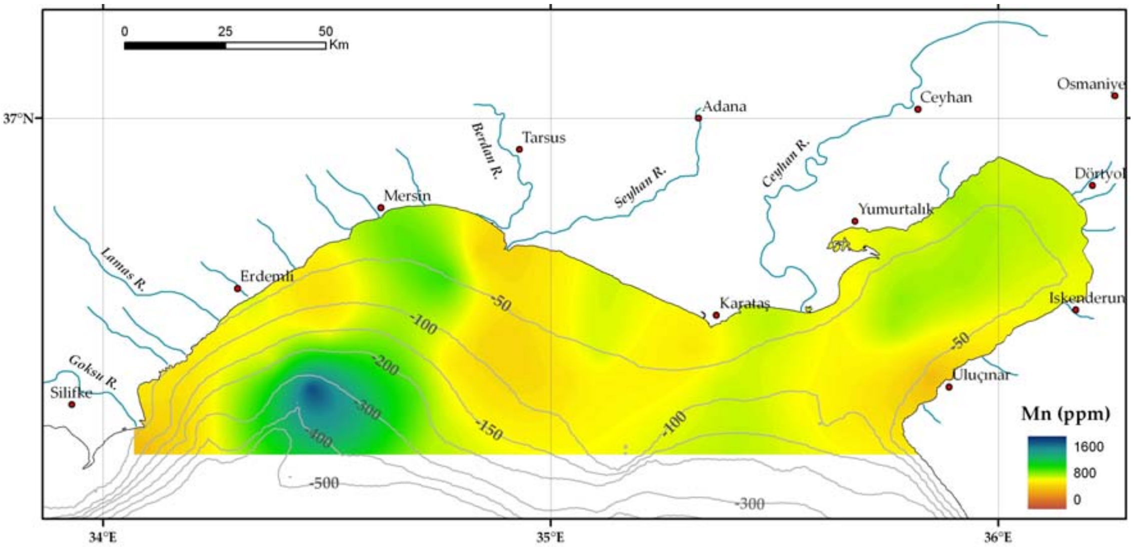


Figure 3. 11 Spatial distribution of Mn concentrations of the surface sediments

3.2.3.3. Chromium (Cr)

The concentration of chromium in the surface sediments varies from 25 ppm to 252 ppm with the average of 157 ppm (Table 3.3; Figure 3.12). There is a distinct Cr enrichment in the coastal sediments from the east of Göksu River Delta to Mersin City. Similarly, the coastal sediments of İskenderun Bay, from the southern corner to the northeastern corner contain high Cr concentrations. On the other hand, Cr concentrations of the coarse-grained sediment patches of the studied are less than 100 ppm.

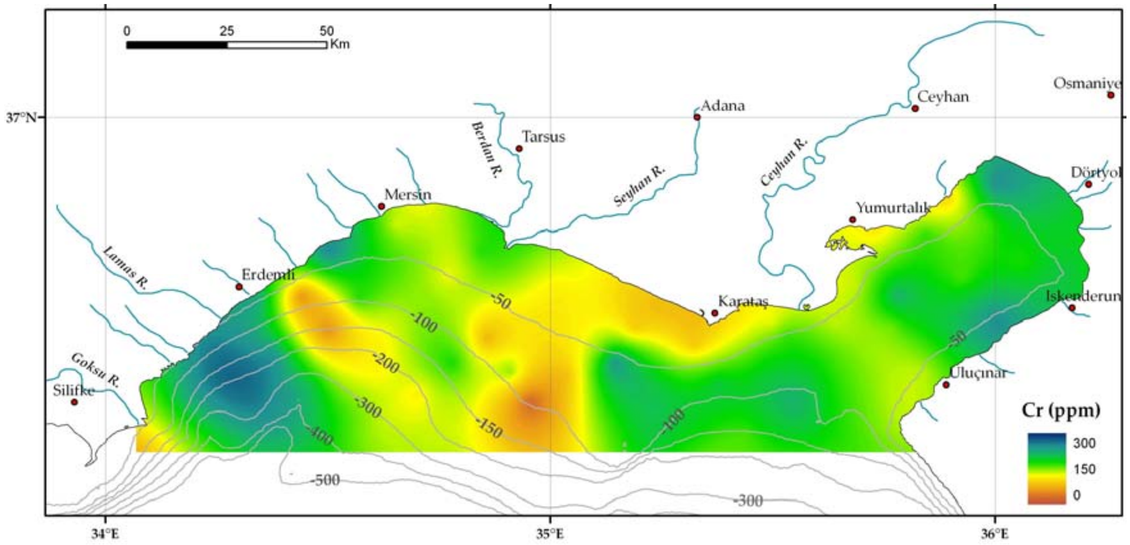


Figure 3. 12 Spatial distribution of Cr concentrations of the surface sediments

3.2.3.4. Nickel (Ni)

The concentration of nickel in the surface sediments varies from 32 ppm to 563 ppm with the average of 274 ppm (Table 3.3; Figure 3.13). The sediments of İskenderun Bay, from south to northeastern corner, include high Ni contents (463 ppm – 563 ppm). Additionally, Ni concentrations of the coastal sediments of the northwestern Mersin Bay, from Lamas to Mersin City, are slightly higher than other surface sediments of the studied area. Low Ni contents were found in the coarse-grained sediment patches of eastern Mersin Bay.

3.2.3.5. Copper (Cu)

The Cu concentrations in the surface sediments are similar to each other over the studied area and range between 9 ppm to 37 ppm with an average value 26 ppm (Table 3.3; Figure 3.14). The Cu concentrations in the majority of the sediments fall in the range 20 ppm - 30 ppm. The coarse-grained sediments of the study area include low Cu contents.

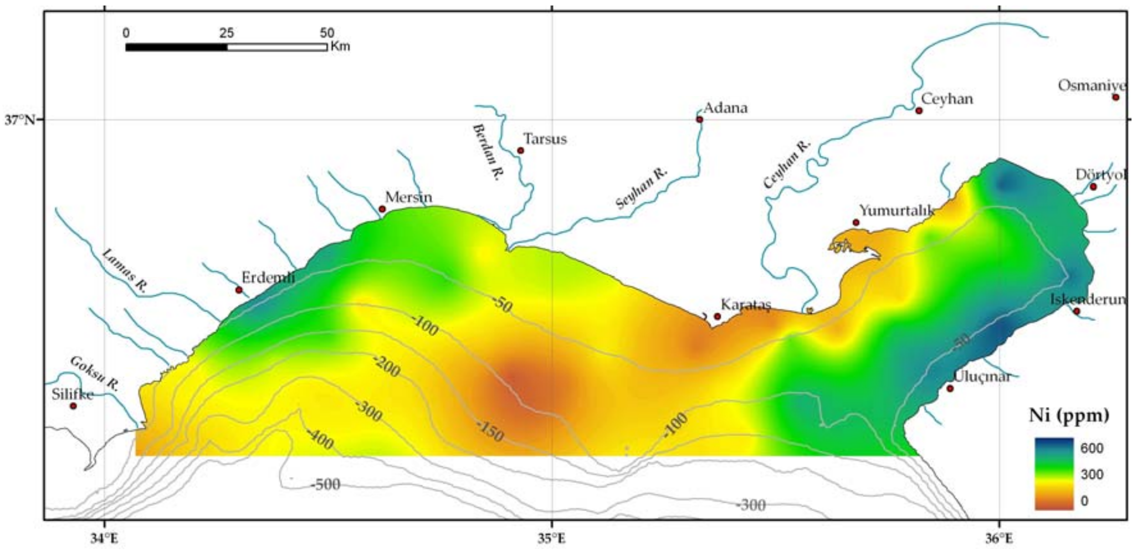


Figure 3. 13 Spatial distribution of Ni concentrations of the surface sediments

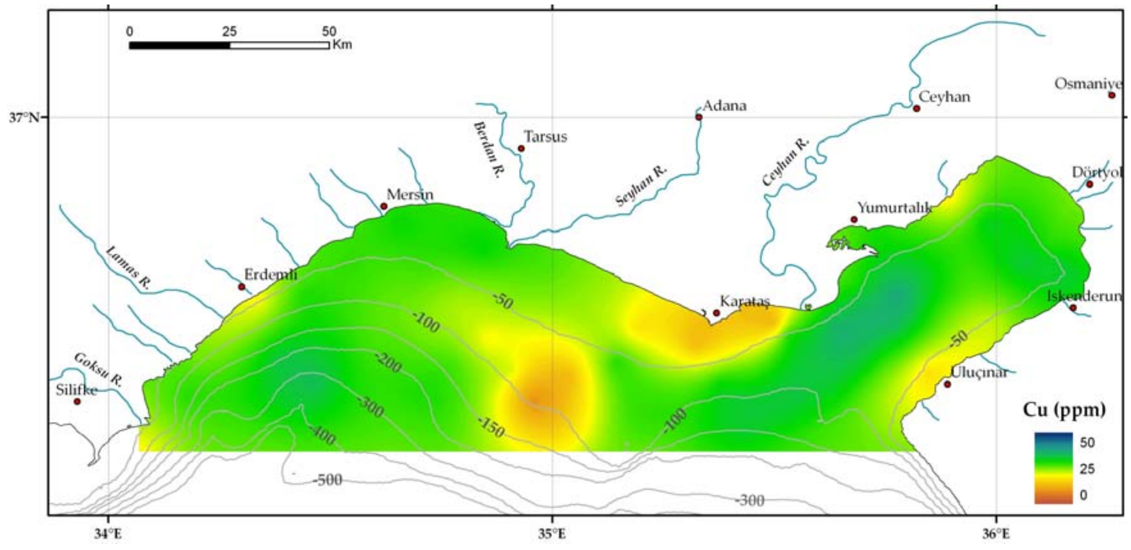


Figure 3. 14 Spatial distribution of Cu concentrations of the surface sediments

3.2.3.6. Cobalt (Co)

The Co concentrations of the surface sediments varied in the ranges between 1 ppm and 18 ppm with an average value of 5 ppm (Table 3.3; Figure 3.15). The majority of the sediments contain less than 10 ppm Co along the study area. High Co contents were found in the coastal sediments staying between Göksu River Delta and Lamas River Delta. These high values gradually decrease towards the eastern part of the study area.

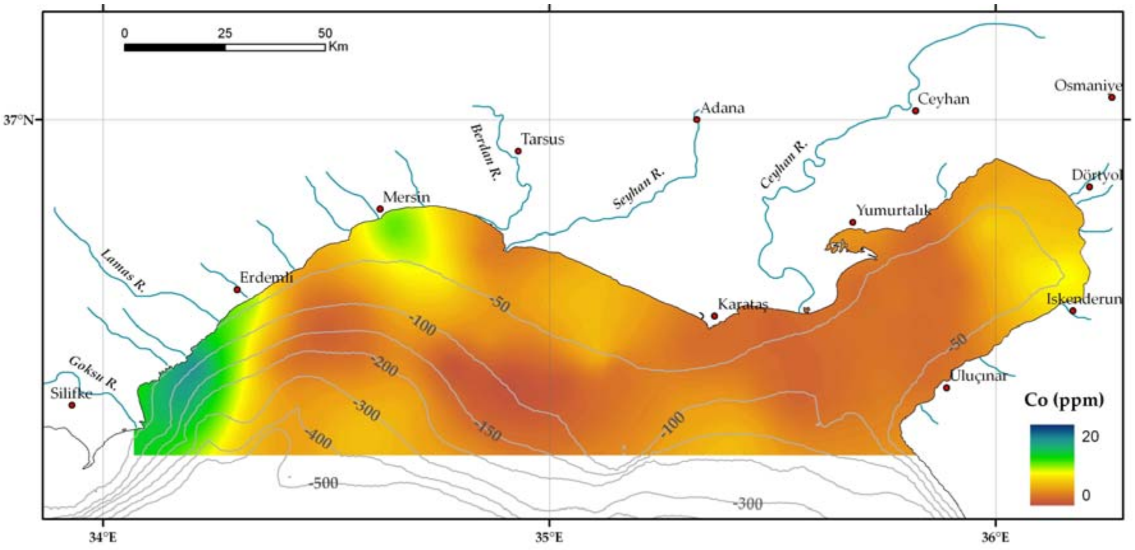


Figure 3. 15 Spatial distribution of Co concentrations of the surface sediments

3.2.3.7. Zinc (Zn)

The Zn concentrations of the surface sediments have similar values, except one sediment sampling station, along the study area and vary between 24 ppm and 286 ppm with an average value of 64 ppm (Table 3.3; Figure 3.16). There is an apparent Zn enrichment (286 ppm) in the western Ceyhan River Delta sediments.

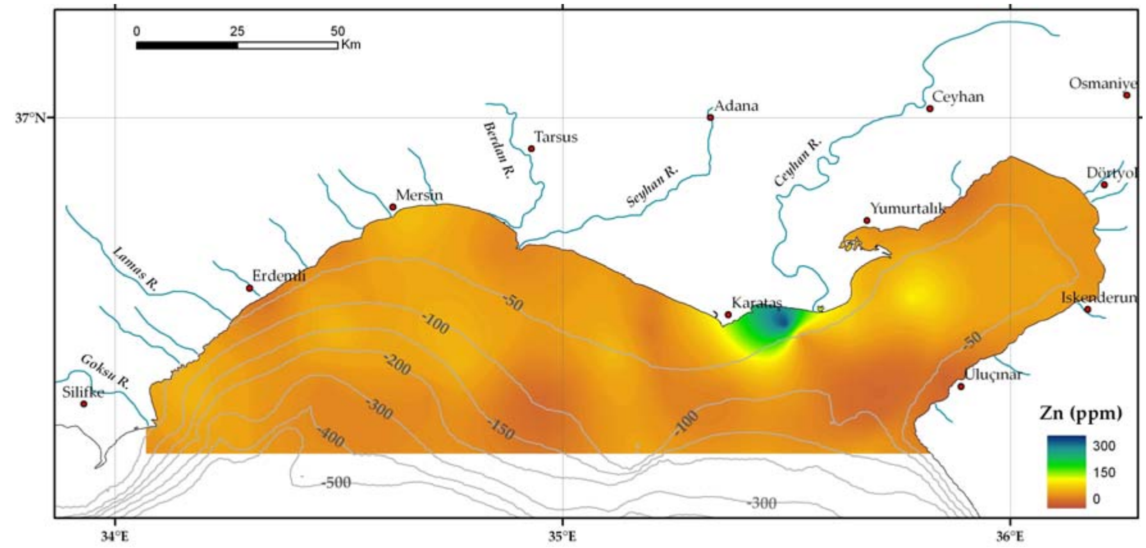


Figure 3. 16 Spatial distribution of Zn concentrations of the surface sediments

4. DISCUSSION

4.1. GRAIN SIZE DISTRIBUTION

The general grain size distribution pattern of the northeastern Mediterranean surface sediments mainly acquire a shape depending on the irregular bottom topography of the region and various terrigenic inputs carried by perennial rivers. Local eddies and coastal filaments occurring in the area are the other important factors controlling the grain size composition and distribution of the surface sediments.

Accumulated sediments show various sediment textures ranging from sandy gravel to mud due to the different depositional conditions mentioned above. The surface sediments examined in this study area are dependent strongly on the lithogenic and biogenic sources.

The recent sediments of the study area are dominantly characterized by their relatively high mud contents with varying silt and clay fractions (Figure 4.1). The coarse-grained sediment patches which are dominantly represented by sand size material are confined to regions with high benthic organism remains and terrigenic sources. At most stations, the total proportion of the gravel and sand fractions (coarse fractions) are less than 10% (Figure 4.1).

Terrigenic material inputs from rocky coasts and biogenic shell accumulation caused an increase in coarse-grained material percentages in the coastal sediments off the Karataş Cape, the Erdemli province, and the ephemeral rivers of the northeastern and southwestern İskenderun Bay. However, an unexpected coarse-grained sediment patch located between the 50 m and 150 m contour intervals of northeastern Mersin Bay. The high amount of relict coarse material in these sediments is explained with the presence of the ancient deltaic system in the area when the global sea level was about 125 m below today's sea level at the last glacial maximum about 20.000 years ago (Weedon, 1983).

Silt contents are generally ranged between 20% and 40%. However, there is a significant increase in silt contents of the northeastern coastal sediments of Mersin Bay (>50%). The dams on Göksu, Seyhan and Berdan Rivers act as a trap for coarse sediments. Especially, coarse-grained Seyhan River sediments are trapped at the end of the water dam and the finer sediments which escape from dams reach and accumulate at the delta systems of these rivers. The enrichment in silt contents of the sediments in the northeastern side of Karataş Cape may be the result of the movement of the suspended sediments with the swiping effect of the cyclonic coastal filaments of current system prevailing in this region.

The accumulation of clay fractions in surface sediments is generally controlled by the bottom topography and related hydrodynamic conditions. Clay fractions constitute less than 35% in the shelf sediments and as expected from the low sinking rate of clayey fraction, these values gradually increase from shelf to offshore. Besides, high sediment discharge in the coastal areas and the presence of biogenic shells are the other factors leading to decreased percentages of the clay fraction in the coastal sediments. The clay enrichment on the sloping face of offshore Ceyhan Delta reflects the typical delta-front, pro-delta and offshore deposition (Ergin *et al.*, 1998).

The surface sediments contain high amount of mud fraction (>90%) along the İskenderun Gulf. The presence of high biogenic material and fluvial input from rocky coasts cause dilution and decrease the mud percentages of the sediments at two patches. Similar to Mersin Bay sediments, the grain size distribution pattern of the İskenderun Bay sediments is under the effect of the several coastal rivers draining into the gulf and strictly coinciding with the complex circulation system suggested by İyiduvar (1986).

Table 4.1 shows the correlation coefficient values for the chemical and grain size parameters of the surface sediments measured in this study.

There is no significant relationship between the water depths and coarse-grained fractions of the sediments along the study area. However, the mud contents show a close relationship with the water depths of the sediment sampling stations (Figure 4.2).

Figure 4.3 shows the relationships among the various grain size fractions. Generally, there is no significant relationship between grain size parameters of the sediments. Coarse-grained (gravel and sand) and fine-grained (silt and clay) fractions are not in correlation in each other. On the other hand, sand contents of the sediments show inverse correlation (r: -0.97) with the mud (silt+clay) contents of the sediments.

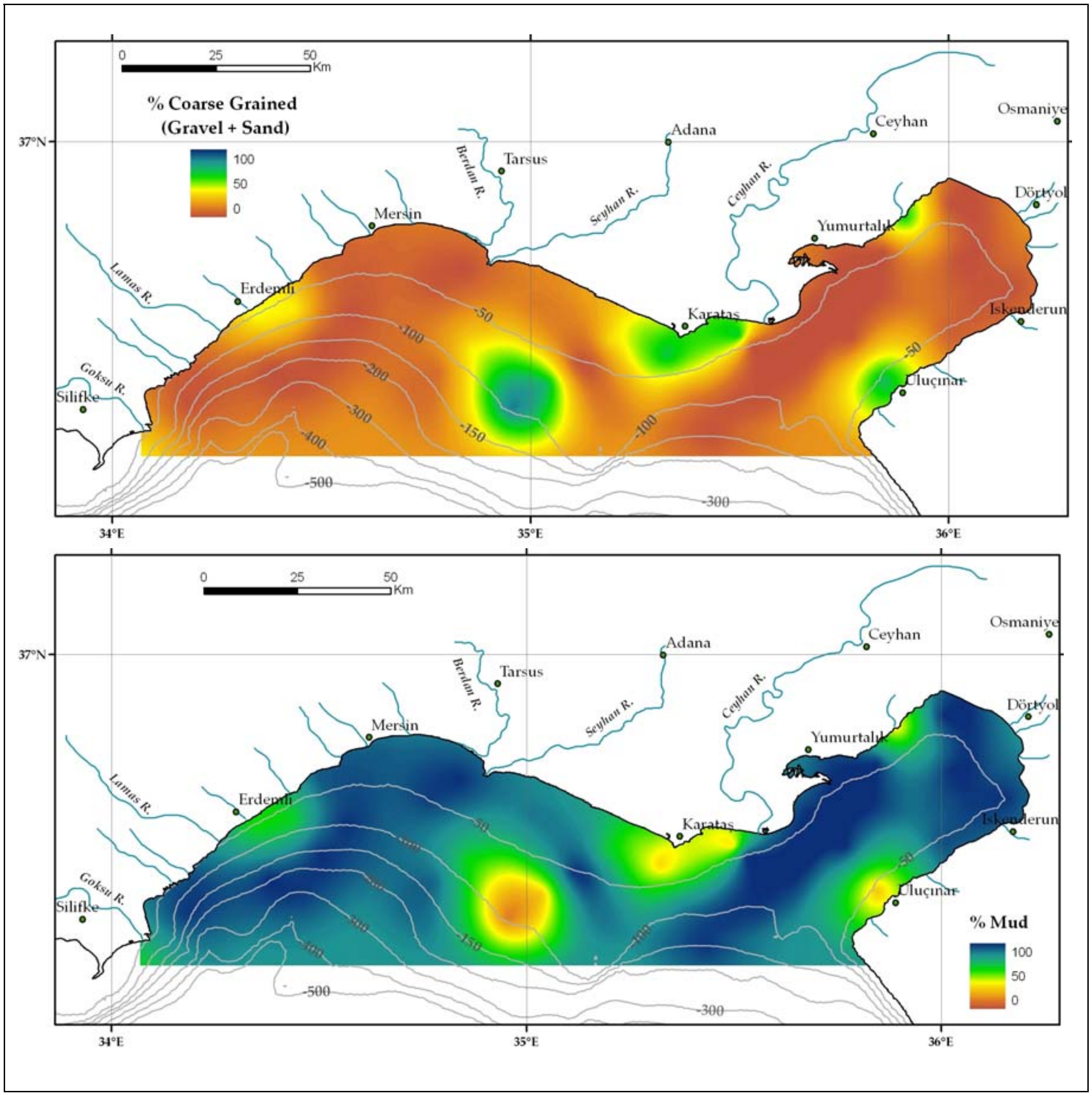


Figure 4. 1 Distribution of coarse fractions and mud in the recent sediments

Table 4. 1 Correlation coefficient values (r) for the chemical and grain size parameters of the surface sediments in the study area

	Gravel	Sand	Silt	Clay	Mud	CaCO3	Corg	Co	Mn	Ni	Zn	Fe	Cu	Cr
Gravel	1.00													
Sand	0.37	1.00												
Silt	-0.43	-0.59	1.00											
Clay	-0.32	-0.67	-0.16	1.00										
Mud	-0.57	-0.97	0.63	0.67	1.00									
CaCO3	0.71	0.66	-0.62	-0.36	-0.75	1.00								
Corg	-0.01	0.20	0.08	-0.28	-0.17	-0.16	1.00							
Co	-0.11	-0.24	0.44	-0.13	0.23	-0.34	0.07	1.00						
Mn	-0.32	-0.25	0.13	0.26	0.30	-0.37	-0.06	0.01	1.00					
Ni	0.04	-0.46	0.26	0.25	0.40	-0.26	-0.25	0.34	0.07	1.00				
Zn	-0.16	0.08	0.07	-0.10	-0.03	-0.31	0.56	-0.05	0.07	-0.20	1.00			
Fe	-0.53	-0.75	0.42	0.60	0.79	-0.74	-0.17	0.01	0.52	0.30	0.08	1.00		
Cu	-0.43	-0.86	0.48	0.63	0.86	-0.66	-0.23	0.25	0.38	0.34	-0.06	0.77	1.00	
Cr	-0.31	-0.54	0.38	0.34	0.55	-0.47	-0.15	0.16	0.19	0.50	-0.02	0.57	0.48	1.00

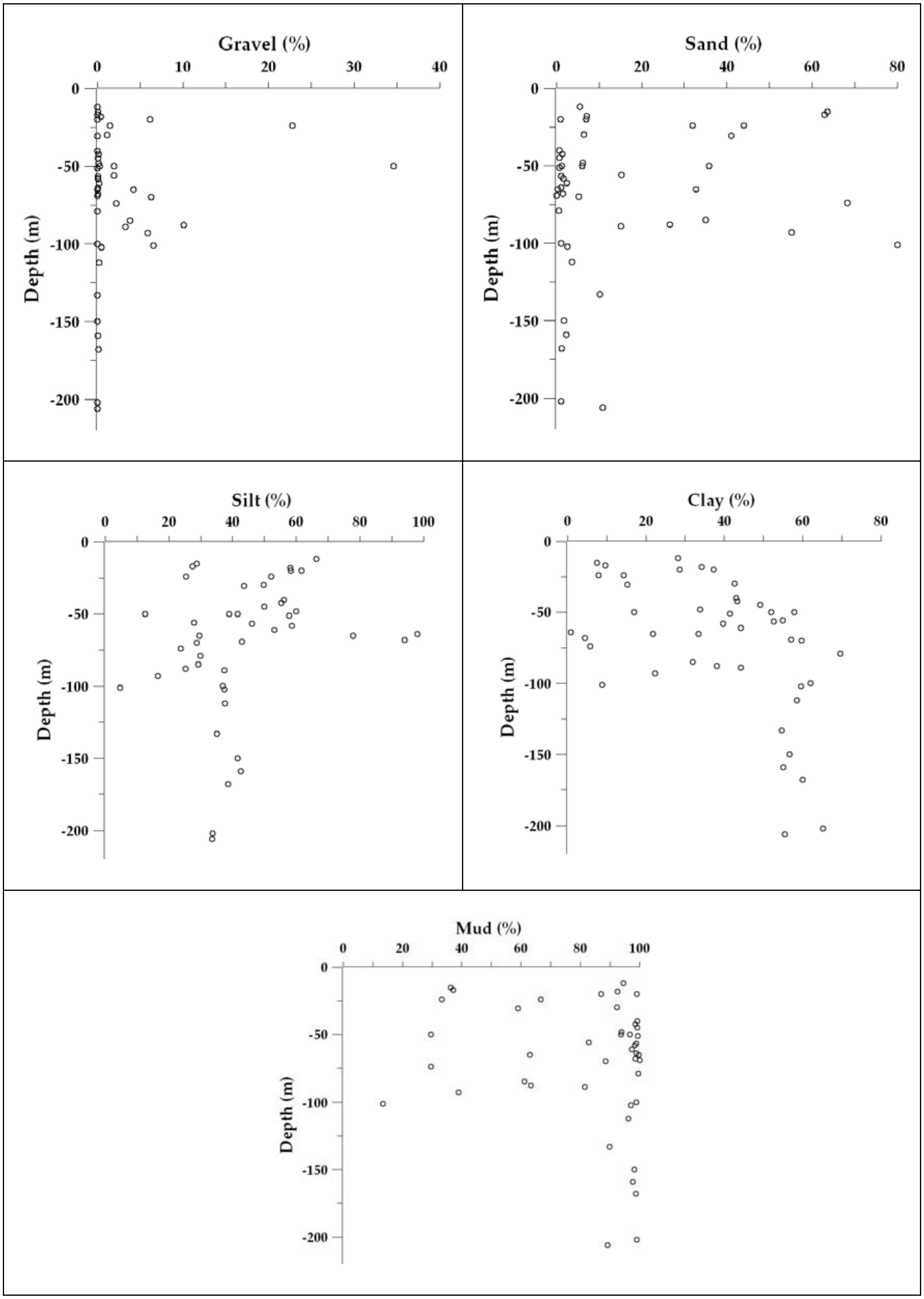
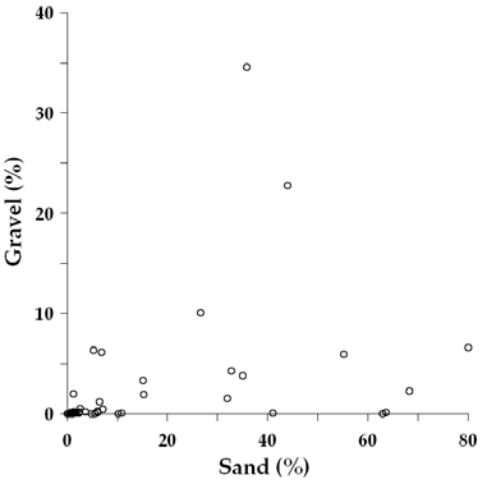
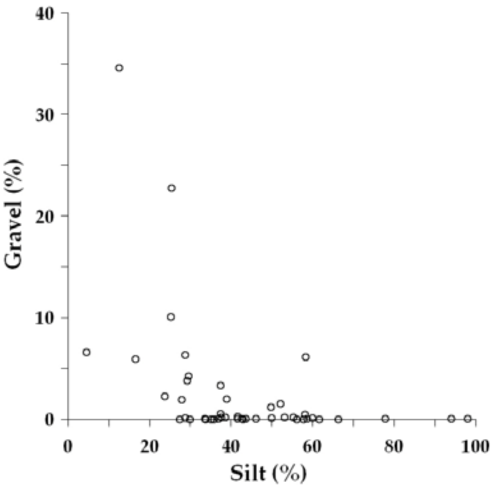
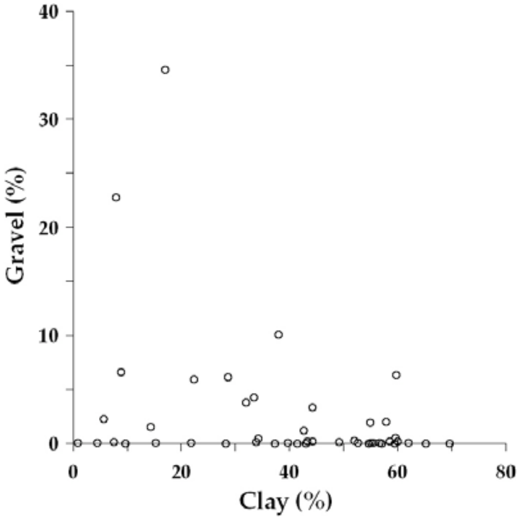
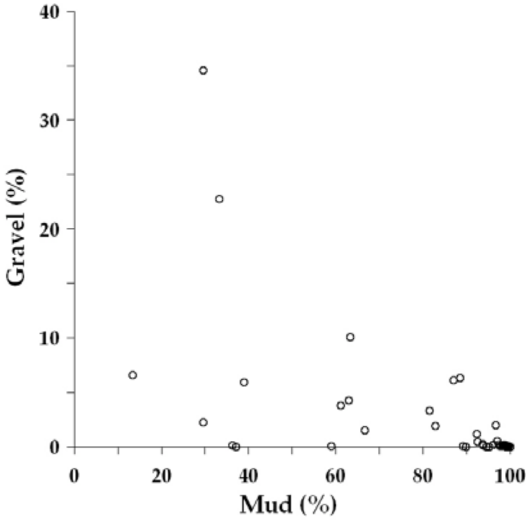


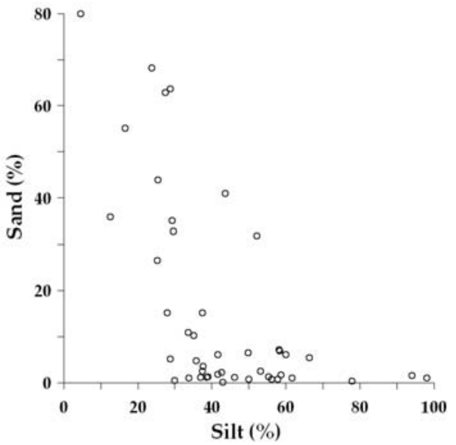
Figure 4. 2 Plots of the grain size fractions versus water depths of the sampling stations

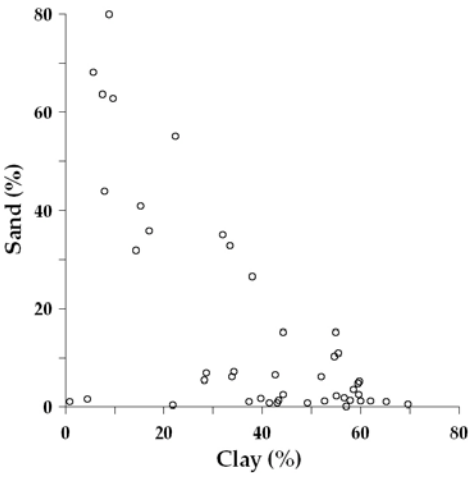

Gravel (%)
Sand (%)
0
10
20
30
40
0
20
40
60
80


Gravel (%)
Silt (%)
0
10
20
30
40
0
20
40
60
80
100


Gravel (%)
Clay (%)
0
10
20
30
40
0
20
40
60
80


Gravel (%)
Mud (%)
0
10
20
30
40
0
20
40
60
80
100


Sand (%)
Silt (%)
0
20
40
60
80
0
20
40
60
80
100


Sand (%)
Clay (%)
0
20
40
60
80
0
20
40
60
80

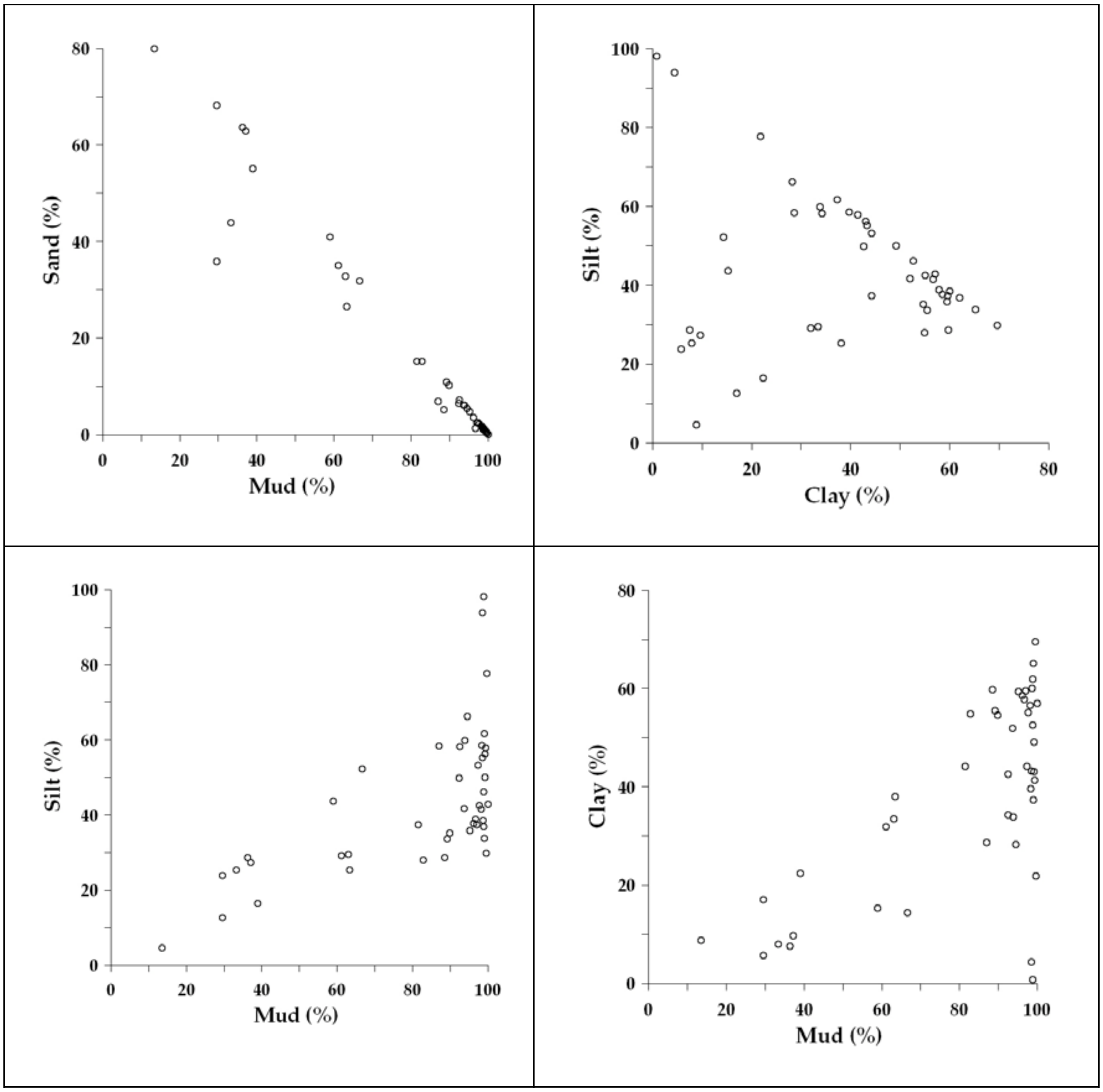


Figure 4. 3 Plot of the various grain size fractions versus each other

4.2. $CaCO_3$ DISTRIBUTION

$CaCO_3$ contents are generally less than 40% in the sediments of study area and show close relationships with the grain size fractions (Table 4.1; Figure 4.4; Figure 4.5). A significant and positive correlation obtained between $CaCO_3$ and gravel (r = 0.71) and sand (r = 0.66) contents suggests the predominance of carbonates in the coarse grained sediment fractions. However, the carbonate contents show inverse correlation with the fine-grained sediment (mud) fractions (r = -0.75).

General $CaCO_3$ distribution pattern of the surface sediments in Mersin Bay shows a close relationship with the swiping pattern of wind-generated coastal filaments suggested by Evans *et al*. (1995) and Ediger and Evans (2007). Low carbonate contents obtained in the Mersin Bay sediments are associated with the movement effect of these filaments on the siliciclastic materials carried by perennial and ephemeral rivers. High amounts of biogenic material accumulated in the coarse-grained sediment patches of the studied area causes the high carbonate concentrations in these sediments.

$CaCO_3$ contents in sediments of İskenderun Bay show a gradual increase in the southeastern entrance of the gulf. Microscopic studies on gravel and sand fractions of İskenderun Bay sediments carried by Kazan (1994) show that the higher carbonate contents of the sediments are related to the presence of the calcareous remains of biogenic organisms such as pelecypods, gastropods, foraminifera and bryzoa.

$CaCO_3$ concentrations obtained in Mersin Bay are generally similar to those found in İskenderun Bay. However, these values are slightly higher than those found in the fine-grained Mediterranean sediments (avg. 20%; Emelyanov and Shimkus, 1986)

There is no significant relationship between the water depths and $CaCO_3$ contents (Figure 4.6). This shows that $CaCO_3$ accumulation in surface sediments is related with the hydrodynamic conditions of the northeastern Mediterranean and biogenic production occurring in the area.

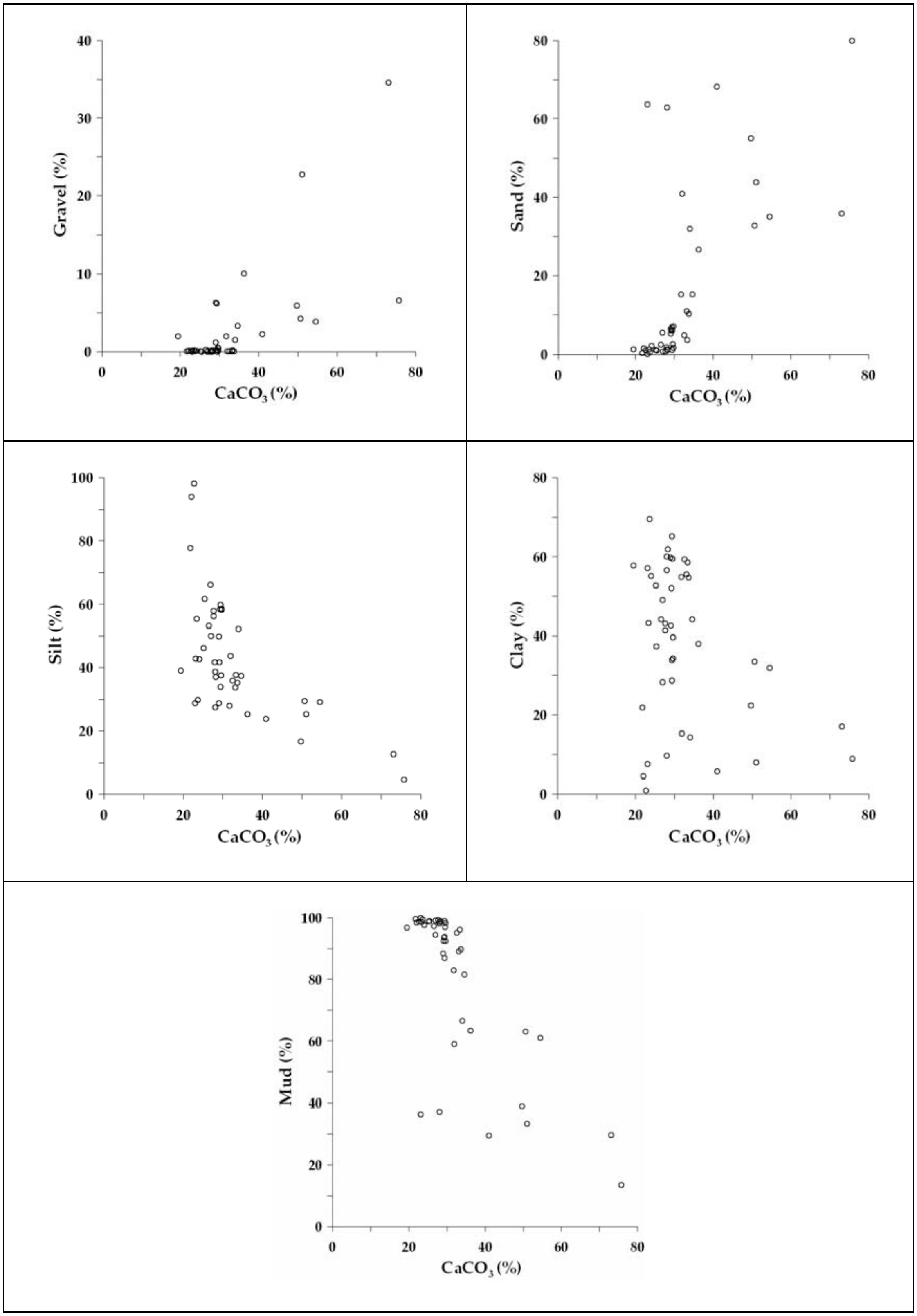


Figure 4. 4 Plot of the CaCO3 percentages versus various grain size fractions

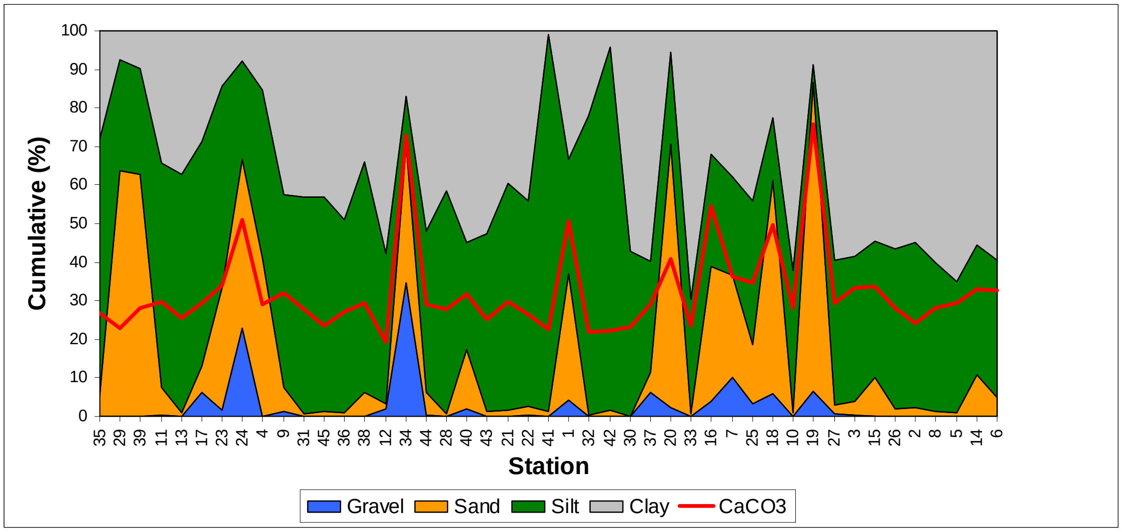


Figure 4. 5 Cumulative grain size and CaCO3 distribution of the surface sediments along the study area (from coast to offshore)

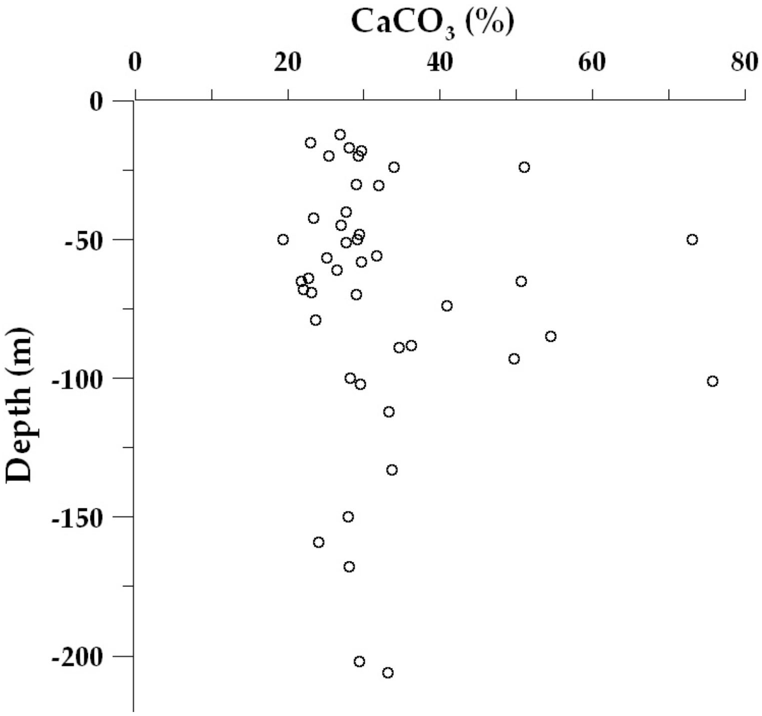


Figure 4. 6 Plots of the CaCO3 contents versus water depths of the sampling stations

4.3. ORGANIC CARBON DISTRIBUTION

The total organic carbon contents of the surface sediments in the study area vary regionally depending on the complex interaction of biogenic, terrigenic, hydrodynamic and anthropogenic factors (Ergin *et al*., 1996).

Hedges and Keil, 1995 suggested that the major part of the preserved organic matter in marine sediments occurs under oxygenated waters along continental margins (Figure 4.7). Similarly, the organic carbon enrichment in coastal waters of northeastern Mediterranean exists in the northeastern shelf of Mersin Bay, from Mersin City to the west of Ceyhan River Delta. The high organic carbon contents found in these sediments can be explained by the discharge of contaminated waters carried by Ceyhan, Seyhan and Berdan rivers which are affected by increasingly developing industrial and agricultural complexes. However, a busy international harbor located in Mersin Bay and sewage outfalls to this region are considerable factors in the local enrichment of the organic carbon percentages (Tuğrul *et al*., 2005).

The high organic carbon contents found in sediments can be explained by the discharge of contaminated waters carried by Ceyhan, Seyhan and Berdan rivers which are affected by increasingly developing industrial and agricultural complexes. However, a busy international harbor located in Mersin Bay and sewage outfalls to this region are considerable factors in the local enrichment of the organic carbon percentages (Tuğrul *et al*., 2005). The organic carbon concentrations of offshore Mersin Bay sediments are generally less than 1% at most stations. Similarly, due to the less fluvial input from land and the smooth bathymetry, the organic carbon contents of İskenderun Bay sediments are generally similar to each other and at low values.

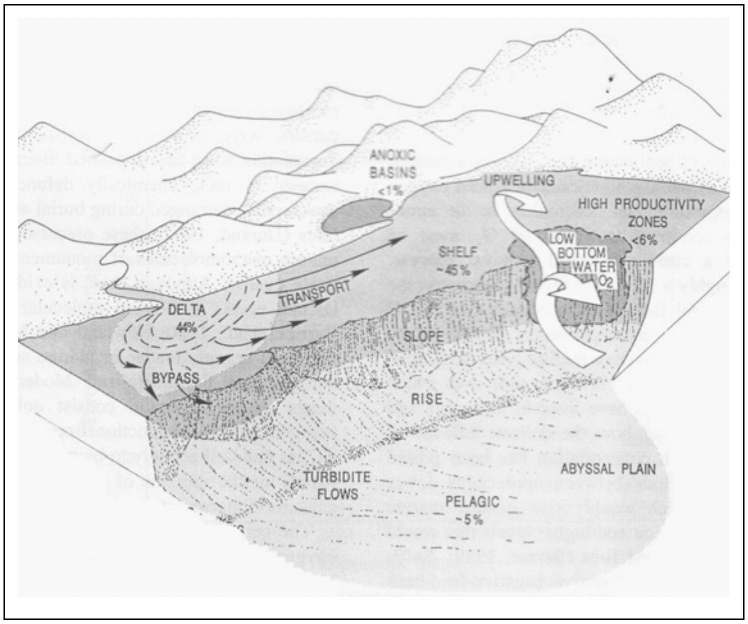


Figure 4. 7 Diagram showing the percentage of total organic matter burial occurring within the various sediment types (after Hedges and Keil, 1995)

Regional comparisons of the results indicate that the amounts of organic carbon measured in this study are generally similar to those reported by Emelyanov, 1972; Voutsinou-Taliadouri and Satsmadjis, 1982; Ergin *et al.*, 1988, 1990 (0.28-0.80%) in the eastern Mediterranean Sea. Accordingly, these low values are typical for the Mediterranean Sea and reflect the organic matter production in the Mediterranean Sea (Ergin *et al.*, 1996).

As seen in Figure 4.8, there is no significant relationship between the organic carbon and grain size fractions (r values for gravel: -0.01; sand: 0.2; silt: 0.08; clay: -0.28). Furthermore, no relationship is found between organic carbon and $CaCO_3$ (r: -0.16) contents of the sediments. However, depth versus organic carbon values show close relationship in the study area (Figure 4.9; Figure 4.10).

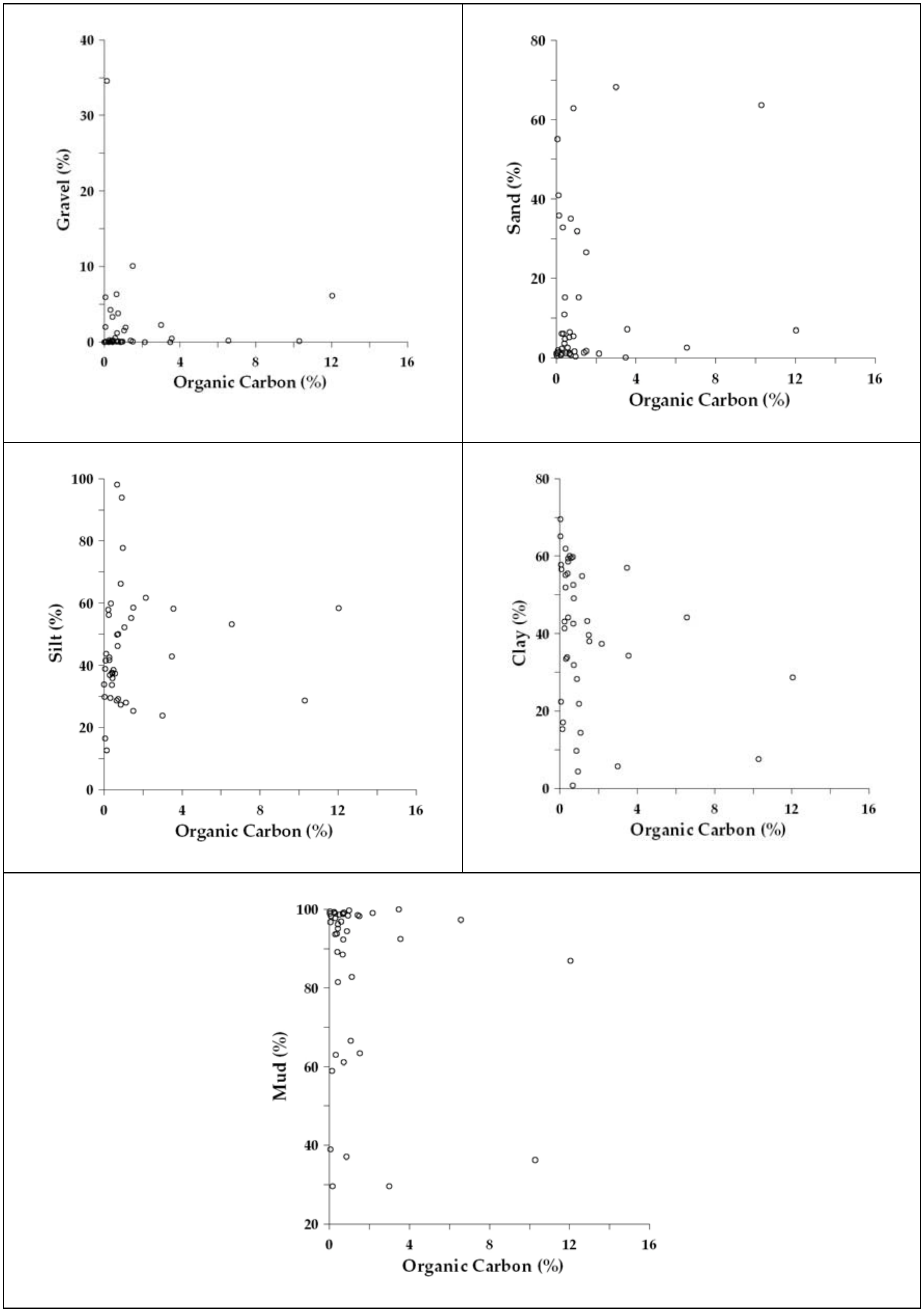


Figure 4. 8 Plot of the organic carbon percentages versus various grain size fractions

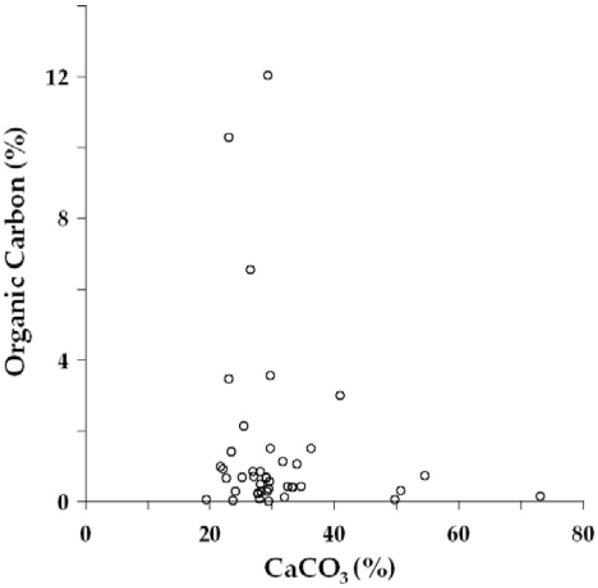


Figure 4. 9 Plot of the organic carbon percentages versus CaCO3 contents of the sediments

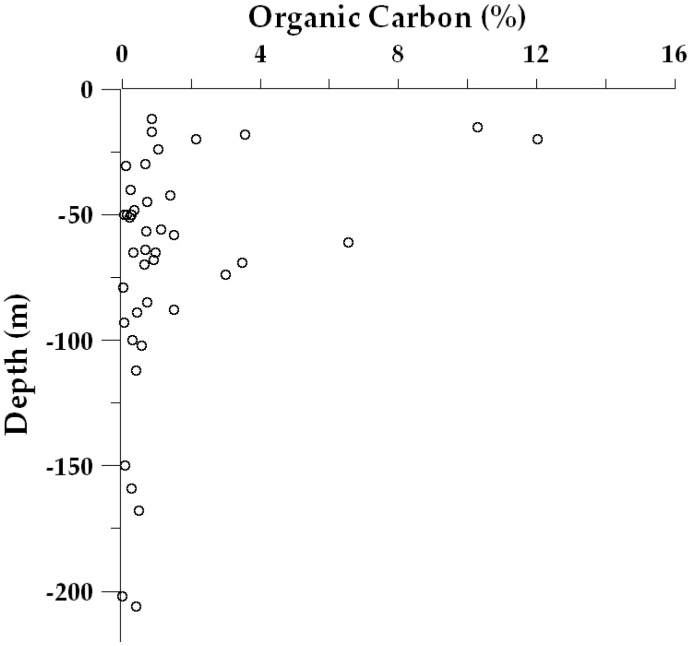


Figure 4. 10 Plots of the organic carbon contents versus water depths of the sampling stations

4.4. HEAVY METAL DISTRIBUTION

The total concentrations of the studied metals (Fe, Co, Mn, Ni, Zn, Cu, Cr) in the surface sediments of the northeastern Mediterranean, together with those from in the adjacent areas, average rocks are shown in Table 4.2.

Major part of the metal values obtained in this study is well coinciding with those of an average composition of crustal rocks. The deviations in heavy metal concentrations of the sediments are probably related with the variations in geological sources (texture and lithology) and local anthropogenic inputs. Figure 4.11 shows the possible inland sources increasing the heavy metal contents of the studied sediments.

4.4.1. Iron (Fe)

Iron is often enriched as oxidized Fe(III) oxyhydrates under oxic conditions (Murray, 1979) and is reduced to Fe(II) under reducing conditions. Iron oxyhydrides are known to absorb species that exist in anionic forms.

Fe contents of the northeastern Mediterranean sediments range from 2.0% to 4.0% at most stations (Figure 4.12) and these values are largely comparable with those of the average composition of crustal rocks (3.0% - 5.0%), as well as with the sedimentary rocks (Table 4.12). However, these values are slightly low when compared with the ultrabasic (5.0% - 7.6%) and basic (1.5% – 8.5%) rocks (Table 4.2).

Table 4. 2 Comparison of metal concentrations obtained in the surfical sediments with those found in the adjacent regions and some average rocks

	Fe(%)	Mn(ppm)	Cu(ppm)	Ni(ppm)	Cr(ppm)	Zn(ppm)	Co(ppm)
This Study (General)	0.4 - 4.7	411 - 1517	9 - 37	32 - 563	25 - 252	23 - 286	1 - 18
(1) Crustal Average	3.5	600	25	20	35	71	10
(2) Crustal Average	3.09	527	14.3	18.6	35	52	11.6
(3) Crustal Average	5.0	950	55	75	100	70	25
(4) İskenderun Bay	1.5 - 9.0	281 - 1130	9 - 39	179 - 808	70 - 694	30 - 117	6 - 99
(5) Mersin Bay	5.3	1103	42	326	551	107	-
(6) Eastern Aegean Shelf	0.5 - 5.7	103 - 2625	3 -77	11 - 406	9 - 312	19 - 162	2 - 41
(7) Marmara Sea Shelf	1.7 - 5.1	307 - 2059	14 - 104	42 - 173	89 - 186	50 - 169	13 - 33
(8) Black Sea	3.28	570	49	77	110	87	11
(9) Black Sea	-	722	36	51	93	-	22
(10) Ultrabasic Rocks	5.0 - 7.6	700 - 2600	46 - 62	1700 - 2900	500 - 700	-	75 - 101
(11) Basic Rocks	1.5 - 8.5	500 - 4900	39 - 87	200 - 3200	400 - 3000	-	25 - 112
(12) Shales	4.7	850	45	68	90	90	9
(13) Ceyhan River	3.2 - 5.9	285 - 2159	40 - 84	115 - 1066	124 - 683	121 - 318	25 - 95
Mersin Bay (This Study - Average)	2.95	668	25	230	147	57	5
İskenderun Bay (This Study - Average)	2.91	684	28	333	170	71	3

(1)Taylor and McLennan (1985,1995) - (2)Wedepohl (1995) - (3)Mason and Moore (1982) - (4)Ergin et al. (1996) - (5)Shaw and Bush (1978) - (6)Ergin et al. (1993) - (7)Bodur and Ergin (1994) - (8)Yücesoy (1991) - (9)Çağatay et al. (1987) - (10,11)Aslaner,1973) - (12)Turekian and Wedepohl (1961) - (13)Sevim (1991)

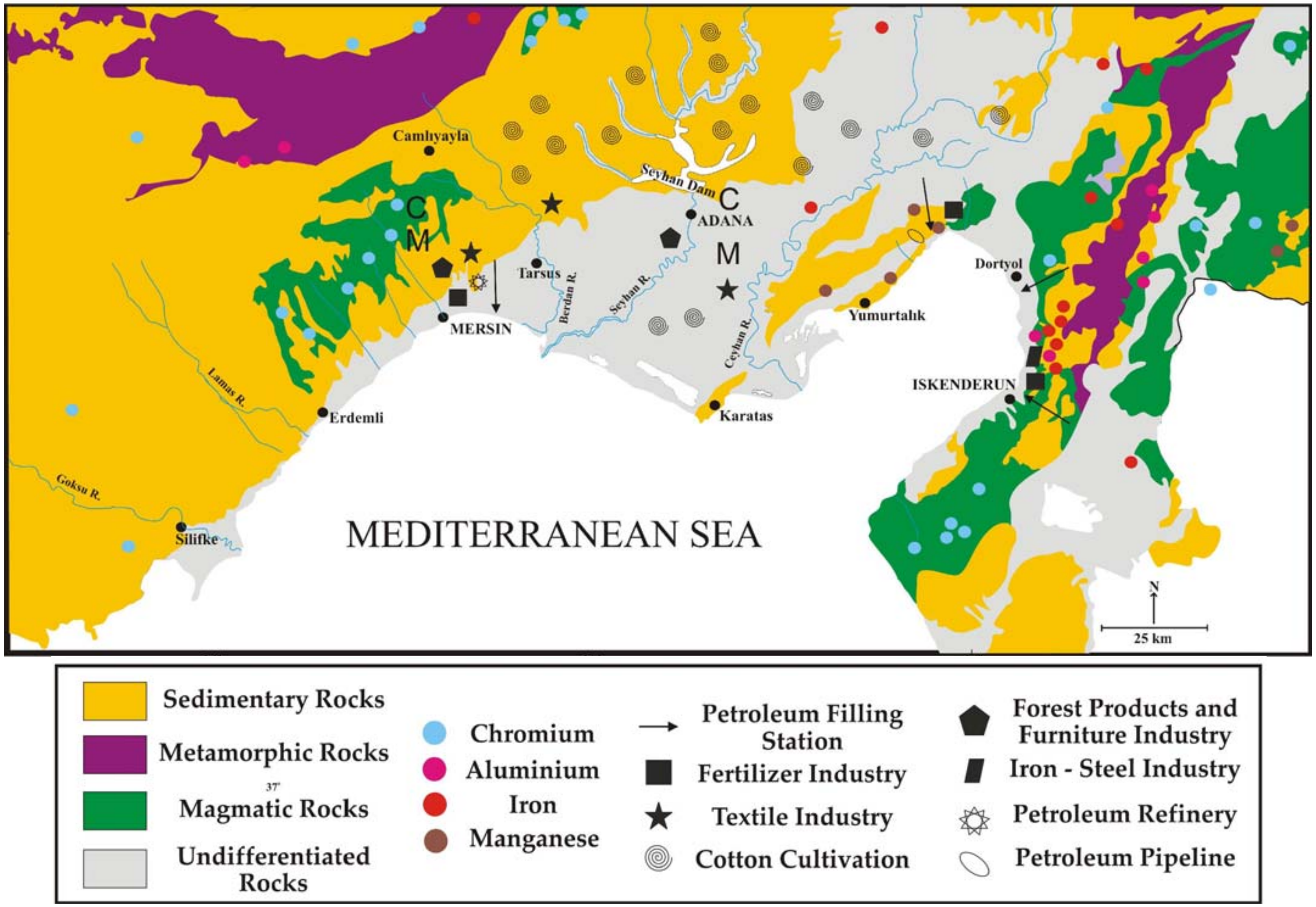


Figure 4. 11 The possible inland sources increasing the heavy metal contents of the studied sediments

It seems that the Fe contents of the northeastern Mediterranean sediments are mostly derived from the terrigenic material when compared with the average composition of the sedimentary rocks. The highest Fe concentrations are determined in the fine-grained sediments collected from stations greater than 200 m water depth in the west of the study area (Figure 4.13). Shaw and Bush (1978) explained Fe enrichment in this region with the high proportion of clay in these sediments. The positive and significant correlation between Fe and clay (r:0.60) and mud (r:0.79) contents of the surface sediments supports the argument that the distribution and transportation of Fe is primarily controlled by the fine-grained sediments (Table 4.2; Figure 4.14).

Fe enrichment occurring in the northeastern İskenderun Bay sediments may be related with the intense industrial waste disposal from the iron-steel complex (İSDEMİR) (Kazan, 1994) and iron-rich clastic sediments derived from ultrabasic-basic rocks and associated metallic ores on the nearby coast (Table 4.2)

Low Fe concentrations are generally obtained in the coarse-grained sediments which also contain high quantities of carbonate. The significant and negative correlation between Fe and gravel (r:-0.53) and sand (r:-0.75), as well as carbonate (r:-0.74) contents of the sediments reflects the dilution effect of the biogenic carbonates (Table 4.1; Figure 4.15).

Unlike to the other studies carried in the Turkish coasts (Kazan, 1994; Ergin *et al.*, 1993; Bodur, 1991), there is a negative and insignificant correlation between Fe and organic carbon contents of the northeastern Mediterranean sediments (Table 4.1; Figure 4.15).

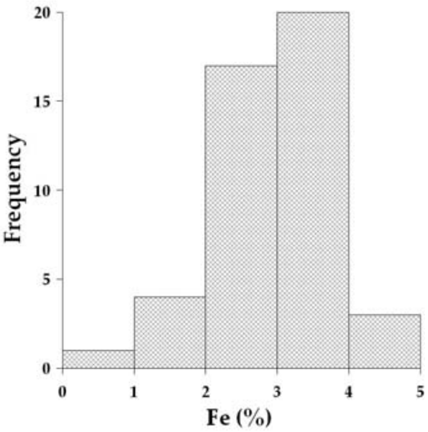


Figure 4. 12 Frequency histograms of Fe concentrations of surface sediments

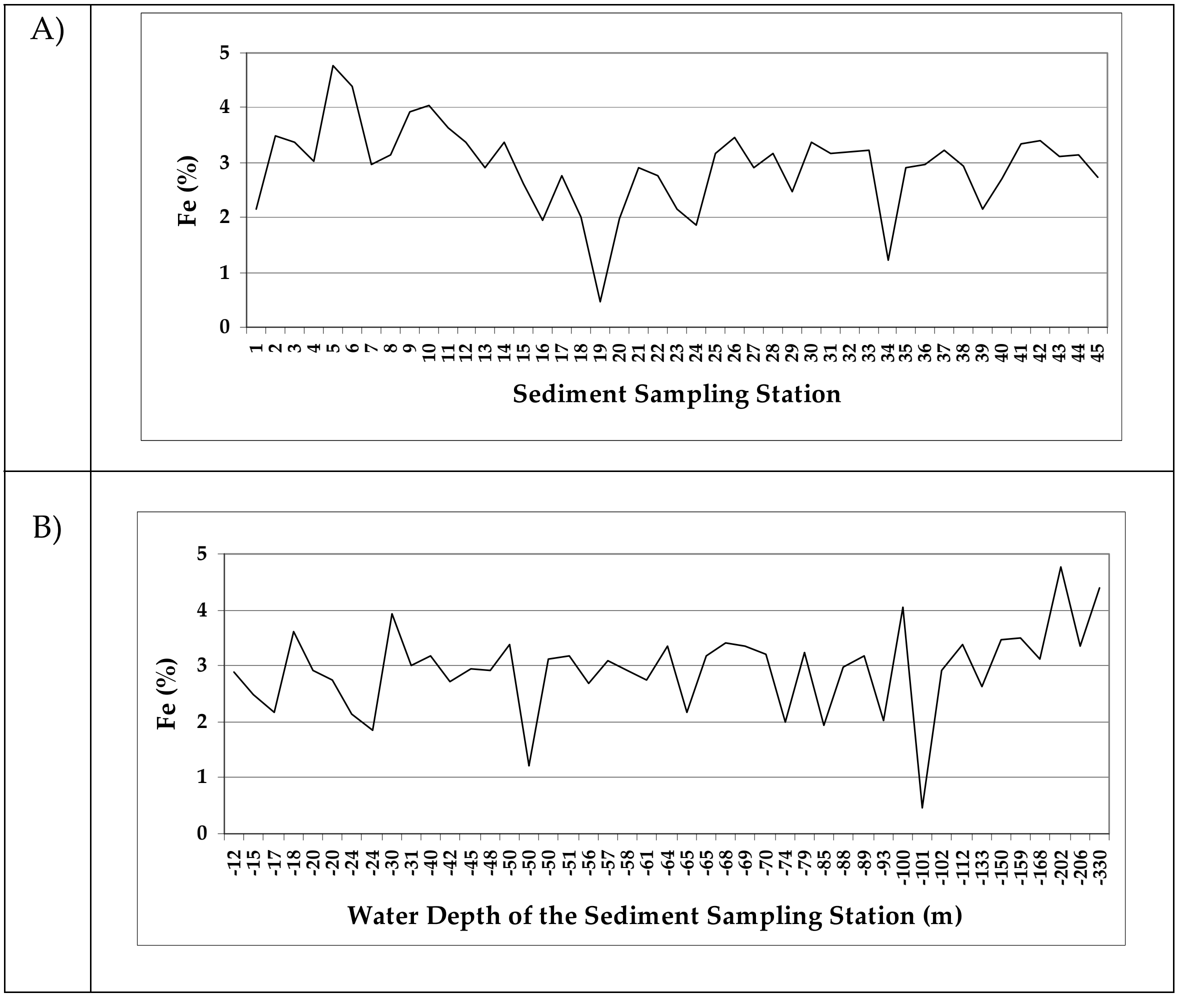


Figure 4. 13 Fe concentrations of the surface sediments collected from the northeastern Mediterranean (A) from west to east, (B) from coast to offshore

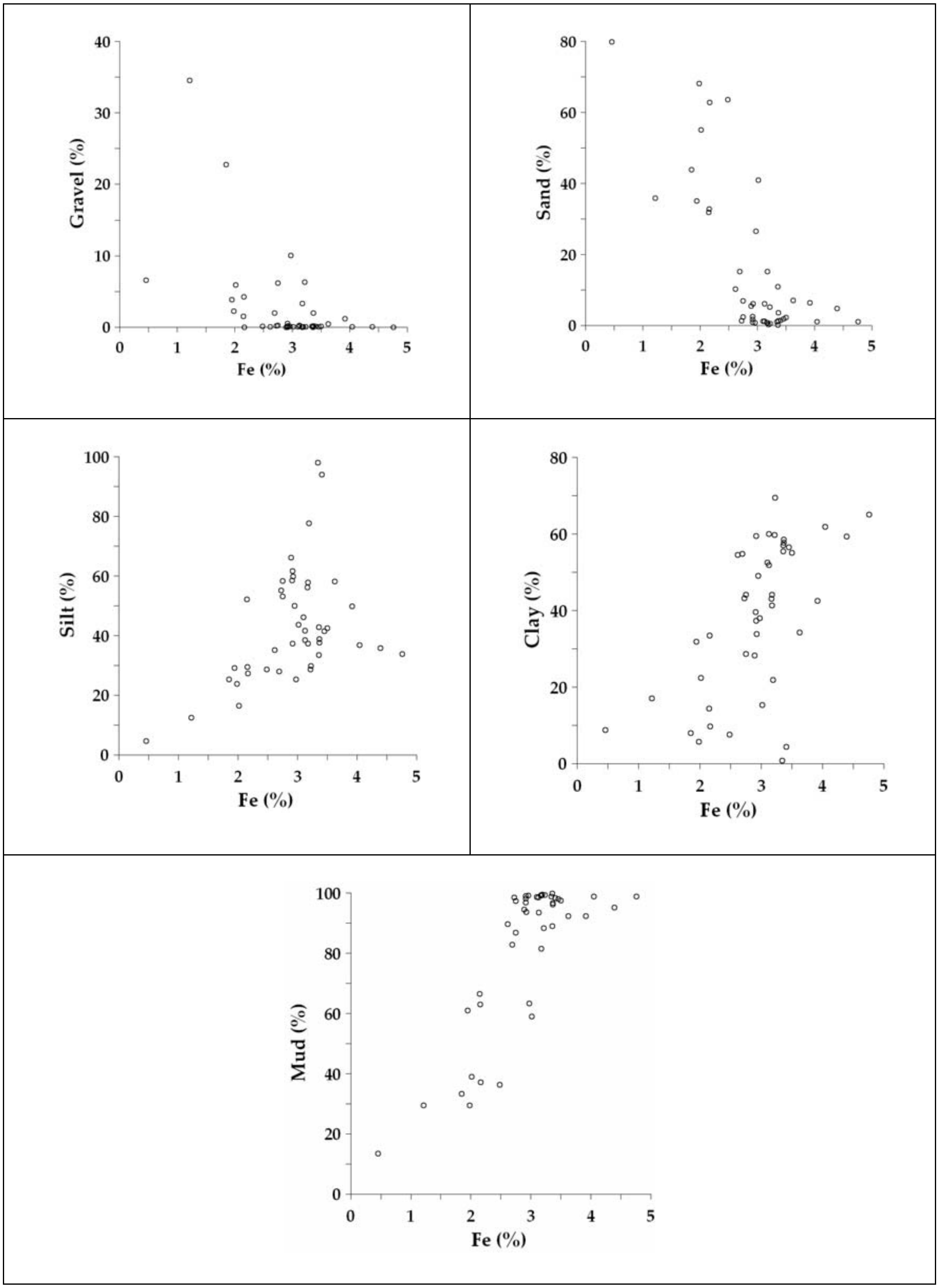


Figure 4. 14 Plot of the Fe concentrations versus various grain size fractions of the surface sediments

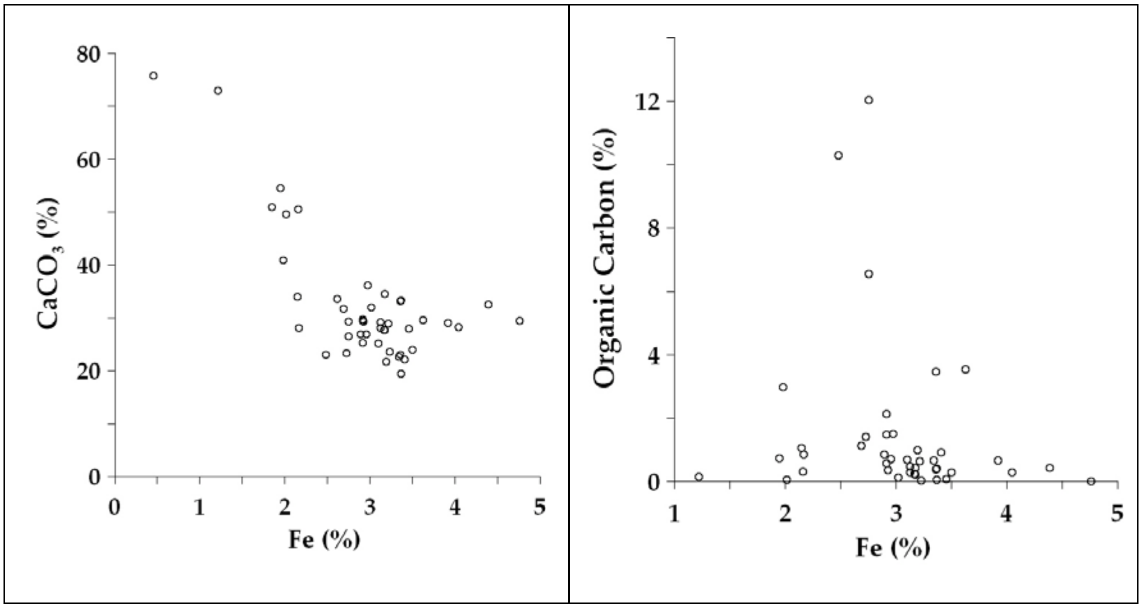


Figure 4. 15 Plot of the Fe concentrations versus $CaCO_3$ and organic carbon contents of the surface sediments

4.4.2. Manganese (Mn)

Manganese exist mainly as insoluble Mn(III, IV) oxides and oxyhydroxides in oxygenated seawater. Its chemical forms (oxides and oxyhydroxides) are important particle substrates for the scavenging of other metals (Burton and Straham, 1988).

The spatial distribution of Mn contents of the sediments shows various similarities with that of Fe. The majority of the sediments contain 600 ppm to 800 ppm Mn and fall in the range of average compositions of crustal rocks (527 ppm – 950 ppm) (Figure 4.16; Table 4.2).

Mn enrichment in Turkish coastal sediments is generally related with terrigenic inputs from land. However, biogenic – organic and diagenetic processes play important role in Mn enrichment of the Cilician Basin (Shaw and Bush, 1978), the Black Sea (Hirst, 1974; Yücesoy and Ergin, 1992) and the Marmara Sea (Evans *et al*., 1989; Bodur, 1991) sediments.

As in the case for Fe, the highest Mn contents are found in the west of the studied area collected at the stations having water depth greater than 200 m (Figure 4.17). When compared with the high Mn contents of the ultrabasic and basic rocks, it is interpreted that the relatively low Mn contents of Mersin Bay sediments is mostly resulted from the contribution of weathered sedimentary rocks on land.

There are weak and positive correlations between Mn and clay (r:0.26) and mud (r:0.30) contents of the northeastern Mediterranean surface sediments (Table 4.1; Figure 4.18). However, Mn and gravel (r:-0.32) and sand (r:-0.25) contents of sediments show a negative correlation along the study area. Similar relationships are obtained in the sediments of İskenderun Bay (Kazan, 1994), Marmara Sea (Bodur, 1991) and Black Sea (Yücesoy and Ergin, 1992) sediments (Table 4.1; Figure 4.18). This shows the important role of the fine-grained fractions in accumulation of the Mn in sediments of the northeastern Mediterranean, as well as other Turkish coasts.

It has been found that the Mn contents of sediments do not associate with the organic carbon accumulation. These parameters show no significant correlation along the study area (r:-0.06) (Table 4.1; Figure 4.19).

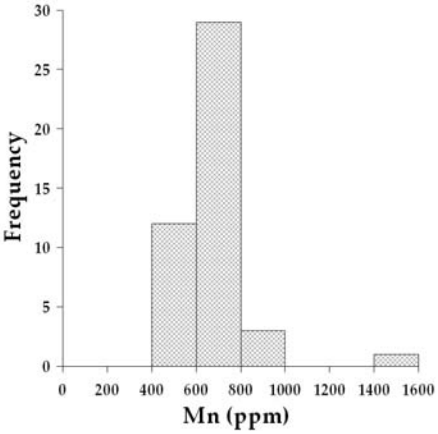


Figure 4. 16 Frequency histograms of Mn concentrations of surface sediments

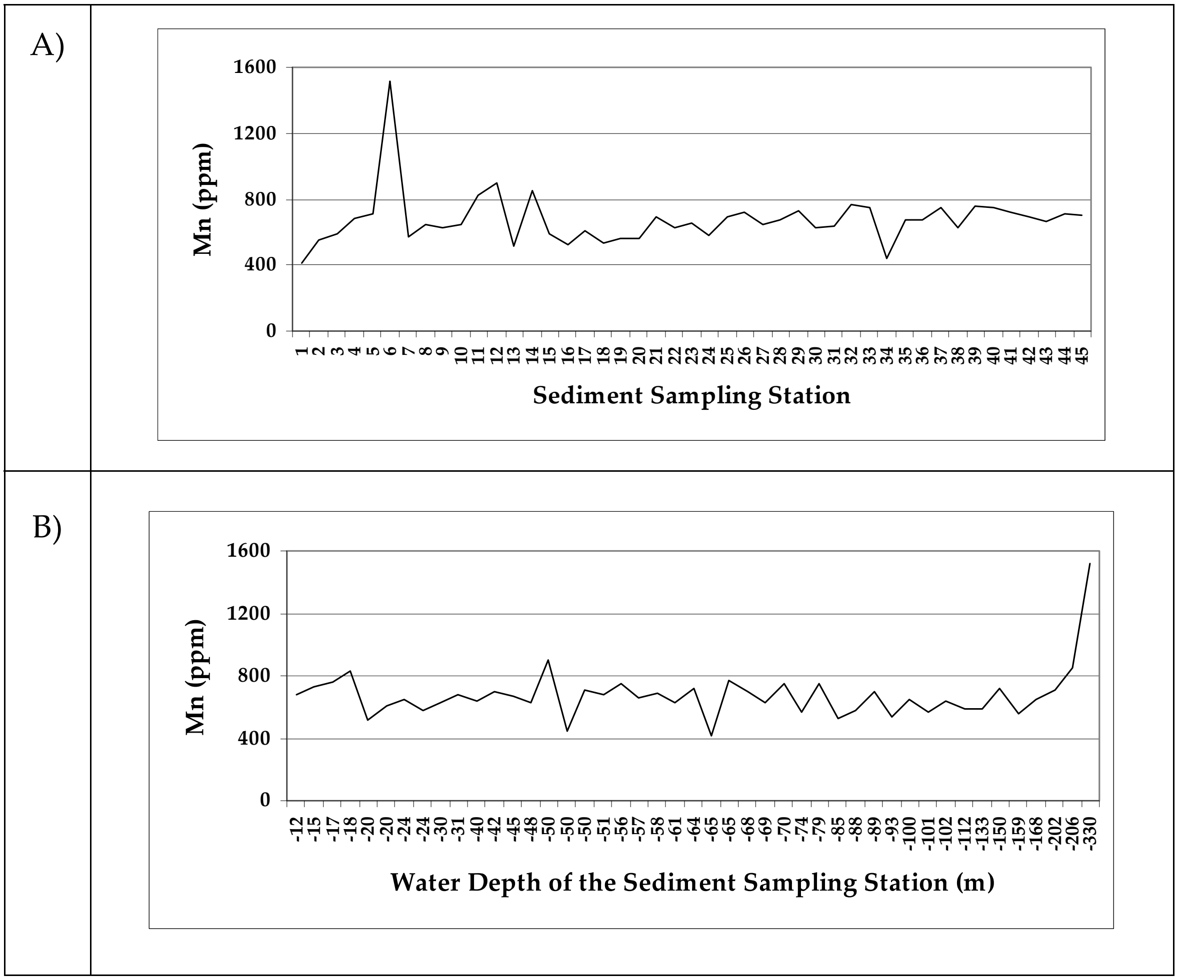


Figure 4. 17 Mn concentrations of the surface sediments collected from the northeastern Mediterranean (A) from west to east, (B) from coast to offshore

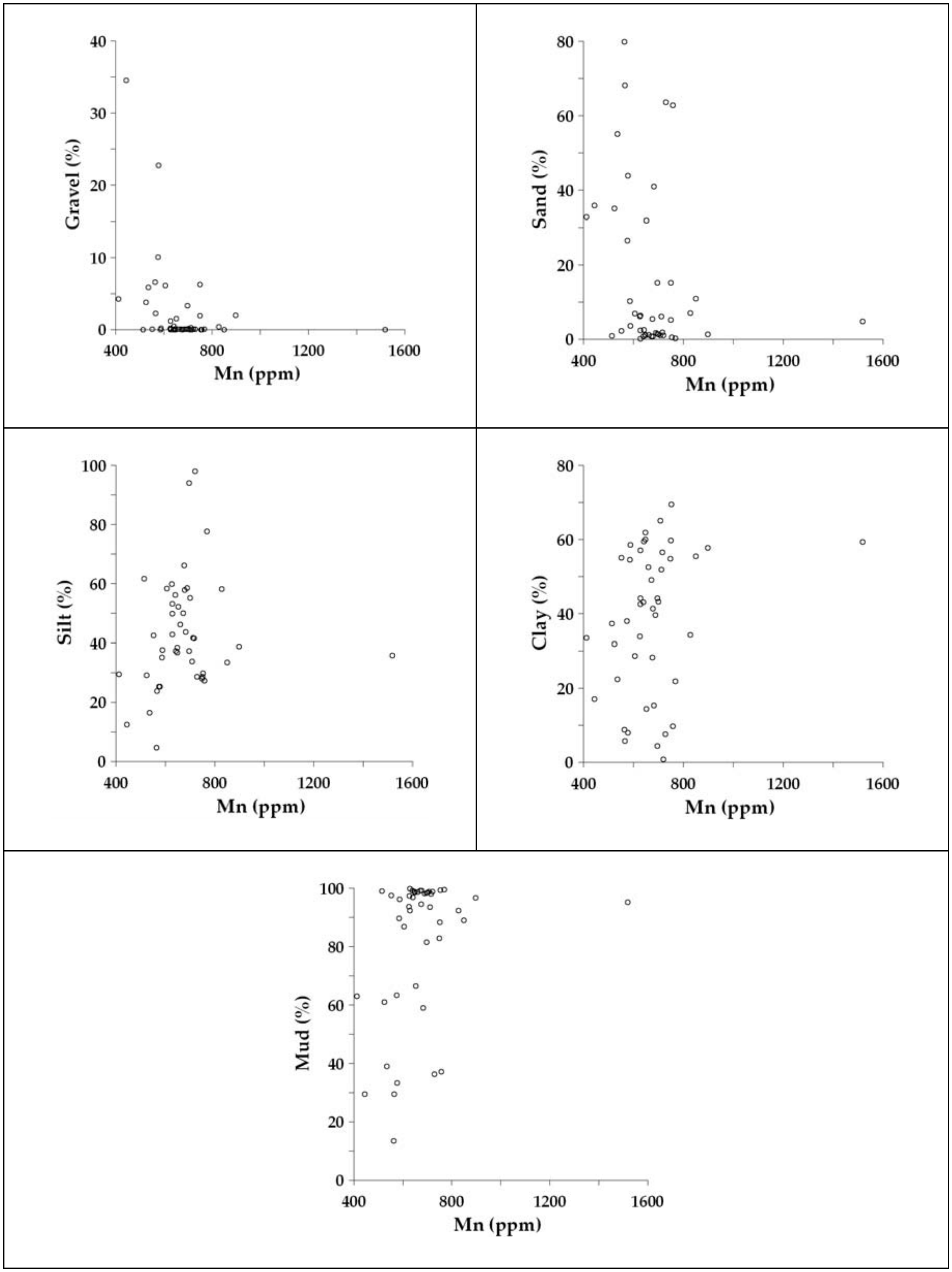


Figure 4. 18 Plot of the Mn concentrations versus various grain size fractions of the surface sediments

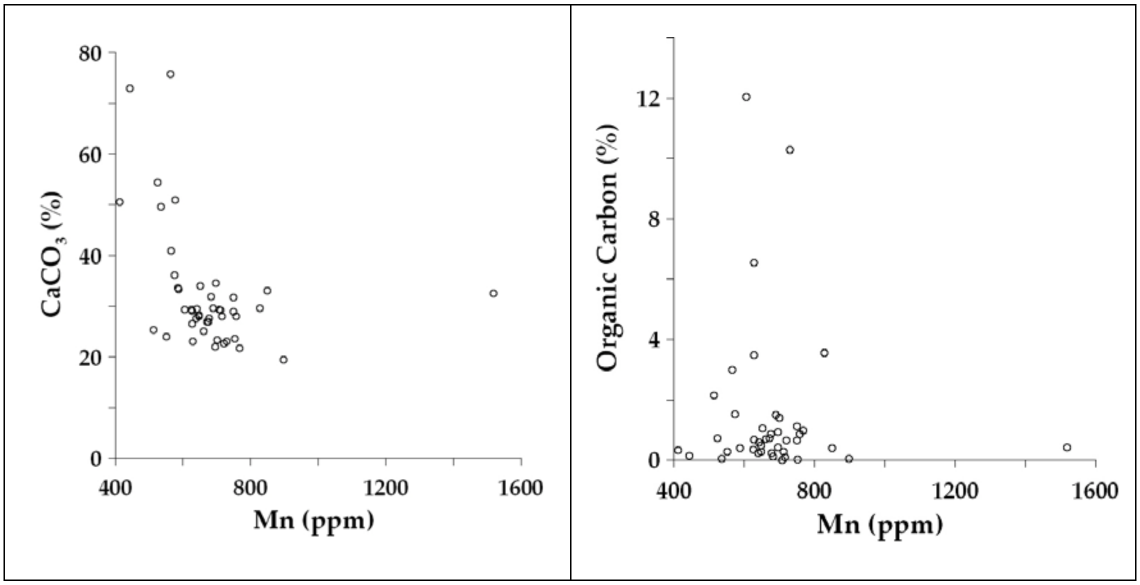


Figure 4. 19 Plot of the Mn concentrations versus $CaCO_3$ and organic carbon contents of the surface sediments

4.4.3. Chromium (Cr)

The main oxidation state of chromium in oxygenated seawater is Cr(VI) which forms soluble chromate anion (CrO_4^{-2}). Some Cr(III) is produced in surface waters as a result of biological and photochemical reactions which forms hydrolyzed species that known to be extremely particle reactive and forms strongly scavenged hydrolysis species (Murray et. al., 1983).

The concentration of Cr obtained in surface sediments are generally high when compared with the average composition of crustal rocks (35 – 100 pm) and range between 150 ppm and 200 ppm at most stations (Table 4.2; Figure 4.20). However, these values highly confirm to the average composition of the ultrabasic and basic rocks (400 ppm – 3000 ppm).

The distribution pattern of Cr contents of the northeastern Mediterranean sediments does not represent a regular trend along the study area. Especially, the sediments collected from lower than 30 m water depth contain relatively low Cr values (Figure 4.21).

Many researches in Turkish coastal sediments clearly indicate that the abundance and distribution of Cr largely indicate the influences from the natural weathering of terrigenic sources on the adjacent coasts and hinterland. Especially, studies carried in the sediments of the eastern Aegean Sea (Ergin and Yemenicioğlu, 1997) and the southeastern Black Sea (Yücesoy and Ergin, 1992) show the considerable contribution of the ultrabasic - basic rocks and associated chromite deposits on the distribution pattern of Cr. On the other hand, Ergin *et al*. (1991) suggested that high Cr contents obtained in the sediments of the northeastern Marmara Sea (Golden Horn Estuary) are mostly associated with the Cr-consuming anthropogenic activities such as textile and electro-metal industries.

Studies carried on the river and beach sediments between Seyhan River catchment and Erdemli suggest that the Cr_2O_3 contents show a distinct enrichment in the coastal area, as well as in the rivers staying in the west of Berdan River (Çağatay *et al*., 2002). High Cr contents in the coastal sediments from the east of Göksu River Delta to Mersin City may be readily explained by the presence of the magmatic and metamorphic rocks and related economic chromite ores (Shaw and Bush, 1978) and the industrial complexes in the catchment areas of the rivers which drain this parts of the study area.

In the same way, Kazan (1994) explained the Cr-rich sediment patches in the southern and northeastern İskenderun Bay with the significant weathering products of the source rocks and associated Cr deposits in the Taurus and Amanous Mountains.

Yücesoy and Ergin (1992) and Kazan (1994) mentioned the significant correlation between the Cr contents and clay fractions of the surface sediments. A positive correlation (r= 0.55) between Cr and mud contents shows that the distribution of Cr is mostly controlled by the amount of mud material in sediments (Table 4.1; Figure 4.22).

Cr concentrations show negative correlation with the coarse-grained fractions and $CaCO_3$ contents of the surface sediments (Table 4.1; Figure 4.23). This shows the dilution effect of biogenic carbonates present in coarse-grained sediments on Cr contents (Kazan, 1994).

It has been found that the Cr contents of sediments do not associate with the organic carbon accumulation. These parameters show no significant correlation along the study area (r:-0.15) (Table 4.1; Figure 4.23).

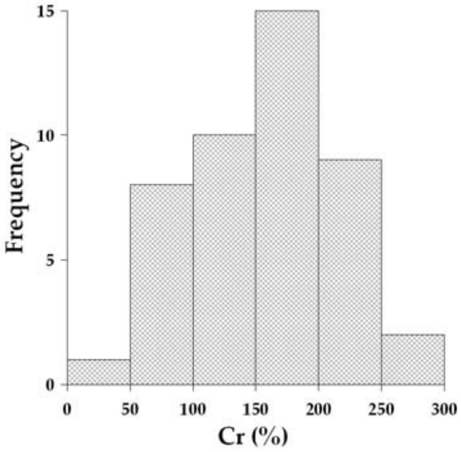


Figure 4. 20 Frequency histograms of Cr concentrations of surface sediments

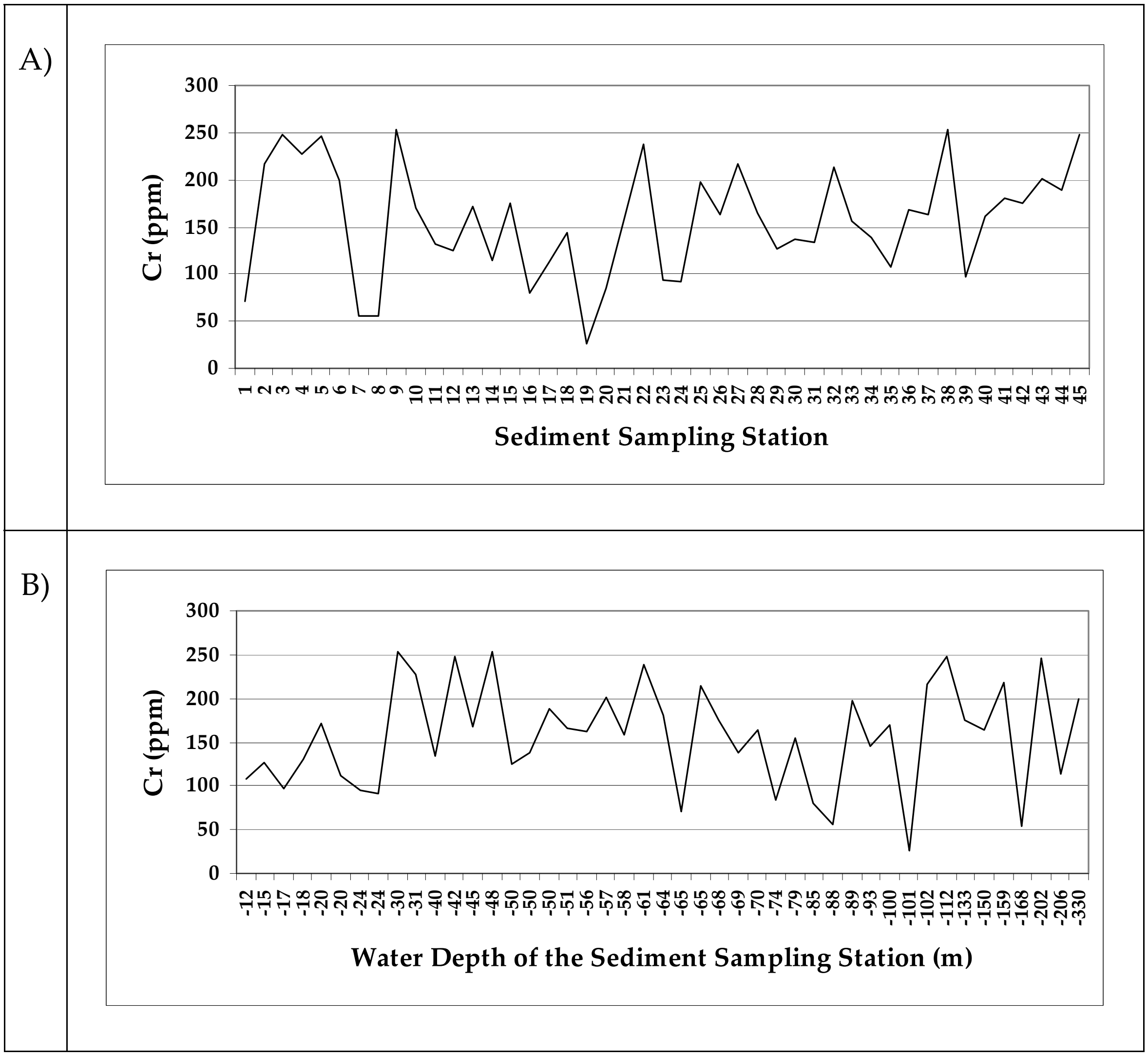


Figure 4. 21 Cr concentrations of the surface sediments collected from the northeastern Mediterranean (A) from west to east, (B) from coast to offshore

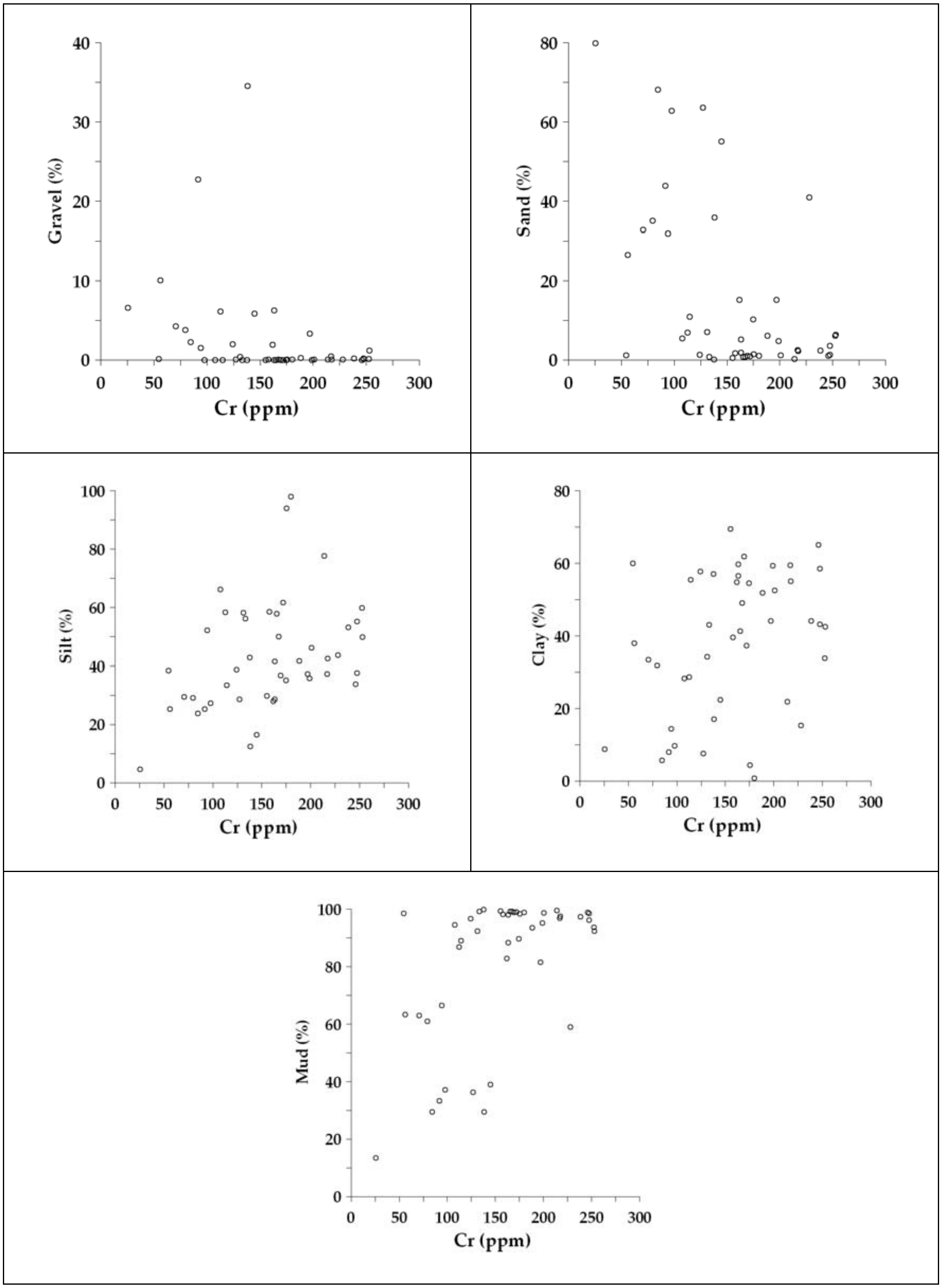


Figure 4. 22 Cr concentrations of the surface sediments collected from the northeastern Mediterranean (a) from west to east, (b) from coast to offshore

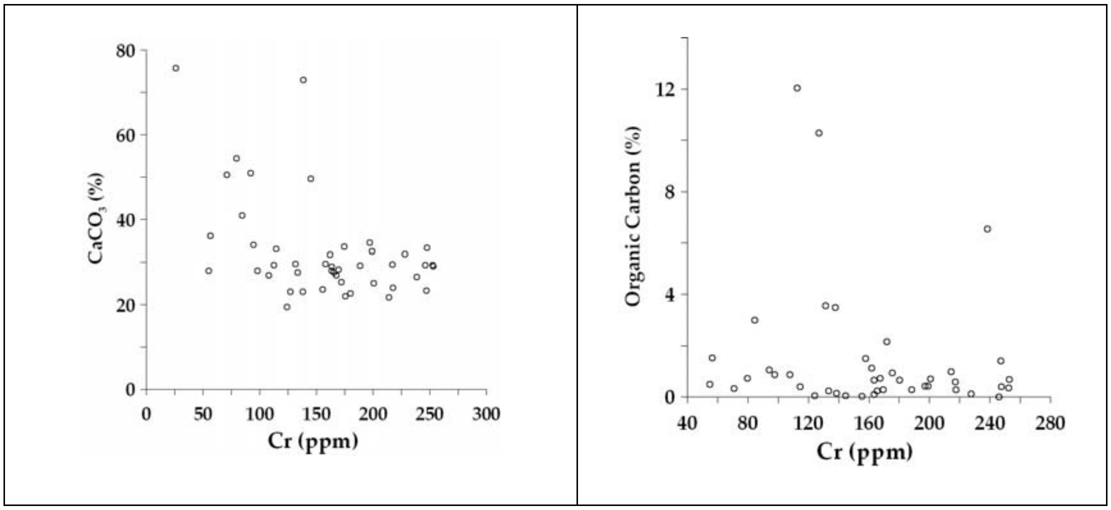


Figure 4. 23 Plot of the Cr concentrations versus $CaCO_3$ and organic carbon contents of the surface sediments

4.4.4. Nickel (Ni)

Nickel has one oxidation state in the seawater Ni(II), thus its solution chemistry is not complicated. It forms chloro and carbonate complexes and adsorb loosely on metal oxides and other particulate surfaces (Murray 1975). Its distribution is controlled by physical circulation and internal cycling of biogenic materials (Bruland 1980, 1983).

Distribution pattern of Ni contents of the surface sediments shows significant similarities with the distribution pattern of Cr contents and Ni appears to be more abundant in coastal sediments (30 – 60 m water depth) of the study area (Figure 4.24). The concentrations of Ni (32 ppm – 563 ppm) measured in the northeastern Mediterranean sediments are noticeably high when compared with the relative abundances of those element in average crustal rocks (20 ppm – 75 ppm) (Table 4.2). Ni contents range between 200 ppm – 300 ppm at most stations (Figure 4.25) and these values reflect contributions from the Ni-rich source rocks (ophiolitic series, volcanics, chromite deposits, etc) on land.

Similar studies carried by Shaw and Bush (1978), Yücesoy and Ergin(1992), Kazan (1994), Ergin and Yemenicioğlu (1997), Çağatay (2007) show that Ni enrichment in coastal sediments of Turkey are generally results of the seaward dispersal of Ni-rich minerals of inland basic-ultrabasic rocks.

Ni enrichment in coastal sediments of the northwestern Mersin Bay, from Mersin City to the west of Lamas Delta, and off Ceyhan Delta, as in the case for Cr, may be explained by the presence of the basic-ultrabasic rocks and probable effects of the waste disposal from nearby industrial complexes. High Ni concentrations off Karataş Cape may be interpreted with the movement of suspended sediments off Ceyhan delta by means of hydrodynamic factors.

Sediments with Low Ni contents are generally confined to regions with the water depths higher than 100 m. Low Ni concentrations measured in the coastal zone discharged by Seyhan and Berdan Rivers are related with the masking effect of siliciclastic sediments (5314x103 ton/year) carried by these rivers.

Hirst (1974) suggested that clay minerals (mainly chlorite and montmorillonite) constitute the major part of the Cr, Ni and Cu input from mafic and ultramafic rocks in southern Black Sea. Yücesoy and Ergin (1992) showed the similar relationship between clay fractions and Ni contents of the sediments in this region. Also, the study carried by Kazan (1994) clearly indicates the positive correlation between these two parameters in İskenderun Bay. It has been found that Ni concentrations show a positive correlation with mud contents in this study (r:0.40; Figure 4.26). This shows that the Ni contents are generally prominent in fine-grained sediments of the northeastern Mediterranean. The negative and insignificant correlation between Ni and $CaCO_3$ contents (r:-0.26) suggests the dilution effect of the coarse-grained carbonates which cause the local anomalies of Ni along the study area (Table 4.1; Figure 4.27).

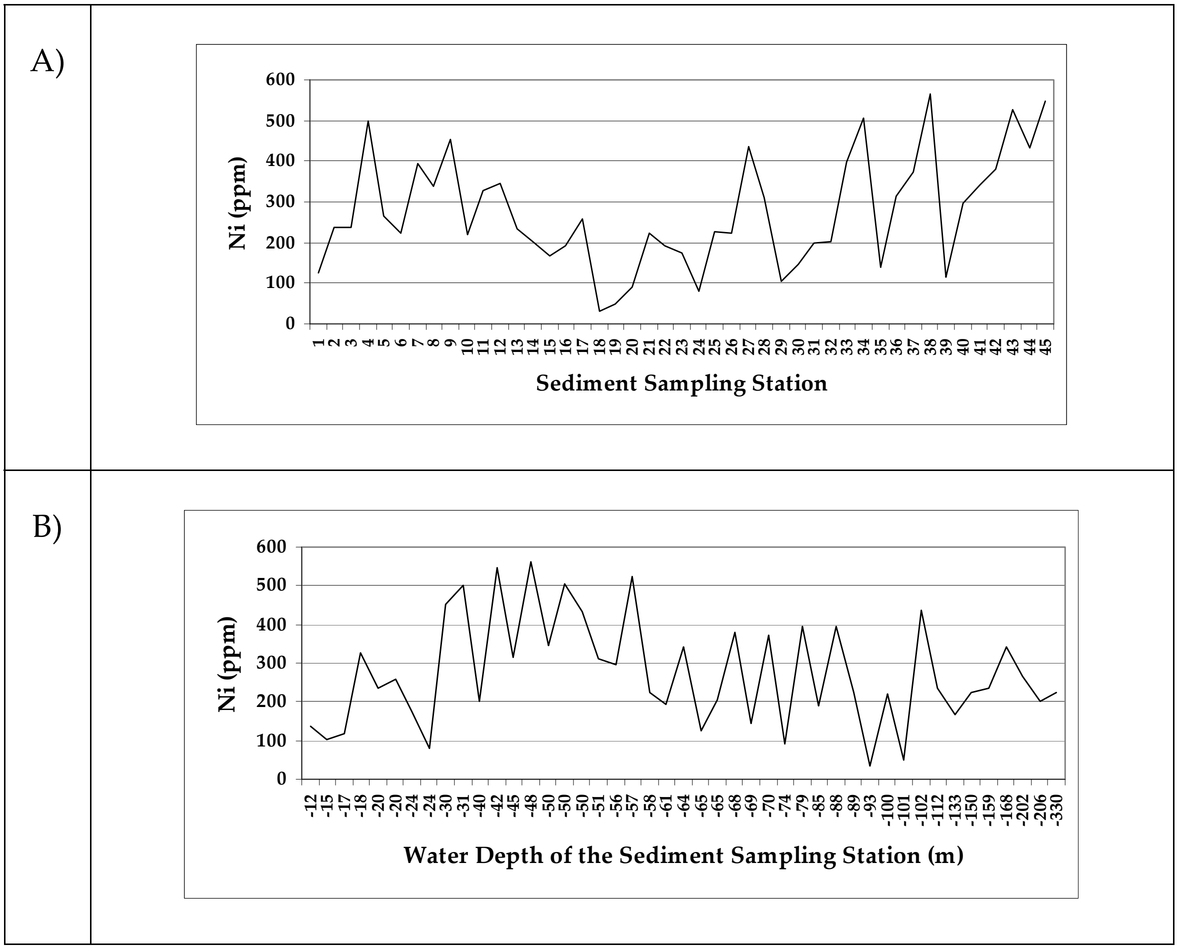


Figure 4. 24 Ni concentrations of the surface sediments collected from the northeastern Mediterranean (A) from west to east, (B) from coast to offshore

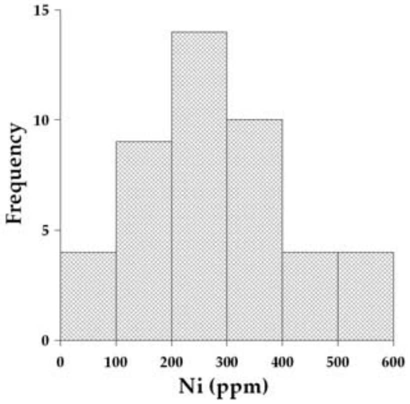


Figure 4. 25 Frequency histograms of Ni concentrations of surface sediments

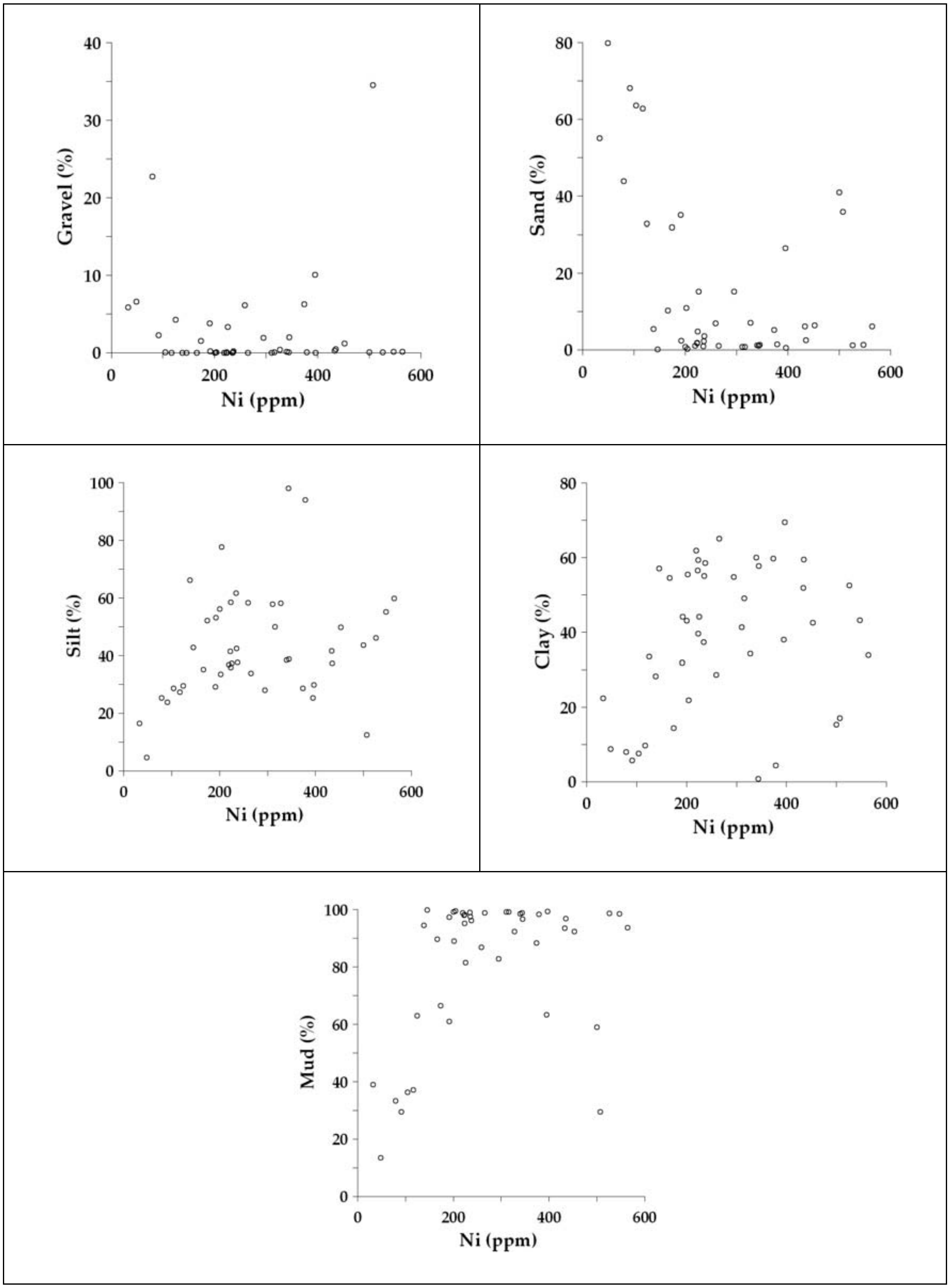


Figure 4. 26 Plot of the Ni concentrations versus various grain size fractions of the surface sediments

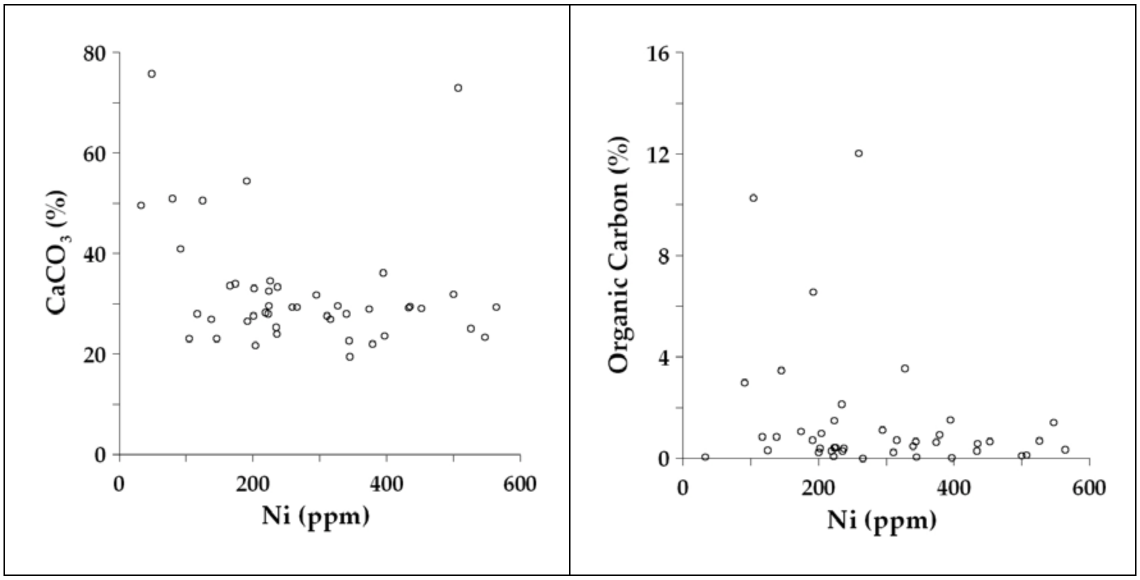


Figure 4. 27 Plot of the Ni concentrations versus $CaCO_3$ and organic carbon contents of the surface sediments

4.4.5. Copper (Cu)

The speciation of copper in seawater is determined by Cu(II) oxidation form. The major speciation of copper in seawater is $CuCO_3$, $Cu(OH)^+$ and ionic Cu(II). Copper forms strong complexes with organic ligands and has a strong biological affinity (Bruland 1980).

The Cu contents of the northeastern Mediterranean sediments show a significant regional trend along the study area. There are some exceptions at which coarse-grained sediment patches occur. The majority of the sediments have similar Cu concentrations (20 ppm – 30 ppm) with those found in average crustal rocks (15 ppm – 55 ppm) (Table 4.2; Figure 4.28; Figure 4.29).

Although the Cu contents of Ceyhan River sediments (40 ppm – 84 ppm) and the ultrabasic-basic rocks (39 ppm – 87 ppm) on hinterland are relatively high, there is not a significant Cu enrichment in the sediments of study area. The positive correlation between Cu and pathfinder elements such as Cr (r:0.48) and Ni (r:0.34) can be interpreted as the Cu contents of the surface sediments is primarily related with the weathering process of the source rocks (ultrabasic-basic) on land.

Shaw and Bush (1978) suggested that the Cu enrichments with distance from coastal areas are related with the increase in the clay fractions of the sediments. Similar to this study, Kazan (1994) showed the strong and positive correlations observed between Cu contents and fine-grained sediments (Table 4.1; Figure 4.30). The Cu enrichment in studied sediments, especially in muddy sediments, may be readily explained by the increase of the clay minerals or other colloidal phases in sediments (Shaw and Bush, 1978; Emelyanov and Shimkus, 1986; Kazan, 1994).

Low Cu contents of the sediments are obtained in the coarse-grained sediment patches of the region. The negative relationship between Cu contents and coarse grained sediments rich in carbonate show dilution effect as in the case for other heavy metals measured in this study (Figure 4.31).

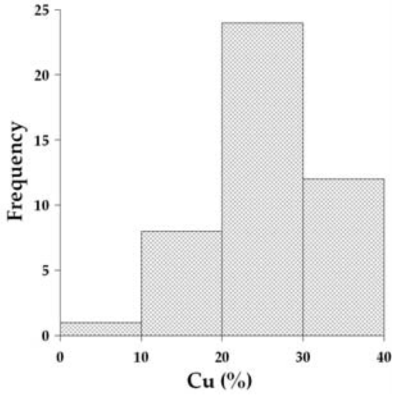


Figure 4. 28 Frequency histograms of Cu concentrations of surface sediments

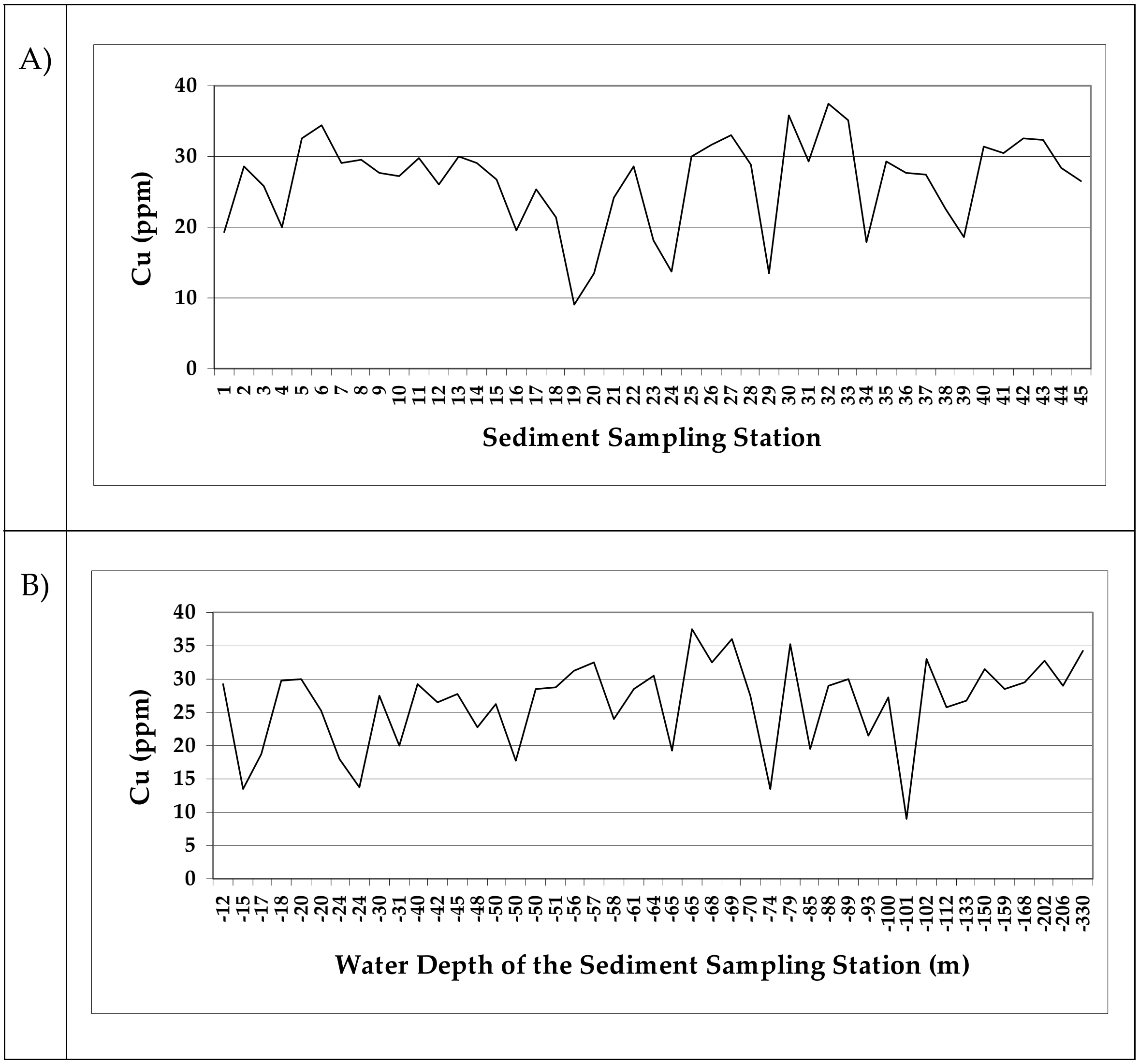


Figure 4. 29 Cu concentrations of the surface sediments collected from the northeastern Mediterranean (A) from west to east, (B) from coast to offshore

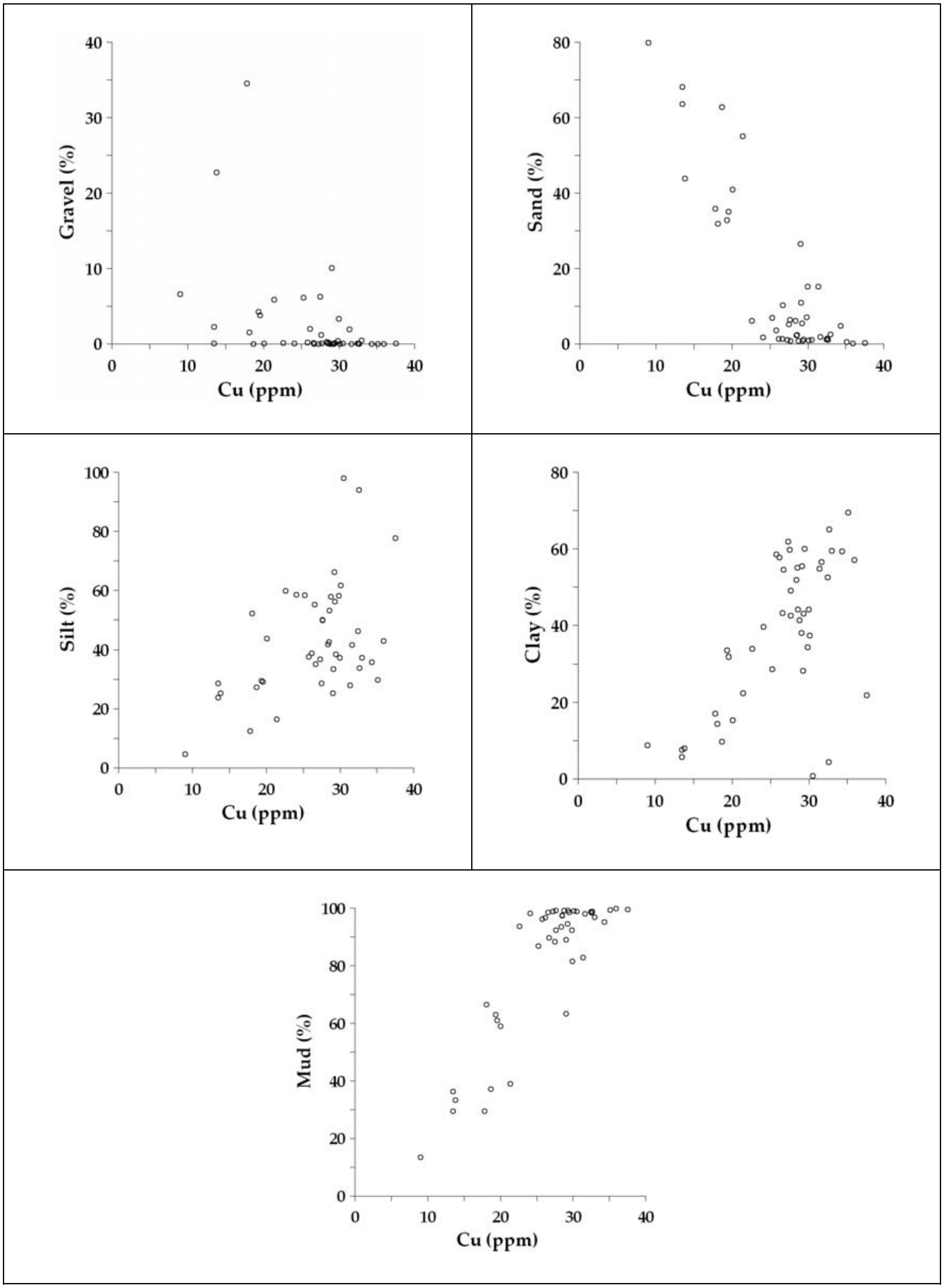


Figure 4. 30 Plot of the Ni concentrations versus various grain size fractions of the surface sediments

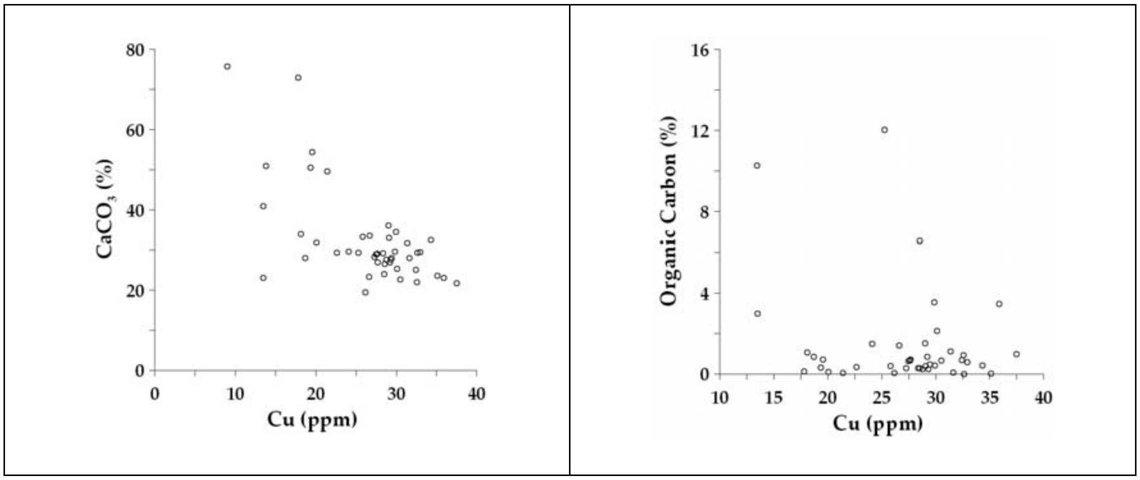


Figure 4. 31 Plot of the Cu concentrations versus $CaCO_3$ and organic carbon contents of the surface sediments

4.4.6. Cobalt (Co)

In oxic seawater environment cobalt exists in Co(II) oxidation state. It primarily exist as chloro and carbonate complexes and ionic forms (Murray 1975).

The Co concentrations obtained in northeastern Mediterranean sediments are less than 10 ppm at most stations and these values are roughly consistent with the composition of the average crustal rocks (10 ppm – 11 ppm) (Table 4.2; Figure 4.32). Besides, Co concentrations are relatively low when compared with the ultrabasic-basic rocks (25 ppm – 112 ppm; Table 4.2).

Co contents of the surface sediments gradually increase from east to west and the highest concentrations were obtained in the sediments collected from the area staying between Göksu River Delta and Lamas River (Figure 4.33). Figure 4.34 – 4.35 show the relationships between Co and other measured parameters.

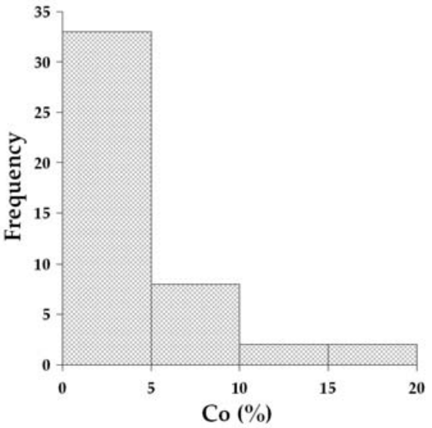


Figure 4. 32 Frequency histograms of Co concentrations of surface sediments

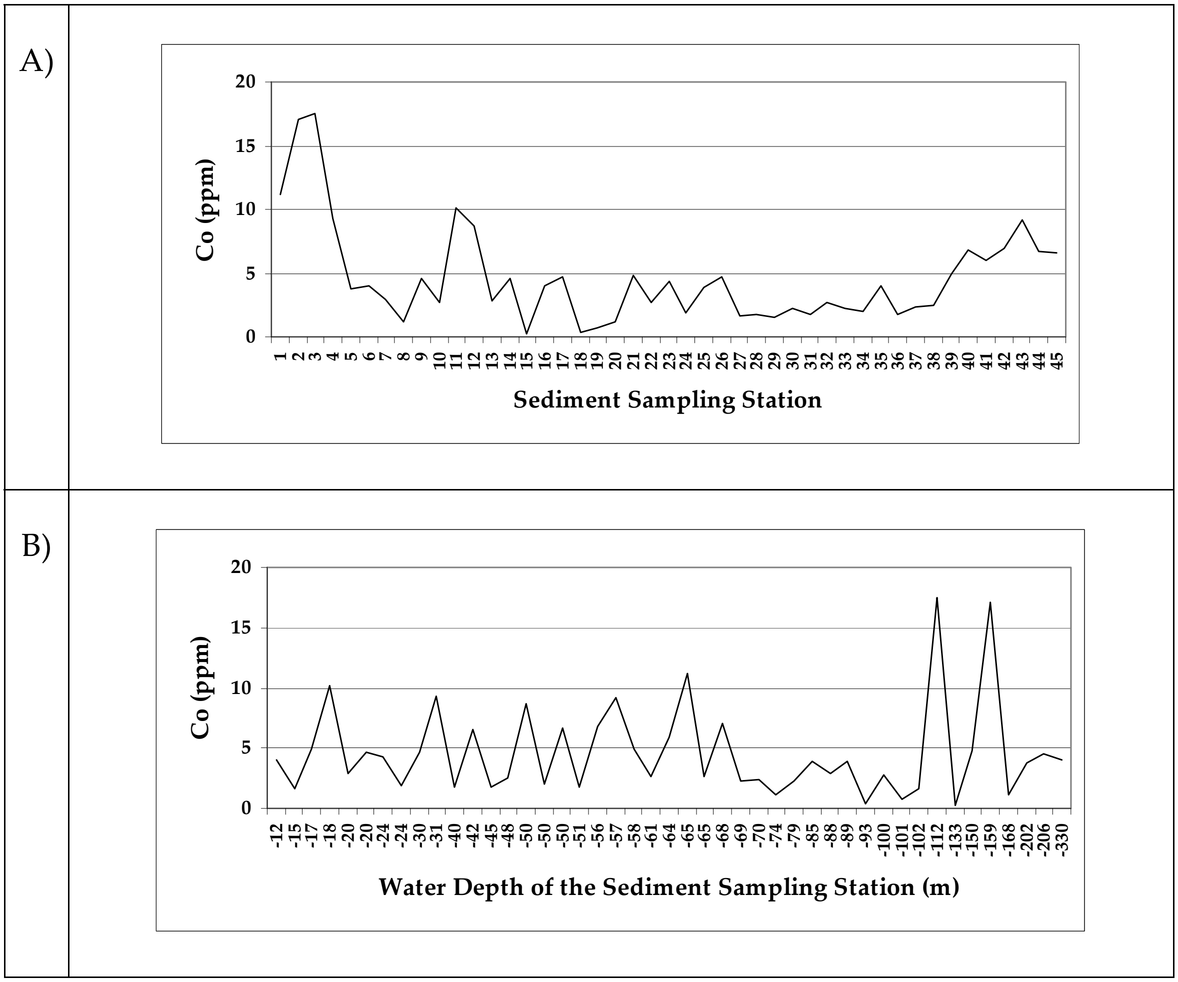


Figure 4. 33 Co concentrations of the surface sediments collected from the northeastern Mediterranean (A) from west to east, (B) from coast to offshore

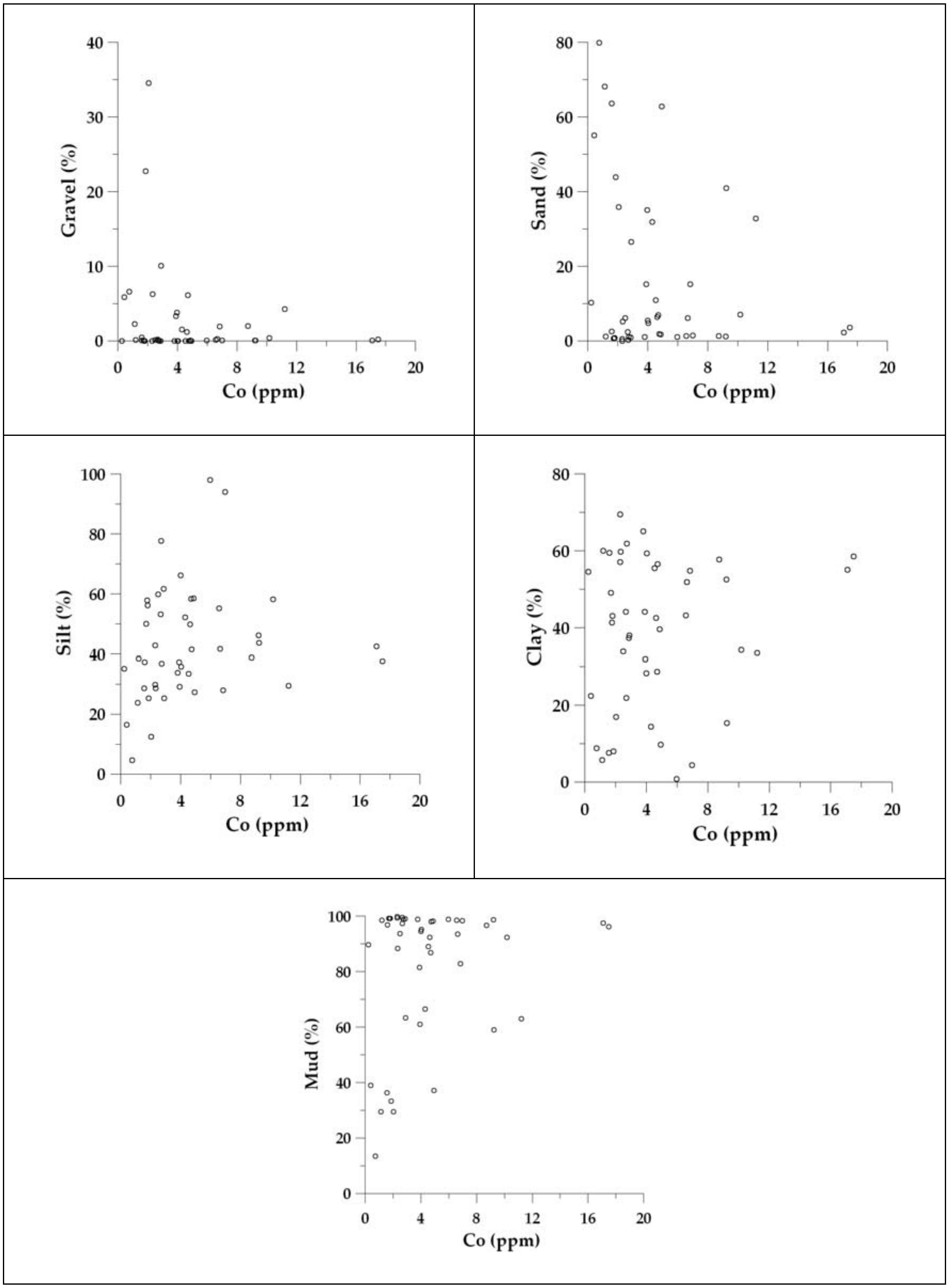


Figure 4. 34 Plot of the Co concentrations versus various grain size fractions of the surface sediments

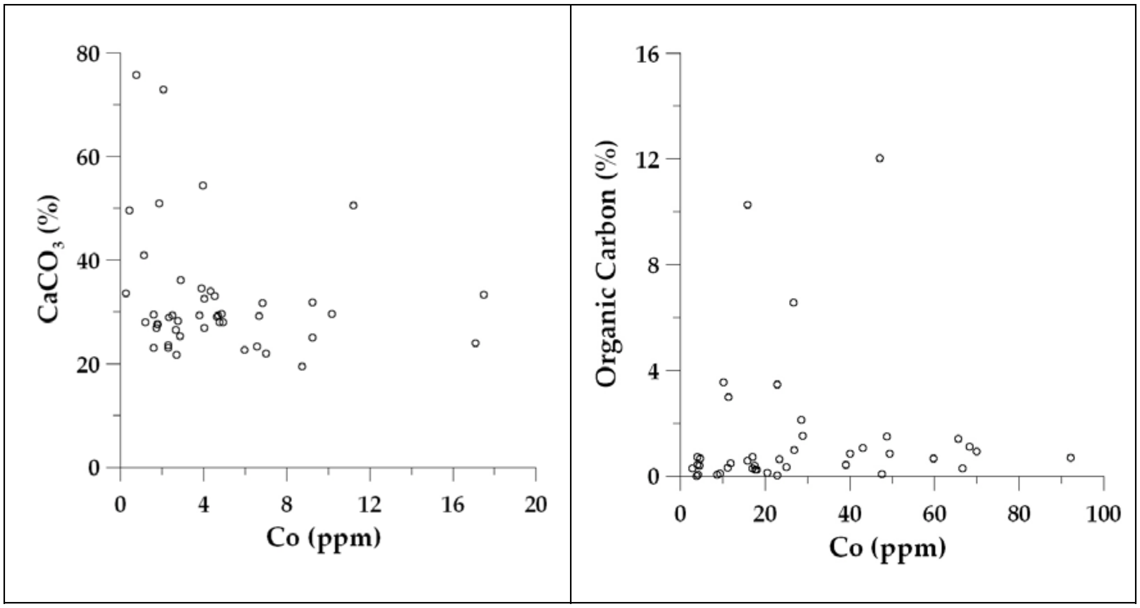


Figure 4. 35 Plot of the Co concentrations versus $CaCO_3$ and organic carbon contents of the surface sediments

4.4.7. Zinc (Zn)

Zinc has one oxidation state in oxic seawater and forms strong organic complexes (Muller *et al*. 2001).

The Zn concentrations of the northeastern Mediterranean sediments are less than 100 ppm at almost all stations (Figure 4.36; Figure 4.37). These values highly conform to the average composition of the crustal rocks (52 – 71 ppm; Table 4.2).

The significant Zn enrichment obtained in the western Ceyhan River Delta is mostly related with the high Zn contents of the fine sediments of the Ceyhan River (Sevim, 1991). These high values are associated with the variety of anthropogenic inputs such as industrial and domestic waste disposal. The insignificant correlations between Zn and tracer elements such as Cr (r:-0.02) and Ni (r:-0.20) suggest that the ultrabasic-basic rocks do not have an important contribution on the distribution of Zn.

Low Zn concentrations measured in the coastal zone discharged by Seyhan and Berdan Rivers are due to the dilution and the masking effect of siliciclastic sediments (5314x103 ton/year) carried by these rivers.

The insignificant correlations obtained between the Zn concentrations and grain size fractions of the sediments shows that grain size composition of the northeastern Mediterranean sediments is not a major factor controlling the distribution and sedimentation of Zn (Table 4.1; Figure 4.38).

There exists an important negative relationship between the Zn and carbonate contents of the sediments. The presence of high amounts of carbonate has a dilution effect on Zn concentrations of the studied sediments (Figure 4.39).

Kazan (1994) related the significant and positive correlation between the Zn and organic carbon contents of İskenderun Bay sediments (r:0.61) to the common associations of this element with organic matter (adsorption, complexation; e.g., Nissenbaum and Swaine, 1976; Calvert *et al.*, 1985 or uptake by plankton; Francois, 1988; Pratt and Davis, 1992). Similarly, Hirst (1974) suggested the considerable role of organic matter in the accumulation of heavy metals in the Black Sea sediments due to the formation of humic substances. A significant and positive correlation is also obtained between organic carbon and zinc concentration in this study (r:0.56; Table 4.1; Figure 4.39).

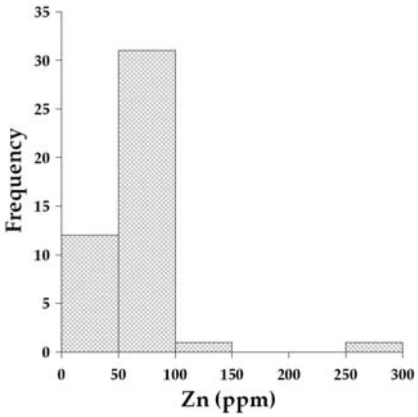


Figure 4. 36 Frequency histograms of Zn concentrations of surface sediments

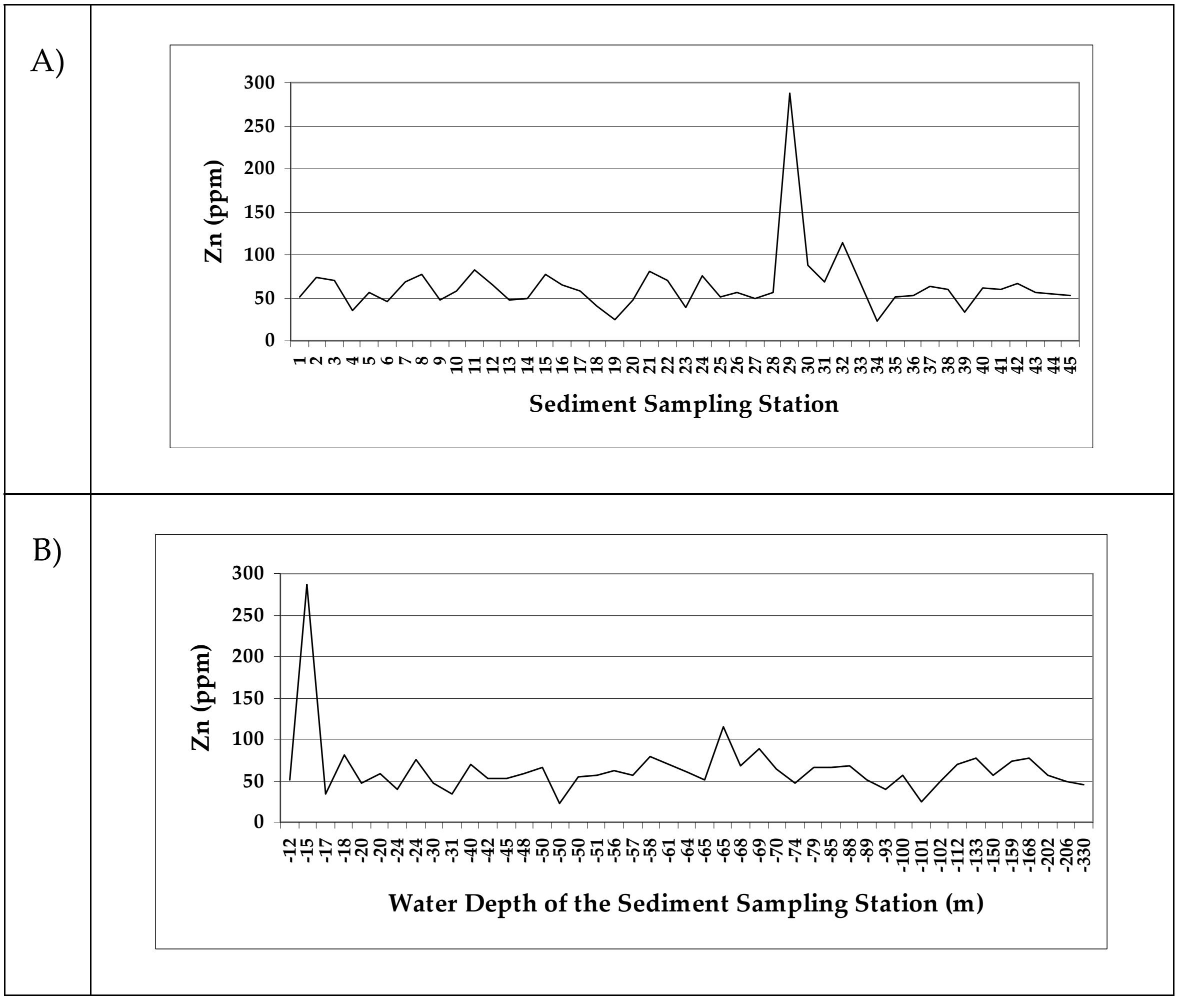


Figure 4. 37 Zn concentrations of the surface sediments collected from the northeastern Mediterranean (A) from west to east, (B) from coast to offshore

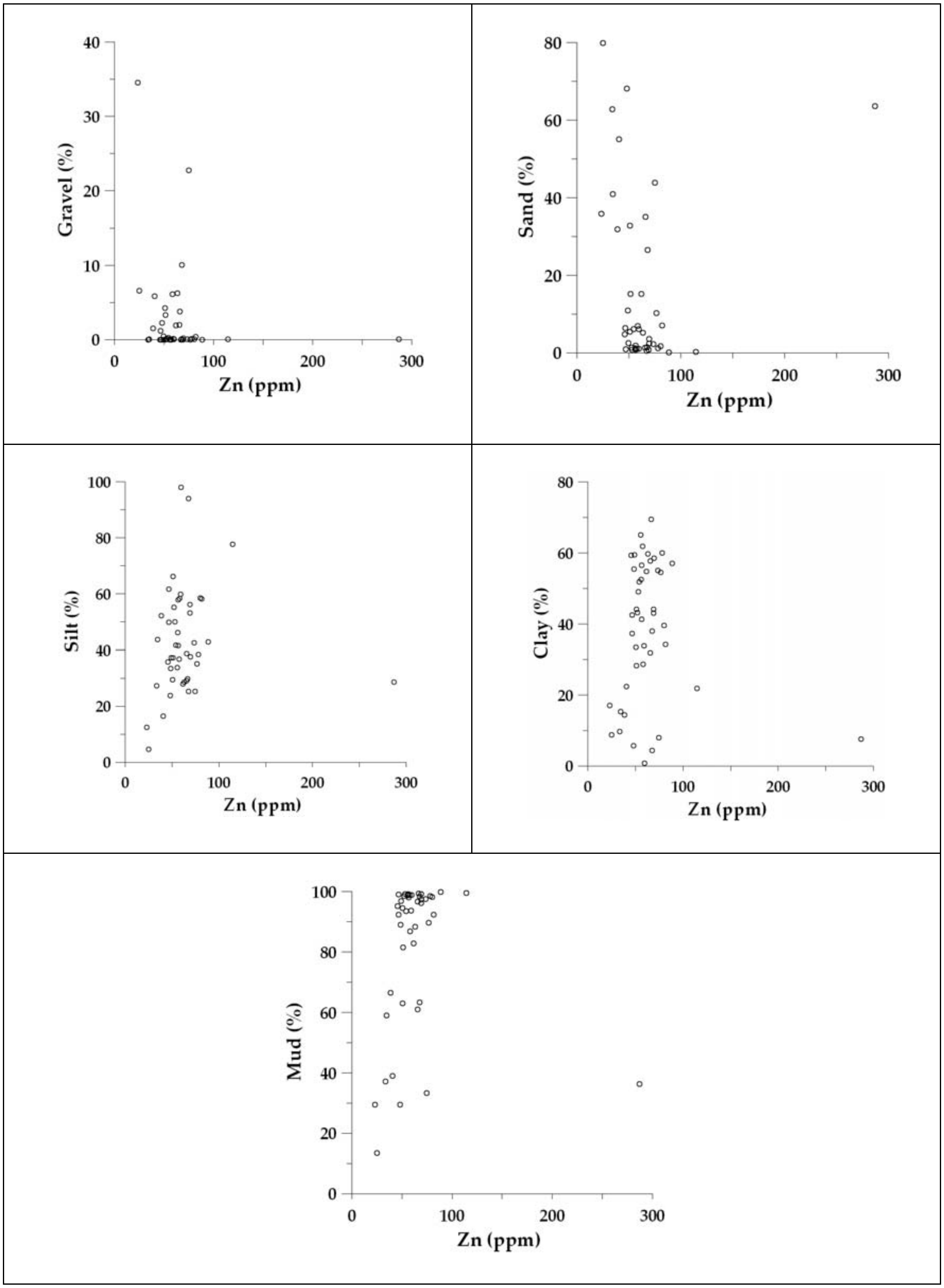


Figure 4. 38 Plot of the Zn concentrations versus various grain size fractions of the surface sediments

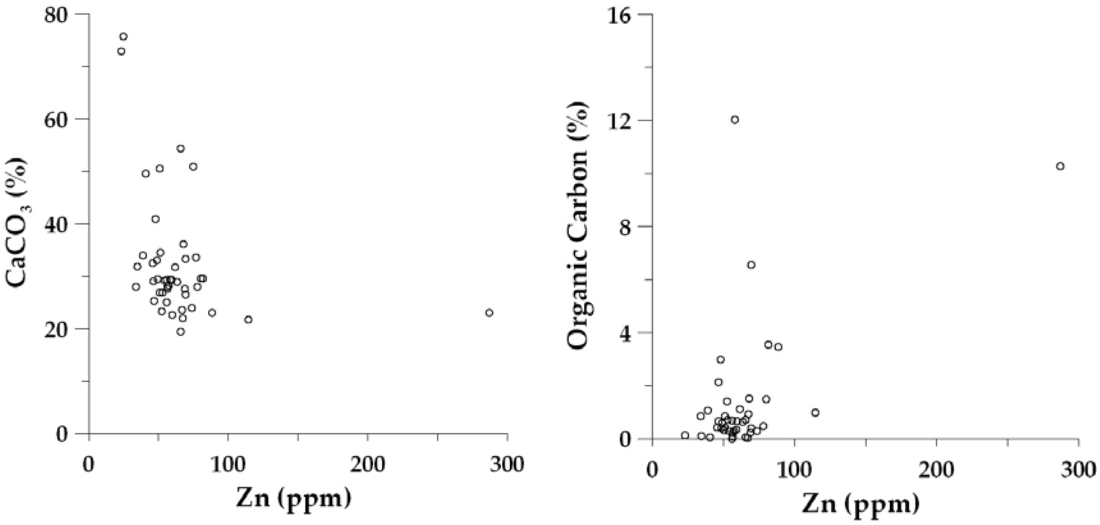
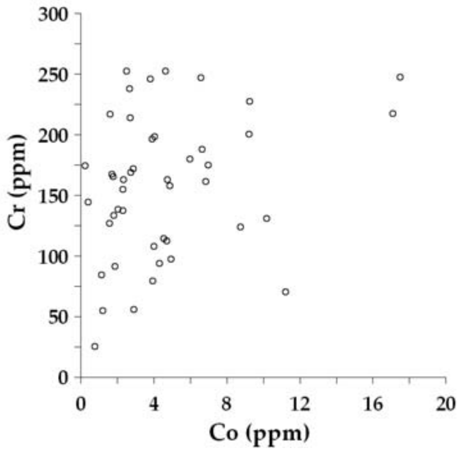
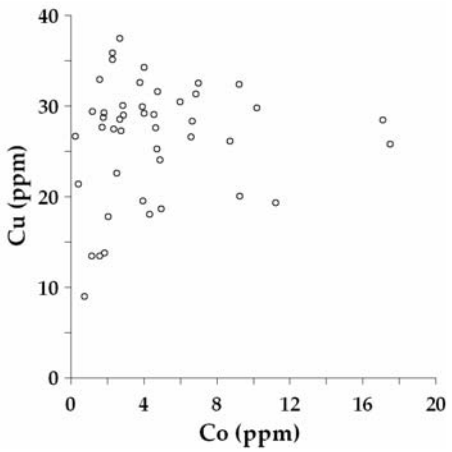


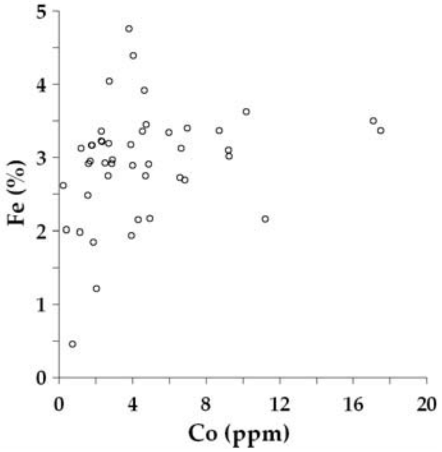
Figure 4. 39 Plot of the Co concentrations versus $CaCO_3$ and organic carbon contents of the surface sediments

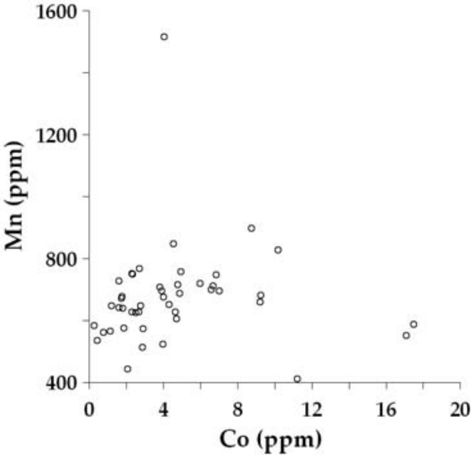
4.5. RELATIONSHIPS AMONG THE STUDIED HEAVY METALS AND REGIONAL COMPARISONS

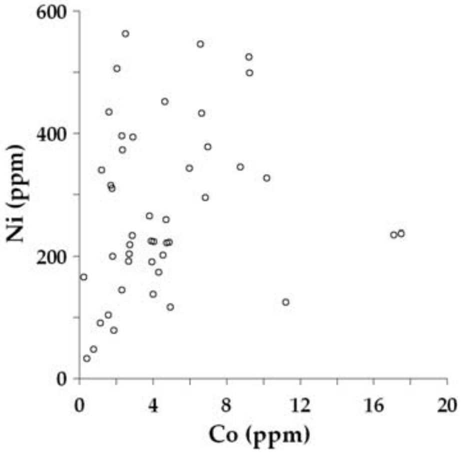
It has been found that there exist significant and positive correlations among the concentrations of several heavy metal pairs such as Cr-Ni (r:0.50), Cr-Fe (r:0.57), Cr-Cu (r:0.48), Cu-Mn (r:0.38), Cu-Ni (r:0.34), Cu-Fe (r:0.77), Fe-Mn (r:0.52), Fe-Ni (r:0.30), Ni-Co (r:0.34) (Table 4.1). However, Zn shows no considerable correlationship with other heavy metals. The plots of the concentrations of the studied heavy metals versus each other are given in (Figure 4.40).

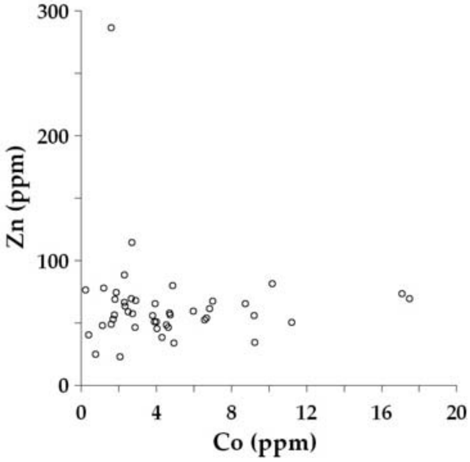

Cr (ppm)
0
50
100
150
200
250
300
0
4
8
12
16
20
Co (ppm)


Cu (ppm)
0
10
20
30
40
0
4
8
12
16
20
Co (ppm)


Fe (%)
0
1
2
3
4
5
0
4
8
12
16
20
Co (ppm)


Mn (ppm)
400
800
1200
1600
0
4
8
12
16
20
Co (ppm)


Ni (ppm)
0
200
400
600
0
4
8
12
16
20
Co (ppm)


Zn (ppm)
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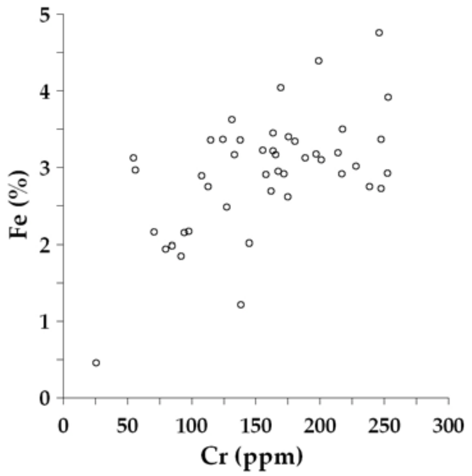
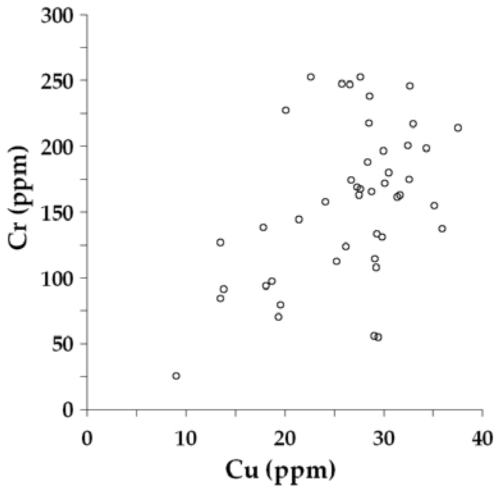
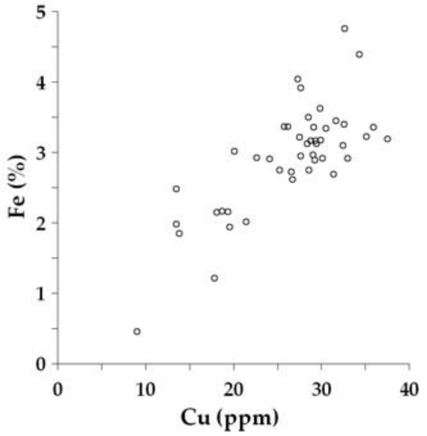
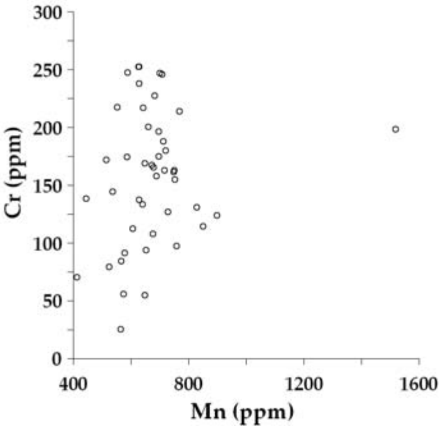
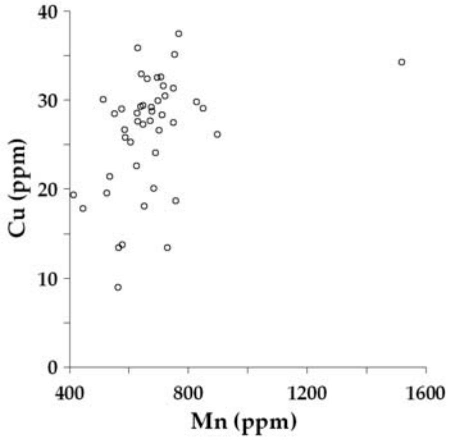
100
200
300
0
4
8
12
16
20
Co (ppm)

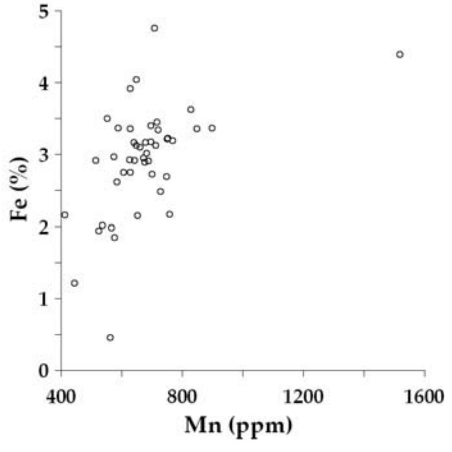

Fe (%)
Cr (ppm)
0
1
2
3
4
5
0
50
100
150
200
250
300

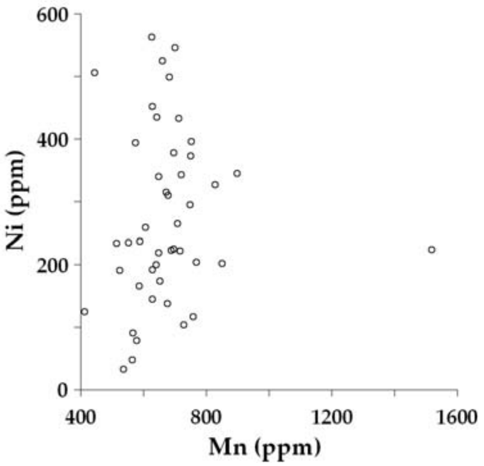

Cr (ppm)
Cu (ppm)
0
50
100
150
200
250
300
0
10
20
30
40

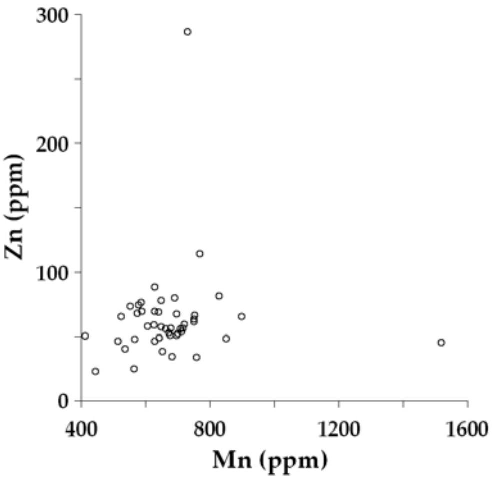

Fe (%)
Cu (ppm)
0
1
2
3
4
5
0
10
20
30
40

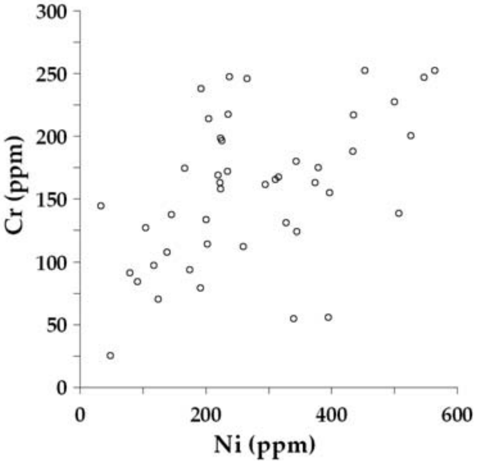

Cr (ppm)
Mn (ppm)
0
50
100
150
200
250
300
400
800
1200
1600

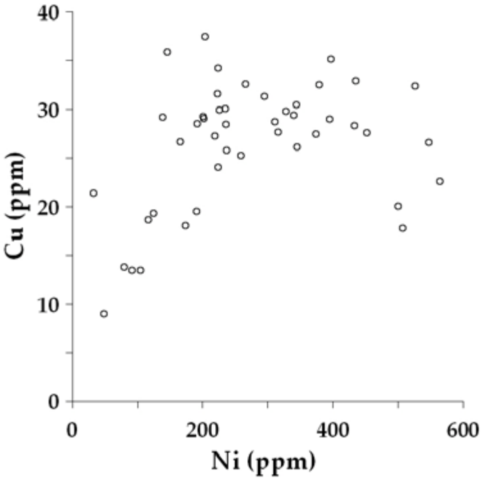

Cu (ppm)
Mn (ppm)
0
10
20
30
40
400
800
1200
1600

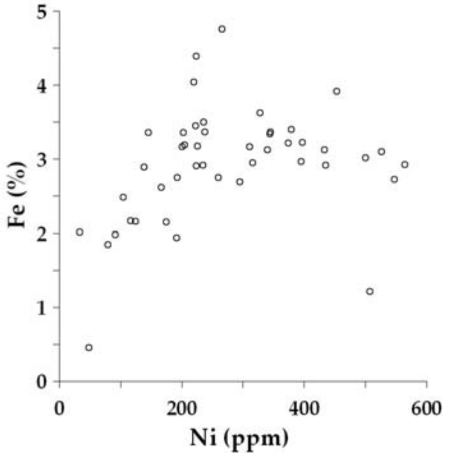

Fe (%)
Mn (ppm)
0
1
2
3
4
5
400
800
1200
1600

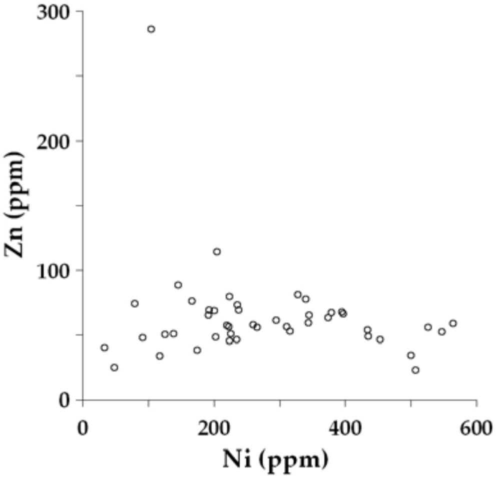

600
400
200
0
Ni (ppm)
400
800
1200
1600
Mn (ppm)


300
200
100
0
Zn (ppm)
400
800
1200
1600
Mn (ppm)


300
250
200
150
100
50
0
Cr (ppm)
0
200
400
600
Ni (ppm)


40
30
20
10
0
Cu (ppm)
0
200
400
600
Ni (ppm)


5
4
3
2
1
0
Fe (%)
0
200
400
600
Ni (ppm)


300
200
100
0
Zn (ppm)
0
200
400
600
Ni (ppm)

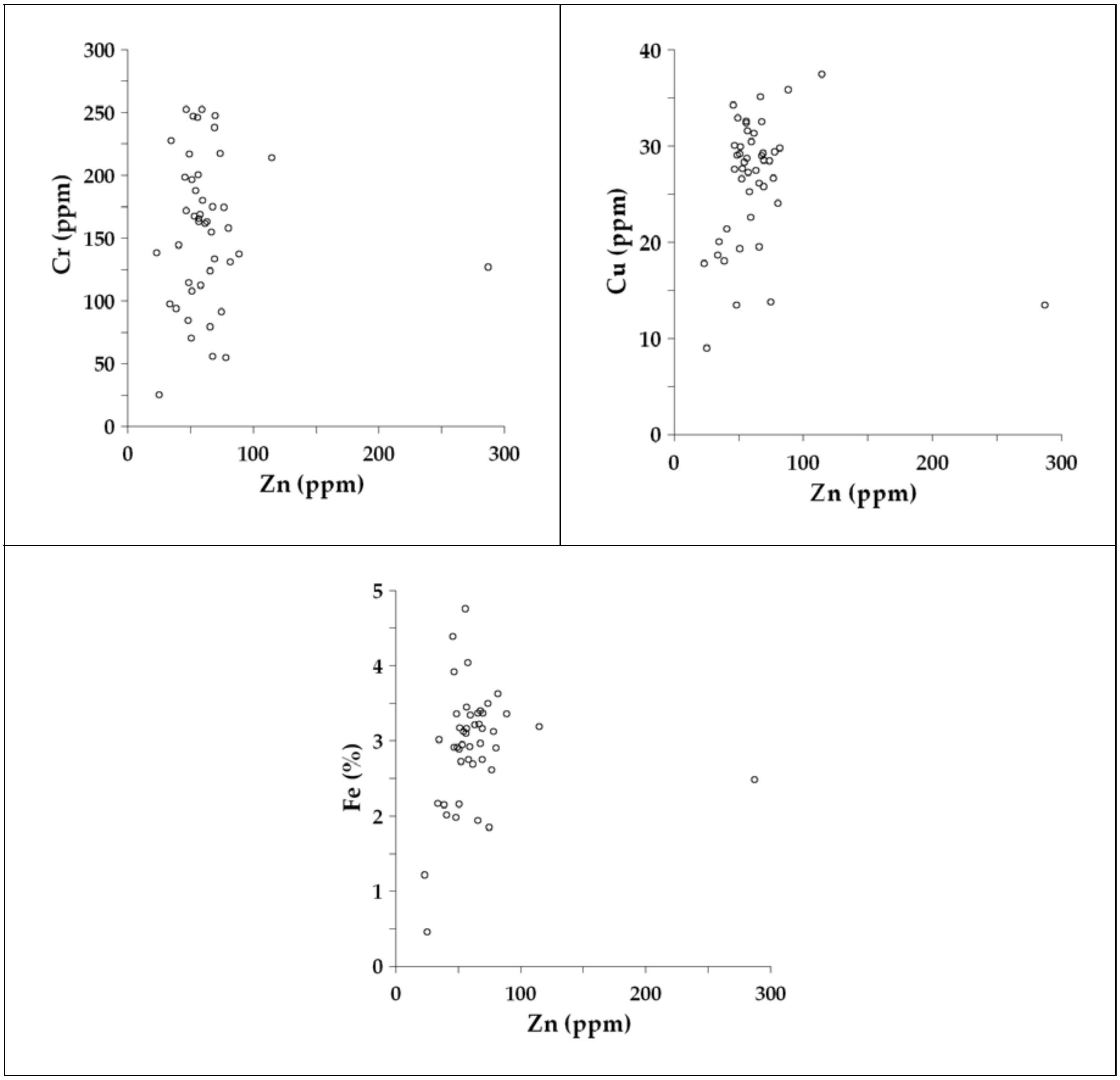


Figure 4. 40 Plots of the concentrations of the studied heavy metals versus each

The calculated correlation coefficient values suggest that there are significant correlations between Fe and Mn (r:0.52) and Cu (r:0.77) in clay-sized fractions (Table 4.1). It is very common that the Mn (together with Fe) is mostly present in oxides and hydroxides and related with the clay minerals (Ergin *et al.*, 1993). Relatively low Mn and Cu concentrations of sediments are probably linked with the decreasing Fe contents. The distributions of the Mn/Fe and Cu/Fe ratios show a significant regional trend along the study area (Figure 4.41). However, with respect to Mn and Cu, there is a relatively high decrease in Fe contents of the coarse-grained sediment patches in the northeastern Mediterranean. This shows the considerable dilution effect of the high amount biogenic carbonate contents on Fe concentrations.

As has also been observed in Turkish coastal sediments (Hirst, 1974; Shaw and Bush, 1978; Ergin *et al.*, 1988; Bodur, 1991; Yücesoy and Ergin, 1992; Kazan, 1994), the distribution pattern of Cr and Ni shows major similarities. The enrichments of these metals in studied sediments mainly related with the weathering products of the mafic-ultramafic rocks on land. Cr/Ni ratios of the northeastern Mediterranean sediments show a significant regional trend along the study area (Figure 4.42).

In most cases, Cr and Ni show correspondence with the Fe, Cu and mud contents of the sediments. The distribution of the Cr/Fe and Cr/Cu ratios represent almost similar patterns (Figure 4.43). The considerable amounts of Cr and Ni are associated with Fe and Mn, especially in the fine-grained sediments. The relationships among these variables are interpreted that, whatever the sources of the Cr and Ni, it is closely associated with the Fe and Cu in the fine-grained fractions of the sediments.

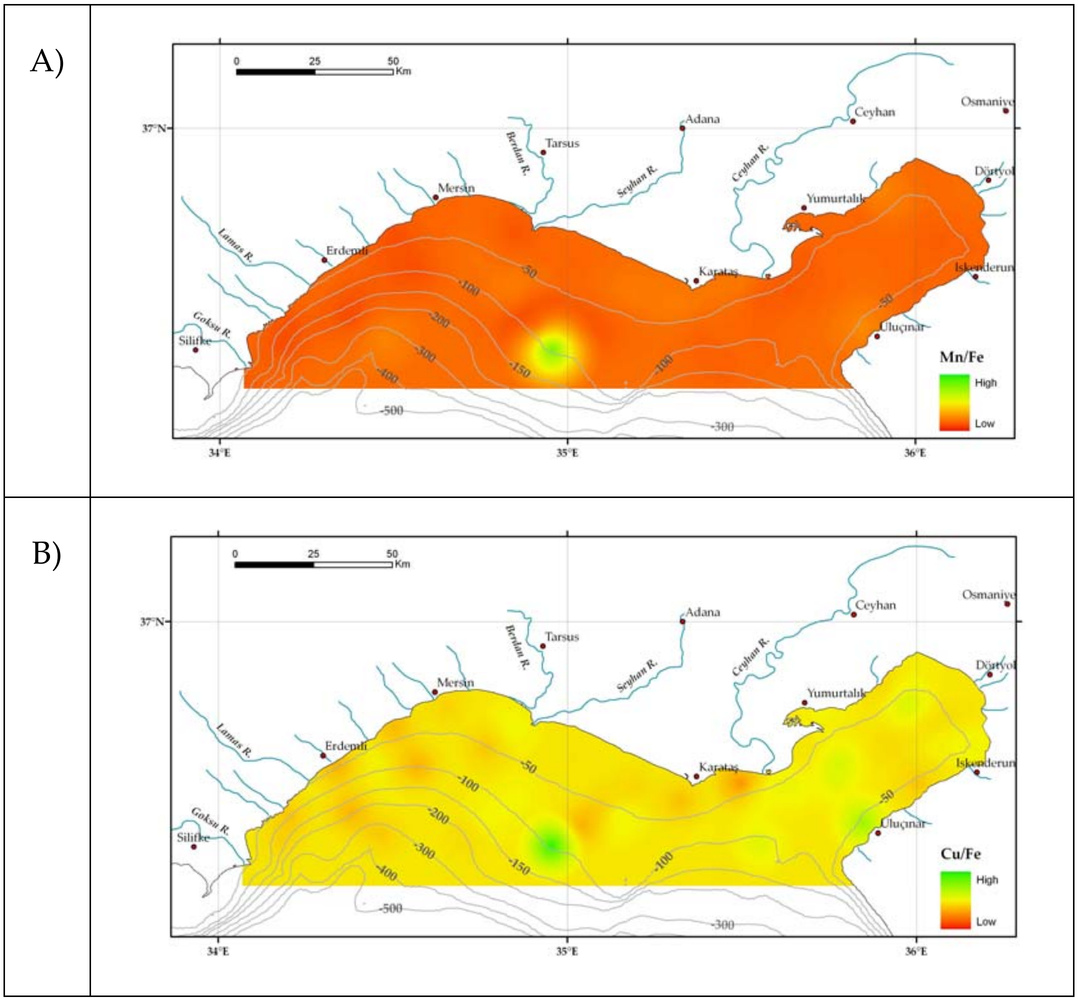


Figure 4. 41 The distributions of the A) Mn/Fe and B) Cu/Fe ratios

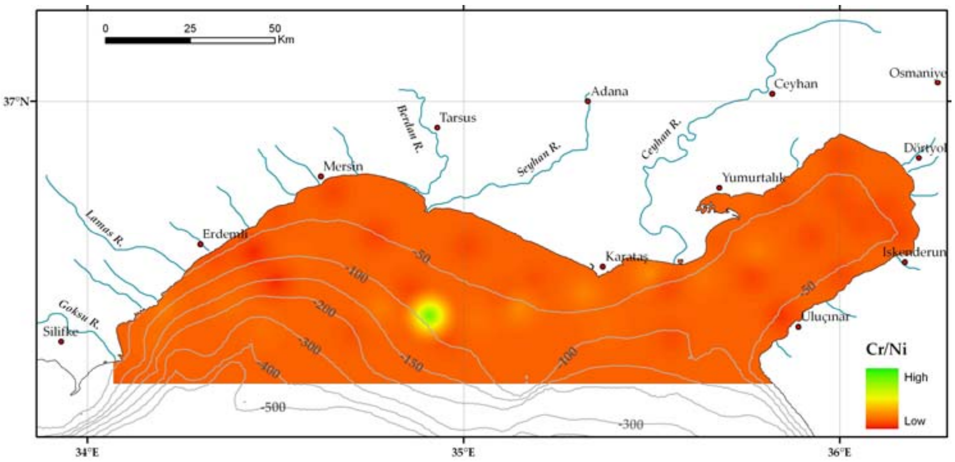


Figure 4. 42 The distributions of the Cr/Ni ratios

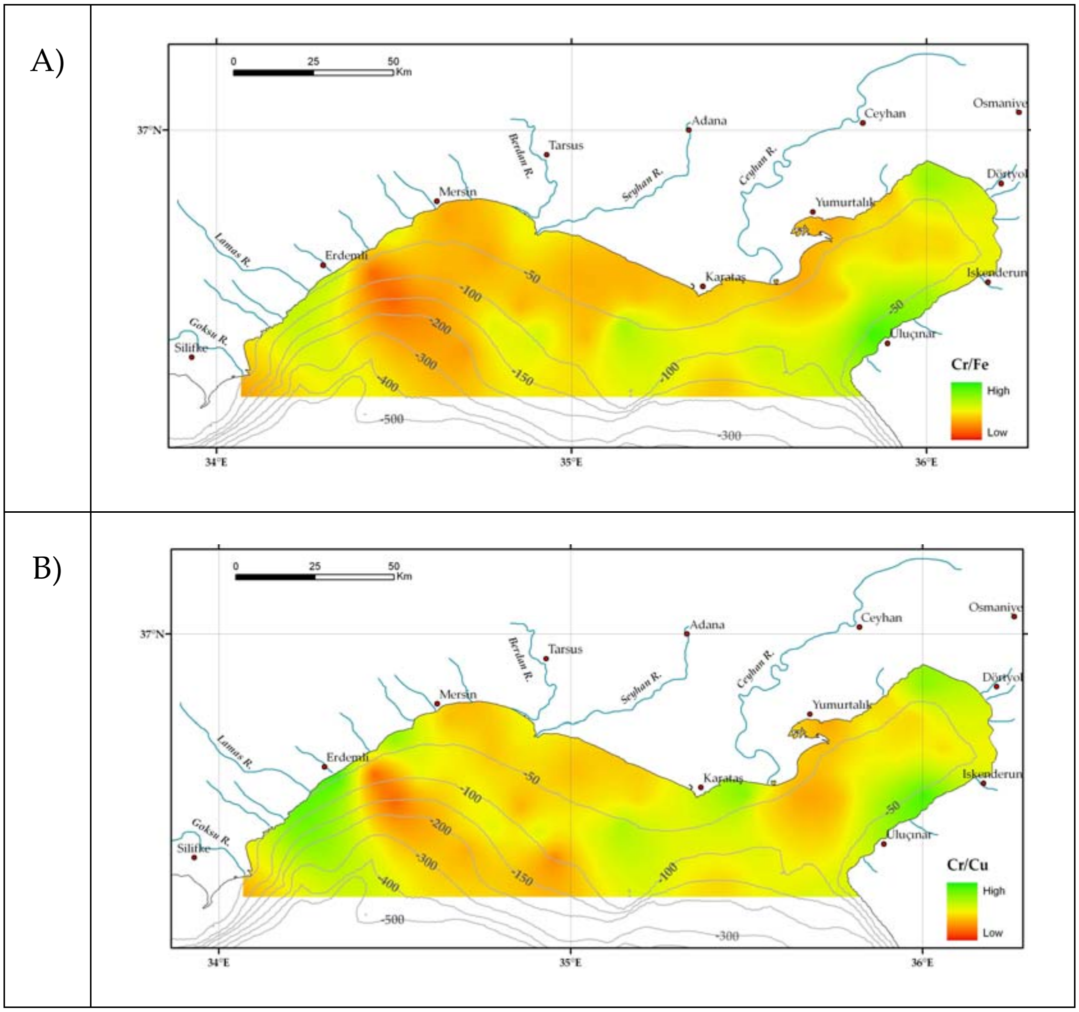


Figure 4. 43 The distributions of the A) Cr/Fe and B) Cr/Cu ratios

In comparison with the average concentrations of Mersin Bay sediments obtained in this study, Iskenderun Bay sediments are generally similar in their heavy metal concentrations (Table 4.2) and the deviations from them suggest differences in the types and amounts of the lithogenic and biogenic materials. Furthermore, these values are well coinciding with the previous studies carried on the northeastern Mediterranean (Mersin and İskenderun Bays) sediments (Table 4.2). However, Co concentrations obtain by Ergin et al. (1996) in İskenderun Bay are slightly higher than Co values found in this study. Similarly, Fe, Ni and Cr are more abundant in Mersin Bay sediments according to the studies carried by Shaw and Bush (1978).

Regional comparisons indicate that heavy metal concentrations obtained in this study show significant similarities when compared with the heavy metal concentrations of Turkish coastal sediments (Table 4.2). Especially, Fe, Mn, Cu and Zn concentrations of the northeastern Mediterranean surface sediments are almost at same values with the concentrations obtained in Aegean, Marmara and Black Sea shelf sediments. However, due to the presence of high terrigenic input originated from basic and ultrabasic rocks and related Cr deposits surrounding the regions, Cr and Ni contents of the northeastern Mediterranean and Aegean surface sediments are markedly higher than those found in Black Sea shelf sediments.

5. CONCLUSION

A wide variety of sediment samples are collected at fourty-five sampling points from the northeastern Mediterranean Sea and studied respect to sedimentological and geochemical properties to clarify the origin of the surface sediments and to indicate the factors controlling the heavy metal distribution in the light of prevailing physical, chemical, biological and geological processes.

The recent sediments of the northeastern Mediterranean are composed of various sediment textures ranging from mud to gravelly mud. The general grain size distribution pattern of the surface sediments mainly acquire a shape depending on the irregular bottom topography of the region and various terrigenic inputs carried by perennial rivers. The complex wave and current system including local eddies and coastal filaments is the other important factors controlling the grain size composition of the sediments.

The surface sediments are dominantly characterized by their relatively high mud contents with varying silt and clay fractions. The total proportion of the coarse-grained fractions is less than 10% in most sediment. However, due to the presence of high amounts of benthic organism remains, the coarse-grained sediment patches which are mainly represented by sand size material occur in the study area.

Generally, the $CaCO_3$ contents are less than 40% in the surface sediments and show significant correlations with the grain size fractions. The swiping effect of the wind-generated coastal filaments plays an important role on the general

$CaCO_3$ distribution pattern of the Mersin Bay sediments. Low carbonate contents obtained in the Mersin Bay sediments are associated with the movement effect of the prevailing current regime on the siliciclastic materials carried by perennial and ephemeral rivers. High amounts of biogenic material accumulated in the coarse-grained sediment patches of the studied area causes the high carbonate concentrations in these sediments.

Total organic carbon contents of the northeastern Mediterranean sediments mostly indicate the normal marine production and hydrographically-related deposition. However, the coastal sediments of the eastern Mersin Bay, from Mersin City to the west of Ceyhan River Delta, contain relatively high organic carbon. This enrichment is mainly related to the discharge of the contaminated waters carried by Berdan, Seyhan and Ceyhan which are affected by increasingly developing industrial and agricultural complexes. There exist insignificant correlation between the grain size fractions, organic carbon and carbonate contents of the sediments. However, the variations in the organic carbon concentrations show a close relationship with the changes in the depth of the sampling stations.

In general, the variations in the heavy metal contents of the northeastern Mediterranean recent sediments can be satisfactorily explained in terms of the variations in texture (fine-grained or coarse-grained) or genetic type (terrigenous or biogeneous dominance) of the sediments. Furthermore, the heavy metal concentrations were affected by both geological and anthropogenic contributions.

The Fe, Mn, Cu, Zn and Co concentrations obtained in this study indicate consistency with the average distribution of these elements in the earth`s crust. However, the Ni and Cr concentrations are noticeably high when compared with their crustal abundances. These high values mostly conform to the average composition of the igneous rocks on the surrounding land.

It appears that the source of Fe, Mn, Cu, Co and mostly Zn in the northeastern Mediterranean sediments is primarily weathering of average crustal rocks. However, there exist local anomalies for the concentrations of the heavy metals in the northeastern Mediterranean sediments. Low heavy metal contents generally show close correlations with the high $CaCO_3$ contents of the sediments. This suggests the considerable dilution effect of the coarse-grained carbonate components on the measured element concentrations in the sediments. Furthermore, the high amounts of siliciclastic material carried by rivers cause a masking effect on the heavy metal concentrations of the coastal sediments, especially the Seyhan-Berdan deltaic sediments.

The local metal enrichments are mostly associated with the intense anthropogenic inputs carried by rivers such as industrial and domestic waste disposal. The positive and significant correlation between Zn and organic carbon contents shows that whatever the sources of the Zn, it is closely associated with the organic matter in the surface sediments. The distribution patterns of Cr and Ni show major similarities along the study area. The enrichment of these elements, especially in the coastal sediments, suggests that the distribution of these elements is mainly controlled by the weathering of the ultrabasic-basic rock series and associated ore deposits in the Taurus and Amanous Mountains.

REFERENCES

Abu-Hilal, A.H., Badran, M.M., 1990. Effect of pollution sources on metal concentration in sediments core from the Gulf of Aqaba (Red Sea). Marine Pollution Bulletin, 21 (4), 190 – 197.

Aksu, A.E., Uluğ, A., Piper, D.J.W., Konuk, Y.T., Turgut, S., 1992a. Quaternary sedimentary history of Adana, Cilicia and İskenderun Basins: northeast Mediterranean Sea. Marine Geology, 104, 55 – 71 pp.

Aksu, A.E., Calon, T., Piper, D.W.J., Turgut, S., Izdar, E., 1992b. Architecture of later orogenic Quaternary basins in northeastern Mediterranean Sea. Tectonophysics, 210, 191 – 213 pp.

Aksu, A.E., Hall, J., Yaltırak, C., 2005a. Miocene to recent tectonic evolution of the eastern Mediterranean: New pieces of the old Mediterranean puzzle. Marine Geology, 221, 1 – 13 pp.

Aksu, A.E., Calon, T.J., Hall, J., Yaşar, D., 2005b. Origin and evolution of the Neogene Iskenderun Basin, northeastern Mediterranean Sea. Marine Geology, 221, 161 – 187 pp.

Aksu, A.E., Calon, T.J., Hall, J., Mansfield, S., Yaşar, D., 2005c. The Cilicia – Adana basin complex, eastern Mediterranean: Neogene evolution of an active fore-arc basin in an obliquely convergent margin. Marine Geology, 221, 121 – 159.

Aslaner, M., 1973. Geology and petrography of the ophiolites in the Iskenderun

– Kirikhan region. Publ. Min. Res. Explor. Inst., Ankara, 50, 71 pp.

Ataktürk, S.S., 1980. Atmospheric variability and air – sea interactions in the northern margins of Cilicia Basin. M.Sc. thesis, Department of Marine Science, METU, İçel, Turkey, 84 pp.

Bal, Y. and Demirkol, C., 1987. Coastline changes in Eastern Mediterranean, Turkey. Earth Science Rewiev Engineering Facility, İstanbul University, 6, 69 – 91 pp.

Balkas, T.I., Tuğrul, S., Salihoğlu, İ., 1982. Trace metal levels in fish and crustacea from northeastern mediterranean coastal waters. Marine Environmental Research, 6, 281 – 289.

Biji-Duval, B., Dercourt, J., Le Pichon, X., 1977. From the Tethys Ocean to the Mediterranean Sea: a plate tectonic model of the evolution of the western Alpine system. In: B. Biji-Duval and L. Montadert (Editors), International Symposium on the Structural History of the Mediterranean Basins. Split, Yugoslavia, 25 – 29 October 1976, Editions Technip, Paris, pp. 143 – 164.

Bodur, M.N. and Ergin, M., 1988. Heavy metal associations in recent inshore sediments from the Mersin Bay, Turkey. Bolletino Di Oceanologia Teorica Ed Applicata, Vol VI, 15 – 34 pp.

Bodur, M.N., 1991. Sedimentology and geochemistry of the Late-Holocene sediments from the sea of Marmara and its strait. P.hd. Thesis, METU, Institute of Marine Sciences, Erdemli – İçel, TÜRKİYE, 248 p.

Bodur, M.N. and Ergin, M., 1992. Holocene sedimentation patterns and bedforms in the wave-current-dominated nearshore waters of eastern Mersin Bay (eastern Mediterranean). Marine Geology, 108, 73 – 93.

Bodur, M.N., Ergin, M., 1994. Geochemical characteristics of the recent sediments from the Sea of Marmara. Chem. Geol., 115, 73 – 101.

Bruland, K. W., 1980. Oceanographic distribution of cadmium, zinc, nickel and copper in the North Pacific. Earth Planet Sci. Letter, 47: 176-198.

Bruland, K. W., 1983. Trace elements in seawater. In: Chemical Oceanography (Riley, J. P. And Chester, R. Ed) Academic Press, New York, 8:157-221.

Burton, J. D., Stratham, P. J., 1988. Trace metals as tracers in the ocean. Phil. Trans. R. Soc. Lon., 325: 127-145.

Burton-Ferguson, R., Aksu, A.E., Calon, T.J., Hall, J., 2005. Seismic stratigraphy and structural evolution of the Adana Basin, eastern Mediterranean. Marine Geology, 221, 189 – 222.

Calvert, S.E., Mukherjee, S., and Morris, R.J., 1985. Trace metals in humic and fulvic acids from modern organic-rich sediments. Oceanol. Acta, Vol 8, pp 167 – 173.

Calvert, S.E., Pedersen, T.F., 1993. Geochemistry of recent oxic and anoxic marine sediments: Implications for the geological record. Mar. Geol. 113: 67-88.

Collins, M.B., Banner, F.T., 1979. Secchi disc depths; suspensions and circulation, North-Eastern Mediterranean Sea. Marine Geology, 31, M39 – M46.

Çağatay, N., Saltoğlu, T., Gedik, A., 1987. Karadeniz`in güncel çökellerinin jeokimyası (Geochemistry of the recent Black Sea sediments). T.M.M.O.B. Jeol. Müh. Dergisi, 30 – 31, 47 – 64 pp.

Çağatay, N., Yiğitbaş, E., Güney, A., 2002. Mersin – Tarsus arasındaki bölgede yer alan alüvyonda ve sahil kumlarında kromit minerali dağılımı, miktarı ve kökeninin araştırılması projesi raporu. İTÜ Maden Fakültesi, 33 pages.

Çağatay, N., 2007. Marmara Denizi çökel jeokimyası atlası. TÜBİTAK Raporu No: 103Y053, İTÜ – Doğu Akdeniz Deniz ve Göl Araştırma Merkezi, 81 pp.

Çelik, U., Oehlenschlager, J., 2005. Zinc and copper content in marine fish samples collected from the eastern Mediterranean Sea. Eur. Food Res. Technol., 220, 37 -41.

Dewey, J.F., Hempton, M.R., Kidd, W.S.F., Şaroğlu, F., Şengör, A.M.C., 1986. Shortening of continental lithosphere: the neotectonics of eastern Anatolia – a young collision zone. In Coward, M.P. Ries, A.C. (Eds.), Collision Tectonics, Geological Society Special Publication, vol. 19, 3 – 36 pp.

Ediger, V., 1991. Recent sedimentology and Holocene evolution of the western shelf of the Mersin Bay (NE – Mediterranean Sea), PhD Thesis, Institute of Marine Sciences, METU, Erdemli, İçel, Turkey, 170 p.

Ediger, V., Evans, G., Ergin, M., 1997. Recent surficial shelf sediments of the Cilicia Basin (Turkey), northeastern Mediterranean. Continental Shelf Research, Vol. 17, No. 13, pp. 1659 – 1677.

Ediger, V., Velegrakis, A.F., Evans, G., 2002. Upper slope sediment waves in the Cilicia Basin, northeastern Mediterranean. Marine Geology, 192, 321 – 333.

Ediger, V. and Evans, G., 2007. Surficial sediments of the Cilicia – Adana Basin (northeastern Mediterranean) and factors controlling deposition. (submitted to Sedimentology in 2007)

EIE, Elektrik İşleri Etüd İdaresi Genel Direktörlüğü, 1984. 1981 water year discharge, 304 pp.

EIE, Elektrik İşleri Etüd İdaresi Genel Direktörlüğü, 2003. 2000 water year discharge, 316 pp.

Emelyanov, E.M., 1972. Principal types of recent bottom sediments in the Mediterranean Sea – Their mineralogy and geochemistry. In: D.J. Stanley (Editor), The Mediterranean Sea – A natural sedimentation labaratory. Dowden, Hutchinson and Ross, Stroudsburg, Pa., pp. 355 – 386.

Emelyanov, E.M. and Shimkus, K.M., 1986. Geochemistry and Sedimentology of the Mediterranean Sea. Reidel, Dordrecht, pp. 553.

Emerson, S.R., Huested, S.S, 1991. Ocean anoxia and the concentrations of molybdenum and vanadium in seawater.; Marine Chemistry. Vol. 34, no. 3-4, pp. 177-196. 1991.

Erendil, M., 1984. Petrology and structure of the upper crustal units of the Kızıldağ ophiolite. In Geology of the Taurus Belt Proceedings, edited by Tekeli O., and Göncüoğlu M.C., pp. 269 – 284.

Erinç, S., 1978. Changes in the physical environment in Turkey since the end of the last glacial. The Environmental History of the Near and Middle East since the Last Ice Age. Academic Press, London, 87 – 110 pp.

Ergin, M., Alavi, S.N., Bodur, M.N., Ediger, V., and Okyar, M., 1988. A review of the geology and geochemistry of the northeastern Mediterranean basins. Middle East Tech. Univ., Inst. Mar. Sci., Erdemli, İçel, 145 pp.

Ergin, M., Ediger, V., Bodur, M.N. and Okyar, M., 1990. A preliminary study of the principal recent sediment types along the eastern margin of the Aegean Sea. Rapp. Comm. Int. Mer Mediterr., 32 (1): 103.

Ergin, M., Saydam, C., Baştürk, Ö., Erdem, E., Yörük, R., 1991. Heavy metal concentrations in surface sediments from the two coastal inlets (Golden Horn Estuary and Izmit Bay) of the northeastern Sea of Marmara. Chemical Geology 91, 269 – 285.

Ergin, M., Okyar, M., Timur, K., 1992. Seismic stratigraphy and late Quaternary sediments in inner and mid-shelf of eastern Mersin Bay, Northeastern Mediterranean Sea. Marine Geology, 104, 73 – 91 pp.

Ergin, M., Bodur, M.N., Ediger, V., Yemenicioğlu, S., Okyar, M., Kubilay, N., 1993. Sources and dispersal of heavy metals in surface sediments along the eastern Aegean shelf. Boll. Oceanol. Teor. App., 11(1): 27 – 44.

Ergin, M., Kazan, B., Ediger, V., 1996. Source and depositional controls on heavy metal distribution in marine sediments of the Gulf of İskenderun, Eastern Mediterranean. Marine Geology, 133, 223 – 239 pp.

Ergin, M., Yemenicioğlu, S., 1997. Geological assessment of environmental impact in bottom sediments of the eastern Aegean Sea. Intern. J. Environmental Studies, 51, 323 – 334 pp.

Ergin, M., Kazan, B., Yücesoy – Eryılmaz, F., Eryılmaz, M., Okyar, M., 1998. Hydrographic, deltaic and benthogenic controls of sediment dispersal in the Gulf of İskenderun, SE Turkey (E. Mediterranean). Estuarine, Coastal and Shelf Science, 46, 493 – 502 pp.

Ergin, M., Aktar, M., Eyidoğan, H., 2004. Present-day seismicity and seismotectonics of the Cilicia Basin: Eastern Mediterranean Region of Turkey. Bulletin of the Seismological Society of America, Vol. 94, No. 3, pp. 930 – 939.

Ergün, M., Oral, E.Z., 2000. Doğu Akdeniz`in genel tektonik elementleri ve etkileri. Batı Anadolu`nun depremselliği sempozyumu, BADSEM-2000, Bildiriler, 20 – 29, İzmir.

Evans, G., 1971. The recent sedimentation of Turkey and the adjacent Mediterranean and Black Seas: A review. In Campbell, A.S. (Ed.), Geology and History of Turkey, Petr. Expl. Soc., Libya, Tripoli., 385 – 406 pp.

Evans, G., Erten, H., Alavi, S.N., Von Gunten, H.R. and Ergin, M., 1989. Superficial deep-water sediments of the eastern Marmara basin. Geo-Marine Letters, 9, 27-36.

Evans, G., Lane-Serff, G.F., Collins, M.B., Ediger, V., Pattiaratchi, C.B., 1995. Frontal instabilities and suspended sediment dispersal over the shelf of the Cilician Basin, southern Turkey. Marine Geology, 128, 127 – 136.

Folk, R.L., 1974. Petrology of Sedimentary Rocks. Hemphill Publishing Company, Austin, Texas, 184 pp.

Förstner, U., Reineck, H.E., 1974. Die Anreicherung von Spurenelementen in den Rezenten Sedimenten eines Profilkerns aus der Deutschen Bucht. Senckenbergiana Maritima 6, 175 – 184.

Francois, R., 1988. A study on the regulation of the concentrations of some trace metals (Rb, Sr, Zn, Pb, Cu, V, Cr, Ni, Mn and Mo) in Saanich Inlet, British Columbia, Canada. Mar. Geol., Vol 83, pp 285 – 308.

Fukushima, K., Saino, T., Kodama, Y., 1990. Trace metal contamination in Tokyo Bay, Japan. Sci. Total Env. 125, 373 – 389.

Garfunkel, Z., 1998. Constrains on the origin and history of the eastern Mediterranean basins. Tectonophysics, 298, 5 – 35.

Garfunkel, Z., 2004. Origin of the eastern Mediterranean basin: a reevolution, Tectonophysics, 391, 11 – 34.

Görür, N., 1985. Depositional history of Miocene sediments of NW flank of Adana Basin. In: E. Izdar and E. Nakoman (Editors). Sixth Colloquium on Geology of the Aegean Region. Dokuz Eylül University, Inst. Mar. Sci. Technol., Piri Reis Int. Contrib. Ser., 2: 185 – 208.

Grant, A., Middleton, R., 1990. An assessment of metal contamination of sediments in the Humber Estuary, U.K. Estuarine Coastal and Shelf Science, 31 (1), 71 – 85.

Hancock, P.L., Barka, A.A., 1981. Opposed shear senses inferred from neotectonic mesofractures systems in the North Anatolian fault zone. J. Structure Geology. 3, 383 – 392 pp.

Hastings, D.W., 1994. Vanadium in the Ocean: A Marine Mass Balance and Paleoseawater Record. Ph.D. thesis, University of Washington.

Hecht, A., 1986. The hydrology and the water masses of the Eastern Mediterranean Sea, In: Proceedings of a UNESCO/IOC First Poem Workshop, Erdemli – İçel, Turkey, 1986. Part 2, A.R. Robinson and Malanotte – Rizzoli editors, POEM Scientific Reports No:1, Cambridge, Mass.

Hedges, J.I. and Keil, R.G., 1995. Sedimentary organic matter preservation: An assessment and speculative synthesis. Marine Chemistry. 49, pp: 81 – 115.

Hirst, D.M., 1974. Geochemistry of sediments from eleven Black Sea cores. In: E.T. Degens and D.A. Ross (Editors), The Black Sea – Geology – Chemistry – Biology. Am. Assoc. Pet. Geol., Mem. No. 20, pp. 430 – 455.

İyiduvar, Ö., 1986. Hydrographic characteristics of İskenderun Bay. M.Sc Thesis, Institute of Marine Sciences, METU, Erdemli, İçel, Turkey, 157 pp.

Jongsma, D., van Hinte, J.E., Woodside, J.M., 1985. Geological structure and neotectonics of the north African continental margin south of Sicily. Mar. Pet. Geol., 2, 156 – 179 pp.

Jonsma, D., Woodside, J.M., King, G.C.P., van Hinte, J.E., 1987. The Medina Wrench: a key to the kinematics of the central and eastern Mediterranean over the past 5 Ma. Earth Planet. Sci. Lett. 82, 87 – 106 pp.

Kalay, M., Koyuncu, C.E., Dönmez, A.E., 2004. Mersin Körfezi`nde yakalanan Sparus aurata (L.1758) ve Mullus barbutus (L. 1758)`un kas ve karaciğer dokularındaki kadmiyum düzeylerinin karşılaştırılması. Ekoloji, 13, 52, 23 – 27.

Kapur, S., Gökçen, S.L., Saydam, C., Şenol, M., Senol, S., Karaman, C., 1989. The clay mineralogy and geochemistry of the recent surface sediments of İskenderun Bay as indicators of terrestrial provenance. Z. Geomorph. N. F., Suppl-Bd. 73, 167 – 180 pp.

Kazan, B., 1994. Geochemistry of surface sediments in the gulf of İskenderun, Eastern Mediterranean, M.Sc. Thesis, Institute of Marine Sciences, METU, Erdemli, İçel, Turkey, 146 p.

Kelling, G., Gökçen, S.L., Peter, A.F., Gökçen, N., 1987. Neogene tectonics and plate convergence in the eastern Mediterranean: new data from southern Turkey. Geology, 15, 425 – 429.

Koral, H., Kronfeld, J., Avsar, N., Yanko, V., Vogel, J.C., 2001. Major recent tectonic uplift in İskenderun Bay, Turkey. Radiocarbon, Vol. 43, Nr 2B, p 957 – 963.

Kozlu, H., 1987. Structural development and stratigraphy of the Misis-Andirin region. In: Proceeding of the 7th Petroleum Congress of Turkey. Turkish Association of Petroleum Geologists, 104 – 116.

Krijgsman, W., 2002. The Mediterranean: Mare Nostrum of Earth Sciences. Earth and Planetary Sciences Letter, 205, 1 – 12.

Lacombe, H., Tchernia, P., 1972. Caracteres hyrologiques et circulation des eaux en Mediterranee. In: Stanley, D.J. (Ed.), The Mediterranean Sea: A natural sedimentation laboratory. Dowden Hutchinson and Ross, Inc., Stroudsburg, Pennsylvania, pp. 25 – 36.

Latif, M.A., Özsoy, E., Saydam, C., Ünlüata, Ü., 1989. Oceanografic investigations of the gulf of İskenderun. First Progress Report, METU-IMS, Erdemli, İçel, Turkey, 72 p.

Mange-Rajetzky, M.A., 1983. Sediment dispersal from source to shelf on an active continental margin, S. Turkey. Marine Geology, 52, 1 – 26.

Mascle, J., Benkhelil, J., Bellaiche G., Zitter T., 2000. Loncke, Prismed II Scientific Party, 2000. Marine geological evidence for a Levantine – Sinai plate: a new pieces of the Mediterranean puzzle. Geology, 28, 779 – 782 pp.

Mason, B., Moore, C.B., 1982. Principles of Geochemistry. John Wiley&Sons, New York, 344 pp.

Meteorological Bulletin, 1970. Mersin (İçel) iklimi. Türkiye Cumhuriyeti Tarım Bakanlığı Devlet Meteoroloji İşleri Genel Müdürlüğü Teknik ve Yayın Şubesi Araştırma Servisi (In Turkish), Ankara, Turkey, 9 pp.

Morford, J., Emerson S., 1999. Geochemistry of Redox-sensitive trace metals in sediments, Geochem. Cosmochim. Acta, 63, 1735 - 1750.

Muller, F. L. L., Gulin, S.B., Kalvoy, A., 2001. Chemical speciation of copper and zinc in surface waters of the western Black Sea. Marine Chemistry, 76: 233-251.

Müller, G., 1967. Methods in Sedimentary Petrology. Schweizerbart, Stuttgart, 283 pp.

Murray, J. W., 1975. The interaction of metal ions at manganese dioxide solution interface. Geochim. Et Cosmochim. Acta, 39:505-519.

Murray, J. W., 1979. Iron oxides. In:. Marine minerals: Short course notes (Burns R. G. Ed): Mineralogical Society of America, 6, 47-98.

Murray, J. W., Spell, B., Paul, B., 1983. The contrasting geochemistry of manganese and chromium in the eastern tropical Pacific Ocean. In: Trace Metals in seawater (Wong, C.S. ed), Plenum Press., 643-669.

Nameroff, T.J., Calvert S.E., Murray, J.W., 2004. Glacial-interglacial variability in the eastern tropical North Pacific oxygen minimum zone recorded by redox-sensitive trace metals. Paleoceanography, Vol 19.

Nissenbaum, A., and Swaine, D.J., 1976. Organic matter-metal interactions in recent sediments: The role of humic substances. Geochim. Acta, Vol 40, pp. 809 – 816.

Okyar, M., Ediger, V., 1997. Sea-floor sediments and bedforms around Turkey, revealed by side-scan sonar imagery. Oceanologica Acta, Vol. 20, No.5, 673 – 685.

Okyar, M., Ergin, M., Evans, G., 2005. Seismic stratigraphy of Late Quaternary sediments of western Mersin Bay shelf, (NE Mediterranean Sea). Marine Geology, 220, 113 – 130 pp.

Over, S., Ozden, S., Unlugenc, U.C., Yılmaz, H., 2004. A synthesis: Late Cenozoic stress field distribution at northeastern corner of the Eastern Mediterranean, SE Turkey. Geodynamics, 336, 93 – 103 pp.

Özer, B., Biju-Duval, B., Courrier, P., Letouzey, J., 1974. Geology of Neogene basins of Antalya, Mut and Adana. In: Proceedings of the 3rd Petroleum Congress of Turkey. Turkish Association of Petroleum Geologists, pp. 57 – 84.

Özhan, G., 1988. The North-Eastern Mediterranean Sea, in the lights of marine seismic reflection data. Geological Bulletin of Turkey, V. 31, 51 – 62 pp.

Özsoy, E., 1981. On the atmospheric factors affecting the Levantine Sea. Technical Report No:25, European Centre for Medium Range Weather Forcasts, 29 pp.

Özsoy, E., Hecht, A., and Ü., Ünlüata, 1989. Circulation and Hydrography of the Levantine Basin, Results of POEM Coordinated Experiments 1985/1986, Prog. Oceanogr., bf 22 125-170.

Pampal, S., Kurtman, F., 1984. New data on the Neo-Tethys rifting in the Eastern Taurus region. In Taurus Belt., pp. 217 – 222.

Pedersen, T.F., Shimmield, G.B., Price, N.B., 1992. Lack of enhanced preservation of organic matter in sediments under the oxygen minimum on the Oman Margin. Geochimica Cosmochimica Acta 56, pp 545-551.

Perinçek, D., Eren, A.G., 1990. Origin of the Amik Basin within the strike-slip East Anatolian and Dead Sea fault zones. In: Proceedings of the 8th Petroleum Congress of Turkey. Turkish Association of Petroleum Geologists, pp. 180-192.

Perinçek, D., Çemen, I., 1990. The structural relationship between the East Anatolian and Dead Sea fault zones in southeastern Turkey, Tectonophysics, 172: 331 – 340.

Pinardi, N., Arneri, E., Crise, A., Ravaioli, M., Zavatarelli, M., 2004. The physical and ecological structure and variability of shelf areas in the Mediterranean Sea. The Sea, Vol. 14, Chapter 32, in press.

Pratt, L.M. and Davis, C.L., 1992. Intertwined fates of metals, sulfur and organic carbon in black shales. In:L.M. Pratt, J.B. Comer and S.C. Brassel (edt.), Geochemistry of organic matter in sediments and sedimentary rocks. SEPM Short Course 27, Oklahoma, pp. 1 – 27.

Robertson, A.H.F., Dixon, J.E., 1984. Introduction: aspects of geological evolution of the Eastern Mediterranean. In: J.E. Dixon and A.H.F. Robertson (Editors), The geological evolution of the eastern Mediterranean. Geol. Soc. Spec. Publ., 17: 1 – 74.

Robertson, A.H.F., 1998. Mesozoic – Tertiary tectonic evolution of the easternmost Mediterranean area: integration of marine and land evidence. Proceedings of the Ocean Drilling Program, Scientific Results, Vol. 160, 723 – 782.

Robinson, A.R., Wayne, G.L., Alexander, T., Alex L., 2001. Ocean Currents/Mediterranean Sea Circulation. Academic Press ,19 pp.

Rosenthal, Y., Boyle, E.A., Labeyrie, L., Oppo, D., 1995. Glacial enrichments of authigenic Cd and U in Subanctartic sediments: A climatic control on the elements` oceanic Budget? Paleoceaongraphy, 10: 395 – 413.

Russell, R.J., 1954. Alluvial morphology of Anatolian rivers. Ann. Assoc. Am. Georg., 44, 363 – 391 pp.

Salamon, A., Hofstetter, A., Garfunkel, Z., Hagai, R., 2003. Seismotectonics of the Sinai subplate – eastern Mediterranean region. Geophys. J. Int., 155, 149 – 173 pp.

Sanın, S., Tuncel, G., Gaines, A.F., Balkaş, T.I., 1992. Concentrations and distribution of some major and minor elements in the sediments of the river Göksu and Taşucu Delta, Turkey. Marine Pollution Bulletin, Volume 24, No.3, pp. 167 – 169.

Schmidt, G.C., 1961. Stratigraphic nomenclature for the Adana region petroleum district. VII. Petrol İşleri Genel Müdürlüğü Yayınları, Ankara, No.6 (In Turkish).

Sevim, H.E., 1991. Umweltgeochemische und sedimentologische Unterschungen an Sedimenten der Flüsse Sakarya, Yesilırmak, Ceyhan und Menderes (Türkei) – Geogene anthropogene Einflüsse. Heidelb. Geowiss. Abh., 45, 162 pp.

Shaw, H.F., Bush, P.R., 1978. The mineralogy and geochemistry of the recent surface sediments of the Cilicia Basin, northeastern Mediterranean. Marine Geology, 27, 115 – 136.

Shaw, H.F., Evans, G., 1984. The nature, distribution and origin of a sapropelic layer in sediments of the Cilicia Basin, northeastern Mediterranean. Marine Geology, 61, 1 – 12.

Şengör, A.M.C., Yılmaz, Y., 1981. Tethyan evolution of Turkey: a plate tectonic approach. Tectonophysics, 75, 181 – 241 pp.

Şengör, A.M.C., Görür, N., Şaroğlu, F., 1985. Strike-slip faulting and related basin formation in zones of tectonic escapes: Turkey as a case study. SEPM. Spec. Publ., 37, 227 – 264.

Subramanian, V., Jtta, P.K., Griekan, R.V., 1988. Heavy metals in the Ganges Estuary. Marine Pollution Buletin 21 (4), 190 – 197.

Taylor, S.R. and McLennan, S.M., 1985. The Continental Crust; Its composition and evolution; an examination of the geochemical record preserved in sedimentary rocks. Blackwell, Oxford. 312.

Taylor, S.R. and McLennan, S.M., 1995. The geochemical evolution of the continental crust. Reviews in Geophysics 33: 241-265.

Tekeli, O., Göncüoğlu, M.C., 1984. Geology of the Taurus Belt, International Symposium on the Geology of the Taurus Belt. Reprinted from Maden Tetkik Arama Enstitüsü, Ankara, pp 133 – 158.

Tolun, N., Pamir, H.N., 1975. Explanotary text of the geological map of Turkey: Hatay Sheet, 1/5000.000 scale. Publ. Min. Res. Explor. Inst., Ankara, 99 p.

Tuğrul, S., Yemenicioğlu, S., Ediger, D., Uysal, Z., Mutlu, E., Doğan-Sağlamtimur, N., Yılmaz, D., Devrimci, A., 2005. Ege Denizi ve Kuzeydoğu Akdeniz kıyı alanlarında uzun süreli biyolojik izleme, değişim ve uyum izleme, Mersin Körfezi ötrofikasyon izleme programı, Kasım 2005, Final Raporu, ODTÜ DenizBilimleri Enstitüsü, Erdemli, 352 pp.

Turekian, K.K., Wedepohl, K.H., 1961. Distribution of the elements in some major units of the earth`s crust. Geol. Soc. Am. Bull. 72: 175 – 192.

Türkmen, A., Türkmen, M., Tepe, Y., Akyurt, İ., 2005. Heavy metals in three commercially valuable fish species from İskenderun Bay, North East Mediterranean Sea, Turkey. Food Chemistry, 91, 167 – 172.

Ünlüata, Ü., Latif, M.A., Bengü, F., Akay, H., 1978. Towards an understanding od shelf dynamics along the southern coast of Turkey. IV Journees Etudes Pollutions en Mediterranee, November 1978 Antalya. CIESM, pp. 535 – 542.

Voutsinou-Taliadouri, F., Satsmadjis, J., 1982. Concentration of some metals in Aegean sediments. Rev. Int. Oceanogr. Med., 66/67: 71 – 76.

Wedepohl, K.H., 1995. The composition of the continental crust. Geochimica et Cosmochimica Acta 59: 1, 217-1, 239.

Weedon, GP., 1983. The Pleistocene – Recent geology of part of the Misis-Kyrenia Ridge South of Turkey, Deg. submitted in partial fulfillment of the degree of B.Sc. in Geology, Royal School of Mines: 36 pp.

Yalçın, M.N., Görür, N., 1984. Sedimentological evolution of the Adana Basin. In: Tekeli O. And Göncüoğlu M.C. (Editors), Geology of the Taurus Belt. Maden Tetkik ve Arama Enstitüsü, Ankara, pp. 165 – 172.

Yılmaz, A., Salihoğlu, İ., Yemenicioğlu, S., Tuğrul, S., Baştürk, Ö., Yayla, M., 1998. Akdeniz kıyılarında karasal kaynaklı kirlenmenin boyutu ve canlılara etkisi. Türkiye`nin Kıyı ve Deniz Alanları II. Ulusal Konferansı, Türkiye Kıyıları 98 Konferansı Bildiriler Kitabı, ODTÜ, Ankara, 665 – 673.

Yılmaz, A.B., 2003. Levels of heavy metal (Fe, Cu, Ni, Pb, and Zn) in tissue of Mugil cephalus and Trachurus mediterraneus from Iskenderun Bay, Turkey. Environmental Research, 92, 277 – 281.

Yücesoy, F., 1991. Geochemistry of the heavy metals in the surface sediments from the southern Black Sea Shelf and Upper Slope. M.Sc. Thesis, METU, Institute of Marine Sciences, Erdemli – İçel, TÜRKİYE, 150 p.

Yücesoy, F., Ergin, M., 1992. Heavy metal geochemistry of surface sediments from the southern Black Sea shelf and upper slope. Chemical Geology, 99, 265 – 287.

Zitter, T.A.C., Woodside, J.M., Mascle, J., 2003. The Anaximander Mountains: a clue to the tectonics of southwest Anatolia. Geol. J., 38, 375 – 394 pp.