# Controlling factors of sediment deposition in the Northeastern Mediterranean basin

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**Abstract-** River loads, coastal erosion, *in-situ* production, and anthropogenic inputs are the main sources of sediments of the Cilicia-Adana Basin (northeastern Mediterranean). Surface sediments shows of a wide range of grain sizes, carbonate and organic carbon contents, which vary mainly in response to sediment sources, bottom topography, and hydrodynamic factors. Misis-Kayrenia Range, diapiric-knolls, coastal cyclonic eddies, reversal coastal currents, and upslope currents trap the most of the sediments in shelf and prevent some of the sediment to move into the deeper parts of the Basin. However, the Cilicia-Adana Basin loses sediments and allow infilling of the Latakia Basin with overflowed excess sediment along the Range.

**Keywords-** grain-size, organic-carbon, carbonate, diapiric-knolls, sand-waves

## Introduction

The study area is located in the easternmost part of the Mediterranean Sea. The sea is an inland sea, characterised by the presence of narrow shelves, deep basins and shallow straits. Cilicia-Adana Basin is a small NE-SW peripheral basin (Wong et al. 1971), bounded to the north and northwest by the Taurus Mountains and to the east and southeast by the fault block of Misis High, which extends southwestward as a submarine ridge linking up with the Kyrenia Range of Cyprus (Evans et al. 1978) (Fig. 1).

The major deltaic complex at the eastern side of the Taşucu Bay is formed by the Göksu River, which emerges from the mountains to form a delta. From the flank of the Göksu delta to a point near Erdemli, rocks reach the coast forming seacliffs. From Erdemli to a point east of Mersin, the mountains recede slightly from the coast and there is a narrow coastal plain. There is dramatic change in the coastal area east of Mersin. The mountains and the fans at their foot, which front the coastline to the west, swing inland to the northeast and the wide deltaic plain of the Tarsus, Seyhan and Ceyhan Rivers intervenes between the mountains and the sea. This plain is bounded to the east by the Misis Mountains, which ends in a rocky headland southwest of Karataş.

The onshore continuation of the Basin, the Adana Basin, is one of the major Neogene Basins flanking the Taurus orogenic belt. Sediments up to 6000 m thick are present, ranging in age from Buldigalian to Recent (Biju-Duval et al. 1979).



The Quaternary sediments are mainly represented by the Pleistocene Kuransa Formation and Holocene alluvium (Yalçın and Görür, 1984). Gently warped deposits are found in the deeper basin, due to the flow of underlying Messinian evaporates (Evans et al. 1978).

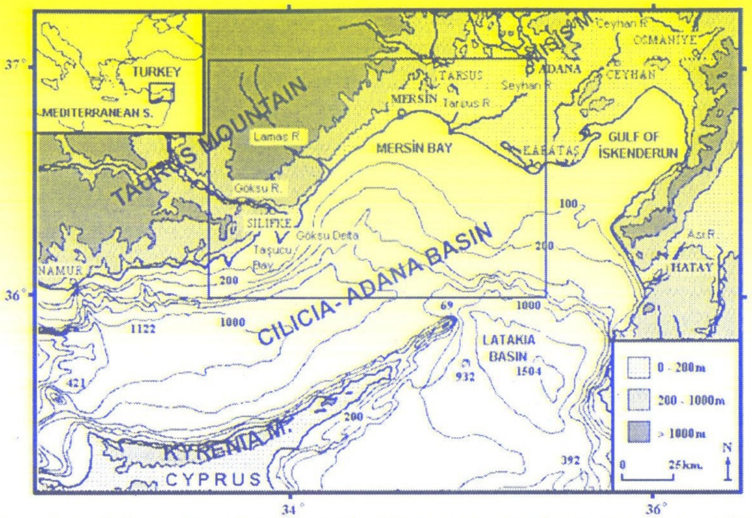


Fig. 1. Location of the study area and coastal river systems, in relation to onshore and offshore topography.

The water circulation in the northeastern Mediterranean has a general cyclonic character (Collins and Banner, 1979). The surface and intermediate waters in the Cilicia Basin are believed to flow almost parallel to the continental margin in a W-SW direction along the northern shelf; no significant seasonal variation in this circulation pattern has been observed (Ovchinnicov, 1966). However, during periods of strong winds that blow down the Göksu and Lamas valleys (Figs.1, 2), the surface shelf currents may reverse in direction and flow towards the northeast (Ünlüata et al. 1978). Also, due to frontal instabilities of the shelf waters, eddies are developed during the spring and early summer (Evans et al. 1995).

Perennial rivers, which have their greatest discharges in winter and spring, characterize the northern coastal zone of the study area: the most important of which are the Göksu, Lamas, Tarsus, Seyhan, and Ceyhan Rivers (Fig. 1). There are also numerous short season streams that flow only during the rainy periods. The maximum discharge of the rivers usually occurs in April and the minimum discharge occurs in June-December. Tides in the area investigates are weak (maximum range of $\pm$0.5 m) and the tidal currents are regarded negligible regarding sediment transportation (Ediger et al. 1997).

The major objective of the present contribution is to report the presence and describe some of the characteristics of the surface sediment and controlling factors of deposition observed along the continental shelf, slope and deeper parts of the northeastern corner of the Mediterranean Sea.

## Material and Methods

Total 141 seabed surface sediments were collected using a standard grab and a gravity core sampler from the sea floor of the northeastern corner of the Mediterranean Sea. The samples were taken during four different cruises with the RV Shackleton and RV Bilim from the study area (Fig. 2).

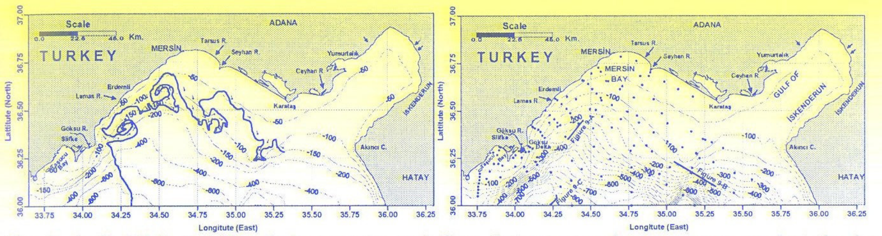


Fig. 2. Left; High turbidity inshore water and flow features are shown arrows, against the low turbidity offshore water (Evans et al. 1995), Right; Bathymetry of the northeastern corner of the Mediterranean Sea (depths are in meter), locations of the total bottom-sampling stations, and the seismic track-lines.

Standard sieve and pipette analysis techniques (Folk, 1974) were applied to determine the clay (<0.002mm), silt (0.002-0.063mm), and total coarse grains (gravel+sand) (>0.063mm) fractions of the sediments. Sand carbonate contents were determined volumetrically in an Scheibler apparatus through the release of $CO_2$ (Müller, 1967). Total organic carbon was determined by wet oxidation of organic matter with chromic acid and back titration with diphenylamine indicators (after Gaudette et al. 1974).

A continuous-reflection seismic survey (using a standard EG&G sparker source) was carried out during the 1972 and 1974 cruises with the RV Shackleton in the Mersin bay. During the survey, the signal energy and the firing interval varied between 1 and 6 kJ and 1 to 4 s, respectively; returns were recorded in the frequency range of 80 to 200 Hz. The records were analysed using standard seismic stratigraphic techniques.

## Result and Discussions

### *Grain-size distribution*

In the area, coarse (gravel+sand), silt and clay fractions vary between 0.4-99%, 0.1-91%, and 0.2-89% respectively. Elsewhere, at most stations, the coarse fractions constituted no more than 10% in the bulk sediment. Especially, subaqueous delta of the Göksu River are probably separated two different coarse grain and Silt/Clay>3 patches by the deposition of the fine-grained sediments off the river mouth after construction of the dam on the Göksu River (Fig.3). Eastern and western coarse grain patches in the Göksu delta, between the mouths of the



Seyhan and Ceyhan Rivers are composed of a mixture of the coarse terrigeneous and biogenic grains. The proportion of the coarse fraction is usually higher and Silt/Clay>3 in the sediments off the rocky coastal zone and the deltaic complexes (Fig. 3).

Shaw and Bush (1978) have mentioned that the presence of the high amount of Cr and Ni concentrations around the coarse-grain patches off Karataş Cape (Fig. 3). The enrichment of both elements and coarse fractions in this area may be readily explained by the presence of these elements in the catchments area of the Seyhan River and the presence of the winnowing action of the cyclonic coastal filaments. The offshore expansion of coarse-grained sediment patches is generally located between the 100 m and 200 m contour intervals. The concentration of the high amount of the relict coarse grained materials in these patches also specify the ancient deltaic system when the sea level was lowered nearly 125 m during the Last Glacial Maxima (Weedon, 1983). The existence of the coarse sediment patches at the western side of the Göksu River mouth represents recent deltaic growth under the recent oceanographic conditions of the region (Fig. 3).

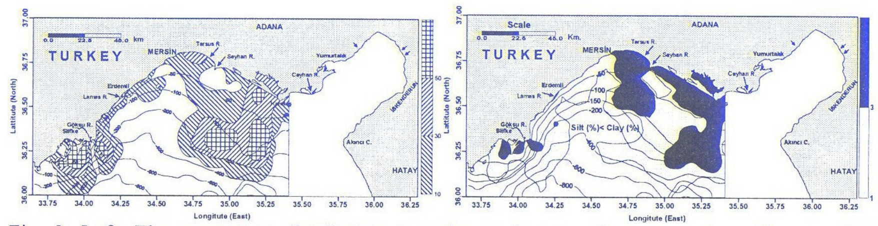


Fig. 3. Left; The percentage distribution over the study area of coarse grain sediments, Right; Distribution pattern of the silt/clay ratio.

Off the coastal rivers' mouths, Silt/Clay ratio is generally less than one. The high (>3) Silt/Clay ratio patches that are located between the 100 and 200 m contour intervals are probably an effect of the winnowing processes of the cyclonic coastal filaments (Figs. 2 and 3). Clay fraction forms >30% of sediments offshore the Göksu and Seyhan River mouths, it gradually increases with increasing water depth. Generally, the clay contents are <30 all around the shelf.

### *$CaCO_3$ in sand fraction*

Carbonate contents (expressed as % $CaCO_3$) in sand fraction of the surface sediments of the Mersin Bay vary between 32-99% (Fig. 4). The majority of the Mersin Bay sediments contain less than 75% $CaCO_3$ of the sand fraction of the sediments and show poor correlation with the content of the mud fraction. There is a nearly positive correlation between $CaCO_3$ and sand contents due to the dominance of carbonates in the coarse-grained sediment fractions along the midshelf zone. Qualitatively microscopic analysis on coarse-fractions revealed that the higher carbonate contents in the sediments appear to have a predominantly biogenic origin (Ediger et al, 1997). Low carbonate concentration (<60%) in sand fraction occurs along the innershelf zone between the west of Karataş Cape-Lamas River mouth and 150-300m contour intervals along the outer shelf zone as a result of high siliciclastic fine grained sediment inputs (Fig. 4). Also, high carbonate patches (75-90%) are found off the rocky coastal zone between the Göksu delta and Lamas River Mouth due to both benthic productions and to erosion of this rocky coastal zone.

Location of the high sand carbonate patch (>75%) along the shelf (50-100m depth of water) of the Mersin Bay is strictly coinciding with the location of the coastal filaments and the swiping pathway of these wind-generated current systems (Figs. 2 and 4). Especially, there are two different high carbonate patches (>90) at the central parts of these filaments. The eastern high carbonated and high coarse-grained zone are probably a remnant of the earlier deltaic systems of the Seyhan, Ceyhan Rives. The enrichment of carbonate grains in this area may be readily explained by the presence of high benthic population, algal fragments, the carbonate rock outcrops in the catchments area of the coastal rivers and the winnowing action of the cyclonic coastal filaments.

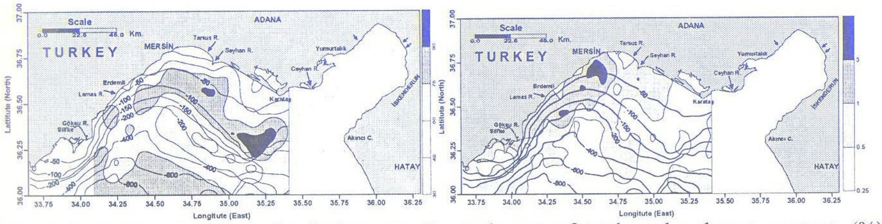


Fig. 4. Left; The percentage distribution over the study area of total sand carbonate contents (%), Right; The percentage distribution over the study area of total organic carbon contents (%).

### *$C_{org}$ in total sediments*

Generally, total organic carbon deposition occurs beneath oxygenated bottom waters of deltas, continental shelves and upper continental slopes (Hedges and Keil, 1995) in the northeastern Mediterranean Basin. The abundance of the organic carbon concentration in the surface sediments of the area (0.1-4.4%) appears to be controlled primarily by the variations in lithogenic and biogenic admixtures of the sediments (Fig. 4). In general, fine-grained sediments rich in clay and silt percentages have slightly positive correlation with the total organic carbon contents. Low $C_{org}$ contents also reflect variations in the degree of dilution by the coarse-grained biogenic and terrigenic components and total $CaCO_3$ contents. Therefore, at the some parts of the subaqueous deltaic lobes of the Göksu and Seyhan Rivers and the deeper parts of the area, the total organic carbon concentrations reach the basin minimum values (Fig. 4).

The enrichment of the $C_{org}$ (>3%) in three different patches off Mersin and Erdemli may be readily explained by the presence of the cyclonic coastal filaments, general cyclonic Mediterranean circulation system, and coastal river and anthropogenic inputs (Figs. 2 and 4). Although the high concentration of the coarse



fraction, organic carbon content of the sediments changes between 1-2 % in the inner part of the Taşucu Bay and the vicinity of the Göksu River mouth. Terrestrial organic and anthropogenic inputs from the Göksu River, industrial and sewerage outputs are the main sources of the organic matter in this part of the area (Fig. 4). Therefore, it appears that the distribution of organic carbon in the study area is controlled by a complex interplay of hydrodynamic, biogenic, terrestrial, and anthropogenic factors.

### *Seismic profiles*

Fine-grained sediment waves have been identified at the upper slope of the Cilicia-Adana Basin (Fig. 5-A). These still active large sediment waves are located at the head of a local submarine canyon and at water depths between 210 and 280 m. The dimensions of the sediment waves vary along the sedimentary deposition, with the larger bed-forms found at the bottom of the sedimentary sequence. Sediment waves have been formed under the influence of complex flows present within the Cilicia-Adana Basin are migrated up-slope by reversal coastal current system. The origin of this reversal current system is the cyclonic coastal filaments generated by the coastal winds. The coastal reversal currents and the upslope migration of the sediment waves (Fig. 5-A) indicate that the shelf sediment trapping along the upper slope of the Cilicia-Adana Basin.

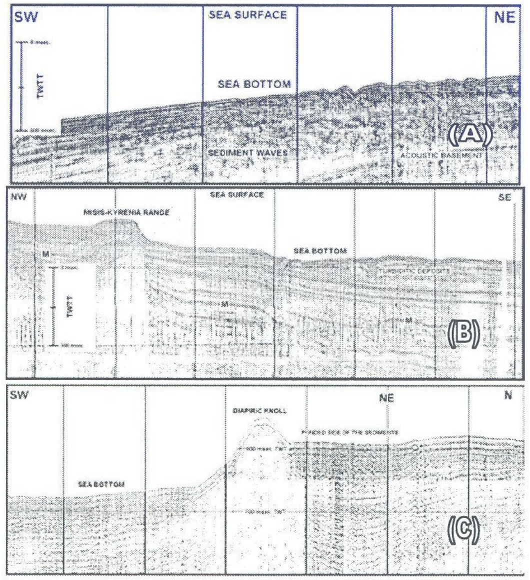


Fig. 5. Seismic profiles (locations in Fig 2). (A); the generations of the surface and deep sediment waves, (B); well-stratified sediments at the NW and turbidite deposits at the SE of the Misis-Kyrenia Range (M: Multiple.), (C); A typical abyssal plain surface Diapiric Knoll.

Extension of the coarse grain sediment (Fig. 3) and high carbonate sediment patches (Fig. 4) along the southeastern slope of the Missis-Kyrenia Range (off Karataş Cape) indicate that the overflowing of the Cilicia-Adana Basins' sediments towards the Latakia Basin by turbiditic processes. Also, seismic records collected from the same location of these patches support apparent flowing of the sediments by turbiditic processes towards the Latakia Basin (Fig. 5-B).

Some part of the abyssal plain surface of the Cilicia-Adana Basin has been displaced subsurface doming. In some instances, these diapiric knolls apparently form dams behinds which sediment is ponded. For example, in Fig. 5-C smoothing of sediment strata over uplifted subsurface domes indicates that depositional processes are now dominant; these processes are active on only sediment input side of adjacent knolls standing in relief on the sea-floor, and would suggest a damming effect by these knolls. Thickening of the sediments at the coastal side of the domes are the other main seismic evidence of the sediment trapping mechanisms along the outer shelf zone of the Basin.

## Conclusion

Cilicia-Adana Basin is align between the NE to SW directions and surrounded by the Taurus Mountains and Misis-Kyrenia Range. Marine sediments in this dynamic basin are characterized by extremely high sedimentation rates of primarily terrigeneous material. The surface sediments of the area are composed of a wide variety of grain-size reflecting the various depositional environmental conditions. The relatively high carbonate contents of the sand fractions are mainly have biogenic and terrigenous origin. The characteristic distribution of high carbonate and coarse grain contents are observed particularly in sediments along the rocky coastal zones, recent and ancient deltaic influences and the areas effected by the bottom currents. The total organic carbon contents of the sediments usually indicate normal marine conditions. The highest organic carbon contents are between the Erdemli and Mersin shelf where an intensive organic matter of biogenic and anthropogenic origin accumulated due to the presence of coastal filaments and the general cyclonic Mediterranean Circulation System. Generally, distribution characteristics of the bottom sediments in the study area are controlled by a complex interplay of hydrodynamic, biogenic, terrestrial, and anthropogenic factors. Seismic records show the up-slope movement of the deposits by the probable action of the upslope current regime. This type inshore movement of the bottom water towards the inner shelf is not allow the most part of the bottom sediment move to deeper parts of the Basin. Some parts of the abyssal plain surface have been displaced subsurface doming. These diapiric knolls apparently form dams behinds which sediment is ponded and trapped. Excessive bottom sediments of the shelf are loosed over the Misis-Kyrenia Range to the Latakia Basin by turbiditic processes. The general cyclonic circulation regime, wind generated cyclonic coastal filaments, sedimentation rates, type of the bottom topography, presence of the Misis-Kyrenia Range and diapiric knolls are the main controlling factors of sediment deposition in the Northeastern Mediterranean Basin.



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