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Recent surficial shelf sediments of the Cilician Basin (Turkey), northeastern Mediterranean

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Abstract—The continental shelf of Mersin Bay forms the northwestern margin of the Adana-Cilician Basin; it extends from the Göksu delta (in the southwest) to the Seyhan-Tarsus-Ceyhan delta (in the northeast) and is narrower and steeper in the southwest than in the northeast.

Five depositional zones are recognised on the basis of the analysis of surficial sediments: (1) a "*Modern Terrigenous Prism*"; extending from the coast to 50 m water depth; (2) a "*Shelly Zone*" on the mid-shelf (50–100 m), characterised by an abundance of skeletal debris; (3 and 4) "*Prodeltaic Zones (I and II)*" in the northeastern and southwestern parts of the shelf, where silty sediment from the major Seyhan-Tarsus and Göksu rivers, respectively, has been deposited; and (5) the "*Outer Shelf Zone*", extending from the 100-m contour to the shelf edge, characterised by clay-sized sediment and abundant remains of planktonic micro-organisms.

Sediment appears to be reaching the shelf from two main sources: (i) a lateral supply from the coastal rivers between the two major deltas, which is being dispersed along the coast to form the "Modern Terrigenous Prism" and is dominated by near-shore wave activity and wave-generated currents; and (ii) fine-grained sediment from the Seyhan-Tarsus rivers, transported along the shelf under the action of the cyclonic Mediterranean circulation. Some of the latter sediments settle to form the distal tongue of the Seyhan-Tarsus delta (Prodeltaic Zone I), whilst the remainder settles over part of the shelf to the southwest. The sediment supplied by the Göksu river is generally swept away to the southwest, by the southwesterly-flowing cyclonic Mediterranean Current and it influences the shelf only within its immediate vicinity to form Prodeltaic Zone II.

The mid-shelf area (Shelly Zone), lying at water depths of between 50 and 100 m, receives some fine silt and clay. However, it is cloaked in a thin layer of skeletal debris, which is difficult to explain but may be partly of anthropogenic origin although this requires further investigation.

1. INTRODUCTION

The recent sediments of Mersin Bay have been the subject of various geological, geochemical and geophysical investigations by many researchers (e.g. Evans, 1971; Evans *et al.*, 1978; Bodur and Ergin, 1988a,b; Ergin *et al.*, 1988, 1989; Ediger *et al.*, 1988; Alavi *et al.*, 1989; Bodur and Ergin, 1989; Ediger and Ergin, 1990; Ediger, 1991; Okyar, 1991; Aksu *et al.*, 1992; Ergin *et al.*, 1992). More general studies have been undertaken on the recent sediments of the Cilician Basin, including Mersin Bay, as follows: clay mineralogy (Shaw,

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1978); mineralogy and geochemistry (Shaw and Bush, 1978); the nature, distribution and origin of sapropelic sediments (Shaw and Evans, 1984); heavy mineral distribution (Mange-Rajetzky, 1983); and micropalaeontology (Alavi, 1980). The present paper describes the grain-size and composition of the coarser fraction of the superficial sediments and attempts to use this to explain the processes and pattern of contemporary sedimentation on the shelf bordering the Cilician Basin.

1.1. *Geographical and physiographical setting*

Mersin Bay covers an area of nearly 1150 km^2 of the continental shelf to the southeast of Turkey, between the Göksu and Seyhan Deltas. Landwards, it is bounded to the north and northwest by a narrow coastal plain flanking the Taurus Mountains; to the northeast, by the wide deltaic plain of the Seyhan-Tarsus-Ceyhan rivers; in the south, it passes into the deeper waters (> 100 m) of the Cilician Basin (Fig. 1).

The region has a typically "Mediterranean Climate" with hot dry summers and mild, wet winters (Mediterranean Pilot, 1961). The air temperature varies between 10°C in January and 30°C in July and the annual rainfall and mean humidity are nearly 600 mm and 70%, respectively (Meteorological Bulletin, 1970).

The southeastern coastal area of Turkey is drained mainly by perennial rivers (the Göksu, Lamas, Tarsus, Seyhan and Ceyhan), together with numerous short ephemeral streams which flow only during the rainy periods (the Alata, Kargicak, Tomuk, Gilindirez, Tece, Mezitli and Müftü rivers) (Fig. 2). The maximum discharge of the rivers usually occurs in April, when the snow melts in the nearby mountains: the minimum discharge occurs in June–December. The Seyhan discharge shows a typical variation from a monthly average rate (1972–81) of approximately 100 m^3 s^{-1} in summer and autumn to 400–700 m^3 s^{-1} in the winter and spring months (E.I.E., 1984).

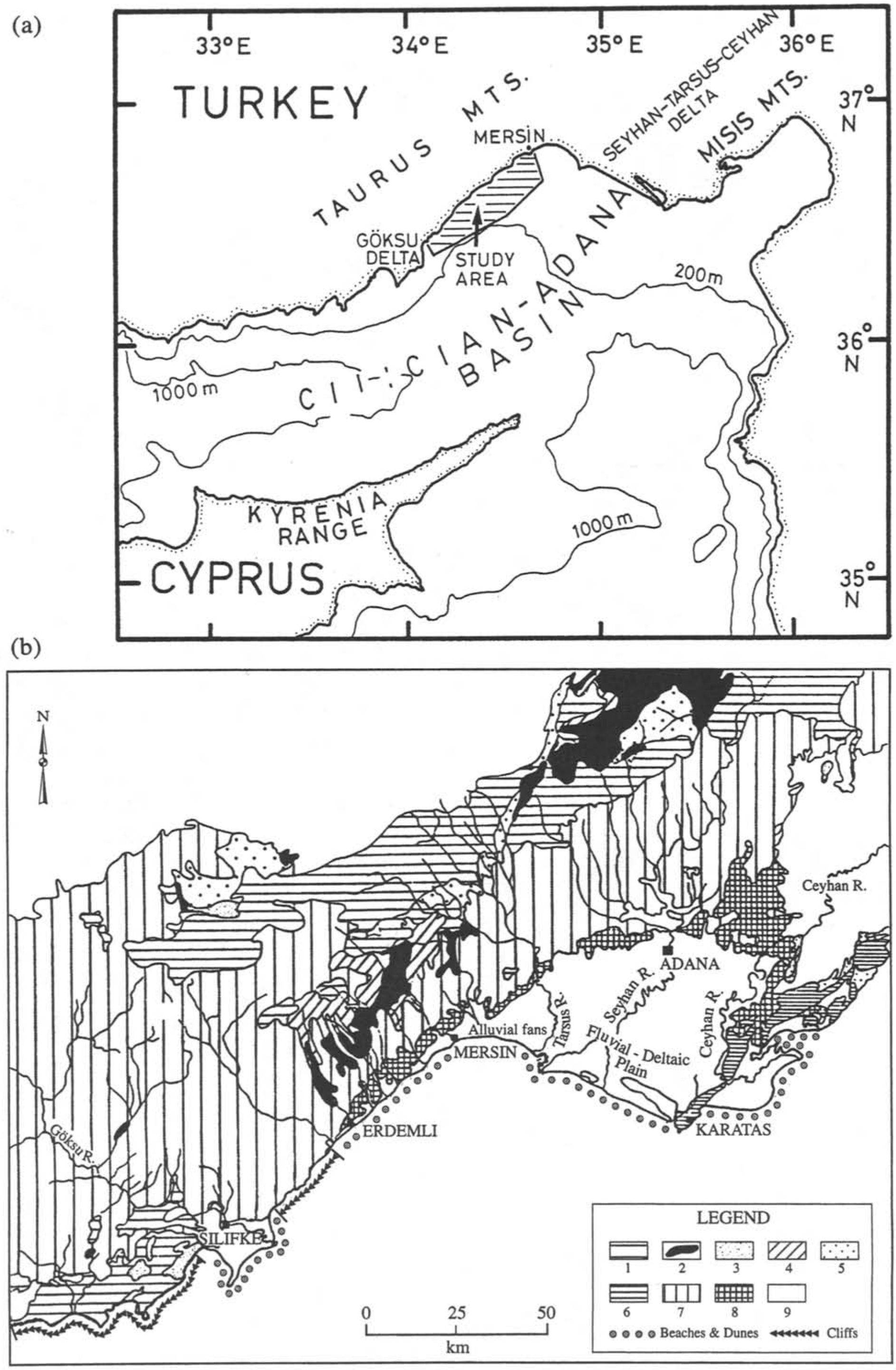
Generally, the dominant wind direction along the southeastern coast of Turkey is from the southwest in summer (from April to October), whilst northwesterly and northeasterly winds are dominant in winter (from November to March) (Meteorological Bulletin, 1970; Ataktürk, 1980).

1.2. *Geological setting*

Mersin Bay forms the northwestern flank of the Cilician-Adana Basin, which is bounded to the north and northwest by the Taurus orogenic belt and to the east and southeast by the fault block of the Misis High. The latter feature continues southwestward, as a submarine ridge linking it with the Kyrenia Range (Evans *et al.*, 1978) (Fig. 1). The Adana-Cilician Basin is claimed to have been formed as a result of the differential incompatibility arising at an intracontinental FFF-triple junction, where the East Anatolia and the Dead Sea Transform Faults meet (Sengor *et al.*, 1980).

The onshore part of the basin, the Adana Basin, is one of the major Neogene basins

Fig. 1. General bathymetry of the eastern Mediterranean, showing the location of the region studied. (b) Geological sketch-map of the study area and the surrounding region. Based on M.T.A. 1:500 000 geological map of Turkey, 1961–1964. 1 = Palaeozoic–Mesozoic; 2 = ophiolites; 3 = Upper Cretaceous occasionally with ophiolites and Palaeocene; 4 = Mesozoic ophiolite series; 5 = Eocene–Oligocene; 6 = Oligo–Miocene; 7 = Miocene, mainly calcareous; 8 = travertine; 9 = Pleistocene–Holocene.


(a)
33°E
34°E
35°E
36°E
37° N
36° N
35° N
TURKEY
TAURUS MTS.
MERSIN
SEYHAN-TARSUS-CEYHAN DELTA
MISIS MTS.
GÖKSU DELTA
STUDY AREA
CILICIAN-ADANA BASIN
200m
1000 m
KYRENIA RANGE
CYPRUS
(b)
N
Ceyhan R.
ADANA
Seyhan R.
Tarsus R.
Ceyhan R.
Alluvial fans
MERSIN
Fluvial - Deltaic Plain
ERDEMLI
KARATAS
Göksu R.
SILIFKE
0 25 50
km
LEGEND
1 2 3 4 5
6 7 8 9
Beaches & Dunes
Cliffs

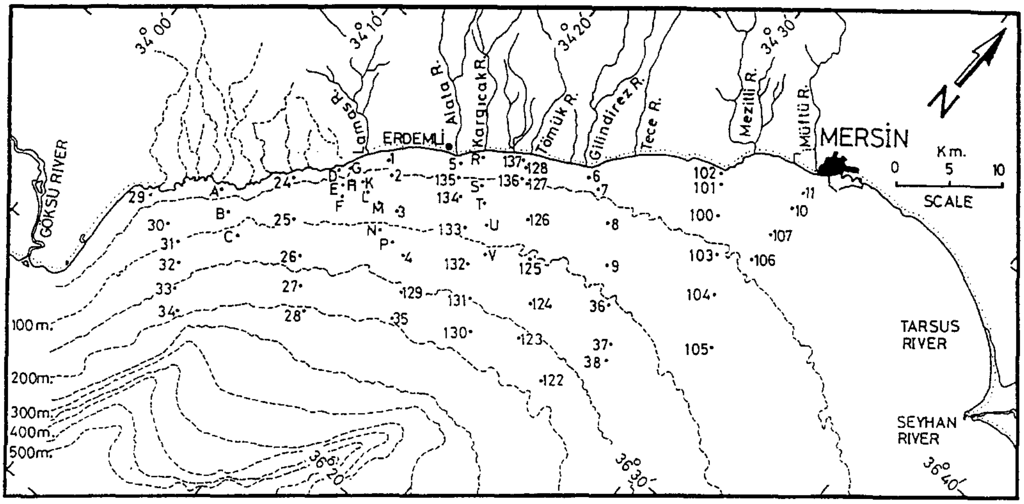


Fig. 2. Location map of the sampling stations (cores 1–137 and grabs A–V).

flanking the Taurus orogenic belt where a wide range of sediments as well as ophiolitic rocks are exposed; it contains sediments up to 6000 m in thickness, of variable facies and ranging in age from Burdigalian to Recent (Ternek, 1953, 1957; Özer *et al.*, 1974; Görür, 1977; Evans *et al.*, 1978; Hsü and Bernoulli, 1978; Biju-Duval *et al.*, 1979). This basin contains up to 1300 m of Pleistocene (Kuransa Formation) unconsolidated or slightly cemented gravels, sands, silts and clays of fluvio-deltaic origin and Recent alluvium. The accumulation of a thick Tertiary–Quaternary sedimentary column was accompanied by continued basinal subsidence and movements along the margins. Flow of Messinian evaporites caused deformation of the sediments in the offshore Cilician Basin and bordering continental shelves (Evans *et al.*, 1978; Aksu *et al.*, 1992).

1.3. *Bathymetry*

The shelf of Mersin Bay is deepest in the southwest and gradually becomes shallower to the northeast. The term "inner shelf" has been used to describe the zone <50 m, "mid-shelf" for the zone between the 500- and 100-m isobaths, and "outer shelf" for the zone with depths >100 m. Between the mouths of the Göksu and Lamas rivers in the southwest, where the coast is formed by cliffs of Miocene limestone, the shelf has a relatively steep slope (2.5°) from 0 to 50 m; it becomes more gentle offshore ($\sim 0.8°$), between 50 and 200 m. Near Erdemli, the sea-floor slopes approximately 1° between the coastline and 50-m contour; it flattens to 0.6° between 50 m and 200 m. Between Erdemli and the edge of the Seyhan delta near Mersin, where the coast is formed by a complex of alluvial fans fringed by a cordon of beaches and dunes, the sea-floor has a gentler slope (0.3° from 0 to 50 m) and flattens to 0.4° between the 50- and 200-m contours. Throughout the area, the sea-bed profile is smooth but with irregularities in the mid-shelf region; these are probably relict coastal features which still have a topographic expression (but from which shallow water relict deposits have never been encountered in the short cores collected during the present study).

1.4. *Oceanography*

The general water circulation in the eastern Mediterranean is essentially unidirectional and is generally cyclonic in character (Wust, 1961; Ovchinnikov, 1966; Engle, 1967; Lacombe and Tchernia, 1972; Moskalenko, 1974; Gerges, 1976; Collins and Banner, 1979). A steady surface current flows along the coasts of Israel, Lebanon and Syria and turns west to flow along the southern Turkish coast, parallel to the shoreline of Mersin Bay, with the maximum flow in summer (Gerges, 1976; Özsoy *et al.*, 1987, 1989). The surface currents on the shelf have an average velocity of about 10 cm s^{-1}, from east to west, off Erdemli (Ünlüata *et al.*, 1978, 1980, 1983).

This water circulation pattern is modified by local winds and by some eddies in the coastal zones (Gerges, 1976; Özsoy *et al.*, 1987, 1989; Evans *et al.*, 1995). Measurements in 10 m depth of water off Erdemli have revealed current reversals due to these wind effects (Ünlüata *et al.*, 1978). Tidal forces are weak and the tidal currents unimportant in this area. Wind-generated waves and currents, combined with river flow during high spring rainfall, are the main source of turbulence in the inshore areas. Wave action is strong only during autumn–spring and the occasional storms in summer, when waves of 1–2 m in height are common. Generally, wave action is very limited during summer except for those generated by afternoon onshore winds.

The dominant south-westerly wind produces predominant littoral transport towards the northeast, but this is reversed over short periods by winds from the easterly quadrant. The dominance of this drift is not great, as is witnessed by the only slight asymmetry to the cuspate pattern of the alluvial coastline between the mouth of the Lamas and Mersin. In the nearshore areas of Mersin Bay, depressed salinity, temperature and density variations occur in response to the influxes of river water (IMS-METU, 1986). The area is generally one of low productivity: the most productive areas are limited to the coastal zone, close to the river mouths where nutrients are supplied (IMS-METU, 1984, 1986; Salihoglu *et al.*, 1987; Göcmen, 1988). The maximum concentrations of suspended material in the waters occur in spring, due to influx from the coastal rivers and in response to biological environmental factors, such as primary productivity (Evans *et al.*, 1995). The suspended sediment is typically composed of approximately equal amounts of smectite and illite (40–50%) with subsidiary amounts of kaolinite and chlorite (5–10%) (Shaw, 1978). Dissolved oxygen (DO) ranges between 4.9–7 mg l^{-1} and the average pH of the sea water is 8.23 ± 0.06 in the coastal waters (IMS-METU, 1984, 1986).

2. FIELD AND LABORATORY PROCEDURES

Fieldwork was carried out during 1984–1989, from *R/V Lamas* and *R/V Erdemli*, of the Institute of Marine Sciences (METU) and a small local fishing boat, *Sulunkus*. Fifty gravity cores (maximum length 76 cm) and 18 Dietz-LaFonde and Van-Veen grab samples were collected on the shelf of Mersin Bay (Fig. 2), from the shoreline to a depth of 200 m. The positions of the vessels were determined using a Decca Trisponder Navigation System (Type RO3C). A portable Raytheon (DE-719B) echo-sounder was used for water depth determination. Gravel (>2 mm) and sand (2.0–0.063 mm) size fractions of the surface sediment samples were separated using standard dry sieving. The silt (0.063–0.00039 mm) and clay (<0.0039 mm) fractions were determined by standard pipette technique (Folk, 1974). Sub-samples from the sand fractions (2.0–0.125 mm) of the upper parts (3 cm) of all the cores and surface grab samples were examined under the binocular microscope, for the determination of the relative percentages of the various terrigenous and biogenic constituents. Between 200 and 1000 grains were identified from each sample.

3. RESULTS AND DISCUSSION

3.1. *Grain-size distribution*

The gravel percentages are generally very low and, consequently, were considered together with the sand as the coarse fraction. In the nearshore areas, the coarse fraction content of the samples decreases with increasing depth (Fig. 3A). It forms a high proportion of the bottom sediments on the inner shelf (< 50 m) with a secondary zone of high percentages on the middle shelf (maximum 41%), due to the presence of biogenic material. The content of coarse fraction is usually higher in the sediments off the alluvial coast between the Lamas river mouth and Mersin, than off the rocky coast between the Göksu delta and the mouth of the Lamas river; this is due to variation in the sediment supply by the coastal rivers. The skeletal-rich sediments on the middle shelf are a recent development; they form a layer only a few centimetres thick, underlain by terrigenous-rich sediment. On the outer shelf (> 100 m), off Mersin, the sediment contains less than 5% coarse material (Fig. 3B).

Silt constitutes <40% in the sediments of the inner shelf, between the mouth of the Lamas river and Mersin, and > 50% elsewhere; it increases towards the Seyhan delta (Fig. 3B), indicating the lateral transport of sediment from the Seyhan river mouth. Similarly, a relatively high silt content occurs to the northeast of the Göksu delta, but here it is less extensive due to the prevailing southwesterly-directed shelf currents which sweep the suspended river sediment towards the southwest. Clay forms <40% of the sediments over the inner shelf, and southwestern and northeastern parts of the middle shelf (Fig. 3C); it increases gradually with water depth. The silt to clay ratio (claimed by Folk (1974) to be important for the identification of lithofacies) decreases offshore, as has been found on other shelves in many other studies (Fig. 3D). The presence of the Seyhan delta 20 km to the northeast of the area examined is reflected by this parameter.

3.2. *Composition of the coarse fraction of the sediments*

The coarse-grained fraction of the sediments is composed of a mixture of terrigenous and biogenic grains. The term "terrigenous" rather than "siliciclastic" is used here, as the sediment derived from the hinterland contains considerable lithoclastic $CaCO_3$. The amounts of coarse terrigenous sediment decreases with a concomitant increase in biogenic materials in an offshore direction. On the inner shelf, the ratio of terrigenous to bioclastic components is > 1 (i.e. T:B > 1) whereas, on the middle and outer shelf is less than 1 (Fig. 4A).

3.3. *Distribution of the terrigenous constituents of the coarse fraction*

Quartz, micas, green minerals (hornblende, pyroxene and olivine), reddish chert fragments, calcareous rock fragments and various other unidentified lithic grains are the main terrigenous constituents of the surface sediments. The percentage of quartz (10–20%)

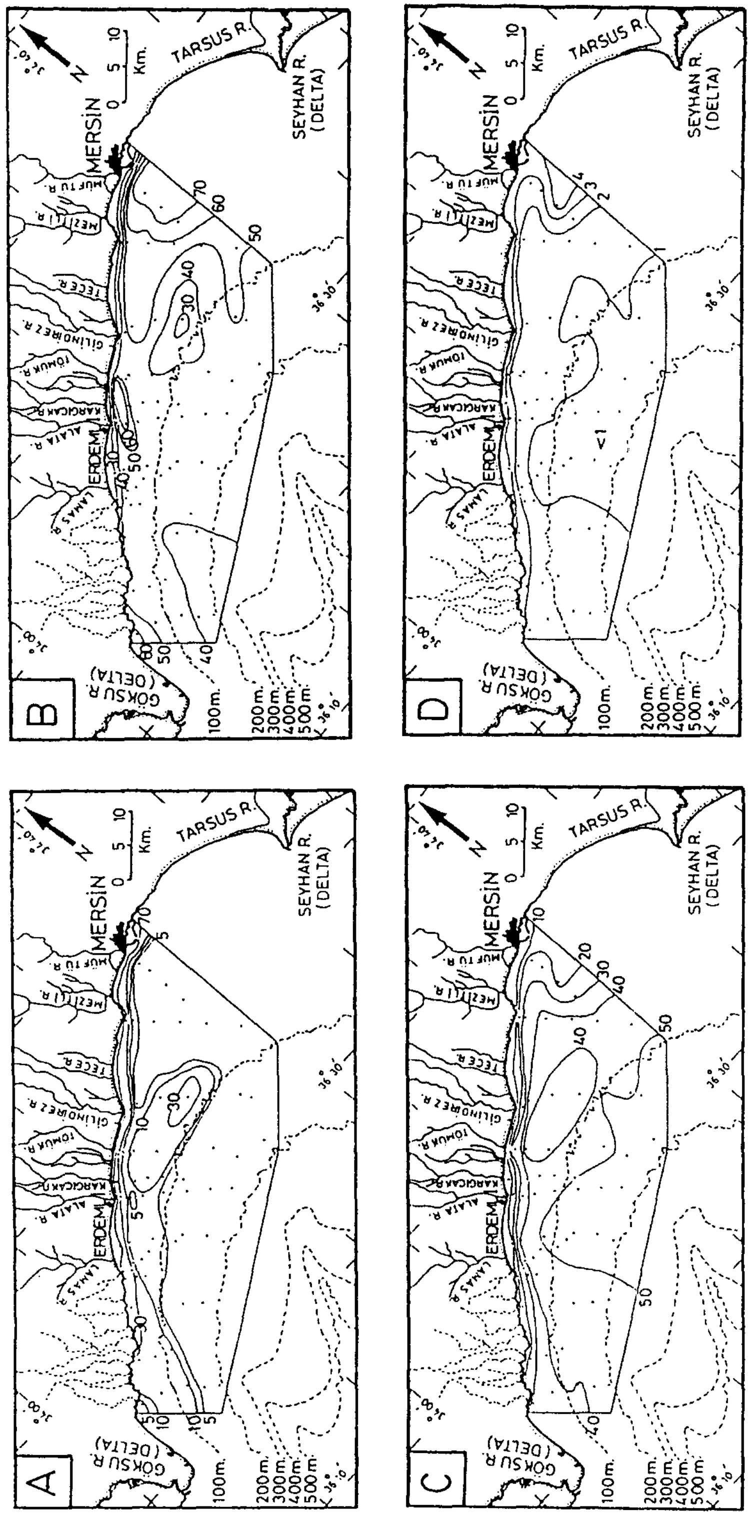
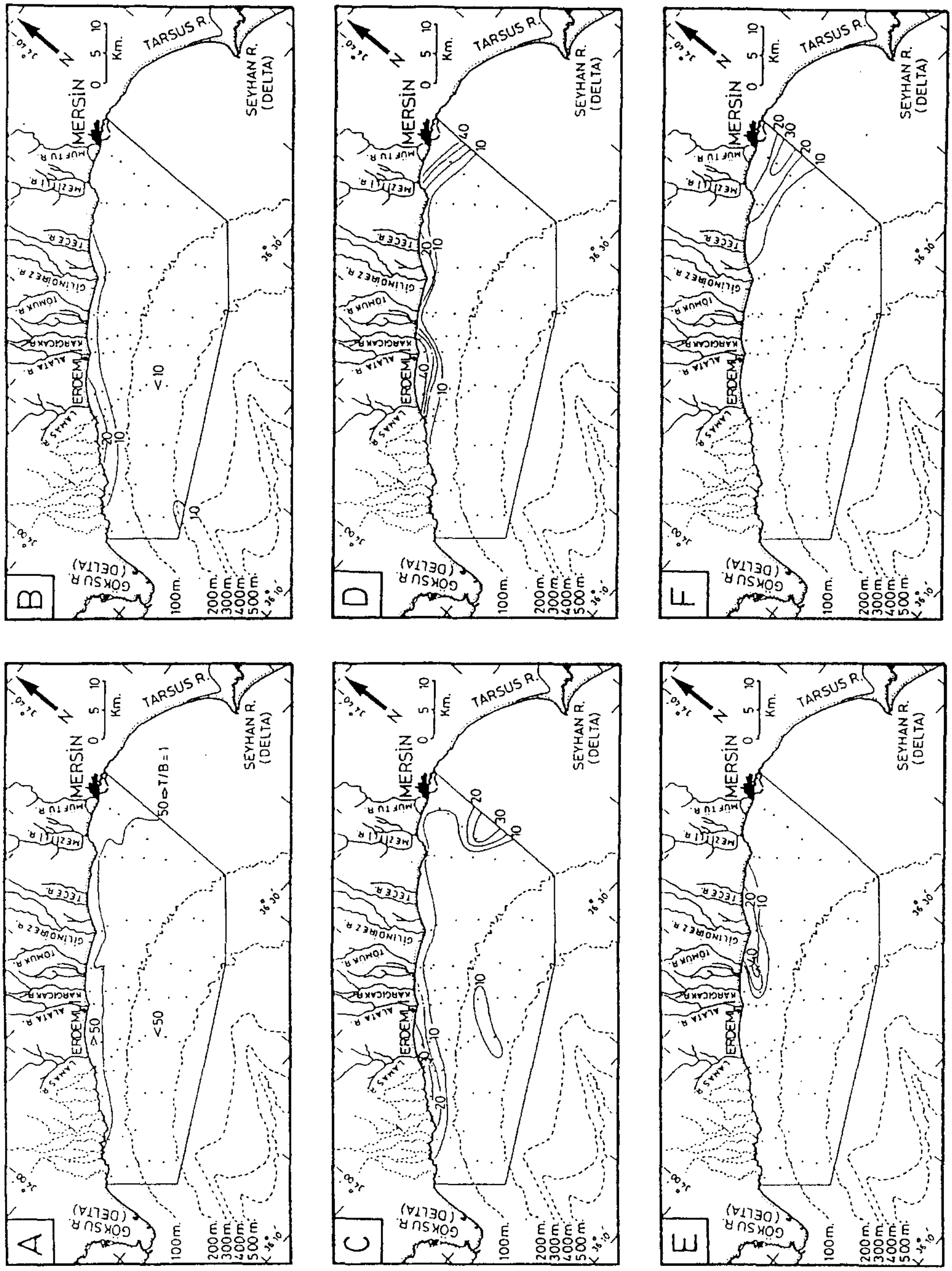


Fig. 3. The percentage distribution over the study area of: (A) coarse fraction (gravel + sand); (B) silt fraction; (C) clay fraction; and (D) silt to clay ratio.


A
B
C
D
E
F
MERSİN
TARSUS R.
SEYHAN R. (DELTA)
GÖKSU R. (DELTA)
ERDEMLİ
0 5 10 Km.
100m.
200m.
300m.
400m.
500m.
50⇔T/B=1
>50
<50
<10

decreases towards the outer shelf (Fig. 4B), confirming the findings of Shaw and Bush (1978), who carried out X-ray studies on a few surface samples. Although the Lamas river and adjacent rivers drain mainly Miocene limestones, the percentage of quartz is higher (20–23%) close to the mouth of the Lamas river as these limestones contain quartz and some mica but few other minerals as accessory components. Most mica (12%) occurs in the nearshore sediments west of Erdemli, where it is supplied probably by the Lamas river, whose mouth lies to the east. The mica is believed to be transported by the shelf-coastal currents. The sediments of the remainder of the area are poor in mica (< 10%).

Calcareous lithoclasts (mainly of Miocene limestone) occur very commonly within the sand fraction of the sediments, particularly in the vicinity of the mouth of the Lamas river and offshore of the adjacent rocky coasts (Fig. 4C). Generally, there is an offshore decrease in the percentage of terrigenous carbonates within the sediments.

Rivers to the east of the Lamas drain areas with a great variety of rocks exposed in their catchments. Greenish-coloured rock and mineral fragments (mainly hornblende, pyroxene and olivine) are very common in the sands in the nearshore areas (Fig. 4D). These materials originate from streams draining the ophiolitic complexes of the Taurus Mountains (Mange-Rajetzky, 1983); they are very common to the northeast of the mouth of the Lamas, around the mouths of the Alata, Kargicak and Gilindirez rivers and off the Müftü river near Mersin. However, the rivers to the west of the Lamas drain mainly Miocene limestone and mafic minerals are rare in the sea-floor sediments. Reddish cherts are distributed widely near the mouths of the Tomuk, Gilindirez and Tece rivers (Fig. 4E); they are derived from the radiolarites, sandstones and limestones, with accessory cherts which crop out in the nearby Taurus Mountains. Large amounts of other lithic grains (partially cemented sand grains) occur in the inner shelf sediments recovered off Mersin (Fig. 4F). Elsewhere, these grains are usually less abundant (< 10%) in the sands. This distribution pattern indicates that their sources are possibly the Müftü and the Deliçay rivers. Pumice and clasts of beach rock are other noticeable, but quantitatively unimportant, constituents.

3.4. *Distribution of the biogenic constituents of the coarse fraction*

The calcareous remains of foraminifers, ostracods, molluscs, bryozoans and echinoids are the main biogenic constituents of the surface sediments. The amount of foraminifers is at a minimum in the sediments of the inner shelf (Fig. 5A), due to dilution by terrigenous sediments (cf. Kukal, 1971). The greatest quantities occur in the deeper water sediments, with benthic foraminifers dominating the middle shelf and planktonic foraminifers the outer shelf sediments (from the mid-shelf zone).

The benthic foraminifers are least common in the inner shelf zone (Fig. 5B) but occur in greatest abundance in the sediments marginal to the areas of deltaic influence (i.e. of the Göksu and Seyhan-Tarsus, respectively). Where large amounts of nutrients are introduced by the rivers (Balkas *et al.*, 1980; Salihoglu *et al.*, 1987). Planktonic foraminifers form less than 10% of the coarse fraction of the sediments of the inner and middle shelf; they increase gradually below the 100-m depth contour, to the deeper water zones of the shelf (Fig. 5C). The planktonic to benthic ratio increases offshore, as elsewhere in the Mediterranean

Fig. 4. The percentage distribution within the surface sediments of: (A) terrigenous components; (B) quartz; (C) calcareous rock fragments; (D) green rock and mineral fragments; (E) reddish rock fragments; and (F) lithic grains within the coarse fraction (2–0.125 mm).

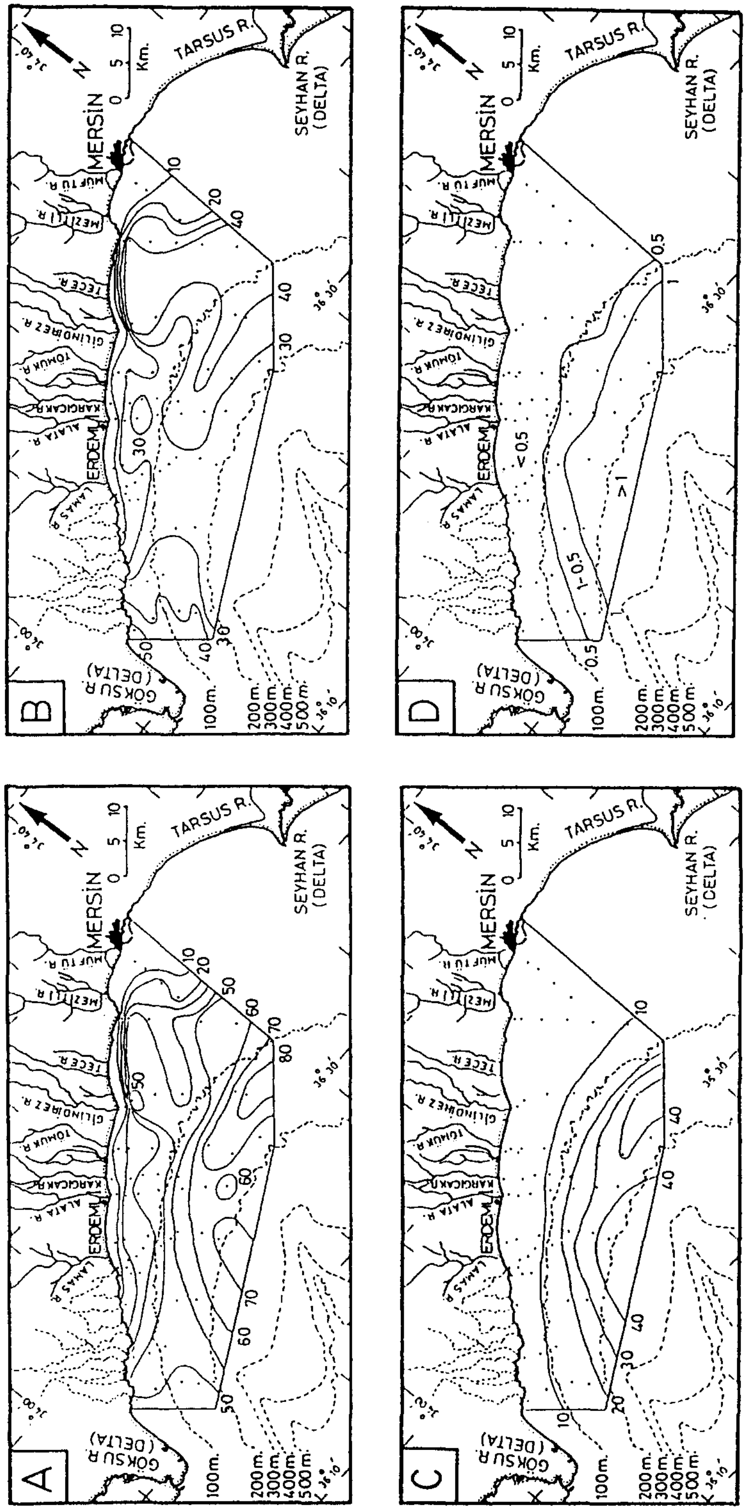


Fig. 5. The percentage distribution within the surface sediments of: (A) total foraminifers (planktonic + benthic); (B) benthic foraminifera; (C) planktonic foraminifers; and (D) planktonic to benthic foraminifers ratios, in the coarse fraction (2–0.125 mm).

(Parker, 1958; Korneva, 1966) and reaches 1.7 around the 200-m bathymetric contour (Fig. 5D). High sediment inputs and variable oceanographic conditions, together with coastal current systems, appear to preclude the presence of planktonic foraminifers in the sediments of the inner shelf.

The distribution of ostracods is similar to that of benthic foraminifers. The percentage of ostracods generally forms less than 10% in the coarse fraction of sediments. Their greatest concentration occurs in the middle shelf sediments of the northeastern part of the shelf (Fig. 6A), where the 10% contour of ostracods in the coarse fraction coincides approximately with the distal limits of the Seyhan delta system, off Mersin. Here, the ostracod to benthic foraminifer ratio (O:BF), is high (>0.4) (Alavi, 1980), whereas elsewhere, the ratio varies between 0.1 and 0.4 (Fig. 6B).

Pelecypods and pteropods are the dominant types of molluscan remains present in the coarse fraction of the sediments. The highest percentages of pelecypod remains are found in the sediments of the middle shelf; they form less than 10% in the coarse fraction of the inner and outer shelf sediments (Fig. 6C) and sometimes are completely absent (Stations 1, 5 and 6). In the middle shelf, coarser brown, thick-shelled fragments are very common. In the deeper water sediments, thinner shelled and smaller pelecypod remains are more common. The pteropods (generally $<5\%$ of the coarse fraction) occur only in the sediments from the middle and inner shelf areas associated usually with the planktonic foraminifers (Fig. 5CFig. 6D); they show a marked increase in the sediments of the outer shelf (Fig. 7D).

Bryozoans occur infrequently (usually $<10\%$ of the coarse fraction) in the sediments of the inner and outer shelf (Fig. 6E), but are abundant in the sediments of the middle shelf. The low content of bryozoans in those sediments off Mersin is due probably to the influx of freshwater and fine-grained muddy sediment from the Seyhan, Tarsus, Müftü and Mezitli rivers (Fig. 6E). Bryozoans are known to be particularly sensitive to environmental change; they disappear as the flux of deltaic waters and sediments affect the adjacent marine environment (cf. to the situation offshore of the Rhone delta (Lagaaij and Kopstein, 1964)). There is a clear positive correlation between the abundance of pelecypods and bryozoans showing that similar ecological conditions favour these two benthic groups on the middle part of the shelf.

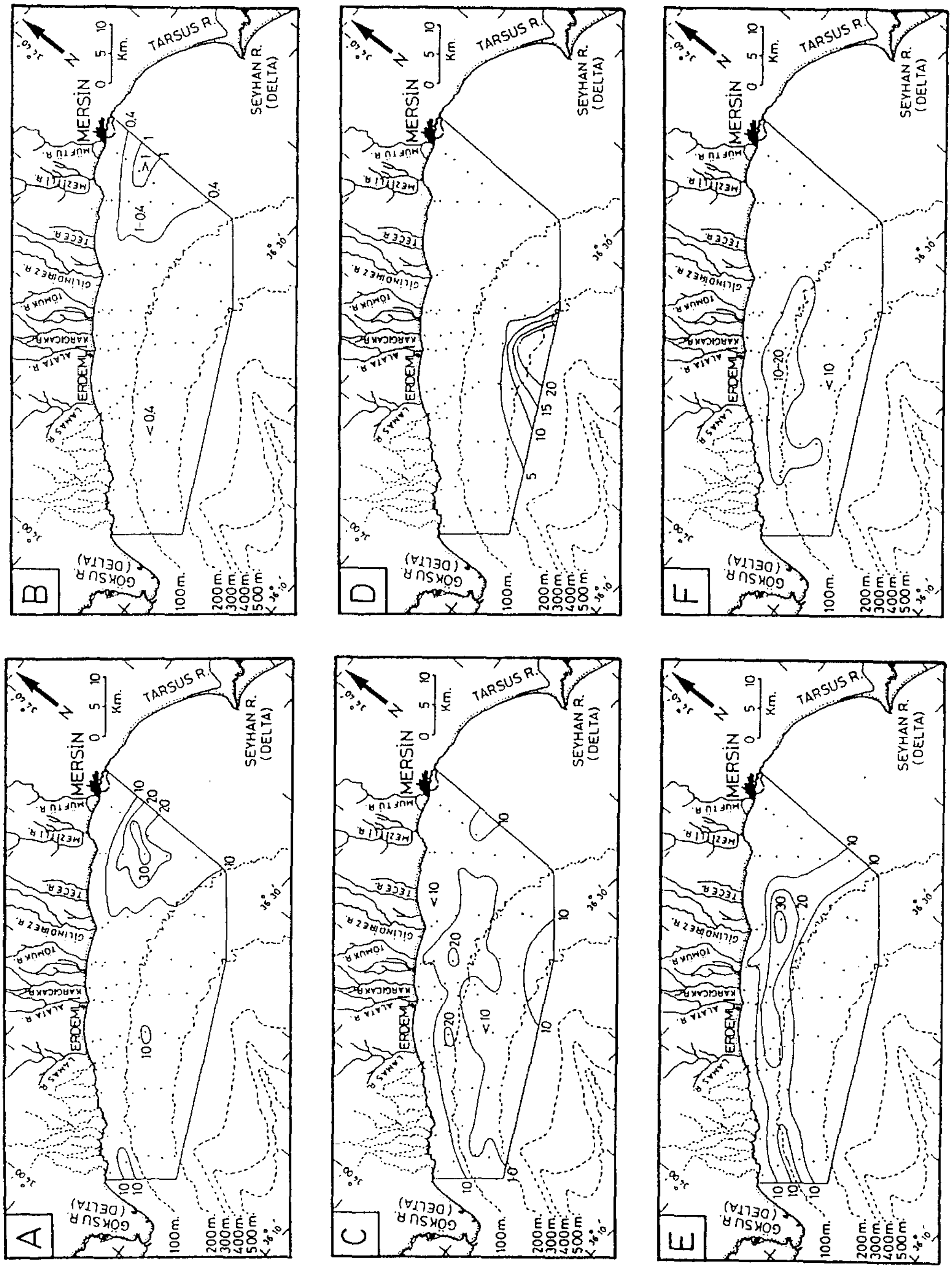
Echinoid debris forms usually less than 10% of the coarse-grained fraction of most of the area (Fig. 6F), except around the 100-m depth contour where echinoids form 10–20% of the sediment and where pelecypods and bryozoans are common.

3.5. *Lithofacies*

A modified version of the triangular diagram of Folk (1974) was used to clarify the lithofacies (Fig. 7). Sand, silty sand and slightly clayey sandy silt form a narrow belt which parallels the coastline on the inner shelf and extends seawards to the 50-m isobath.

Most of the central and southwestern middle shelf (50–100 m) is covered with clayey sandy silt and silty sandy clay. This zone contains considerable skeletal debris in the coarse fraction of the sediments.

In the northeastern part of this middle shelf, the sediments pass into clayey silts and, ultimately, silts as the margins of the Seyhan-Tarsus delta are approached. The limited sample network in the southwest has revealed only a narrow belt of clayey silt to the northeast of the Göksu delta. The outer shelf (100–200 m) has a cover of silty clay and clayey silt with noticeably less skeletal debris than the sediments of the middle shelf.


A
B
C
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F
MERSİN
TARSUS R.
SEYHAN R. (DELTA)
GÖKSU R. (DELTA)
ERDEMLİ
0 5 10 Km.
N
100m.
200m.
300m.
400m.
500m.
36° 30'
36° 10'

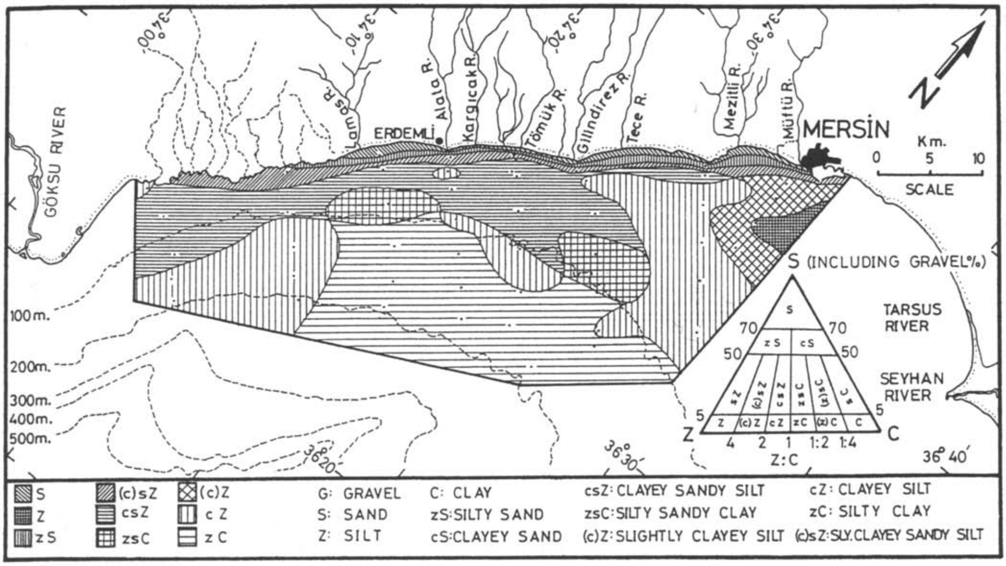

Fig. 7. Lithofacies map of the surface sediments of the western shelf of Mersin Bay. A modified trilinear diagram of Folk (1974) is used for the classification of sediments. **Note**: The scales are linear and % boundaries and ratios are shown but the boundaries between the various classes are displaced on the figure, for ease of drafting.

3.6. *Biofacies*

A biofacies map for the surface sediments was prepared on the basis of the dominant benthic components as well as the ratios of: terrigenous to biogenic sediment (T:B); planktonic to benthic foraminifera (P:B); and the ostracod to benthic foraminifera ratio (O:BF) of the coarse fractions of the samples studied.

Biofacies A is delimited generally to seaward by the 50-m depth contour. This facies is dominated by coarse-grade terrigenous sediment with a T:B > 1 which contrasts with all other biofacies except Biofacies F which have T:B ratios < 1 (Fig. 8); it has an O:BF < 0.4 and a P:B < 0.5. Abundant wood, coal and seeds of terrigenous origin are concentrated along the boundary between Biofacies A and B.

The sediments of Biofacies B cover the shelf between the 50- and 100-m contours, but extend to slightly greater depths in the southwest. These sediments contain the highest amounts of benthic calcareous remains with a T:B < 1. Bryozoans, molluscs (mainly pelocypods) and echinoids, together with foraminifers and ostracods, are the principal components. The planktonic foraminifers are less common (P:B < 0.5) and pteropods are present only in amounts < 5%. Many of the shells are stained brown and are polished, worn and broken with sponge and fungal borings.

Towards the Seyhan-Tarsus delta (Biofacies F), there are noticeable changes in the sediment. The T:B ratio becomes > 1, as the delta is approached. There is an increase in the

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Fig. 6. The percentage distribution within the surface sediments of: (A) ostracods; (B) ostracods–benthic foraminifers ratio (O/BF); (C) pelecypods; (D) pteropods; (E) bryozoans; and (F) echinoid debris, in the coarse fraction (2.0–0.125 mm).

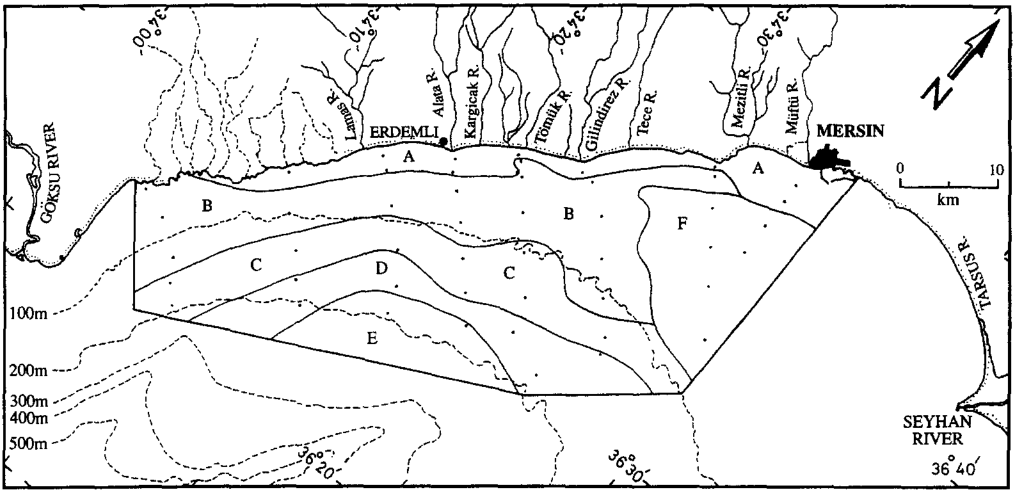

Fig. 8. Biofacies map of the surface sediments of the western shelf of the Bay of Mersin. Refer to Section 3.6 for meaning of A, B, C, D, E and F.

percentages of ostracods and benthic foraminifers with the ostracod benthic ratio increasing (O:BF > 0.4). The content of pelecypods, bryozoans and echinoids decreases (Fig. 6D,E,F) in the same direction. There are less marked changes towards the Göksu delta, although there is again an increase in benthic foraminifers and a decrease in bryozoans and echinoids.

The skeletal remains in the sediments of the outer shelf (100–200 m) are noticeably smaller in size, thinner shelled and fresher and less altered than those of the middle shelf (Biofacies B). The remains have been divided into three biofacies.

Biofacies C occurs immediately to seaward of B, between water depths of 100–150 m; but in the southwest, this extends to 150–200 m. The facies contains less bryozoa, molluscs and echinoids than Biofacies B. Foraminifers are abundant with P:B ratios 0.5–1.0. Pteropods form < 5% of the coarse fraction, as in the other biofacies except A and F which have O:BF ratios < 0.4.

Biofacies D (150–200 m) is again depleted in bryozoa, molluscs and echinoids in comparison with B, but with similar O:BF ratios (< 0.4); it has a high content of foraminifers with P:B ratios higher than C (1.0–1.5).

Biofacies E is found only on the outer shelf in the central part of the area; it has a high content of foraminifers, with P:B ratios > 1.5. The biofacies has similar O:BF ratios (< 0.4) to those of the outer shelf sediments remote from the influence of the deltas, with low values of bryozoa, and higher values of pelecypods and pteropods.

3.7. *$CaCO_3$ and clay mineralogy of the sediments*

The sediments contain 20–30% $CaCO_3$ in the nearshore sediments increasing to 30–40% offshore (Shaw and Bush, 1978). The carbonate is partly of biogenic origin but is also in part clastic carbonate derived from the abundant limestones in the hinterland of the Taurus Mountains. The clay fraction of the sediments consists of 40–50% illite and 40–50% smectite with lesser amounts of kaolinite (5–10%), chlorite (5–10%) and local traces (3–5%)

of serpentine (Shaw, 1978). There is an increase in smectite relative to illite in an offshore direction probably due to differential settling (Shaw, 1978).

4. CONCLUSIONS

The continental shelf of western Mersin Bay is deepest in the southwest and shallows gradually towards the northeast. The slopes are steeper between the Göksu delta and the Lamas river, in the southwestern part adjacent to the rocky cliffed coast, than in the northeastern part of the area studied (off the alluvial coastline).

Coarse-grained sediments are concentrated in the coastal area between the mouth of the Lamas river (in the southwest) and Mersin (in the northeast); this lies adjacent to the coastal plain, fed by ephemeral streams during spring and early summer. The silt and clay contents of the sediments increase slightly from nearshore to offshore. Sand, silty sand and slightly clayey, sandy silt are present, in succession from the shoreline to a water depth of around 50 m. The outer boundary of these sediments defines the boundary of what is here termed the Modern Terrigenous Prism (Fig. 9); this coincides approximately with the distribution of Biofacies A. The coastal rivers are the main source of coarse-grained terrigenous sediments; their distribution is undoubtedly controlled by the wave and wave-generated current regimes of this zone.

The percentages of the coarse-grained fraction of the sediments of the middle shelf zone range between 5 and 50%, whilst the silt to clay ratio is between 1 and 2 in the clayey sandy silt zone. Biogenic shell fragments are abundant within the sediments of the western and central parts of the middle shelf zone and, consequently, this region is referred to as the Shelly Zone. The boundaries of this zone correspond remarkably well with those of Biofacies B.

Silt, slightly clayey silt and clayey silt are present on the northeastern part of the shelf to form what is here named the Prodeltaic Zone I; this is produced by deposition of suspended

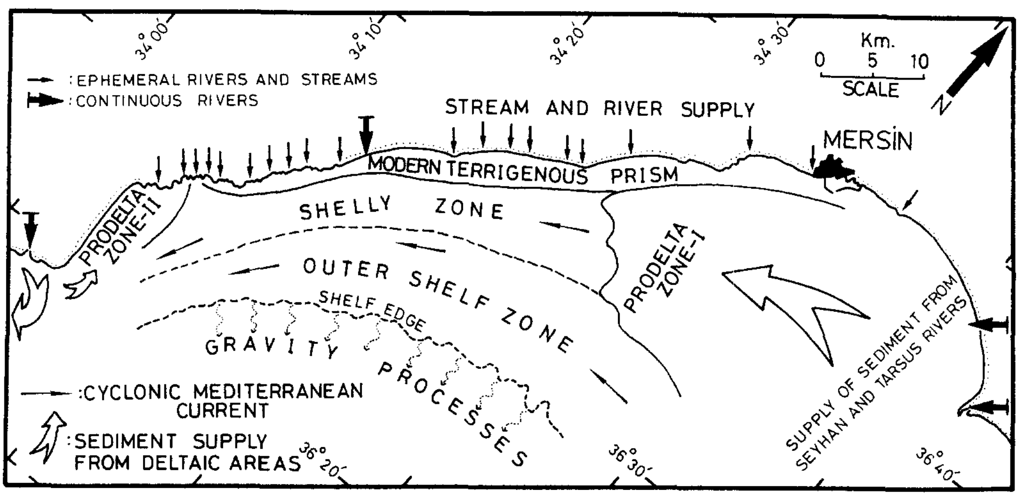

Fig. 9. General (schematic) pattern of sediment supply, transport and deposition on the continental shelf of Mersin Bay, northeastern Mediterranean Sea.

sediments from the Seyhan-Tarsus rivers, transported along the shelf by the coast-parallel regional water circulation. These silt-dominated areas correspond well with Biofacies F, whose faunas are affected by the Seyhan-Tarsus river system. The southwestern part of the area which is affected to a much lesser extent by the Göksu river system and is again covered with silt-dominated sediments is referred to as Prodeltaic Zone II.

The coarse and silt fractions decrease gradually from the 100- to 200-m isobaths, on the outer shelf. Silty clay is the dominant sediment over the deeper parts of the shelf forming the Outer Shelf Zone. The abundance of planktonic molluscs and foraminifers as well as clay reflect the remoteness of the coastal waters with their variable oceanography combined with the relatively deep and low energy conditions respectively. Differential settling appears to result in the offshore clays being enriched in smectite relative to illite (Shaw, 1978).

Sediment appears to be reaching the shelf of Mersin Bay between the deltas of the Göksu and the Seyhan-Tarsus from two main sources. First, there is the lateral supply from the coastal rivers between the two deltas, which is important over the area between Mersin and the mouth of the Lamas river; to the southwest, between the latter and the Göksu delta, this supply is much more limited. The lateral supply of sediment is dispersed along the coastline by wave and wave-generated currents. Occasionally, some of the fine-grained sediments are dispersed across the shelf as sediment plumes (or eddies) during periods of abundant runoff in spring and early summer (Evans *et al.*, 1995). However, most of the sediment is deposited along the coast, to form the Modern Terrigenous Prism.

The other main source of supply is the fine-grained sediment originating from the Seyhan-Tarsus delta (5314×10^3 t year^{-1}); this is carried along the shelf, from the northeast towards the southwest, under the action of the cyclonic Mediterranean circulation. The Ceyhan supplies 5462×10^3 t year^{-1} but most of this sediment is trapped in the Gulf of Iskenderun and only a small part leaks on to the shelf in front of the Seyhan-Tarsus delta. Much of the sediment from the Seyhan and Tarsus rivers is deposited within the northeastern part of the continental shelf of Mersin Bay, to form the distal parts of the Seyhan-Tarsus delta (Prodeltaic Zone I). Some sediments are carried farther towards the southwest, to accumulate over the middle part of the shelf (the Shelly Zone and, more particularly over the outer shelf, the Outer Shelf Zone). The Göksu supplies 2539×10^3 t year^{-1} of sediment to the coastal zone. However, apart from in its immediate vicinity, this input has little effect on the continental shelf of Mersin Bay. Instead, the sediments are swept away by the southwesterly cyclonic Mediterranean current (repeated observations on the sediment plume of this river, over several years by the second author show it to be advected towards the southwest).

The middle shelf area is of considerable interest; here, the sediments of the so-called Shelly Zone are noticeably rich in benthic skeletal debris. It appears that this zone is one in which there is an increase of skeletal material, as compared to terrigenous silt and clay. This may have developed because conditions over this part of the shelf favour benthic biological activity in contrast to: (i) the inner shelf, where there is rapid deposition of terrigenous sediment and where oceanographic conditions are variable, and (ii) the outer shelf where water depths are greater and there is a smaller supply of nutrient. Alternatively, the shelf currents may be limiting the deposition of terrigenous silt and clay within this zone. However, the measured shelf currents are low and this explanation seems unlikely.

An interesting and curious feature of this middle shelf Shelly Zone is that the skeletal-rich sediment only forms a thin layer (several cm thick) over sediment richer in terrigenous silt and clay, but which contains a similar shelf fauna. It appears that the development of this skeletal rich layer is a relatively recent phenomenon. These sediments are not relict or palimpsest deposits, as there is no evidence of mixing of faunas of shallower water environments with contemporary shelf faunas within the modern surface deposits. Instead, the surface deposits of the Shelly Zone are best regarded as a condensed horizon. Perhaps it has originated by a recent decrease in the amount of terrigenous sediment supplied to the area due to, as yet, unknown changes in the hinterland. Certainly, there has been a change in sediment supply due to the construction of a dam on the Seyhan in the 1950s, but this is probably too recent to explain the phenomenon. Alternatively, there may also have been changes in productivity or else in the intensity of the cyclonic Mediterranean water circulatory currents. However, there is no independent evidence to indicate either of these possibilities.

There is the further possibility that the surface concentration of skeletal debris, in the area relatively remote from the coastal or deltaic supply of sediment, may be due to anthropogenic activities. The shelf between 50 and 100 m is extensively trawled, in this particular area, by fishing boats. Generally, bottom lines disturb the bottom sediment to a depth of several cm (F. Bingol, personal communication). Disturbance of surface sediments by trawling gear has been suggested from elsewhere by other investigators (Hoffman *et al.*, 1990). Recently, Lesueur and Tastet (1994) have drawn attention to the possibility of such disturbance on the Aquitanian shelf of SW France. Further studies are being undertaken to attempt to evaluate the likelihood of such activities causing disturbance to sediments on the continental shelf of Mersin Bay.

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