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Seismic stratigraphy and late Quaternary sediments in inner and mid-shelf areas of eastern Mersin Bay, Northeastern Mediterranean Sea

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ABSTRACT

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High-resolution shallow-seismic reflection (Uniboom) profiles obtained in inner and mid-shelf areas of eastern Mersin Bay (Turkey, northeastern Mediterranean) show that the sedimentary column comprises two major and distinct lithological sequences (C and B) separated by a reflector (R) which is interpreted as the pre-Holocene surface. The upper sedimentary sequence (C) is thought to represent roughly the Holocene and is characterized by parallel/divergent to sigmoidal reflection patterns above (Unit 1) and sigmoidal-oblique to disrupted, wavy and hummocky reflection configurations below (Unit 2). This may reflect changes in relative sea level and/or depositional conditions during the earlier and later stages of Holocene. The Holocene sequence (C) reaches a maximum thickness of approximately 35 m about 500–600 m seaward of the mouth of Seyhan River and thins in all directions away from this point. Adjacent shelf areas are characterized by thinner (10–15 m thick) depositional sequences. Holocene sediment accumulation rates range from 1 to 3.5 m/ka.

The lower sedimentary sequence, B, is marked by chaotic reflection configurations and is interpreted as having formed largely during the Plio-Pleistocene. The top of this sequence displays various channel/onlap fills with parallel to oblique reflectors. This record may represent the pre-Holocene surfaces produced by subaerial, fluvial erosion of the pre-existing shelf. At least two or three orders of strong, continuous reflectors similar to Late Pleistocene/Holocene unconformities are observed within sequence B, and the repetitive pattern of the interfaces indicates cyclic sedimentation due to climatic fluctuations and oscillating sea-level changes, mostly in the Pleistocene.

Lithological logs from numerous soil borings on the adjacent coast suggest a significant increase in the thickness of the Plio-Quaternary sequences, from a few metres on the alluvial fan-delta systems west of Mersin to a few hundred metres on the fluvial plain–delta system east of Mersin. Climatic and sediment-discharge fluctuations and coastal morphology controlled the temporal and spatial distributions of Late Pleistocene and Holocene sediments in eastern Mersin Bay.

Introduction

The study area, Mersin Bay, is situated in the northeastern Mediterranean Sea, between the Seyhan River delta to the east, and the Goksu River delta to the west, and extends seaward onto the middle shelf. However, the emphasis here is placed on the eastern part of Mersin Bay where the coastal plain broadens remarkably towards the east-northeast, from the Gilindirez River fan-delta to the Seyhan River delta (Fig. 1).

Mersin Bay has a wide shelf (42 km) off the mouths of Delicay–Tarsus–Seyhan rivers which narrows to 20 km off the Gilindirez River mouth (Fig. 2). While alluvial fan-delta associations are prominent west of Mersin, wide delta plains and lagoons are characteristic morphological units that occur on the eastern coast of Mersin Bay (Evans, 1971). In general, the study area is bound to the north by a SE–NW-trending coastal plain which is flanked by the Taurus Mountains of Turkey to the west and north. The coastal plain in the west

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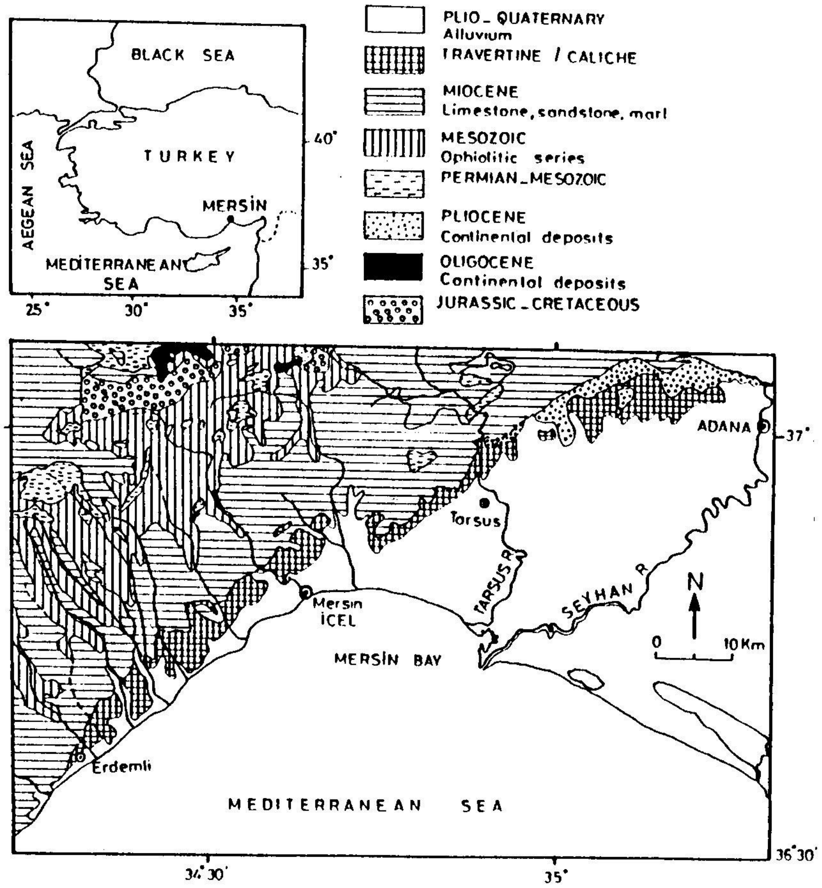

Fig. 1. Generalized geological map of the coastal hinterland of Mersin Bay in the northeastern Mediterranean (compiled from various sources).

is often crossed by a series of ephemeral streams which form complex alluvial fan and delta systems (Fig. 2).

Previous seismostratigraphic studies have focused on the deeper waters off Mersin Bay (Wong and Zarudzki, 1969; Wong et al., 1971; Malovitsky et al., 1975; Stanley, 1977; Woodside, 1977; Woodside and Williams, 1977; Biju-Duval et al., 1978; Evans et al., 1978; Hooker, 1981). In addition, Aksu and Ulug (pers. commun., 1990) have recently carried out deep-penetration seismic surveys in the offshore areas of Mersin Bay using an airgun system. Surprisingly little, however, is known about the shallow seismic characteristics of the shelf sediments in this area (Bodur and Ergin, 1989; Ergin et al., 1989).

The main purpose of the present study is to interpret the Late Quaternary sediments formed in response to the various topographic, hydrographic and climatic factors that have prevailed in Mersin Bay.

Geological and hydrographic settings

The geology of the surrounding coast is dominated by Plio-Quaternary deposits overlying late Tertiary [mainly Neogene (Miocene)] limestones, marls, sandstones and conglomerates (DSI, 1978, and unpubl. data) (Figs. 1 and 3). Plio-Quaternary deposits are composed mainly of clay, silt, sand and gravel of diverse origins. The latter contains fragments of limestones, cherts, sandstones, and basic/ultramafic igneous rocks. These have been transported by several streams (partly ephemeral) from the Tertiary and Cretaceous terrains of the hinterland mountains to form small alluvial fans,

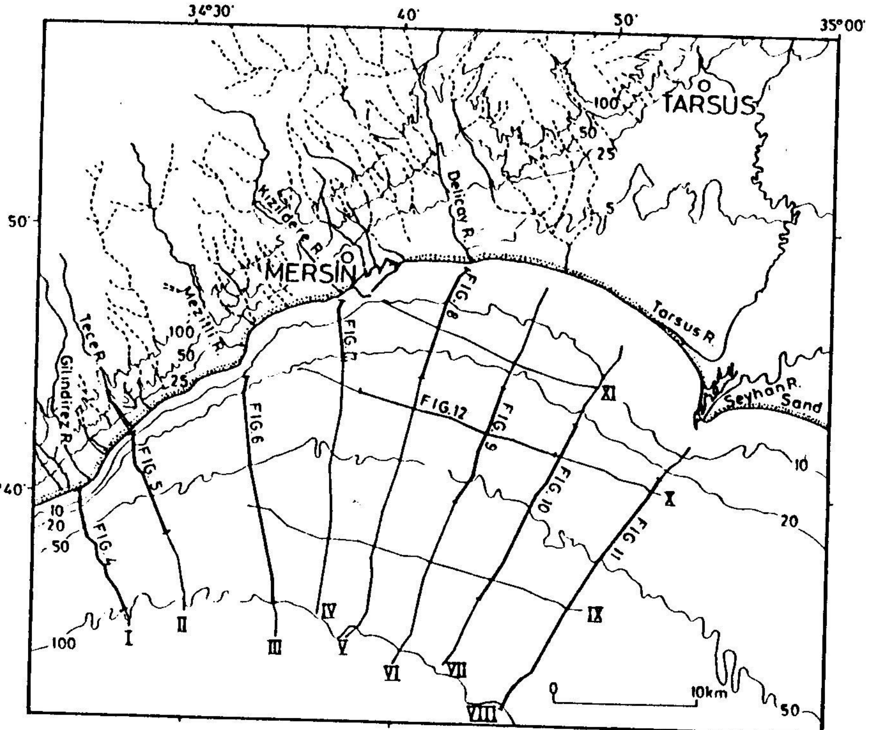

Fig. 2. Location map of the seismic-surveyed marine region east of Mersin Bay. Note the numbers on tracklines showing continuous seismic profiles. The seismic reflection profiles used in this study (Figs. 4–12) are also given. Water depths are in metres.

especially on the narrow coastal plain west of Mersin. For convenience in this study we shall distinguish between the fluvial–deltaic systems east of Mersin Bay, and the alluvial fan-deltaic systems west of the bay, based on coastal morphology and fluvial inputs.

The Plio-Quaternary deposits attain their minimum thicknesses on the western coast where several Tertiary basement rocks outcrop. By contrast, they appear to be much thicker (up to 1250 m; Schmidt, 1961) towards the east on the wide fluvial plains of the Tarsus and Seyhan rivers. The coastal plain extends southwards beneath the waters of the Mediterranean. Farther to the south, in deeper waters offshore Mersin Bay, the unconsolidated Plio-Quaternary sediment sequences range from < 250 m on the shelf/upper slope zone (Malovitsky et al., 1975; Stanley, 1977; Weedon, 1983) to 1–2 km thick in the eastern Cilicia Basin (Stanley, 1977; Ozhan, 1988).

Surface sediment patterns show that siliciclastic mud is the dominant type on the Mersin Bay shelf, and sand and gravel are frequently found beneath the nearshore waters at depths of < 10 m (Shaw and Bush, 1978; Bodur and Ergin, 1988; Ergin et al., 1988; Ergin et al., 1989). The Seyhan, Tarsus (Berdan), Delicay, Kizildere (Efrenk), Mezitli and Gilindirez rivers carry most of the sediment into the marine region studied, in eastern Mersin Bay (Fig. 1). Of these, the Seyhan, and Tarsus flow all the year round, while the others constitute ephemeral flows for 3–4 months of the year. The streams and rivers with seasonal flows, however, have much greater erosional effects on their banks and beds (DSI, 1978). The drainage areas and the discharge rates of these rivers are given in Table 1.

The climate of the study area is of the Mediterranean type—hot and dry in summer and mild and rainy in winter. The annual average rainfall is about 650 mm. The circulation in Mersin Bay is mainly characterized by the westward flow of surface currents (Ovchinnikov, 1966; Ozsoy et al., 1987; Unluata, 1986). However, several cyclonic and anticyclonic circulation systems exist at rela-

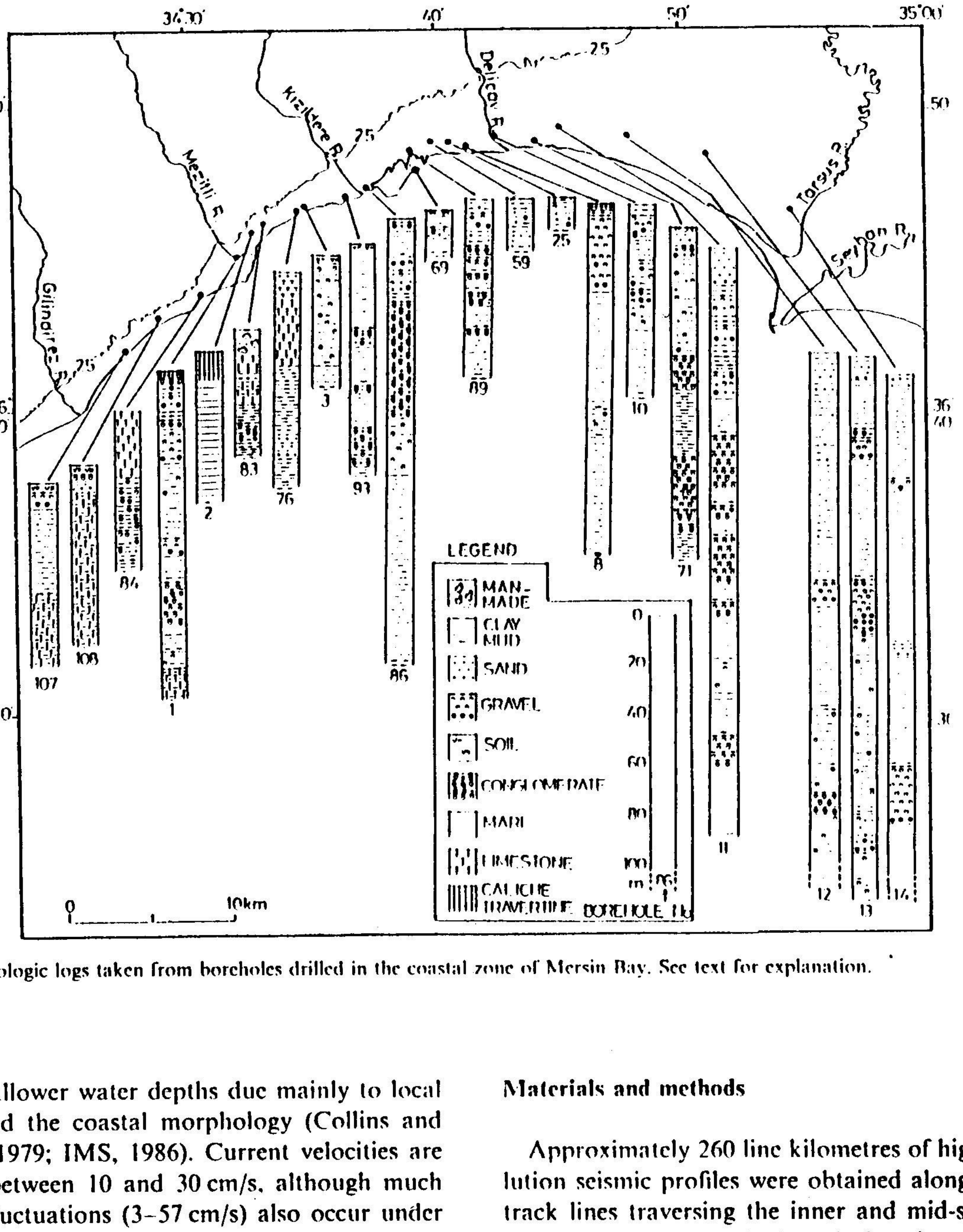

Fig. 3. Lithologic logs taken from boreholes drilled in the coastal zone of Mersin Bay. See text for explanation.

tively shallower water depths due mainly to local winds and the coastal morphology (Collins and Banner, 1979; IMS, 1986). Current velocities are usually between 10 and 30 cm/s, although much greater fluctuations (3–57 cm/s) also occur under the influence of changing hydrographic conditions (IMS, 1986). The nearshore currents in particular (also known as high-turbidity waters) carry most of the detritus from coastal erosion and river runoff (based on Secchi-depth measurements and ERTS imagery) (Collins and Banner, 1979; IMS, 1986). Tidal ranges are small (+65 to −90 cm: cf. Bal and Demirkol, 1987/1988).

Materials and methods

Approximately 260 line kilometres of high-resolution seismic profiles were obtained along eleven track lines traversing the inner and mid-shelf regions of eastern Mersin Bay during the cruise of R.V. *Lamas* in 1989 (Fig. 1). An EG&G Uniboom shallow-seismic system (100–300 J) was used. The effective acoustic frequency range was 400 Hz–14 kHz. An assumed seismic velocity of 1500 m/s was used to derive water depths. The seismic velocity for unconsolidated sediments is assigned a value of approximately 1600 m/s, i.e., a value which is

TABLE I

Surface area of drainage basins and water discharge rates of the important rivers and streams in the vicinity of Mersin Bay (n.a. = no data available)

	Drainage area (km)	Flow rates (m/s)	
		Min.	Max.
Seyhan	14015	44	1960
Tarsus (Berdan)	1416	1	1222
Delicay	305	0	330
Efrenk (Muftu)	345	0	110
Mezitli (Kizildere)	n.a	0	8
Gilindirez	n.a	0	n.a
Lamas (limonlu)	1055	2	62

Sources: IMS (1986); EIE (1981, 1989); cf. Ebren (1982)

close to that derived for Pliocene–Quaternary sediments in Mersin Bay (Malovitsky et al., 1975). Positioning was maintained using a Del Norte/Decca Radio Navigation Trisponder System.

Numerous lithological logs were available for consultation from a total of 90 boreholes along the coastal zone (Fig. 3); these were drilled by several state and private institutions for the purpose of various hydrogeological, coastal and harbour engineering surveys. The coastal alluvial deposits are known to be the best groundwater reservoirs around the study area (DSI, 1978).

Recognition of depositional sequences and the interpretation of data are based on the seismic stratigraphic analysis methods outlined by Mitchum and Vail (1977), Vail et al. (1977), Sangre and Widmier (1979) and Brown and Fisher (1980).

Coastal-plain lithofacies

Boreholes drilled in the coastal zone north of the seismic-surveyed marine regions (Fig. 3) reveal a considerable lateral thickness variation in the Plio-Quaternary sequences which overlie the Miocene marls and limestones. In the northwest of Mersin, where bedrock (mostly karstic and caliche) is exposed in many areas, the Plio-Quaternary deposits range in thickness from less than 1 m in Boreholes 2 and 84 to about 50 m in Boreholes 107 and 3. Exceptions are Boreholes 1, 93 and 86 where thick sequences of alluvial fan and associated fluvial deposits are prominent (Fig. 3). Here, particularly on the Mezitli River alluvial fan, the Plio-Quaternary deposits constitute a 110 m thick infill sequence within a fault-controlled valley cutting across the Miocene bedrock (Fig. 3). Observations on land reveal several other such deep valleys now in the form of channeled river beds which consist of very coarse gravel sediments derived from limestone and ophiolitic sources from the northern hinterland. This indicates high-energy fluvial conditions (possibly ephemeral), and the braided streams in this region are comparable with many storm-generated alluvial fans (e.g., Wells and Harvey, 1987). To the east of Mersin Bay, where wide, fluvial deltaic coastal plains are cut by the Delicay, Tarsus, and Seyhan rivers, the Plio-Quaternary sequence attains thicknesses of over 250 m (e.g., Boreholes 11, 12, 13 and 14; Fig. 3).

The presence of vertically alternating sequences of coarse and fine sediments in the studied boreholes (Fig. 3) indicates that coarser grained deposits periodically occupied the high-energy fluvial channel position; at other times, low-energy flood basin deposition and overbank flows of finer grained sediments prevailed. This is a common feature in many alluvial fan associations (e.g., Schumm, 1961; Hooke, 1967; Reineck and Singh, 1975; Collinson, 1978; Hallam, 1981).

Lithological logs from the ten soil borings recovered from about 400 m offshore, south of the coast bordering Mersin Bay, display stiff and yellow-brownish clay/mud sequences underlying the most recent black mud. It is likely that the surface of these oxidized and indurated clays represents subaerial erosion, most probably that which occurred during the Last Glacial (Würm) maximum (from about 25,000 to 18,000 yrs B.P.), as sea level dropped 90–140 m below the present level (e.g., Morner, 1971; Clark et al., 1978; Aksu and Piper, 1983; Coutellier and Stanley, 1987).

Seismostratigraphic sequences

As shown in Figs. 4–12, two distinctive seismic stratigraphic sequences (C and B) have been identified on the seismic profiles. These sequences are separated by a reflector (R), which, with its highly contrasting gross seismic reflection character,

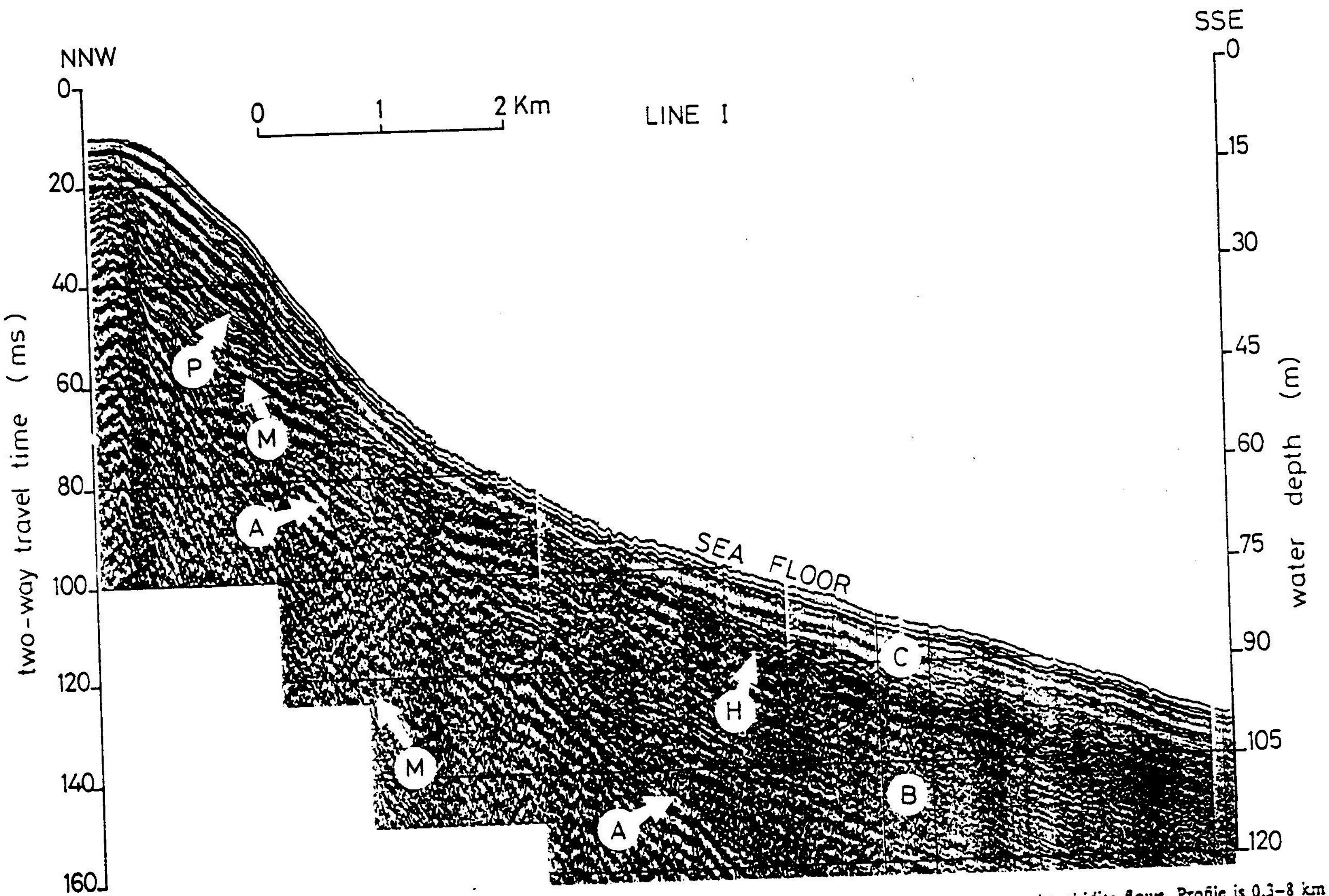

Fig. 5. High-resolution seismic profile off the Gilidirez River mouth showing fan-delta progradation (*P*) with the downslope slump and turbidite flows. Profile is 0.3–8 km from the coast. *A* = pre-Plio-Quaternary basement rock; *H* = channel fill; *C* = Holocene sequence; *B* = Plio-Pleistocene seqeunce; *M* = multiple.

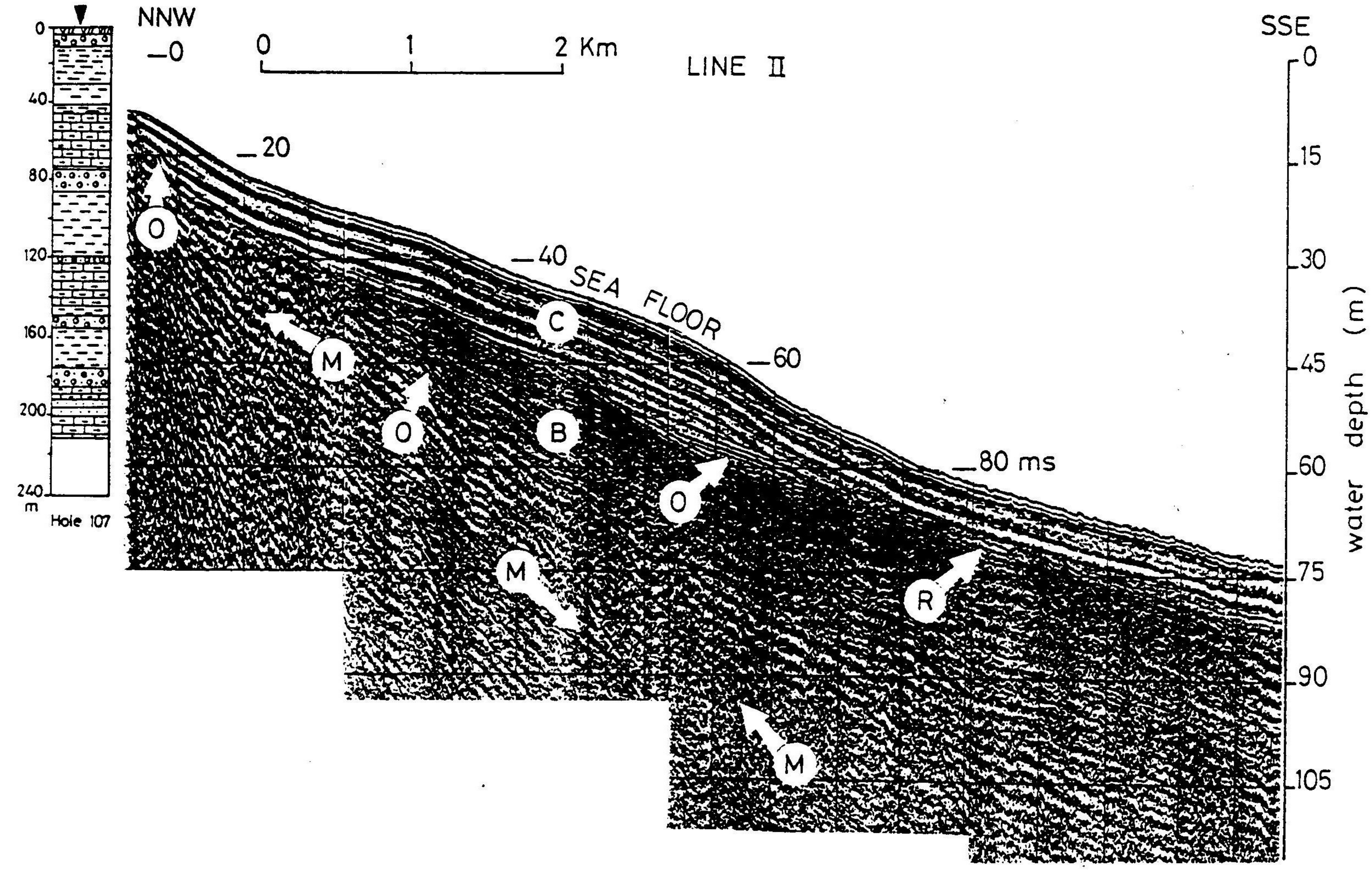

Fig. 4. High-resolution seismic profile off the Tece River mouth (for location of all profiles, see Fig. 1) Profile is 0.3–8 km from the coast. Note the shallowing upward (onlap) sequence of a gently prograding shelf/delta system over an erosional surface (*R*) and the Plio-Pleistocene sequence (*B*) below it. *O* = onlap fill; *C* = mainly Holocene. The irregular and uneven surface of sequence C downdip indicates slope facies with possibly distal and proximal turbidities. *M* = multiple. For borehole information in profiles, see Fig. 3.

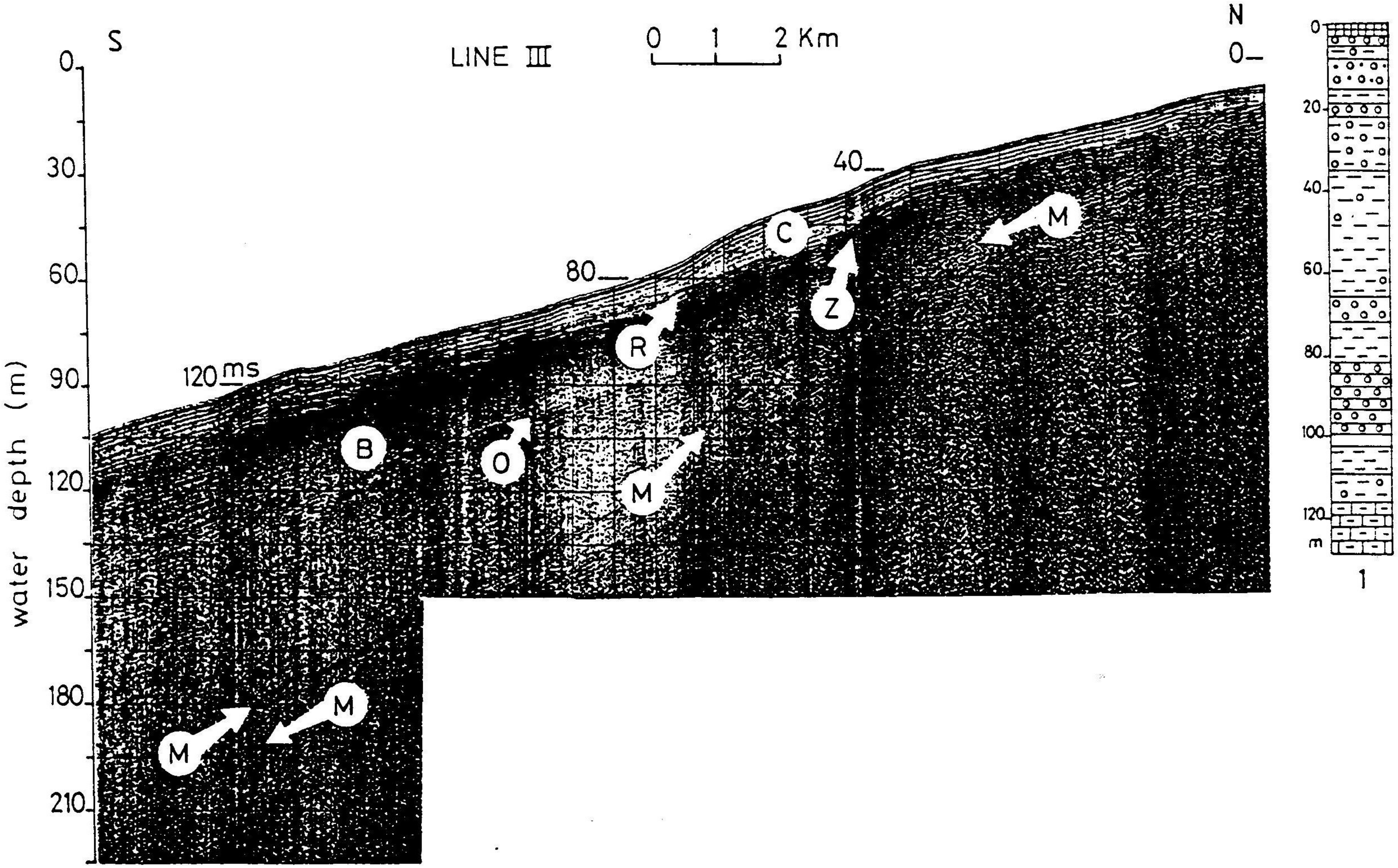

Fig. 6. High-resolution seismic profile off the Mezitli River mouth showing widespread sheet of parallel/divergent to gently sigmoidal reflections indicating rather uniform deposition (*C*) over a pre-Holocene (*B*) surface (*R*). Note the opaque zone of gaseous layers (*Z*). Profile is 1.3–19.3 km from the coast. Note also the repetetive sequences with marine onlap configuration (*O*) reflecting cyclic sedimentation patterns during pre-Holocene times (*B*). *M* = multiple.

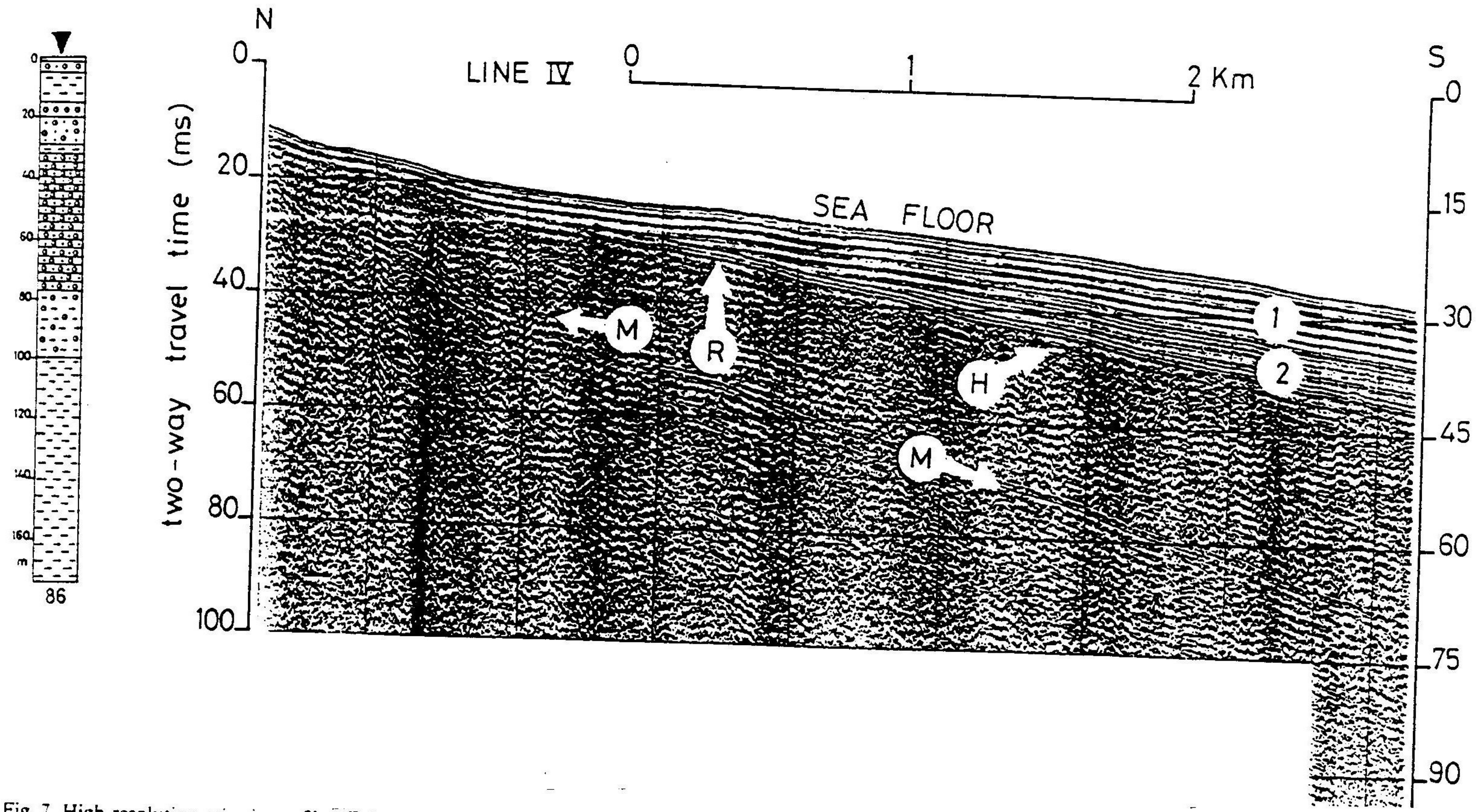

Fig. 7. High-resolution seismic profile off the Kizildere River mouth. Note the shallowing upward sequences (onlap) of progradational delta facies developed on an erosional (*H*) pre-Holocene surface (*R*). The underlying angular unconformity of Unit 1 is onlapped by the marine transgressive facies (Unit 2). The profile is 0.4–4.5 km from the coast. *M* = multiple.

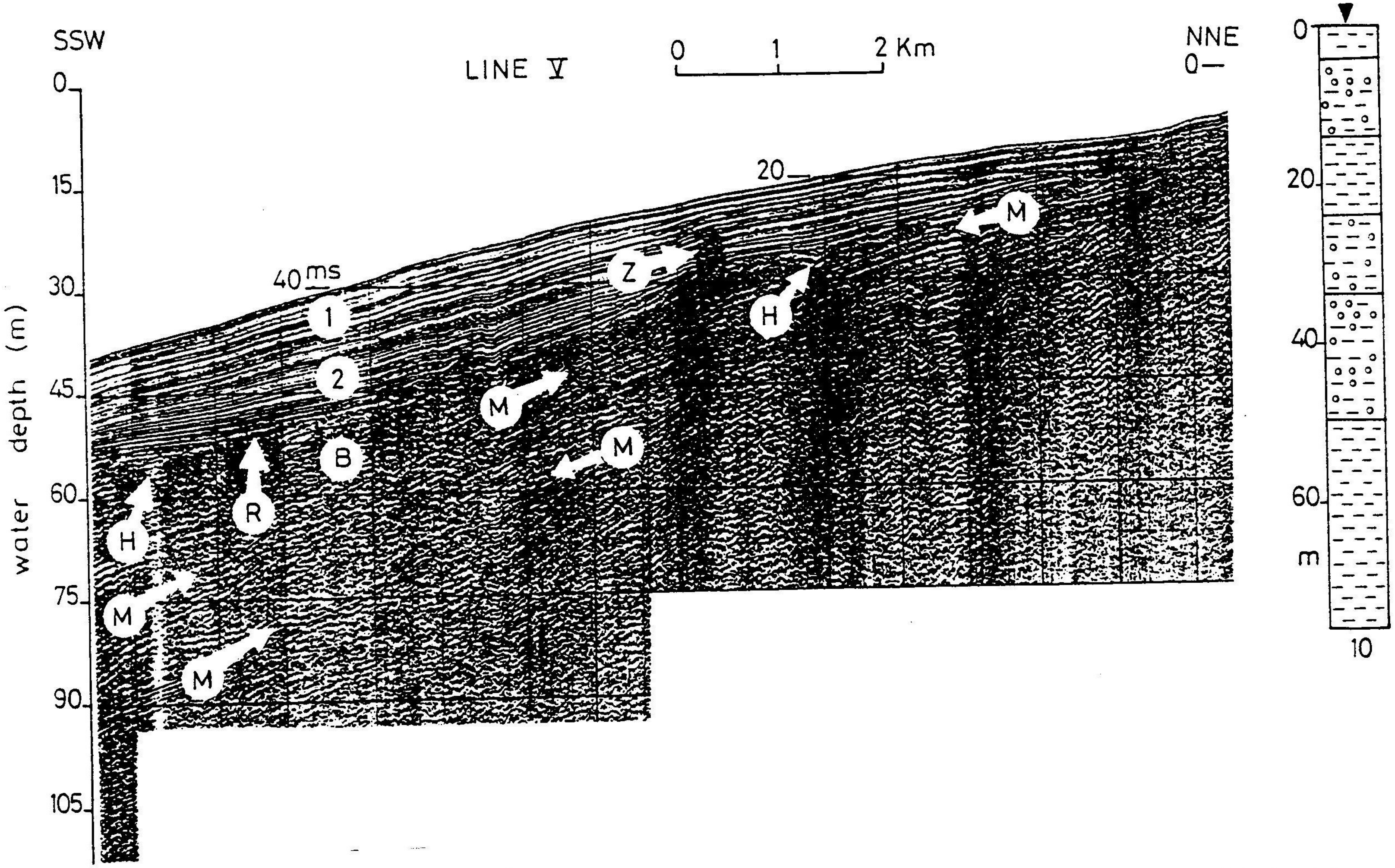

Fig. 8. High-resolution seismic profile off the Delicay River mouth showing the shallowing upward sequences (onlap) of prograding delta facies (Units 1 and 2) on an erosional (*H*) pre-Holocene (*B*) surface (*R*). Profile is 0.4–11 km from the coast. *Z* = opaque zone possibly due to gas or fluid occurrences.

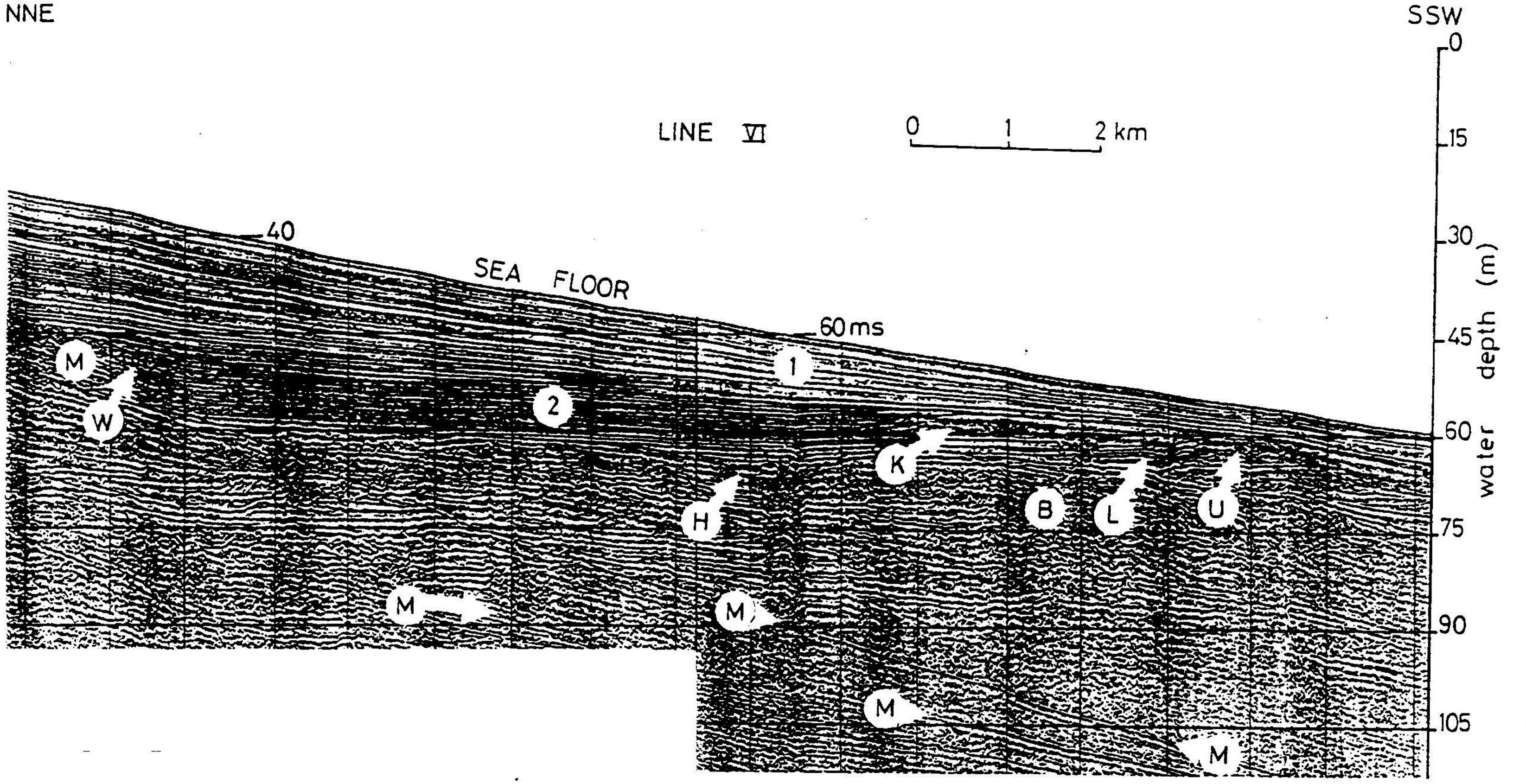

Fig. 9. High-resolution seismic profile off a presently abandoned river mouth (between Delicay and Tarsus rivers). Profile is 8.8–18.2 km from the coast. Note the Holocene delta progradation Units 1 and 2 on an erosional (*H*) pre-Holocene (*B*) surface (*R*). *M* = multiple reflectors; *W* = wave-cut platform; *K* = chaotic fill, perhaps of coarser sediments; *L* = lee foresets; *U* = mounded or dammed fill.

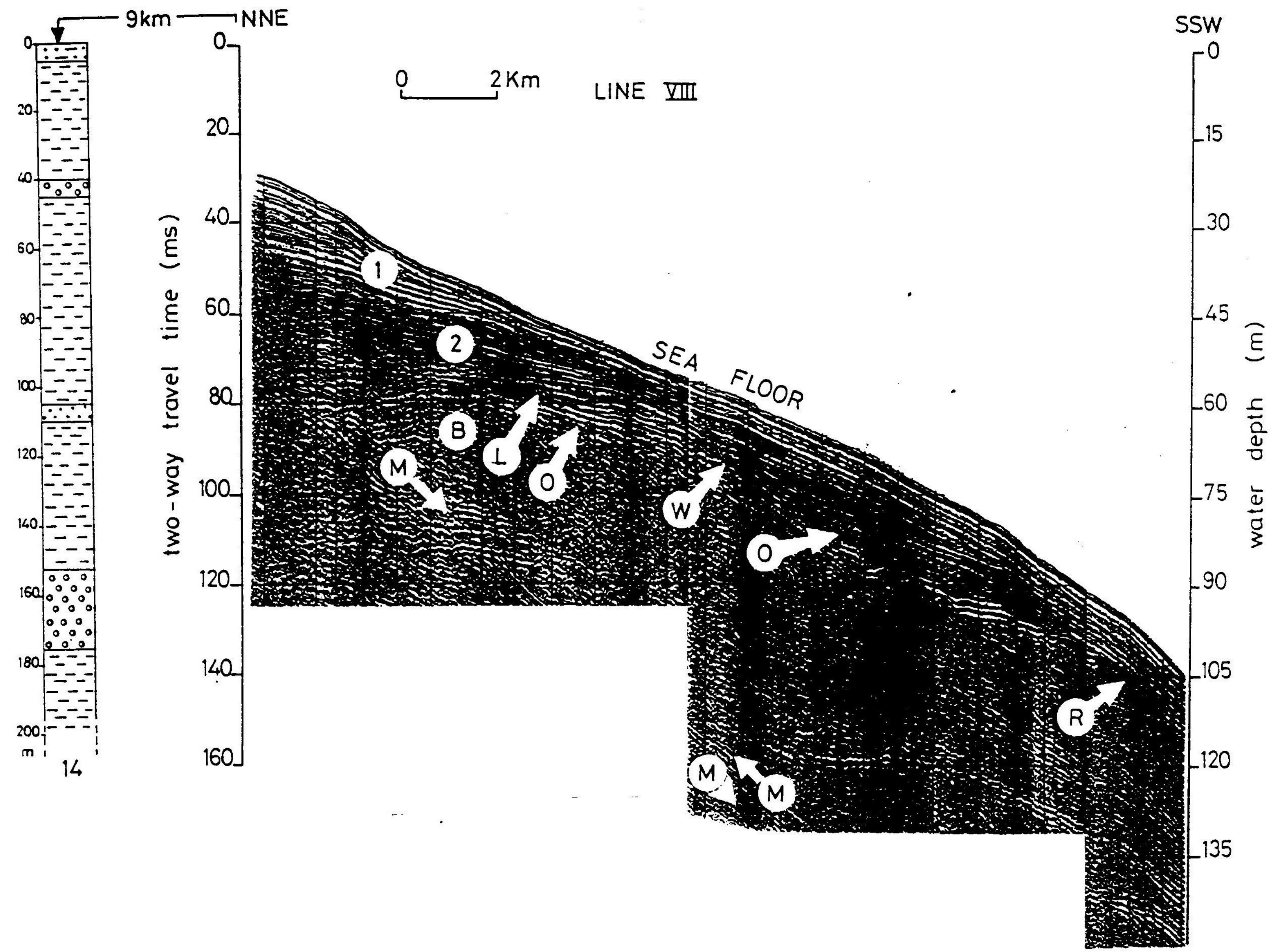

Fig. 11. High-resolution seismic profile off the Seyhan River mouth showing progradational delta facies. Note the irregular erosional surface (*R*) overlain by the Holocene units (1 and 2). Profile is 4.5–23.3 km from the coast. *B* = Plio-Pleistocene sequence; *L* = lee foresets; *O* = onlap fill; *W* = wave-cut platform; *M* = multiple.

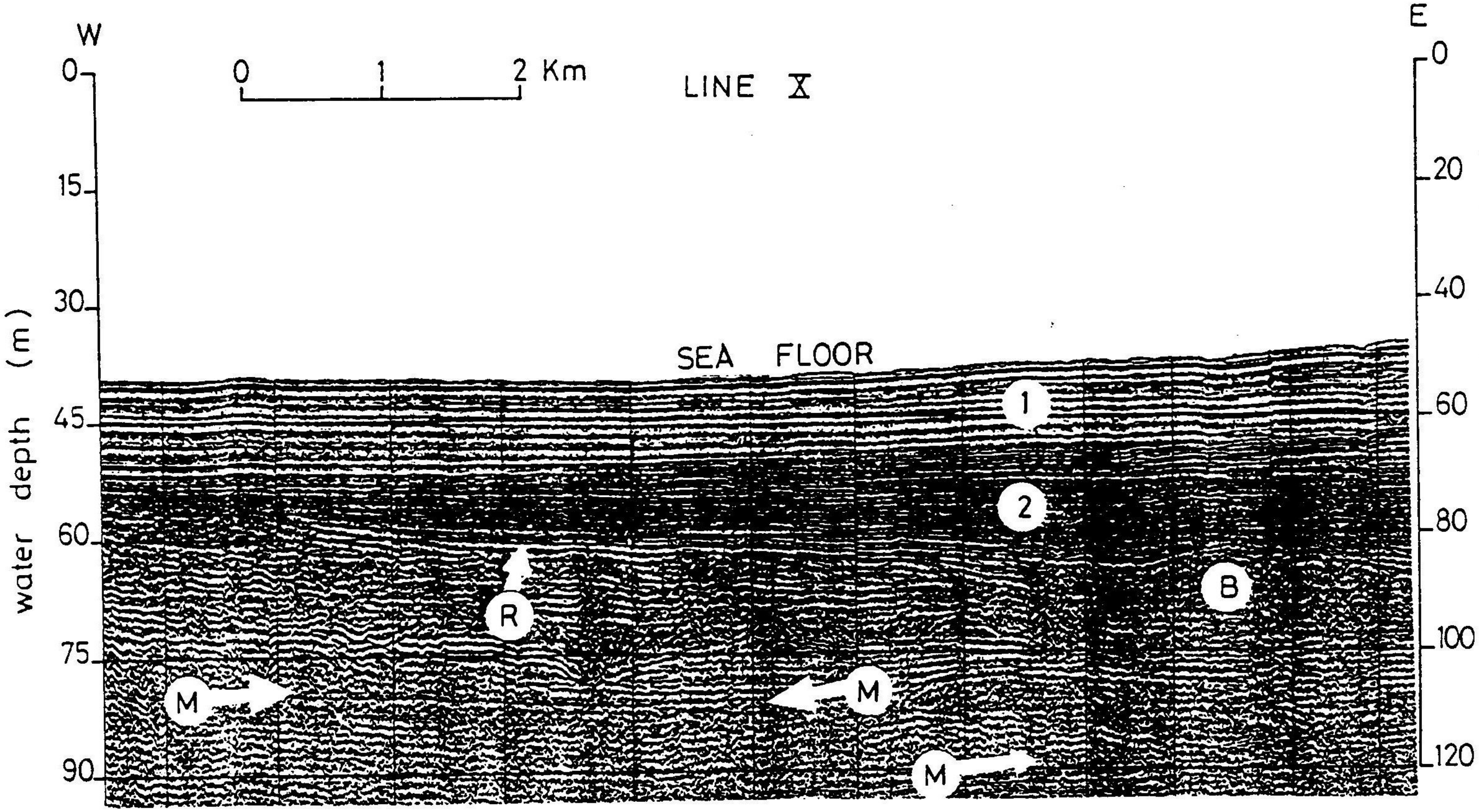

Fig. 12. High-resolution seismic profile parallel to the coast, between Seyhan (right) and Kizildere (left) deltas. Profile is ca. 1.1–1.2 km from the coast. Note the erosional pre-Holocene surface (*R*) covered by the earlier (Unit 2) and later (Unit 1) stages of Holocene deposits. *M* = multiple.

accentuates the difference between the depositional horizons. There also exists a third sequence (A) which forms the acoustic basement underlying depositional sequences B and C; sequence A is only observed off the fan-delta system of Tece River, west of Mersin Bay (Fig. 4). If projected onshore from its landwardmost position on the seismic profile, basement reflector A appears to correspond to the Miocene limestones and marls that outcrop along the rocky coast (Figs. 2 and 3).

Here we define a depositional sequence as a seismic stratigraphic unit composed of a relatively conformable succession of genetically related strata bounded at its top and base by unconformities or their correlative conformable surfaces. They can best be recognized by their reflection patterns on seismic sections.

Sequence C

Depositional sequence C represents the relatively younger sedimentary units overlying reflector R and is characterized by a simple- to complex-stratified reflection configuration on the seismic profiles (Figs. 4–6). The top of this sequence forms the present seafloor.

Sediments of sequence C deposited off the mouths of Gilindirez (Fig. 5, Line I), Tarsus (Fig. 10, Line VII), and Seyhan (Fig. 11, Line VIII) rivers, as well as those from presently abandoned rivers (Fig. 9, Line VI) show typical seaward prograding delta-front/prodelta wedges formed under the influence of locally high terrigenous influxes. These prograding sequences (offlap) of relatively uniform lateral extent may grade, basinward, into clastic slope slumps and gravity deposits, presumably turbidites. In particular, the C-sequences off the Gilindirez fan-delta (Fig. 5, Line I) provide a good example of distal-fan and prodelta sediments. These were progressively reworked into deeper water by slumping and density flow to produce contemporaneous "slope" facies on the shelf. The presence of wavy/uneven fills with locally chaotic to reflection-free clinoforms indicates the dominance of gravitational settling of density and turbidity flows (cf. Stanley, 1985), especially off the Gilindirez and Tece river mouths (Figs. 4 and 5).

It thus appears that significant differences exist between the eastern and western parts of Mersin Bay with respect to the configuration of the basin, the rate of supply of sediments, and the intensity of hydrodynamic processes. Of these, local changes in sediment supply, together with coastal morphology, are the most important in affecting the depositional environments.

Based on stratal geometry and types of reflection configuration, depositional sequence C can be divided into two major units (Unit 1 and 2) on some seismic sections (Figs. 7–12):

Unit 1 represents the upper horizons of depositional sequence C, and is characterized by stratified to reflection-free configurations with parallel/divergent (e.g., Figs. 9 and 12) to slightly sigmoidal/oblique (e.g., Figs. 7, 8. and 10) reflectors extending from nearshore areas to the outer mid-shelf (ca. 100 m) over most of the study area. Because of its wide, relatively uniform lateral extent, this unit is commonly interpreted as having been deposited at fairly uniform rates on a relatively stable surface. Studies of surficial bottom sediments show that the uppermost layers of this facies consist of gravelly to sandy mud in nearshore areas grading into mud offshore (Shaw and Bush, 1978; Ergin et al., 1988).

Unit 2 is the lower section of sequence C and is characterized by relatively thin, parallel reflections. In contrast, overlying Unit 1 is characterized by much thicker parallel reflectors (e.g., Figs. 7, 8 and 9). This indicates the presence of different lithologies of the deposits accumulated in the early and later stages of the Holocene, and usually developed east of Mersin Bay.

Occasionally, the parallel patterns of continuous reflections of Unit 2, especially at or near its base, are associated with or disturbed by sigmoidal–obliquely inclined and hummocky–disrupted horizons (e.g., Figs. 8, 10, 11 and 12) which can be interpreted as being due to high-energy environments, rapid sea-level changes and large sediment input from streams and rivers, or a combination of these factors at some time during the early Holocene.

The other characteristic feature of Unit 2 is the occurrence of pockets of acoustically opaque zones. These occur in isolated areas (Fig. 8) but sometimes (at the boundary between sequences C and B) may extend over a distance of several kilometres (Fig. 6). The mechanism of formation of this opacity is interpreted, by analogy with other regions (Kim et al., 1985; Stefanon et al., 1981), to be the entrapment of gas bubbles produced by the biochemical degradation of organic matter; land-derived groundwater may also play a role.

The onlapping nature and tendency to fill lows are also characteristics of Unit 2 (e.g., Figs. 7–12). This suggests that Late Pleistocene–early Holocene marine transgressions must have been interrupted by fluctuations (stillstands and/or regressions).

Sequence B

Depositional sequence B underlies sequence C and is characterized by chaotic reflection configurations (Figs. 4–12). The top of sequence B (reflector R) shows various valley- and channel-like depressions cutting the underlying surfaces and now filled with parallel to oblique reflectors which onlap onto the channel margins (e.g., Figs. 7, 8 and 10). Such vertical boundary relationships and related unconformities are usually indicative of pre-Holocene surfaces produced by subaerial fluvial erosion of the shelf sediments (Stefanon, 1985; Park and Yoo, 1988). Similar latest Pleistocene and buried subaerial surfaces have been identified on many other continental shelves (e.g., Van Andel and Sachs, 1964; Moody and Van Reenan, 1967; Coutellier and Stanley, 1987; Kindinger, 1988).

Therefore, we interpret with confidence the basal reflector R in the seismic profiles of this study as a Late Pleistocene and early Holocene erosional land surface at lowered sea level (Würmian regression; − 100 to − 125 m between 20,000 and 18,000 yrs B.P.; Clark et al., 1978; Coutellier and Stanley, 1987) now buried under the sediments of the subsequent post-glacial (Flandrian) transgression.

Stratigraphic correlations of Recent marine sediments with lithologies on the coast determined from well logs suggest that sequence B mainly represents the Plio-Pleistocene substratum in the study area. Several orders of sedimentary cycles similar to Late Glacial to Holocene (unconformity as indicated by reflector R) cycles are observed off the Mezitli River mouth (Fig. 6), with depositional sequences being repetitive. These cyclic sedimentation patterns are attributed to climatic fluctuations and oscillating sea-level changes at various times in the Pleistocene (e.g. Vail et al., 1977; Aksu et al., 1987).

Thickness distribution of Holocene sequences

An isopach map (Fig. 13) indicates the total thickness of Holocene sediments (sequence C). All the thickness values on this map are calculated assuming an average seismic velocity of 1600 m/s as described in this area by Malovitsky et al. (1975). Maximum sediment accumulations occur in the areas off the mouths of the Delicay, Tarsus and Seyhan rivers, where Holocene sequences reach a thickness of up to 35 m. The thickness of sequence C generally decreases seaward, with thicknesses of approximately 10–15 m in most of the offshore areas (Fig. 13). From this picture, the growth of a complex delta system of the Delicay, Tarsus and Seyhan rivers appears to have occurred in a west-southwest direction, parallel to the main current of the northeastern Mediterranean waters.

There is general agreement among most workers that extensive seaward extension of deltas in the eastern Mediterranean occurred during the last 10,000 years (e.g., Vita-Finzi, 1972; Aksu and Piper, 1983; Coutellier and Stanley, 1987). This seems to apply also for the Tarsus and Seyhan deltas in eastern Mersin Bay. If 10,000 yrs B.P. is taken as the approximate boundary of the latest Pleistocene-earliest Holocene, the thicknesses of sequence C would require sedimentation rates of approximately 1–3.5 m/1000 ka during the Holocene in eastern Mersin Bay. Much higher Holocene sedimentation rates are reported elsewhere in the Mediterranean, such as on the eastern Nile Delta (5 m/ka, Coutellier and Stanley, 1987) and the Po Delta (10 m/ka, Schreiber al., 1968).

Historical records suggest a southwestward deltaic progradation distance of 2–6 km for the last 2000–2500 years off the Seyhan River mouth (Russel, 1954; Erinc, 1978). The studies of Evans (1973) and Bal and Demirkol (1987/1988) indicate coastal

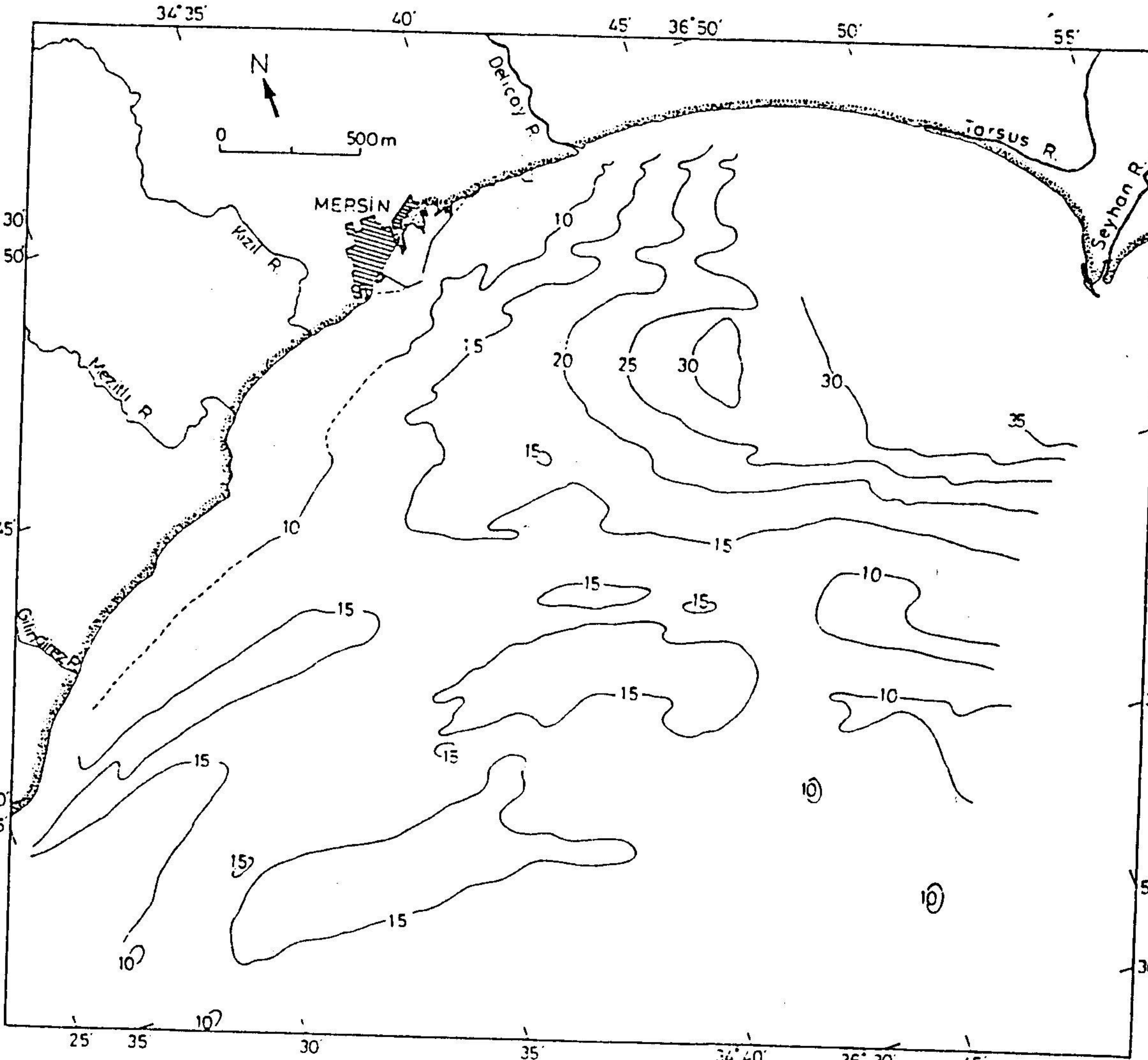

Fig. 13. Isopach map showing the thicknesses of Holocene sediments (sequence C) on the inner and mid-shelf areas of eastern Mersin Bay. Contours in metres.

progradation of the Seyhan delta at rates of 0.5–2 km/1000 ka for the past 3500 years.

Conclusions

The continental shelf off Mersin Bay was subaerially exposed during the last glacial (Würm) maximum and, as a result, the pre-existing Pleistocene alluvial and deltaic deposits were reworked by erosion. This resulted in various types of channels and/or depressions. Compared to earlier Holocene sediments (Unit 2) the deposits of the mid- to upper Holocene (Unit 1) are marked by relatively uniform and laterally extensive seismic reflection configurations, i.e. with a sheet-like to wedge-shaped geometry.

The prograding sediment sequences are widespread off the mouths of the Gilindirez, Tarsus and Seyhan rivers, thus indicating the importance of direct sources of terrigenous fluvial input into the study area. Progradational sequences are progressively reworked toward deeper water by slumping and density flows to produce gravity-flow facies, particularly on the narrow shelf west of Mersin Bay.

Within the Plio-Pleistocene substratum (sequence B) repetitive depositional sequences are observed, and these may perhaps be a response to oscillating sea-level changes that occurred in pre-Holocene time.

The total thickness of most of the Holocene sediment (sequence C) is estimated to range from over 35 m close to river and stream mouths to 1 m further offshore. From this, mean Holocene sedimentation rates of approximately 1–3.5 m/ka have been calculated for the area seaward of the important fluvial sources.

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References

Aksu, A.E. and Piper, D.J.W., 1983. Progradation of the Late Quaternary Gediz delta, Turkey. Mar. Geol., 54: 1–25.

Aksu, A.E., Piper, D.J.W. and Konuk, T., 1987. Quaternary growth patterns of Buyuk Menderes and Kucuk Menderes Deltas, Western Turkey. Sediment. Geol., 52: 227–250.

Bal, Y. and Demirkol, C., 1987/1988. Coast line changes in the Eastern Mediterranean, Turkey. Istanbul Univ. Eng. Fac. Earth Sci. Publ., 6(1–2): 69–91.

Biju-Duval, B., Letouzey, J. and Montadert, L., 1978. Structure and evolution of the Mediterranean basins. Init. Rep. DSDP, 42(1): 951–984.

Bodur, M.N. and Ergin, M., 1988. Heavy metal associations in Recent inshore sediments from the Mersin Bay, Turkey. Boll. Ocean. Teor. Appl., 6(1): 15–34.

Bodur, M.N. and Ergin, M., 1989. High resolution seismic reflection studies of the Quaternary coastal deposits in the Bay of Mersin (Turkey), NE Mediterranean. Ann. Geophys., 14 (Spec. Iss.): 15 (Abstr.).

Brown, Jr., L.F. and Fisher, W.L., 1980. Seismic Stratigraphic Interpretation and Petroleum Exploration. (American Association of Petroleum Geologists Continuing Education Course Note Ser., 16.) Am. Assoc. Pet. Geol., Tulsa, Okla., 125 pp.

Clark, J.A., Farrell, W.E. and Pellketier, W.R., 1978. Global changes in post-glacial sea-level: A numerical calculation. Quat. Res., 9: 265–278.

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

Collinson, J.D., 1978. Alluvial sediments. In: H.G. Reading (Editor), Sedimentary Environments and Facies. Blackwell, Oxford, pp. 15–60.

Coutellier, V. and Stanley, D.J., 1987. Late Quaternary stratigrahy and paleogeography of the eastern Nile Delta, Egypt. Mar. Geol., 77: 257–275.

DSI, 1978. Mersin-Berdan and Efrenk Plains: Hydrogeological investigation report. Gen. Dir. State Hydraul. Works, Ankara, 60 pp. (in Turkish).

Ebren, G., 1982. Morphology and flow characteristics of the Lamas River Mouth. M.Sc. Thesis, Inst. Mar. Sci., Middle East Tech. Univ., Erdemli, Icel, 133 pp. (Unpubl.).

EIE, 1981. 1978 Water Year Discharges. EIE Publ., Ankara, 288 pp.

EIE, 1989. Water Quality Data for Surface Waters in Turkey. EIE Publ., Ankara, 163 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. Inst. Mar. Sci. Rep. Middle East Tech. Univ., Erdemli, Icel, 145 pp.

Ergin, M., Timur, K., Okyar, M., Bodur, M.N., Ediger, V. and Yucesoy, F., 1989. Marine geological and geophysical investigations related to construction of a landing place. Inst. Mar. Sci., Middle East Tech. Univ., Icel, 43 pp.

Erinc, S., 1978. Changes in physical environments in Turkey since the end of the last glacial. In: W.C. Brice (Editor), The Environmental History of the Near and Middle East since the Last Ice Age. Academic Press, London, pp. 87–110.

Evans, G., 1971. The recent sedimentation of Turkey and the adjacent Mediterranean and Black Sea: a review. In: A.S. Campbell (Editor), Geology and History of Turkey. Pet. Explor. Soc. Libya, pp. 385–406.

Evans, G., 1973. Recent coastal sedimentation: a review. In: D.J. Blackman (Editor), Marine Archaeology. Proc. 23rd Symp. Colston Res. Soc. Butterworth, London, pp. 89–114.

Evans, G., Morgan, P.E., Evans, W.E., Evans, T.R. and Woodside, J.M., 1978. Faulting and halokinetics in the northeastern Mediterranean between Cyprus and Turkey. Geology, 6: 392–396.

Hallam, A., 1981. Facies Interpretation and the Stratigraphic Record. Freeman, Oxford, 291 pp.

Hooke, R., 1967. Processes on arid region alluvial fans. J. Geol., 75: 438–460.

Hooker, A.T., 1981. Interpretation of seismic record sections from the Cilician Basin, northeastern Mediterranean. M.Sc.

Thesis, New Mexico State Univ., La Cruces, 83 pp. (Unpubl.).

IMS (Institute of Marine Sciences), 1986. Mersin Kanalizasyon Deniz Desarji Osinografi Calismalari Fiziksel-Kimyasal Bulgu Sonuc Raporu. Inst. Mar. Sci., Middle East Tech. Univ., Erdemli, Icel, 69 pp.

Kim, C.S., Kim, S.W., Cho, K.J., Chang, J.H., Kim, W.S. and Choi, W.S., 1985. Acoustostratigraphy and facies development of Quaternary sediments on the Southeastern Yellow Sea. Rep. Kor. Inst. Energy Resour., 32 pp.

Kindinger, J.L., 1988. Seismic stratigraphy of the Mississippi-Alabama shelf and upper continental slope. Mar. Geol., 83: 79-94.

Malovitsky, Ya.B., Emelyanov, E.M., Kazakov, O.V., Moskalenko, V.N., Osipov, G.V., Shimkus, K.M. and Chumakov, I.S., 1975. Geological structure of the Mediterranean sea floor (based on geological and geophysical data). Mar.Geol., 18(4): 231-261.

Mitchum, R.M. and Vail, P.R., 1977. Seismic stratigraphy and global changes of sea level. Part 7. Seismic stratigraphic interpretation procedure. In: C.E. Payton (Editor), Seismic Stratigraphy—Applications to Hydrocarbon Exploration. Am. Assoc. Pet. Geol. Mem., 26.

Moody, D.W. and Van Reenan, E.B., 1967. High resolution subbottom seismic profiles of the Delaware Estuary and its bay mouth. U.S. Geol. Surv. Prof. Pap., 575-D: 247-252.

Morner, N.A., 1971. Eustatic changes during the last 20,000 years and a method of seperating the isostatic and eustatic factors in an uplifted area. Palaeogeogr., Palaeoclimatol., Palaeoecol., 9: 153-181.

Ovchinnikov, I.M., 1966. Circulation in the surface and intermediate layers of the Mediterranean Sea. Oceanology, 5: 48-58.

Ozhan, G., 1988. The North-Eastern Mediterranean Sea, in the light of marine seismic reflection data. Geol. Bull. Turk., 31: 51-62.

Ozsoy, E., Oguz, T., Latif, M.A. and Unluata, U., 1987. Oceanography of the North Levantine Sea: Physical Oceanography. Inst. Mar. Sci., Middle East Tech. Univ., Erdemli, Icel, 169 pp. (in Turkish).

Park, S.C. and Yoo, D.C., 1988. Depositional history of Quaternary sediments on the continental shelf off the southeastern coast of Korea (Korea Strait). Mar. Geol., 79: 65-75.

Reineck, H.E. and Singh, I.B., 1975. Depositional Sedimentary Environments. Springer, Berlin, 439 pp.

Russel, R.J., 1954. Alluvial morphology of Anatolian rivers. Ann. Assoc. Am. Geogr., 44: 363-391.

Sangree, J.B. and Widmier, J.M., 1979. Interpretation of depositional facies from seismic data. Geophysics, 44(2): 131-160.

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

Schreiber, B., Tassi Pelati, L., Mezzadri, M.G. and Motta, G., 1968. Gross beta radioactivity in sediments of North Adriatic Sea: a possibility of evaluating the sedimentation rate. Arch. Oceanogr. Limnol., 16: 45-62.

Schumm, S.A., 1961. Effect of sediment characteristics on erosion and deposition in ephemeral stream channels. U.S. Geol. Surv. Prof. Pap., 352 C: 31-70.

Shaw, H.F. and Bush, P.R., 1978. The minerology and geochemistry of the Recent surface sediments of the Cilicia Basin, northeast Mediterranean. Mar. Geol., 27: 115-136.

Stanley, D.J., 1977. Post-Miocene depositional patterns and structural displacament in the Mediterranean. In: W.H. Kanes and F.G. Stehli (Editors), The Ocean Basins and Margins, 4A. The Eastern Mediterranean. Plenum, New York, pp. 77-150.

Stanley, D.J., 1985. Mud redepositional processes as a major influence on Mediterranean Margin—basin sedimentation. In: D.J. Stanley and F.-C. Wezel (Editors), Geological Evolution of the Mediterranean Basin. Springer, New York, pp. 377-410.

Stefanon, A., 1985. Marine sedimentology through modern acoustical methods—II Uniboom. Boll. Oceanol. Teor. Appl., 3: 113-144.

Stefanon, A., Rabitti, S. and Boldrin, A., 1981. Gas detection capabilities and resolution of UNIBOOM systems. Boll. Geof. Teor. Appl., 23(90/91): 125-134.

Unluata, U., 1986. A review of the physical oceanography of the Levantine and the Aegean Basins of the eastern Mediterranean in relation to monitoring and control of pollution. Inst. Mar. Sci., Middle East Tech. Univ., Erdemli, Icel, 55 pp.

Vail, P.R., Mitchum, R.M., Jr., Todd, R.G., Widmier, J.M., Thompson, S., Sangree, J.B., Bubb, J.N. and Hatlelid, W.G., 1977. Seismic stratigraphy and global changes of sea level. Part III. In: C.E. Payton (Editor), Seismic Stratigraphy—Applications to Hydrocarbon Exploration. Am. Assoc. Pet. Geol. Mem., 26.

Van Andel, T.H. and Sachs, P.L., 1964. Sedimentation in the Gulf of Paria during the Holocene transgression: A subsurface acoustic reflection study. J. Mar. Res., 22: 30-50.

Vita-Finzi, C., 1972. Supply of fluvial sediment to the Mediterranenan during the last 20.000 years. In: D.J. Stanley (Editor), The Mediterranean Sea: A Natural Sedimentation Laboratory. Dowden, Hutchinson and Ross, Stroudsburg, Pa., pp. 43-46.

Weedon, G.P., 1983. The Pleistocene-Recent geology of part of the Misis-Kyrenia Ridge, south of Turkey. B.Sc. Dissert., R. Sch. Mines, London, 36 pp. (Unpubl.).

Wells, S.G. and Harvey, A.M., 1987. Sedimentologic and geomorphic variations in storm-generated alluvial fans, Howgill Fells, northwest England. Geol. Soc. Am. Bull., 98: 182-198.

Wong, H.K. and Zarudzki, E.F.K., 1969. Thickness of unconsolidated sediments in the eastern Mediterranean Sea. Geol. Soc. Am. Bull., 80: 2611-2614.

Wong, H.K., Zarudzki, E.F.K., Phillips, J.D. and Giermann, G.K.F., 1971. Some geophysical profiles in the eastern Mediterranean. Geol. Soc. Am. Bull., 82: 91-99.

Woodside, J.M., 1977. Tectonic elements and crust of the eastern Mediterranean Sea. Mar. Geophys. Res., 3: 317-354.

Woodside, J.M. and Williams, S.A., 1977. Geophysical data report on the Eastern Mediterranean Sea: RRS Shackleton Cruises 3/72, 5/72, 1/74. Cambridge Univ. Dep. Geod. Geophys., 225 pp.