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Distribution and Texture of the Bottom Sediments in a Semi-enclosed Coastal Inlet, the Izmit Bay from the Eastern Sea of Marmara (Turkey)

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Thirty-one surficial sediment samples were collected from the floor of Izmit Bay with a grab onboard the *R/V Bilim* in summer 1987 and analysed for their grain size, total carbonate, and organic carbon distribution.

Low calcareous-terrigenous mud (2–45% $CaCO_3$) with a relatively high silt percentage was the principal sediment type found on the floor of Izmit Bay. Sediments rich in sand and gravel usually occur in the narrow and shoal areas of the bay, where biogenic and topography-related hydrodynamic conditions are dominant factors controlling the nature of bottom deposits. The carbonates are made up almost entirely of the remains of calcareous organisms. Organic carbon concentrations of the sediments (0·35–1·62%) are probably associated with the high primary production rates in this region. Thus, the rates of sedimentation in the Izmit Bay calculated from the organic carbon and primary productivity data are estimated to be up to 70 cm/1000 years.

Introduction

Izmit Bay forms an E–W-elongated and semi-enclosed water body on the eastern Sea of Marmara (Figure 1). It is one of the densely urbanized and industrialized coastal inlets of Turkey lying on an active earthquake zone. Although Izmit Bay has increasingly become of interest in terms of its hydrographic (e.g. Sumer, 1983; Markoc, 1964; Oguz & Sur, 1986; TUBITAK-MRI, 1966), environmental (e.g. Timur *et al.*, 1982; Taymaz *et al.*, 1983; Orhon *et al.*, 1984; Basturk *et al.*, 1985), and biological (e.g. Markoc *et al.*, 1988) aspects, little information is available about the bottom sediments in this bay. The grain-size distribution in surface sediments from the inner Izmit Bay was investigated by DAMOC (1971). Taymaz *et al.* (1983) indicated that anthropogenic metal enrichment of Hg, Cd, and Pb occurred in some surface sediments from the shores of Izmit Bay. Sediment analyses performed by Yoruk (1988) on Recent bottom deposits of Izmit Bay have shown that Fe, Mn, Zn, Cr, and Ni occur largely at natural background levels, and part of the Pb and Cu probably originates from anthropogenic sources.

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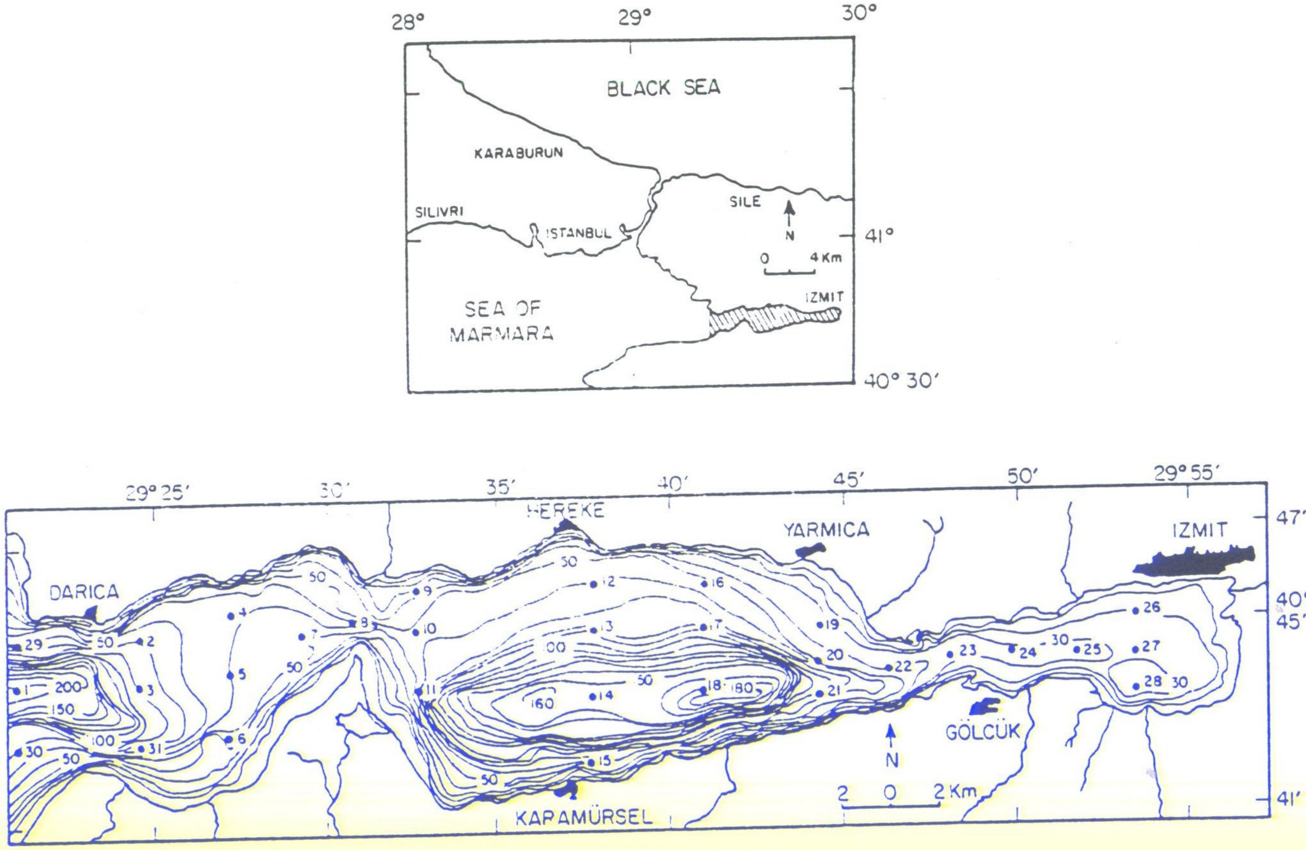

Figure 1. Bathymetry of the Izmit Bay also showing the bottom-sampling stations in this study. Depths are in metres.

This paper discusses the types and modes of distribution of surficial bottom sediments in the Izmit Bay, with the purpose of attempting a better understanding of the recent hydrographic and biologic processes in this region.

Geologic and hydrographic settings

Geologically, the evolution of Izmit Bay is related to the late-Tertiary epeirogenic crustal movements, which dissected the older structure to form graben-like depressions along the north Anatolian Fault zone (Brinkman, 1976; Ilhan, 1976; Ketin, 1983). Subsidence and transgressions during the Miocene must have shaped most of its present morphology (Akartuna, 1968; Altanli *et al.*, 1970). The Quaternary history of the Izmit Bay is dominated by several fluviatile events related to glacial and interglacial periods (Pfannenstiel, 1944).

Izmit Bay is 50 km long and 2 to 10 km wide and has a surface area of approximately 310 km^2. In terms of its morphological characteristics, the bay may be divided into three distinct sections which are connected to each other through narrow openings (Figure 1). The eastern section (inner) is the smallest (44 km^2) and shallowest part of the bay (approximately 25 m deep), being connected to the central section by a 2 km wide opening. The central section with about 170 km^2 surface area (on average 50–150 m deep; maximum 183 m on the southern part of it) is separated from the western section (outer, average 50–200 m deep, 100 km^2) by a narrow opening having 3 km width and 55 km sill depth (Cape of Dil). The western section (outer Izmit Bay) has a direct communication with the deep eastern Marmara Sea through a 5·5 km wide opening; it forms a transition zone between the Black and the Aegean Seas.

The hydrologic regime of Izmit Bay is governed by a permanent two-layered system of flow involving both the surficial Black Sea and the subsurficial Mediterranean waters, which are marked by different temperature and salinity levels (DAMOC, 1971; Basturk *et al.*, 1985; Tugrul *et al.*, 1985; Oguz & Sur, 1986). The surface layer exhibits a wide range of salinity (20–30‰), temperature (7–23 °C), and dissolved oxygen (2–10 mg l^{-1}) values, in comparison to the underlying waters with much higher salinity (37–38·5‰) but lower temperature (14–15 °C) and dissolved oxygen (0·2–3·0 mg l^{-1}) levels. Depending on the rate of seasonal exchange of water masses, the surface layer is generally separated from the lower layer by a sharp interface zone located between 10 and 30 m depth (Basturk *et al.*, 1985; Oguz & Sur, 1986). During stagnant periods, particularly between August and October, organic inputs of anthropogenic origin and high *in situ* production of organics can lead to an oxygen deficiency, thus creating anoxic conditions in the bottom waters, particularly in the eastern section of the Bay. The north-easterly and westerly winter winds (up to 10 m s^{-1} or more) can, however, generate water exchange both in vertical and horizontal directions which, in turn, allows the cold oxygen-rich Black Sea waters to enter Izmit Bay, thus replacing the anoxic bottom waters (Orhon *et al.*, 1984; Oguz & Sur, 1986).

Although no major rivers enter the bay, small streams, particularly from the north, often act as flood channels after heavy rainfalls (Orhon *et al.*, 1984).

Materials and methods

Surface sediment samples were recovered at 31 stations by means of a grab on board the *R/V Bilim* in summer 1987, and stored frozen in plastic bags. The sampling locations are identified in Figure 1. After removal of interstitial waters by means of centrifugation, splits from bulk samples were dried at 50–60 °C and used for textural analysis and organic carbon and total carbonate determinations.

By using standard techniques (sieve plus pipette analysis; after Muller, 1967; Folk, 1974), the subsampled bulk sediments were separated into clay (0·002 mm), silt (0·002–0·063 mm), sand (0·063–2 mm), and gravel (>2 mm) fractions. The total carbonate was determined gasometrically, by treating ground subsamples (1·00 g) with 10 ml 10% HCl. The results are expressed as % $CaCO_3$ (absolute error is ±0·5% $CaCO_3$). Organic carbon was determined by wet oxidation of organic matter with chromic acid and back titration with diphenylamine indicator (after Gaudette *et al.*, 1974; accuracy: ±0·25%).

Estimation of the sedimentation rate in Izmit Bay is based on calculations using the equation:

$$\%\ \text{Org.C.} = \frac{0{\cdot}0030 \times R \times S^{0{\cdot}30}}{P_s(1 - \emptyset)}$$

(after Muller & Suess, 1979)
where R represents primary productivity rate; S, sedimentation rate; P_s, dry sediment density; and $\emptyset$, porosity.

Microscopic investigations were carried out on the coarse-grained sediment particles in support of the chemical and physical parameters obtained in this study. Bulk sediment samples were classified according to their granulometric (Shepard, 1954; Folk, 1974) and genetic (Lisitzin, 1986) compositions.

Results and discussion

Textural classification

The recent sediments of Izmit Bay range from clayey silt to sandy gravel [Figure 2(a)]. Sediment textures comprise 1 to 34% gravel, 1 to 51% sand, 12 to 94% silt, and 2 to 43% clay. Mud, with varying portions of clay and silt is the dominant sediment type in the Izmit Bay [Figure 2(b)], probably due to the elongated shape of the bay and lack of substantial river input. Based on the relative percentages of gravel, sand, silt, and/or mud in the samples, the following sediment types are distinguished: clayey silt, silt, gravelly mud, gravelly-muddy sand, and muddy-sandy gravel. In general, low mud contents are characteristic of the elevations separating the three sections, suggesting a relatively higher energy regime, that prevents sedimentation of fine-grained particles [Figure 2(a)].

High sand and gravel contents are widely distributed in the narrowest areas of the bay, between the three sections [Figure 2(a)]. In particular, at Station 22, where the sea-floor slopes steeply westward, detrital materials from lithogenic sources dominate over the biogenic ones. Likewise, the sediments from Station 8, located in the narrow part of the bay between the central and western sections, consist predominantly of sand and gravel rich in lithogenic components. The presence of these coarse-grained sediments can be explained in two ways: either the prevailing current regime (5–10 cm s^{-1}; Oguz & Sur, 1986) prevents deposition of fine-grained materials and/or the bottom deposits are relict in origin. The latter possibility is based on findings of Pfannenstiel (1944), who believes that the two narrow openings possibly represent the only land connections between the northern and southern coastlines of the Bay at times of low sea level (during early-Quaternary) in a Bosphorus Strait–Marmara Sea–Sapanca Lake–Sakarya River system. In the northern part of the western section of the bay, at Stations 2, 4, and 7, the gravels

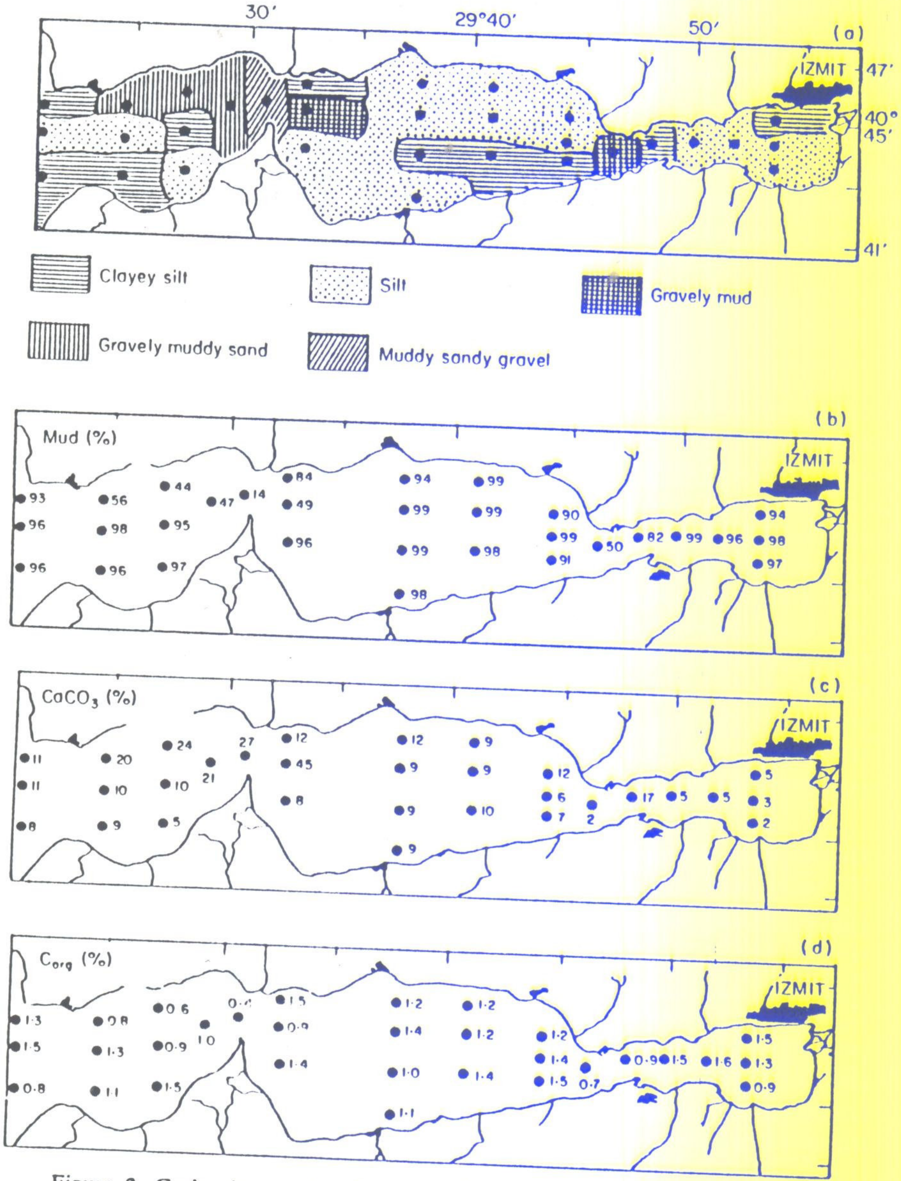

Figure 2. Grain size, total carbonate and organic carbon distribution in surficial sediments of the Izmit Bay.

largely consist of biogenic materials, whereas the sand fractions contain considerable amounts of lithogenic particles. Exceptionally high proportions of biogenic sand and gravel occur in the sediments at Station 10, from the western and central section [Figure 2(a)].

Total carbonate contents

The total carbonate concentrations (expressed as $CaCO_3$) ranged from 2 to 45% [Figure 2(c)], reflecting the relative abundance of biogenic carbonates, mostly derived from

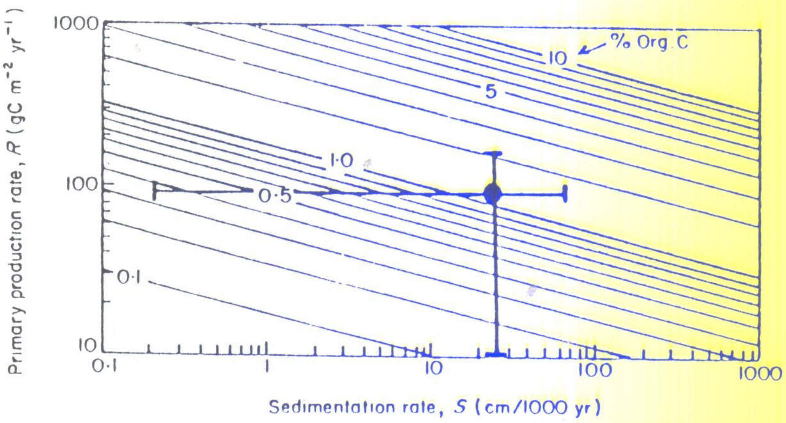

Figure 3. Range of the estimated rates of sedimentation in the Izmit Bay. Values are calculated from equation: $\%\ \text{Org.C} = 0{\cdot}0030 \times R \times S^{0\cdot30}/P_s(1-O)$ (after Muller & Suess, 1979). Data of primary productivity rates are taken from Markoc (1984).

the remains of gastropods, pelecypods, scaphopods, foraminifera, echinoderms and ostracods. With the exception of a single sample (Station 10), the Izmit Bay sediments reveal a low-calcareous, terrigenous dominance. High carbonate percentages are commonly found in samples from the narrow and shoal waters of between the central and western sections of the bay [Figure 2(c)], a region which seems to favour high biogenic activity, especially for the benthic organisms.

Organic carbon distribution

Organic carbon concentrations range from 0·40 to 1·61% by dry weight [Figure 2(d)]. These values, compared to offshore sediments from the Aegean and the eastern Mediterranean Seas (0·28–0·80%: Emelyanov, 1972; Voutsinou-Taliadouri, 1982; Ergin *et al.*, 1988), seem to be generally high. Obviously, the high primary productivity in Izmit Bay (up to 168 gC m^{-2} yr^{-1}; recalculated from Markoc, 1984) is responsible for the high C_{org} concentrations in the Izmit sediments. In fact, the annual average rates of primary productivity in the eastern Mediterranean (24–25 gC m^{-2} yr^{-1}: Murdoch & Onuf, 1974) and in the Black Sea (200 gC m^{-2} yr^{-1}: Sorokin, 1983) are much lower. Additional amounts of organic matter must enter the region from industrial, domestic, and agricultural sources (Orhon *et al.*, 1984). The distribution pattern of organic carbon [Figure 2(d)] shows markedly low concentrations in the areas of narrow and shoal waters, between the central and western sections, where also low carbonate percentages occurred. Such an inverse relationship between the C_{org} and $CaCO_3$ contents in the samples reflect the dilution effect of carbonates on the organic carbon contents. In other words, finer-grained sediment samples in this study are generally associated with the high organic carbon values. Furthermore, as inferred from the correlation coefficient matrix data, organic fractions of the sediments, in general, are important carrier substances for Fe, Zn, Cr, and Cu (Yörük, 1988).

Estimation of the rate of sedimentation

As shown from comparison of rates of accumulation of organic carbon in the surficial marine sediments from the central North Pacific, the continental Margin off north-west

Africa, north-west and south-west America, the Argentine Basin, and the western Baltic Sea, the organic carbon preserved in the sediments is universally related to the bulk sedimentation rate (Muller & Suess, 1979). Accordingly, such an estimation of the sedimentation rate was introduced in this study (Figure 3). Assuming the primary productivity rates (R) are 10—170 gC m^{-2} year^{-1} (from Markoc, 1984), the sediment density (P_s) is 2·71, the porosity ($\varnothing$) is 0·77, organic carbon contents of the sediments in this study (0·35–1·62%) suggest rates of sedimentation up to 70 cm/1000 year (average 25 cm/1000 year) (Figure 3) in Izmit Bay.

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