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Distribution of Surficial Sediment in Long Island Sound and Adjacent Waters: Texture and Total Organic Carbon

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ABSTRACT

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The surficial sediment distribution within Long Island Sound has been mapped and described using bottom samples, photography, and sidescan sonar, combined with information from the geologic literature. The distributions of sediment type and total organic carbon (TOC) reveal several broad trends that are largely related to the sea-floor geology, the bathymetry, and the effects of modern tidal- and wind-driven currents.

Sediment types are most heterogeneous in bathymetrically complex and shallow nearshore areas; the heterogeneity diminishes and the texture fines with decreasing bottom-current energy. Lag deposits of gravel and gravelly sand dominate the surficial sediment texture in areas where bottom currents are the strongest (such as where tidal flow is constricted) and where glacial till crops out at the sea floor. Sand is the dominant sediment type in areas characterized by active sediment transport and in shallow areas affected by fine-grained winnowing. Silty sand and sand-silt-clay mark transitions within the basin from higher- to lower-energy environments, suggesting a diminished hydraulic ability to sort and transport sediment. Clayey silt and silty clay are the dominant sediment types accumulating in the central and western basins and in other areas characterized by long-term depositional environments.

The amount of TOC in the sediments of Long Island Sound varies inversely with sediment grain size. Concentrations average more than 1.9% (dry weight) in clayey silt, but are less than 0.4% in sand. Generally, values for TOC increase both toward the west in the Sound and from the shallow margins to the deeper parts of the basin floor. Our data also suggest that TOC concentrations can vary seasonally.

ADDITIONAL INDEX WORDS: *Long Island Sound, surficial sediment, grain size, total organic carbon*

INTRODUCTION

The present distribution of surficial sediment in Long Island Sound is influenced by the deposits left by the last glaciation and the cumulative effects of sediment erosion, transport, sorting, and deposition by tidal and (to a lesser degree) other bottom currents during and since the Holocene eustatic rise in sea level (LEWIS and STONE, 1991; KNEBEL *et al.*, 1999; KNEBEL and POPPE, this volume; LEWIS and DIGIACOMO-COHEN, this volume). In this paper, we present and describe detailed regional maps which outline the grain size and the total organic carbon (TOC) content of the surficial sediments. We also discuss some of the bottom processes which have controlled the distributions of these attributes.

Earlier studies of sediment distribution in Long Island Sound were not comprehensive in scope. This is because they were based on relatively small geographic areas (*e.g.* ELLIS, 1962; GROSS *et al.*, 1972; AKPATI, 1974; TOLDERLUND, 1975; HASKELL, 1977; HUBBARD, 1985; BROWN *et al.*, 1986; WATERMAN and DEMOS, 1987), on a restricted number of samples (*e.g.* BUZAS, 1965; DONOHUE and TUCKER, 1970; SCHLEE, 1973; WILLIAMS, 1981), on qualitative visual descriptions (*e.g.* PELLEGRINO and HUBBARD, 1983), or on incomplete grain-size analyses (*e.g.* BOKUNIEWICZ *et al.*, 1977; WAKELAND, 1977). Earlier studies did, however, outline the following salient points about the sedimentology of the Sound: (1) fine-grained sediments are prevalent in the deeper areas of the western and central Sound; (2) coarse sediments are dominant along most of the shores and on the bottom in the easternmost part of the basin; (3) coarser-grained sediments are found where the currents are strongest, such as within constricted channels and on shoals; (4) finer-grained sediments accumulate where currents are weakest, such as in basins and bays; and (5) the sediments generally become progressively finer grained westward in the Sound.

Sedimentary organic matter affects many biologic, chemical, and geologic processes and, ultimately, the character of the sediments themselves. For this reason, analyses of TOC are commonly conducted as a measure of the total organic material. Previous studies have not outlined the regional distribution of TOC within the Sound. Prior limited or site-specific measurements of TOC include those presented by HATHAWAY (1971), REID (1982), and KRISHNASWAMI *et al.* (1984).

PHYSIOGRAPHIC AND GEOLOGICAL SETTING

Long Island Sound is bordered on the north by the rocky shoreline of Connecticut, on the east by Block Island Sound, on the south by the eroding bluffs of Long Island, and on the west by the New York metropolitan area (Figure 1). The Connecticut shoreline, which is characterized by numerous bays and inlets, is controlled by north-south trending shallow bedrock. On Long Island, the shoreline west of Port Jefferson, New York, is punctuated by bays that reflect the shape of the underlying coastal-plain remnant (LEWIS and DIGIACOMO-COHEN, this volume). The shoreline east of Port Jefferson is characterized by gently curved beaches separated by headlands and a near-absence of inlets (KOPPELMAN *et al.,* 1976).

The surficial geology of the Sound is a result of glacial and eustatic processes (SCHAFER and HARTSHORN, 1965; FLINT and GEBERT, 1976; GOLDSMITH, 1982; STONE and BORNS, 1986; LEWIS and NEEDELL, 1987; NEEDELL *et al.,* 1987; LEWIS and STONE, 1991; STONE *et al.,* 1992; LEWIS and DIGIACOMO-COHEN, this volume). The late Wisconsinan Laurentide Ice Sheet scoured the surface, deposited drift, and produced a recessional moraine across northern Long Island and a succession of minor recessional moraines in Connecticut. Glacial Lake Connecticut, which occupied most of the Long Island Sound basin, was forming by 19 ka when meltwater was impounded in the expanding basin between the recessional moraine on Long Island and the retreating ice. Deltaic and varved sediments deposited in this lake variously overlie the glacial drift throughout much of the basin. Erosion of a spillway at its eastern end drained glacial Lake Connecticut by 15.5 ka, and subaerially exposed the lakebed until the marine transgression that began about 15 ka. Since about 13.5 ka, the glaciolacustrine and marine deltaic deposits in the eastern Sound have been eroded, selectively sorted, and transported westward (KNEBEL and POPPE, this volume; LEWIS and DIGIACOMO-COHEN, this volume). The marine mud facies, which occurs in lower-energy areas throughout the western and central parts of the Sound, accumulated during the Holocene eustatic sea-level rise.

Circulation within Long Island Sound is tidally dominated, and is stronger in constricted areas where large volumes of water must pass through relatively narrow openings and weaker in broad deeper basins (KOPPELMAN *et al.,* 1976; BOKUNIEWICZ and GORDON, 1980; SIGNELL *et al.,* 1998). However, wind-driven and wave-produced currents are relatively important in shallow, nearshore areas, especially during aperiodic storms when strong winds blow the length of the Sound. Minor nontidal estuarine circulation affects residual bottom currents throughout the year (GORDON and PILBEAM, 1975; SIGNELL *et al.,* 1998).

Three main basins (and intervening topographic highs) characterize the complicated bathymetry of Long Island Sound (Figure 1B). The sea floor in the easternmost basin, which is connected to Block Island Sound through the Race and Fishers Island Sound, is extremely irregular owing to strong tidal currents that have scoured the bottom (LEWIS and STONE, 1991; KNEBEL *et al.,* 1999; KNEBEL and POPPE, this volume; LEWIS and DIGIACOMO-COHEN, this volume). In addition, the western part of the eastern basin contains large west-southwest-trending tidal ridges and channels which are mantled by sand ribbons and sand waves (LEWIS and NEEDELL, 1987; FENSTER *et al.,* 1990). These features have developed on the eastern part of the remnant of a −40-m postglacial marine delta that separates the erosional and nondepositional environments of the eastern basin from the depositional environments prevalent in the central basin (LEWIS and STONE, 1991; KNEBEL and POPPE, this volume; LEWIS and DIGIACOMO-COHEN, this volume)

The topography in the central and western basins is characterized by broad areas of relatively smooth sea floor, separated by the Stratford and Norwalk shoal complexes (KNEBEL *et al.,* 1999; KNEBEL and POPPE, this volume). The Stratford shoal complex (Figure 1B) is a coastal plain outlier capped by glacial drift (LEWIS and STONE, 1991; TWICHELL *et al.,* 1998) that lies between the central and western basins. Farther west, the Norwalk shoal complex bisects the western basin. The two shoal complexes are generally oriented north-south across the Sound and form partial barriers to bottom water circulation. Locally, small knolls, ridges, and bathymetric lows interrupt the otherwise smooth sea floor in the central and western basins.

DATA COLLECTION AND METHODS

Surficial sediments (0–2 cm below the sediment-water interface) were sampled and (or) photographed at 1643 locations (Figure 1A) within the study area between June 1992 and March 1998 aboard the research vessels *Asterias, John Dempsey,* and *Seaward Explorer* using a Van Veen grab sampler equipped with a videocamera system. Videocamera images were used to appraise bottom variability, examine small-scale sedimentary features, and observe boulder fields and bedrock outcrops where samples could not be collected. A total of 1,554 samples for grain-size analysis and 580 samples for TOC were placed in sealed containers aboard ship and frozen for later analysis.

In the laboratory, samples for grain-size analysis were disaggregated and wet sieved to separate the coarse and fine fractions. The fine fraction (less than 62 μm) was analyzed by Coulter Counter (MCCAVE and SYVITSKI, 1991); the coarse fraction was analyzed by sieving and a rapid sediment analyzer (SCHLEE, 1966). Bivalve shells and other biogenic carbonate debris were manually removed from the gravel fraction before analysis. Size classifications were based on the method proposed by WENTWORTH (1929), the inclusive graphics statistical method of FOLK (1974), and the nomenclature proposed by SHEPARD (1954). A detailed discussion of the computer processing of the raw textural data is given in POPPE *et al.* (1998b). The computer software used to extrapolate the grain-size distributions to the colloidal-clay boundary (0.1 μm) to account for material not detected by the Coulter Counter (<0.6 μm) is given in POPPE and ELIASON (1999).

Samples for TOC analysis were thawed and homogenized.

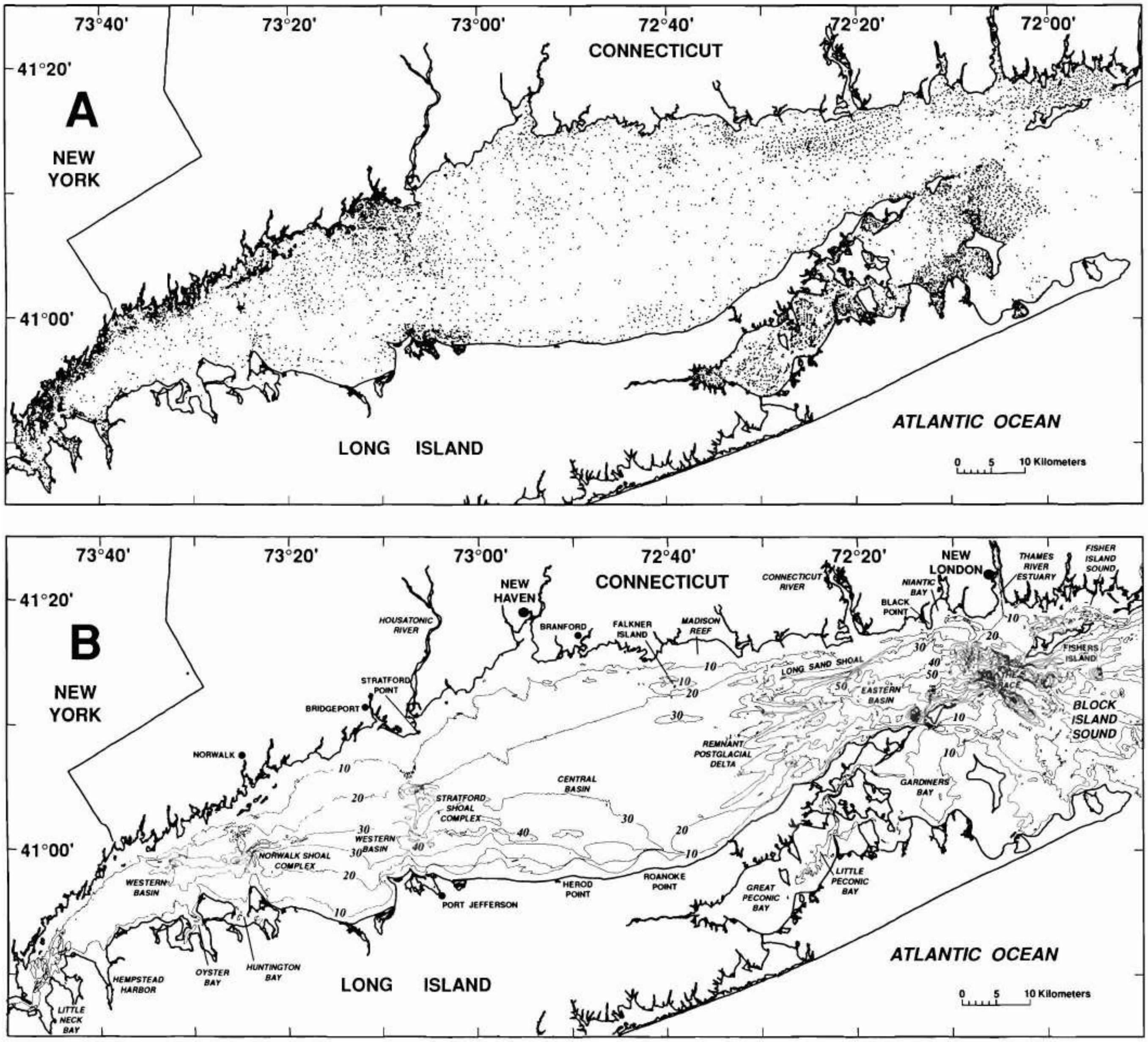

Figure 1. Index maps of the study area. (A) Map showing new and historical sample stations used for the textural part of this study (solid circles). Both new and historical data are compiled in POPPE *et al.* (1998b). (B) Map showing the generalized bathymetry of Long Island Sound. Depth contours are from digital versions of NOAA charts (DIGIACOMO-COHEN *et al.*, 1998).

A 0.5-g split was removed; large animals and shell fragments were eliminated during sub-sampling. The samples were dried at 60°C, ground to a fine (<62 μm) homogeneous powder, placed in a desiccator containing concentrated HCL, and allowed to digest for 24–48 hours to remove the carbonates. This vapor-phase acidification converted the calcium carbonate in the sample to water vapor, CO_2, and calcium chloride (ZIMMERMANN *et al.*, 1992). After digestion, the samples were disaggregated, re-dried at 60°C, and stored in a desiccator until analysis. Analysis was performed using a Perkin Elmer 2400 CHN Elemental Analyzer. About 40% of the CHN analyses were standards and (or) blanks, which were run to calibrate the instrument and check precision. Precision was always better than one standard deviation. All textural and organic-carbon data were salt corrected.

The grain-size and TOC data from this project were combined with over 12,900 published textural analyses and descriptions (Figure 1A; POPPE *et al.*, 1998b), and with information from previous studies which did not provide basic data or sample locations (e.g. ELLIS, 1962), to produce the maps and interpretations presented herein. Bathymetry (Figure 1B), backscatter data from continuous and regional si-

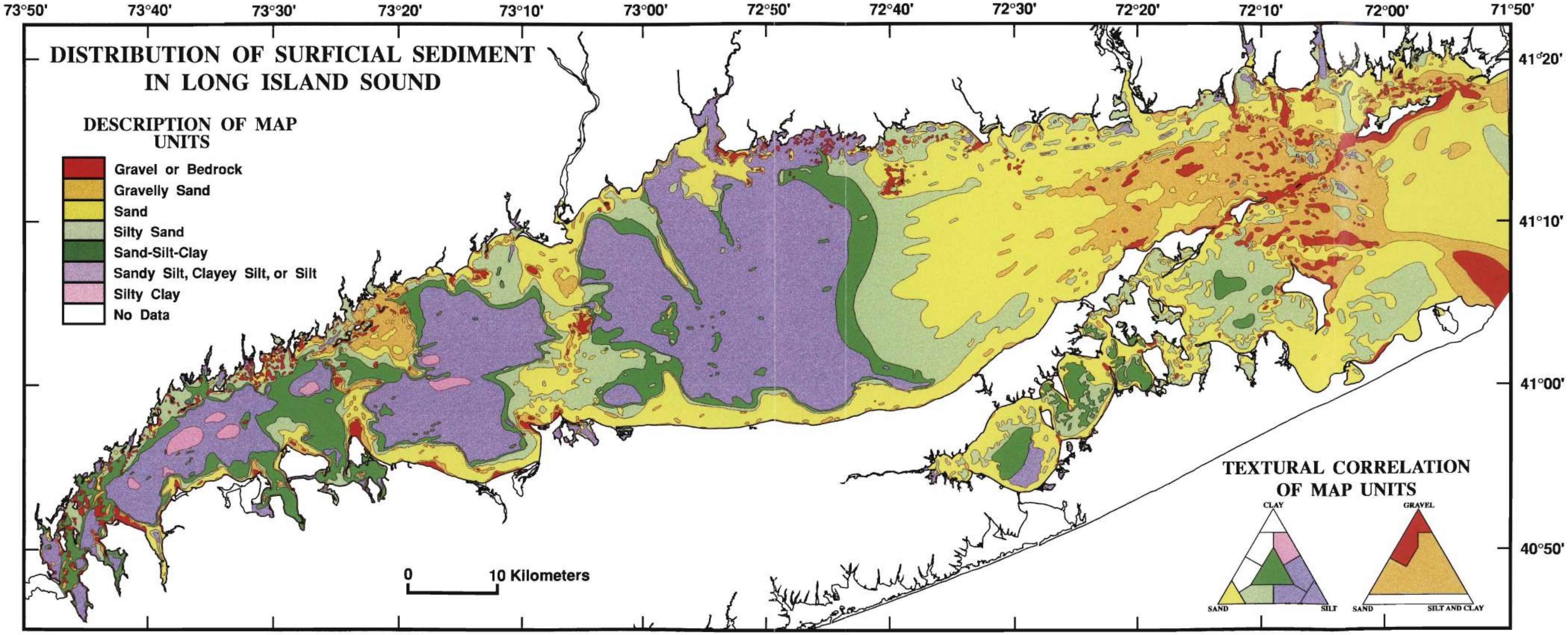

Figure 2. Map showing the distribution of surficial sediments in Long Island Sound and adjacent waters. Triangular and block diagrams explain the map units; certain textural categories were combined because of the paucity of some sediment types.

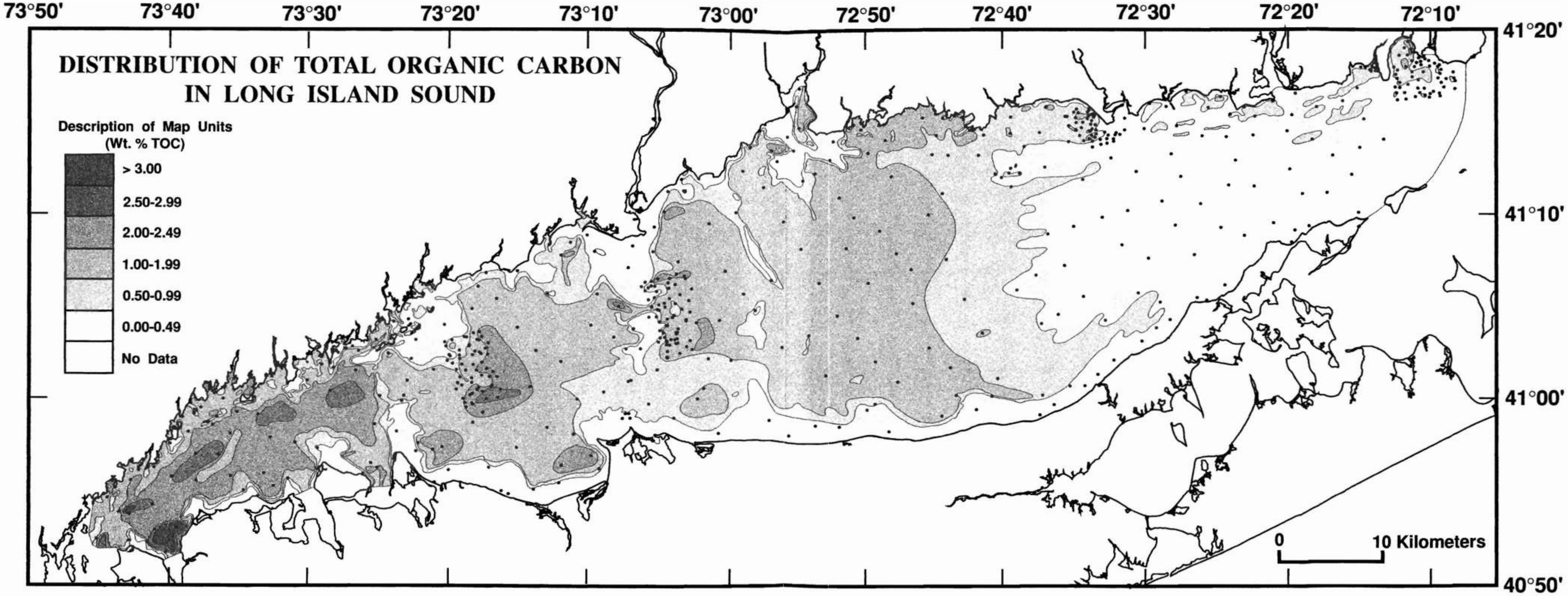

Figure 3. Map showing the distribution of TOC in the surficial sediments of Long Island Sound. Block diagrams explain map units; sample locations are shown as solid circles.

descan-sonar surveys (KNEBEL and POPPE, this volume), and bottom videocamera data were used to extrapolate between sampling stations. Units on the sediment map represent predominant textures; small-scale heterogeneity is common. All contacts are inferred because the transitions between the various lithologies are gradational, and lateral changes in texture and TOC are seldom abrupt.

RESULTS AND DISCUSSION

Textural Distribution

The regional textural map is extremely patchy (Figure 2). In general, sediment types are most heterogeneous in bathymetrically complex areas, such as where the subsurface geology crops out on the sea floor, and shallow areas, where the bottom currents are highly variable (SIGNELL *et al.,* 1998; KNEBEL *et al.,* 1999; KNEBEL and POPPE, this volume). These areas include the easternmost part of the Sound, the Stratford and Norwalk shoal complexes, and the nearshore margins. Moreover, along the central axis of the Sound, the grain size progressively decreases from gravel prevalent near the Race to clayey silt on the flat floor of the central basin. This progression reflects the general east-to-west succession of sedimentary environments (from erosion to transport to sorting to deposition) caused by the decreasing gradient of tidal-current speeds coupled with the net westward estuarine bottom drift (KNEBEL *et al.,* 1999; KNEBEL and POPPE, this volume).

Gravel and gravelly sand dominate the surficial sediment texture in easternmost Long Island Sound where tidal currents are strong (SIGNELL *et al.,* 1998; KNEBEL *et al.,* 1999), and in areas characterized by glacial tills, such as around Falkner Island (POPPE *et al.,* 1999) over the Stratford and Norwalk shoal complexes (TWICHELL *et al.,* 1997, 1998), along the central axis of Fishers Island Sound (POPPE *et al.,* 1998c), and over the submerged extensions of the morainal deposits along the Connecticut shore (FRIEDRICH *et al.,* 1986; POPPE *et al.,* 1994; 1997). This gravel is a lag left after removal of fines from the till. Gravelly sediments are also prevalent at other places along the nearshore margins where bottom currents are strong enough to winnow finer fractions, especially over bathymetric knolls and in areas directly offshore from promontories. Examination of the grab samples revealed that the gravelly sediments often form thin surficial layers, which are underlain by finer-grained sediments. As such, the lag deposits of gravel armor the bottom.

The size distributions of these gravelly sediments tend to be poorly sorted and bimodal because: (1) the sediments are derived from till, which by definition is poorly sorted; (2) the grab sampler penetrated the lag deposits described above, collecting both the gravel armor and the underlying sediment; and (3) seaweed-encrusted coarse gravel was commonly observed being "rafted" by currents during bottom photography. When the seaweed dies, the gravel is stranded in finer-grained, hydraulically-unequivalent sediment. A thin (<2 cm), possibly seasonal, layer of fine-grained detritus covers boulders and bedrock in the central and western parts of the Sound. The thinness of this veneer suggests that it is aperiodically removed by storm-generated currents.

The irregular bedrock surface crops out locally on the sea floor just off the Connecticut coastline. Examples of prominent outcrops include Madison Reef (POPPE *et al.,* 1997), the inner Norwalk Islands, and off Black Point (POPPE *et al.,* 1998d; Figure 1B); outcrops are especially common southeast of Branford and along the shore west of the Norwalk shoal complex. Individual outcrops typically have north-south orientations that mirror onshore topographic trends (Figures 1B, 2). Although common, these outcrops are not depicted separately from gravel on the textural map because they are typically encrusted by mussels, or strewn with glacial erratics and, therefore, could not be differentiated.

Yellow, quartzose sand is the dominant sediment across the east-central Sound, along most of the nearshore margins, on the flanks of the Stratford and Norwalk shoal complexes, and in western Block Island Sound (SAVARD, 1966). The most striking sand deposit occurs in the western part of the eastern basin, overlying the uneroded remnant of the −40-m postglacial marine delta (LEWIS and DIGIACOMO-COHEN, this volume). In this region, tidal currents have shaped the sea floor into a series of ridges and channels which contain sand waves (on the ridges) and sand ribbons (in the channels) (FENSTER *et al.,* 1990; KNEBEL *et al.,* 1999; KNEBEL and POPPE, this volume). The sand, which is typically medium-to-fine grained and moderately well sorted, is generally finer grained on the ridges and sand-wave crests and coarser grained in the tidal channels and sand-wave troughs. Sorting and grain size of the sand decrease westward and toward the southern edge of the basin floor within this region.

Other conspicuous accumulations of sand include Long Sand Shoal and the headland-associated shoals along the northeastern shore of Long Island, such as those off Herod and Roanoke Points (Figures 1B, 2). Sediments presently maintaining Long Sand Shoal are scoured from the surrounding sea floor and driven obliquely up the flanks of the shoal by tidal currents (HASKELL, 1977; SIGNELL *et al.,* 1998; KNEBEL *et al.,* 1999). Along the northern shore of Long Island, on the other hand, bottom circulation and prevailing winds combine to produce a strong eastward littoral drift (BOKUNIEWICZ and TANSKI, 1983). Sediments eroded from the bluffs in this area are transported along the coast to headlands where most are deflected offshore and accumulate in shoreface-attached arcuate shoals, such as at Roanoke Point (POPPE *et al.* 1998a).

The sand along the nearshore margins of the eastern and central Sound is ubiquitously rippled, and generally is unimodal, medium-grained, and moderately well sorted. Sorting and grain size of the sand typically decreases with increasing water depth and distance from shore, except in more protected nearshore areas, such as east of New Haven and shoreward of Falkner Island and the Norwalk Islands. Also, with increasing distance from shore, the margin sands become more finely skewed, olive green, and less quartzose. Similar characteristics were found for the sand associated with the Stratford and Norwalk shoal complexes, and within Gardiners Bay and the Peconic Bays. Relatively little sand is present along the Connecticut shoreline west of the Norwalk shoal complex.

Silty sand and sand-silt-clay mark transitions within the

Sound from higher to lower energy environments (KNEBEL *et al.,* 1999; KNEBEL and POPPE, this volume). These sediment types are found: (1) on the sides of the central and western basins; (2) on the flanks of bathymetric highs; (3) in the lee of coastal headlands; and (4) in shallow depressions on the nearshore margins. They are also prevalent along the irregular northern shoreline west of the Norwalk Islands and in Huntington, Oyster, Gardiners, and the Peconic Bays. The locations of these sediment types (relative to the coarser and finer sediments) suggest that bottom currents in these areas have a limited ability to sort and winnow the bottom. The silty sands are typically finely skewed, whereas the sand-silt-clay deposits are mainly symmetrical to coarsely skewed.

Dark olive-gray, siliciclastic clayey silt is the dominant sediment type in areas characterized by depositional environments (KNEBEL *et al.,* 1999; KNEBEL and POPPE, this volume). Clayey silt is prevalent: (1) over most of the flat sea floor in the western basin and western part of the central basin; (2) in protected nearshore areas, such as the Thames River Estuary, Little Neck Bay, the southern half of Great Peconic Bay, and Branford and New Haven Harbors; and (3) in isolated depressions, such as at the eastern mouth of the channel between the shoals south of Stratford Point and the Stratford shoal complex (TWICHELL *et al.,* 1998). These fine-grained sediments are predominantly very poorly sorted ($\sigma > 2.0$) and unimodal. In general, the silt in the westernmost basin is finer than in the central basin, and the silt in the central basin fines southward. Small patches of clayey silt and silty sand found adjacent to Long Sand Shoal and the Race occur in scour depressions where older fine-grained glaciolacustrine and deltaic sediments have been exposed by erosion (HASKELL, 1977).

The distribution of silty clay is limited to relatively small patches in the western basin. This sediment type, which has accumulated in deeper water surrounded by clayey silt, is found in low-energy environments protected by bathymetric highs, such as areas on either side of the Norwalk shoal complex. The silty clay is predominantly poorly sorted, coarsely skewed, and unimodal.

Although the deeper (>20 m) waters of the central and western Sound are primarily long-term depositional areas characterized by relatively weak bottom-current regimes, videocamera observations reveal that benthic biologic activity can remobilize muddy sediments on the basin floors. For example, bioturbation, especially by crustaceans, creates mounds and resuspends sediment during feeding and burrowing activities. The mounds, which extend above the surrounding sediments, can be modified by tidal currents into rippled or undulating bedforms. More importantly, resuspended fine-grained sediment can be laterally dispersed by residual velocity and duration differences in the relatively weak tidal flow (BOKUNIEWICZ and GORDON, 1980; KNEBEL *et al.,* 1999).

Our data also reveal the localized presence of erosional bedforms, sedimentary furrows and longitudinal ripples, in the silt and clayey silt of the central basin. The furrows, which typically form in environments having recurrent, directionally stable, and occasionally strong currents, trend west-southwest and have junctions that generally open toward the east, indicating net westward sediment transport (FLOOD, 1983). Although the furrows are probably only intermittently active, they are indicative of a process by which fine-grained sediment can be remobilized and made available for transport elsewhere in the estuary (POPPE *et al.,* 1998e).

In some localized areas, beds composed largely of shell debris cover the bottom, providing a unique habitat. Although not shown on the texture map, these beds commonly occur adjacent to sandy shoals where strong tidal currents can winnow mollusc shells from the shoal crest and deposit them in a basal apron around the shoal front (POPPE *et al.,* 1998a).

Total Organic Carbon Distribution

Sample locations and TOC concentrations contoured in weight percent of the surficial sediments are presented in Figure 3. The highest TOC values exceed 3% and occur north of Hempstead Harbor (Figure 1B) in the western Sound; the lowest values are less than 0.1% and occur along the north shore of Long Island in the eastern Sound. TOC concentrations in Long Island Sound are generally elevated relative to open-marine environments, but similar to TOC concentrations in the bottom sediments of most other U.S. east-coast estuaries (GORSLINE, 1963; FROELICH *et al.,* 1971; FOLGER, 1972; POPPE *et al.,* 1990).

Our TOC results generally agree with other previously reported concentrations in the estuary. For western Long Island Sound, HATHAWAY (1971) and REID (1982) reported average TOC values of 1.79% and 2.77%, respectively. In the central Sound, KRISHNASWAMI *et al.* (1984) found average TOC values of 1.44%.

The TOC concentrations in Long Island Sound vary inversely with grain size (Figure 4A). Coarser-grained sediments, such as gravelly sediments and sands, tend to contain less organic carbon than finer grained sediments, such as clayey silts. TOC concentrations average 1.91% in clayey silts from the Sound, but only 0.37% in the sands. This inverse relationship has been observed elsewhere along the United States east coast (HULSEMANN, 1967; FROELICH *et al.,* 1971; EMERY and UCHUPI, 1972; MACIOLEK *et al.,* 1986; POPPE *et al.,* 1990),

The inverse correlation between the amount of organic carbon and sediment texture is dependent on the fine-grained nature of the organic carbon, the adsorption of organic particles onto the charged surfaces of clay minerals, and the grain-surface area available for adsorption (FROELICH *et al.,*1971; MAYER, 1994). Because of the relatively shallow nature of the Sound and because the finer-grained sediments tend to accumulate in lower energy environments, the depth or redox state of the overlying water column do not appear to be limiting factors in the distribution of TOC.

The data from this study (Figures 3, 4B) and earlier work (HATHAWAY, 1971; REID, 1982) suggest that TOC concentrations generally increase westward within the Sound. For example, TOC concentrations in clayey silts and sand off Stratford Point average only 1.76% and 0.80%, respectively, but average 2.11% and 0.94%, respectively, off the Norwalk Islands (POPPE *et al.,* 1996). Similarly, TOC concentrations from all samples analyzed in the western Sound average

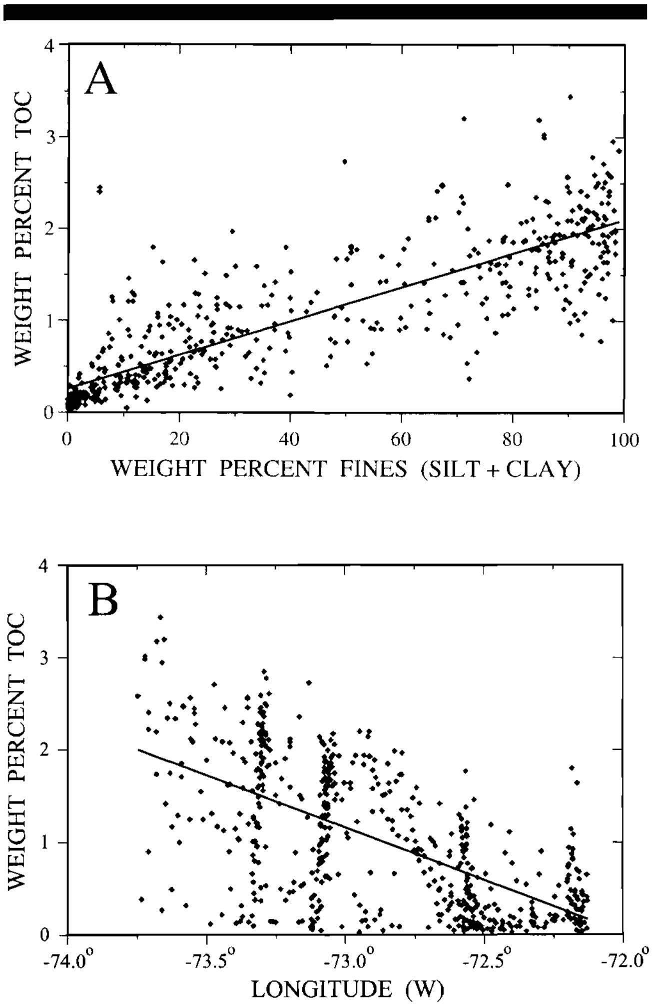

Figure 4. A) Plot showing the general relationship between increasing TOC percentages and decreasing grain size. B) Plot showing the general westward increase in TOC concentrations in Long Island Sound.

1.46%, but only 0.61% in the eastern Sound. This westward increase in TOC in the sediments is probably related to higher nutrient inputs, to seasonal stratification of the water column, and to the east-to-west progression of sedimentary environments. Higher nutrient inputs result in a high production rate of organic matter, whereas seasonal stratification promotes hypoxia in the bottom waters, which increases preservation by limiting macro- and microbiologic scavenging (STEIN, 1990; LONG ISLAND SOUND STUDY, 1994). Lower energy environments in the central and western Sound allow the deposition of fine-grained sediment, which contains more organic matter (KNEBEL and POPPE, this volume).

Data collected seasonally during 1995 as part of this study suggest a decrease in the amount of organic matter in the surficial sediments between spring and late summer. TOC concentrations average 1.73% in the samples collected during April, but average only 1.42% in samples collected at the same locations during August. This seasonal variability in the TOC, which has been noted by earlier studies along the United States mid-Atlantic slope and rise (MACIOLEK *et al.*, 1986), is probably related to increased oxidation and macrobiologic reworking of the organic matter during the late spring and early summer.

Sedimentary organic matter in the marine environment is primarily derived from phytoplankton and, to a lesser degree, from continental sources. Because marine and land plants contain different amounts of carbon and nitrogen, molar elemental carbon/nitrogen (C/N) ratios can be used as a rough means of differentiating between algal and terrigenous organic matter (PREMUZIC *et al.*, 1982; MEYERS, 1994). Aquatic (marine and lacustrine) algae typically have atomic C/N ratios of less than ten, whereas vascular land plants have C/N ratios greater than 20. This difference arises from the absence of cellulose in algae and its abundance in vascular plant material (MEYERS, 1994). The C/N molar elemental ratios from sediments near the Stratford shoal complex average 10.775 (POPPE *et al.*, 1996) and suggest that marine algae are the primary source of sedimentary organic matter in this area. Although similar C/N ratios are present in the sediments from most of the southern and central parts of the Sound off Norwalk, those from near the northern shore are much higher. The high ratios from this shoreward area commonly exceed 20 and suggest a more terrigenous source for the sedimentary organic matter.

SUMMARY

The distribution of sediment types in Long Island Sound results primarily from different sedimentary environments and, to a lesser extent, from the underlying geology, but not from restrictions imposed by the grain size of the source materials. In general, there is a progressive decrease in grain size from east to west across the length of the Sound and from the shallow margins to the deeper floor in the central and western basins.

Gravels and gravelly sands are the dominate surficial sediments in easternmost Long Island Sound where the bottom flow is dominated by strong tidal currents. Gravels also are found in smaller areas of relatively strong bottom currents where a lag has developed over outcrops of glacial till. Sand is the dominant sediment across the east-central Sound, along most of the shallow nearshore margins, on the flanks of the shoal complexes, and in western Block Island Sound; these deposits reflect environments of sediment transport and winnowing. Silty sand and sand-silt-clay occupy the sides of the central and western basins, form basal aprons around bathymetric highs, and are prevalent along the irregular northwestern shoreline; they mark transitional zones from relatively high to relatively low energy. Clayey silt is the dominant sediment type on the floor of the central and western basins and in shallow, protected areas, such as harbors, smaller estuaries, and bays. The finest-grained sediment type, silty clay, is limited to relatively small patches on the sea floor of the western basin. Clayey silt and silty clay occupy long-term depositional environments having low energy.

The regional distribution of TOC closely follows the grain-size distribution in Long Island Sound. TOC values vary inversely with grain size. As a result, TOC concentrations increase both toward the west along the Sound and from shallow to deeper water across the Sound. Despite these general trends, the TOC distribution is locally patchy due to the variable bottom-energy regime. The overall TOC concentrations in the Sound are similar to those reported for other U.S. east-coast estuaries.

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