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Sidescan Sonar Image, Surficial Geological Interpretation, and Bathymetry of the Long Island Sound Sea Floor off Milford, Connecticut

Roman Zajac

University of New Haven, rzajac@newhaven.edu

David C. Twichell

Larry J. Poppe

USGS Science Center for Coastal and Marine Geology (Woods Hole, Mass.)

Ralph S. Lewis

University of Connecticut - Avery Point. Long Island Sound Resource Center

VeeAnn Cross

USGS Science Center for Coastal and Marine Geology (Woods Hole, Mass.)

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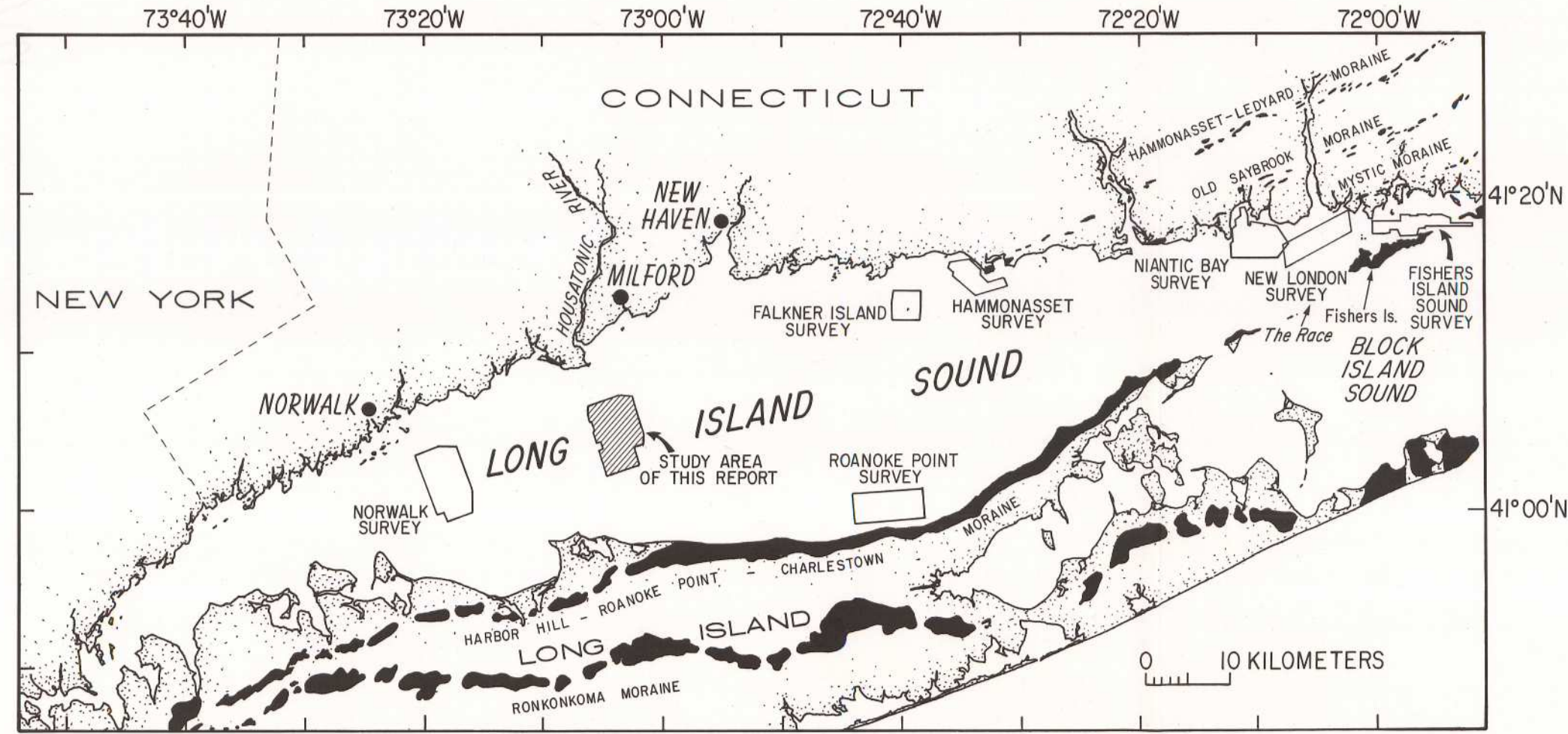
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[The Texture of Surficial Sediments in Central Long Island Sound off Milford, Connecticut](#)

[The Texture of Surficial Sediments in Western Long Island Sound off the Norwalk Islands, Connecticut](#)



Location map showing the study area in Long Island Sound off Milford, Conn., and major offshore moorings. Also shown are the sites of other sidescan sonar surveys that are part of this series. Norwalk—Twitchell and others (1997); Bozelske Point—Pope and others (1998a); Falkner Island—Pope and others (1997b); Hammonasset—Pope and others (1997a); Nantux Bay—New London—Pope and others (1998b); New London—Pope and others (1992); Moffett and others (1994); and Zaje and others (1995). Fishers Island Sound—Pope and others (1994) and in press.

INTRODUCTION
The surficial geology of a 6 km x 8 km section of the floor of the western part of Long Island Sound has been mapped. The map area is 4 to 12 km north of the mouth of the Housatonic River in 14 to 40 m water depth (see location map). This study is part of an interdisciplinary program to define the surficial geology and benthic habitats in Long Island Sound and to see how they are changing with time, and includes, in addition to this map area, the other survey areas shown on the location map. The U.S. Geological Survey, in cooperation with the University of New Haven and the Connecticut Geological and Natural History Survey, completed a bathymetric, sidescan sonar, and high-resolution seismic-reflection survey of the study area during August 1995. Presented in this report is the surficial geologic information including the bathymetry, a sidescan sonar mosaic, a preliminary interpretation of the mosaic, and a sediment distribution map of the study area.

GEOLOGIC SETTING
Long Island Sound is a large estuary that is underlain by Precambrian and Paleozoic rocks along its northern side and by Cretaceous strata along its southern side (Bodgett, 1985; Fiske, 1914). Surficial sediments in the Sound were deposited primarily during the Wisconsinan glacial stage and the subsequent Holocene interglacial stage. Because this report deals only with the shallow stratigraphy, this geologic summary is limited to the glacial and post-glacial history of the Sound. A more detailed discussion of the entire geologic history of the Sound has been presented by Lewis and Stowe (1991).

The Laurentide ice sheet advanced across Long Island Sound during the Wisconsinan and formed the Block Islands and Harbor Hill (Bozelske Point, Charlestown, and moorings on Long Island (Schaller and Harshbarger, 1965; Seltin, 1982). After the ice retreated, a small lake, Lake Connecticut, formed behind the moorings in the present location of the Sound (Lewis and Stowe, 1991). Varied clays accumulated in the central part of the Sound, and deltaic clays formed along the northern edge of the lake. Deltaic facies presently underlie much of the northern part of the Sound (Lewis and Stowe, 1991). The moorings that served as the dam for the lake broke at The Race (see location map). Glacial Lake Connecticut drained into Block Island Sound and from there southward across the continental shelf (Lewis and Stowe, 1991). The exposed lake floor was cut by tributary rivers and a central river that drained eastward down the axis of the Sound. As sea level rose, the Sound was encroached. The transgression was eroded the underlying strata and partially eroded the fluviatile cut surface. On top of this marine transgression unconsolidated, sediments have accumulated during the Holocene.

DATA COLLECTION
Bathymetric data, sidescan sonar imagery, and 3.5-kHz subbottom profiles were collected during November 7–11, 1995, aboard the research vessel R/V John Dempsey operated by the Connecticut Department of Environmental Protection along tracks spaced about 150 m apart (fig. 1). The bathymetric data were collected by using an Odom 6041H echo sounder, and the data were logged digitally on an IBM personal computer. The sidescan data were collected by using an Ocean Research Equipment 3.5-kHz sidescan sonar profile transmitting at a 0.25-s repetition rate. These data were logged in analog form on a paper chart recorder with Ocean Research Equipment 3.5-kHz sidescan sonar profile transmitting at a 0.25-s repetition rate. The data were then digitized and the data were logged digitally on an IBM personal computer. The sidescan data were collected by using a 100-kHz Klein sidescan sonar system set to transmit a 100-m swath to either side of the ship's track. These data were logged digitally on a QMPDS data logger (Dunbar and others, 1991) and were written to tape as 256K pixels per scan. The completed sidescan data were then processed and interpreted (fig. 2) using the software described in figure 3. Ship's navigation was by differential Global Positioning System (DGPS) using the software described in figure 3. The sidescan sonar data were sampled and bottom photography was attempted at 77 locations during the April 26–30 and August 27–28, 1995, cruises aboard the R/V John Dempsey using a Vixen grab sampler equipped with video and still camera systems (fig. 6). These photographic systems were used to capture information about bottom variability and to observe boulder fields where sediment samples could not be collected. Surficial sediments subsampled from the sidescan water interface down to 2 m below the seafloor were subsampled from the grab sampler. These samples were frozen and stored for later analysis.

DATA PROCESSING
Post-cruise processing was performed on the digital data sets, and an interpretive geologic map was made of the analog 3.5-kHz subbottom profiles. The bathymetric data were corrected for the 2-m tidal range in the study area. The correction was done by subtracting the tide level measured at the Bridgeport, Conn., tide station during the study period from the measured depth values. The depths were corrected to mean sea level measured at Bridgeport, Conn.

The sidescan sonar data were processed, and a digital mosaic was compiled of the entire study area. The processing steps included: (1) removing the sidescan sonar data with a median filtering routine to suppress speckle noise (Malinverno and others, 1991; Dunbar and others, 1991) and correcting for short range distortion, signal attenuation, and dropped lines in the sonar data. These processing procedures are summarized by Dunbar and others (1991) and Paley (1992a,b). After the preliminary processing, these data were used to make the composite digital mosaic. The processing procedure included placing each strip of sonar data in its proper geographic location at the appropriate scale and projection (Pavlenko, 1992), removing unwanted data where two sonar images overlapped, then matching the sidescan sonar images if there were differences, and combining the individual strips into a composite image. The final steps of filtering data, matching lines between different strips, and combining the strips was completed by using a software package developed by PCI (Nelson, 1991). The digital mosaic was output to film and photographically reduced to a scale of 1:15,000.

In the laboratory, the sidescan images were corrected for roll, compass, drag, and tilt, and were viewed through a monitor (250, 600, and 640 lines) to accurate the color and line functions. The line function was analyzed by Coulter Counter (Schaller, 1970), the ground function was analyzed by using a line function analysis, and the sidescan data were analyzed by using a sidescan analysis (Schaller, 1966). Because biogenic carbonates commonly form in situ, they usually are the most resistant of the deposited sediment to erosion. Therefore, biogenic carbonates and other biogenic carbonates debris were manually removed from the gravel lenses. Sea urchin tests were removed by the method proposed by Wentworth (1929). The vertical equivalent was calculated by using the inclusion graphics statistical method (Folk, 1974) and was based on the recommendations proposed by Shepard (1954). A detailed discussion of the laboratory methods employed is given in Pope and others (1985); the raw grain size data, associated statistics, and detailed descriptions of the bottom photography are reported in Pope and others (1996).

The map of surficial sediment distribution shown in figure 6 is based on data from the sediment sampling and bottom photography stations, on tonal changes in bathymetry on the sidescan sonar image, and on the bathymetry.

GEOLOGIC INTERPRETATION

Bathymetry and Tidalities

The bathymetry was contoured at a 2-m interval (fig. 3). The sea floor in the eastern half of the study area has a smooth gradient that slopes uniformly to the south. Water depths along the northern edge of the study area are 14 to 20 m and along the southern edge are about 30 m. The western half of the study area has a more complex morphology. The gentle southerly gradient seen in the eastern part of the study area is interrupted by an elongate steep-sided depression and by irregular bathymetric highs. Stratford Shoal (U.S. National Oceanic and Atmospheric Administration, 1992). The depression extends westward from the eastern part of the study area to the extent of the area. Its 40-m depth is the deepest part of the study area and is 14 m deeper than the sea floor immediately to the east. Stratford Shoal, south of the depression, rises to 10 m depth in the west-central portion of the study area.

Sea-Floor Seismic Facies and Stratigraphy

Three seismic facies were identified on the 3.5-kHz subbottom profiles (figs. 2, 3): (1) a facies having a highly reflective and prolonged surface return with no subbottom reflections below it (shown as drift on profiles A and C); (2) a facies having a moderately reflective and prolonged surface return with no subbottom reflections below it (shown as glaciolacustrine deposits on profiles B–E); and (3) an acoustically transparent facies having a moderately reflective surface return shown as marine deposits on profiles A, D, and E. In places the acoustically transparent facies is charged with gas and is acoustically opaque. The gas-charged sediments blank out everything below them (profile E).

The facies with the highly reflective and prolonged surface return is the oldest unit mapped in the study area. On the basis of the regional stratigraphy of Lewis and Stowe (1991), this unit probably is glacial drift. The presence of beds of boulders in the sidescan mosaic where the drift crops out is consistent with this interpretation (figs. 4, 5). Profile B (fig. 2) shows that it underlies the facies with the moderately prolonged surface return, and profile A (fig. 2) shows that it underlies the acoustically transparent facies as well. The 3.5-kHz profile shows that the drift is exposed on Stratford Shoal (fig. 3). It cannot be traced in the subsurface northward from Stratford Shoal under the depression, but it can be traced east from the limit of outcrop for 300 to 1,000 m under a 1- to 3-m-thick veneer of the acoustically transparent facies before it drops off abruptly to greater than 30 m below the sea floor (fig. 2, profile A).

The facies with the moderately reflective and prolonged surface return (fig. 2, profiles B–E) crops out in the northeastern part of the study area where it extends southward to the northern edge of Stratford Shoal (fig. 3). The regional stratigraphy (Lewis and Stowe, 1991) suggests that this facies is a sandy glaciolacustrine deposit that accumulated along the northern side of the Sound when it was occupied by Glacial Lake Connecticut. This unit is of unknown thickness because the 3.5-kHz subbottom profiling system could not penetrate it. This unit is younger than the drift because it erodes the drift along the northern edge of Stratford Shoal (fig. 2, profile B).

The acoustically transparent facies is the youngest of the three units and overlies both the drift (fig. 2, profile A) and the glaciolacustrine deposits (fig. 2, profile D). This unit is interpreted to be a fine-grained marine deposit of Holocene age (Lewis and Stowe, 1991). In the southwestern part of the study area, the thickness of the marine deposits could not be determined because the 3.5-kHz profile could not penetrate below them. In most of the northern part of the study area, where the 3.5-kHz profile could penetrate through the marine deposits, they are less than 8 m thick, and thin gradually to the west where the glaciolacustrine deposits crop out (fig. 3). Gas-charged sediments occur in the marine deposits and is confined to the deepest part of the bathymetric depression in the central part of the study area (fig. 3).

Sidescan Sonar Mosaic

The sidescan sonar mosaic (fig. 4) reveals nine distinctive seafloor patterns, and when combined with the water depth data (fig. 3) can be used to make inferences about the surficial geology (fig. 5). The nine patterns include (1) low-acoustic backscatter (dark tones), (2) high-acoustic backscatter (light tones), (3) gas-charged sediment, (4) fields of positive relief high-backscatter targets interpreted to be clusters of boulders, (5) isolated high-backscatter targets interpreted to be individual boulders, (6) broad continuous low-backscatter stripes inferred to be bedforms, (7) circular depressions with high-backscatter floor, (8) short, linear high-backscatter stripes, (9) shallow, linear depressions interpreted to be gravel marks, and (10) long, thin, linear high-backscatter stripes interpreted to be pipelines and cables. Boat wakes are a water-column phenomenon that were observed as well.

The study area is divided into two provinces, high and low acoustic backscatter (fig. 5). We use the boundary between these provinces in a digital contour of 35 because the distribution of values exceeding a digital number of 35 correlates closely with the glaciolacustrine deposits and glacial drift shown on figure 6. One exception to the rule is the area of the glaciolacustrine deposits immediately east of the bathymetric depression where the area of high backscatter (fig. 5) is smaller than the extent of the high backscatter on the near-surface echo character map (fig. 3). Perhaps there is a thin cover of marine deposits over much of this area that cannot be resolved on the 3.5-kHz profiles and is reducing the backscatter intensity below the threshold of 35.

The area of low backscatter on the sidescan image coincides with finer grained Holocene-aged marine deposits (fig. 6). The boundaries between the high- and low-backscatter regions are gradational, and the distribution of it is not uniform throughout the low-backscatter area. The values are lowest in the deepest part of 35 because the glaciolacustrine deposits and glacial drift shown on figure 6. One exception to the rule is the area of the glaciolacustrine deposits immediately east of the bathymetric depression where the area of high backscatter (fig. 5) is smaller than the extent of the high backscatter on the near-surface echo character map (fig. 3). Perhaps there is a thin cover of marine deposits over much of this area that cannot be resolved on the 3.5-kHz profiles and is reducing the backscatter intensity below the threshold of 35.

The other features identified on the sidescan mosaic are found within either the

high- or low-backscatter provinces. Boulders, bedforms, and gravel marks all are found in the high-backscatter province. Fields of boulders are limited in their occurrence to Stratford Shoal and its flanks (figs. 4–6), mostly where drift crops out (fig. 3). Isolated boulders are found in the low-backscatter province in a 300- to 1,000-m-wide zone around the area where the drift crops out. In this area, the 3.5-kHz profiles show a thin layer of marine deposits covering the drift (fig. 2, profile A) with the boulders being large enough to still stick through this cover. High-backscatter stripes, perhaps indicating current scour, occur in the low-backscatter province. Shallow circular (40 m in diameter) depressions with high-backscatter floors occur in the northern part of the study area (figs. 4, 5), mostly in areas of low acoustic backscatter. Where the 3.5-kHz profile passes over them, there is no evidence of any factors or relief. The origin of these features is unknown and needs to be addressed during subsequent studies in the area.

North to northwest-trending, linear to curvilinear, low-relief ridges are interpreted to be reef beds. These features are 1 to 2 m high, occur in a small area immediately north of the bathymetric depression, and tend to be asymmetrical with their steep sides facing east (fig. 2, profile C). The absence of smaller bedforms on the backs of these features (fig. 4) suggests that they are not actively moving under the present hydraulic regime.

Evidence of human activity also is present. A pipeline was clearly imaged by the sidescan (figs. 4, 5) and subbottom (fig. 2, profile B) systems, and another continuous but fainter high-backscatter location may be a smaller diameter pipe or cable. Trawl marks are most evident in the northwestern corner of the study area where the glaciolacustrine deposits crop out (fig. 3). Whether this association is because trawls show up more clearly in these sandy sediments than in the muddy ones or whether it is because these sandy sediments are a preferred habitat for trawling is being left unknown. Two types of draggins are observed on the sidescan image (figs. 4, 5). Faint locations that are several hundred meters in length and occur near-ward leeward are interpreted to be caused by trawl doors while shorter (<200 m in length) single locations with low backscatter beneath the bottom to either side are caused by some other dredging process. One dip track that coincides with the location of one on the navigation chart (U.S. National Oceanic and Atmospheric Administration, 1992) is shown in the southern part of the study area.

Surficial Sediment Distribution
The locations of the sample and photographic stations are shown in figure 6. The distribution of boulders and gravel, which were observed on the sidescan image and at two of the bottom photography stations around Stratford Shoal, becomes more discontinuous toward the northwestern portion of the shoal. The rocks at these stations were overgrown by hydrozoans and, to a lesser extent, by sponges. Gravelly sediments were confined to two shallow areas: the northwestern corner of the study area and the west-central part of the study area surrounding the boulders and gravel at Stratford Shoal. These gravelly sediment maps from very poorly to extremely poorly sorted and are primarily fine to medium and coarse sand.

As water depth increases, the gravelly sediments progressively grade into beds of sand and finer grained lithologies. The sands are poorly to very poorly sorted, finely shelled, and leptoclastic. The silty sands and sandy silt surrounding the coarse lithologies tend to have more symmetrical and mesoclastic to planolitic distributions. Sandy silt present in the southern part of the study area reflect subbottom beneath Long Island, New York. One exception to the relation between increasing water depth and the trend to finer grained lithologies occurs in and around the channel immediately north of Stratford Shoal where tidal currents are apparently strong enough to winnow away much of the silt and clay.

Sandy and silty clays and clays dominate the deeper south-central (main axis of the Long Island Sound, north-central depression at the eastern end of the channel north of Stratford Shoal, and eastern portion of the study area. Clays also occur in the slight depression north of a sandy shoal that extends seaward from the gravelly sediments present in the northwestern part of the study area. These fine-grained sediments are predominantly very poorly sorted and have nearly symmetrical to coarsely shelled distributions. The sandy and silty clays are nearly planolitic, the clayey silts are primarily mesoclastic.

Observations of the bottom video reveal that benthic biologic activity and tidal currents are important mechanisms that contribute to control the recycling and resuspension of bottom sediments. For example, while by low tide, corals trace the fine-grained sediment directly up into the water column. Lobsters, shrimp, and crabs, at the low tide, often around the sediments. Once these invertebrates extend above the surrounding sea floor, they can be transported or redeposited by the strong tidal currents into the sand bottom in present in much of the bottom video.

CONCLUSIONS
The detailed view of the surficial geology of the part of Long Island Sound shown that is closely related to the shallow sedimentary stratigraphy. Areas of high acoustic backscatter mostly coincide with outcrops of coarser grained glacial drift and glaciolacustrine deposits. Boulders are found where drift is exposed on the sea floor or buried by only a thin sediment cover. The area of low acoustic backscatter coincides with the finer grained Holocene-aged marine deposits. High-backscatter stripes and high-backscatter depressions mostly fall within the area of the marine deposits. This limited interpretation of the surficial geology based on the bathymetry, sidescan information, sampling, and bottom photography provides a base map for future studies of sedimentary processes and the interaction of biological, physical, and chemical activity on the sea floor in Long Island Sound.

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REFERENCES CITED

- Dunbar, W.W., Orban, F.F., and Schwab, W.C., 1991, USGS image processing system: New real-time processing of high-resolution sidescan SONAR data. See Technology, v. 32, p. 54–60.
Folk, R.L., 1974, The petrology of sedimentary rocks. Austin, Tex.: University of Texas Press, 348 p.
Folk, R.L., 1981, The geology of Long Island, New York. U.S. Geological Survey Professional Paper 82, 231 p.
Lewis, R.S., and Stowe, J.H., 1991, Late Quaternary stratigraphy and depositional history of the Long Island Sound basin, Connecticut and New York. Journal of Coastal Research, v. 11, p. 1–23.
Malinverno, Alberto, Edwards, M.F., and Ryan, W.B.F., 1990, Processing of SeaMARC swath sonar data. Institute of Electrical and Electronic Engineers Journal of Oceanic Engineering, v. 15, p. 14–23.
Moffett, A.M., Pope, L.J., and Lewis, R.S., 1994, Trace metal concentrations in sediments from eastern Long Island Sound. U.S. Geological Survey Open-File Report 94-600, 17 p.
Nelson, L.J., 1991, An "intelligent" image database tool commercialized in Canada. Advanced Imaging, v. 6, no. 4, p. 56–58.
Pavlenko, V.F., 1992a, Woods Hole image processing system software implementation. Using NetCDF as a software interface for image processing. U.S. Geological Survey Open-File Report 92-25, 69 p.
———, 1992b, Digital processing of side-scan sonar data with the Woods Hole image processing system. U.S. Geological Survey Open-File Report 92-204, 9 p.
———, 1992c, Digital mapping of side-scan sonar data with the Woods Hole image processing system software. U.S. Geological Survey Open-File Report 92-204, 87 p.

———, 1993, E. Elson, A.H., and Fredericks, J.L., 1985, APASAS: An Automated Petroleum Side Scan System. U.S. Geological Survey Circular 903, 77 p.
Pope, L.J., Lewis, R.S., and Moffett, A.M., 1992, The texture of sedimentary rocks in northeastern Long Island Sound. U.S. Geological Survey Open-File Report 92-550, 13 p.
Pope, L.J., Lewis, R.S., Dunbar, W.W., Zaje, R.N., Roman, and Moffett, A.M., 1994, Map showing the distribution of surficial sediments in Long Island Sound, New York, Connecticut, and Rhode Island. U.S. Geological Survey Miscellaneous Investigations Series Map I-2636, scale 1:25,000.

———, 1995, A modified Woods Hole rapid sediment analysis. Journal of Sedimentary Petrology, v. 65, p. 103–118.
Shepard, F.P., 1954, Nomenclature based on sand-silt-clay ratios. Journal of Sedimentary Petrology, v. 24, p. 151–158.
Shepard, F.P., 1954, Nomenclature based on sand-silt-clay ratios. Journal of Sedimentary Petrology, v. 24, p. 151–158.

———, 1957, A comparison of electronic particle counting and pipette techniques in routine mud analysis. Journal of Sedimentary Petrology, v. 27, p. 103–107.
Seltin, L.A., 1982, Wisconsinan glaciation of Long Island, New York to Block Island, Rhode Island, in Larson, G.J., and Stone, B.D., eds., Late Wisconsinan glaciation of New England. Dubuque, Iowa, Kendall/Hunt Publishing Co., p. 35–60.

Twitchell, D.C., Zaje, R.N., Pope, L.J., Lewis, R.S., Cross, V.A., Nichols, D.E., and DiGiacomo-Cohen, M.L., 1997, Sidescan sonar image, surficial geologic interpretation, and bathymetry of the Long Island Sound sea floor off Norwalk, Connecticut. U.S. Geological Survey Geologic Investigations Series Map I-2589, 2 sheets, scale 1:15,000.

U.S. National Oceanic and Atmospheric Administration, 1992, Long Island Sound. Eastern part. U.S. National Oceanic and Atmospheric Administration Chart 12504, 1:150,000.

Wentworth, C.K., 1929, Method of computing mechanical composition types in sediments. Geological Society of America Bulletin, v. 40, p. 771–779.
Zaje, R.N., Pope, L.J., Roman, Edward, Dunbar, W.W., Lewis, R.S., Pope, L.J., and Voss, J., 1995, The use of side scan sonar and other mapping tools to assess sea floor habitats and associated benthic communities in Long Island Sound (see). Geological Society of America Abstracts with Programs, Northeastern Section, v. 27, no. 1, p. 94.

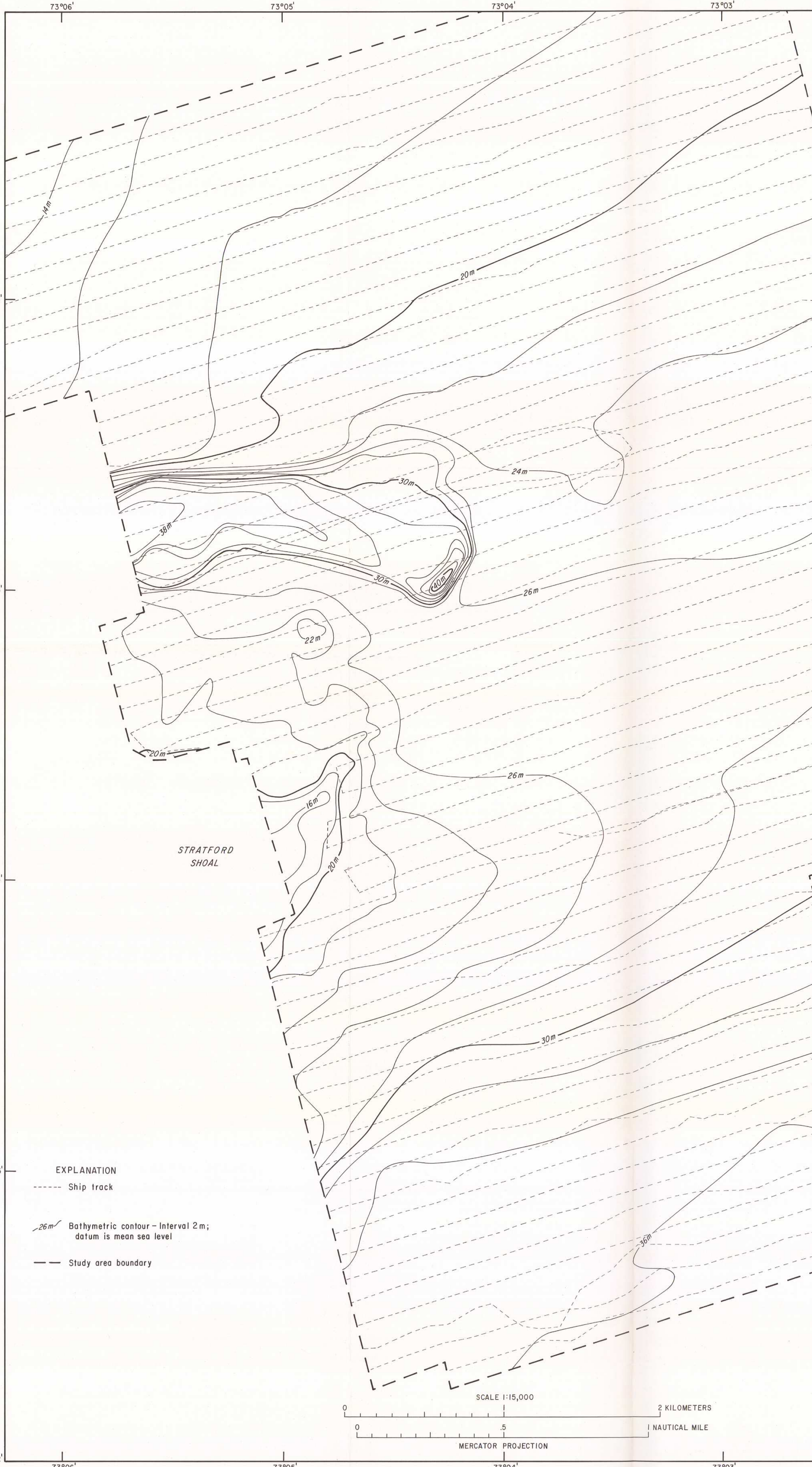


Figure 1—Bathymetric map of the study area. Depths have been corrected for tides and are adjusted to mean sea level. Dashed lines represent tracks along which geophysical data were collected.

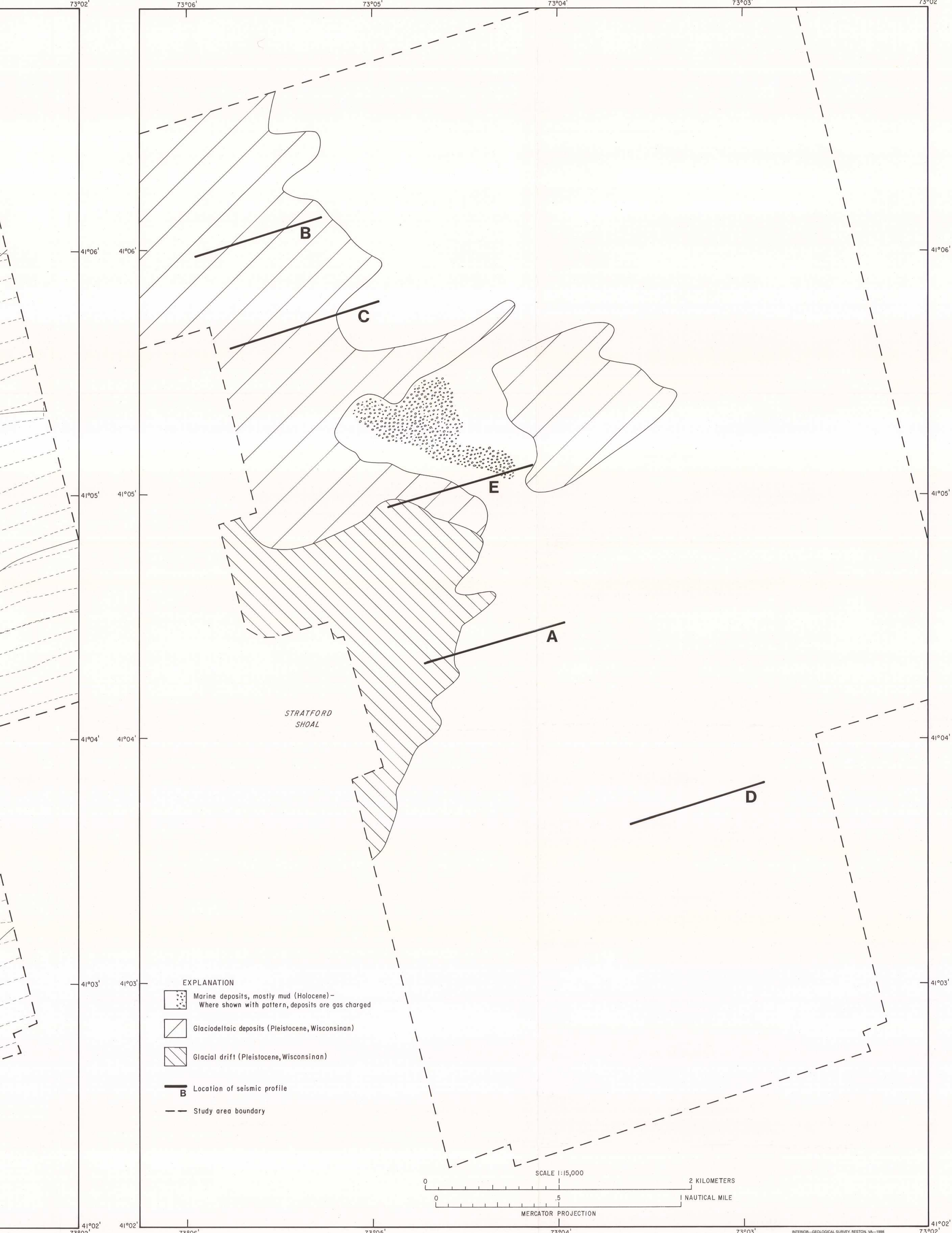


Figure 2—Near-surface echo character map compiled from the 3.5-kHz subbottom profiles showing the distribution of the three acoustic facies that were identified by the subbottom profiles.

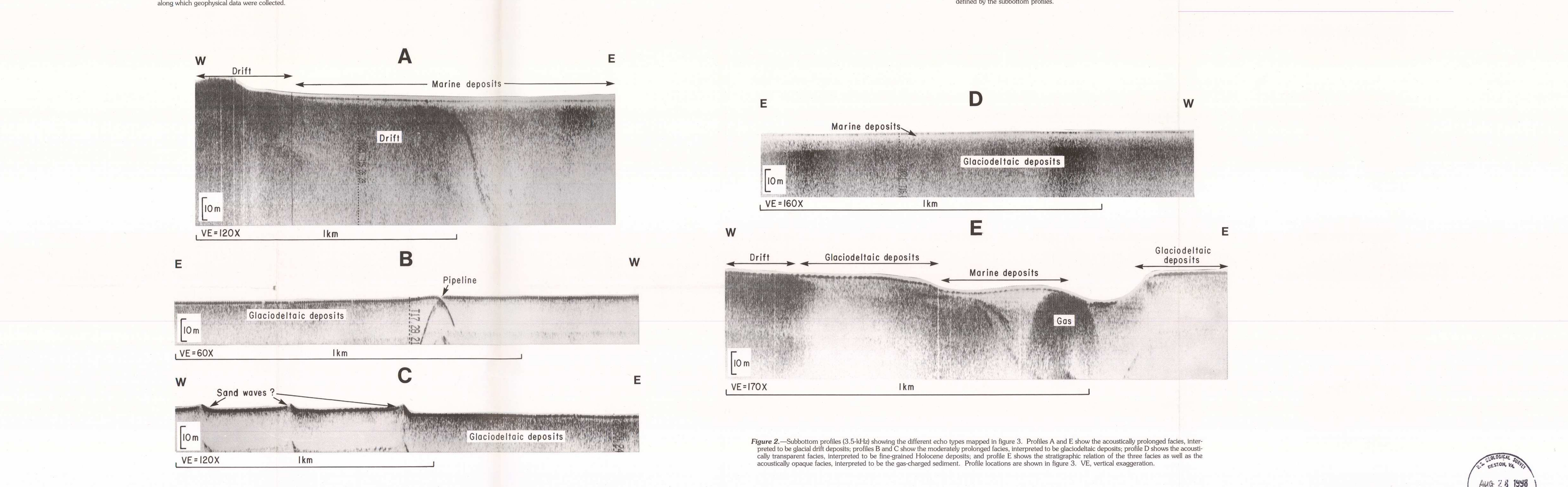


Figure 3—Subbottom profiles (3.5-kHz) showing the different echo types mapped in figure 2. Profiles A and E show the acoustically prolonged facies, interpreted to be glacial drift deposits; profiles B and C show the moderately prolonged facies, interpreted to be glaciolacustrine deposits; profile D shows the acoustically transparent facies, interpreted to be fine-grained Holocene deposits; and profile E shows the strongly reflective facies, interpreted to be the gas-charged sediment. Profile locations are shown in figure 3. VE, vertical exaggeration.

SIDECAN SONAR IMAGE, SURFICIAL GEOLOGIC INTERPRETATION, AND BATHYMETRY OF THE LONG ISLAND SOUND SEA FLOOR OFF MILFORD, CONNECTICUT

By

David C. Twitchell,¹ Roman N. Zaje,² Lawrence J. Pope,¹ Ralph S. Lewis,³
VeeAnn A. Cross,¹ David R. Nichols,¹ and Mary L. DiGiacomo-Cohen³

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AUTHOR AFFILIATIONS
¹U.S. Geological Survey, Woods Hole, MA 02543.
²University of New Haven, New Haven, CT 06516.
³Connecticut Geological and Natural History Survey, University of Connecticut at Avery Point, Groton, CT 06340.



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