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Sidescan Sonar Image, Surficial Geologic Interpretation, and Bathymetry of the Long Island Sound Sea Floor off Hammonasset Beach State Park, Connecticut

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Comments

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See also these related documents:

Map Showing the Distribution of Surficial Sediments in Fishers Island Sound, New York, Connecticut, and Rhode Island

Organic Carbon, Hydrogen, and Nitrogen Concentrations in Surficial Sediments from Western Long Island Sound, Connecticut and New York

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

The Texture of Surficial Sediments in Western Long Island Sound off the Norwalk Islands, Connecticut

The Texture of Surficial Sediments in Central Long Island Sound off Milford, Connecticut

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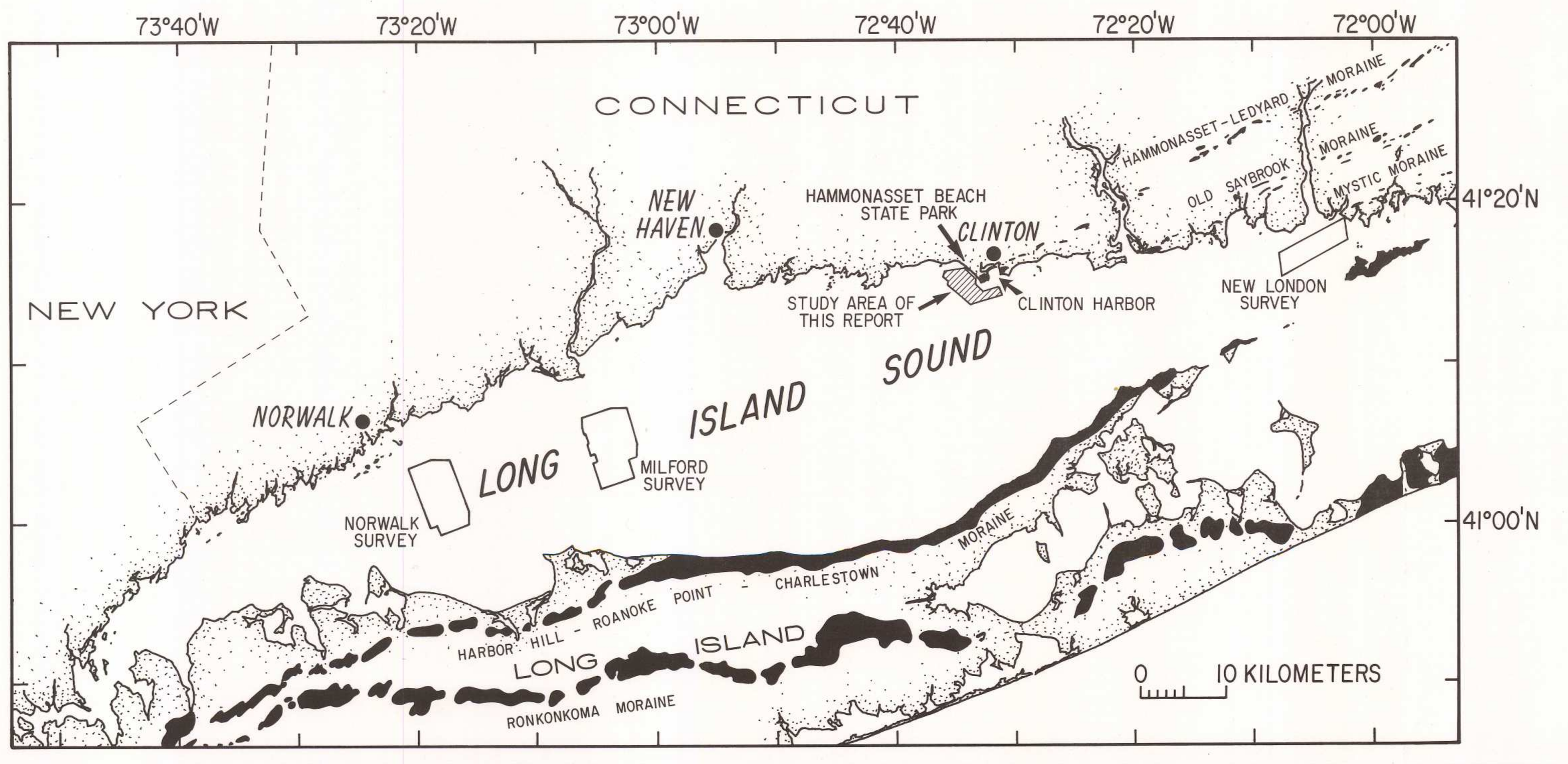

Figure 1.—Map showing location of the study area off Clinton, Conn. Also shown are major onshore moraines and the locations of other sidescan sonar surveys completed to date as part of this series (Norwalk—Twichell and others (1997); Milford—Twichell and others (1995); New London—Poppe and others (1992) and Moffett and others (1994)).

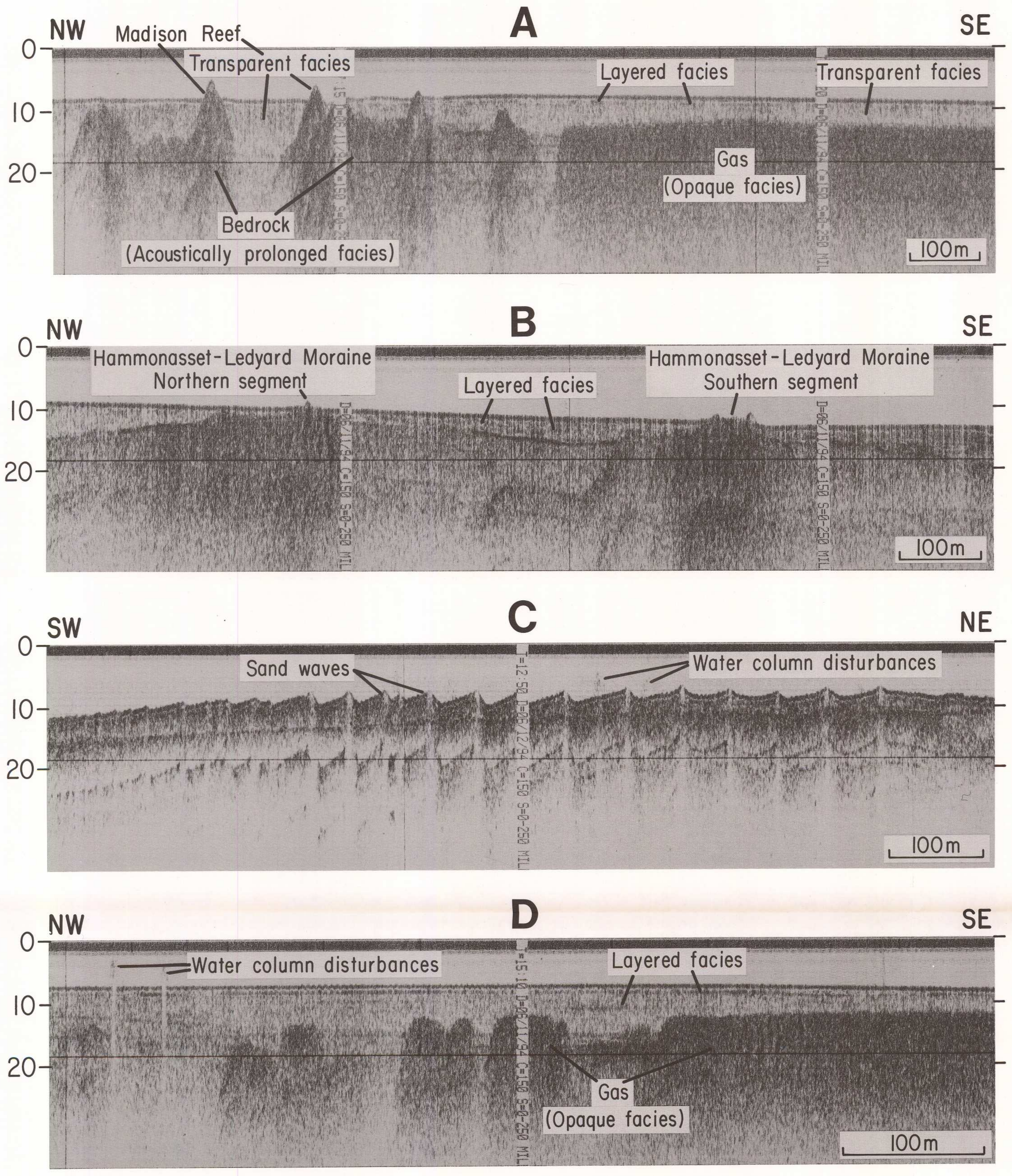

Figure 3.—Subbottom profiles (3.5-kHz) showing different echo-character types. (**A**) Profile shows the acoustically prolonged facies interpreted to be the bedrock substrate of Madison Reef and the acoustically opaque facies interpreted to represent gas-charged sediment. The upper, highly reflective surface of the prolonged facies commonly represents acoustic basement. (**B**) Profile shows the prolonged seismic character and twin segments of the Hammonasset-Ledyard moraine. (**C**) Profile shows sand waves and seismic returns from the water column possibly caused by fish, biogenic gas seeps, kelp beds, or suspended sediment. (**D**) Profile shows the acoustically opaque facies interpreted to be the result of gas-charged sediment, and seismic returns from the water column causing some of the high-backscatter spots shown in figures 6 and 7. Locations of the profiles are shown in figures 2 and 4.

INTRODUCTION

Ongoing research by the U.S. Geological Survey (USGS) in Long Island Sound, a major East Coast estuary surrounded by the most densely populated region of the United States, is building upon cooperative research with the State of Connecticut that was initiated in 1982. During the initial phase of this cooperative program, geologic framework studies in Long Island Sound were completed and results published (Lewis and Needell, 1987; Needell and others, 1987; Lewis and Stone, 1991). Emphasis of the present program in Long Island Sound is shifting from framework studies toward studies of the sediment distribution, processes that control this sediment distribution, nearshore environmental concerns, and the relation of benthic community structures to the sea-floor geology.

Because of the enormous surrounding population, large inputs of anthropogenic wastes (e.g., fertilizer and sewage) and toxic chemicals have produced stresses on the environment of the Sound, causing degradation and potential loss of benthic habitats (Long Island Sound Study, 1994). To examine this problem, we are constructing sidescan sonar mosaics (complete-coverage acoustic images) of the sea floor within areas of special interest, such as in areas affected by seasonal hypoxia like the Norwalk survey or near major coastal resources like the Hammonasset Beach survey (fig. 1). The mosaic that we have constructed off Hammonasset Beach State Park and which is presented herein allows insight into the geological variability of the sea floor, which is one of the primary controls of benthic habitat diversity. It also provides a detailed framework for future research, monitoring, and management activities, and it improves our understanding of the complex processes that control the distribution of bottom sediments, benthic habitats, and associated infaunal community structures off one of the most significant coastal recreational facilities within the State of Connecticut. Because precise information on environmental setting is important to the selection of sampling sites and to the accurate interpretation of point measurements, the sidescan sonar mosaics also act as base maps for subsequent sedimentological, geochemical, and infaunal sampling and bottom photography.

GEOLOGICAL SETTING

Long Island Sound occupies an elongate east-west basin that is about 182 km long by a maximum of 32 km wide (Lewis and Stone, 1991). It is bordered on the north by the rocky shoreline of Connecticut and on the south by the eroding sandy bluffs of Long Island, N.Y. The study area (figs. 1 and 2), which covers about 12.7 km^2, lies in northeastern Long Island Sound offshore from two major recreational facilities, Hammonasset Beach State Park and Clinton Harbor.

The bedrock beneath the study area is believed to be composed of gneissic metamorphic rocks of pre-Mesozoic age (Lundgren and Thurrell, 1973; Rodgers, 1985). The bedrock is unconformably overlain by two tills, one of pre-Wisconsinan age and one of late Wisconsinan age (Flint, 1971). Glacial lake deposits, stratified drift, and Holocene marine sediments variously overlie the bedrock and till (Lewis and Stone, 1991). The northward retreat of the late Wisconsinan ice sheet is marked in southeastern Connecticut by a series of minor recessional moraines (the Hammonasset-Ledyard, Old Saybrook, and Mystic moraines; see fig. 1) and associated outwash deposits (Goldsmith, 1980). These moraines, prominently represented within the study area by the Hammonasset-Ledyard moraine (Stone and others, 1992; J.R. Stone and J.P. Schafer, USGS, unpub. data, 1994), are relatively linear, discontinuous, usually capped by boulders, and commonly aligned as double ridges that parallel the major recessional Harbor Hill - Roanoke Point - Charlestown moraine and Ronkonkoma moraine complexes on Long Island. West-southwestward from Hammonasset Point, the Hammonasset-Ledyard moraine extends offshore and appears to correlate with a submerged moraine and lacustrine fan complex south of New Haven to the west, and with the Ledyard moraine to the northeast beyond the area of figure 1 (Goldsmith, 1980; J.R. Stone and J.P. Schafer, USGS, unpub. data, 1994).

Strong tidal currents have extensively eroded and reworked both the glacial and postglacial deposits and continue to influence sedimentary processes and surficial sediment distributions in eastern Long Island Sound. The irregular bottom topography and extensive lag deposits of the eastern Sound reflect scour, transport, and reworking of the sediments (Lewis and Stone, 1991).

DATA COLLECTION AND PROCESSING

Sidescan sonar imagery, bathymetry, 3.5-kHz subbottom profiles, and navigational data were collected along tracks spaced 150 m apart aboard the RV *Asterias* during June 11–15, 1994 (figs. 2, 3, and 6). The bathymetric data were collected by means of a 200-kHz echo sounder, and the data were logged digitally to a computer. The subbottom data were collected in analog form using an Ocean Research Equipment 3.5-kHz profiler transmitting at a 0.25-s repetition rate. The sidescan sonar data were collected using a 100-kHz Klein sidescan sonar system set to sweep 100 m to either side of the ship's track. These data were logged digitally to 8-mm tape on a QMIPS data acquisition system (Danforth and others, 1991). Ship position was determined with a differential Global Positioning System (GPS); navigational data were logged on a computer at 10-s intervals. The bathymetric data were corrected for the approximately 1.4-m tidal range in the study area. These data were corrected by adjusting the measured depth values to the predicted mean sea level for Madison, Conn., approximately 2 km northwest of the study area. The Madison values were calculated from actual tidal-height measurements performed at Bridgeport, Conn.

The sidescan sonar data were processed according to procedures summarized by Danforth and others (1991). Briefly, the sonar data were multiplexed and filtered to convert them into a format useable by the processing routines and to remove speckle noise. The data were corrected for slant-range distortions, striped noise was removed, and shading was corrected to compensate for signal attenuation. Then, statistics from the sonar data were accumulated to determine the dynamic range of the data, and a contrast enhancement was applied. Corrected ship navigation, which accounted for changes in ship speed, was merged with the sonar data, and the data were geographically oriented and displayed on a Mercator grid. After processing, the files were output to a thermal printer. The final image was a manually constructed mosaic.

Surficial sediments were sampled and bottom photography attempted at 62 locations during April and May 1995 aboard the RV *John Dempsey* by means of a Van Veen grab sampler equipped with video and still camera systems (fig. 5). These photographic systems were also used to appraise intra-station bottom variability and to observe boulder fields and bedrock outcrops where sediment samples could not be collected. Surficial sediments (sediments from the sediment-water interface down to 2 cm below the interface) were collected from the grab sampler; these subsamples were frozen and stored for later analysis.

In the laboratory, the sediment samples were corrected for salt content, disaggregated, and wet sieved through a number 230, 62-µm (4 ϕ) sieve to separate the coarse and fine fractions. The fine fraction was analyzed by Coulter Counter (Shideler, 1976); the coarse fraction was analyzed by sieving (gravel) and by rapid sediment analyzer (sand; Schlee, 1966). Because biogenic carbonates commonly form in situ, they usually are not representative of the depositional environment from a textural standpoint. Therefore, bivalve shells and other biogenic carbonate debris were manually removed from the gravel fraction. Size classifications are based on the method proposed by Wentworth (1929). The verbal equivalents were calculated using the inclusive graphics statistical method (Folk, 1974) and are based on the nomenclature proposed by Shepard (1954). A detailed discussion of the laboratory methods employed is given in Poppe and others (1985); the raw grain-size data, associated statistics, and detailed descriptions of the bottom photography are reported in Poppe and others (1995).

The map of surficial sediment distribution shown in figure 5 is based on data from the sediment sampling and bottom photography stations, on tonal changes in backscatter on the sidescan sonar image, and on the bathymetry.

INTERPRETATION

Near-Surface Echo Character

Four acoustic facies were identified on the 3.5-kHz subbottom profiles (fig. 3): prolonged, opaque, transparent, and layered. More than one of these facies may occur together: the layered and transparent facies commonly grade into each other, and gas-charged sediment, which is believed to cause the opaque facies, can be associated with both the layered and transparent facies. Outcropping subbottom units of the prolonged facies and surficial sedimentary structures, such as sand waves, are also recorded on the 3.5-kHz profiles. Disturbances in the water column are commonly present in the 3.5-kHz profiles and are discussed below in relation to the sidescan sonar mosaic.

The acoustically prolonged facies has a highly reflective upper surface that commonly represents acoustic basement (figs. 3 and 4). In the western part of the study area this facies delineates the steep gradients of the bedrock substrate of Madison Reef (fig. 3A); in the central part of the study area this facies is produced by two parallel segments of the Hammonasset-Ledyard moraine (fig. 3B). Subbottom profiles across the moraine show that the smaller, northern segment overlies and is younger than the southern, main part of the moraine, and that the moraine dips below the surficial sediment cover toward the southwest. The shallow gradient of this surface along the southern extent of the moraine may reflect the accumulation of thick ice-proximal meltwater deposits.

The acoustically opaque facies is interpreted to result from gas-charged sediment (figs. 3A, 3D, and 4). The distribution of this facies is primarily limited to areas where the depth to acoustic basement is relatively greater, such as the area between Madison Reef and the Hammonasset-Ledyard moraine and the area between the moraine and the sand-wave field. The top of this facies occurs 3–11 m beneath the sediment-water interface. Gas-charged sediment can be associated with both the transparent and layered acoustic facies, but where detected, gas obscures most of the underlying units and acoustic basement in these areas.

The transparent and layered facies, which overlie and are younger than the prolonged acoustic facies, probably represent Holocene deposition. The transparent facies dominates beneath the sand-wave field, along Hammonasset Beach, shoreward of Madison Reef, and in elongate patches between the reef and the moraine. The layered facies is more prevalent around the moraine and in the lower-energy areas west of Hammonasset Point.

Sand waves and megaripples cover the southern and eastern parts of the study area (figs. 3C and 4). The average crest-to-trough height of these features is less than 2 m, but occasionally exceeds 3 m; asymmetry of the sand waves suggests that they migrate. Based on the orientations of this asymmetry, the net transport direction is to the east over the northernmost part of the sand-wave field and to the west over the remainder of the field. This distribution suggests that the flood tide is most intense on the south side of the sand-wave field, and that the ebb tide is strongest on the north side.

Bathymetry

The corrected bathymetry was contoured at 2-m intervals (fig. 2). Maximum water depths exceed 21 m and occur in the southern and southeastern parts of the study area. Water depths gradually shallow shoreward, around Hammonasset Point, and toward the northwest. The steepest bathymetric gradients occur along the seaward edge of the submerged Hammonasset-Ledyard moraine and in the eastern part of the study area. Elsewhere, especially at depths shallower than 14 m, the gradients are much gentler.

Isolated bathymetric highs occur in the northwestern, central, and eastern parts of the study area. The highs in the northwestern part of the study area delineate Madison Reef (fig. 3A); in the central part of the study area the highs are related to the northern and southern segments of the Hammonasset-Ledyard moraine (fig. 3B); and to the east the highs are associated with a sand-wave-covered shoal (fig. 3C). There are few other outlying areas of elevated relief greater than 2 m, and the sea floor is generally smooth. Isolated depressions with relief greater than 2 m occur only in the area between the Hammonasset-Ledyard moraine and the field of sand waves, and between the two segments of the Hammonasset-Ledyard moraine.

Sidescan Sonar Mosaic

The sidescan sonar mosaic (fig. 6) recreates an acoustic image of the sea floor that, when used in combination with the seismic data (figs. 3 and 4), provides an overall perspective of the benthic character (fig. 7). Distinctive acoustic patterns revealed by this mosaic include the following: outcropping subbottom reflectors (bedrock; boulders and gravel), elongate patches of alternating high and low backscatter (sand waves), areas of low backscatter (dark; probably relatively fine-grained sediment), areas of high backscatter (light; probably relatively coarse-grained sediment), and areally limited spots of high backscatter (light; interpretation is problematic).

Outcrops of subbottom reflectors occur both in the northwestern part of the study area and in southwest-trending linear bands off Hammonasset Point. The outcrops in the northwestern part of the study area are primarily bedrock, probably of the Waterford Group (Lundgren and Thurrell, 1973; Rodgers, 1985), and represent the surface exposures of the Madison Reef substrate. Scattered occurrences of boulders and gravel can be observed adjacent to some of these bedrock outcrops. Southwest of Hammonasset Point subbottom reflectors crop out (fig. 4), but here the sea floor is covered by boulders and gravel (figs. 6 and 7) that are interpreted to be the offshore equivalent of the Hammonasset-Ledyard moraine. As in some onshore segments of this moraine (Goldsmith, 1980), the offshore part exhibits a characteristic double morphology. These two linear accumulations of boulders and gravel diverge toward the southwest and progressively narrow in surficial extent. About 1.8 km offshore they become discontinuous owing to cover by postglacial sediments. The strong, oscillato-

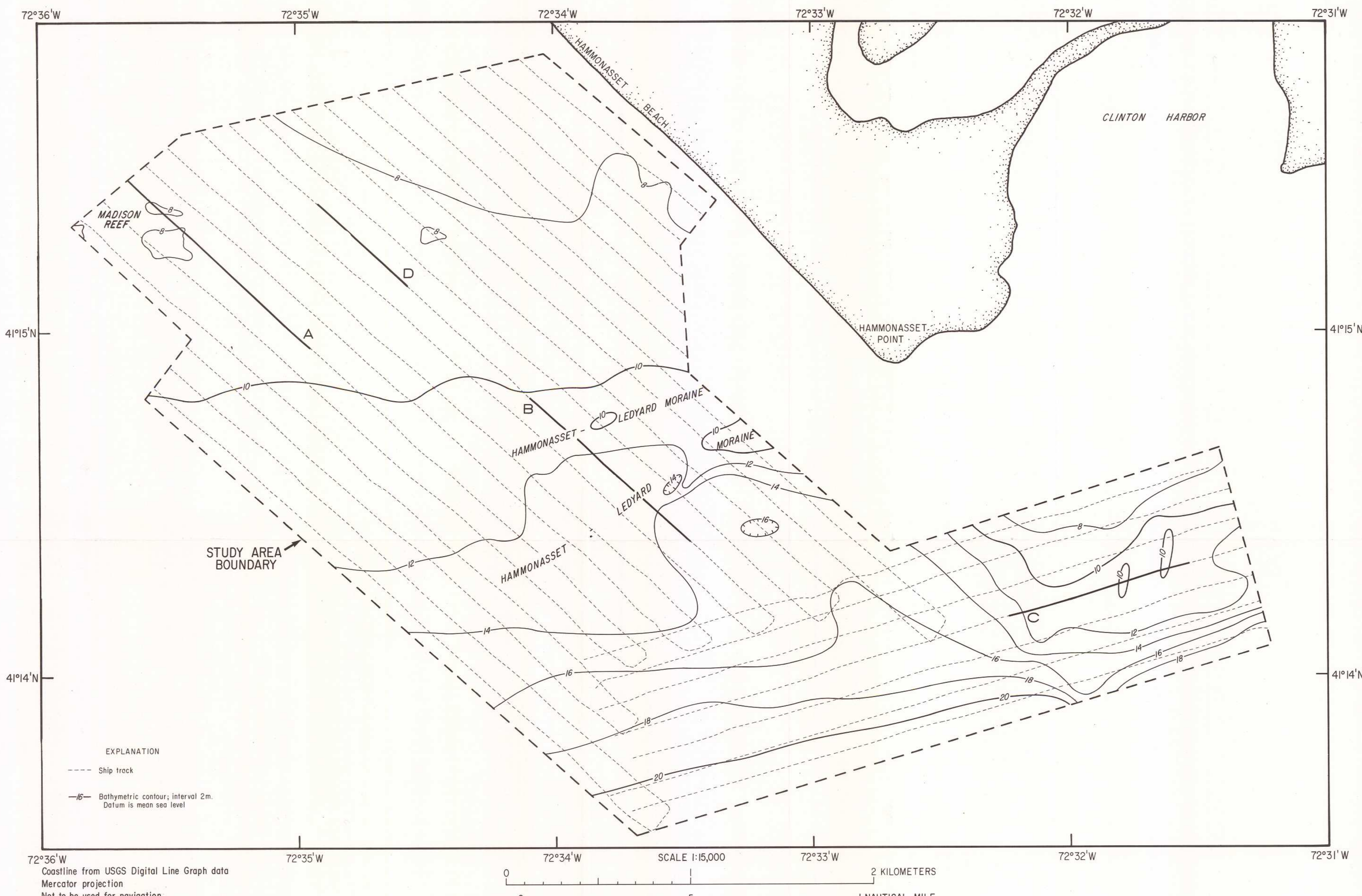

Figure 2.—Bathymetric map of the study area. Contour interval 2 m. Depths have been corrected for tides and are adjusted to mean sea level. Fine dashed lines represent tracks along which geophysical data were collected. Locations of profiles A, B, C, and D, shown in figure 3, are indicated.

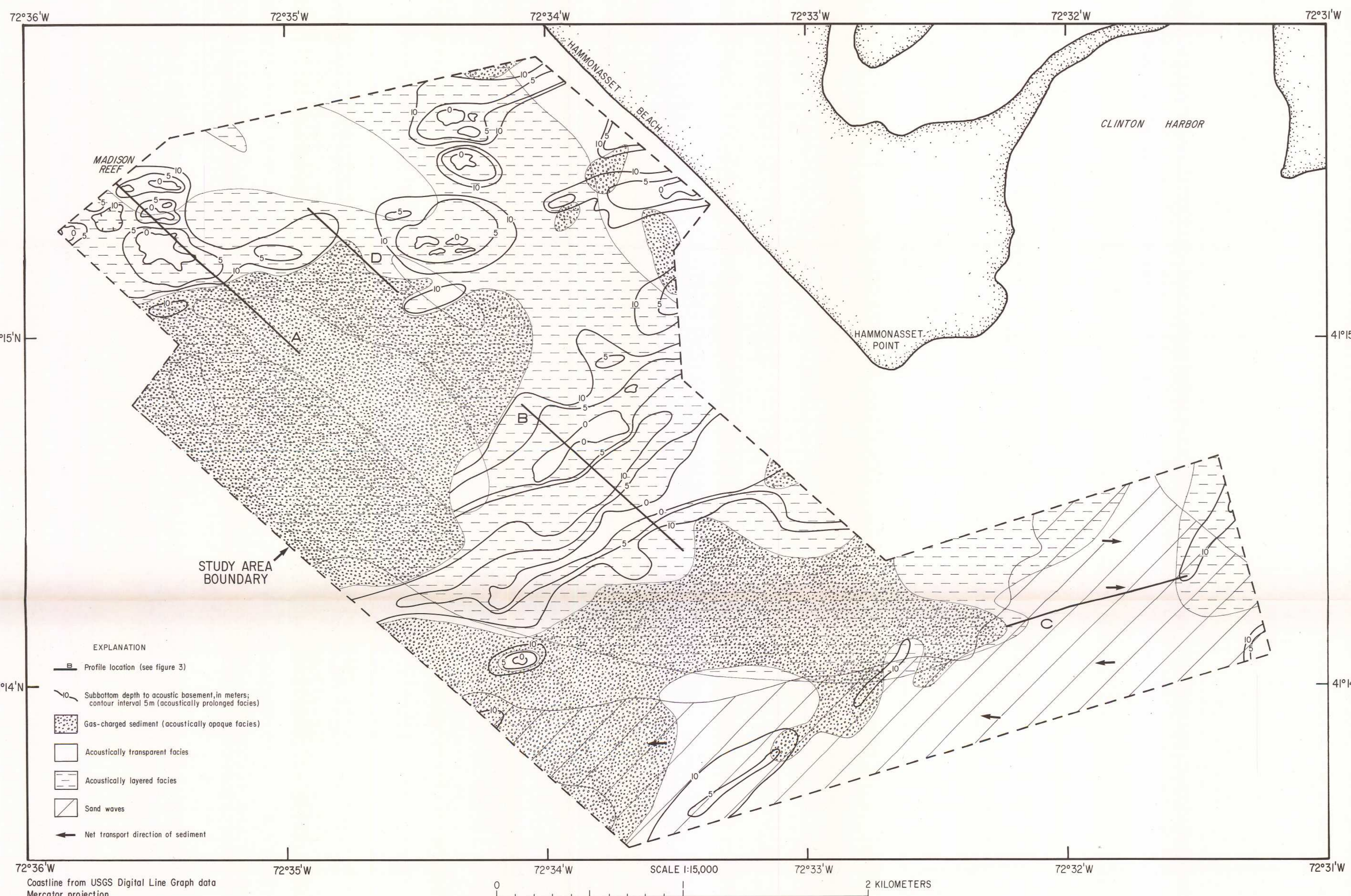

Figure 4.—Near-surface echo-character map showing the distribution of the four acoustic facies: prolonged, opaque, transparent, and layered. The prolonged facies commonly represents acoustic basement, and the opaque facies is interpreted to be the result of gas in the sediments. The prolonged facies coincides with the sea floor within the 0-m contour. Figure also indicates the location of profiles A, B, C, and D, shown in figure 3.

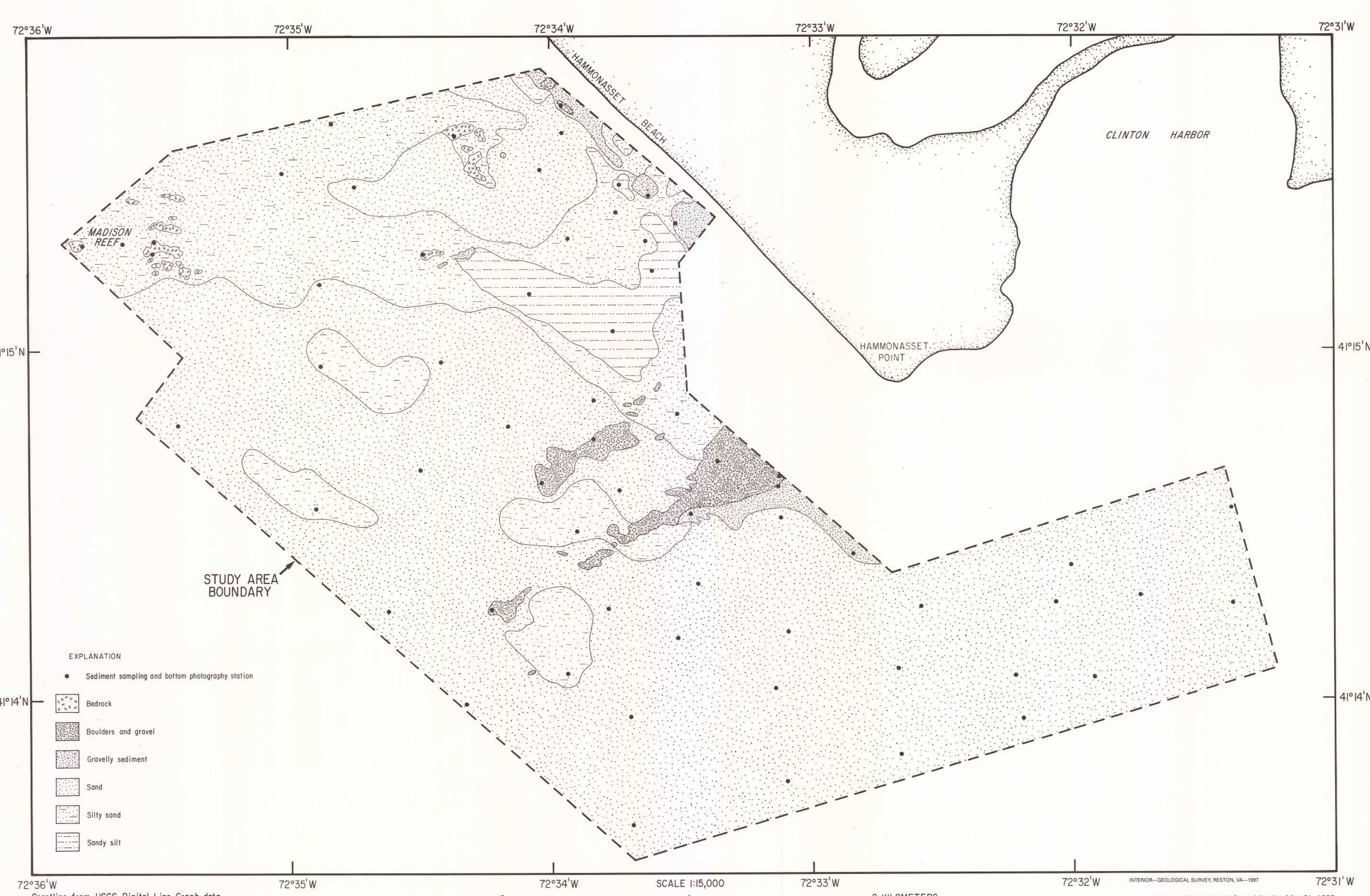

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Figure 5.—Map showing the distribution of surficial sediments and the locations of the sediment sampling and bottom photography stations. Interpretation of the sediment distribution is based on data from these stations, on tonal changes in backscatter on the sidescan sonar image (fig. 6), and on the bathymetry (fig. 2).

SIDESCAN SONAR IMAGE, SURFICIAL GEOLOGIC INTERPRETATION, AND BATHYMETRY OF THE LONG ISLAND SOUND SEA FLOOR OFF HAMMONASSET BEACH STATE PARK, CONNECTICUT

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