Surficial Sediments

George L. Freeland
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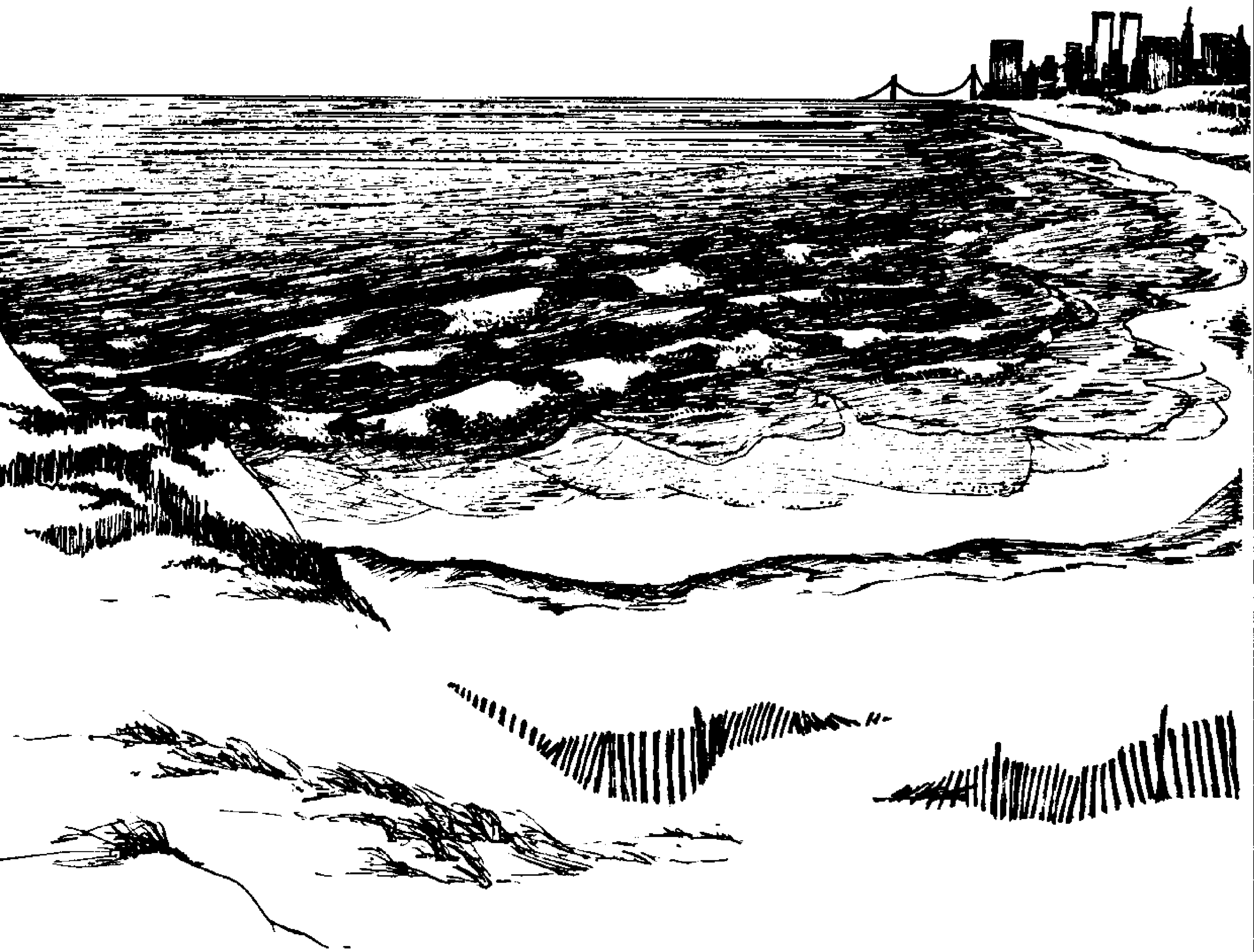

MESA NEW YORK BIGHT ATLAS MONOGRAPH 10

The offshore water in the bend of the Atlantic coastline from Long Island on one side to New Jersey on the other is known as New York Bight. This 15,000 square miles of the Atlantic coastal ocean reaches seaward to the edge of the continental shelf, 80 to 120 miles offshore. It's the front doorstep of New York City, one of the world's most intensively used coastal areas—for recreation, shipping, fishing and shellfishing, and for dumping sewage sludge, construction rubble, and industrial wastes. Its potential is being closely eyed for resources like sand and gravel—and oil and gas.

This is one of a series of technical monographs on the Bight, summarizing what is known and identifying what is unknown. Those making critical management decisions affecting the Bight region are acutely aware that they need more data than are now available on the complex interplay among processes in the Bight, and about the human impact on those processes. The monographs provide a jumping-off place for further research.

The series is a cooperative effort between the National Oceanic and Atmospheric Administration (NOAA) and the New York Sea Grant Institute. NOAA's Marine EcoSystems Analysis (MESA) program is responsible for identifying and measuring the impact of man on the marine environment and its resources. The Sea Grant Institute (of State University of New York and Cornell University, and an affiliate of NOAA's Sea Grant program) conducts a variety of research and educational activities on the sea and Great Lakes. Together, Sea Grant and MESA are preparing an atlas of New York Bight that will supply urgently needed environmental information to policy-makers, industries, educational institutions, and to interested people.

ATLAS MONOGRAPH 10 describes what is known about surficial and suspended sediment in New York Bight. The surficial sediment cover of the continental shelf in the Bight consists of a sheet of sand up to 10 m thick with small areas of gravel and muddy sand. Off the shelf edge, mud increases to become the dominant sediment. Modification of the natural pattern of sedimentation has occurred in the Bight apex where man has dumped his wastes for over 60 years. The apex, say Freeland and Swift, is now a "worst case" example of ocean pollution. With proper management of municipal and industrial wastes, they contend the apex may eventually return to a near-natural setting, still in use by man, but without harmful ecological effects.

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Marine EcoSystems Analysis (MESA) Program
MESA New York Bight Project

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Contents

Maps, Figures, Tables 4
Acknowledgments 5
Abstract 7
Introduction 7
Bathymetry and Morphology 8
    Continental Shelf 9
    Continental Slope and Submarine Canyons 12
    Continental Rise 12
Sediment Properties 13
    Source and Age 13
    Type and Texture 15
    Composition 24
    Color 40
    Suspended Sediments 46
    Radioactivity 53
Stratigraphy 54
Regional Studies 55
    New Jersey Shelf 55
    Bight Apex 61
    Hudson Shelf Valley 65
    Long Island Shelf 71
    Continental Shelf Edge, Submarine Canyons, and Continental Slope 75
    Other Areas 81
Summary 83
Glossary 84
Appendixes 87
References 89

Maps

1. Bight bathymetry 9
2. Middle Atlantic Bight morphology 10
3. Glacially related shelf floor features 11
4. Linear lows on continental shelf surface 12
5. WHOI/USGS sample stations 14
6. Sediment type by grain size 15
7. Percent sand 17
8. Percent gravel 18
9. Percent silt 19
10. Percent clay 20
11. Median grain size 21
12. Grain size of principal mode 22
13. Sorting 23
14. Skewness 24
15. Kurtosis 25
16. Percent calcium carbonate 26
17. Carbonate assemblages 27
18. Percent mollusks in carbonate sand fraction 28
19. Percent echinoids in carbonate sand fraction 29
20. Percent shell fragments in sand-sized fraction 30
21. Percent foraminifera 31
22. Percent quartz and feldspar 32
23. Ratio of feldspar to feldspar plus quartz 33
24. Percent glauconite 34
25. Percent mica 35
26. Percent heavy minerals in sand-sized fraction 36
27. Percent amphiboles in heavy mineral fraction 37
28. Percent epidote in heavy mineral fraction 38
29. Percent garnet in heavy mineral fraction 39
30. Percent staurolite in heavy mineral fraction 40
31. Percent illite in clay fraction 41
32. Percent chlorite in clay fraction 42
33. Percent kaolinite in clay fraction 43
34. Percent organic carbon 44
35. Percent Kjeldahl nitrogen 45
36. Ratio of organic carbon to Kjeldahl nitrogen 46
37. Sediment color 47
38. Percent iron-stained grains in 2 to 3 phi fraction 48
39. Radioactivity 49
40. Tracklines for seismic reflection profiles 56
41. Detailed study areas 59
42. Gravel deposit on inner New Jersey shelf 60
43. Bight apex bathymetry and locator 63
44. Bight apex bathymetric net change, 1936-73 66
45. Bight apex percent sand 66
46. Bight apex percent gravel 67
47. Bight apex percent mud 67
48. Bight apex phi mean 68
49. Tracklines from 1973 NOAA survey in Bight apex 68
50. Bight apex composite of sonographs 69
51. Fine sediment transport in Bight apex, autumn 1973 69
52. Distribution of ferric hydroxide particles in water column, November 1973 70
53. Bight apex CERC geophysical tracklines and core locations 72
54. Bathymetric net change, 1845 to 1936, Bight apex 72
55. Bottom sediment types in Hudson Shelf Valley 73
56. Grain-size distribution of sand-sized fraction, area 2D1 on Map 41 74
57. Morphologic features, area 2D2 on Map 41 75
58. Grain-size distribution of sand-sized fraction, area 2D2 on Map 41 76
59. USGS geophysical tracklines and bottom grab sample locations 77
60. Long Island nearshore study area and Suffolk County outfall study area 79
61. CERC vibracore locations for proposed Suffolk County sewer outfall studies 80
62. Fire Island ridge and swale study area 3A on Map 41 81
63. Long Island south shore CERC tracklines and vibracore locations 82
64. Long Island south shore surficial sediment 82

Figures

1. Erosional shoreface retreat 13
2. Coastal fine sediment transport 16
3. Suspended fine sediment transport 51
4. Five erosional unconformities 54
5. Evolution of ridge and swale topography 55
6. New Jersey shelf transect, surficial sediment composition 61
7. Structural cross section at Atlantic generating station site 62
8. Bathymetry of apex-dredge spoil dumpsite, 1936 and 1973 64
9. Sonograph of patchy texture north of apex cellar-dirt dumpsite 65
10. Vertical distribution of total suspended sediment load off Long Beach, LI 71
11. Long Island shelf transect, surficial sediment composition 71

Tables

1. Source of solids transported into marine waters of New York Bight 50
2. Volumes of erosion and deposition in New York Bight apex between 1936 and 1973 62

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Abstract

The surficial sediment cover of the continental shelf in New York Bight consists of a sheet of sand up to 10 m thick with small areas of gravel and muddy sand. Off the shelf edge, mud increases to become the dominant sediment. Most sediment was first deposited during or soon after the last glacial maxima when the present shelf was land and has been reworked by the advancing shoreline. Most shelf morphologic features also reflect these conditions.

Modification of the natural pattern of sedimentation has occurred in the Bight apex where man has dumped his wastes for over 60 years. Dredge spoil dumping has created several knolls on the bottom, and with outfalls, the dumping of sewage sludge, acid wastes, construction, and other rubble, has made the apex a "worst case" example of ocean pollution. With proper management of municipal and industrial wastes, however, the apex may eventually return to a near-natural setting—still in use by man, but without harmful ecological effects.

Introduction

The nature of bottom sediments and suspended sediment particles interests environmental managers when man's ocean activities cause perturbations on the bottom and in the near-bottom water column. These managers must consider not only immediate results but also long-term effects. How are natural processes affected by what man has done, or more important, how do natural processes modify what man has done to disturb the environment. Fisheries biologists, sanitary and ocean engineers, public health officials, vessel captains, and countless government planners use the information collected and presented by geologists, among others. This monograph covers one area of critical environmental concern—sediments.

Without attempting to reinterpret other authors' work, we have summarized what is currently known about surficial and suspended sediment in New York Bight. Primary information sources were the two bibliographies of the Bight—Ali et al (1973) and NOAA (1974). Additional sources are the work our laboratory is doing as part of the MESA New York Bight Project, and other laboratory projects on the Atlantic shelf. Data are presented mostly as maps showing results of completed work or tracklines of records. Only two examples of plotted geophysical data are included to illustrate the type of data available (Figure 4).

The sediments on the floor of New York Bight are important to man in many ways. How man exploits the continental shelf surface is outlined below.

Food Resources. The Bight is an important commercial source of surf clams and ocean quahogs, lobsters and crabs, and benthic fishes, which live on or in the substrate. These animals are directly affected by the texture of ocean bottom sediment and its stability. Most benthic fauna have restricted ecological niches and will not survive if those niches are severely disturbed. Therefore, marine biologists need to know what sediments are present and their variability in a small area, whether they are being eroded or additional sediments are being deposited, at what rates, and the impact of seasonal changes, if any.

Recreation. The main recreational uses of the Bight are bathing and fishing. Good water quality for swimming, essential to any beach community, depends chiefly on the amount and type of suspended particles in the water column and whether these particles are hosts for contaminants. Although most fine sediment has a *terrigenous* source, much nearshore material has been resuspended from shelf and bay bottoms during storms to adversely affect water quality.

Recreational fishing and clamming are also adversely affected where benthic fish and clams, abundant and popular in the New York area, live in contaminated sediments, usually muddy bottoms.

Waste Disposal. Waste disposal is currently the most critical environmental problem in the Bight. Dredge spoil, sewage sludge, construction rubble, chemical wastes, wrecks, and *ocean outfalls* contribute to the modification of the marine environment, especially in the Bight apex (Gross 1976). Because most chemical and biological poisons introduced into seawater become attached to very fine particles, studies of fine-grained sediments, both suspended in the water column and on the ocean bottom, are particularly important. Some chemicals, in solution when dumped, precipitate when they come in contact with seawater, becoming suspended particulate matter. Many dumped particles are fine-grained, and are only slightly denser than seawater, allowing currents to carry them considerable distances before depositing them on the bottom. Even after deposition they may be resuspended—depending on particle density and shape—by bottom currents and wave surge, especially during storms. Muddy bottom sediment is reworked by benthic organisms that bring buried sediment, often in a *reduced state,* to the sediment-water interface where oxidation occurs. Thus, toxic material may once again become entrained in the water column.

Construction. Up to now there has been little construction on the Bight's floor: Ambrose Light Tower and a few ocean outfalls constitute the major structures. However, offshore nuclear power plants, oil exploration and production platforms, offshore tanker terminals, pipelines, and more and longer ocean outfalls are planned in the next decade. The nature of sediments and their stability must be studied in the area of each project.

Beach and Channel Maintenance. Knowledge of nearshore and estuarine sediment stability is necessary for preventing or diminishing beach erosion, for keeping harbors and channels open, and for understanding sandbar and barrier spit migration.

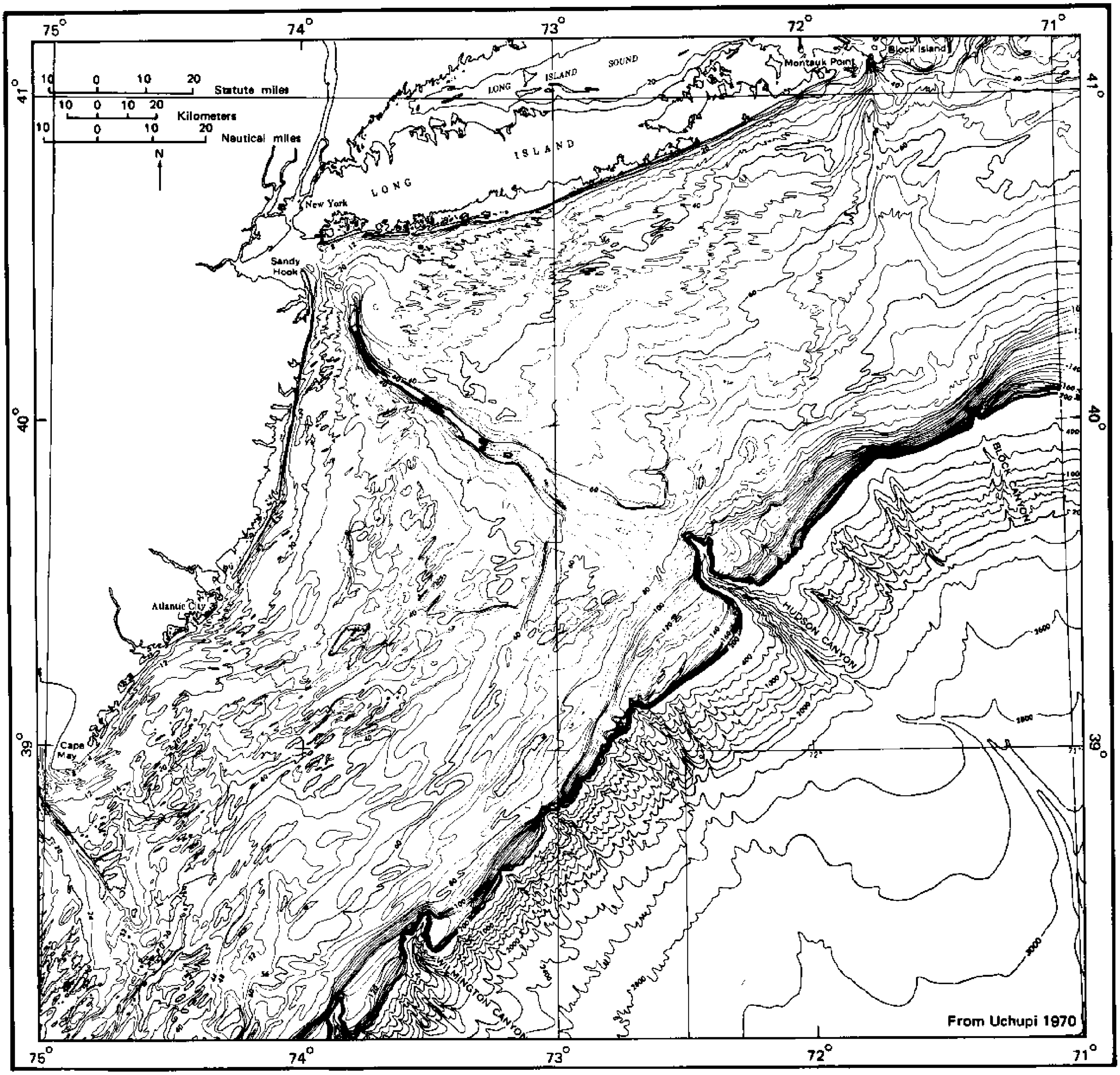
Mineral Resources. The Bight has not yet been used extensively for sea-floor mineral mining, but with the ever-growing demands on land use, the importance of marine minerals will increase. Among these resources are sand for beach maintenance and replenishment, for building and roadway aggregate, and *placer* materials as a source of metals.

Bathymetry and Morphology

The morphology of the Bight floor and the distribution of its surficial sediments may be explained by sea-level fluctuations from continental glaciation over the past several millions years. At the time of the last major ice advance, the North American ice sheet extended from Canada to Long Island and northern New Jersey. Sea level was lowered to about 145 m (480 ft) below the present level in the vicinity of Hudson Canyon (15,000 years ago) (Milliman and Emery 1968); hence the continental shelves became dry land. Since then, the ice has been melting and the shoreline has retreated over the shelf to its present position. Many features on the shelf today are the result of this fall and rise of sea level.

In 1836, the Survey of the Coast of the United States—the predecessor to the Coast and Geodetic Survey—initiated periodic hydrographic surveys in nearshore areas. From these and pre-World War II surveys the most recent bathymetric maps of the Bight were made at 1 fm (2 m or 6 ft) contour intervals (Stearns and Garrison 1967) and, as in Map 1, at 4 m (13 ft) contour intervals on the shelf

Map 1. Bight bathymetry



Note: contour intervals 4 and 20 m

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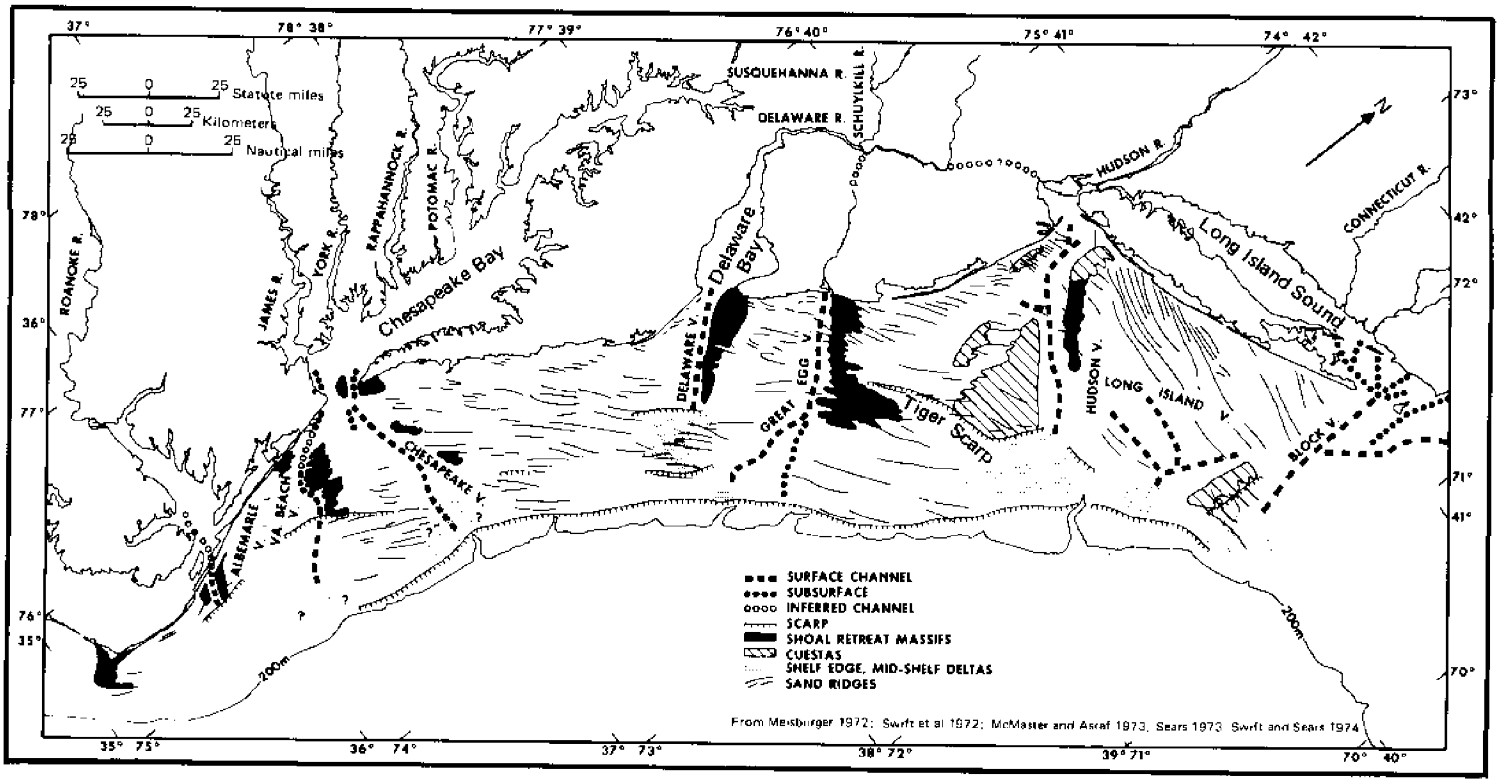
surface, and 200 m (656 ft) intervals on the continental slope (Uchupi 1970). Maps from 1975 NOAA surveys updating information in the Bight are now available.

Continental Shelf

Morphological features of the Middle Atlantic Bight from Cape Hatteras to Block Island are shown in Map 2. Within this area New York Bight is morphologically bounded to the northeast by Block Shelf Valley, to the south by Delaware Shelf Valley, and is divided into two sections by its most prominent feature, Hudson Shelf Valley. Small shelf features include other *shelf valleys, shoal retreat massifs, cuestas,* shelf *deltas, ridge and swale* topography, and *antecedent* stream systems (Swift 1975; Swift et al 1972).

Shelf valleys, cut by streams crossing the shelf during lowered sea level, were estuary mouth retreat paths during the post-glacial rise of sea level; estuarine

Map 2. Middle Atlantic Bight morphology



Transverse Mercator Projection

sedimentation then partly or completely filled old *subaerial* river valleys (Swift 1973). The most distinct shelf valley is the Hudson, entrenched up to 37 m (121 ft) below the shelf surface. The head of the valley is presently an amphitheater-shaped depression east of Sandy Hook; it had several northwest tributaries before waste dumping began in the late 1800s (Williams and Duane 1974). From its upper end, the valley axis extends 18 km (10 nmi) due south, then gently curves to the southeast and continues almost 45 km (24 nmi) in a nearly straight line. About 120 km (65 nmi) from the entrance to New York Harbor, the valley flattens and becomes indistinct in an area known as the Hudson Apron (Veatch and Smith 1939); repeated deltaic sedimentation occurred here during several stages of glacial sea-level lowering (Ewing, LePichon, and Ewing 1963; Knott and Hoskins 1968). This deltaic buildup resulted in a northeastward offset of the head of Hudson Canyon relative to the seaward end of Hudson Shelf Valley. The valley and the canyon are both being studied to determine whether they are acting as conduits for pollutants dumped into the Bight apex.

To the northeast, Block Shelf Valley is incised up to 10 m (33 ft) below the shelf surface.

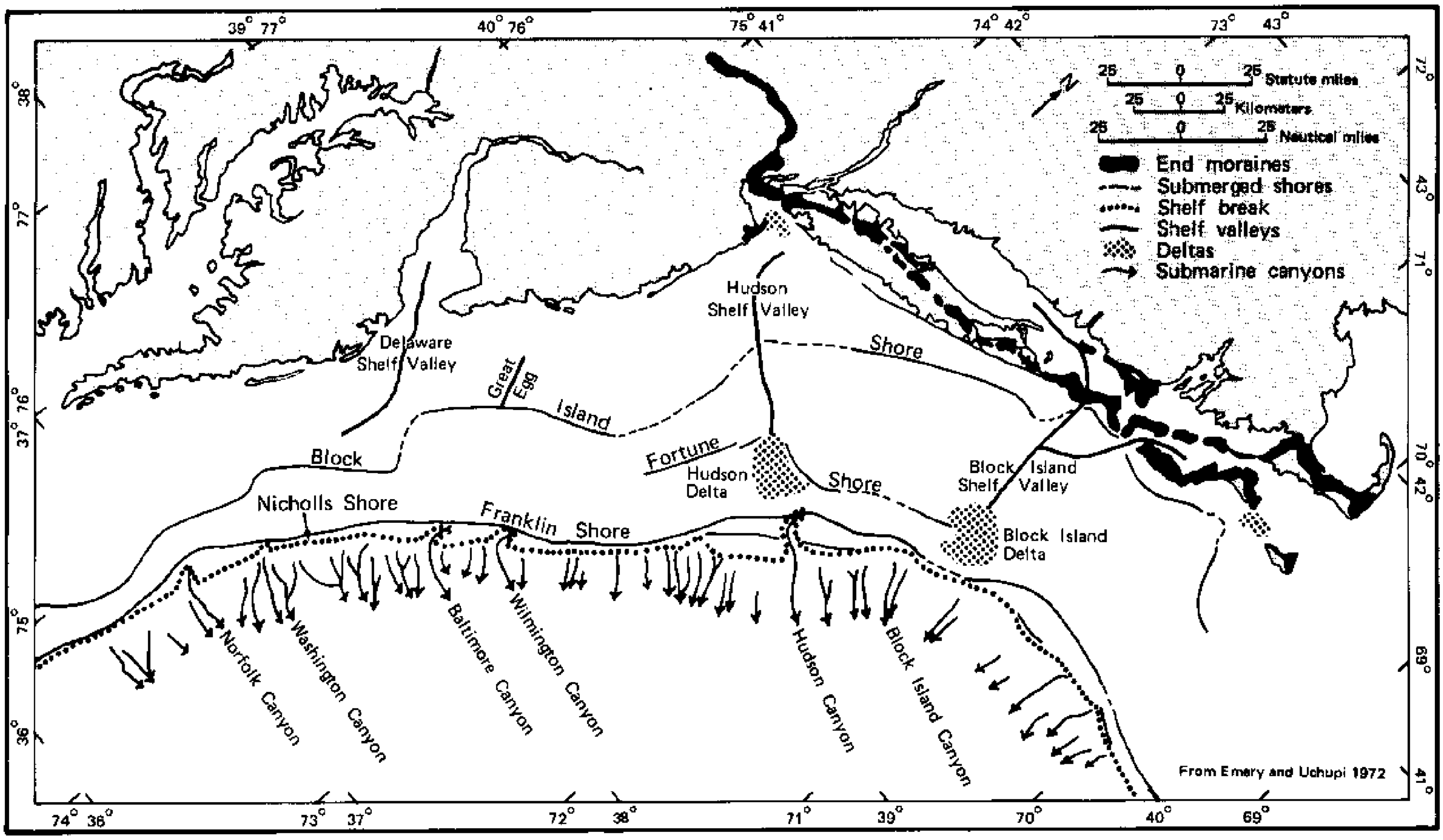
Off the New Jersey coast, Great Egg Shelf Valley was formed by the ancestral Schuylkill River when it cut across southern New Jersey to Wilmington Canyon during an early glacial stage (Maps 1 and 3). During the latest ice age, however, the shelf valley terminated instead at Baltimore Canyon (Map 3) (Swift 1973). Since then, it has been mostly filled and modified by sea-level advance across the shelf. In its present form, Delaware Shelf Valley (Map 2) is apparent only on the shoreward half of the shelf.

Shoal retreat massifs are constructional features resulting from the withdrawal of nearshore *depositional centers* (Swift et al 1972). They represent the retreat paths of *littoral drift* convergences at estuary mouths or off *cuspate forelands* during the last sea-level rise. In the Middle Atlantic Bight, shoal retreat massifs tend to occur on the southeastern flanks of shelf valleys, where they were deposited during the retreat of estuary mouth shoals.

Several areas of dissected cuestas are also present; the most prominent is immediately south of Hudson Shelf Valley (Map 2). Its crest is a low, broad ridge called Hudson Divide, which terminates abruptly against Tiger Scarp to the east. Recent studies suggest that this feature is of compound origin, and is in part a constructional feature similar to a shoal retreat massif (H. Knebel, personal communication).

At the seaward ends of shelf valleys lie deltas formed when sea level was shoreward of its farthest

Map 3. Glacially related shelf floor features



Transverse Mercator Projection

retreat. Block Shelf Delta created a bulge in the shelf edge; other shelf deltas—at the seaward terminations of Hudson, Delaware, and Great Egg shelf valleys and the Long Island River—form smaller bulges, or are contained wholly on the shelf surface.

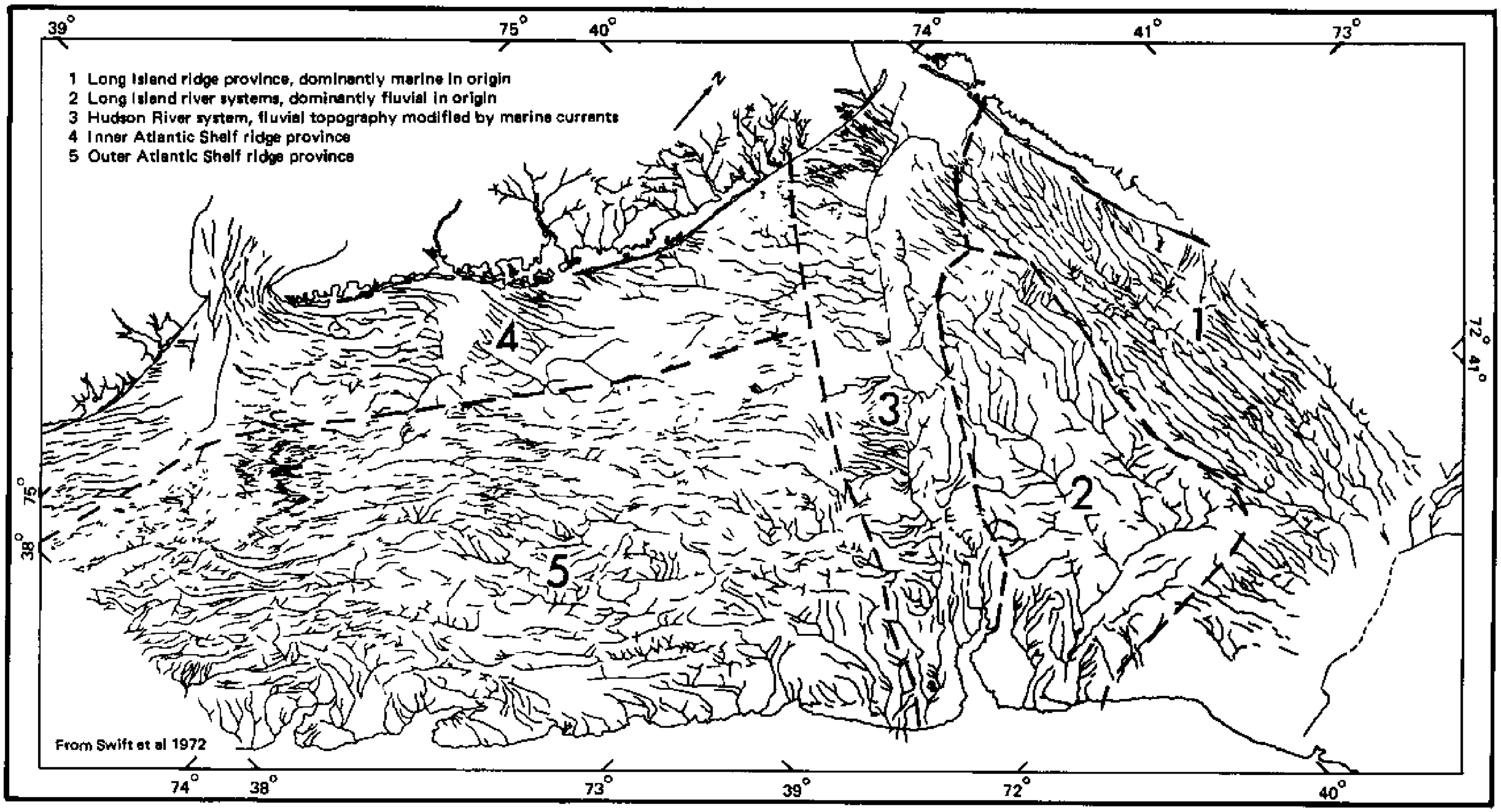
Terraces and *scarps* are remnants of sea-level stillstands during the time of shoreline advance. Most prominent are the Franklin and Nicholls shores (Map 3).

Almost completely covering the shelf surface are two interrelated features that, although individually small, dominate local topography: antecedent stream systems and ridge and swale topography (Maps 2 and 4). The stream systems, left from times of lowered sea level, were modified during and after transgression, particularly on the inner shelf; they are completely obliterated in most places.

Ridge and swale topography dominates the inner shelf but is subdued on the outer shelf. Duane et al (1972) and Swift et al (1972) discussed these features in detail. Ridge spacing is generally about 2 km (1 mi), amplitude about 2 to 10 m (7 to 33 ft), and length 9 to 56 km (6 to 35 mi). Their alignment is mostly east to northeast, at 20° to 30° angles with the shoreline. Once considered *relicts* of barrier islands and beach dune topography, they are now thought to be *Holocene* features formed by currents from storms with northeast winds (Duane et al 1972). *Seismic* profiles and radiocarbon dates indicate that the ridges rest on a nearly flat surface of early Holocene or Pleistocene lagoonal and nearshore deposits. The older substrate, locally exposed in troughs, is veneered by lag deposits consisting of a few centimeters of shelly gravel or coarse, shelly sand (see Appendix). In some areas, troughs have been incised to 6 m (20 ft) into the older substrate (Freeland and Swift 1975; Stubblefield et al 1975). Hence the ridge topography is both erosional and constructional.

The ridges are particularly important to studies of sediment stability in areas proposed for offshore structures and pipelines. Moody (1964) measured net movement of a nearshore sand ridge off Bethany Beach, DE: 125 m (410 ft) during a 42-year period and nearly 80 m (262 ft) during a major 1962 storm. These figures are extremes, however. Ridges further seaward probably exhibit much slower rates of movement, or are essentially immobile, though there may be considerable sediment movement.

Map 4. Linear lows on continental shelf surface



Transverse Mercator Projection

Continental Shelf and Submarine Canyons

At the edge of the continental shelf a sharp increase in gradient marks the beginning of the continental slope. The shelf break is generally at 140 m (459 ft) below present sea level in the Bight but may vary from 80 to 160 m (262 to 525 ft). Map 1 shows that the slope flattens out into the continental rise at about 2,000 m (6,562 ft). Whereas the shelf gradient off New York averages 0.87 m/km, or 0.05°, the slope gradient from Block Canyon to approximately 39°N averages 17.3 m/km, or 1°, on the upper slope to the 1,000 m (3,281 ft) isobath and 52 m/km, or 3°, to the base of the slope at 2,200 m (7,218 ft) (Uchupi 1968). South of 39° N the slope is irregular, cut by numerous canyons and valleys, and has an average gradient of about 70 m/km, or 4° (Uchupi 1968). Great water depths and distances from shore, wide line-spacing on *hydrographic surveys*, and the wide spread of sound waves in deep water during recording present difficulties in making accurate bathymetric maps; many small bottom features are missed. Submersible dives on the slope reveal much more varied topography than has been mapped (Emery and Ross 1968).

Many canyons and small canyon-like valleys and gullies cut the surface of the continental slope. Only Hudson Canyon extends shoreward of Franklin Shore (Map 3); it stretches almost 340 km (183 nmi) across the continental slope and rise to depths of 4,100 m (13,451 ft) (Belding and Holland 1970). On the upper slope, Hudson Canyon averages from 12 to 15 km (6 to 8 nmi) wide; at the shelf edge break at 155 m (508 ft) depth the relief is over 750 m (2,461 ft) and at mid-slope, nearly 1,000 m (3,281 ft). Some slopes in the canyon walls are nearly vertical at rock outcrops. Canyons are thought to have formed by submarine erosion but their age is unknown (Shepard 1963).

Continental Rise

The continental rise is a *sedimentary apron* beginning in New York Bight at about 2,200 m (7,218 ft) depth and extending seaward some 560 km (302 nmi) to about 5,300 m (17,388 ft) depth. Gradients are generally less than 17 m/km, or 1° (Uchupi 1968). Numerous channel-like extensions of canyons which cut into the slope diminish and die out on the rise.

Considerable work has been done on the continental shelf by many geological laboratories on the east coast. However, most workers have sampled small, discrete areas, mostly near shore. In the only comprehensive sampling program for the entire shelf, the Woods Hole Oceanographic Institution (WHOI) and the US Geological Survey (USGS) used a 19 km (10 nmi) spacing (Map 5). The Bight regional maps in this monograph are taken from papers reporting on this work. Detailed studies of individual areas are discussed later.

Source and Age

During a transgression, tide-, wind-, and wave-driven currents of the inner-shelf water column interact with the shelf floor, forming a surface profile that is approximately a concave-up exponential curve (Figure 1); the steep limb comprises the shoreface immediately seaward of the wave-breaker zone (Swift et al 1972). With a loose, sandy substrate this surface tends to extend laterally across the mouths of bays, closing them off by depositing sand in peninsulas (barrier spits) and islands. Estuaries and lagoons behind these spits and islands become traps for suspended fine sediment (mud). The barriers are nourished by sand transported laterally from eroding headlands and onshore from the sea floor.

As sea level rose during the Holocene transgression, *fluvial* and old land-surface sediments on the present shelf were covered by estuarine and lagoonal sediments behind barrier islands or were directly reworked by the retreating shoreline. Shoreface erosion then moved the inner-shelf profile shoreward. Some eroded sand was swept back onto the barrier islands by storms and buried there, only to be reexposed at the eroding shoreface. Littoral drift washed most of the material down the coast and seaward to accumulate as a discontinuous sand blanket 0 to 10 m (up to 33 ft) thick (Stahl, Koczan, and Swift 1974). Thus, the dominant material on the shelf floor is sand-sized sediment; unconsolidated, fine-grained sediment has been resuspended and transported back into the estuaries or off the shelf edge. The underlying stratum of transgressed lagoonal and estuarine (semiconsolidated) mud deposits are exposed locally on the seafloor (Swift et al 1972; Sheridan, Dill, and Kraft 1974; Stahl et al 1974; Freeland and Swift 1975) and are recognizable from angular clay fragments and oyster shells.

Unlike the shelf, the continental slope and rise are floored with mud (silt and clay fractions combined), most of which was deposited during lowered sea level. The uppermost layer was transported by inner shelf water during the post-glacial sea-level rise.

Mud is largely held in suspension in the nearshore zone by two-layer density circulation (Figure 2) whereby freshwater runoff from land moves seaward over ocean water as a surface layer, mixing with and transporting seaward a portion of the salty lower layer. Offshore bottom water then flows landward and upward to replace bottom water thus entrained. As a result, relatively little suspended mud can escape the nearshore zone; suspended particles move seaward with the upper layer only to settle into the landward-moving lower layer. This nearshore turbid water mass mixes with the turbid water within lagoons and estuaries via tidal inlets and estuary mouths. Much of the suspended mud is trapped out on the surfaces of marginal salt marshes that build up to near the high tide line. Although the annual suspended sediment discharge of Atlantic coastal rivers is about equal to the annual deposition on marsh surfaces (Meade

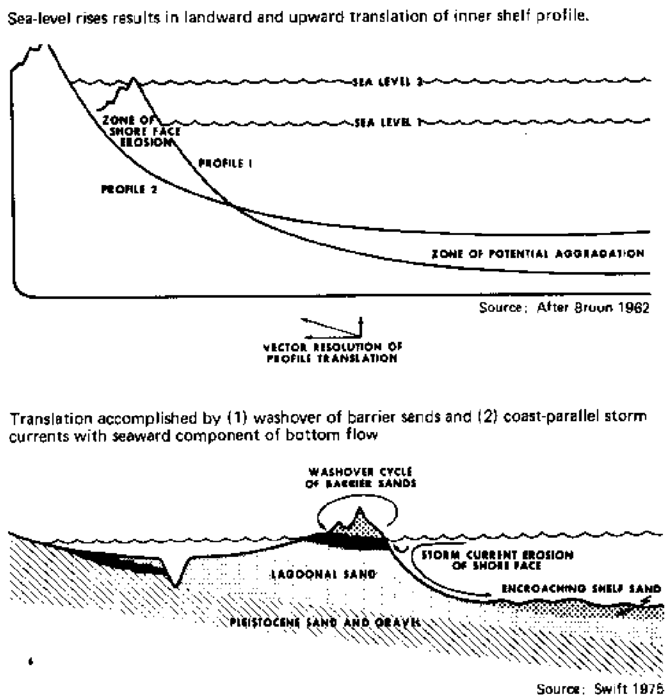
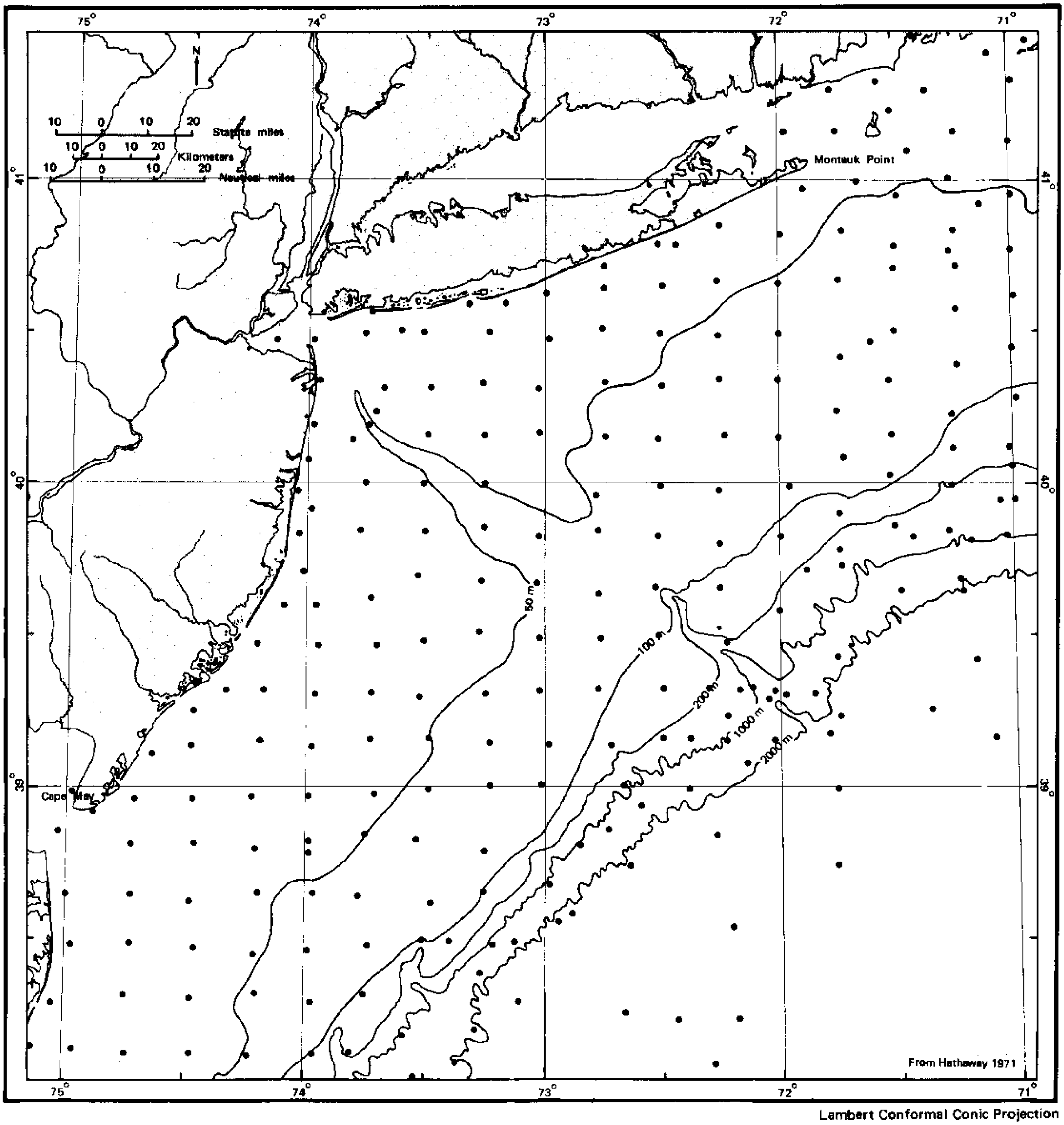


Figure 1. Erosional shoreface retreat

Map 5. WHOI/USGS sample stations



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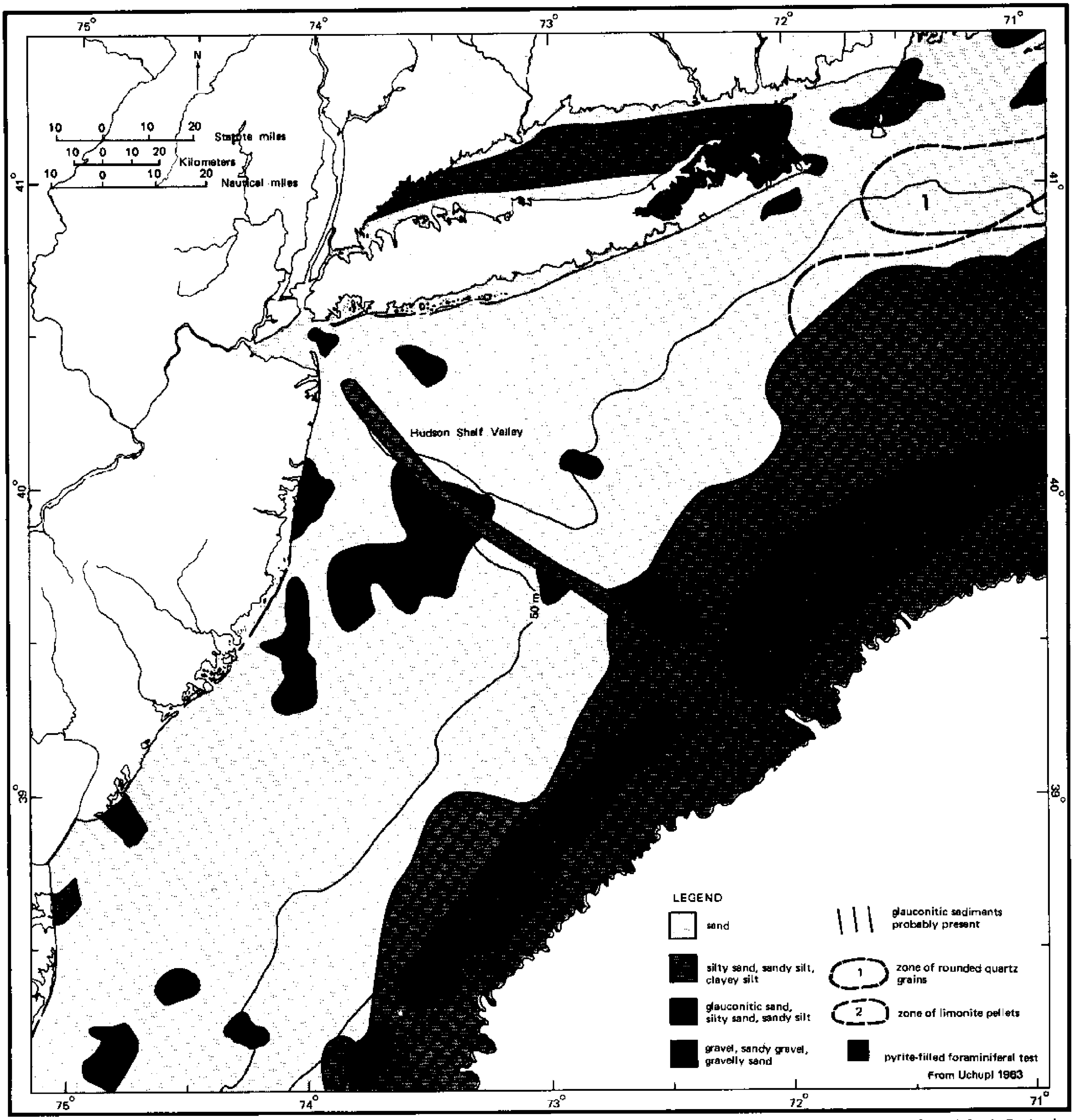
1972*b*), much of the deposited material reenters the shelf water column through *shoreface* erosion, after the shoreline has passed over the marsh (Fischer 1961). Shoreface erosion can also erode older clay deposits.

During the last great glacial sea-level lowering when the shoreline was located at the shelf edge, the nearshore turbid zone was very rich in suspended fine sediment from sediment discharge of the Atlantic coastal rivers swollen by glacial meltwaters. Much mud was deposited on the upper continental slope and redistributed to the lower slope and rise by *turbidity currents*, apparently caused by sediment instability on the slope. Large sediment masses suddenly break loose, mix with bottom water, and move rapidly down the slope and out over the rise. Deposits from these currents, called *turbidites*, are known from modern slope and rise cores showing

Map 6. Sediment type by grain size



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coarse-to-fine upward grading in the sediment bedding, and from ancient turbidite deposits now exposed on land. Large scale slumping of blocks of sediment which remain intact also occurs.

As the nearshore turbid zone migrated across the shelf, the rate of sedimentation on the continental slope and rise decreased abruptly; the post-glacial sediment sequence in most places is only a meter or so thick.

Type and Texture

Sediment types have been mapped in the Bight primarily by dominant grain size (Map 6). Generally the shelf is covered by sand-sized sediment, with scattered patches of exposed gravel. Seaward of the 60 m (197 ft) isobath, and in lagoons and estuaries where wave action is less pronounced, silt becomes the dominant sediment.

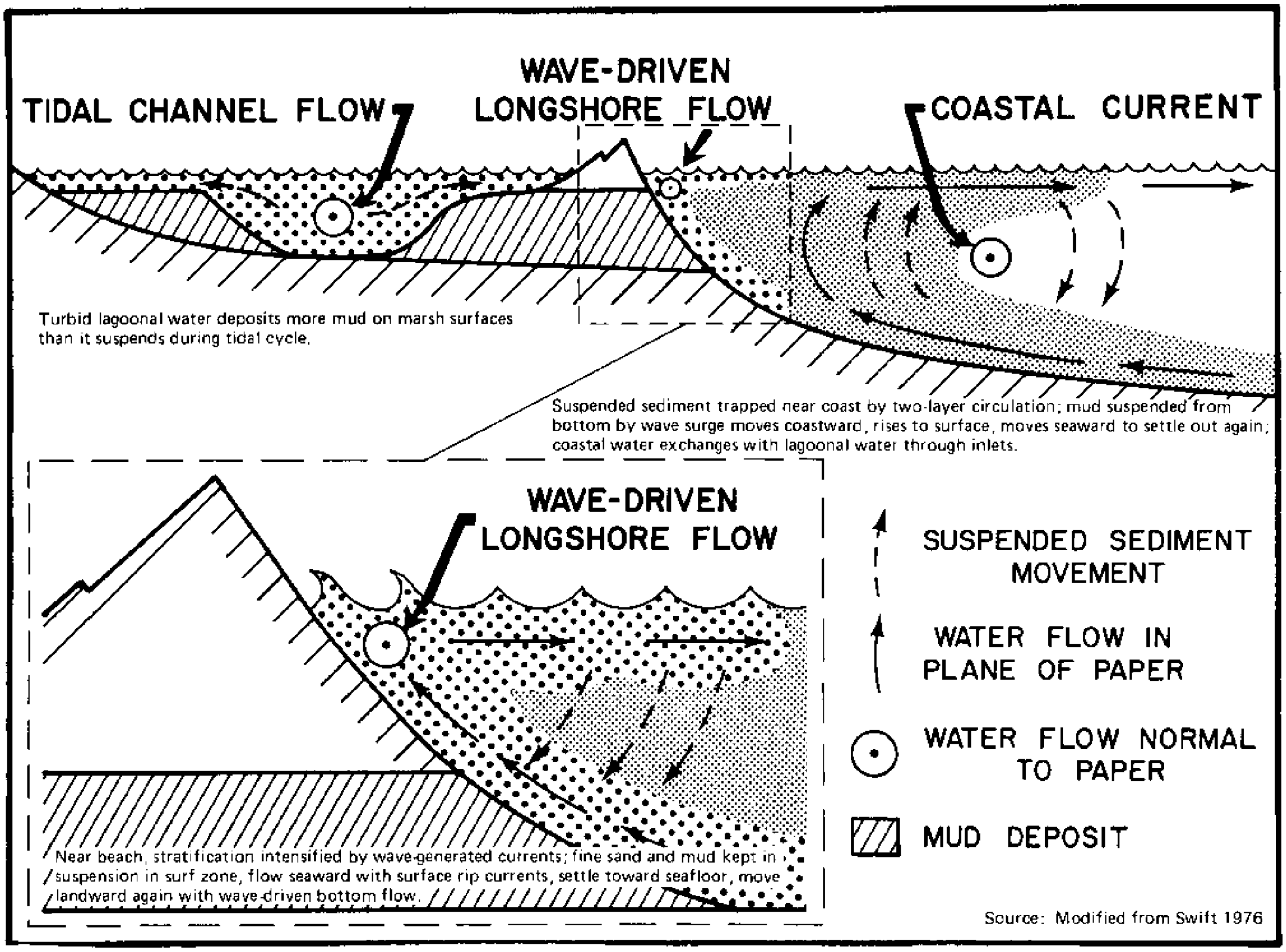


Figure 2. Coastal fine sediment transport

Sediment textural properties can be measured and calculated from the grain-size measurements—frequency distribution, *median* diameter, *mode*, *sorting*, *skewness*, and *kurtosis*.

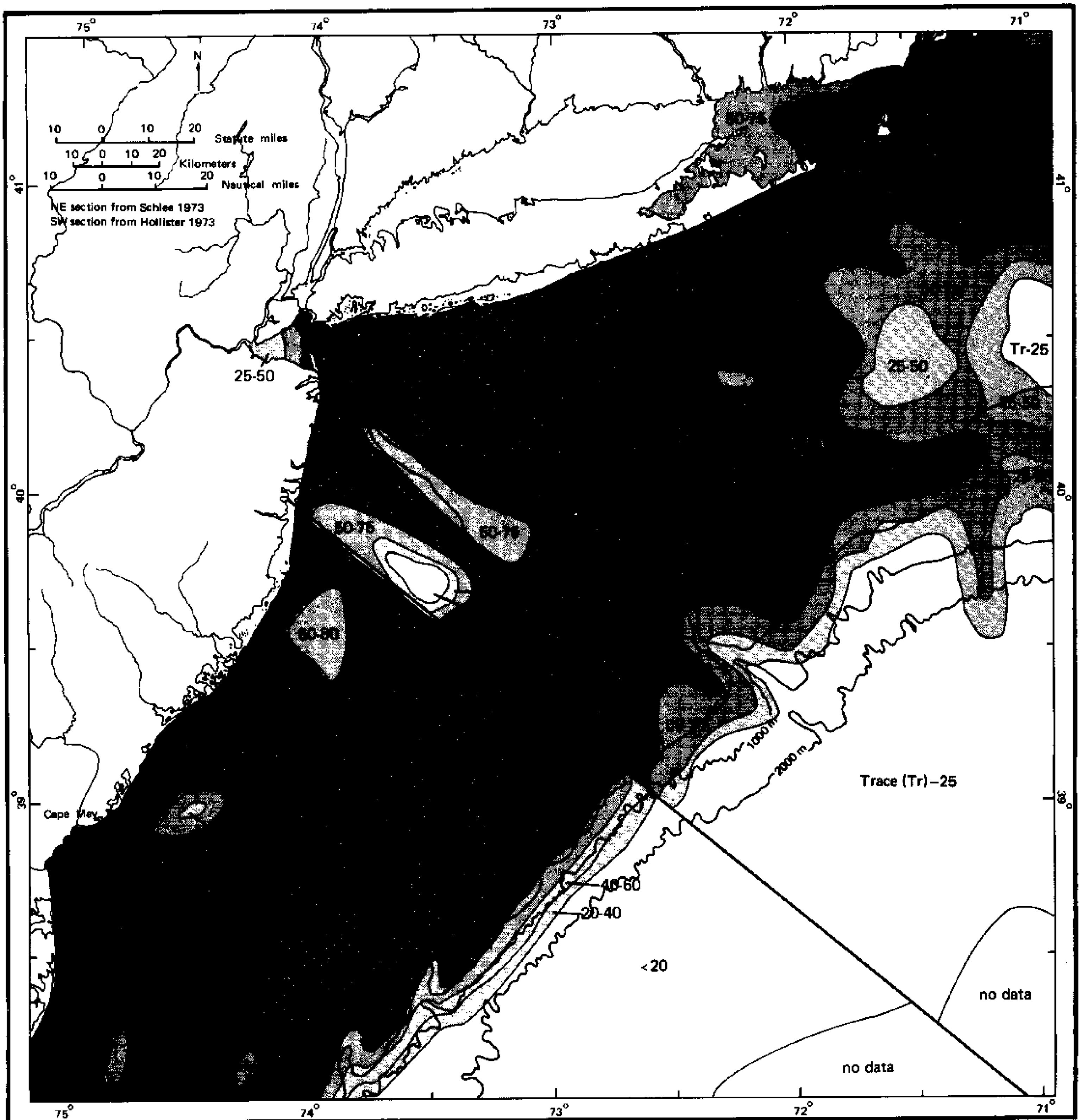
Measured Grain-Size Distribution. Sand composes most of the Bight's surficial sediment, decreasing below 50% only where gravel is exposed and to the northeast where high concentrations of mud occur (Map 7). On most of the shelf, sand content is over 75%. Beyond the shelf edge, sand content drops rapidly to below 25% as the percentage of fines (mud) increases.

Gravel distribution on the shelf surface varies from none to over 75% off north central New Jersey (Maps 8 and 42). The *basal stratum* of the surficial sand sheet tends to be composed of gravel from outwash; where this sheet thins to less than a meter, the gravel is exposed.

Silt, the coarser fraction of mud, occurs in low percentages on the shelf proper except to the northeast. The silt deposits of the outer Long Island shelf were evidently laid down during lowered sea level when the nearshore turbid zone was enriched by glacial meltwater discharge from southern New England streams (McKinney and Friedman 1970). Silt content increases in Hudson Shelf Valley, although this is not shown on Map 9 because of the wide sample spacing. Silt content increases to over 40% on the continental slope and to over 75% in parts of the Hudson Canyon axis.

Clay, the finest sediment size, is almost negligible on the shelf because fine silt- and clay-size material is constantly winnowed out of shelf surficial sediment by storm-generated waves and currents. Exceptions are in Hudson Shelf Valley, where small amounts of clay have been found, and in shelf muds to the northeast (Map 10). Clay content increases

Map 7. Percent sand

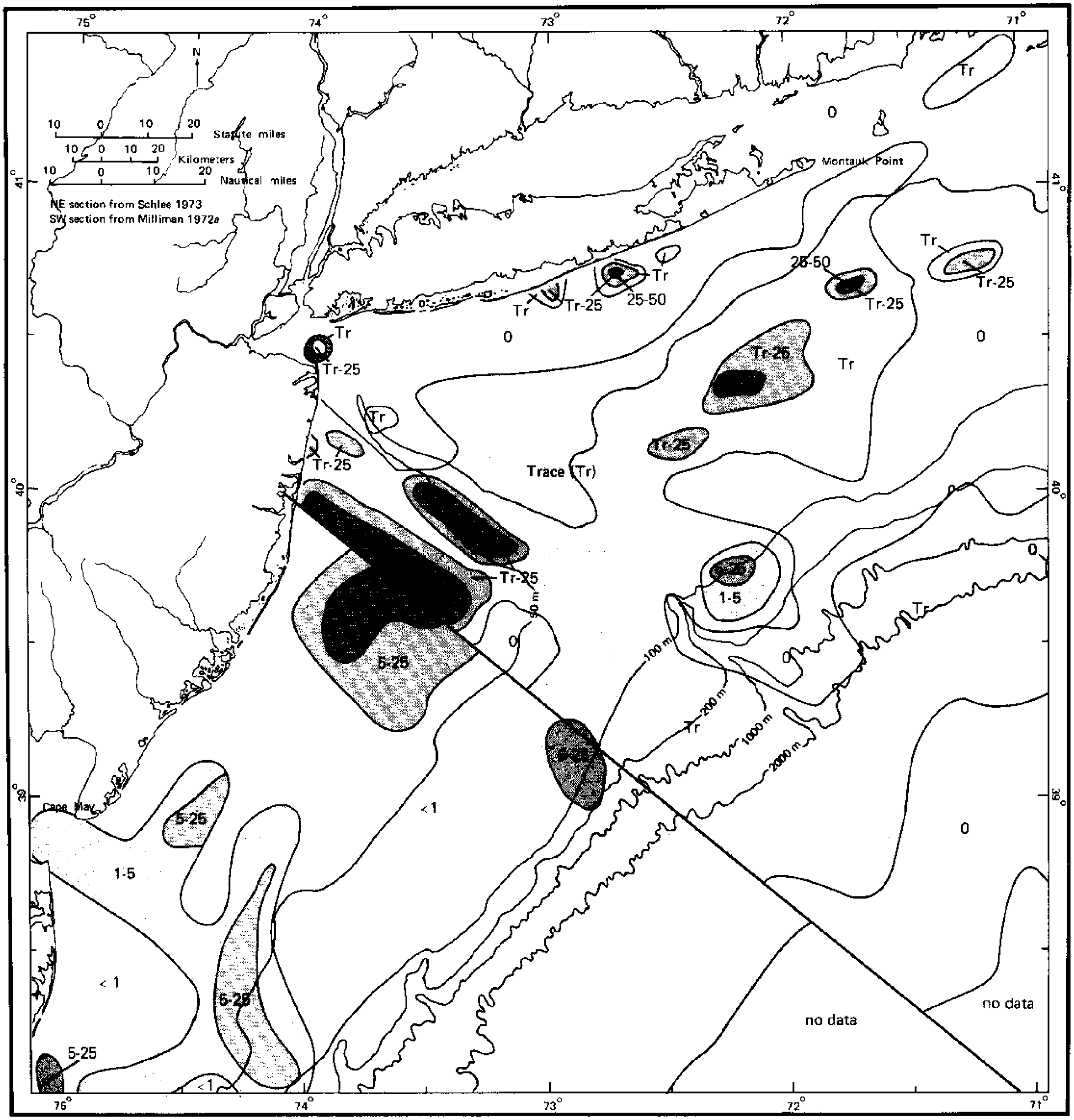


Lambert Conformal Conic Projection

rapidly seaward of the shelf edge to about 40%, and to more than 50% on the continental rise. Clays in the water column and in bottom deposits are of considerable interest in present environmental studies because of their capacity to absorb chemicals, metals, and microorganisms which are considered contaminants.

Calculated Parameters. Grain-size frequency distributions of shelf sediments tend to be normally distributed–that is, when weight percent is plotted against size classes, the resulting histogram approximates a normal (Gaussian) curve. A *normal distribution* is defined by its mean value and by its *standard deviation*. The extent to which it deviates

Map 8. Percent gravel



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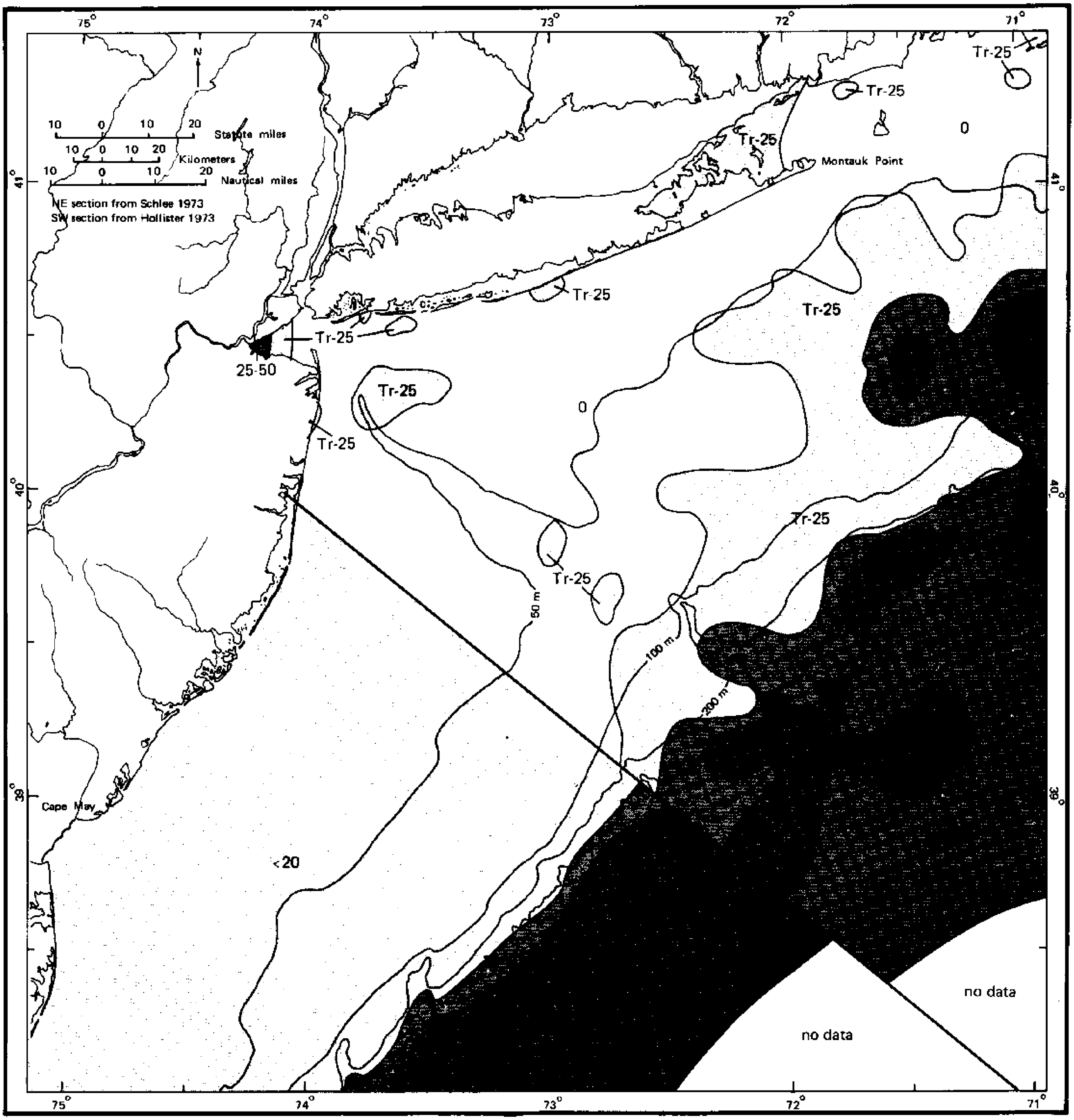
from normal is defined by skewness and kurtosis. These four parameters of grain-size frequency distribution may be considered measures of depositional history of a sample.

Median diameter, expressed in *phi (ϕ) units,* is defined as the value for the 50th percentile on the cumulative curve, which is a graphic approximation of the *mean diameter,* a more rigorous statistical parameter. This measure of the central tendency of the distribution reflects the vigor of the *hydraulic climate* at the deposition site, as expressed in the available range of grain sizes. In general, the coarser the median diameter, the stronger the associated currents. However, grain size is also a function of the availability of various size fractions. Median diameter varies irregularly over the shelf surface. The shelf

Map 9. Percent silt

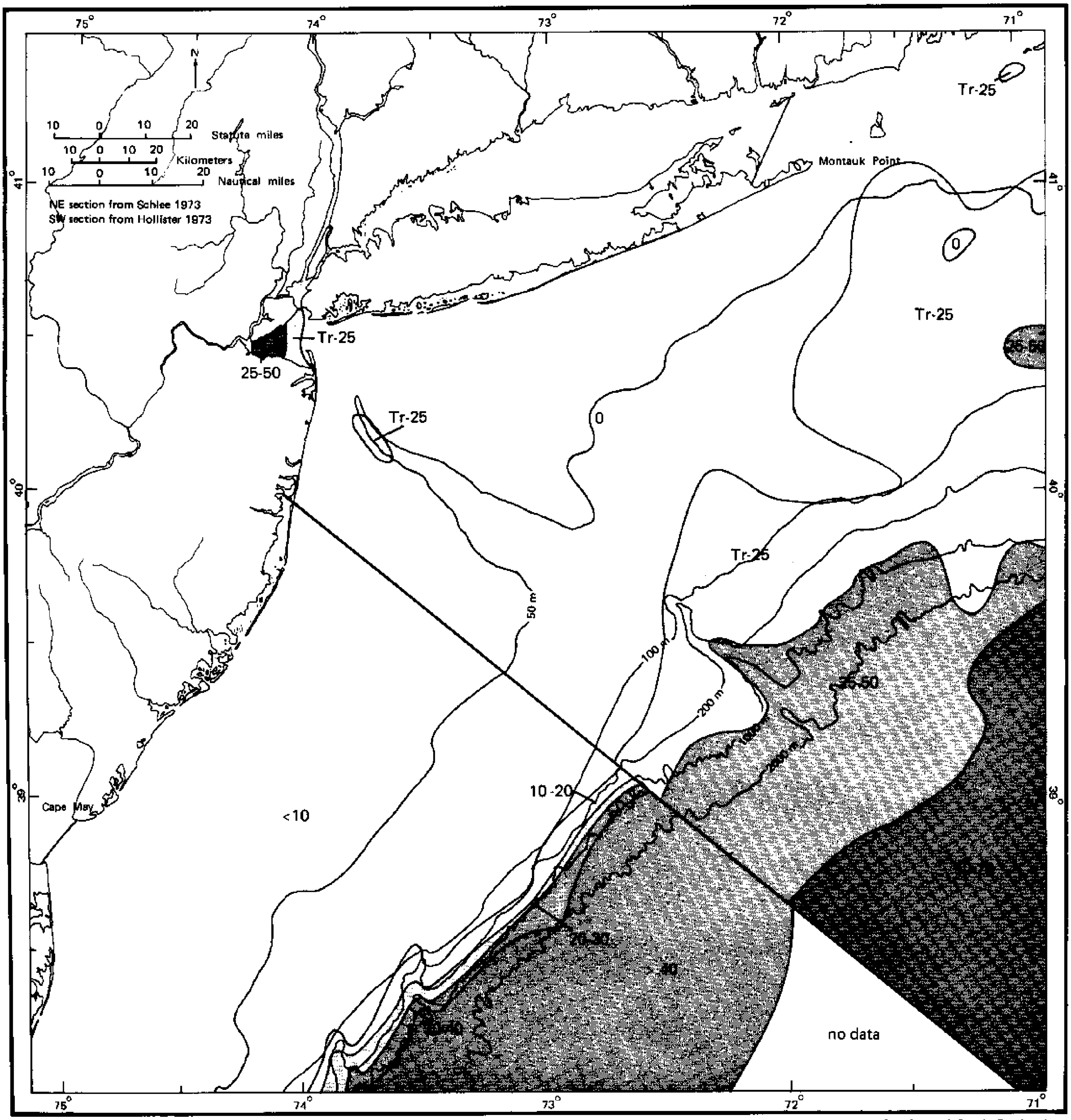


valleys tend to contain finer sand (higher phi value) than the shelf surface. On the continental slope, sediment becomes finer downslope.

In the Bight, sand sizes (less than 4 phi, see Table 2) dominate the shelf, whereas silt and clay occur in estuaries and lagoons and on the slope and rise (Map 11).

Mode (the most frequently occurring particle diameter) again reflects irregular distribution of grain size on the shelf and the sand-silt-clay gradation of sediment size from the shelf to the slope and rise (Map 12). Where two separate size ranges are nearly equally represented, two peaks will occur on the frequency curve. Such a sediment is referred to as being *bimodal*. Most of the shelf contains *unimodal* sand; where gravel content is high, however, the

Map 10. Percent clay



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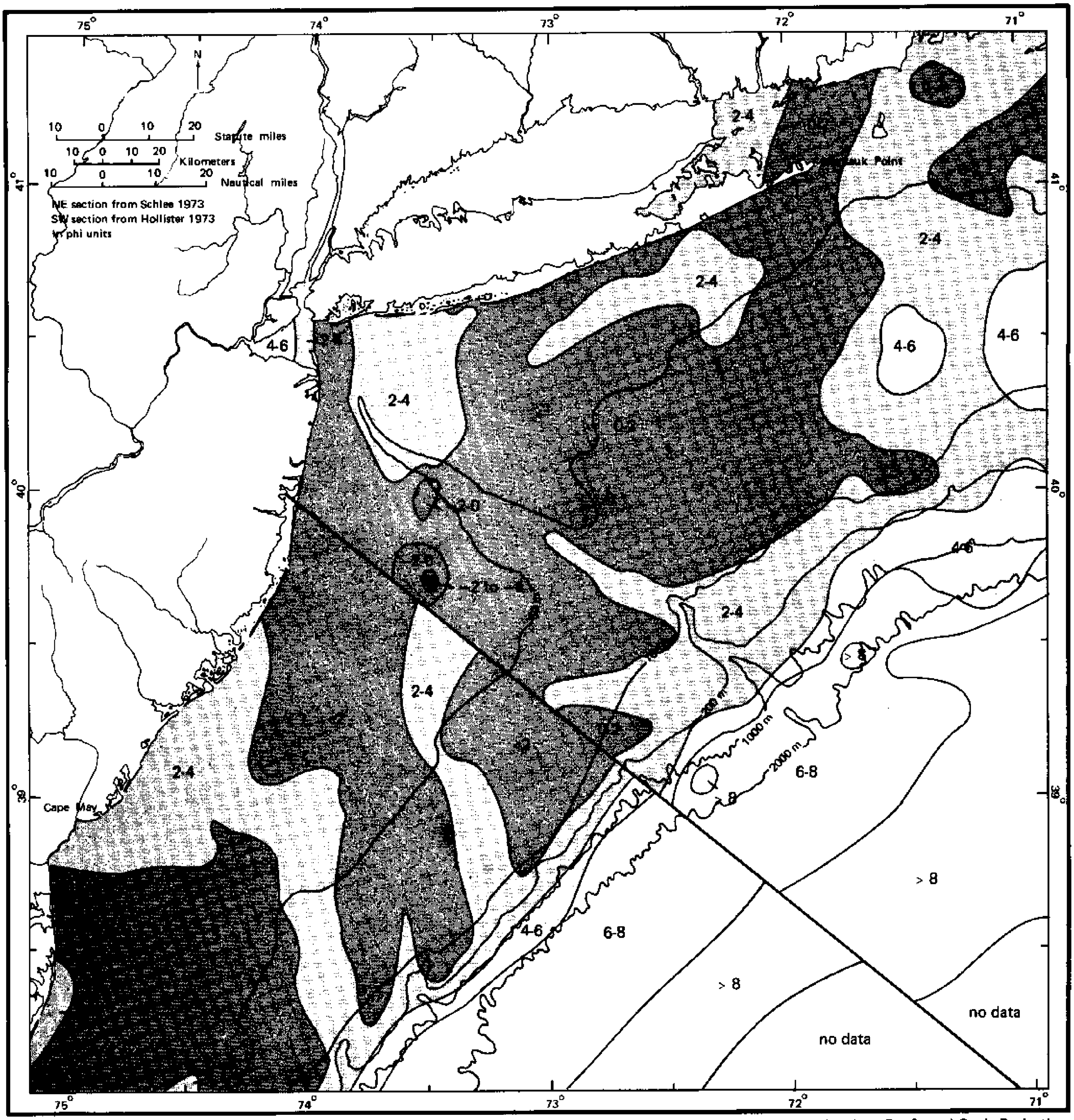
sediment is bimodal sand and gravel. Similarly, on the upper slope the sediment is predominantly bimodal sand and silt, with areas of trimodal sand-silt-clay. Mid-slope sediment is either unimodal silt or, as on the rise, bimodal silt and clay (Schlee 1973).

Sorting is a measure of the spread of the distribution about the mean value. It is expressed as standard deviation or the graphic approximation of standard deviation. It reflects to some extent the rigor, duration, and consistency of currents responsible for the deposition of the sediment. Beach sands and wind-blown sands have grains nearly all equal in size (the best sorted) and reflect the highest energy levels. Sorting is primarily a secondary measure of

Map 11. Median grain size



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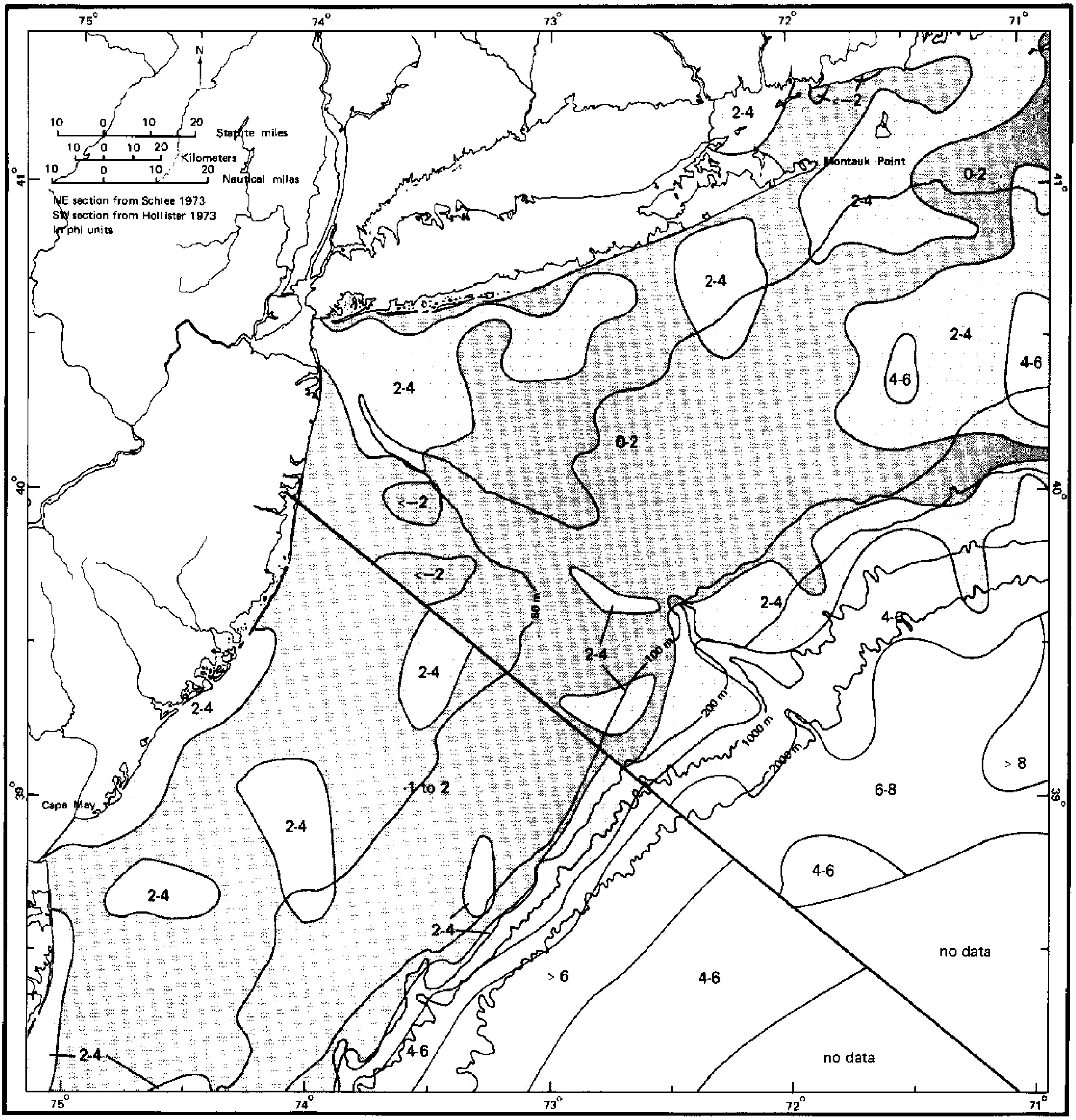
grain size: other things being equal, it improves (standard deviation decreases) with increasing median diameter. In Map 13, shelf sands appear better sorted than the fine sediments of the slope and rise. Muddy deposits in Hudson Shelf Valley are poorly sorted; here shelf sands are mixed with finer-grained sediment.

Skewness is a measure of the extent to which hydraulic activity has altered a regional grain-size pattern by removing material from the coarse or fine end of the grain-size curve. Coarse sand and gravel tend to be a *lag deposit;* these sizes have remained in place while currents washed away the fine sizes. Such deposits tend to have longer coarse tails than fine tails

Map 12. Grain size of principal mode



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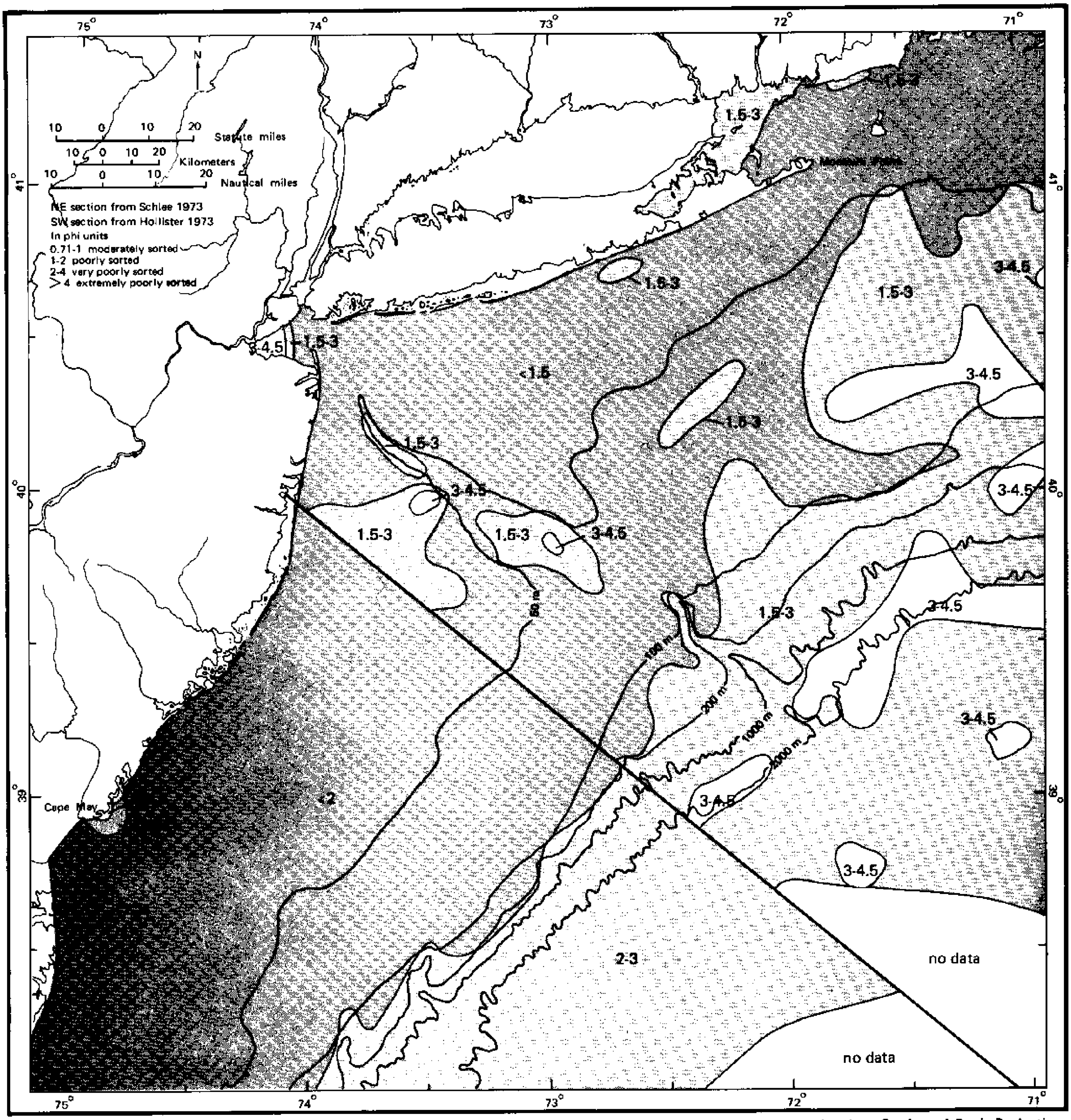
on the frequency curves (they are negatively skewed). Farther from the zone of hydraulic activity, fine sands or muds may come to rest. They tend to show longer fine tails on the frequency curve (they are positively skewed).

In the Bight, shelf sands are generally coarse-skewed, whereas the muddy sediments of the slope and rise are fine-skewed. This reflects the removal of fines from the shelf and their deposition over the shelf edge or in protected areas on the shelf (Map 14).

Kurtosis measures the deviation of peakedness from normal probability on the frequency curve. It

Map 13. Sorting



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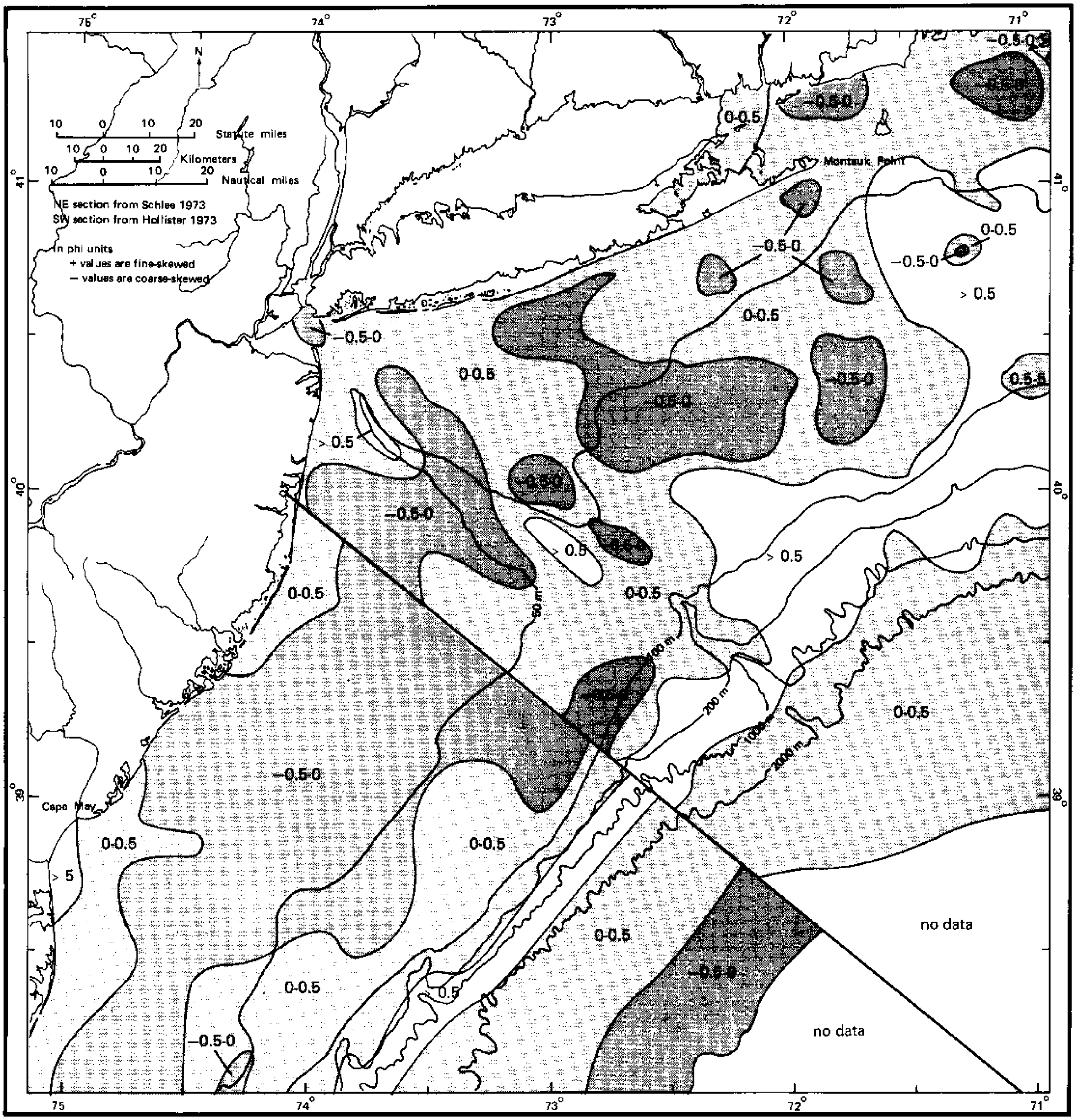
indicates the ratio between sorting in the tails, or low-frequency values of the curve, and sorting in the central or high-frequency portion. High positive values of kurtosis indicate a very peaked distribution (well-sorted central part, poorly sorted flanks), and low or negative values indicate a flattened frequency curve (better sorted flanks and poorly sorted central part). It is used as a possible indicator of mixing of sediment populations—that is, most high values are in areas of unimodal size distribution.

In the Bight, central shelf kurtosis values are near 0 (Map 15). High values are associated with high silt content to the northeast, in parts of Hudson Shelf Valley, and along the outer shelf edge. Negative

Map 14. Skewness



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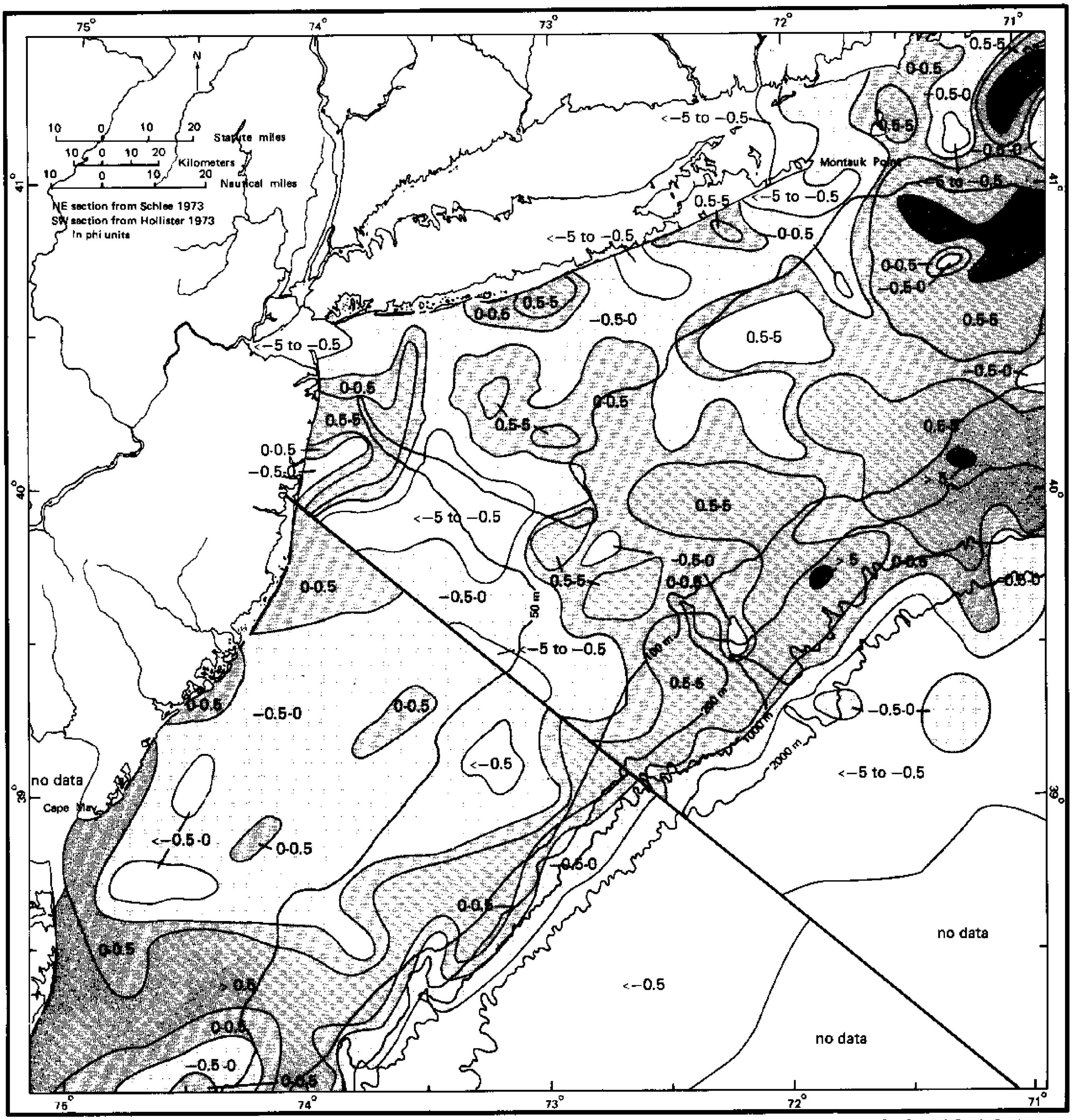
values are associated with the area of high gravel content off northern New Jersey and of high clay content on the continental rise; these areas are probably bimodal.

Some geologists believe kurtosis values are too insensitive to yield meaningful information concerning sediment origin or depositional environment; therefore they should be used with caution.

Composition

The mineral composition of shelf sediments varies fundamentally with the sediment source. On some continental shelves, the sediment is entirely of biochemical origin, made up of calcium carbonate remains of skeletons of various organisms. On the Bight shelf, the sediment is mainly a weathering

Map 15. Kurtosis



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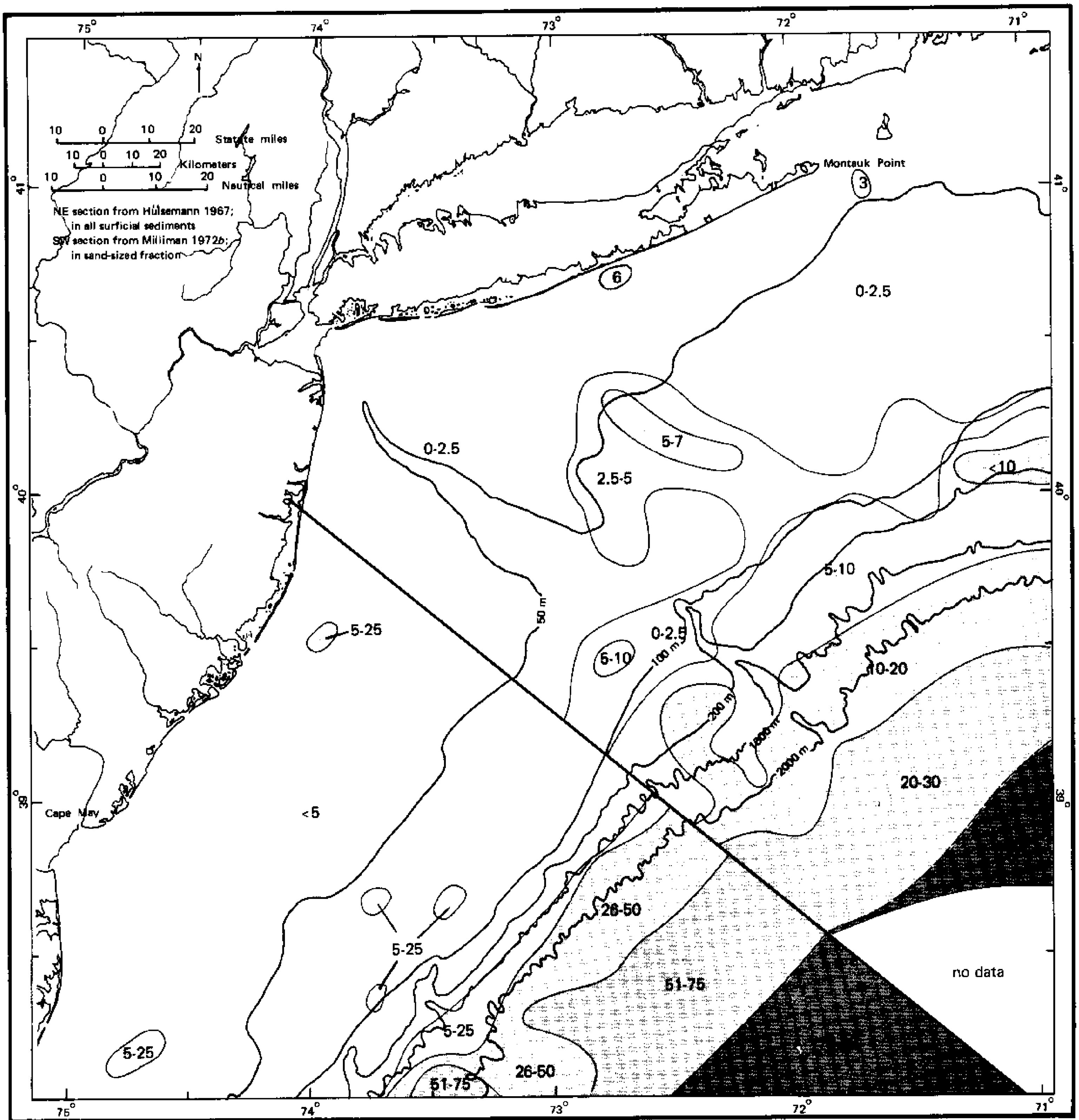
product (soil) transported from adjacent land and sorted by hydraulic processes into various size fractions. Sediment composition varies systematically with its median diameter: fine sediment (mud) consists mainly of clay mineral particles; coarse sediment (sand and gravel) consists mainly of quartz and feldspar grains and rock fragments. Other mineral particles are present in smaller amounts.

Calcium carbonate. Calcium carbonate content has been measured in the Bight in the sand-sized fraction south of Hudson Shelf Valley and in all size ranges elsewhere (Map 16). Carbonate content is generally less than 5%, with small areas of up to 25%. On the slope and rise, carbonate content rises to over 90% of the sand-sized fraction and 30% of total sediment due to *microfaunal* remains.

Map 16. Percent calcium carbonate



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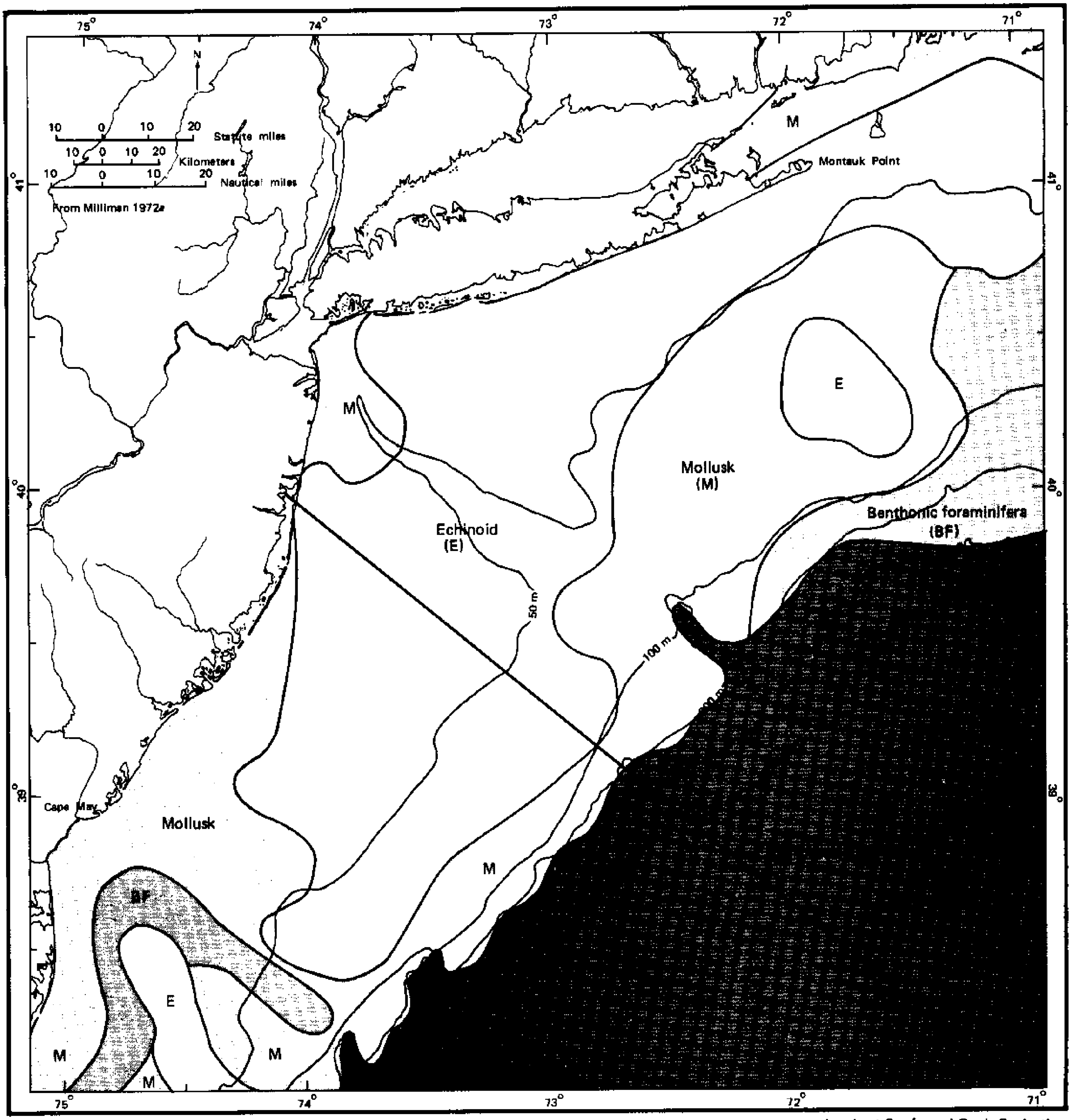
The size distribution of carbonate grains closely follows that of the total sample. Where there is some variance, the carbonate grains are larger than the noncarbonate ones and are concentrated in the coarse sand and gravel sizes (Hülsemann 1967).

The major carbonate constituents on the shelf are mollusk and echinoid shell fragments (Maps 17-19); other shell fragments (Map 20) and *foraminifera* (Map 21) are minor constituents. Seaward of the shelf edge the *macrofauna* are not as abundant; foraminiferal remains dominate.

The mollusk assemblage consists primarily of clam shells, mostly surf clams (*Spisula solidissima*) on the inner shelf and ocean quahog (*Arctica islandica*)

Map 17. Carbonate assemblages



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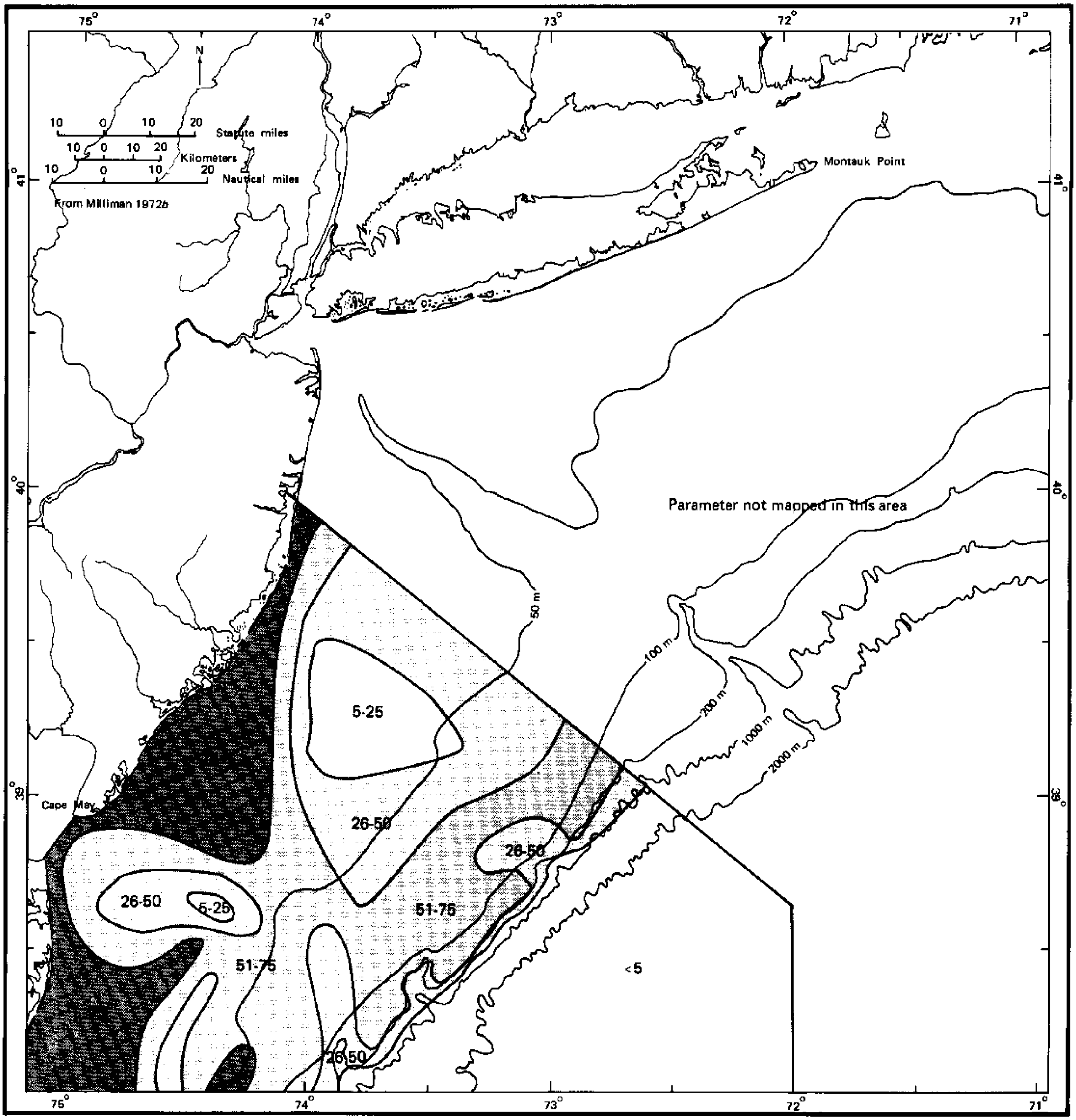
on the mid-shelf bottom, seaward of the 35 m (115 ft) isobath. Although rarely seen, oyster shells are an important mollusk indicator to the geologist as they are eroded from the lagoonal clay underlying the Holocene sand sheet. Recovery or sighting of an oyster shell on the bottom is positive identification of nearby exposure of the clay bed. Because of their relatively higher ratio of weight-to-surface area, compared to clam shells, oyster shells probably are not transported far from their source.

In the mollusk assemblage areas, calcium carbonate comprises 3% of the average sediment sample; mollusk fragments comprise 60% to 100% of this carbonate fraction (Map 18).

Map 18. Percent mollusks in carbonate sand fraction



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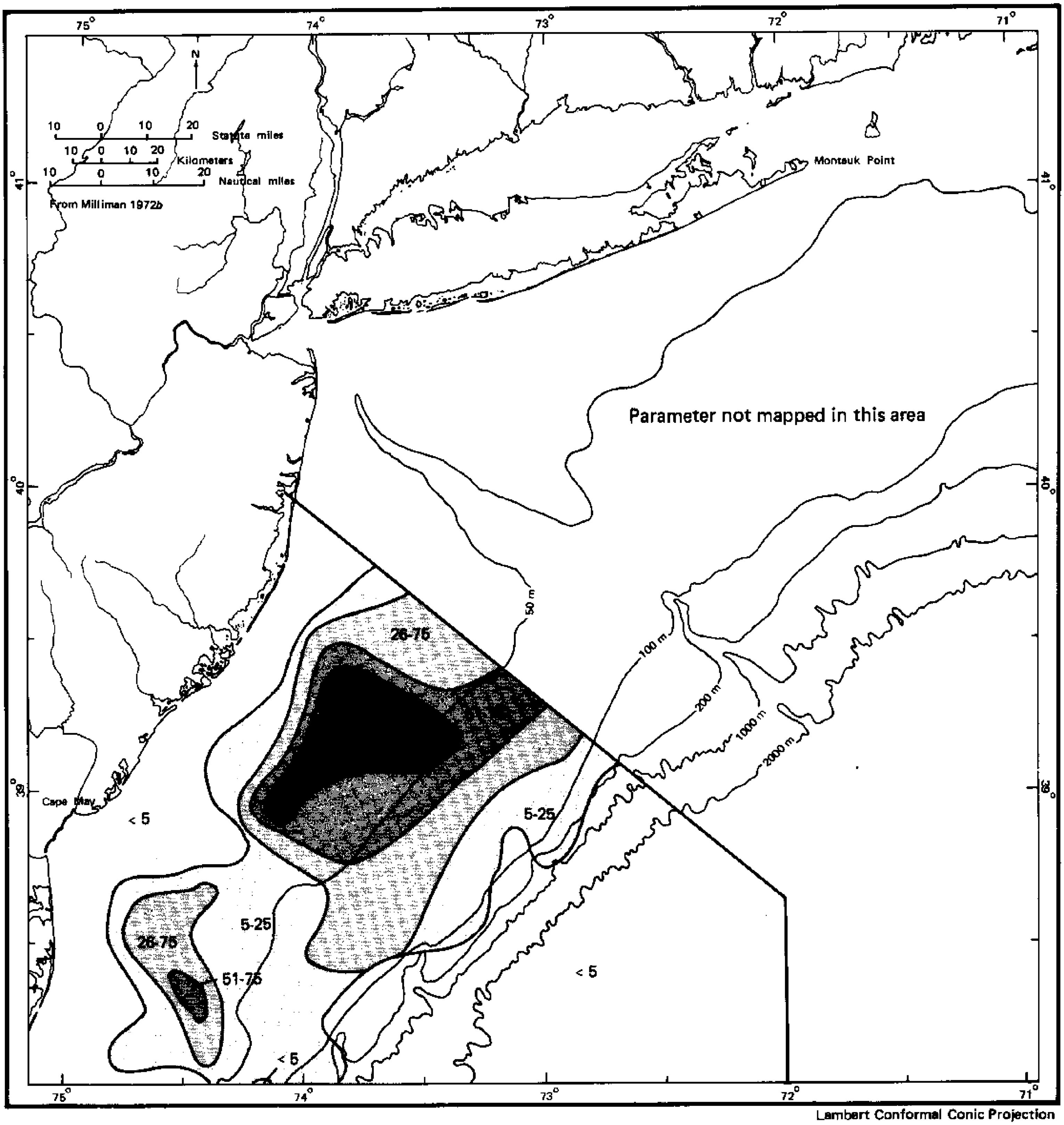
The echinoid assemblage consists mostly of sand dollar remains. These animals are locally abundant, occasionally covering 100% of small bottom areas where fine to medium sand is present, mostly on sand ridge crests. In the echinoid assemblage areas, calcium carbonate comprises 2% of the average sample; echinoid fragments comprise 20% to 100% and mollusk fragments 0% to 80% of the carbonate fraction (Map 19).

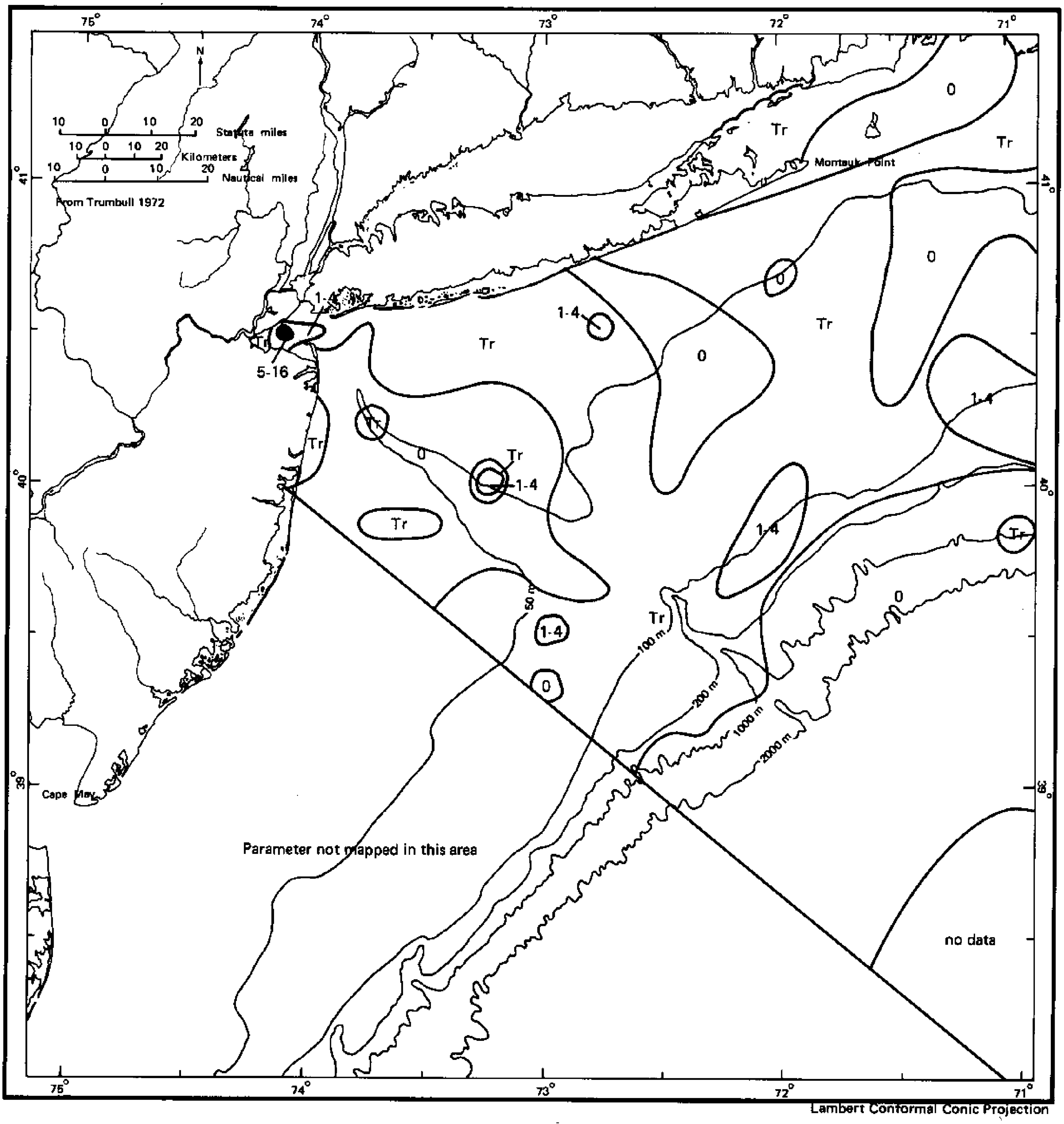
Benthonic foraminifera occur in relatively large concentrations off Delaware Bay and in muddy bottoms south of Martha's Vineyard (Map 21). In

Map 19. Percent echinoids in carbonate sand fraction



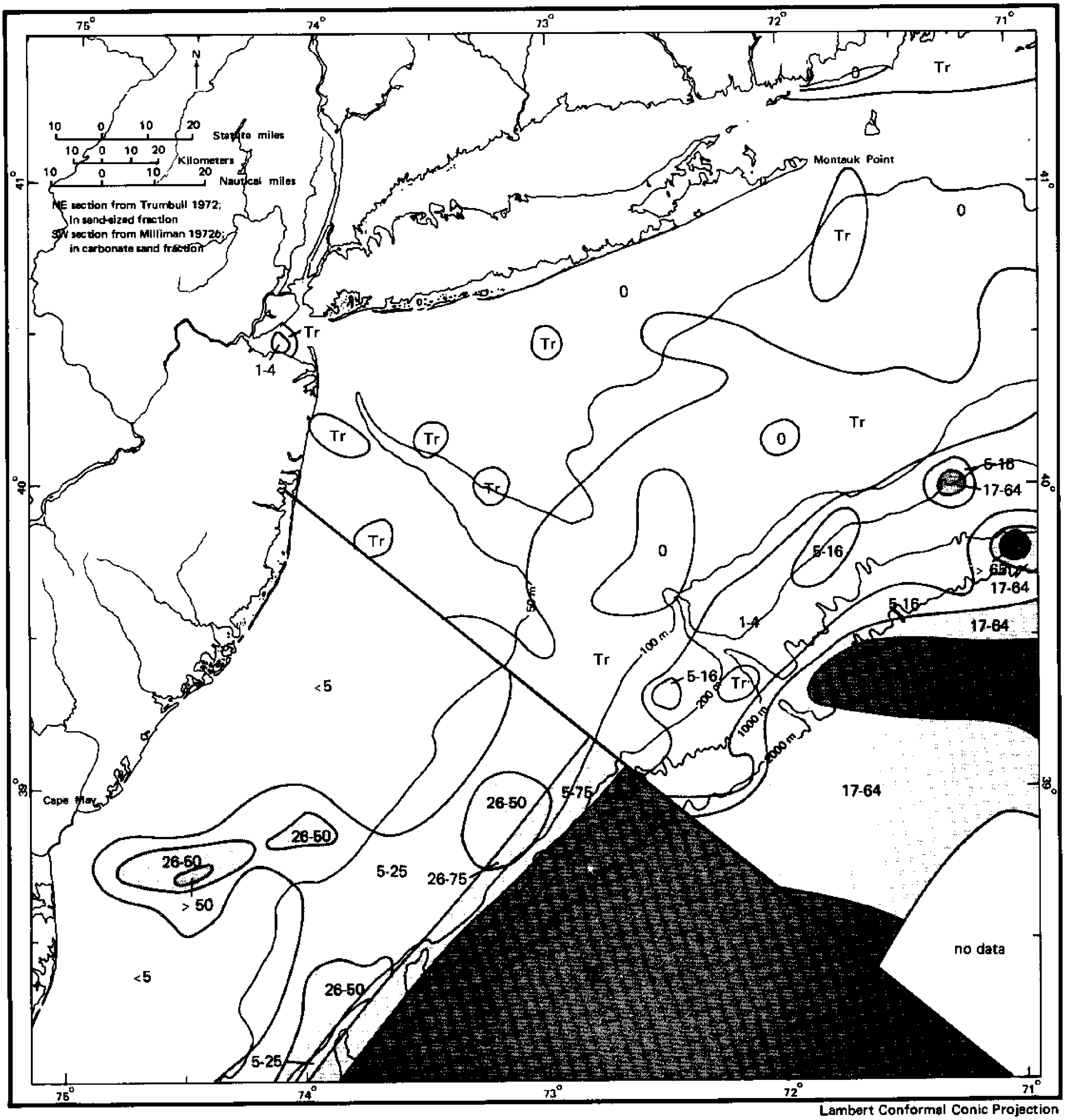
water depths from 0 to 15 m (0 to 49 ft), *Elphidium* is the dominant genus; between 15 and 90 m (49 and 295 ft), *Quinqueloculina semilulum, Eggerella advena,* and *Triloculina* sp. are diagnostic of the depth range (Parker 1948). In water deeper than 90 m (295 ft), both individual numbers and number of species increase greatly, as does the change from benthonic to *planktonic* types. In the benthonic assemblage areas, calcium carbonate comprises 2% of the average sample; benthonic *tests* comprise 20% to 70% and mollusk fragments 15% to 70% of the carbonate fraction (Milliman 1972*a*).

Map 20. Percent shell fragments in sand-sized fraction



Light Minerals. Quartz, feldspar, and glauconite are the dominant, recognizable minerals with densities less than 2.87 g/cm^3; quartz and feldspar grains dominate the sand-sized fraction. Derived either from direct weathering of igneous and metamorphic rocks or as *second-cycle erosional material* from sedimentary rocks, quartz and feldspar are primary indicators of a terrigenous source. Most of these grains have been reworked from sediment on the surface of the exposed shelf during lowered sea level, but some grains were eroded from early and pre-Holocene strata underlying the surficial sand sheet.

Map 21. Percent foraminifera



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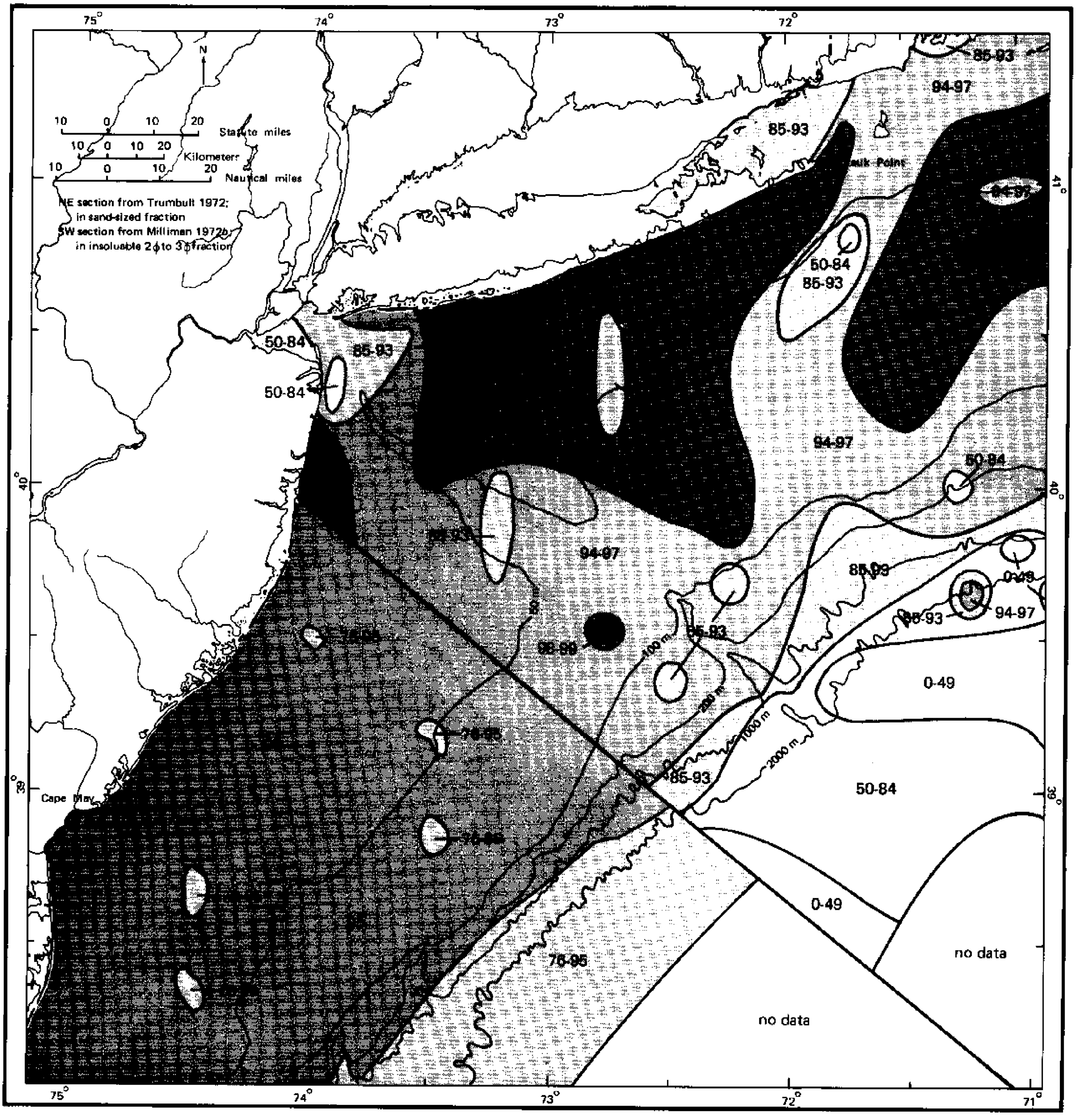
In the Bight, the combined quartz and feldspar total is usually more than 90% of the sand-sized fraction on the shelf (Map 22), decreasing down the slope to less than 50% on the rise. The ratio of feldspar to feldspar plus quartz (Map 23) characterizes sand types known as *arkose* and *subarkose* (Pettijohn 1957), which have high feldspar ratios. Since feldspar weathers more easily than quartz, high feldspar ratios reflect the rapid river transport of relatively unweathered feldspar grains, common during glacial times (Milliman, Pilkey, and Ross 1972). The bands of high feldspar ratios coincide

Map 22. Percent quartz and feldspar



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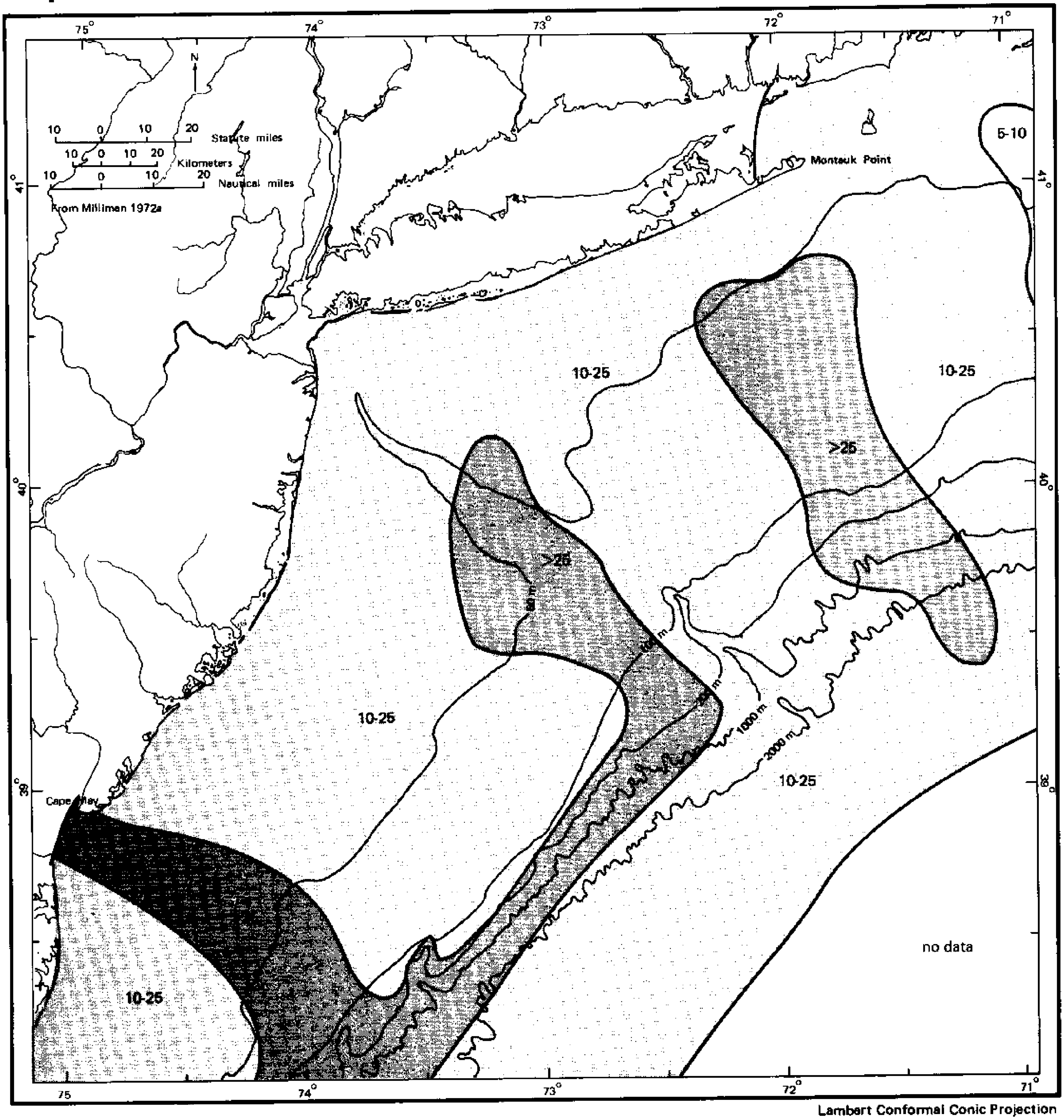
with shelf valleys, indicating that these sediments have not moved very much since deposition. Subarkosic sands (less than 25% feldspar) are probably remnants of the short cycle of subaerial chemical weathering in between glacial stages when feldspar was removed relative to quartz.

Glauconite grains are primarily reworked and rounded foraminiferal *molds* (Milliman 1972*a*). This greenish mica-like mineral was formed by the interaction of other clay minerals in the reducing microenvironment found in foraminiferal shells resting on the seafloor. Most of the shelf contains less than 2%

Map 23. Ratio of feldspar to feldspar plus quartz



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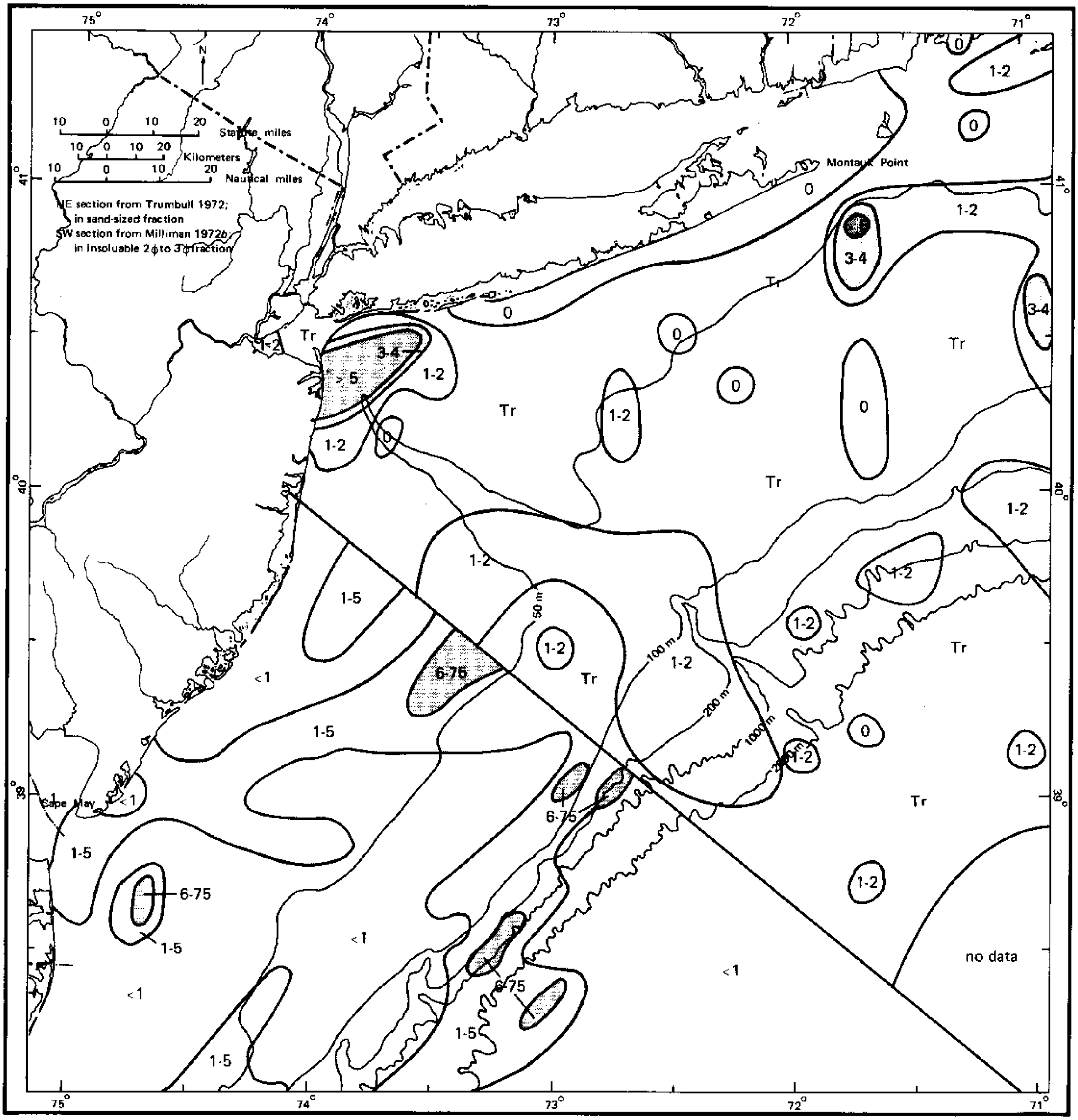
glauconite, but some small patches contain considerably more (Map 24). McMaster (1954) suggested that much of the glauconite was derived from glauconite-rich Cretaceous or lower Tertiary strata exposed in either subaerial or submarine outcrops.

Mica also has been mapped in shelf sediments, occurring only in small amounts (Map 25). Mica grains are hydraulically equivalent to fine spherical grains and are thus associated with the fine-size fraction on the slope and in and near estuaries.

Heavy Minerals. Minerals with densities greater than

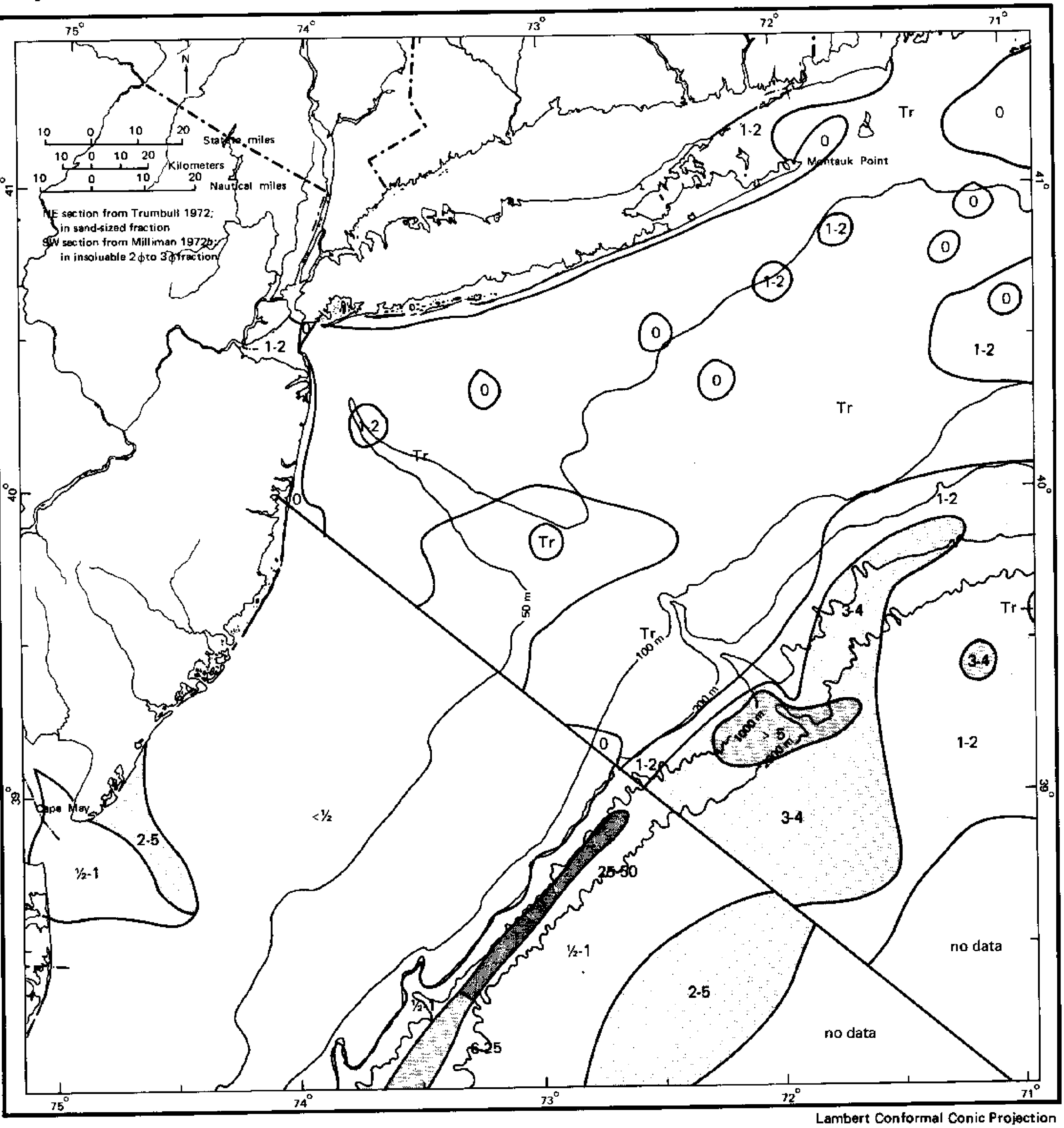
Map 24. Percent glauconite



2.87 g/cm^3 are mapped as heavy minerals (Map 26). They are generally dark and sometimes opaque. High heavy mineral content might indicate possible relict *strand lines* or placer deposits, but the wide sample spacing precludes such interpretation. In the area off southern New Jersey showing over 4% heavy mineral content, concentrations reach as high as 15% (Hathaway 1971).

Nonopaque minerals in the heavy mineral fraction are amphiboles (Map 27), epidote (Map 28), garnet (Map 29), and staurolite (Map 30). Ross (1970) divided the shelf off Long Island and northern New Jersey into four provinces: garnet-staurolite, Long Island garnet, mixed amphibole-garnet, and mixed amphibole-garnet-epidote. These occur in bands from nearshore to slope in the above order.

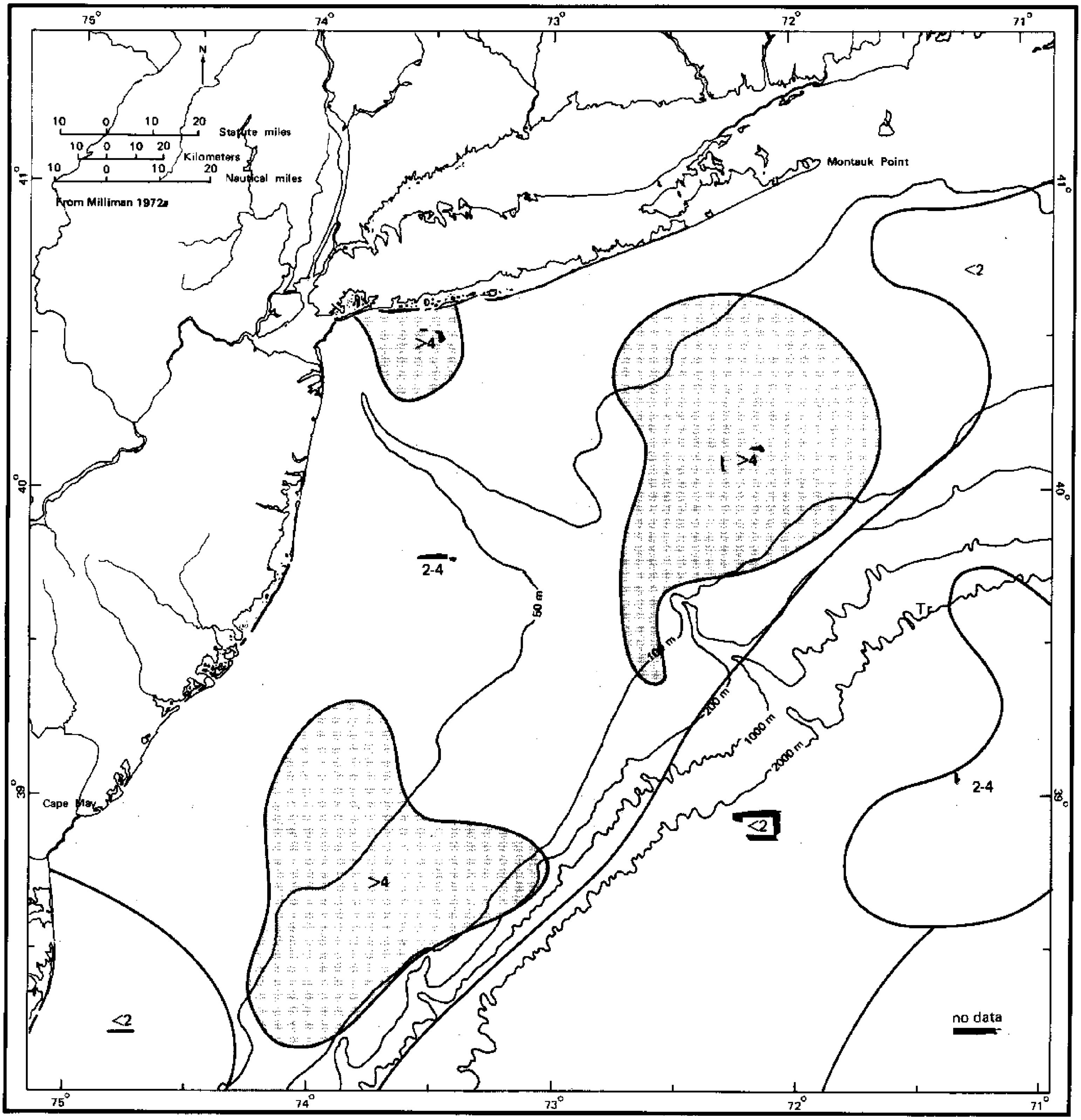
Map 25. Percent mica



The inner and mid-shelf garnet-staurolite and garnet provinces are thought to be derived from coastal plain strata on land and to underlie the thin veneer of shelf Holocene sediment. The increase in garnet in mid-shelf areas is thought to be associated with increased grain size (Map 11): the garnet assemblage is coarser grained than the garnet-staurolite assemblage. The mixed amphibole-garnet province is similar in heavy mineral composition to a complex Gulf of Maine-Georges Bank assemblage behind Georges Bank but with less augite than is associated with the Gulf of Maine assemblage. Ross proposed that this assemblage was derived from fine-grained sediments reworked from the Georges Bank province.

Epidote concentrations (Map 28) appear high on the slope and rise and show a tongue of high concentration near Hudson Canyon extending shore-

Map 26. Percent heavy minerals in sand-sized fraction



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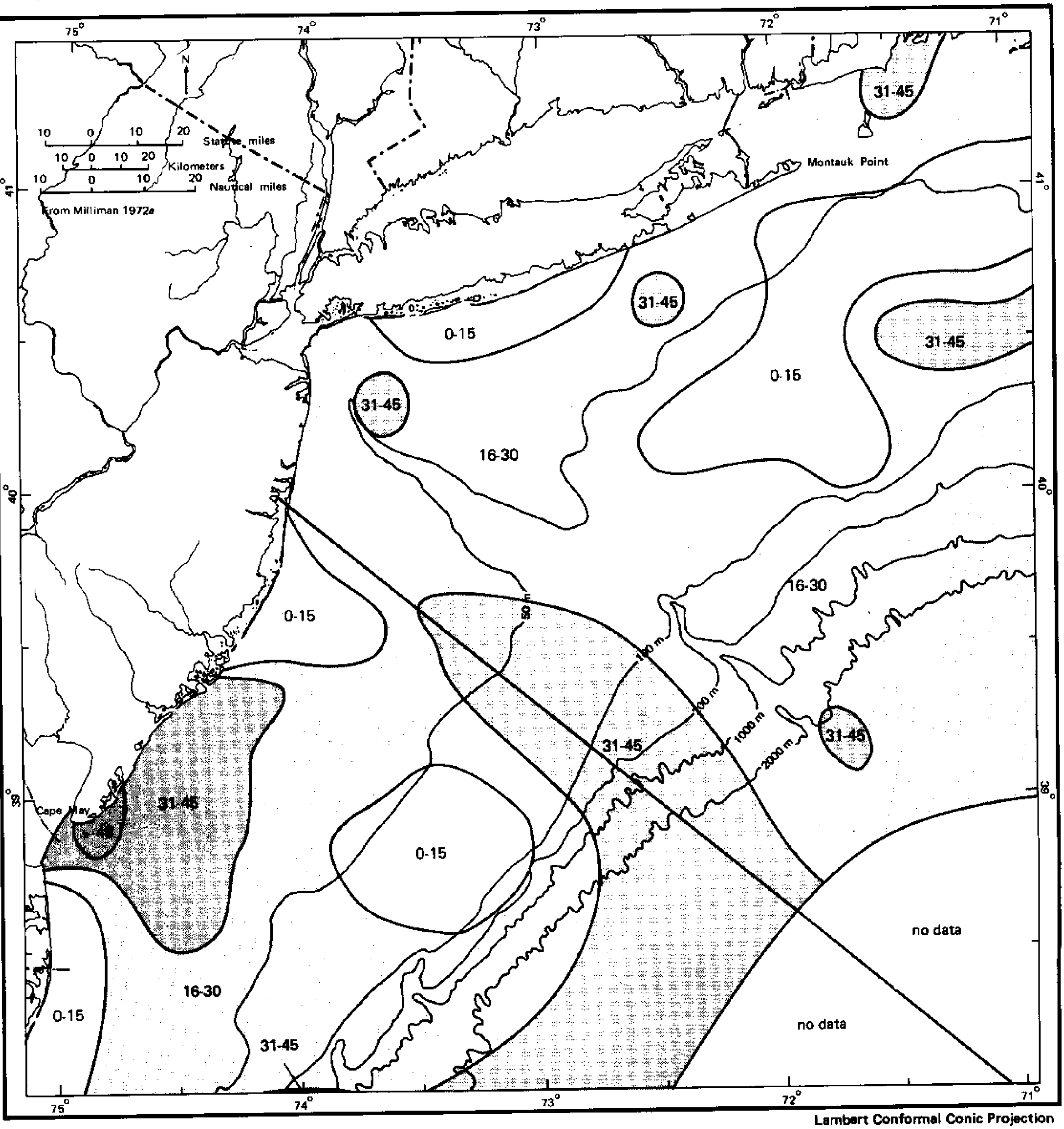
ward north of Hudson Shelf Valley, possibly indicating its shoreward movement (Ross 1970). The high garnet-to-staurolite ratio off the southern New Jersey, Delaware, Virginia, and northern North Carolina shelf decreases sharply toward eastern Long Island, suggesting northeastward transport either at a lowered sea level stand or at present (Ross 1970). This conflicts somewhat with concepts of present-day southwestward sediment transport in the Bight (Swift et al 1972). McMaster and Garrison (1966) indicated northeast transport only at the shelf edge during a lower sea level stand.

Map 27. Percent amphiboles in heavy mineral fraction



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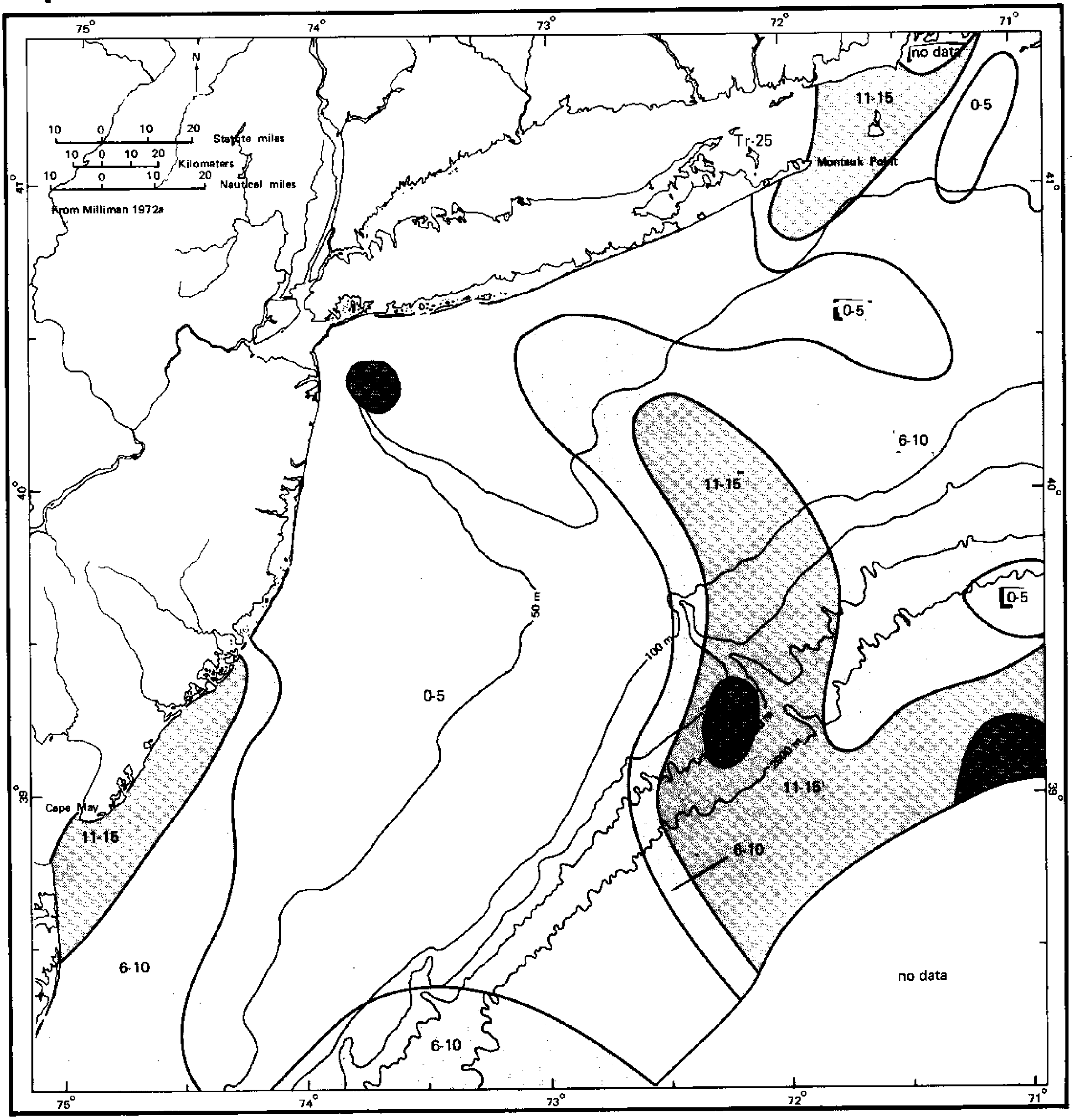
Clay Minerals. The composition and distribution of clay minerals (less than 2 microns grain size; illite, chlorite, kaolinite and vermiculite) were reported by Hathaway (1971, 1972). Clay is nearly absent on the continental shelf (Map 10), but in estuaries and on the slope illite (Map 31) and chlorite (Map 32) are present in large amounts. Kaolinite (Map 33) occurs in high concentrations only on the lower slope and rise. However, rivers flowing into Chesapeake and Delaware bays are low in illite and chlorite and high in kaolinite. Hathaway (1972) suggested that the shelf and estuarine clays (illite and chlorite) in their

Map 28. Percent epidote in heavy mineral fraction



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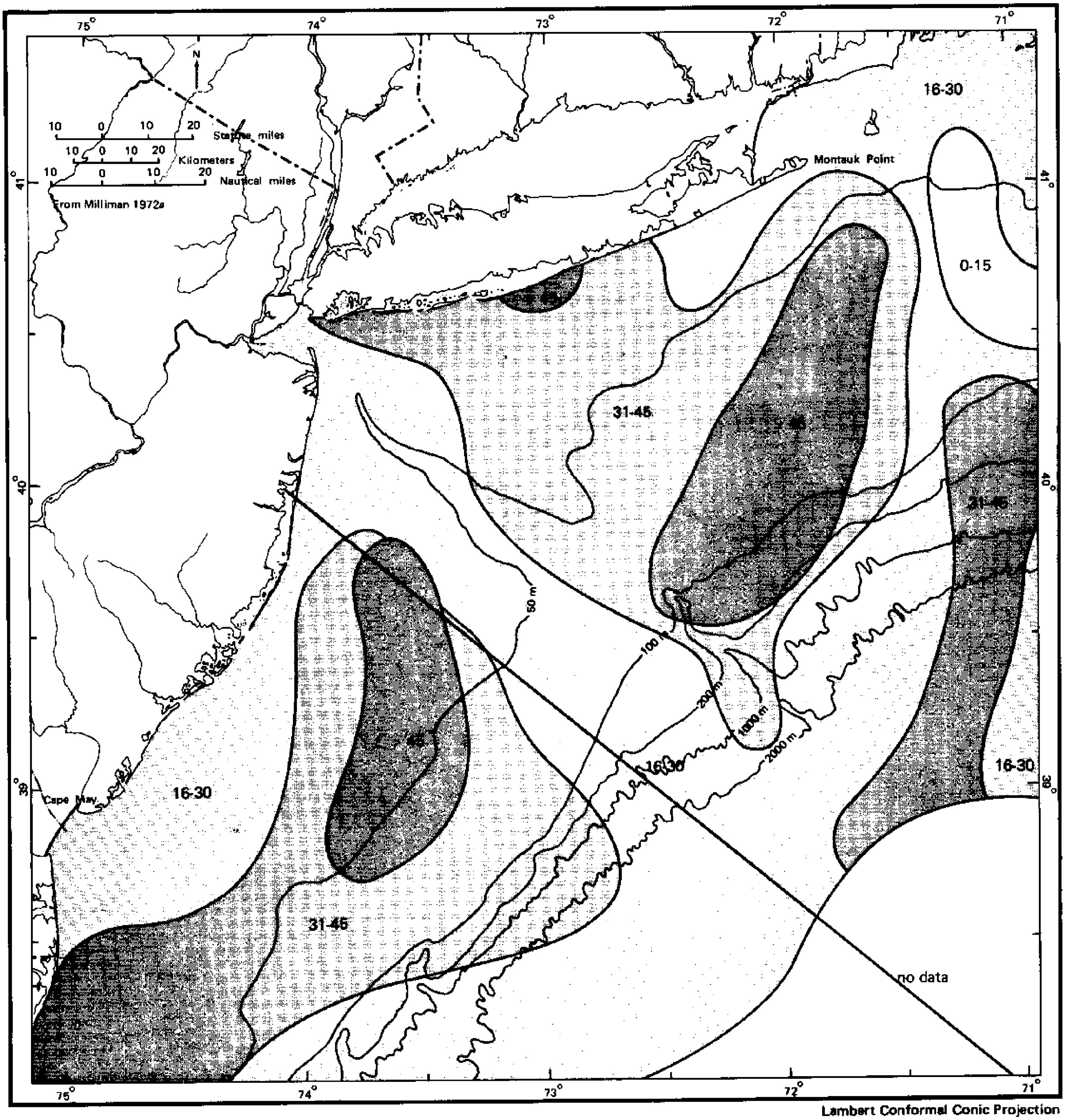
unweathered state are probably Pleistocene or early Holocene, whereas kaolinite and associated dioctahedral vermiculite river assemblages resulted from chemical weathering during the warm Holocene time. Similarities between clay mineral assemblages in modern estuaries and those on the outer shelf suggest that they migrated shoreward by winnowing from clayey areas on the shelf. The illite/chlorite *facies* may also be relict from times of cold climate.

Organic Matter. The amount of organic matter in sediments is usually expressed as organic carbon and

Map 29. Percent garnet in heavy mineral fraction



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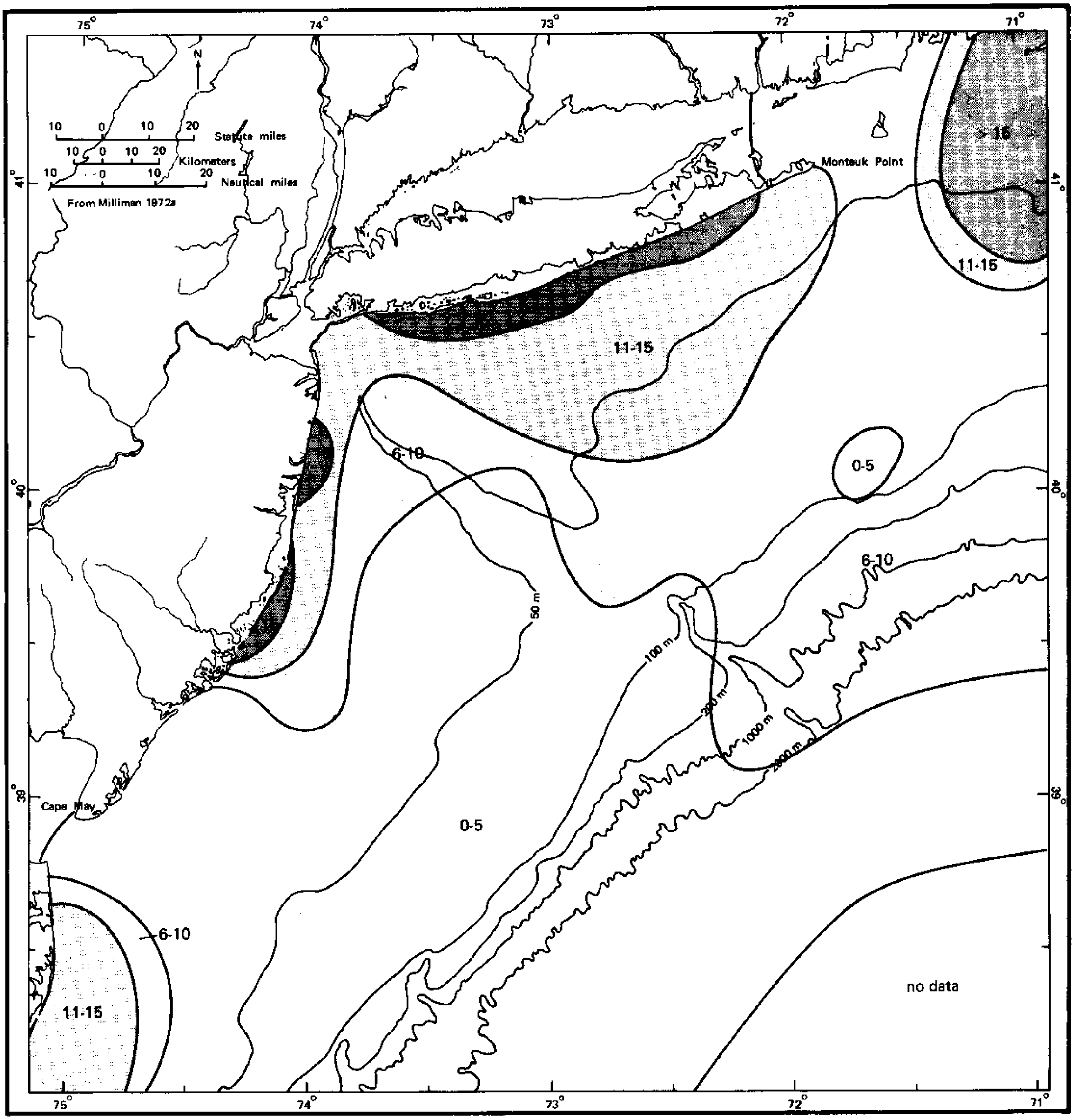
nitrogen content (measured by the Kjeldahl method). Organic content increases as grain size decreases: the more silt and clay, the higher the organic content. Terrestrial organic particles are usually well broken up by the time they reach the sea, and most marine organic material is small-sized when grown. In Maps 34 and 35 absolute values of organic carbon and nitrogen are low in shelf sediments but increase in the fine sediments of Hudson Shelf Valley and the slope and rise. The ratio of organic carbon to Kjeldahl nitrogen (C/N; Map 36) has been used to indicate the type of organic material(s) and possibly the age. Terrigenous

Map 30. Percent staurolite in heavy mineral fraction



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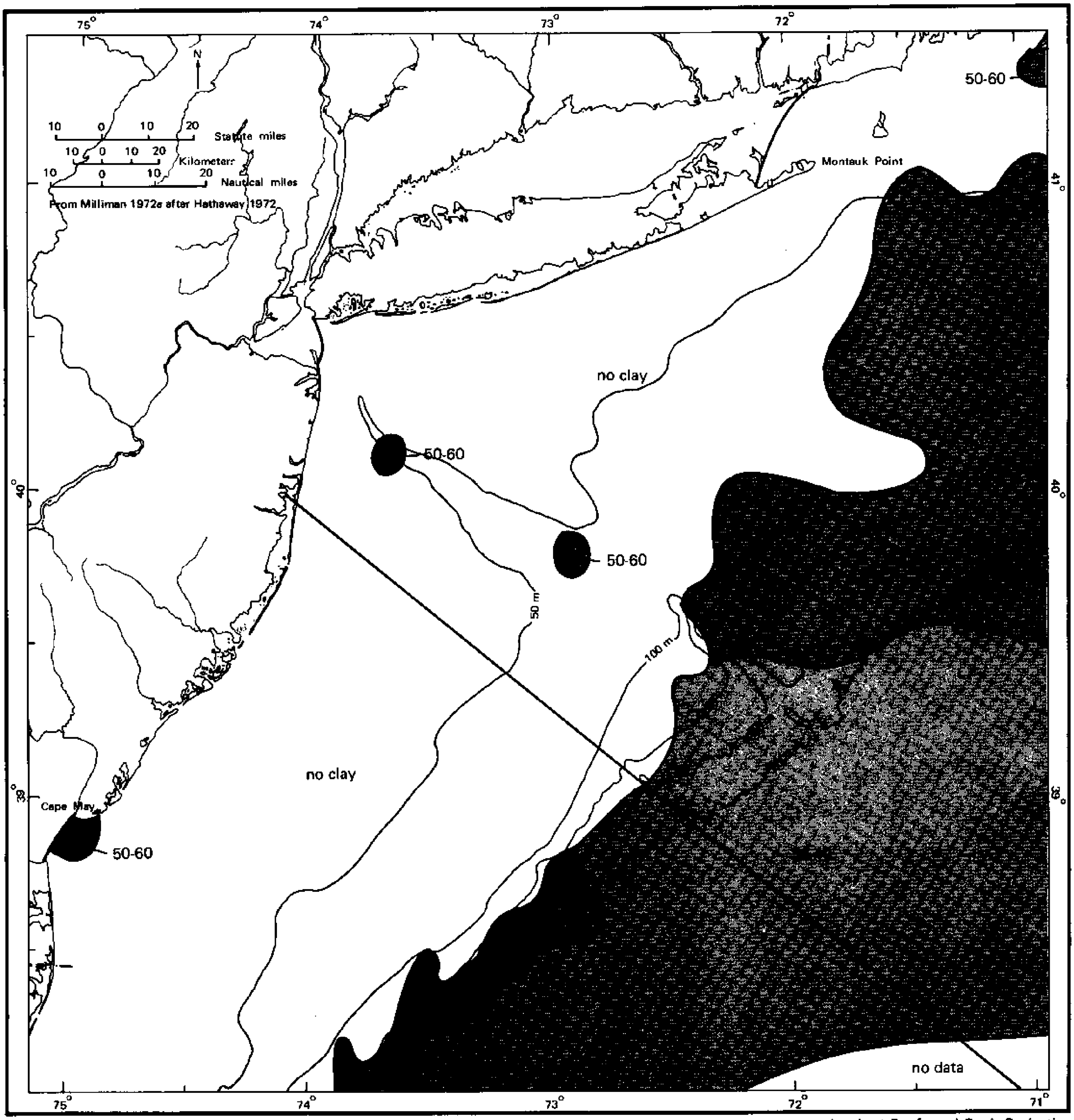
organic matter tends to contain relatively high C/N ratios; therefore, high values are found in estuaries and in relict sediment (Milliman 1972*a*). C/N ratios decrease down the continental rise, possibly reflecting the greater distance from the terrigenous source. Bottom photographs and submersible observations in mid-shelf troughs have revealed exposures of early Holocene lagoonal clays, which also contribute some organic matter to surficial sediments.

Color

The color of shelf sediments tends to be a function of grain size and chemical environment (Swift et al 1972). Coarse sand is usually brownish. The large voids between grains allow water to pass freely with the pressure surge from surface waves; hence the voids are well oxygenated. The grains become coated with brownish, hydrated iron-oxide precipitate. Fine

Map 31. Percent illite in clay fraction



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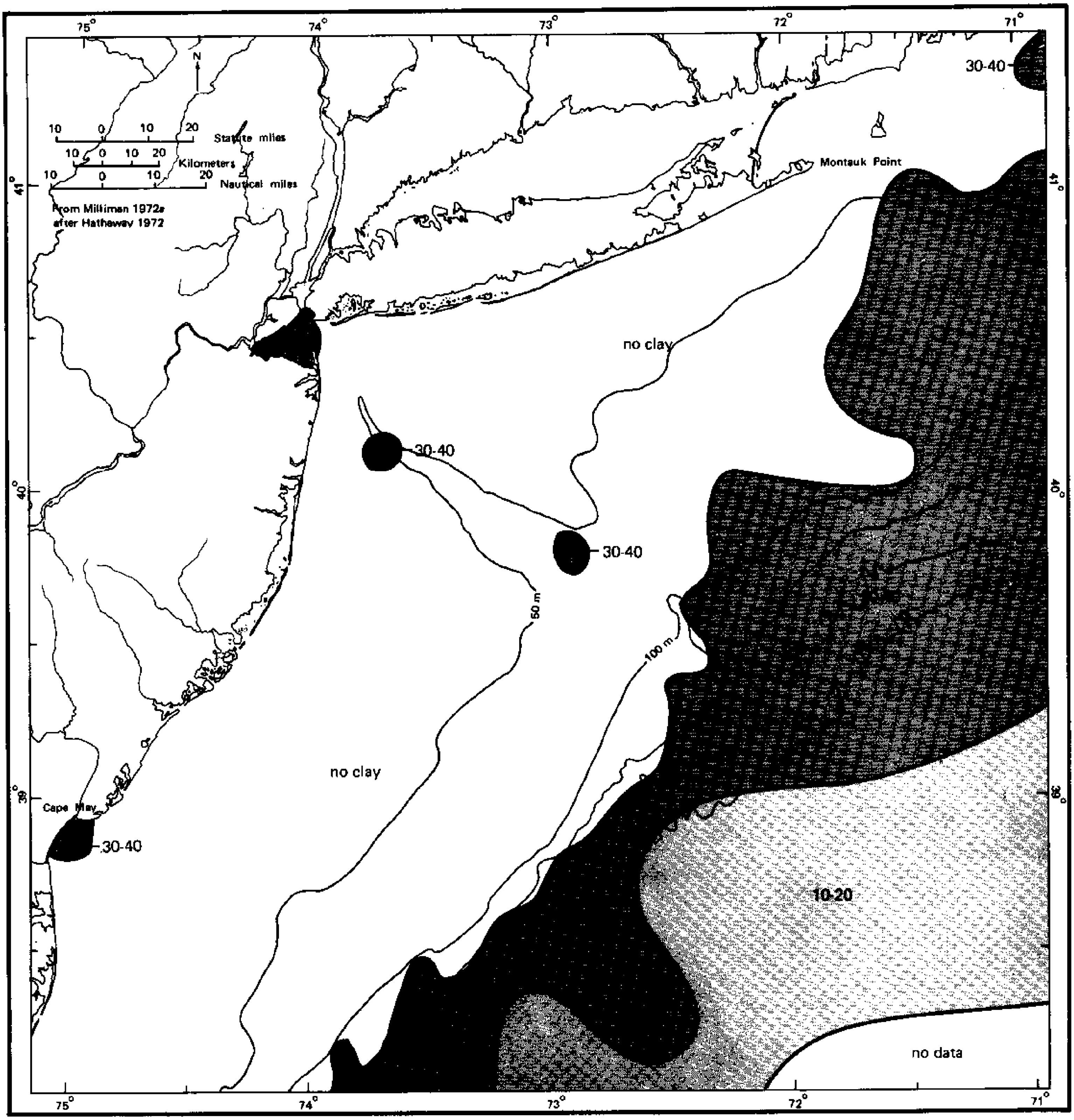
sands have small voids and are often mixed with silt and clay particles. *Interstitial water* then has limited free passage, and organic materials associated with silt and clay particles tend to react with and consume all of the available oxygen. Hence, the interstitial environment of fine sands and mud is usually reducing. Iron is not precipitated, and the sediment is colored dark by organic pigment. Sediment color may also be influenced by specific minerals, such as glauconite (dark green) and orthoclase feldspar (reddish).

Stanley's 1969 paper is the only published detailed study of sediment color on the Atlantic

Map 32. Percent chlorite in clay fraction



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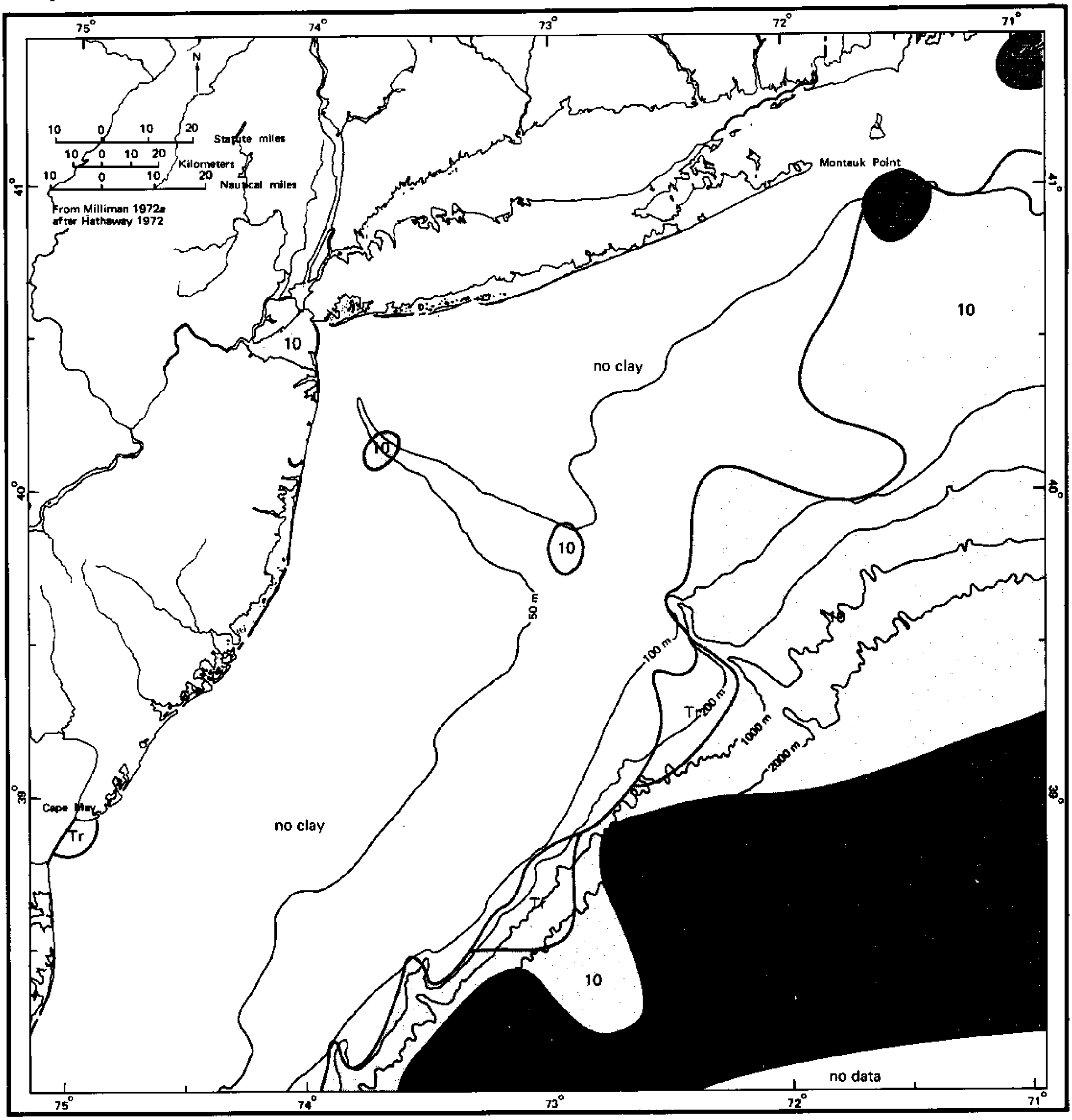
continental margin (Map 37). Since the color change in sampled sediments is great and often immediate, particularly in fine sediments, Stanley reconstructed original colors by wetting partly or completely dried samples. His results indicate that two distinct color bands dominate the shelf in the Bight: a band of yellow-ochre and dusky-yellow sediment on the inner shelf, locally extending out 125 km (67 nmi), and a triangular zone of greenish-black sediment with a maximum width of 125 km (67 nmi) on the outer shelf and upper slope. Together the two belts are generally less than 185 km (100 nmi) wide. On the

Map 33. Percent kaolinite in clay fraction



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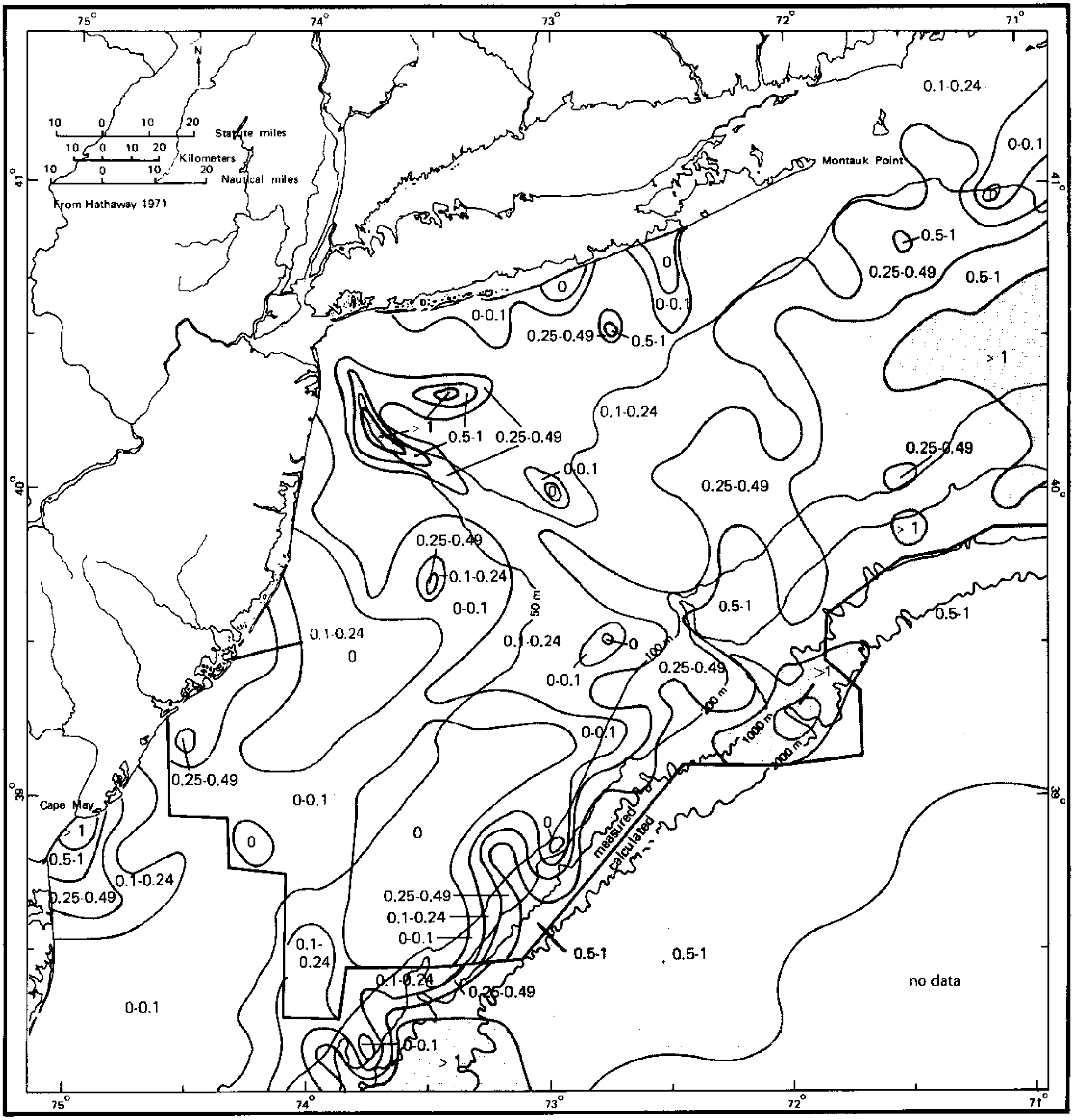
continental slope and rise, in a fairly uniform band about 100 km (54 nmi) wide, pale-olive to grayish-olive sediment dominates, except in the area of greenish-black sediment on the upper slope. Much of the greenish-black sediment at depths more than 200 m (656 ft), are in tongue-shaped patches related to depressions, including canyons and valleys. Farther downslope, starting at about 3,000 m (9,842 ft), are bands of pale-yellowish-brown and dusky-yellowish-brown sediments.

North and east of Hudson Canyon, the greenish-black sediment color is apparently due to glauconite

Map 34. Percent organic carbon



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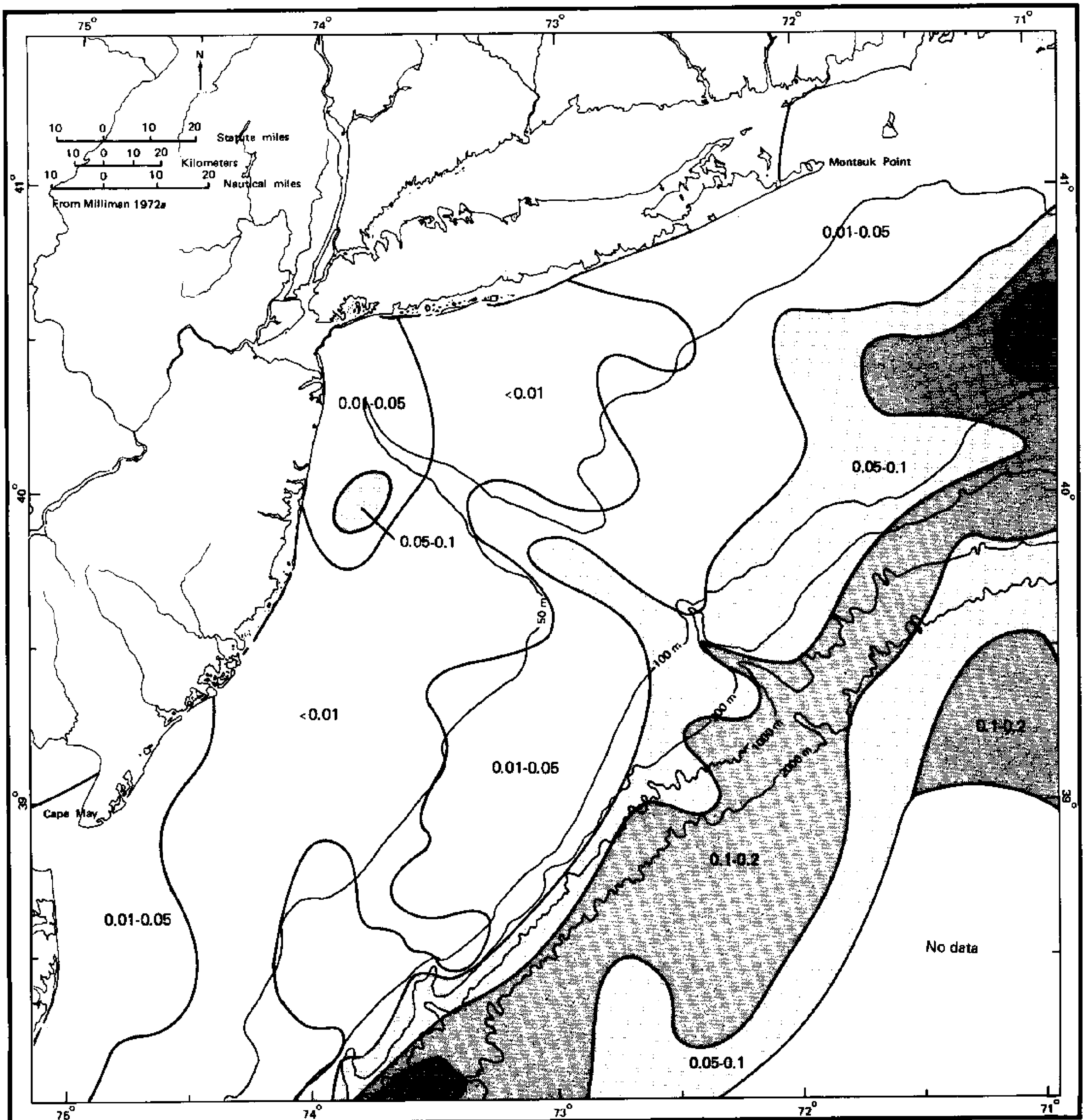
in the sand fraction, to high organic content, to low quartz content and feldspar-to-quartz ratios, and to the abundance of ferric iron in the clay fraction (Map 38). Yellow-ochre and dusky-yellow shelf sediment is generally associated with an iron-oxide coating on sand and gravel grains. On the slope and rise, olive-colored sediments contain more sand-sized dark minerals, more mica, generally more foraminiferal remains, and more organic carbon (0.5% to 1.0% *vs.* less than 0.5%) than the brown and gray clays farther offshore.

The seaward transition from olive and green through light-gray and pale-yellowish-brown to brown and yellow is probably related to the oxidation-

Map 35. Percent Kjeldahl nitrogen



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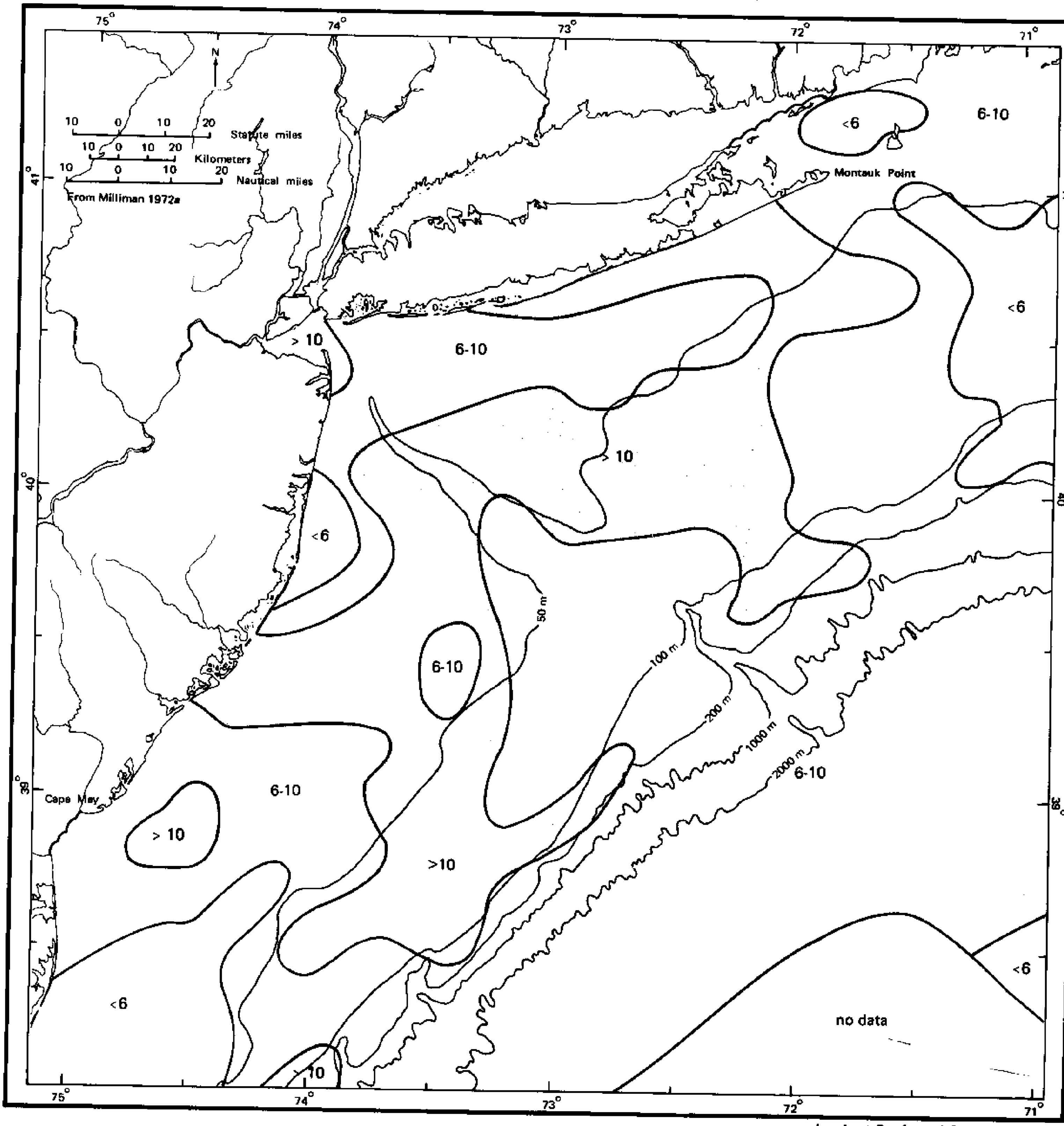
reduction potential of the environment, resulting from a balance between the rate of deposition and the rate of bacterial decomposition of organic matter. In very deep water, clay content increases and conditions are better for decomposition of organic matter before it reaches the bottom, and for oxidation of sediment on the bottom. At shallow depths on the continental rise, deposition is rapid, producing neutral colors from intermediate stages of oxidation-reduction. In topographically low areas, dark-green to black sediment, often with a noticeable hydrogen-sulfide odor, indicates a strong reducing environment. In almost all environments sampled, the uppermost several millimeters are lighter than the underlying material, due to oxidation.

Map 36. Ratio of organic carbon to Kjeldahl nitrogen

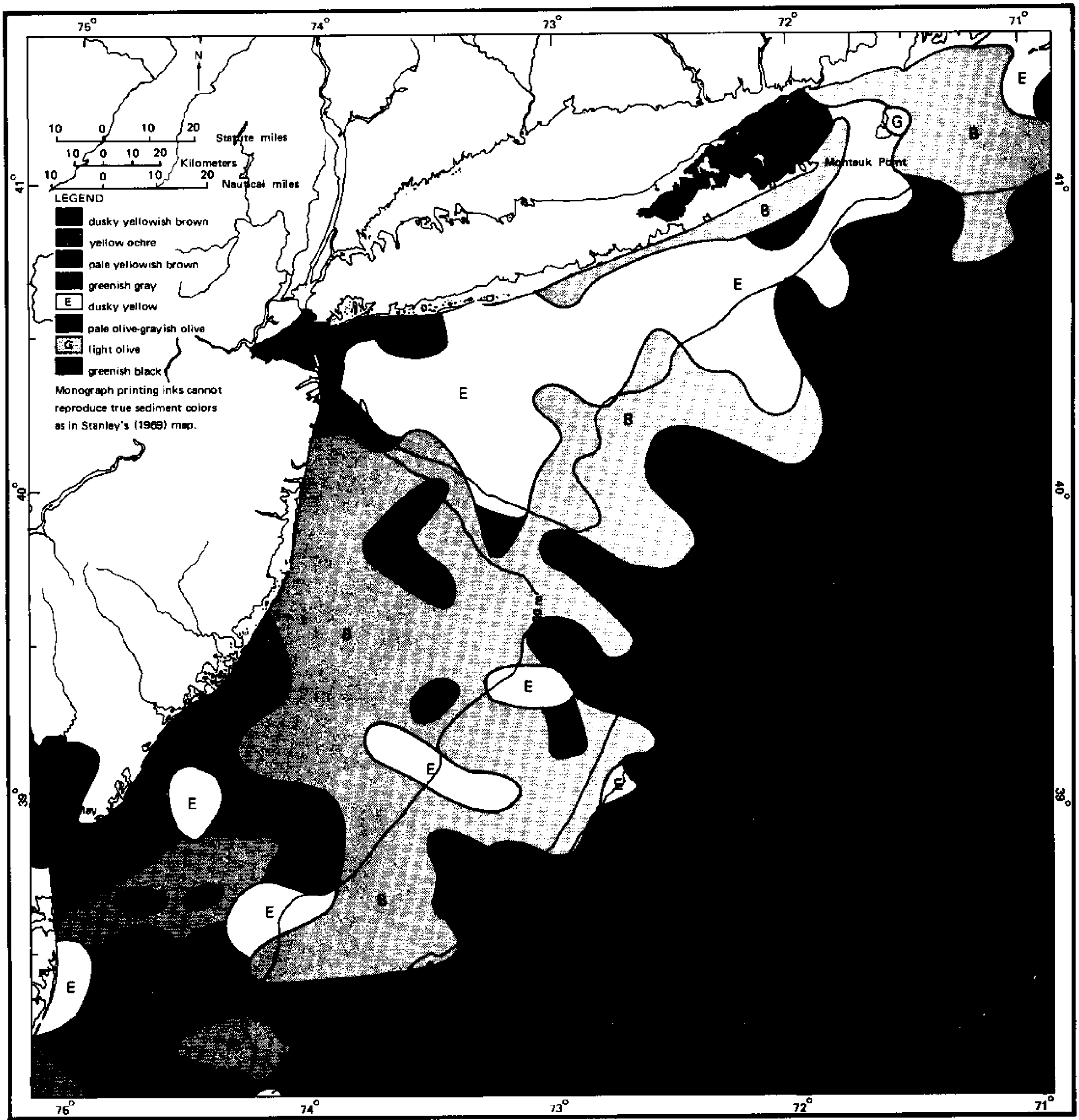


Suspended Sediments

Studies of particulate matter suspended in the water column are increasingly important in areas such as the Bight apex where dumped fines are the major fraction of the suspended load from all sources. Studies of suspended sediment in the Bight include Panuzio (1965), Holeman (1968), Manheim, Meade, and Bond (1970), Drake (1974), Biscaye and Olsen (1976), and Meade et al (1976).

The fate of fine-grained sediment in water masses basically depends on the nature of the source materials and the dynamic processes acting on the sediments—that is, the balance among the particle settling rates, resistance to corrosion and abrasion,

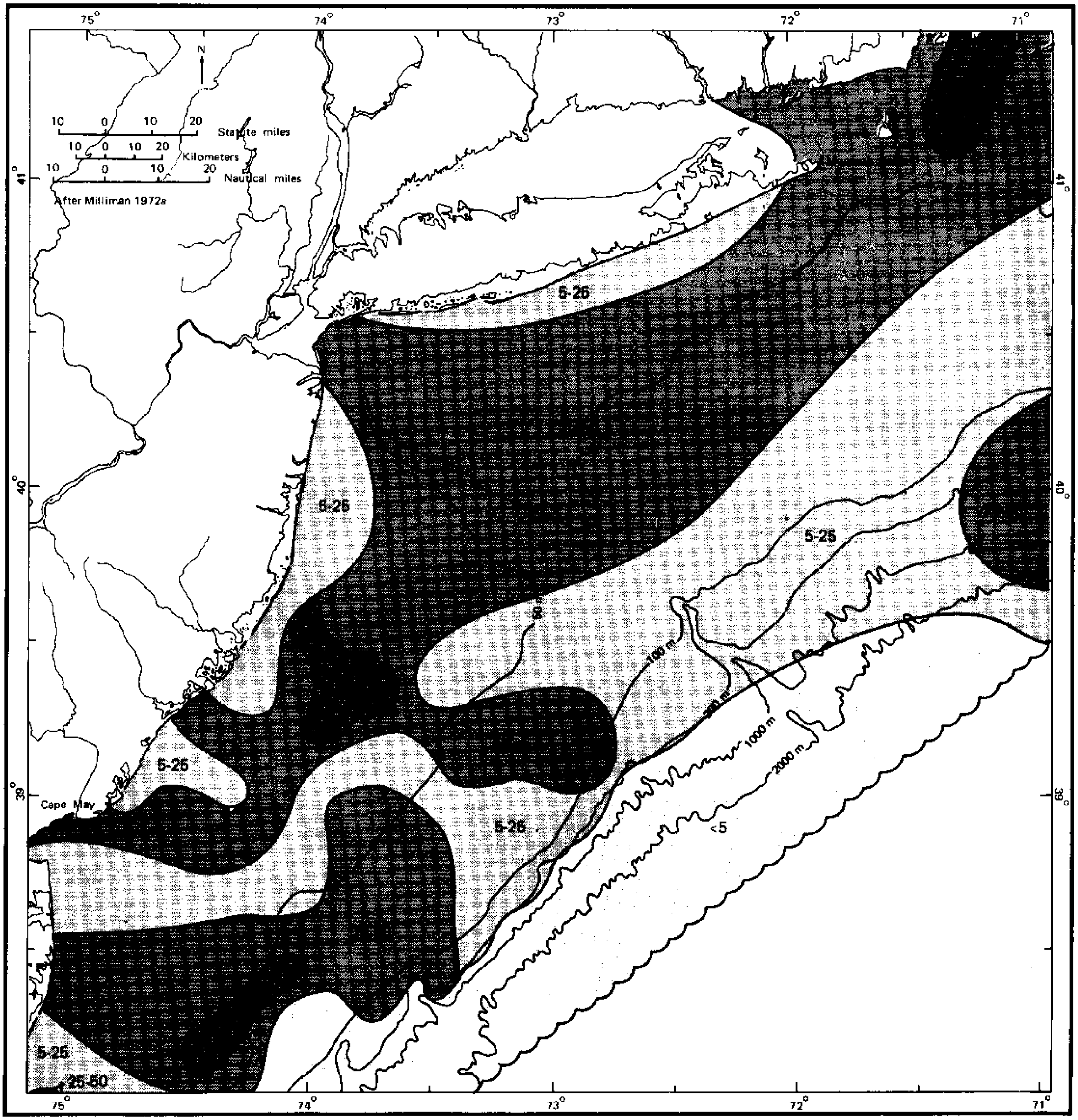
Map 37. Sediment color



Lambert Conformal Conic Projection

and the energy field. Natural sediment dispersal is complex because of wide ranges in settling properties, resistance to chemical solution, and degrees of involvement in biologic cycles. Furthermore, the transporting mechanisms are affected by a variety of factors, including time and space. Because of these complexities, we know most about rivers and estuaries, which are easily studied, and little about sediment movement in the ocean. As pointed out by Meade (1972*a,b*): 1) Pleistocene glaciations and sea-level fluctuations drastically altered the composition and distribution of sediments on continental margins (it is not always evident whether present shelf deposits reflect modern or Pleistocene condi-

Map 38. Percent iron-stained grains in 2 to 3 phi fraction



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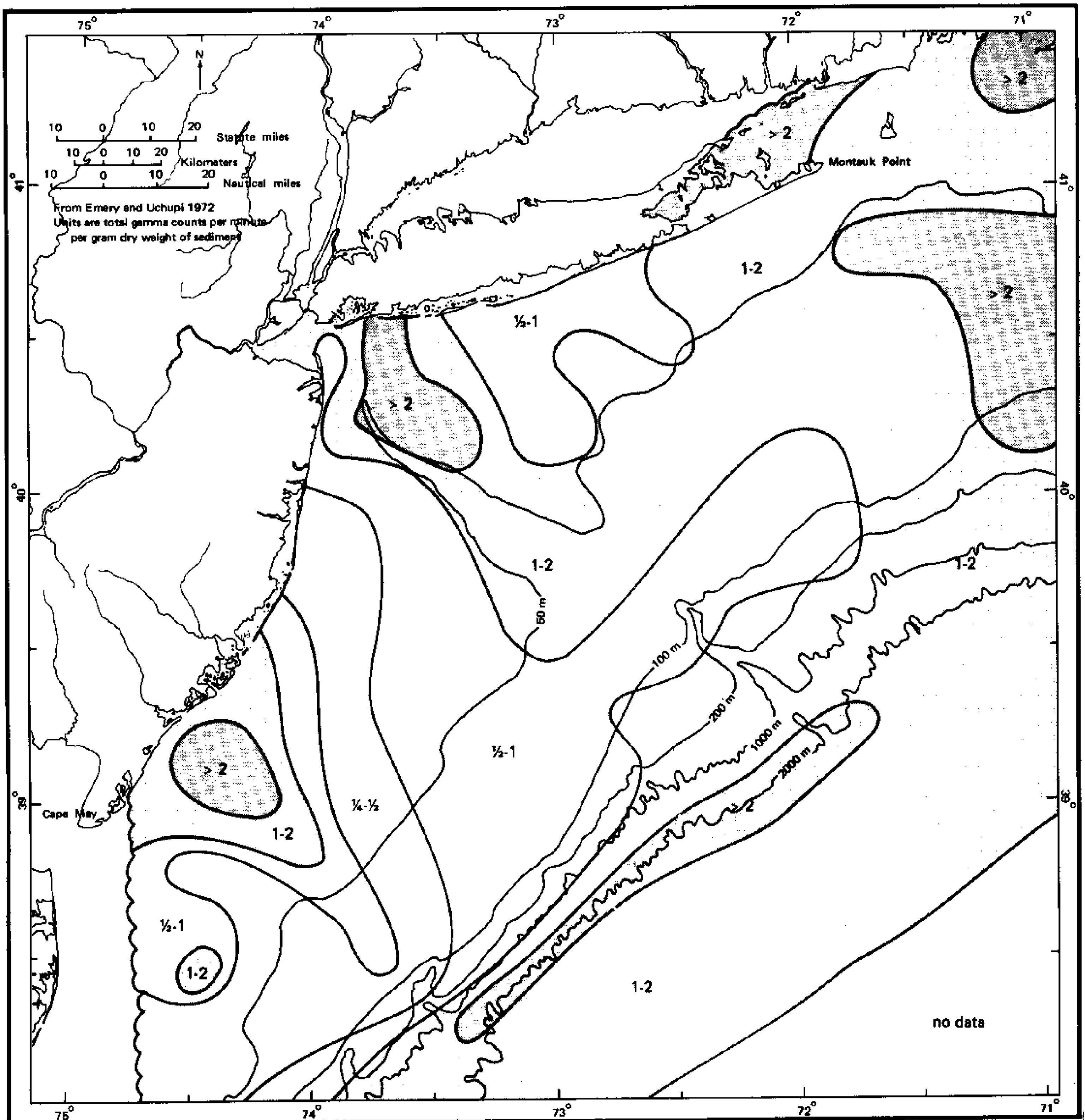
tions); 2) fine sediment transport studies are hindered because deposited sediments may reflect processes acting over thousands of years whereas suspended sediment studies are commonly limited to a few days or months of observations; and 3) natural processes may be impossible to separate from changes produced by man's activities, particularly in estuaries.

Fine Sediment Sources. Fine sediment discharged by rivers in the New York region amounts to 2.5×10^6 metric tons/yr (Mueller et al 1976) and is comprised of roughly 85% inorganic and 15% combustible organic material. The fine inorganic fraction is mostly illite, chlorite, feldspar, and hornblende in the Hudson River (Hathaway 1972). This compares to 8.8 x

Map 39. Radioactivity



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10^6 metric tons/yr of waste solids dumped in the Bight apex from the New York metropolitan region (Gross 1972, 1976; Mueller et al 1976) (Table 1).

Shelf erosion appears to be a significant and perhaps major source of suspended material today and during the Holocene transgression. Hathaway (1972) demonstrated that the composition of fine sediments near the mouths of coastal plain estuaries is quite different from the composition of river-borne sediments. Probably much fine sediment is being eroded from shelf deposits and returned to and trapped in estuaries (Meade 1969). Sediment composition of modern rivers indicates that river sediment is either by-passing lower estuaries or is trapped almost completely at the heads of estuaries. Along the US east coast, the Susquehanna (Chesapeake) and Delaware rivers enter the estuaries far from their estuary mouths; therefore most river sediment is deposited far from the sea. The Hudson River mouth is closer to its estuary mouth so more mixing of riverborne and shelf-derived sediment can be expected. Meade (1972*b*) has shown that the rate of depositon of fine sediment on the coastal wetlands of the Atlantic seaboard is equal to 90% of the rate of fluvial sediment input. However, at least some and perhaps much of the sediment may pass repeatedly between the estuary and inner shelf before final deposition in estuarine or lagoonal wetlands (Figure 3). The term "final" here is relative, for the estuary-lagoon mud belt extends seaward beneath the coastal barrier and outcrops on the shoreface, where it is released to shelf circulation as the shoreface undergoes erosional retreat (Figure 1).

Particles derived from biologic processes are also a significant component of suspended matter in estuaries and on the shelf; they range from 20% to 90% in surface waters (Manheim et al 1970). Concentrations of *combustible biogenic matter* decrease rapidly with depth, and little of this material is preserved in bottom sediments (Folger 1972; Gross 1972).

Atmospheric fallout over the Bight contributes less than 500,000 metric tons/yr (Mueller et al 1976) to the sediment input (Table 1). Whereas this source may be small relative to other sediment sources, it may be a significant transport path for specific pollutants like lead from vehicular exhaust emissions.

Clearly, the highest concentrations of both organic and inorganic suspended materials are in the inner 10 km (5 nmi) of the shelf water column, with a nearly exponential decrease from the coast seaward (Manheim et al 1970; Drake, Kolpack, and Fischer 1972). Mineral grains larger than 4 μm (silt) comprise 10% to 25% of nearshore suspended sediment samples and only 2% to 5% of offshore samples; the remainder is organic matter. However, this analysis excluded particles less than 4 μm in size (clay). In any case, the zone of strong terrigenous influence is restricted to nearshore waters and specifically to the inner-shore zone of turbid water drifting downcoast. The coarse grains in this zone are trapped in estuarine circulation, which reinforces surface concentrations, and are transferred from one estuary to the next with the longshore inner shelf current.

Table 1. Source of solids transported into marine waters of New York Bight

Source	Volume		Dry Weight		
	$10^6 m^3$	% of barged	10^6 metric tons	% of barged	% of total input
Dredge spoil	8.8	53	4.7	85.3	53.4
Sewage sludge	4.3	26	0.165	3.	1.9
Cellar dirt	0.5	3	0.6	10.9	6.8
Acid waste	2.5	15	0.04	0.73	0.5
Chemical waste	0.5	3	0.003	0.05	0.03
Total barged	16.6	100	5.51	100.00	62.6
Atmospheric fallout			0.427		4.8
Wastewater*					
Municipal			0.35		4.0
Industrial			0.02		0.2
Runoff*					
Gaged			1.4		15.9
Urban			1.1		12.5
Total input			8.81		100.00

*98% of these coastal zone inputs come through the Rockaway Point-Sandy Hook transect. Figures do not include shelf-derived sediment from outside the Bight.

Source: From Mueller et al 1976

Transport. When suspended fine sediments settle, the resulting mud layer begins to expel *pore water* and becomes cohesive. The smooth surface of the deposit is hydrodynamically stable. Nevertheless, on the inner shelf, bottom surge associated with storm waves is sufficient to erode and entrain this material into the water column. When entrained, the clay mineral particles comprising the inorganic mud fraction tend to be carried in suspension as low-density agglomerates, loosely bound by chemical forces and gelatinous organic material. These particles require days or weeks to settle and form a turbid *nepheloid layer* in the lower few meters of the shelf water column. Concentrations of inorganic particulate matter range from 0.1 to 60 mg/l. The bulk of suspended sediment is transported by slow, fair-weather drift or by accelerated stormflow within the nepheloid layer.

The regional fine sediment budget is very complex, and as yet poorly understood. The central elements are the turbid water masses of the inner shelf, New York Harbor, and associated bays. These waters exchange suspended material through every tidal cycle (Figure 3). The semidiurnal tidal flow has a two-layer residual stratification (*pycnocline*) caused by surface outflow of brackish, less dense water and landward underflow of salty, dense water. On every tidal cycle each water mass also exchanges fine particulate material with a variety of seafloor deposits. In bays and lagoons, particles settle out during slack-water periods and are partially reentrained by the intense flows of the falling and rising tide. On the open shelf floor, deposition and erosion are controlled primarily by the *wave regime.*

Studies of other areas (Postma 1967) suggest that the volumes of suspended sediment transported on the many *feedback loops* (Figure 3) are probably orders of magnitude greater than both the net volume transported across the shelf from the Hudson River and the amounts introduced by dumping. Coastal flow of suspended fine sediment—westward along the Long Island shore and south along the New Jersey shore—is probably less voluminous than circulation of suspended sediment locally in the Bight apex and estuary, but may nevertheless be greater than the fluvial or anthropogenic fine sediment input. Swift and associates (1975) have shown that a single fall storm can resuspend a volume of fine sediment equivalent to 12 days of sewage sludge dumping.

Although factors influencing suspended sediment dispersal can be defined, many large gaps in our

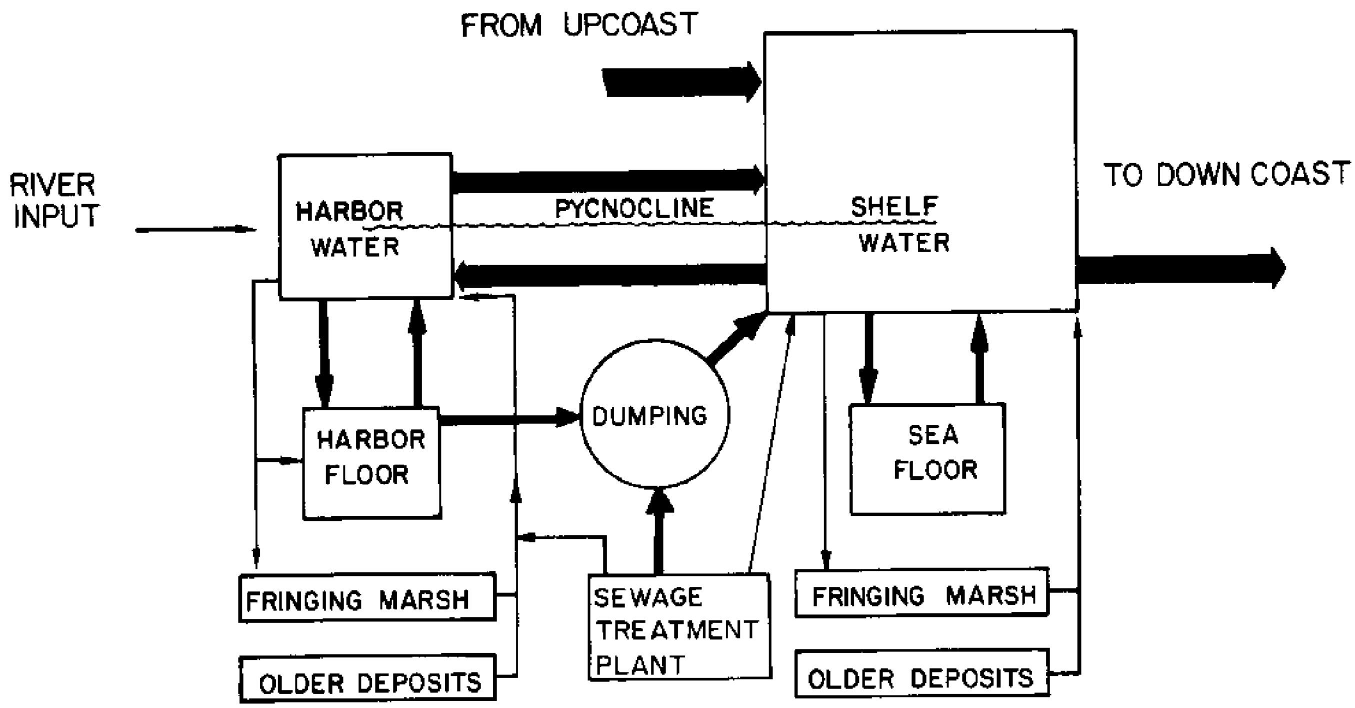

Figure 3. Suspended fine sediment transport

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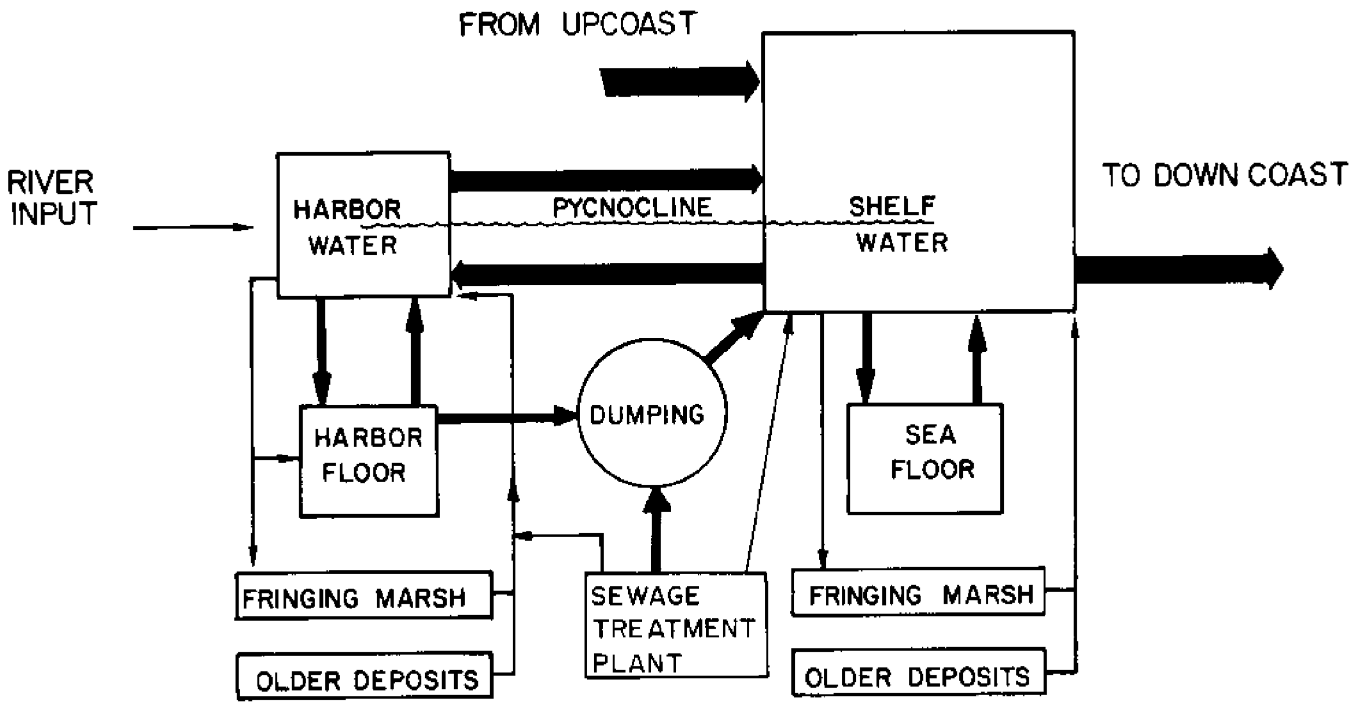


Figure 3. Suspended fine sediment transport

knowledge must be closed before quantitative regional transport budgets can be constructed. The most important of these are: shelf circulation patterns and mechanisms, particularly during storms; hydraulic properties of suspended sediments, particularly resuspension and settling properties; and the influence of *flocculation* and biologic aggregation of particles on settling. Nevertheless, a qualitative summary of fine sediment transport and deposition patterns is useful.

1. In strongly embayed coasts, fluvial sediments are largely trapped near the heads of estuaries by the net nontidal circulation. Probably 10% or less of the finest particles escape in the seaward, near-surface flow (Meade 1972*b*; Morton 1972; Schubel 1972; Schubel and Okubo 1972).

2. Salt flocculation may be important locally but many experts doubt whether this process is significant in determining deposition sites (Schubel 1968; Meade 1972*a*).

3. Biogenic aggregation may be influential in shelf waters (Manheim et al 1970) but sedimentation in estuaries is controlled predominantly by the hydraulic regime.

4. Landward transport and estuarine deposition of sediment derived from longshore currents and the shelf are supported by much evidence. Concentrations of particulate matter in surface waters over the shelf show a roughly exponential decrease seaward; most terrigenous material is confined to the inner shelf floor and the near-bottom water layer. Nearshore suspended matter is probably cycled many times by estuarine circulation and estuarine-like inner-shelf circulation.

5. Microscope studies of shelf suspended sediment suggest that only the finest terrigenous particles are transported to the outer shelf and deep sea. Their loss from the estuarine inner-shelf transport system apparently represents only a minor drain from the total sediment mass in those areas. Much of the cross-shelf movement of silt-sized sediment may be localized within shelf valleys and submarine canyons.

6. The effect of dumping varies with the area and with the material dumped. At the sewage sludge dumpsite in the Bight apex, there are only small amounts of sludge on the seafloor. The sludge has a 95% water content and a bulk density barely over 1 g/cc. Particles are mostly low-density organic material, such as floccules and paper fibers, which settle slowly; these particles may be dispersed and transported some distance before reaching bottom, although a portion goes to the bottom immediately after dumping (Proni et al 1976). The dumpsite is located on a shallow bank (Cholera Bank; see Map 43) where bottom sediment is continually being reworked so that fines are resuspended and removed. Within a mile to the north and west, the bottom drops into the Christiaensen Basin (see Map 43) where naturally occurring muds may be contaminated with sludge, although no detectable shoaling occurred from 1936 to 1973 (Map 44).

A few miles west, at the dredge spoil dumpsite, the water has shoaled up to 10 m (34 ft) in 37 years due to dumping. New York dredge spoil is high in mud-sized mineral grains and has a bulk density of about 1.3 g/cm^3; although most of this material settles rapidly, some fines have been deposited in low areas around the mound.

Effluents from sewer outfalls contain particles similar to sludge but generally finer and far less concentrated. These particles enter the inner shelf circulation where some contamination of naturally occurring muds is possible. However, particulate matter itself is not harmful; the chemical and biological contaminants that tend to attach to fine particles are the real danger. The presence of dark, smelly mud, naturally occurring in estuaries and in nearshore low areas, is not proof of contamination. These muds are the first place to look for such contamination, however.

7. Storms stir up and resuspend fine bottom sediment. When the wind direction, strength, and duration are favorable, unidirectional bottom currents are set in motion. These, in conjunction with the oscillatory bottom currents caused by waves, create enough energy to cause fine sand to move. Gradually, with more bottom energy, increasingly coarser sand, finer silt, and eventually clay-sized particles are resuspended. During the height of a storm, a large range of particle sizes may be in motion. As the storm subsides, the coarsest sizes immediately settle out. The finest sizes, particularly in the clay-sized ranges, may be transported for days or weeks after the storm is over (Duursma and Gross 1971).

Radioactivity

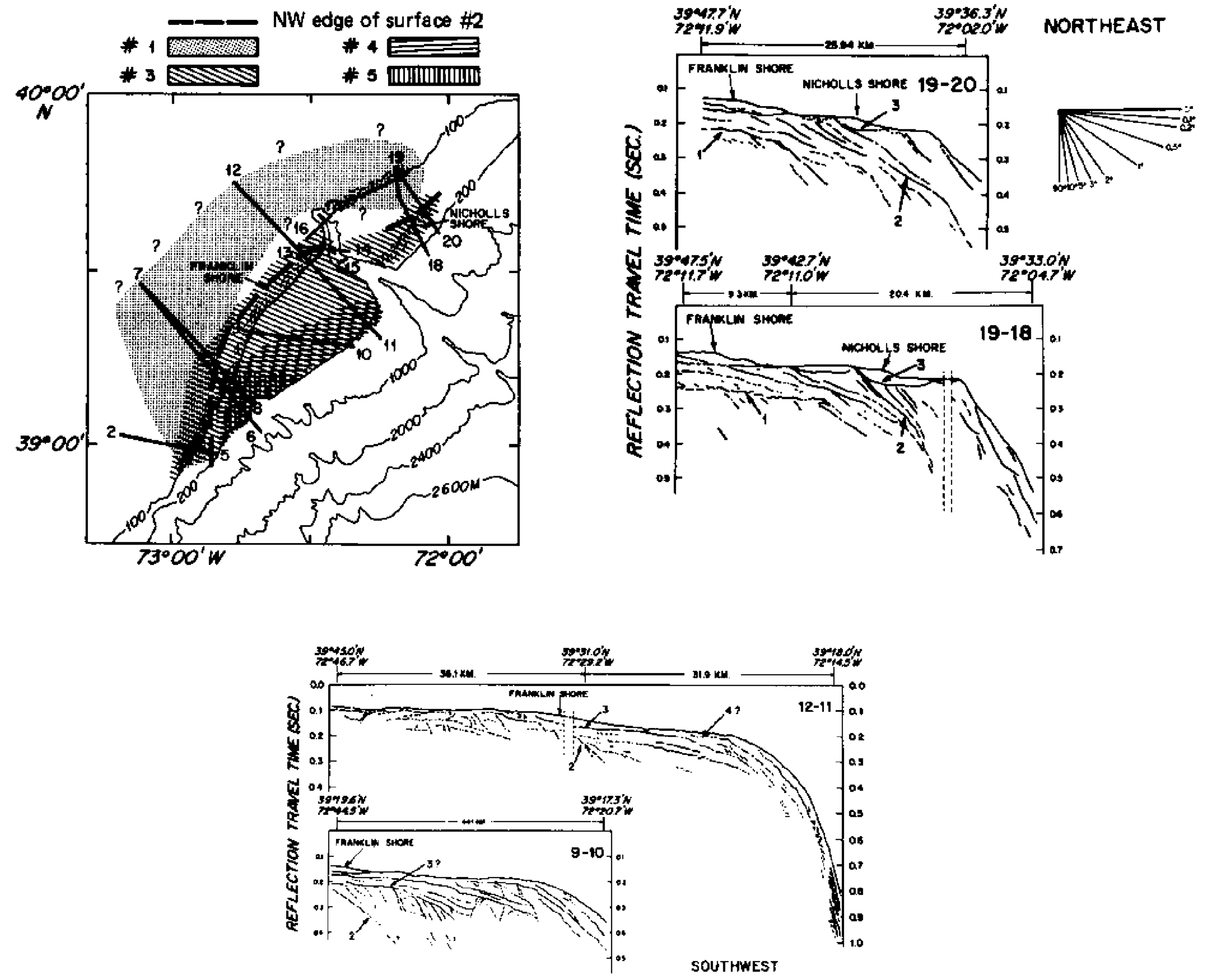
Studies on radioactivity in sediments show that natural radioactivity is a function of mineralogy and grain size (Emery and Uchupi 1972). Progressively greater radioactivity counts are usually found for sands, fine sand, and silt, but not necessarily for clay. The three principal natural radioisotopes in sediments are potassium-40 (half-life 1.25×10^{9} years; average concentration in sediments 0.8 to 4.5×10^{-6} g/g); thorium-232 (half-life 1.42×10^{10} years; average concentration in sediments 5×10^{-6} g/g); and uranium-238 (half-life 4.5×10^{9} years; average concentration in sediments 1.0×10^{-6} g/g, Joseph et al 1971). Potassium-40 and its far more abundant stable isotope potassium-39 are found most in feldspars, micas, and illite. Thorium and uranium are most abundant in heavy minerals. After deposition, sediments–particularly the clay minerals illite and montmorillonite–may absorb radioisotopes from seawater and assimilate tissue from organisms that may have greatly concentrated trace elements and radioisotopes while feeding.

The greatest concentrations of radioactivity in sediments are in estuaries, on the upper continental slope, and in two shoal areas near the New York Harbor entrance and northeast of Cape May in the vicinity of Great Egg Shelf Valley (Map 39).

Stratigraphy

The stratigraphy and structure of the entire continental shelf sediment pile is outside the scope of this monograph. However, the internal structure and geometry of the surficial sediments and their contact with underlying units are pertinent to our discussion. Geophysical data are collected with shallow-penetration seismic reflection systems (see Map 40) and are verified wherever possible by means of vibracores. These data show that the surficial sediments are generally a discontinuous sand sheet with a sinusoidally varying upper surface and a flat lower surface (McClennen and McMaster 1971; Swift et al 1972). *Linear lows* in the ridge and swale topography are where the sand sheet thins or pinches out altogether. Locally these lows are incised through the sand sheet into the underlying strata (Freeland and Swift 1975; Stubblefield and Swift 1976).

Around Hudson Canyon and elsewhere along the continental shelf edge, several ancient shorelines have been mapped from bottom topography and sub-bottom reflectors. These shorelines, Nicholls and Franklin shores (Figure 4), were formed during the last sea-level lowering and represent stillstands of sea level when wave action cut the shoreface profile (Figure 1) into the shelf edge. Other geophysical work in the Bight is discussed in the following detailed-study sections (Maps 45, 55, and 59).



Source: Knott and Hoskins 1968

Figure 4. Five erosional unconformities

Detailed studies of several areas in New York Bight (Map 41) are discussed below.

New Jersey Shelf

Ridge and swale topography is common on the central New Jersey shelf. Ridges, apparently both constructional and erosional in origin, have crests which appear to build up concurrently with trough (swale) scour. Fine sands are scoured from depressions during northeast storms, causing erosion into the underlying early Holocene lagoonal clay in particularly deep troughs. Trough axes are locally floored with coarse sand, shell debris, occasional to common lagoonal clay fragments, or may have a mud covering in deep holes. Sandy bottoms are usually strongly rippled. Seaward ridge flanks are overlain with fine to very fine sand; landward flanks and crests consist of medium to fine sand. The ridges appear to have been formed at the foot of the shoreface as the shoreline crossed the shelf during transgression, then were isolated on the deepening shelf floor (McClellen and McMaster 1971; Swift 1973; Swift et al 1972, 1974; and Stubblefield et al 1974). Evidence suggests they continued to be modified by the shelf flow field after departure of the shoreline (Duane et al 1972; Swift et al 1972; Stubblefield et al 1975; Stubblefield and Swift 1976).

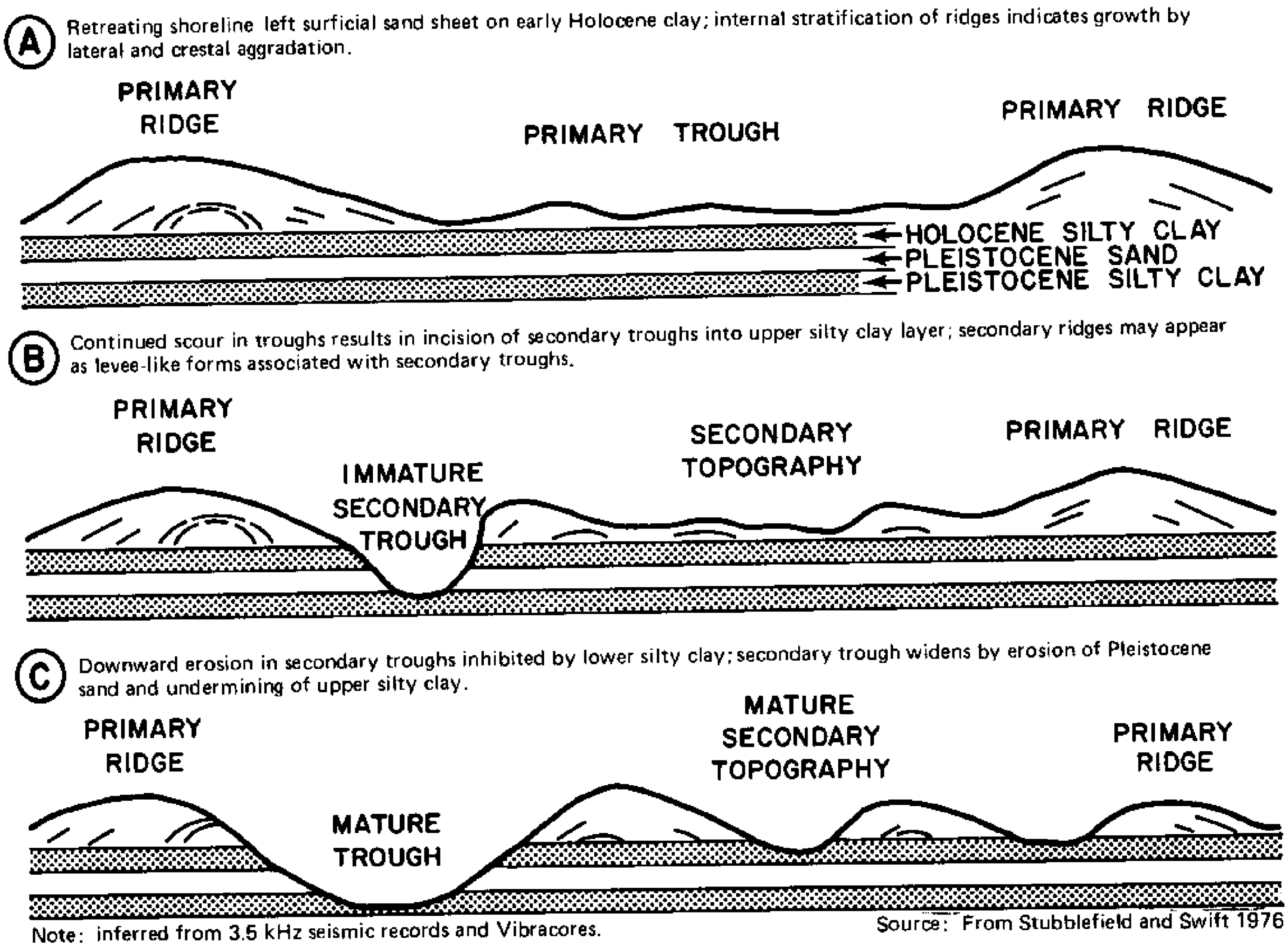
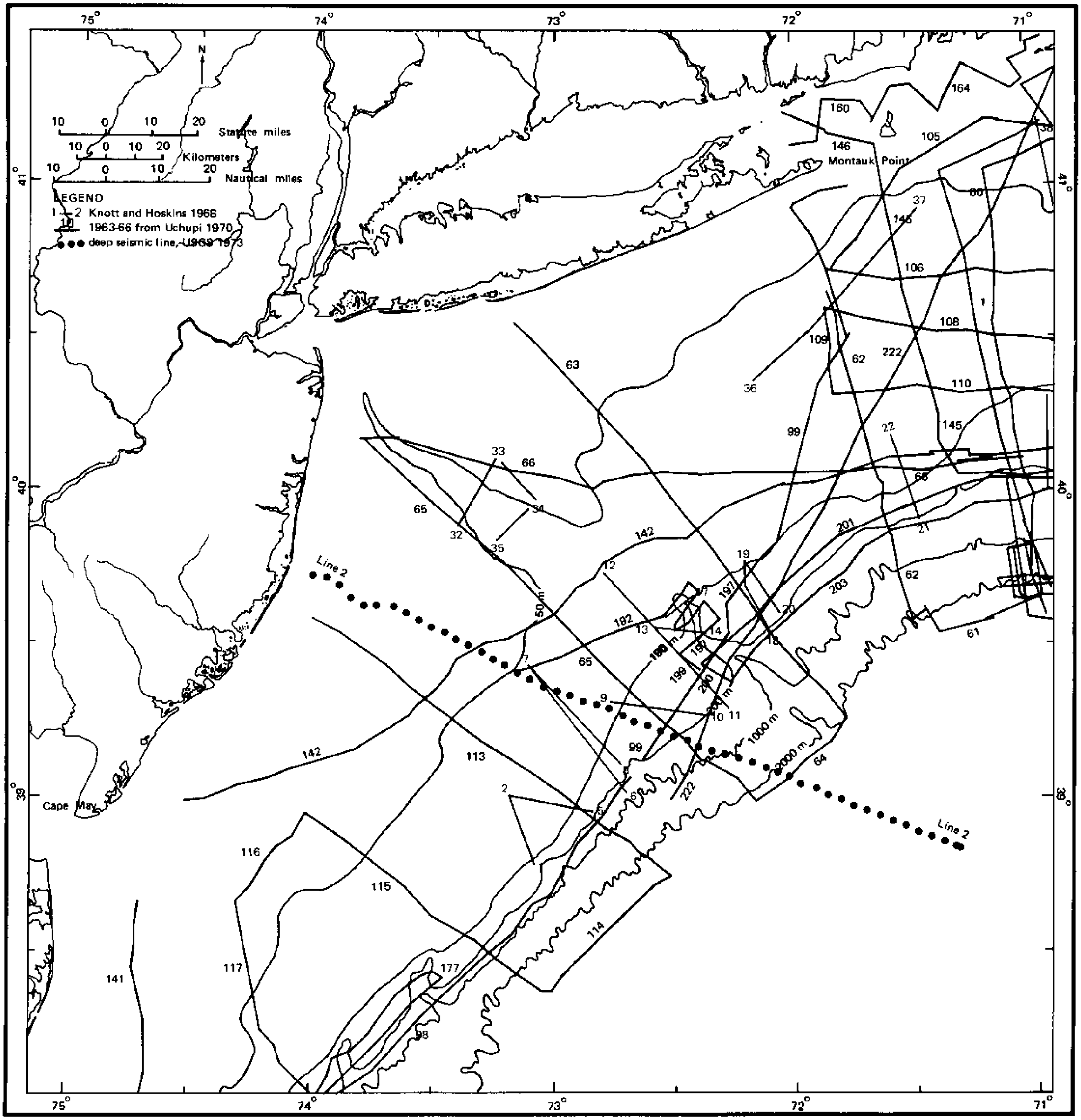


Figure 5. Evolution of ridge and swale topography

Map 40 A. Tracklines for seismic reflection profiles



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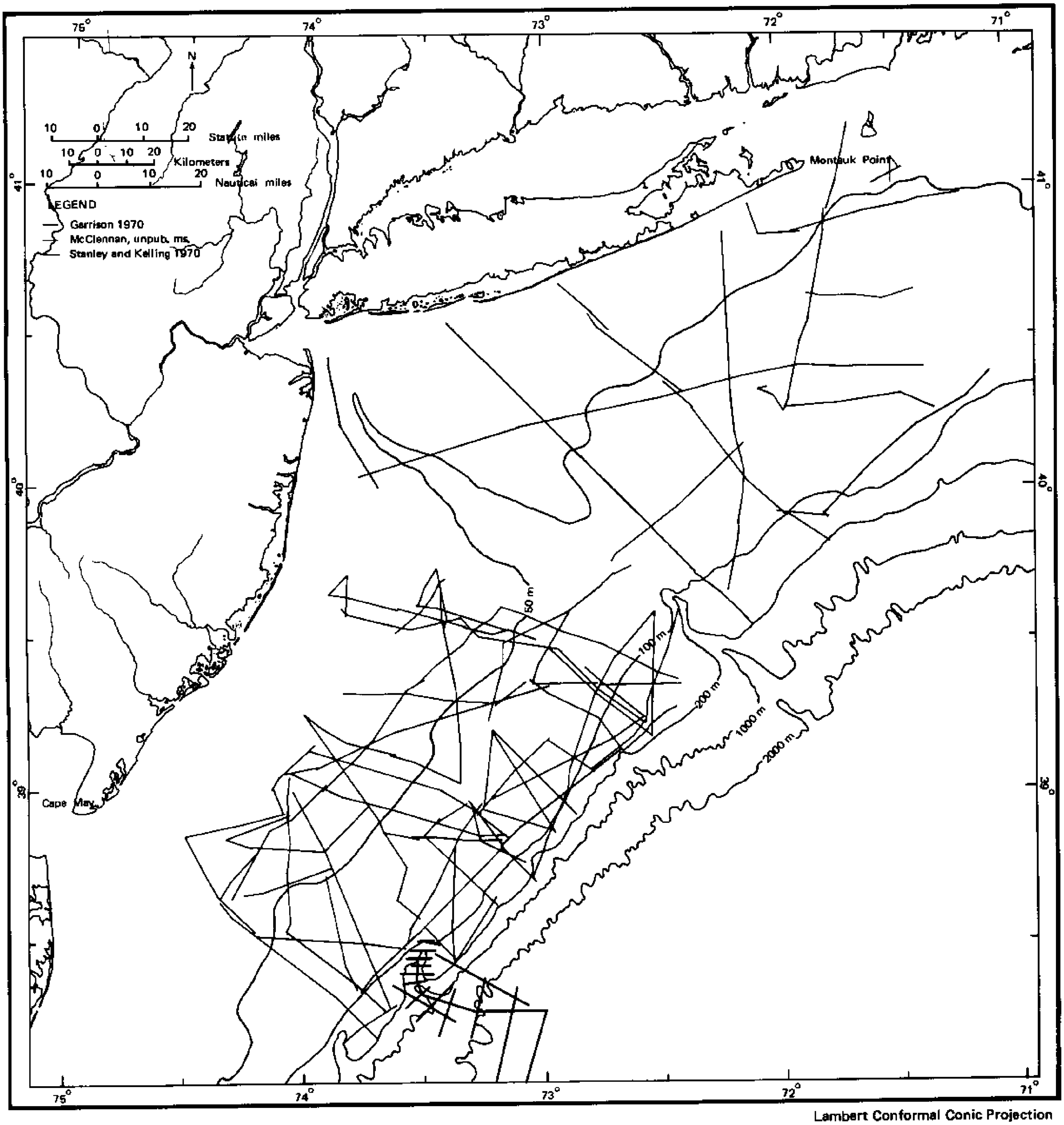
The ridge topography of the central New Jersey shelf is also characterized by current lineations (sand ribbons and erosional furrows). These are slightly elevated strips of sand over a coarse substrate (sand ribbons), or slightly depressed strips of coarse sand or shelly gravel in a fine sand surface (erosional furrows). They are 5 to 50 m (16 to 164 ft) wide, 15 to 500 m (49 to 1,640 ft) apart, and trend about 15° more westerly than the grain of the ridge topography. Like the larger scale ridge topography, they appear to be responses to storm flow (McKinney, Stubblefield, and Swift 1974).

Map 40 B.

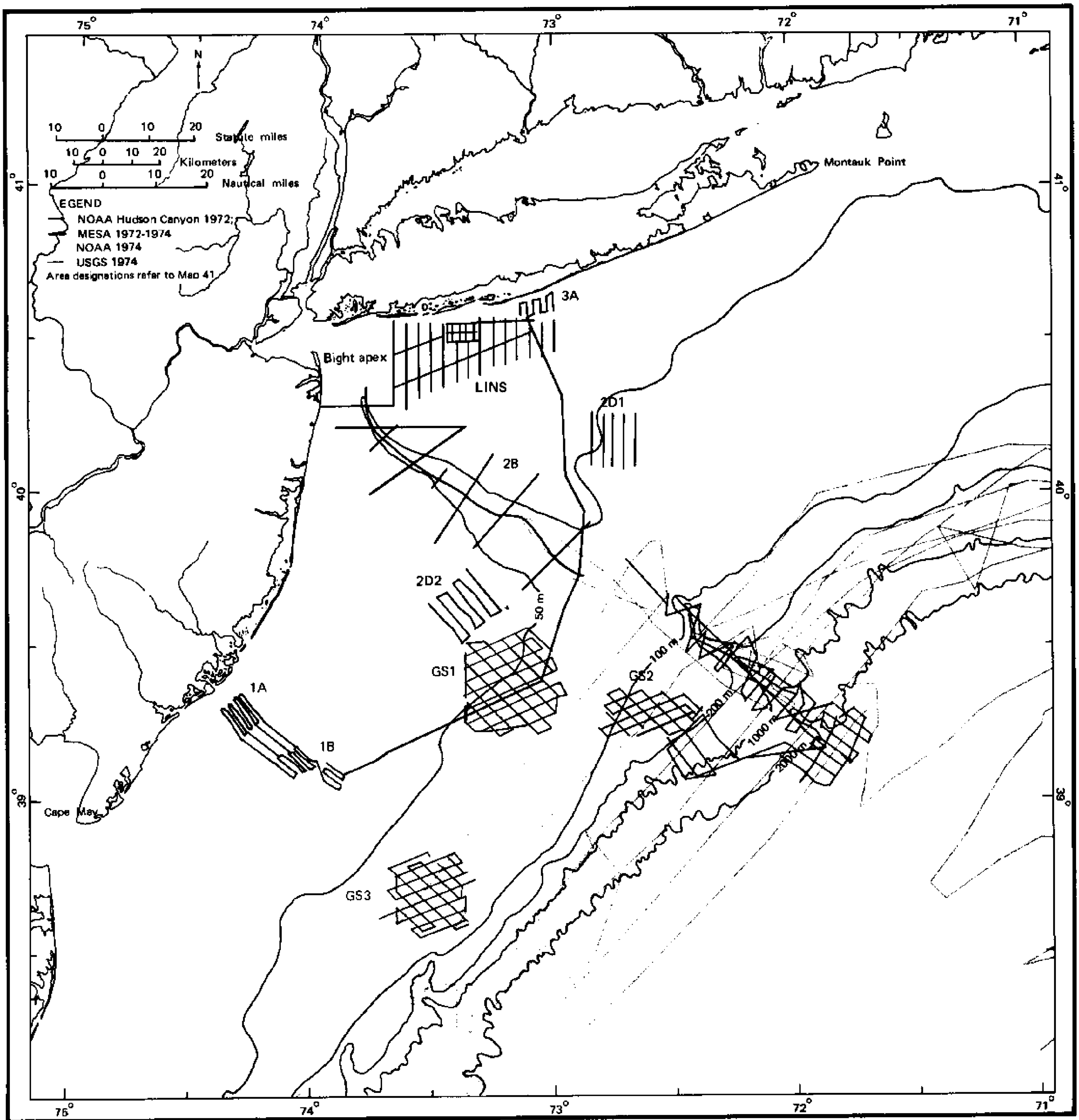


Lambert Conformal Conic Projection

The Frank and Friedman (1973) transect across the New Jersey shelf (Map 41; Figure 6), encompasses a 37 x 141 km (20 x 76 nmi) area from the shoreline to the 183 m (600 ft) isobath. They found moderately well sorted, medium-grained sand almost devoid of sediment smaller than 125 microns in size. This was attributed to reworking during the Holocene transgression. There was also evidence for sea level still stands at the 146, 124, 73, and 55 m (480,408, 240, and 183 ft) isobaths; the first two are the Nicholls and Franklin shores.

On the inner New Jersey shelf, studies for a

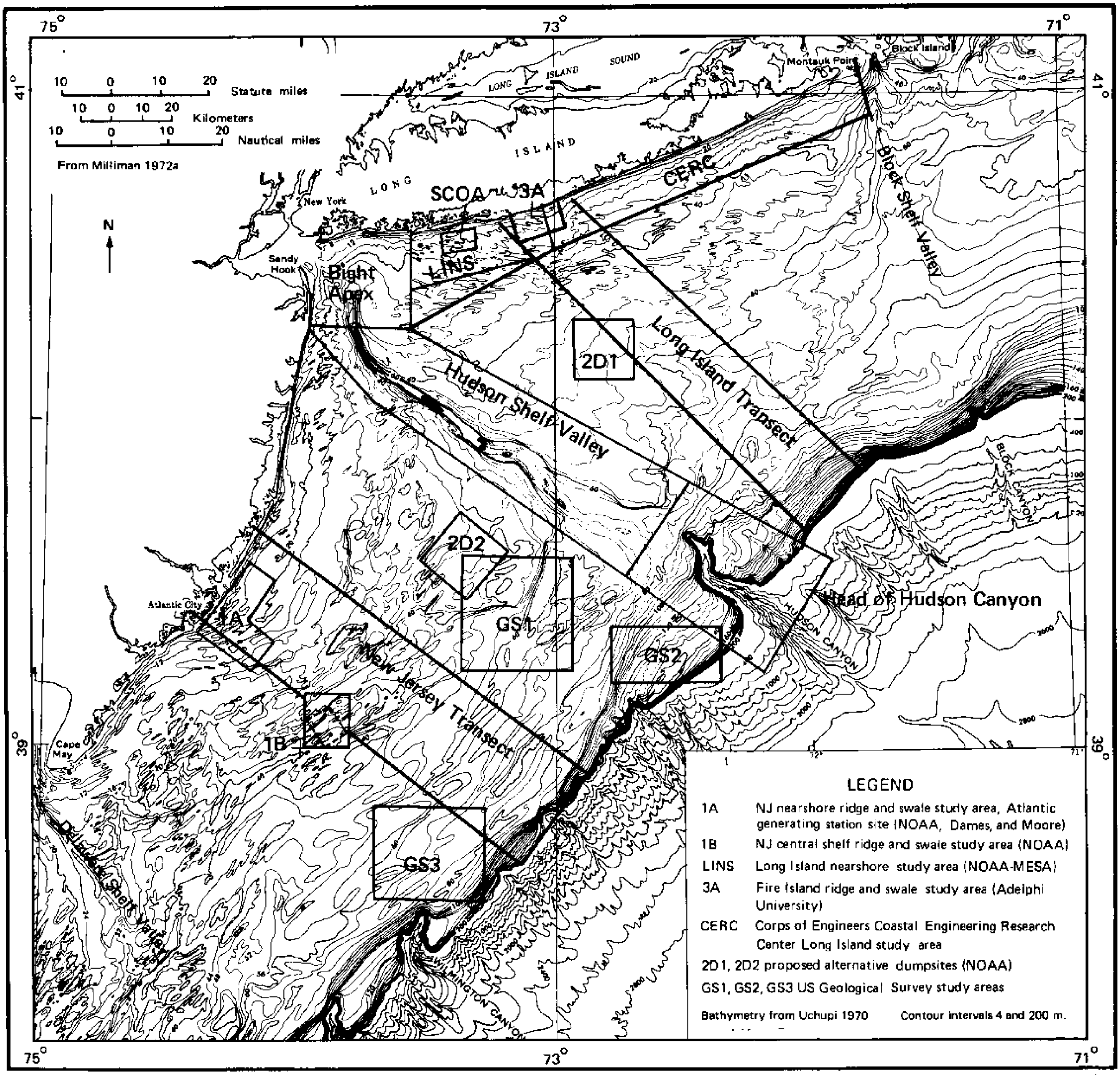
Map 40 C.



Lambert Conformal Conic Projection

nuclear power plant site 6 km (3 nmi) southeast of Little Egg Inlet were extensive: 48 vibracores and closely spaced seismic reflection lines using three seismic systems were taken in a 2,438 x 3,048 m (8,000 x 10,000 ft) area centering on the plant site at approximately 39°28′N, 74°15′W (Dames and Moore 1974; Miller and Dill 1974). Subsurface features found were five Pleistocene and Holocene horizons, and a 30 to 671 m (100 to 2,200 ft) wide late Wisconsin channel with five tributaries lying over 6 m (20 ft) below the bottom. The northeast-trending Holocene ridge, upon whose northwest flank the site

Map 41. Detailed study areas



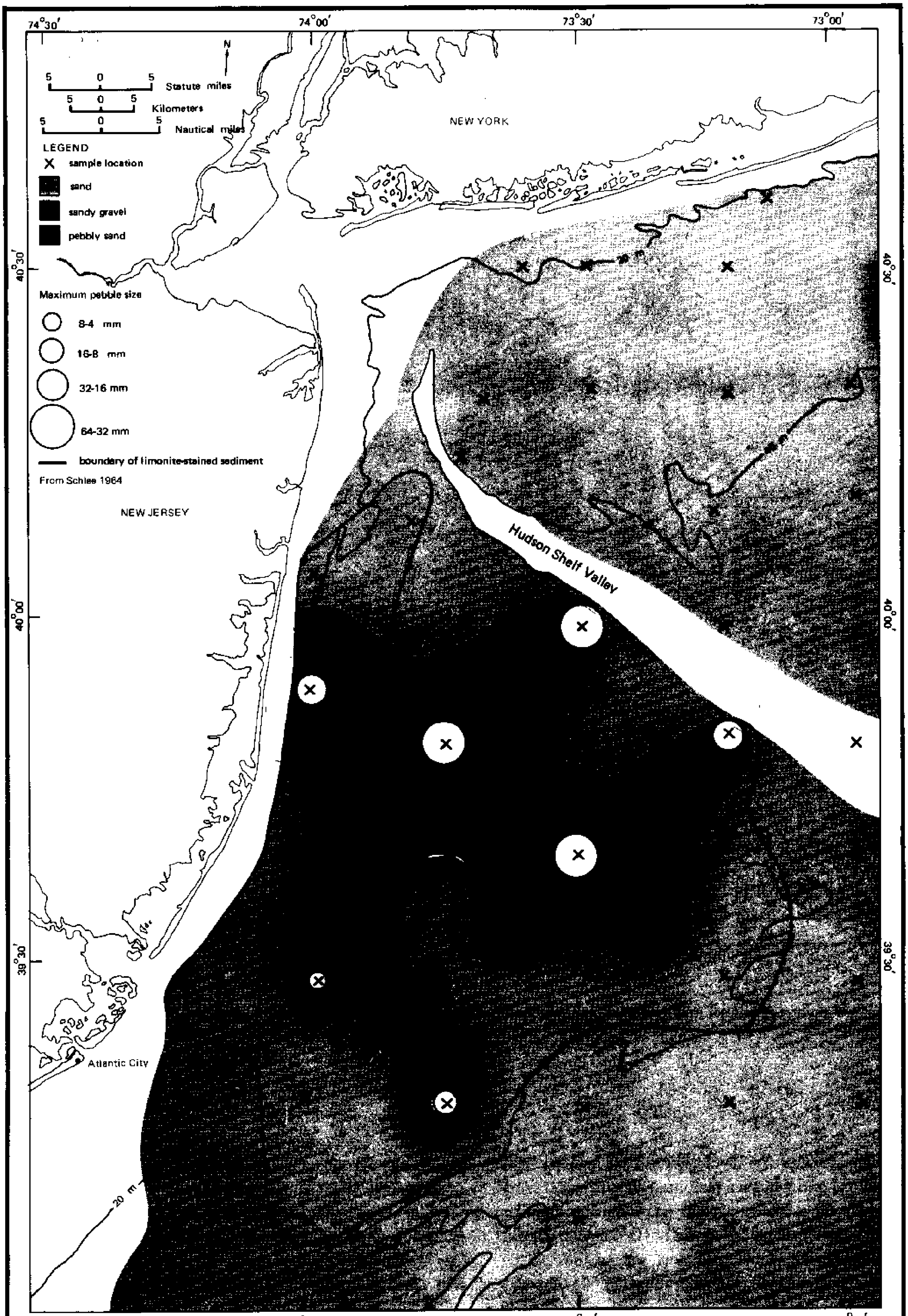
Lambert Conformal Conic Projection

is located, is about 3,658 m (12,000 ft) long by 610 m (2,000 ft) wide, has up to 5 m (16 ft) of relief, and consists of very well sorted, fine to medium sand with little or no silt resting on an early Holocene lagoonal clay sheet (Figure 7).

Off northern New Jersey, Schlee (1964) mapped (Map 42) a broad expanse of basal gravel that constitutes a potentially commercial deposit extending from the shoreline to the 40 m (131 ft) isobath (see also Schlee and Sanko 1975).

Detailed study of three areas between Hudson Shelf Valley and Wilmington Canyon (Map 41) on the

Map 42. Gravel deposit on inner New Jersey shelf



Mercator Projection

New Jersey shelf were initiated by the USGS as part of its continuing work on the continental margin (Map 59) (Knebel and Spiker 1977). Two areas (GS1 and GS3) are on the shelf proper and a third (GS2) is on the outer shelf south of the head of Hudson Canyon, where depths increase from 100 to 200 m (328 to 656 ft). Geophysical data were taken in all three areas; bottom grab samples were taken in area GS1.

Bight Apex

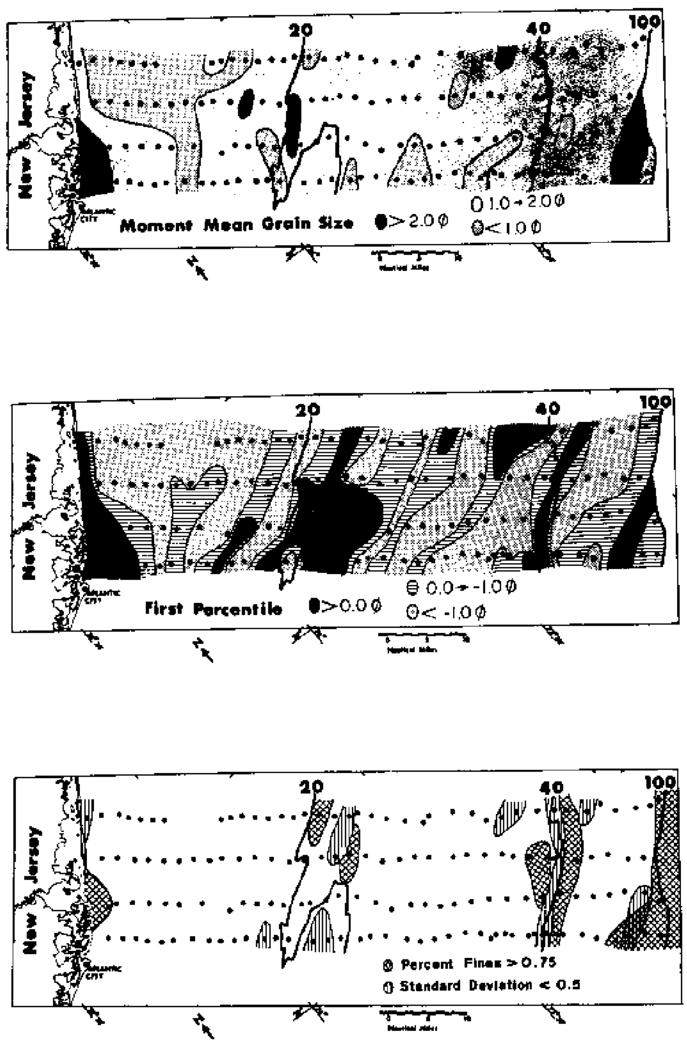
The Bight apex has been extensively studied by NOAA as part of the MESA New York Bight Project. Geological results available at the time of writing are presented here.

A new bathymetric map (Map 43) of the Bight apex was drawn after a NOAA/Corps of Engineers survey in summer 1973 (Freeland and Merrill 1976, in press). Principal topographic features are the northern end of Hudson Shelf Valley, Cholera Bank, and Christiaensen Basin (Veatch and Smith 1939). Dumpsites for dredge spoil, cellar dirt, sewage sludge, and acid wastes are shown. Knolls northwest of Ambrose Light and north and northwest of the dredge spoil dumpsite were formed in the early 1900s from the dumping of building excavation material and from the dredging of Ambrose and Sandy Hook channels (Williams 1975).

Comparison of the 1973 survey results with data from the previous survey in 1936 (Map 44; Table 2) reveals only one area of significant change: the dredge spoil dumpsite. Figure 8 shows the 1973 and 1936 bathymetry of the site and the net change between the two surveys. The 15 m (50 ft) knoll of the 1936 map (relatively unchanged in 1973) is from early dumping. The amount of material accumulated during these years was calculated at approximately 93 million m^3 (122 million yd^3), 87% of the estimated amount of material dumped.

Surficial sediments have been mapped from over 700 bottom grab samples taken at 0.9 km (0.5 nmi) spacing (Maps 45-48). Map 47 shows that the topographically low Hudson Shelf Valley and Christiaensen Basin are floored with fine-grained sediment, much of which is contaminated by newly dumped sewage sludge and dredge spoil, whereas most of the rest of the apex contains surficial sand and both artifact (dumped by man) and natural gravel deposits.

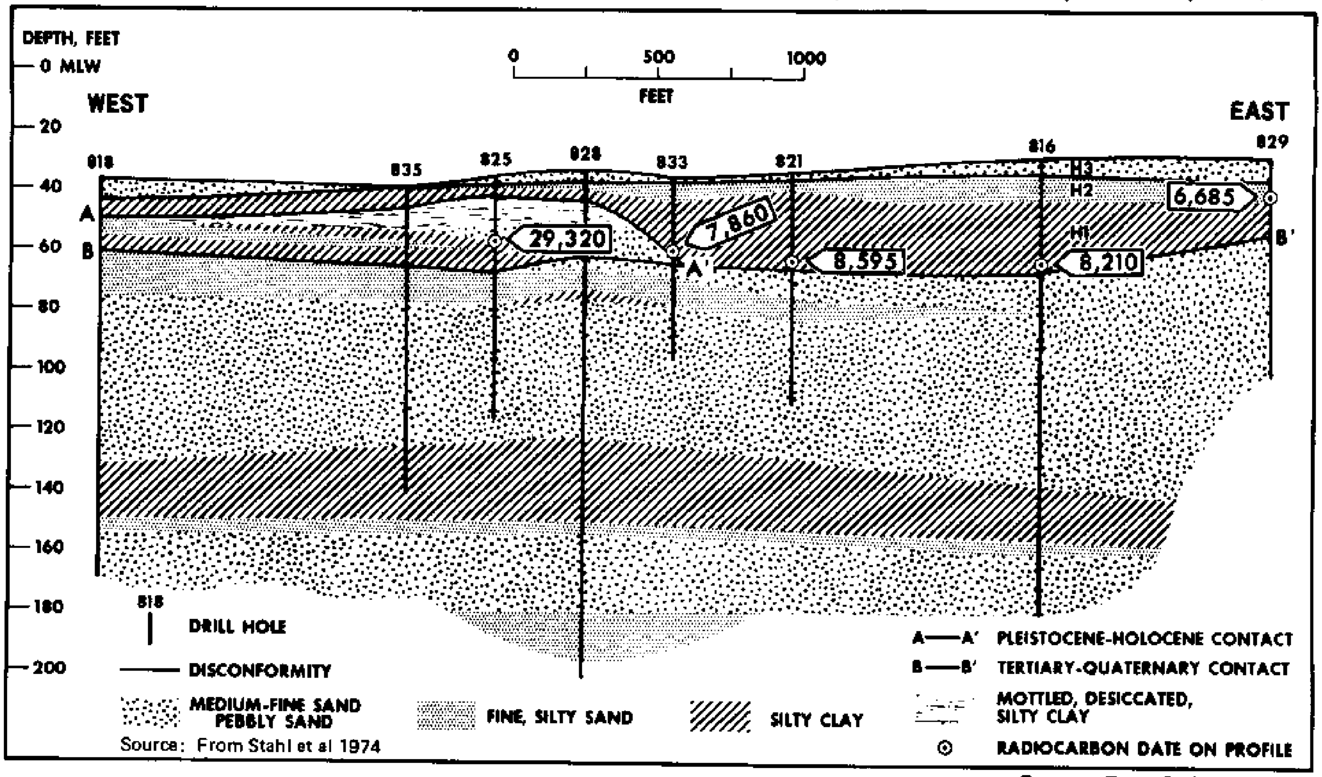
Geophysical data taken during the 1973 survey were 3.5 kHz shallow-penetration seismic reflection records, and *side-scan sonar* records with a 152 m (500 ft) range on each side of the tracklines (Map 49). The composite of the apex sonographs is shown on Map 50. Rough bottom, causing higher sonic return and dark images on the record, shows at the cellar dirt dumpsite, to a lesser extent at the dredge-spoil dumpsite, and in current-related bedforms off New Jersey and Long Island. On sonographs, bedforms appear as alternating light and dark bands corresponding to fine- and coarse-grained sediment, or as isolated dark bands. Near the Long Island south shore, these patterns make a high angle with the shoreline. Here the dark bands tend to be asymmetrical with sharply defined eastern margins. These features are inferred to be degraded current-



Source: Frank and Friedman 1973

Figure 6. New Jersey shelf transect, surficial sediment composition

Marine sand sheet formed by erosional shoreface retreat (H3) lies unconformably on back-barrier sand (H2) and clay (H1); thicker clay sequence between cores 833 and 816 is early Holocene lagoonal tidal channel; radiocarbon dates are years before present.



Source: From Stahl et al 1974

Figure 7. Structural cross section at Atlantic generating station site

Table 2. Volumes of erosion and deposition in New York Bight apex between 1936 and 1973

	Area (km^2)	Volume ($10^6 m^3$) Erosion (E)	Deposition (D)	Net Change
1. Entire Apex	718	161	162	1 D
2. Dredge spoil dumpsite	36		93	93 D
3. Cellar dirt dumpsite	9		5	5 D
4. Ambrose and Sandy Hook channel areas	86	49	31	18 E
5. Σ anthropogenic (2-4)	131	49	129	80 D
6. Christiaensen Basin[a]	83	13	6	7 E
7. Hudson Shelf Valley[b]	23	10	2	8 E
8. Other nonanthropogenic	397	89		} 64 E
	84		25	
9. Σ nonanthropogenic (6-8)	587			79 E[c]
Σ erosion	477	112		
Σ deposition	110		33	

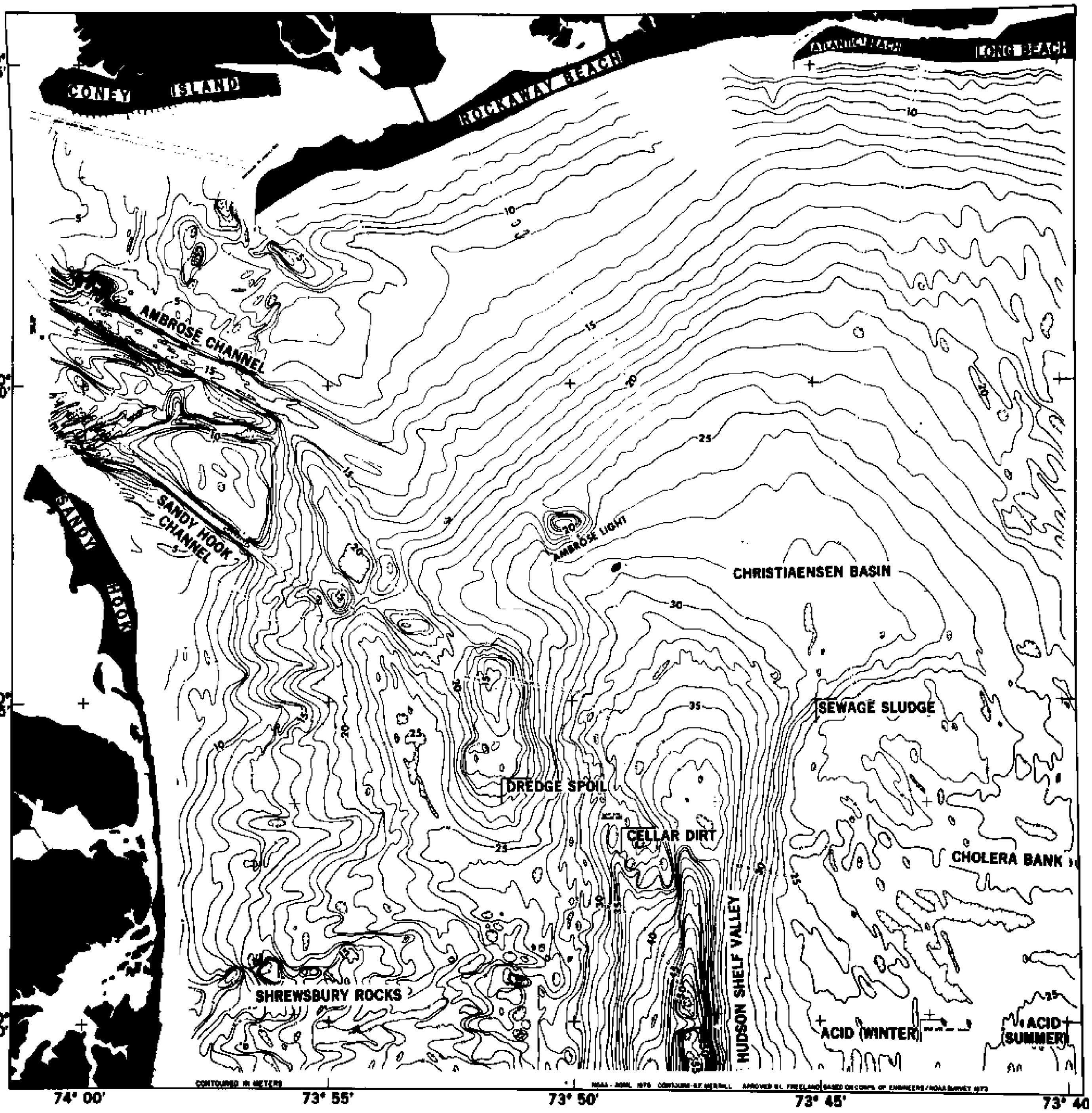
[a]Area between 26 and 37 m depth north (Map 43) of 40°24′N

[b]Area deeper than 37 m depth north (Map 43) of 40°19.22′N

[c]Equal to a layer 13.5 cm thick (3.6 mm/yr)

Source: From Freeland and Merrill 1976

Map 43. Bight apex bathymetry and locator



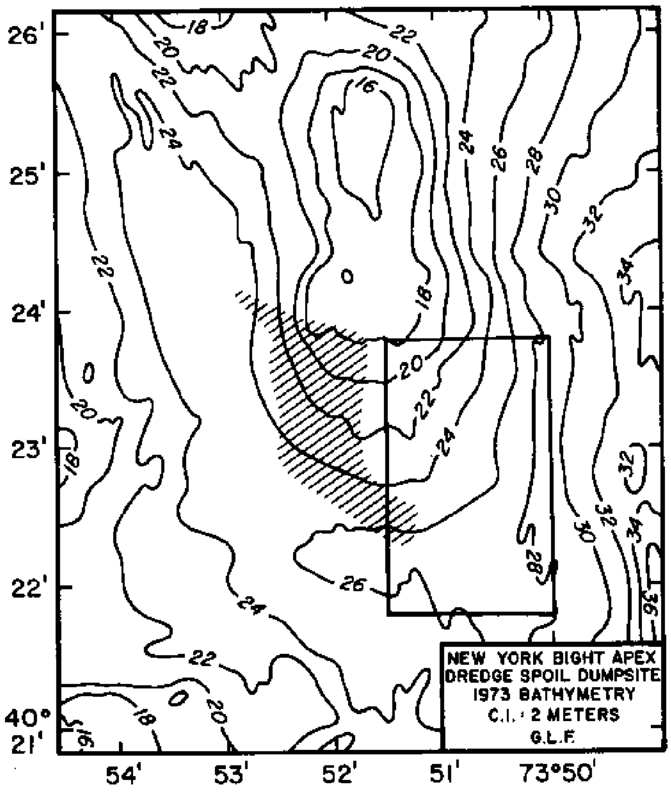
Sources: NOAA 1973 survey; Freeland and Merrill, in press

Note: contour interval 1m

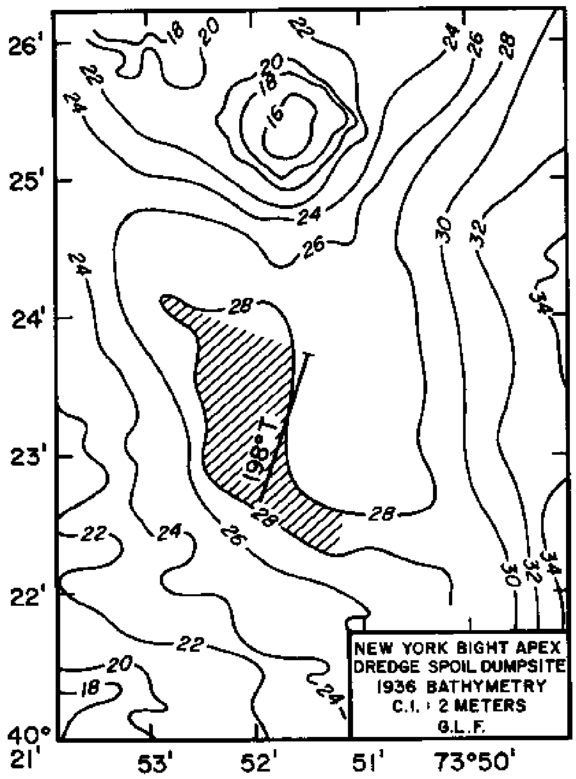
transverse sand waves formed by storm-generated bottom currents that trend west and southwest along the coast. Along the New Jersey shore, the patterns are broader, generally symmetrical, and are nearly shore-parallel. They are inferred to be flow-parallel (sand ribbons and erosional furrows).

The orientation of the coast changes 90° between Long Island and New Jersey, but the orientation of the bedforms changes much less and rather gradually.

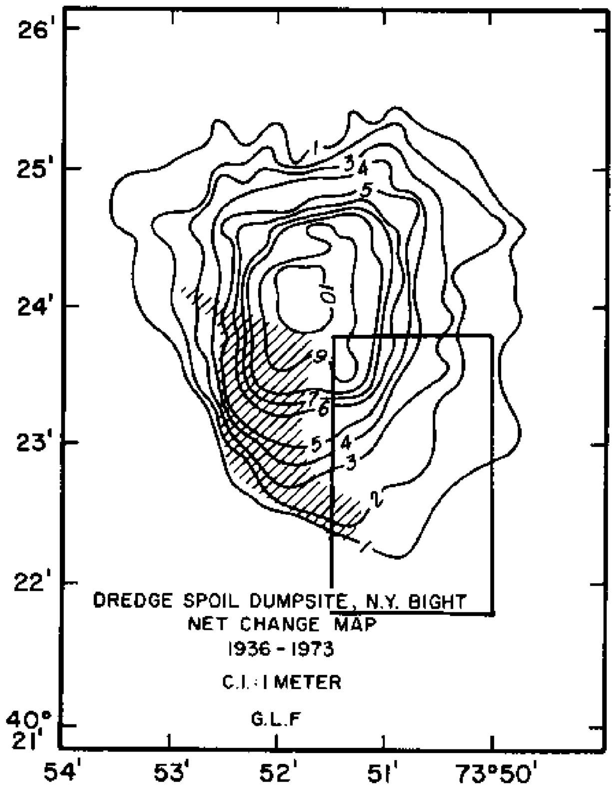
Streaky, patchy, and rough textures in the sonograph in Figure 9 are associated with the



1973



1936



net change 1936 to 1973

Note: The 198° azimuth and 90 ft isobath define designated dumpsite in 1936: this approximate area has been shaded for reference in the other two figures.
Units are meters.

Source: From Freeland and Merrill 1976

Figure 8. Bathymetry of apex dredge-spoil dumpsite, 1936 and 1973. Rectangular area encloses new dumpsite for dredge spoil.

dredge-spoil and cellar-dirt dumpsites and are probably related to individual dumpings from barges.

Suspended sediment studies were initiated in the Bight apex in 1973 along with chemical and physical oceanographic data. At 25 stations, water samples taken at the surface, at 10 m (33 ft), and at the bottom were filtered and examined. The data indicate the existence of a fair-weather, clockwise current-circulation gyre, driven in part by the southwesterly drift of offshore shelf water (Map 51) (Drake 1974). This has been verified by current meter studies in the apex (Charnell and Hansen 1975). Part of the total suspended load in the apex is red-orange ferric hydroxide particles (Map 52) generated by iron precipitation from acid waste dumping. These particles are excellent tracers of suspended sediment circulation as they remain suspended and are easily identifiable. The vertical distribution of suspended sediment shows high values near the surface and very high values in the near-bottom nepheloid layer, typical of shelf areas (Figure 10). This layer may transport much of the suspended particulate matter and associated contaminants.

The US Army Corps of Engineers Coastal Engineering Research Center (CERC), Ft. Belvoir, VA, conducted extensive shallow-penetration seismic surveys and vibracoring for a sand resource study (Williams and Duane 1974; Williams 1975) in the Bight apex (Map 53). In tracing the history of dumped materials, Williams calculated the net change in bottom topography from 1845 to 1936 (Map 54) and found that most changes during that time were anthropogenic (man-induced).

Hudson Shelf Valley

Only preliminary results are available from NOAA studies of Hudson Shelf Valley. There is a concentration of fine-grained sediment in enclosed lows in the valley axis, muddy sand in the remainder of the valley axis, and coarser sediment up the flanks of the valley and onto the shelf (Map 55).

Two mid-shelf areas were investigated as alternative dumpsites for sewage sludge and possibly dredge spoil from the New York metropolitan region. In the northern area (2D1 on Map 41), a sampling grid was placed partly over a tributary valley of the

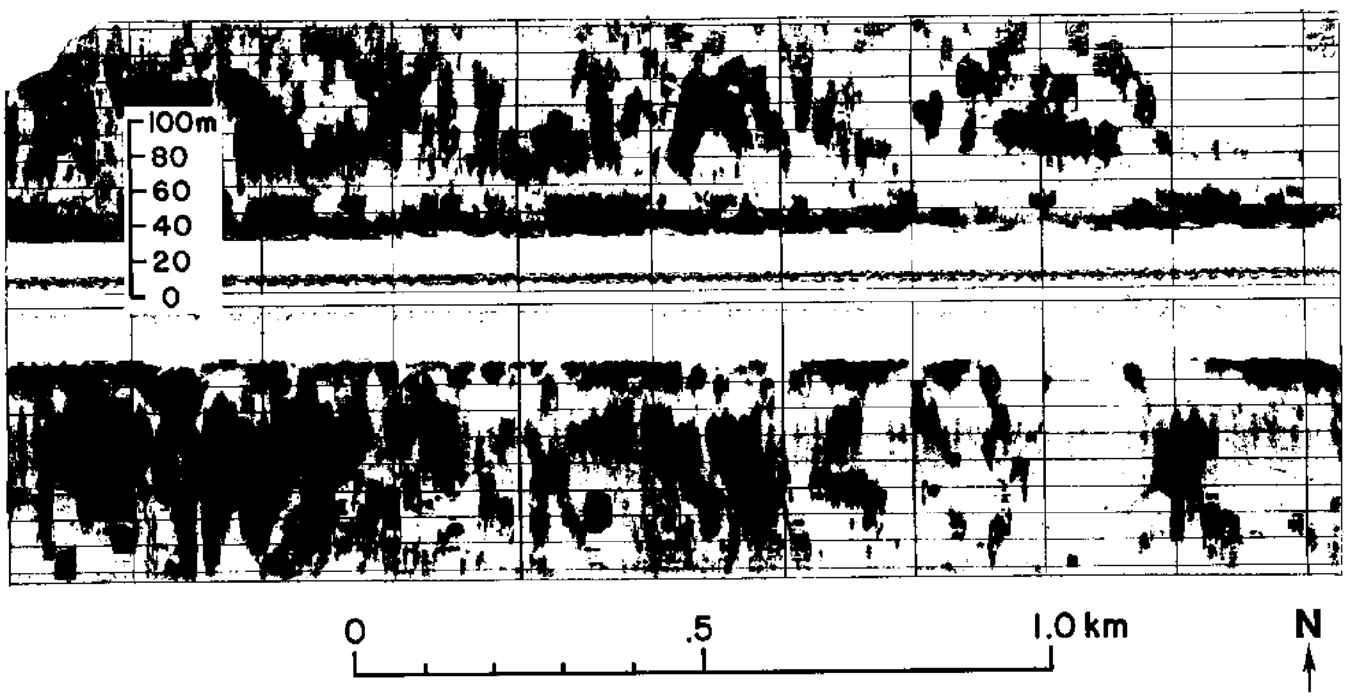
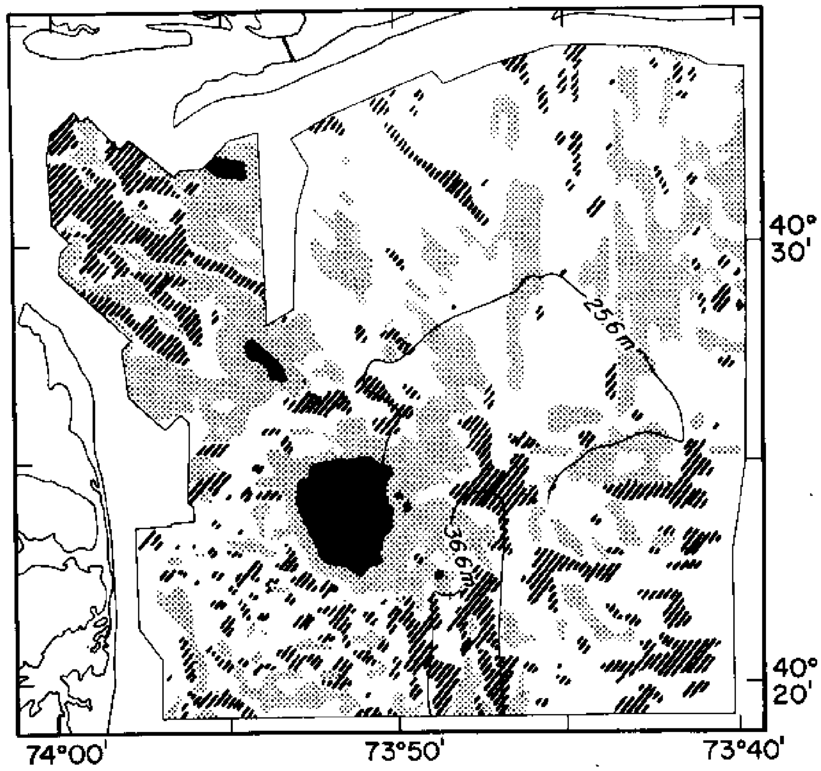


Figure 9. Sonograph of patchy texture north of apex cellar-dirt dumpsite. Dark areas are coarse, rubby material, probably artifact gravel from dumping; light areas are muddy sand. From Freeland, Swift and Cok, in press.

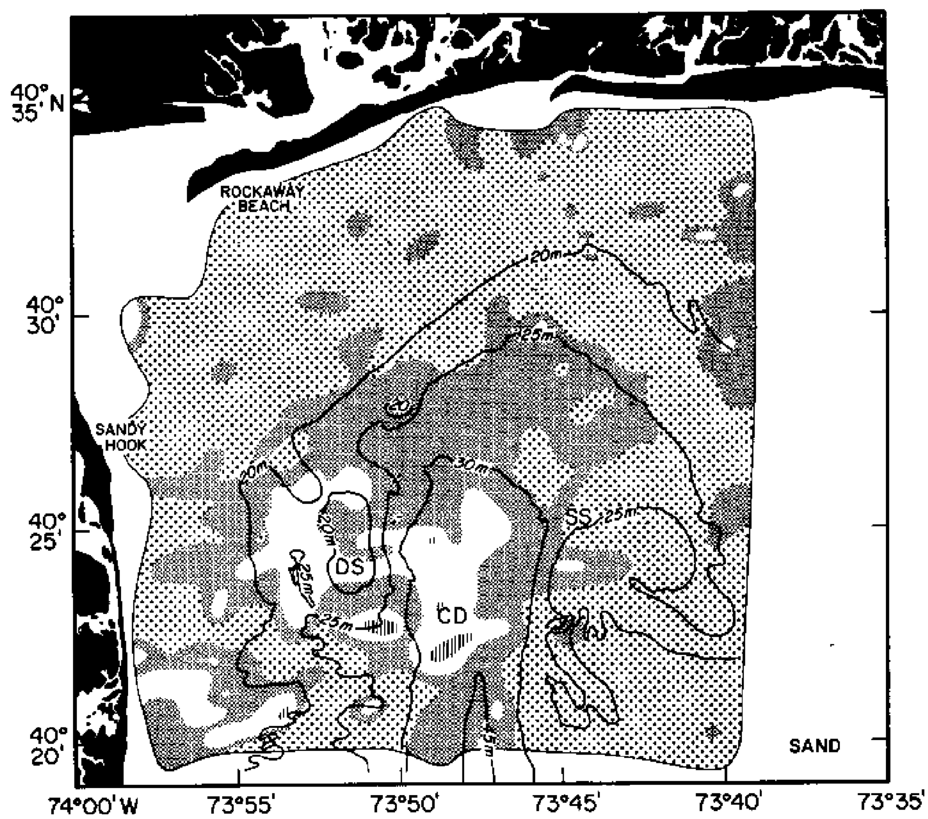
Map 44. Bight apex bathymetric net change, 1936-1973



DEPOSITION 0-1.8 m
DEPOSITION >1.8 m
EROSION 0-0.6 m
EROSION >0.6 m

Source: Freeland, Swift, and Cok, in press

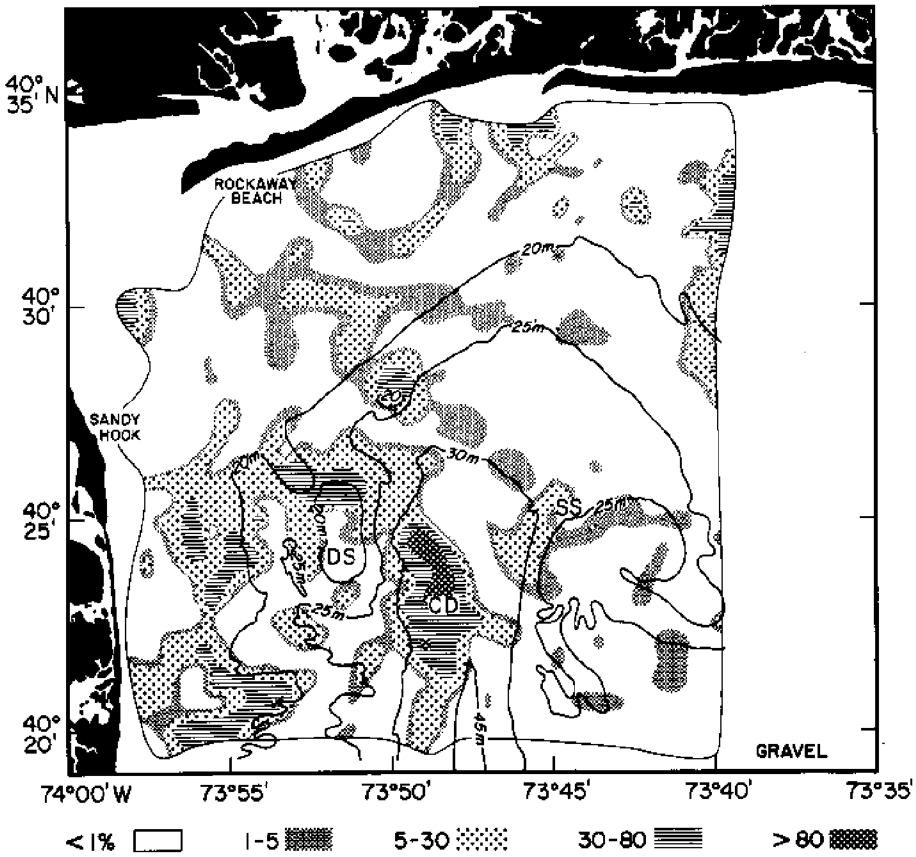
Map 45. Bight apex percent sand



< 10%   10-50   50-90   >90

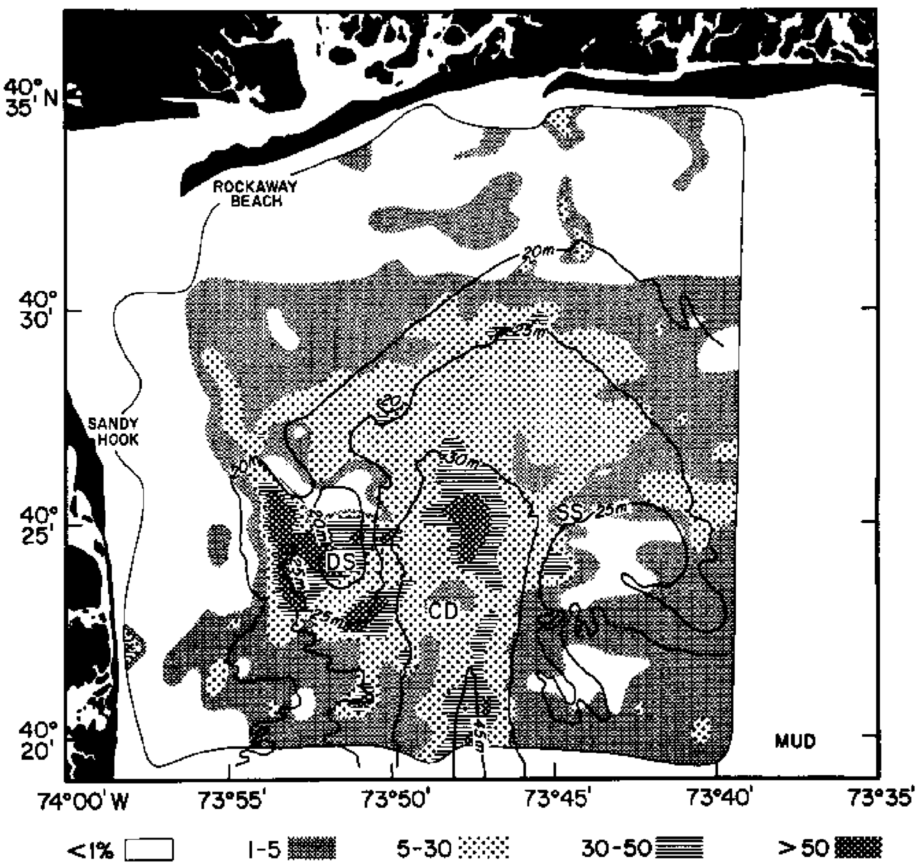
Source: Freeland and Merrill 1976

Map 46. Bight apex percent gravel



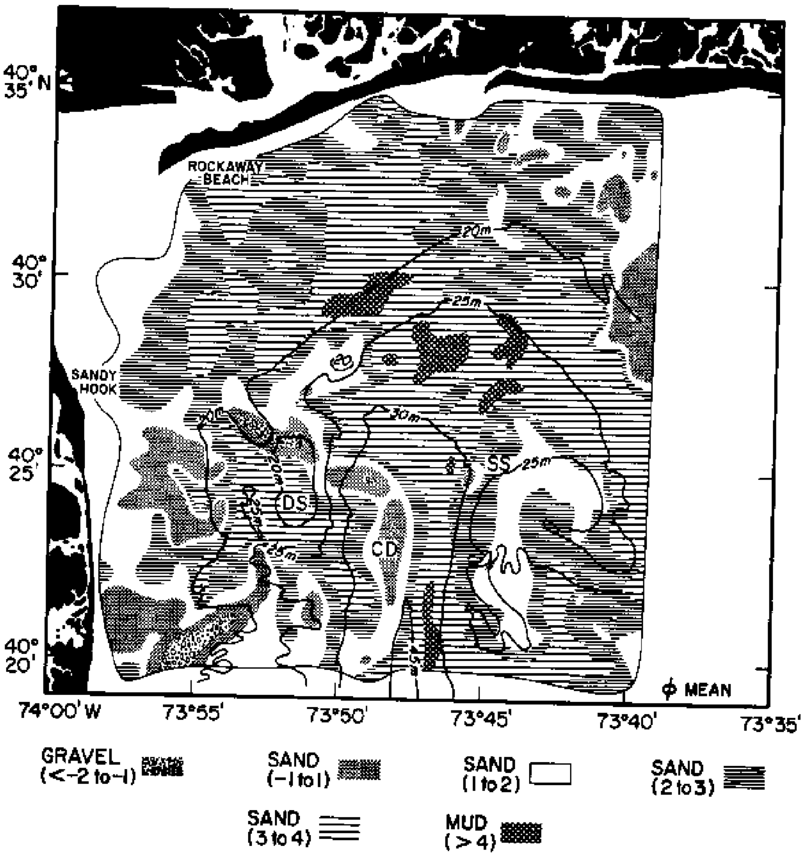
Source: Freeland, Swift, and Cok, in press

Map 47. Bight apex percent mud



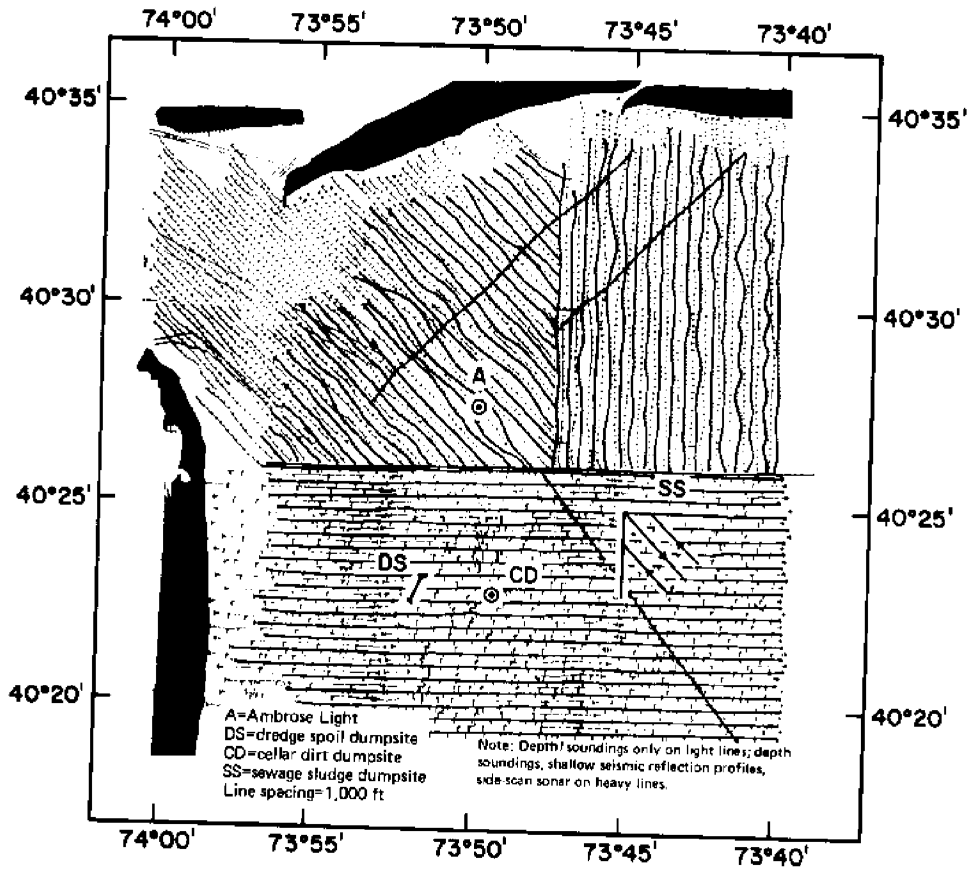
Source: Freeland, Swift, and Cok, in press

Map 48. Bight apex phi mean



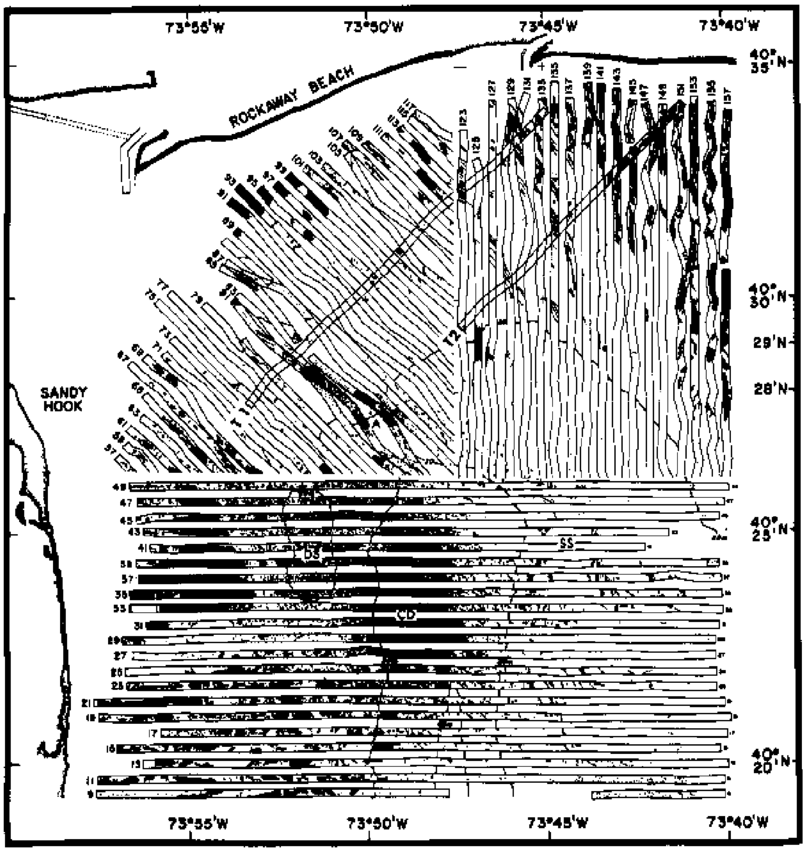
Source: Freeland, Swift, and Cok, in press

Map 49. Tracklines from 1973 NOAA survey in Bight apex



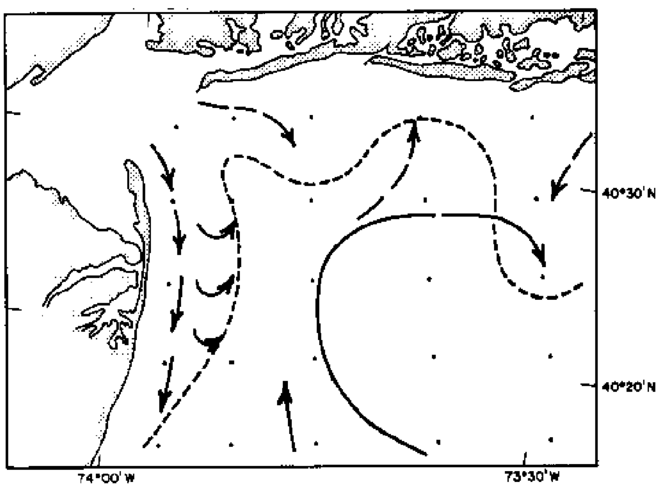
Source: Freeland, Swift, and Cok, in press

Map 50. Bight apex composite of sonographs



Source: Freeland, Swift, and Cok, in press

Map 51. Fine sediment transport in Bight apex, autumn 1973



mean position of boundary between more turbid coastal water and less turbid offshore water

persistent regional currents

From Drake 1974

Source: Drake 1974

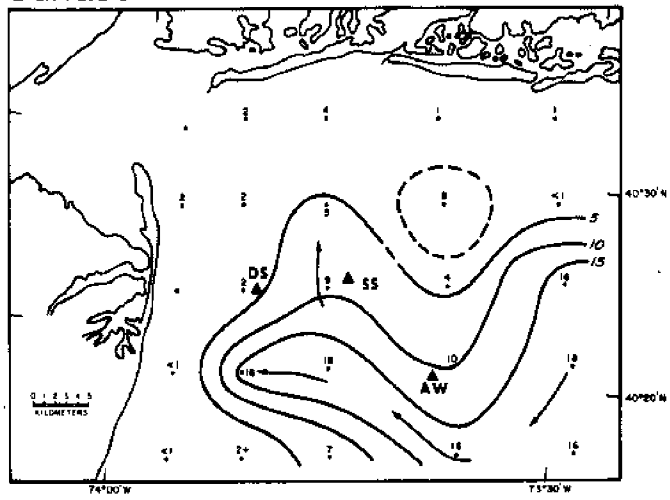
ancestral Long Island River system. The surficial sediments consist of sand (Map 56) with some patches of more than 5% gravel: fine sands in the northeastern part of the area, coarse to medium sands in the western and southern parts, and a gravel deposit (up to 39% gravel) at one station, associated with an area of coarse medium sand in the southern part. Only two stations contained over 5% mud (5.7% and 8.2%). Bottom photographs showed a smooth, slightly undulatory, mounded or rippled bottom. Side-scan sonar records revealed elongated dark areas, which may be *erosional windows* exposing basal Holocene pebbly sand through the Holocene sand sheet or which may be areas of higher percentages of large shell fragments.

The southern alternative dumping area (2D2 on Map 41) was centered over the broad, flat high of Hudson divide (Map 57). To the northeast the bottom grades gently into Hudson Shelf Valley; to the west lies deeply incised, northeast-trending ridge and swale topography. Grain-size patterns appeared related to bottom topography: coarse sand and gravel deposits lay on the crest and east flank of Hudson divide; medium and fine sand occurred in the ridge and swale topography (Map 58). These distributions point to the winnowing of fine sediment from the crest and east flank of the divide and deposition to the west. Submersible observations in a particularly deep trough (Veatch and Smith trough) revealed a veneer of shelly, pebbly sand with large, angular, clay pebbles and occasional oyster shells from the underlying early Holocene lagoonal clay. Seismic data also revealed that the *reflector* associated with this surface outcrops on the ridge flank. Storm-generated currents from the northeast apparently winnowed the east flank of Hudson divide and formed or maintained the ridge and swale topography on the west side of the divide.

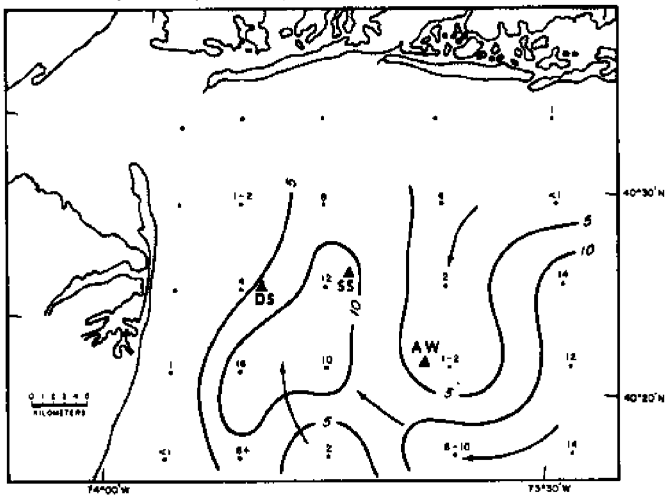
Solids in suspension at all levels of the water column in the alternative dumping areas were predominantly combustible plankton and their noncombustible remains. Total suspended matter concentration in surface water was from 100 to 500 μg/l, comprised of 5% or less terrigenous matter, 80% combustible matter, and 15% siliceous and *calcareous* noncombustible planktonic remains (D.E. Drake, personal communication). Subsurface water suspended matter concentration was somewhat less than surface water suspended matter concentration, except

Map 52. Distribution of ferric hydroxide particles in water column, November 1973

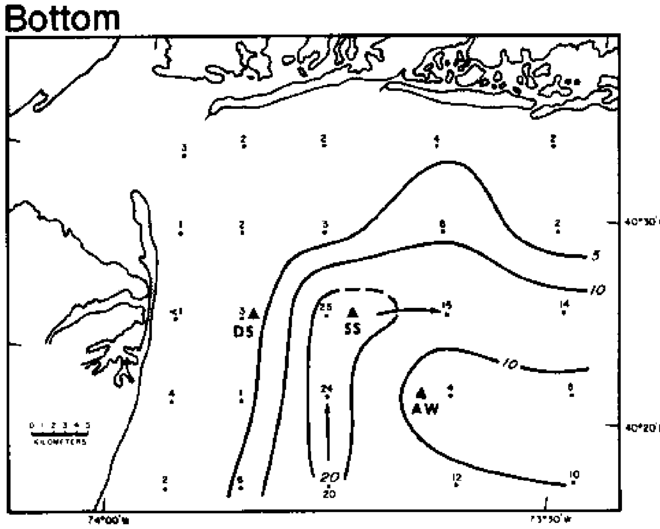
Surface



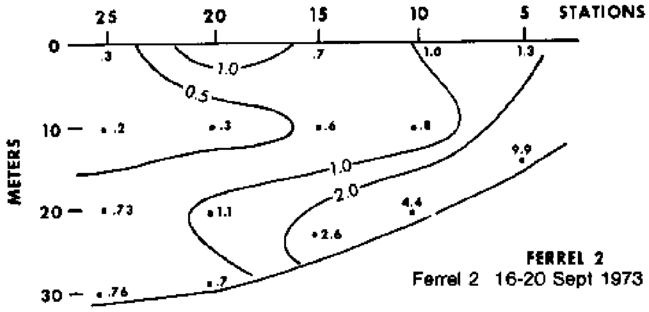
Mid-depth (10 m)



Bottom



Units are grains x 10^3/l.   Source: Drake 1974 in the nepheloid layer 5 to 10 m (16 to 33 ft) above the bottom. There, suspended matter concentrations were 500 to 2,000 μg/l, consisting of 10% to 20% terrigenous matter, 30% to 60% combustible matter, and 50% to 80% noncombustible matter (D.E. Drake, personal communication). Textural properties of bottom sediments in the alternative dumpsites showed that very little sediment finer than 62 microns was deposited.



Source: Drake 1974

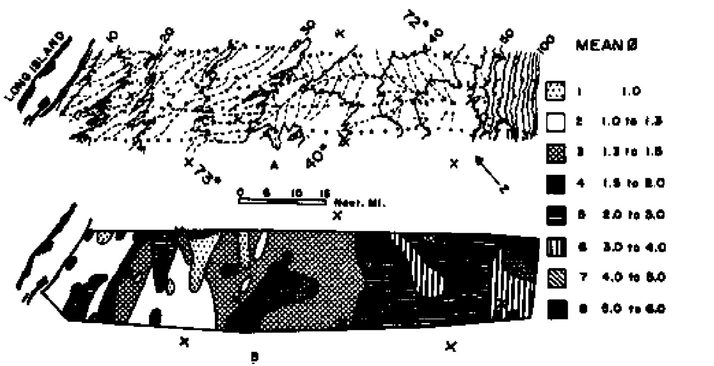
Figure 10. Vertical distribution of total suspended sediment load off Long Beach, LI

Long Island Shelf

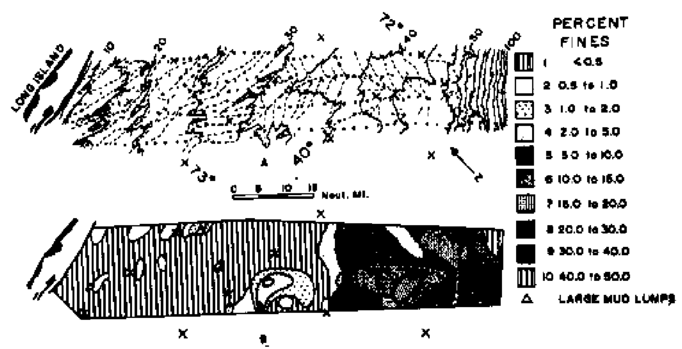
Several studies have been made or are underway along the south shore of Long Island. NOAA studies are concentrating in the western nearshore area (LINS and SCOA areas on Map 41; see also Map 60). Adelphi University (Garden City, LI) personnel studied a Fire Island ridge and swale area (3A on Map 41; see also Map 62) (Chiang 1974; Dietrich 1975) and CERC completed a study of seismic and vibracore data for the entire south shore from Montauk Point to the Bight apex (Maps 61, 63, and 64) for sand inventory (Williams 1976) and for beach erosion studies (Taney 1961*a*,*b*). Most of the sediment in the nearshore area is fine to medium sand with occasional patches of both finer and coarser material (Map 64).

McKinney and Friedman (1970) studied a Long Island shelf transect from the shoreline to the 183 m (600 ft) isobath similar to the Frank and Friedman (1973) study across the New Jersey shelf (Figure 11). On the inner shelf (0 to 46 m or 0 to 150 ft) and middle shelf (46 to 64 m or 150 to 210 ft), there were clean sands; on the outer shelf (deeper than 64 m or 210 ft) there were muddy sands. Muddy sands also occurred in erosional remnants on the middle shelf and inside shells buried in the clean sand facies. This evidence supports the view that the outer muddy sands facies is relict (Garrison and McMaster 1966) and that the sharp change to the sandy facies shoreward of the 64 m (210 ft) isobath resulted from winnowing of a formerly extensive area of muddy facies.

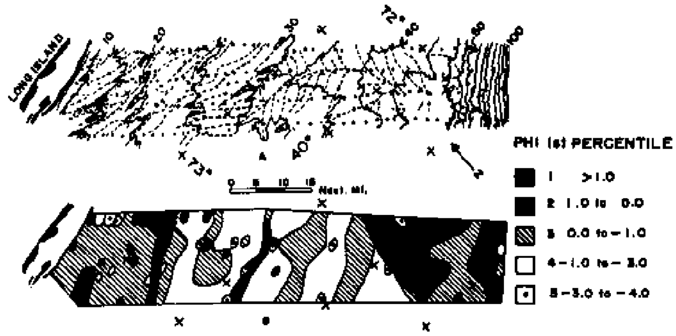
Textural analysis showed that most of the shelf sands appear to have been initially deposited in nearshore environments; many of the mid-shelf sands had textures suggesting surf-zone deposition. Outer-shelf sands appeared to have been swept by currents



a. Long Island shelf transect. A. Sample locations and bathymetry (contour interval 5 fathoms). B. Mean grain size map.



b. Long Island shelf transect. A. Sample locations and bathymetry (contour interval 5 fathoms). B. Percentage of fine sediments (less than 62 microns).

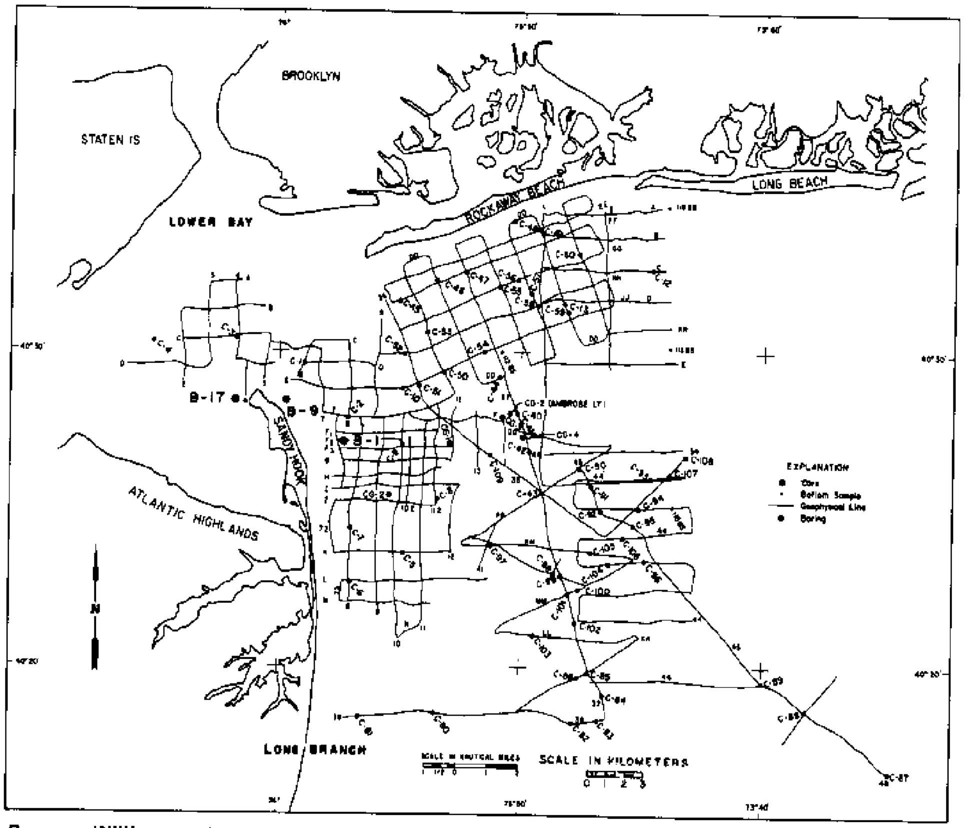


c. Long Island shelf transect. A. Sample locations and bathymetry (contour interval 5 fathoms). B. First percentile values (in ϕ units) of size distribution.

Source: From McKinney and Friedman 1970

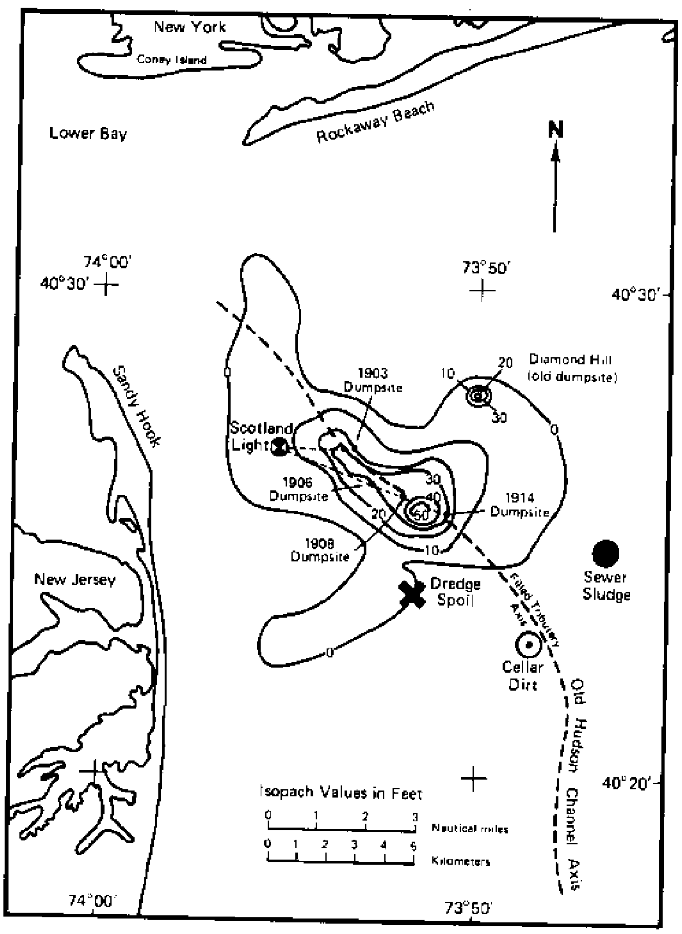
Figure 11. Long Island shelf transect, surficial sediment composition

Map 53. Bight apex CERC geophysical tracklines and core locations



Source: Williams and Duane 1974

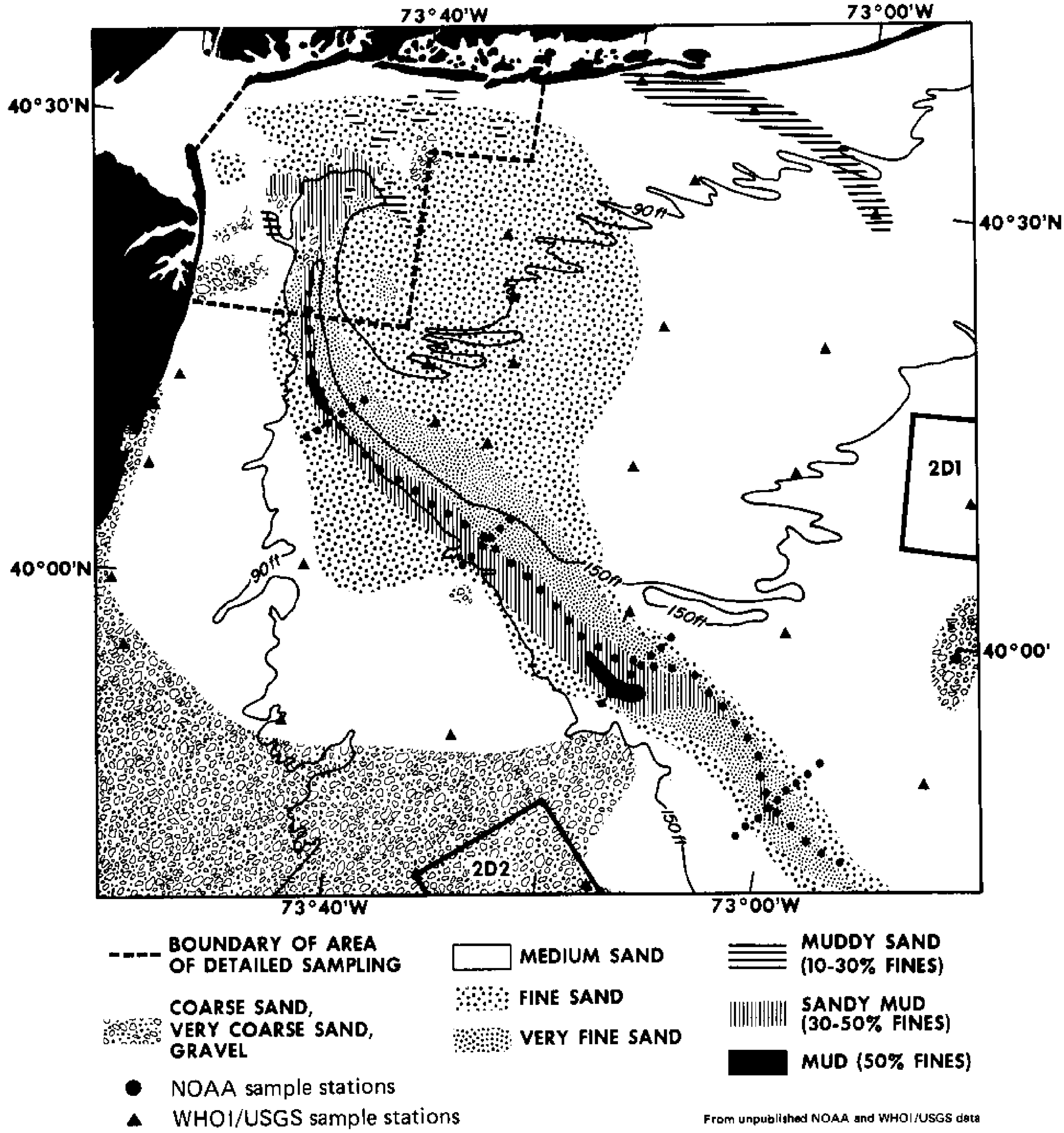
Map 54. Bathymetric net change, 1845 to 1936, Bight apex



Source: Williams and Duane 1974

Mercator Projection

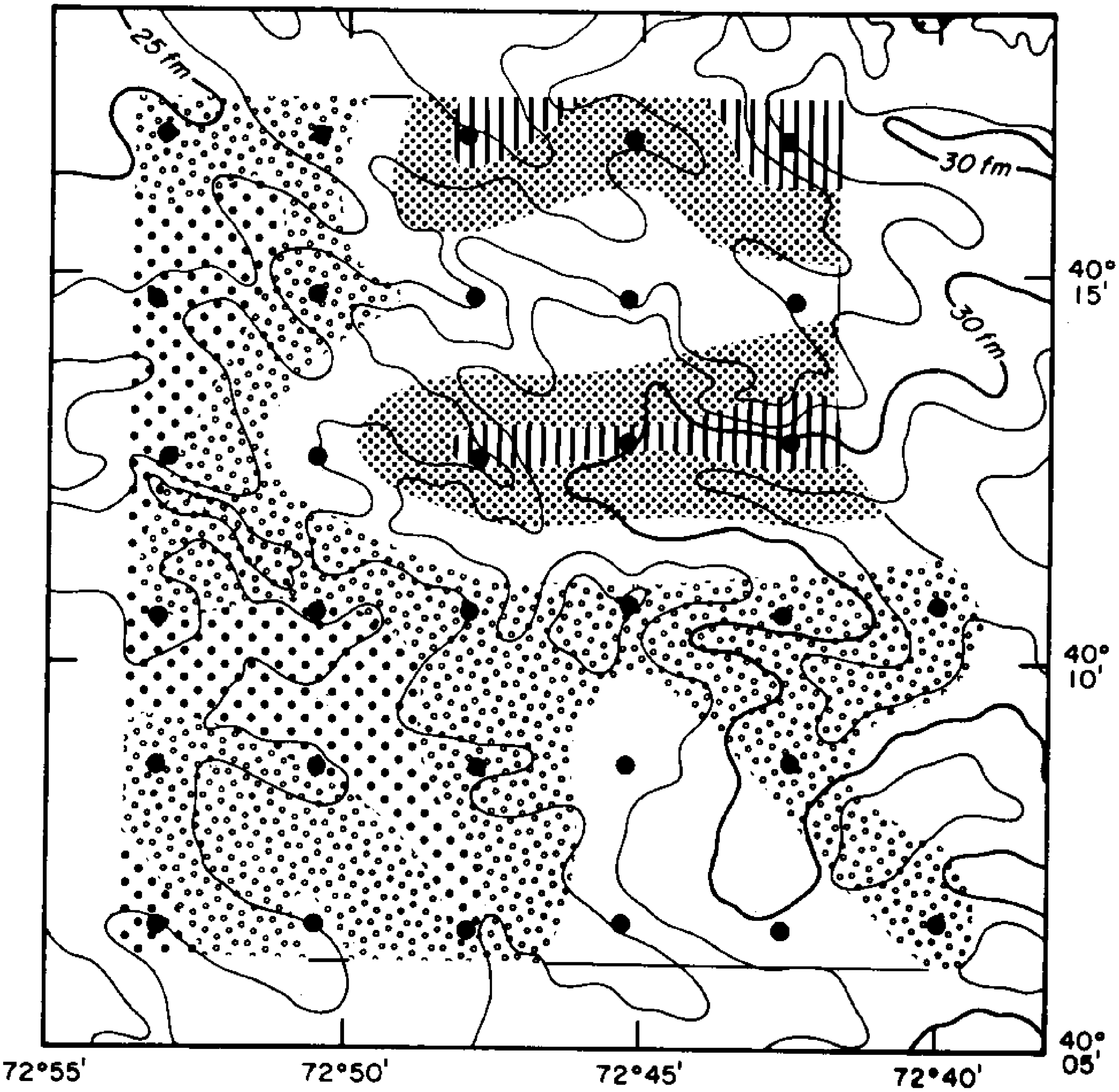
Map 55. Bottom sediment types in Hudson Shelf Valley



from shoal areas northeast of the transect area into the embayment formed by the flooding of the ancestral Long Island River system, then spread southwestward and mixed with coarse basal sands of the transgression.

A comparison of the Long Island and New Jersey transect study areas shows only minor differences north and south of Hudson Shelf Valley, despite the proximity of the Long Island transect to the Pleistocene ice sheet, which terminated on Long

Map 56. Grain-size distribution of sand-sized fraction, area 2D1 on Map 41



contour interval 1 fm
● sample stations

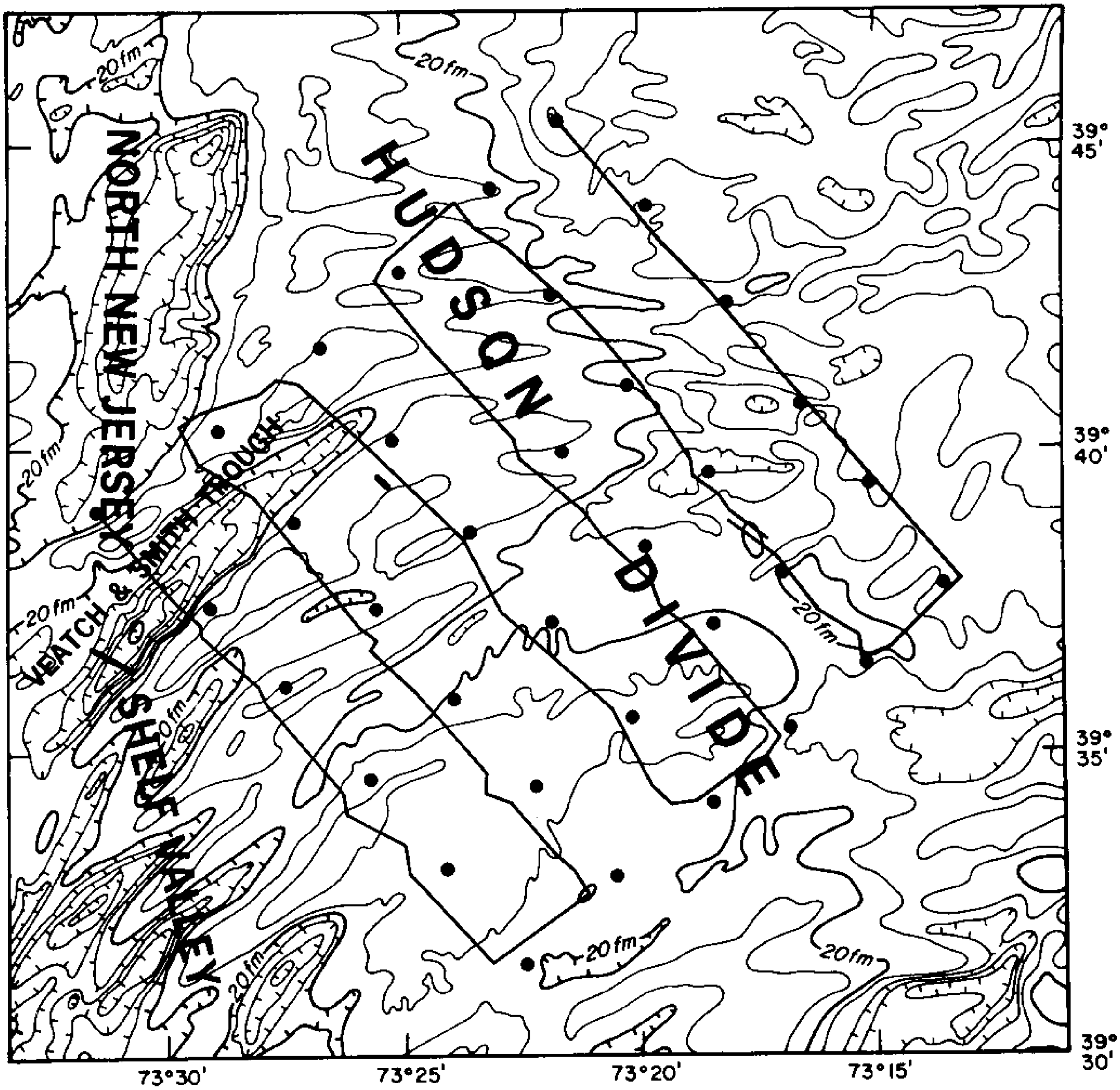
1.00 - 1.24 ϕ
1.25 - 1.49 ϕ
1.50 - 1.74 ϕ
1.75 - 1.99 ϕ
} MEDIUM SAND

> 2.00 ϕ FINE SAND

Bathymetry from Stearns and Garrison 1967
Source: From unpublished NOAA data

Island (Frank, McKinney, and Friedman 1972). Both areas contained thin sheets of sands and gravels overlying silty sands and clays deposited in a *lagoonal back-barrier facies,* and both were extensively winnowed during the Holocene transgression. On the New Jersey shelf, winnowing almost completely removed material finer than sand; on the Long Island shelf, winnowing reworked a formerly extensive mud deposit so that muds (exclusive of the small inshore mud patches off the south shore of Nassau and Queens counties) are now found only seaward of the 64 m (210 ft) isobath.

Map 57. Morphologic features, area 2D2 on Map 41



LEGEND
- ● Smith–MacIntyre bottom grab sample and photo station
- —— geophysical trackline
- ▬▬ submersible dives

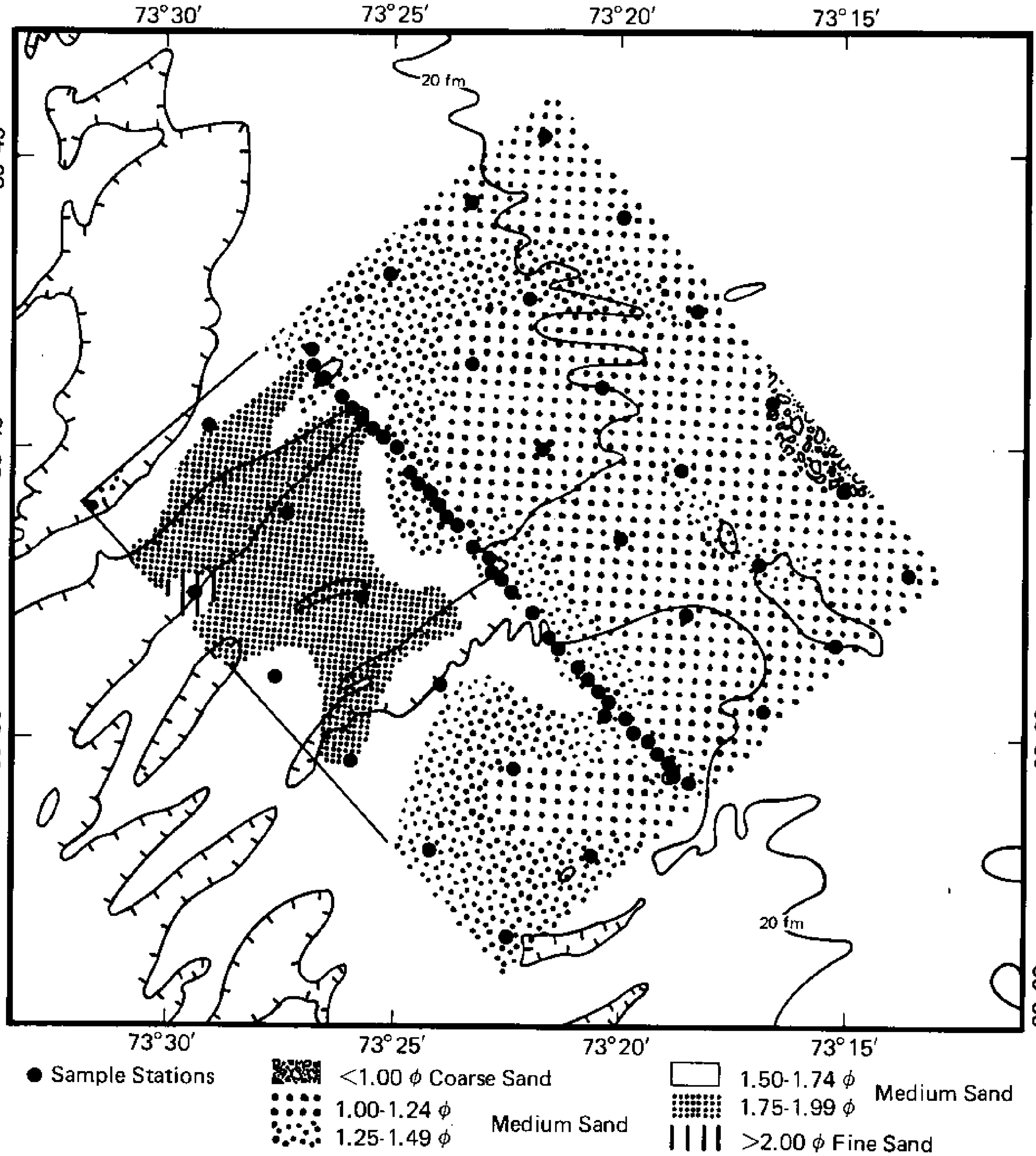
Contour interval 1 fm

Bathymetry from Stearns and Garrison 1967
Source: From Freeland and Swift 1975

Continental Shelf Edge, Submarine Canyons, and Continental Slope

Data for the Atlantic continental shelf edge and slope came from regional studies of the continental margin by the USGS/WHOI group, (Stetson 1949; Uchupi 1963, 1968, 1970; Hoskins 1967; Emery and Ross 1968; Emery and Uchupi 1972; Gibson, Hazel, and Mello 1968; Garrison 1970; Hathaway 1971; MacIlvaine 1973) and from other studies of smaller areas. Stanley studied Wilmington Canyon (Stanley and Kelling 1970; Stanley and Unrug 1972; Stanley and

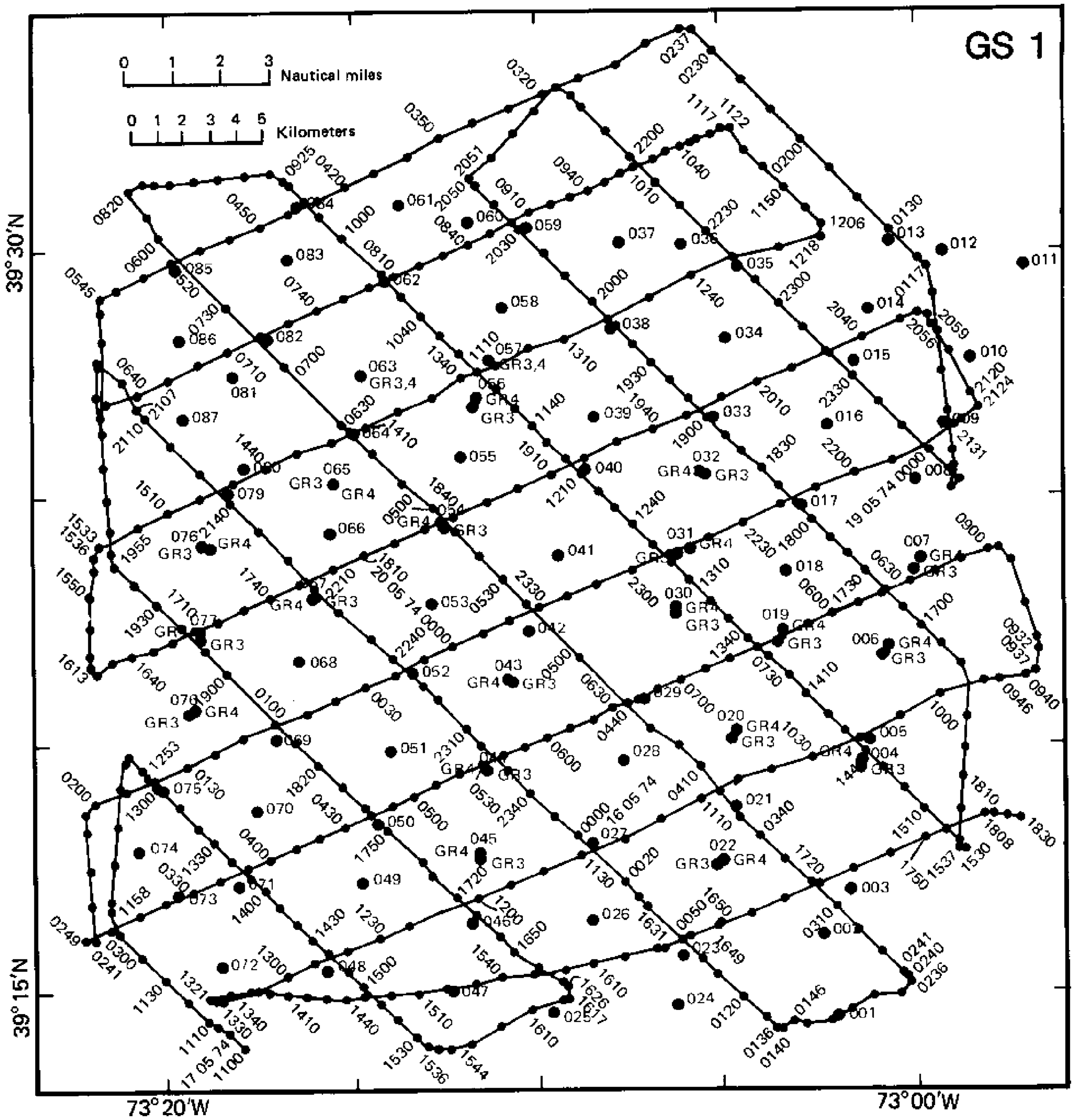
Map 58. Grain-size distribution of sand-sized fraction, area 2D2 on Map 41



Source: From Freeland and Swift 1975

Fenner 1973) and the shelf break to the south (Wear, Stanley, and Boula 1974). He reported sand spilling from the shelf into the canyon axis to be more extensive on the east wall, reflecting predominant sediment transport to the west. There was also a rapid decrease in shell fragments below the shelf break. The distribution of Pleistocene blue clay fragments in the head of Wilmington Canyon pinpointed the presence of rock exposures and erosion by rock fall and slumping along the upper canyon walls; increased bottom firmness on the east canyon wall reflected the presence of sediment tongues coarser than those of

Map 59. USGS geophysical tracklines and bottom grab sample locations

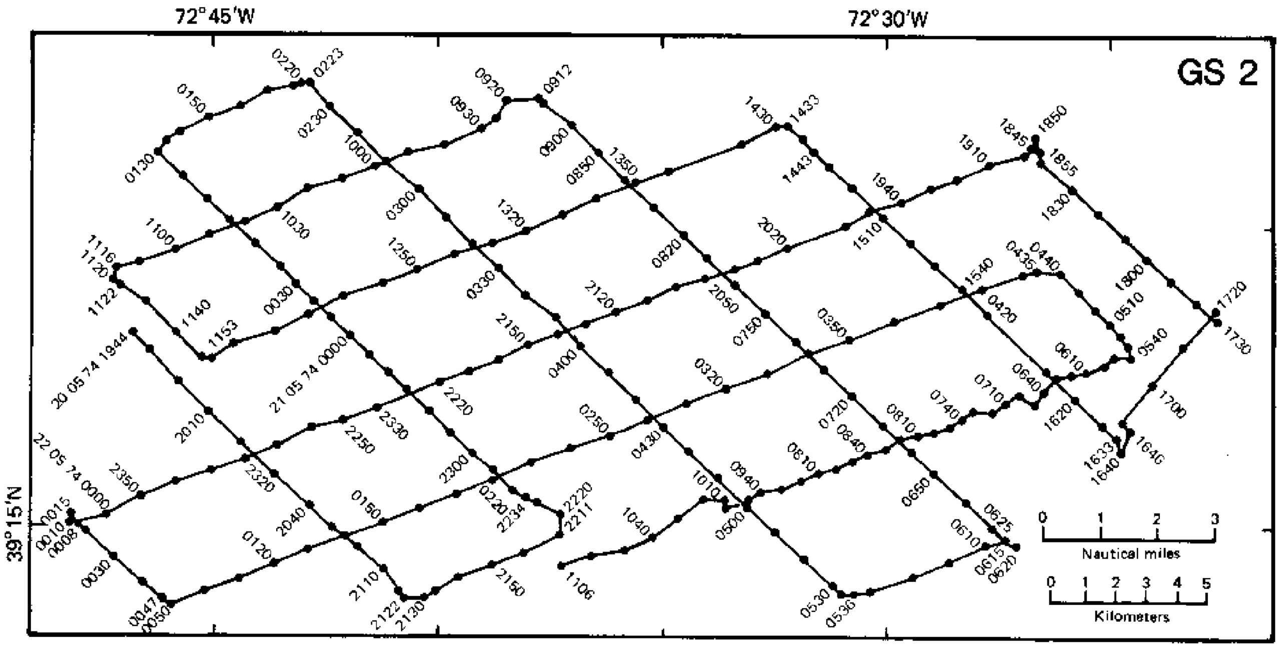


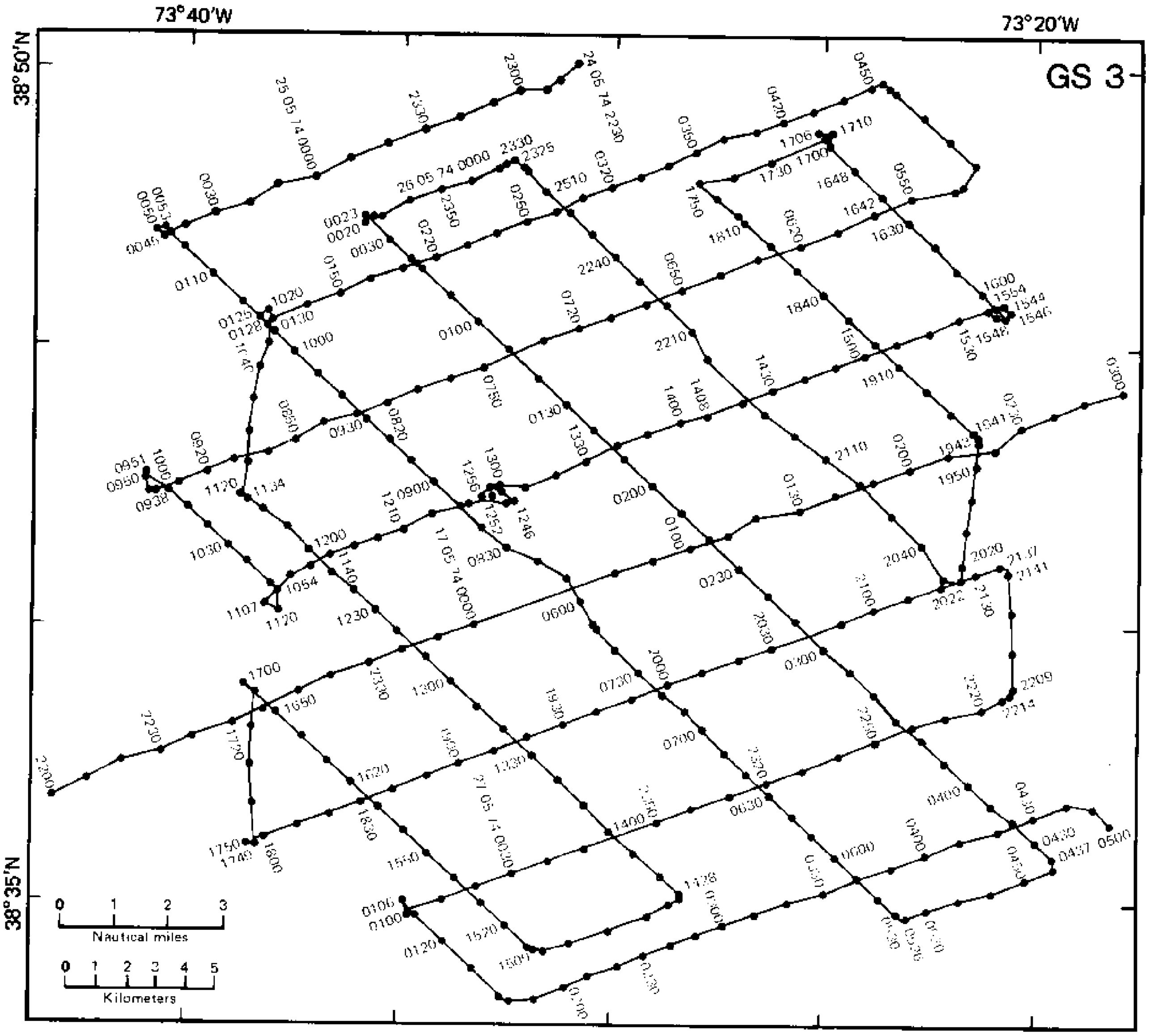
Source: From Knebel and Spiker 1977

the west wall. Finally, suspended matter concentrations in the nepheloid layer were observed to be higher landward of the shelf break and slightly to the west of the canyon than in the canyon proper. This is possibly the downcurrent tail of fines stirred up from slumping on the canyon's east side and carried landward by upcanyon currents.

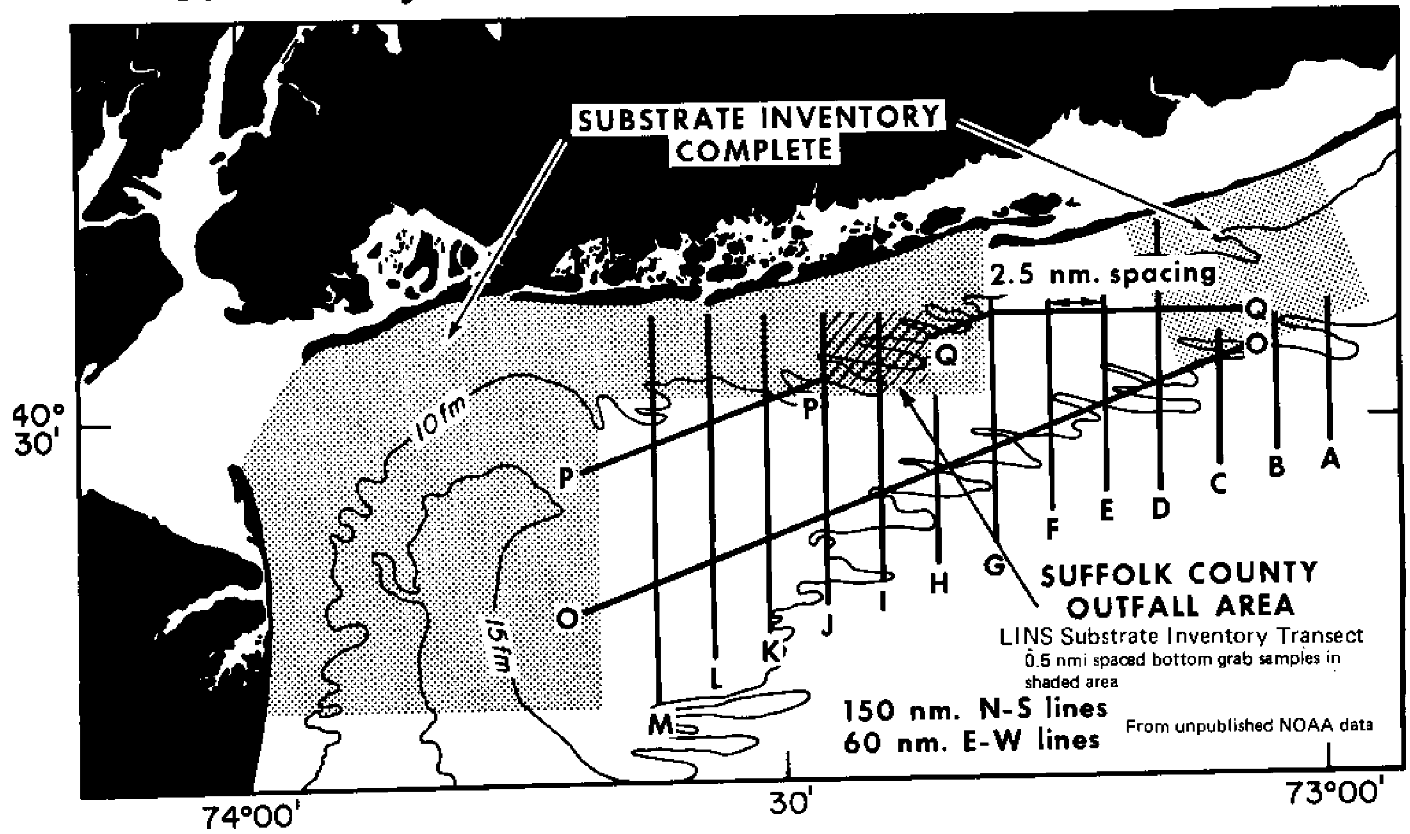
NOAA studies are in progress in Hudson Canyon (Keller et al 1973; Rowe et al 1974), in Wilmington, Washington, and Norfolk canyons to the south, and in Hydrographer Canyon to the northeast. Extensive geophysical surveys of the intervening continental slope are also being conducted (Bennett et al, in press; McGregor and Bennett, in press; McGregor, in press).

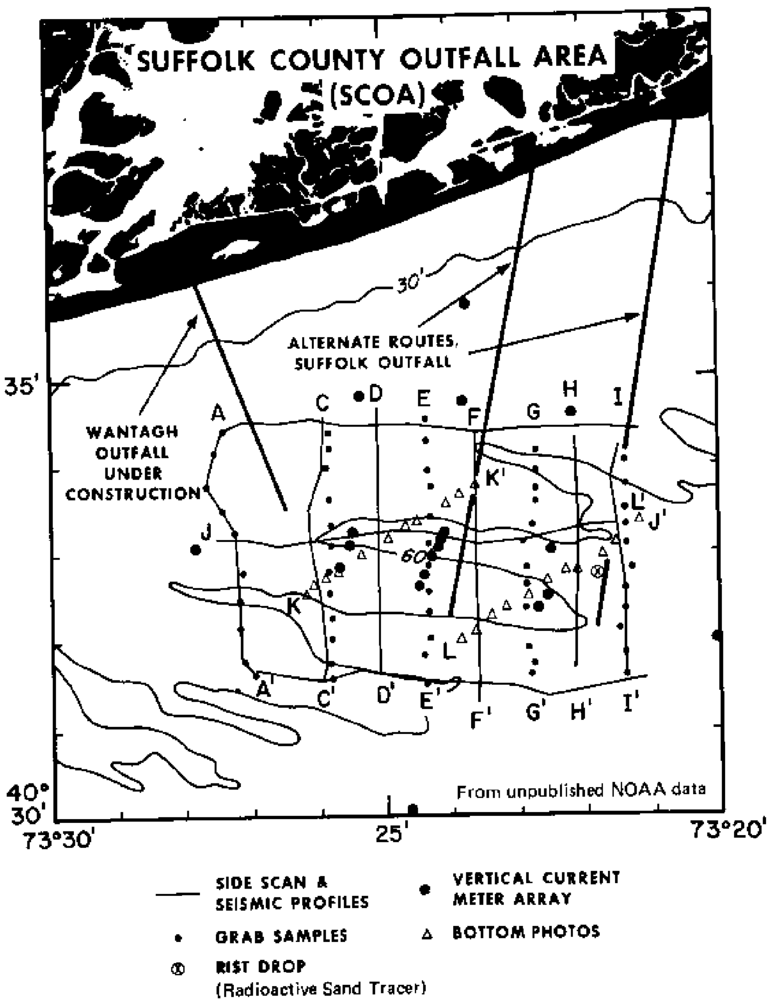
USGS geophysical tracklines and bottom grab sample locations



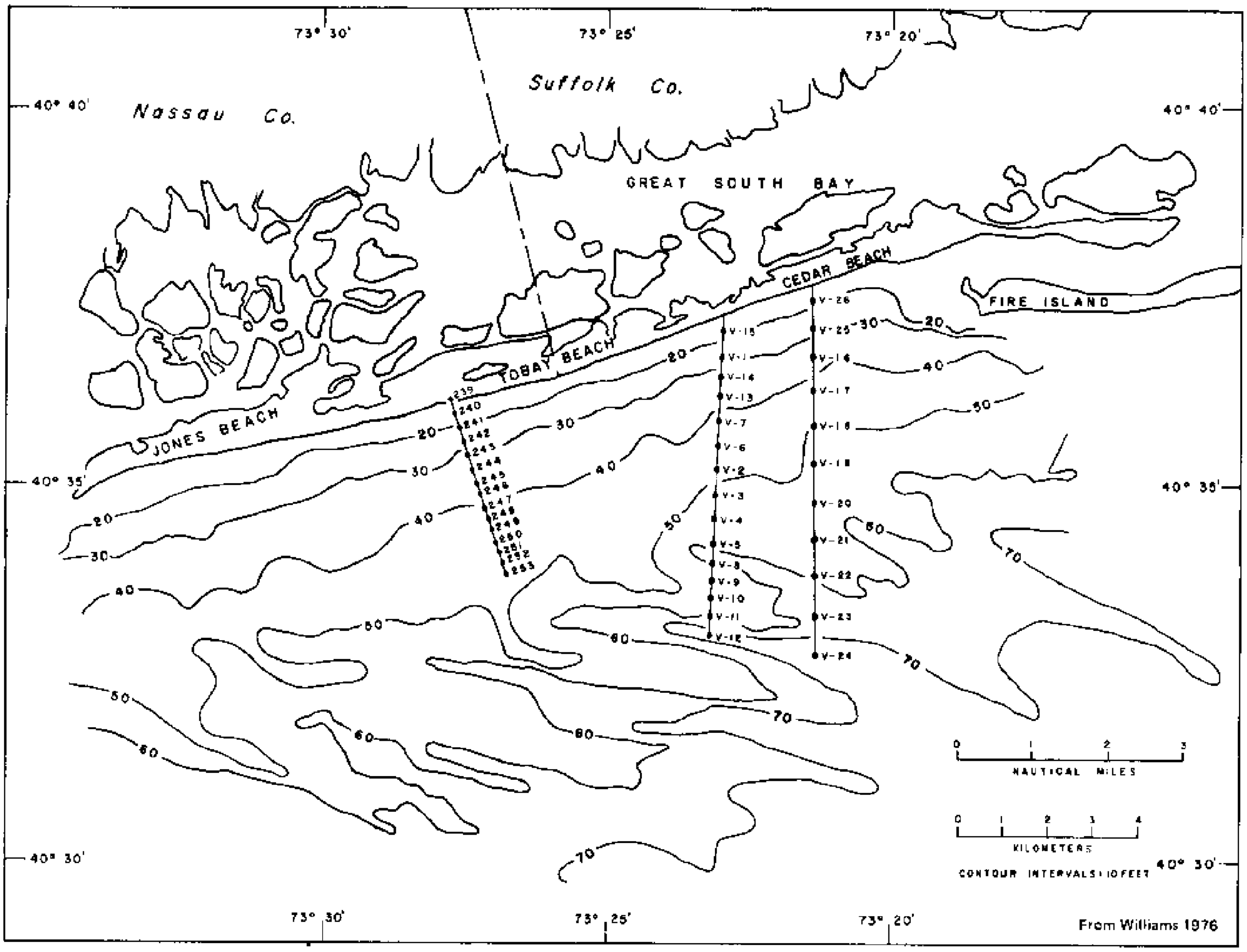


Map 60. Long Island nearshore study area and Suffolk County outfall study area



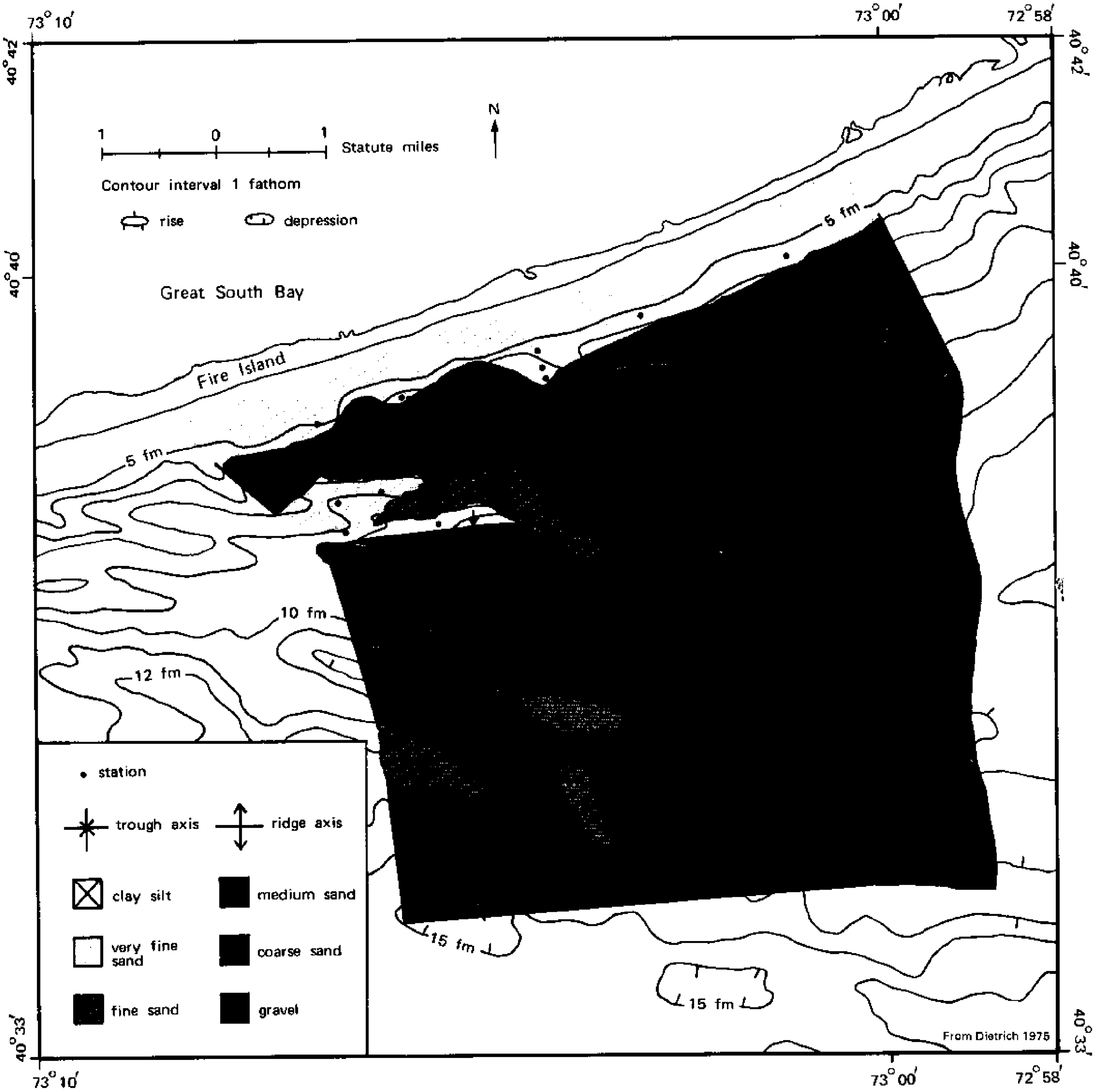


Map 61. CERC vibracore locations for proposed Suffolk County sewer outfall studies



The continental slope and rise continue to accumulate modern sediment, although in submarine canyons and gullies deposition and erosion alternate. Sedimentation rates are poorly defined at present. Holocene accumulation on the upper slope and upper rise off southern New England has been greater than 15 cm (6 in)/1,000 years, whereas lower slope rates are less than 2 cm (0.8 in)/1,000 years (MacIlvaine 1973). The high sedimentation rates and numerous massive *slump deposits* shown in upper-slope cores and seismic profiling indicate both deposition and erosion were greater during the Pleistocene than at present. Deposition rates on the upper slope and rise south of Hudson Canyon are reported to average 6.8 cm (2.7 in)/1,000 years and on the lower rise 3.4 cm (1.3 in)/1,000 years (Ericson et al 1961).

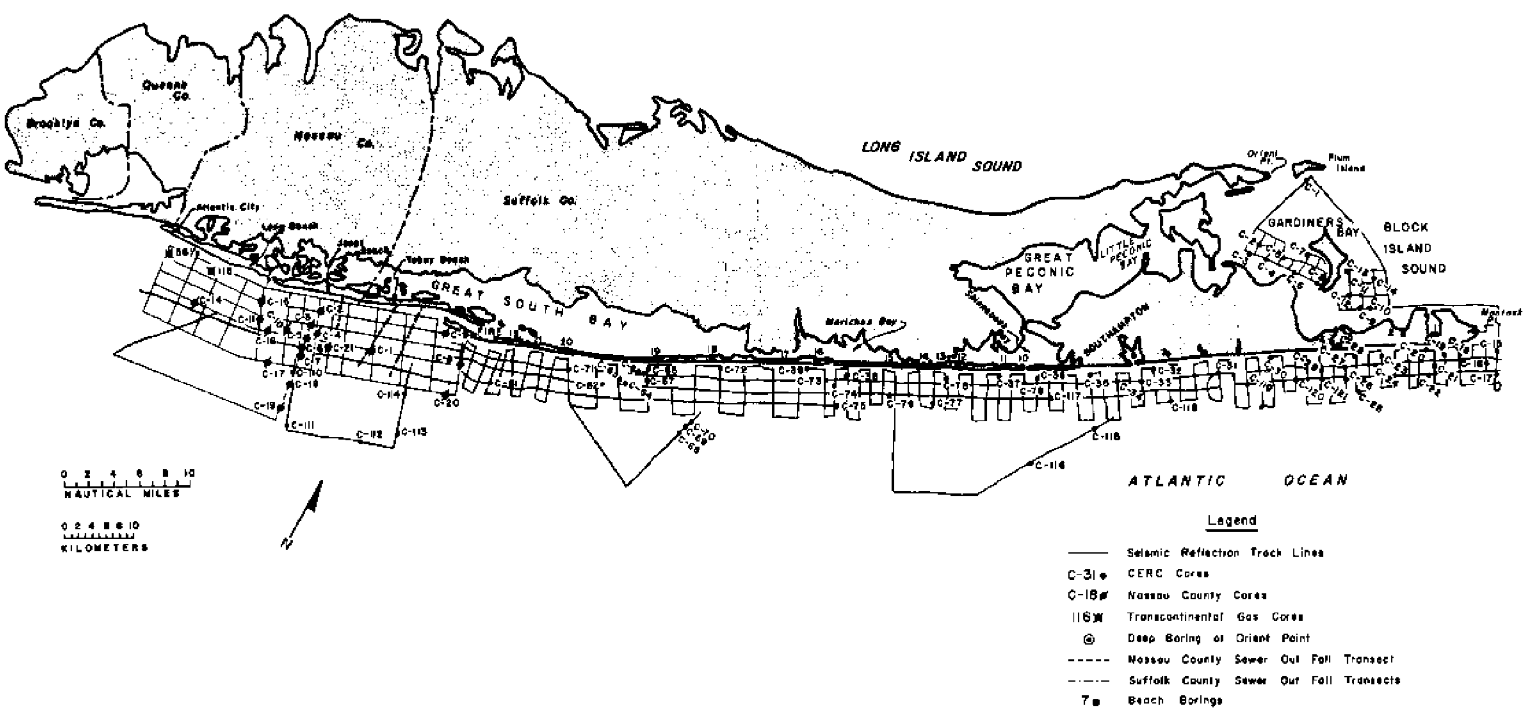
Map 62. Fire Island ridge and swale study area 3A on Map 41



Other Areas

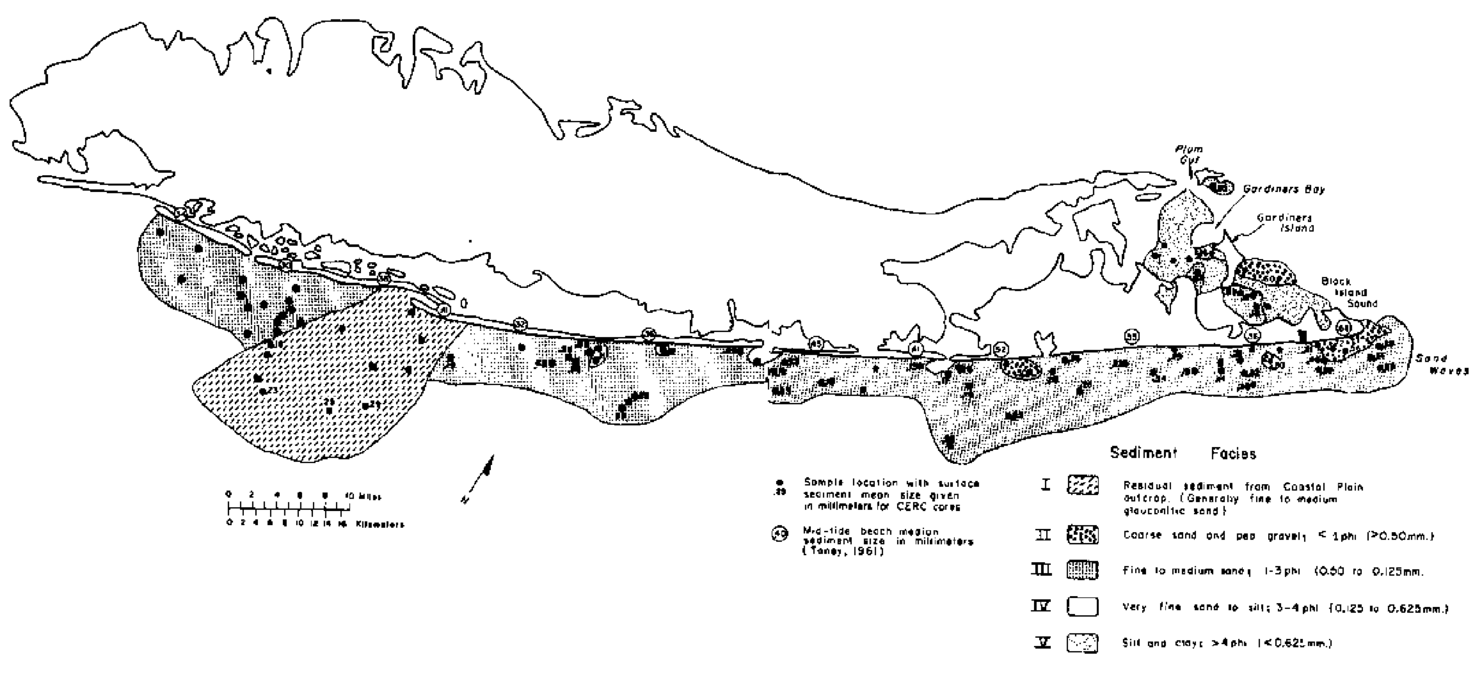
In 1951, a Cornell University team under a US Navy contract took 84 bottom grab samples in Long Island Sound, along the Long Island inner shelf, and on the northern New Jersey inner shelf (Ayers 1953). An additional 353 stations were occupied along two slightly diverging transects extending some 83 km (45 nmi) southeastward from the vicinity of Ambrose Light. Bottom grab samples and short cores (1 m or 3 ft) were collected at these stations. Sediment type was mapped from these data, and depth of unconsolidated sediment was mapped from published (Hobbs 1905; Berkey 1911; Suter, DeLaguna, and Perlmutter 1949; Ewing et al 1950) and unpublished data.

Map 63. Long Island south shore CERC tracklines and vibracore locations



Source: From Williams 1976

Map 64. Long Island south shore surficial sediment



Source: From Williams 1976

Summary

The surficial sediment of New York Bight is a sheet of sand 0 to 10 m (0 to 33 ft) thick, resting on early Holocene lagoonal and estuarine clays. The basal 20 cm (8 in) of the sand sheet consists of coarse sand, gravel, and *shell hash*, which is exposed where the sand sheet is very thin. Occasionally the underlying clay layer is exposed in troughs between ridges. Over the shelf edge, Pleistocene muds are overlain by Holocene muds generally less than 2 m (7 ft) thick.

The shelf surface is divided into compartments by transverse shelf valleys that were the retreat paths of estuaries during the post-Pleistocene sea-level rise. Between the shelf valleys, broad plateau-like surfaces have been partly molded into areas of sand-ridge topography where the ridges are up to 10 m (33 ft) high and from 2 to 4 km (1 to 2 nmi) apart. The ridges appear to have been initiated at the foot of the retreating shoreface by coastal storm currents and were stranded on the shelf floor as the shoreline receded. Studies suggest that southwest-trending storm currents continue to scour troughs and aggrade ridge crests and flanks, transporting the fine sand particles and any accumulated mud across the shelf surface toward the southwest.

Fine sediments enter the water column by discharge from river mouths and tidal inlets, by erosion of the sea floor, and by man's dumping. They are largely entrained in nearshore waters, especially the bottom nepheloid layer, and are deposited on the bottom during periods of low current velocities. Fines may then be resuspended during storms if bottom currents reach appropriate velocities. When the shoreline lay beyond the shelf edge about 15,000 years ago, there was rapid deposition of fines on the continental slope, but as the nearshore turbid zone migrated landward, slope deposition rates fell abruptly. Shelf mud deposits in the northeastern part of the Bight appear to be the result of intense glacial outwash and deposition in an embayment when the shoreline was in a mud-shelf position.

Surficial sediment studies indicate there has been little additional sediment transported from the land to the shelf since lowered sea level. However, there appears to be a vigorous southwestward flux of bottom materials in response to storm flows, and bottom features are being slowly altered in response to sediment transport during storms.

The Bight apex studies reveal that while considerable sediment has been dumped, there has been negligible bottom sediment deposition except at the dredge spoil dumpsite. Fines from dumping disperse readily and are hard to distinguish from natural muds except by chemical analysis. A large effort is now underway by NOAA to define the spatial, temporal, and chemical characteristics of nearshore Long Island fine sediments on the bottom and in the water column.

Glossary

antecedent: "formed before." A feature formed prior to present conditions, currently retaining its shape. The word is usually applied to streams and their patterns.

arkose: typically a coarse-grained sand or sandstone with quartz as the dominant mineral and with at least 25% feldspar. Since feldspar weathers more easily than quartz, arkose indicates rapid erosion of granite masses where transport of grains is short and grain weathering is minimal.

basal stratum: the lowest, or base layer of sediment or rock in an upward sequence.

benthonic: any type of marine organism which lives on or near the bottom.

bimodal: a sediment grain-size distribution which has two peaks not necessarily equal in height, indicating two sizes which are the most frequent.

calcareous: being composed of calcium carbonate (shell material).

combustible biogenic matter: planktonic organic matter which, after drying, can be removed from a sample by combustion.

cuesta: a hill or ridge with one face long and with a gentle slope, and the other face steep and narrow—formed by beds of tilted sedimentary rock resistant to erosion.

cuspate foreland: a broadly triangular point of land extending seaward, marking the division between cusps, or crescent-shaped stretches of coastline; formed by long-continued nearshore sediment movement.

delta: a deposit of sediments at a river mouth usually forming a fan-shape—a shelf delta formed on the shelf during lowered sea level.

depositional center: an area where sedimentation was concentrated, resulting in a thicker deposit than in the flanking areas, for example, a delta.

erosional window: an opening in a surficial sediment layer, created by erosion of that layer, exposing an underlying sediment layer.

facies: a group of sediments in which one grain size dominates, but may contain other sizes, for example, sand facies, mud facies, arkose facies. The term may also relate to the origin of a deposit, for example, deltaic facies, fluvial facies.

feedback loop: in a diagram modelling a system, a path that goes from a result back to an event preceeding the result; a cycling in the system.

flocculation: a process whereby a number of suspended particles draw together to form a larger mass, which may or may not be denser than the original individual particles—agglomeration.

fluvial: formed by stream action, a stream deposit.

foraminifera: a unicelled protozoan group of marine animals which secretes calcium carbonate shells that become part of the sediment; may be planktonic (surface dwelling) or benthonic (bottom dwelling).

Holocene: the most recent epoch of geologic time, representing the present post-glacial period, generally agreed to have started about 10,000 years ago. It is also called the Recent.

hydraulic climate: the energy in a moving water mass. Influencing factors are density (temperature and salinity), and speed and direction of current. Energy affecting bottom sediments includes unidirectional currents and oscillatory, high-frequency currents caused by surface waves.

hydrographic survey: water depth surveys, usually performed by NOAA's National Oceanic Survey (formerly the Coast and Geodetic Survey) primarily for the preparation of navigation charts. These are also done in the deep sea for research or defense needs.

interstitial water: water in between the grains of minerals in a marine deposit.

kurtosis: the condition of peakedness of the sediment grain-size frequency distribution curve (the concentration of particles about the median diameter). $K = (Q_3 - Q_1)/2(P_{90} - P_{10})$, where Q_3 and Q_1 are the particle diameters at 75% and 25% cumulative frequency, and P_{90} and P_{10} are the particle diameters at which 90% and 10% of the particles are larger, or is calculated from the fourth moment in the *method of moments;* indicates the sorting in the tails, or low frequency portion of the frequency curve.

lag deposit: a deposit of sediment left behind when other sediment grains—more easily moved due to their size, density, or shape—are washed away.

lagoonal back-barrier facies: that facies typical of lagoons or bays behind a barrier island, typically mud at the surface and blue or gray clay when buried.

linear low: an elongate low area on the shelf.

littoral drift: a current or the material carried by the current next to the shoreline caused by waves approaching the coast at an angle.

macrofauna: any animal or whole remains of an animal large enough to be seen with the naked eye.

mean diameter: the arithmetic average of all grain sizes in a sediment sample. The mean is the first moment in the method of moments.

median: in sedimentary geology, the grain size of the sediment in which 50% of the grains are larger and 50% are smaller.

method of moments: a mathematical method (vs. graphical) of obtaining values of mean, median, standard deviation (sorting), skewness, and kurtosis.

microfauna: an animal or whole remains of an animal too small to be seen with the naked eye (foraminifera, diatoms, for example).

mode (modal diameter): the sediment particle size that is the most frequent; is highest on the frequency curve.

mold: a fossil remains formed by infilling of a shell where the original shell material is no longer present, or an impression made by a shell, bone, footprint, or a hardened piece of sediment.

nepheloid layer: a layer in the water column on top of the bottom where there is an increase in suspended particulate matter.

normal distribution: a frequency distribution (of sediment grain sizes) whose plot is a continuous bell-shaped curve that is symmetrical about its arithmetic mean, mode, and median; a Gaussian curve.

ocean outfall: a pipe extending into the ocean (or bay) discharging wastewater from a sewage treatment plant. The effluent may or may not contain active contaminants.

phi ϕ unit: an expression used by sedimentologists to denote grain size. $\phi = -3.32 \log$ (size in mm).

placer: a mineral deposit concentrating heavy mineral grains by current action, mostly streams. Placer deposits found on the present shelf were formed during lower sea levels.

planktonic: any type of marine organism which floats or lives near the surface.

pore water: interstitial water, water in between sediment grains.

pycnocline: a layer in the water column where there is a rapid density change with depth.

reduced state: a chemical condition of sediment wherein all oxygen is depleted, leading to gray to black sediment, smelling of hydrogen sulfide (rotten eggs); occurs when water circulation through the sediment is restricted by fine-grained material. Opposite: oxidized state.

reflector: in geophysics, a line on the geophysical record in the subsurface representing a change in sediment density, usually caused by a change in sediment type and/or composition (that is, sand to mud or clay) that reflects sound waves (see **seismic**).

relict: a geologic feature or deposit formed in the past, but which at least partly survived to the present.

ridge and swale: a series of low ridges and intervening topographic lows (swales) on the shelf formed by current action on bottom sediments. The exact method of formation is unknown.

scarp: a line of cliffs produced by erosion or faulting. On the shelf, scarps were produced during lowered sea level either by subaerial erosion, or during a time when sea level rose and then remained at a fixed level for some time prior to rising again.

second-cycle erosional material (sediment): sediment grains in their second cycle of deposition: originally deposited, eroded, and redeposited.

sedimentary apron: a mass of sediment deposited in a fan-shaped body. It may be deltaic or submarine in origin.

seismic: a geophysical term referring to a vibration in the earth. Seismic records are produced by artificially-produced sound waves penetrating the earth's surface and returning to the surface after being reflected back by sediment or rock layers, or by naturally occurring earthquakes.

shelf valley: a valley incised across the shelf floor during one or more sea level lowerings.

shell hash: ground up or broken shell material.

shoal retreat massif: a low, broad ridge across the continental shelf, perhaps a kilometer wide, nearly perpendicular to the shore–formed by the landward displacement of a littoral drift depositional zone as the shoreline retreats in response to the post-glacial rise in sea level.

shoreface: the narrow zone of relatively steeper slope of the bottom immediately seaward of the surf zone. The shoreface may move seaward or landward with season, rising or lowering of sea or lake level, or storms.

side-scan sonar: a geophysical instrument that maps the bottom roughness by sending out sound beams transverse to the ship's path, recording the return signals.

skewness: a measure of asymmetry of the frequency of grain-size distribution of sediment. Skewness is calculated by dividing the difference between arithmetic mean and mode by the standard deviation and taking the logarithm to the base 10, or from the third moment. Positive skewness indicates the distribution is biased to coarser particles; negative skewness is biased to finer particles.

slump deposit: a deposit formed from a mass of sediment which became dislodged from its original place of deposition and slid downslope to a new location.

sorting: a measure of the variance (second moment about the mean in the method of moments), spread, or range of particle-size distribution on either side of an average in sediments. Sorting may be replaced by standard deviation, a more accurate calculation of sorting.

standard deviation: the square root of the average of the squares of the deviations about the mean (the square root of the variance, or second moment) of a data set (frequency distributions), a statistical measure of dispersion.

strand line: the line of the water's edge.

subaerial: formed under "air" (on land) vs. submarine (under water).

subarkose: an arkosic sand where feldspar is between 5% and 25%.

terrace: a long, narrow, level, or gently sloping surface; a large bench; usually formed by a temporary halt in sea level rise.

terrigenous: pertaining to or from the land.

test: the hard-part remains of many invertebrates, especially the gelatinous, calcareous, or siliceous remains of single-cell marine animals such as foraminifera and diatoms.

turbidite: a sedimentary deposit caused as the result of a turbidity current, when coarser material is deposited first (as the current decreases), then finer and finer sized sediment is deposited in beds overlying the next coarser size. A turbidite may contain large (meters across) blocks of partially consolidated sediment if initial slump does not completely break up or if the turbidity current erodes other sediment.

turbidity current: a *density* current in water, air, or other fluid caused by particles in suspension; that is, an avalanche. In the ocean, turbidity currents occur along the continental slope when large amounts of sediments are set in motion by earthquake, tsunami (tidal wave), or other sudden instabilities. The high density water-sediment mixture flows downslope at rapid rates, occasionally travelling hundreds of kilometers to very deep water, before dissipating. A turbidite current may cause erosion and be the origin of submarine canyons.

unimodal: when a sediment grain-size distribution curve has only one peak, indicating only one most-frequent size.

wave regime: the sum total of the surface wave patterns during a storm event or during a specified period of time: week, month, season, year, or longer.

Appendixes

Appendix 1. Sediment grain size scales

Millimeters	Microns	Phi (ϕ)	Wentworth Size Class	
4096		−12		
1024		−10	boulder	
256		− 8		
64		− 6	cobble	
16		− 4	pebble	Gravel
4		− 2		
3.36		− 1.75		
2.83		− 1.5	granule	
2.38		− 1.25		
2.00		− 1.0		
1.68		− 0.75		
1.41		− 0.5	very coarse sand	
1.19		− 0.25		
1.00		0.0		
0.84		0.25		
0.71		0.5	coarse sand	
0.59		0.75		
0.50	500	1.0		
0.42	420	1.25		
0.35	350	1.5	medium sand	Sand
0.30	300	1.75		
0.25	250	2.0		
0.210	210	2.25		
0.177	177	2.5	fine sand	
0.149	149	2.75		
0.125	125	3.0		
0.105	105	3.25		
0.088	88	3.5	very fine sand	
0.074	74	3.75		
0.0625	62.5	4.0		
0.053	53	4.25		
0.044	44	4.5	coarse silt	
0.037	37	4.75		
0.031	31	5.0		
0.0156	15.6	6.0	medium silt	
0.0078	7.8	7.0	fine silt	
0.0039	3.9	8.0	very fine silt	Mud
0.0020	2.0	9.0		
0.00098	0.98	10.0		
0.00049	0.49	11.0	clay*	
0.00024	0.24	12.0		
0.00012	0.12	13.0		
0.00006	0.06	14.0		

*some use 9ϕ as clay boundary

Source: Folk 1974

Appendix 2. Grain size nomenclature for sediments

G gravel
g gravelly
(g) slightly gravelly

S sand
s sandy

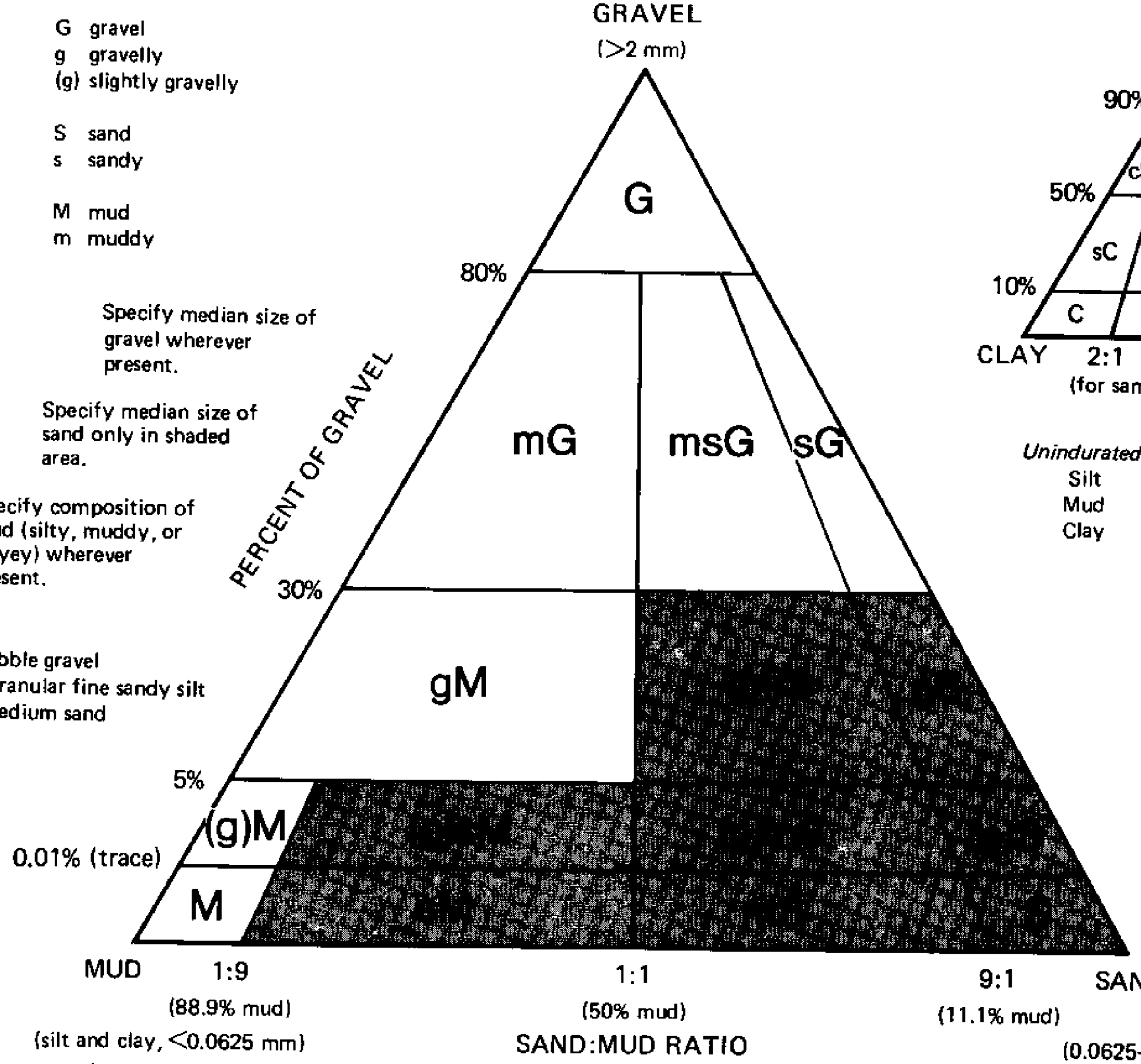
M mud
m muddy

Specify median size of gravel wherever present.

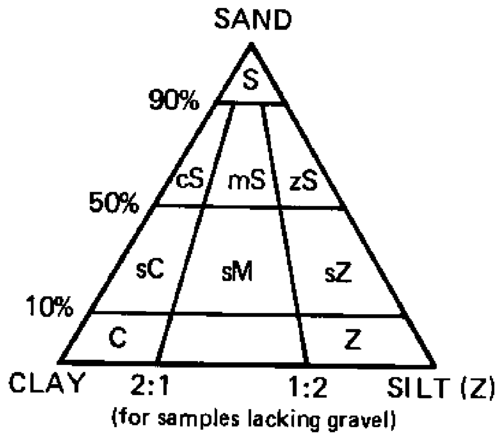
Specify median size of sand only in shaded area.

Specify composition of mud (silty, muddy, or clayey) wherever present.

EXAMPLES:
sG sandy cobble gravel
(g)sM slightly granular fine sandy silt
mS clayey medium sand



From Folk 1974.



Unindurated	*Indurated*	*Fissile*
Silt	Siltstone	Silt–shale
Mud	Mudstone	Mud–shale
Clay	Claystone	Clay–shale

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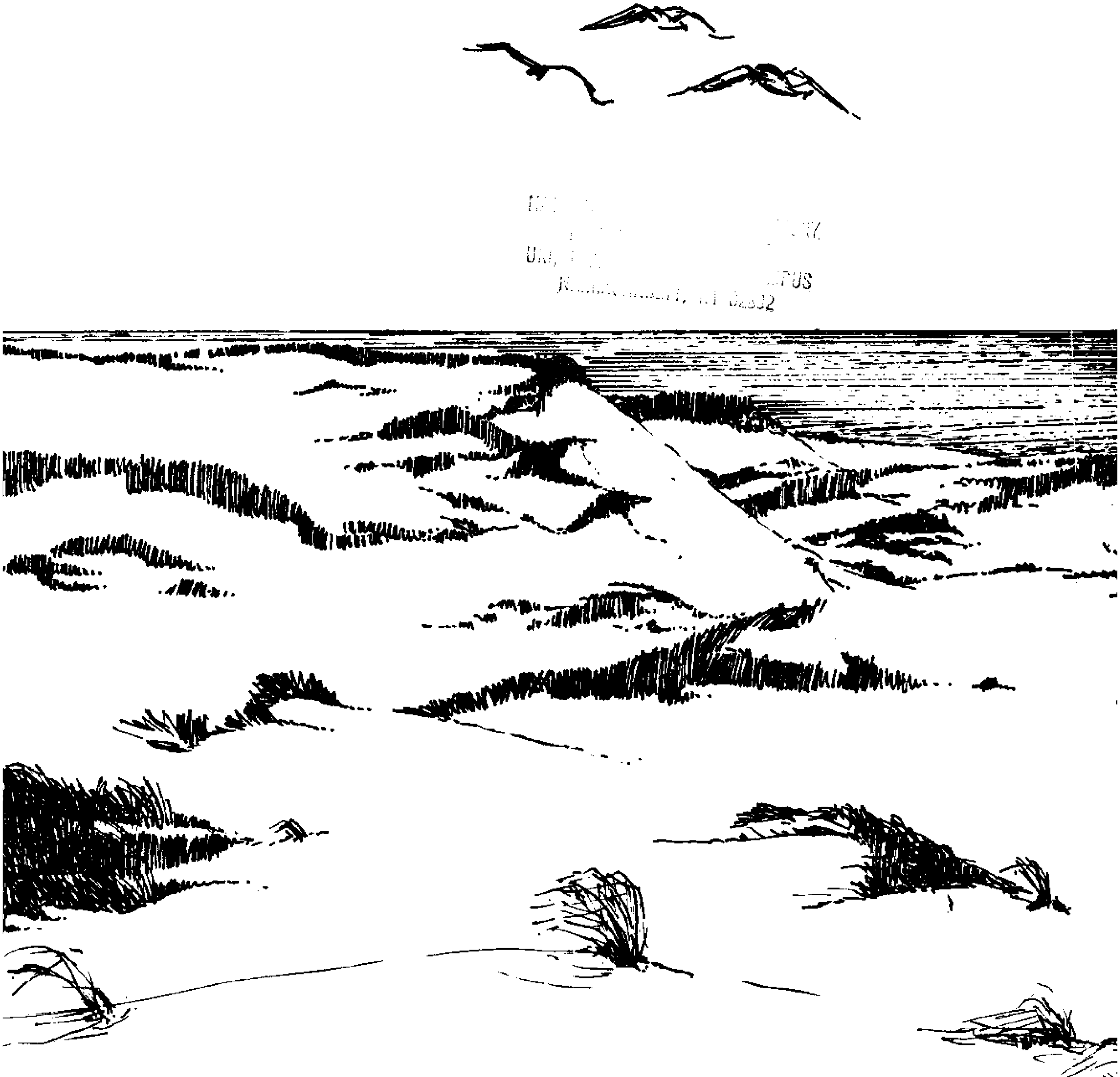

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