PREPARED IN COOPERATION WITH
THE COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF PUBLIC WORKS
AND
THE WOODS HOLE OCEANOGRAPHIC INSTITUTION

INTRODUCTION

This set of maps covers part of the continental shelf from about 15 km north of Cape Ann, Massachusetts, to Casco Bay, Maine (42°50' to 43°N. and west of 70°W). It extends data presented in a companion study that covered the contiguous area to the south as far as Cape Cod, Massachusetts (Schlee and others, 1973). The maps in both studies are intended to serve as guides to surficial sediment distribution. Because sediment texture is in part a reflection of long-term hydrologic conditions, the maps will also help to infer the important sediment transport mechanisms in the area and thus will be useful in problems relating to offshore disposal of solid and liquid waste (Schlee and others, 1973).

All geophysical data (3.5 kHz echo-sounding profiles) and most bottom sediment data (137 grab samples) were collected during GOSNOLD cruise 164 in June 1970 as part of the U.S. Geological Survey-Woods Hole Oceanographic Institution (WHOI) joint investigation of the continental margin of the eastern United States. The remaining grab samples, about 50, were collected aboard R/V DOLPHIN cruise 10, 1969, R/V ALBATROSS IV cruise 2, 1965, R/V ASTERIAS cruise 2, 1964, R/V GOSNOLD cruise 12, 1963, and R/V DELAWARE Cruise 10, 1961 as part of the same program. Most grab samples were collected with a Van Veen grab sampler (2 litres capacity) or Dietz-LaFond snapper (½ litre capacity). Some were collected with Smith-McIntyre or Campbell grab samplers. Average station spacing was about 5 km; in some areas, however, spacing was closer in order to define sediment type boundaries more accurately. Stations were located by triangulation with sextant or pelorus near shore and with radar and loran A offshore; some stations and track lines were relocated so that 12 and 3.5 kHz echo-sounding records were compatible with bathymetry presented on National Ocean Survey Chart 0808N-69 (Hampton Harbor to Maquoit Bay, 1970). All data were plotted on this chart (scale 1:125,000; contour interval 5 m).

Sediment texture[1] was determined by pipette for the fine fraction (<62 μm), and by the Woods Hole Rapid Sediment Analyzer (Schlee, 1966) for the coarse fraction (>62 μm). Organic carbon content of sediments was determined with the LECO gas analyzer according to procedures outlined in the manual of the Laboratory Equipment Corporation (1959).

Subbottom data were obtained with a towed 3.5 kHz four-element transducer (manufactured by Ocean Research Equipment, Inc.), and EDO model 248-A transceiver, and a recorder built by K. E. Prada of the Woods Hole Oceanographic Institution.

ACKNOWLEDGMENT

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GEOLOGY

The rocky coastline between Cape Ann and Casco Bay is characterized by exposures of steeply dipping metamorphic rocks that strike north-northeast. Most are Devonian and Silurian in age (Hussey and others, 1967). The metamorphic rocks and the Mesozoic and upper Paleozoic granitic rocks that intrude them are well exposed except where overlying glacial and post-glacial deposits, such as the marine Presumscot Formation of Bloom (1959), are particularly thick. The Presumscot Formation is widespread in the area around Portland and Casco Bay where it is between 0 and 36 m thick (Bloom, 1960; Upson and Spencer, 1964). It apparently was deposited immediately after the Wisconsin ice sheet started to retreat and consists mostly of silts and clays derived from glacial rock flour (Bloom, 1960). Other unconsolidated deposits that occur along the southwest coast of Maine consist mostly of till, outwash, and estuarine muds. These sediments are thickest in bedrock valleys but rarely occur all at one place (Upson and Spencer, 1964).

The resistant metamorphic bedrock erodes slowly except where it is of particularly low grade. For example, in the area of Old Orchard Beach, relatively soft phyllites, argillites, and greenstones contribute abundant detritus composed of a characteristic suite of rock fragments to the depositional basin of Saco Bay (Farrell, 1970). However, unconsolidated glaciomarine sediments and till probably are major sources for sediments that have accumulated offshore during the Holocene.

Offshore, most islands are alined in the north-northeasterly grain of mainland structures and are underlain by the same crystalline rocks exposed along the coast. The submarine geology below the bottom in the Gulf of Maine has been inferred mainly from seismic data (Drake and others, 1954; Hoskins and Knott, 1961; Emery and Uchupi, 1965; Uchupi, 1966; Tagg and Uchupi, 1966; Oldale and Uchupi, 1970; Oldale and others, 1973; Tucholke and others, 1972), from a few rock and partly consolidated sediment samples dredged from the bottom (Verrill, 1878; Dall, 1925; Toulmin, 1957; Schlee and Cheetham, 1967), and from two piston cores collected in Stellwagen and Tillies Basins (Tucholke and Hollister, 1973). These data suggest that in the area included in this study crystalline bedrock and overlying Tertiary and Cretaceous strata, were eroded in the late Tertiary(?) and during advances of the glacial ice sheets when sea level was low. The glacial deposits scattered over this erosional surface are probably particularly thick on Jeffreys Ledge and Stellwagen Bank (south of the map area), if these features are moraines, and in valleys and basins. Upper Pleistocene glaciomarine and Holocene silts and clays overlie the glacial detritus.

SEDIMENT DISTRIBUTION[2]

Silty clay is the predominant sediment type in the map area; it covers much of the bottom where water is more than 100 m deep (sheet 1). Jeffreys Basin, therefore, is floored by silty clay except on local hillocks where clayey silt, mixtures of sand, silt, and clay, and muddy, sandy gravel occur. The silty clay grades to coarser textured material landward along sinuous boundaries that parallel isobaths in some areas, but cross them in others. Near Old Scantum the silty clay grades westward to clayey silt, and finally to sand and gravel near shore. Mixtures of sand, silt, and clay are common in the central and northern areas; they grade landward to silty clayey sand, and finally to sand in the central area, and to gravel in the northern area.

The gravel and gravelly sand on Jeffreys Ledge apparently grade abruptly to silty clay in Jeffreys Basin; the ledge, therefore, probably contributes little coarse detritus to the adjacent basin.

Most of the bottom of Casco Bay northwest of Peaks, Long, and Great Chebeague Islands is covered by silty clay that grades abruptly to coarser material or gives way to bedrock near shore.

Gravel is most abundant on Jeffreys Ledge and on the north and west sides of Jeffreys Basin in areas where water is about 25–50 m deep (gravel map). Near shore, sand apparently overlaps gravel whereas offshore silt, clay, and sand cover it (Schlee, in press). Gravel with a lesser admixture of sand and minor silt and clay is associated with bedrock along most of the near-shore area. The transition from gravel to finer textured material is abrupt on the western flank of Jeffreys Ledge. Data are not sufficient to delineate the nature of the boundary more precisely or to assess the thickness of gravel deposits on the ledge.

Sand is most concentrated (>50 percent) near shore where water is less than about 25 m deep, offshore where water is between about 50–75 m deep, and on top of Jeffreys Ledge (sand map). Most widespread deposits appear to be in the old drainage systems of such rivers as the Saco, Scarboro, and Merrimack (southwestern corner of area). Onshore bottom current drift related to tidal and wave action is most likely responsible for the abundance of sand along the shore (Farrell, 1970; Graham, 1970; Bumpus, in press). Near shore the veneer of sand apparently accounts for areas with relatively smooth bathymetry whereas smooth offshore bathymetry is produced by an increasing accumulation of finer materials toward basin centers.

The distribution of gravel, bedrock, and sand are doubtless more complex than we have shown, particularly in the near-shore area. Many pockets of coarse sedimentary debris, relict from Pleistocene glaciation, may be widespread over the areas depicted as bedrock. Representative sampling of bottom material in areas of sandy gravel is seldom achieved. If, for example, a small pebble prevents the jaws of the grab sampler from closing tightly, all of the sand is often lost; therefore, the abundance of gravel may be overestimated.

[1] Grain-size classes follow Wentworth (1922): gravel >2 mm; sand 2.00–0.062 mm; silt 0.062–0.004 mm; clay <0.004 mm.

[2] The sediment types are derived from the textural analyses of the grab samples and are based on a modification (Schlee, in press) of Shepard's (1954) sediment classification. Each sample was located on two ternary diagrams (see explanation for sediment type map) on the basis of its gravel, sand, silt, and clay content and plotted on the map as one of ten sediment types. Areas of bedrock and (or) coarse glacial debris were mapped where acoustic energy (3.5 kHz) did not penetrate bottom, where we were unable to recover a grab sample, or where similar bathymetry (sheet 1) could be traced from rock outcrops partly exposed above sea level. Bathymetry and echo-sounding profiles were used to extrapolate sediment-type boundaries between sample stations.

Silt and clay cover most of the bottom in Jeffreys Basin and in Casco Bay (silt and clay maps). Silt is most abundant (>40 percent) in the southern part of the area in the deepest part of Jeffreys Basin and to the west in shallower waters adjacent to Old Scantum. Clay is present in concentrations exceeding 40 percent in most of the area where water depths are greater than about 100 m; it is most abundant (>60 percent) in the northern part of Jeffreys Basin.

ORGANIC CARBON

In the offshore area, the highest concentration of organic carbon observed, about 2.1 percent (dry weight), was measured in a sample of silty clay that was collected near the deepest part of Jeffreys Basin (organic carbon map). Other samples with high values, 1.9–2.0 percent, were also collected near the axis of the basin. To the west (shoreward) values decline as sediment texture becomes coarser. Less than 0.5 percent organic carbon is common in sands and gravels. No samples were analyzed from the top of Jeffreys Ledge east of the basin, but values probably decline abruptly as sediment coarsens from silty clay in the basin to gravel and gravelly sand on the ledge. Most organic matter accumulating in the area is probably derived from indigenous organisms.

In the six samples analyzed from Casco Bay the highest organic carbon concentration observed was 2.7 percent. Values are probably higher toward the head of the estuary as they are in Penobscot Bay and Somes Sound, Maine (Folger, 1972; Folger and others, 1972).

The map showing organic carbon distribution is based on analyses of only 43 samples. Because these data are so sparse, placement of contours was guided mostly by sediment type and bathymetry. The distribution of organic carbon is doubtless far more complex than the map portrays; nevertheless, the information is valuable because it shows that few organic pollutants reach the area or are retained in the sediments.

SUBBOTTOM DATA

Acoustically penetrable sediments are thin in most of the northern part of Jeffreys Basin, and except in ponded areas, discrete layers could not be differentiated. In much of the southern part of Jeffreys Basin, however, three acoustic units were distinguished.[3] The lowermost of these is acoustically opaque to the 3.5-kHz system used. The layer crops out at the bottom near shore, on the flanks and tops of Jeffreys Ledge and Old Scantum, and on small knobs or hillocks scattered throughout the area. This unit (acoustic basement) probably comprises bedrock, gravel, sand, or till. Much of it probably is bedrock near shore. Till-like material, including boulders, however, was observed from the submersible ALVIN on the flanks of Jeffreys Ledge where the bottom is also acoustically opaque (John Schlee, oral communication, 1971). The middle unit that overlies acoustic basement contains several internal reflectors; henceforth it will be called the laminated layer. It is about 20 m thick in Jeffreys Basin and most often conforms to the topography of the underlying acoustic basement. Locally, it is truncated at the sea floor and hence has apparently undergone erosion. The uppermost unit is acoustically transparent and contains few internal reflectors. This layer, which probably consists mostly of clay and silt, lies on acoustic basement or on the laminated layer and is widely distributed in Jeffreys Basin.

DISCUSSION AND CONCLUSIONS

Bedrock exposed along the coast of New Hampshire and Maine is partly covered by gravel and sand for a distance of 10–20 km offshore. The coarse-textured sediment grades seaward to silty-clayey sand and finally to the silty clay that covers most of the bottom of Jeffreys Basin. In contrast, the gravel and sand that cover the top of Jeffreys Ledge grade abruptly to silty clay toward the basin center. The sand and gravel are most likely lag deposits consisting of the coarser components of glacial debris laid down by the last advance of the Wisconsin glacier. The finer components apparently have been winnowed out and redeposited in Jeffreys Basin and in the estuaries along the shore. The lag deposits are probably thin because the roughness of the glacially scoured bedrock is still evident whereas offshore, in the basin, the fine detritus has buried the rough topography more deeply and the bottom is smoother. If Jeffreys Ledge is a moraine, sand and gravel are probably thick on its top.

The Presumscot Formation is exposed widely in southeastern Maine. If it was also deposited offshore over glacial debris it apparently has been eroded from the near-shore region and from Jeffreys Ledge. The average grain-size distribution of 43 samples of the Presumscot Formation is 23.5 percent sand, 37.5 percent silt, and 39 percent clay (Bloom, 1960). It plots close to the boundary between sand-silt-clay and silty clay on our ternary diagram. This suggests that the Presumscot Formation and the glacial detritus from which it was derived are compatible source materials for the two sediment types that are now most widespread in the basin. Bottom sediments in Casco Bay probably contain much reworked material derived from the Presumscot Formation which is widely exposed around the bay. If the formation did extend seaward over West Cod Ledge where bedrock and gravel now predominate, then much of its finer components probably were transported into the estuary by bottom currents (Meade, 1969; Hurlburt, 1970).

Acoustic basement for the 3.5-kHz system that we used appears to consist mostly of bedrock, coarse glacial debris, or till. In some places the laminated layer that overlies basement could be the equivalent of the Presumscot Formation. However, this cannot be resolved with the acoustic data and grab samples available. Much of the laminated layer and most of the transparent layer are probably Holocene in age.

Organic carbon is sparse (about 2 percent) even in the silty clays of Jeffreys Basin which indicates that few organic pollutants are being transported to the area. Highest values are similar to those measured to the south in Stellwagen Basin and Cape Cod Bay (Schlee and others, 1973). Even samples analyzed from Casco Bay contain low concentrations of organic carbon (<2.7 percent).

The fate of other pollutants in the area can be broadly predicted by the texture of the bottom sediments. Liquid waste, for example, probably will be dispersed most rapidly where waves and currents are most vigorous, for example, near shore and on Jeffreys Ledge where fine natural detritus has apparently been winnowed away. Note, however, that similar fine material dumped or resuspended by dredging near shore may be deposited on nearby beaches (Folger and others, 1971). In contrast, fine-textured solid wastes will probably be stabilized near the center of Jeffreys Basin where bottom current circulation is apparently sluggish.

In summary, much of the silty clay that covers the bottom of Jeffreys Basin probably is Holocene in age and has been derived from glacial and glaciomarine sediments that covered bedrock after the glacier receded. Sand and gravel have been concentrated as lag deposits in the near-shore region and offshore on Jeffreys Bank where waves and currents have winnowed out fine detritus and transported it to adjacent basins.

[3] Sediment types can be broadly delineated by the character of the acoustic pulse. With the system used, for example, gravel and sand reflect most energy but silt and clay do not and hence are relatively transparent to sound; therefore acoustic horizons below a silt and clay bottom often were observed whereas those beneath sand or gravel were not. The character of the return pulse from the water-sediment interface was also useful to extrapolate sediment-type boundaries between sampling stations.

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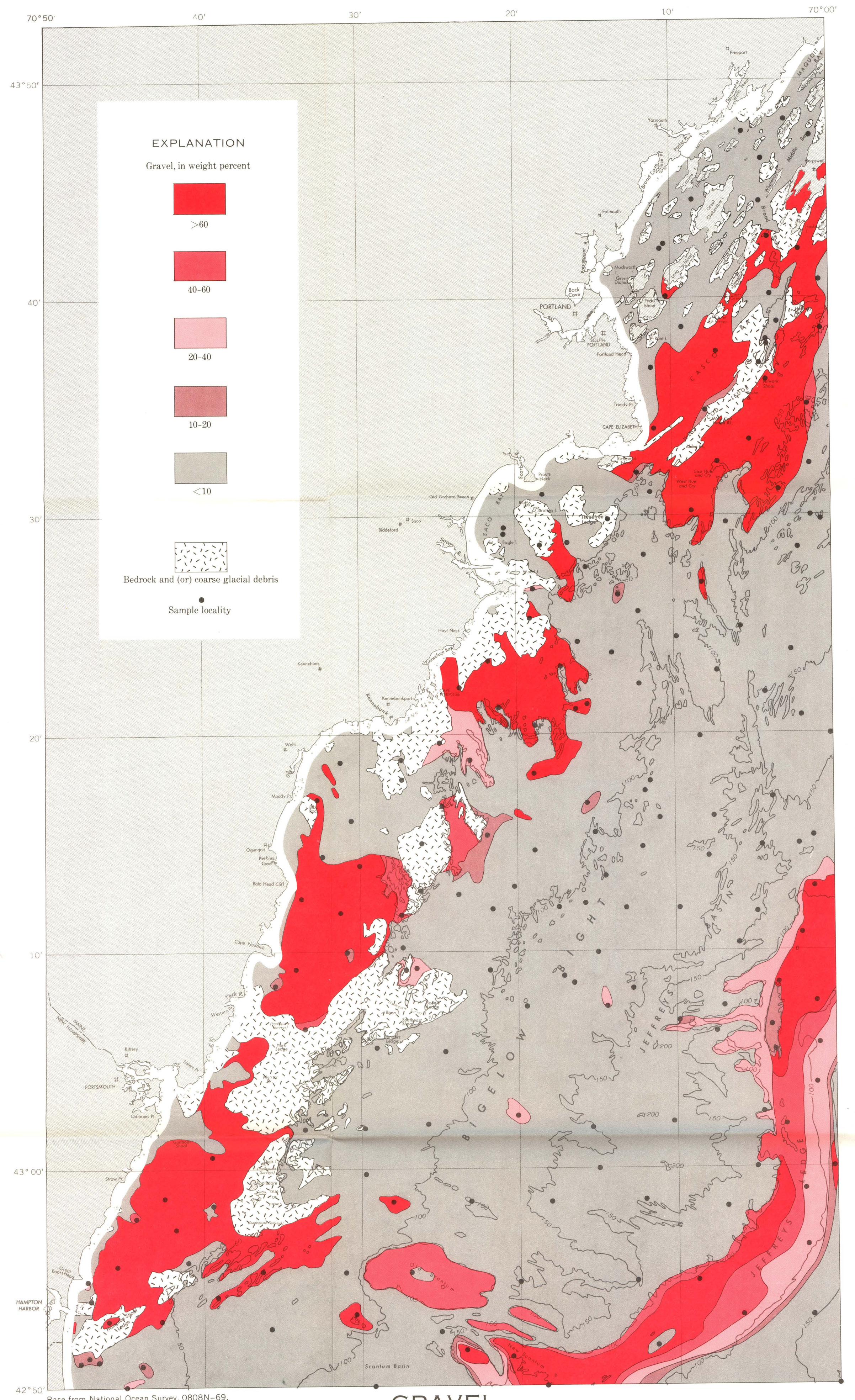
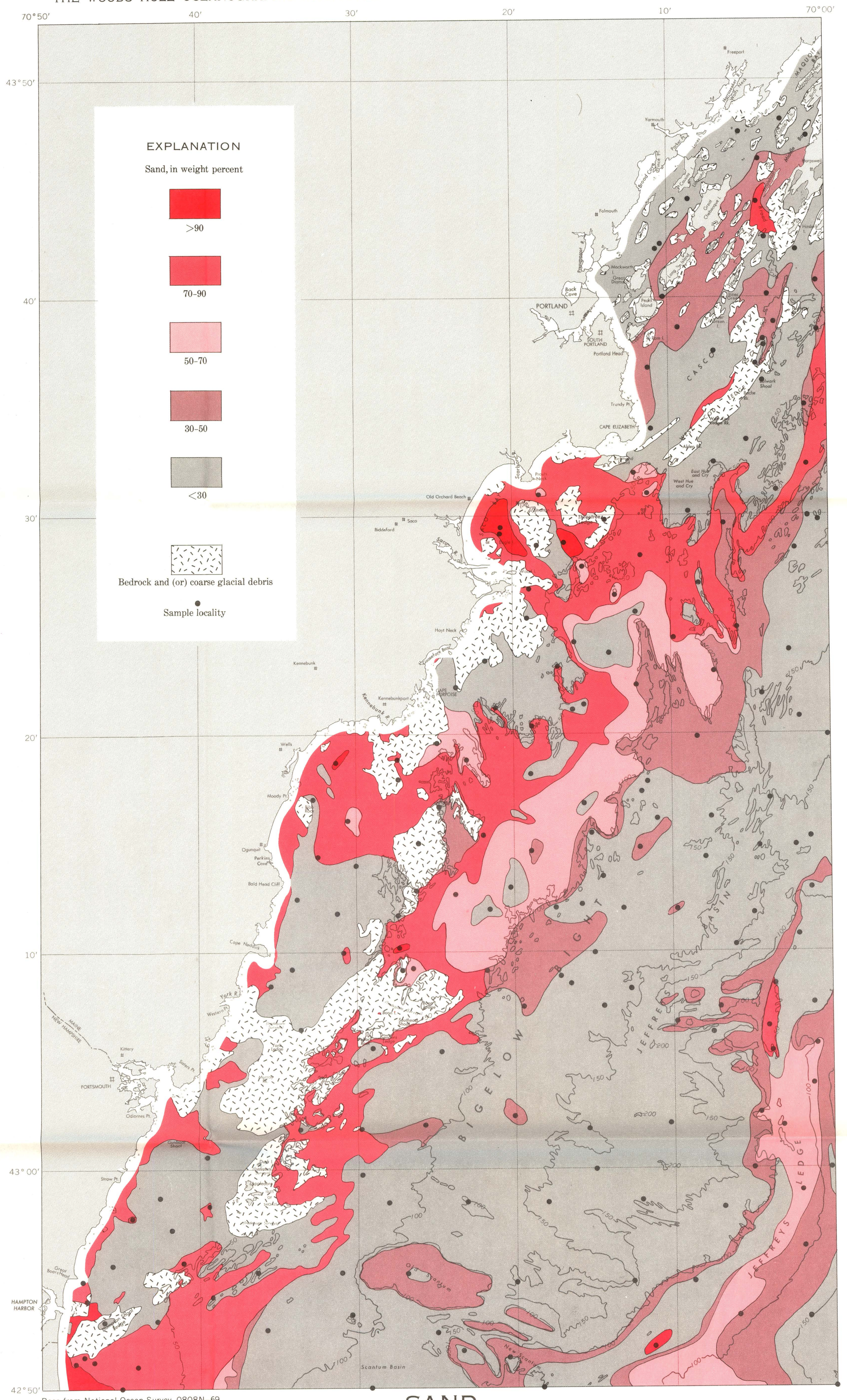


Base from National Ocean Survey, 0808N–69, Hampton Harbor to Maquoit Bay, 1970

GRAVEL



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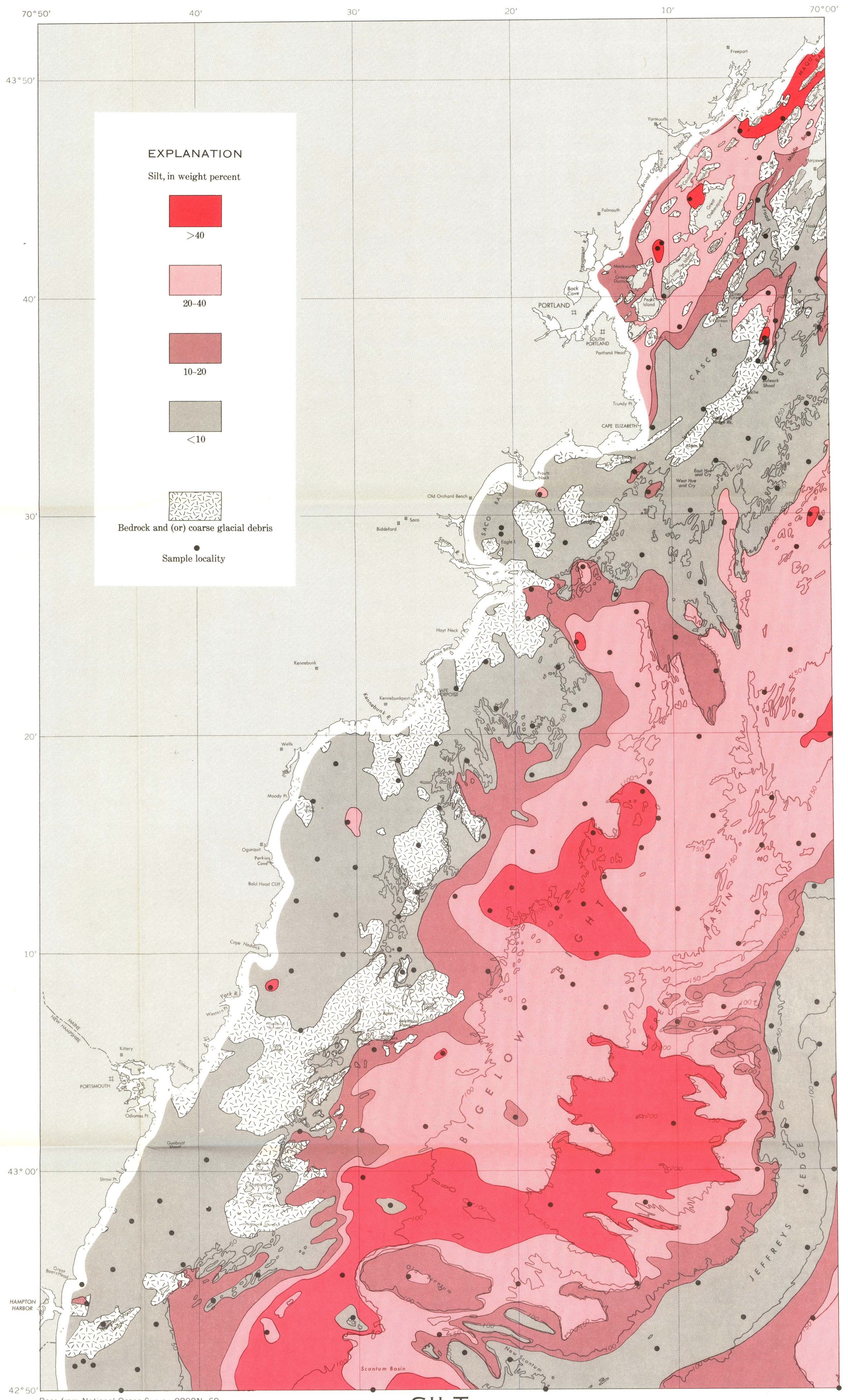
SAND



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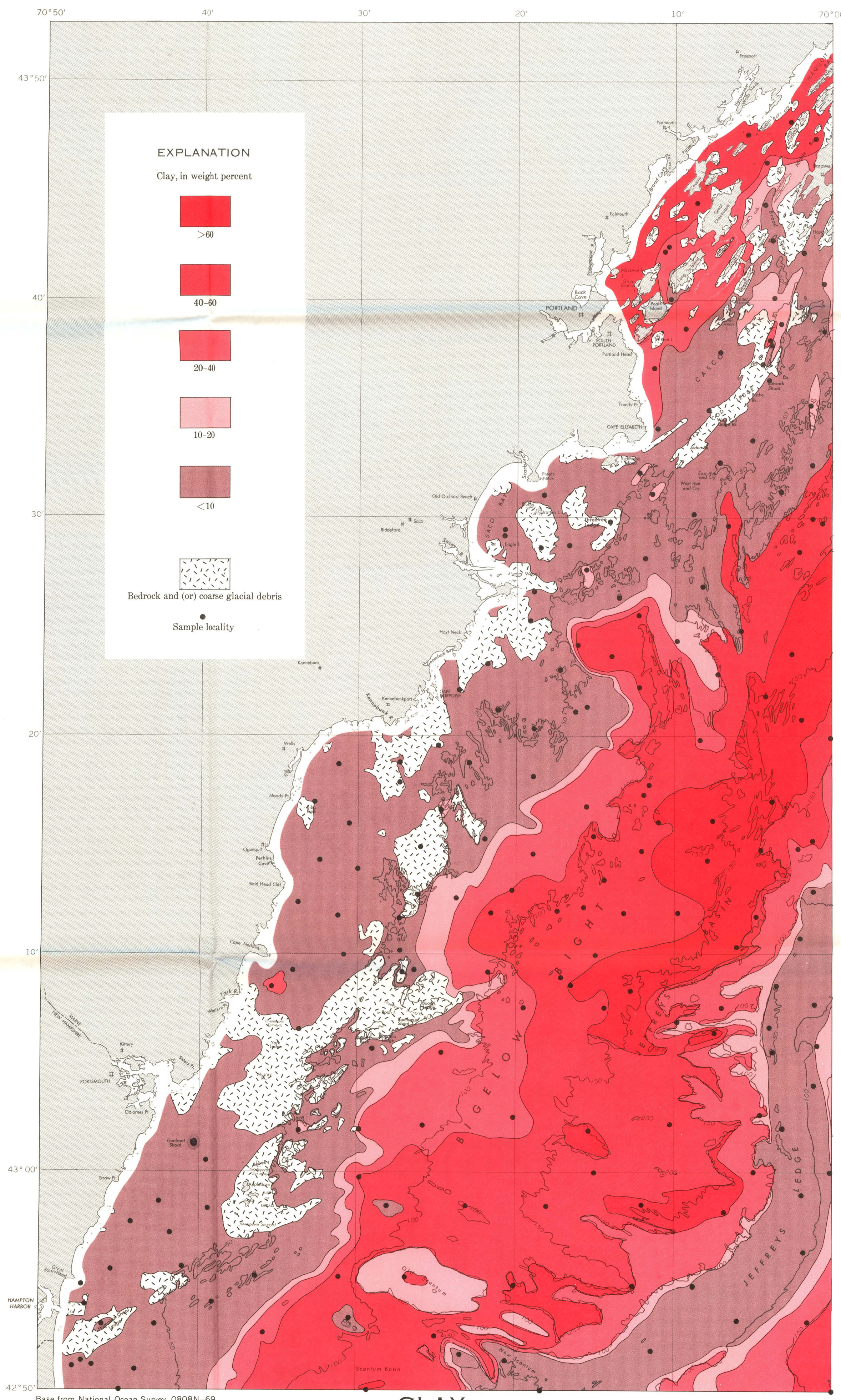
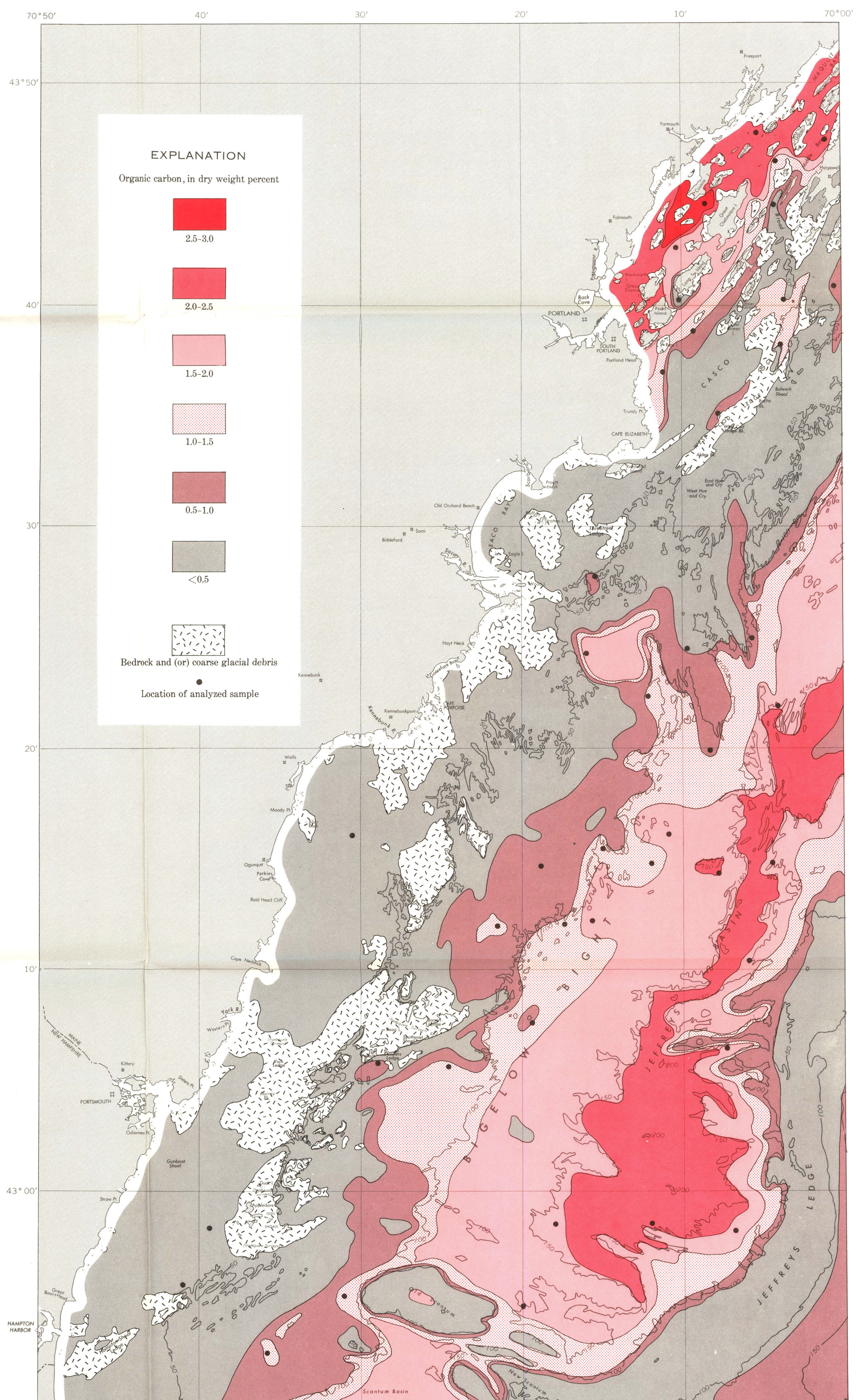
SILT



Base from National Ocean Survey, 0808N–69, Hampton Harbor to Maquoit Bay, 1970

CLAY



Base from National Ocean Survey, 0808N–69, Hampton Harbor to Maquoit Bay, 1970

ORGANIC CARBON

SCALE 1:250 000

BATHYMETRIC CONTOUR INTERVAL 50 METRES
DATUM IS MEAN LOW WATER

MAPS SHOWING BOTTOM SEDIMENTS ON THE CONTINENTAL SHELF OFF THE NORTHEASTERN UNITED STATES CAPE ANN, MASSACHUSETTS TO CASCO BAY, MAINE

By
David W. Folger, Charles J. O'Hara, and James M. Robb

1975