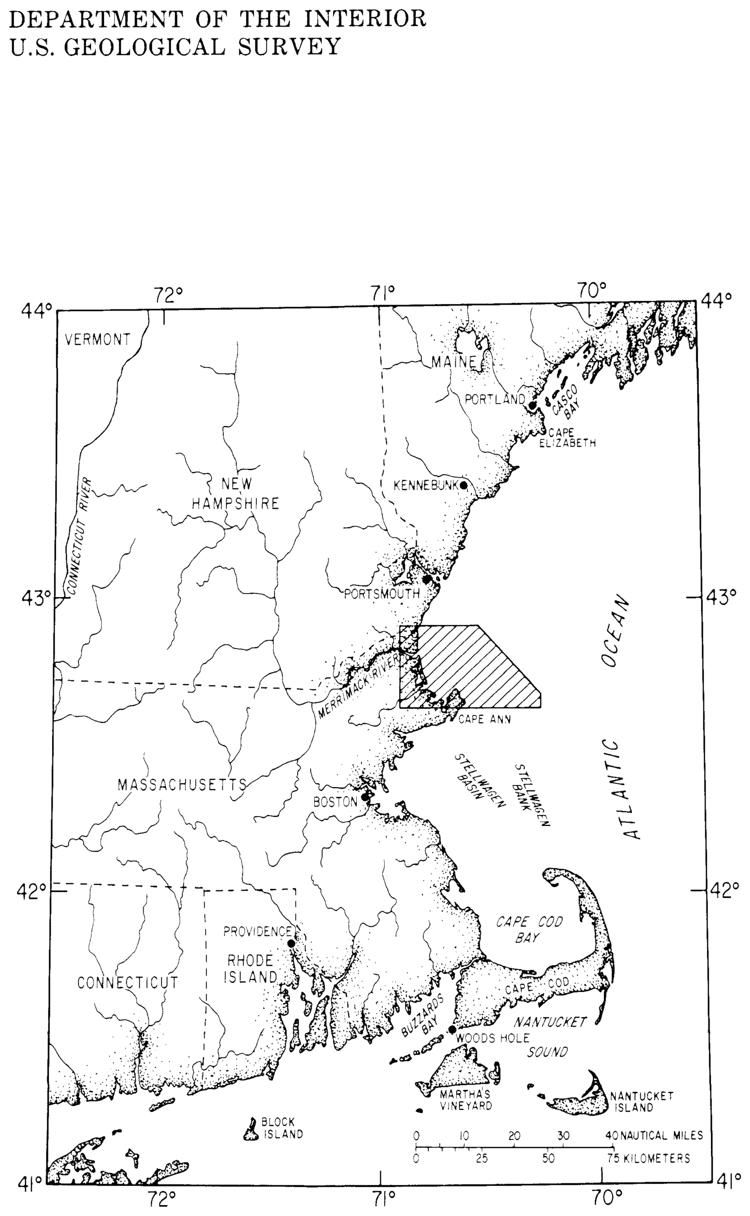
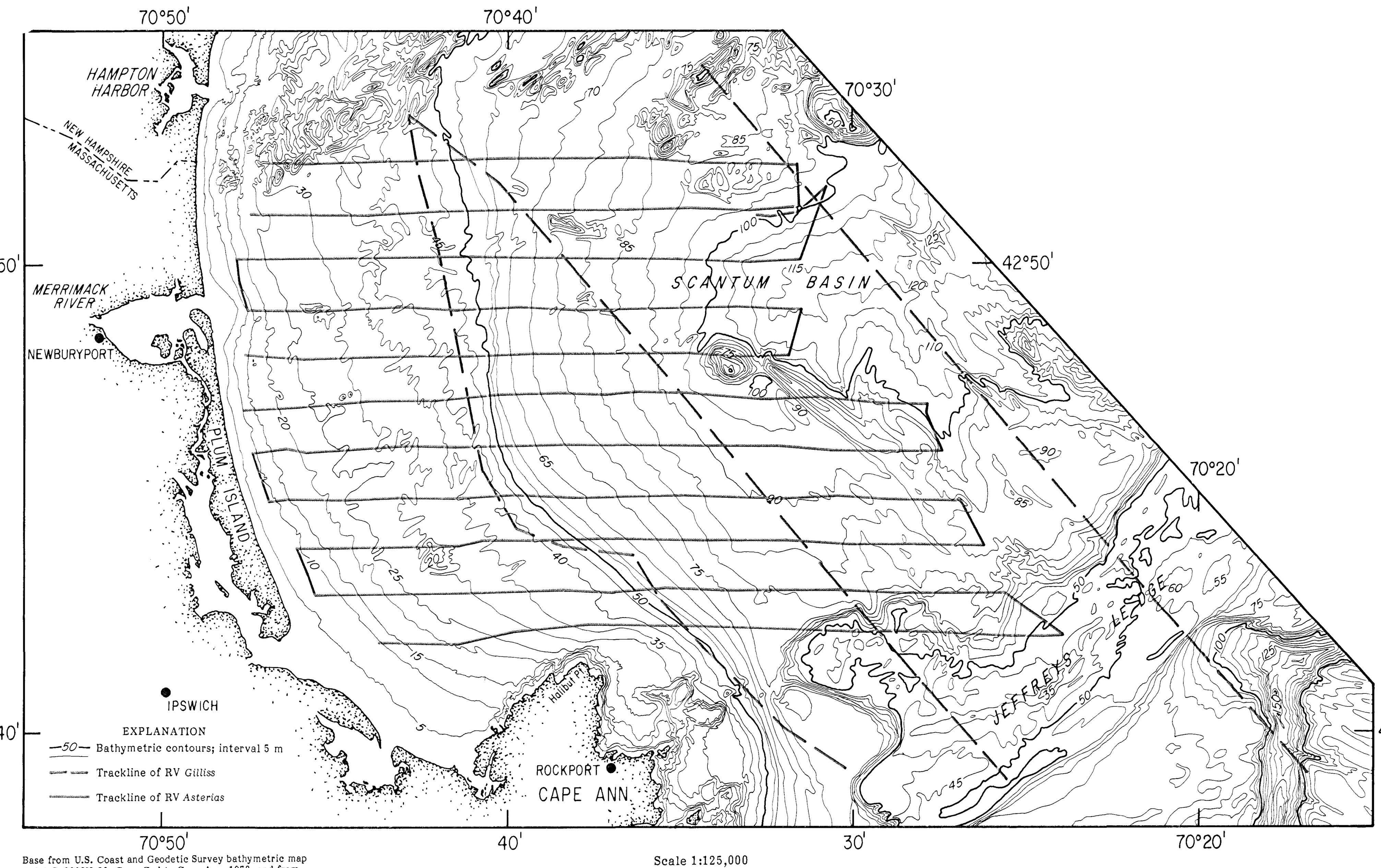


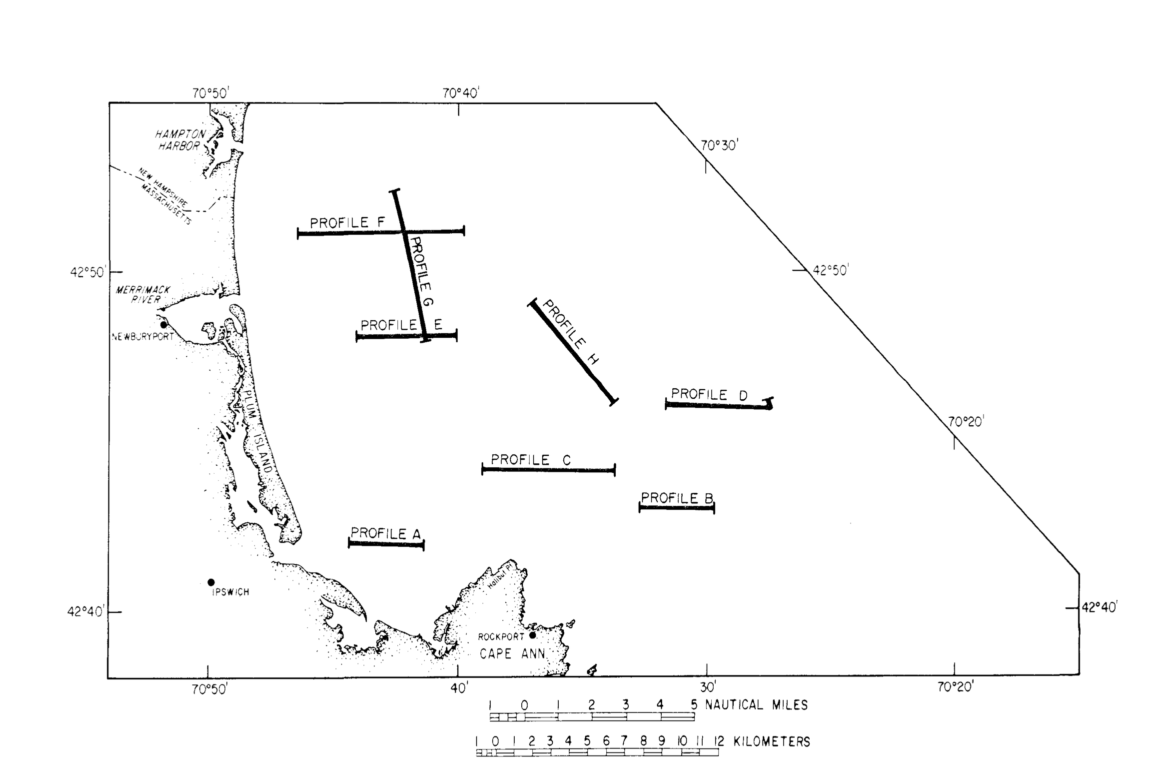

Figure 1.--Index map of eastern New England showing the study area (ruled pattern) and locations discussed in the text.




Base from U.S. Coast and Geodetic Survey bathymetric map C.&G.S. 0808N-50, Cape Cod to Cape Ann, 1970; and from National Ocean Service bathymetric map N.O.S. 0808N-69, Hampton Harbor to Maquoit Bay, 1970.
Transverse Mercator projection
Bathymetry has been modified
Not to be used for navigational purposes

Scale 1:125,000

Figure 2.--Bathymetry and tracklines.

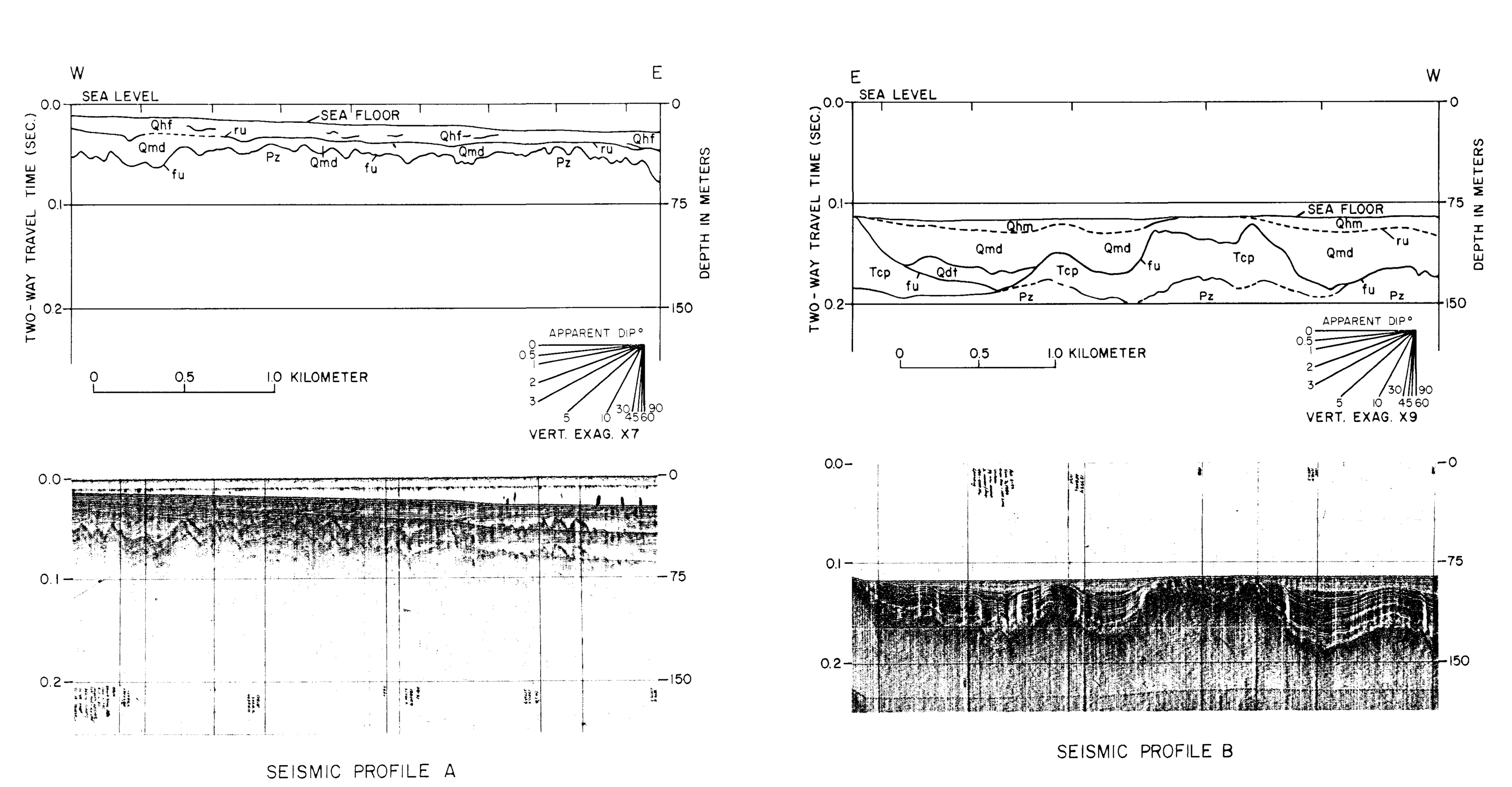



LOCATION MAP

**EXPLANATION OF SEISMIC UNITS AND UNCONFORMITIES**
(See figure 11 for correlation and more-detailed description of units)

Qhb Bar deposits (Holocene)
tu Transgressive unconformity
Qhf Fluvial deposits (Holocene)
Qhd Deltaic deposits (Holocene)
ru Regressive unconformity
Qhm Marine deposits (Holocene)
Qmd Glacial marine deposits (Pleistocene)
Qdt Coarse submarine glacial drift (Pleistocene)
fu Fluvial unconformity
Tcp Coastal plain deposits (Tertiary)
Pz Bedrock (Mesozoic or older)

Apparent-dip scale and vertical exaggeration are based on a seismic velocity of 1.5 km/s. Horizontal scales are approximate. Contacts are dashed where inferred. Vert. exag., vertical exaggeration; sec., seconds.



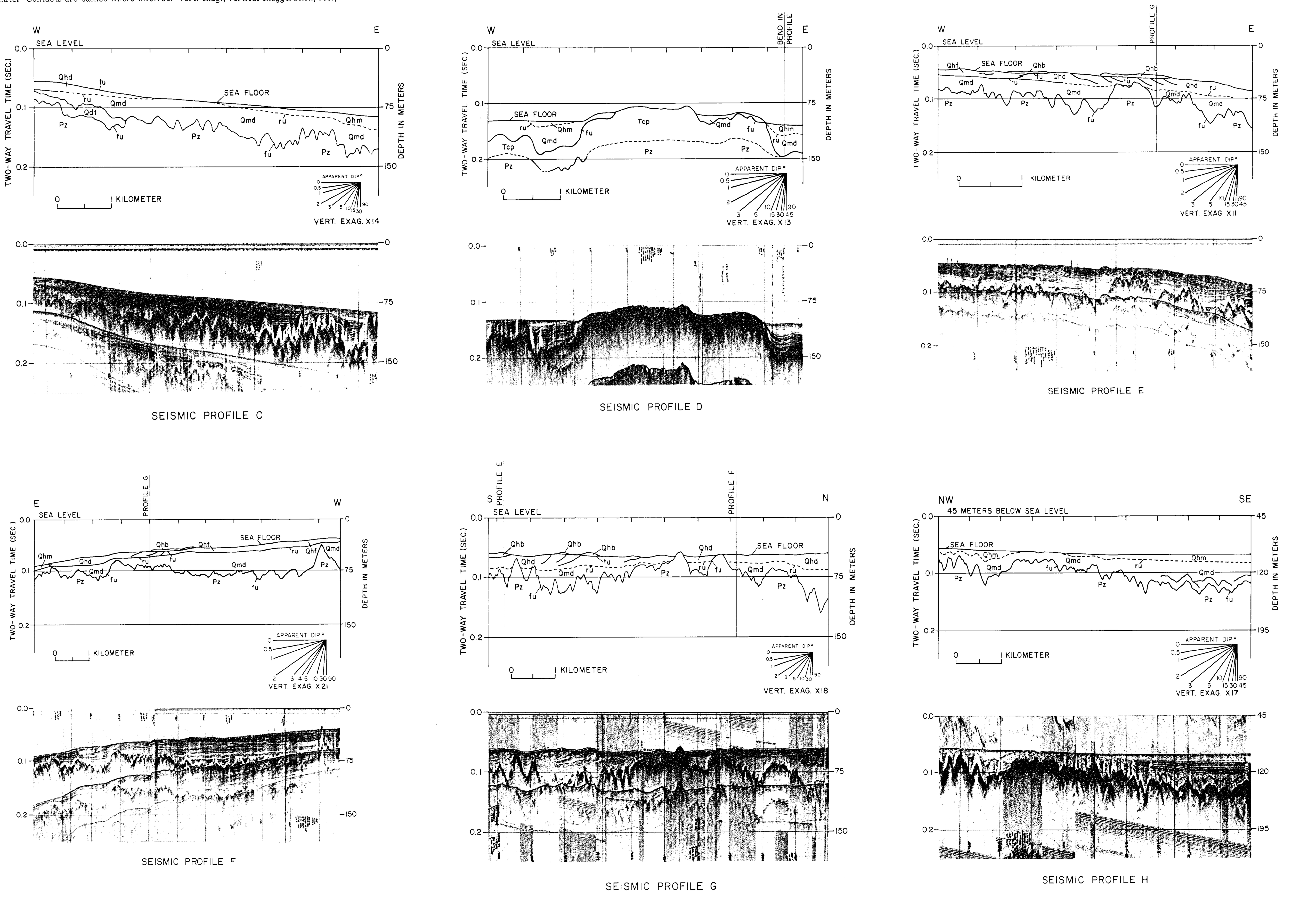




Figure 3.--Photographs and interpretive line drawings of selected seismic profiles.

## Introduction

This interpretation of the geology of the Inner Continental Shelf from Cape Ann, Mass. to New Hampshire (fig. 1) is based on high-resolution seismic-reflection surveys conducted in 1979 and 1980 as part of a cooperative program between the Massachusetts Department of Public Works and the U.S. Geological Survey. Seismic data were collected aboard the RV *Gilliss* along 104 kilometers (km) of widely spaced trackline (fig. 2). These tracks trend subparallel to the coast. About 290 km of trackline, spaced approximately 2 km apart and oriented roughly normal to the coast, were taken aboard the RV *Asterias* (fig. 2).

Early studies in the western Gulf of Maine have outlined the general geology and geologic history of the region. Seismic-reflection data have defined the major stratigraphic units and unconformities (Oldale and Uchupi, 1970; Ballard and Uchupi, 1972; Oldale and others, 1973). Two long cores provided information on the glacial and postglacial sediments in the deep offshore basins (Tucholke and Hollister, 1973). Generalized bottom-sediment type and distribution were determined by Schlee and others (1973) and by Folger and others (1975). Investigations on land, which have provided information on the late Quaternary history of the offshore area, include descriptions of ice retreat and marine submergence (Bloom, 1963; Smith, 1982; Stone and Peper, 1982; Thompson, 1982). Radiocarbon dates from coastal marsh peats have established the middle to late Holocene sea-level-rise history (McIntire and Morgan, 1964; Keene, 1971). Submarine moraines that recently were recognized off Cape Ann provide additional information on the nature and chronology of ice retreat (Oldale, 1985a). A submerged delta of the Merrimack River and a submerged barrier spit have been used to establish an early Holocene lowstand of sea level of about 50 meters (m) below present sea level (Oldale and others, 1983; Oldale, 1985b).

## Acknowledgments

The authors wish to thank Diane Eskenasy for her assistance during the RV *Gilliss* cruise and Ann Whitney who performed ably as a member of the scientific crew during the RV *Asterias* cruise. We are indebted to Arthur D. Colburn for his enthusiastic and capable help as skipper of the RV *Asterias*. This study was supported in part by the Massachusetts Department of Public Works.

## Geologic setting

The bedrock of northeastern Massachusetts consists mostly of volcanic and plutonic rocks of Silurian and Devonian age (Cameron and Naylor, 1976). Rock units and major faults strike generally northeast and continue offshore (Bothner and others, 1983). The submerged Paleozoic rocks may be overlain locally by sedimentary rocks of Triassic age (Ballard and Uchupi, 1972; Kaye, 1983a) and by coastal plain strata of Cretaceous and Tertiary age (Oldale and others, 1973). The surface atop the bedrock (including Triassic rocks, if present) is a complex unconformity that is at least pre-Tertiary in age where overlain by coastal plain strata, and Tertiary or early Pleistocene in age elsewhere (Oldale and others, 1973). The fluvially carved bedrock surface was glacially eroded at least twice (Hanson, 1984). Glacial drift, mostly of late Wisconsinan age, and marine deposits of Holocene age unconformably overlie the bedrock and coastal plain strata. The drift includes till and subaqueous ice-contact and outwash deposits (Oldale, 1985a), although it is made up mostly of glacial marine sediments, similar to those mapped along the coast of Massachusetts, New Hampshire and Maine. In Maine they were named the Presumpscot Formation by Bloom (1963). Upper Wisconsinan glacial marine sediments were deposited adjacent to and seaward of the retreating ice front.

The late-glacial and postglacial history of relative sea level is complex (Oldale and others, 1983). During deglaciation, the bedrock surface was depressed by the load of the glacier to a point below worldwide sea level, and ice-front retreat and submergence were contemporaneous. Following retreat of the ice, the crust rebounded and the sea regressed. As rebound slowed or ceased and as worldwide sea level rose, the result of glacial meltwater returning to the ocean basins, the sea transgressed. Results of these changes in sea level include a drowned fluvial unconformity atop the glacial drift, the formation and subsequent drowning of the Merrimack River paleodelta (Oldale and others, 1983), and a wave-cut marine unconformity atop the drift and postglacial fluvial and marine deposits. Post-transgressive marine deposits occur above the marine unconformity in places.

## Methods

Seismic-reflection profiles were collected using an EG&G Uniboom[1] seismic system. The sound source was triggered every half-second. Returning seismic signals were filtered between 400 and 4,000 Hertz (Hz) and were recorded using a quarter-second sweep. Sediment layers less than about 1 m thick were not resolved by the Uniboom system. Navigation aboard the RV *Gilliss* was based on the U.S. Geological Survey integrated navigation system and on loran-C. Fixes were taken every 2 minutes. Navigation aboard the RV *Asterias* was based on loran-C, with fixes recorded every 15 minutes and at the beginning and end of each trackline.

Assumptions as to the geologic nature and age of major seismic reflectors and seismic units are based on the adjacent subaerial stratigraphy, on information from cores and bottom samples from nearby offshore areas, and on correlation with reflectors and seismic units determined in seismic studies of adjacent offshore areas.

The depths below sea level of the major seismic reflectors and the thickness of the seismic units are based on inferred sound-velocities of 1.5 km/second (s) for water and for sediment inferred to be of Holocene age, 1.8 km/s for sediment inferred to be of Pleistocene age, and 2.5 km/s for sediment inferred to be of Tertiary or Cretaceous age.

## Interpretation of the seismic data

Photographs and line drawings of seismic profiles (fig. 3) illustrate our geologic interpretation of the seismic data. The stratigraphically lowest reflector in the profiles is inferred to be the bedrock surface. The bedrock (unit Pz, fig. 3) is probably similar to rocks cropping out on land to the west and south (Bothner and others, 1983; Cameron and Naylor, 1976). The bedrock surface is highly irregular where it directly underlies glacial drift (fig. 3) and relatively smooth where it underlies deposits thought to be pre-Pleistocene in age (fig. 3, profiles B and D). The depth to the bedrock surface increases from less than 20 m along the shore to more than 210 m along the eastern margin of the mapped area (fig. 4). Locally, the bedrock surface is characterized by closed depressions up to 70 m deep.

East of long. 70°34' W., the bedrock surface is overlain by thick deposits, up to 140 m, inferred to be coastal plain and shallow-marine sediments of pre-Pleistocene age (fig. 3, unit Tcp in profiles B and D; fig. 5; fig. 6). Deposits of this nature have not been sampled in the map area, but dredge hauls on Fippennies Ledge, about 85 km to the east, contained limestone of Eocene age (Schlee and Cheetham, 1967) and indicate that the major bathymetric highs in the Gulf of Maine, those that are not composed of bedrock, may be composed of strata of Tertiary and possibly Cretaceous age. Outcrops of Tertiary strata along the Massachusetts shore about 35 km southeast of Boston (Kaye, 1983b) support the conclusion that the thick deposits in the eastern part of the map area are probably of Tertiary age.

The seismic reflector that marks the bedrock surface, and, farther offshore, the surface of the coastal plain deposits, is inferred to be a fluvial unconformity (fu, fig. 3) carved during late Tertiary time and modified by glacial scour during the Pleistocene (Oldale and others, 1973). From the shore, the depth to the unconformity increases to the center of Scantum Basin (fig. 2) and then shallows atop the coastal plain deposits in the eastern part of the map area (fig. 5). Closed depressions up to 80 m deep in this surface may be remnants of preglacial or interglacial courses of the Merrimack River.

A discontinuous and sparsely distributed seismic unit (fig. 3, unit Qdt in profiles B and C), overlying the unconformity atop bedrock and coastal-plain deposits, is inferred to be coarse stratified drift and till of submarine origin. These deposits do not crop out on the sea floor and generally lie deeply buried by younger glacial drift. They may resemble submarine ice-contact deposits, outwash, and till that underlie the Presumpscot Formation in southwestern coastal Maine (Smith, 1982).

A thick, widespread seismic unit (Qmd, fig. 3) is considered to be mostly glacial marine silt and clay deposited during the retreat of the late Wisconsinan ice from the Gulf of Maine. The unit is acoustically identical to a seismic unit in Stellwagen Basin, located about 30 km south of Cape Ann (fig. 1), where cores penetrated a marine silty clay (Tucholke and Hollister, 1973). The glacial marine silty clay in the map area is also believed to be equivalent to the emerged marine silt and clay of late Wisconsinan age from Maine (Presumpscot Formation of Bloom (1963)), New Hampshire and Massachusetts (Hanson, 1984). The thickness of the glacial marine stratified deposits and till is shown in figure 7. The deposits are generally 20-50 m thick, but are locally much thicker within deep depressions in the bedrock surface.

The reflector marking the surface of the glacial marine deposits is interpreted to represent a geologic contact (ru, fig. 3) that is conformable in water deeper than 50 m, and unconformable in shallower water. Cores from Stellwagen Basin (water depth greater than 80 m) show that the contact is conformable and represents the change from high glacial sedimentation rates to low postglacial sedimentation rates (Tucholke and Hollister, 1973). In shallow water, generally less than 50 m deep (Oldale and others, 1983), the contact is unconformable and is inferred to be a seaward extension of the oxidized erosion surface on the emerged glacial marine deposits (Bloom, 1963). The unconformity is thought to have been formed by wave erosion during the regression and by fluvial erosion during emergence in early postglacial time. The depth to the glacial drift surface is shown in figure 8.

Seismic reflectors and seismic units above the glacial drift represent Holocene postglacial geologic features. A conformable and widespread seismic unit (Qhm, fig. 3) overlies glacial marine silt and clay in the bathymetric lows and is inferred to represent a deep-water marine facies, relatively unaffected by sea-level change, that was laid down continuously throughout the Holocene. In Stellwagen Basin, cores showed the deep-water facies to be composed of silt and clay near the basin center, and of silt, clay, and sand along the east side of the basin adjacent to Stellwagen Bank (fig. 1) (Tucholke and Hollister, 1973). Seismic units labeled Qhd and Qhf (fig. 3) are inferred to be shallow-water nearshore marine and fluvial facies, respectively, related to the Holocene lowstand of sea level. The more seaward unit (Qhd) contains internal reflectors that have steep apparent dips (fig. 3, profiles E, F, and G); the unit represents a deltaic facies deposited during the lowstand (Oldale and others, 1983). Cores in the delta deposits showed them to be mostly fine sand to coarse silt containing sparse shells (G. Edwards, U.S. Geological Survey, oral commun., 1983). Farther offshore, the deltaic facies grades into the deep-water marine facies. Landward of the delta, a seismic unit (Qhf) is inferred to represent mostly a fluvial facies laid down by the Merrimack River and possibly by other streams enroute to the lowstand delta. In water depths of less than about 50 m the sea-floor reflector represents an unconformity (tu) cut as the sea transgressed the delta and fluvial deposits. Locally, the transgressive unconformity is overlain by a seismic unit (Qhb) that represents bar deposits in the form of sand ridges built by waves and currents during and following transgression. The total thickness of the Holocene-age deposits is shown in figure 9. They are generally thin (thicker than 8 m) near the coast and seaward of the submerged Merrimack delta; and they are thickest in the delta, where sediments flushed from the Merrimack Valley were deposited during the lowstand, and in the deepest part of Scantum Basin, where deposition has been continuous throughout the Holocene.

[1]Use of trade names is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey or the Massachusetts Department of Public Works.

The bathymetric map (fig. 2) represents the morphology of the sea floor, a surface generated for the most part by past erosional and depositional events. Preglacial fluvial erosion and glacial scour produced the large-scale morphologic features including Scantum Basin, Jeffreys Ledge, and Cape Ann. Within Scantum Basin the sea floor is generally smooth, the result of thick deposits of glacial and postglacial silt and clay that, in all but a few places, deeply bury the bedrock surface. Small-scale irregularities in the bottom on Jeffreys Ledge are underlain by end moraines and ground moraine of late Wisconsinan age (Oldale, 1985a), and by a barrier spit and lagoon system of Holocene age (Oldale, 1985b). Thick deposits of the drowned Merrimack River delta (Oldale and others, 1983) bury the bedrock surface and along with the wave-eroded transgressive unconformity produce the generally smooth bottom landward of the 65-m bathymetric contour. Minor bottom irregularities in the region are mostly sand ridges atop the transgressive unconformity. Locally, outcrops of bedrock, for example seaward of Hampton Harbor, produce very irregular bottom morphology.

The total thickness of sediment above bedrock is shown in figure 10. Maximum thicknesses (120 m to 160 m) occur where glacial marine deposits fill deep glacially scoured depressions in the bedrock surface, and where, in the eastern part of the map area, major bathymetric highs are underlain by coastal plain strata. Sediments are generally thinnest along the coast where bedrock lies at relatively shallow depths.

Cross sections and a geologic map (fig. 11) show the generalized stratigraphy and the distribution of geologic units that crop out at the sea floor or are overlain by younger deposits too thin to be resolved in the seismic profiles. Marine and fluvial deposits of Holocene age form the sea floor in the western, central, and northeastern parts of the map area. Deposits are mostly sand nearshore and atop the delta, and silt and clay offshore. Holocene marine deposits are generally thin, as shown by the cross sections. Sparse outcrops of glacial drift and bedrock are scattered throughout the areas where the Holocene deposits make up the sea floor. Glacial marine deposits dominate the southeastern part of the map area. They generally occur atop bathymetric highs where the Holocene transgression eroded the drift surface and where post-transgressive deposition has been slow or absent. The glacial marine deposits are generally thick atop the bathymetric highs, as shown by the southeastern end of cross section A-A' (fig. 11), but numerous outcrops of coastal plain strata indicate that in places the drift is relatively thin.

## Geologic history

Coastal plain strata (Tcp), inferred to underlie much of the eastern part of the map area, are most likely of Tertiary age and similar to Eocene and Miocene strata found elsewhere in coastal Massachusetts and at Fippennies Ledge in the Gulf of Maine. They probably represent a shallow-water marine environment (Schlee and Cheetham, 1967; Folger and others, 1978; Kaye, 1983b). Strata of Cretaceous age, if present, would likely be similar to strata of that age in the subsurface of Nantucket and Martha's Vineyard that were deposited mostly in nonmarine environments (Folger and others, 1978; Hall and others, 1980). The fluvial unconformity atop bedrock and coastal plain strata (fu) attests to subaerial conditions and fluvial erosion that probably occurred during Tertiary time, possibly when sea level fell during the Pliocene Epoch (Vail and others, 1977). The deep, glacially scoured depressions in the bedrock surface may represent channels of the ancestral Merrimack River cut in late Tertiary time.

The inner shelf off northeastern Massachusetts was glaciated at least twice. Deposits mapped as till (Qdt) may represent, in part, drumlin till similar to that which occurs on Plum Island and elsewhere in northeastern Massachusetts (Hanson, 1984). The drumlin till, or "lower till" as it is commonly called in New England, is thought to be Illinoian (Oldale and Eskenasy, 1983) or early Wisconsinan (Hanson, 1984) in age. Retreat of the late Wisconsinan ice was accompanied by marine submergence, the result of the crust being depressed by glacial ice to a level below the glacially lowered worldwide sea level. Consequently, the upper Wisconsinan drift (Qdt, Qmd) is mostly of marine origin. The discontinuous drift (Qdt), which occurs below glaciomarine silt and clay (Qmd), may be, at least in part, submarine sand and gravel deposited close to the retreating ice front in the same manner as that described by Rust and Romanelli (1975) for subaqueous ice-contact and outwash deposits in the Ottawa Valley, Canada, that were associated with the Champlain Sea. In the map area, large quantities of fine-grained sediments (Qmd) discharged into the sea by glacial meltwater were deposited beyond the ice front generally to thicknesses greater than 30 m. Retreat of the ice front across the map area probably occurred between 14,000 years before present, the age of the Cambridge readvance near Boston to the south (Kaye and Barghoorn, 1964; Stone and Peper, 1982) and 13,200 years before present, the age of the Kennebunk readvance to the north in southern coastal Maine (Borns, 1973; Smith, 1982). Shortly thereafter, the shore regressed rapidly as the crust rebounded, the result of glacial unloading. Regression continued until relative sea level was about 50 m below present sea level, about 10,500 years before present (Oldale and others, 1983; Oldale, 1985b). The Merrimack River and lesser rivers eroded the glacial sediments choking their valleys, producing the regressive unconformity (ru) atop the drift. The eroded material was redeposited nearshore as stream (Qhf) and deltaic (Qhd) sediments and offshore as fine-grained marine sediments (Qhm). These Holocene-age deposits are generally less than 20 m thick. Wave erosion during the Holocene transgression formed the marine unconformity (tu) atop glacial and postglacial deposits. Bar sediments (Qhb) were laid down and later were reworked by the rising sea level. The marine unconformity is time transgressive and now forms the seaward shore of Plum Island (fig. 2). Estuarine and riverine sediments are also time transgressive and are now forming in the Merrimack River estuary and in smaller estuaries along the coast. Fine-grained sediments continue to be deposited offshore in deep water.

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# MAPS AND SEISMIC PROFILES SHOWING GEOLOGY OF THE INNER CONTINENTAL SHELF, CAPE ANN, MASSACHUSETTS TO NEW HAMPSHIRE

By
Robert N. Oldale and Lynne E. Wommack

1987

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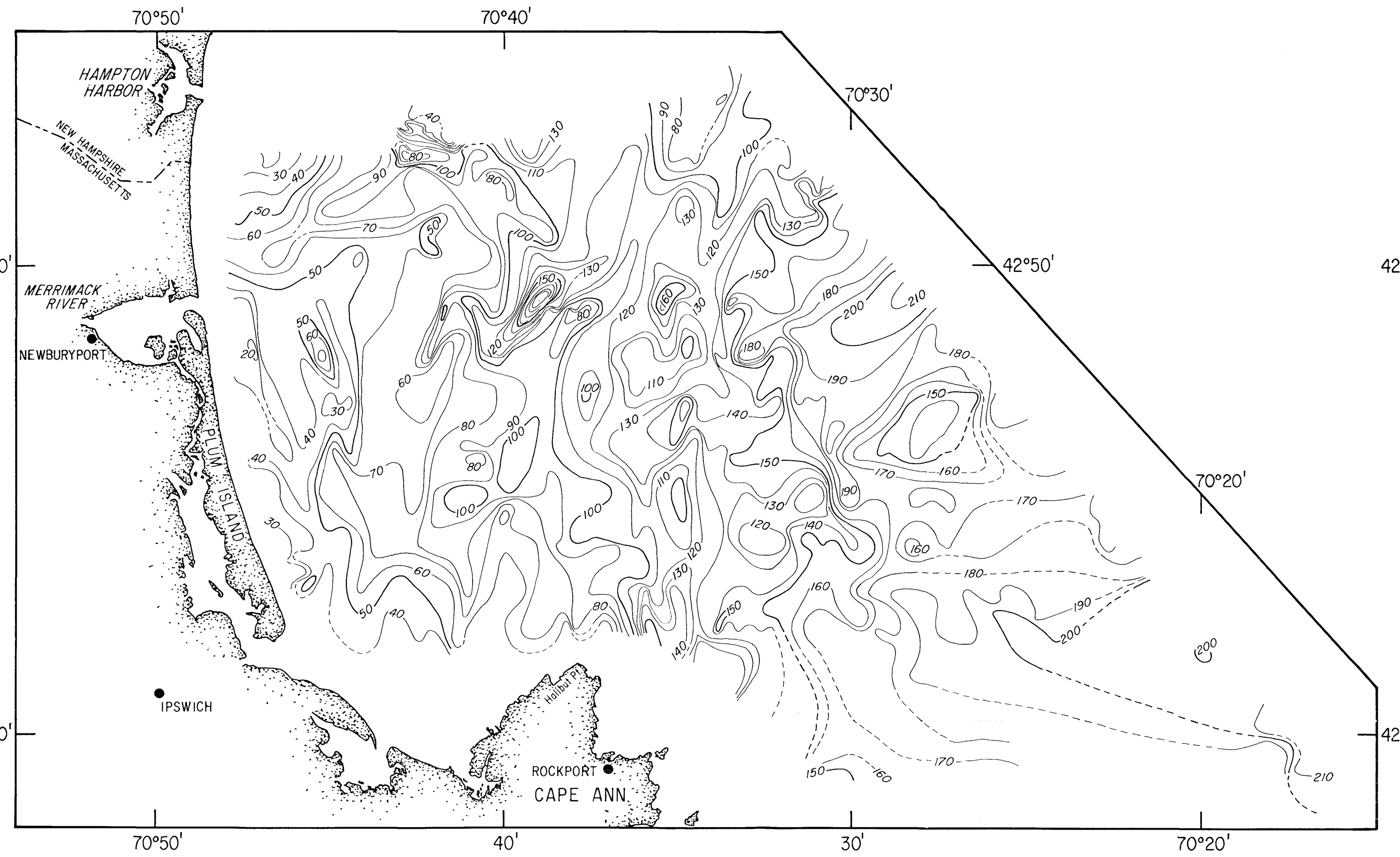
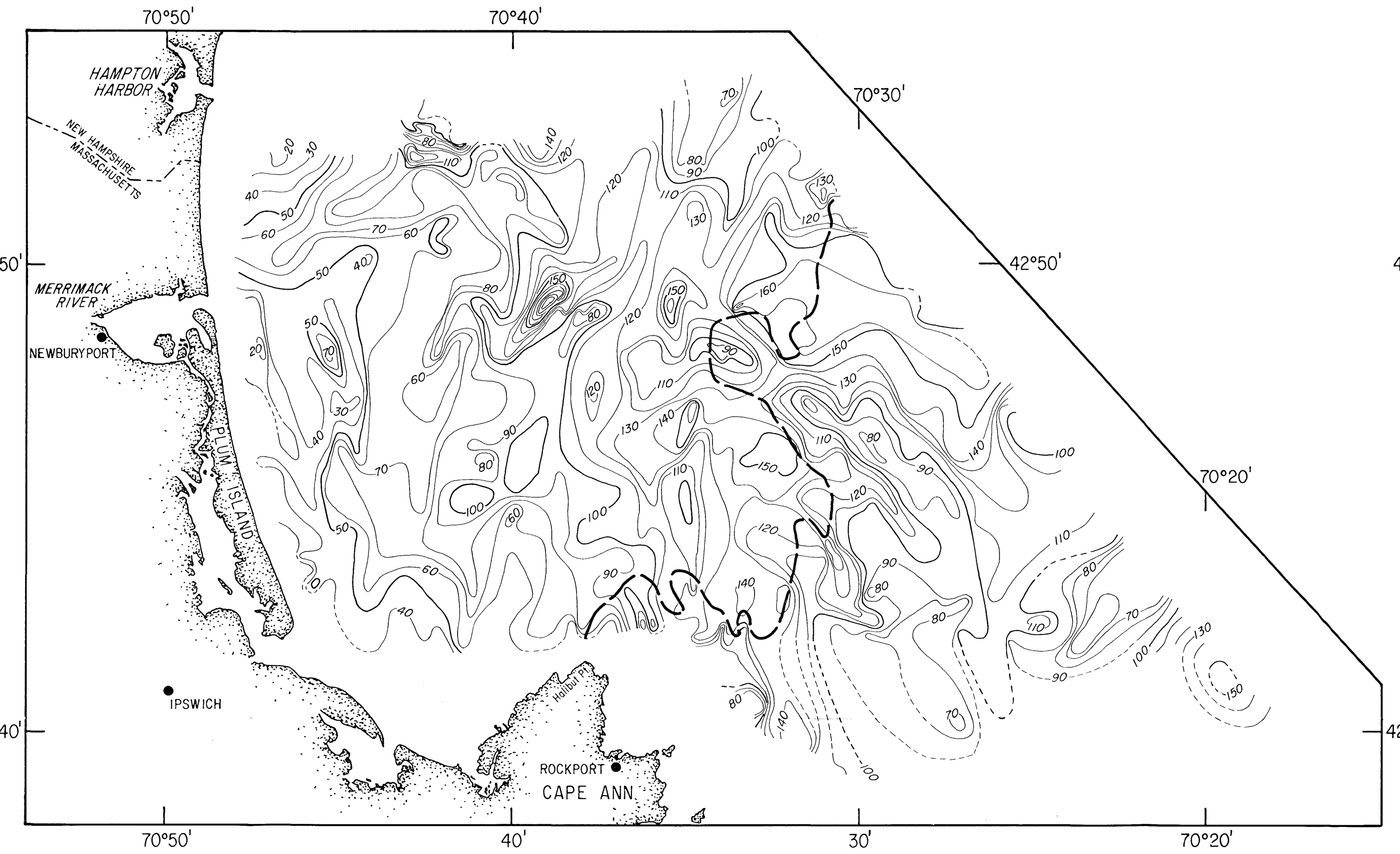



Base from U.S. Coast and Geodetic Survey bathymetric map C.&G.S. 0808N-50, Cape Cod to Cape Ann, 1970; and from National Ocean Service bathymetric map N.O.S. 0808N-69, Hampton Harbor to Maquoit Bay, 1970. Transverse Mercator projection

Scale 1:125,000
0 1 2 3 4 5 Nautical Miles
0 1 2 3 4 5 Kilometers

Figure 4.--Depth to bedrock surface. Contour interval 10 m. Based on assumed seismic velocities of 1.5 km/s for water and for sediments inferred to be of Holocene age, 1.8 km/s for inferred Pleistocene sediments, and 2.5 km/s for sediments inferred to be of Tertiary or Cretaceous age. Contours dashed where seismic data provide little control.

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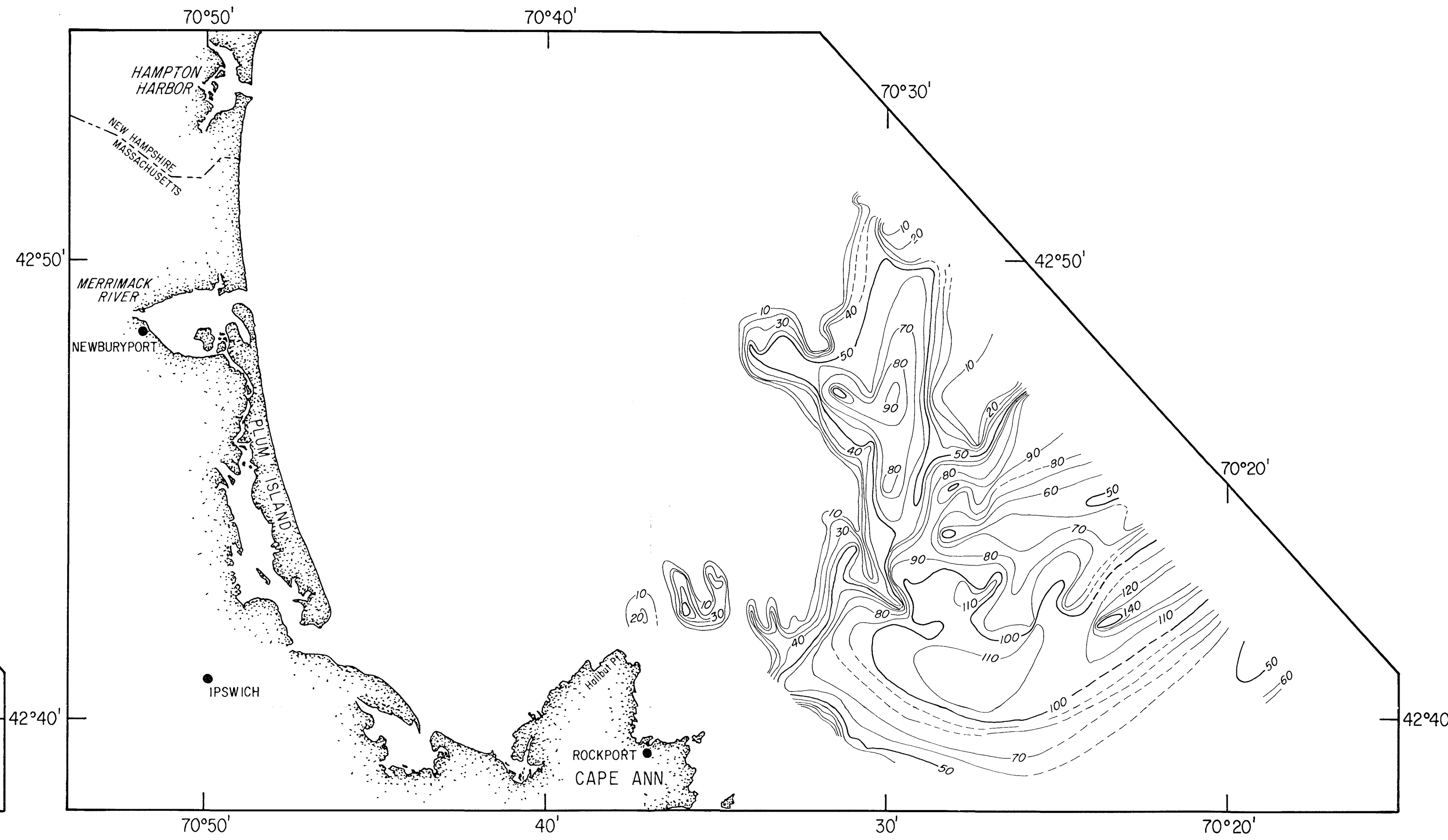
Scale 1:125,000
0 1 2 3 4 5 Nautical Miles
0 1 2 3 4 5 Kilometers

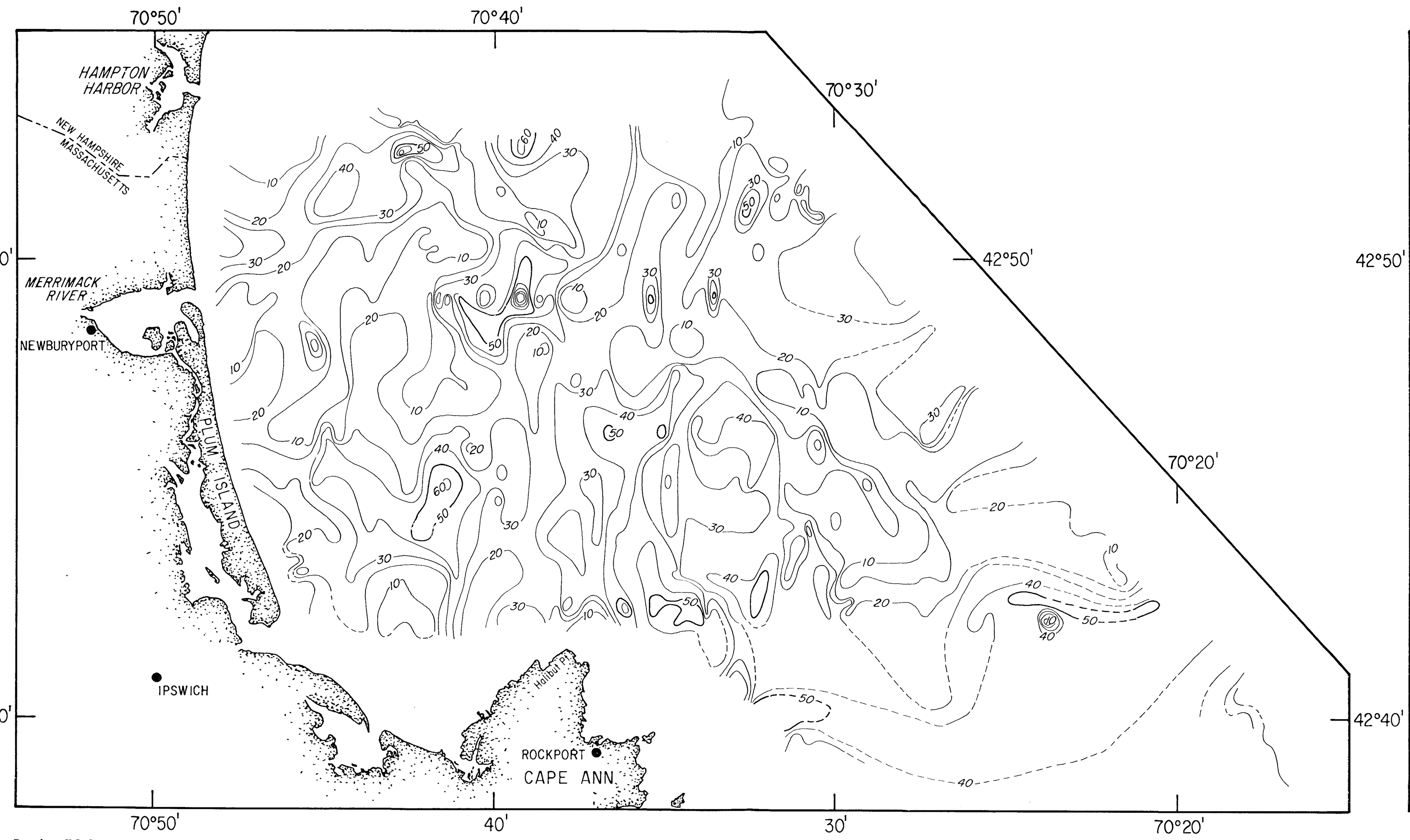
Figure 5.--Depth to seismic reflector (fu) which marks the surface of bedrock (west of heavy dashed line) or of coastal plain deposits (east of heavy dashed line). Contour interval 10 m. Based on assumed seismic velocities of 1.5 km/s for water and for sediments of Holocene age, and 1.8 km/s for glacial drift. Contours dashed where seismic data provide little control.




Base from U.S. Coast and Geodetic Survey bathymetric map C.&G.S. 0808N-50, Cape Cod to Cape Ann, 1970; and from National Ocean Service bathymetric map N.O.S. 0808N-69, Hampton Harbor to Maquoit Bay, 1970. Transverse Mercator projection

Scale 1:125,000
0 1 2 3 4 5 Nautical Miles
0 1 2 3 4 5 Kilometers

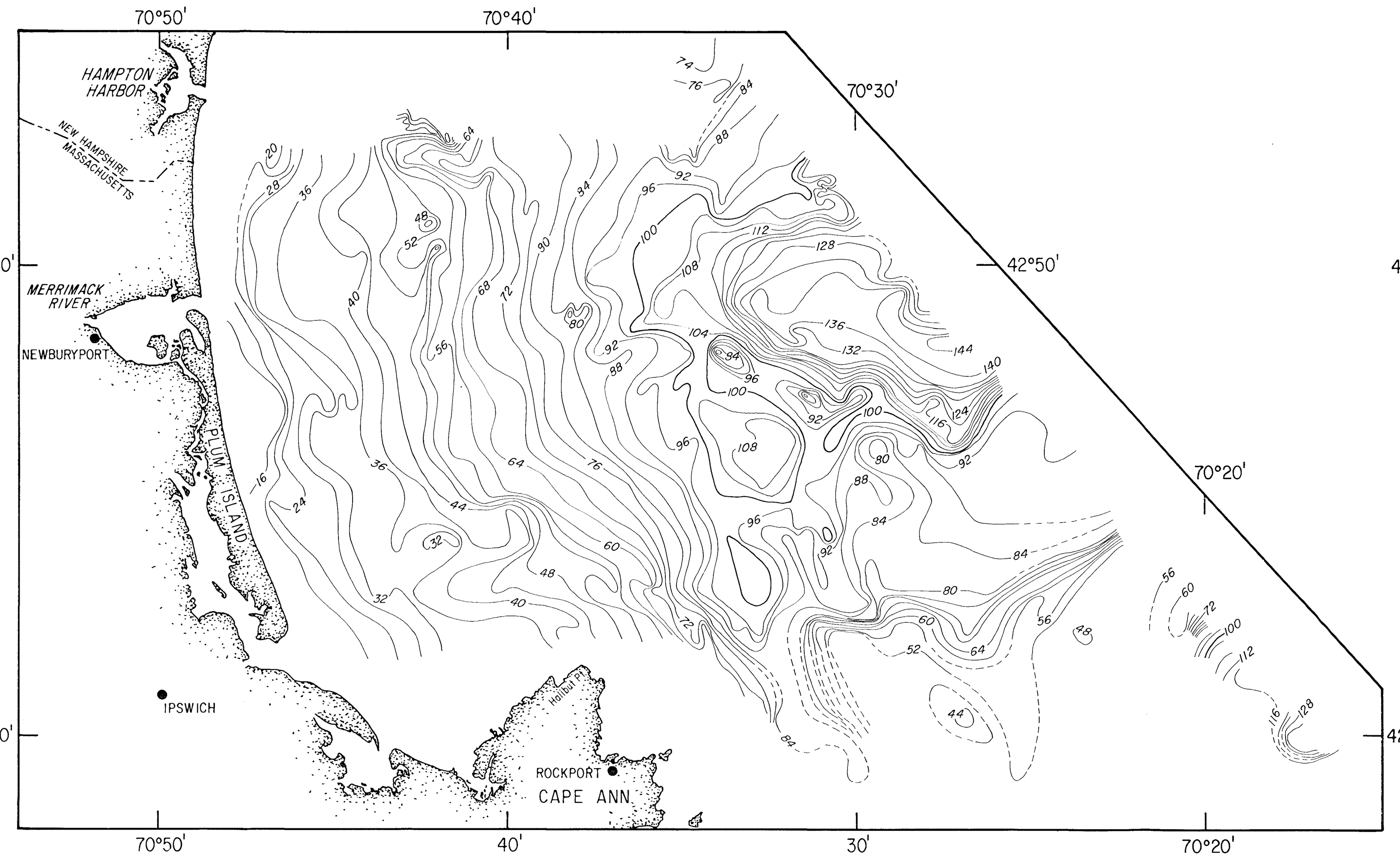
Figure 6.--Thickness and distribution of coastal plain deposits of probable Tertiary age. Contour interval 10 m. Thickness calculated using an assumed seismic velocity of 2.5 km/s. Contours dashed where seismic data provide little control.




Base from U.S. Coast and Geodetic Survey bathymetric map C.&G.S. 0808N-50, Cape Cod to Cape Ann, 1970; and from National Ocean Service bathymetric map N.O.S. 0808N-69, Hampton Harbor to Maquoit Bay, 1970. Transverse Mercator projection

Scale 1:125,000
0 1 2 3 4 5 Nautical Miles
0 1 2 3 4 5 Kilometers

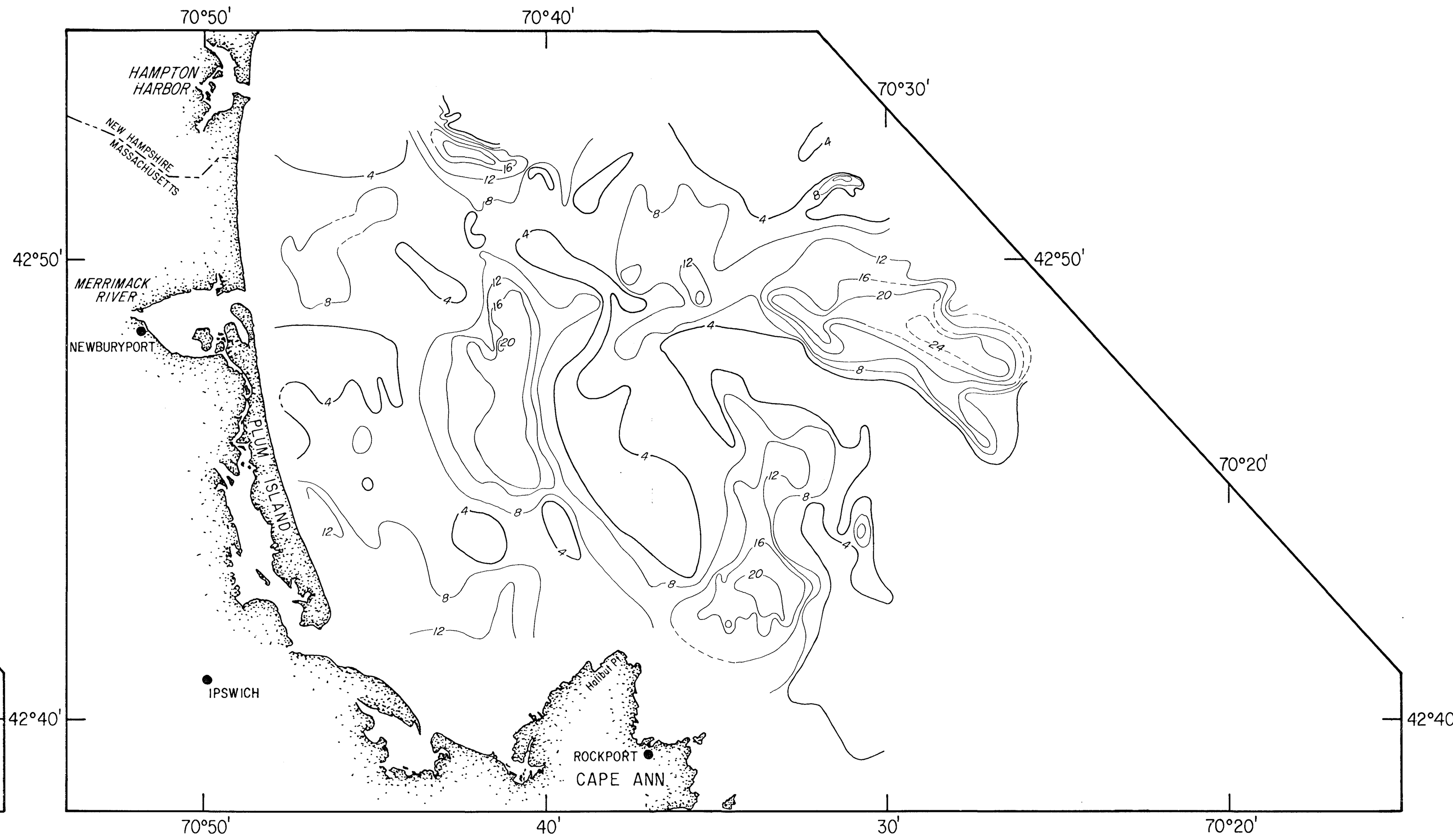
Figure 7.--Thickness of glacial drift. Includes coarse-grained submarine deposits (Qdt) and fine-grained glacial marine deposits (Qmd). Contour interval 10 m. Thickness calculated using an assumed seismic velocity of 1.8 km/s. Contours dashed where seismic data provide little control.




Base from U.S. Coast and Geodetic Survey bathymetric map C.&G.S. 0808N-50, Cape Cod to Cape Ann, 1970; and from National Ocean Service bathymetric map N.O.S. 0808N-69, Hampton Harbor to Maquoit Bay, 1970. Transverse Mercator projection

Scale 1:125,000
0 1 2 3 4 5 Nautical Miles
0 1 2 3 4 5 Kilometers

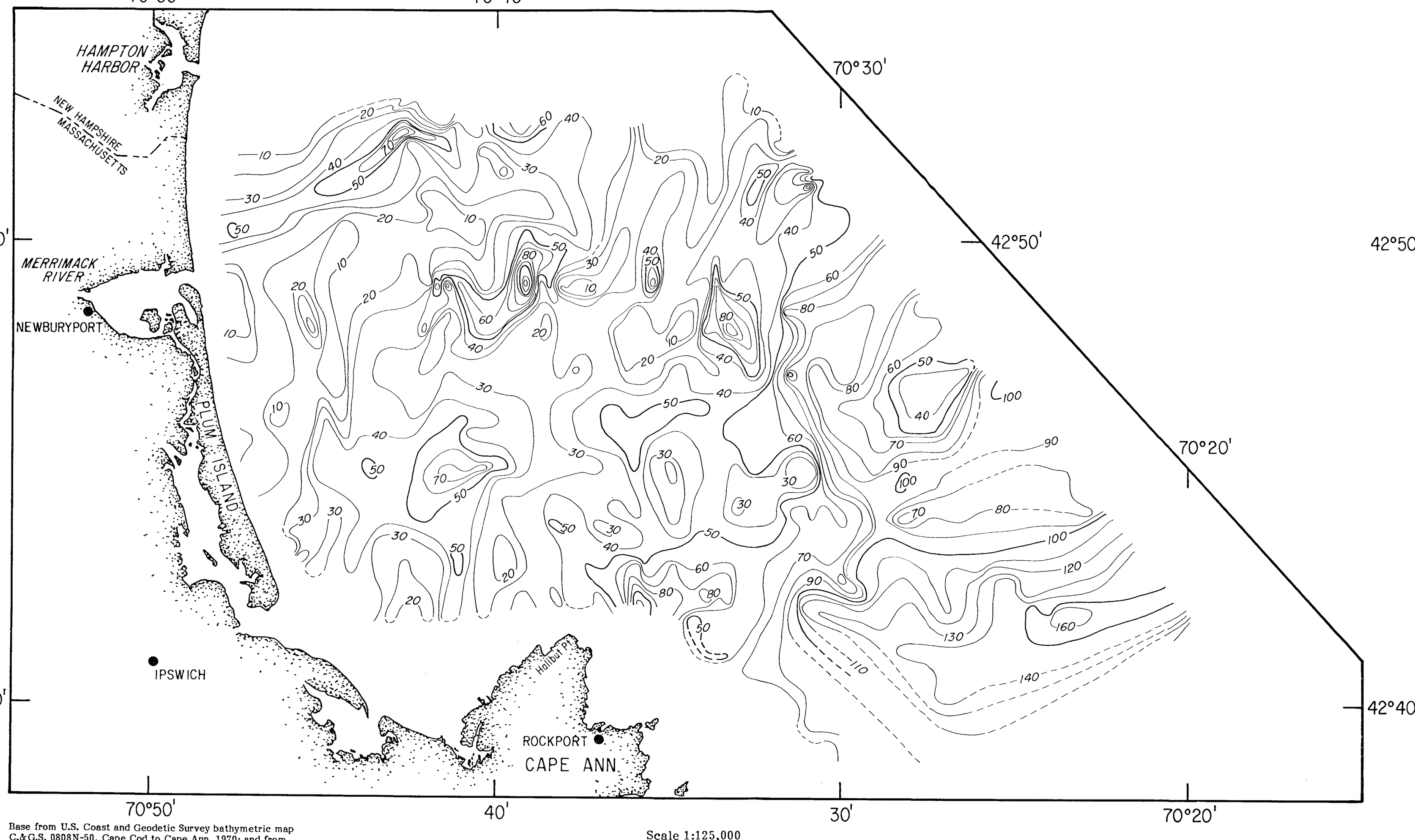
Figure 8.--Depth to the glacial drift surface (ru; see figure 3). Contour interval 4 m. Based on an assumed seismic velocity of 1.5 km/s for water and for sediments of Holocene age. Contours dashed where seismic data provide little control.




Base from U.S. Coast and Geodetic Survey bathymetric map C.&G.S. 0808N-50, Cape Cod to Cape Ann, 1970; and from National Ocean Service bathymetric map N.O.S. 0808N-69, Hampton Harbor to Maquoit Bay, 1970. Transverse Mercator projection

Scale 1:125,000
0 1 2 3 4 5 Nautical Miles
0 1 2 3 4 5 Kilometers

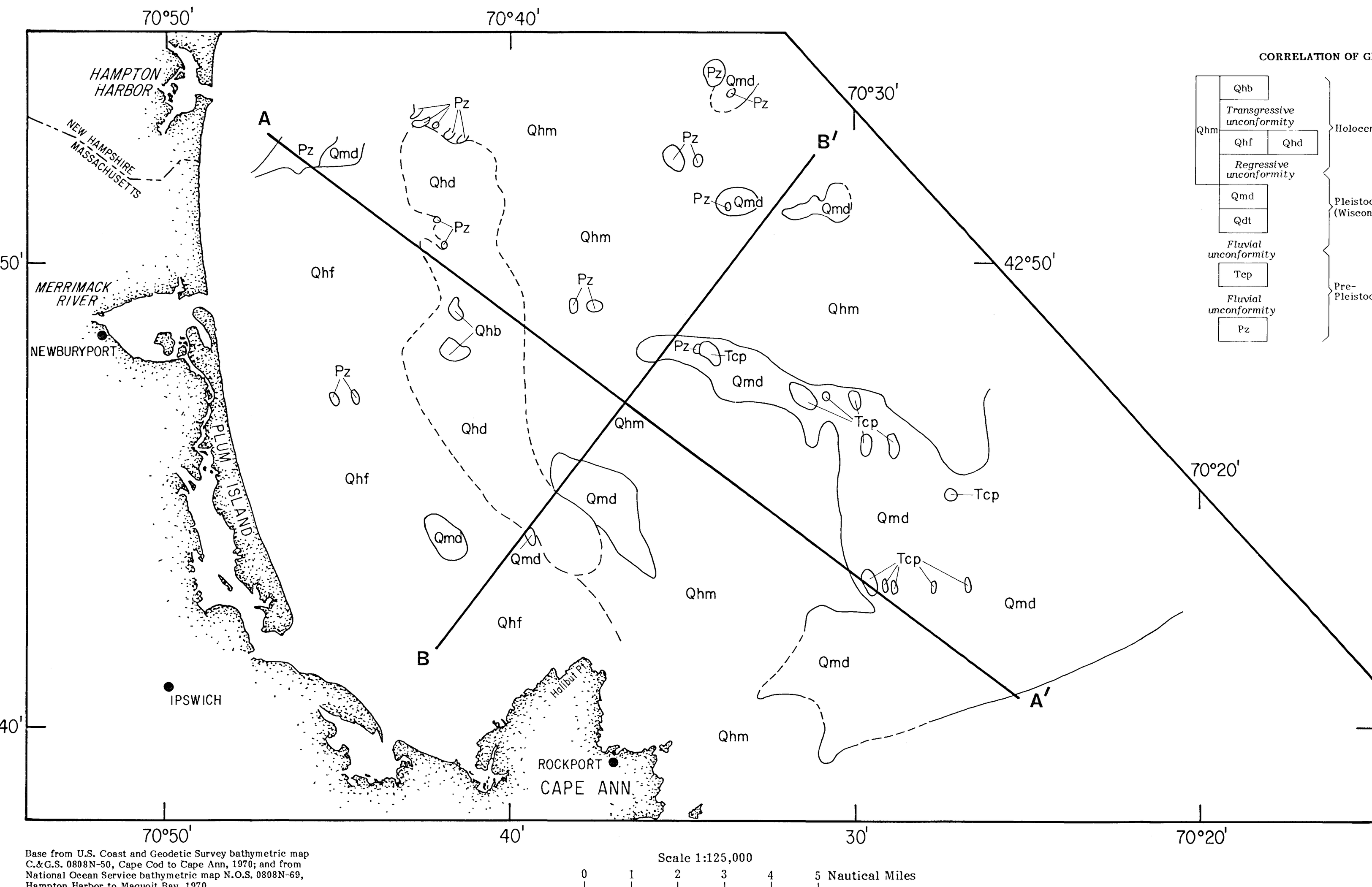
Figure 9.--Thickness of Holocene marine deposits. Contour interval 4 m. Based on an assumed seismic velocity of 1.5 km/s. Contours dashed where seismic data provide little control.




Base from U.S. Coast and Geodetic Survey bathymetric map C.&G.S. 0808N-50, Cape Cod to Cape Ann, 1970; and from National Ocean Service bathymetric map N.O.S. 0808N-69, Hampton Harbor to Maquoit Bay, 1970. Transverse Mercator projection

Scale 1:125,000
0 1 2 3 4 5 Nautical Miles
0 1 2 3 4 5 Kilometers

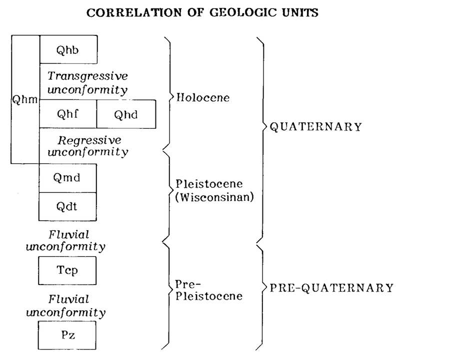
Figure 10.--Total sediment thickness above bedrock. Contour interval 10 m. Based on assumed seismic velocities of 2.5 km/s for coastal plain sediments, 1.8 km/s for glacial drift, and 1.5 km/s for marine sediments of Holocene age. Dashed where seismic data provide little control.




Base from U.S. Coast and Geodetic Survey bathymetric map C.&G.S. 0808N-50, Cape Cod to Cape Ann, 1970; and from National Ocean Service bathymetric map N.O.S. 0808N-69, Hampton Harbor to Maquoit Bay, 1970. Transverse Mercator projection

Scale 1:125,000
0 1 2 3 4 5 Nautical Miles
0 1 2 3 4 5 Kilometers

## CORRELATION OF GEOLOGIC UNITS




## DESCRIPTION OF GEOLOGIC UNITS

Qhb **Bar deposits (Holocene)**—Mostly sand; may include some gravel. Unit generally less than 4 m thick. Forms sand waves and ridges atop the transgressive unconformity (tu; see figure 3, profiles C, E, F, and G)

Qhf **Fluvial deposits (Holocene)**—Mostly sand; may include some gravel, silt, and clay. Unit generally 8-12 m thick. Overlies the regressive unconformity (ru; see figure 3, profiles A-H). Considered to be subaerial stream and marine estuarine deposits formed during the late Wisconsinan to early Holocene lowstand of sea level. Grades offshore into deltaic deposits

Qhd **Deltaic deposits (Holocene)**—Mostly sand; includes silt and probably some gravel and clay. Unit up to 20 m thick. Underlain by drift. Makes up a drowned delta of the Merrimack River. Grades offshore into deep-water marine deposits

Qhm **Marine deposits (Holocene)**—Mostly silt and clay; includes sand and possibly gravel. Unit up to 24 m thick. Occurs offshore in deep water. Conformably overlies glacial marine silt and clay in most places

Qmd **Glacial marine deposits (Pleistocene)**—Mostly silt and clay with minor sand; may become sandier adjacent to bathymetric highs. Unit averages 40 m thick but is as much as 90 m thick in glacially scoured valleys. Overlies ice-contact drift and outwash; unconformably overlies coastal plain deposits and bedrock

Qdt **Coarse submarine glacial drift (Pleistocene)**—Ice-contact and outwash deposits of sand and gravel, and till. Thin and discontinuous drift below glacial marine deposits (Qmd). Unit may include older drift, possibly drumlin till of early to pre-Wisconsinan age. Unconformably overlies bedrock and coastal plain deposits. Shown on interpreted seismic profiles (fig. 3) only

Tcp **Coastal plain deposits (Tertiary)**—Inferred to be unconsolidated to consolidated gravel to clay similar to coastal plain and continental shelf sediments on Fippennies Ledge in the Gulf of Maine and in the subsurface of Martha's Vineyard and Nantucket (Schlee and Cheetham, 1967; Folger and others, 1978). Unit unconformably overlies bedrock

Pz **Bedrock (Mesozoic or older)**—Igneous, metamorphic, and sedimentary rock similar to that exposed on land adjacent to the map area

**Contact**—Dashed where approximately located or where inferred

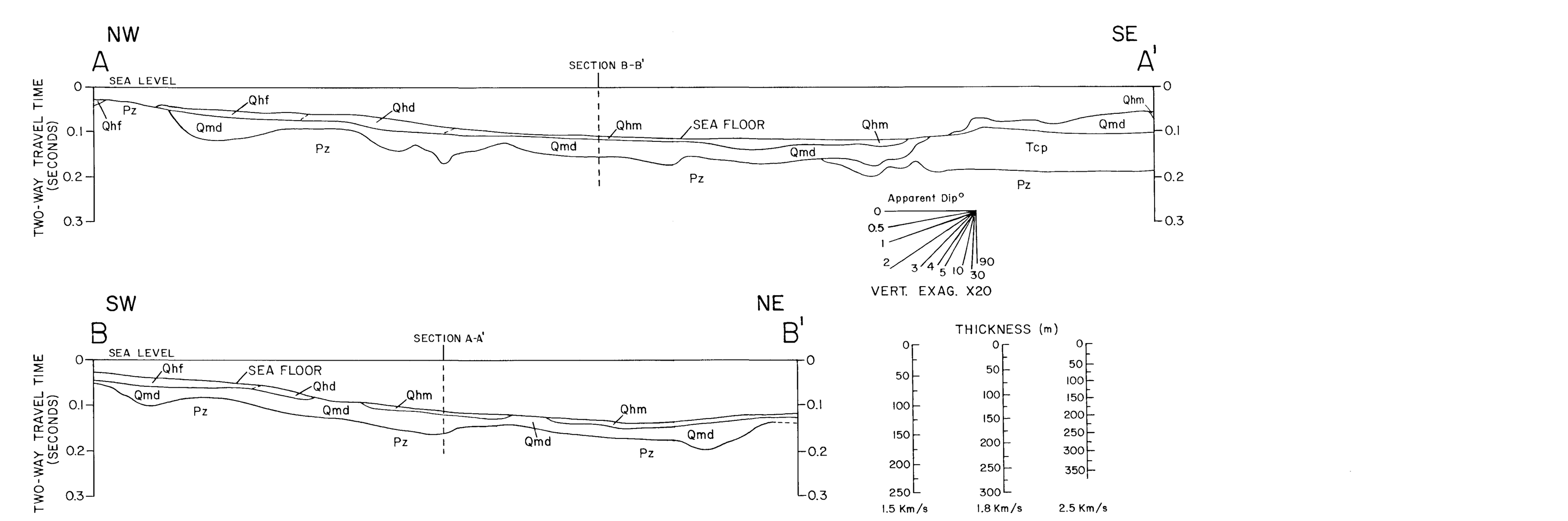



Figure 11.--Map and cross sections showing distribution and stratigraphy of the geologic units. Units shown crop out at the sea floor or are overlain by younger sediments too thin to resolve in the seismic data. Seismic velocities assumed for the geologic units are 2.5 km/s for coastal plain sediments, 1.8 km/s for glacial drift, and 1.5 km/s for marine sediments of Holocene age. In cross sections, apparent-dip scale and vertical exaggeration are based on a seismic velocity of 1.5 km/s. Vertical exaggeration is abbreviated vert. exag.

# MAPS AND SEISMIC PROFILES SHOWING GEOLOGY OF THE INNER CONTINENTAL SHELF, CAPE ANN, MASSACHUSETTS TO NEW HAMPSHIRE

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