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Volume and Quality of Sand and Gravel Aggregate in the Submerged Paleodelta, Shorelines, and Modern Shoreface of Saco Bay, Maine

by

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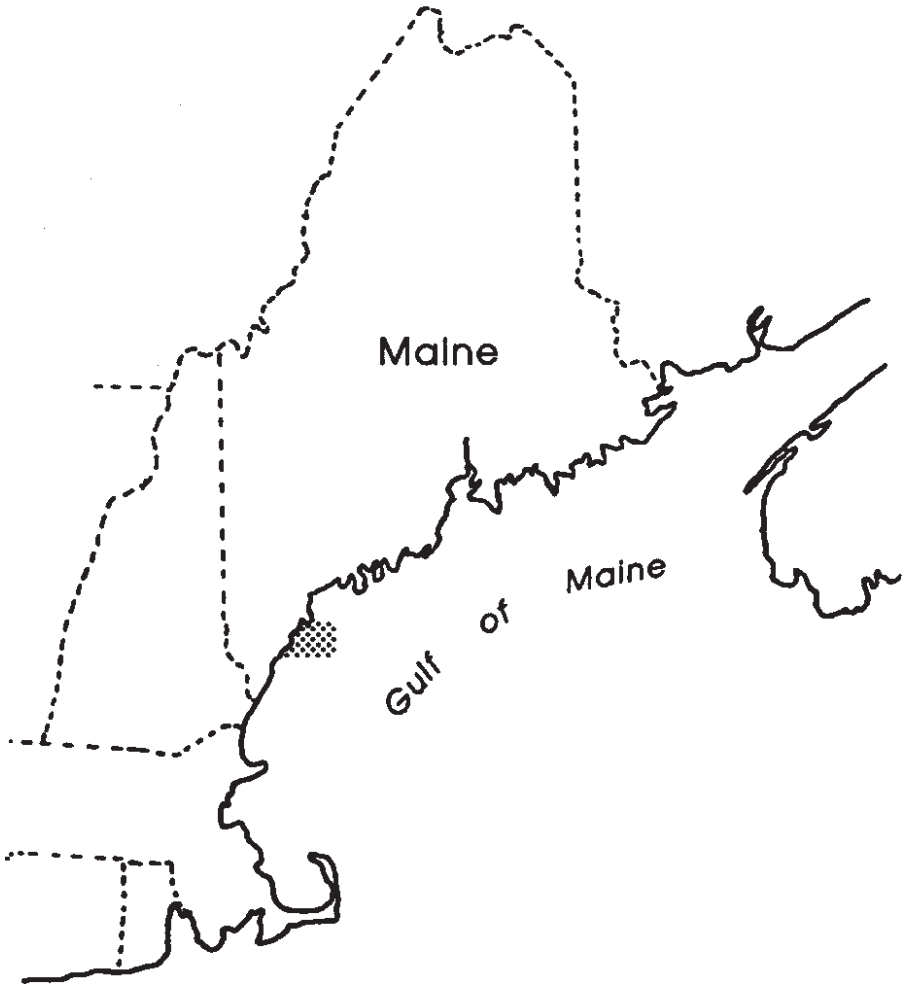

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DEPARTMENT OF CONSERVATION

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Year 9 Report to the Minerals Management Service-
American Association of State Geologists Continental Margins Program

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INTRODUCTION

Sand and gravel aggregate is an increasingly valuable commodity for use as beach replenishment along eroding shorelines. This project was developed to assess sand-reservoir volumes near Maine's eroding beaches as part of the American Association of State Geologists-Minerals Management Service's Continental Margins Program.

Preliminary work by the Maine Geological Survey indicated that three major repositories for sand and gravel are located along the southern Maine inner continental shelf. The repositories lie: (1) directly offshore of major sand beach systems, (2) along shelf valleys between the modern beach and the lowstand-shoreline position, and (3) near the late Quaternary lowstand-shoreline position of 50-60 m depth. This report presents results of a geophysical and coring investigation of sand volumes in those three environments in Saco Bay, Maine (Figure 1).

STUDY AREA AND PREVIOUS WORK

Saco Bay is located in the Arcuate Bays coastal compartment of southern Maine (Figures 1, 2)(Kelley, 1987). This region is characterized by large arcuate sandy beaches, of which Saco Bay's are the longest (Figures 1, 2). The curved bay stretches generally northeast-southwest between Biddeford Pool and Cape Elizabeth, and is punctuated by the peninsula of Prouts Neck and Richmond Island. There are several smaller islands in the bay that are associated with extensive rocky shoals (Figure 2).

Seaward of the beaches a Nearshore Ramp (shoreface) extends to approximately 20 m - 30 m depth (Figure 3) (Kelley et al., 1989a, 1989b). There, the sandy ramp terminates against an extensive Rocky Zone surrounding several small islands. Shelf Valleys project from the Nearshore Ramp around the islands and continue into water depths of about 50 m - 60 m (Kelley et al., 1989a). This study focuses on the sediment and stratigraphy of the Nearshore Ramp seaward of Old Orchard Beach to a depth of 30 m (Figure 2), on a large Shelf Valley, and on the region near the termination of the Shelf Valleys at 50 m - 60 m depth.

Farrell (1972) conducted the first study of the seafloor sediments of Saco Bay. Using fewer than 75 grab samples he determined that sandy material dominated the bottom to about 30 m, except near rock outcrops where gravel also occurred. Kelley et al. (1987) collected 176 bottom samples from the bay and coupled their collection with seismic reflection profiles and side-scan sonar records. Their preliminary work indicated a gradual transition from sand to muddy sand to sandy mud along transects extending from the beach to water depths greater than 30 m. They also recognized the extensive area of muddy sandy gravel near Prouts Neck as a reworked till deposit (Kelley et al.,

1987; 1989a). At a water depth between 50 m and 60 m, Kelley et al. (1987, 1989a) inferred that lower-than-present shorelines existed. Subsequent preliminary vibracoring generally supported that conclusion (Kelley et al., 1990, 1992).

The first published seismic reflection records demonstrated that glacial-marine mud existed beneath the surficial sand sheet and cropped out near bedrock pinnacles (Kelley et al., 1987). In several places this unit formed Quaternary sediment thicknesses greater than 40 m, with sand deposits inferred to be up to 20 m thick in the inner bay area (Figure 4). The strong surface acoustic return masked the upper 10 m, however, and multiples confused the interpretation in water depths less than 15 m. Cores that were collected later indicated that the surficial sand was relatively thin (<5 m) in many places in the bay and that the contact between glacial-marine mud and overlying sand had not been recognized in earlier work (Kelley et al., 1990, 1992; Luepke and Grosz, 1986). Similarly, the lowstand-shoreline positions were inferred to contain relatively thick deposits of sand, but early efforts at coring were inconclusive (Kelley et al., 1990, 1992). The confusion over the thickness of the surficial sand sheet and lowstand-shoreline deposits led directly to this investigation.

SEISMIC STRATIGRAPHIC AND CORING METHODS

Based on earlier geophysical and coring work, effort was directed at three specific locations within Saco Bay: (1) a nearshore, shallow-water region, (2) a channel leading from nearshore areas, and (3) an offshore deep-water location (Figure 5). Seismic records were collected with an ORE Geopulse Boomer seismic system. Vibracores were gathered with Rossfelder P-5 and P-6 Underwater Vibracorers. Navigation was with LORAN-C, with coordinate transformation to latitude/longitude through LORCON (J. Stewart, NOAA, personal communication). All spatial data were entered into the Arc/Info Geographic Information System (GIS), where calculations of sand volume were made.

TABLE 1: LOCATION OF VIBRACORES

CORE NUMBER (SCVC92-)	DEPTH (m)	LATITUDE	LONGITUDE
01	16.0	43° 29’ 22.3"	70° 21’ 44.3"
02	14.1	43° 30’ 19.0"	70° 20’ 58.3"
04	59.6	43° 30’ 40.6"	70° 13’ 2.2"
05	55.1	43° 30’ 39.2"	70° 13’ 22.4"
06	63.2	43° 29’ 13.8"	70° 12’ 51.4"
07	68.4	43° 29’ 13.5"	70° 12’ 41.8"
08	14.4	43° 30’ 35.7"	70° 20’ 15.3"
09	13.3	43° 30’ 7.1"	70° 21’ 22.9"
10	40.7	43° 29’ 47.0"	70° 17’ 3.9"
11	41.2	43° 29’ 46.7"	70° 17’ 1.8"

Following collection, the vibracores were sealed in their liners until they reached the University of Maine’s sedimentology laboratory. There, the cores were described and photographed. Subsamples were removed for textural and radiocarbon analyses.

Previous work in the Gulf of Maine relating geophysical records to submersible and coring observations has led to confidence in our interpretation of seismic data (Belknap et al., 1989; Shipp, 1989). In most regions, acoustic basement is crystalline bedrock, which often exhibits tens of meters of relief over short horizontal distances. It is often overlain by till, which is sometimes indistinguishable from bedrock on seismic records. Glacial-marine sediment (locally called the Presumpscot Formation (Bloom, 1963)) may overlie till or bedrock, and in most regions forms the largest portion of the Quaternary section. The glacial-marine sediment is generally muddy and appears as an acoustically transparent seismic unit with parallel acoustic reflectors either draped or ponded over the underlying material (Belknap et al., 1989; Kelley et al., 1989a). This unit was recognized in many cores and seismic lines from earlier studies in Saco Bay (Kelley et al., 1987, 1990, 1992). Unconformably overlying the glacial-marine material, relatively thin units of sand or mud are common. In Saco Bay, Holocene sand dominates the nearshore region, while sand and mud occur at the surface offshore (Kelley et al., 1987).

RESULTS

Nearshore Region

The shore-normal seismic records provide a view of the stratigraphy of the shoreface that is much less ambiguous than earlier observations (Kelley et al., 1987). The acoustic basement, which is crystalline bedrock (br), exhibits more than 30 m of relief over short horizontal distances, and sporadically crops out on the seafloor (Figures 6 - 12). It is overlain by up to 25 m of glacial-marine sediment (Pgm) which possesses subparallel reflectors that are draped over bedrock. These reflectors are truncated by an unconformity which dips gently seaward in the shore-normal seismic lines (Figures 6, 10, 12). In several locations, channels are cut into the glacial-marine material and truncate seismic reflectors (Figures 6, 8). A wedge-shaped unit with a strong acoustic return overlies the glacial-marine material (Figures 6, 10, 12). This unit may be subdivided into two wedges of similar shape (Hs, He) on the basis of a faint reflector partly obscured by the surface return (Figures 6, 8). Surface samples collected for earlier studies show that the upper part of this wedge of material is well-sorted sand (Kelley et al., 1987). Seaward of the wedge, a vibracore collected on an earlier study (VC 8805, Kelley et al., 1990) penetrated only glacial-marine sediment (Figure 10) (Kelley et al., 1992). A generally shore-parallel seismic line suggests that the upper wedge of sediment is thicker toward the northeast (Pine Point, Figures 2, 8).

Three of the 4 vibracores penetrated through the upper wedge into glacial-marine sediment (Figures 7, 11, 13). Core SCVC92-01 was collected from a depth of 16 m very near the toe of the upper wedge of sediment (Figure 12) and is composed of 25 cm of well-sorted, fine sand at the surface, with a fining-upward unit of coarse, shelly gravel to fine sand below (Figure 13). The shells were fragments of echinoids and Arctica islandica with articulated Mya arenaria specimens. Pebbles were at the bottom of the core, but the core catcher contained a bluish clay that is probably of glacial-marine origin.

Cores SCVC92-02 and SCVC92-09 were gathered from shallower depths (14.1 m and 13.3 m, respectively) at a more landward location along the upper wedge of material and appear to have penetrated a more complete section (Figures 6, 10). Glacial-marine mud forms the bottom of each core and is unconformably overlain by less than 0.5 m of poorly sorted, fine sand in each core. Above this, several meters of muddy sand with a few shells and wood fragments compose most of the cores. Plant remains associated with foraminifera characteristic of salt marshes (Trochomina sp., Tiphotrocha sp., R. Gehrels, personal communication) make up a layer 20 cm thick at the base of this unit in core SCVC92-02 (Figures 7, 11). The plant fragments provided a radiocarbon date of 6,110 50 BP. Twenty centimeters above the muddy sandy unit, a shell from Macoma baltica, a common intertidal organism, yielded a date of 7,058 BP. Between 60 and 70 cm depth in the cores an abrupt change to well-sorted fine sand occurs. Within this well-sorted sand, two fining-upward packages of sediment occur in SCVC92-09, and one coarsening upward package in SCVC92-02. Fine-medium sand occurs at the top of each core.

SCVC92-08, collected in 14.4 m of water in the northeastern area of the bay, apparently failed to penetrate through the upper wedge of sandy sediment (Figure 8). The core contains several packages of coarse sand and gravel with shells (Arctica islandica, Astarte castanea, Nassarius sp.) fining-upward to medium sand (Figure 9).

On the basis of the new cores and re-interpretation of the earlier seismic reflection data (Kelley et al.,1987), it is estimated that 6.63 x 10^7 m^3 of Holocene sediment comprise the nearshore wedge overlying glacial-marine sediment (Figure 14). Although the surface material (Hs) is 100% sand, the unit beneath it (He) contains from 8.7 % to 48.5 % mud (Barber, 1995, in prep.). Based on an average sand content for this unit of 32.4 %, the nearshore wedge of Holocene sediment contains approximately 5.62 x 10^7 m^3 of sand.

The thickness of the nearshore Holocene sand wedge generally increases toward the beach (Figure 14). Just seaward of the breaker zone, the limit of seismic data, the thickness of the wedge averages 6 m. There are rock outcrops which form "bullseyes" of thinner sand deposits scattered across the beach region, however. There are also areas with up to 7 m of Holocene sediment just seaward of the Saco River mouth, Camp Ellis, Goosefare Brook, and Pine Point. Seaward of the Saco River mouth, it is notable that the two 6 m - 7 m thick deposits of sediment are elliptical and parallel to one another. In general the Holocene wedge of sediment is wider in the Pine Point area than any other place in the bay, with the exception of a 1 m to 2 m thick, L-shaped deposit in the southern part of the bay.

Shelf Valley

Seismic records across the Shelf Valley reveal up to 20 m of Quaternary sediment (Figures 4, 15), but most of it appears to be muddy, glacial-marine material (Pgm). The truncated acoustic reflectors along the axis of the Shelf Valley imply that some of this material has been eroded during the earlier regression and transgression. Above the truncated seismic reflectors there is a relatively thin but patchy seismic unit, Hm (Figure 15).

Cores through through the upper unit demonstrate that it is less than a meter thick, and composed of poorly sorted sandy gravelly mud (Figures 16, 17). Shells and shell fragments of Mya arenaria and Mytilus edulis are common along with pebbles and cobbles. In SCVC92-11, the upper unit is less than 40 cm thick and shares a sharp contact with the underlying mud correlated with Pgm. In SCVC92-10, the upper unit possesses several mud laminae and grades into uniform mud over an interval of 30 cm. Although the lowermost 40 cm of SCVC92-10 is uniform mud (Figure 15), assumed to be glacial-marine sediment, the equivalent unit in SCVC92-11 possesses shell fragments and occasional cobbles (Figure 16).

No assessment of the thickness of the upper unit or the overall sand volume in the Shelf Valley could be made owing to the very thin nature of the deposit and its patchiness. On many seismic lines collected earlier (Kelley et al., 1987), the upper unit was not even resolved through the acoustic bubble pulse. Where examined in this study, the upper seismic unit was thicker than in any other location observed in the area.

Offshore Lowstand-Shoreline Position

Seismic lines normal to the trend of the inferred lowstand shoreline were selected to permit additional cores from near locations where cores were gathered in 1988 (Figures 18, 19, 20). Each of the lines shows a feature with a pronounced break-in-slope between 50 m and 60 m depth that has been interpreted as a paleo-shoreline (Shipp et al., 1991; Kelley et al., 1992). In lines SC84-22 and SC84-23, the shoreline appears erosional with truncated clinoform seismic reflectors (Pgm) overlain by a thin and patchy seismic unit which possesses a strong surface return above the shoreline (Hs) and a weak surface return below it (Hm) (Figures 18, 19). The older cores (SCVC88-03, SCVC88-04, SCVC88-01, SCVC8-02) along seismic lines SC84-22 and SC84-23 contained very coarse-grained sediment in their upper sections (Kelley et al., 1990, 1992), corresponding to seismic unit Hs with the strong surface return, and abruptly became finer with depth. Core SCVC92-04 penetrated almost 2 m into muddy sand and sandy

mud below the shoreline, corresponding to seismic unit (Hm) with the weak surface return (Figure 21). Shells of Arctica islandica, Astarte borealis and Placopecten magellanicus are common in the core and yield radiocarbon ages ranging from 5,180 70 to 7,330 80 BP (Figure 21). The lowermost sediment in the core appears somewhat sandier and refusal may have occurred because of a coarsening of sediment texture. Pebbles were observed throughout the core, but did not occur as discrete layers. Cores SCVC92-06 and SCVC92-07 (Figure 22) were also muddy at the surface and coarsened at the bottom. Pebbles were only observed at the bottom of these cores.

Seismic line SC91-41 crosses an inferred shoreline which appears as a raised mound, a more constructional feature than the other shorelines that were observed (Figure 20). The core contains mostly mud and sandy mud with two layers of muddy sand and other discrete bodies of sand (Figure 23). These latter bodies of sand appear to have been washed into place during the act of coring. Scattered shells and fragments of Arctica islandica occurred through the core. Although, on the basis of core length, the core is depicted as penetrating glacial-marine sediment, no obvious unconformity was recognized here as it was in other cores.

No isopach map of sand thickness could be drawn for the lowstand-shoreline deposits. Landward of the shoreline the sandy material, Hs, is discontinuous and contained in scattered but thin deposits as it was in the Shelf Valley. Seaward of the lowstand shoreline, the sand deposits may be thicker, but they are covered by a Holocene mud deposit, Hm. No core penetrated well-sorted sand in the deeper areas, although seismic data suggest that such sand exists (Figures 18, 19, 20).

DISCUSSION

Sand Volumes

Each of the three areas thought to contain sand deposits did yield sand in the cores, but the quality and volume of the sand differed significantly from one place to another. Near the lowstand-shoreline position, clinoform reflectors dipping offshore resemble deltaic foreset beds, and may represent a relatively large volume of sand. These deposits are covered by mud (Figures 21, 22, 23), however, and no core penetrated well-sorted sand and gravel that deltaic forsets should contain.

Immediately landward of the lowstand-shoreline position, cores collected earlier (Kelley et al., 1990) indicated sand and gravel at the seafloor. Cores from this study just landward of the shoreline (Figure 23), and from the Shelf Valley (Figures 16, 17), indicate that the sand deposits are very thin, probably less than a meter in most places. The sand is also mixed with shells and gravel, and probably represents a transgressive lag deposit. It is possible that the sand is undergoing transport under existing conditions, but no current meter data are available.

The greatest volume of sand in the Saco Bay system exists near the present shoreline (Figure 14). Most of this sand is dynamically associated with the modern beach and tidal deltas and represents the shoreface, or submerged beach.

Two nearshore areas may be isolated from the beach, however. The first is represented by the L-shaped deposit of sand extending into deeper water seaward of Camp Ellis. This appears to be a body of sand which is resting against, and possibly trapped by, a bedrock shoal (Figure 14). A second, and larger body of sand is represented by the elliptical deposit just north of the present mouth of the Saco River. It is similar in shape to the present tidal delta just seaward of the jetties at the river mouth, and probably represents an older delta that was abandoned when jetties were first built.

Sand Quality

Of the three reservoirs of sand, only the inshore deposits are of potential value as beach fill. The Shelf Valley and Lowstand Shoreline deposits are each: (1) too patchy in distribution; (2) too thin; (3) too poorly sorted; (4) too deep; and (5) too far offshore be of interest. The inshore bodies of sand have not been individually cored, but probably contain well-sorted sand and gravel.

ACKNOWLEDGMENTS

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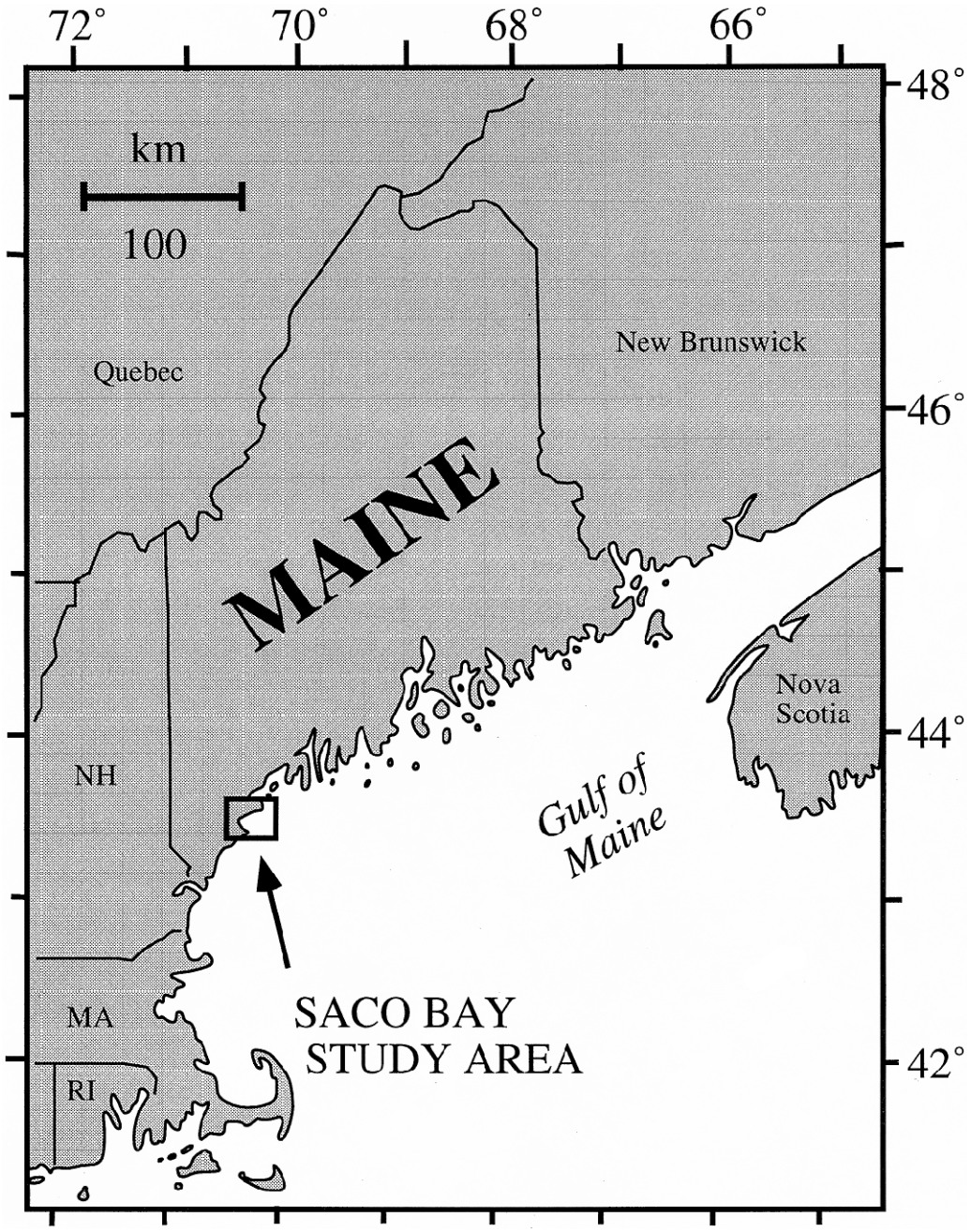


Figure 1. Location of Saco Bay within the Gulf of Maine.

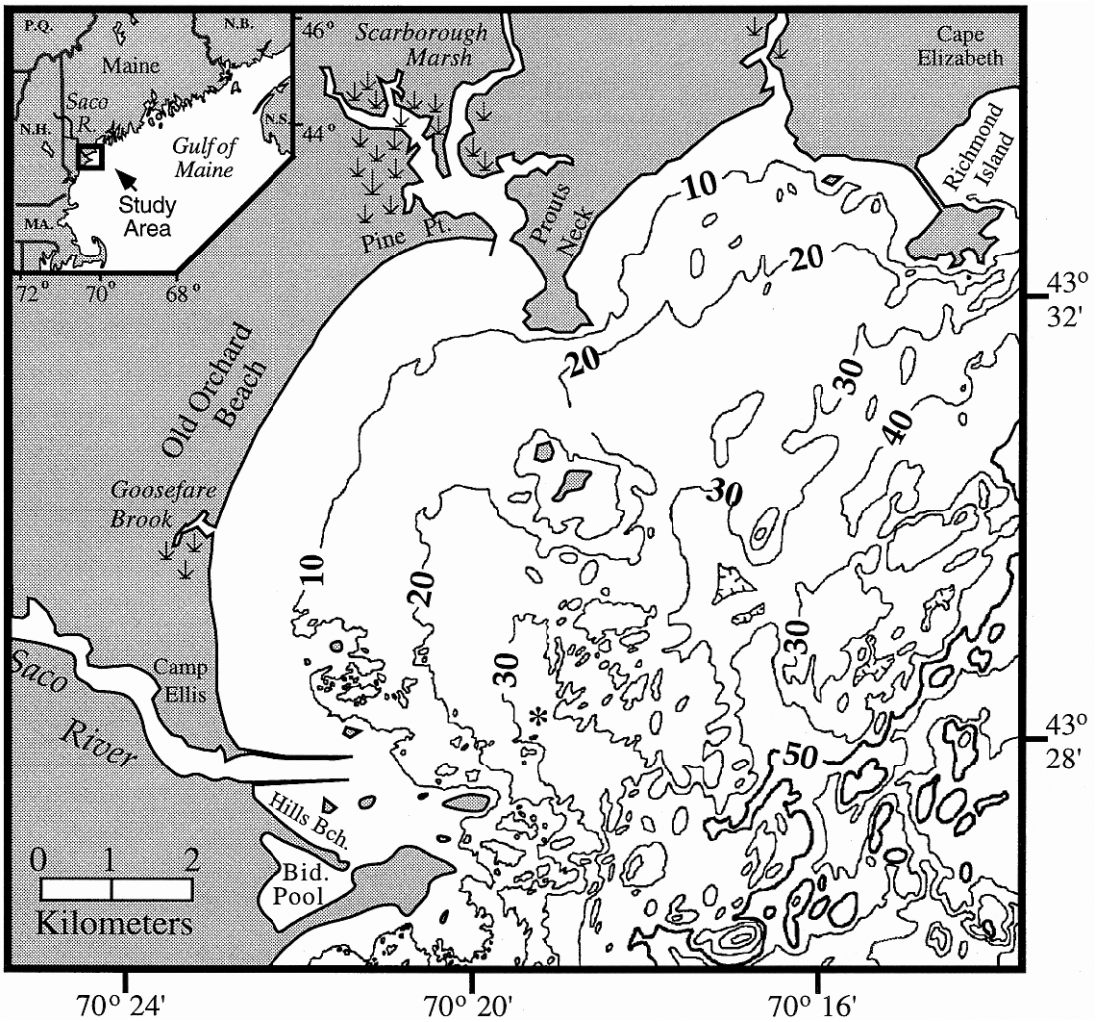


Figure 2. Saco Bay bathymetric map with locations mentioned in the text.

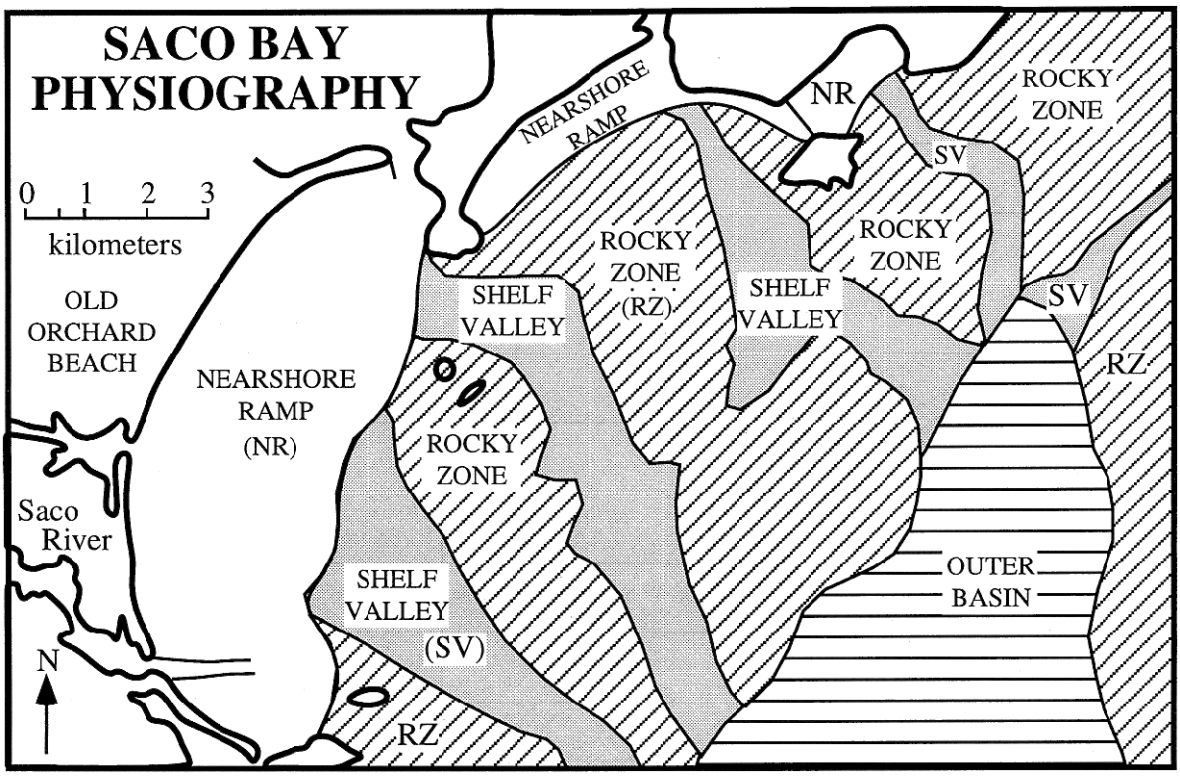


Figure 3. Physiographic zones of Saco Bay (modified from Kelley et al., 1987).

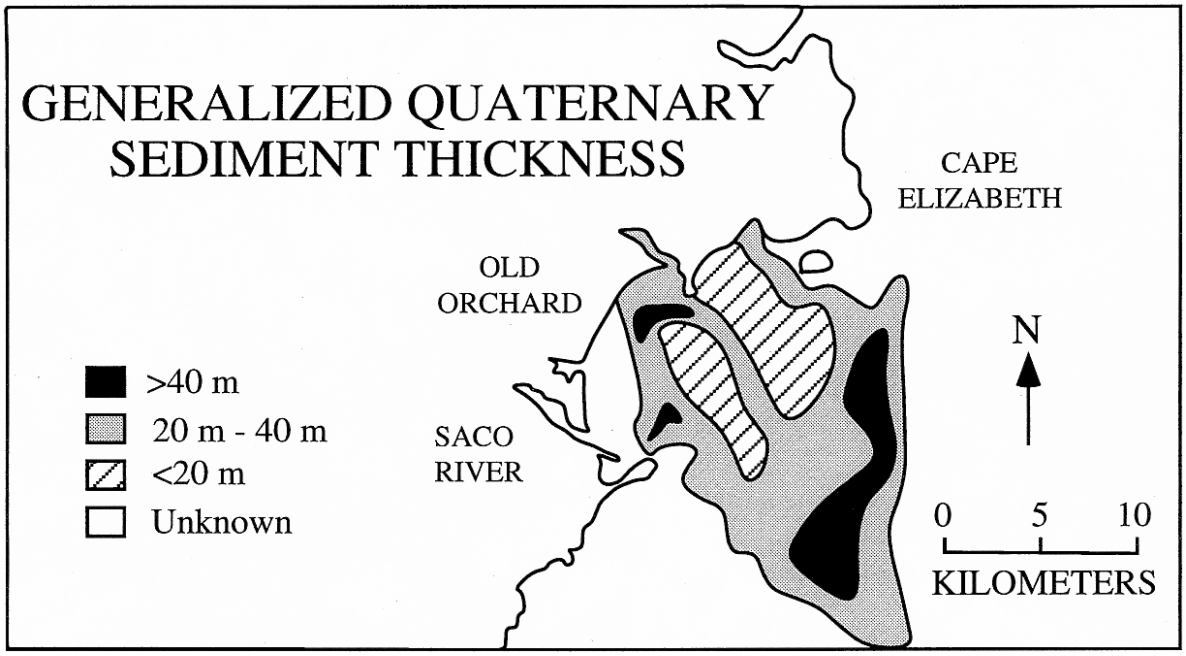


Figure 4. A generalized isopach map of Quaternary sediment thickness in Saco Bay (modified from Kelley et al., 1987).

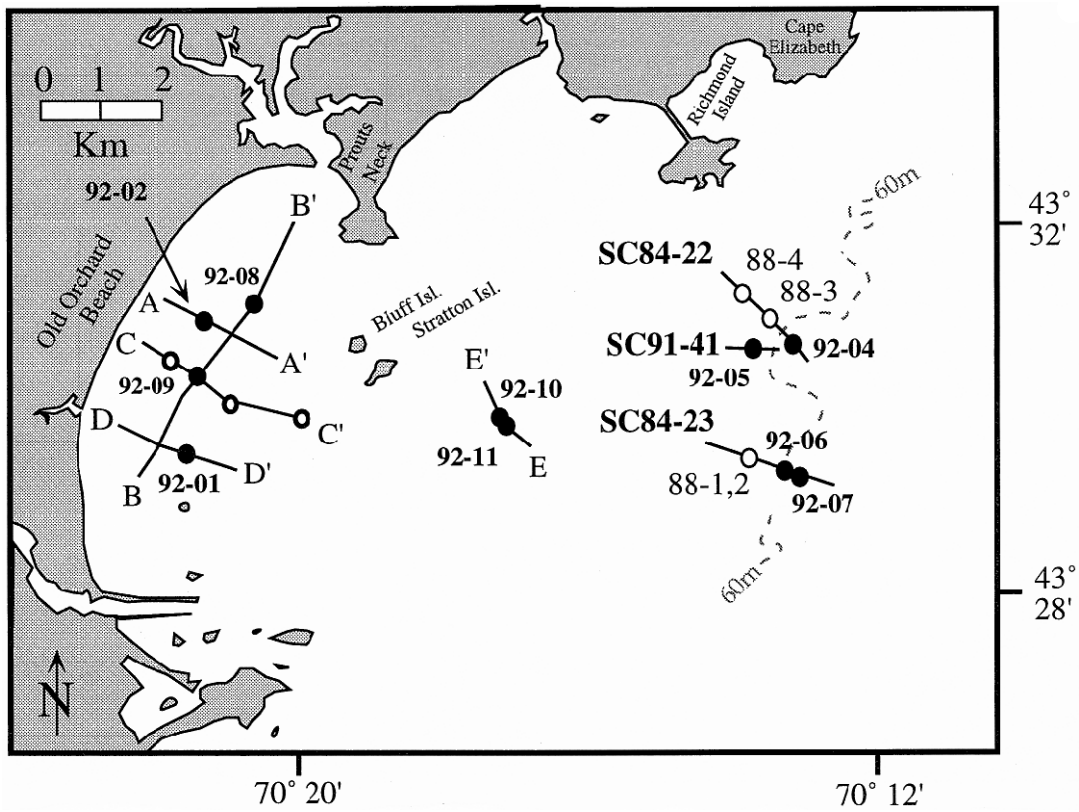


Figure 5. Locations of offshore cores and seismic profiles in Saco Bay. The seismic lines are indicated by the "SC" preface or A-A', the new vibracores are marked by the filled circles. The older cores are marked by unfilled circles. The lowstand-shoreline position around 60 m depth is dashed.

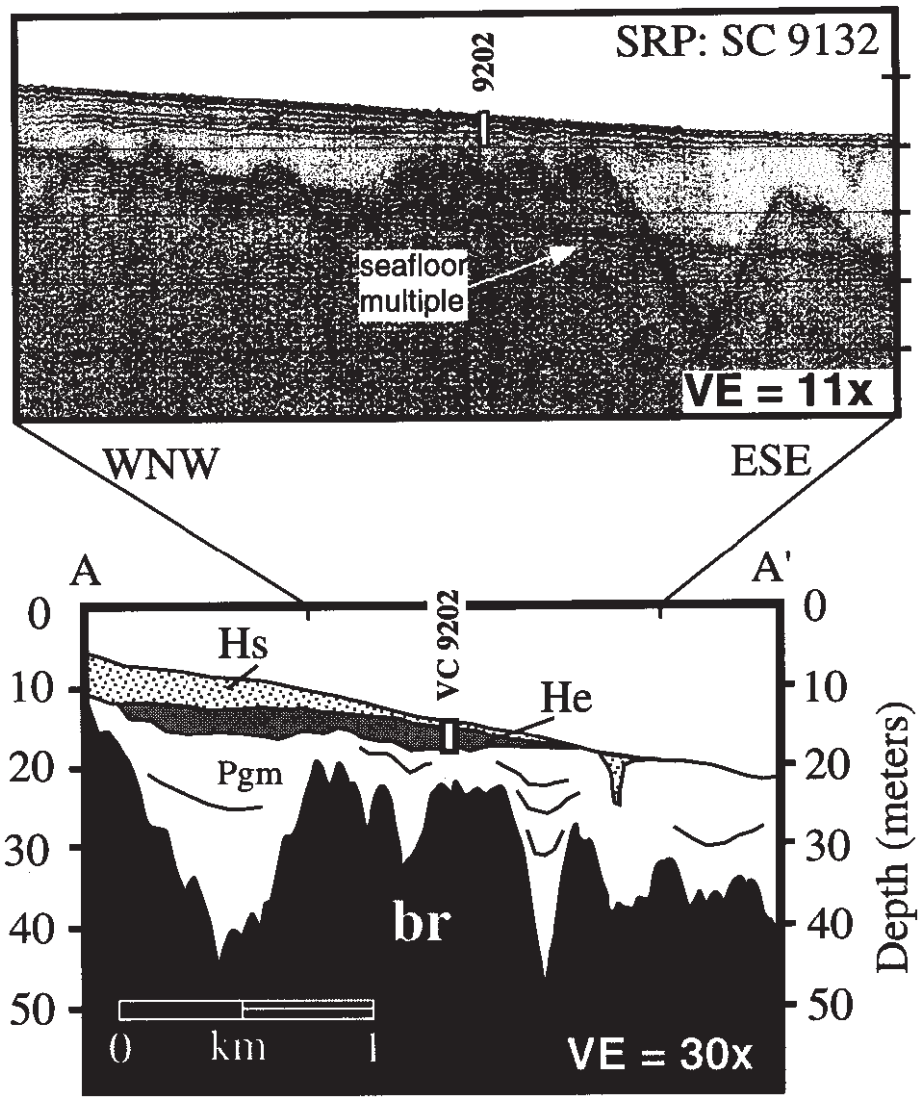


Figure 6. Shore-normal section offshore Old Orchard Beach, based on seismic reflection profile (inset, above) and vibracore SCVC92-02 (Figure 7). Note different vertical exaggerations (VE) in raw record and interpretation. Note channel incision in glacial-marine surface (on right in seismic record) at a depth of about 20 nmeters. Unit designations: **Hs** - Holocene and modern shoreface sand, **He** - mid-Holocene estuarine sandy mud, **Pgm** - Pleistocene glacial-marine mud, **br** - bedrock. From Barber, 1995, in prep.

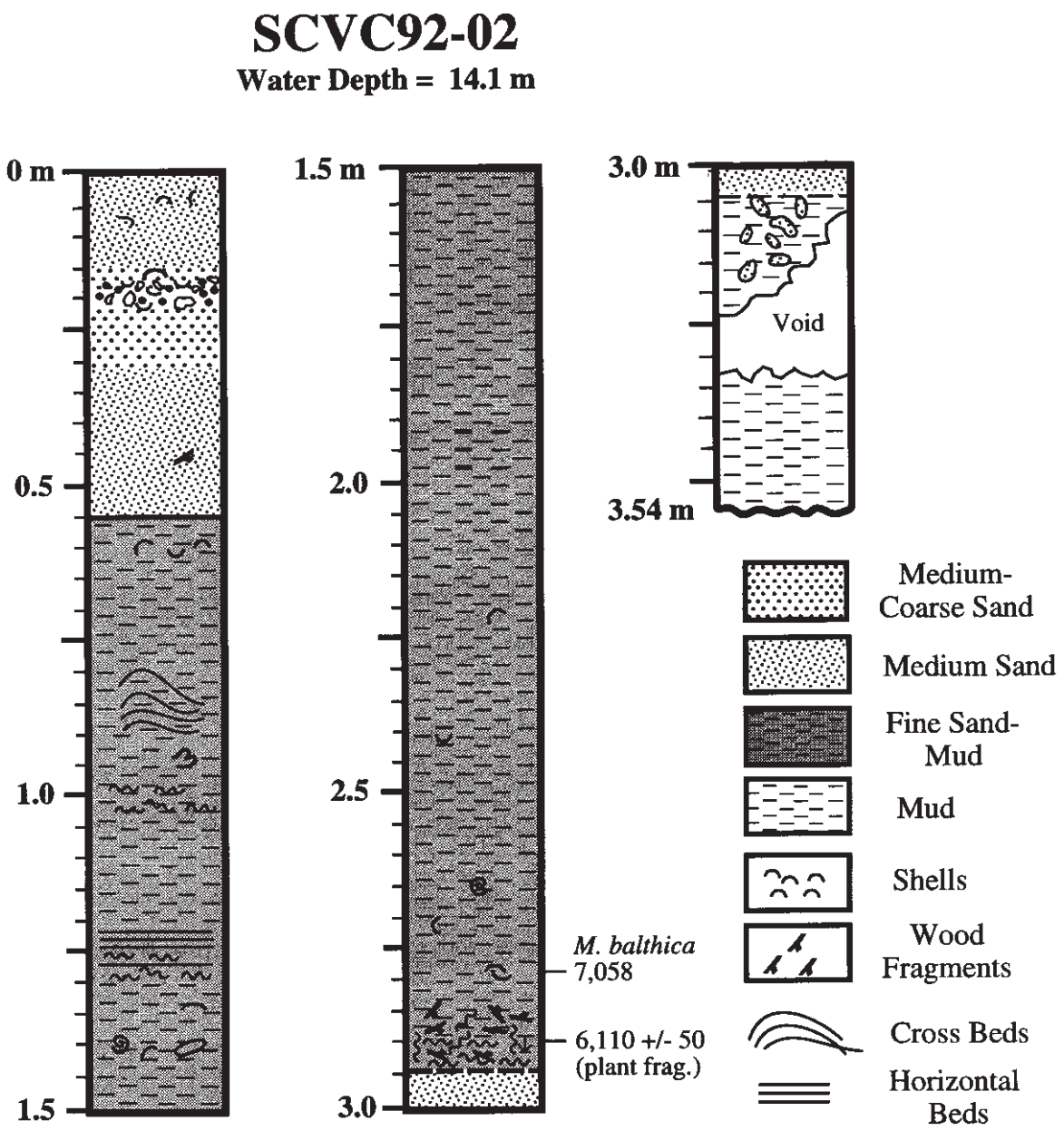


Figure 7. Log of vibracore SCVC92-02. Seismic line past core site is shown in Figure 6. From Barber, 1995, in prep.

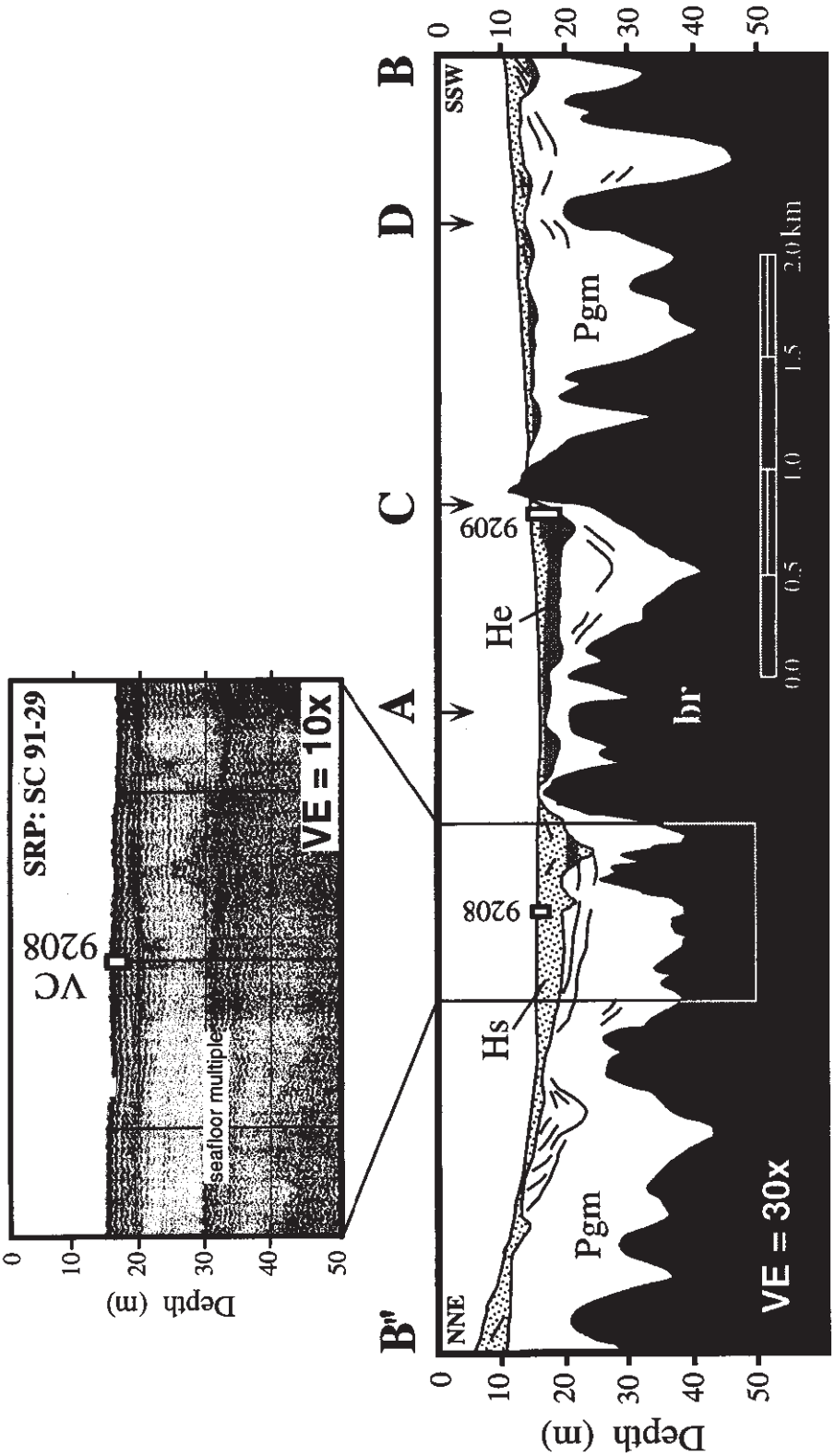


Figure 8. Cross-section sub-parallel to shore, along outer edge of shoreface in Saco Bay. View is looking seaward (see Figure 5 for location map). Note difference in vertical exaggeration (VE) between seismic record and cross-section interpretation. Unit designations: **Hs** - Holocene and modern shoreface sand, **He** - mid-Holocene estuarine sandy mud, **Pgm** - Pleistocene glacial-marine mud, **br** - bedrock. Intersections with shore-normal profiles marked with vertical arrows. From Barber, 1995, in prep.

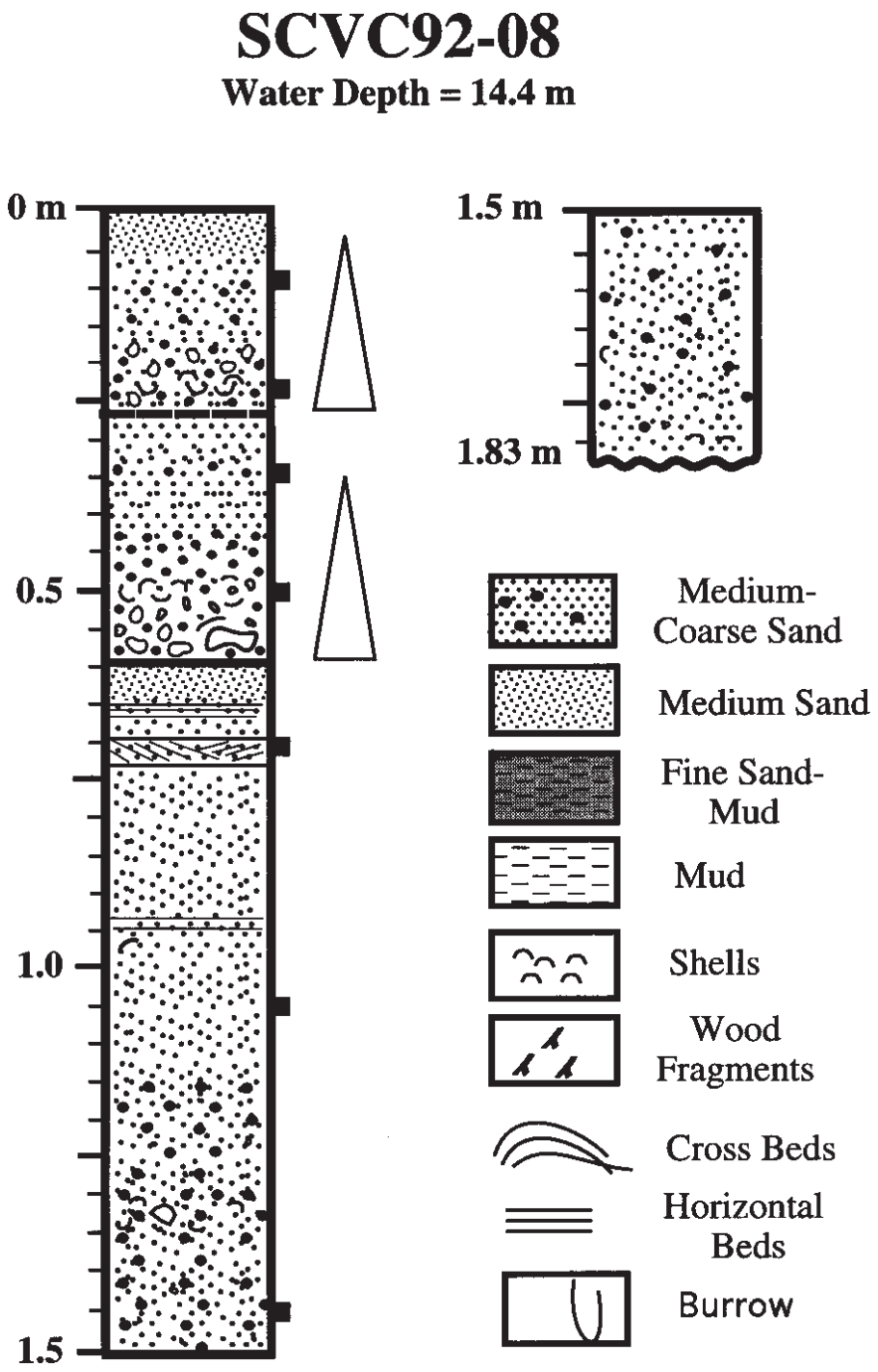


Figure 9. Log of vibracore SCVC92-08. Seismic line past core site is shown in Figure 8. Black squares on side of core represent grain-size sample sites. From Barber, 1995, in prep.

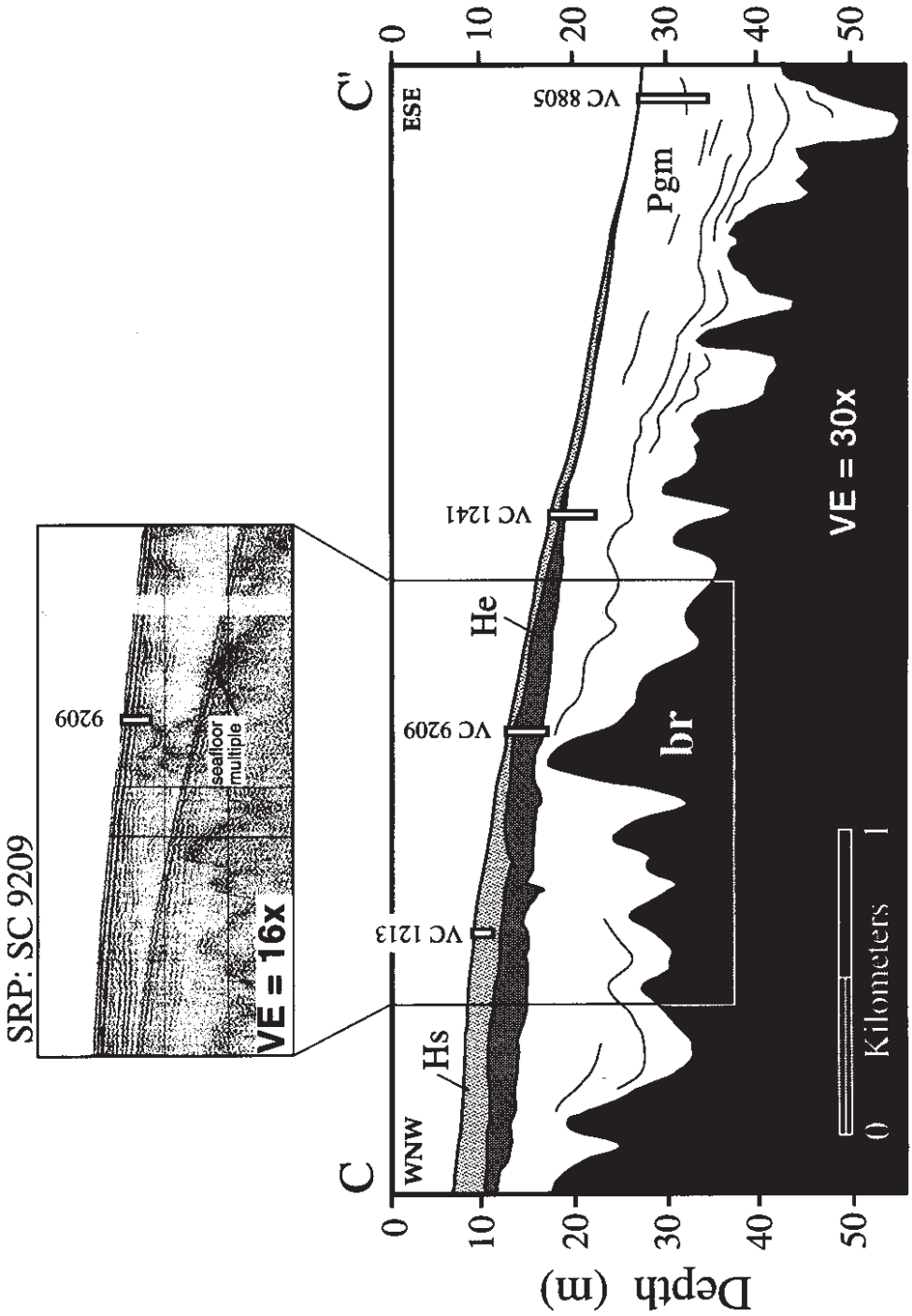


Figure 10. Shore-normal section across shoreface to axis of inner Saco Bay paleovalley (See figure 5 for location). USACoE cores 1213 and 1241 are described in Luepke and Grosz, 1986. MMS core 8805 is described in Kelley et al., 1990. Unit designations: **Hs** - Holocene and modern shoreface sand, **He** - mid-Holocene estuarine sandy mud, **Pgm** - Pleistocene glacial-marine mud, **br** - bedrock. From Barber, 1995, in prep.

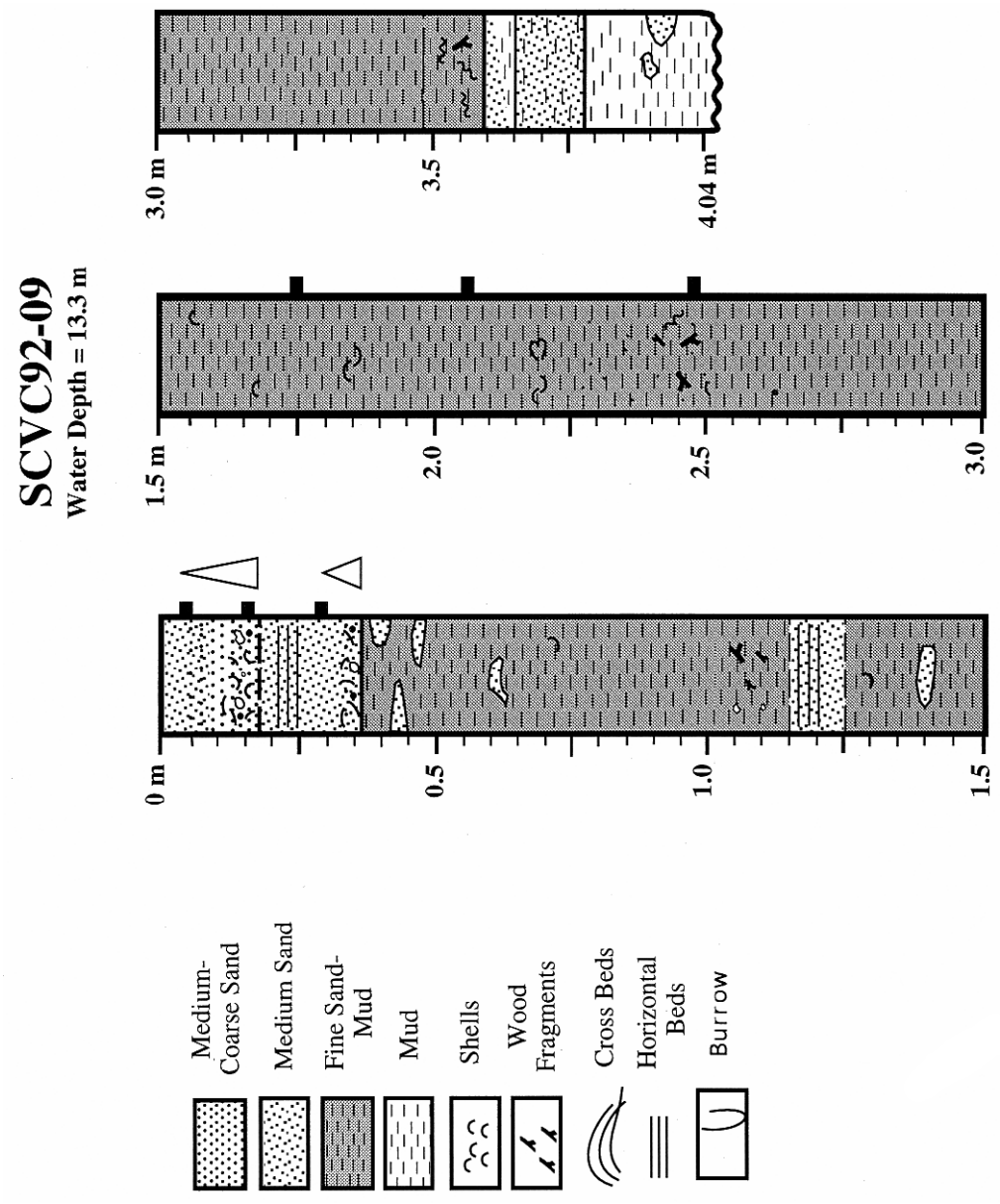


Figure 11. Log of vibracore SCVC92-09. Seismic line past core site is shown in Figure 10. Black squares on side of core represent grain-size sample sites. From Barber, 1995, in prep.

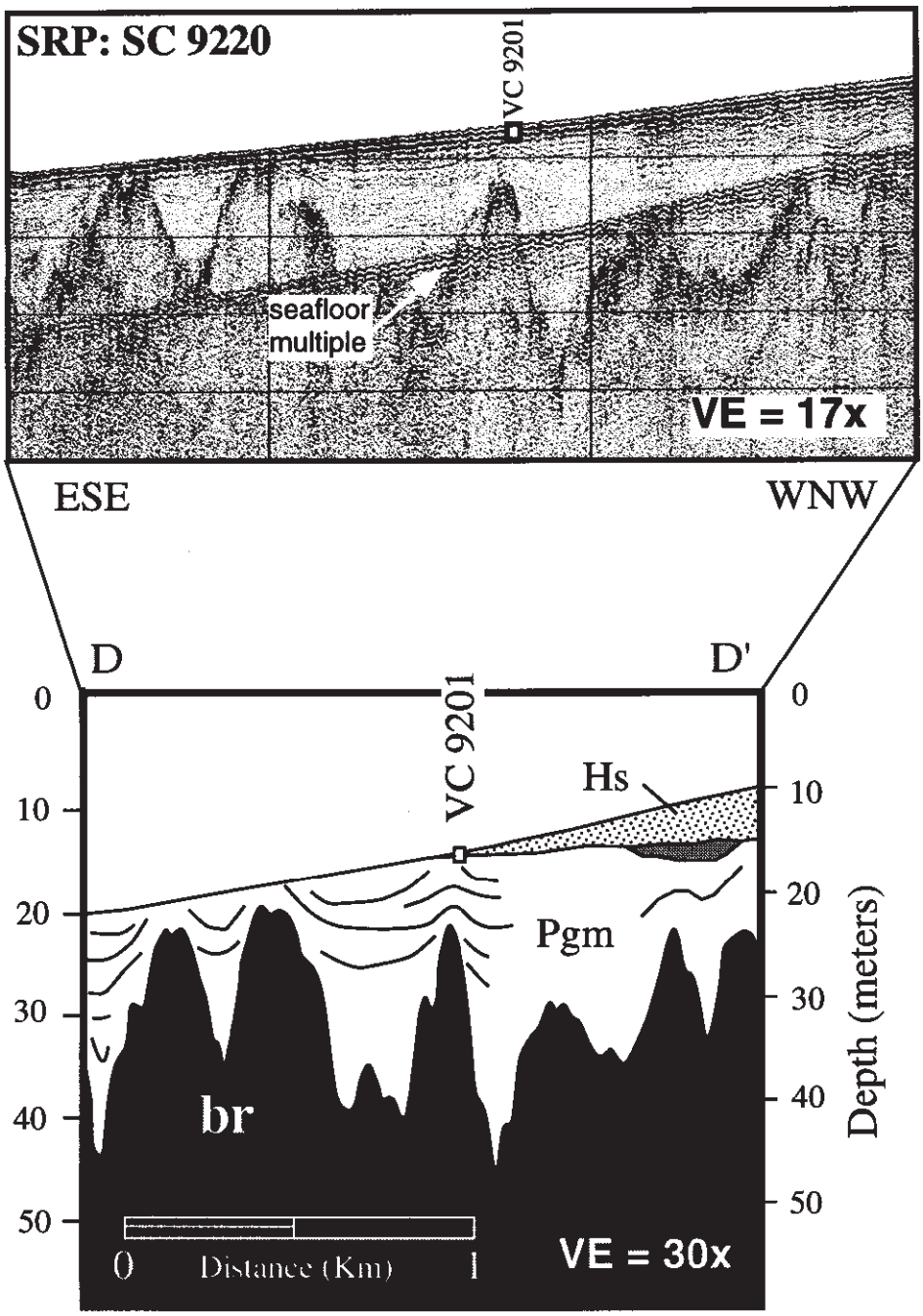


Figure 12. Shore-normal section offshore Goosefare Inlet. Note different vertical exaggerations (VE) in raw record and interpretation (See Figure 5 for location). Unit designations: **Hs** - Holocene and modern shoreface sand, **He** - mid-Holocene estuarine sandy mud, **Pgm** - Pleistocene glacial-marine mud, **br** - bedrock. From Barber, 1995, in prep.

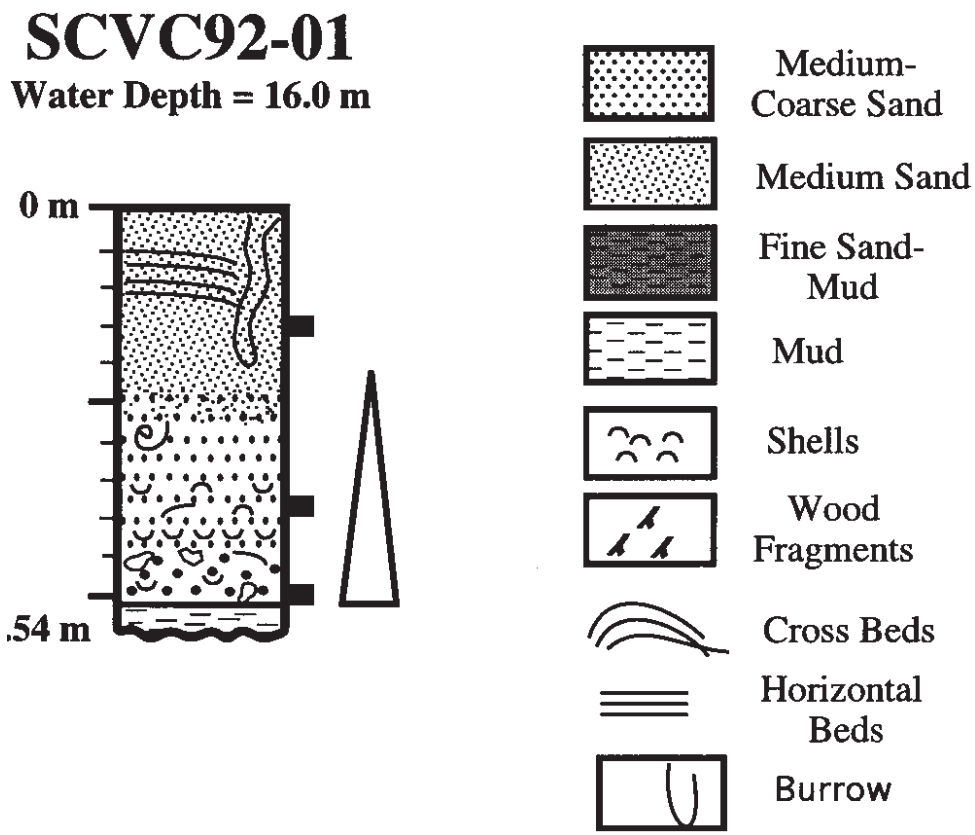


Figure 13. Log of core SCVD92-01. Seismic line over core location is in Figure 12. Cores are located in Figure 5. Black squares on side of core represent grain-size sample sites. From Barber, 1995, in prep.

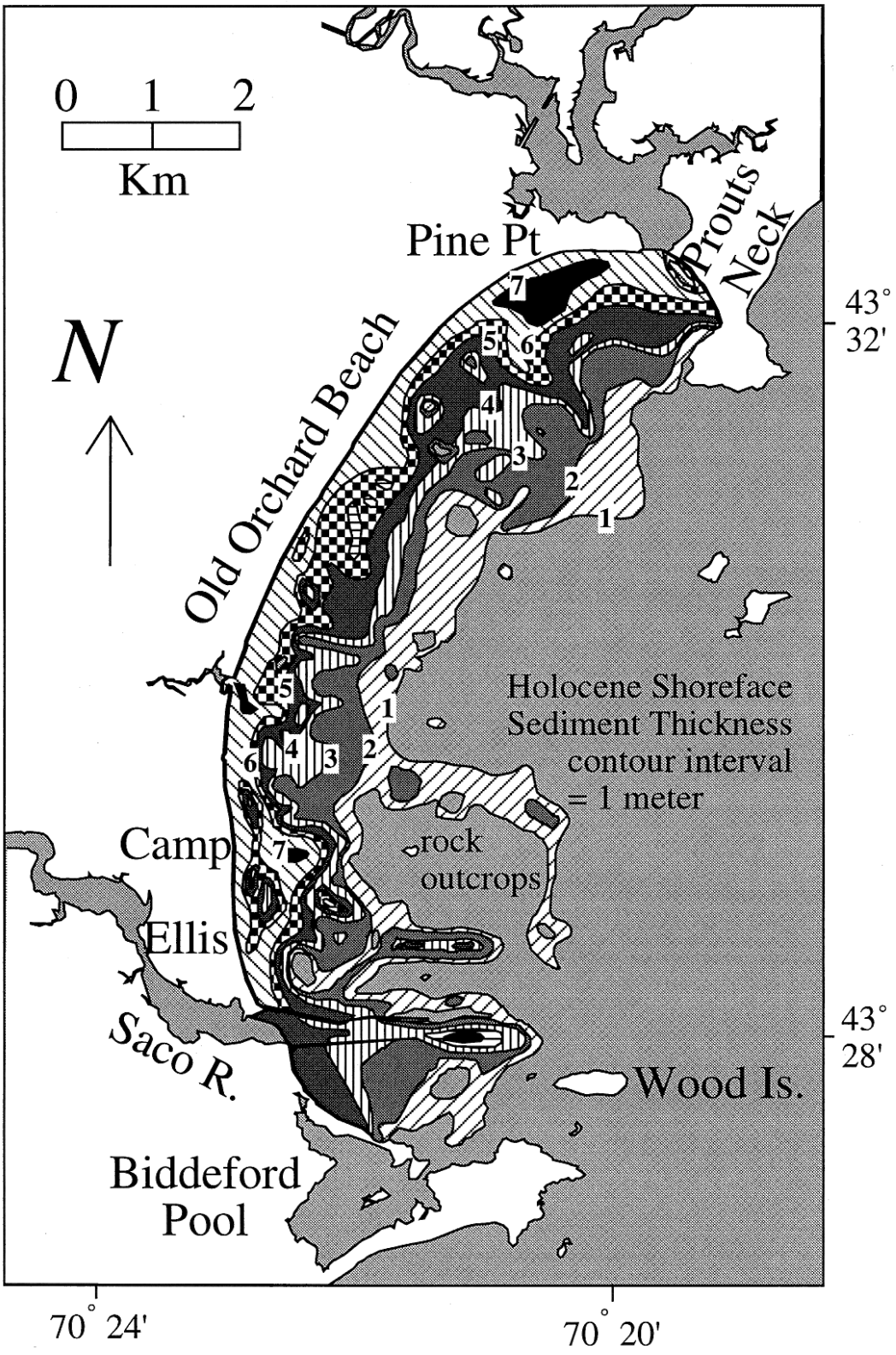


Figure 14. Volume of sand in the nearshore region of Saco Bay. Volume estimates are based on interpretation of seismic reflection data in conjunction with vibracores. Contour interval is 1 m. After Barber, 1995, in prep.

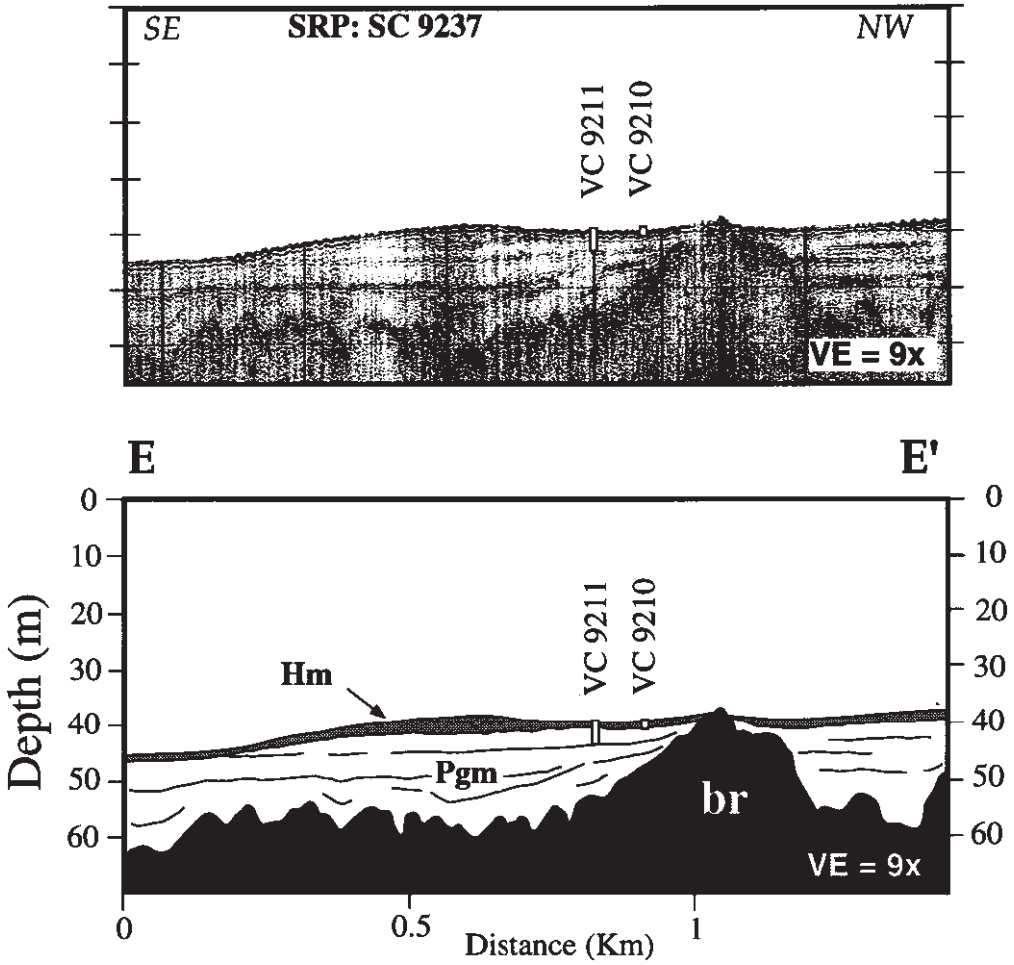


Figure 15. Seismic section along Shelf Valley east-southeast of Bluff Island (Figure 5). Unit designations: **Hm** - Holocene and modern mud, **Pgm** - Pleistocene glacial-marine mud, **br** - bedrock. From Barber, 1995, in prep.

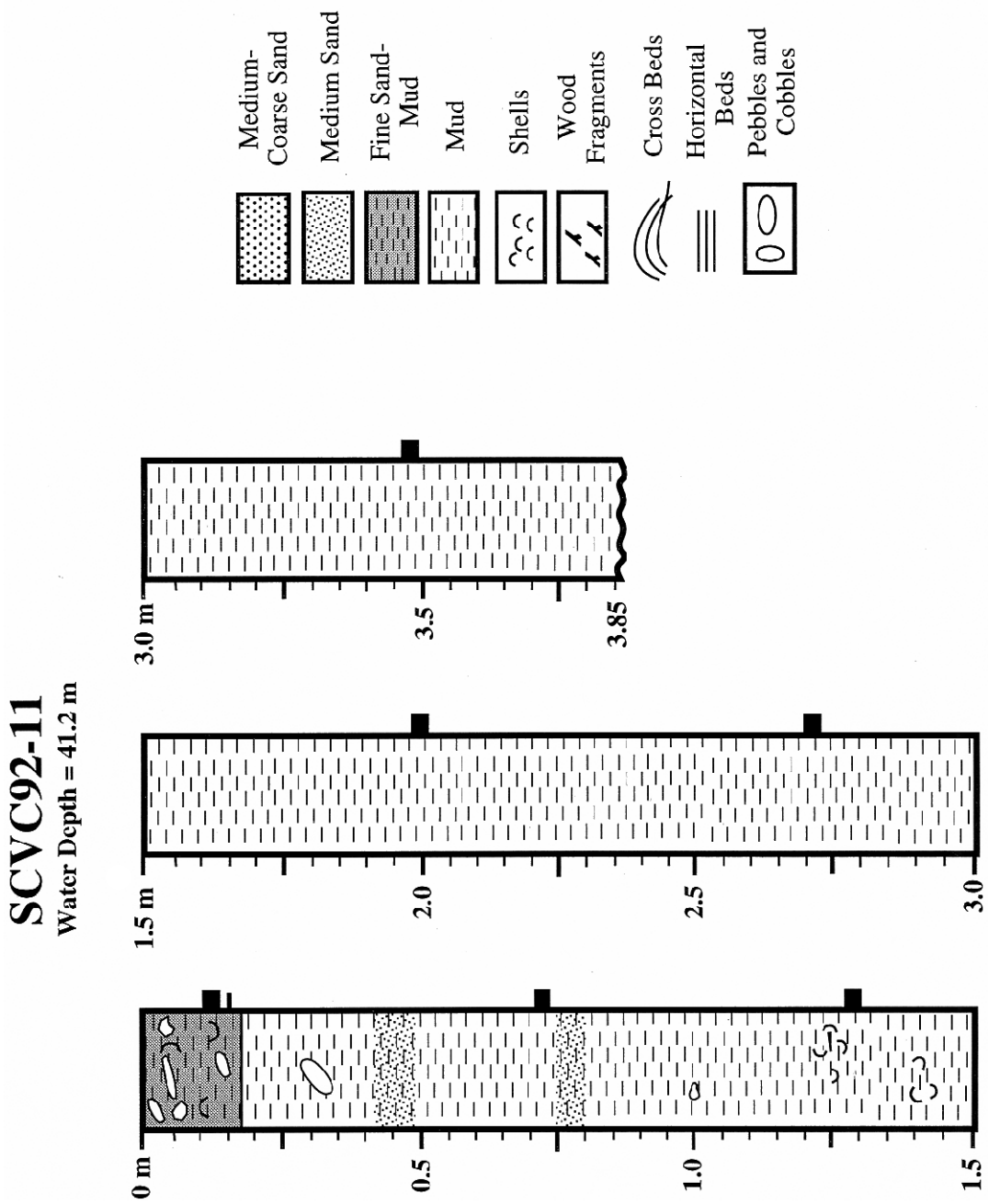


Figure 16. Log of vibracore SCVC92-11. Seismic line over core site is in Figure 15. Black squares on side of core represent grain-size sample sites. From Barber, 1995, in prep.

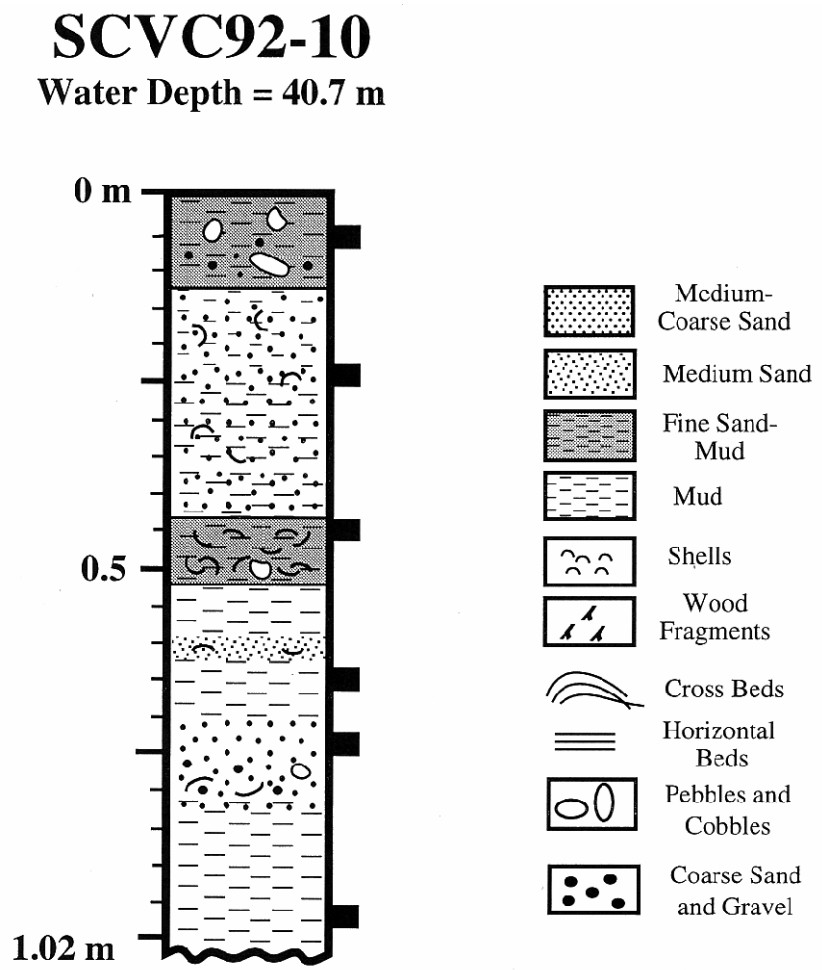
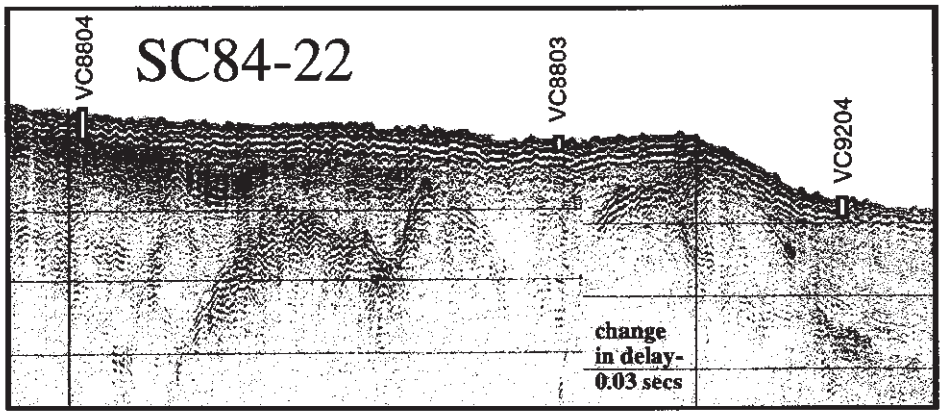


Figure 17. Log of vibracore SCVC92-10. Seismic line over core site is in Figure 15. Black squares on side of core represent grain-size sample sites. From Barber, 1995, in prep.



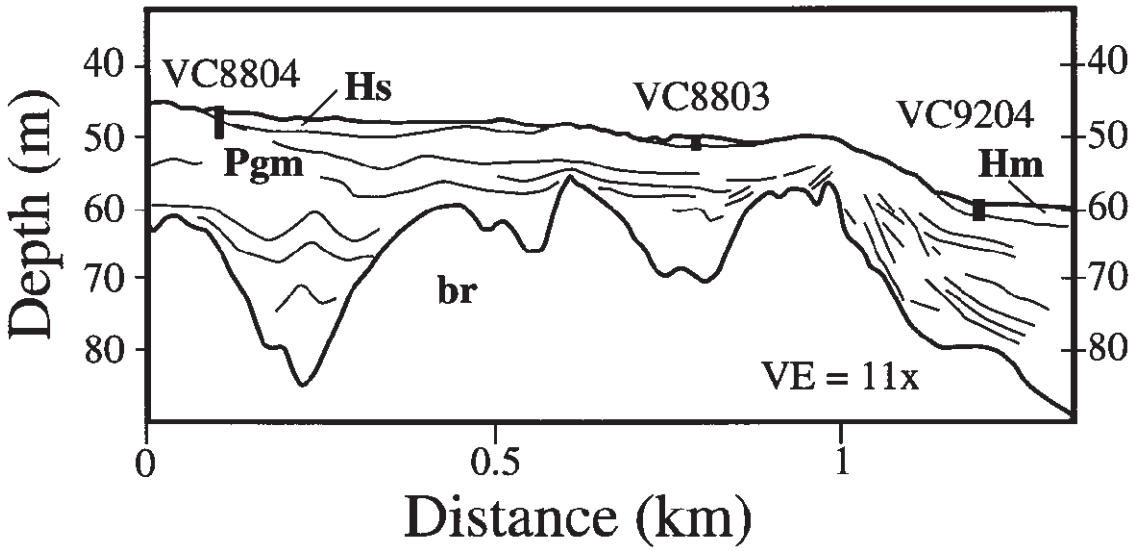


Figure 18. Seismic line normal to inferred lowstand shoreline in outer Saco Bay. Seismic data from Kelley et al., 1987; logs of cores VC88-04 and VC88-03 from Kelley et al., 1990. Core VC92-04 in Figure 21. Figure from Barber, 1995, in prep.

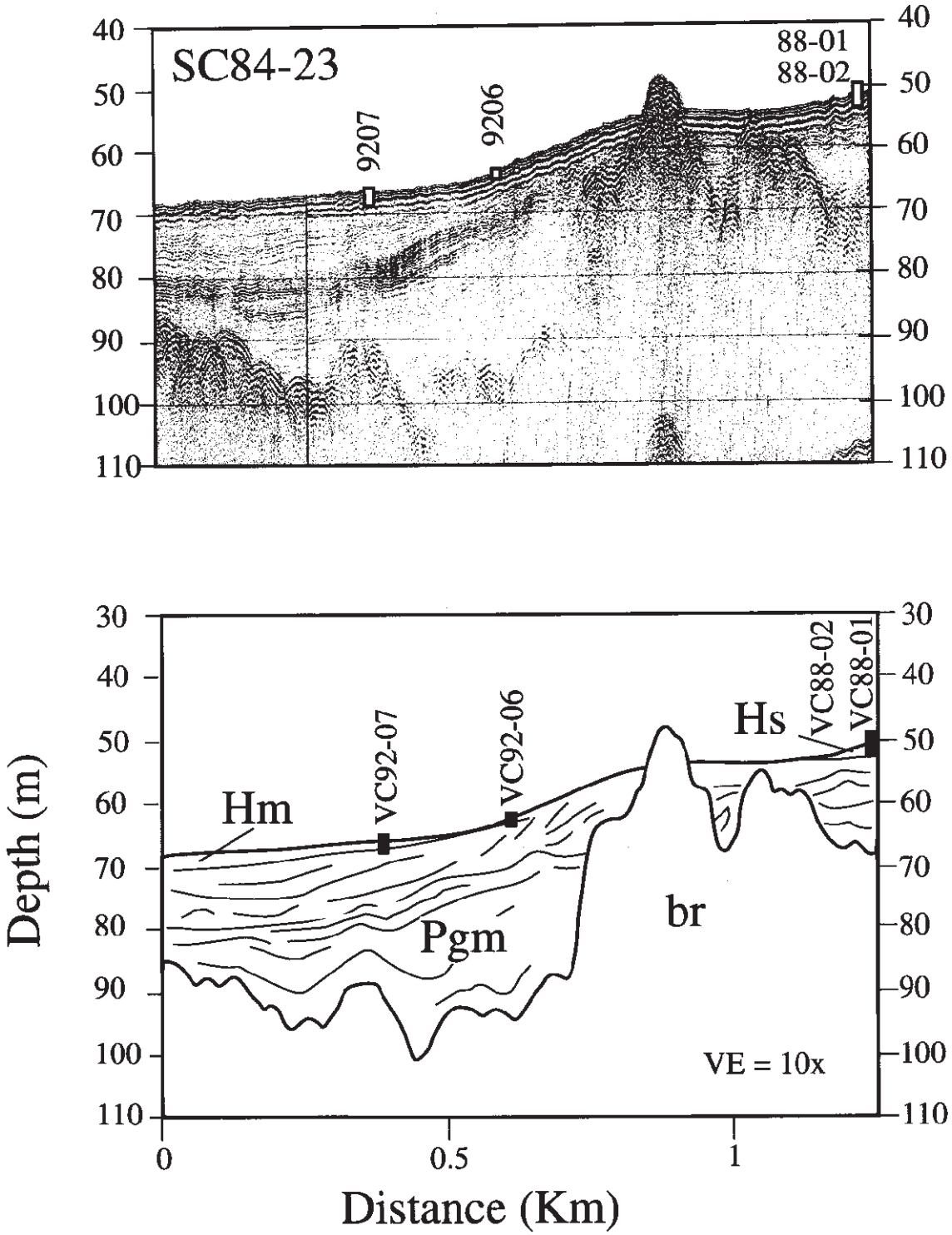


Figure 19. Seismic line normal to inferred lowstand shoreline in outer Saco Bay. Seismic data from Kelley et al., 1987; logs of cores VC88-01 and VC88-02 from Kelley et al., 1988. Cores VC92-06 amd VC92-07 in Figure 22. Figure from Barber, 1995, in prep.

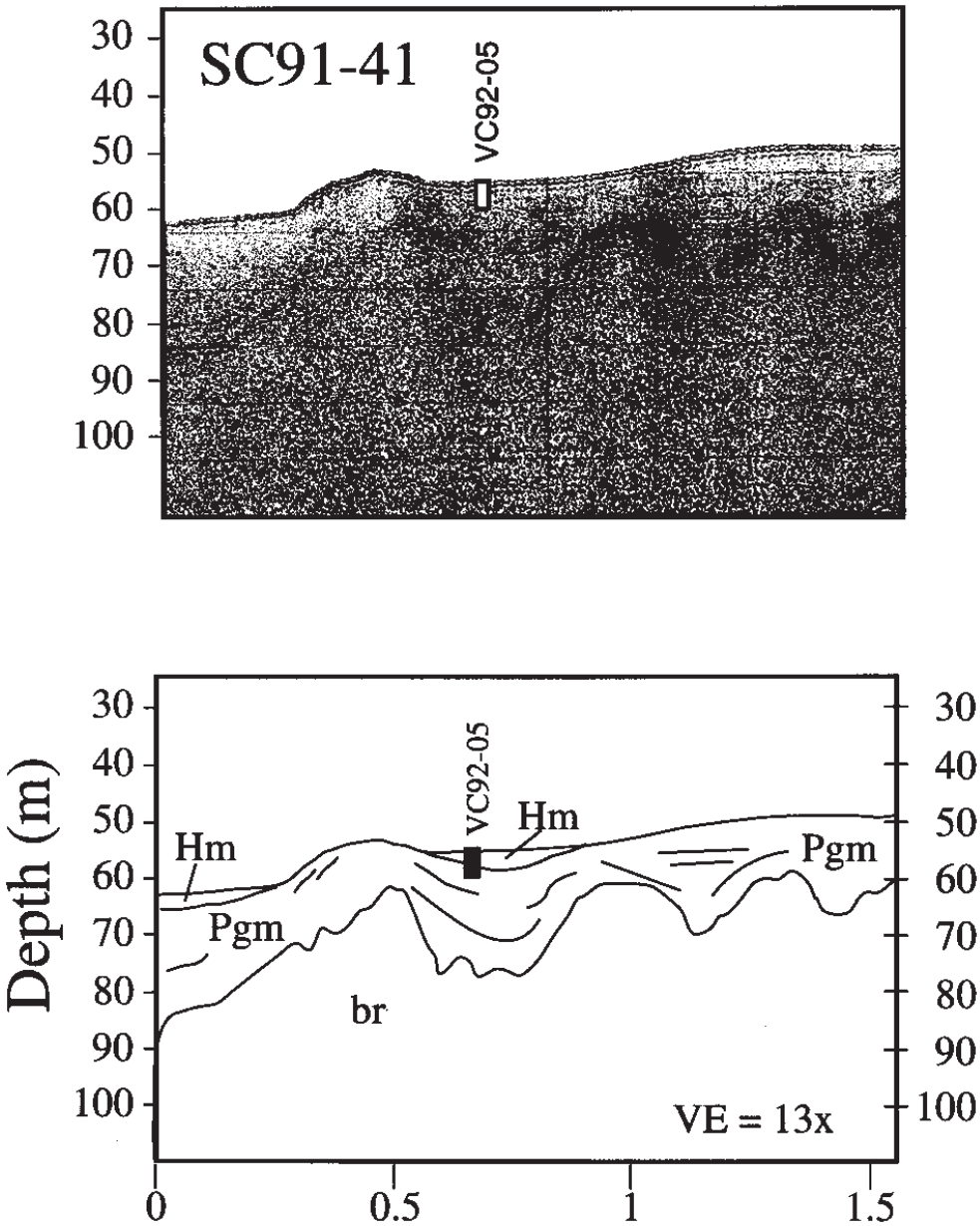


Figure 20. Seismic line normal to inferred lowstand shoreline in outer Saco Bay. Seismic data from Kelley et al., 1987, Core VC92-05 in Figure 23. Figure from Barber, 1995, in prep.

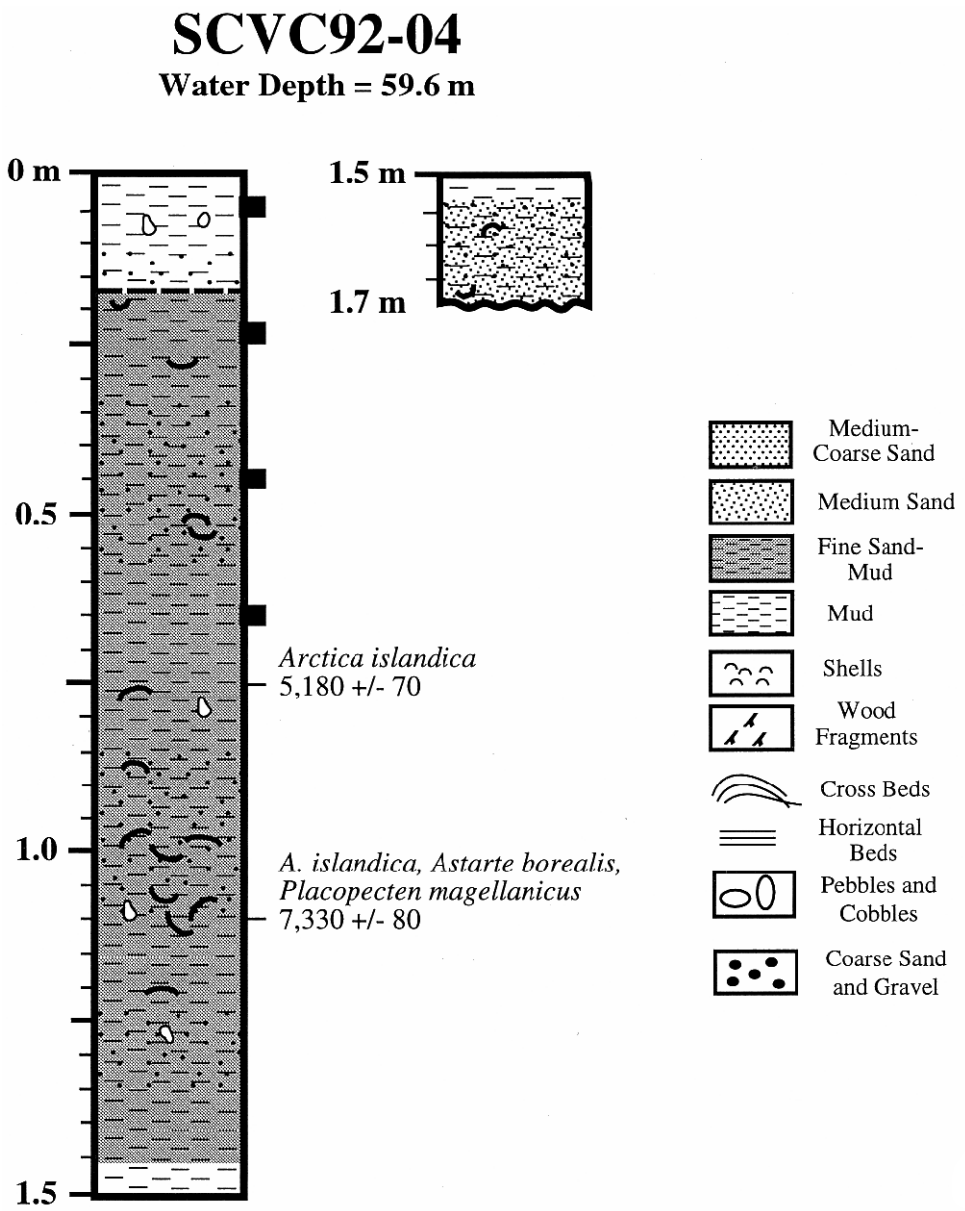


Figure 21. Log of vibracore SCVC92-04. Seismic line over core site is in Figure 18. Black squares on side of core represent grain-size sample sites. From Barber, 1995, in prep.

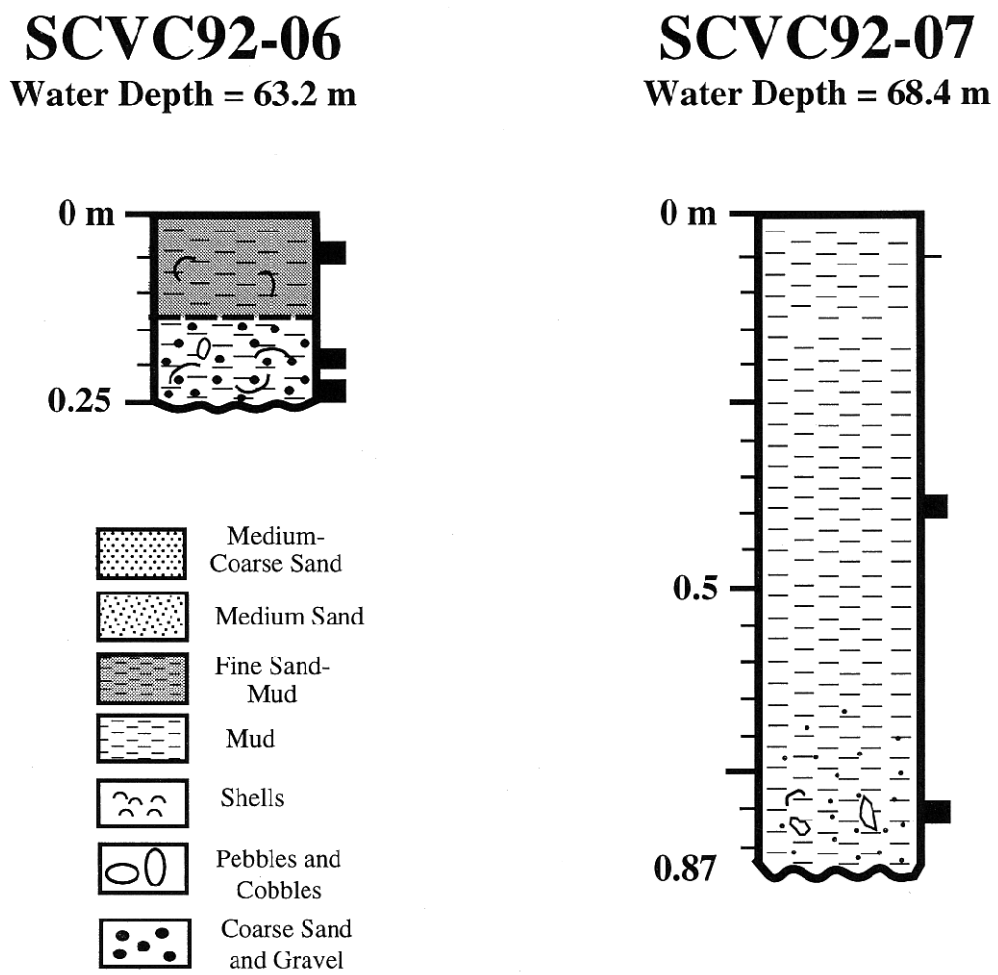


Figure 22. Lob of vibracores SCVC92-06 and SCVC92-07. Seismic line over core site is in Figure 19. Black squares on side of core represent grain-size sample sites. From Barber, 1995, in prep.

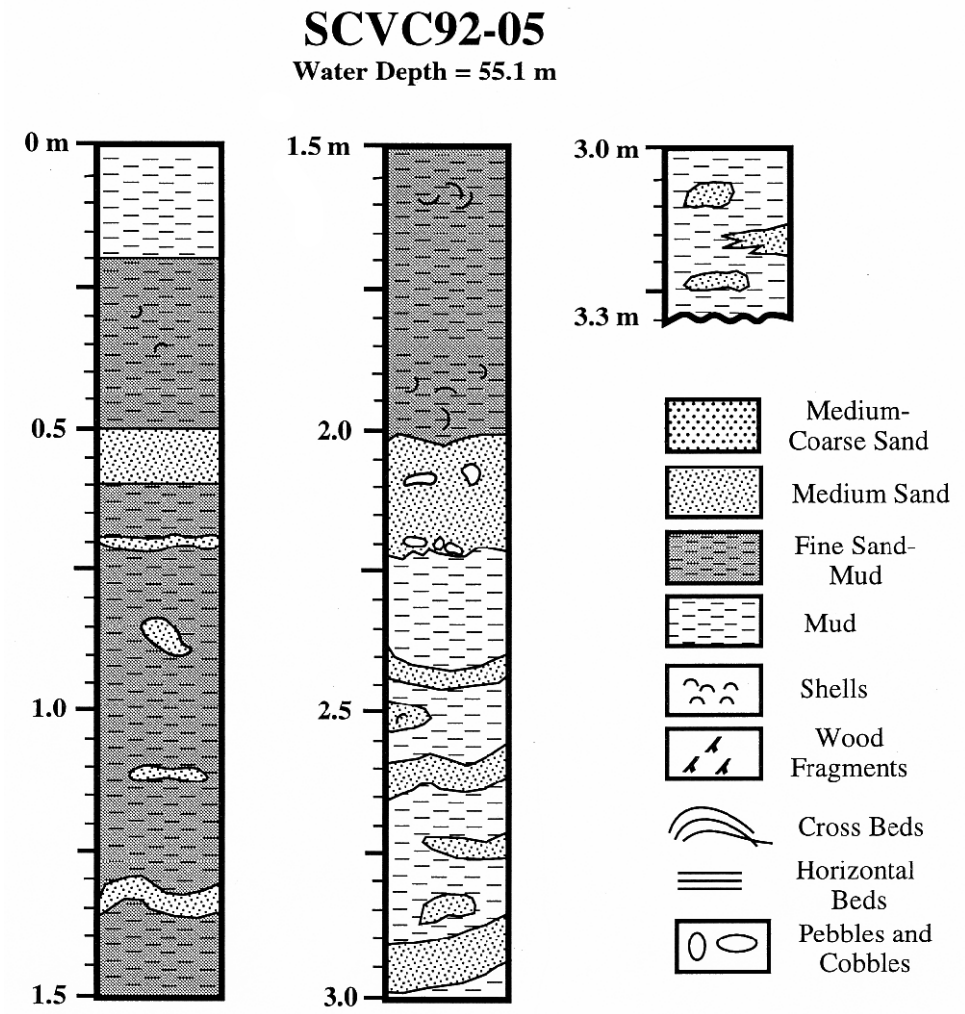


Figure 23. Log of vibracore SCVC92-05. Seismic line over core site is in Figure 20. From Barber, 1995, in prep.