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Surficial Geology of the Biddeford Pool 7.5-minute Quadrangle, York County, Maine

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INTRODUCTION

The Biddeford and Biddeford Pool 7.5-minute quadrangles comprise an area of about 55 square miles (142 km^2) along the coast of southwestern Maine, within the Seaboard Lowland physiographic province, about 15 miles south of Portland. Altitudes range from sea level to about 200 feet (61 m) above sea level. The drainage pattern is dominated by the Biddeford pluton (Figure 1), a large oval-shaped biotite granite mass that intruded the surrounding Precambrian-Silurian metasedimentary rocks of the Kittery and Berwick Formations about 354 million years ago during the Mississipian Period (Hussey, 1985). The Saco River skirts the northeast edge of the pluton, and some of its minor tributaries drain the northwest edge and northern part. The Kennebunk River flanks the southern edge, and some of its tributaries, including Goff Mill Brook, drain the southern part. (NOTE: No major stream lies along the plutonic contact; perhaps there is a contact-metamorphic hornfels border zone in the metasedimentary rocks that is equally resistant to weathering and erosion as the marginal phase of the pluton itself.) The central and eastern part of the pluton is drained by several small rivers and brooks, all of which enter the Atlantic Ocean via Goosefare Bay (Figure 1), where a barrier island of sandy beach and dune deposits has formed across the mouths of their estuaries. The stream pattern over the pluton itself is remarkably rectilinear, reflecting two major roughly right-angle joint sets—northeast and northwest trending. The joint pattern is very obvious on air photos, especially in areas of abundant outcrop, but the pattern is not obvious on the topographic map because the 20-foot contour interval is too large to show the many distinct, closely spaced, parallel bedrock ridges and poorly drained valleys throughout the areas of abundant outcrop (by far the major characteristic of the land surface in this area).

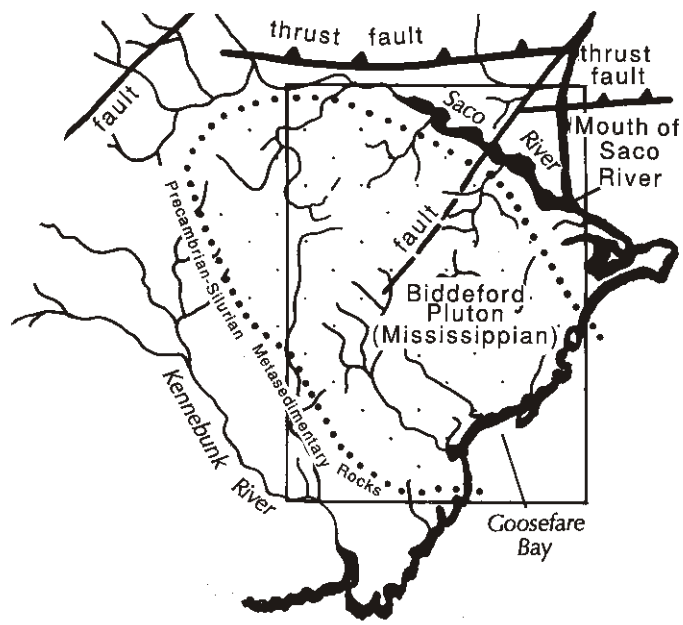

Figure 1. Biddeford quadrangle (outlined), showing relationship of drainage pattern to bedrock structure (from Hussey, 1985).

Parallel to the northeast-trending joint set, a 60-foot escarpment that roughly bisects the pluton reflects a mapped fault (Hussey, l985) that has apparent relative upward displacement of the northwest block and apparent horizontal southwest displacement of the southeast block, though the actual movement is unknown. Note also in Figure 1 that the fault trace is uncertain and shown as a dashed line near the southern end of the pluton. Drainage off this escarpment follows the general rectilinear pattern, except near its southern end where several tributary streams have a pronounced change in course to south-southwest just below the scarp (instead of a right-angle bend to a southwest direction, which is what would be expected); this course change may reflect a change in the overall joint pattern near the fault, or a change in the fault direction, or movement along the fault, or any combination thereof.

The landscape north of the Saco River in the Biddeford quadrangle is primarily a broad, sandy plain drained eastward to the Atlantic by Goosefare Brook; the shore there is characterized by a classic Holocene sandy beach complex that stretches for miles northward as "Old Orchard Beach."

The Biddeford Pool quadrangle contains many rock islands, the largest two of which are connected to the mainland by two sandy tombolos—Fletcher Neck and Hills Beach—which enclose a shallow tidal pool that is presently open to the sea only through a deep narrow channel between the two rock islands (Hulmes, 1981).

There is some indication that part of the glacial and preglacial Saco River may have followed a more southerly course before entering the sea, as inferred from the distribution of meltwater deposits (Caldwell and others, 1985). One such course could have been into the lower Kennebunk River, around the northwest nose of the Biddeford pluton (see Figure 1). This thought invites further investigation beyond the scope of this report. Also, during re-emergence of the coastline in postglacial time, part of the Saco may have flowed briefly along an abandoned channel(?) that begins at its upstream end along the current shore of the Saco between Jordan Point and St. Francis College, thence southeast landward of Hills Beach into Back Bay and The Pool. The surface of the Presumpscot marine clay in The Pool is 15 to 20 feet below sea level and deepens to the south of Fletcher Neck (Hulmes, 1979, 1981), where there appears to be an offshore submarine channel. The present author proposes that, in downcutting its channel through glaciomarine sediments, the ancestral Saco encountered the bedrock at the northern end of this abandoned channel and was thereby diverted easterly into its current course.

PREVIOUS WORK

Early work on the surficial geology in southwestern Maine, including the Biddeford and Biddeford Pool area, was done generally at a reconnaissance level and at a smaller scale (Bloom, 1960, 1963; Smith, 1977a-c). Subsurface data was collected as part of a basic data set (Prescott and Drake, 1962) and significant sand and gravel aquifers were mapped (Tolman and Lanctot, 1985). Publications on the glacial geology of the southwestern Maine coastal zone include Smith (1984, 1985), Stuiver and Borns (1975), Thompson (1979, 1982), and Thompson and Borns (1985). The Holocene stratigraphy of the Biddeford Pool area was studied in detail by Hulmes (1979, 1980, 1981). The Soil Survey of York County (National Cooperative Soil Survey, 1982) greatly facilitated fieldwork.

GLACIATION

Southwestern Maine probably experienced several advances of the Laurentide continental ice sheet during the Pleistocene Ice Age, but virtually all evidence in this area for previous glaciations was obliterated during the last glaciation (late Wisconsinan) when the continental glacier advanced from the northwest across the area to a terminal position on the continental shelf. Glacial erosion within this area is mainly noticeable as glacial striations on freshly exposed bedrock surfaces; some ramp and pluck topography on bedrock knobs, including a few roche moutonnée and small-scale crag-and-tail features in conjunction with the striations, definitely record southeast movement of the ice. It should be noted that glacial striations weather rapidly and survive for a very short time (generally only a few years) after exposure to surface elements in this climate; those along the shore of the Saco River and Atlantic Ocean are on bedrock exposures recently stripped of overlying surface sediments by storm wave action. Most others were found on recently excavated bedrock surfaces in borrow pits. Generally, the striations indicate a south to southeast direction of ice flow; some variations can be attributed to local deflection of the ice flow around irregularities of the bedrock topography. At least four localities had two sets of intersecting striations—(1) in the West Brook valley, east of downtown Biddeford (135° striations are older than 169-183°); (2) in a borrow pit between the Biddeford City Line and Beaver Pond (153-158° striations are older than 165-175°); (3) along the shore south of East Point in the Biddeford Pool quadrangle (133-137° striations are older than 158-152°); and (4) in a house foundation excavation on South Road next to the Maine Turnpike where age relations of the striations were not clear. Where age relations between two sets on the same outcrop are clear, the younger striations represent a more southerly (in places, even southwesterly) ice flow direction. However, this does not mean that all southerly or southwesterly striations are of the same age, nor does this meager set of measurements constitute sufficient data to postulate anything greater than a minor secondary pulse of ice flow in a slightly different direction from the earlier flow at the same site. Even though some previous workers interpreted some features in the Kennebunk area as evidence of a glacial readvance, the controversy is ongoing (Smith, 1981).

After reaching its terminal position on the continental shelf, the late Wisconsinan ice sheet began to recede between 17,000 and 15,000 years ago, retreating across the Gulf of Maine to an offshore position roughly parallel to the present coastline about 14,000 years ago (Smith, 1985). Shells collected from glaciomarine sediments apparently deformed by ice shove in Kennebunk, just to the southwest, were radiocarbon dated at 13,200 yr B.P. (Smith, 1985). Thus, the ice sheet terminus must have been in the Biddeford area about that time, although some workers feel that ice had retreated far inland from the coast by 13,000 yr B.P. based on other evidence (Thompson and Borns, 1985). Additional data may clarify the picture, eventually. (NOTE:

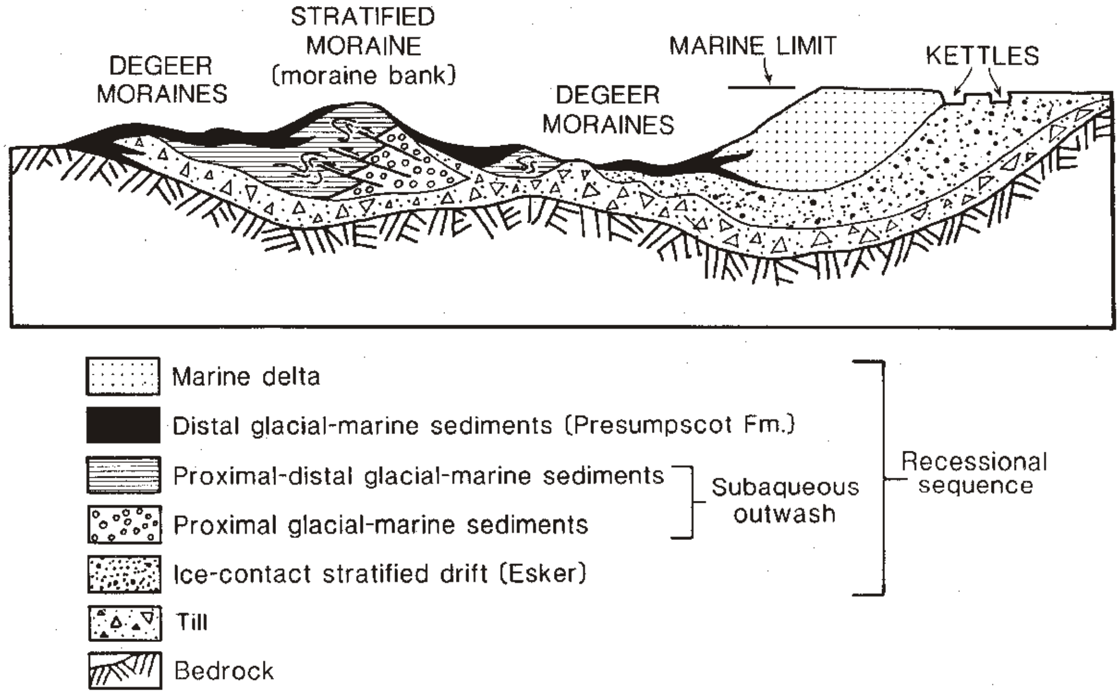

Figure 2. Generalized glacial stratigraphy for the southern Maine coastal zone (from Thompson and Smith, 1988).

Some fossil shells were collected in a pit near Beacon Corner in the Biddeford quadrangle during fieldwork for the present report, but have not yet been identified or dated.)

"Two indirect effects of glaciation had a very strong bearing on the character of ice retreat and the deposition of the glacial sediments in this portion of the coastal zone. First, the great weight of the Laurentide continental ice sheet depressed the crust beneath the glacier significantly below its present level throughout the region. Secondly, as glaciers expanded worldwide, water was trapped on land as ice, causing sea level to be lowered by several hundred feet. Later, as the ice began to melt and retreat, water was returned to the ocean and sea level rose immediately. At the same time, the crust began slowly to rebound to its original level. The interaction of these effects resulted in submergence of the entire Maine coastal zone for a period of several hundred years following the retreat of the ice" (Smith, l999). Within the Biddeford area, marine submergence reached an estimated 190 feet (58 m) above present sea level (Clinch and O'Toole, 1999a,b). Boulder accumulations around the sides of the 200+ foot a.s.l. standpipe hill south of Five Points in downtown Biddeford suggest the presence of a shoreline at about that level here. Only a few scattered spots in the quadrangle reach barely above the 200-foot contour, so nearly the entire area was submerged during the maximum marine transgression.

GLACIAL AND POSTGLACIAL DEPOSITS

The generally accepted concept of the succession of Pleistocene (Late Wisconsinan) glacial deposits in southwestern Maine is depicted in Figure 2 (Smith, 1985). In the Biddeford and Biddeford Pool quadrangles, only distal glacial-marine sediments (Presumpscot Formation), proximal-distal glacial-marine sediments, and till are recognized, but most of these sediments have been modified and some have been completely transformed by wave and current action during marine offlap. Thus, areas that are predominantly sand and gravel which may have been originally deposited directly from glacial meltwater have been reworked and exhibit many characteristics of marine shoreline or nearshore deposits and are therefore mapped as such (Pms and Pmn). The succession of surficial deposits (Holocene and Pleistocene) in the Biddeford area is given on the correlation chart showing the relative ages of the map units (Figure 3).

Till (map unit Pt) occurs throughout the Biddeford area; its thickness is variable, as is its composition. Although various genetic types have been found throughout Maine, only the general lodgement till was observed here. Lodgement till was deposited beneath the ice sheet and forms a blanket deposit over the underlying bedrock; it is inferred to underlie younger deposits throughout the area (Figure 2). In most exposures this till is typically a compact boulder-pebble silt-clay.

Distal glacial-marine sediments of the Presumpscot Formation (Pp) and sandy marine sediments deposited during the regression of the sea (Pmrs) "occur as a discontinuous cover up to 50 m thick throughout the area of late-glacial marine submergence. The general distribution of the marine sediments was originally mapped by Goldthwait (1949), and the sediments were described in detail and given formational status by Bloom (1960). The marine clay and silt (Pp) is the type Presumpscot

Formation described by Bloom. It has a gradational contact with the overlying sandy facies of the marine sediments (unit Pmrs), which is a regressive deposit" (Smith, 1999). The sand-silt surface material that characterizes the Pmrs unit is generally only 1-3 feet thick, but may be as much as 10 feet thick in places (National Cooperative Soil Survey, 1982). Where present, the Pmrs unit is found overlying the clay-silt Pp unit, but the former is not everywhere present and may be older at one site than some of the clay-silt deposited at another site; thus, these are time-transgressive units. The clay-silt facies of the Presumpscot Formation generally overlies till and can be found overlying, underlying, and intertonguing with proximal-distal glacial marine deposits, including the Pleistocene marine shoreline deposits (Pms), as seen in borrow pits at Beacon Corner and Oak Ridge.

"Stratified deposits of sand and gravel that both underlie and intertongue with the Presumpscot Formation are considered to be subaqueous outwash sediments (Smith, 1982, 1985; Thompson, 1982). These materials are not exposed at the ground surface in the study area, and thus are not shown on the geologic map, but they form an extensive blanket of deposits beneath the younger marine sediments. Many exposures of these materials in nearby areas of southwestern Maine display a variety of distinctly fluvial primary structures" (Smith, 1999).

The surfaces of both the till and subaqueous outwash sediments have been substantially reworked by waves and currents in areas below the marine limit to form nearshore marine deposits (Pmn). Nearshore marine deposits include a wide variety of materials, from reworked till and clay to sand and gravel, that form a generally thin blanket over bedrock. Such deposits above the 120-foot contour are included in Pmn_1, whereas those below this elevation are mapped as Pmn_2; this boundary corresponds roughly with the edge of the fault scarp and a mapped 120-foot marine shoreline, based on beach deposits and depositional and erosional terraces of Pms_2. This was a simple Pmn subdivision to make because of the coincidence of the shoreline features with the scarp, but the contour interval of the base map is too great for further "meaningful" subdivision of this type of deposit in the map area.

The units mapped as Pms_{1-4} may have originally been deposited as proximal glacial deposits; for example, the fan-shaped sand and gravel deposits that spread southeastward down West Street and Proctor Road may have been marine outwash fans (proximal glacial-marine sediments of Figure 2), but these deposits have been so well reworked by wave and current action that exposures in them consistently reveal sedimentary features characteristic of marine shorelines, such as openwork gravel in apparent beach ridges, lag boulder terraces and horizons, and depositional directions more compatible with marine shoreline processes than with glacial meltwater flow directions in this area. Pms deposits are predominantly sand and gravel representing shallow marine and/or marine shoreline deposits associated with particular sea-level stands mapped on the basis of erosional and/or depositional features at scattered sites in the area. Pms_1 represents deposits associated with sea-level stands of 160+ and 140+ feet, based on terraces and depositional features within these deposits -- especially those observed in borrow pits west of Blue Star Memorial Highway in Biddeford. A cobble-pebble-boulder gravel ridge at 160+ feet along Proctor Road is also interpreted as a beach ridge of this stand. Pms_2 represents deposits associated with a sea-level stand of 120- feet a.s.l., based on lag boulder deposits along West St., and depositional and erosional terraces at that level around West and Dungeon Brooks and tributaries of the Little and Batson Rivers. Pms_3 represents deposits associated with sea-level stands of 60+ and 80+ feet, based on well-sorted sand and gravel deposits and related scarps at these elevations. Fossil marine shells were dredged up from marine clays below sand and gravel of Pms_2 at Beacon Corner, a lag boulder horizon was found in pits northeast of Adams Corner, a cobble-boulder beach ridge dominates the unit along Newtown Road, and a pocket of marine clay was found within the Oak Ridge pits. (As noted previously, the cores of some of these deposits may be proximal glacial deposits, but I saw no unequivocal evidence of that). Pms_4 (mapped only in the Biddeford Pool quadrangle) represents deposits associated with a sea-level stand of 40- feet a.s.l., based on an uplifted beach ridge in the golf course at Biddeford Pool village. Some deposits mapped as Pmrs in the Biddeford quadrangle may belong in the Pms_4 unit, but I did not notice any shoreline features near this elevation there.

Deposits of Holocene age are generally associated with modern streams, wetlands, and marine shorelines. Along the coastline they include salt marsh (Hwsm), marine shoreline (beach) (Hms), and dune (Hd) deposits. A few small thin dune deposits cover saltwater marsh deposits along the Saco and Batson Rivers. One elongate sand ridge whose crest elevation is about 180 feet a.s.l. is interpreted to be a dune deposit; it is lumped with the Holocene dunes on the modern coastline, but may have formed when sea level stood near it while Pms_1 deposits were accumulating. Freshwater marsh (Hwfm) and swamp (Hws) deposits are found scattered throughout the area. These and the salt marshes are characterized by accumulations of decayed organic matter. Some are underlain by peat, in which case the deposit is further classified as to thickness and ash content of the peat (see map explanation). Alluvial deposits (Ha) of variable thickness and composition underlie the floodplains of most modern streams; it should be noted that swamp deposits and alluvial deposits are coincident along many stretches of the stream floodplains in this area.

Moors Brook has cut a channel as much as 20 feet deep through clay-silt deposits of the Presumpscot Formation; the resulting banks are nearly vertical in places and landslides (Hlsd) have developed in a few places where the steep banks have been recently undercut by the brook.

Finally, where the surface consists of substantial artificial materials used by man to fill depressions, both man-made and natural, or where the surface has been so altered by construction so as to obliterate the natural landscape, that area has been mapped as "af".

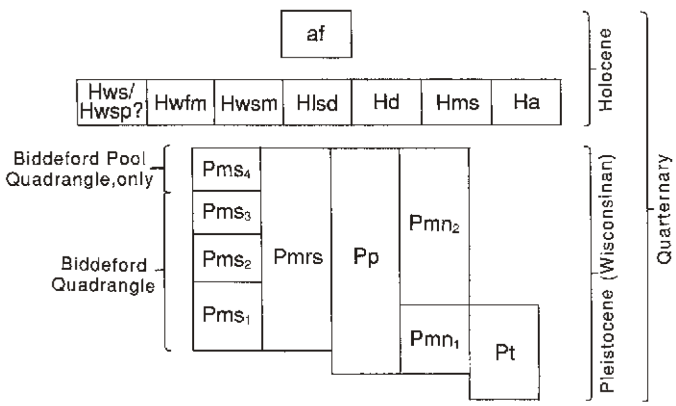

Figure 3. Provisional relative ages of map units for Biddeford and Biddeford Pool quadrangles.

DEGLACIAL AND HOLOCENE HISTORY

The Presumpscot Formation, which consists predominantly of rock flour, was carried by glacial meltwaters and deposited in a marine estuarine environment (Bloom, 1960) that included practically the entire study area, as the maximum submergence in the Biddeford area was around 190+ feet elevation. As the continental ice sheet retreated northwestward, the land began to rebound isostatically and relative sea level began to fall. Meltwater streams continued to carry sediment to the sea as sea level fell. "With progressive lowering of sea level, materials deposited during earlier stages of glaciation and deglaciation passed through the wave zone, were eroded, and shed sandy sediment (Pmrs) over the silt and clay (Pp) deposited when sea level was higher. Sandy to silty sediments eroded from till deposits (Pmn) form a veneer over till and bedrock in some parts of the study area. Short-term pauses in the lowering of relative sea level allowed for greater erosion at certain elevations, producing wave-cut scarps and accumulations of beach sediments (Pms). Several of these pauses occurred between the time of maximum submergence and offlap to the position of present sea level. Particularly prominent stands of sea level are recorded at elevations of 220-, 200+, 190+, 140+, 100+, 80+, 60+, 40-, and 20+ ft" (Smith, 1999) in nearby coastal areas. Some of these stillstands were identified in the Biddeford area and Pms deposits were subdivided accordingly. Some stream terraces are graded to these same levels and so are included in the corresponding deposits.

There is some evidence that the land emerged isostatically "until areas seaward of the present coastline were a minimum of 11 m (35 ft) above present sea level at that time. Weathered surfaces and tree stumps (now submerged) date this emergence to be at least 4,000 years B.P." (Hulmes, 1981). "Relative sea level on the coast of Maine has been rising since 4,200 years ago as recorded by radiocarbon-dated stumps. Tide gauge records indicate this submergence is continuing" (Hulmes, 1981, p.198), due primarily to eustatic sea level rise. Coastal marine processes have developed beaches of various types, including "clean" gravel to classical sandy beaches backed by dunes, which shelter the stream estuaries where saltmarsh deposits (some of which are greater that 5 feet thick) form within the zone of tidal fluctuation. The present shoreline configuration was probably established by about 1,000 yr B.P., based on a radiocarbon date for relict salt marsh recently exposed in the beach face at Fletcher's Neck (Vibracore 3, Section A-A', Biddeford Pool quadrangle), indicating a relatively slow (18 cm/yr) landward migration of that beach spit (Hulmes, 1981). Evidence in the study area for a postglacial lower sea level includes the apparent erosion channel in the Presumpscot Formation below Holocene tidal delta deposits in The Pool (See discussion on same in Introduction and Hulmes, 1980, 1981).

Modern streams have built floodplains that are graded to the present position of sea level, and freshwater wetland areas continue to accumulate deposits of organic matter (including peat) and fine-grained sediments. Evidence of modern erosion was presented in the discussion on exposures of glacial striations in the introduction.

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APPENDIX A. EDITED CORELOG DESCRIPTIONS AND INTERPRETATIONS.

(from Hulme 1980, Appendix A)

VIBRACORE 1. Flood-tidal delta - 510 cm

Depth (cm)	Description	Interpretation
0 - 40	Slippery mud, *Spartina alterniflora* rhizomes	Marsh
	Sharp contact	
40 - 65	Sand (2.0); decrease in organic content to 10%	Channel sand
65 - 130	No organics - sharp increase in mica; better sorted; 2.5 coarsens downward to 2.0	Edge of flood-tidal delta
	Sharp contact	
130 - 320	Silt layer; layers of silt and organic matter interspersed with sand, wood fragments; sorting and grain size vary 1.5 to 2.5 ; bioturbation throughout	Tidal pool muds and sands; some sands washed in through tidal inlet
	Abrupt contact	
320 - 350	Clean, moderately well-sorted sand 1.5	Tidal delta sand washed in through tidal inlet
350 - 510	Interbedded silty sands and sandy silts; very micaceous; organic layers; possible bioturbation; shell fragments scattered throughout	Tidal pool muds and sands

VIBRACORE 2. Flood-tidal delta - 498 cm

Depth (cm)	Description	Interpretation
0 - 40	Sandy mud with *Spartina alterniflora*	Marsh
	Sharp contact	
40 - 85	Moderately sorted sand 2.0 organic content 30 - 50%; *Spartina alterniflora* rhizomes decrease downward to 0%; sand fines downward into mud	Marsh
85 - 130	Silt and sand (3.0); scattered rhizomes	Marsh
130 - 200	Clean, well-sorted sand 3.0 to 2.5	Tidal-delta sands
200 - 267	Minor layers of silt, mica organics in clean sand 2.0 to 2.5	Tidal-delta sands
	Sharp contact	
267 - 400	Sandy silt; discreet sand layers, but may be some reworking of sand into mud by organisms	Tidal pool muds and sands
400 - 468	Laminated sand; shell fragments	Tidal-delta sands
468 - 476	Cross-bedded sands with mud drape; slipface	Tidal-delta sands
476 - 498	Silty sands; some organics	Tidal pool

APPENDIX A. CONTINUED.

VIBRACORE 3. Beach face - Fletcher Neck. Exposed relict marsh - 230 cm

Depth (cm)	Description	Interpretation
0 - 70	Dark brown sandy mud; *Spartina alterniflora* rhizomes	Relict marsh C^{14} date 985 80 yr B.P.
70 - 90	Transition into cleaner sand 1.5	
90 - 230	Clean sand with some pebbles and granules; variation in color and sorting; 1.5 to 2.0	Barrier sands

VIBRACORE 3A. Beach face - Fletcher Neck. 30 meters southwest of vibracore 3 - 180 cm

Depth (cm)	Description	Interpretation
0 - 48	Sandy mud grading into sand	Marsh
48 - 180	Well-sorted and rounded sand 1.5 to 2.0 ; coarse lens - 0.5	Barrier sands

VIBRACORE 4. Edge of marsh behind Fletcher Neck - 255 cm

Depth (cm)	Description	Interpretation
0 - 28	Dark brown mud with *Spartina alterniflora*	Marsh
28 - 110	Sand with orange-brown mottling (oxidation ?); sorting and grain size decrease downward; moderately well-sorted 1.5 at 40 cm; poor sorting 2.5 at 110 cm; mud content increases with depth	Washover sands
110 - 210	Muddy sand; occasional mud lens; wood fragments	Tidal pool muds and sands
210 - 220	Transition - more sand, less mud; orange-brown mottling	
220 - 233	Sand, poor sorting .5 to 1.5	Washover sand
233 - 255	Muddy sand with organics	Tidal pool

VIBRACORE 5. Beach face - Hills Beach - 521 cm

Depth (cm)	Description	Interpretation
0 - 24	Moderately sorted sand 2.5	Barrier sands
24 - 38	Coarse, poorly sorted sand 0 to 1.0 ; ridge slipface (?); pebbles	
38 - 57	Same sand matrix with wood fragments in layers	From paper mills (?); Seen on present beach face
57 - 182	Sand 1.0 to 1.5 ; some organic mottling	
182 - 238	Minor clay lenses in sand	Possible Presumpscot Formation contact
238 - 521	Compacted gray clay with light to heavy mottling throughout	Presumpscot Formation

VIBRACORE 6. Back barrier - Hills Beach - 387 cm

Depth (cm)	Description	Interpretation
0 - 80	Sandy mud; plant rhizomes; shell and wood fragments	Marsh
80 - 100	Mud; organics minor	Tidal pool
100 - 360	Clean, well-sorted sand layers 2.5 to 3.5 with gray clay layers	Washover sands mixing with tidal pool
360 - 387	Compacted gray clay; minor sand lenses	Presumpscot Formation

VIBRACORE 7. Marsh on tip of lobe on western side of Pool - 210 cm

Depth (cm)	Description	Interpretation
0 - 86	Dark brown sandy mud; *Spartina alterniflora*; few small pebbles	Marsh
86 - 136	Fine sand - dark brown, coated with organics; wood fragments	Tidal pool muds and sands
136 - 163	Sand to silt; abundant mica	Tidal pool
163 - 176	Well-sorted sand 3.0	
176 - 194	Coarse granules and pebbles	Washed down from adjacent highlands
194 - 210	Compacted coarse sand; very poorly sorted; numerous large pebbles	Highland sands

VIBRACORE 8. Tidal flats in Pool - 464 cm

Depth (cm)	Description	Interpretation
0 - 415	Sandy mud to mud; whole shell and 8 cm long pebble together; abundant mica; organics scattered throughout; occasional sand lenses	Tidal pool muds and sands
415 - 464	Very compacted gray clay; orange-brown mottling (oxidixed)	Presumpscot Formation

VIBRACORE 9. Tidal flats behind Fletcher Neck - 509 cm

Depth (cm)	Description	Interpretation
0 - 509	Sandy mud to mud throughout; abundant mica; organics and shell fragments throughout; sand layers at 80 - 110 158 - 180 2.0 372 - 380 1.5 to 2.0 400 - 404 2.5 438 - 490 1.0 to 2.0 494 - 509 1.5	Tidal pool muds with washover sands

APPENDIX A. CONTINUED.

VIBRACORE 10. Fringing marsh on western side of Pool - 374 cm

Depth (cm)	Description	Interpretation
0 - 30	Sandy mud; heavy rhizomes *Spartina alterniflora*	Marsh
30 - 54	Sand 2.0 with scattered large pebbles	Washed down from adjacent highlands
54 - 86	Sandy mud	Tidal pool
86 - 100	Gray mud/clay	
100 -174	Sand with shells; mud content increases downward; large wood fragments	
174 - 194	Rock fragments, pebbles, granules in mud; twigs	Washed down from highlands
194 - 266	Mud to clay	Tidal pool
266 - 324	Sandy mud; scattered pebbles	Tidal pool
324 - 374	Clean sand; oxidized, 1.5 ; large angular pebbles	Washed down; pebbles same as found in sample from adjacent highlands

VIBRACORE 11. Near wave-cut scarp, fringing marsh - 135 cm.

Depth (cm)	Description	Interpretation
0 - 18	Sandy mud; *Spartina alterniflora*; large angular pebbles throughout .5 to 2 cm	Marsh with some washed down sediments
18 - 26	Muddy sand; decreasing rhizomes	Marsh
26 - 41	Pebble layer; muddy sand matrix; very poorly sorted	Washed down
57 - 88	Brown to orange-brown (oxidized) sand; poorly sorted	
81 - 135	Compacted clay; oxidation	Presumpscot Formation

VIBRACORE 12. Fringing marsh, near vibracore 11 - 186 cm

Depth (cm)	Description	Interpretation
0 - 55	Dark brown mud; *Spartina alterniflora* rhizomes	Marsh
55 - 96	Muddy sand; scattered rhizomes	Marsh
96 - 122	Green-gray clay; sharp lens	Tidal pool
122 - 175	Sand 2.5 to 3.0	Washed down
175 - 185	Compacted sandy mud	Tidal pool

VIBRACORE 13. Meandering tidal creek behind Hills Beach - 140 cm.

Depth (cm)	Description	Interpretation
0 - 20	Sand -0.5 ; large pebbles (8 cm); grades down into pebble layer	Tidal channel sands
20 - 32	Sand 1.5 to 2.0 with mud matrix	Tidal channel sands with slack water fines
32 - 37	Clean sand lens 2.0	Washover (?)
37 - 43	Sand with organic mottling; wood fragments	Tidal channel sand with organics from beach or channel
43 - 75	Clean sands with mud lenses Sharp contact	
75 - 90	Clean sands 1.0 to 1.5	
90 - 140	Compacted clay; pebbles at bottom	Presumpscot Formation

VIBRACORE 14. Beach face Hills Beach - 129 cm..

Depth (cm)	Description	Interpretation
0 - 129	Sand - varied sorting and grain size .5 to 2.5 ; slipface 39 to 46 cm; pebbles	Barrier sands

VIBRACORE 15. Tidal flats on east/west transect behind flood-tidal delta - 468 cm.

Depth (cm)	Description	Interpretation
0 - 9	Sand; shell fragments	Tidal delta sands
9 - 31	Mud with some shell fragments and organics	Tidal pool
31 - 247	Mottled (bioturbated) sand with varying mud content (0 to 5%)	Tidal delta sands
247 - 290	Dark gray muds and sandy mud	Tidal pool
290 - 335	Orange-brown (oxidized) sand; numerous shell fragments; minor mud lenses	Tidal pool
335 - 468	Dark brown sandy mud; some shell fragments; sand lens	Tidal pool

VIBRACORE 16. Fringing marsh, northwest edge of Pool - 180 cm

Depth (cm)	Description	Interpretation
0 - 70	Dark brown mud with *Spartina alterniflora*	Marsh
70 - 180	Compacted clay; some oxidation; sand lenses; minor plant material near bottom	Presumpscot Formation

APPENDIX A. CONTINUED.

VIBRACORE 17. Tidal channel near Hills Beach - 685 cm.

Depth (cm)	Description	Interpretation
0 - 14	Sand 1.5 moderately well-sorted	Channel sands
14 - 31	Gray sandy mud with bioturbated brown sands	Tidal pool
31 - 48	Very fine sand coated with organics; slipface	Tidal pool/channel
48 - 444	Alternating layers of mud/clay and sand 2.5 to 3.0 bioturbation	Tidal pool with washovers
444 - 685	Compacted greenish-gray clay with organic mottling and poorly-sorted sand lenses; 2 sand layers bioturbated	Presumpscot Formation

VIBRACORE 18. Beach face, Fletcher Neck - 134 cm

Depth (cm)	Description	Interpretation
0 - 134	Clean sand 1.0 to 1.5 pebbles	Barrier sands

VIBRACORE 19. Tidal creek behind Fletcher Neck - 94 cm.

Depth (cm)	Description	Interpretation
0 - 17	Muddy sand with *Spartina alterniflora*; some pebbles	Marsh
17 - 48	Sharp contact with clean sand	Washover
48 - 86	Sandy mud; shell and wood fragments	Tidal pool
86 - 94	Organic material (*Spartina alterniflora?*)	Possible old marsh (?)

VIBRACORE 20. Flood-tidal delta near vibracore 1 -647 cm

Depth (cm)	Description	Interpretation
0 - 76	Sandy mud; *Spartina alterniflora*	Marsh
76 - 284	Sand; no rhizomes; wood fragments throughout; abundant mica; some oxidation	Tidal delta
284 - 448	Thin lenses of muddy sand and sandy mud	Tidal pool
448 - 475	Sand 2.0 ; scattered shell fragments; some wood fragments	Tidal pool
475 - 585	Alternating lenses of mud and sandy mud; some shell fragments; scattered rhizomes; wood fragment layer	Tidal pool
585 - 647	Compacted blue-gray clay	Presumpscot Formation

VIBRACORE 21. Fringing marsh, Fletcher Neck near vibracore 4 - 537 cm

Depth (cm)	Description	Interpretation
0 - 20	Mud with *Spartina alterniflora*	Marsh
20 - 124	Moderately sorted sand 1.5 to 2.0	Barrier washover
124 - 240	Sandy mud; minor lenses of organics with mica, and sand; minor shell fragments	Tidal pool
240 - 537	Layers of mud and silt; organics; shell fragments; several layers of sand with heavy concentrations of shells	Tidal pool with storm washovers

VIBRACORE 22. Basket Island tombolo

Depth (cm)	Description	Interpretation
0 - 217	No core recovered	Barrier-type sands

VIBRACORE 23. Spit between Basket and Stage Island - 243 cm

Depth (cm)	Description	Interpretation
0 - 217	Sand 1.5 with scattered shell fragments; several wood fragment layers; some large pebbles near bottom	Barrier-type sands

VIBRACORE 24. Shoal in front of flood-tidal delta - 158 cm

Depth (cm)	Description	Interpretation
0 - 158 sands	Sand 1.0 to 1.5 ; moderately to poorly-sorted; some shell fragments; layers of wood fragments; no structures	Tidal delta/channel

"DUTCH" CORE D-1. Above wave-cut scarp, fringing marsh - 47 cm

Depth (cm)	Description	Interpretation
0 - 13	Divot removed - grasses in sand	High marsh/dune vegetation
13 - 47	Poorly-sorted sand and pebbles	Same material as on adjacent hillside and on marsh edge

APPENDIX A. CONTINUED.

CORE D-2. On northern end of marsh lobe - 65 cm

Depth (cm)	Description	Interpretation
0 - 25	Divot removed - mud with *Spartina alterniflora*	Marsh
25 - 42	Black mud with *Spartina alterniflora* Sharp contact	Marsh
42 - 65	Poorly sorted pebbly sand	Same as Core D-1

CORE D-3. Small creek, west side behind Hills Beach - 100 cm

Depth (cm)	Description	Interpretation
0 - 8	Soupy brown mud	Marsh
8 - 78	Compacted brown mud with *Spartina alterniflora*	Marsh
78 - 100	Compacted blue clay	Presumpscot Formation also visible along banks of tidal creek at low water, approx. 1 m below marsh surface

CORE D-4. Just north of D-3 - 200 cm

Depth (cm)	Description	Interpretation
0 - 145	Mud with some sand; *Spartina alterniflora* rhizomes decreasing to 0% at 140 cm	Marsh
145 - 153	Sharp contact with silty sand	Channel sands
153 - 184	Fairly clean sand 2.0	Channel sands
184 - 192	Clean sand 2.0	Channel sands
192 - 200	Mud and sand mixed	Channel sands

CORE D-5. East side of creek behind Hills Beach, opposite D-4 - 200 cm

Depth (cm)	Description	Interpretation
0 - 173	Brown mud with *Spartina alterniflora*	Marsh
173 - 200	Sand 1.5 to 2.0 with fine (mud/clay) matrix	Channel sands

CORE D-6. East side of creek behind Hills Beach, just north of D-5 - 81 cm

Depth (cm)	Description	Interpretation
0 - 20	Divot removed - mud with *Spartina alterniflora*	Marsh
20 - 71	Mud with *Spartina alterniflora*	Marsh
71 -76	Gradational increase in sand; no rhizomes	
76 - 81	Sand 2.0 to 2.50 with minor silt matrix	Tidal channel sands

CORE D-7. Opposite D-6. - 83 cm

Depth (cm)	Description	Interpretation
0 - 19	Mud with *Spartina alterniflora*	Marsh
19 - 41	Mud with *Spartina alterniflora* with increasing sand content downward	Marsh
41 - 83	Sand 1.0 to 2.0 rhizomes gone; some wood fragments at base; muddy matrix	Tidal channel sands

CORE D-8. Back-barrier marsh, southern end behind Fletcher Neck - 36 cm

Depth (cm)	Description	Interpretation
0 - 36	Sand 2.0 with minor amounts of silt throughout and *Spartina alterniflora* rhizomes	Marsh on washover

CORE D-9, D-10, D-11, D-12. Washover lobe behind Fletcher Neck.

Depth (cm)	Description	Interpretation
0 - 60	Soupy muds with *Spartina alterniflora*	Marsh
60 - 70	Sand	Washover sands

CORE D-13. Marsh behind Fletcher Neck, approx. 30 meters from MLW.

Depth (cm)	Description	Interpretation
0 - 30	Soupy marsh mud	Marsh; same as D-9 through D-12
30 - 35	Clean sand	Washover sands

CORE D-14. Marsh behind Fletcher Neck, approx. at MLW

Depth (cm)	Description	Interpretation
0 - 80	Soupy mud	Marsh; same as above
80 -	Clean sand	Washover sands