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Surficial Geology of the Yarmouth 7.5-minute Quadrangle, Cumberland County, Maine

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INTRODUCTION

The surficial geology of the Yarmouth 7.5-minute quadrangle was mapped during 1995 through 1996 as part of the cooperative mapping program of the Maine Geological Survey and the U.S. Geological Survey in the coastal lowland corridor of southwestern Maine. Two maps are associated with this report: a surficial geologic map (Retelle, 1999c; which shows landforms and geologic map units interpreted from the underlying surficial materials) and a materials map (Retelle, 1999d) which shows thickness and textural composition of sediments in the map area.

Location and Topographic Setting

The Yarmouth 7.5-minute quadrangle is located in the coastal zone of southwestern Maine in Cumberland County. The map area includes portions of the towns of Yarmouth, Falmouth, Cumberland, Pownal, and Freeport. The map area is rural to rural residential throughout much of the western and northern portions of the quadrangle. The eastern part of the quadrangle borders Casco Bay and is predominantly residential. Commercial boating and fishing and other service industries border Casco Bay adjacent to Routes 1 and 95, which cut northeastward through the study area near the coast.

Most of the quadrangle is of low to moderate relief with the highest elevation of 308 feet on Hedgehog Mountain in Freeport in the northeastern corner of the quadrangle. For the most part the area is low-lying and mantled by a thick accumulation of fine-grained surficial materials that are incised by the Royal River in the west-central part of the field area and the Cousins River in the east-central part of the quadrangle. The Royal River enters the northwestern corner of the quadrangle and then trends south-southeastward to Casco Bay. At Yarmouth, it descends to Casco Bay in a short waterfall. The Cousins River and its main tributary, Pratts Brook, drain the eastern portion of the quadrangle, meandering through salt marsh at their lower ends. In the lowlands, surficial materials conceal the bedrock topography; in some areas the surficial blanket is thin and bedrock outcrops are more common.

Cousins and Littlejohn Islands, located in the southeast corner of the quadrangle in Casco Bay, are accessible by bridge and ferry.

Previous Surficial Geologic Mapping and Related Studies

A reconnaissance map of the surficial geology of the Yarmouth quadrangle was completed by Prescott and Thompson (1977). Smith (1980) also mapped moraines and stratified drift features of the quadrangle as part of a regional compilation of these features in Cumberland County. Reconnaissance surficial geologic maps in the adjacent area include the Portland West (Thompson, 1976a) and Gray (Thompson, 1976b) quadrangles. In the quadrangles bordering Yarmouth more recent detailed mapping was undertaken, including the Freeport quadrangle (Weddle, 1999a,b), the Cumberland Center quadrangle (Retelle, 1999a,b) and several that are currently in review.

Bedrock Geology

Bedrock in the quadrangle is made up of two distinct lithologic types separated by a contact that trends southwest to northeast across the center of the map sheet. The northwestern half is comprised of rocks of the southeastern corner of the Carboniferous-age Sebago batholith (Osberg and others, 1985). While there are some variations in composition of the rocks within the Sebago pluton (Creasy, 1993) most of the granite that comprises the pluton is gray, foliated, medium-grained and muscovite bearing.

The bedrock in the southeastern half of the quadrangle consists of polydeformed metasedimentary rocks that crop out along a northeast-southwest structural trend typical of the regional

strike of the metamorphic rock belt of this part of the coastal zone.

Most of the metasedimentary rock of the mainland area consists of the Ordovician to Silurian-age Vassalboro Formation, which is exposed mainly in the hilly terrain in the southwestern corner of the quadrangle and in small low-relief hills that are exposed through the surficial sediment cover (Osberg and others, 1985). Southeast of this unit lies a thin band of two units of the Cushing Formation (Precambrian to Ordovician-age) that is exposed on the peninsula southeast of the town of Yarmouth and on Cousins and Littlejohn Islands.

Methods Used in this Study

Various methods were employed in the geologic investigation. Preliminary analysis of topography and landforms was made using vertical aerial photography. Information obtained from air photo analysis was correlated with topography expressed on the 1:24,000 scale base map and then field-checked by foot and automobile traverses.

The primary data was obtained by field investigation of natural and artificial exposures. Natural exposures of surficial materials were limited to a few small exposures such as stream and river cuts. More extensive artificial exposures in active borrow pits provided the best picture of surface and subsurface materials. Numerous inactive pits are also located within the quadrangle and provided a limited view of the materials. In addition, temporary exposures such as building excavations, telephone pole holes, and trenches for water and sewage lines were often utilized. Many hand auger holes and small shovel holes were dug in the surface sediments.

Well and boring logs provided valuable subsurface data, although this data is sparse in some areas and concentrated in other locations. Boring logs were obtained from several sources. A detailed network of borings was made for the town of Cumberland during expansion of water and sewer service for the town. The town of Yarmouth conducted two surveys (1946 and 1957) for location of the town water supply. Selected well logs from the two latter sources are listed in Appendix A of this report.

SURFICIAL DEPOSITS

The following is a description of the various surficial geologic map units, their principal identifying characteristics that were employed during the mapping of the field area and the geological significance of the units explained in terms of the local and regional geological history.

Till (Map unit Pt) - In this study, the term till is defined as poorly sorted sediment deposited directly by the action of glacial ice. Till includes a generally fine-grained matrix (consisting of a mixture of sand, silt, and clay) and clasts of varying composition (metamorphic and igneous) and size, ranging from pebbles to boulders. In some locations, the till displays minor deformed stratification with more sorted layers or lenses of fine to coarse sand. Clasts in the till are commonly subrounded to subangular with percussion marks and fractured edges. Some clasts are striated and polished. The till in the field area is generally compact and ranges in color from dark olive gray to dark olive brown.

Till occurs in several stratigraphic and morphologic associations in the field area. Most till mapped in the quadrangle is in the hilly areas, where a veneer of till of varying thickness overlies bedrock. Where the till veneer is thin, the surface topography reflects that of the underlying bedrock and bedrock outcrops may be common. In this case a horizontally ruled pattern is shown on the surficial geologic map.

Where till occurs at the surface and masks the underlying bedrock, a gently rolling topography with a bouldery surface is common. Along with an assortment of stratified materials, till occurs in some end moraines and other ice-contact deposits (Smith, 1985; Retelle and Bither, 1989).

Till also occurs beneath a variable thickness of glacial-marine and glacial-fluvial deposits and overlying bedrock. In rare instances, thin layers and pods of till may occur within stratified sediments. This type of till, deposited in sediment gravity flows, is commonly referred to as flowtill (Hartshorn, 1958; Boulton, 1971).

The definitive age of till in the field area is unknown. It is assumed that the till was most likely deposited during the last advance and retreat of the Laurentide Ice Sheet through the area during the late Wisconsinan glaciation. It is possible, however, that some till exposed at depth may be older, deposited during a pre-late Wisconsinan glaciation (cf. Thompson and Borns, 1985a; Weddle and others, 1989).

End Moraines (Map unit Pem) - Several small end moraines have been mapped in the field area. End moraines are interpreted as linear ridges of varying composition deposited parallel to, and along, the former front of the retreating glacier margin. In this study, end moraines were identified in the field by their linear morphology and also by aerial photograph analysis (Smith, 1980, 1982) followed by field checking. The moraines vary in height, length, and spatial distribution across the quadrangle and the region. Small end moraines may be as small as several feet high and several tens of feet in length, whereas larger moraines may be over 20 feet high with individual segments over 1/4 mile long. However, distinct moraine ridges are usually difficult to distinguish from ground level in the field because the ridges are usually draped by a veneer of fine-grained glacial-marine sediment. Smith (personal communication, 1989) therefore has frequently identified moraines on air photographs based on color or tonal variations (indicative of varying sediment textures) of linear landforms arranged perpendicular to the direction of ice flow. In this report, most moraines, being so narrow, are designated by line symbols on the surficial geologic map.

When exposed in borrow pits, it is commonly seen that the internal structure of the end moraines is complex, containing a wide range of materials including slabs of till, folded and faulted

sand and gravel and fine-grained marine sediments (Smith, 1982; Smith and Hunter, 1989; Retelle and Bither, 1989).

Moraines were mapped in two parts of the quadrangle. A series of small moraines was mapped on the north half of Cousins Island (shown by heavy red lines on the geologic map). These low-relief features are seen on the ground as bouldery ridges and visible on the topographic map as lineaments oriented roughly perpendicular to the general direction of ice flow.

A second small moraine (Pem) was mapped in the northwestern corner of the quadrangle west of the Royal River. The low, linear ridge lies on a north- facing slope of a till hill and was presumably bulldozed into place by a slight forward pulse of the ice margin against the hill.

Stratified Drift Deposits

The lowland areas and valleys of the quadrangle were depositional sites for abundant quantities of sediment that originated from the meltwater system of the retreating marine-based ice sheet in a tidewater setting. Sediment derived from subglacial and englacial drainage is delivered to the marine environment through ice-walled tunnels to glacial-marine fans and deltas. These features are commonly morphologically and stratigraphically complex. In modern tidewater glacier settings, fans occur at the glacier grounding lines where meltwater streams enter the sea and hence are termed grounding line fans (Powell, 1990). Where an ice margin may halt for a period of time at a valley constriction or a subglacial bedrock topographic high (termed a pinning point) and abundant sediment is delivered to the proglacial zone, fans may aggrade towards the surface of the sea and eventually become flat-topped deltas (cf. Powell, 1990).

Glacial-Marine Fans (Map unit Pmf) - These deposits are seaward-dipping and wedge-shaped, and consist principally of sand and gravel delivered to the sea floor at the glacier margin by subglacial or englacial streams. Other sediments such as till and fine-grained marine sediments may be associated with the submarine fan deposits. In the Pleistocene age Champlain Sea deposits in the Ottawa area, Rust and Romanelli (1975) and Rust (1987) referred to these deposits as subaqueous outwash, while Powell (1990) has referred to the deposits as grounding line fans. The size of the fans depends on the supply of sediment and rate of retreat of the glacier margin. Commonly, fans contain subhorizontal, seaward-dipping beds of gravel and gravelly sand. Primary sedimentary structures, such as graded beds, are common in the sandy units. The direction of dip of the bedding is also variable, however most current indicators demonstrate paleocurrent flow ranging from southwest through southeast.

Glacial-marine fans are exposed in several areas of the map sheet although the primary area of coarse-grained fan sediment accumulation was along the western border where a marine fan complex is exposed in numerous gravel pits. Along this zone the retreating ice margin temporarily halted at several locations in the Piscataqua and Royal River valleys. The fan complex is comprised of small fans and composite fans that represent ice retreat to the northwest into the Royal River valley. The landforms in this area occur as generally south-sloping and linear ridges that parallel the former ice margin in an east-northeasterly orientation or as smaller features with the same orientation. Other smaller fans occur in the field area and represent less-centralized meltwater systems of the retreating ice sheet.

Fine-Grained Marine Mud (Map unit Pp) - The fine-grained deposits that blanket much of the interior of the quadrangle, and more generally, the low-lying terrain of the coastal lowland in Maine, were originally defined by Bloom (1963) as "glacial-marine clay" and named the **Presumpscot Formation.** The unit is generally found to be rather complex, consisting of a fining-upward sequence of sand, silt, and clay with marine mollusc fossils and dropstones common. The deposit is the distal component of a continuum with the esker-submarine fan systems that delivered glacial sediments to the sea floor. There are usually complex spatial and vertical relationships between the coarse fan sand and gravel and the finer sand, silt, and clay deposited predominantly by suspension settling distal to, or adjacent to, meltwater point sources.

The fine-grained unit is commonly found in varying shades of gray to olive gray when weathered. In some cases the clay has been referred to as "the blue clay" from its bright bluish-gray unweathered appearance. Grain-size analysis of the fine unit commonly indicates that the "clay" contains a high proportion of silt and a smaller proportion of fine sand. Large vertical exposures of the fine-grained unit are noticeably absent in the field area although shallow exposures in stream banks and road cuts were common. In addition, several exposures of the fine-grained unit were seen in the distal portions of fans, overlying the sandy foreset beds.

In the Presumpscot marine mud of the Yarmouth quadrangle several fossil localities have been documented including a rich fauna from a pit near Walnut Hill from which samples have been dated during studies by Bloom (1963), Stuiver and Borns, (1975), and Crossen (1984) The suite of conventional radiocarbon dates on shells range in age from 11,920   110 to 12,345   100 years. Presumably all the samples date stages of the regression phase of marine sedimentation in the area.

Nearshore Deposits (Map unit Pmn) - Generally coarse-grained deposits were formed by nearshore processes (predominantly wave reworking) during the late phase of marine submergence of the coastal zone. Gravel and sand deposited in submarine fans were reworked as sea level fell during glacio-isostatic emergence of the coastal zone. Morphologically and sedimentologically distinctive nearshore deposits are present along several till hills in the quadrangle. In addition, nearshore deposits commonly occur over and adjacent to marine fans and are sometimes difficult to distinguish from the original fan deposit.

Eolian Dunes and Eolian Sand (Map Units Qed and Qe) - In several areas of the quadrangle significant thicknesses of eolian sand occur as distinctive dunes, complexes of dunes, and as extensive, or discontinuous, sheets. The most spectacular de-

posit of eolian material in the quadrangle is the famous "Desert of Maine" located in Freeport, southwest of Hedgehog Mountain and north of Harvey Brook. The "Desert," a popular tourist attraction, consists of coalesced dunes and interspersed blowout surfaces in an area greater than 0.5 miles by 0.5 miles. The dune field likely first accmulated in early postglacial time when the recently deglaciated land surface, including sandy marine fans and deltas, was not yet vegetated and deflation carried sandy sediment over the uplifted sea floor. The fields were reactivated during agricultural expansion in the 1800's and the sediment on the dunes is presently mobile (cf. Trefethen, 1949; Allen, 1955).

Less extensive and less morphologically distinctive eolian deposits occur as more-or-less discontinuous sheets or small dunes as high as 10 feet.

Alluvium and Stream Terraces (Map units Ha and Hst) - The Yarmouth quadrangle has been extensively modified by postglacial streams that were superimposed on the recently deglaciated landscape. The dendritic network of numerous streams has downcut into the predominantly fine-grained glacial-marine deposits in the lowlands. Alluvium and stream terraces are mapped along many of the present-day stream courses in the field area. Poorly sorted silty sand and debris such as tree limbs and other vegetation are commonly deposited on terraces and low-lying areas bordering the modern streams during periods of high water. This process is important during spring melt and following periods of heavy rain. In several valleys terraces are preserved due to stream downcutting in the fine-grained surface material. A fine example of a postglacial stream terrace is in the town of Yarmouth in the Royal River valley. Presumably, terracing and deposition of alluvial sediment commenced as sea level fell from the marine limit and drainage was superimposed on the former marine landscape.

Wetlands (Map units Hws, Hwfm, and Hwsm) - The most extensive wetlands in the quadrangle are located along tidal channels and along protected areas of Casco Bay where salt marsh deposits occur as flat terraces overlying peat. The salt marsh peats generally overlie tidal mudflat deposits, however in the upper reaches of Cousins River and Pratt Brook they overlie the Pleistocene marine muds of the Presumpscot Formation.

Several small freshwater wetlands were also mapped in the quadrangle. These are located in the southwestern section of the map area, where they are situated in localized depressions in the bedrock and till topography.

GLACIAL AND POSTGLACIAL HISTORY

The field evidence seen in the Yarmouth quadrangle suggests that the area has been subjected only to the latest, or late Wisconsinan, advance and retreat of the Laurentide Ice Sheet. The limited exposures of till in the area do not show advanced weathering typical of deposits from older ice advances (Weddle and others, 1989), and hence the till should be assigned a late Wisconsinan age. Till was probably deposited subglacially during late stages of ice advance or during the retreat phase of the late Wisconsinan ice.

During the last advance of the ice sheet and also during early stages of retreat, ice flowed through the Yarmouth quadrangle from north-northwest to south-southeast. The average azimuth of striae and grooves ranges from 160^{o} to 170^{o}, however local variations (150^{o} to 185^{o}) occur where ice deformed plastically around bedrock obstructions. The single drumlin axis mapped on Cousins Island follows the same trend as the striae, as does a fluted till surface in the southwestern portion of the quadrangle. Both drumlin and striation orientations are consistent with regional flow patterns as suggested on the Surficial Geologic Map of Maine (Thompson and Borns, 1985b).

During the maximum of the last glaciation, the Laurentide Ice Sheet extended beyond the present Maine coastline onto the continental shelf and probably began to recede from that position around 17,000 to 15,000 years ago (Tucholke and Hollister, 1973). Stuiver and Borns (1975) estimate that the ice margin reached the present coastline around 13,500 yr B.P. Recent radiocarbon age estimates obtained on *Portlandia arctica* shells collected in a collaborative research program by the Maine Geological Survey and University of Maine (Weddle and others, 1993) suggest that deglaciation of the southwest coast may have occurred as early as 14,000 to 14,800 yr B.P. In fact, Weddle and others, (1993) report a ^{14}C TAMS date of 14,045 95 yr B.P. from *Portlandia arctica* shells recovered from marine mud just above ice-contact sediments in the adjacent Lisbon Falls quadrangle to the northeast.

During ice retreat, the ice margin was in contact with the sea forming a grounded, calving glacier margin. In addition to extensive calving, the retreating ice thinned by melting. However the occurrence of large and small moraines and glaciotectonic features suggest that retreat was not continuous. Instead, minor readvances interrupted the general pattern of retreat. Ice retreat was also halted temporarily where the grounded ice margin was pinned against topographic obstructions such as narrows in valleys and subglacial bedrock highs.

Marine submergence of the coastal zone occurred from the time of deglaciation until the ice margin had receded to the interior of Maine and isostatic rebound caused sea level to retreat to the continental shelf (Schnitker, 1974; Belknap and others, 1986). Elevations of geomorphic features such as ice-contact deltas (surveyed topset-foreset contacts) and raised beaches in adjacent field areas of higher relief (Thompson and others, 1989) range from roughly 280 to 300 feet asl in the field area, thus providing an estimate of the upper limit of marine submergence (marine limit) in the Cumberland Center quadrangle to the west. In the Forest Lake delta, Thompson and others (1989) measured the topset-foreset contact at 283 feet asl. Thus, during the maximum of the marine inundation, most of the Yarmouth quadrangle was submerged below contemporaneous sea level. Till/bedrock uplands emerged first from the postglacial sea as islands and island complexes, sometimes tied together by nearshore marine deposits such as spits. Submarine fans, such as

those in the western portion of the quadrangle, were deposited along the ice margin on the sea floor in water depths exceeding 100 feet. In the northeastern corner of the quadrangle, however, the Hedgehog Mountain fan built close to contemporaneous sea level at approximately 280 feet asl. The fan deposits graded laterally and distally to finer grained deposits on the sea floor. Along with some large and small end moraines, the pattern of ice retreat through the quadrangle is documented by submarine fans and associated deposits.

Ice retreat is recorded by ice-marginal deposits in the valleys and lowlands of the study area. Near the southern margin of the quadrangle, recession is documented by a series of small moraines on Cousins Island which indicate a northwesterly retreat to what is presently the coastline. North of the present coast, the topography of the two main valleys of the Royal and Cousins Rivers likely controlled the style of retreat from Casco Bay. The greatest accumulation of meltwater deposits is located along the western margin of the Royal River where there are thick submarine fan sequences. Ice marginal retreat was likely slowed along bedrock highs in the valley, causing larger accumulations of sediment to be deposited. The northeast-southwest orientation of the fans and moraines shows that ice retreated northwesterly, subparallel to the present course of the Royal River, indicating that perhaps the subglacial topography influenced both the direction of advance and retreat of the Casco Bay sublobe of the Laurentide Ice Sheet.

Marine sediments accumulated in the field area from ca. 14,000 yr B.P. (Weddle and others, 1993) until isostatic rebound caused sea level to fall beyond the present coastline and onto the continental shelf. As sea level fell, and wave base came into contact with the unconsolidated glacial and glacial-marine sediments, nearshore deposits and shallow marine sands were deposited across virtually the entire quadrangle. In some exposures fine-grained silty marine clay coarsens upward with the introduction of lenses and layers of sand to be finally succeeded by a thick sand unit extending to the top of the sequence. In other exposures the change is abrupt, with the regressive sand unit overlying till or sand and gravel deposits with a distinct unconformity. With the rate of isostatic emergence of the recently deglaciated landscape exceeding sea level rise, relative sea level continued to fall until the coastal zone emerged. Based on submarine geomorphology, Schnitker (1974) estimates that the low stand of sea level was approximately -60 meters below present.

With the field area subaerially exposed, fluvial drainage developed on the former seafloor in the fine-grained, low-lying valleys and broad lowlands. In poorly drained areas, swamps and wetlands formed. A modified dendritic drainage pattern formed over the fine-grained deposits in the low-lying areas. Some materials have been reworked by winds forming sand sheets and dune deposits. Glacial and postglacial deposits continue to be reworked by modern alluvial processes. In addition, with current sea-level rise, drowning of former terrestrial deposits has occurred and salt marsh deposits now accumulate in numerous valleys and fringing Casco Bay.

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Appendix A: Selected well and test borings (thickness of units indicated in feet).

Cumberland Sewer Survey

I-100

1.8	gravelly sand (fill)
8.1	silty clay
7.0	silty fine sand
4.6	gravelly silty sand

I-112

1.3	gravel, rotten rock

I-115

3.5	gravelly silty sand with silty fine sand
7.5	silty clay with fine sandy silty layers
0.5	silty gravelly sand

I-127

2.0	sandy gravel
9.5	clay with many silty sand layers
3.5	gravelly sand
	refusal

I-131

4.0	silty, gravelly sand (fill)
1.8	silty sand with stones
	refusal at 5.8'

I-138

5.0	gravelly sand
3.0	med-coarse sand and silty clay
7.0	silty clay with silt and sand layers
12	silty clay with silty sand layers

I-139

4.0	silty gravelly sand
5.0	fine sandy silt
3.0	silty clay with silty sand layers

I-141

6.0	silty fine sand
7.8	silty gravelly sand
	refusal at 13.8'

I-339

4.0	silty,gravelly sand
5.5	silty clay with silty sand layers
	refusal at 9.5'

C-214

7.0	silty gravelly sand with rock fragments
9.5	fine to medium sand

C-228

6	silty sand with some stones
2.0	silty clay
9.5	silty clay with few thin sand layers

PS-31I

8.0	silty clay
22.5	silty clay with silty sand layers
1.8	silty gravelly sand

1946 Wells, Town of Yarmouth

46-1

20.0	brown clay
65.0	blue clay
8.5	gravel and hardpan

46-2

10.0	brown clay
79.0	blue clay
	ledge

46-3

20.0	brown clay
50.0	blue clay
5.0	fine clay,sand
3.0	coarse sand
10.5	hardpan

46-4

5.0	blue clay
5.0	fine sand
20.0	coarse sand

46-5

5.0	brown clay
15.0	blue clay
17.0	brown clay

46-6

80.0	med top coarse sand and gravel
	ledge

1957 Wells, Town of Yarmouth

57-1

18.0	brown clay
22.0	sand

57-2

14.0	brown clay
16.0	blue clay
43.0	ledge

57-3

12 .0	gravel and clay
26.0	sand
2.0	coarse gravel

57-4

48.0	sand and gravel

57-5

20.0	fine sand
20.0	sharp gravel

57-6

12.0	brown clay
5.0	blue clay
57.0	fine sand/blue clay

57-7

10.0	sharp gravel and brown clay
25.0	fine sand
44.0	fine to medium sand

57-8

5.0	sandy clay

57-9

22.0	hard sand and clay
5.0	fine sand

57-10

19.0	gravel
2.0	hardpan