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

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INTRODUCTION

The York Harbor quadrangle is an area of about 55 mi^2 (142 km^2) that lies along the coast of southwestern Maine in York County. Altitudes in the quadrangle range from sea level to 691 ft (211 m) above sea level (a.s.l.), but are generally less than 300 ft (91 m). The major drainage system is the York River, which drains the southern half of the quadrangle. Drainage in the northern half is quite poor and characterized by ponds and swamps fed by small streams and creeks. The underlying bedrock consists of metamorphosed igneous and sedimentary rocks which are exposed at numerous small outcrops (bedrock descriptions below are summarized from Hussey, 1985). The surficial material is primarily the result of a late Wisconsinan glaciation during which the Laurentide Ice Sheet covered all of New England.

BEDROCK GEOLOGY

The Kittery and Eliot Formations, both of the Merrimac Group, underlie the southern third of the York Harbor quadrangle. The Kittery Formation is also found in the extreme northwest corner of the quadrangle. The absolute ages of these formations are uncertain, with estimates ranging from Precambrian to Silurian. The Kittery Formation is thought to be the older of the two units and consists of three different rock types: (1) a thinly laminated calcareous and feldspathic quartzite, (2) a gray feldspathic, micaceous, calcareous quartzite; and (3) a dark-gray chlorite or biotite phyllite. The Kittery Formation is interpreted as having formed mostly as turbidites in a deep-sea fan environment.

The Eliot Formation lies conformably above the Kittery Formation. This formation outcrops in the southwest portion of the map area in a northeast-southwest strip through Cutts Ridge and the town of Scotland. In map view, the Eliot Formation is bounded to the northwest and southeast by the Kittery Formation. Three units are present within the Eliot Formation: (1) a calcite-bearing quartz phyllite and dark-gray, finely crenulated phyllite; (2) thin-bedded alternations of fine-grained quartz-plagioclase-biotite granofels and brown biotite schist or phyllite; and (3) a massive quartz-mica-carbonate phyllite.

The northern two-thirds of the York Harbor quadrangle is underlain by a series of intrusive rocks. The oldest of these rocks is thought to be part of the Webhannet pluton, a post-tectonic pluton (early Devonian in age) which intrudes the Kittery and Eliot Formations. The Webhannet pluton lies in a strip approximately 0.75 mi (1.2 km) wide trending southwest-northeast through Warren Pond and Bickel Mountain. Although the Webhannet pluton consists of three phases of intrusions, only one exists in this quadrangle: a weakly foliated, gray biotite granite.

The entire area east of Warren Pond and north of a line connecting the southern portion of Boulter Pond and Bridges Swamp is underlain by a series of younger alkalic plutons (Triassic age) known as the Agamenticus Complex. This complex is roughly circular in shape and occurs almost entirely within the York Harbor quadrangle. Four plutonic phases compose the Agamenticus Complex, with the age relationship between the older three uncertain. The presumed oldest phase is a medium-grained, brown to olive-green syenite located in the northeastern portion of the quadrangle in the Groundnut Hill-Clay Hill area. The next younger phase is thought to be an alkaline quartz syenite which surrounds the older syenite, stretching from Folly Pond to Scituate Pond and around Whipporwill Swamp. This intrusive is also found in the Cockle Hill-Long Hill area.

Two granitic bodies are the youngest phases of the Agamenticus Complex. The older of these is an alkaline granite which forms two separate bodies within the complex. The first occurs just south of the intersection of Route 1 and the eastern border of the quadrangle. Bridges Swamp delineates the southern limit. This body is fine-grained and buff to salmon colored. A second, and much larger, crescent-shaped body of alkaline granite extends from the town of Scotland, up through the Horse Hills and Mt. Agamenticus, and around to the intersection of Interstate Route 95 and the northern border of the quadrangle. The youngest phase of the Agamenticus Complex is a fine to medium grained, light pink, porphyritic biotite-hornblende granite found

in the area denoted by Hooper Swamp, Chases Pond, and Agamenticus Village.

GLACIAL AND POSTGLACIAL DEPOSITS

The surficial geology of the York Harbor quadrangle is primarily the result of glacial activity which took place during late Wisconsinan time. The late Wisconsinan deposits can be divided into four types: (1) materials deposited directly by the glacial ice (i.e., till); (2) outwash fans; (3) deposits related to deglacial processes associated with the late-glacial marine submergence (i.e., the Presumpscot Formation); and (4) a thin mixture of sediments eroded from till and the Presumpscot Formation. Only minor reworking and deposition of surficial materials has taken place since regression of the sea from southwestern coastal Maine.

Two types of tills are present in the York Harbor quadrangle. The first type, interpreted to be a lodgement till and labeled as unit Ptl on the geologic map, is a tight compact sediment found only in drumlins. Where exposed, this unit displays a good fissility and has a matrix of silt and clay with minor amounts of sand. Pebbles and cobbles in this till include granites, phyllites, quartzites, schists, and basalts that were derived from the northwest. Many of the granites and schists are weathered to ghosts in the upper 20 ft (6.1 m) of this unit. At two localities, Cutts Ridge and Groundnut Hill, a 10-15 ft (3.0-4.6 m) thick, olive-gray to gray oxidized zone is developed in the bluish-gray non-oxidized till. The contact between the oxidized and non-oxidized till is abrupt, but some surface staining and oxidation is present on joint planes and fissility surfaces for several inches below the contact. This weathering profile may have formed during a prolonged weathering episode following deposition of the till which would suggest an early Wisconsinan or Illinoian age for the till. Alternatively, the weathering may be the result of ground water oxidation of the low-permeability till, which may have occurred during he Holocene. The till composition, the occurrence of the till in drumlins, and the presence of an oxidized horizon suggests a correlation with the "lower till" of Schafer and Hartshorn (1965). However, no multiple-till sections were located within the quadrangle, so the name "lower till" is unjustified here, and no correlation can be equivocally proven.

The second type of till (map unit Pt) is a loose sandy-matrix diamicton which blankets much of the quadrangle and comprises the two small recessional moraines near Mt. Agamenticus and Bickel Mountain. The till is generally a thin, nonsorted to poorly sorted, nonstratified mixture of sand, pebbles, cobbles, and boulders. As is the case with the lodgement till, erratics in the surface till appear to have been derived from the northwest. Field identification of the till was made on the basis of hummocky topography and abundance of erratics, and supplemented by auger-hole subsurface data. This till is generally found at elevations above 60-80 ft (18-24 m), where it is not overlain by Presumpscot Formation clays and silts. The surface till is very thin over the northern two-thirds of the quadrangle. It commonly is less than 10 ft (3.0 m) thick, as shown by the ruled pattern on the geologic map. The distribution of thicker till suggests that much of the till has colluviated downslope. This till is inferred to be an ablation till deposited during ice retreat, and is characteristically similar to the "upper till" of New England. However, as previously mentioned, no multiple-till exposures were found in the map area, so the name "upper till" is not justified.

Two outwash deposits, laid down by meltwater during the retreat of the ice margin, are present within the quadrangle: a marine fan (map unit Pmf) located at Cutts Ridge, and a marine delta (unit Pmd) situated one mile north of Brixham Corners. The Cutts Ridge marine fan is developed on the southwest side of the Cutts Ridge drumlin and consists of slightly oxidized sand and gravel which overlies both oxidized and non-oxidized lodgement till. The fan is composed of interlayered coarse gravel, gravel, and sand foreset beds which dip to the southwest. In addition, at least one interbedded diamicton, interpreted as a flowtill, is present at this site. The highest elevation where the foresets are exposed is 140 ft (43 m), which is approximately 50 ft (15 m) below the upper marine limit.

The age of the Cutts Ridge marine fan is uncertain. The foresets overlie, and therefore postdate, the oxidation of the drumlin till, suggesting a late Wisconsinan age. On the other hand, the foreset beds are truncated at the surface of Cutts Ridge, implying the removal of material by erosion. This eroded material is not present near the base of the hill, and the overall form of the hill is drumlinoid, which suggests that the fan was developed during the onset of the Wisconsinan glaciation and was overridden and reshaped by the ice. Alternatively, if the fan was deposited during glacial retreat, it may have been reshaped by a minor readvance.

Foreset beds were also observed at the York Dump at an elevation of 190 ft (58 m) a.s.l. Virtually all of the sand and gravel at this site has been removed for construction purposes, and most of the remaining material has been covered during landfill operation. However, Maine Department of Transportation reports and the location and elevation of the delta suggest that the deposit was an ice-contact marine delta formed during glacial retreat.

The Presumpscot Formation (map unit Pp) and sandy regressive marine deposits (unit Pmrs) are glaciomarine, marine, and shoreline sediments deposited as the glacier retreated in contact with ocean waters. The Presumpscot Formation consists of silts and clays derived from glacial rock flour. It typically is bluish-gray in fresh exposures and is oxidized to an olive-gray to green color with prominent manganese stains in weathered exposures. While the Presumpscot Formation may be found anywhere below the marine limit (locally 180-190 ft; 55-58 m), it is only found in mappable thicknesses in low-lying areas from 5-30 ft (1.5-9.1 m) a.s.l. in the southern half of the quadrangle, and is characterized by low relief. The sandy marine sediments (Pmrs) may include ice-proximal deposits, beach or nearshore deposits, and reworked deposits formed during the marine reces-

sion. Locally the sands are medium to coarse grained, yellow to rust-colored, oxidized, and situated downslope from steeper till-covered hills, suggesting a reworking origin. Marine regressive sands have also been mapped at the abandoned gravel pits southwest of Scituate Pond at an elevation of 180 ft (55 m) a.s.l. The elevation of these sands suggests that they may have been a beach deposit, but virtually all of this material has been removed for construction purposes.

In many places the surficial material is a thin mixture (less than 10 ft (3.0 m) thick) of sediments derived from till and Presumpscot Formation. These marine nearshore deposits are mapped as Pmn. Local bedrock outcrops exist in these areas, but are too small to map individually. Pmn is the result of marine erosion and redeposition of Pleistocene sediments during the marine offlap. Identification in the field was based on the presence of bedrock outcrops, erratic boulders, and Presumpscot Formation silts and clays. Contacts between map units Pmn and Pt, and Pmn and Pp are gradational, and many of the mapped boundaries are approximately located. Pmn is generally found near the coast in areas of moderate elevation (20-80 ft (6.1-24 m) a.s.l.).

Holocene deposits also exist in the quadrangle. They include wetlands, marine shoreline deposits (map unit Hms), and alluvium (Ha). Wetlands are classified according to whether they are freshwater marshes (Hwfm), salt-water marshes (Hwsm), or swamps (Hws). Some of the wetlands are underlain by peat, and are further classified according to thickness and ash content of the peat (see map explanation [Clinch and O'Toole, 1999]). The freshwater wetland deposits consist primarily of muck, peat, and silt, and are found in areas of low relief underlain by either Pp or bedrock. The salt marshes generally have less than 5 ft (1.5 m) of fibrous peat, which is interlayered with silt. Marine shoreline deposits include beaches and zones of wave-reworked sediments. The beach in Lobster Cove and a few isolated spots in the extreme southeast portion of the quadrangle represent the only areas where this unit may be found. The only alluvial deposit in the map area is located in the extreme northwest corner and consists of sands and minor amounts of gravel deposited by the Great River.

LATE WISCONSINAN GLACIAL HISTORY

Although southwestern Maine probably has undergone several glaciations, subsequent glacial advances and interglacial weathering and erosion have destroyed virtually all evidence for ancient glacial activity. As a result, evidence for only two glacial advances is now preserved within the York Harbor quadrangle, and the paucity of ice-marginal deposits precludes a detailed account for even these glacial episodes.

The first of the two glacial advances is recorded by the lodgement till found in the core of drumlins (specifically Frost Hill, Cutts Ridge, Beech Ridge, and Groundnut Hill). Flow during this glacial advance was approximate S 50° E to S 60° E, as indicated by the drumlin orientation and a striation exposure beneath the lodgement till at Groundnut Hill. Following the retreat of this glacier, the till was oxidized to a depth of approximately 20 ft (6.1 m) during a prolonged weathering episode. The age of this glaciation is uncertain, with estimates ranging from Illinoian to early Wisconsinan.

The last glacial advance occurred in late Wisconsinan time, when the entire Gulf of Maine was covered by the Laurentide Ice Sheet, which at its maximum extended south to Long Island, New York. Regionally, ice flow directions were from the northwest to the southeast, as shown by drumlin orientations and striations, but no evidence was found in the quadrangle to confirm this. The single late Wisconsinan striation locality, found one mile (1.6 km) north of Brixham Corners at the York Dump, preserves striations oriented S 10° W. The disparity between this reading and the general ice flow direction is the result of a localized topographic diversion of the ice sheet.

Recession of the late Wisconsinan glacier reached the southern coast of Maine at approximately 14,000 years B.P. to 13,500 yr B.P. This is supported by radiocarbon dates of 13,800 ± 100 yr B.P. and 13,200 ± 120 yr B.P., both of which were obtained from Kennebunk, located a few miles to the northeast (Smith, 1985; Thompson and Borns, 1985). No radiocarbon dates are available from the quadrangle itself. Recession was caused by calving into marine waters and was accompanied by marginal thinning and drawdown of the ice. By analogy with modern glaciers, the configuration of the ice margin probably was controlled by local topography. Regionally, the glacier retreated to the northwest; and successive ice marginal positions, reconstructed from grounding line moraines and radiocarbon dates, generally parallel the present coastline.

Within the York Harbor quadrangle there are no ice-marginal positions that can be clearly and unequivocally traced across the quadrangle, or correlated to marginal deposits in adjacent quadrangles. However, two terminal moraine segments in the northwestern corner of the quadrangle, an ice-contact delta, and minor grounding-line moraines mapped north and south of the York River can be used to reconstruct the probable sequence and mechanism of deglaciation of the quadrangle.

Due to thinning caused by marine drawdown, ice flow could not be maintained over Third Hill, Second Hill, Mount Agamenticus, and the highlands southwest towards Payneton and Brixham Lower Corners. This caused stagnation of the ice southeast of these highlands, resulting in the deposition of only extremely thin tills and the preservation of no mappable ice marginal deposits in this area. Active ice was diverted by the Mount Agamenticus highlands north into the North Berwick quadrangle and south into the York River basin, as recorded by the S 10° W striations at the York Dump. As the Mount Agamenticus highlands rose above the marine limit, locally estimated as 190 ft (58 m) a.s.l., they served as lateral pinning point for tidewater glacier lobes north and south of the highlands.

The tidewater glacier occupying the York River drainage basin retreated to the northwest by calving into a marine embayment. No recessional deposits are preserved southeast of Route

1, due to subsequent wave reworking during marine recession. Northwest of Route 1, several clusters of DeGeer moraines are exposed, including swarms immediately east of Wilson Road, on the east side of Cutts River, north of Beech Ridge, and along South Berwick Road between Scotland and Payneton. These moraine ridges are typically 5-10 ft (1.5-3.0 m) high and spaced 150-200 ft (46-61 m) apart. Typically, the moraines are preserved on the flanks of ridges and are buried downslope by Presumpscot Formation clays. Most moraine ridges trend N 40-50° E, except for those along south Berwick Road, near the lateral margin of the glacier, which trend N 60-80° E. While no continuous ice margin can be traced across the quadrangle, the moraine trends suggest an ice margin concave downglacier, which is typical of calving glacier margins. The trend of the moraines east of Wilson Road is convex downvalley, but these moraines are preserved atop a broad ridge separating the York River drainage from the Piscataqua River, again typical of calving glacier margins.

Following recession of the ice from the York River basin, the delta north of Brixham Upper Corners was deposited. As this delta is located at the local drainage divide, it was probably deposited in contact with the now-grounded glacier and was probably fed from a subglacial tunnel. However, extensive mining of the gravel for road construction and backfilling of the site during landfill operations has obscured evidence for the exact location of the ice marginal position.

Two short moraine segments (up to about 3,600 ft (1,000 m) long) were deposited on the northwest sides of Second Hill and Bickel Mountain. The trends of these two moraines show that they are not correlative. Both moraines were deposited at or near the local marine limit and may represent deposition for relatively long periods of time as Second Hill and Bickel Mountain acted as lateral pinning points for the calving glacier lobes north and west of the Mount Agamenticus Highlands.

Contemporaneous with the deglaciation of the area, the southern one-third of the quadrangle was inundated by the transgressing sea, the result of an isostatic depression caused by the weight of the ice and eustatic sea-level rise due to melting and retreat of the Laurentide Ice Sheet. At its maximum extent (approximately 13,000 years B.P.) the marine submergence extended inland 9-12 mi (15-20 km) in this part of Maine. The marine limit in the quadrangle is approximately 190 ft (58 m) a.s.l., based on the elevation of the York Dump delta, the upper limit of the sandy Presumpscot Formation near Scituate Pond, and the data from Thompson and others (1983). It was during this time, when southwestern Maine was submerged, that the Presumpscot Formation (Pp) was deposited as a blanket on small hills and in valleys.

The marine offlap is thought to have started shortly after the ice margin had retreated beyond the inland limit of marine submergence (Thompson and Borns, 1985). During the marine recession, sediments that had been deposited on the steeper slopes were reworked to form sandy sediments. Till and Presumpscot Formation silts and clays that covered bedrock in the southeast portion of the quadrangle were extensively reworked and eroded, leaving only a thin layer of erratics and clay over bedrock. The marine recession continued until sea level was considerably lower than modern sea level. The only local evidence for this recession is in test borings along the Bragdon Bridge, near York Harbor. There, the Presumpscot Formation clays have been truncated by erosion to a depth of 55 feet (16.8 m). Since that time, sea level has risen to its modern height, accompanied by the deposition of modern beach deposits and the development of salt marshes and other wetlands.

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APPENDIX A. SURFICIAL MATERIALS DATA, YORK HARBOR QUADRANGLE

1. Auger hole; 6 feet of medium to coarse grained, rust-stained sand, coarsening upward. Interpreted as Pps, marine offlap sand, reworked from the surrounding till.

2. Road-cut exposure; 3+ feet of medium, rust-stained sand, interpreted as marine offlap sand.

3. Auger hole, supplemented by information from a water well driller working at the site. Auger hole stratigraphy is 3 feet of rust-stained sand, interpreted as marine offlap sand, over 3+ feet of olive gray-green weathered clay, interpreted as Presumpscot Formation. Well driller's information is that the total depth to bedrock is 8 feet: 3 feet of sand, 5 feet of clay.

4. Auger hole; 1.5 feet of colluviated till over 4 feet of weathered Presumpscot Formation clay.

5. Road cut; 0-2 feet of colluviated, sandy-matrix till and local bedrock blocks overlying bedrock.

6. Graded gravel pit; unknown thickness of medium to coarse, rust-stained sand; sedimentary structures obscured by grading; interpreted as Pps.

7. Building foundation pit; 6 to 8 feet of Pps over syenite bedrock.

8. Building foundation pit; 2 feet of colluviated till over 5 feet of marine offlap sand (Pps).

9. Graded gravel pit; angular chips and grains of local bedrock, interpreted as a local pocket of grus.

10. Inactive gravel pit at southwest end of Groundnut Hill drumlin; 0-40 feet of olive-gray, compact silty diamicton, interpreted as lodgement till. Striations on pit floor trend S 60° E, agreeing with the long axis of the drumlin.

11. Inactive gravel pit on Bell Marsh Road, now badly slumped. Pit stratigraphy is 1 foot of colluviated till over 2 feet of marine offlap sand, over 4 feet of sandy-matrix till, over bedrock.

12. Stream cut south of York Dump; 6 feet of marine offlap sand (Pps).

13. Auger hole, north of Beech Ridge road; 3 feet of Pp clay over bedrock.

14. Auger hole, Beech Ridge; 2-4 feet of marine offlap sand (Pps) over silty-matrix till.

15. Stream exposure; 3 feet of Presumpscot Formation clay (Pp).

16. Building excavation pit; 6 feet of Presumpscot Formation clay.

17. Drainage ditch exposure; silty-matrix till (Ptl).

18. Property owner's report; 150-foot water well in silty till; till identification not verified.

19. Slumped gravel pit in Cutts Ridge; 20-25 feet of poorly exposed sand and gravel; one bedding attitude measured as N 40° W, 25° S.

20. First Parish Cemetery, York Harbor, grave exposure; 4 feet of poorly bedded sand and gravel, interpreted as offlap sand over rock; rock exposures surround cemetery.

APPENDIX B. TEST HOLE LOGS FROM THE MAINE DEPARTMENT OF TRANSPORTATION, WITH INTERPRETATION OF MATERIALS

TH-1

10 cy	Presumpscot Formation clay
rk	

TH-2

7 og	wetlands organic soil
25 cy	Presumpscot Formation clay
rk	

TH-3

8 cy	Presumpscot Formation clay
rk	

TH-4

5 og	wetlands organic soil
6 cy	Presumpscot Formation clay
7 ds	sandy-matrix till
rk	

TH-5

62 cy	Presumpscot Formation clay
5 s	ice-proximal Presumpscot Formation sand
15 ds	sandy-matrix till

TH-6

10 og	wetlands organic soil
33 cy	Presumpscot Formation clay
15 s	ice-proximal Presumpscot Formation sand
10 ds	sandy-matrix till
rk	

TH-7

57 cy	Presumpscot Formation clay
10 s	ice-proximal Presumpscot Formation sand
12 ds	sandy-matrix till
rk	

TH-8

25 cy	Presumpscot Formation clay
10 ds	sandy-matrix till
rk	

TH-9

6 cy	Presumpscot Formation clay
38 ds	sandy-matrix till
rk	

TH-10

10 cy	Presumpscot Formation clay
35 ds	sandy-matrix till
rk	

TH-11

10 cy	Presumpscot Formation clay
24 ds	sandy-matrix till
rk	

TH-12

20 af	artificial fill
15 cy	Presumpscot Formation clay
12 s	ice-proximal Presumpscot Formation sand
32 sg	ice-contact stratified drift (?)
10 ds	sandy-matrix till

TH-13

15 water	
18 s	post-Presumpscot alluvium
23 cy	Presumpscot Formation clay
28 ds	sandy-matrix till
rk	

TH-14

15 water	
40 s	post-Presumpscot alluvium (fill of an erosional cut)
5 ds	sandy-matrix till

TH-15

12 af	artificial fill
4 og	wetlands organic soil
6 s	post-Presumpscot alluvium
19 cy	Presumpscot Formation clay
6 s	ice-proximal Presumpscot sand
35 ds	sandy-matrix till

In addition, 12 other exposures (indicated by four-digit numbers on the materials map) were studied and logged in more detail. Data sheets for these exposures are available from the Maine Geological Survey