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**Author:** *John C. Gosse*

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# *Surficial Geology of the Standish 7.5-minute Quadrangle, York and Cumberland Counties, Maine*

***John C. Gosse***
*Department of Geology*
*University of Kansas*
*Lawrence, Kansas 66045*

## INTRODUCTION

The Standish 7.5-minute quadrangle encompasses a region in southern Maine that lies approximately 12.5 mi (20 km) west of Portland and 1 mi (1.5 km) south of the southern tip of Sebago Lake, occupying portions of both Cumberland and York Counties (Figure 1). The area is characterized by gently rolling topography and bedrock knobs which extend to over 530 ft (160 m) above sea-level (asl) in the north-central portion of the quadrangle, where the maximum relief is about 200 ft (60 m). Higher portions of the quadrangle are above the limit of late-glacial marine submergence, so the area contains well-preserved exposures of both marine and terrestrial late Wisconsinan surficial deposits. Evidence of pre-Wisconsinan glaciations have not been found. Cultivation and tree growth have generally disturbed only the uppermost 1 m of the surficial materials, so the original sedimentary deposits remain generally intact. More than 54 sand and gravel pits in submarine fans and deltaic deposits are distributed over the 10 x 14 km map area, with at least 20 pits active in 1992.

Bedrock in the Standish quadrangle is dominantly folded and metamorphosed Ordovician and Silurian plagioclase-biotite granofels of the Vassalboro Formation and northeast-trending synformal belts (up to 2 km wide) of muscovite-biotite-garnet schist belonging to the Windham Formation (Hussey, 1985). The Devonian-age Lyman pluton intrudes the Vassalboro Formation and outcrops near the town of Hollis. Rindgemere Formation metasedimentary rocks northwest of Tylers Corner are covered by glaciomarine sediments and therefore have limited outcrop exposure. Foliation and schistosity within the Standish quadrangle parallel the northeast fabric imparted by Acadian deformation. Ridges controlled by these rock structures trend parallel to the general orientation of the retreating margin of the last ice sheet. The ridges temporarily anchored the ice margin, enabling deposition of ice-contact and leeside glaciomarine deltas (Thompson and others, 1989).

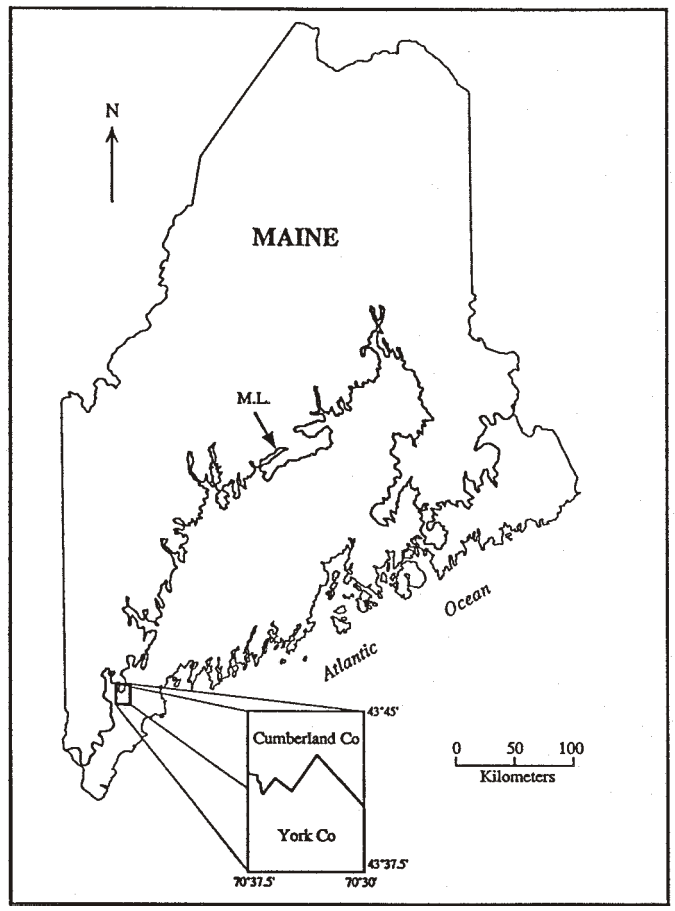


**Figure 1.** Location of the Standish 7.5-minute quadrangle. M.L. indicates the inland marine limit (taken from Thompson et al., 1989). The marine limit cuts through the northern portion of the Standish map. The York and Cumberland County line is shown on the inset.

The regional bedrock includes no unique lithologies which could be used individually as indicator rocks to assist in provenance determination or ice flow direction. The sources of the majority of clast lithologies are areally too extensive to allow exact source localities to be pinpointed. The entire area north of the quadrangle is occupied by the Sebago pluton granite (more than 80 km radius), while non-distinct Rindgemere Formation interbedded marble and metamorphosed argillite and pelite occur to the northwest. It is notable that cobble counts and field estimates of lithology indicate that the widespread and easily comminuted metapelites and schists were important sources for the large volumes of sediment which comprise the moraines and other glacial deposits, but not for glaciofluvial sediments. Clasts of the Rindgemere Formation in tills appear to be found mainly near their bedrock source (within 1-2 km), presumably because they are relatively easier to comminute. However, Sebago pluton granite was found in deltaic and esker cobble gravels as far south as Groveville (at least 11 km from the inferred bedrock source). These are minimum travel distance estimates.

The abundance of previous surficial geology studies conducted in the Standish region reflects the diversity and importance of the Quaternary geology there. Reconnaissance surficial geologic maps (1:62,500) of the region were published by Smith and Thompson (1977). Aquifer studies in the region were conducted by Tolman and others (1983) and Tolman and Lanctot (1985). Soil survey reports for Cumberland and York Counties (Flewelling and Lisante, 1982; Hedstrom, 1974) were used in the initial aerial photograph interpretation for the present study. Other data, including well logs from local soil exploration companies (e.g. Avalanche), have helped constrain depth to bedrock and surficial sediment thickness (Caswell and Lanctot, 1975; Caswell and Lanctot, 1978; King, 1984; Maine State Highway Commission, 1950).

The present study involves detailed (1:24,000) mapping of surficial deposits and interpreting the local glacial history of the Standish 7.5–minute quadrangle. Two maps depicting the surficial geology (Gosse, 1999) and surficial materials (Gosse, 1998) for the Standish area are associated with this report. All data collection sites (ST-90-#) referred to in the following text and Appendix A are plotted on the surficial materials map. Appendices summarize important surficial and glacial geologic data collected from the Standish quadrangle.

## GLACIAL AND POSTGLACIAL DEPOSITS

### *Overview*

Our understanding of the deglacial history of southern Maine has greatly improved over the last three decades (Bloom, 1960; Stuiver and Borns, 1975; Thompson, 1982; Borns, 1985; Smith, 1985; Belknap and others, 1989) although many important details remain unresolved, particularly the late-glacial chronology of ice recession. The late Wisconsinan Laurentide ice sheet advanced south and southeastward over the present Maine coast and onto the continental shelf where it reached its maximum extent by about 18000 years ago (18 ka). Crustal subsidence on the order of 100 m resulted from the weight of this late Wisconsinan ice. The majority of surficial deposits exposed at the land surface in the Standish quadrangle were formed during the recession of this ice sheet.

For convenience of presentation, the late-glacial and postglacial surficial deposits mapped in the Standish quadrangle have been classified into three facies, in accordance with Reading (1986): a *glacial facies*, a *glacial-retreat eustatic facies*, and a *postglacial isostatic facies*. Terrestrial and marine deposition of these facies is well recorded here. In the Standish region the *glacial facies* is characterized by an extensive but sporadic till veneer and associated glaciofluvial deposits. Rapid stagnation-zone retreat (Koteff, 1974; Koteff and Pessl, 1981) of the Late Wisconsin Laurentide ice sheet northwestward from the Gulf of Maine occurred between 15 ka and 13 ka (Tucholke and Hollister, 1973; Smith, 1985; Thompson and Borns, 1985). The retreat slowed when the glacier margin reached the Bar Mills area to the south of Standish (Hunter, 1999a,b) by about 13.2 ka (Smith, 1985). The retreat was accompanied by a marine transgression over ice-free regions where isostatic uplift had not yet reached equilibrium with eustatic sea-level rise (Bloom, 1960; Stuiver and Borns, 1975; Smith, 1985). The marine limit in the Standish region was approximately 300 ft (91 m) above the present sea-level (Figure 1). Consequently, the entire southern half of the Standish quadrangle (plus lowlands in the northern half) experienced submergence by the sea in late glacial time. During this transgression, *glacial-retreat eustatic facies* marine and glaciomarine sedimentation occurred. Relatively coarse sediments near the glacier margin formed glaciomarine deltas and fans (ice-proximal deposits) while further away from the margin marine clays and fine silts settled on the sea bottom (distal deposits).

By about 11 ka (Thompson and Borns, 1985) accelerated isostatic rebound of the depressed crust began to force the sea to recede. The falling relative sea-level during marine regression caused many of the glaciomarine deposits (especially those which were paleobathymetric highs) to be eroded and redeposited as beaches and overwash or nearshore deposits. The deposits formed during this period of time, when isostatic rebound was rapid enough to cause marine regression, are referred to as the *postglacial isostatic facies* . The resulting regional surficial geology was mapped using the units summarized in Table 1 and is described in detail below. The surficial deposits are categorized according to depositional environment.

### *Terrestrial Deposits*

Terrestrial glacial deposits are composed of sediments which were deposited on land. The majority of terrestrial deposits therefore lay above the marine limit. If terrestrial sediments lay below the marine limit, they were deposited before marine transgression. In the Standish region, extensive deposits of *till* (map unit Pt; Table 1) are located above and below the marine

TABLE 1: UNITS SHOWN ON THE SURFICIAL GEOLOGY MAP

| Symbol | Unit | Description |
|---|---|---|
| Ha | Alluvium | Generally well-sorted and stratified silt, sand, and gravel deposited by modern rivers and streams. |
| Qst | Stream terrace | Former flood plain with flat depositional surface on fluvial sediments. The terrace surface is higher than the modern flood plain of the associated river or stream. |
| Hws | Swamp | Poorly drained wetland area with variable tree cover, commonly associated with Pp and standing water; includes marshes and heaths. |
| Pmrs | Marine regressive sand deposits | Well-sorted massive to finely laminated silt to coarse sand. May be formed with Pp, as distal facies of Pmd or Pmf, or during regression of the sea as a result of wave reworking of Pmd or Pmf. |
| Pp | Presumpscot Formation | Greenish-gray to bluish-gray marine silt and clay, usually occurring as random laminite but often massive. Occurs as variably thick veneer below the marine limit, overlying older units. |
| Pmd | Marine delta | Laterally extensive and thick packages of sorted and commonly interbedded sand and gravel, with well developed foreset beds. Topset beds are present or inferred. Grades seaward to Pmrs or Pp, which commonly overlies distal facies. If present, subscript refers to marine delta morphosequence (Table 2, Figs. 4 and 5). Delta surfaces often show evidence of wave reworking. Deposited by glacial meltwater discharge into late-glacial sea. Commonly kettled. |
| Pmf | Marine fan | Thick packages of sorted and commonly interbedded sand and gravels. Foreset beds commonly well-developed. No topset beds. Grades seaward to Pmrs or Pp. Closely associated with Pemc. Formed by meltwater discharge into late-glacial sea. |
| Pge | Esker | Sinuous, generally discontinuous, ridges of massive and stratified, commonly interbedded, glaciofluvial sand and gravel deposited in subglacial and englacial conduits during glacial retreat. Cobble to boulder-size clasts are commonly highly rounded and spherical. Associated with Pmd. |
| Pgi | Ice-contact stratified drift | Highly deformed, interbedded, well-sorted, internally massive and bedded, very fine to coarse sands and gravels. Commonly shows evidence of deformation, including reverse and thrust faults and folding resulting from ice contact, or evidence of collapse in the form of normal faults. |
| Pemc | End moraine complex | Cluster of closely- (and often evenly-) spaced ridges comprised of till or poorly sorted stratified sediment, deposited at the ice margin. Usually with variably-thick veneers of Pp or Pmrs. Can also contain subaqueous fans. |
| Pt | Till | Homogeneous, locally compact, poorly sorted mixture of a wide range of particle sizes ranging from silt to boulders. Unit is widespread but of very variable thickness (typically 0 to 5 m). Associated with bedrock highs. Both lodgement and melt-out tills identified. The lodgement till is the oldest surficial unit and can therefore be overlain by all others. |

limit (Figures 2a, b). Terrestrial till is a glacial facies which outcrops in the northern portion of the map sheet, generally above the marine limit. Most terrestrial till is a massive, poorly sorted, homogeneous, and moderately compact silty diamicton. The till has a wide range of clast sizes (pebbles to boulders) and clast lithologies which reflect the regional and local bedrock geology. Most terrestrial till occurs as a thin veneer on highlands above 300 ft (91 m) asl. Examples of terrestrial till occur on Oak Hill (ST-90-059) and Breakheart Hill, where till thickness rarely exceeds 2 m and is commonly associated with protruding striated bedrock. In topographic lows, such as west of Oak Hill (ST-90-117), the till is generally thicker and often overlain by Holocene (postglacial) fluvial or lacustrine sediments. Based on their compaction and association with underlying bedrock, most terrestrial tills here are interpreted to be lodgement tills, although rare lenses of sorted sediment may indicate the presence of melt-out till. A till fabric at site ST-92-083, west of Bonny Eagle, indicates that the unit is characterized by a strong clustering of pebble long-axis orientations ($S_1$=0.64 for 30 pebbles, Figure 3), which supports the interpretation that the terrestrial till was deposited through a lodgement process ('deformed lodgement till'; Dowdeswell and Sharp, 1986). It is conceivable that a discontinuous but extensive lodgement till was deposited subglacially over the entire region during glacial advance, but below the marine limit this unit has been concealed by marine deposits which were subsequently emplaced during glacial retreat and marine transgression. This stratigraphic relationship was found at site ST-92-083 (Figure 2b) where the lodgement till is overlain by glaciomarine silts (Pp, described below) and gravels (Pmd, described below).

Rare deposits of *ice-contact stratified drift* (map unit Pgi; Table 1) occur only along the flanks of hills (e.g. ST-90-218, 800 m west of Standish), probably due to the ponding of meltwater between the ice and hill. The stratified drift is comprised of interbedded, well-sorted, internally massive and bedded sands and gravels that are highly deformed, with fold axes perpendicular to the general direction of ice flow (Table 3).

In the Standish region, *eskers* (map unit Pge; Table 1) are sinuous, discontinuous ridges up to 7 m high, comprised of moderately to very well sorted sands and gravels characterized by well-rounded and spherical clasts up to about 1 m in diameter. Below the marine limit, the eskers have been reworked to vari-

**TABLE 2.** SUMMARY OF OBSERVATIONS ON MAJOR GLACIOMARINE DELTAS IN THE STANDISH REGION

| Delta # | $Pmd_1$ | $Pmd_2$ | $Pmd_3$ | $Pmd_4$ | $Pmd_5$ | $Pmd_6$ | $Pmd_7$ | $Pmd_8$ |
|---|---|---|---|---|---|---|---|---|
| Name | Groveville† | Finn Parker Rd† | Rocky Dundee Rd | Plains Rd† | Chicopee† | Dingley Spring Rd† | Bonny Eagle | Saco |
| Delta ID. no.† | 21 | 20 | N/A | 16 | 19 | 18 | N/A | 17 |
| Delta Type* | Ice-contact† | Ice-contact† | Esker-fed, Leeside, Ice-contact | Ice-contact† | Ice-contact† | Leeside† | Distal outwash, Ice- contact?; Esker-fed | Distal outwash† Ice-contact? |
| Maximum Known Thickness [site#] | 85 ft [347] | 69 ft [311] | 35 ft [330] | 98 ft [332] | 32 ft [322] | 39 ft [219] | 86 ft [343] | 79 ft [346] |
| Morphology | steep ice-contact slope; wave-cut terrace | steep ice-contact slope | moderately steep ice-contact slope | very steep ice-contact slope (100 ft drop) | moderately steep ice-contact slope | very steep ice-contact slope (50 ft drop) | partial ice-contact slope | no ice-contact slope |
| Grading | yes: B-S | yes: B-S | yes: C-S | yes: B-S | yes: C-S | yes: C-S | yes: C-St | yes: C-S |
| Striated Clasts Found at Ice Marginal Sites | not observed | not observed | no | till stones and diamicton clumps | till stones | not observed | not observed | no |
| Kettles | yes | yes | yes | yes | yes | yes | yes | yes |
| Foundered at Marginal Site | normal faulting | not observed | normal faulting | normal faults | normal faults and interrupted bedding | not observed | silt-clay filled depression, normal faults | normal faults |
| Recessional Facies or Topset / Foreset Contact Elevation | ? | Recessional | Recessional | Recessional | Recessional (beach) | 300 ft ** | Recessional | Recessional |
| Comments | Beach at 185 ft | Blocked to south by stagnant ice | | Dissected by Saco River | Spit formed at distal edge | | limited exposure | limited exposure |

† from Thompson et al., 1989
* Refer to Figure 6 for location of deltas
** W.B. Thompson, pers. commun., 1993

able degrees and are often characterized by shallower slopes and flatter, broader tops (Bonny Eagle Pond esker, ST-90-062). Due to poor exposure, an interpretation of subaerially–deposited *channel filling* cannot be ruled out for the glaciofluvial gravel ridge situated north of Watchic Pond (C. Koteff, 1992, pers. commun.). Although esker deposits are here considered terrestrial facies, Boulton (1990) points out that eskers can also form beneath marine-based ice.

A discontinuous sheet of loess (silt layer generally less than 50 cm thick) blankets much of the quadrangle. No eolian sand dunes were observed from air photos or identified while mapping, but dense forest canopies may easily conceal any small dune patches that are present.

### *Marine and Glaciomarine Deposits*

Below the marine limit, the till (map unit Pt) commonly occurs as end moraine deposits which are interfingered with or covered by various marine and glaciomarine sediments. This submarine till is a glacial retreat eustatic facies which resembles the glacial facies terrestrial till (described above), but often has a higher clast content and a more clay-rich matrix. The end moraine tills are also characterized by a lower degree of compaction and a weaker pebble fabric ($S_1$=0.47 for 30 pebbles, Figure 3) relative to the lodgement tills. Such a low fabric strength is typical of debris flows (Dowdeswell and Sharp, 1986) and therefore supports a subaquatic debris-flow origin for the end moraines as suggested by Smith (1982).

Striking exposures of end moraines occur extensively over the southern half of the Standish quadrangle. Most of the end moraines are curvilinear till ridges that are laterally continuous for over 500 m (about 0.3 mi). Where the end moraines occur as sets of closely- and generally regularly-spaced ridges with only a thin clay cover, they have been mapped as end moraine complexes (map unit Pemc, following Hunter, 1999a,b; Table 1). The typical height of the moraine ridges in these complexes averages about 6 ft (~2 m), but may reach as high as 12 ft (3.5 m). This relief is partly a function of the thickness of the marine clay veneer and extent of ridge truncation during marine regression. The average ridge-to-ridge spacing of the end moraines is about

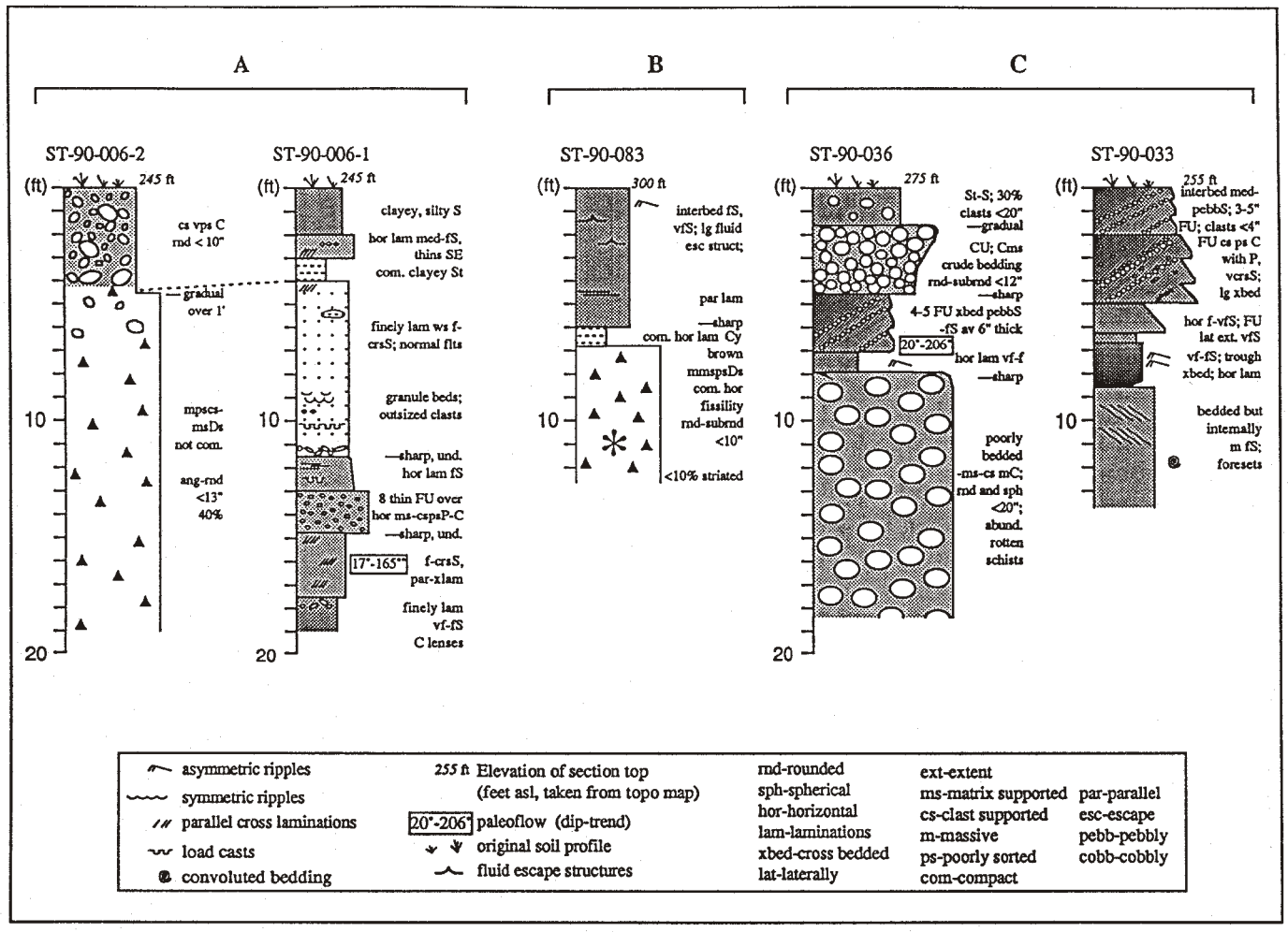


**Figure 2**. Schematic representations of measured stratigraphic pit sections that represent the main glacial and glaciomarine facies in the Standish region. The base of each section was not exposed. Index to abbreviations is provided in Appendix A. ST-90-006, southwest of Groveville; ST-90-083, west of Bonny Eagle; St-90-033 and 036, 1 mi northeast of Groveville. **A**. Typical marine fan sediments. These sections are 70 ft apart. Section ST-90-006-2 exposed the very coarse proximal fan facies with an underlying gravelly diamicton, interpreted to represent the seaward flank of an end moraine. These very poorly sorted upper gravels of ST-90-006-2 rapidly grade seaward to the fine sand and silts shown in the upper 4 ft of ST-90-006-1. **B**. At ST-90-083, glaciomarine sediment over a compact diamicton interpreted to be lodgement till. The lodgement till differs significantly from the end moraine till at ST-90-006-2 as discussed in the text. **C**. Typical proximal (ST-90-036) and mid-distal (ST-90-033) glaciomarine delta stratigraphy. Both sections are from $Pmd_1$, but not along a single paleoflow direction. The gravels in the uppermost 5 ft are interpreted to be recessional facies sediments but, may be delta topset beds. Delta foreset beds are well preserved at ST-90-033. (The * indicates the approximate depth of the till fabric shown in Figure 3).

230 ft (70 m). If these end moraines were deposited annually they can be considered deGeer moraines (Smith, 1982). Where postglacial trellis and dendritic drainage has incised the marine and glaciomarine sediments of the emerged sea floor, the resulting trough-ridge morphology often closely mimics the morphology of end moraine complexes. Only areas with unambiguous moraines with thin clay cover have been mapped as Pemc. Elsewhere, in areas with thick marine sediment cover or where the paleo sea-floor relief is of uncertain origin, the surficial materials are mapped as Presumpscot Formation or regressive sandy marine deposits (Pp or Pmrs; described below).

Closely associated with, and generally occurring seaward of the end moraines, are *submarine fan* deposits (map unit Pmf; Table 1). The fans are a glacial retreat eustatic facies consisting of interfingering units of fine sand to boulder gravel of variable thickness (Figure 4). Grain size decreases and sorting increases seaward and away from associated end moraines and ultimately the fan deposits grade into the Presumpscot Formation (Pp, described below). Southwest of Groveville (ST-90-006) proximal boulder and cobble gravel of a marine fan grades seaward into fine sand and the Presumpscot silty unit over a distance of only 70 ft (21 m) (Figures 2a, 4). Fans are characterized by foreset

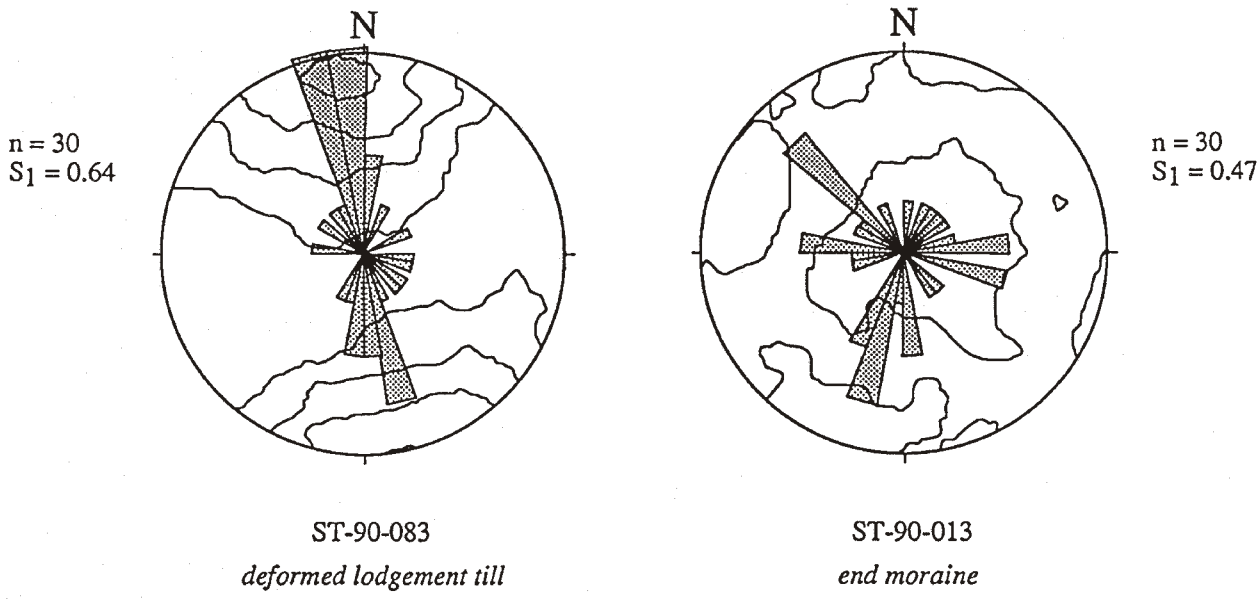


**Figure 3.** Combined rose and contoured diagrams of pebble fabric data from two till localities. A till fabric is a means of describing (1) the strength of the alignment of the longest axis of pebbles and (2) the direction of the strongest pebble alignment. For this study, the orientations of 30 pebbles with long axis between 5-30 cm were measured with a compass. The selection of the fabric site and the pebbles was according to the method of Lawson (1979) and Drake (1974). We used the eigenvalue method to evaluate the strength of the three-dimensional alignment of these pebbles (i.e. the tendency of all the pebble long axes to cluster about a single direction in space). Eigenvalue $S_1$ measures the strength of clustering in the direction of maximum clustering of pebble long axes ($S_1$ of 1.0 would indicate that all clasts are exactly aligned). The contours plotted on the Schmidt equal-area projections, with contour interval of two standard deviations (Kamb plot), show graphically the strength and orientation of the pebble fabric. So, two pieces of information can be obtained from the pebble (till) fabric. We can say something about the origin of the deposit by comparing the calculated $S_1$ values for the deposit with $S_1$ values for deposits of known genesis (lodgement till should have strong fabric, a debris flow should have a weak fabric, Dowdeswell and Sharp, 1986). If the deposit is a till, and if the fabric is strong, the direction of ice flow may be implied from the orientation of the stongest clustering (maximum eigenvector). The rose diagram (shaded slices of pie in each projection) reveals the direction (not strength) of the pebble orientations.

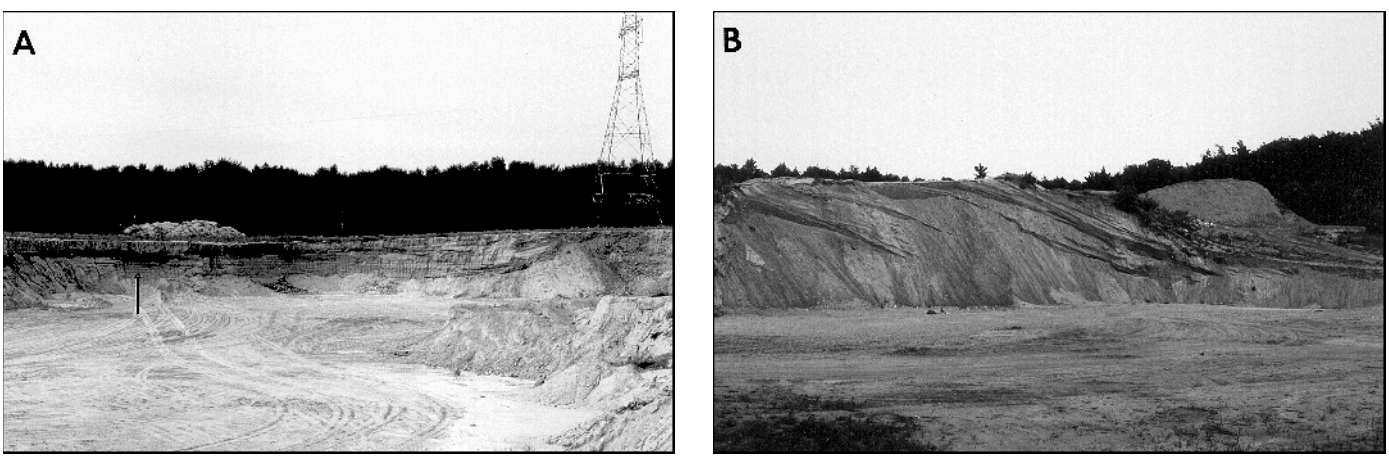


**Figure 4.** Examples of active sand and gravel pits in the Standish region. (a) Site ST-90-006, southwest of Groveville. Grading and paleoflow toward the left. Electrical tower (scale) stands on proximal part of the subaqueous fan, near the end moraine. Dark unit indicated with an arrow consists of distal silt and fine sand, mapped as Presumpscot Formation, which interfingers with the subaqueous fan sediments. (b) Delta foreset beds exposed in active sand and gravel pit at site ST-90-008, north of Groveville. Section approximately 40 feet high. Overlying topset gravels have been removed at this site, but were present in situ elsewhere in the pit.

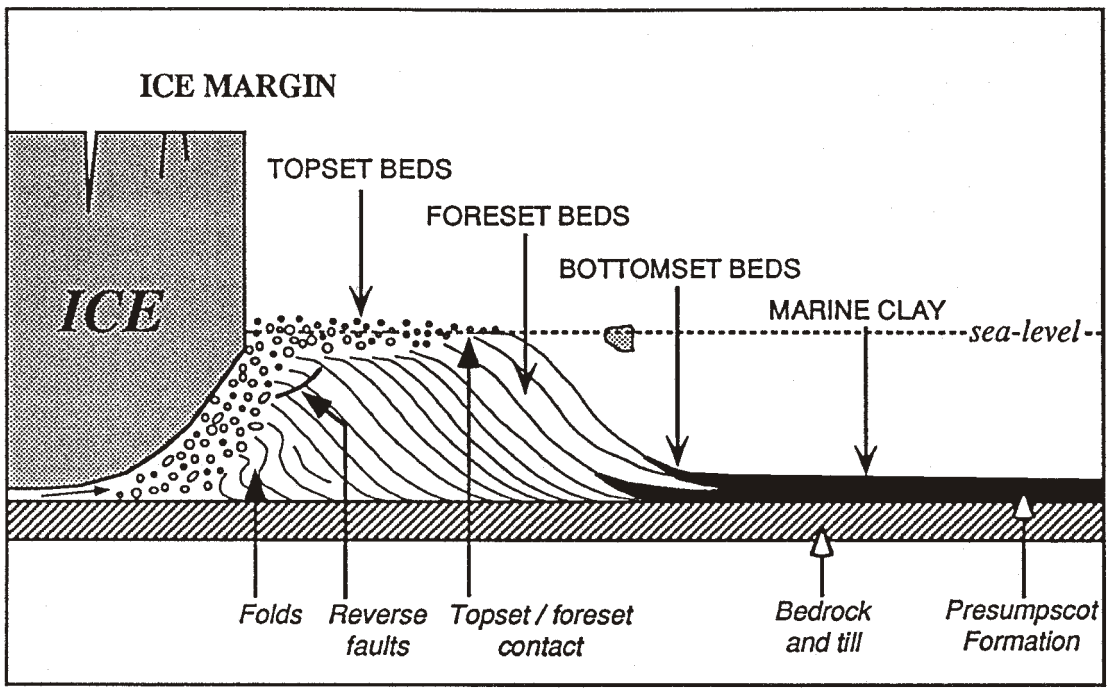


Figure 5. Vertically exaggerated diagram showing the components of an ice-contact delta environment. Small arrow under the ice indicating the flow direction of the sediment-laden meltwater could also represent an esker channel which feeds the delta. Normal faults and large-scale folding are evidence of deformation at the ice-contact portion (back slope) of the delta. Topset beds shown are predominantly comprised of cobble gravels; Foreset beds: sand; and Bottomset beds: silt.

TABLE 3. ICE FLOW DIRECTION DATA FOR THE STANDISH QUADRANGLE.

ST–90–ID refers to sample sites on Materials map. Indicators of ice flow direction include striae, S; grooves, G; stoss-and-lee forms on bedrock, SL; till fabric, TF (see Fig. 3); and fold axes of folded stratified drift, FA (the fold axes trend perpendicular to the implied glacier-induced principal stress direction). Azimuth of ice flow given in degrees. Uncertain or poor data have been excluded. †indicates older of two ice flow directions recorded at a single site.

| ST-90-ID | Indicator | Azimuth |
|---|---|---|
| 051 | S | 168 |
| | S | 100 |
| | S | 115 |
| 056S | S | 152-160 |
| | G | 180† |
| 083 | TF | 167 |
| 086 | S | 180 |
| 096 | S | 189 |
| 100 | S | 168-178 |
| | G | 192 |
| 120 | G | 156 |
| 131 | G | 152 |
| | S | 140 |
| 132 | S | 180 |
| 133 | G,S | 149-154 |
| | S | 180† |
| 177 | S | 169 |
| 211 | S,SL | 157 |
| 218 | FA | 210 |

beds without the overlying topset beds that occur in deltas (Figure 5). By definition then, no portion of the fan was subaerial during deposition. The fans can be cone-shaped where they radiate from a point source on an end moraine, but more commonly form wedges that extend along moraine ridges for several hundred meters (ST-90-006). The fans are interpreted to have been deposited contemporaneously with the end moraines from which they prograde and therefore mark ice marginal positions. Unless mappable as an individual deposit, the fans have been mapped as part of the encompassing end moraine complex unit (Pemc) or as sandy marine deposits (Pmrs).

About one third of the map sheet is occupied by *glaciomarine deltaic* sediments (map unit Pmd; Table 1). All of the deltas within the quadrangle are Gilbert-type deltas with thick foreset units (Figures 4b, 5) that are composed of variably interbedded and usually well-sorted fine sand to cobble gravel with dips locally as steep as 33° or more. Like the fans, deltaic sediments grade into marine clay (Figure 5). Also, some of the fine sand mapped as Pmrs along delta fringes may actually be deltaic bottomset beds or distal foreset beds (Figure 5).

Deltas have topset beds which overlie the foreset beds. The topset units are generally poorly sorted sand to gravel beds, usually with fluvial cross-bedding which indicates a seaward paleoflow direction. While the delta is forming, the topset beds are deposited at least partially above water level (Figure 5), so the contact between topset and foreset beds is commonly used to estimate what the sea-level elevation was during the formation of

the delta (e.g. Thompson and others, 1989). The interpretation of thick (up to 3 m) packages of gravels which in places unconformably overlie foreset beds (Figure 2c) throughout the Standish quadrangle requires more detailed investigation. It appears that true topset beds are preserved on only two deltas ($Pmd_1$ and $Pmd_6$; Table 2) although this interpretation is tentative. The topset gravels that were originally deposited on other deltas were eroded and redeposited as postglacial isostatic facies overwash and beaches. Recessional overwash sediments identified at $Pmd_3$ (ST-90-097) are subhorizontally bedded, moderately sorted gravels. In other areas the gravel deposits which overlay the foreset beds have characteristics of fluvial topset beds (e.g. trough cross-bedding, ST-90-045, 270 ft (82 m) asl and ST-90-220, 305 ft (93 m) asl), yet the paleoflows indicated by the gravel cross-beds are often landward, counter to the seaward flow anticipated for fluvial topset deposition. The recessional facies has been mapped as a part of the underlying marine delta until further detailed study resolves this ambiguity. Powell (1990) argues that many ice-contact marine deltas have developed from grounding-line fans when the fans aggrade to the contemporaneous sea-level. The distinction between aggrading fans and incipient deltas is a difficult one and discernible only if well developed topset beds or prodelta rhythmites are present (which have rarely been identified with certainty in the Standish region). The absence of marine clay over the deltas in the Standish region is not surprising, considering they were deposited near maximum transgressive sea-level.

Depositional environments of all four delta categories described by Thompson and others (1989) are represented in the Standish quadrangle (Table 2) due to the optimum position along the marine limit. The Groveville ($Pmd_1$), Finn Parker Road ($Pmd_2$), Plains Road ($Pmd_4$), and Chicopee ($Pmd_5$) deltas all have characteristics of ice-contact deltas (Table 2). All have steep ice-contact slopes, none are definitely esker-fed, and all have characteristics in their proximal parts which indicate that the deltas were deposited from an ice margin: coarse bouldery and cobbly gravel (all), striated or angular clasts ($Pmd_4$ and $Pmd_5$), structures indicating foundering due to melting of ice supports (all except $Pmd_2$), and kettles. According to Thompson and others (1989), leeside deltas occur on the seaward sides of hills that protruded above the contemporaneous onlapping sea. The deltas were fed through gaps in the hills by debris-laden meltwater streams discharging from ice that was pinned on the landward sides of the hills. Two deltas in the Standish region (Rocky Dundee Road ($Pmd_3$) and Dingley Spring Road ($Pmd_6$)) have this association with the regional topography; however no definite meltwater channels were identified. The presence of kettles in the central parts of these deltas may have resulted from ice blocks stranded in the lee of the ridges (Thompson and others, 1989), reinforcing the role of topography in the depositional environment. The presence of well-rounded and well-sorted cobble gravels in esker-shaped deposits (ST-90-98) suggests that $Pmd_3$ may also have been an esker fed delta. Unfortunately much of this exposure has been removed so definitive interpretations are difficult. The depositional environments of the Bonny Eagle ($Pmd_7$) and Saco ($Pmd_8$) deltas remain problematic. Thompson and others (1989) interpreted $Pmd_8$ as a distal outwash delta on the basis of the distance from the contemporaneous ice margin, however they admit that the presence of kettles (especially evident in the adjacent Limington quadrangle) may indicate an ice-contact origin. Likewise, $Pmd_7$ appears to range from esker-fed to outwash (the latter transported through a confined meltwater channel between Elmwood and Dow Corner). The presence of major ice-foundering structures in the distal facies of this delta (ST-90-129) forces attention to possible ice-contact conditions. These two deltas have not been considered useful morphosequence deposits because of the uncertainty of their origin relative to the ice margin.

Figure 6 shows the longitudinal profile of glaciomarine deltas $Pmd_1$ through $Pmd_6$. These deltas are components of glaciomarine morphosequences (Koteff, 1974, and Koteff and Pessl, 1981) which are useful for delineating the contemporaneous ice-margin positions. Glaciomarine morphosequences assist in interpreting the nature of deglaciation in the Standish region. The orientation of the longitudinal profiles is approximately parallel to the paleoflow direction indicated by foreset bedding (see the index map of Figure 6). The profiles are drawn in order of deposition from right to left. As the ice margin retreated north-northwestward, $Pmd_1$ was deposited first, followed by $Pmd_2$, $Pmd_5$, and $Pmd_6$ (refer to the index map). On the surficial geology map, tracing the ice margin position from delta ice-contact slopes along adjacent end moraine ridges indicates that the deposition of $Pmd_3$ would have been approximately coeval with $Pmd_2$. Accordingly, the proximal (near-ice) end of the $Pmd_3$ profile in Figure 6 is drawn directly below the proximal end of the $Pmd_2$ profile. A similar extrapolation of end moraines and delta ice–contact slopes for $Pmd_4$ and $Pmd_5$ suggests that $Pmd_4$ was completely deposited before or during the deposition of $Pmd_5$.

Distinct benches and terraces are evident at elevations between 280 ft (85 m) and 250 ft (76 m) asl on most delta profiles in the Standish quadrangle. This suggests that local relative sea-level was stabilized for a period of time during marine offlap. This 30 ft (or greater) zone with evidence of wave erosion may mark one or several significant stillstands in the relative sea-level drop. More complete erosion and redeposition of delta topset sediments would have resulted during periods of significant sea-level stillstands, relative to topset beds situated at higher or lower elevations. The only two beach remnants identified with confidence in the Standish region—northeast of Kimbles Corner (ST-90-167) and east of Groveville (ST-90-030)—lie at the top of the zone at an elevation of 285 ft (85 m) asl. A buried nearshore deposit (elevation ~260 ft (79 m) asl) was found north of Groveville (ST-90-052; sand pit section revealed a cross-sectional view of a thick and laterally extensive lensoid deposit of sand and gravel with alternating cross-bedding dip attitudes—interpreted to be a spit, underlain by silty and clayey Pp and overlain by sandy beds).

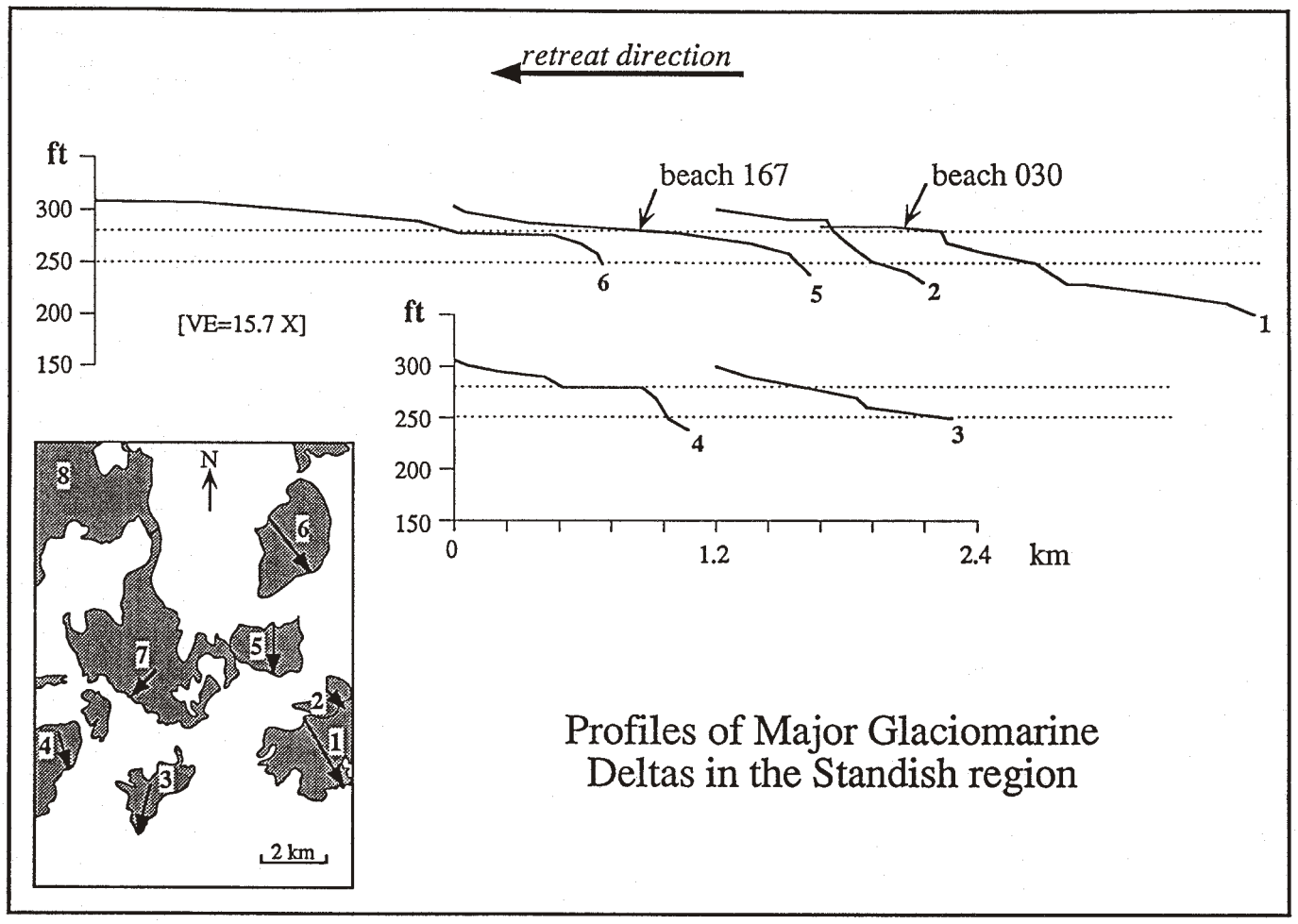


**Figure 6.** Longitudinal profiles for six deltas in the Standish quadrangle. The inset map shows the outlines of major glaciofluvial and glaciomarine deposits. Elevations were taken from the 7.5-minute (1:24,000) topographical map. The orientation of the profile lines (indicated by the arrows in the inset map) is approximately parallel to the mean paleoflow directions indicated by delta foreset beds (Table 4), and approximately perpendicular to topographic contour lines. The maximum elevation along 600 ft segments which cut perpendicular to the profile line was used to plot the profile in order to average out the minor variations in relief due to ice disintegration features. The numbers 1 - 6 correspond to the marine deltas described in the text and Table 2, as shown in the inset. The dotted lines are contours at 250 ft and 280 ft asl which are drawn to emphasize the elevations of increased delta erosion and redeposition during prolonged sea-level standstills. Ice margin retreat (and order of deposition) was from right to left, as discussed in the text. The two profiled sequences (1-2-5-6 and 3-4) are arranged horizontally to indicate relative age of deposition (oldest to the right). Deposition of deltas 3 and 2, and deltas 4 and 5 is considered approximately contemporaneous. Positions of the beaches are based only on their approximate elevations taken from the topographic map. The delta altitudes (at the ice-contact end) increase with their depositional order ($Pmd_1$ is the lowest). This is expected for a series of marine delta morphosequences that have been tilted by isostatic uplift.

The *Presumpscot Formation* (map unit Pp; Table 1) is the glaciomarine silt and clay found extensively below the marine limit (Bloom, 1960). The Presumpscot Formation consists of rock flour that flocculated and settled to the sea floor during marine submergence. Thickness of the clay-silt glacial retreat eustatic facies varies considerably, being thickest (at least 15 ft near Tylers Corner) in paleo sea-floor depressions. In the Standish quadrangle, the noticeable lack of laminite (laminated marine sediment) comprised only of clay is attributed to the shallow marine environment where coarser components (sand and silt) accompany the clay. Voluminous, uninterrupted accumulation of clay would only have been possible in paleobathymetric lows when maximum sea level was reached and where the water depth was sufficiently below the effective wave base. To the author's knowledge, no shells have been found in the Presumpscot Formation anywhere within the Standish quadrangle. Due to their impermeability, Pp deposits can form significant aquitards and are responsible for the majority of the wetlands in the quadrangle.

The coarser facies of the marine sediments (Pmrs) is characterized by well-sorted silt and fine to medium-grained sand. Most of the Pmrs unit was deposited during marine regression and is an important postglacial isostatic facies. Sediment eroded from deltas and other submarine highs was redeposited as over-

TABLE 4. MELTWATER PALEOFLOW DIRECTIONS FOR GLACIOMARINE DEPOSITS IN THE STANDISH QUADRANGLE.

ST-90-ID refers to sample sites on Materials map. Surficial deposits include glaciomarine deltas (Pmd) and fans (Pmf). The mean direction of paleoflow (in degrees) is inferred from the dip direction (trend) of foresets (f) and cross-beds in topsets (t). Ambiguous measurements are indicated where bedding may be disturbed or collapsed (d) or genesis of bedding is uncertain (?).

| ST-90-ID | Deposit | Trend Dir. | Mean |
|---|---|---|---|
| 002 | ?Pmd | 205 | 205 |
| 006 | fPmf | 160 | 160 |
| 007 | fPmf | 220 | 220 |
| 008/039/040 | fPmd | 228,222,249 | 233 |
| 025/026 | fPmf | 172 | 172 |
| 033/034/035 | fPmd | 110 | 110 |
| 036 | dPmd | 026 | 026 |
| 045/046 | fPmd | 270,336 | 303 |
| 052 | fPmd | 106 | 106 |
| | ?Pmd | 070 | 070 |
| 061 | fPmd | 300 | 300 |
| 085 | fPmd | 250 | 250 |
| 088/220 | fPmd | 150,160 | 155 |
| | fPmd | 270 | 270 |
| 097 | dPmd/f | 200,210 | 205 |
| 129 | fPmf/d | 138 | 138 |
| 146 | ?tPmd | 230 | 230 |
| 219 | fPmd | 295,310 | 303 |

wash deposits or more commonly as wedges of fine sand which extend seaward from the deltas, fans, or moraines from which they were derived. Some materials mapped as Pmrs, especially in the Saco Valley, may have been deposited fluvially by early postglacial stream action. The thickness of the Pmrs sediments is variable but generally less than 14 ft (4 m). Unit Pp and unit Pmrs are closely associated with fans and deltas (Figure 5) so delineation of certain unit boundaries was often arbitrary but usually accurate to 330 ft (100 m).

During offlap of the sea, sediments on paleobathymetric highs (bedrock hills or deltas for example) were eroded and redeposited as shoreline deposits or Pmrs. Shoreline deposits found in the Standish quadrangle include beach berms (here, characterized by openwork and highly imbricated pebble gravels and interbedded sand to granule beds which dip both landward and seaward; ST-90-030; ST-90-167) and a spit deposit (ST-90-052). It should be pointed out that imbricated gravels can also be deposited at the proximal end of grounding-line fans (Powell, 1990), however those deposits would not be expected to be as openworked as the sediments interpreted here as beach gravels.

## HOLOCENE GEOLOGY

During the Holocene, the Standish region witnessed swamp formation and sparse alluvium deposition over the entire area. *Swamps* (map unit Hws; Table 1) formed in depressions that are commonly underlain by Presumpscot Formation clays and silts or other impermeable sediments such as clay-rich till. The most extensive Holocene alluvial deposits (map unit Ha; Table 1) occur as flood plain sediments and gravel bars along the Saco River. No evidence of major rapid mass wasting was found, despite the numerous localities of high angle and unstable slopes in the region (especially along the Saco River). The strategic position of impermeable clay beds (commonly exposed in the river cut sections (ST-90-010)) that could increase lubrication and instability of overlying sediment packages makes mass-wasting events highly probable in these areas. Although no colluvium has been mapped, slope processes probably have lowered hillside gradients and partially filled valleys (for example, the valley between Dow Corner and Elmwood.)

## MARINE LIMIT DELINEATION

The marine limit elevation in the Standish area was estimated using a number of field and geological principles. Quaternary marine features were identified to elevations of at least 310 ft (94 m) asl in the northern portion of the quadrangle. This is the highest elevation of marine sediments (they may be delta topset beds) and so are taken as an upper limit of the maximum late-glacial sea-level elevation in this quadrangle. The highest elevation of the Presumpscot Formation clays and silts, 300 ft (91.4 m) asl in the northeastern portion of the quadrangle, provides another approximate estimate of the maximum late-glacial relative sea-level elevation. Glaciomarine clay and silt deposition occurred below the contemporary marine wave base, so this estimate is lower than the actual marine limit elevation. The presence of till-stone fences is considered another useful (albeit much less accurate) method of approximating the marine limit. In Maine, the construction of rock walls from till stones commonly accompanied land clearing for cultivation (although recently they have been used as a garden ornament). Few till-stones would be exposed in fields with a marine sediment veneer, so till-stone fences should not be found significantly below the marine limit. In the Standish region the lowest mapped elevation of till-stone fences is approximately 290 ft (88 m) asl, which is lower than (but close to) the two previous estimates of the marine limit elevation. Delta foreset-topset contacts record the sea-level elevation at the time of their formation. Thompson et al. (1989) have used this technique in a study of glaciomarine deltas in Maine. Their data also indicates that the marine limit was about 300 ft (91 m) asl (Table 2; see their Figure 2). Beach elevations and wave-cut terraces do not indicate maximum sea-level elevation (the marine limit), but rather are indicators of recessional phase sea-level strand lines.

## GLACIAL AND POSTGLACIAL HISTORY

### *Ice Flow Direction*

Ice flow direction (Table 3) was determined locally from glacial erosional features (nail head striations and crescentic and

lunate gouges - 11 sites), till fabric analysis (near Bonny Eagle, ST-90-083; Figure 3), orientation of streamlined landforms and end moraine ridges, and fold axes in glaciotectonized ice-contact stratified drift (just west of Standish, ST-90-218). Two distinct ice flow directions dominate the area. Although it is almost certain that pre-Wisconsin Laurentide ice covered the Standish region, both flows are interpreted to be of late Wisconsinan age (most recent glaciation) due to the lack of evidence to the contrary. At two sites, cross-cutting striations and grooves clearly constrain the relative ages of the last two flow directions in the Standish region. Indicators of an initial southward (180°–192°) glacial advance are cross-cut by evidence of south to southeast (140°–178°) flow which was influenced by the local topography during glacial retreat. Notably, this ice flow relationship does not agree with the regional ice flow pattern, which is characterized by a southeastward initial flow. In the Standish quadrangle, it appears that the earliest flow direction was the southward advance of the late Wisconsin ice. This initial flow direction is recorded solely by erosional marks. However, it is possible that the later southeast flow may have also occurred during peak late Wisconsin glaciation, since this is the dominant regional direction (Thompson and Borns, 1985). The later flow direction may also be the deglacial-phase flow which trends from southward in the western portion of the map sheet to southeastward in the eastern half of the map sheet. The larger range of directions (compared to the earlier southward flow) for this later flow, expressed by erosional marks, the till fabric, and particularly the orientations of end moraine ridges throughout the area, probably reflects the greater control of topography on the flow of the waning ice sheet. The orientation of the streamlined bedrock-cored hill situated south of Bonny Eagle Pond trends parallel to this later (SE) ice flow direction. The pebble fabric in deformed lodgement till at ST-90-083 also records the influence of a later southeastward flow which is interpreted to have altered an original southward-trending lodgement till fabic. This relationship at ST-90-083 is confirmed by nearby cross-cutting striae and grooves.

### *Deglacial Model for the Standish Region*

The qualitative lithofacies model for the deglaciation of Maine proposed by Thompson and Borns (1985) is appropriate to understanding the surficial geology in the Standish area. For other works which describe the glaciation and deglaciation of southern and eastern Maine the reader is referred to Ashley et al. (1991), Borns (1973), Smith (1985), Stuiver and Borns (1975), Thompson (1982), and Weddle et al. (1993).

Morphosequence mapping as described by Koteff (1974) and Koteff and Pessl (1981) was used to help delineate the type and progress of ice marginal retreat through the Standish area. Morphosequences are simply groups of associated deposits (e.g. eskers and deltas) which were deposited in a sequence that was controlled by the retreating ice. Useful morphosequences in the Standish region are: (1) the pervasive end moraine and associated submarine fan sequences, and (2) the glaciomarine deltas and feeding esker systems. The lateral continuity of individual moraine ridges across the map area suggests that where the topographic relief was lowest (at least on the scale of this map sheet) the ice margin retreated in a regular and organized manner. The absence of these well-developed end moraines in the northern portion is mostly attributed to the increase in influence of glacial hydraulics and a greater subglacial and sea-floor relief on ice margin geometry. As described earlier, the glaciomarine (delta) morphosequences record the systematic retreat of the ice across the Standish quadrangle. Ice-contact, leeside, and esker-fed deltas were particularly useful for delineating the positions of the retreating ice margin. The ice–marginal positions during delta deposition (indicated by the steep delta ice-contact slopes, esker-delta contacts, and intense ice disintegration features and delta sediment deformation in the proximal parts of the deltas (Figure 5)) can be correlated to end moraines so the ice margin position across the entire map area can be approximated in several places.

Figure 7 is a schematic diagram illustrating a possible relationship between the retreating ice margin and associated glacial sediments during the deposition of $Pmd_5$. This position is marked by an anomalous abundance of kettle features across the map area (refer to the geologic map). The abundance of kettle holes along this ice marginal position may reflect a significant pause in the ice marginal retreat. Lodgement till (Pt) is shown to be the lowest stratigraphic unit. Deltas $Pmd_1$, $Pmd_2$, $Pmd_3$, and $Pmd_4$ have already been deposited and are surrounded by the sea. The morphosequences suggest an irregular but continuous glacier margin which trends west-southwestward across the quadrangle. The possibilities of a floating vs. grounded margin were considered in the Standish region. Both end moraines and submarine fans can be deposited at the grounding line of either a floating or grounded margin. If Alaskan tidewater glaciers are an appropriate analogy, then the results of Brown et al. (1982) seem to suggest that a floating margin in water depth on the order of 130 ft (40 m) is possible for ice marginal thicknesses of less than 100 m (the maximum depths of deltas in the Standish region is about 98 ft; Table 2). However, as Thompson et al. (1989) point out, the formation of delta topset beds (T, Figure 7) requires that no ice shelf extend beyond the grounding line (Figure 5). Accordingly, only small portions (if any) of the margin could have been floating when the margin was in the Standish region. A thin, grounded, calving margin is portrayed in Figure 7 where the contemporaneous sea level was against the ice. As the margin continued to retreat it would have uncovered the highlands to the north. The greater topographic relief would produce a more irregular ice margin geometry. Locally, smaller portions of the ice would have remained in contact with the onlapping sea as the margin approached and passed above the marine limit elevation. The Saco River Valley to the northwest of the quadrangle would most likely have been drowned by this marine transgression.

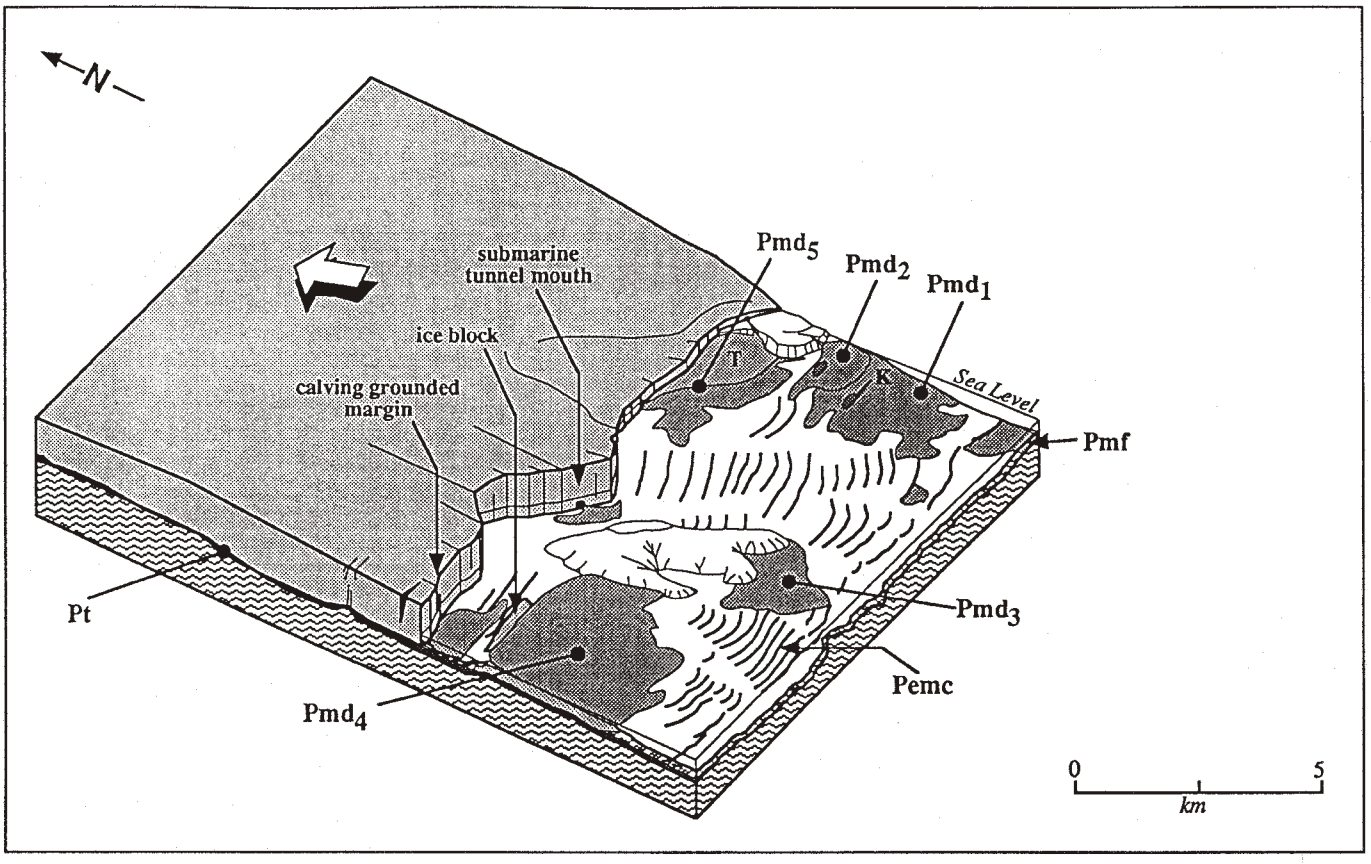


**Figure 7.** Schematic block diagram illustrating an ice margin position and glacial sedimentation during the retreat of the Wisconsinan ice sheet below the marine limit. Shadowed arrow indicates retreat direction. Location and geometry of the deposits are inferred and are meant to represent the transgressive relationships, i.e. before major reworking during sea regression. Ice margin is mostly grounded but calving in places. Paleo sea-level is estimated as described in the text. Units Pemc, Pmf, and Pmd are described in Table 1. Pmd numbers refer to specific glaciomarine deltas (Table 2). T = delta topset beds, K = kettle. Presumpscot Formation not shaded, but would cover most of the sea bottom. Location of the ice margin in this figure approximately coincides with retreat positions marked by a belt of ice disintegration features that extends across the map sheet (see the surficial geology map).

## SIGNIFICANCE OF SURFICIAL DEPOSITS IN THE STANDISH QUADRANGLE

The extensive and highly accessible deltaic and fan deposits are a significant high-grade aggregate resource for southern Maine. Although there are several large sand-and-gravel pits operating in the more exposed deposits (eskers and deltas), well-log data indicates that a large amount of gravel and sand (on the order of 1 $km^3$) may still be available from this quadrangle. However, much of this reserve is probably of lower quality and less accessible than the material already mined, especially where it lies below the water table in mapped sand and gravel aquifers (Tolman et al., 1983).

The Standish quadrangle has a classic assemblage of Quaternary glaciomarine sediments. Beautiful examples of glaciomarine fans, deltas, and end moraines are preserved throughout the quadrangle. The spectacular end moraine complexes are among the best examples in North America. These moraines are easily accessed by the roller-coaster–style roads which cross them. The usefulness of the glaciomarine deltas for further constraining the history of sea-level change in southern Maine is uncertain. Some deltas in the region appear to lack unambiguous, well-preserved topset beds (the topset beds are replaced by recessional-facies overwash sand and gravel deposits) so a closer inspection of these gravels is necessary before using the gravel-foreset contact as a transgressive paleo sea-level indicator. However, the beach deposits and wave-cut benches record strand lines which will provide important information for ongoing regional crustal uplift and sea-level studies.

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## Appendix A

### *Brief description of sites located within the Standish quadrangle*

(refer to materials map for further explanation of sediment texture abbreviations)

| Site # ME-90- | MATERIALS DESCRIPTION (Abbreviations below) |
|---|---|
| 001 | Bedrock exposure, north side of R114, 0.2 mi east of Wards Cove Rd. coarse phlogapite pegmatite; streamlined, but too coarse for glacial polish; some plastic glacial erosion forms (p-forms) are present |
| 002 | Active sand and gravel pit; 20 ft sections; 4 ft subhorizontal, crossbedded fluvial wsS-psG; 5% striated cobbles; predominantly felsic intrusives, metasediments, mafic porphyry, basalt; over 8 ft f-med S; Pleistocene marine fan |
| 003 | 10 ft road cut section; open work alternating P, Ps, P-S interbedded with ws cs P-C over massive and matrix supported Dst; normal fault displacement up to 15 in. ; beach? [also 167] |
| 004 | Large active sand and gravel pit; Pleistocene marine delta [see 082, 083, 084, 085] |
| 005 | 40 in. shovel hole; into light brown gray massive and matrix supported Ds to Dst; not compact; pebbly |
| 006 | New active gravel and sand pit; 20 ft sections exposing graded ( Pleistocene marine fan) St - B, D |
| 007 | Active sand and gravel pit; interbedded psC-wsS; 12 ft sections; Pleistocene marine fan |
| 008 | Active sand and gravel pit; 50 ft thick wsS; steeply dipping foresets overlain by 10 ft crossbedded C-P; Pleistocene marine delta [also 039 and 040] |
| 009 | bedrock; (not on the mapsheet) |
| 010 | Inactive sand pit; 70 ft section of horizontal vf-c wsS to Cy; interbedded P lenses; diamicton clasts < 4 in.; normal fault displacement up to 4 in.; 15 ft thick Cy laminite at top [also 081] |
| 011 | Inactive pit; 7 ft section of Cy-sSt-stS rhythmite sequences; underlain by matrix supported Ds |
| 012 | 4 ft road cut; vps S, weakly stratified; contains subangular-subrounded clasts < 10 in. |
| 013 | 4 ft section, active pit; massive and matrix supported Dst, not compact, horizontal fissility, rotten clasts; fabric site |
| 014 | 40 in. shovel hole; 3 ft of Cy-St Cy; very compact |
| 015 | 15 in. shovel hole; not compact St-S |

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|---|---|---|---|---|---|---|
| <=maximum length | AF=artificial fill | C=cobble gravel | crs=coarse | cs = clast supported | CU=coarsen upward | Cy=clay |
| D=diamicton | f=fine | FU=fining upward | G=gravel | med=medium | P=pebbly gravel | ps=poorly sorted |
| S=sand | s=sandy matrix | St= silt | st=silty matrix | v=very | ws=well sorted | |

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|---|---|
| 016 | 30 in. shovel hole; brown, massive and matrix supported Dst with 30% clasts |
| 017 | 42 in. shovel hole; brown massive and matrix supported Dst; not compact; angular-subrounded clasts <24 in. |
| 018 | 30 in. shovel hole; 4 in. gray, laminated Cy over brown St; not compact; no clasts |
| 019 | 24 in. shovel hole; brown clayey St |
| 020 | 36 in. shovel hole; 12 in. clayey St over light brown vf-fS |
| 021 | 36 in. shovel hole; light brown-orange massive and matrix supported Dst; not compact; angular. clast < 12 in. |
| 022 | 6 ft section on power line; 28 in. brown St over massive gray silty Cy |
| 023 | 36 in. shovel hole; brown clayey St with 10% granules over gray Cy |
| 024 | 30 in. stream cut; Cy |
| 025 | Inactive pit; landfill; 10 ft section; 20 in. light brown massive, clayey St, over 3 ft dark gray blocky, compact laminated Cy to silty Cy with interbedded fS, over crudely bedded crs pebblyS |
| 026 | same pit as 025; 25 ft section; vf-medium S; horizontal bedded; pit was mined for C; Pleistocene marine fan |
| 027 | 24 in. shovel hole; dark brown massive and matrix supported Dst; angular clasts <10 in. ; overlies bedrock |
| 028 | Same as [027] |
| 029 | Active sand and gravel pit; 8 ft section; 10 in. brown clayey silt; 32 in. crs-med C and Sps - ws; cs in places; sharp horizontal contact over crudely bedded f-medS; Pleistocene marine delta |
| 030 | Same pit as [029]; 8 ft section; 36 in. non-compact brown vps csm P-C with imbricated and rounded clasts <8 in.; sharp contact over finely laminated and cross bedded to massive fS-P; beach? |
| 031 | Active sand and gravel pit; 6 ft trench on 24 ft section uncovered subhorizontal finely bedded vf-fS; Pleistocene marine delta |
| 032 | Same pit as [031]; 14 ft crs-med S; Pleistocene marine delta |
| 033 | Same pit as [031]; 16 ft section; 2 ft cross bedded and interbedded 3-5 in. FU sequences of pebbly S and S; over 3 ft cross bedded csps C-P; over 12 in. horizontal FU f-vfS over laterally extensive 1 in. vfS with asymmetric ripples; over 2 ft trough-crossbedded vf-fS with basal Cy over predominantly m fS; Pleistocene marine delta |
| 034 | Same pit as [031]; 11 ft section; 4 ft cross bedded FU sequences; S-P over horizontally laminated fS with undulatory contact over 9 in. laterally extensive gray laminated silty Cy over mS, with normal fault displacement ~1.5 in. ; Pleistocene marine delta |
| 035 | Same pit as [031]; 14 ft section; 2 ft crudely bedded fS over 6 ft vf-med S with fluid escape and load structures over 2 ft massive P and S; over 12 in. cross bedded vcrsS; over massive and poorly sorted C; Pleistocene marine delta |
| 036 | Inactive gravel pit; landfill; 18 ft section; 18 in. massive sandy St with cobbles <20 in.; over 3 ft CU crudely bedded mS-psC with rounded to subrounded clasts <12 in.; over 2 ft cross bedded FU pebblyS-fS; over 1 ft horizontally laminated vf-fS; over massive B-C with rounded and spherical clasts <20 in.; Pleistocene marine delta |
| 037 | Same pit as [036]; massive to cross bedded S with pebbles. |
| 038 | bedrock; good striae on polished surface, 180°-183° |

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|---|---|---|---|---|---|---|
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|---|---|
| 039 | see [008] |
| 040 | see [008] |
| 041 | 42 in. shovel hole; 12 in. brown silty sand; 30 in. massive vf-fS over cobbles |
| 042 | 36 in. shovel hole; silty vf-fS |
| 043 | 30 in. shovel hole; 30 in. brown fS over cobbles |
| 044 | 7 ft road cut section; 2 ft massive ws vf-fS over 5 ft matrix supported Gs with rounded-subangular clasts up to 10 in. |
| 045 | Active gravel and sand pit; 21 ft section; 6 ft channel fill FU trough cross bedded C-fS with v well rounded and spherical clasts <11 in.; over massive f-crs S |
| 046 | Same pit as [045]; 12 ft section; 2 ft brown silty fS over 5 ft predominantly massive med-crsS over parallel laminated and cross bedded fS to granularS. |
| 047 | 30 in. shovel hole; 12 in. clayey St over gray clay; locally, land owner reports sand greater than 3 ft deep |
| 048 | 40 in. shovel hole; 14 in. brown silty S over fS |
| 049 | 40 in. shovel hole; fS |
| 050 | 5 ft road cut section; 1 ft brown siltyS over massive and matrix supported crs-medS and C with 40% clasts, subrounded; some laminated fS |
| 051 | Active gravel pit; 8 ft section; massive poorly sorted matrix supported and cs C - P; bedrock; striae at 109-119°, 100°, and grooves at 168° |
| 052 | Active sand and gravel pit; several sections and mine benches; variable surficial material; entire stratigraphy: 2 ft psP-C over 2 ft mS interbedded with pebbly S; over 2 ft laminated asymmetric rippled massive S; over 10 ft convoluted, parallel laminated clayey St with fluid escape structures, in packages which pinch out laterally over 40 m; over horizontal bedded f-medS |
| 053 | 42 in. shovel hole; fS |
| 054 | 42 in. shovel hole; fS |
| 055 | Inactive gravel pit; 15 ft section; 1 ft pebby silty fS over 4 ft FU sequences; pebblyS to vfS over FU ps-moderatedly sorted C with clast <4 in. |
| 056 | Inactive gravel pit; bedrock under 15 ft moderately sorted B-sandyG to csD with boulders <2 ft; good striae 146-158°, and 180°; good grooves 155-160° crosscut 180° striae |
| 057 | see [002] |
| 058 | cultivated field with broad and long (>50 ft) rills covered by Pp with trough-crest relief=3 ft; trend 170° |
| 059 | Excavation for swimming pool; bedrock at 12 ft to 6 ft depth; gray massive and matrix supported Ds with subangular clasts <10 in. |
| 060 | bedrock; too coarse for striae |
| 061 | Inactive sand and gravel pit; 30 ft section; 15 ft interbedded laminated med-fS with P-C (max clast = 10 in. ) over finely bedded fS, graded eastward |

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|---|---|
| 062 | 40 in. shovel hole; not compact, massive vf-fS with <10% pebbles and well rounded to subrounded clasts up to 4 in. ; esker ridge |
| 063 | Inactive sand pit; 10 ft section; med S; over massive pebbly vf-crsS with clasts <16 in.; esker |
| 064 | Inactive gravel pit; 15 ft section, overgrown; massive and matrix supported D found locally; esker |
| 065 | Grass field with rills having trough-crest relief of 1-2 ft, trending 128° |
| 066 | 7 ft road cut section; clay laminite, no shells; Pp |
| 067 | 28 in. shovel hole; cultivated field with moraine ridge; trough-crest relief 12 ft; on sharp crested ridge no or little clay on top (likely modified during cultivation) just gray brown v compact matrix supported Dst with 60% clasts <12 in. ; in trough, 2 ft blue f lam Cy (no shells) with 6 in. clast over 8 in. f-medS over D; Pleistocene end moraine complex |
| 068 | 2 ft shovel hole on 7.5 ft high moraine ridge; massive and matrix supported Ds with clast <4 in. |
| 069 | 7 ft road cut section; solid gray Cy, compact, silty, no fossils; Presumpscot Formation |
| 070 | 3 ft shovel hole; light brown matrix supported Dst with subangular to rounded clasts <12 in. ; 60% D not compact; moraine flanked by Presumpscot Formation |
| 071 | 3 ft shovel hole; 1 ft clayey St over f-med S |
| 072 | 42 in. shovel hole; light brown matrix supported Dst with sub angular-rounded clasts <18 in. |
| 073 | dug well; resident indicates 15 ft Cy over bedrock |
| 074 | 4 ft road cut section; 2 ft massive silty S over f-medS with few pebbles |
| 075 | 20 in. shovel hole; clay and fS |
| 076 | 3 ft shovel hole; brown gray massive and matrix supported Dst with clasts <4 in. |
| 077 | 60 ft road cut section; > 4 ft blue Cy and silty Cy overlain by predominantly massive silty fS |
| 078 | 2 ft shovel hole into massive med S with 30% pebbles < 1 in. |
| 079 | Excavation; 5 ft section poorly exposed; med-fS with granules and pebbles |
| 080 | 16 in. road cut section; fS |
| 081 | 70 ft road cut / river cut section; [see 010] |
| 082 | Active sand and gravel pit; 8 ft section below original soil profile; 3 ft cross laminated f-medS over 2 ft wsP with clasts <10 in. over medS with fluid escape structures. |
| 083 | Same pit as [082]; 12 ft section with no soil profile; 6 ft interbedded f-vfS with asymmetric and symmetric ripples, large fluid escape structures, and parallel laminated over 1 ft compact, blocky horizontally laminated silty Cy with granules; over compact brown massive and matrix supported Ds with horizontal fissility and rounded to subangular clasts <10 in. ; till fabric done here |
| 084 | Same pit as [082]; 12 ft section with no soil profile; 5 ft FU seq of interbedded thick and laterally extensive f-medS and pebbly S with psG basal layer; over 4 ft interbedded crs and med S over f-medS; bedding horizontal and laterally extensive, but lenses common |
| 085 | Same pit as [082]; 12 ft section with no soil profile; 2 ft interbedded f-medS, silty Cy, and FU G-fS over predominantly silty Cy with vf-medS horizontal interbedded; mud clasts in lower section |

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|---|---|---|---|---|---|---|
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| 086 | Active rock quarry (pegmatitic aplite with mafic dikes), was gravel pit; bedrock; good striae 178-182°; no grooves or gouges, but appears streamlined N-S |
| 087 | Inactive pit and landfill/dump; predominantly pebblyS to fS fining southeastward |
| 088 | Active gravel and sand pit; 12 ft sections of poorly to moderately sorted csP also with large cross beds and listric S foresets |
| 089 | 24 in. shovel hole; light brown massive and matrix supported Ds, not compact, about 70% clasts > 10 in. ; boulder at base |
| 090 | 8 ft road cut section; massive and matrix supported Ds not compact, 40% clasts, cobbles average 10 in. , weak fissility |
| 091 | 3 ft shovel hole; sandy Cy (Presumpscot Formation?) |
| 092 | 3 ft shovel hole; silty fS; loess? |
| 093 | 24 in. shovel hole; 18 in. silty fS over compact Cy |
| 094 | bedrock; no striae. |
| 095 | Surface observ.; large boulders in massive and matrix supported D |
| 096 | bedrock; good striae 188°; good groove 190° |
| 097 | Active gravel pit; 24 ft sections; 2 ft interbedded wsP and granule G with subrounded-rounded pebbles; over 1 ft pebbly S; this is in sharp contact with 20 ft horizontally laminated f-medS with pebbly S and fine grained channel fill sediments, and fluid escape structures; evidence of collapse toward base; locally, cover gravels much coarser and less sorted |
| 098 | Active gravel and sand pit; 12 ft sections; mined gravels first; f-medS over mod.s P-C flanked by clayey St; gravels may have been esker? |
| 099 | 8 ft road and river cut exposes Cy overlain by siltyS; no diamicton but bedrock in proximity |
| 100 | bedrock; poor striae 178-168°; good groove 192° |
| 101 | Inactive sand or gravel pit, remediated; filled with water |
| 102 | Inactive gravel pit; matrix supported csC and matrix supported csP with vf-medS matrix; bordered by massive and poorly sorted D, which appears to have been scraped off top; also [169] |
| 103 | Active sand and gravel pit; 11 ft section; 1 ft silty S over subhorizontal interbedded fS and pebblyS; over fS with fluid escape structures; over gray not compact matrix supported Ds with subangular to rounded clasts <16 in. ; [also 167] |
| 103b | 2 ft auger hole; massive and matrix supported Ds with boulders |
| 104 | Inactive sand pit; 25 ft section; fS-pebblyS; but locally 15 ft Cy over bedrock |
| 105 | Inactive sand and gravel pit; landfill; AF |
| 106 | Active and inactive sand and gravel pits; maximum 6 ft wsC-P over 33 ft interbedded f-crsS, pebbly S, wsP, all which form well developed foresets; Pleistocene marine delta |
| 107 | Active gravel pit; pit into ridge 25 ft high, 15 ft wide consisting of wsC with v rounded and spherical clasts <25 in. and flanked by massive f-medS; esker? |
| 108 | Six auger holes; overall 1.5 to 5 ft medS over massive and matrix supported Dst |

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| 109 | 4 ft auger hole; 1 ft fS over gray Cy laminite |
| 110 | 6 ft auger hole; f-medS, some pebbly |
| 111 | 3 ft auger hole; medS |
| 112 | till stone fences |
| 113 | 5.5 ft auger hole; Cy with pebbly, no shells |
| 114 | Excavation; interbedded wsPs and f-medS; normal faulted, displacement >8 in. |
| 115 | Inactive sand and gravel pit; S and G |
| 116 | Four auger holes; 18 in. silty fS; locally, well in 7 ft S and G |
| 117 | Two auger holes; first 12 in. massive and matrix supported D; next 18 in. oxidized medS over bedrock; alluvium? |
| 118 | 6 ft auger hole; fS (FU: medS at base) |
| 119 | 30 in. auger hole; ws f-medS with pebbles; over boulder |
| 120 | bedrock; good striae 154-160°; good groove 156° |
| 121 | 3 ft road cut section; massive medS; locally, 10 ft S and Gs |
| 122 | 4 ft road cut section; interbedded S, G-S, P; locally with rounded cobbles in fences |
| 123 | Excavation; 3-5 ft Gs |
| 124 | 30 in. shovel hole; 12 in. silty vf-medS with pebbles over well rounded C; over medS |
| 125 | 5 ft road cut section and inactive pit; interbedded wsG and S-G over C; till locally |
| 126 | 12 in. shovel hole; Cy; till stone fences common |
| 127 | 24 in. shovel hole; S and Cy; |
| 128 | bedrock; no striae |
| 129 | Inactive sand pit; 30 ft section; FU f-crs S, few vfS, and fluid escape structures |
| 130 | Active sand pit; landfill; interbedded f-crs S, pebblyS, wsP; kettle filled with >7 ft Cy |
| 131 | bedrock; moderately well–preserved grooves 152°; good striae 140-142°; good striae 136° |
| 132 | bedrock; good striae 180° |
| 133 | bedrock; good grooves and striae 149-154° crosscut good striae 180° |
| 134 | Excavation into hill side; S-G |
| 136 | 24 in. shovel hole; brown - dark brown v compact medS |
| 137 | 6 ft auger hole; 10 in. siltyS with <10% pebbles; over f-crsS with pebbly layer; no soil profile |
| 138 | shovel hole; massive and matrix supported D |

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| 139 | 6 ft auger hole; f-vcrs S with <25% cobbles and pebbles |
| 140 | 30 in. shovel hole; S to G over massive and matrix supported D over bedrock; well 7 ft to bedrock |
| 141 | 24 in. auger hole; silty fS with cobbly <10 in. ; bedrock? |
| 142 | 30 in. shovel hole; sC over med-crsS |
| 143 | 3 ft shovel hole; f-med S with 10% subrounded-subangular pebbles |
| 144 | 6 ft auger holes; 18 in. vf-fS over 38 in. fS over pebbly mS |
| 145 | 8 ft road cut section; msG with fS matrix; subrounded - rounded C; v little structure; esker or beach berm? |
| 146 | Inactive pit/road cut; 24 ft section; f-crsS with horizontal fissility; interbedded G-pebbly S in places imbricated; ws; rounded cobbles <10 in. |
| 147 | 24 in. shovel hole; light brown Ds stratified; white and brown layers; compact; 20-30% clasts; in place?? |
| 148 | 18 in. shovel hole; sC |
| 149 | 24 in. shovel hole; crsS and pebbly S |
| 150 | 24 in. shovel hole; gray Cy |
| 151 | 24 in. shovel hole; massive and matrix supported Ds with subangular pebbles and cobbles |
| 152 | 6 ft road cut section; brownish gray Cy |
| 153 | 4 ft road cut section; brown massive and matrix supported Dst; subrounded cobbles |
| 154 | 24 in. auger hole; brown Cy |
| 155 | 6 ft auger hole; f-medS, <5% pebbly; rounded cobbles locally |
| 156 | 18 in. shovel hole; cobbly S |
| 157 | 18 in. shovel hole; Cy |
| 158 | 3 ft shovel holes; brown-gray Cy; bedrock |
| 159 | bedrock; garnetiferous Biotite Schist with quartz augens; veneer of D |
| 160 | Excavation; 2 ft fS over Cy |
| 161 | Inactive sand and gravel pits; S to Gs |
| 162 | Excavation; 42 in. Cy over fS according to local resident |
| 163 | 3 ft auger holes; f-medS over pebblyS to B?; no soil profile |
| 164 | 6 ft auger hole; 5 ft fS-vfS over interbedded f-vfS and blue laminated Cy |
| 165 | 2 ft road cut section; fS |
| 166 | Inactive gravel and sand pit; 12 ft ridge cored with pebblyS; some P imbricated, but poorly sorted; ridge flanked by f-medS with normal faulted S |

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|---|---|
| 167 | see [003] |
| 168 | 18 in. shovel hole, massive and matrix supported D |
| 169 | see [102] |
| 170 | Inactive gravel pit being remediated; predominantly matrix supported to cs Ds interbedded with f-crsS; striated clasts |
| 171 | 24 in. shovel holes; not compact massive and matrix supported Ds with angular-subrounded clasts <13 in. ; locally, 1 ft silty Cy containing large subrounded-subangular clasts |
| 172 | 12 in. shovel hole; massive and matrix supported D |
| 173 | 2 ft road cut section; massive and matrix supported D |
| 174 | bedrock; no striae; overlain by till |
| 175 | bedrock; no sand |
| 176 | 24 in. shovel hole; massive and matrix supported D |
| 177 | bedrock; poor striae 169° |
| 179 | 6 ft deep hole; test pit? ms-wsG and v clean ws med-vcrsS; pebbles imbricated; normal faulted S and discontinuous bedding; no shells and doesn't look like beach |
| 180 | 6 ft auger holes; 5 ft f-crsS over brown Cy; no soil profile; same all over |
| 181 | 18 in. shovel hole; massive and matrix supported D |
| 182 | 4 ft road cut section; fS with pebbles |
| 183 | 6 ft auger hole; fS |
| 184 | 5 ft auger hole; 4 ft FU crs to fS over pebbly S-C; no soil profile |
| 185 | 2 ft auger hole; f-medS to bedrock or C |
| 186 | 6 ft auger hole; vfS; some brown Cy locally |
| 187 | 3 ft auger hole; Cy |
| 188 | 30 in. shovel hole; massive and matrix supported D with 10% angular-subrounded clasts, <24 in. |
| 189 | shovel holes; massive and matrix supported D thin veneer in places |
| 190 | 4 ft road cut section; fS |
| 191 | Same as [190] |
| 192 | 2 ft shovel hole; gray silty Cy |
| 193 | 3 ft shovel hole; 30 in. interbedded sandy silty Cy and fS over fS |
| 194 | 12 in. shovel hole; fS to bedrock |
| 195 | 3 ft shovel hole; pebbly fS to C over bedrock |

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|---|---|
| 196 | 12 in. shovel hole; Cy |
| 197 | 18 in. shovel holes; fS and Cy in all holes |
| 198 | 24 in. shovel holes; on ridges, massive and matrix supported D; ridges flanked by fS and Cy with angular cobbles; bedrock at 8 ft according to local resident |
| 199 | 24 in. shovel holes; Cy in all holes |
| 200 | 24 in. shovel hole; massive and matrix supported D, not compact, with subrounded clasts <6 in. |
| 201 | Road cut section; massive and matrix supported D and till fences |
| 202 | 6 ft auger holes; 5 ft interbedded f-medS,fS, and Cy over brown Cy, siltier toward top |
| 203 | 5 ft auger hole; 4 ft fS with few pebbles; boulder at base |
| 204 | 24 in. shovel holes; massive and matrix supported D on high ground, Cy on lower areas |
| 205 | 24 in. shovel hole; massive and matrix supported D with sub angular-subrounded clasts <16 in. |
| 206 | 24 in. shovel hole; massive and matrix supported D over bedrock |
| 207 | 24 in. shovel hole; massive and matrix supported D |
| 208 | 4 ft auger hole; sG |
| 209 | bedrock; Cy cover; no striae |
| 210 | Shovel holes on islands in Watchic Pond; all 30 in. sG |
| 211 | bedrock; good striae 157° with stoss and lee forms |
| 212 | bedrock; beautiful striae 161-166°; good grooves 162° |
| 213 | bedrock; beautiful striae and grooves 160-163°; striae 180° |
| 214 | 6 ft auger hole; upper 2 ft not in place; vcrs-fS FU |
| 215 | 30 in. shovel hole; massive and matrix supported Dst |
| 216 | 24 in. shovel hole; fS |
| 217 | 6 ft auger hole; 24 in. medS v. compact over fS; water table near surface |
| 218 | Excavation; 25 ft section of variably sorted and deformed S to G; predominantly interbedded siltyvfS, fS, crsS, P, C; fluid injection structures in vfS; average bedding thickness 10 in.; laminations draped around clasts; fS lenses common; faceted and striated clasts; fold axes 120° |
| 219 | see [105] |
| 220 | Same pit as [088]; 25 ft sections; 16 ft interbedded variably cross bedded (some trough cross bedding) crsS, csP, csC, f-crsS over interbedded pebblyS, fS, and P which form beautiful foresets |

| | | | | | | |
|---|---|---|---|---|---|---|
| <=maximum length | AF=artificial fill | C=cobble gravel | crs=coarse | cs = clast supported | CU=coarsen upward | Cy=clay |
| D=diamicton | f=fine | FU=fining upward | G=gravel | med=medium | P=pebbly gravel | ps=poorly sorted |
| S=sand | s=sandy matrix | St= silt | st=silty matrix | v=very | ws=well sorted | |

| | |
|---|---|
| 250 | 5-276§ |
| 251 | 5-790§ |
| 252 | 5-960§ |
| 253 | 5-1366§ |
| 254 | 5-1459§ |
| 255 | 5-2157§ |
| 256 | 5-3424§ |
| 257 | 5-3427§ |
| 258 | 31-247§ |
| 259 | 31-249§ |
| 260 | 31-263§ |
| 261 | 31-266§ |
| 262 | 31-267§ |
| 263 | 31-268§ |
| 264 | 31-269§ |
| 265 | 31-270§ |
| 266 | 31-272§ |
| 267 | 31-274§ |
| 268 | 31-275§ |
| 269 | 31-276§ |
| 270 | 31-278§ |
| 271 | 31-279§ |
| 272 | 31-280§ |
| 273 | 31-281§ |
| 274 | 31-282§ |
| 275 | 31-283§ |
| 276 | 31-286§ |
| 277 | 31-287§ |
| 278 | 31-288§ |
| 279 | 31-289§ |
| 280 | 31-291§ |

| | |
|---|---|
| 305 | gravel well† |
| 306 | driven point† |
| 307 | drilled well† |
| 308 | gravel well† |
| 309 | dug well† |
| 310 | dug well† |
| 311 | drilled well† |
| 312 | gravel well† |
| 313 | driven point† |
| 314 | dug well† |
| 315 | driven point† |
| 316 | dug well† |
| 317 | dug well† |
| 318 | dug well† |
| 319 | dug well† |
| 320 | dug well† |
| 321 | dug well† |
| 322 | driven point† |
| 323 | dug well† |
| 324 | dug well† |
| 325 | gravel well† |
| 326 | drilled well† |
| 327 | driven point† |
| 328 | dug well† |
| 329 | dug well† |
| 330 | dug well† |
| 331 | drilled well† |
| 332 | 12 channel seismic line† |
| 333 | 12 channel seismic line† |
| 334 | driven point† |
| 335 | observation well (project)† |

| | |
|---|---|
| 281 | 31-297§ |
| 282 | 31-298§ |
| 283 | 31-299§ |
| 284 | 31-300§ |
| 285 | 31-301§ |
| 286 | 31-303§ |
| 287 | 31-304§ |
| 288 | 31-306§ |
| 289 | 31-307§ |
| 290 | 31-308§ |
| 291 | 31-309§ |
| 292 | 5-1364§ |
| 293 | 5-3390§ |
| 301 | gravel well† |
| 302 | test pit† |
| 303 | drilled well† |
| 304 | dug well† |
| 336 | drilled well† |
| 337 | gravel well†¥ |
| 338 | dug well† |
| 339 | driven point† |
| 340 | dug well† |
| 341 | dug well† |
| 342 | dug well† |
| 343 | gravel well† |
| 344 | gravel well† |
| 345 | 12 channel seismic line†¥ |
| 346 | 12 channel seismic line†¥ |
| 347 | 12 channel seismic line†¥ |
| 348 | 12 channel seismic line†¥ |
| 349 | gravel well† |
| 350 | 12 channel seismic line†¥ |
| 351 | 12 channel seismic line†¥ |

§ Maine Geological Survey Well Data Inventory; Cumberland (5) and York (31) Counties; as of Sept, 1990
† From Tolman and Lanctot, 1985
¥ From Tolman et al., 1983