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INTRODUCTION

Surficial mapping in the Lisbon Falls North 7.5' quadrangle was conducted during 1998 as part of the Maine Geological Survey's basic geologic mapping program, funded in part by the U.S. Geological Survey STATEMAP program. The purpose of this program is to provide detailed geologic information for use by the general public; municipal, state, and federal agencies; and for fundamental background information for site-specific studies. A surficial geologic map (Weddle and others, 1999) and a surficial materials map (Weddle and others, 1999), both at 1:24,000 scale, have been compiled. The materials map shows the thickness and composition of surface materials at points where surface and subsurface observations were made. The geologic map shows the distribution of geological units and features that record the geological history of the quadrangle. This report describes the surficial deposits mapped in the quadrangle and presents the glacial and postglacial history of the quadrangle.

PREVIOUS WORK AND ACKNOWLEDGMENTS

Early descriptions of the surficial geology in the study area are found in Stone (1899) and Leavitt and Perkins (1935). A regional overview of the glacial geology of southwestern Maine can be understood by reading Bloom (1960, 1963), Stuiver and Borns (1975), Smith (1982, 1985), Thompson (1982, 1987), Thompson and Borns (1985a), Thompson and others (1989), Smith and Hunter (1989), Retelle and Bither (1989), Kelley and others (1992), Weddle and others (1993), and Weddle and Retelle (1995). Soils in the quadrangle were mapped by McEwen (1970) and Hedstrom (1974).

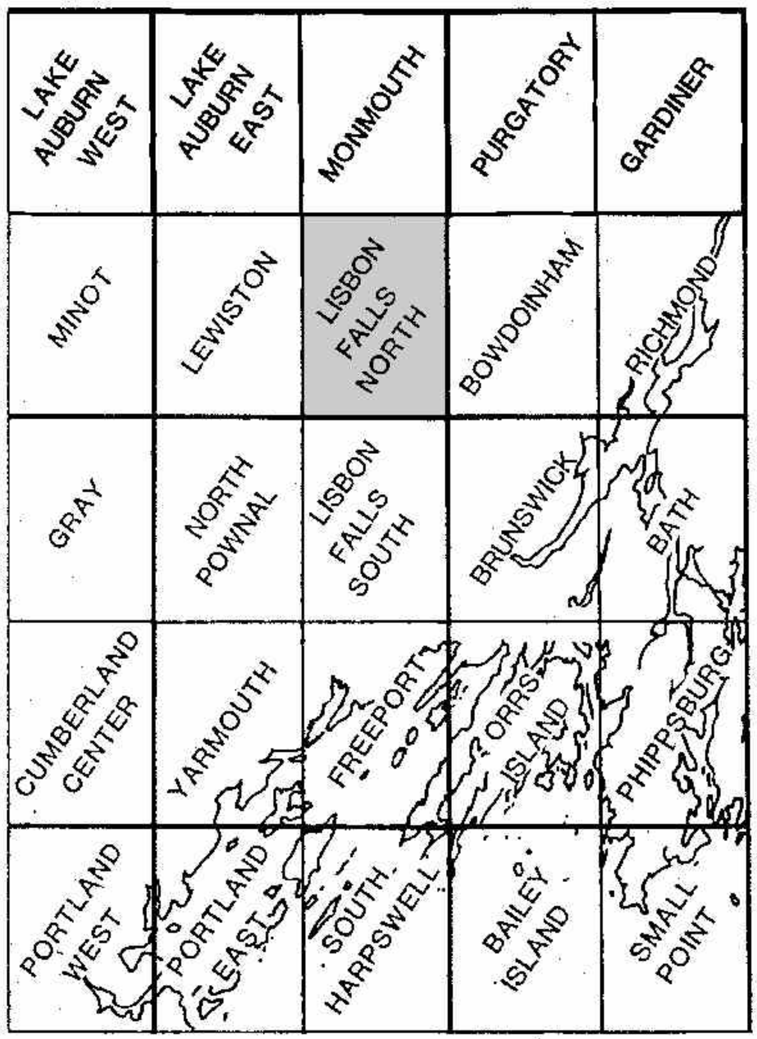
The surficial geology of the Lisbon Falls North quadrangle was mapped previously at reconnaissance level by Bloom (1960) and Smith and Thompson (1980). Other modern work incorporating surficial geology in the study area includes Prescott (1979, 1980) and Tepper and others (1985). Bernotavicz (1994) mapped a portion of the quadrangle as part of a Senior Thesis at Bates College, Lewiston, Maine. Wetlands mapping of the quadrangle is published by the U.S. Department of the Interior National Wetlands Inventory.

Sources of materials information in the quadrangle include boring logs along the Maine Turnpike and Interstate-95, and other roads and bridge borings courtesy of the Maine Turnpike Authority and the Maine Department of Transportation (MDOT), and in MDOT unpublished materials inventory maps, which describe many abandoned gravel pits that provided construction material for Interstate 95. The Maine Geological Survey's (MGS) bedrock well database inventory also provided depth to bedrock information. (Note: the location of wells in the MGS well inventory is based on tax lot map locations and not necessarily on field observations.) Numerous gravel pit operators and private landowners allowed permission to access their property.

LOCATION, TOPOGRAPHY, AND DRAINAGE

The Lisbon Falls North 7.5' quadrangle is located just inland from the Maine coast between 44°00'00" and 44°07'30"N latitude, and 70°00'00" and 70°07'30" W longitude (Figure 1). It comprises parts of Androscoggin, Kennebec, and Sagadahoc Counties, and parts of the communities of Bowdoin, Durham, Lewiston, Lisbon, Litchfield, Sabattus, and Topsham. Elevations within the quadrangle range from about 100 feet above sea level (asl) in the Androscoggin River valley to over 630 feet asl in the northeastern corner of the quadrangle. The quadrangle has moderate relief, with maximum relief of 530 feet between the Androscoggin River in the southwest and Whitten Hill in the northeast.

The major drainage in the quadrangle is by tributaries of the Androscoggin River, which makes a bend into the southeastern part of quadrangle and exits there as well. The western half of the quadrangle is drained by the Sabattus River and its tribu-



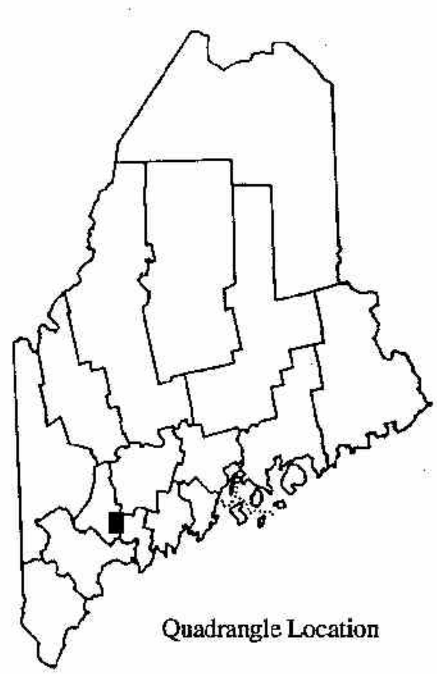


Figure 1. Location map showing the Lisbon Falls North 7.5' quadrangle.

taries, Maxwell Brook, Barker Brook, and No Name Brook. Drainage in the eastern half of the quadrangle is by the Little River and its tributaries, Fisher Stream, Prington Brook, Gillespie Brook, Potter Brook, and Dearing Brook.

BEDROCK GEOLOGY

Bedrock in the quadrangle is chiefly comprised of feldspathic biotite granofels mapped by Hussey (1983) as the Vassalboro Formation. The northwestern corner and a part of the northeastern corner of the quadrangle have schists and granofels mapped by Hussey (1983) as the Smalls Falls Formation, the Waterville Formation, and the Sangerville Formation. More information on the bedrock geology of the region can be found in Hussey (1988, 1989).

SURFICIAL GEOLOGY

Bedrock and Thin-Drift Areas

Gray areas on the map represent bedrock where it crops out. Much of the northeastern part of the quadrangle is mapped as thin drift (Ptd) where surficial material over bedrock is less than 10 feet thick. Individual outcrops in these areas are not always indicated on the map. The lithologies of the surficial deposits most often found in thin-drift areas may be till, marine deposits, glaciomarine deposits, or nearshore deposits.

Till

Till (Pt) is found at some surface localities and reported in subsurface test borings. It is commonly a loose to compact, gray to olive gray, pebbly, silty, sandy, poorly sorted deposit (diamicton) often found overlying bedrock.

Stratified-Drift Ice-Marginal Deposits

Ice-contact stratified drift deposts (Pgi). Sand and gravel deposited against remnant masses of glacial ice is recognized by the coarse-grained texture of its deposits, and the irregular, hummocky topography usually associated with melting ice masses. It is found in one area in the highland of the northeastern corner of the quadrangle.

End moraines (Pem), submarine outwash fans (Pmf) and glaciomarine deltas (Pmd). Certain ice-marginal deposits in Maine have been termed stratified end moraines because of their geomorphologic and sedimentologic character (Ashley and others, 1991). They are linear lobate ridges, comprised of ice-tunnel deposits (eskers), submarine fans, deltas, and associated ice-proximal diamicton deposits, and may contain deformation structures due to ice-marginal push or overriding. The location of these deposits is controlled by glaciology and glacial hydrology as well as topography (Gustavson and Boothroyd, 1987; Ashley and others, 1991; Crossen, 1991; Warren and Ashley, 1994). Subglacial or englacial drainage followed the present-day valleys and where the ice margin was slowed in its retreat, there was time to build relatively large deposits. The internal structure and composition of similar features elsewhere in Maine has been described in detail by Smith and Hunter (1989), Retelle and Bither (1989), and Ashley and others (1991). The end moraines are most likely complexes of submarine fans comprised of subaqueous outwash, or they may be "washboard" or DeGeer moraines (Sugden and John, 1988; Lundqvist, 1981), but because of lack of exposure are here only termed end moraines. These ice-front deposits are generally parallel to the former margin of the retreating ice sheet (Ashley and others, 1991), and therefore can be used to trace ice-marginal positions during deglaciation.

End moraines (Pem) are common in the quadrangle. More moraines are probably present in the area, but may be buried by overlying glaciomarine deposits. In general, the moraines have an east/northeast-west/southwest trend (azimuth range 60^{o} - 90^{o}) . The moraines are commonly associated with submarine fan deposits. These moraines are small to moderately large, usually occurring in clusters, not more than 10-30 feet high, 100-200 feet wide, and 1000-3000 feet in length. The curvilinear orientation of the moraines reflect the importance of upland pinning positions of the ice margin. During its retreat, the glacier margin was retarded by uplands, whereas in adjacent lowlands the ice front retreated somewhat more rapidly than on the upland. Good examples of moraines are found in the area adjacent to and between Potter Brook and Fisher Brook.

Submarine outwash-fan (Pmf) deposits are present in several areas in the quadrangle, especially in the Sabattus River and Purington Brook valleys. These series of fans reflect the trend of a meltwater drainage system in the glacier. In both areas, the fans identify ice-marginal positions where the margin remained long enough for the fans to form. Later, as the ice-margin retreated to a new position to the north, distal glacial deposits from the more northerly position partially buried the ice-marginal deposits to the south. The valley fans are traceable along trend to other stratified drift deposits to the north on the Lisbon Falls quadrangle, and beyond onto adjacent quadrangles as part of an extensive esker system in western Maine (Thompson and Borns, 1985b).

Two glaciomarine deltas (Pmd) are present in the quadrangle. At the north end of the Sabattus River valley, adjacent to Sabattus Pond, is the Pleasant Hill Delta (Thompson and others, 1989). This delta is characteristic of many ice-contact deltas with its steep northward dipping ice-contact slope, lobate kidney-shaped form, and ice-block depressions (kettles) on its surface. On its northen edge, a traceable ridge (esker) along Pleasant Hill Road is present, and represents the position of an ice tunnel at or near the ice margin, where sediment emanated from the tunnel to build the delta (Retelle and Weddle, 2001).

The other delta in the quadrangle is the Purington Brook delta (Kettlebottom Road delta of Thompson and others, 1989). This delta is not an ice-contact deposit, but was formed at some distance from the ice margin. It is an example of a leeside delta (Thompson and others, 1989), so-called because they are found on the lee sides (generally to the south) of ridges or ranges of hills that extended above the ocean surface during the marine submergence. Here the maximum marine limit of submergence is approximately 300 feet above sea level. Ice-contact deposits are found farther north adjacent to Kettlebottom Road and which are above the marine limit mark the approximate position of the ice margin that fed the sediment-laden meltwater discharge to the ocean to form the Purington Brook delta.

Presumpscot Formation

Glaciomarine mud (Pp) in the southern Maine region has been named the Presumpscot Formation by Bloom (1960). The silt and clay of this unit occupies most of the valleys in the study area. Subsurface data and surface exposures show that the unit directly overlies bedrock, till, fans, and end moraines, and can be interbedded with subaqueous outwash. It can be massive or layered, containing outsized clasts, and in places is fossiliferous. It has a blue-gray color unweathered, and an olive-gray color when weathered. Fracture surfaces in the weathered Presumpscot Formation commonly are stained by iron-manganese oxides. The Presumpscot Formation was deposited by glaciofluvial activity discharging material into the glacial sea. Based on associated fossil assemblages, it is considered a late Pleistocene cold-water marine unit (Bloom, 1960). It can be stratigraphically related to ice-marginal deposits, hence in its oldest stratigraphic position, it is also glaciomarine in origin. However, upsection at some point it becomes exclusively marine when it is no longer directly linked with glacial ice in contact with the ocean. A good exposure representing both the ice-proximal and ice-distal/basinal nature of the Presumsumpscot Formation is found at the gravel pits in the Sabattus River fans about 0.5 miles south of Crowley Road on the west side of the Sabattus River valley

A sandy facies of the Presumpscot Formation found overlying the fine-grained facies has been described (Smith, 1982, 1985; Thompson, 1982, 1987). The contact between the facies is reported to be sharp or gradational, and the origin of the sandy facies appears to be associated with shoaling during the regression of the sea. It also has been described as a gradational facies between the clay and the deltaic/fan facies (Koteff, 1991), although this interpretation places it stratigraphically below the regressive deposits.

Interbedded sand and clayey silt overlying massive Presumpscot Formation mud is present in the Lisbon Falls North quadrangle, as well as at locations in adjacent quadrangles and in test-boring reports in the area. However, the informal term sandy Presumpscot Formation as used by others as a mappable unit (e.g., Weddle, 1987; Smith, 1999; Hildreth, 1999; Hunter, 1999) is not used in the Lisbon Falls North quadrangle. This unit has been associated by these workers with marine regressive deposits, stratigraphically above the massive mud of the Presumpscot Formation (sensu stricto). In some instances, massive sand of fluvial origin and unconformably overlying the Presumpscot Formation has been mapped as sandy Presumpscot Formation (Weddle, 1987; Smith, 1977). In the Lisbon Falls North quadrangle, the term nearshore deposit (Pmn) is used for shallow water or wave reworked deposits associated with marine transgression and regression (see below). Distal sand related to subaqueous glaciomarine fan or delta deposition and which is interbedded with the Presumpscot Formation is considered part of the Presumpscot Formation and is mapped as such (Pp).

Nearshore and Shoreline Deposits and Pleistocene Alluvium

Subsequent to the deposition of the Presumpscot Formation, existing units were reworked by the marine regression, and nearshore deposits (Pmn) were laid down. Water depth and relative sea level in the region was controlled by glacio-isostatic rebound and eustatic sea level changes, and during the late Pleistocene in this area, isostatic conditions were prevalent (Stuiver and Borns, 1975; Belknap and others, 1987; Kelley and others, 1992). These deposits are found in many locations, as a thin to thick veneer of sediments ranging in grain size from coarse gravels to massive mud; however, most are not shown on the map because they are not thick enough to obscure the underlying units. These deposits are the result of wave activity in late Pleistocene nearshore or shallow-marine environments (subtidal, lagoonal, and beach environments of Retelle and Bither, 1989), and compositionally reflect the underlying parent material. However, they do not necessarily have a shoreline morphology. Thick nearshore deposits (Pmn) shown on the map are found flanking the slopes of hillsides and deltas, and in broad low areas in the Sabattus River and Little River valleys. Also, nearshore deposits often are associated with thin-drift areas.

Pleistocene alluvium deposits (Pa) are found as terraces along the Androscoggin River valley at elevations above the modern flood plain. Where exposed they consist of trough-cross bedded sand and gravel, characteristic of braided-stream deposits (Weddle, 1997).

Holocene Deposits

Eolian deposits are common in the area. However, they are not shown on the map because they are not thick enough in most areas to mask the underlying units. Holocene deposits have been mapped as fresh water wetlands (Hw) and stream alluvium (Ha).

GLACIAL AND POSTGLACIAL HISTORY

Quaternary Geology

The glacial deposits in the Lisbon Falls North quadrangle were derived from the last ice sheet which covered Maine, the late Wisconsinan age Laurentide Ice Sheet, which reached its maximum in New England about 25,000 yr B.P. (Stone, 1995). Glacial striations and streamlined hill orientations reflect ice flow through the quadrangle and generally vary within 10^{o} - 15^{o} of 180^{o}, although one location on an upland in the northwest corner of the quadrangle has a striation trend of 143^{o}. In the adjacent North Pownal quadrangle (Marvinney, 1999) and Raymond quadrangle (Retelle,1997), several upland striations trending near 140^{o} are present. At one location in the northwest part of the quadrangle, cross-cutting striations are found where a southwest trend (208^{o}) cuts across an older southeast trend (163^{o}). In other nearby quadrangles where multiple-striation localities are found, southeast-trending striations are more commonly older than the south- and southwest-trending striations (Weddle, 1997, 1999; Maine Geological Survey, unpublished data). Good examples of streamlined hills in the Lisbon Falls North quadrangle include Lisbon Ridge, Whitten Hill, and the hill whose north end begins between Spear Cemetery and Loon Pond.

Ice recession from the Gulf of Maine probably began sometime around 17,000 yr B.P. (Smith, 1985; Smith and Hunter, 1989). Radiocarbon dates in the immediate area provide minimum dates for the deglaciation of the region (Stuiver and Borns, 1975; Smith, 1985). A previously reported age of 14,045 ± 95 yr B.P. (Weddle, 1999) from a *Portlandia arctica* shell in glaciomarine deposits in Freeport was reanalysed because its del^{13}C value (-9.1 o/oo) is well beyond the suggested mean del^{13}C value for marine carbonate (0 ± 2 o/oo; CALIB 4.0 Manual, Table 1; http://www.radiocarbon.org/). A new age estimate on another *Portlandia* from the same deposits is 13,000 ± 55 yr B.P. (OS-18899; del^{13}C -1.15 o/oo. However, an age analysis on *Mytilus edulis* shells found in mud overlain by nearshore deposits in Phippsburg (13,600 ± 380 yr B.P. (GX-21931; Weddle and Retelle, 1998; Retelle and Weddle, 2001) provides a minimal date for deglaciation in the Casco Bay region. Degla-

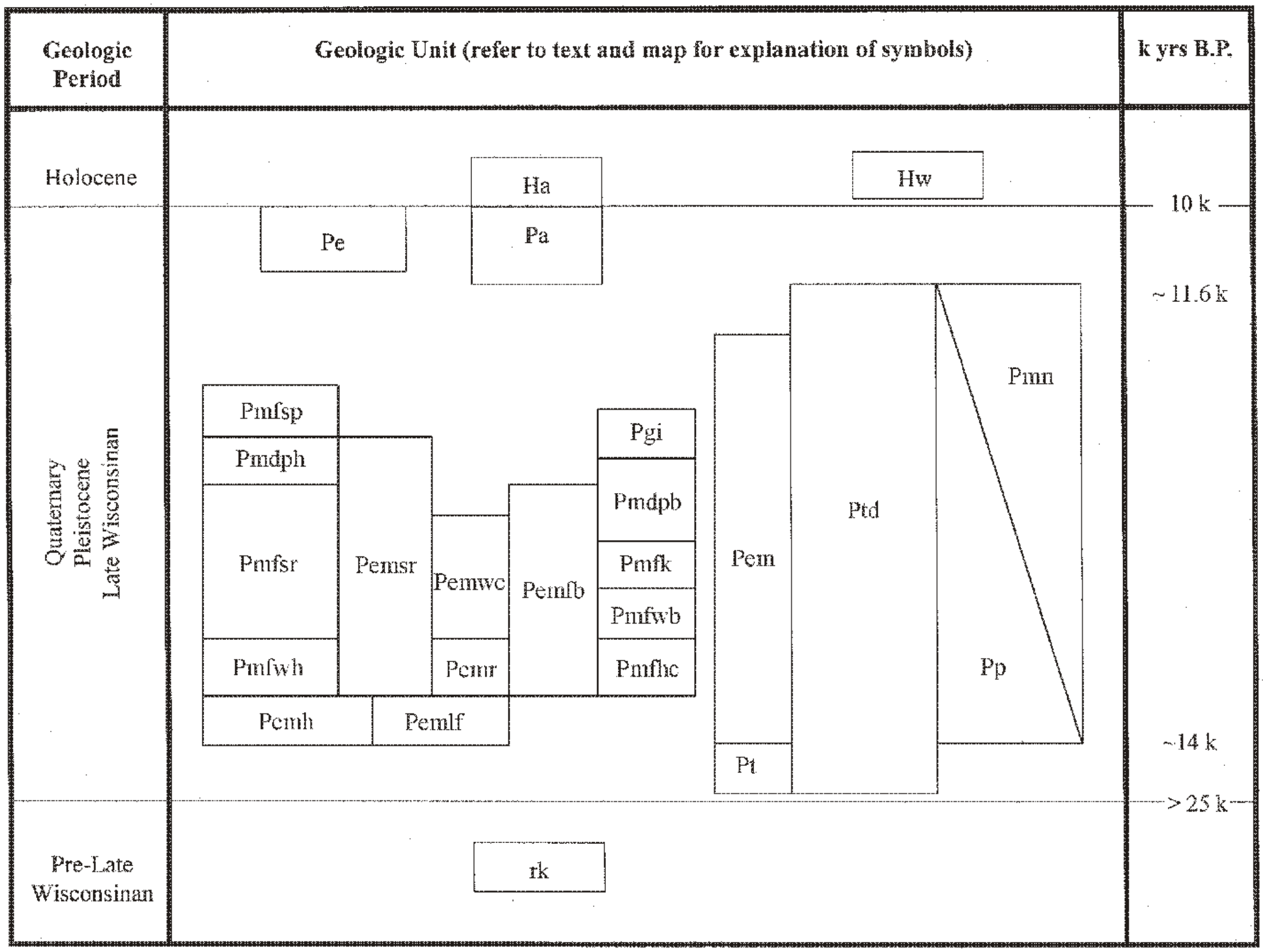


Figure 2. Schematic chart showing correlation of geologic units in the Lisbon Falls North 7.5' quadrangle. End moraine (Pem) and marine fan (Pmf) units are read from left to right and bottom to top, corresponding to west to east and south to north, respectively, on the surficial geology map. Age estimates are in uncorrected radiocarbon years.

ciation probably occurred several hundred years earlier, most likely closer to 14,000 radiocarbon years B.P.

During the retreat of the glacier, the ocean was in contact with the ice margin. Pleistocene sea level at the time of deglaciation in the study area was approximately 320 feet above modern sea level (Thompson and others, 1989). The 320-330 foot flat-topped surface of the Pleasant Hill delta southeast of Sabattus Pond approximates this high synglacial sea-level stand. As the ice margin passed through the Lisbon Falls North quadrangle, all the present-day land below about 320 feet was completely submerged. The areas above 320 feet in the quadrangle were islands and those areas just below that elevation were shoals. The tidal range in the Gulf of Maine during this time was less than a meter (Scott and Greenburg, 1983).

The distribution and orientation of ice-marginal submarine and deltaic deposits also reflects the flow of ice indicated by the striation direction data. The moraines and glaciomarine deposits occur along a trend near perpendicular to the striation directions and indicate that the glacier withdrew from the modern coastal zone and progressively retreated inland as a near east-west trending, active ice sheet grounded in a glaciomarine environment. The deposits are regularly younger from south to north, reflecting the systematic retreat of the ice in the quadrangle. The correlations and approximate age of the deposits are schematically represented on Figure 2.

As the ice retreated, it was pinned on bedrock highlands and was grounded in the intervening low areas as evidenced by shape and location of the moraines and ice-marginal positions. At the ice-marginal positions, end moraines and fans comprised of subaqueous outwash represent deposition by ice-tunnel or stream discharge, or by ice-push at the margin (Ashley and others, 1991). With reasonable correlation, these deposits can be used to reconstruct the orientation and relative position of the ice margin in time during deglaciation. These landforms reflect the shape of the ice margin during deglaciation, which appears to have been slightly lobate down valley.

The ice-marginal positions inferred on the map are found in the lowlands of the Sabattus River and Little River. These two areas are separated by central highlands, and bordered by highlands to the east and west. The oldest ice-margin positions identified are represented by the Little Falls (Pemlf) and Hudon Road (Pemh) end moraines located at the southwest corner of the quadrangle. North of these deposits are numerous unnamed small moraines, which represent minor stillstands or readvances of the ice margin. As the margin retreated north to Lisbon Ridge, it was impeded by and pinned on the ridge long enough for the Whites Hill (Pmfwh) and Higgins Corner (Pmfhc) fans to be deposited. The moraine complexes north of Lisbon Ridge, from west to east the Sabattus River (Pemsr), Ridge Road (Pemr), Webster Corner (Pemwc), and Fisher Brook (Pemfb) end moraine complexes represent the retreat of the margin through the central low-lying area in the quadrangle. The lobate nature of the ice margin is well represented by the orientation of these moraines. To the east, the retreat of the margin is relected by the deposition of the West Bowdoin fan (Pmfwb) and the Kettlebottom fan (Pmfk), so called because of a large kettlehole in its center marking the position of a melted ice block. Today, half of the kettlehole is mined away by a gravel pit operation. On the west side of the quadrangle, the Sabattus River fans are a good example of a deposit known as a "beaded esker" (Sollid and Carlson, 1984; Caldwell and others, 1985; Warren and Ashley, 1994). Instead of a long ridge (esker) forming from deposition within an ice tunnel, the margin of the glacier retreats rapidly as material from the ice-tunnel is deposited at the margin as a series of segmented fans, possibly representing annual retreat of the ice margin. In the Lisbon Falls North quadrangle, the Sabattus River fans separate two larger deposits, the Whites Hill fan and the Pleasant Hill delta. These larger deposits may represent a period when the ice margin was at a relative stillstand as compared with the smaller intervening fans. Alternatively, the larger deposits could reflect an increase in meltwater discharge from the ice tunnel.

The Pleasant Hill delta marks the most prominent ice marginal position in the northern portion of the quadrangle. Immediately north of the delta, more small fans are found, the Sabattus Pond fans (Pemsb). These fans continue north in this lowland into the Monmouth quadrangle in the same beaded manner as the Sabattus River fans to the south, and terminate at another large deposit, the Marr Point delta (cf., Figure 7 in Retelle and Weddle, 2001). The ice-marginal position associated with the Pleasant Hill delta is not readily traced across the northeastern part of the quadrangle. North of the Kettlebottom fan, the Purington Brook delta is found at a slightly lower elevation than the Pleasant Hill delta. As mentioned previously, it is a lee-side delta formed at some distance from the ice margin, and thus does not immediately mark an ice-marginal position. This delta may have buried moraines and glaciomarine fans as it prograded seaward during its formation. Its surface is dissected by meltwater channels that incised the delta top as relative sea level fell because of rebound of the land by the removal of the weight of the ice mass by melting. The ice-contact deposits found north of the Purington Brook delta most likely represent the ice-marginal source of the meltwater that provided the sediment to form the delta.

The Presumpscot Formation (Pp) was deposited coeval with the ice-marginal deposits. These sediments settled out both near and beyond the margin of the ice and can be found interfingering with the fan sediments or as a blanket draping older deposits. Marine fossils in the Presumpscot Formation are found at several locations in the quadrangle, and some of these have yielded radiocarbon age-dates.

Local uplift due to isostatic rebound occurred during deglaciation and resulted in regression of the glacial sea. An uncorrected radiocarbon date of 13,300 ± 50 yr B.P. on *Mytilus edulis* from nearshore deposits in a pit at approximately 200 feet (61 m) asl in the adjacent North Pownal quadrangle to the east records the earliest date for marine regression in the immediate area. During this relative fall of sea level, nearshore and shoreline deposits were formed. Pleistocene nearshore deposits are found along glaciomarine delta flanks and fronts, as well as over glaciomarine mud over a considerable area in the quadrangle, and wave-cut terraces have been reported on the delta slopes (Crossen, 1984, 1991).

The timing of regression in the Lisbon Falls North quadrangle is not very well known. If as in the adjacent quadrangles, nearshore deposits were forming at approximately 200 ft asl about 13,300 radiocarbon yr B.P., and had fallen to about 150 ft by approximately 12,800 (Retelle and Weddle, 2001), an estimate of relative sea-level fall in the region can be determined and is about 8.3 ft / 100 yr (2.5 m / 100 yr). The lowest elevation in the Lisbon Falls North quadrangle is at approximately 100 ft, so based on the estimated emergence rate above and assuming a near steady relative sea-level fall, the marine regression would have been complete in the quadrangle by around 12,200 radiocarbon yr B.P. However, evidence exists for periods of relative stillstands during the marine regression in the region, hence the above estimate of when marine regression in the quadrangle was complete is tentative (Weddle and Retelle, 1995; Retelle and Weddle, 2001).

As relative sea-level reached its lowest level around 10,500 radiocarbon yr B.P. well offshore of the modern coastline (Kelley and others, 1992; Barnhardt and others, 1995), present day drainage became established. Deep erosion in the glaciomarine mud, such as the gullies now found in the Little River valley also formed during this time. Many of these gullies have downcut to bedrock, and most of the gullies are floored by wetland deposits; however, a thin veneer of Holocene alluvium is present along stretches in some valleys. Most gullies have steep sidewalls bounding a broad, flat-floored valley, in which streamflow during floods can be dramatic. Slumping and erosion of the gully sidewalls during floods is a modern process; however, most of the gully erosion probably occurred during late glacial time prior to vegetation. After reaching its lowest level, sea level began to rise resulting in aggradation within river channels and drowning of the channels near the modern coast to form estuaries.

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