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Surficial Geology of the North Pownal 7.5-minute Quadrangle, Androscoggin and Cumberland Counties, Maine

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INTRODUCTION

Surficial geologic mapping of the North Pownal 7.5-minute quadrangle map was conducted during 1992 and 1993 as part of the COGEOMAP program of the United States Geological Survey and the Maine Geological Survey. This program provides detailed geologic information for use by the general public; municipal, state, and federal agencies; and background information for site-specific studies. Along with this written report describing the surficial geology, a surficial geologic map (Marvinney, 1999a) and a surficial materials map (Marvinney, 1999b) have been compiled at 1:24,000 scale. The materials map consists of point data showing thickness and composition of surficial sediments where surface and subsurface observations were made. The geologic map shows the distribution of geologic units and, when possible, features that record the geologic history of the quadrangle.

PREVIOUS WORK AND ACKNOWLEDGMENTS

Regional studies of the glacial history of southern Maine and its associated deposits are presented in Leavitt and Perkins (1935), Bloom (1960, 1963), Stuiver and Borns (1975), Smith (1982, 1985), Thompson (1982), Thompson and Borns (1985), Thompson and others (1989), Smith and Hunter (1989), Retelle and Bither (1989), Kelley and others (1987), Crossen (1991), and Weddle and others (1993).

Reconnaissance mapping of the North Pownal quadrangle was completed by Smith and Thompson (1986) at a scale of 1:62,500. Bither (1989) completed a more detailed surficial geologic and bedrock map (1:24,000) of the northeastern corner of the North Pownal quadrangle, and portions of Bither's bedrock mapping were utilized for outcrop locations in the present investigation. Other sources of surficial information were gathered from Bolduc (1983), and the Androscoggin and Cumberland County soils maps (McEwen, 1970; Hedstrom, 1974). Wetlands information was obtained from direct observation and from the draft wetlands inventory map provided by the U.S. Department of the Interior National Wetlands Inventory.

Specific subsurface information was compiled from well drillers' logs obtained as part of a subsurface investigation by the Central Maine Power Company Substation in Pownal, Maine. Site-specific information was also obtained from drillers' logs taken during the construction of a new addition to the Pownal School, and from drillers' logs of monitoring wells installed at the North Pownal Store.

Depth-to-bedrock information was obtained from the Maine Geological Survey's bedrock well database inventory.

LOCATION AND PHYSIOGRAPHY

The North Pownal 7.5-minute quadrangle is located near the coast in southeastern Maine, along the borders of Androscoggin and Cumberland Counties. Extending from 70°07'30"W to 70°15'W and from 43°52'30"N to 44°N, it covers approximately 42 square miles. Most of the area is rural. Although the area contains the townships of Auburn, Lisbon, Durham, New Gloucester, Pownal, North Yarmouth, and Freeport only two small cross-road communities are located within the quadrangle: North Pownal, in the central portion of the quadrangle, and Pownal Center, three miles to the south. Elevations within the area range from approximately 470 feet above sea level (asl) atop Bradbury Mountain, to 80 ft asl along southern portions of Chandler Brook and East Branch. Moderate relief exists throughout much of the quadrangle, with some level terrain occurring toward the eastern and southern portions of the area. The maximum local relief of approximately 360 ft occurs between Bradbury Mountain and East Branch Stream. The moderate relief is largely created by northeast-southwest trending valleys and bedrock ridges, which are obvious throughout the area.

The central portion of the quadrangle is drained by Chandler Brook and its tributaries. Runaround Pond is a dammed portion of this stream. A small segment of the Androscoggin River drains the northeasternmost section of the area. East Branch drains the southeastern sector, joining Chandler Brook just south

of the North Pownal quadrangle. This water then joins the Royal River flowing southeast to Yarmouth.

BEDROCK GEOLOGY

The bedrock geology has been mapped by Hussey and Pankiwskyj (1975) and Hussey (1985). As mapped, most of the area is underlain by the eastern part of the Sebago batholith, a large granitic intrusion. The eastern edge of the batholith consists of a zone of thin igneous intrusions related to the batholith, with abundant metasedimentary inclusions and pegmatites. The northeast corner of the area is mapped as Waterville Formation, while the southeast corner is mapped as Hutchins Corner Formation (Osberg, 1988). A strong northeast-southwest bedrock trend is evident in the western third of the North Pownal 7.5-minute quadrangle. More detailed information concerning the bedrock geology of the northeast portion of the quadrangle can be found in Bither (1989).

SURFICIAL GEOLOGY

Bedrock and Thin-Drift Areas (Unit Ptd)

Although bedrock strongly controls the topography in the North Pownal quadrangle, large areas of continuous exposure are few. Many places contain numerous small bedrock exposures interspersed with a thin (less than 10 feet) veneer of glacial sediments. They are indicated by the horizontal line pattern on the geologic map and the symbol, Ptd. These thin drift deposits cover much of the quadrangle. The western portion of the area shows many examples of bedrock ridges and knobs thinly mantled by the overlying material. Where elevations exceed 300 ft asl, the estimated marine limit for this area (Thompson and others, 1989), the sediment is till or soil as seen on Bradbury Mountain or Tryon Mountain. Below 300 ft elevation, the veneer may consist of till, marine deposits, glacimarine deposits, or nearshore deposits.

Till (Unit Pt)

Glacial till, also called diamicton because of its poorly sorted texture, is present throughout much of the North Pownal quadrangle. It is found both with ice-marginal deposits of sand and gravel and as a randomly occurring blanket deposit.

When found as a blanket deposit, the diamicton is dense and massive with a sandy to silty matrix. It is tan to brown in color, possibly due to weathering, with numerous angular clasts up to boulder size. Based on these characteristics, I interpret this diamicton as a basal lodgement till. A large exposure of this till is located in a driveway roadcut on Libby Hill. The embankment is approximately 10 ft high with the till being exposed in the upper 4 ft. Many exposures of till are also found within the area of the intersection of Lawrence and Stackpole Roads. Generally, exposures of lodgement till are seen above 150 ft (asl), and within the western two-thirds of the quadrangle. Lodgement till commonly covers the bedrock areas mapped as thin drift.

Diamictons are also found in association with ice-marginal deposits. This is the case in the Larabee Gravel Pit, located off of Route 9, where subglacial fan sediments and marine muds are interbedded with diamicton. The source of the diamicton in this instance is most probably a type of mudflow derived from glacial ice.

End Moraines (units Pem, Pemc)

End moraines (Unit Pem): End moraines in the study area include "washboard" or DeGeer moraines (Sugden and John, 1979) and other ice-marginal deposits containing accumulations of glacial material with generally ridge-shaped topography (Sugden and John, 1979). Submarine outwash fans are discussed in the following section.

Several clusters of DeGeer moraines are found within the north-central portion of the North Pownal quadrangle ($Pemcr_1$, $Pemcr_2$, Pemcs). Approximately 1.5 miles north of North Pownal, directly west of Runaround Pond, is a "textbook" example of these deposits ($Pemcr_2$). Here the moraines are steep-sided ridges, approximately 10-30 ft high. The ridges are spaced 100-200 ft apart and are up to 3000 ft in length (all measurements are approximated from the North Pownal 7.5-minute topographic map). Test pits, excavated into the ridges, show their composition as that of a dense, sandy-matrix diamicton. Marine mud of the Presumpscot Formation is present between the ridges; however, it has not been found to overlie them. Although DeGeer called such ridges "annual moraines," this is not a widely accepted interpretation (Sugden and John, 1979). Till fabrics measured within these moraines by Bates College students (personal communication, M. Retelle, 1993), indicate that the ice was flowing to the southeast.

End moraine complexes, consisting of various intermixtures of till, flowtill, clay, sand, gravel, and boulders are also found within the North Pownal quadrangle. Most of the mapped moraines in these complexes are relatively small, being no more than 1000 ft long and from 10 to 40 ft high. Such a deposit is seen in an old gravel pit located on the south side of Bowie Hill Road, adjacent to Gerrish Brook (Pemgb). Here the moraine is approximately 40 ft thick. It consists of pockets and layers of dense till adjacent to and interbedded with layers of sand, gravel, and cobbles. Large boulders are present in the pit. Layered clay and silt/sand overlie portions of these morainal deposits to the north. In places there appears to be a cobble lag above the layered "mud," which is overlain in turn by a fine massive sand, approximately 3ft thick. A similar deposit is also found approximately 0.75 mi south of Bowie Hill.

The Pownal Center end moraine(Pempc) is located at the intersection of Libby and Dyer roads east of Pownal Center and is a stratigraphically complex end moraine . Rapid changes in the stratigraphy occur both laterally and vertically, as seen in the Blackstone gravel pit on Dyer Road. Layered sands with some

gravel are found at the base of the deposit. Deformed bedding is present along with discontinuous lenses of till. (Although the layered sands and gravels represent the formation of a submarine fan, this deposit is considered to be a moraine because its linear topographic expression can be traced westward from the exposed fan deposit.) The Blackstone pit also contains a large exposure of the Presumpscot Formation, containing the only fossil shells found in this investigation. Most of the shells are bivalves with some possible sponges. The exposure containing the fossils is located in the central portion of the pit. Unfortunately the ice-contact portion of the moraine has been removed by excavation. This moraine can be traced westward to Pownal Center, approximately three quarters of a mile on the basis of topography.

End moraines near Fickett Road, West Pownal, and Pownal Center were mapped on the basis of morphology, surface augering, and/or limited exposure. The moraine north of Fickett Road consists of numerous boulders on the surface. Augering to a depth of 1 ft revealed a diamicton with a clayey silt matrix. The moraine near West Pownal has a small slumped exposure of unconsolidated material varying in size from silt to gravel. Small boulders rest upon the slipface of the exposure.

Few moraines have been mapped in the western half of the area and none in the northwesternmost corner. This is possibly a function of the bedrock topography. Bedrock ridges here trend northeast-southwest, the same orientation as may be expected for an end moraine. Therefore the topographic expression of moraines may be masked by the bedrock topography, or if moraines were formed across elevated bedrock knobs they may have been completely reworked by wave action during the marine submergence and subsequent recession of the sea.

Submarine Outwash Fans (Unit Pmf)

Submarine outwash fans in the North Pownal quadrangle may also be described as "stratified end moraines" (Ashley and others, 1991), in that they represent ice-marginal positions and often include a variety of deposits. Much of the internal structure of these deposits is often missing due to numerous gravel removal operations which have been ongoing in the area. Several large stratified end moraine deposits exist in the east-central portion of the quadrangle. Three coalesced glacial-marine fan deposits in West Durham (Pmfwd) represent the largest and most topographically obvious stratified moraine. These fans form the western edge of a large grounding-line moraine, the Cox Pinnacle Moraine (Weddle, 1997a,b), which can be traced (although not continuously) 4.5 miles to the east into the Lisbon Falls South 7.5-minute quadrangle (Weddle and others, 1993).

Within West Durham, several gravel pits expose portions of the internal structure of fan deposits. The Larabee gravel pit ($Pmfwd_1$), located just north of the Route 9-Rabbit Road intersection exposes ice-proximal material. The stratigraphy changes rapidly in the northern (ice-proximal) side of the pit. For example, till is juxtaposed against fine sand, and underlying bedded sand and gravel. Bedded sands and marine mud, exposed high on the northern pit wall, appear to dip northward suggesting slumping into an area vacated by retreating or melting ice. Above approximately 40 ft of slumped material on the northwest pit wall lies an esker tunel remnant; it contains subrounded to rounded boulders which are incorporated into a coarse, loose gravel matrix. This was a feeder to the fan system. The southwestern wall of the pit is close to 60 ft high. Here bedded material, ranging from fine sand to cobble gravel, constitutes the lower 45 ft of the deposit. Directions of dips on these beds range from 195-200°. Above the bedded material lies a layer approximately 5 ft thick which contains pebbles, cobbles, and boulders in a gravelly matrix. Clasts are subrounded to subangular. A second bouldery, clast-supported layer overlies the latter unit, but here the incorporated clasts are more rounded. This upper layer is interpreted as a reworked deposit, formed during the marine regression. Fine sand of undetermined thickness overlies portions of the fan complex, especially at lower elevations.

The Hanna pit ($Pmfwd_2$) abuts the Larabee pit to the south. It is excavated into the mid and distal portions of the fan complex. Approximately 12 ft of well-exposed forset beds, located in the northwestern portion of the pit, dip SSE to S (166-180°). Bed composition varies from very fine sand to pebble gravel, with bed thickness no greater than 6 inches. Marine mud interbedded with the fan is found in the central portion of the pit. Low amplitude open folds, possibly formed by ice shove, mark the upper clay/sand interface, suggesting that active ice was nearby. A massive 3-4 ft thick layer of rounded to subrounded cobbles and small boulders, incorporated in a sandy matrix, is found above the foreset beds. This unit is believed to be associated with the marine regression because it unconformably overlies all units, as was seen in the Larabee pit. In places a fine-grained, very uniform sand overlies the regressive unit.

The Dugas pit ($Pmfwd_3$) abuts the above pits to the west. Although it has been abandoned, the exposed upper foreset beds dip to the south-southwest. A regressive unit similar to that in the Hanna pit is also found here. It is massive, 3-4 ft in thickness, and contains rounded cobbles and small boulders incorporated into a loose sandy matrix. Layered marine mud with incorporated diamicton is found in the western portion of the pit.

A second topographically prominent fan/fan complex (Pmfcr) is located 1 mi to the south of that found in West Durham. Although the elevation of the top of the feature is over 300 ft (320 ft if the 15' topographic map is used), very close to the upper marine limit in the area (Thompson and others, 1989), no delta topset/foreset contact has been identified. Foreset beds dominate the exposure. They are best seen in the central portion of the pit where they dip uniformly to the southwest. For the most part the foreset beds are composed of fine sand to gravel and dip to the SW (230°). However, they contain occasional beds of well rounded to subrounded cobbles and/or pebbles. Interbedded sand, silt, and clay of the Presumpscot formation overlie the foreset beds in the southern, distal portion of the pit. Small-scale syndepositional faults and dewatering structures are apparent in fresh pit faces. Worm burrows are present along bed-

ding planes, but no other fossils, such as shells, have been found. Best exposed in the northern portion of the pit, a reworked sandy deposit overlies the foreset beds, representing wave reworking of the fan at the marine limit. A massive clast-rich unit uncomformably overlies the sand and reworked beds. It is itself a reworked beach or near-shore deposit formed during the marine regression. Consisting of rounded small to medium sized boulders, incorporated into a matrix of fine sand to gravel, this unit is traceable down the topographic slope of the fan. Although no bedding is visible within the coarse-grained material, pockets of fine-grained material do contain cross-bedding. A massive, uniformly bedded sand, also associated with the marine regression, caps the deposit.

Excavation and slump obscure much of a fan ($Pmfb_3$) located one-half mile southeast of the Cushing Road fan. Remnant material -- numerous, large, angular boulders, diamicton and deformed material, layered gravel, sand, silt, and clay -- indicate that this deposit was formed at the ice margin. Unique to this deposit is its association with an esker, the feeder system of the fan. The esker is inferred based on surface topography and constituent material. Although no exposures into the esker were found, augering to a depth of one foot indicated that the surface material was composed of coarse sand and gravel, with incorporated rounded pebbles and cobbles. Reworked sands and gravels associated with the marine regression lie above the ice-marginal deposits.

Presumpscot Formation (Unit Pp)

Thick deposits of glacimarine mud, known as the Presumpscot Formation (Bloom, 1960; 1963), underlie virtually all of the low-relief areas of the quadrangle. Surface and subsurface data indicate that the Presumpscot directly overlies bedrock, till, fans, and end moraines and can be interbedded with subaqueous fans and end moraines. Presumpscot mud can be either massive or layered, may contain outsized clasts, and is locally fossiliferous. Unweathered deposits are blue-gray in color, but alter to olive-gray with weathering. The silts and clays of this unit were deposited into the ocean by glacifluvial processes. Coarser material was deposited as submarine fans, with the finer silt and clay being transported farther from the ice margin.

Relatively thick deposits of the Presumpscot Formation are found within the quadrangle. Approximately 25 ft of these sediments are exposed within the Blackstone gravel pit on Dyer Road (Pempc). Streamcuts along Chandler Brook and East Branch often expose 15-20 ft of Presumpscot Formation, while subsurface borings at the Central Maine Power substation west of North Pownal indicate thicknesses to 50 feet. Greater thickness are likely, for well drillers' logs indicate overburden thicknesses in excess of 140 ft southwest of Marston Hill in an area which is most likely Presumpscot Formation.

Fossil shells occur within the Presumpscot Formation in the Blackstone gravel pit east of Pownal Center (Pempc). They have also been noted in drillers' logs taken during construction of an addition to Pownal School, located on Elmwood Road.

Nearshore Deposits (Unit Pmn)

Subsequent to Presumpscot Formation deposition, surficial materials below the upper marine limit were subjected to wave activity associated with the marine recession. Thus, surface material at this time was reworked. The resulting deposit is a thin to thick blanket of silty to gravelly sand mapped as a nearshore deposit. Although formed by wave activity in shallow water and along ancient shorelines, these deposits are not associated with any definite beach morphology and thus are not mapped as beaches.

Many large areas of low relief are covered with this recessional sand. For the most part these areas are located in the eastern and southern portions of the North Pownal quadrangle. A borrow pit on Goddard Road exposes approximately 12 ft of layered silt/silty sand and sand. Many roadcuts expose less than 5 ft of the sand above Presumpscot mud.

Eolian Deposits (Unit Qe)

As sea level continued to fall, fine sand of the Presumpscot Formation and that of the nearshore material were subaerially exposed and locally reworked into eolian deposits. These deposits were identified based on topographic expression, composition of constituent material, lack of internal structure, and previous work (Smith and Thompson, 1986). Eolian sand is mapped along the northeast corner of Tryon Mtn., 1.5 mi east of North Pownal, northeast of the Androscoggin River, and west of the intersection of Dyer and Verrill Roads.

Holocene Deposits

Wetlands (Unit Hw) constitute most of the Holocene deposits within the North Pownal quadrangle, except for deposits of stream alluvium located along the Androscoggin River and a few other streams. The location of the wetland deposits is based upon the U.S. Department of the Interior National Wetlands Inventory draft map (1:24,000) of the North Pownal quadrangle, and field mapping.

Wetlands occur throughout the North Pownal quadrangle. Many of the wetlands are narrow bands developed along streams whose beds have eroded to lie within the Presumpscot Formation. Three large wetland areas are found within the quadrangle. The first is adjacent to the northern portion of Runaround Pond. A second large wetland area lies east of Route 9 and north of Rabbit Road. The third area is bisected by Poland Range Road, in the central portion of the quadrangle. All three sizable wetlands are developed on large low-relief areas which were once ocean bottom. They are underlain by Presumpscot muds and are formed by its poor drainage properties.

GLACIAL AND POSTGLACIAL HISTORY

The glacial and postglacial history of the North Pownal quadrangle begins with deposits laid down during the most recent glacial advance, and subsequent retreat, within Maine. Striation trends, 120-200°, indicate that the ice was advancing from the north-northwest. One half of the striations trend between 170-180°, indicating a southerly component to the ice flow. A smaller group of striations, located in the north-central portion of the quadrangle, cluster between 140-145°. Many small moraines are oriented NE-SW in this portion of the quadrangle, supporting a direction of ice flow to the southeast as shown by the striations. Southwest of Lauraffe Ledge, a striation measurement of 200° was recorded along a bedrock ridge which parallels the trend of the striation. Northeast of the no-longer operational Pownal airport, two striation trends were measured, 172° and 185°, at the same location. However, the age relationship between the two is indeterminant.

Trends of moraines range from E-W to ENE-WSW, to NE-SW. The NE-SW-trending moraines are located in the north-central portion of the quadrangle, as previously mentioned. ENE-WSW and E-W-trending moraines are found throughout the quadrangle. Their orientations suggest ice flow to the S-SE during their deposition. At some point a change in the ice-flow direction occurred, either from S to SE or SE to S; the temporal relationship of this change can only be inferred.

The east-central portion of the quadrangle contains several large glacial marine fans, both mapped and inferred based on morphology and surficial material. These fans form stratified moraines trending E-W and WNW-ESE. A WNW-ESE trend indicates ice flow from the north-northeast. This may have been a local phenomenon occurring as the ice margin was receding.

Several drumlins are found within the North Pownal quadrangle. Bowie Hill and the hill adjacent to Harmony Grove Cemetery have both been drumlinized. They are both composed of glacially streamlined surficial material. Three other streamlined hills consist of glacially sculpted bedrock: Libby Hill, a hill north of North Pownal, and a hill along the northern border of the quadrangle.

Ice recession from the Gulf of Maine probably began sometime around 17,000 yr B.P., with the ice retreating to near the North Pownal area by approximately 14,000 yr B.P. Weddle and others (1993) reported an occurrence of *Portlandia arctica* shells associated with an end moraine in the Lisbon Falls South quadrangle (just east of the North Pownal quadrangle). These shells were radiocarbon dated at 14,045 95 yr B.P. (AA10164), thus establishing the approximate time of deglaciation in the area. Within the North Pownal quadrangle itself, *Mytilus edulis* shells were found in the Knight Pit, located a short distance east of Pownal Center. These shells probably lived in shallow marine waters, indicating a falling relative sea level. They were radiocarbon dated at 13,300 50 yr B.P. (0S-4419; Weddle and Retelle, 1995).

Due to isostatic crustal depression, the ocean remained in contact with the ice margin along coastal Maine during deglaciation. Sea level, at the time of deglaciation in the study area, was approximately 300-310 feet above modern sea level (Thompson and others, 1989). Thus as the ice retreated through the North Pownal quadrangle most of the land area was flooded by the sea. Several isolated places remained above the sea as islands: Bradbury Mtn. and Tryon Mtn., a promontory east of Bradbury Mtn., Marston Hill, Pisgah Hill, and Lauraffe Ledge. These areas, as well as several other bedrock knobs, pinned the ice during its retreat, allowing deposition of stratified end moraines and subaqueous fan complexes. In general the ice-marginal deposits are younger from south to north and from east to west.

The oldest ice-marginal position identified is located directly east of Pownal Center (Pempc). Here, fine to coarse interbedded sands are interpreted to be subaqueous fan material. Deformation of the fan sediments and interbedded diamicton suggest that the fan was formed at the ice margin. This ice margin is traced to the west on the basis of geomorphology. The Pempc moraine was most likely formed as ice was pinned upon Bradbury Mtn. and a mountain directly north of it.

Highlands located west of West Pownal also provided a pinning point for the retreating ice. The West Pownal moraine (Pmewp) at West Pownal delineates the ice margin in this area. Topographically, the West Pownal moraine cannot be linked to the ice margin mapped at Pownal Center.

As ice pulled away from the high area associated with Bradbury Mtn., a succession of subaqueous fan deposits marked its northward retreat in the eastern section of the quadrangle. The first two ice-marginal positions ($Pmfb_1$ and $Pmfb_2$) are inferred solely upon geomorphology. Deposits of the succeeding ice marginal positions, $Pmfb_3$ and Pmfcr, contain exposures of fan deposits consisting of bedded sand and gravel. During fan deposition the ice was most likely anchored successively on bedrock in North Pownal and upon a bedrock knob east of Harmony Grove Cemetery. As the ice retreated, it left smaller deposits such as $Pmfrr_1$ and $Pmfrr_2$. Following continued glacier retreat, a well-defined ice margin was developed as evidenced by a series of submarine fans ($Pmfrr_3$, $Pmfwd_1$, $Pmfwd_2$, and $Pmfwd_3$). These deposits mark the largest and most obvious fan-moraine system in the quadrangle. This ice-marginal position (Weddle and others, 1993) can be mapped four miles to the east into the Lisbon Falls South quadrangle.

Numerous small moraines are located north of the North Pownal bedrock high. They represent small, possibly yearly, fluctuations of the retreating ice margin. The deposits are oldest to the southeast and become progressively younger to the northwest. Their age relationship with respect to the larger moraines located to the east is unknown. Assuming that the deposits to the south are oldest, then the deposition of the eastern moraines occurred first. At first the ice may still have been pinned at North Pownal. However as $Pmfwd_1$, $Pmfwd_2$, and $Pmfrr_3$ were being deposited North Pownal may well have been ice-free. The orien-

tation of the deposits, northeast-southwest for the moraines north of North Pownal, and northwest-southeast for the eastern ice margins, suggests that the retreat of the ice sheet may have been controlled by the underlying bedrock topography. To the west, the northeast-southwest trend of the bedrock ridges most likely controlled the orientation of the retreating ice margin; hence morainal deposits within the area are oriented northeast-southwest. The prominent bedrock topography may also serve to mask ice marginal deposits in this region as very few moraines are mapped in the western portion of the area.

As previously mentioned, the glacier margin was pinned at several places in the West Durham area in the eastern section of the quadrangle. East of West Durham, however, the ice margin was unconstrained for several miles. This may have permitted a change in the shape of the ice margin such that the eastern deposits are oriented WNW-ESE in the North Pownal quadrangle. Such may have been the case if this area was on the west end of a big ice lobe that protruded to the south.

As the ice retreated to the north and isostatic adjustment overtook eustatic sea level changes, the land began to rebound and the ocean receded. Modern sea level was reached at approximately 11,000 yr B.P. (Belknap and others, 1987). As sea level fell, material from existing glacial deposits was reworked and redistributed as the deposits came through wave base and near-shore areas were covered with a veneer of the reworked material. Much of the eastern section of the quadrangle is covered with this material.

Relative sea level continued to fall, reaching its lowest stand at approximately 9,000 yr B.P. (Belknap and others, 1987). With falling sea level, large areas of fine glacial sediments were exposed. Some of this material was redistributed as windblown deposits, as mapped in several small areas of the quadrangle. Extensive windblown sand deposits occur to the south in the Yarmouth quadrangle, such as the Desert of Maine.

With the continued fall of sea level, major streams downcut their beds to below current base level. Then as sea level rose to its current level, aggradation occurred within the river channels. Fresh-water wetlands formed after deglaciation, and soil horizons began to develop.

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