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

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INTRODUCTION

The surficial geology of the Raymond 7.5-minute quadrangle in southwestern Maine was mapped during 1996 through 1997 as part of the STATEMAP program of the Maine Geological Survey and the U.S. Geological Survey. This report is associated with two maps: a surficial geologic map (Retelle, 1997; which shows landforms and geologic map units interpreted from the underlying surficial materials) and a materials map (Retelle, 1998). which shows thickness and textural composition of sediments in the map area.

Location

The Raymond 7.5-minute quadrangle (43°52'30" to 44° 00' north latitude and 70°22'30" to 70°30' west longitude) is located in the transition between the coastal lowland zone and the foothills of the White Mountains in southwestern Maine, in Cumberland and Androscoggin Counties. The map area includes portions of the towns of Raymond, Casco, and Gray, as well as small portions of Windham, New Gloucester, and Poland. Much of the map area is rural to rural residential and much of the land is utilized for agriculture. As a significant portion of the quadrangle is covered by lakes and ponds, this region has long been a major recreation area. Seasonal and year-round residences surround much of the shorelines of the waterbodies.

The topography of the quadrangle is strongly influenced by bedrock. Total relief in the area is approximately 776 feet, ranging from the summit of Rattlesnake Mountain (1016 feet asl) to Sebago Lake (267 feet asl). The two major accumulations of waterlaid glacial and postglacial deposits lie in valleys situated between prominent north-south trending bedrock ridges. In the western half of the quadrangle, the Crescent Lake, Panther Pond, and Sebago Lake lowland is bounded to the west by Rattlesnake Mountain and Brown Hill. A long ridge complex comprised of (north to south) Tenny Hill, Pismire Mountain, Raymond Hill, Tarklin Hill, and Mount Hunger separates the western lowland from the Little Sebago Lake-Raymond Pond lowland to the east. Several peaks along the crest of the ridge reach 800 feet in elevation. The eastern sector of the quadrangle is also dominated by bedrock topography in which several valleys lead to the broader lowland valleys in the adjacent Gray quadrangle.

In general, in the lowlands, surficial materials including sand, silt, clay, and till commonly blanket the bedrock topography; in some areas the surficial blanket is thin and bedrock outcrops are more common.

Bedrock Geology

The majority of the study area lies within the Carboniferous-age Sebago batholith (Osberg and others, 1985; Creasy, 1996). While there are some variations in composition of the rocks within the Sebago pluton (Creasy, 1993) most of the granite that comprises the pluton is gray, foliated, medium-grained and muscovite bearing. In addition, a younger intrusive complex consisting of Jurassic-age syenite and trachyte forms the Rattlesnake Mountain highland in the northwestern sector of the quadrangle (Creasy, 1993). The igneous rocks and minor occurrences of metasedimentary rocks are intruded by Mesozoic-age basaltic dikes (Creasy, 1996).

Methods Used in this Study

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

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

Well and boring logs provided valuable subsurface data, although this data is sparse in some areas and concentrated in other locations. Well logs provided by the Maine Geological Survey indicated the depth to bedrock.

SURFICIAL DEPOSITS

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

Till (map unit Pt)

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

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

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

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

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

End Moraines (map unit Pem)

One end moraine complex was mapped in the field area in the lower Hayden Brook valley east of Panther Run, the outlet of Panther Pond in Raymond. End moraines are interpreted as linear ridges of varying composition deposited parallel to, and along, the former front of the retreating glacier margin. In this study, end moraines were identified in the field by their linear morphology and also by air photograph analysis (Smith, 1980, 1982) followed by field checking. In general, moraines vary in height, length, and spatial distribution across the region. The small end moraines in this quadrangle are composed of sandy till ridges approximately 20 feet high with individual segments approximately 100 feet long. The moraines were likely deposited by the oscillation of the retreating lobate ice margin in the Panther Pond lowland. However, distinct moraine ridges are usually difficult to distinguish from ground level in the field because the ridges are usually draped by a veneer of fine-grained glacial-marine sediment.

Stratified Drift Deposits

The lowland areas and valleys of the quadrangle were depositional sites for abundant quantities of sediment that originated from the meltwater system of the retreating Laurentide Ice Sheet. The deposits in the Raymond quadrangle reflect a complex set of ice-marginal and proglacial environments reflecting a distinct transition from retreat in a glacial-marine setting, as is typical of the coastal lowland region, to a terrestrial upland setting. As ice retreated above the marine limit in the Raymond quadrangle, ice marginal lakes were impounded in the valleys dammed by stratified drift accumulations to the south and the retreating ice margin to the north.

Sediment derived from subglacial and englacial drainage is delivered to the proglacial environment through ice-walled tunnels and channels to ice-contact glacial-marine fans and deltas. These features are commonly morphologically and stratigraphically complex. In modern tidewater glacier settings, fans occur at the glacier grounding lines (bottom edges of the ice margin) where meltwater streams enter the sea and deposit sediment on the seafloor, and hence are termed grounding line fans (Powell, 1990). Where an ice margin may halt for a period of time at a valley constriction or a subglacial bedrock topographic high (termed a pinning point) and abundant sediment is delivered to the proglacial zone, fans may aggrade towards the surface of the sea and eventually become flat-topped deltas (map units $Pmdi_1$, $Pmdi_2$; cf. Powell, 1990).

Eskers (map unit Pge) - Linear ridges of poorly sorted sand and gravel, oriented roughly parallel to former ice flow and perpendicular to end moraines were mapped in close association with other ice-contact stratified drift and deltaic deposits. Below the marine limit, esker ridges may be found in two general associations: (1) a coarse bouldery gravel core in the fan complexes and (2) as feeder tails on the marine fans or deltas (cf. Thompson and others, 1989; Crossen, 1991). Sharpe (1987) refers to deposits in a similar glacial-marine setting in the Ottawa area as **conduit deposits**, formed by englacial or subglacial streams that delivered sediments to the submarine fans. Eskers may be found directly overlying bedrock or till and are generally associated with other ice-contact or collapsed topography. In eastern Maine, Ashley and others (1991) distinguish between *ice tunnel deposits* which are comprised of sediments deposited in the subglacial fluvial environment and *eskers* which they define as sinuous ridges of stratified and unstratified material oriented subparallel to ice flow.

In the study area there are several excellent examples of eskers. Along the eastern margin of the Browns Point delta in Raymond, ice-contact topography grades southward along the valley wall to feed deltaic deposits in the North Windham quadrangle. Several distinct esker ridges in this complex are composed of coarse boulder and cobble gravel. Other examples include several short esker segments in the ice-contact topography deposited along the west shores of Panther Pond and Crescent Lake. Sediments in the eskers are commonly faulted and slumped, the result of melting of supporting ice.

Ice-Contact Stratified Drift (map units $Plpp_1$ to $Plpp_3$, Plc_1 to Plc_6, $Plls_1$ to $Plls_5$, $Pgif_1$ to $Pgif_7$, $Pgin_1$ and $Pgin_2$) - Ice-contact stratified drift deposits are designated in two ways on the geologic map for the Raymond quadrangle. Where the ice-contact deposits are related morphologically and temporally to ice-marginal positions graded to distinct base levels (such as a lacustrine or marine water plane or a bedrock threshold) they are mapped as individual morphosequences (cf. Koteff and Pessl, 1981). The relative ages of the morphosequences that comprise the bulk of the stratified glacially derived sediments in the Panther Pond-Crescent Lake lowland and the Little Sebago Lake-Raymond Pond lowland are shown in Figure 1. The morphosequences generally consist of ice-contact landforms such as eskers, ice channel fillings, kames, kame terraces, and kame plains which are generally not mapped as separate landforms.

Where ice-contact stratified drift deposits form neither an association with a former ice margin nor can be related to a former lacustrine or marine water plane in the quadrangle the deposits are designated Pgi.

Glacial-Marine Deltas (map unit Pmdi) - Glacial-marine deltas formed at the margin of the late-glacial sea where sand and gravel aggraded on the sea floor and/or prograded seaward from a meltwater sediment source such as an esker conduit or an outwash plain (cf. Thompson and others, 1989). These deposits are generally flat-topped in plan view, and tabular to wedge-shaped in cross section. Three distinct sedimentary units typify the glacial-marine deltas including coarse topset beds with fluvial structures; seaward-dipping foreset beds (sand and gravel) and finer-grained bottomset beds that intertongue with the foreset beds. In a vertical sequence, the seaward progradation of the delta causes a coarsening-upward sequence capped by the fluvial topset beds.

A fine example of a glacial-marine delta in the map area is the Browns Point delta, located on the northeast shore of Jordan Bay of Sebago Lake. This is an ice-contact delta, bordered in the north by collapsed ice-contact landforms comprised of coarse gravel and sand. A short esker segment along Panther Run likely fed the delta (map unit Pge) and grades into the northeast corner of the delta. The north side of the delta is an ice-contact slope. The flat modern surface that was the fluvial topset plain of the ice-contact delta is at roughly 315-320 feet elevation, and the surveyed elevation of a probable topset/foreset contact seen in a gravel pit is 311 feet (W. B. Thompson, personal communication, 1997). These elevations are comparable to a delta on the west shore of Jordan Bay from which Thompson and others (1989) measured a topset-foreset contact of 312 feet asl, as an approximation of sea level in this area.

The Browns Point delta has been extensively mined in several areas, although at present exposures in the delta are limited. Coarse cobble to boulder gravel topset beds with fluvial channel structures and south-trending trough and planar cross-stratification are exposed in several locations in pits in the northern part of this delta. The cobble-gravel topset beds overlie finer-grained gravelly, sandy foreset beds that dip southward. The distal foreset beds dip southward and are composed of finer sandy material exposed in several abandoned pits at the southern end of the flat delta top. These beds grade southward into finer-grained silt and clay of the former sea floor.

Fine-Grained Marine Mud (map unit Pp)

The fine-grained deposits that blanket the low-lying terrain of the coastal lowland in Maine were originally defined by Bloom (1963) as the "glacial-marine clay" and named the **Presumpscot Formation.** The unit is generally found to be rather complex, consisting of a fining-upward sequence of sand, silt, and clay with marine mollusc fossils and dropstones common. The deposit forms a continuum with the esker-submarine fan systems that delivered glacial sediments to the sea floor, hence there is a complex relationship between the coarse fan sand and gravel and the finer sand, silt, and clay deposited predominantly by suspension settling distal to, or adjacent to, meltwater point sources.

The fine-grained unit is commonly found in varying shades of gray to olive gray when weathered. In some cases the clay has been referred to as "the blue clay" from its bright bluish-gray unweathered appearance. Grain-size analysis of the fine unit commonly indicates that the "clay" contains a high proportion of silt and a smaller proportion of fine sand. Large vertical exposures of the fine-grained unit are noticeably absent in the field area al-

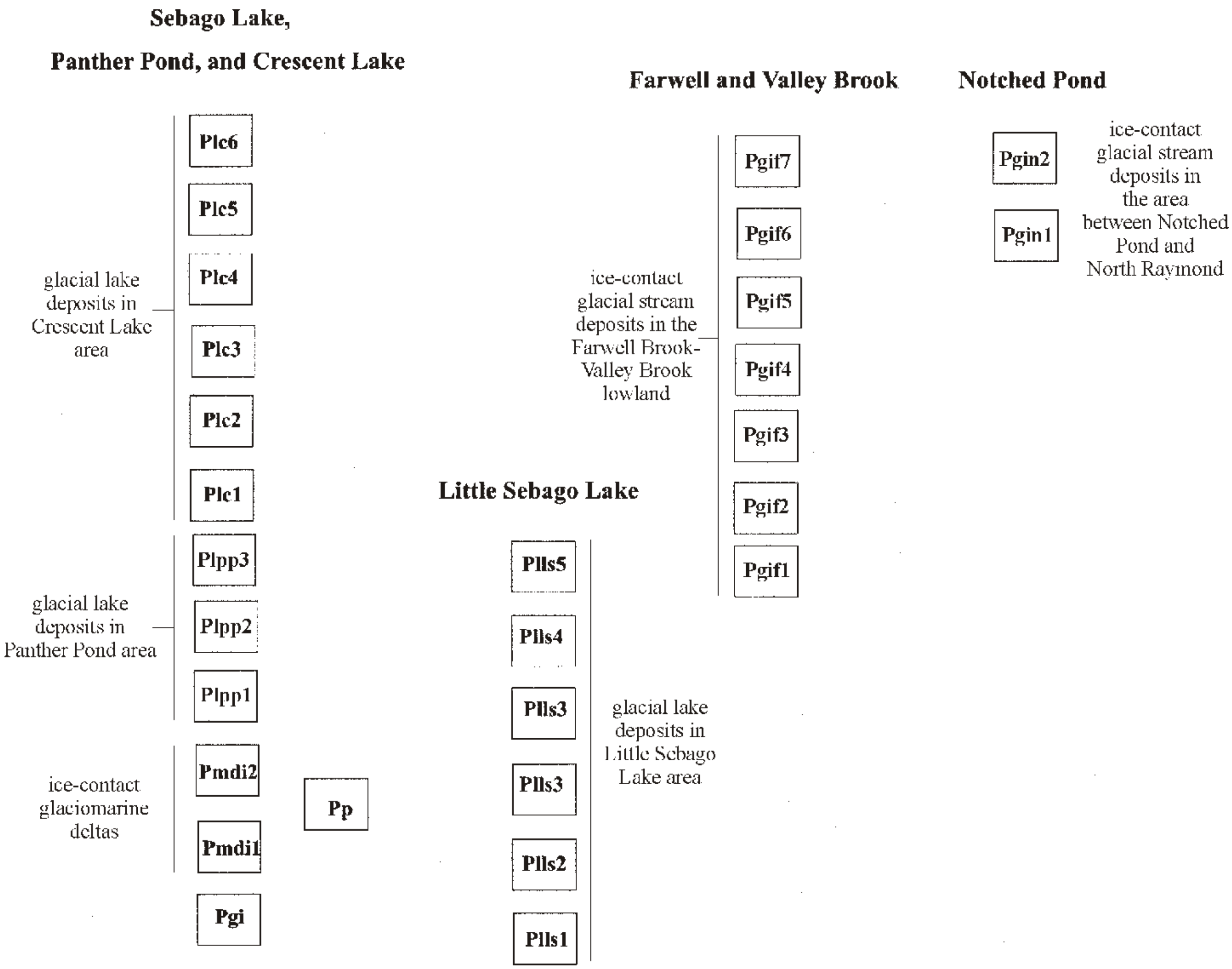

Figure 1. Relative age designations for morphosequences in the Raymond quadrangle.

though shallow exposures in stream banks and road cuts were common. In addition, several exposures of the fine-grained unit were seen in the distal portions of fans, overlying the sandy foreset beds.

The one significant deposit of marine mud in the quadrangle was located in the low-lying flats north of the Browns Point delta when several trenches were dug for sewer service.

Lake Shore Deposits (map unit Hls)

Generally coarse-grained deposits were formed by nearshore processes (predominantly wave reworking) through the Holocene history of deposition in the various lakes in the quadrangle. In Little Sebago Lake accumulation of nearshore sand and silt are found below a distinctive former bouldery shoreline of the lake. Although the exact age of the higher shoreline is unknown it may relate to one of several catastrophic drainages of Little Sebago Lake caused by human alteration of the outlet stream in the early and mid-1800's (Thompson and others, 1995; Thompson, personal communication, 1997)

Alluvium and Stream Terraces (map units Ha and Hst)

Alluvium and stream terraces, presumably of Holocene age, are mapped along many of the present-day stream courses in the field area. Poorly sorted silty sand and debris such as tree limbs and other vegetation are commonly deposited on terraces and low-lying areas bordering the modern stream during periods of high water. This process is important during spring melt and following periods of heavy rain. In several valleys distinctive terraces are preserved due to stream downcutting in the fine-grained surface material. Examples of stream terraces are located along Tenny River and Panther Run, the outlet streams to Crescent Lake and Panther Pond, respectively.

Presumably, terracing and deposition of alluvial sediment commenced as sea level fell from the marine limit and ice-marginal lakes were drained and modern drainage was superimposed on the former landscape.

Wetlands (map unit Hws)

Several extensive and numerous small wetlands were mapped in the quadrangle. The largest deposit mapped in the area is referred to as Morgan Meadow, a broad extensive wetland located in the north-central part of the quadrangle. This area is situated on top of the poorly-drained fine-grained marine sediments. Other locally less extensive deposits are situated along poorly drained floodplains of the various streams in the area and in localized depressions in the bedrock and till topography.

GLACIAL AND POSTGLACIAL HISTORY

Although numerous authors have demonstrated that northern New England (cf. Koteff and Pessl, 1985) and specifically Maine (Borns and Calkin, 1977; Thompson and Borns, 1985a) have been subjected to multiple glaciation, primary evidence for multiple glaciation (multiple drift sheets and crossing striation sets) were not found in the field area. The field evidence seen in the Raymond quadrangle suggests that the area has been subjected only to the latest, or late Wisconsinan, advance and retreat of the Laurentide Ice Sheet. The limited exposures of till in the area do not show advanced weathering typical of older ice advances (Weddle and others, 1989) and hence the till is assigned a late Wisconsinan age. Till was probably deposited subglacially during late stages of ice advance or during the retreat phase of the late Wisconsinan ice.

During the last advance of the ice sheet and also during early stages of retreat, ice flowed across the region from roughly north-northwest to south-southeast. Because of the moderate to high relief , especially in the northwestern area of the quadrangle, some divergence likely occurred around some of the larger bedrock obstructions such as Rattlesnake Mountain. The average azimuth of ice flow seen in striae and grooves is 160^{o}. Streamlined till-covered hills and drumlinoid forms follow the same trend as the striae. Both drumlin and striation orientations are consistent with regional flow patterns as suggested on the surficial geological map of Maine (Thompson and Borns, 1985b).

During the maximum of the last glaciation, the Laurentide Ice Sheet extended beyond the present Maine coastline onto the continental shelf and probably began to recede from that position around 17,000 to 15,000 years ago (Tucholke and Hollister, 1973). Stuiver and Borns (1975) estimate that the ice margin reached the present coastline around 13,500 yrs B.P. However, recent radiocarbon age estimates obtained on *Portlandia arctica* shells collected in a collaborative research program by the Maine Geological Survey and University of Maine (Weddle and others, 1993) suggest that deglaciation of the southwest coast may have occurred as early as 14,000 to 14,800 yrs B.P. During the retreat, the ice margin was in contact with the sea, forming a tidewater glacier margin. In this marine environment, retreat was probably carried out by extensive calving in addition to thinning by melting, however the occurrence of large and small moraines and glaciotectonic features suggests that retreat was not continuous. Instead, minor readvances interrupted the general pattern of retreat. Ice retreat was also halted temporarily where the grounded ice margin was pinned against topographic obstructions such as narrows in valleys and subglacial bedrock highs.

Marine submergence of the coastal zone occurred from the time of deglaciation until the ice margin had receded to the interior of Maine and isostatic rebound caused sea level to retreat to the continental shelf (Schnitker, 1974; Belknap and others, 1986). Elevations of geomorphic features such as ice-contact deltas (surveyed topset-foreset contacts) and raised beaches (Thompson and others, 1989) are roughly 310 feet asl in the field area thus providing an estimate of the upper limit of marine submergence (marine limit). In the adjacent Naples 7.5-minute quadrangle to the west, Thompson and others (1989) measured the topset-foreset contact in the delta on Raymond Neck at 312 feet asl. Thus, during the maximum of the marine inundation the southwestern portion of the quadrangle was submerged below sea level.

After ice retreated from the Browns Point delta (**Pmdi$_1$**), the next significant ice-marginal position (**Pmdi$_2$**) was developed at the present site of the town of Raymond in the narrowed valley of Panther Run. Here, the retreating ice encountered narrowing of the valley and shallowing of water depth. Although at present no deltaic structures are exposed in the landform, the elevation (approximately 310 feet) and composition (gravel and sand) of the remnants of this deposit indicate that it was likely the last delta of true marine character deposited in this valley. In addition, blue-gray clay, some of which is rhythmically laminated and similar to exposures at many locations in the coastal lowland zone (cf. Bloom, 1963), was located in several trench sections in the low area in front of this landform.

Subsequent progressive ice retreat is recorded by ice-contact stratified drift deposits in the main valleys that trend north-south through the field area (Figure 2). Although the surfaces of the ice-contact landforms rise steadily in elevation from south to north, indicative of isostatic tilting towards the thicker ice load in the interior (cf. Thompson and others, 1989), a more complex history of development and drainage of successive ice-dammed lakes occurred in the valleys. North of the delta at Panther Run (Pmdi$_2$), the receding ice margin was most likely in contact with fresh water. The development of proglacial lakes occurred as ice retreated from the Raymond delta, which acted as a drift dam in the narrow valley, and meltwater and sediment accumulated between the drift dam and the retreating ice margin to the north. Morphosequences **Plpp$_1$** through **Plpp$_3$** represent deposits graded to a glacial lake in the Panther Pond Basin. The flat

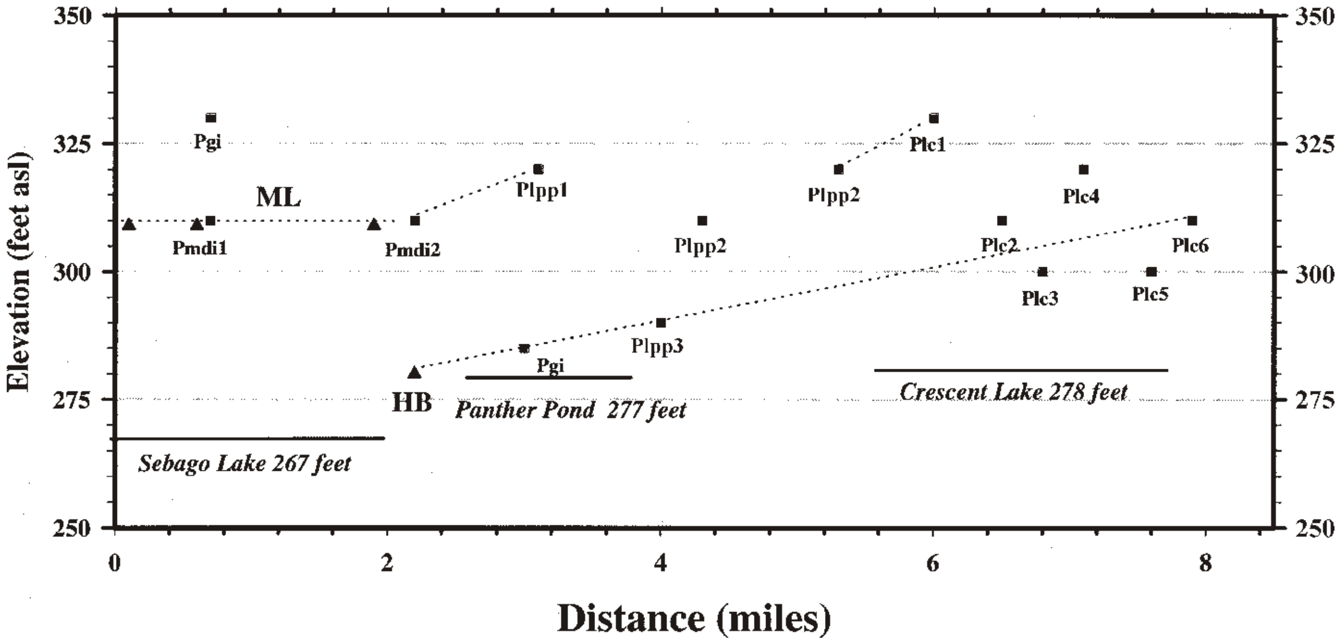

Figure 2. Plot of morphosequence elevation and distance from the southern border of the quadrangle (plotted parallel to direction of ice retreat in the valleys) in the Sebago Lake-Panther Pond-Crescent Lake valley. Triangles indicate base levels to which morphosequences are graded. Squares represent the elevation of the uppermost flat surface of deltas and ice-contact terraces graded to base levels. Dotted lines indicate shorelines tilted by postglacial isostatic rebound. Modern lake elevations are shown by solid lines.

upper surface (320 feet) of the gravelly sandy deposit at Bettys Neck ($Plpp_1$) is most likely a delta built into a highstand of the lake held in by the ice-contact (north) margin of the Panther Run delta at 310 feet. Younger deposits along the west and north shore of Panther Pond ($Plpp_2$, $Plpp_3$, and **Pgi**) are most likely graded to lower, or falling levels of the lake as the outlet channel was incised into the Panther Run delta.

Another substantial gravel and sand body ($Plpp_2$) was deposited in the valley of Tenny River in the constriction between the north end of Panther Pond and the south end of Crescent Lake. Although the surface of this sandy deposit is highly modified by subsequent fluvial erosion, the ice-contact nature of the northern end and remnants of a flat-topped surface at approximately 320 feet indicate that the landform was probably built as a delta into a water body in the Panther Pond basin. Paleocurrents from foreset beds in the Town of Raymond sand and gravel pit north of Plains Road indicate meltwater flow from the northeast to the southwest from the ice margin in the narrow valley. Near the south end of the landform, on the grounds of Camp Hinds, sandy sediments overlie fine silty sands that were likely bottomset beds in the lake. The Tenny River delta ($Plpp_2$), in turn, acted as a dam for a short-lived glacial lake that developed as ice retreated to the triangular flat-topped landform (**Plc_1**) along the west shore of Crescent Lake. It appears that some time shortly after ice retreat from this position, downcutting of the delta $Plpp_2$ allowed deposits **Plc_2** to **Plc_6** to be graded to a lower outlet, perhaps a threshold in the falling glacial Crescent Lake or the outlet of Panther Pond, which today are separated by only one foot in elevation.

The history of ice retreat in the valleys to the east is similarly complex. In the Little Sebago Lake-Raymond Pond valley, Thompson and others (1989) placed the boundary of the inland extent of the synglacial sea in the middle of Little Sebago Lake, a problem which is currently being evaluated in the Sebago Lake area by R. Johnston (cf. Thompson and others, 1995) and in the bordering Naples quadrangle (Hildreth, 1997a,b). In this report, it is assumed that in the Raymond quadrangle, Little Sebago Lake was not drowned by marine waters and that ice-contact deposits accumulating in the valley (**$Plls_1$** to **$Plls_5$**) were graded to a lacustrine water plane dammed by the massive drift accumulation of the North Windham delta at the south end of the basin (on the adjacent North Windham quadrangle, Bolduc and others, 1999a,b). It is also possible that a temporary glacial lake was dammed in the present upper bay of Little Sebago Lake by the closing of the Upper Narrows by progradation of the fluvio- deltaic deposits originating in Farwell Brook valley. These deposits include a series of shingled fluvial ice-contact morphosequences (**$Pgif_1$** to **$Pgif_7$**) in the Farwell Brook and Valley Brook lowlands that fed meltwater and sediment southward until the ice retreated over the divide into Raymond Pond.

In the northeastern sector of the quadrangle coarse-grained ice-contact stratified drift (**$Pgin_1$**, **$Pgin_2$**) was deposited in the valley north of Notched Pond by southeastward-flowing meltwater streams that provided sediment to a portion of the large

Gray delta though a gap in the western hills of the Gray quadrangle (Weddle, 1997a,b). These deposits include numerous narrow ridges of poorly sorted, but coarse-grained gravel that thinly overlie till and bedrock. The thin underlying till deposits appear to be the source of the ice-contact material as the downwasting ice margin stagnated in the narrowing bedrock valley.

With the field area exposed from the ice, sea level receded and lakes established themselves at stable levels as postglacial drainage developed on the landscape. In poorly drained areas, swamps and wetlands were formed. Glacial and postglacial deposits continue to be reworked by modern alluvial processes.

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