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INTRODUCTION

The Minot 7.5-minute quadrangle has an area of about 133 km^2 (52 mi^2). It is located in southwestern Maine, within the Seaboard Lowland physiographic province, about 42 km (26 mi) northwest of Portland. Altitudes range from 48 m (160 ft), which is the level of the Royal River where it flows south near the southeast edge of the quadrangle, to over 207 m (690 ft) at the crest of a southeast-trending ridge on the north edge of the quadrangle between the drainages of Cool and Morgan Brooks. Much of the western and southern part of the map area is underlain by granitic bedrock of the Sebago pluton. The Sebago pluton is light-gray to pink, medium-grained, non- to slightly foliated, biotite-muscovite granite. The granite is intruded in places by Mesozoic pegmatite dikes and basalt or diabase dikes. In some places in the quadrangle, there are exposures of roof pendants of metasedimentary rocks that the Sebago pluton intruded during the Mississippian Period about 354 million years ago (Hussey, 1985). Rocks exposed in the north and eastern part of the quadrangle include folded metasedimentary rocks of the Patch Mountain and limestone members of the Silurian Sangerville Formation, which are intruded in places by small stocks of Devonian granite (Osberg and others, 1985).

Ridges in the Minot quadrangle commonly were shaped by glacial ice flowing south-southeast and have been elongated in that direction. The topography in the study area is also controlled partly by jointing in the Sebago pluton and folding in the Silurian metasedimentary rocks. Major stream drainage in the quadrangle includes the northerly drainage of the Range Ponds and Worthley Brook into the Little Androscoggin River. The Little Androscoggin flows southeastward through the northern part of the quadrangle and is joined by the minor drainages of Cool, Morgan, and Indian Brooks from the north and Davis Brook from the south. Finally, Taylor Brook, which drains Taylor Pond, joins the Little Androscoggin east of the quadrangle, shortly before it meets the Androscoggin River in the cities of Auburn and Lewiston. The Royal River and its tributaries drain the southeastern part of the quadrangle; its southernmost headwaters drain the area just south of Bald Hill in New Gloucester, flowing southward into the northern part of the Gray quadrangle for a short distance, thence eastward and then northward, back into the Minot quadrangle, then eastward and finally southward again into the Gray quadrangle near the eastern edge of the quadrangle. Named tributaries of the Royal River in the Minot quadrangle are Moose and Fosters Brooks.

PREVIOUS AND CURRENT WORK

Early work on the surficial geology in this part of Maine was done generally at a reconnaissance level and at a smaller scale (Hanley, 1959; Prescott, 1968; Thompson and Borns, 1985; Smith and Thompson, 1980). Significant sand and gravel aquifers were mapped by Prescott (1968) and Williams and Lanctot (1987). The soil surveys of Cumberland and Androscoggin Counties (Hedstrom, 1974; McEwen, 1970) facilitated fieldwork. Surficial geologic mapping has been completed at 1:24,000 scale in several adjoining quadrangles, including Raymond (Retelle, 1997), Gray (Weddle, 1997), Mechanic Falls (Hildreth, 2001), Oxford (Thompson, 2001b) and Lake Auburn West (Thompson, 2001a). Additional information on the surficial geology was obtained from an archeology report on a Paleoindian site just south of the runway of the Auburn Airport (Spiess and Wilson, 1987).

GLACIAL HISTORY

Southwestern Maine probably experienced several episodes of glaciation during the Pleistocene Ice Age, but virtually all evidence of previous glaciations in the Minot area was obliterated during the last (late Wisconsinan) episode, when the Laurentide ice sheet advanced from the northwest to a terminal position on the continental shelf.

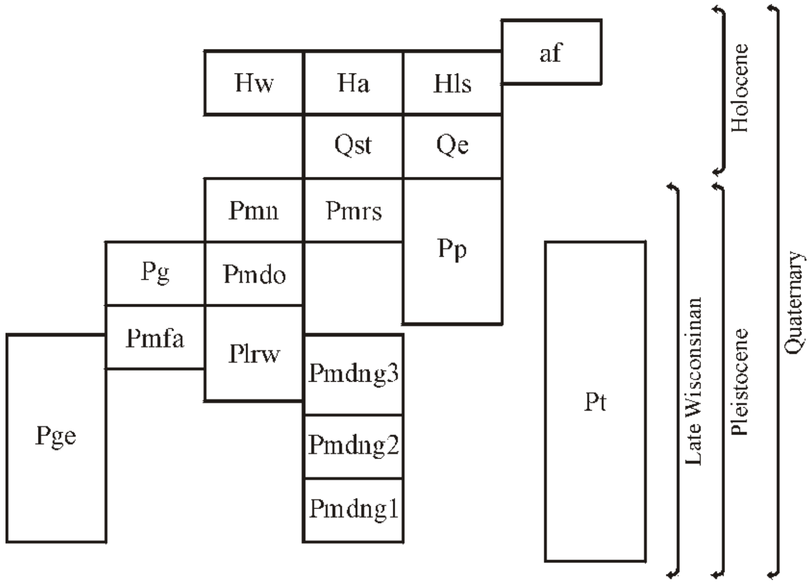

Figure 1. Correlation of map units, Minot quadrangle.

Evidence of glacial erosion within this area is noticeable mainly as south-southeast-trending glacial striations on freshly exposed bedrock surfaces. In the Minot area there are drumlins (such as Peacock, Shaker, Ricker, Bailey, and Harris Hills) and streamlined hills that have bedrock cores; most of these are also elongated in the same south- to southeast-trending direction.

After reaching its terminal position on the continental shelf, the late Wisconsinan ice sheet began to recede between 15,000 and 17,000 years ago. Shells collected from glaciomarine sediments deformed by ice shove in the Freeport area (southeast of Minot) have a radiocarbon age of 14,045 yr B.P. (Weddle and others, 1993). The ice sheet terminus is inferred to have reached the Minot area a short time after that. As the ice sheet melted northward, sea level rose and inundated the entire Maine coastal zone, including much of the area in the Minot quadrangle lying below an elevation of approximately 350 ft, which is the upper limit of marine submergence for this part of Maine. As summarized by Thompson and Borns (1985), the marine submergence reached its maximum inland extent at about 13,000 yr B.P. and regressed from the area somewhat before 11,450 yr B.P. (Smith, 1985; Thompson and Borns, 1985), based on shells that indicate the approximate offlap of the late-Wisconsinan sea at Little Falls, Gorham, about 39 km (23 mi) south of the Minot quadrangle.

GLACIAL AND POSTGLACIAL DEPOSITS

The succession of Pleistocene and Holocene surficial deposits in the Minot area is given in the correlation chart (Figure 1) showing the relative ages of the map units.

Till (unit Pt)

Till occurs throughout the Minot area. Its thickness is variable, as is its composition. The till was deposited from the glacial ice sheet and forms a blanket over the underlying bedrock; it is inferred to underlie younger deposits throughout the area. In most exposures in the Minot area, this till is light olive-gray, sandy, stony, and moderately compact, showing weathering only in the uppermost few feet. Where sandy, the texture reflects its derivation from coarse granitic rocks of the Sebago pluton.

Some drumlins are found in the Minot area, but most hills that are drumlin-shaped (and oriented in the expected direction for drumlins relative to the direction of striations in the area) have bedrock cores that have been plastered with till. Many more of these rock-cored hills exist in the quadrangle than do true drumlins.

Esker deposits (unit Pge)

An esker deposit extends southeastward through the Lower Range Pond and Worthley Pond area. "This segmented ridge of sand and gravel was deposited by meltwater streams flowing south in a tunnel in the bottom of the last ice sheet. In places it is bordered by depressions (kettles) left when masses of glacial ice melted" (Thompson, 2000). Worthley and parts of Lower Range Ponds, as well as many unnamed smaller ponds and swamps along its flanks are examples of kettle holes. "The ridge is part of a branching esker system that can be traced from northwest of the Mahoosuc Range discontinuously south for many miles to a large glaciomarine delta complex in New Gloucester. Whether meltwater flowed simultaneously through this entire tunnel network is debatable, but it is likely that the esker segments formed progressively from south to north as the tunnel became clogged with sediment during deglaciation" (Thompson, 2000). The esker system appears to end just south of the quadrangle border and is inferred to be the main feeder system for the large Sabbathday and New Gloucester delta complex in the Gray quadrangle (Weddle, 1997).

Some exposed segments of the esker are more than 50 ft (15 m) high, but in many places it is more or less buried by adjacent younger outwash deposits. Most subsurface data indicate a maximum depth of less than 70 ft (21 m). Pits contain mostly sand to pebble-cobble gravel, with occasional boulders. The esker is useful as a source of sand and gravel and as a municipal aquifer (Prescott, 1968). Deposits of this unit and adjoining Plrw in the Poland Spring area, particularly near Lower Range and Worthley Ponds, serve as a major source of commercial bottled water.

A smaller esker system exists in the Minot area near the northwest part of the map. Much of this particular esker system is covered by younger deposits (Pmrs) and marine clays (Pp) and is only exposed in gravel pits there; the esker appears to be feeder tunnel deposits of the meltwaters that laid down the marine fan deposits (unit Pmfa) just to the southeast. This esker may be as much as 40 ft (12 m) thick.

Glaciolacustrine deposits of the Lower Range and Worthley Ponds area (Plrw)

Sand and gravel were deposited in contact with glacial ice by meltwater streams issuing from the ice margin into a relatively shallow glacial lake that was dammed by detached ice masses and glacial drift south of Worthley Pond, and, further south, in the Sabbathday Pond basin in the Gray quadrangle (Weddle, 1997). Abundant kettle holes are present in these partly collapsed deposits, and a radiocarbon date from a kettle pond in the Poland Spring area yielded a radiocarbon age estimate of 12,860±325 years (SI-4567 from Davis and Jacobson, 1985). Though controversy over the methods is ongoing, this age tentatively supports a time of deglaciation of the southern part of the Minot quadrangle sometime prior to 13,000 radiocarbon yr B.P. (Weddle, 1997).

The adjoining esker system (Pge) is partly buried by these deposits in many places; and Plrw deposits serve as a major aquifer source for commercial spring water in the Poland Spring area. There are extensive pits in the Plrw deposits, some of which expose subaqueous fan deposits underlain by predominantly sandy materials. The deposits are as much as 96 ft (29 m) thick, but generally are less than 70 ft (21 m) thick.

Glaciomarine delta and fan deposits of the New Gloucester area (unit Pmdng1-3)

Sand, gravel, silt, and mud of these deposits were graded to the contemporary sea and represent ice-contact deposits of the New Gloucester glaciomarine delta described by Weddle (1997) in the Gray quadrangle to the south. The three units indicate sequential stillstand positions of the ice margin as it retreated northward through the area. The positions are based on topographic expression, including collapsed kettle topography and ice-contact slopes. Deltaic and subaqueous fan deposits of units Pmdng 1&2 are graded directly southward, but represent two relatively short stillstands of the ice front as it retreated northward. Unit Pmdng3 contains similar materials, but represents an even farther northern position of the ice front. Deposits of Pmdng may be as much as 100 ft (30 m) thick and may be overlain by unmapped thin dune deposits.

Glaciomarine fan deposits of the Little Androscoggin River valley (unit Pmfa)

Sand, silt, gravel, and mud deposited as subaqueous fans were laid down in contact with and beyond the northward-retreating ice margin in the valley of the Little Androscoggin River. One ice-frontal position was recognized near Hacket Mills, where various ice-contact landforms such as kames and kettle holes mark the approximate location of a stillstand head of outwash. Pmfa may be as much as 100 ft (30 m) thick, but is generally thinner; and one test hole records 45 ft of sand (Pmfa) over 28 ft of clay (Pp) over 3 ft of till (Pt). Unit Pmfa may be overlain in places with thin unmapped dune and marine nearshore deposits.

Northwest of the head of outwash of Pmfa in the western part of the map there is an esker segment (Pge) that was probably part of the subglacial ice tunnel system that supplied sediment to the Pmfa fan.

Undifferentiated Glaciofluvial Deposits of Cool Brook (unit Pg)

Sand, silt, and gravel, deposits above the modern flood plain of Cool Brook near the north edge of the map are interpreted as thin glaciofluvial outwash and/or ice-contact deposits laid down by meltwaters flowing south. These deposits are less than 10 ft (3 m) thick.

Glaciomarine delta deposits (unit Pmdo)

Sand and gravel deposits with flat tops at the elevation of the upper marine limit are inferred to be glaciomarine deltaic deposits. Parts of this unit may have been laid down in contact with the ice margin, and some of it may have been eroded during offlap of the sea. In the western portion of the quadrangle, unit Pmdo is the eastward continuation of a sandy delta plain that follows the Little Androscoggin River valley. In places, unit Pmdo is overlain by dune deposits (Qe), some of which are thin and unmapped.

Much of unit Pmdo in the Minot area is underlain by silt and clay of probable glaciomarine origin (Presumpscot Formation, unit Pp). For the most part, the underlying silt and clay are not exposed except in stream valleys that have cut down through the overlying sands or in man-made excavations.

Glaciomarine bottom deposits (Presumpscot Formation) (unit Pp)

Materials consisting of predominantly silt and clay with local sandy beds and intercalations are interpreted here as late-glacial submarine (marine mud) deposits of the Presumpscot Formation (Bloom, 1960). These deposits were derived from glacial meltwaters and laid down at the bottom of the late-glacial sea following the retreat of the ice sheet from the area and prior to uplift of the area above the sea. The silt and clay commonly lies beneath units Pmdo and Pmrs in the Minot quadrangle. For example, the sides of a recently constructed drainage detention pond in a new housing development north of Stevens Mill along Hotel Road, exposed 4 ft of fine sand and silt overlying 2 feet of thin-bedded silt and clay. Unit Pp is exposed in the valley of Taylor Brook, and in the lower elevations in the valleys of the Little Androscoggin and Royal Rivers. The clay is mined in clay pits in the Royal River area. It is as much as 74 ft (22 m) thick. In places, Pp is overlain by relatively thick dune deposits (Qe) and thin unmapped dune deposits.

Marine regressive sand deposits (unit Pmrs)

Sand plains (unit Pmrs) with relatively thin deposits of sand and minor gravel are interpreted as reworked marine delta and fan deposits graded by streams to falling sea level during late-glacial time, long after the glacier left the immediate area. Following deposition of the Presumpscot Formation (unit Pp), glacial sediments were reworked and sandy stream deposits were laid down at elevations below the earlier marine limit, often on top of the marine clay. Commonly these deposits are less than 10 ft (3 m) thick. They overlie parts of units Pmdo, Pmfa, and Pp; and in places, Pmrs is overlain by relatively thick dune deposits (Qe) or thin unmapped dune deposits.

Following deglaciation, northward stream drainage from the Gray quadrangle (in the vicinity of the Maine Turnpike) cut into the Pmdng units and redeposited some of these sediments as a northward-prograding marine sand plain. The reversal of drainage in this area occurred during regression of sea level, which is recorded in the Gray quadrangle by topset/foreset bedding contacts in the Sabbathday delta at elevations well below the marine limit (Weddle, 1997).

Marine nearshore deposits (unit Pmn)

Thin deposits of sand and gravel were formed by reworking of earlier glacial sediments by marine currents and wave action in late-glacial time. These deposits are commonly found on and around bedrock or till hills that were subjected to wave attack as sea level fell. Unit Pmn typically is less than 10 ft (3 m) thick.

Eolian deposits (unit Qe)

When sea level fell and exposed the glacial outwash and marine regressive sand deposits, wind erosion was extensive before vegetation was able to take root and anchor the sediments. As a result, generally thin deposits of windblown sand formed, mostly on the west sides and tops of hills in the area, indicating a prevailing westerly or northwesterly wind regime at the time. The major deposits in the quadrangle are near or over materials mapped as Pmdo and Pmrs -- the dune material apparently being originally derived from those deposits. Only the larger Qe deposits are mapped here. Thin dune deposits are far more extensive than the area mapped as Qe in the Minot area, because they are patchy and not easily recognized except in excavations, which are sparse. Detailed mapping of all these dune deposits in the area may help decipher the complex history of their formation.

Stream terrace (unit Qst)

In cutting down their channels to their present levels, the late-glacial and modern Little Androscoggin and Royal Rivers cut into glacial deposits and built or carved stream terraces along their paths, parts of which are preserved as elevated terraces along margins of the modern flood plains. Some of the Qst area may be inundated during major floods, but most appears to be high enough to miss being flooded during ordinary flooding. Where the terrace is underlain by alluvial material, it may contain as much as 15 ft (5 m) of sand and gravel.

Holocene lakeshore deposits (Hls)

Modern beach and nearshore deposits (Hls) have formed along scattered stretches of the Taylor Pond shoreline, especially as spits of headlands and islands, as pocket beaches, and as baymouth bars. Deposits are generally less than 6 ft (2 m) thick.

Wetland deposits (unit Hw)

Freshwater swamp deposits characterized by accumulations of fine-grained organic-rich sediments, deposited in low, flat, poorly drained areas are scattered throughout the quadrangle. Little information is available on the thickness of these deposits in the Minot area, though Cameron and others (1984) report that peat deposits in southwestern Maine generally average less than 20 ft (6 m). In places the unit is indistinguishable from, grades into, or is interbedded with alluvium (Ha). It should be noted that both swamp (Hw) and alluvial deposits (Ha) are coincident along many stretches of flood plains in this area, particularly in the Little Androscoggin and Royal River valleys; and

Worthley, Foster, Moose, Davis, Taylor, Indian, Morgan, Cool, and Hodgkins Brook valleys.

Stream alluvium (unit Ha)

Sand, gravel, silt, and organic material are deposited by modern streams on their flood plains. The extent of alluvium indicates areas that flooded in the past that may be subject to flooding in the future. In places the unit is indistinguishable from, grades into, or is interbedded with wetland deposits (Hw). It should be noted that both swamp (Hw) and alluvial deposits (Ha) are coincident along many stretches of flood plains in this area, particularly in the Little Androscoggin and Royal River valleys; and Worthley, Foster, Moose, Davis, Taylor, Indian, Morgan, Cool, and Hodgkins Brook valleys.

Artificial fill (unit af)

Areas where the original ground surface is covered by a substantial thickness of imported material, both man-made and natural, are mapped as artificial fill (unit af). The material varies from natural sand and gravel or till to quarry waste and landfills. The thickness varies, but usually doesn't exceed 20 ft (6 m).

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APPENDIX A
GLOSSARY OF TERMS USED ON MAINE GEOLOGICAL SURVEY SURFICIAL GEOLOGIC MAPS

compiled by
John Gosse and Woodrow Thompson

Note: Terms shown in italics are defined elsewhere in the glossary.

Ablation till: *till* formed by release of sedimentary debris from melting glacial ice, accompanied by variable amounts of slumping and meltwater action. May be loose and stony, and contains lenses of washed sand and gravel.

Basal melt-out till: *till* resulting from melting of debris-rich ice in the bottom part of a glacier. Generally shows crude stratification due to included sand and gravel lenses.

Clast: pebble-, cobble-, or boulder-size fragment of rock or other material in a finer-grained *matrix*. Often refers to stones in glacial till or gravel.

Clast-supported: refers to sediment that consists mostly or entirely of *clasts*, generally with more than 40% clasts. Usually the clasts are in contact with each other. For example, a well-sorted cobble gravel.

Delta: a body of sand and gravel deposited where a stream enters a lake or ocean and drops its sediment load. Glacially deposited deltas in Maine usually consist of two parts: (1) coarse, horizontal, often gravelly topset beds deposited in stream channels on the flat delta top, and (2) underlying, finer-grained, inclined foreset beds deposited on the advancing delta front.

Deposit: general term for any accumulation of sediment, rocks, or other earth materials.

Diamicton: any poorly-sorted sediment, containing a wide range of particle sizes, e.g. glacial *till*.

Drumlin: an elongate oval-shaped hill, often composed of glacial sediments, that has been shaped by the flow of glacial ice, such that its long axis is parallel to the direction of ice flow.

End moraine: a ridge of sediment deposited at the margin of a glacier. Usually consists of till and/or sand and gravel in various proportions.

Englacial: occurring or formed within glacial ice.

Eolian: formed by wind action, such as a sand dune.

Esker: a ridge of sand and gravel deposited at least partly by meltwater flowing in a tunnel within or beneath glacial ice. Many ridges mapped as eskers include variable amounts of sediment deposited in narrow open channels or at the mouths of ice tunnels.

Fluvial: Formed by running water, for example by meltwater streams discharging from a glacier.

Glaciolacustrine: refers to sediments or processes involving a lake which received meltwater from glacial ice.

Glaciomarine: refers to sediments and processes related to environments where marine water and glacial ice were in contact.

Head of outwash: same as *outwash head*.

Holocene: term for the time period from 10,000 years ago to the present. It is often used synonymously with "postglacial" because most of New England has been free of glacial ice since that time.

Ice age: see *Pleistocene*.

Ice-contact: refers to any sedimentary deposit or other feature that formed adjacent to glacial ice. Many such deposits show irregular topography due to melting of the ice against which they were laid down, and resulting collapse.

Kettle: a depression on the ground surface, ranging in outline from circular to very irregular, left by the melting of a mass of glacial ice that had been surrounded by glacial sediments. Many kettles now contain ponds or wetlands.

Kettle hole: same as *kettle*.

Lacustrine: pertaining to a lake.

Late-glacial: refers to the time when the most recent glacial ice sheet was receding from Maine, approximately 15,000-10,000 years ago.

Late Wisconsinan: the most recent part of *Pleistocene* time, during which the latest continental ice sheet covered all or portions of New England (approx. 25,000-10,000 years ago).

Lodgement till: very dense variety of till, deposited beneath flowing glacial ice. May be known locally as "hardpan."

Matrix: the fine-grained material, generally silt and sand, which comprises the bulk of many sediments and may contain *clasts*.

Matrix-supported: refers to any sediment that consists mostly or entirely of a fine-grained component such as silt or sand. Generally contains less than 20-30% clasts, which are not in contact with one another. For example, a fine sand with scattered pebbles.

Moraine: General term for glacially deposited sediment, but often used as short form of "*end moraine*."

Morphosequence: a group of water-laid glacial deposits (often consisting of sand and gravel) that were deposited more-or-less at the same time by meltwater streams issuing from a particular position of a glacier margin. The depositional pattern of each morphosequence was usually controlled by a local base level, such as a lake level, to which the sediments were transported.

Outwash: sediment derived from melting glacial ice, and deposited by meltwater streams in front of a glacier.

Outwash head: the end of an *outwash* deposit that was closest to the glacier margin from which it originated. *Ice-contact* outwash heads typically show steep slopes, *kettles* and hummocks, and/or boulders dumped off the ice. These features help define former positions of a retreating glacier margin, especially where *end moraines* are absent.

Pleistocene: term for the time period between 2-3 million years ago and 10,000 years ago, during which there were several glaciations. Also called the "Ice Age."

Proglacial: occurring or formed in front of a glacier.

Quaternary: term for the era between 2-3 million years ago and the present. Includes both the *Pleistocene* and *Holocene*.

Striation: a narrow scratch on bedrock or a stone, produced by the abrasive action of debris-laden glacial ice. Plural form sometimes given as "striae."

Subaqueous fan: a somewhat fan-shaped deposit of sand and gravel that was formed by meltwater streams entering a lake or ocean at the margin of a glacier. Similar to a *delta*, but was not built up to the water surface.

Subglacial: occurring or formed beneath a glacier.

Till: a heterogeneous, usually non-stratified sediment deposited directly from glacial ice. Particle size may range from clay through silt, sand, and gravel to large boulders.

Topset/foreset contact: the more-or-less horizontal boundary between topset and foreset beds in a *delta*. This boundary closely approximates the water level of the lake or ocean into which the delta was built.