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Robert G. Marvinney, State Geologist

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Author: *Woodrow B. Thompson*

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Woodrow B. Thompson
Maine Geological Survey
State House Station 22
Augusta, Maine 04333-0022

INTRODUCTION

This report describes the surficial geology and Quaternary history of the Fryeburg 7.5-minute quadrangle in southwestern Maine. Surficial earth materials include unconsolidated sediments (sand, gravel, etc.) of glacial and nonglacial origin. Most of these deposits formed during and after the latest episode of glaciation in Maine, within the last 25,000 years. Surficial sediments cover the bedrock over most of the quadrangle and are subject to many uses and environmental considerations. These include sand and gravel extraction, development and protection of ground-water supplies, siting of waste disposal facilities, and agriculture.

The surficial geology of the Fryeburg quadrangle appears simple. The topographic map shows a landscape of low hills, river flood plains, and wetlands. Yet, many complexities and points of interest arise when this area is considered in relation to the history of the Saco River valley. Ground-water investigations have yielded a wealth of data on the thickness and character of sediments in the valley, and fossil plant remains have provided the first ages for lake deposits hidden beneath the Saco flood plain. Along the east side of the valley are extensive deposits of windblown sand -- a forested "desert" of sand dunes showing the influence of wind in the geologic past.

The field work for this study was carried out in stages, first to gather data for the Maine Geological Survey's (MGS) sand-and-gravel aquifer mapping program (Williams and others, 1987) and later to complete the surficial geologic mapping of the Fryeburg quadrangle. Field work to update earlier observations, and preparation of the present report, were done in 1998.

Two maps are associated with this report. The *geologic map* (Thompson, 1999c) shows the distribution of the sedimentary units and indicates their age, composition, and known or inferred origin. It also includes information on the geologic history of the quadrangle, such as fossil localities and features indicating the flow direction of glacial ice. This map, along with mapping done by the author in adjacent quadrangles, provides the basis for the discussion of glacial and postglacial history presented here.

The *materials map* (Thompson, 1999h) shows specific data used to help construct the geologic map. These data include observations from gravel pits, shovel and auger holes, construction sites, and natural exposures along stream banks. Sand and gravel aquifer studies by the MGS and USGS provided much useful data on the stratigraphy of the Saco River valley, including numerous test boring and seismic logs (Prescott, 1979; Morrissey and others, 1985; Johnson and others, 1987; Williams and others, 1987; and Tepper and others, 1990).

Geographic Setting

The Fryeburg quadrangle is located in the White Mountain foothills of southwestern Maine. The western boundary is nearly coincident with the state line separating Maine and New Hampshire, and a very small part of the quadrangle lies within New Hampshire. The map area extends in latitude from 44°00'00" to 44°07'30" N, and in longitude from 70°52'30" to 71°00'00" W. It includes parts of the towns of Fryeburg, Sweden, Lovell, Stow, Conway, Denmark, and Brownfield. However, Fryeburg village is the only major population center in the quadrangle.

The most significant geographic features in the Fryeburg quadrangle are the Saco River and its flood plain, which is very wide compared to other Maine valley floors. The Saco Valley has figured prominently in the geologic and human history of the region. Its rich agricultural land, water transportation, and abundant fish and game attracted both Native American and European settlers. The unusual "Great Bend" in the Saco north of Fryeburg enabled people to travel down the river for many miles and return across Lovewell Pond, ending the water journey less than two miles from their starting point!

Several ponds occur in the quadrangle. The only other major stream is the Kezar River, which drains into the Saco in the northeast part of the map area. The terrain adjacent to the Saco Valley is hilly. Elevations in the quadrangle range from 360 ft (110 m) above sea level (where the Saco River crosses its southern border) to 1073 ft (327 m) on the summit of Mt. Tom.

Numerous artifacts have been found in the Saco Valley, indicating occupation by Native Americans at least since Terminal Archaic time (3,800 to 2,700 years ago) (Cox, 1992). The discovery of a Paleoindian projectile point in nearby Conway, New Hampshire (Byers, 1966), suggests an even earlier occupation dating back to about 10,000 yr B.P. (years before present). The inhabitants of the Fryeburg-Conway region during the arrival of European settlers were the Pigwacket band, who were part of the Abenaki Indian Nation. Barrows (1938) described the more recent history of the town of Fryeburg and its residents.

A remarkable event in the history of the Saco River, which may be unique among the major rivers of Maine, was the diversion of its course in the early 1800's. Flooding was a persistent problem for the early farmers in Fryeburg. In 1812 a committee was formed to study the feasibility of alleviating this problem by digging a canal through a narrow ridge at the present site of Canal Bridge, on Route 5 just south of Fryeburg Center. Two ponds were located on the Saco flood plain on either side of this ridge: Bear Pond to the west and Bog Pond to the east. (A remnant of the latter pond still exists.) The proposed canal would connect these ponds and then continue east through the swampy flood plain to meet the main river channel, greatly shortening the Saco's course.

Major floods in 1785 and 1814 began the process of cutting through the ridge where the ditch would eventually be dug. The project dragged on for years, and by 1824 the final segment of the canal had been dug from Bog Pond eastward to rejoin the river. The completed channel was now capable of floating logs. Additional floods helped widen and deepen the canal, such that by 1830 the Saco was established in its new course. Bear Pond was drained as a consequence and Bog Pond greatly reduced in size. Anderson (1982) has written a detailed history of the canal project, and brief accounts were provided by Barrows (1938) and Vinton (n.d.).

Bedrock Geology

The Fryeburg quadrangle is underlain by granite of Carboniferous age, which is part of an extensive granite body called the Sebago pluton (Osberg and others, 1985). This light-gray granite was formerly quarried on Starks Mountain and Oak Hill, just south of Fryeburg village. The Oak Hill quarry was worked at least as early as 1870 (Barrows, 1938, p. 188). Small farm quarries probably yielded additional stone for foundations and fence posts.

Because of the widespread cover of glacial and postglacial sediments in the quadrangle, bedrock exposures over much of the area are limited to scattered small outcrops. The more extensive ledge exposures occur on hilltops, where they often consist of resistant granite pegmatite. The best known of these pegmatite knobs -- and a local tourist attraction -- is "Jockey Cap, "adjacent to U. S. Route 302 on the northeast side of Fryeburg village. The prominent cliff on the south face of Jockey Cap is the result of glacial erosion.

PREVIOUS WORK AND ACKNOWLEDGMENTS

Stone (1899) conducted a reconnaissance of the Saco Valley region during his statewide USGS study of Maine's glacial gravel deposits. Leavitt and Perkins (1935) likewise examined the area for their *Survey of Road Materials and Glacial Geology of Maine*. Prescott (1979) compiled well and test hole data, and carried out preliminary surficial and gravel aquifer mapping (Prescott and others, 1979; Prescott, 1980). Thompson compiled a more detailed aquifer map that included the Fryeburg quadrangle, as part of the Significant Sand and Gravel Aquifer Project sponsored by the MGS, USGS, and Maine Department of Environmental Protection (Williams and others, 1987).

An innovative study by Morrissey and others (1985) used a boat-mounted seismic system to obtain a continuous seismic reflection profile of sediments beneath the Saco River from Center Conway to Fryeburg Center. Lewis (1985) investigated the stratigraphy and geomorphology along a segment of the Saco Valley north of Fryeburg. The most important source of subsurface data for this portion of the Saco Valley is the multi-agency study of the "Saco River Valley glacial aquifer" from Bartlett, N.H., to Fryeburg, Maine, which was published by the USGS (Johnson and others, 1987; Tepper and others, 1990).

The author is indebted to the staff of the Augusta office of the USGS Water Resources Division for supplying the results of the aquifer studies mentioned above. I especially thank Dorothy Tepper and Carole Johnson for productive discussions of the Saco Valley stratigraphy, and providing samples of organic material from well borings that yielded important radiocarbon dates for this study.

Wilbur Tidd (Maine Department of Transportation) provided data from DOT test borings, and many local residents were helpful in granting access to their property. The Fryeburg town library supplied historical information on drainage modifications along the Saco River. Information regarding the Native American history of the Fryeburg region was obtained courtesy of Richard Boisvert, New Hampshire Division of Historical Resources.

DESCRIPTION OF GEOLOGIC MAP UNITS

The surficial deposits represented on the geologic map have been classified on the basis of their age and origin. Map units are designated by letter symbols, such as "Pt." The first letter indicates the age of the unit:

"P"- Pleistocene (Ice Age)
"H"- Holocene (postglacial, i.e. formed during the last 10,000 years)
"Q"- Quaternary (encompasses both the Pleistocene and Holocene epochs)

The Quaternary age is assigned to units which overlap the Pleistocene-Holocene boundary, or whose ages are uncertain. The other letters in the map symbol indicate the origin and/or assigned name of the unit, e.g. "t" for glacial till and "lpb" for sediments deposited on the bottom of Lake Pigwacket. Surficial map units in the Fryeburg quadrangle are described below, starting with the older deposits that formed in contact with glacial ice.

Till (unit Pt)

Till is a glacially deposited sediment consisting of a more-or-less random mixture of sand, silt, and gravel-size rock debris. In southern Maine it typically includes numerous boulders. Till blankets much of the upland portions of the quadrangle, where it is the principal surficial material; and test borings show that it commonly underlies younger deposits in the valleys. Some of the till in Maine probably was derived from glacial erosion of older surficial sediments (either glacial or non-glacial), while the remainder was freshly eroded from nearby bedrock sources during the latest glaciation.

Pit exposures in the Fryeburg region have revealed up to 20 ft (6 m) of till, and the thickness locally may be 50-100 ft or more (15-30 m). Test borings for the new Route 5 bridge (Canal Bridge) across the Saco River in Fryeburg indicated a till thickness of up to 79 ft (24 m). Till is thin on the tops of many hills, where bedrock is likely to be exposed. A ruled line pattern on the geologic map indicates areas where bedrock outcrops are common and/or the till thickness is inferred to be less than 10 ft (3 m).

Till is, by definition, a poorly sorted sediment (diamicton) in which there is a very wide range of rock and mineral particle sizes. However, the texture and structure of individual till deposits vary depending on their source and how they were formed. In the Fryeburg area, till may include a small percentage of clay, but it has a dominantly sandy or silty-sandy matrix as a consequence of having been eroded from coarse-grained bedrock. Till has little or no obvious stratification in some places. Elsewhere it is crudely stratified, with discontinuous lenses and laminae of silt, sand, and gravel resulting from sorting by meltwater during the depositional process.

Stones are abundant in this unit, and boulders scattered across the ground surface often indicate the presence of till. Till stones in the Fryeburg quadrangle chiefly consist of coarse-grained igneous and metamorphic rocks, especially granitic rocks derived mainly from local bedrock sources. Most till stones are more-or-less angular, and some have smooth, flat, striated surfaces due to subglacial abrasion. These faceted surfaces are best developed on dense, fine-grained rocks such as basalt (basalt occurs as dikes cutting other rock types in southwestern Maine).

Varieties of till formed beneath a glacial ice sheet include lodgement and basal melt-out tills. Lodgement till was deposited under great pressure beneath the ice sheet. It may be very compact and difficult to excavate ("hardpan"), with a platy structure (fissility) evident in the upper, weathered zone. Basal melt-out till is difficult to identify with certainty, but typically shows a crude stratification inherited from debris bands in the lower part of the glacier. Ablation till formed during the melting of the ice and tends to be loose-textured and stony, with numerous lenses of washed sediment. More than one of these till facies may occur at a single locality. For example, a thin veneer of stony ablation till commonly overlies lodgement till.

Field evidence in the Fryeburg area, coupled with studies elsewhere in New England (e.g. Koteff and Pessl, 1985; Thompson and Borns, 1985b; Weddle and others, 1989), suggests that till deposits of two glaciations are present here. The "upper till" is clearly the product of the most recent, late Wisconsinan glaciation, which covered southern Maine between about 25,000 and 13,000 years ago. Exposures of upper till can be seen in many shallow pits, road cuts, and temporary excavations. It is unweathered (except in the near-surface zone of modern soil formation) and usually light olive-gray in color. Lodgement, basal melt-out, and ablation facies of the upper till are all present in the Fryeburg quadrangle. The darker, olive-gray color of some outcrops of lodgement upper till may reflect inclusion of reworked older till (described below).

The "lower till" consists chiefly of compact, silty-sandy lodgement deposits. In southwestern Maine, as in other parts of New England, it is likely to be found in smooth, glacially streamlined hills where a considerable thickness of till has accumulated. These thick deposits often occur as "ramps" on the gentle northwest-facing slopes of hills, while bedrock is exposed on the steeper, glacially plucked southeast slopes.

The lower till is distinguished by its thick weathering profile, which may extend to a depth of 10 ft (3 m) or more. Within this weathered zone, the till is oxidized and has an olive-gray to dark olive-gray or dark grayish-brown color. Dark-brown iron/manganese oxide staining coats the surfaces of stones and joints. Probable equivalents of this till in southern New England are believed to be have been deposited during an earlier glaciation in Illinoian time, prior to 130,000 years ago (Weddle and others, 1989).

Material believed to be lower till was seen in only a single temporary exposure in the quadrangle, located in a house foundation hole southwest of Highland Park in Fryeburg (site no. 86-78 on materials map). The rarity of lower till exposures may be attributed to two factors: burial beneath upper till, and lack of borrow pits in this very hard-to-excavate sediment. The two tills have been observed in superposition in a few places in adjacent quadrangles. The contact between them is sharp and erosional; and fragments of the lower till occur in the basal part of the upper till (see, for example, Thompson, 1986).

Ribbed Moraine (unit Prm)

Ribbed moraine is a geomorphically distinct unit consisting of ridges and hummocks of glacial till. It occurs over a small area southwest of Pleasant Pond, in the southeast corner of the Fryeburg quadrangle and part of the adjoining Brownfield quadrangle. There are no exposures in this unit, but similar landforms elsewhere in Maine include sand and gravel interbedded with the till.

The manner in which ribbed moraine was deposited is uncertain. It might be an ice-marginal deposit, in which case the unit consists of end-moraines, or it may have formed subglacially. Davis and Holland (1997a,b) described similar deposits in the nearby Kezar Falls quadrangle, and concluded that they probably formed beneath the ice.

Lake Pigwacket Deposits

During and following the deglaciation of southwestern Maine, a succession of temporary lakes formed in the Saco River valley. Sediments deposited in these lakes, or in glacial streams tributary to them, have been recognized over a long stretch of the valley, extending at least from the Hiram area upstream to Bartlett, New Hampshire. The town of Fryeburg is situated on a sand plain deposited in a lake as it filled with sediment; and test borings have shown that thick accumulations of lake-bottom sand, silt, and clay underlie the Saco River valley.

The existence of a lake in the Fryeburg area was proposed long ago by George H. Stone, in his volume titled *The Glacial Gravels of Maine and Their Associated Deposits*. Stone noted that "In this [lake] was deposited a broad fluvial delta extending from Conway, New Hampshire, east to Lovell and Brownfield" (Stone, 1899, p. 256). He referred to the lake deposits as "alluvium" and "valley drift," but did not give a clear opinion regarding their age and origin.

Leavitt and Perkins (1935) observed that ice-marginal lakes formed preferentially in north-draining tributary valleys in the Saco and Ossipee River basins, indicating that glacial meltwater was ponded against tongues of stagnating ice that retreated northward and temporarily blocked the lower ends of the valleys. These authors also noted the presence of varved (annually layered) lacustrine clays beneath the Fryeburg-Conway sand plain. They referred to the main water body in the Saco Valley as a "great fresh water lake covering this part of western Maine and eastern New Hampshire" (p. 94). It was described as a glacial lake that drained down the valley, with sand deposits covering the clay as the lake filled with sediment (p. 210).

In 1938, a brief summary of the postglacial evolution of the Saco Valley by Richard Lougee (then professor of geology at Colby College) was included in a town history of Fryeburg (Barrows, 1938, p. 134-135). According to Lougee, a glacial lake first occupied the valley at the close of the Ice Age, with deltas in Stow and North Chatham marking the water level. This lake supposedly emptied due to tilt of the land, following which "The newly-formed post-Glacial Saco River, possibly still fed by meltwater from ice in the headwaters of the valley, spread immense deposits of fine sand into the lowland, burying the clay beds and any pre-Glacial channels in the bed rock, and building up a widespread sandy flood-plain."

The deltas mentioned by Lougee are much higher than lake-level indicators around Fryeburg village, and probably were deposited in an early ice-dammed lake in the Stow area (Chatham and Center Lovell quadrangles). However, it is significant that Lougee described the Fryeburg sand plain as a "flood plain" which was not necessarily built by glacial streams.

On the Maine side of the state border, from Fryeburg to Hiram, the upper surfaces of many lacustrine deposits in the Saco Valley cluster around 400-420 ft (122-128 m) in elevation. The similarity in elevations suggests the possibility that a single lake existed throughout this section of the valley. However, it is questionable whether such a continuous water body ever existed at one time. The morphology, textures, and spacing of the lake deposits, together with new fossil evidence presented in this report, indicate that sedimentation was episodic over an interval ranging from late-glacial into early postglacial time.

During deglaciation of the Saco Valley, ice-contact lake sediments and residual masses of stagnant ice probably choked the valley in several places, separating some of the lake stages in time and space. Glaciolacustrine deltas plugging the valley could have dammed younger lake stages upstream, as happened in other narrow, south-draining river valleys in New England such as the Housatonic in Connecticut (Stone and others, in press).

The system of adjoining and interrelated water bodies that formerly existed in the Saco River valley between Hiram, Maine, and Bartlett, N.H., is here called **"Lake Pigwacket**." The lake system is named in honor of the Pigwacket band of Abenaki Indians, who inhabited the upper Saco Valley and figure prominently in the history of the Fryeburg-Conway area. This name is often spelled as "Pequawket," and the preliminary naming of the lake by Thompson (1991) used the latter spelling. However, "Pigwacket" is the spelling currently used by Native American historians (Calloway and Porter, 1989). Evans (1939) likewise preferred "Pigwacket" in his book of that name, since this "was the choice of the historians, Penhallow, Belknap, and other well-informed authorities...." Evans listed 68 variant spellings of this word in the works of earlier historians who tried to put in writing the Abenakis' spoken language!

Some of the Lake Pigwacket deposits described below are chiefly located in neighboring quadrangles, with only small portions included in the Fryeburg quadrangle. However, these outlying units are important to an integrated discussion of lake history in the Fryeburg area. They are described here for this reason, and more information about them can be found in other quadrangle reports by Thompson (1999 a,b,d,e,f,g).

Undifferentiated Lake Pigwacket deposits (unit Plp). There are a few small sand and gravel deposits in the quadrangle

that were probably emplaced by streams flowing into Lake Pigwacket, but whose relation to the history of the lake is unclear. At least one such deposit, located on Route 302 in East Fryeburg, formed in an ice-contact environment. This sand and gravel deposit reaches an elevation of 460 ft (140 m), and thus may have washed into the early, high-level Pleasant Mountain stage of Lake Pigwacket, which is recorded by nearby deposits at similar elevations (see below).

Oak Hill Stage Deposits (unit Plpo). A high-level deposit of sand and gravel is banked against the west side of Oak Hill, near the south edge of the quadrangle. This deposit forms a hillside terrace at about 480 ft (146 m), the upper surface of which slopes gently to the west. It ranges in texture from sand to boulder gravel, and also includes lenses of silt. A thin layer of silt and sand caps the section in the gravel pits at sites no. 88-19 and 88-20 (see materials map). Stones as large as 6 ft (2 m) in diameter occur randomly throughout the unit.

Fluvial cross-bedding occurs throughout the exposed sections in this unit, and is a diagnostic feature for interpreting its origin. The cross-bedding and cut-and-fill structures indicate that the unit was deposited by streams flowing in a generally southward direction. The morphology and position of the deposit are typical of kame terraces built between hillsides and residual masses of glacial ice in adjacent valleys. In this case the silt beds show that there was intermittent small-scale ponding of the meltwater. The presence of locally collapsed bedding, and scattered large stones that were ice-rafted or simply rolled off the glacier, further indicate the proximity of glacial ice.

Unit Plpo continues southeastward into the Brownfield quadrangle, where it underlies the Eastern Slopes Regional Airport. It steadily decreases in elevation, reaching about 410-420 ft (125-128 m) where it terminates against the slightly lower Saco River flood plain. The smoother topography south of the airport suggests that stagnant ice masses were less common in the southern part of the unit.

The Oak Hill deposits are a good example of a "morphosequence," i.e. a contemporaneous set of water-laid glacial sediments which originated at or near the glacier margin, and which were deposited by meltwater streams controlled by a common base level (which was often sea level or a lake at the downstream end) (Koteff and Pessl, 1981). In this instance, the near-ice end of unit Plpo -- known as the "head of outwash" -- marks a temporary position of the retreating glacier margin in the valley west of Oak Hill. The streams that deposited this morphosequence emptied into Lake Pigwacket in the Saco Valley southeast of Love-well Pond. For this reason, the unit is assigned to the Oak Hill stage of Lake Pigwacket even though the headward part of the unit was deposited at some distance upstream from the lake.

Pleasant Mountain Stage Deposits (unit Plpp). Small portions of this unit occur along the eastern margin of the study area; most of it is located in the adjoining Pleasant Mountain and Hiram quadrangles. Unit Plpp is a series of sandy glacial deposits in a narrow, north-south valley between the Saco River and Pleasant Mountain (east of the Fryeburg quadrangle). The Plpp deposits flank a long esker system that passes down the middle of this valley. The deposits of unit Plpp are not well exposed, and there is little information from test borings. In the Pleasant Mountain quadrangle they typically have uneven ice-contact topography, though a few are flat-topped (having been graded to former water levels).

Unit Plpp is interpreted as a complex of glaciolacustrine deltas, subaqueous fans, and lake-bottom deposits. Individual morphosequences are not clearly delineated, but five ice-margin positions have been recognized by Thompson (1999f,g) in the Pleasant Mountain quadrangle. This unit is assigned to a late-glacial stage of Lake Pigwacket, defined here as the Pleasant Mountain stage. It was deposited in an area of ponded meltwater between the hills to the east and a remnant mass of glacial ice inferred to have existed in the Saco River lowland to the west. Delta(?) elevations west of Pleasant Mountain suggest a lake level of about 450 ft (137 m). See Thompson (1999f,g) for further information on this area.

Kezar Valley Stage Deposits (unit Plpk). Unit Plpk extends from Lovell village northeast along the Kezar River valley and its tributaries. The southern extremity of this unit is located in the northeast corner of the Fryeburg quadrangle. Here it forms a sand plain at elevations of 400-420 ft (122-128 m). As the unit is followed up the valley into the Center Lovell and North Waterford quadrangles, the upper surface quickly rises to 500 ft (152 m) and reaches a maximum of about 525 ft (160 m) just below the Kezar Falls gorge.

Plpk deposits in the North Waterford quadrangle are pockmarked by depressions (kettles) resulting from melting of glacial ice blocks. Surface exposures typically show fine sand, but gravel is present toward the north end of the unit. The depth of stream dissection suggests that the unit is locally quite thick, and this is confirmed by borings and seismic data. Well 13-7 in the northeast corner of the Fryeburg quadrangle penetrated 81 ft (25 m) of sand, silt, and clay (fining downward) without reaching the bottom of the unit; and a nearby seismic line (FR-15) showed a depth-to-bedrock of 200 ft (61 m) (see materials map and Appendix B for subsurface data).

The thick sand deposits that form much of unit Plpk are poorly exposed. A few shallow pits and road cuts in the Center Lovell and North Waterford quadrangles show well-sorted, thin-bedded fine sand and silt with current ripples. The texture of these sediments suggests they are lake-bottom and/or delta-front deposits that formed in a low-energy (quiet-water) environment. The ice-contact topography along the Kezar River valley is evidence that the unit was deposited when remnants of glacial ice still existed in the area.

Unit Plpk originally may have been a delta that was built to a lake level of approximately 500 ft (152 m), but the downvalley decrease in elevation and reduction of ice-contact topography suggest that the southern part of the delta has been modified. The low sand plain in the northeast corner of the Fryeburg quadrangle may have resulted from fluvial processes and/or shoreline erosion during the later Fryeburg stage of Lake Pigwacket (see

below). However, most of this plain is inferred to be a remnant of the original lake sediments and thus is included with unit Plpk.

The water body in which unit Plpk was deposited is here called the Kezar Valley stage of Lake Pigwacket. Like the Plpp unit described above, the lake sediments in the Kezar River valley reach significantly higher elevations than the floor of the neighboring Saco Valley, which is only about 370 ft (113 m) in elevation. A temporary dam of some kind was required to impound the lake at an elevation of about 500 ft (152 m) in the Kezar Valley. The Kezar Valley lake may have either spilled southwestward across ice/sediment barriers in the Saco Valley, or southward across older Lake Pigwacket deposits of the Pleasant Mountain stage. In the latter case, the spillway would have been located in the southwestern part of the Pleasant Mountain quadrangle, and the Kezar Valley deposits could be assigned to the youngest part of the Pleasant Mountain stage. This alternative would require a long, narrow lake corridor to open up along the east side of the Saco River basin, while the basin itself remained choked with ice. Perhaps the high-energy meltwater drainage that formed the esker in this area also caused rapid ice disintegration and opening of the lake.

Fryeburg stage deposits (unit Plpf). Unit Plpf forms the sand plain overlooking the Saco River on which Fryeburg village is situated. The top of this plain ranges in elevation from 475 ft (145 m) in the Center Conway area to 400-410 ft (122-125 m) where it merges with the Saco flood plain near West Fryeburg. Between Center Conway and West Fryeburg it has a gradient of 8.46 ft/mi (1.6 m/km) in a northerly direction. The map boundaries and original surface elevations of unit Plpf are obscured on the east side of the Saco Valley by younger deposits of eolian sand (described below). This sand blew across the valley, forming large dune fields that conceal the contacts where the unit laps against adjacent till slopes. For this reason, the Plpf boundaries around Fryeburg are approximately located. The eolian sands are mapped as a separate unit in some areas, but they also form a patchy cover on deposits mapped as Plpf.

Borings and shallow surface exposures in Plpf deposits show that they are composed of very fine to very coarse sand and pebbly sand. Sedimentary structures observed in the upper part of the unit -- including trough cross-bedding, cut-and-fill structure, and current ripples -- indicate deposition in a fluvial environment. The direction of stream flow recorded in two exposures in the vicinity of Fryeburg Academy was generally eastward, and northward flow was evident from exposures in the Fryeburg Fairgrounds area.

The logs from wells drilled in Fryeburg (Appendix B) reveal that the Plpf deposits become finer grained with depth and grade into lake-bottom deposits consisting of very fine sand, silt, and clay (part of unit Plpb, described below). Unit Plpf is most likely a delta that formed as sediments from the North Conway area washed down the Saco Valley and were deposited into Lake Pigwacket at Fryeburg. These sandy deltaic sediments are assigned to the Fryeburg stage of Lake Pigwacket. It has commonly been assumed that the Plpf sand plain is outwash deposited by glacial meltwater. However, radiocarbon dates on the underlying lake-bottom sediments (unit Plpb) indicate that the Fryeburg stage of the lake was still in existence between 12,000 and 11,000 years ago, at least 1,000-2,000 years after the probable time of deglaciation in the Fryeburg-Conway area.

The elevation of the Fryeburg stage lake level is uncertain, due to the lack of unequivocal water-level indicators. The elevation of the fluvial/deltaic sand plain in Fryeburg village is about 430 ft (131m), and silty lake-bottom deposits in the quadrangle (unit Plpb) occur as high as 400-410 ft (122-125 m). Therefore, the elevation of the lake surface is assumed to have been at least 420-425 ft. There is no apparent dam for Lake Pigwacket at this elevation in the Fryeburg quadrangle. However, in the Brownfield-Hiram area to the southeast, there are abundant sand and gravel deposits (from early stages of Lake Pigwacket) that may have blocked the Saco Valley during the Fryeburg stage.

The deepest exposure seen in the Plpf deposits is a 30 ft (9 m) high bank cut by the Saco River just north of the fairgrounds (site no. 86-96). The lower part of this section is usually concealed by slump, but the upper part shows two stratigraphic units. The upper unit consists of 6-8 ft (1.8-2.4 m) of cross-bedded and rippled medium-to-pebbly sand. The lower unit is finer-grained sand with delta foreset bedding, extending to an unknown depth. The contact between these units (where examined in the field) is erosional and channeled. Sedimentary structures in both units indicate flow to the north, in the same direction as the modern river. The foreset beds in the deltaic sand are believed to indicate deposition in a shallowing lake. The upper unit is fluvial, but its relation to the delta foresets is uncertain. Since the ground surface here is at an elevation of only 410 ft (125 m) or less, the fluvial sands are most likely a stream-terrace deposit left by the Saco River while downcutting the Fryeburg sand plain.

The same conclusion applies to deposits exposed in a small pit on the west side of the Saco Valley, just north of West Fryeburg Cemetery. This pit shows 3 ft (1 m) of fluvial sand and pebble gravel overlying north-dipping sand beds that are clearly delta foresets. The fluvial beds are too low and appear too fine-grained to be the original delta topsets, so they are interpreted as younger stream-terrace deposits.

Assuming a water level of 425 ft (130 m) for Lake Pigwacket in the Fryeburg village area, this water body would have been nearly divided into two lakes by the series of hills that separate the Fryeburg agricultural valley from the swampy Kezar Pond lowland to the east. The original "Old Course" of the Saco River cuts through a narrow gap in these hills at the Route 5 bridge, where the river level is about 370 ft (113 m) and the bedrock surface elevation is 362 ft (110 m). The eastern and western arms of the lake may have also connected through the narrow gap where the canal was dug to create the new course of the river, just south of Fryeburg Center. The original elevation of this gap is estimated to have been about 400 ft (122 m).

Deposition of water-laid (Plpf) and eolian sediments at Fryeburg village must have blocked any eastward river drainage

that formerly occurred through the Lovewell Pond area. Otherwise, it is hard to explain why the postglacial Saco River detoured far to the north when it could have taken a much more direct path through the Lovewell Pond basin. This basin could have been occupied by a block of stagnant glacial ice, but the age constraints on unit Plpf suggest that ice was gone from the area during the Fryeburg stage of Lake Pigwacket.

The sediments comprising unit Plpf and associated lake-bottom deposits were at least partly derived from erosion of lake sediments farther up the Saco Valley, in the North Conway area. The deposits in the latter area are similar in some respects to the sequence at Fryeburg. Remnants of a higher sand and gravel unit form terraces on both sides of the Saco flood plain in North Conway. This unit is a lacustrine delta complex that formerly extended across the valley. Both the delta and younger flood-plain deposits are widely underlain by lake-bottom sand, silt, and clay.

The principal difference between the Fryeburg and North Conway deposits is that the lake sediments in North Conway were deposited directly from glacial ice into an early stage of Lake Pigwacket in the upper Saco Valley (here called the North Conway stage). Ice-contact topography is present in the headward part of the delta complex, and no definite organic materials have been found in the lake-bottom sediments. (Abundant plant remains were recovered from well OW-4, between Intervale and Lower Bartlett (Johnson and others, 1987), but these materials probably occur in a Holocene alluvial deposit.)

The glacial lake in the vicinity of North Conway probably was not continuous with the Fryeburg lake. Between Center Conway and Fryeburg, the Saco River cuts through a till barrier that flanks both sides of the river. The lacustrine delta plain on the upstream side of the barrier is about 20 ft (6 m) higher than on the downstream side, suggesting that the till acted as a dam for the Conway lake. After this lake filled with sediment and/or the dam was eroded, sediments from the Conway area could wash into the Fryeburg basin. Postglacial uplift and tilting of the land would have steepened the river gradient and promoted this process. The Fryeburg stage of Lake Pigwacket also could have trapped sediments eroded from glacial deposits in the Weeks Brook and Cold River valleys, located west and north of the Fryeburg quadrangle respectively.

Lake-Bottom Deposits (Plpb). The fine-grained sediments deposited on the floor of Lake Pigwacket are grouped as a single unit, since their ages in relation to the lake stages are uncertain. This unit consists of silt, clay, and sand that was washed into the lake by glacial and postglacial streams. The sandy facies probably were deposited in a prodelta environment, close to where streams entered the lake, while the muddy sediments settled from suspension and dispersed more widely across the lake bottom.

Where this map unit occurs at the ground surface, it usually consists of massive to laminated silt. The silt was encountered in auger holes and shallow exposures in widely scattered low-lying areas such as the Fight Brook valley (north of Lovewell Pond), the Black Brook area (near East Fryeburg), and the Kezar River valley.

An especially interesting exposure of lake-bottom sediments was found in a shallow excavation on the Robert Wales property, next to the southwest side of Lovewell Pond in Fryeburg, at an elevation of approximately 380-390 ft (116-119 m). This site showed annually layered (varved) silt and clay over glacial till. Each varve has a silty layer deposited on the lake floor during the warmer part of the year, followed by a very thin winter clay layer. The varved sediments were sampled in 1997 by scientists from the Institute of Solid Earth Physics in Bergen, Norway. In the thickest part of the unit (2.03 m), they recorded 303 varves with an average thickness of about 7 mm (Reidar Lovlie, personal communication) This unit is overlain by silt and sand that probably formed as Lake Pigwacket became shallower, followed in turn by windblown sand.

Varved silt-clay closely resembling the sediments at the Lovewell Pond site was seen in a deep gully next to the Saco River in the southwest corner of the quadrangle. This small exposure is no more than 5-10 ft (3 m) above normal river level, so the highest exposed varves are probably at an elevation of about 405-410 ft (123-125 m). They are overlain by sandy Lake Pigwacket deposits.

The thickest lake-bottom sediments are beneath the Saco River flood plain, where they are largely concealed under younger alluvial, wetland, and eolian deposits. Detailed studies of the Saco Valley aquifer in the Fryeburg-Conway-Bartlett area have provided much information on the distribution and character of the buried lake sediments (Johnson and others, 1987; Tepper and others, 1990). Subsurface data and locations of seismic lines from those investigations are included in Appendix B and the materials map accompanying the present report.

Lake sediments in the Fryeburg-North Fryeburg basin probably attain thicknesses of more than 100 ft (30 m). The maximum recorded thickness from borings is at least 87 ft (27 m) (OW 66, just south of Fryeburg village). Many of these deposits are sandy, but substantial thicknesses of laminated silt and clay (10 ft or more) are included in the logs from at least 13 borings. The log from OW 66 revealed 75 ft (23 m) of the clay-silt facies.

In general, the lake-bottom deposits between Fryeburg and North Fryeburg are coarser grained toward the top of the unit. This is the result of Lake Pigwacket (Fryeburg stage) being filled with sediment as sandy deltaic or prodelta sands washed into the lake. The sandy facies covered the fine-grained mud that had previously accumulated on the lake floor during a period of quiet water. The log from OW 67 in Fryeburg village shows a good example of this sequence. The lowest unit is till, overlain in turn by clay, silt, and sand.

Although the lake-bottom sediments usually lie directly on till, seismic and test-boring data indicate the presence of a thick deposit of cross-bedded coarse sand beneath finer sediments in the vicinity of OW 64 in Fryeburg (Morrissey and others, 1985). The identity of this coarse unit is uncertain. It may be a subaque-

TABLE 1. RADIOCARBON AGES.

Sample/ Well no.	Sample depth	Sample elevation	Date no.	Radiocarbon age
OW 51-D	67-69 ft	328-330 ft	AA-10158	11,675 +/- 125 yr B.P.
OW 52	57-59 ft	342-344 ft	AA- 4769	11,680 +/- 105 yr B.P.
OW 65	22-24 ft	357-359 ft	AA-10157	11,255 +/- 80 yr B.P.

ous fan deposited at the mouth of a glacial ice tunnel early in the history of Lake Pigwacket.

Fossil plant remains were encountered in the lake-bottom sediments in several borings done for Saco Valley aquifer studies (Johnson and others, 1987; Prescott, 1979). Split-spoon samples containing organic materials were recovered during the installation of monitoring wells and supplied to the author by Dorothy Tepper (USGS). Hu (1989) identified a variety of plant pollen and macrofossils in three of these samples from wells north of Fryeburg village: OW 51-D, OW 52, and OW 65 (Appendix B). He concluded that they came from a forest environment indicative of a relatively warm, nonglacial climate.

Plant fragments from the same three borings were dated by accelerator mass spectrometry (AMS) at the University of Arizona. This technique yields ages in "radiocarbon years," which for late-glacial time are about 2,000 years younger than actual ages in calendar years. All ages given in this report are in radiocarbon years. The ages listed in Table 1 were determined for the Fryeburg samples.

The age and identity of the plant fossils show that the Fryeburg stage of Lake Pigwacket persisted into early postglacial time. The dated material probably corresponds to the Allerod climatic interval, marked by moderately warm conditions (Stuiver and others, 1995). There is very close agreement between the ages of samples from OW 51-D and OW 52, which were taken at similar depths and less than a mile apart. It is possible that the dated organic materials from these samples accumulated during a single depositional event, or at least during events that were closely related in time.

Given the above dates, the earliest Native American inhabitants of the region may have seen the final stage of Lake Pigwacket in the Fryeburg basin. Paleoindians lived in Maine soon after deglaciation, and Byers (1966) reported that a Paleoindian artifact was discovered in the Intervale district of Conway.

Eolian Deposits (Qe)

Although they have generally been overlooked in the past, the extensive deposits of eolian (windblown) sand in Fryeburg are one of the most distinctive geologic features in the quadrangle. These deposits occur mainly along the east side of the Saco Valley, especially north and east of Fryeburg village. Were it not for the vegetation cover, they might be as well known as the "Desert of Maine" in Freeport.

Unit Qe consists almost entirely of very fine to very coarse sand. In places it is even coarser-grained, with thin beds of granules (particles 2-4 mm in diameter). Pebbles may be present, especially at the base of the unit, where they were winnowed from underlying deposits. The pebbles often show a smooth, frosted surface texture resulting from sandblasting by the wind, and in extreme cases have been faceted by this process. These wind-polished stones are called "ventifacts."

Pit exposures in eolian sand typically show thin planar bedding and large-scale cross-bedding. This bedding is either subhorizontal or dips in a downwind direction. Locally it has an antiformal (arched) shape, and sets of beds may truncate older adjacent sets. Sets of cross-beds dip as steeply as 30° and resemble the foreset beds of lacustrine deltas. However, the eolian deposits usually do not contain silt, clay, or gravel-size material, and they lack some of the sedimentary structures (such as current ripples) found in water-laid sediments.

The thickness of unit Qe may vary abruptly over short distances, and can be as much as 20 ft (6 m) or more. One of the thickest and most extensive exposures of this unit was a sand pit (now reclaimed) at site no. 86-54, west of Lovewell Pond. Other good exposures were seen in small pits southwest of Highland Park (86-79), northeast of Fryeburg Fairgrounds (86-95), and east of "Fish Street" in North Fryeburg (83-30). At the last two sites, the eolian sand is underlain by Lake Pigwacket deposits.

Eolian deposits in the Fryeburg quadrangle exhibit four types of surface morphology: (1) blanket deposits, with a smooth horizontal to moderately sloping surface (e.g. east side of Route 5, opposite the fairgrounds); (2) mound-shaped dunes (e.g. large parking area in field west of fairgrounds); (3) longitudinal dune ridges, which parallel the wind direction at time of deposition; and (4) parabolic dunes, which are horseshoe-shaped ridges that are convex in the downwind direction. Fine examples of longitudinal and parabolic dunes occur in the large forested dune field northeast of Fryeburg village. Elongate east-west gullies and depressions in the dune field west of Lovewell Pond appear to be blowouts, which are further evidence of the intense wind activity that must have occurred in this area.

McKeon (1989) measured the orientations of longitudinal dunes in central Maine and found that they consistently indicate

a prevailing wind from the west-northwest, the same as today. Dunes in the Fryeburg area show a range of wind directions (see geologic map), but all are generally from the west. The wind-blown sands occur on the east sides of valleys and are presumed to have been derived from waterlain sediments on the valley floors.

Many eolian sand deposits in Maine, such as those described by McKeon (1989), probably originated in late-glacial time, when freshly deposited glacial outwash sands were not yet stabilized by vegetation. However, the dunes on the east side of the Saco Valley were derived from postglacial Lake Pigwacket deposits. One dune field near Fryeburg Center is surrounded by the Saco flood plain, raising the question of whether the dunes are older or younger than adjacent alluvial sediments. Augering along the contact between these units revealed flood-plain silt overlapping dune sand, so the dunes are older. The cohesive silt resists wind erosion and has simply accumulated around an older dune field that developed on deltaic sands of Lake Pigwacket.

Wetland Deposits (Hw)

Unit Hw consists of fine-grained and organic-rich sediments deposited in low, flat, poorly drained areas. In the Fryeburg quadrangle this unit occurs mainly on the flood plain of the Saco River. The boundaries of unit Hw were mapped primarily from aerial photographs. These boundaries are approximately located and should not be used rigorously for land-use zoning.

The distinction between "wetland" and "stream alluvium" in the Saco Valley is often subtle and arbitrary. Areas mapped as alluvium (unit Ha) on the geologic map are presumed to consist largely of inorganic sediment deposited by floods, while the wetland deposits -- though commonly part of the flood plain -- are inferred to include more organic muck and peat. However, large parts of the alluvial unit are also poorly drained and may have vegetation typical of wetlands, as suggested by the marsh-grass pattern printed on the topographic map.

There is little information on the thickness of wetland deposits in the quadrangle. A report by Cameron and others (1984) describing peat deposits in southwestern Maine found that they usually average less than 20 ft (6 m) thick.

Stream Alluvium (Ha)

Unit Ha consists of alluvial silt, sand, gravel, and organic material deposited by modern streams. In the Fryeburg quadrangle these deposits occur in great abundance along the Saco River and its tributaries, including the rich agricultural land in the broad valley floor north of Fryeburg village. The river has meandered back and forth across this flood plain, repeatedly changing course and leaving many abandoned channels that form striking arcuate patterns in aerial views of the Saco Valley. Gravelly alluvium in this area is usually not coarser than pebble-size, and is limited to high-energy environments such as present or former stream channels. The slack-water deposits on the Saco flood plain are finer grained, typically silt and sand (Lewis, 1985).

Numerous wells have been drilled through the alluvium in the Saco River valley (Johnson and others, 1987; Tepper and others, 1990). The boundary between the alluvium and underlying Lake Pigwacket sediments is not obvious from the textural descriptions in most of the well logs. In some cases the thickness of alluvial deposits can be inferred from the logs on the basis of an abrupt change in particle size. For example, observation well 13-9 (near the north edge of the quadrangle) indicated 16 ft (5 m) of very fine sand, silt, and clay overlying medium to very coarse sand with granules and pebbles (Williams and others, 1987). Surface observations often show that the flood plain deposits are fine-grained, so the coarse sediments in this log are thought to be related to the filling of Lake Pigwacket. Inspection of other well logs in the Saco Valley suggests that the river alluvium can be up to 20 ft (6 m) thick and perhaps even thicker. Just north of Fryeburg Fairgrounds, the topographic map shows elevations of 400+ ft on a point bar along the river bank and 386 ft in the bottom of a nearby abandoned channel on the flood plain, so at least 14 ft (4 m) of alluvium is present in the bar.

Two noteworthy alluvial features are seen along the Saco River in Fryeburg. The first is called a "lake-outlet delta." This is a delta formed where a lake drains into an adjacent river at nearly the same elevation. When the river floods, the rising water backs up *into* the lake and deposits deltaic sediment at the point which is normally the lake's outlet (Chormann, 1983; Caldwell and others, 1989). An example in the Fryeburg quadrangle can be seen on the southwest side of Kezar Pond. Other lake-outlet deltas are forming where the Saco River floods into the southeast end of Lovewell Pond (Brownfield quadrangle) and the Lower Bay of Kezar Lake (Center Lovell quadrangle). These lakes are subject to a great rise in water level during flood periods (Caldwell and others, 1989; Army Corps of Engineers, 1971).

The other distinctive feature is the large sand splay north of Bog Pond, at the outlet of the old canal where the Saco River was diverted through a till ridge north of Fryeburg village. One consequence of this diversion was a local steepening of the river's gradient, because the new course of the Saco loses the same elevation in a much shorter distance between Fryeburg and East Fryeburg. The change in the river's regimen caused sand to be eroded upstream from the canal and deposited as a large fan where the gradient decreases at the downstream end. Barrows (1938) described this process in his Fryeburg town history: "The change of the current and the shortening of the whole course of the river quickened the current, and thereby *washed the bottom out of the whole course of the river*, from the rapids at Swan's [Falls] to the change of direction at Bear Pond."

The ponds on the Saco flood plain vary greatly in depth. Maps by the Maine Department of Inland Fisheries and Wildlife show that Kezar Pond and Pleasant Pond are less than 15 ft (5 m) deep. These shallow ponds appear to be just backwaters dammed behind levees along the river. The central part of

Lovewell Pond is 30-40 ft (9-12 m) deep; and the floor of Lower Kimball Pond slopes southwest, reaching a maximum depth of 64 ft (20 m). Air photos and the bathymetric map reveal an alluvial delta built into Lower Kimball Pond from the edge of the Saco flood plain along its northeastern shore. Considering the greater depth of the latter ponds, they are believed to be remnants of ancestral Lake Pigwacket that were incompletely filled by Saco River deposits.

GLACIAL AND POSTGLACIAL GEOLOGIC HISTORY

The following reconstruction of the Quaternary history of the Fryeburg quadrangle and surrounding area is based on the interpretations of surficial earth materials described in this report, together with related topographic features. It is uncertain how many episodes of glaciation have affected the Fryeburg area during the Pleistocene Ice Age. Till deposits clearly record the most recent (late Wisconsinan) glaciation, and probably one earlier event. The deeply weathered lower till found elsewhere in central and southern New England has also been recognized in southern Maine (Thompson and Borns, 1985b; Weddle and others, 1989). Although it is not well-dated, the lower till was deposited during the penultimate glaciation, of probable Illinoian age.

Data summarized by Stone and Borns (1986) indicate that the late Wisconsinan Laurentide Ice Sheet expanded out of Canada and spread into Maine approximately 25,000 radiocarbon years ago. As the glacier continued to flow across the state for thousands of years, it reshaped the surface of the land by eroding, transporting, and depositing tremendous quantities of sediment and rock debris. The combined effects of erosion and deposition have given some hills a streamlined shape, with their long axes parallel to the south-southeastward flow of the ice. The best example in the Fryeburg quadrangle is Stanley Hill in the southeast part of the map area.

Late Wisconsinan glaciation produced a large portion of the stony till deposits that blanket the upland areas of the quadrangle. Glacial plucking on the lee sides of bedrock hills eroded steep south-facing slopes and cliffs on many hills in Maine, such as Mt. Tom and Jockey Cap in Fryeburg. Rocks torn from these hills were scattered in the direction of glacial transport. One of the largest boulders in the quadrangle can be seen next to the road leading from Route 5 to Highland Park (see geologic map).

On a smaller scale, abrasion by rock debris dragged at the base of the glacier polished and striated the bedrock surface. The striations are not easy to see in the Fryeburg area because they are either concealed beneath surficial sediments, or have been destroyed by weathering where the coarse granite ledges are exposed at the ground surface. Only four striation localities were encountered during this study. Striations found under the base of a fallen tree on Mt. Tom trend 180°, indicating southward ice flow. Similar trends are evident from striations on two hills north of Kezar Pond, and on a hill between Jockey Cap and Highland Park. This southward flow was a regional event that is believed to have resulted from reorganization of ice flow in southwestern Maine as the glacier thinned over the Mahoosuc Range to the north (Thompson and Koteff, 1995).

The minimum age of glacial retreat from the Fryeburg quadrangle can be determined through radiocarbon dating of organic material in sediments that were deposited on lake bottoms soon after deglaciation. Thompson and others (1996) obtained an age of 13,200 radiocarbon years from nearby Cushman Pond in Lovell, so the Fryeburg area probably was likewise deglaciated by this time. However, isolated masses of stagnant ice may have lingered in valleys. The Saco Valley was certainly ice-free by 12,000 years ago, judging from the dated plant remains in Fryeburg.

In coastal Maine it is possible to trace the retreat of the glacier margin in detail because there are hundreds of end-moraine ridges, submarine fans, and deltas that were deposited at the edge of the ice during its recession in a marine environment. End moraines and other ice-margin indicators are essentially absent in the Fryeburg quadrangle, making it difficult to reconstruct the pattern of deglaciation. However, in adjacent quadrangles to the east and south, the ice-contact sand and gravel deposits left by meltwater streams flowing into Lake Pigwacket provide clues to the history of ice retreat from the Fryeburg area. The locations, elevations, and other properties of these deposits are the basis for the sequence of events proposed below.

Early in the deglacial sequence, a southward-flowing lobe of ice still covered most of the study area, and the glacier margin stood near the south edge of the Fryeburg and Pleasant Mountain quadrangles. Meltwater streams washed sediment out of the ice and into early stages of Lake Pigwacket, which then occupied the Brownfield-Hiram section of the Saco Valley. Unit Plpo formed at this time, as meltwater flowed southward from a tongue of ice between Oak Hill and Starks Mountain in Fryeburg.

The glacier probably melted faster in a narrow corridor just east of the quadrangle, along the Elkins Brook valley and the east side of Kezar Pond (Pleasant Mountain quad). There was an early subglacial drainage in this area, now marked by an esker ridge deposited in a tunnel within the ice. Meltwater discharging from the tunnel may have accelerated local melting and retreat of the ice margin. This drainage system became an open water body -- the Pleasant Mountain stage of Lake Pigwacket -- which expanded northward along the east side of the Saco Valley.

A series of ice-contact deltas and subaqueous fans (unit Plpp) indicate successive positions of the ice margin associated with the Pleasant Mountain stage of Lake Pigwacket (Thompson, 1999f,g). The lake had a surface elevation of about 440-450 ft (134-137 m) near the south edge of the Pleasant Mountain quadrangle and drained southward into the Saco River valley. (The elevations of former glacial lake levels are now generally higher to the north due to uplift and tilt of the earth's crust in response to deglaciation.) The dam for this stage of the lake is not apparent, but presumably was a temporary obstruction caused by

glacial sediments or remnant ice blocking the Saco Valley in the western part of the Hiram quadrangle.

Continued ice retreat uncovered the Kezar River valley in Lovell and Sweden, and the Kezar Valley stage of Lake Pigwacket developed in this area. Sediments discharging from the local esker tunnel were deposited in the lake, eventually filling it and building a deltaic sand plain (unit Plpk) to elevations of 500-520 ft (152-158 m). This stage of the lake may have been continuous with the Pleasant Mountain stage to the south. Some of the Kezar Valley deposits were laid down on top of stagnant ice masses, which later melted and formed kettles.

It is inferred that remnants of glacial ice still occupied the Saco River basin around Fryeburg during the deposition of units Plpp and Plpk, because no lake deposits occur at comparably high elevations over most of the Fryeburg quadrangle. When the main part of the Saco Valley finally became ice-free, this low-lying area was flooded by the Fryeburg stage of Lake Pigwacket. Sediments washed into the lake from the upper Saco Valley in New Hampshire, and from smaller tributary valleys north and west of Fryeburg. The principal sediment source probably was the thick glacial-lake sediments that previously were deposited into the North Conway stage of Lake Pigwacket. The influx of this reworked sediment into the Fryeburg area may have been delayed until the postglacial Saco River cut through till barriers near Conway and Center Conway.

Lake-bottom deposits (unit Plpb) accumulated in Lake Pigwacket over a broad area between Fryeburg and Lovell, reaching elevations of 400-410 feet. However, the thickest deposits underlie the Saco flood plain between Fryeburg and North Fryeburg, where dated plant remains in unit Plpb record sedimentation prior to 11,000 years ago. This part of the valley filled with sand, silt, and clay, and a delta (unit Plpf) prograded northward into the lake at the present site of Fryeburg village. Elevations on this delta plain suggest that the surface elevation of the Fryeburg stage was about 425 ft (130 m). The Fryeburg stage of the lake was probably dammed by sand and gravel deposits temporarily blocking the Saco Valley in the Brownfield-Hiram area.

The Saco River gradually assumed its present form as the remnants of Lake Pigwacket mostly filled with sediment and the river cut through glacial deposits that had choked narrow parts of the valley. Most of this process was accomplished by the beginning of Holocene time (10,000 years ago), judging from the dates on the Fryeburg stage of Lake Pigwacket. Since then the Saco River has eroded the deltaic sand plain at Fryeburg and meandered across the old lake bottom north of town, depositing a substantial thickness of fine-grained alluvium (unit Ha) on its flood plain. Extensive wetlands (unit Hw) have formed on the poorly drained Saco flood plain in the eastern half of the quadrangle.

Rapid uplift and southeastward tilt of the earth's crust occurred soon after deglaciation (Kelley and others, 1992) and may have played a significant role in the evolution of the Saco Valley. The gradient of crustal tilt is known to be approximately 4.75 ft/mi in central New England (Koteff and Larsen, 1989). This tilt steepened the gradient of the south-flowing parts of the Saco River, including the North Conway section and reduced the gradient of the north-flowing section in Fryeburg. Tilting would have accelerated the erosion of glacial-lake sediments in the North Conway area, and promoted the development of the sluggish meander belt in the Old Course of the Saco north of Fryeburg village. The present-day gradients of the river, measured along a straight line, are 9 ft/mi in the Lower Bartlett-North Conway section, and only 1 ft/mi below Swans Falls in Fryeburg. Additional controls on downcutting by the Saco River are the bedrock thresholds in the river bed at Swans Falls (elev.~390 ft) and where Route 5 crosses the Old Course (362 ft).

Large deposits of eolian sand (unit Qe) formed on the east side of the Saco Valley, especially between Fryeburg and North Fryeburg, but their ages are not well known. The dune fields around Fryeburg village postdate the Lake Pigwacket sand plain on which they have developed; and the ages of the buried plant remains described above (unit Plpb) suggest that the dunes are no older than about 11,000 years. However, the dune field in the vicinity of Fryeburg Fairgrounds is truncated by the Saco flood plain and thus predates the latter feature.

Additional information on the relative age of the wind-blown sand was obtained from the dune field in the Saco Valley northwest of Fryeburg Center (see geologic and materials maps). Augering in the floor of a borrow pit in one of the dunes revealed that it is underlain by a thin layer of gray waterlaid silt, which in turn is underlain by sand with a few small pebbles that is probably also a waterlaid deposit. The latter units are interpreted as Lake Pigwacket sediments. Nearby in the same area, brown alluvial silt of Holocene age overlaps the margin of a sand dune. Thus it is likely that the dunes in this area formed after the Lake Pigwacket sediments were deposited, but prior to establishment of the modern flood plain. Some dunes elsewhere in the quadrangle may be younger, or may have been reactivated in historical time, like in other parts of Maine (e.g. McKeon, 1989).

ECONOMIC GEOLOGY

Large volumes of sand exist in the Fryeburg quadrangle, especially in map units Plpf and Qe between Fryeburg and North Fryeburg. Borrow pits have been opened in both of these units, and some gravelly sand has been excavated from channel deposits along the Saco River (unit Ha).

Gravel supplies are limited to a few small areas of the quadrangle, including some of the Lake Pigwacket deposits (unit Plpf and especially unit Plpo). At the time of this investigation, several pits were being worked in the Plpo deposits southeast of Fryeburg village. Coarse material has also been obtained from deposits of glacial till, such as the small pits in the area around Mt. Tom. In some cases till is not too difficult to excavate, and has a silty-sandy matrix that compacts well in applications where fill is needed.

Glacial-lake clay was formerly used for making bricks. One site in the quadrangle where clay is said to have been exca-

vated for this purpose was located next to Prays Brook, south of where it crosses Route 5 in Lovell. Concentrations of brick houses in Lovell and other villages may provide clues to the existence of nearby abandoned clay pits. Although there are thick deposits of silt and clay in the Saco Valley (unit Plpb), many of them are concealed beneath modern river alluvium.

Peat deposits are likely to occur in wetlands such as Swimming Bog (north of Kezar Pond), but the thickness and quality of these deposits are not known.

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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.

APPENDIX B

LOGS OF OBSERVATION WELLS AND OTHER BORINGS IN THE SACO RIVER VALLEY
(from Johnson and others, 1987; see materials map for locations)

OW43D. 4400550705933.01, Drilled 1984.
Altitude 407.5 ft. Depth to water 13.8 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, medium	0 -2	2
Sand, fine	2 -7	5
Sand, fine to medium	7 - 17	10
Sand, fine to very coarse, poorly sorted; little medium to very coarse sand, some granules and pebbles	17 - 22	5
Sand, fine to very coarse, very poorly sorted, some granules and pebbles	22 - 26	4
Sand, very fine to fine, gray	26 - 57	31
Clay and silt, gray-green	57 - 67	10
Sand, very fine to very coarse, some silt, some granules and pebbles	67 - 82	15
Sand, interbedded: layer of well-sorted very fine to fine sand; layer of well-sorted medium to coarse sand; layer of medium to very coarse sand; layer of fine to very coarse sand	82 - 97	15
Sand, very fine and silt; some very fine sand and granules and pebbles; trace silt; trace fine sand	97 - 108	11
Refusal (bedrock?)	at 108	

OW44. 4402190705952.01, Drilled 1985.
Altitude 415.7 ft. Depth to water 10.2 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, medium to very coarse	0 -2	2
Sand, very fine to fine, micaceous	2 -7	5
Sand, fine to medium, micaceous, iron-stained	7 - 12	5
Sand, very fine to fine	12 - 17	5
Clay, interbedded with layers of silt and layers of very fine to fine sand	17 - 19	2
EOH	at 19	

OW45. 4401290705921.01, Drilled 1985.
Altitude 402.0 ft. Depth to water 9.7 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, fine	0 -7	7
Sand, fine to medium	7 - 12	5
Sand, medium to coarse, some fines	12 - 17	5
Sand, interbedded:layer of coarse to very coarse sand; layer of organic-rich fine sand; layer of medium to very coarse sand, some granules and pebbles; layer of fine sand	17 - 22	5
Sand, very fine to fine, gray	22 - 24	2
EOH	at 24	

OW46. 4400580705859.01, Drilled 1984.
Altitude 416.0 ft. Depth to water 8.5 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, medium to coarse, some granules	0 -7	7
Sand, medium, interbedded with layers of clay, silt, and very fine sand	7 -12	5
Sand, medium to very coarse, iron-stained, some granules and pebbles	12 -22	10
Sand, fine, well-sorted	22 -32	10
Sand, fine, interbedded with finely laminated clay and silt	32 -52	20
Clay and silt, gray, interbedded with layers of very fine to fine sand; little fine to coarse sand	52 -62	10
Clay and silt, green-gray	62 -78	16
Till(?)	78 -79	1
EOH	at 79	

OW47. 4402250705913.01, Drilled 1984.
Altitude 402.1 ft. Depth to water 7.1 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, very fine to very coarse, poorly sorted	0 -2	2
Sand, medium to very coarse, with some interbedded clay and silt	2 -9	7
Till(?)	9 -14	5
Refusal (bedrock?)	at 14	

OW48. 4402070705842.01, Drilled 1984.
Altitude 415.8 ft. Depth to water 15.7 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, very fine to medium	0 -2	2
Sand, fine	2 -7	5
Sand, fine to medium	7 -17	10
Silt, very fine to fine sand; trace organics	17 -22	5
Silt and clay, laminated; some layers of very fine sand	22 -32	10
Silt and clay, laminated; and well-sorted very fine sand	32 -34	2
EOH	at 34	

OW49. 4401460705822.01, Drilled 1984.
Altitude 424.4 ft. Depth to water 19.1 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, fine to very coarse, some granules and pebbles	0 -2	2

Sand, medium to coarse . . . . . 2 -7 5
Sand, medium, well-sorted . . . . . 7 -12 5
Sand, medium, some coarse sand . . . . . 12 -22 10
Sand, fine to medium. . . . . 22 -27 5
Sand, medium, some fine to very coarse sand . . . . . 27 -32 5
Sand, fine to medium; some very fine to fine sand, trace clay and silt; little medium sand with trace fine to very coarse sand . . . . . 32 -34 2
EOH . . . . . at 34

OW50. 4403180705758.01, Drilled 1985.
Altitude 393.1 ft. Depth to water 21.4 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, fine to medium.	0 -2	2
Sand, medium to very coarse.	2 -7	5
Sand, medium to very coarse, some granules and pebbles	7 - 22	15
Sand, coarse to very coarse, some granules and pebbles; little medium sand	22 - 27	5
Sand, very fine to fine; some gray clay and silt	27 - 32	5
Sand, very fine to fine, some laminations of gray clay and silt; little medium to very coarse sand	32 - 42	10
Silt, and fine sand, gray, micaceous, some laminations of gray-green clay	42 - 52	10
Clay, and silt, some very fine sand	52 - 96	44
Till	96 - 100	4
Refusal (bedrock).	at 100	

OW51D. 4403510705813.01, Drilled 1985.
Altitude 396.8 ft. Depth to water 22.4 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, fine	0 - 12	12
Sand, medium to very coarse, granules and pebbles	12 - 37	25
Sand, very fine to medium; interbedded with layers of coarse to very coarse sand.	37 - 47	10
Sand, medium to very coarse; little very fine to fine sand	47 - 57	10
Sand, medium to very coarse; interbedded with micaceous fine to medium sand . . .	57 - 67	10
Sand, very fine to medium, micaceous; little fine to very coarse sand; sand is interbedded with gray-green silty clay; trace organics	67 - 87	20
Clay, silty, gray-green; interbedded with very fine to coarse sand; little granules and pebbles	87 - 111	24
EOH.	at 111	

OW52. 4403150705819.01, Drilled 1984.
Altitude 401.4 ft. Depth to water 23.1 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, fine to medium.	0 -2	2
Sand, very fine to fine	2 -7	5
Sand, medium, well-sorted.	7 - 12	5
Sand, medium to very coarse, some granules and pebbles.	12 - 22	10
Sand, medium to very coarse; some iron-stained, brown very fine to fine sand	22 - 27	5
Sand, medium to very coarse, trace fine sand; some very fine to fine sand; some very fine to medium iron-stained sand, little fine to medium sand.	27 - 32	5
Sand, very fine to medium	32 - 37	5
Sand, very fine to very coarse, very poorly sorted.	37 - 47	10
Sand, very fine to fine, gray	47 - 57	10
Sand, very fine to fine; some silt to very fine sand; trace organics	57 - 67	10
Silt, laminated, interbedded with layers of very fine to fine sand; well-sorted very fine to fine sand	67 - 77	10
Sand, very fine to fine, gray, well-sorted, micaceous	77 - 87	10
Sand, very fine to fine, with laminations of green clay and silt	87 - 102	15
Clay and silt, green; some coarse to very coarse sand, trace granules	102 - 104	2
EOH.	at 104	

OW53. 4404330705814.01, Drilled 1984.
Altitude 396.9 ft. Depth to water 16.1 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, fine	0 -12	12
Sand, fine to medium.	12 -17	5
Sand, very fine to fine; little medium sand	17 -22	5
Sand, medium to coarse.	22 -27	5
Sand, medium to very coarse.	27 -37	10
Sand, medium to very coarse; little gray fine to medium sand	37 -47	10
Sand, fine to medium; and medium to very coarse sand	47 -57	10
Sand, very fine to fine, gray, micaceous; trace clay and silt	57 -77	20
Clay and silt, green-gray	77 - 104	27
Till.	104 - 112	8
Refusal (bedrock).	at 112	

OW54. 4404150705737.01, Drilled 1984.
Altitude 394.8 ft. Depth to water 16.2 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, very fine to fine	0 -7	7
Sand, fine to medium	7 -17	10
Sand, medium to very coarse	17 -22	5
Sand, medium to very coarse, some granules and pebbles, trace fine sand	22 -24	2
EOH	at 24	

OW55. 4404570705729.01, Drillled 1985.
Altitude 394.8 ft. Depth to water 14.1 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, fine	0 -2	2
Sand, very fine to fine	2 -7	5
Clay, and silt, some very fine sand	7 -12	5
Sand, medium to coarse; some medium to very coarse sand	12 -17	5
Sand, interbedded:layer of poorly-sorted fine to coarse sand, some very coarse sand; layers of coarse to very coarse sand; layers of medium to very coarse sand; layers of fine to medium sand	17 -22	5
Sand, very fine to medium, micaceous, iron-stained	22 -24	2
EOH	at24	

OW56. 4405190705743.01, Drillled 1985.
Altitude 392.8 ft. Depth to water 14.3 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil	0 -2	2
Sand, fine to medium	2 -12	10
Sand, medium to coarse	12 -17	5
Sand, medium to very coarse, some granules and pebbles	17 -22	5
Sand, gray, interbedded:layers of very-fine to fine sand; layers of medium to coarse sand; layers of medium to very coarse sand	22 -27	5
Sand, very fine to fine, and silt; inter-bedded with gray-green clay	27 -57	30
Clay, silty; some well-sorted fine to medium sand; some very fine sand inter-bedded with silty clay	57 -77	20
Sand, interbedded:layers of very fine to medium sand; layers of medium to coarse sand; layers of clay and silt	77 - 102	25
EOH	at 102	

OW57. 4406100705735.01, Drilled 1984.
Altitude 390.0 ft. Depth to water 11.7 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil	0 -2	2
Sand, fine to medium	2 - 12	10
Sand, very fine to fine	12 - 17	5
Sand, very fine to fine; and medium to very coarse sand	17 - 22	5
Sand, medium to very coarse, trace fine sand	22 - 27	5
Sand, medium to very coarse; and medium to coarse sand, trace fine sand	27 - 47	20
Sand, medium to very coarse, trace fine sand, faintly iron-stained	47 - 52	5
Till (?)	52 - 53	1
Refusal (bedrock)	at 53	

OW58. 4407150705837.01, Drilled 1984.
Altitude 383.1 ft. Depth to water 8.7 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, fine to medium	0 - 12	12
Sand, medium to very coarse, brown	12 - 17	5
Sand, fine, brown; little medium to coarse sand	17 - 22	5
Sand, medium to coarse, some very coarse sand, brown, some iron-staining; little gray very fine sand and silt	22 - 27	5
Sand, medium to very coarse, brown, some granules and pebbles; some gray very fine to fine sand	27 - 37	10
Clay, gray, with laminations of micaceous very fine sand and silt; gray, silty clay and medium sand.	37 - 42	5
Till	42 - 48	6
Refusal (till)	at 48	

OW59. 4406460705651.01, Drilled 1984.
Altitude 380.5 ft. Depth to water 8.4 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, fine to medium	0 -7	7
Sand, fine to very coarse	7 - 17	10
Sand, medium to very coarse; little fine to very coarse	17 - 22	5
Sand, medium to very coarse, some iron-staining; and gray fine to very coarse sand	22 - 24	2
EOH	at 24	

OW60. 4407270705709.01, Drilled 1984.
Altitude 383.6 ft. Depth to water 10.2 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, very fine to fine	0 -2	2
Sand, fine, well-sorted	2 -7	5

Sand, very fine to medium	7 - 12	5
Sand, medium to very coarse	12 - 22	10
Clay, some medium to very coarse sand	22 - 24	2
EOH	at 24	

OW62. 4407010705557.01, Drilled 1984.
Altitude 378.6 ft. Depth to water 10.4 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, very fine to fine	0 -2	2
Sand, very fine, and silt	2 - 12	10
Sand, medium to very coarse, some granules and pebbles, trace fine sand	12 - 17	5
Sand, very fine to fine	17 - 19	2
EOH	at 19	

TH63. 4401120705936.01, Drilled 1984.
Altitude 412 ft. Depth to water 7 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, very fine to fine	0 -2	2
Sand, medium to coarse, brown, well-sorted	2 -17	15
Sand, very coarse, and granules and pebbles	17 -27	10
Sand, very fine, gray, well-sorted	27 -37	10
Sand, very fine, gray, some clay laminations	37 -47	10
Sand, very fine, and silt, some blue-gray clay laminations	47 -62	15
Sand, very coarse, some angular gravel, some fine gray sand	62 -72	10
Till(?)	72 -74	2
Refusal (till?)	at 74	

OW64. 4401370705835.01, Drilled 1984.
Altitude 402.5 ft. Depth to water 10.3 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil	0 -2	2
Sand, fine to medium, iron-stained	2 -7	5
Sand, coarse, brown	7 -17	10
Sand, very coarse, some granules and pebbles, some blue-gray clay	17 -27	10
Sand, very fine to fine, blue-gray, some clay laminations	27 -37	10
Sand, medium to coarse, gray; some clay	37 -47	10
Sand, coarse to very coarse, well-sorted	47 -57	10
Sand, coarse to very coarse, some granules and pebbles	57 -67	10
Sand, coarse, gray, some medium sand, some very coarse sand	67 -77	10
Sand, medium, gray, some fine sand; some fine gray sand	77 -87	10
Sand, coarse to very coarse, gray; some medium sand	87 -95	8
Till	95 -108	13
EOH	at 108	

OW65. 4404050705656.01, Drilled 1984.
Altitude 381.1 ft. Flowing well.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, fine	0 -7	7
Clay and silt	7 -12	5
Clay and silt, gray, with laminations of very fine to fine sand	12 -17	5
Silt, gray, and very fine to fine sand	17 -22	5
Silt, gray, some clay, some very fine to fine sand; trace organics	22 -32	10
Clay; very poorly sorted very fine to coarse sand, granules and pebbles	32 -42	10
Sand, fine to coarse; some very poorly sorted very fine to very coarse sand, granules, and pebbles; little very fine to fine sand; little silt and very fine sand	42 -47	5
Sand, very fine, well-sorted; some very fine to fine sand; some very poorly sorted fine to very coarse sand, some granules and pebbles	47 -52	5
Sand, fine to medium; some silt and very fine sand; little very poorly sorted very fine to very coarse sand, some granules and pebbles	52 -59	7
Refusal (bedrock?)	at 59	

OW66. 4400170705822.01, Drilled 1985.
Altitude 415.1 ft. Depth to water 12.7 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, medium to coarse	0 -7	7
Sand, medium to very coarse	7 - 17	10
Clay, some silt, some very fine sand	17 - 22	5
Clay and silt, tan, laminated, iron-stained	22 - 27	5
Clay and silt, some very fine sand, gray; and tan clay and silt, some very fine sand	27 - 37	10
Clay and silt, gray, some laminations of very fine to fine sand	37 - 77	40
Silt, and very fine to fine sand, trace clay	77 - 92	15
Sand, medium to very coarse, some fine to very coarse, gray	92 -104	12
EOH	at 104	

OW67. 4401010705829.01, Drilled 1985.
Altitude 422.6 ft. Depth to water 16.6 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil	0 -2	2
Sand, medium to coarse, dark brown	2 -7	5
Sand, medium to very coarse, tan	7 - 12	5
Sand, fine to medium	12 - 22	10
Sand, fine to medium; some very fine sand interbedded with fine sand; some clay and silt interbedded with very fine sand	22 - 27	5
Sand, very fine and silt, laminated, iron-stained; trace medium sand	27 - 37	10
Sand, fine to medium, well-sorted	37 - 47	10
Sand, very fine to fine, iron-stained; and very fine sand and silt; trace fine to medium sand	47 - 57	10
Sand, very fine to fine, micaceous; trace clay	57 - 72	15
Silt, and very fine sand; some clay	72 - 82	10
Clay, silty, gray-green	82 - 95	13
Till	95 - 104	9
EOH	at 104	

OW68. 4401430705953.01, Drilled 1985.
Altitude 406.9 ft. Depth to water 13.6 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil	0 -2	2
Silt; clay	2 -7	5
Sand, medium to very coarse, iron-stained	7 - 12	5
Sand, very fine to fine, micaceous; some poorly sorted very fine to very coarse	12 - 17	5
Sand, very fine to fine; some silt	17 - 22	5
Clay, tan; some silt; some very fine sand	22 - 24	2
EOH	at 24	

OW70. 4406050705849.01, Drilled 1985.
Altitude 386.0 ft. Depth to water 8.8 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, very fine to fine	0 -2	2
Sand, medium to very coarse	2 - 17	15
Silt, gray, micaceous, some very fine to fine sand; some medium to very coarse sand	17 - 22	5
Clay, silty, gray-green; some layers of silty clay interbedded with layers of silt and very fine sand	22 - 24	2
EOH	at 24	

OW71. 4406070705809.01, Drilled 1985.
Altitude 391.3 ft. Depth to water 15.1 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, fine	0 -7	7
Sand, very fine to fine, micaceous	7 -17	10
Sand, interbedded, micaceous, iron-stained:layers of silt to very fine sand; layers of fine to medium sand; layer of very fine to very coarse, very poorly sorted sand	17 -22	5
Sand, interbedded:layers of fine to very coarse sand; layers of fine to coarse sand; layers of coarse to very coarse sand; layers of fine to medium sand; layers of silt to very fine sand	22 -27	5
Sand, interbedded:layers of medium to very coarse sand; layers of fine to medium sand; layers of fine to coarse sand	27 -29	2
EOH	at 29	

OW72. 4406310705727.01, Drilled 1985.
Altitude 388.1 ft. Depth to water 13.7 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, fine	0 -2	2
Sand, very fine to fine, some silt	2 -12	10
Sand, medium to coarse; some very fine sand and silt	12 -17	5
Sand, very fine and silt; and medium to very coarse sand with granules and pebbles	17 -27	10
Sand, coarse to very coarse, some granules and pebbles	27 -37	10
Sand, medium to very coarse, some granules and pebbles	37 -47	10
Sand, coarse to very coarse, some granules and pebbles; and fine to medium sand	47 -57	10
Sand, medium to very coarse; interbedded with coarse to very coarse sand, some granules and pebbles	57 -67	10
Clay, silty, gray-green; interbedded with micaceous fine sand	67 -97	30
Clay, silty, gray-green, some color differentiation between layers	97 - 103	6
Till	103 - 105	2
EOH	at 105	

OW73. 4406510705833.01, Drilled 1985.
Altitude 383.0 ft. Depth to water 5.2 ft.
Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, very fine and silt	0 -2	2
Sand, medium to very coarse	2 -7	5
Sand, medium to very coarse, granules and pebbles	7 -12	5
Sand, medium to very coarse	12 -17	5
Sand, fine to coarse; and medium to very coarse sand	17 -22	5
Sand, medium to very coarse, granules and pebbles; some fine sand	22 -24	2
EOH	at 24	

(OW 13-7,8,9 from Williams and others, 1987)

OW 13-7. Latitude: 44°07'22", longitude: 70°53'05". Located in Sweden, near Lovell town line, in field off Wrights Hill Road. Depth to water approximately 5 feet.

Material	Depth	Thickness (feet)
Sand, medium to coarse	0-6	6
Sand, fine to medium	6-21	15
Sand, very fine to fine	21-26	5
Sand, very fine to fine, with laminations of silt and clay	26-81	55
End of boring	81	--

OW 13-7 is screened from 15 to 20 feet below land surface with 0.006-inch slotted PVC screen.

OW 13-8. Latitude: 44°02'05", longitude: 70°58'26". Located in Fryeburg, in field owned by Green Thumb Corporation, east of Rt. 113.

Material	Depth	Thickness (feet)
Sand, medium well-sorted	0-6	6
Sand, fine to medium	6-11	5
Sand, very fine; silt	11-21	10
Sand, coarse to very coarse, well-sorted	21-26	5
Sand, medium to very coarse, moderately well-sorted, stratified	26-31	5
Sand, medium to coarse	31-36	5
Sand, fine to very coarse, moderately well-sorted, stratified	36-46	10
Sand, medium, well sorted	46-56	10
Sand, fine to medium	56-66	10
Sand, very fine to medium, moderately well-sorted, stratified	66-76	10
Sand, fine to medium gray	76-96	20
Sand, fine to coarse, gray, moderately sorted, stratified	96-106	10
Sand, very fine to fine, with faint laminations of silt and clay	106-108	2
End of boring	(108)	--

OW 13-8 is screened from 25 to 30 feet below land surface with 0.008-inch slotted PVC screen.

OW 13-9. Latitude: 44°07'28", longitude: 70°56'27". Located in Fryeburg near the intersection of McNeil Road and River Road. Depth to water approximately 8 feet.

Material	Depth	Thickness (feet)
Sand, very fine to fine; silt; clay	0-16	16
Sand, medium to very coarse, granules and pebbles	16-20	4
Sand, medium to very coarse, moderately sorted, stratified	20-31	11
Sand, medium to very coarse, iron-stained; granules and pebbles	31-41	10
Sand, fine to medium, gray, well-sorted, micaceous	41-48	7
Clay, massive, gray-green	48-53	5
End of boring	(53)	--

OW 13-9 is screened from 20.5 to 23 feet below land surface with 0.010-inch slotted PVC screen.

(OW 615 from Prescott, 1979)

OW 615. Alt. 388 ft. Log of observation well for U.S. Geological Survey at North Fryeburg.

	Thickness	Depth
Alluvium:		
Reddish-brown sand and fine gravel	20	20
Outwash:		
Gray sand and fine gravel	2	22
Gray sand and some fine gravel	8	30
Reddish-brown sand and fine gravel	10	40
Reddish-brown coarse sand and fine gravel	5	45
Gray sand and some fine gravel	5	50
Gray sand with more gravel than previous	5	55
Tan sand and fine gravel	5	60
Gray medium to coarse sand and some fine gravel; contains fragments of organic material	14	74
Gray sand (washed ahead)	5	79
Glacial lake deposits		
Fine gray sand and silt; contains some blebs of gray clay (washed ahead)	33	112
Fine sand with some medium to coarse sand; contains some blebs of gray clay and pieces of wood and leaves; sand and clay may be layered. (washed ahead)	8	120
Refusal (probably bedrock) at		120