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GEOLOGIC QUADRANGLE MAPS OF THE UNITED STATES

SURFICIAL GEOLOGIC MAP OF THE CLINTON QUADRANGLE WORCESTER COUNTY, MASSACHUSETTS

By
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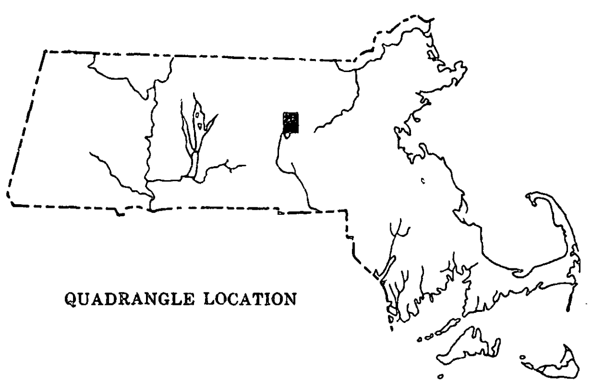

QUADRANGLE LOCATION

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INTRODUCTION

The Clinton quadrangle is an area of about 55 square miles in east-central Massachusetts; it is part of the upland known as the Worcester plateau. Most of the Clinton area is drained by the Nashua River, which flows northward into the Merrimack River. The southeastern part of the area is drained by North Brook, a tributary of the Assabet-Concord River system, which empties into the Merrimack River about 11 miles farther southeast than does the Nashua River. The Nashua River occupies a valley carved out of the relatively soft and less resistant Worcester Formation of Carboniferous age; North Brook flows over more resistant granites and other crystalline rocks that underlie the southeastern part of the area. The course of the Nashua River in the quadrangle is parallel to the regional trend of the underlying bedrock.

The Wachusett Reservoir, constructed in 1908, now floods the upper part of the Nashua River valley. The crosslined pattern on the map south of Coachlace Pond indicates the approximate area used as a bypass for the Nashua River during the construction of the dam. Much grading and disturbance of the original sand and gravel as well as addition of artificial fill has taken place at this locality.

Because of differing interpretation, the geologic boundaries in the Clinton quadrangle locally do not coincide with those mapped in the Hudson quadrangle (Hansen, 1956) to the east.

SURFICIAL DEPOSITS

Till

Till in the Clinton quadrangle is generally a poorly sorted, light- to dark-gray mixture of silt, sand, gravel, and boulders, and minor amounts of clay. Color and texture of the till vary with the source rock. The Worcester Formation is a dark-gray, very fine grained rock that underlies the quadrangle in a north- to northeast-trending belt from Wekepeke Brook in the northwest to the east divide of the Nashua River valley (R. F. Novotny, written commun., 1963). Till derived from the Worcester Formation contains more silt and clay and is darker gray than till derived from the granites and associated crystalline rocks that underlie the remainder of the quadrangle. The dark-gray till also contains fewer and smaller boulders. The till derived from the granites and associated crystalline rocks is similar to till found in many localities throughout eastern Massachusetts.

The thickest till is in the drumlins, which are shown by symbol on the map. Unconfirmed well data indicate that at least 60 feet of till is present in several drumlins. Elsewhere in the area, the till probably averages about 10 feet thick, and less in areas of abundant bedrock outcrop. Small stratified lenses of sand and gravel occur within the till in some places but are not shown on the map.

A temporary excavation south of Main Street in Bolton exposed a till that is distinctly different from the rest of the till in the quadrangle. It is olive brown, compact, and silty, has a conspicuous fissility or cleavage, and resembles the lower or older of two separate tills that have been recognized in the adjoining area to the east and elsewhere in Massachusetts (Hansen, 1956, p. 61; Currier, 1941). It is likely that the gray till of the Clinton area is equivalent to the upper or younger till found elsewhere, and that the olive-brown till in Bolton is the equivalent of the lower or older till.

Uncorrelated glacial stream and lake deposits

Some deposits of sand and gravel laid down by melt water in contact with stagnant ice, chiefly in the western and southeastern parts of the area, do not fit chronologically, and have not been correlated with other deposits. They probably include both glacial stream and glacial lake deposits. In the southeastern part of the area these deposits are composed mostly of sand and minor amounts of pebble gravel; in the western part of the area these deposits generally are coarser grained and include beds of cobble gravel as much as 10 feet thick. The uncorrelated deposits contain very little silt and no clay.

Glacial lake deposits

Deposits of three glacial lakes, Lake Nashua, Lake Assabet, and Lake Leominster, occur in the quadrangle. Various stages have been recognized for each lake. Glacial lake deposits are composed chiefly of sand and pebbly sand, and minor amounts of clay, silt, and gravel. Coarser grained layers generally occur in glacial stream beds graded to glacial lakes and in topset beds of deltas built into these lakes; finer grained layers occur in foreset beds of deltas and in lake-bottom deposits. This textural relationship of topset and foreset beds is well shown in gravel pits in the deposits of glacial Lake Leominster south and west of Pratt Junction in Sterling where topset beds of pebble and cobble gravel 20 to 25 feet thick overlie foreset beds of fine and medium sand. Large pits in the Ayer stage deposits about 1 mile east of North Village in Lancaster expose topset beds of pebbly sand more than 30 feet thick that overlie foreset beds of fine and medium sand and a few thin clay layers.

Lake-bottom deposits are shown on the map only for Boylston stage of glacial Lake Nashua. These deposits are chiefly fine sand and silt, although some gravelly sand occurs at the north side of Greenhalge Point in Wachusett Reservoir. Most other lake-bottom deposits are buried by delta deposits. The only other exposed or known lake-bottom sediments are associated with deposits of the Ayer stage. Alden (1924, p. 70-71) found more than 14 feet of clay beneath 10 to 12 feet of sand and fine gravel about half a mile west of Still River Station in Harvard, and Alden (1910) found clay about three-fourths of a mile east of North Village in Lancaster. These exposures are now slumped and very poorly exposed, but a few auger holes drilled in the vicinity penetrated silt and some clay at depths of 5 feet or more. Clay and silt occur near or at the surface of Ayer stage deposits just east of Whittemore Hill in Lancaster. Other lake-bottom deposits of the Ayer or Groton stages may be present beneath the alluvium and swamp deposits in the Nashua River valley.

North Brook valley deposits

North Brook valley deposits range from fine sand to cobble gravel and include material of glacial stream and glacial lake origin. These sediments were laid down near the divide between the Nashua River and North Brook and have a limited extent and thickness. The thickest and coarsest sediments are in the northernmost body; an exposure of kame delta deposits in the gravel pit south of Runaway Brook Golf Course in Bolton showed 5 to 7 feet of cobble gravel in topset beds overlying more than 15 feet of pebble gravel and pebbly sand in foreset beds. Most pebbles and cobbles are phyllite; concentration of gypsum and iron, formed by weathering of sulfides in the phyllite has caused smaller pebbles to adhere to the bottom of the larger stones. North Brook valley deposits elsewhere are generally finer grained and probably average 10 feet thick or less.

Sand and gravel undivided

Deposits of sand, gravel, and silt of uncertain genesis occur in scattered areas in the quadrangle. These deposits generally have the same texture as the surrounding and higher deposits and are separated chiefly on the basis of morphology. In places, such as the east side of the Nashua River valley, these sediments seem to have been laid down by erosion of surrounding sand and gravel and to have been graded to a level higher than the present alluvium. In other places, such as the Wekepeke Brook area in the northwestern part of the quadrangle, valley bottoms shown as Qsg deposits may have been produced by erosion, or, if large ice blocks occupied this area during deposition of the glacial Lake Leominster deposits, the valleys may have formed as the ice melted.

Thicknesses of the undivided sand and gravel are not well known, although water wells in the southeast corner of Leominster penetrate at least 100 feet of sand and gravel.

River-terrace deposits

River-terrace deposits of sand, silt, and some gravel occur along the Nashua and North Nashua Rivers and North Brook. These deposits generally are finer grained than the adjacent, higher, glacial lake and glacial stream deposits from which they are chiefly derived. The average texture of the river-terrace deposits is medium sand; however, pebble and small cobble gravel at least 5 feet thick was observed in a temporary excavation in a river terrace southeast of Ponakin Mill in Lancaster. Pebbly sand also is found in the river terraces along North Brook.

Alluvium

Alluvium underlies the modern flood plains of the Nashua and North Nashua Rivers and some small areas along Wekepeke and North Brooks. The alluvium commonly is very light gray to almost white and consists chiefly of fine sand and silt; the deposits along North Brook contain some coarse sand and scattered pebbles. In many places swamp deposits overlie the alluvium; in other places they are mixed with the alluvium. The surfaces of the flood plains are marked by many scrolls and meander scars, indicating lateral cutting and undermining of adjacent, higher deposits. The thickness of the alluvium is not well known but is at least 15 feet in a few localities.

GLACIAL AND POSTGLACIAL HISTORY

The Tertiary and preglacial drainage history of the area has been described by Crosby (1899) and Alden (1924). A discussion of this history requires a study of a much larger area than the Clinton quadrangle and is not attempted here except in relation to changes produced by glaciation.

The till in the area is believed to have been deposited by the last ice advance of the Wisconsin Glaciation. A possible exception is the olive-brown till south of Main Street in Bolton. This till is similar in texture and color to till considered elsewhere in eastern Massachusetts to represent an older ice advance. More than one major ice advance probably took place in the Clinton area, but exposures and well records give evidence for only the latest advance. The ice generally moved southward, but, it was diverted southwestward by the Nashua River valley, as shown by striations and by long axes of the drumlins in or near the valley.

The first deposits laid down during retreat of the ice from the quadrangle probably were the uncorrelated sediments in the vicinity of North Brook and in isolated patches to the west.

Most of the recession of the ice sheet from the Clinton quadrangle was marked by a succession of glacial lakes. The preglacial northward-draining valley of the Nashua River formed a lake basin, the ice being a barrier to the north. The direction of lake drainage shifted from south and southeast to north as successively lower outlets were uncovered during northward retreat of the ice.

Sand and gravel of glacial Lake Assabet and the Boylston stage of glacial Lake Nashua were laid down in separate basins at approximately the same time, when the stagnant front of the ice stood along what is now the northern area of these deposits. The Boylston stage was controlled by an outlet at an altitude of about 445 feet, about 2½ miles south of the southwestern corner of the quadrangle.

Deposits and outlets of three stages of Lake Assabet are described in the adjoining area to the east (Hansen, 1956, p. 80), but only the two higher stages are recognized in the Clinton quadrangle. The lowest stage to the east, at an altitude of approximately 250 feet, was too low to extend into this quadrangle.

When ice had retreated far enough northward to uncover the spillway south of Rattlesnake Hill in Boylston, the level of Lake Nashua dropped to the Clinton stage, controlled by a bedrock lip at an altitude of about 350 feet. The Rattlesnake Hill spillway was used as a lake outlet until the stagnant ice front had retreated to a position north of the quadrangle. During this interval, extensive deltas were formed in the lake, the southern parts of which are now covered by the Wachusett Reservoir (Crosby, 1903-04).

The North Brook valley deposits were laid down in the early part of Clinton stage time, shortly before retreating ice had uncovered the divide of the Nashua River valley in the eastern part of Clinton. Three gaps in the divide here were spillways for the Clinton stage lake after ice had retreated from this locality. These spillways are slightly higher than the Rattlesnake Hill outlet and indicate that the lake at this time was divided into two parts by ice in the middle of the valley and by the bedrock and till hills in the center of Clinton. One part of the lake was drained by the Rattlesnake Hill outlet and is represented by deposits west of Clinton; the other was drained by the three higher outlets and is represented by deposits east of Clinton, from Lancaster Mill Pond to perhaps as far north as Runaway Brook Golf Course in Bolton. Further retreat of the ice northward resulted in one integrated lake, controlled only by the Rattlesnake Hill outlet.

Glacial Lake Leominster came into existence when retreat of the ice uncovered outlets in Sterling, east of Redstone Hill. This lake previously was considered to be a stage of glacial Lake Nashua by Alden (1924, pl. 6); but it occupied a higher and separate basin and is considered in this report to have been a separate lake having three stages of its own. The high stage of this lake spilled out through successively lower outlets, from about 450 feet to 430 feet in altitude; no attempt is made in this report to subdivide the high-stage deposits further. When the ice front stood north of Pratt Junction, a new outlet more than 420 feet but less than 430 feet in altitude was uncovered just east of Hawthorn Hill. Lake waters were diverted through this middle-stage outlet because of a barrier formed by the higher stage deposits and stagnant ice blocks. Further retreat of the ice uncovered the outlet for the low stage of Lake Leominster on Ballard Hill, at an altitude of about 415 feet. Lake Leominster ceased to exist when the North Nashua valley was uncovered and the lake level fell to the Clinton stage level of Lake Nashua.

The level of glacial Lake Nashua dropped to the Pin Hill stage when an outlet at about 350 feet in altitude and about 2 miles northeast of the quadrangle was uncovered (Jahns, 1953). Large ice blocks probably still occupied the valleys of the North Nashua and Nashua at this time, as deposits in these localities that can be correlated with the Pin Hill stage are absent. Deposits representing lake stages between that of the Pin Hill and the Ayer may be present in the quadrangle and may be included with those of the Pin Hill stage.

Deposits of the Ayer stage were laid down after retreat of the ice had uncovered an outlet at an altitude of approximately 250 feet, east of the town of Ayer (Jahns, 1953), about 4 miles northeast of the Clinton quadrangle. Large ice blocks still persisted in the North Nashua and Nashua valleys, as indicated by ice-contact or collapse structures observed in the Ayer stage deposits in the southern part of Lancaster and by the absence of deposits west of the center of Lancaster. Because of ice blocks in the valley, the direction of deposition of Ayer stage deposits was easterly from South Lancaster for about 2 miles and then northerly along the east side of the Nashua valley. The profile shows the easterly direction parallel to section B-B', the northerly direction parallel to section A-A'. To show this relationship, B' has been placed on the profile at a point normal to A-A', and the rest of the profile of B-B' has been rotated into the plane of A-A'.

During the Ayer stage, the presence of ice blocks prevented deposition in the southern part of the North Nashua valley, and drainage from the northwestern part of the quadrangle was diverted through the bedrock gap half a mile east of North Village. This gap, at an altitude of about 265 feet, may have ponded melt water behind it temporarily, until headward filling of Ayer stage sediments in the Nashua valley covered the gap. When a later and lower base level was established to the north of the quadrangle, deposits in the gap were eroded to bedrock again.

Jahns (1953) proposes that trenching of sand and gravel deposits of the Ayer stage near the town of Ayer lowered the lake level to what is called the Groton stage of glacial Lake Nashua, at an altitude of about 230 feet. Terraces below the Ayer deposition surface that head at Clinton and can be traced northward along the Nashua River are considered to be Groton stage deposits. Ice probably still blocked the lower part of the North Nashua valley and may have existed also in parts of the Nashua valley, although no ice-contact or collapse structures were observed in the Groton stage deposits. Standing water of the Groton stage probably did not extend southward into the quadrangle. By this time the main front of the retreating ice was far to the north.

Postglacial tilt, attributed to the relief of load on the land surface by the retreat of the glacier, is calculated to be 5 to 6 feet per mile in this quadrangle. It is assumed that glacier advance and retreat was in a north-south direction, and that direction of tilt is the same, with slope toward the south. The Rattlesnake Hill spillway that controlled the Clinton stage of the lake is at an altitude of about 350 feet, and tops of foreset beds in Clinton stage deposits, which are presumed to represent the water level nearly 8 miles north of the spillway, are at an altitude of about 390 feet. The tilt figure for this area is similar to that calculated for an area about 15 miles east of the Clinton quadrangle (Koteff, 1963).

During late-glacial time, before a widespread vegetative cover was well established, a layer of wind-blown sand and silt as much as 4 feet thick was laid down over much of the area. Wind-polished stones occur throughout this layer. On the northeastern shore of Wachusett Reservoir, just north of Carville Basin, wind-abraded rock was found that indicates a late-glacial wind from the north. This is consistent with other data found in Massachusetts (Hartshorn, 1961).

A period of river terracing occurred after drainage or lowering of the Groton stage and before formation of the modern flood plain. The North Nashua River became established in its present course only after disappearance of ice in the lower part of its valley and after breaching of the Groton stage deposits south of the center of Lancaster.

The Nashua River became established in the gorge east of Burdett Hill in Clinton after or perhaps during Groton stage time. Crosby (1899, p. 294-295) determined from results of many test borings that the preglacial valley of the Nashua was west of Burdett Hill, and he considered the present gorge to have been a tributary to the preglacial Nashua. Deposits of the Clinton stage prevented the Nashua River from resuming its preglacial course, and the postglacial river was diverted east of Burdett Hill, although not until the disappearance of any stagnant ice that may have persisted there.

ECONOMIC GEOLOGY

The most important surficial economic deposits in the quadrangle are sand and gravel. Most of the pits shown are in this material, and relative grain sizes of materials in these pits are indicated by letter symbols. The deposits range from fine sand and silt to coarse gravel, with scattered boulders. The uncorrelated glacial lake and glacial stream deposits in the western part of the area are the source of the coarsest gravel and contain beds of cobble gravel as much as 10 feet thick. Topset beds of glacial Lake Leominster deposits are also coarse grained, especially in the northernmost part of the high-stage deposits, where pebble and cobble gravel beds about 20 feet thick overlie pebbly sand; the topset beds become finer in texture and thinner southward. Deposits of glacial Lake Assabet and the Boylston stage of glacial Lake Nashua are chiefly sand and pebbly sand. Clinton stage deposits are generally fine sand to pebbly sand; pebble and some cobble gravel occur in the northeastern part of the area. Pebbly sand more than 30 feet thick overlies fine and medium sand in Ayer stage deposits about 1 mile east of North Village in Lancaster. These deposits become finer grained northward where they grade into lake-bottom deposits.

Clay in significant amounts occurs only in the northeastern part of the quadrangle and is associated with Ayer stage deposits. Clay from a now abandoned pit half a mile west of Still River Station was once used for making bricks (Alden, 1924, p. 70), and clay and silt from the area east of North Village was once used as Fuller's earth (Alden, 1910). These exposures are now covered, and no clay is being excavated at present (1965) anywhere in the area.

The silty till derived from the Worcester Formation is a good source of earth fill of low permeability, and it underlies the area from Wekepeke Brook on the northwest to the east rim of the Nashua River valley. The sandier till, found mostly in the southeastern part of the quadrangle, is sufficiently porous to provide a good source of subgrade material.

Swamp deposits, alluvium, and windblown silt are suitable for use as top dressing on lawns. Large areas of the flood plain surface in Bolton and Lancaster have been stripped as a source for loam.

References

Alden, W. C., 1910, Fuller's earth and brick clays near Clinton, Massachusetts: U.S. Geol. Survey Bull. 430-F, p. 402-404.

________ 1924, The physical features of central Massachusetts: U.S. Geol. Survey Bull. 760-B, p. 13-105.

Crosby, W. O., 1899, Geological history of the Nashua Valley during the Tertiary and Quaternary periods: Technology Quart., v. 12, p. 288-324.

________ 1903-04, Structure and composition of the delta plains formed during the Clinton stage in the glacial lake of the Nashua Valley: Technology Quart., v. 16, p. 240-254, v. 17, p. 37-75.

Currier, L. W., 1941, Tills of eastern Massachusetts [abs.]: Geol. Soc. America Bull., v. 52, p. 1895-1896.

Hansen, W. R., 1956, Geology and mineral resources of the Hudson and Maynard quadrangles, Massachusetts: U.S. Geol. Survey Bull. 1038, 104 p.

Hartshorn, J. H., 1961, Late-glacial eolian activity in Massachusetts [abs.]: Geol. Soc. America Spec. Paper 68, p. 194.

Jahns, R. H., 1953, Surficial geology of the Ayer quadrangle, Massachusetts: U.S. Geol. Survey Geol. Quad. Map GQ-21.

Koteff, Carl, 1963, Glacial lakes near Concord, Massachusetts: U.S. Geol. Survey Prof. Paper 475-C, p. C142-C144.