LAKE BASCOM AND THE DEGLACIATION OF NORTHWESTERN MASSACHUSETTS [1]

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ABSTRACT

Sedimentological evidence and data compilation indicate Laurentide ice ponded numerous lakes as it retreated from western Massachusetts. Glacial Lake Bascom, the most extensive of these lakes, occupied the Hoosic River Basin and was named by T. N. Dale in 1900. At its greatest extent, this lake covered some 300km^2 of the tri-state area and contained about 17km^3 of water. Lake Bascom initially drained south into the Housatonic River through a 317m (1040') bedrock outlet at the SE corner of the lake. As ice retreated to the northwest, a 273m (895') bedrock floored spillway at Potter Hill, New York opened and lake level fell 30m; almost 8km^3 of water drained into the Hudson Lowland. Although upper levels of Lake Bascom can be assigned specific outlets, levels below 273m (895') indicate ice in the Hudson River Valley provided base level control.

About 1.3km^3 of sorted sediment fills the 350km^2 upper Hoosic River Basin. Ice contact, glacial-fluvial, and deltaic deposits are found primarily below 380m (1250') on lower valley walls and valley bottoms, whereas till mantles upland outcrops of schist, phyllite, and quartzite. We mapped fine-grained lacustrine sediment primarily below 290m (950'); at many exposures we observed this material lying directly over till. The volume, location, and character of sorted glacial sediment strongly suggest active ice occupied the Hoosic River Valley during deglaciation. Deltaic and lacustrine sediment, deposited far above the level of Lake Bascom, indicates that the tongues of valley ice ponded marginal lakes in Hoosic River tributaries. Empirically derived ice profiles also support the exposure of highland areas as nunataks and striation data show that ice flow became oriented parallel to local valleys during deglaciation. These data, along with the rapid filling rate we calculated for Lake Bascom, suggest that in the Hoosic River Valley open water directly bordered decaying tongues of Laurentide ice.

INTRODUCTION

The distribution of ice-contact, deltaic, and lacustrine sediment indicates ablating Laurentide ice ponded numerous glacial lakes in the hilly terrain of northwestern Massachusetts. During the latest Wisconsinan glaciation, the Hudson-Champlain lobe advanced southeastward over the region, burying the present-day landscape. By 21,000 years ago (ka) ice cover was at a maximum and ice extended south and east to Long Island and Cape Cod (Stone, 1985). Sometime before 18ka, ice began to thin and the margin retreated north and northwestward. Sedimentological evidence indicates lobes of active ice occupied the major north-south valleys of New England after ice had retreated from adjacent highlands; these lobes blocked drainages, ponded extensive bodies of water, and deposited sediment. By 15ka Massachusetts was probably ice free (Stone, 1985).

In the Berkshire Mountains, ice of the Hudson-Champlain lobe blocked the northward-flowing Hoosic River and its tributaries, ponding water and depositing sediment. As retreat continued and the ice surface lowered, individual bodies of water coalesced to form Lake Bascom. Initially, lake level was controlled by a bedrock-floored spillway north of Pittsfield, Massachusetts at an elevation of 317m (1040'). (Elevations will be given in metric and english units; all other measurements will be given only in metric units). This and several other lake levels persisted sufficiently long to allow deposition of glacial-fluvial and meteoric deltaic deposits graded to specific water planes. Ice retreat to the northwest opened progressively lower spillways. Bedded lacustrine silt and clay, present in most local valleys, provide evidence for ponded water.

We mapped surficial deposits and compiled data from published and unpublished sources to clarify the sequence of deglaciation in the Hoosic River Valley. This study is the first detailed analysis of Berkshire glacial geology in over 80 years. Our results suggest a general pattern for deglaciation in mountainous areas of New England.

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Geology

Bedrock character varies greatly throughout the field area (Herz, 1958 and 1961; Zen, 1983). The South Branch Hoosic River Valley is floored predominantly by dolomitic marble. Schist and phyllite of the Taconic allochthon underlie Mount Greylock and the western valley wall. The eastern valley wall is composed of Hoosac Schist in the north and Cheshire Quartzite to the south. North of Stamford, Vermont, Grenville basement, the Stamford Granite Gneiss, crops out. Clasts of marble, phyllite, and schist weather rapidly and transport poorly; striations are rarely preserved on these lithologies. The Stamford Granite Gneiss also weathers rapidly, separating along mineral boundaries. The Cheshire Quartzite is the most resistant unit; clasts of this lithology were transported with least attrition. Striations and chattermarks are well preserved on outcrops and cobbles of Cheshire Quartzite.

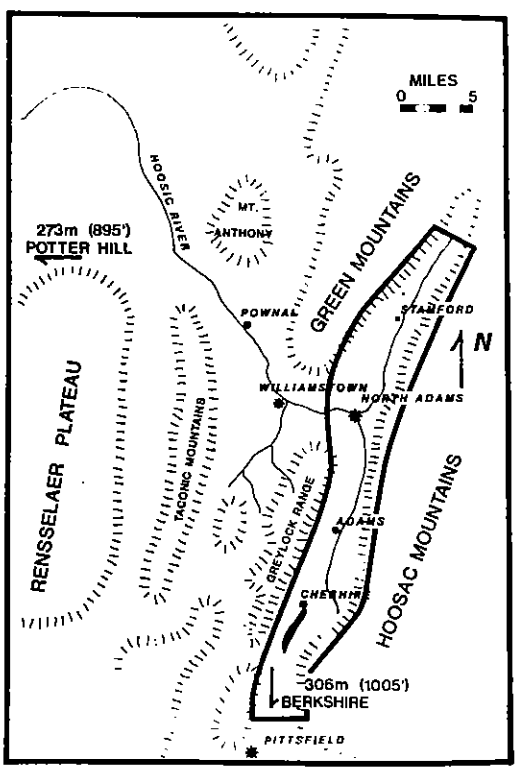
The character and thickness of unconsolidated sediment varies greatly within the field area. Where bedrock is not exposed, till and colluvial deposits cover much of the uplands. Till is also present in valley locations and is covered in many places by thick, waterlaid deposits. Although we found isolated exposures of sorted material as high as 535m (1750'), the largest volume of sorted glacial sediment is on or near the lower valley walls, below 380m (1250'). At many locations on the valley floor, there are extensive deposits of fluvial and subaqueous ice-contact sediment. Lesser volumes of deltaic and fan deposits were mapped at varying elevations where many drainages enter the Hoosic valley. Glacial-fluvial deltas are rarely preserved on the valley floor and most lacustrine sediment is found below 290m (950'). Older and modern alluvium were mapped near the courses of present streams and rivers.

SETTING

Physiography

The upper Hoosic River drains 350km^2 of Massachusetts and Vermont (fig. 1). For much of its course, the river is restricted to a flat or gently sloping plain by steep, abutting highlands. Most tributary drainage basins are small. Early workers (Hitchcock, 1833; Taylor, 1903; Cleland, 1916) report numerous kames or "diluvial hillocks" stood above the floodplain; most of these deposits have since been removed by sand and gravel mining.

The region is an area of substantial relief; elevations range from less than 150m (500') in the lower Hoosic River Basin to 1065m (3487') at the summit of Mt. Greylock. The Hoosac Mountains separate the Hoosic drainage from the Connecticut Valley to the east and the Taconic Mountains rise between Massachusetts and New York's Hudson Lowland to the west. Although different stages of glacial Lake Bascom extended from near Pittsfield, Massachusetts to the Hudson River, fieldwork was primarily conducted between southern Vermont and Berkshire, Massachusetts (fig. 1).



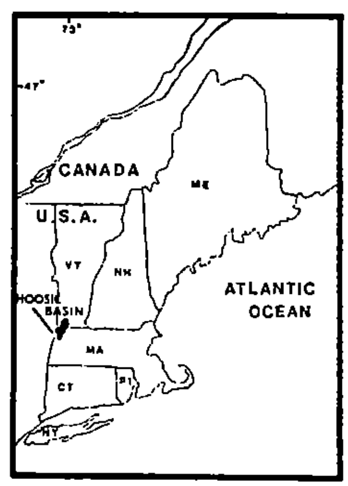


Figure 1. Map of the upper Hoosic River Basin indicating study area (outlined). Lake Bascom spillways at Berkshire, Massachusetts and Potter Hill, New York are identified by arrows.

When retreating continental ice blocked the north-flowing Hoosic River and ponded Lake Bascom, melt and meteoric water initially flowed south into the Housatonic River Basin. As retreat continued, lower outlets opened and north-flowing drainage into the Hudson River was restored. We examined deposits related to several higher levels of Lake Bascom. Lake levels between 317m (1040') and 306m (1005') were controlled by spillways at Berkshire, Massachusetts. The 273m (895') level was controlled by a spillway at Potter Hill, New York. Lower levels were identified on the basis of deposit elevation but were not considered in detail.

PREVIOUS STUDIES

History of Investigation

Early investigators were shrewd observers and their studies, made when Berkshire hillslopes lacked forest cover, have helped guide the present study. In 1830, Edward Hitchcock was appointed by the Commonwealth of Massachusetts to prepare a geologic survey (the first of its kind in the United States). He described several surficial exposures and numerous landforms in the Hoosic River Valley; some of these deposits are still extant. Hitchcock initially relied on the <u>diluvial</u> or flood theory to explain the occurrence and distribution of unconsolidated sediment. By 1860 he accepted, in part, the glacial theory of Louis Agassiz but continued to reject the existence of a continental ice sheet despite mapping stratified deposits, erratics, and striations in western Massachusetts (Hitchcock, 1860). His observations, well illustrated by Mrs. Hitchcock's sketches, have been invaluable in reconstructing the surficial geology of areas now heavily altered by development.

T. N. Dale, best known for his work detailing Taconic structural geology, was probably the first to propose and name a glacial lake in the Hoosic River Valley. From the elevation of terrace features between Williamstown and North Adams, Dale postulated that northwestward retreating ice dammed a lake which emptied through a spillway near Pittsfield. Dale presented these ideas before the Berkshire Historical and Scientific Society on Febuary 8, 1900. "As the lake which formed so conspicuous a feature in the Berkshire landscape of Quaternary time needs a name I propose to call it after a good friend of Mount Greylock <u>Lake Bascom</u> (Dale, 1906, p. 15-17)." It is likely the lake was named after Professor John Bascom, a contemporary of Dale's at Williams College.

In the summer of 1901, F. B. Taylor began mapping the glacial geology of Berkshire County. In 1903 he proposed that, "Geographical considerations, which ought to control wherever possible, would suggest Lake Hoosic as the most appropriate name for this body of water (Taylor, 1903, p. 330)." During early stages of Lake Hoosic (Lake Bascom), small independent lakes occupied the Green River and Little Hoosic Valleys; as the ice withdrew, these small lakes," merged into one long, irregularly shaped body that filled the whole valley up to the contour of about 1,100 or 1,120 feet (Taylor, 1903, p. 329-330)." As the ice continued to withdraw northward, spillways opened at lower elevations and "Lake Hoosic found lower levels of discharge (Taylor, 1903, p. 343)." In a personal letter to H. F. Cleland, Taylor gave the altitudes of two of these lower outlets: 274m (900') and 183m (600').

Herdman Cleland, an associate of Taylor's, was responsible for the most recent work defining Lake Bascom. The striking similarity of Cleland's maps to those of Taylor and the nature of correspondence between the two men, suggest they were in close communication. In published guidebooks (1916 and 1924), Cleland asserted Lake Bascom was formed by northwestward retreating ice and discharged through the Berkshire col at 341m (1120') (present altitude 306m, 1005') until continued ice retreat opened a lower 338m (1110')(present altitude, 341m, 1120') col at Berlin, New York. Cleland's unpublished maps illustrate lower outlets of Lake Bascom at Potter Hill, New York 274m (900') and at unidentified locations to the northwest: 244m (800'), 213m (700'), and 183m (600'). In addition to Lake Bascom (341m;1120'), Cleland recognized and named three temporary lakes which occupied tributary valleys of the Hoosic: Lake Ashford (381m;1250'), Lake Lebanon (338m;1110') and Lake Hancock (no elevation given).

During the 1960's both Vermont and Massachusetts began surficial mapping programs. The Vermont program resulted in several publications including a state surficial geology map (Stewart, 1961; Shilts, 1966; Stewart and MacClintock, 1969 and 1970); the State of Massachusetts produced selected quadrangles in preliminary form (Holmes, 1964; Holmes, 1966; Holmes, Kelly, and Aetherton, 1967; Holmes and Kelly, 1967). Hansen et al (1973,1974) gathered hydrologic and subsurface data for the Hoosic River Basin; they present drill logs, seismic sections, and a plate showing the thickness of unconsolidated sediment covering bedrock in the Hoosic River Valley. They found the greatest depth of fill exceeds 90m.

Elevation of the Berkshire Spillway

Taylor was the first to assign a specific spillway for Lake Bascom, choosing, " a col 3 miles northeast of Pittsfield...the altitude of this col is 1120 feet above tide (Taylor, 1903, p. 327)." Taylor repeatedly stated the altitude of the Berkshire spillway and Lake Hoosic (Lake Bascom) as 338m-344m (1110'-1130') (Taylor, 1903, 1916, unpublished letters, unpublished folio). Cleland, in his published works and unpublished drawings also indicates the Berkshire outlet at elevation 341m (1120'); he wrote that flow would cease through the Berkshire col when a lower, 338m (1110') outlet opened at North Petersburg (Cleland, 1916, p. 45). Why can no 341m (1120') outlet be found today? The survey which produced the topographic maps used by Taylor and Cleland was completed in 1885. The first revision occurred in 1947. On the 1900 edition of the 1:125,000 Taconic sheet and on the 1898 edition of the 1:62,500 Greylock sheet, the Berkshire spillway, a lowland between Berkshire Pond and Cheshire Reservoir, has a minimum elevation of 341m (1120'). On

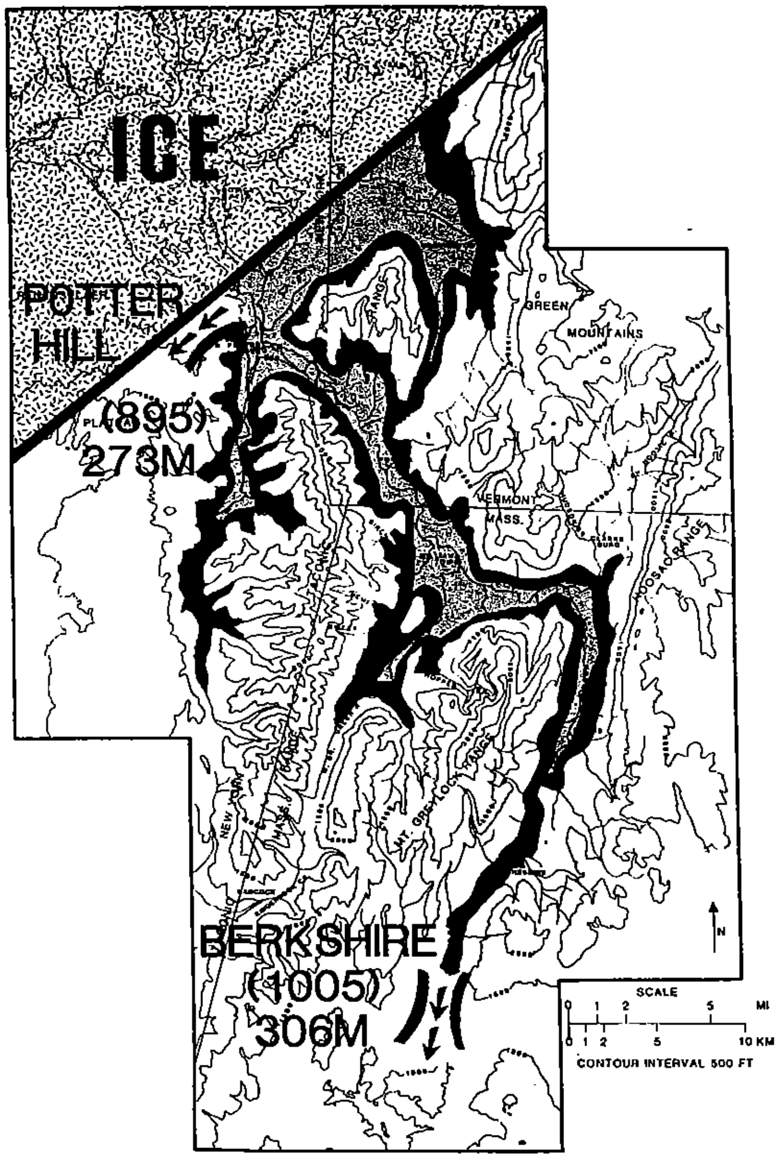


Figure 2. Map showing the extent of Lake Bascom as an idealized ice margin passes northwest of the spillway at Potter Hill. Shading indicates maximum extent of the 306m (1005') level before spillway cleared. Stippling indicates maximum extent of the 273m (895') level after the spillway opened.

the 1947 edition of the 1:31,680 Cheshire sheet this same locality has a minimum elevation of 306m (1005'); this minimum is retained on the 1973 quadrangle map. Since the col is over 500m wide, it is unlikely the topography has been altered. It appears Lake Bascom was never controlled by a 341m (1120') spillway, nor by the hypothesized 338m (1110') spillway near Berlin.

METHODS

We mapped surficial geology below 550m (1800') in the Hoosic River Valley between Pittsfield, Massachusetts and Heartwellville, Vermont at a scale of 1:25,000. In addition, we performed reconnaissance studies west to Potter Hill, New York (fig. 1). Our mapping involved careful examination of gravel pits, excavations, stream cuts, and slope failures. We recorded unit thickness, stratigraphy, sediment texture, sorting, lithologic character, and related information about landform morphology. Where possible, we determined the altitude of each deposit; where critical, we determined maximum elevation and the altitude of topset/foreset contacts with the aid of a precision barometric altimeter. Using sedimentary structures and pebble imbrication, we determined paleocurrent direction. We also measured grooves, striations, and chattermarks.

We calculated the volume of unconsolidated sediment present within the field area after synthesizing subsurface data collected by the Army Corps of Engineers, the Vermont State Department of Water Resources, and Hansen et al (1973;1974). Digitizing the depth to bedrock map of Hansen et al (1973), we determined a minimum estimate of sediment contained in the valley. Adding the volume of sorted material identified by our field work and not included on Hansen's map, we obtained a value for total sorted sediment volume in the valley. Only 78km^2 of the 350km^2 Hoosic River Basin contains significant quantities of sorted sediment. Using these values, we determined the average thickness of sediment. Our calculations are upper limits because they assume the entire volume of unconsolidated sediment within the upper Hoosic River Valley is sorted and was deposited during retreat of the latest ice sheet. This latter assumption is correct for surface exposures which comprise about fifty percent of the total sediment, but some part of the subsurface sediment may predate ice retreat.

We calculated the volume and area of Lake Bascom, assuming the regional orientation of the retreating ice margin was NE-SW (fig. 2). The existence of Lake Bascom strongly suggests this orientation and lacustrine sediment mapped elsewhere in western Massachusetts and eastern New York mandates retreat toward the northwest (Warren and Stone, 1985). For purposes of calculation, the ice margin was projected 45° NE from the Potter Hill spillway. We calculated the volume and surface area of the 306m (1005') and 273m (895') levels of Lake Bascom using USGS 7.5 minute quadrangles and a Numonics Corporation digitizer. Surface area was determined by tracing paleoshorelines. We determined lake volume by dividing the lake into eight sections and constructing representative cross-sections for each. These cross-sections, when integrated along the length of each section, provided volume estimates. No correction was made for differential isostatic rebound but effects should be minimal because valley sides are steep.

We plotted ice profiles using an empirically based parabolic equation (Mathews, 1974) and located the ice margin in the Hoosic River Valley. Profiles were determined along flow lines trending 340°, the regional direction of ice flow as indicated by the orientation of striations and chattermarks on Mt. Greylock and other highland areas. We drew profiles calculated from minimum and maximum reported values of basal shear stress for Laurentide ice (0.2 and 1 bar).

DATA

Sediment and Ice

Deltaic sediment. -- We mapped deltaic deposits graded to several different water planes (fig. 3). Some deltas built into temporary lakes which occupied tributary drainages of the Hoosic River. In these marginal lakes water level was controlled by tongues of ice flowing through the valley below. Other deltas graded to regionally consistent lake levels determined by fixed spillways of Lake Bascom. We used deposit morphology and clast lithology to differentiate glacial-fluvial deltas (built directly off the ice) from meteoric deltas built by highland streams eroding unvegetated slopes. Fluvial sediment in Berkshire deltaic deposits is usually well sorted, well rounded, bedded, and unfaulted; it ranges in size from fine sand to 30cm clasts. Most deltas built off the highlands are small and poorly defined.

Both Hudson Brook and Roaring Brook built deltas into local, ice-dammed lakes above the level of Lake Bascom. Roaring Brook (A) built a small, high-level delta graded to a 525m (1720') water plane. In this deposit, beds of cobbles, gravel, and sand are well exposed; there is a distinct topset-foreset contact. Paleocurrent data indicate this delta was built by water flowing down Roaring Brook -- not from ice in the valley below. Down the delta paleoslope, we observed sediment fining to thinly bedded sand and silt. Hudson Brook (B) built a delta graded initially to a level above 348m (1140') and then to lower levels. At several locations in this delta, an erosional contact at 346m (1135') juxtaposes coarse fluvial gravel overlying lacustrine fine sand and silt. In the same delta complex, well sorted cobble gravel and bedded sand (containing rip-up clasts of silt) overlie impermeable till at altitudes of 323m to 330m (1060' to 1080').

Meteoric deltas were mapped where most major drainages flowed into the 317m (1040') level of Lake Bascom. For instance, Kitchen Brook in Cheshire (C) built a delta of schist and phyllite (highland lithologies) graded to a level of 323m (1060'). Paleocurrent data indicate water depositing this sediment flowed from the west into the Hoosic River Valley.

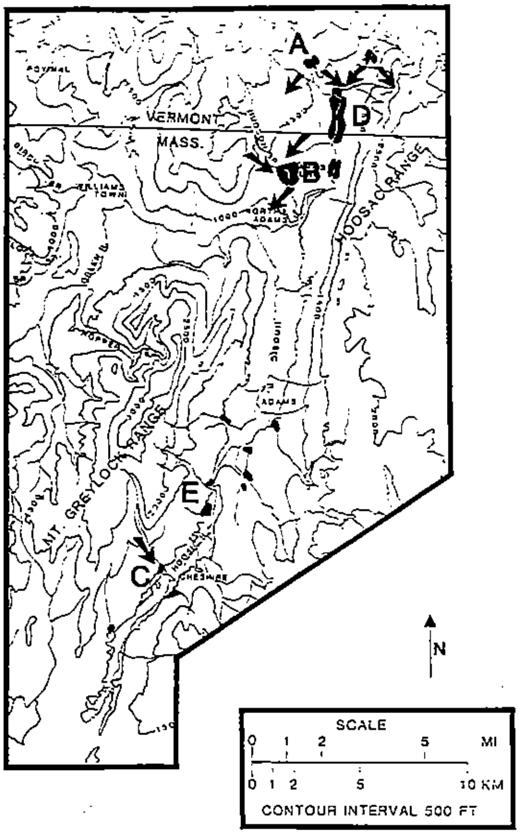


Figure 3. Map showing the distribution of deltaic sediment in the upper Hoosic River Valley. Deltas are shaded. Paleocurrent directions are indicated by arrows and locations cited in the text are identified by letters.

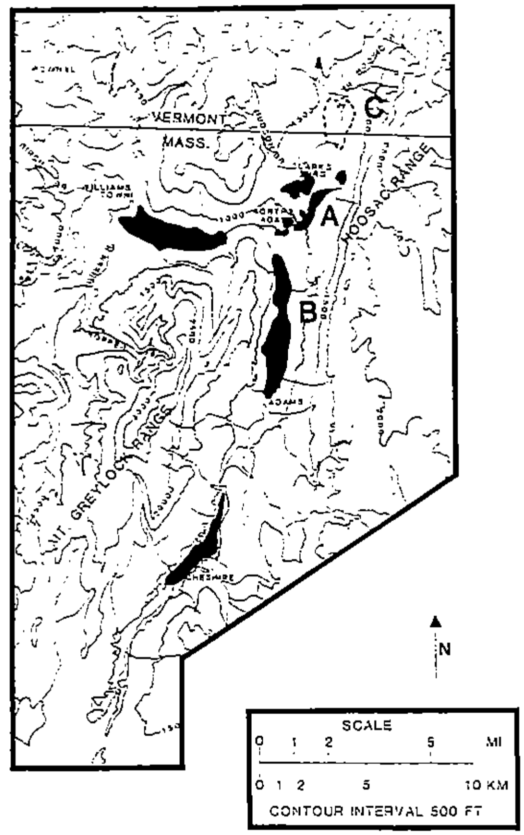


Figure 4. Map showing the distribution of lacustrine sediment in the upper Hoosic River Valley. Areas underlain by silt and clay are shaded and locations cited in the text are identified by letters.

The North Branch Hoosic River (D) built a large, gently sloping delta plain graded to a level of 329m to 335m (1080' to 1100'). Surface exposures reveal well rounded, 10-30cm, cobble gravel; subsurface data indicate that in some places, this deposit is over 10m thick. The majority of clasts in this gravel are high grade metamorphic rocks which suggests sediment in this delta was not derived from sources to the south; rather, sand and gravel were carried to the delta by active ice and/or meltwater coming from the north.

We have identified only one glacial-fluvial delta, (E). Although mining has removed most of the overlying gravel, a large volume of well bedded, ripple-laminated sand remains, graded to a level above 323m (1060'). The sand is well sorted and quartz-rich, indicating deposition directly from the ice rather than from the neighboring highlands of schist and phyllite. Some exposures within this deposit exhibit small scale faulting.

Lacustrine Sediment. -- We mapped the greatest volume of lacustrine sediment on or near the floor of the Hoosic River Valley, below 290m (950') (fig. 4). This material is well sorted, thin bedded to thinly laminated very fine sand, silt, and clay. When fresh the sediment is blue-gray and plastic; when weathered it is brown and mottled. Layers average one centimeter thick and we observed a rhythmic pattern of sedimentation at many sites. At some exposures, outsize clasts (dropstones) were present and had deformed underlying material. Lacustrine sediment is best exposed near river and stream banks or on hillsides where this unstable material often fails.

In North Adams, near the North Branch Hoosic River, we mapped deposits (A) of laminated silt as high as 296m (970'). These deposits are exposed in slumps and slides; in this area bedrock underlies the lacustrine sediment directly. Subsurface data indicate over 30m of clay and silt fill the valley between North Adams and Adams (B). Well data show up to 12m of lacustrine sediment are present in the Stamford Valley (C). This silt and clay is overlain by about 15m of cobble gravel and sand. An excavation near Roaring Brook (fig. 3, location A), at an elevation of 480m (1575'), exposed 4m of thickly laminated lacustrine silt overlying till.

Ice contact stratified deposits (ICSD). -- We found the greatest volume of ICSD on or near the valley floor below 320m (1050') (fig. 5). The character of ICSD varies greatly. Some exposures reveal poorly sorted, inconsistently stratified, frequently faulted material in which the largest clasts often exceed 4m. Other exposures contain well sorted, distinctly stratified, unfaulted sand and gravel. In some instances we observed both styles of sedimentation either juxtaposed in erosional contact or as endmembers of a gradational sequence.

Significant volumes of ICSD are clustered in specific sections of the valley. ICSD is well exposed in gravel pits near the Berkshire spillway (A) and extends to an elevation of 330m (1080'). At the northernmost exposure, we found poorly sorted cobble and boulder gravel; 400m south are over 15m of well stratified but faulted sand and pebble gravel. South of Cheshire Harbor (B), below 302m (990'), are several elongate mounds of ICSD which likely supplied sediment to a glacial-fluvial delta (fig. 3, location E). Along the western valley wall, between Adams and North Adams (C), we mapped a large and well exposed deposit of ICSD. The top of this deposit is below 275m (900'). Older maps indicate a row of elongate features (D) once stood to the northeast of Adams. Hitchcock (1841) reported these "hillocks" contained stratified sand and gravel. We suspect these hills were the remains of an esker system which supplied sediment to prograding subaqueous, ice-marginal fans (C).

Ice flow. -- Most indicators of ice flow direction (striations, chattermarks, and grooves) are poorly preserved or covered by a thick growth of lichen. Upland indicators record ice-flow directions between 355° and 335° ; most lower elevation indicators are oriented valley-parallel (fig. 6). At one location (A) west of North Adams, numerous striations trending nearly W-E crosscut megagrooves which trend 335° . Empirically based ice profiles suggest active ice was restricted to the valleys during later stages of deglaciation. Our modeling indicates flowing ice could not have over-topped the Green Mountains or Mt. Greylock when the margin was located in the upper Hoosic River Valley.

Sediment volume. -- We estimate $1.31km^3$ of sorted sediment was deposited in the $350km^2$ Hoosic River Basin. If this material were spread over the entire basin, it would represent a 4m thick layer. However, if the material were spread only over the $78km^2$ of the valley floor presently covered by sorted sediment, it would represent a layer almost 17m thick.

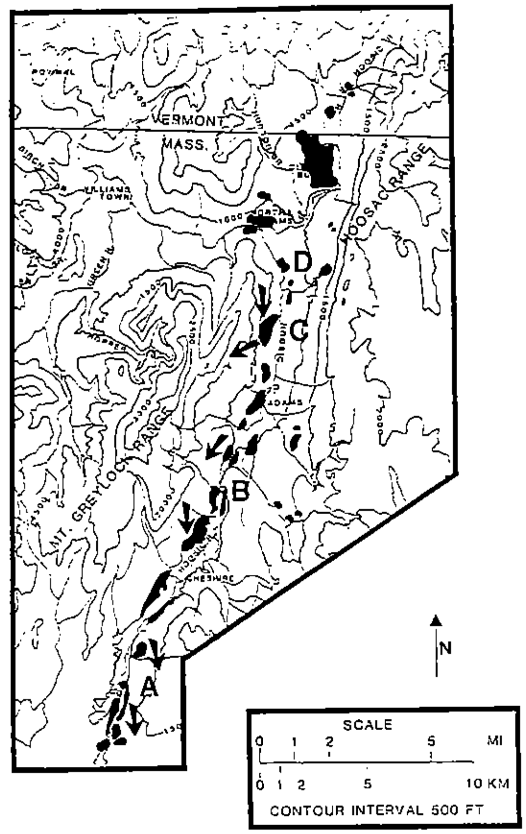


Figure 5. Map showing the distribution ice contact stratified deposits (ICSD) in the upper Hoosic River Valley. ICSD is shaded. Paleocurrent directions are indicated by arrows and locations cited in the text are identified by letters.

Lake Bascom

Spillways. -- We have identified two bedrock floored and one till floored spillway which controlled the level of Lake Bascom. The spillway for the 317m (1040') lake was activated when ice withdrew north of Pittsfield, leaving a substantial ice-supported debris dam (fig. 7). This bedrock channel is about 100m wide and flat-bottomed. After the debris dam near Berkshire failed and the higher spillway was abandoned, water from Lake Bascom poured through a till floored, 306m (1005') outlet. Water continued to flow through the 306m (1005') spillway until ice cleared a 273m (895') bedrock floored spillway near Potter Hill, New York. Contrary to conclusions drawn by earlier workers (Taylor and Cleland), contemporary maps show there are no other outlets available at intermediate elevations.

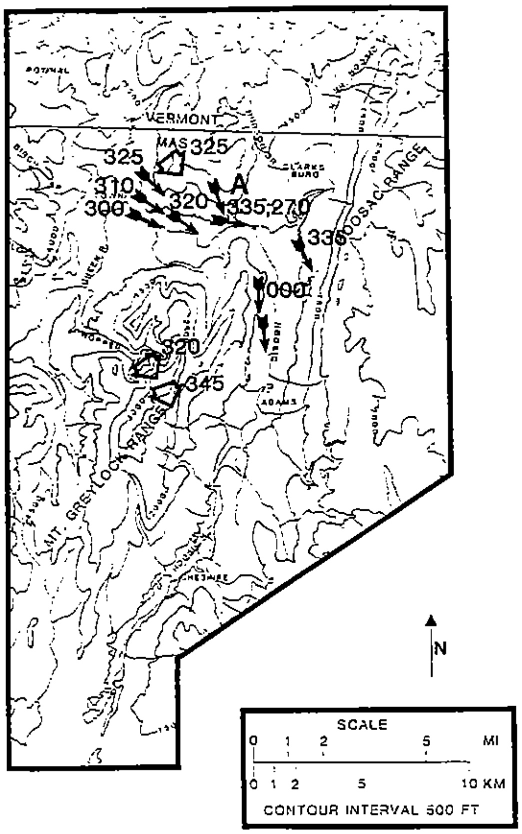


Figure 6. Map showing the location and orientation of striations, chattermarks, and grooves. Wide arrows represent upper elevation outcrops; narrow arrows represent valley outcrops. The location cited in the text is identified by the letter (A).

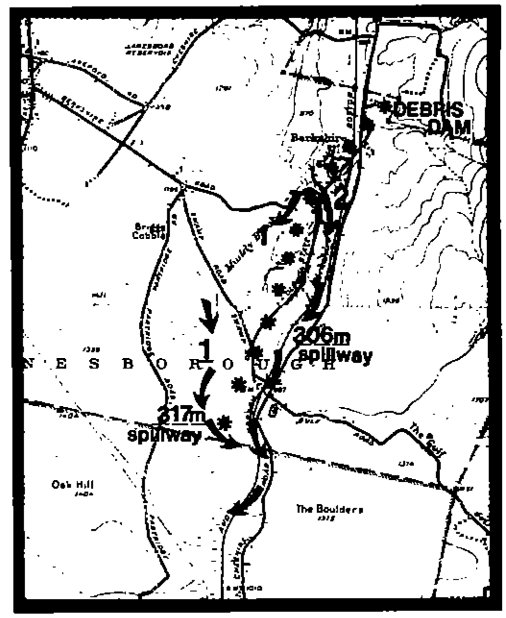


Figure 7. Map showing the location of the debris dam and elevation of spillways at Berkshire. Symbols indicate the dam; arrows indicate water flow. Spillway (1) is bedrock floored at an elevation of 317m (1040'). Spillway (2) was activated when the dam failed and is till floored at an elevation of 306m (1005').

Size of the Lake. -- The maximum surface area ($300km^2$) and maximum volume ($17.2km^3$) of Lake Bascom occurred just as retreating ice cleared the Potter Hill spillway (fig. 2). As water flowed west and south into the Hudson River Basin the area of Lake Bascom shrank by 30% to $215km^2$ and the volume decreased about 50% to $9.4km^3$. The effect of this massive outflow may have been diffused by ice which stood in the Hudson River Valley to the west of the spillway. There is no detailed mapping of this area.

Calculations of this type are by their nature uncertain. The ice margin was not uniform; tongues of active ice extended down individual valleys. Erosion and redeposition of sediment after the lake drained must have extensively modified valley topography. Large blocks of abandoned ice would further reduce actual lake volume. Considering these uncertainties, we feel our calculations represent an estimate within 15% of the true volume.

Filling Rate. -- If the volume of Late Pleistocene precipitation was similar to contemporary values, the Hoosic, Green, and Walloomsac Rivers would take 34 years to fill Lake Bascom. This calculation represents a maximum filling time, neglecting increased runoff from unvegetated slopes and water supplied by ablating ice. Because the filling time was short, the volume of sorted material is large, and rhythmic lacustrine sediment overlies till, we suspect Lake Bascom directly bordered the retreating ice margin. Sediment was probably deposited into the lake from the ice surface and from englacial tunnels dispatching sand and gravel subaqueously.

DISCUSSION

The distribution of glacial sediment in the Hoosic River Valley indicates the mountainous terrain of northwestern Massachusetts strongly influenced the process of deglaciation. Significant topographic relief (over 800m) allowed Mt. Greylock and other highland areas to be exposed as nunataks while ice continued to flow through the lowlands. This valley ice, constrained by the emerging highlands, impounded numerous local and regional lakes. Our mapping indicates ice left the highlands of northwestern Massachusetts by a process of top to bottom melting. In the lowlands, deglaciation proceeded by stagnation zone retreat; however, local topography influenced the size of the stagnant zone. It is likely that large ice masses became detached in some tributary valleys. These findings may suggest a pattern for deglaciation in other mountainous areas of New England.

There is ample evidence that retreating Laurentide ice ponded a deep, still body of water in the Hoosic River Basin; extensive deposits of lacustrine material fill most valleys to depths exceeding 30m. In many locations at valley margins, till directly underlies fine-grained lacustrine deposits, indicating sedimentation began in Lake Bascom immediately after glacial retreat. We found only isolated exposures of lacustrine sediment above 290m (950'). Silt deposited in marginal lakes and higher levels of Lake Bascom was probably removed by erosion or covered by other sediment as lake levels fell.

Water planes of Lake Bascom were controlled by ice, debris dams, and spillways; lake level and duration influenced the development of deltaic features. Precise determination of lake levels in the upper Hoosic River Valley is hampered by the paucity of well exposed deltas. Some deltaic deposits (eg, Roaring Brook, location (A) in fig. 3) were graded to levels which indicate control by other, higher outlets than the Berkshire spillway. We believe these deposits were built into temporary marginal lakes ponded by ice in the valley.

Features graded to the 317m (1040') level of Lake Bascom are most prominent within the upper Hoosic River Valley. Although exposure and consequently altitude control are poor, we have determined that the elevation of deltas built to the 317m (1040') level of Lake Bascom rise to the north at a gradient of 0.6m/km to 0.8m/km. This value of differential rebound, considering the precision of our data for the upper Hoosic River Valley, agrees with that proposed by Koteff (1985) for the Connecticut Valley (0.9m/km) and by Warren and Stone (1985) for northwestern Massachusetts (0.75 to 0.85m/km).

The significant volume of sorted material (1.3km^3) and its concentration in specific zones of ICSD, suggest active ice was present as a sediment source during retreat. Most ICSD in the Hoosic River Valley lies below the 306m (1005') projected surface of Lake Bascom. The character and elevation of this sediment indicates much of it was deposited subaqueously. ICSD deposits are concentrated in hills and elongate features on the valley bottom (dissected eskers or crevasse fillings), are found in zones perpendicular to valley sides (deposits related to ice-marginal positions), and occur in hummocky terrains mantleing valley walls (sediment deposited alongside the ice).

Paleocurrent directions in ICSD (fig.5) indicate ice formed the northern margin of Lake Bascom as water progressively occupied the Hoosic River Valley between Berkshire and North Adams. Flow data and an ice profile model (using basal shear stress values of 0.2 and 1.0 bar) also support the presence of live ice confined in the Hoosic River Valley during deglaciation. Valley parallel striations which cross-cut mega-grooves west of North Adams, indicate that ice initially flowed over the Green Mountains and Mt. Greylock but was increasingly channeled through the valley by steep, abutting highlands as thinning and retreat progressed. Although the ice margin, in a gross sense, melted back to the northwest, the path of retreat through individual valleys was determined by local topography.

The tongues of ice, which occupied the Hoosic River Valley during deglaciation, impounded marginal lakes in most tributary drainages. For instance, ice flowing east from Williamstown through the Hoosic River Valley in North Adams ponded a lake in the Stamford Valley. Subsurface data indicate that 15m of silt and clay were deposited in this lake and covered by an equal amount of coarse gravel. The gravel had originally been deposited by a separate lobe retreating upvalley, but was regraded to lower base levels by the North Branch Hoosic River after the lake drained. This particular lake emptied through a well defined drainage channel east of North Adams at an elevation of 373m (1223').

As ice retreated to the northwest, separate marginal lakes joined to form Lake Bascom which initially emptied through a 317m (1040') bedrock floored spillway near Berkshire. We mapped deltas which indicate that this spillway was active at least until the ice cleared North Adams. The lack of distinct features graded to a 306m (1005') lake suggests that the ice and debris dam at Berkshire may have been breached only shortly before the spillway at Potter Hill opened. To firmly determine the chronology of Lake Bascom levels, detailed mapping west and north of the field area is necessary.

Numerous fluvial and deltaic features are graded to subsequent, low-level stages of Lake Bascom not represented by specific spillways. South of North Adams, for instance, there are two terrace features graded to a level of 223m

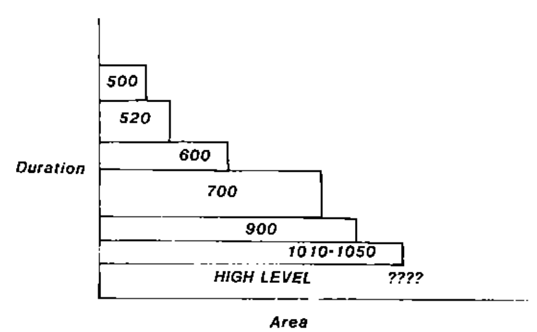


Figure 8. Diagram showing estimated duration, elevation (in feet, uncorrected for isostasy), and extent of major Lake Bascom levels.

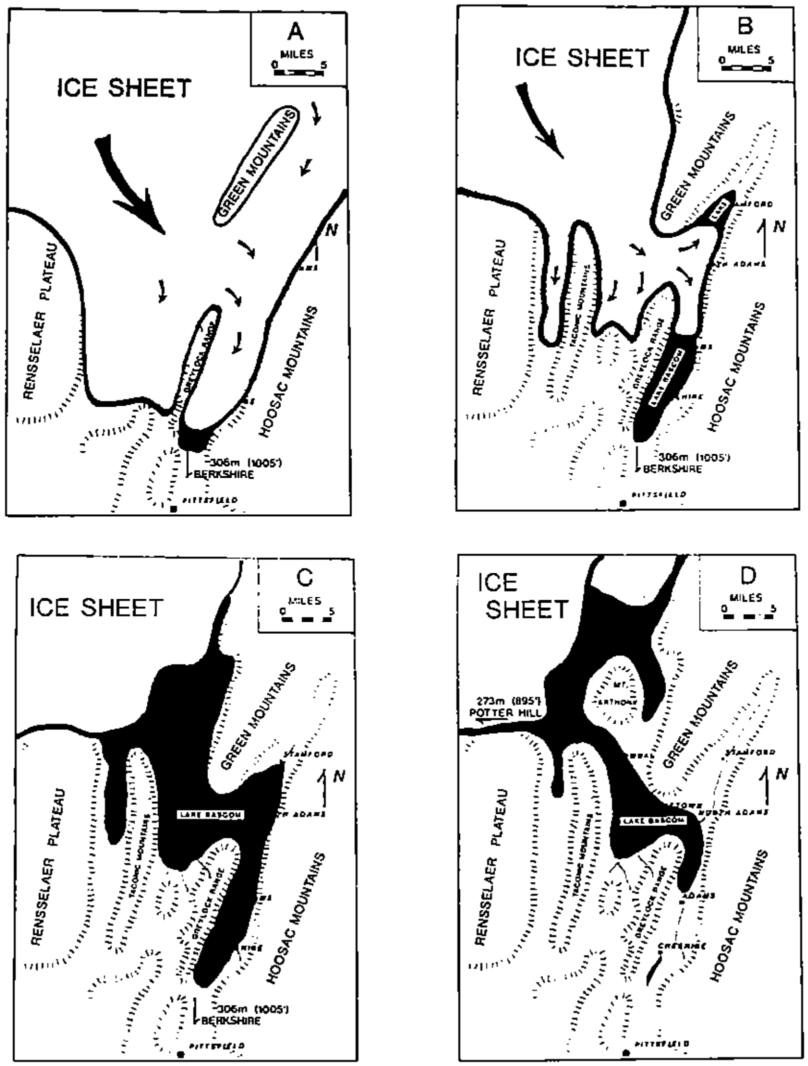


Figure 9. Cartoons illustrating ice retreat and the extent of Lake Bascom in the Hoosic River Valley. Figures modified from unpublished diagrams of Cleland.

(730'). West of Pownal, Vermont there are deltaic features graded to 213m (700'), 183m (600'), and 159m (520'). These terraces and deltas suggest ice in the Hudson River Valley controlled later, lower levels of Lake Bascom. Figure 8 is a schematic diagram of significant Lake Bascom levels. We inferred lake duration from the morphology of deposits graded to each level and approximated lake area from regional maps. The small volume of deltaic sediment and the poor morphological definition of most Bascom deltas, are the result of small tributary basins and the limited persistence of the lake.

Ice Retreat and Lake Bascom

As Laurentide ice thinned over northwestern Massachusetts, Mt. Greylock, the Green Mountains, and other highland areas became exposed as nunataks (fig. 9a); ribbons of flowing ice filled the valleys. Continued retreat and thinning over the southern Vermont caused a lobe of ice to withdraw northward up the Stamford Valley. Fresh ice continued to flow east through the Hoosic River Valley into North Adams. As ice in Stamford melted, a lake filled the valley and drained into Lake Bascom through a distinct channel east of North Adams (fig. 9b). Further shrinkage of the margin lowered this northern lake to the level of Lake Bascom (fig. 9c). As the ice continued to retreat northward and westward through the Hoosic River Valley, Lake Bascom grew larger but remained at a level between 306m-317m (1005'-1040') until retreat cleared the 273m (895') spillway at Potter Hill (fig. 9d). Further withdrawal allowed lower spillways to open and initiated dissection of deposits graded to earlier, higher levels.

CONCLUSIONS

1. This paper supports and expands on earlier work by Dale, Taylor, and Cleland. Laurentide ice retreated to the northwest, blocking drainage and damming Lake Bascom in the Hoosic River Valley. The elevation of some deposits and spillways is incorrect on earlier maps; this adversely affected some workers' conclusions. Lake Bascom was controlled by a 317m-306m (1040'-1005') spillway -- not a 341m (1120') spillway as reported by Taylor and Cleland.

2. Surficial geology within the field area is varied. Thin till and colluvium cover much of the uplands. Waterlaid deposits are found at elevations as high as 535m (1750'), although the greatest volume of ice-contact and deltaic sediment is found below 380m (1250'). Where many modern drainages enter the Hoosic River Valley, we mapped deltas and fan deltas graded to various levels of Lake Bascom. The greatest thickness and largest volume of lacustrine silt and clay lie below 290m (950'). About $1.3km^3$ of sorted sediment occupy the $350km^2$ Hoosic River Valley. The volume and distribution of this material strongly suggest live ice was never far from the stagnant margin. Sediment character, the rapid filling rate we calculate, and repeated instances of rhythmic lacustrine sediment overlying till, indicate the open waters of Lake Bascom directly bordered the retreating ice margin. The small volume of distinctly deltaic sediment probably indicates Lake Bascom did not fill the Hoosic River Valley for a long period of time.

3. Ice flow indicators and the orientation of striations and chattermarks suggest that topography influenced patterns of glacial flow during deglaciation. Cross-cutting relationships, along with empirically based ice profiles, indicate that highland areas such as Mt. Greylock, the Taconics, and the Green Mountains, emerged as nunataks and channeled the ribbons of ice flowing through the valleys below. High-level deltaic deposits and subsurface data suggest significant, ice marginal lakes existed as the ice surface lowered and valley ice tongues impounded water in tributaries of the Hoosic River. When the margin retreated north of the drainage divide at Berkshire, Lake Bascom came into existence. Continued retreat opened the 273m (895') spillway at Potter Hill and northwest-flowing drainage was restored. Fluvial and deltaic deposits graded to water planes below this level and corresponding to no recognized spillway, require that lower levels of Lake Bascom, dammed by ice in the Hudson River Valley, persisted after the Potter Hill spillway was abandoned.

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