HISTORY OF GLACIAL LAKES IN THE DOG RIVER VALLEY, CENTRAL VERMONT

by

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INTRODUCTION

The area traversed on this field trip lies on the Montpelier, Barre West, Northfield, and Roxbury 7.5-minute U.S. Geological Survey topographic maps in central Vermont. The terrain is underlain by metamorphosed eugeosynclinal rocks that are part of a complex zone of imbricate slices bounded by thrust faults. The age of rocks west of the Dog River is Cambrian and Ordovician. To the east the age of the rocks is under debate, but they are in the range of Ordovician to Devonian. The rocks in central Vermont were deformed during the Acadian orogeny and were intruded by Barre-type granites about 380 million years ago.

Erosion has produced a crude trellis drainage pattern characterized by alternating linear ridges and subsequent valleys that trend north-northeast/south-southwest (Fig. 1). Local relief is on the order of 300 meters (1,000 feet) with Scrag Mountain, elevation 887.5 meters (2,911 ft), being the local high point in the Northfield Range.

Critical to an understanding of the deglacial history of the area is the drainage divide separating north-flowing tributaries of the Winooski River from south-flowing tributaries of the White River (Fig. 1). In the larger view this divide separates the St. Lawrence River and Connecticut River drainage basins. In late-glacial time, low spots on the drainage divide acted as thresholds for proglacial lakes that formed after the ice margin had retreated north of the divide. The important thresholds that controlled local ice-marginal lakes are, from west to east: (1) Granville Notch, 430 meters (1,410 ft) ASL, (2) Roxbury, 308 meters (1,010 ft) ASL, and (3) 4.0 kilometers south of Williamstown, 279 meters (915 ft) ASL. A fourth threshold, located at the head of Brookfield Gulf (Ayers Brook) 12 kilometers south of Northfield, has an elevation of 436 meters (1,430 ft) ASL. A small proglacial lake that developed north of this threshold has no major deposits associated with it, and did not play a major role in the deglacial history.

The purposes of this field trip are to: (1) study glacial and postglacial sediments in order to document a sequence of down-dropping proglacial lakes and thereby establish the pattern of deglaciation, and (2) evaluate postglacial rebound as measured by Koteff and Larsen (1985 and in prep.).

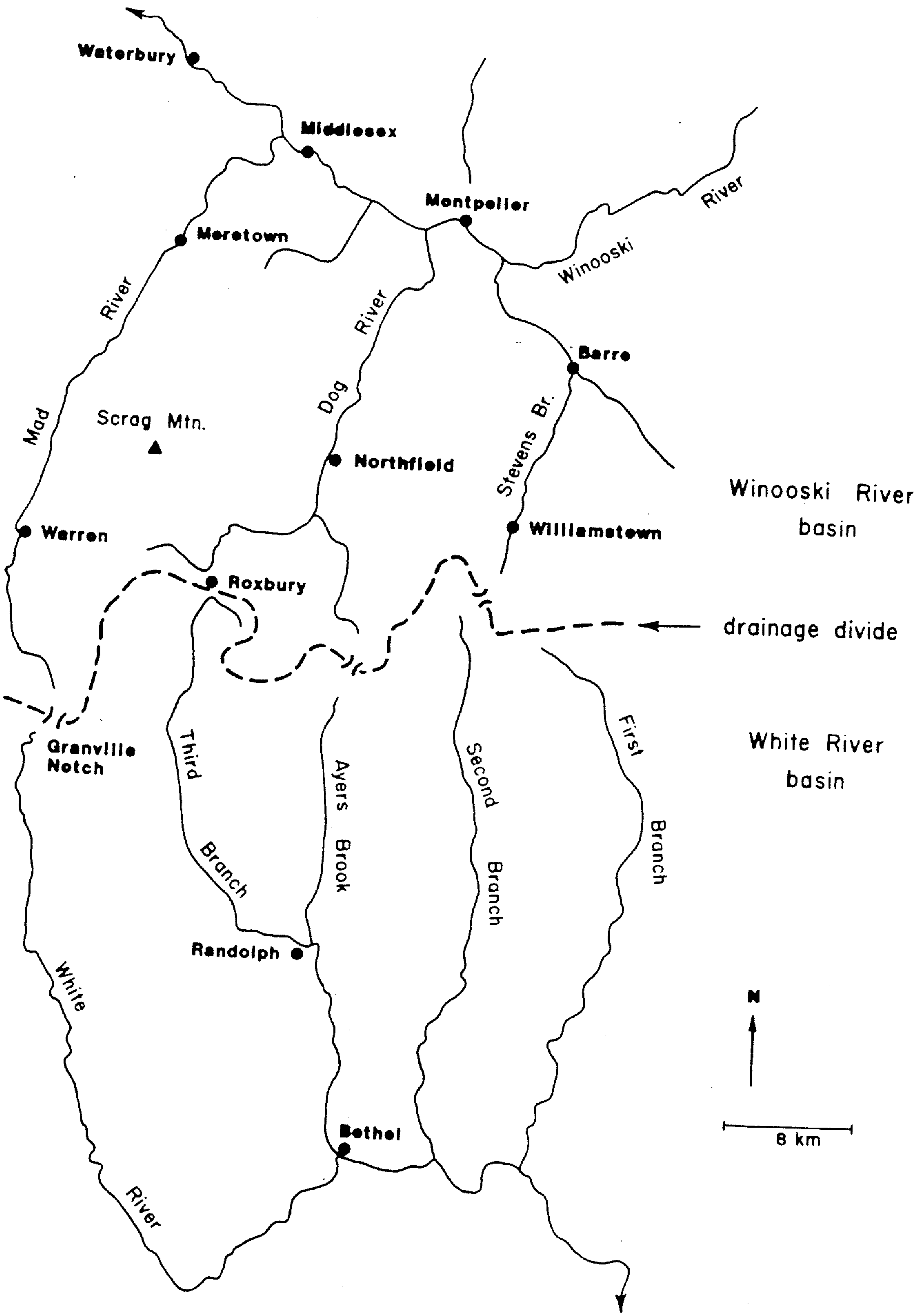


Figure 1. Stream drainage patterns in central Vermont.

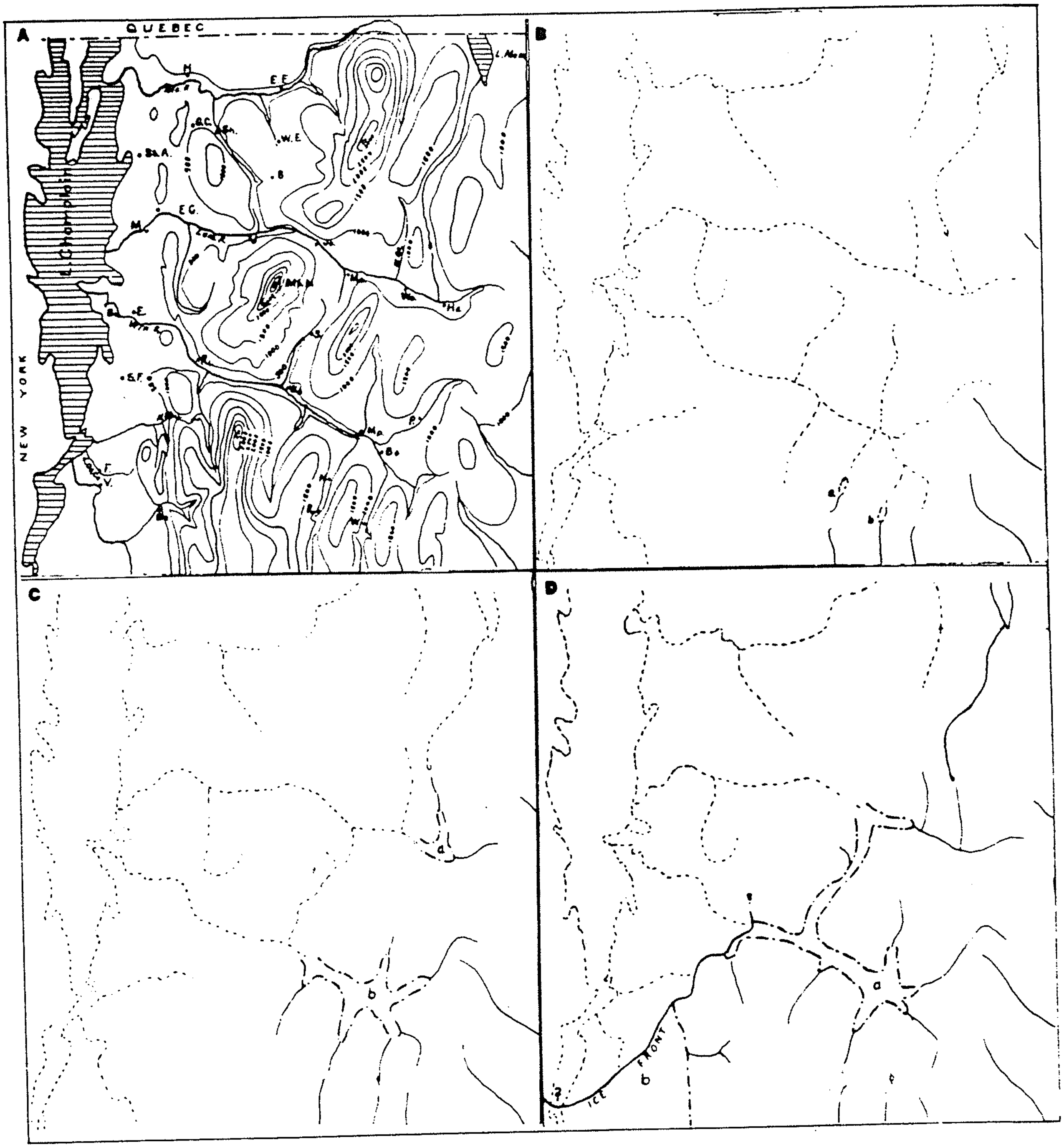


Figure 2. Portion of Plate XXI from Merwin (1908): (A) sketch map of northwestern Vermont; (B)-(D) lake stages in northwestern Vermont; (B) a, marginal lake south of Northfield (945 ft); b, Lake Williamstown (890 ft) discharging into the Connecticut River; (C) a, Second Lake Lamoille, b, First Lake Winooski at a stage represented by an altitude of about 745 feet at Plainfield,; (D) a, Lake Mansfield, b, Lake Vermont or Lake Albany.

HISTORICAL BACKGROUND

Merwin (1908) apparently made the first substantial study of glacial lakes in the Winooski drainage basin. He recognized that the ice margin retreated to the northwest resulting in a sequence of glacial lakes (Fig. 2). In his stage I, Merwin recognized two early ice-marginal lakes in the valleys of the Stevens Branch and Dog River. The lake in the Stevens Branch valley he named "Lake Williamstown", which "discharged into the Connecticut River" (Fig. 2B). He identified the lake in the Dog River valley as "a glacial lake south of Northfield". On the map, Merwin shows this lake draining north into the ice and not south into the Connecticut River basin as the evidence suggests. This latter feature has been named Lake Roxbury because the threshold of the lake is located in the village of Roxbury (Larsen, 1972). Merwin did not recognize a third lake of about the same age in the Mad River valley. That lake has been named Lake Granville because its threshold is located at Granville Notch (Larsen, 1972).

The name "First Lake Winooski" was used to describe an ice-marginal lake that extended from Middlesex to Plainfield and into the lower valleys of the Dog River and the Stevens Branch (Fig.2C). First Lake Winooski was "represented by an altitude of 745 feet at Plainfield" (Merwin, 1908). It is not clear where the outlet for the lake was located, however, we can surmise that he thought that drainage was to the west on or through the ice. Today, it is apparent that, as long as ice blocked the Winooski drainage on the west, meltwater was forced to flow into the Connecticut basin by way of the Stevens Branch valley. In a third stage, Merwin recognized a "Lake Mansfield" that occupied the Stowe valley north to Morrisville and the Winooski valley from Barre to Jonesville. The outlet for Lake Mansfield was on the west side of the Green Mountains and into a glacial lake in the Champlain Valley.

Merwin worked only one summer (1906) and covered all of northwestern Vermont. His analysis suffered from a lack of modern topographic maps with good altitude control. Because of his early recognition of a logical sequence of glacial lakes in the Winooski basin, I have retained his terminology for three lake stages in central Vermont (Larsen, 1972).

Stewart and MacClintock (1969) did not follow Merwin, and devised a sequence of glacial lakes in central Vermont that, in my view, cannot be defended. Their sequence of diagrams (1969, Figs. 18-22) clearly requires 73 meters (240 ft) of erosion at the Roxbury threshold and 33.5 meters (110 ft) of erosion at the Williamstown threshold following ice retreat. This is in spite of the fact that, in each case, constructional ice-contact landforms located immediately north of each threshold are graded to the present-day threshold, and not to some higher level. The reader is invited to read Stewart and MacClintock (1969, p. 139-158) in order to make a judgement.

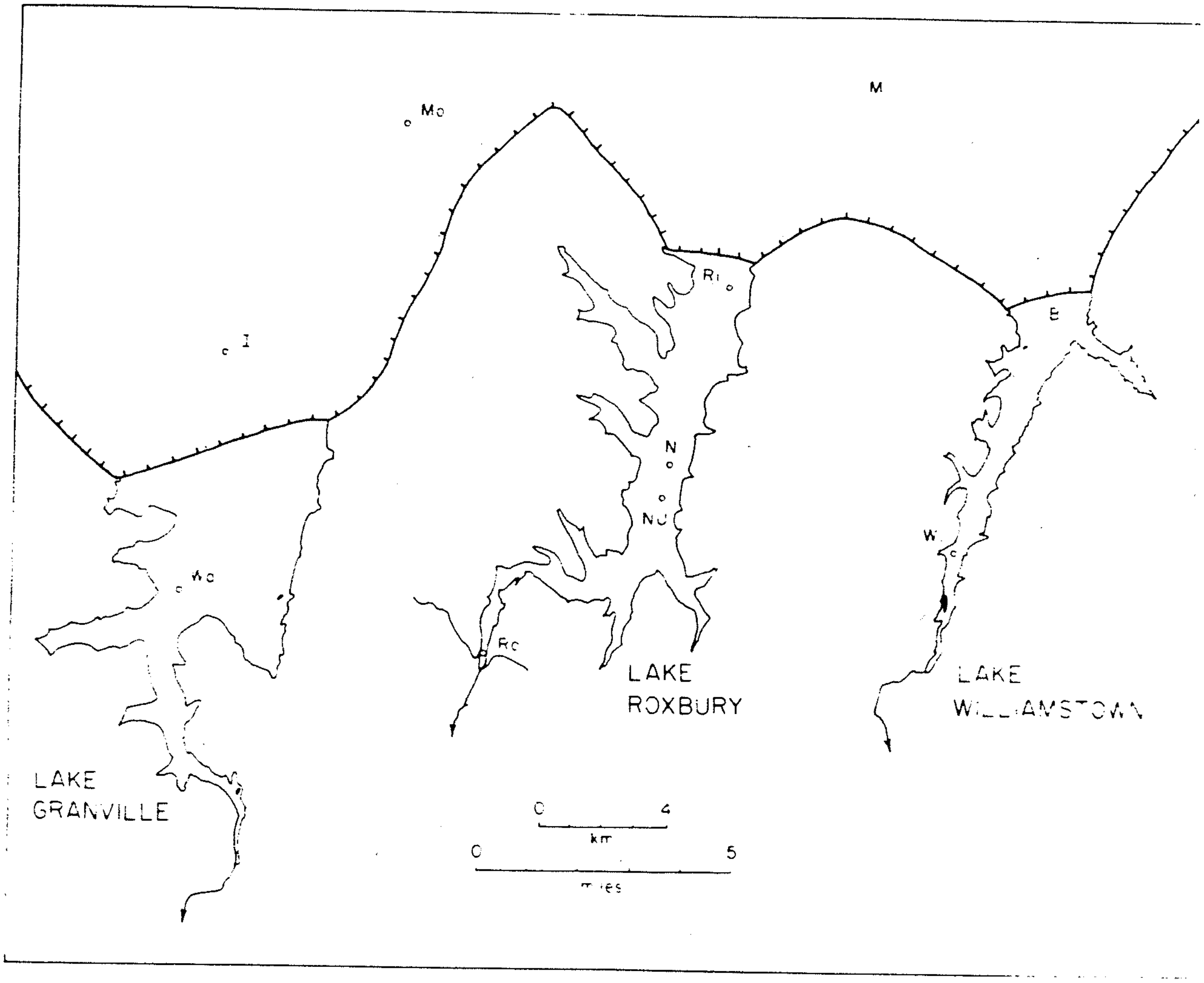


Figure 3. Proglacial lakes of Stage I: Lake Granville, Lake Roxbury and Lake Williamstown. Individual shorelines are based on a projection rising 0.90 m/km toward N21.5°W from the threshold of each lake. Solid triangles denote deltas graded to a lake level. In Figures 3-5 the ice margin damming each lake is shown as a short direct line for diagrammatic purposes. Tongues of stagnant ice probably occupied much of the area of each lake shown. (Explanation for Figures 3-5; B, Barre; H, Huntington; J, Jonesville; I, Irasville; M, Montpelier; Mi, Middlesex; Mo, Moretown; N, Northfield; NU, Norwich University; P, Plainfield; Ri, Riverton; Ro, Roxbury; W, Waterbury; Wa, Warren; Wi, Williamstown; Wo, Worcester.)

GLACIAL LAKES IN THE WINOOSKI VALLEY

In 1972, I proposed a three-stage sequence of glacial lakes in the Winooski valley (Larsen, 1972). In simplest terms, Stage I consisted of three separate ice-marginal lakes that drained south over separate thresholds, Stage II saw integration of those smaller lakes into one large lake draining south, and Stage III occurred when meltwater was permitted to drain west through the Green Mountains.

Stage III	Lake Mansfield II Lake Mansfield I			drained west
Stage II	Lake Winooski			drained south
Stage I	Lake Granville	Lake Roxbury	Lake Williamstown	drained south

STAGE I LAKE WILLIAMSTOWN, LAKE ROXBURY, LAKE GRANVILLE

Three proglacial lakes developed when the north-draining tributaries of the Winooski River, the Mad River, the Dog River and the Stevens Branch were dammed on the north by tongues of the retreating ice sheet. These lakes drained southward over thresholds located at: (1) Granville Notch, (2) Roxbury, and (3) 4.0 kilometers south of Williamstown (Fig. 3). From west to east, the lakes are named Lake Granville, Lake Roxbury and Lake Williamstown. Evidence that these lakes existed is shown by ice-contact deltas that are graded to the controlling threshold in each lake basin. A Lake Granville delta can be seen at Stop 3 (Hartshorn pit) on Field Trip C-1 (Ackerley and Larsen, this volume) and a Lake Roxbury delta will be seen on this trip at Stop 6. In this latter feature, the Roxbury delta, foreset beds; dune crossbedding, and ripple-drift cross-lamination all indicate transport to the south during deposition. The surface of the Roxbury delta is pockmarked with kettles on the north and was fed by a subglacial stream as indicated by an esker that extends 2.0 kilometers east-southeast from the head of the delta.

Retreat of the ice margin to the north resulted in northeastward expansion of Lake Roxbury. At Riverton (Stop 2), south-dipping crossbeds in esker gravel and subaqueous outwash testify that Lake Roxbury existed at least 14.3 kilometers northeast of its threshold. Continued downwasting and retreat of the ice margins bordering Lakes Roxbury and Williamstown finally resulted in the lowering of Lake Roxbury by 24.4 meters (80 ft) to the level of Lake Williamstown. This occurred when the ice withdrew below the 1,040-foot contour on the ridge separating the valleys of the Dog River and the Stevens Branch, or earlier. The locality is on the Barre West quadrangle, 3.7 kilometers north of Berlin Corners.

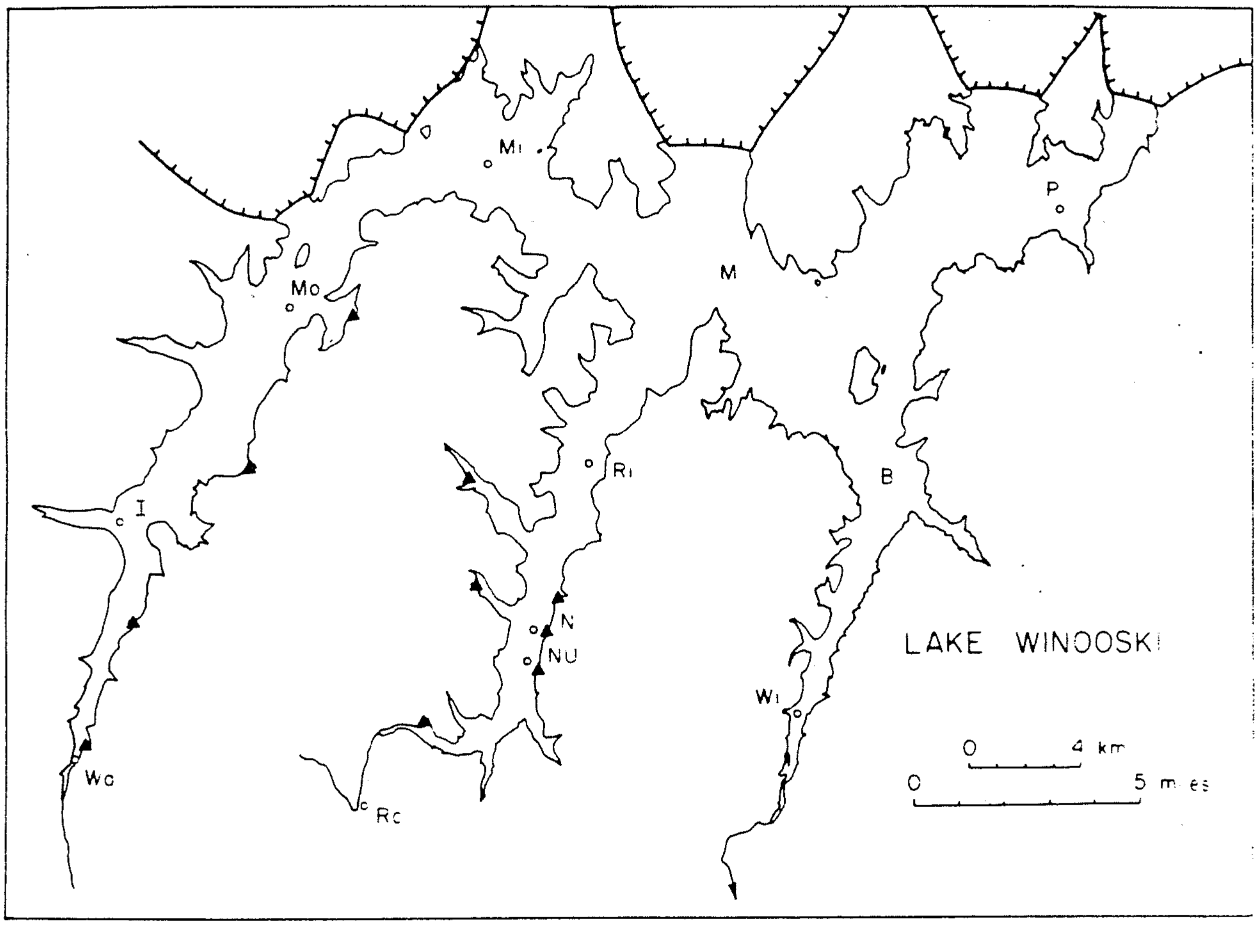


Figure 4. Stage II. Approximate shoreline of glacial Lake Winooski based on a projection rising 0.90 m/km toward N21.5°W from the 279-meter threshold 4.0 kilometers south of Williamstown. Solid triangles denote meteoric deltas built during Stage II. (See Figure 3 caption for abbreviations of town names.)

STAGE II LAKE WINOOSKI

The draining of Lake Roxbury to the level of Lake Williamstown marked the beginning of Lake Winooski, a major proglacial lake that drained south over the Williamstown threshold. At its maximum extent, Lake Winooski extended throughout the valleys of the Mad River, the Dog River, and the Stevens Branch. It is not clear whether Lake Winooski ever extended northward into south-draining tributaries like the North Branch or the Kingsbury Branch. Careful inspection of the North Branch area north of Montpelier on aerial photographs and topographic maps reveals no delta or terrace on or near the projected shoreline of Lake Winooski. This implies that the North Branch valley was filled with ice when Lake Winooski existed. The upper Winooski valley and the Kingsbury Branch valley also may have been filled with ice when Lake Winooski existed.

Figure 4 is confirmation of the amount of postglacial rebound reported by Koteff and Larsen (1985, and in prep., see Field Trip A-3, this volume). In the Connecticut Valley, the Lake Hitchcock shoreline has been measured to be planar and to rise 0.90 m/km (4.74 ft/mi) toward N21.5°W. The uplift of the land was due to the removal of the weight of the ice sheet. Uplift appears to have been delayed until after the Champlain Sea incursion started (Fig. 8 and text, Field Trip A-3, this volume). Because Lake Winooski is older than the Champlain Sea, we can assume that the amount of postglacial uplift measured for Lake Hitchcock applies to central Vermont, and probably to much of western New England. Therefore, using the value of 0.90 m/km to N21.5°W, I projected a shoreline on the topographic map from the Williamstown threshold at 279 meters into the Winooski basin as an approximation of the shoreline for glacial Lake Winooski (Fig. 4). The projected shoreline falls right on the break-in-slope of 6 deltas in the Dog River valley and 4 deltas in the Mad River valley. The 10 deltas are all meteoric deltas that formed after the ice margin had retreated to the north permitting integration of the three lakes of Stage I into one Lake Winooski. The fact that 10 deltas fall right on the projected shoreline confirms both the existence and position of Lake Winooski and the value of postglacial rebound of Lake Hitchcock as measured by Koteff and Larsen.

Retreat of the ice margin that blocked Lake Winooski to the west-northwest down the Winooski valley can be documented at three localities: (1) on the south bank of the Winooski River 3.4 kilometers southeast of Middlesex, (2) at the Vermont Highway Department pit 2.0 kilometers north of Middlesex, and (3) north of the railroad 5.0 kilometers west-northwest of Waterbury. At these localities crossbedding in esker gravel and/or subaqueous outwash consistently dips to the east-southeast indicating that a subglacial meltwater source lay immediately to the west-northwest in the retreating ice sheet.

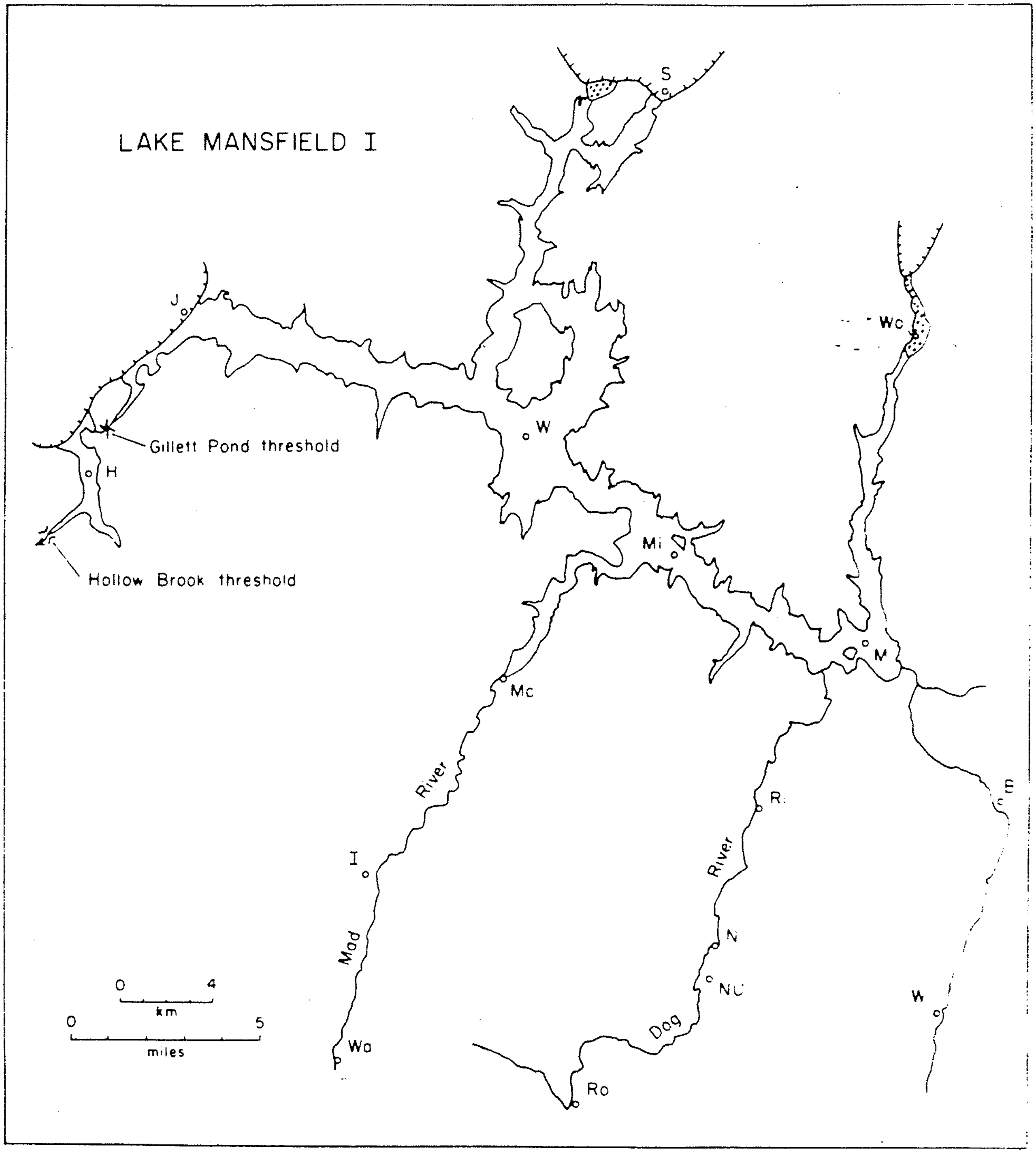


Figure 5. Stage III. Approximate shoreline of glacial Lake Mansfield I based on a projection dropping 0.90 m/km toward S21.5°E from the 229-meter threshold just southwest of Gillett Pond. Exact position of shoreline in the Winooski basin east of Middlesex is conjectural because older lake-bottom deposits that once stood higher than the projection probably have been removed by erosion. (See Figure 3 caption for abbreviations of town names.)

STAGE III LAKE MANSFIELD

When the ice margin retreated to Jonesville and Huntington, meltwater was able to escape to the west through the Green Mountains and south in the valley of the Huntington River (Fig. 5). Lake Winooski was lowered to the level of Lake Mansfield I and the 279-meter threshold south of Williamstown was abandoned. Lake Mansfield had more than one phase because there are several possible thresholds in the vicinity of Huntington ranging from 229 meters (750 ft) at Gillett Pond to 204 meters (670 ft) at the Hollow Brook threshold 3.0 kilometers southwest of Huntington. Wagner (1972) has identified three lakes that drained southwest through Huntington and ultimately over the Hollow Brook threshold. For simplicity, as it pertains to the early postglacial history of central Vermont, I recognize Lake Mansfield I (Gillett Pond threshold) and Lake Mansfield II (Hollow Brook threshold).

If we project a shoreline from the 229-meter Gillett Pond threshold with a gradient of 0.90 m/km down toward S21.5°E, that projection extends into the Dog River valley to Northfield Falls. However, Lake Mansfield I did not occupy the Dog River valley because older lake-bottom deposits lie at least 15 meters (50 ft) above the projection. Stream terraces cut into the older lake-bottom deposits fall on the projection, indicating that the early Dog River was flowing north at that time, or later. In the Mad River valley most of the major stream terraces fall on a concave-up profile that appears to join the above projected shoreline at an elevation of 213.4 meters (700 ft) at the village of Moretown (Fig. 6). On the east side of the Mad River valley, 2.7 kilometers northeast of Moretown, a small delta appears to be graded to the Gillett Pond projection (Fig. 6). Other fluvial surfaces that appear to be graded to this projection are 3.2 kilometers north of Montpelier and 4.0 kilometers west-northwest of Montpelier. Important large deltas at Worcester and 2.4 kilometers west of Stowe are about 14 meters (45 ft) above the Gillett Pond projection and probably were graded across ice, or to an unrecognized threshold.

Retreat of ice from the Gillett Pond threshold permitted Lake Mansfield I to drop 20 meters to the Hollow Brook threshold. A shoreline projected southeast from the Hollow Brook threshold, 20 meters below the Gillett Pond projection, intersects older lake-bottom deposits everywhere in the Winooski basin east-southeast of Waterbury. Therefore, Lake Mansfield II did not extend east of Waterbury and the Winooski River and all of its tributaries east of Waterbury were now on a fluvial grade to Lake Mansfield Phase II. The stream terrace to be observed at Stop 2 and other major terraces in the Dog River were part of that fluvial system (Fig. 7). Retreat of the ice margin from the lower Huntington River caused the draining of Lake Mansfield II to a lower lake thus permitting the Winooski River and its tributaries east of Waterbury, like the Dog and Mad Rivers, to erode down to their present levels.

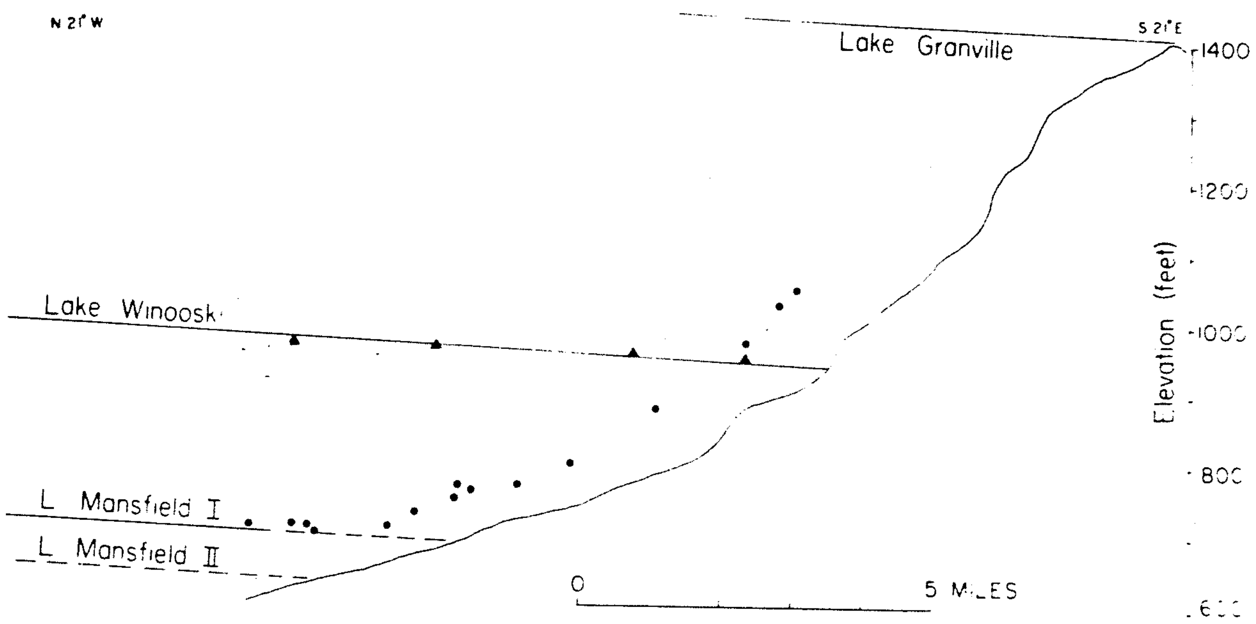


Figure 6. Projected profile showing elevation of major terraces (solid dots) in the Mad River valley. The levels of Lakes Granville, Winooski, Mansfield I, and Mansfield II are shown rising toward N21°W. Deltas built into Lake Winooski are shown by triangles. Terraces below the Lake Winooski level appear to form a single, concave-up, fluvial profile graded to glacial Lake Mansfield I at Moretown. Solid line at bottom denotes projected profile of the Mad River.

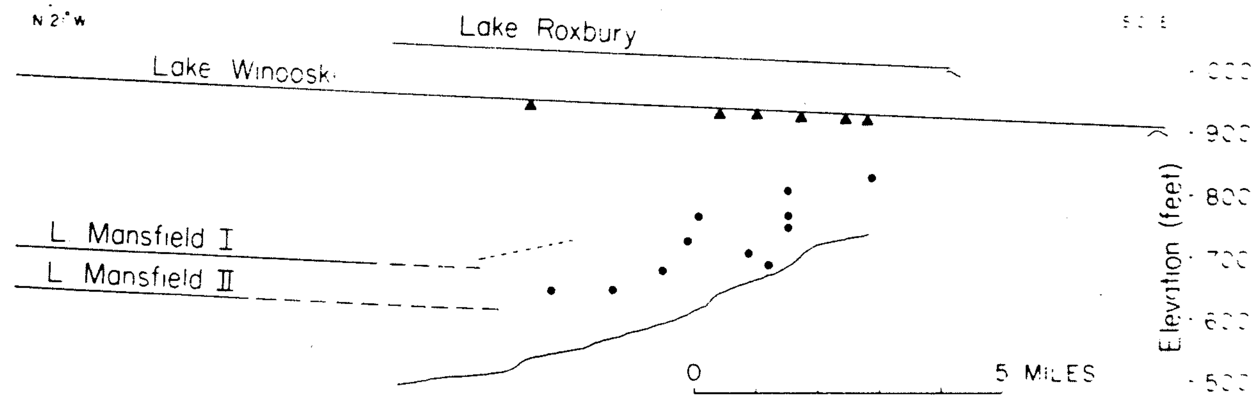


Figure 7. Projected profile showing elevation of major terraces in the Dog River valley (solid dots). Lake levels are shown rising toward N21°W. Lake Winooski deltas in the Dog River valley appear as triangles. Major terraces in the Dog River valley appear to be graded to both Lake Mansfield I and Lake Mansfield II. Solid line at base is projected profile of the Dog River. Line with short dashes is highest level of lake-bottom deposits.

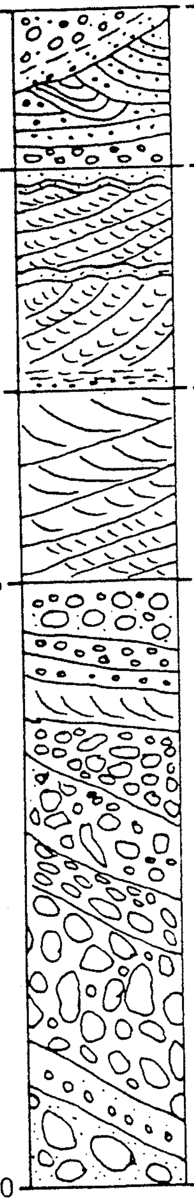
QUATERNARY SEDIMENTS OF THE DOG RIVER VALLEY

Evidence for more than one glaciation has not been found during detailed mapping of the Dog River valley in the Northfield and Roxbury 7.5-minute quadrangles. A small exposure of saprolite represents preglacial material and will be visited at Stop 3. Three facies of till are recognized: (a) a greenish-gray sandy till on the west flank of the Dog River valley, (b) a gray silty till on the east flank, and (c) a gray clayey till in and near the valley bottom. The greenish-gray till is similar in color to underlying bedrock of the Moretown Formation. The gray silty till is similar in color to underlying bedrock of the Northfield and Waits River Formations. The gray clayey till is composed of deformed clay and silt layers resembling varves formed in a glacial lake. This suggests that the last ice sheet dammed a lake in the north-draining Dog River valley just prior to its advance over the region.

The following three sedimentary units are found in a fining-upward sequence at six different pits in the Dog River valley (Fig. 8). The sequence is nearly identical to that described by Rust and Romanelli (1975) for subaqueous outwash in the Ottawa, Ontario, region. The similarity between the sediments that they described in the Ottawa region and those in the Dog River valley is truly remarkable given the physical differences in the two respective environments of deposition. In the Ottawa area, deposition apparently was in a broad, open lake in a region of low relief, whereas in the Dog River valley, deposition was in a very narrow lake in a region of moderate relief.

Coarse-grained ice-contact deposits are common along the axis of the valley between Riverton and Roxbury. Poorly sorted pebble gravel with cobbles in south-dipping crossbed sets 2.0 meters thick commonly is interbedded with pebbly coarse to fine sand and silt. The deposits are confined to narrow elongate areas that are interpreted to be segments of eskers formed by subglacial meltwater streams. Till is rarely observed under the esker sediments and bedrock scoured by meltwater is common. The sediments are rarely collapsed except on their outside margins. The situation requires a subglacial meltwater stream capable of eroding and reworking till. The model of subglacial fluvial erosion described by Gustavson and Boothroyd (1982) for the Malaspina Glacier, Alaska, appears to be applicable here. In their model a groundwater table (potentiometric surface) rises upglacier from a proglacial lake and supplies the head required to drive meltwater and meteoric precipitation through a subglacial stream system. Such a system is required in order to explain the observations made, and to supply the large quantities of subaqueous outwash observed in the Dog River valley.

Overlying the coarse-grained ice-contact deposits are 1.0 to 5.0 meters, or more, of medium to very coarse sand and pebble gravel in trough-crossbed sets 10 to 50 centimeters thick. The dip direction of the crossbeds is highly variable, although gen-



DEPTH (METERS)		GRAIN SIZE (SED. STRUCTURES)	DIRECTION OF SED. TRANSPORT	INTERPRETATION
0	UNIT 4	clean pebble gravel pebbly coarse sand (planar and trough crossbeds)	north	stream-terrace deposits
1.5	UNIT 3	fine to very fine sand, silt, clay (ripple-drift cross-lamination)	south	distal subaqueous outwash
6.5	UNIT 2	medium to very coarse sand, pebble gravel (planar and trough crossbeds)	south	proximal subaqueous outwash
8.5	UNIT 1	poorly sorted pebble gravel with cobbles and boulders, very coarse sand (large-scale crossbeds)	south	esker gravel formed in subglacial tunnel
18.0				

Figure 8. Generalized stratigraphic section for gravel pits in the Dog River valley. Units 1, 2 and 3 constitute a fining-upward sequence produced by northward retreat of an ice margin in a lake. Sediment is delivered to the lake floor by south-flowing turbidity currents issuing from a subglacial tunnel. Unit 4 was formed after the lake drained (Compare with Rust and Romanelli, 1975; depth scale is not linear).

erally it has a southern component. At some localities the dip direction is at right angles to the trend of the esker deposits. At Stops 2 and 8 large channels truncate well-bedded medium and fine sand. The channels are filled with structureless medium sand and contain clasts up to 20 centimeters long of very fine sand and silt. A broad U-shaped channel 16.5 meters wide and 2.0 meters high was formerly exposed at Stop 8 about 15 meters north of the esker gravel. The observations indicate that deposition of Unit 2 was by density currents close to the mouth of a subglacial tunnel. I characterize Unit 2 as proximal subaqueous outwash (Fig. 8).

Second to till, Unit 3 is the most widespread surficial unit in the Northfield 7.5-minute quadrangle. It underlies an area about 1.0 kilometer wide along the bottom of the Dog River valley. The deposits consist of fine to very fine sand, silt and clay that are often rhythmically bedded. In places, angular ice-rafted clasts are common. Ripple-drift cross-lamination formed by south-flowing turbidity currents indicates formation of Unit 3 as distal subaqueous outwash in south-draining Lake Roxbury. Fine-grained lake-bottom deposits, for example varved silt and clay, that might be associated with north-draining Lake Winooski are not common, or are difficult to recognize. A large portion of Lake Winooski bottom deposits probably were removed by post-lake stream erosion, because in many exposures stream-terrace gravels rest directly on fine sand with south-dipping crossbeds.

Unlike Units 1 and 2, which are relatively undeformed except for minor faults, Unit 3 displays various degrees of deformation. At two construction sites studied in 1979 and 1981 at Norwich University highly deformed (collapsed) ice-contact lake deposits were observed to grade upward through lesser deformed sediments into undeformed lake-bottom deposits. This indicates that lake-bottom sedimentation was contemporaneous with melting of buried ice, and suggests a somewhat different configuration of the ice margin than that shown by Rust and Romanelli (1975, Fig. 14) (Fig. 9).

Deltaic deposits of Lake Roxbury are exposed only at Stop 6 (Roxbury delta) where sediments range from pebble gravel with cobbles to very fine sand and silt. Crossbedding at all scales indicates transport to the south during deposition. Compared to the Roxbury delta, the younger Lake Winooski deltas generally are finer grained with clean pebble gravel in the topset beds and pebbly medium to coarse sand on the sides of the deltas.

Stream-terrace deposits, alluvial fan deposits, and alluvium are all similar in that they consist mainly of pebble gravel and pebbly coarse sand. They each display medium-scale crossbeds and imbricated flat pebbles that indicate down-valley transport of sediment after glacial Lake Winooski had drained.

SHAPE OF THE ICE MARGIN DURING RETREAT

A sequence of three fining-upward sedimentary units in subglacial and subaqueous outwash in the Dog River valley is nearly identical to that described by Rust and Romanelli (1975) in the Ottawa, Ontario, region. In two of their "Depositional models for subaqueous outwash in ridges at the ice front", Rust and Romanelli (1975, Fig. 14) show a retreating ice margin that is both straight and steep. In a third model they show a subglacial stream entering a lake at a reentrant formed by two straight and steep ice fronts.

There is an important distinction between Unit 3, distal subaqueous outwash, in the Dog River valley and fine-grained subaqueous outwash in the Ottawa area. In the Dog River valley, Unit 3 commonly is highly collapsed, whereas Units 1 and 2, esker gravel and proximal subaqueous outwash, show only minor faults. This suggests that Unit 3 was deposited on ice, whereas Units 1 and 2 were not. I believe that these observations require both a deep reentrant in, and a low surface gradient of, the subaqueous ice margin during retreat (Fig. 9). A crude and subaerial analog for a deep reentrant in the ice margin occurs today along the stagnant outer margin of the Malaspina Glacier where subglacial streams emerge as fountains that feed narrow ice-bounded outwash plains. If the edge of the Malaspina Glacier were to be submerged, and basal ice contained enough debris so that it would not float, then a subglacial stream would emerge at the head of a deep subaqueous reentrant in the ice margin. Coarse-grained material in traction (Unit 2) would be confined to the reentrant and fine-grained material in suspension (Unit 3) would be carried down-lake and spill out of the reentrant onto stagnant ice. Continuous melting of the stagnant ice on the sides of the reentrant during deposition of the fine-grained material would account for the progressive upward change from highly deformed to undeformed lake-bottom deposits found in the Dog River valley.

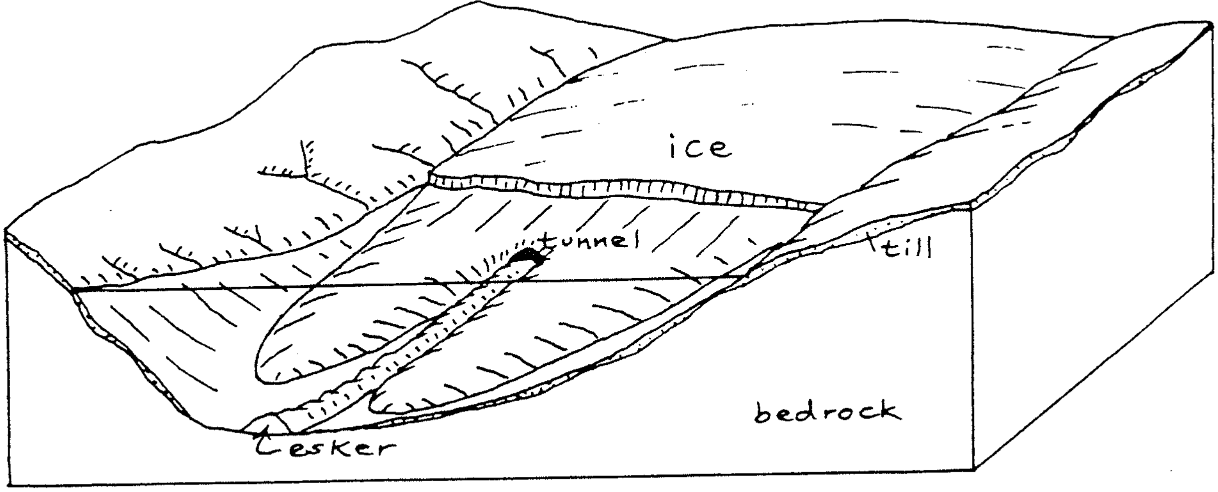


Figure 9. Proglacial environment of deposition for Unit 3, distal subaqueous outwash.

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