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Deglaciation of the Connectiut Valley: Vernon, Vermont, to Westmoreland, New Hampshire

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NEIGC FIELD TRIP A-6

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DEGLACIATION OF THE CONNECTICUT VALLEY: VERNON, VERMONT, TO WESTMORELAND, NEW HAMPSHIRE

by

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INTRODUCTION

The main purpose of this field trip is to study the glacial, late-glacial and postglacial history of the Connecticut Valley between Vernon and Westmoreland. There are several interrelated themes that will be addressed. They include the direction of ice movement, the mode of ice retreat, morphosequences, glacial Lake Hitchcock, post-Lake Hitchcock sediments and crustal rebound. Field trip stops will be made on the following U.S. Geological Survey 7.5'x 15' quadrangles with a metric scale of 1:25,000: Brattleboro, Vt-NH; Newfane, Vt-NH, and Keene, NH-Vt.

Weathering and erosion by streams and continental ice sheets of complex metamorphic rocks intruded by granite have produced a rugged, hilly topography with local relief of 350 m (1,150 ft). The low elevation for most of the field trip area is supplied by the Connecticut River which is a lake, the surface of which is held at 66 m (217 ft) ASL by the Vernon dam. The local high elevation is 417 m (1,368 ft) ASL on Wantastiquet Mountain just east of the Connecticut River at Brattleboro. Stream drainage is controlled by the Connecticut River which flows south and has two major tributaries in this area, the West and Ashuelot Rivers.

The area probably has been covered by ice sheets several times but specific evidence of multiple glaciation in southeast Vermont and southwest New Hampshire is sparse. A loose sandy till overlying very compact till with stained joints can be observed at two localities near Keene. Very compact till with stained joints occurs at several sites in the Newfane and Keene metric quadrangles, including STOP 9 of this field trip. Multiple-till exposures probably representing two separate glaciations are known in northern, east-central, and southern New Hampshire (Koteff and Pessl, 1985), as well as in southern Quebec and southern New England.

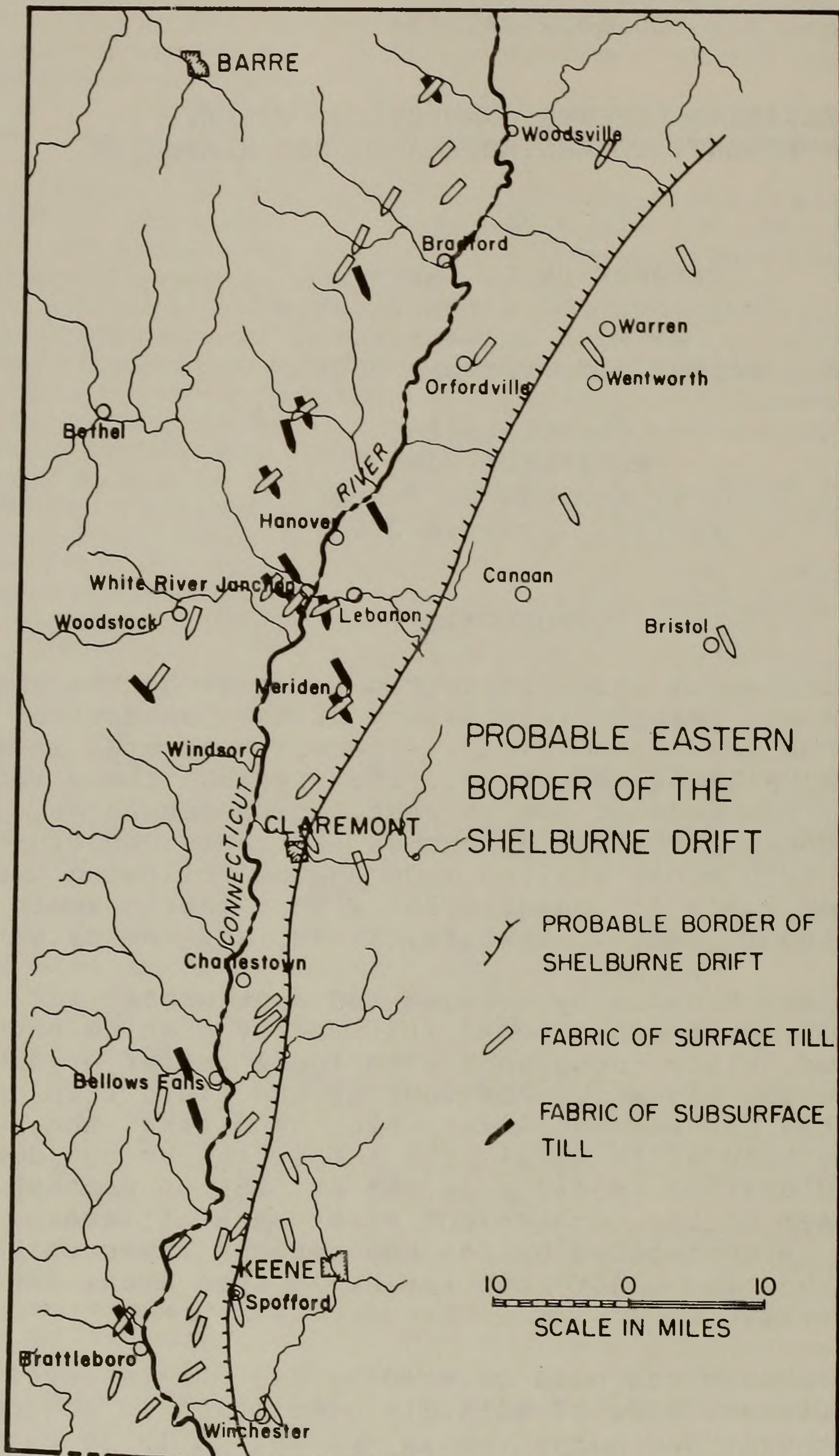

Figure 1. "Probable eastern border of the Shelburne drift". According to Stewart and MacClintock (1969, p.99), the Shelburne drift presumably was derived by ice moving from the northeast. Note that surface-till fabrics west of the border between Winchester and Charlestown indicate that the Shelburne drift came from older drift east of the border. That situation would be highly unlikely if not impossible.

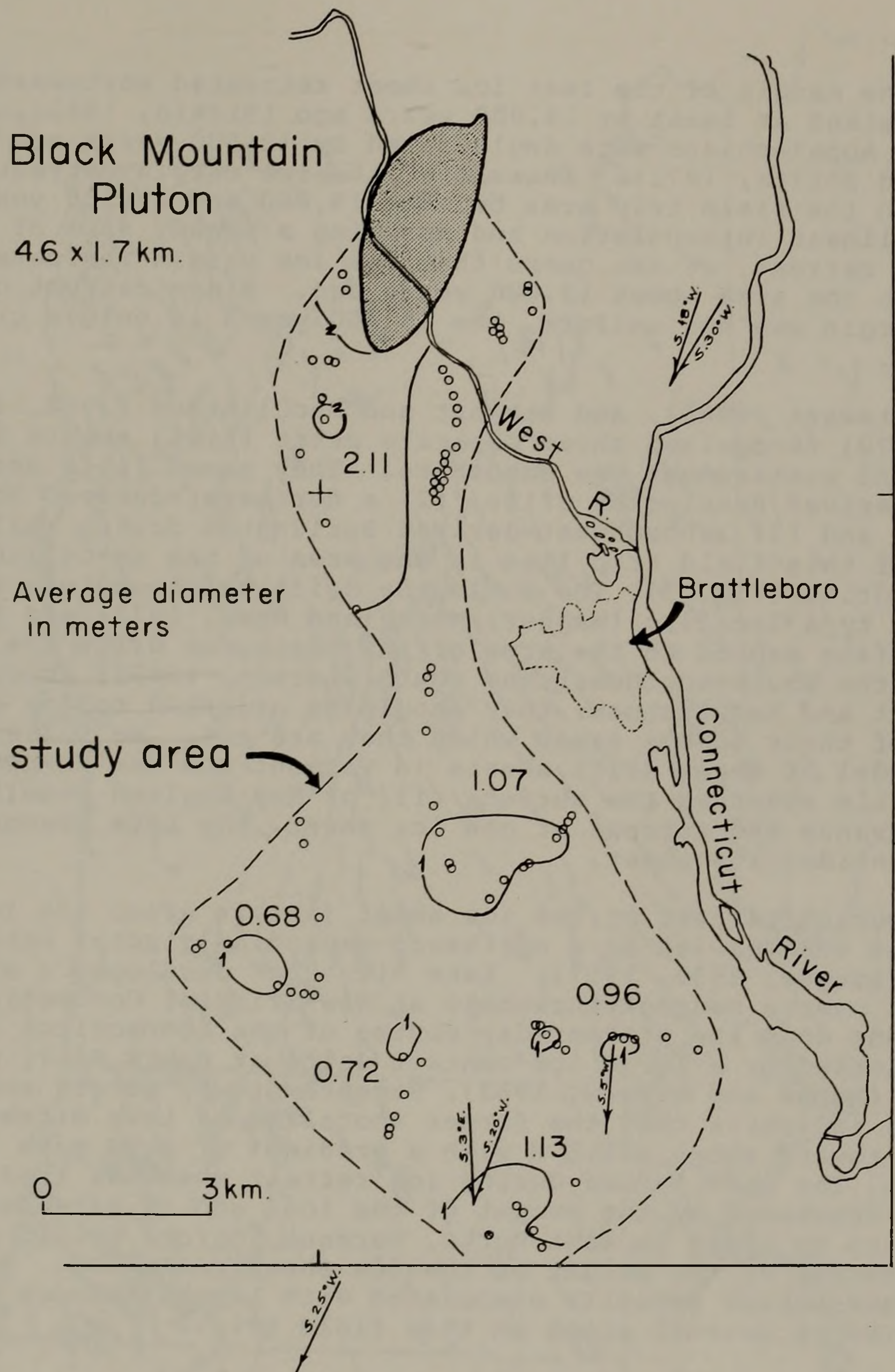

Figure 2. Distribution of glacial erratics of Black Mountain granite (open circles). Erratics were measured within a limited study area (dashed line). Numbers represent the average diameter of the group of erratics where the number is plotted. Arrows represent striations.

The margin of the last ice sheet retreated northward from Long Island at least by 19,000 years ago (Sirkin, 1982), and the Quebec Appalachians were deglaciated by 12,500 years ago (McDonald and Shilts, 1971). Therefore, the ice margin retreated through the field trip area between 19,000 and 12,500 years ago. Using linear interpolation and assuming a steady rate of ice margin retreat, we can guess that the ice margin retreated through the area about 15,000 years ago. Since retreat of the ice margin was not uniform, the 15,000 years is only a crude estimate.

Stewart (1961), and Stewart and MacClintock (1964, 1969, and 1970) recognized three separate drift (till) sheets in Vermont and westernmost New Hampshire. They named (1) a northwest-derived Bennington drift, (2) a northeast-derived Shelburne drift, and (3) a northwest-derived Burlington drift. All of the area of this field trip lies in the area of the so-called Shelburne drift (Fig. 1). The Shelburne drift was found not to exist at its type locality (Wagner, Morse and Howe, 1972) and 9 indicator fans mapped in the area of the Shelburne drift are oriented to the south-southeast and south (Larsen, 1987). According to Stewart and MacClintock, they should be oriented to the southwest of their source areas which they are not. We believe that the model of three drift sheets in Vermont and New Hampshire is untenable and that the surface till of New England resulted from the advance and retreat of one ice sheet, the Late Wisconsinan (Laurentide) ice sheet.

During retreat of the ice sheet in this area, the ice margin was accompanied by a northward-expanding glacial Lake Hitchcock (Lougee, 1939, 1957). Lake Hitchcock developed a stable outlet over a bedrock threshold at New Britain, Connecticut, and drainage down the present-day course of the Connecticut River was blocked by a large ice-contact delta at Rocky Hill, Connecticut (Stone and others, 1982). Recent work by Koteff and Larsen (1988) indicates that the former shoreline of Lake Hitchcock now rises toward about N21.5 W with a gradient of 0.90 m/km (4.74 ft/mi). The lake formed during ice retreat when the land was still depressed by the weight of the ice, and it extended 320 km from its spillway to West Burke, Vermont, before uplift due to the removal of the weight of the ice sheet commenced. Deltaic and lake-bottom deposits associated with Lake Hitchcock will be observed at several stops on this field trip.

DIRECTION OF ICE MOVEMENT

The direction of movement of the former ice sheet in the Brattleboro area can be ascertained by a study of striations, roche moutonnée forms, and the distribution of granitic erratics from the Black Mountain pluton (Fig. 2). Striations, including some not shown on Figure 2, occur in two modal groups. One is S5E to S5W and the other is S20W to S35W. Due south-trending

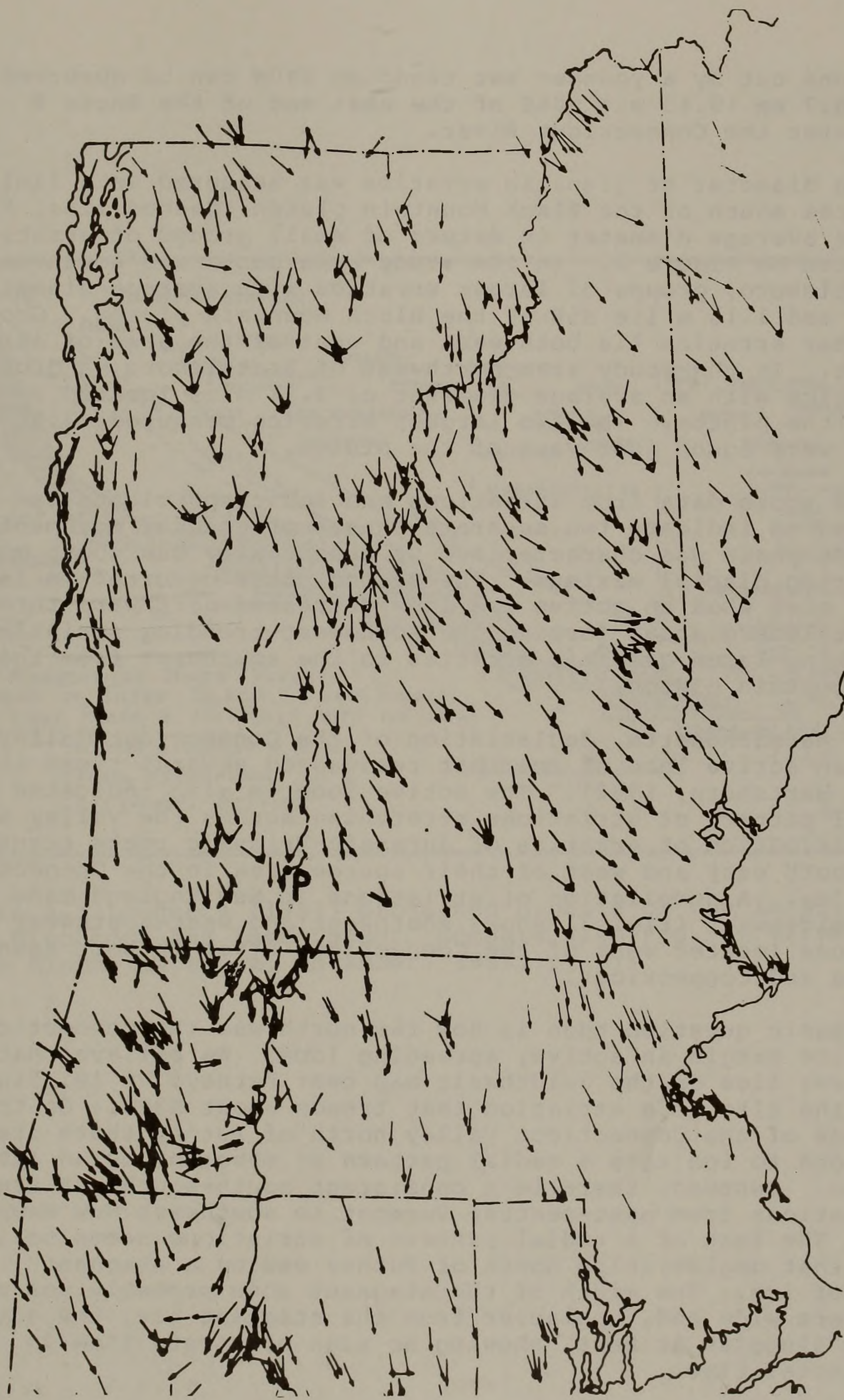

Figure 3. A portion of James W. Goldthwait's compilation of glacial striations in New England; P, Putney, Vt., (Flint, 1957, p. 60).

striations cut by a younger set trending S40W can be observed at a site 0.7 km (0.43 mi) S86E of the east end of the Route 9 bridge over the Connecticut River.

The diameter of granitic erratics was measured in a limited study area south of the Black Mountain pluton (dashed line, Fig. 2). The average diameter in meters of small groups of erratics is plotted on Figure 2. In the study area south and southwest of Brattleboro, groups of larger erratics with average diameters of 1.07 and 1.13 m lie S5E of the Black Mountain pluton. Groups of smaller erratics lie both east and west of the area of larger erratics. In the study area northwest of Brattleboro, a group of erratics with an average diameter of 2.11 m is located southwest of the pluton. The two largest erratics measured, 3.66 and 4.06 m, were found just west of the pluton.

The above data from striations and indicator clasts can interpreted to indicate two separate phases of glacial movement. The first phase was characterized by essentially due south movement during glacial maximum. The second phase occurred in late-glacial time when an active ice lobe retreated northward through the Brattleboro area, forming the southwest-trending striations and pushing large granitic erratics to the southwest from the Black Mountain pluton.

In Massachusetts, deglaciation of the Connecticut Valley was by an active lobe of ice that readvanced several times (Larsen and Hartshorn, 1982). The active lobe is also indicated by a radial pattern of striations stretching across the valley and the distribution of erratics of Jurassic-Triassic rocks transported both east and west of their source area in the Connecticut Valley. A compilation of striations in New England made by James Goldthwait (Fig. 3) shows southwest and west-southwest striations located west of the Connecticut River in both Massachusetts and Connecticut.

A basic question then is how far north was the Connecticut Valley ice margin an active, spreading lobe? We believe that the answer lies on the Goldthwait map near Putney, Vt (P, Fig. 3), at the site of a striation that trends about S30W. On the west side of the Connecticut Valley north of Putney there are no striations to indicate a radial pattern of movement by an active ice lobe. Instead, there is a consistent south-southeast trend of striations from east-central Vermont to southwest New Hampshire. The lack of a radial pattern of striations seems to indicate that deglaciation north of Putney was by a stagnant tongue of ice. The width of the stagnant zone probably was many kilometers wide and, upglacier from the stagnant ice, the active ice was sluggish at best, showing no sign of lobate flow in late-glacial time.

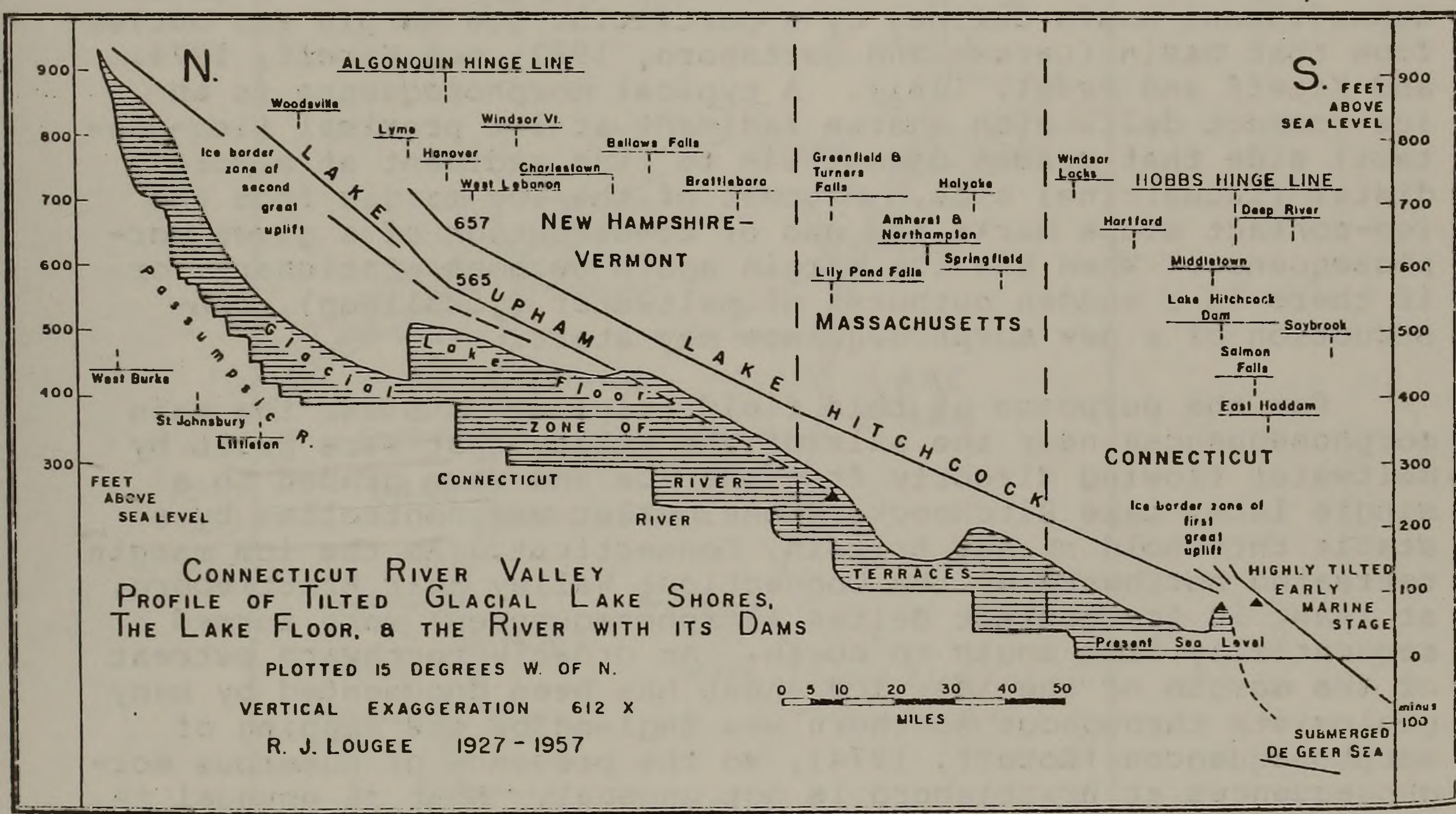

Figure 4. Lougee's (1957) projected profile of the levels of Lake Hitchcock and Lake Upham. Compare with Fig. 6. (From Dartmouth Alumni Magazine, November, 1957, p. 37)

MORPHOSEQUENCES

A change in the regimen of the retreating ice sheet when its margin was near Putney, as suggested by the ice-directional features, can also be seen in the evidence from morphosequences.

A morphosequence consists of all the stratified deposits formed by one meltwater stream system and deposited in a given depositional basin defined by a particular ice margin and outlet from that basin (Larsen and Hartshorn, 1982; see Koteff, 1974, and Koteff and Pessl, 1981). A typical morphosequence is an ice-contact delta with coarse sediment at its proximal (ice-contact) side that grades downstream to fine sediment at a more distal (lacustrine) side. Retreat of the ice margin from the ice-contact slope marks the end of construction of a given morphosequence. When the ice margin again becomes stationary, or if there is a sudden outburst of meltwater (jőkullaup), construction of a new morphosequence may start.

For the purposes of this field trip, we consider the main morphosequences near the axis of the valley that were built by meltwater flowing directly from the ice and were graded to a single lake, Lake Hitchcock, whose outlet was controlled by a stable threshold at New Britain, Connecticut. As the ice margin retreated northward up the Connecticut Valley near Brattleboro, at least 10 ice-contact deltas (morphosequences) were formed sequentially from south to north. An orderly northward retreat of the margin of the last ice sheet has been documented by many geologists throughout southern New England by the mapping of morphosequences (Koteff, 1974), so the presence of numerous morphosequences at Brattleboro is not unusual. What is unusual is the fact that near the axis of the Connecticut Valley north of Putney there are very few morphosequences built directly from the ice and there is no place that matches the number and close spacing of morphosequences as can be observed at Brattleboro.

It appears that the vitality or the activity of the Connecticut Valley lobe dropped considerably when the ice margin was located near Putney. Borns and Calkin (1977) have suggested that, when the Laurentide ice sheet thinned over the Appalachian Mountains of northwest Maine to the point where the ice surface strongly intersected the regional topography, then the ice sheet south of the mountains lost a regional supply of ice from the north and its regimen dropped sharply. Borns and Calkin further note that the large esker systems in Maine were formed in this zone of sluggish ice south of the mountains. That same zone extends southwest into Vermont and New Hampshire and includes the large Connecticut Valley esker that extends from Windsor, Vt, to Lyme, NH. Whether or not the rate of retreat of the ice margin in the Connecticut Valley can be related to the lowering of the ice sheet over the Green Mountains remains to be seen. It does appear that the ice sheet had a diminished ability to supply sediment to the ice margin when it retreated north of Putney.

Figure 5. Map of Lake Hitchcock and Lake Upham by Lougee (1957, from Dartmouth College Alumni Magazine, November issue, p. 27).

HISTORICAL NOTE PERTAINING TO THE VERMONT-NEW HAMPSHIRE PORTION OF LAKE HITCHCOCK

(1) Richard J. Lougee's projected profiles of Lake Hitchcock and Lake Upham are oriented "15 degrees west of north" (Fig. 4) (Lougee, 1957). This is not far from its probable true value near N21.5W as shown by Koteff and Larsen (1985, 1988). Lougee thought that Lake Hitchcock drained when its northern end was located at the ice margin near Lyme and that Lake Upham, a lower and younger lake, extended north to Burke, Gilman and Littleton (Fig.5). Lougee extended the "Algonkian hinge line" across the Connecticut valley at Lyme. Lougee's "Lake Upham" north of the hinge line plus his "Lake Hitchcock" south of the hinge line essentially is the same as the Lake Hitchcock shown by Koteff and Larsen for Vermont and New Hampshire (Figs. 6 and 7). We see no evidence for hinge lines in the area of Lake Hitchcock and believe that Lougee came within a hinge line (or two) of unraveling the true story of Lake Hitchcock in 1957.

(2) Stewart and MacClintock (1969, 1970) on the Surficial Geologic Map of Vermont show a "Connecticut Valley Lake" extending along the entire Connecticut valley of Vermont from Massachusetts (at elevation 435 ft) to the International Border near Canaan (at elevation 1,101 ft). They assumed that maximum uplift was due north with a gradient of 4.15 ft/mi (Stewart and MacClintock, 1969). Such a lake as the "Connecticut Valley Lake" shown by Stewart and MacClintock on the Surficial Geologic Map of Vermont never existed.

(3) Larsen (1983) measured the elevation of 11 topset-foreset contacts between Brattleboro and Lisbon. It became apparent in 1983 that Lake Hitchcock extended to Burke, Gilman and Littleton, and was similar in those areas to the map of "Lake Upham" by Lougee (Fig. 5). Based on the 11 data points in Vermont and New Hampshire plus 4 others in Massachusetts, it was noted that the best-fit plane for the uplifted Lake Hitchcock shoreline rose toward N20W at 4.54 ft/mi (Larsen, 1983). That study has since been extended and now includes 28 data points on or near the Lake Hitchcock water plane, which is now thought to rise 4.74 ft/mi toward N21.5W (Koteff and Larsen, 1988).

GLACIAL LAKE HITCHCOCK

As the ice margin retreated through the Brattleboro area it was accompanied by a northward-expanding Lake Hitchcock. For an up to date treatment of the origin and early history of Lake Hitchcock see Stone and others (1982) and Koteff and others (1987). By the time the ice margin was in the vicinity of the Holyoke Range in Massachusetts, the level of Lake Hitchcock had become stable because downcutting at the New Britain spillway had reached bedrock and ceased. Koteff and Larsen (1988) have established the location and orientation of the stable shoreline of Lake Hitchcock by measuring the elevation of the topset/fore-

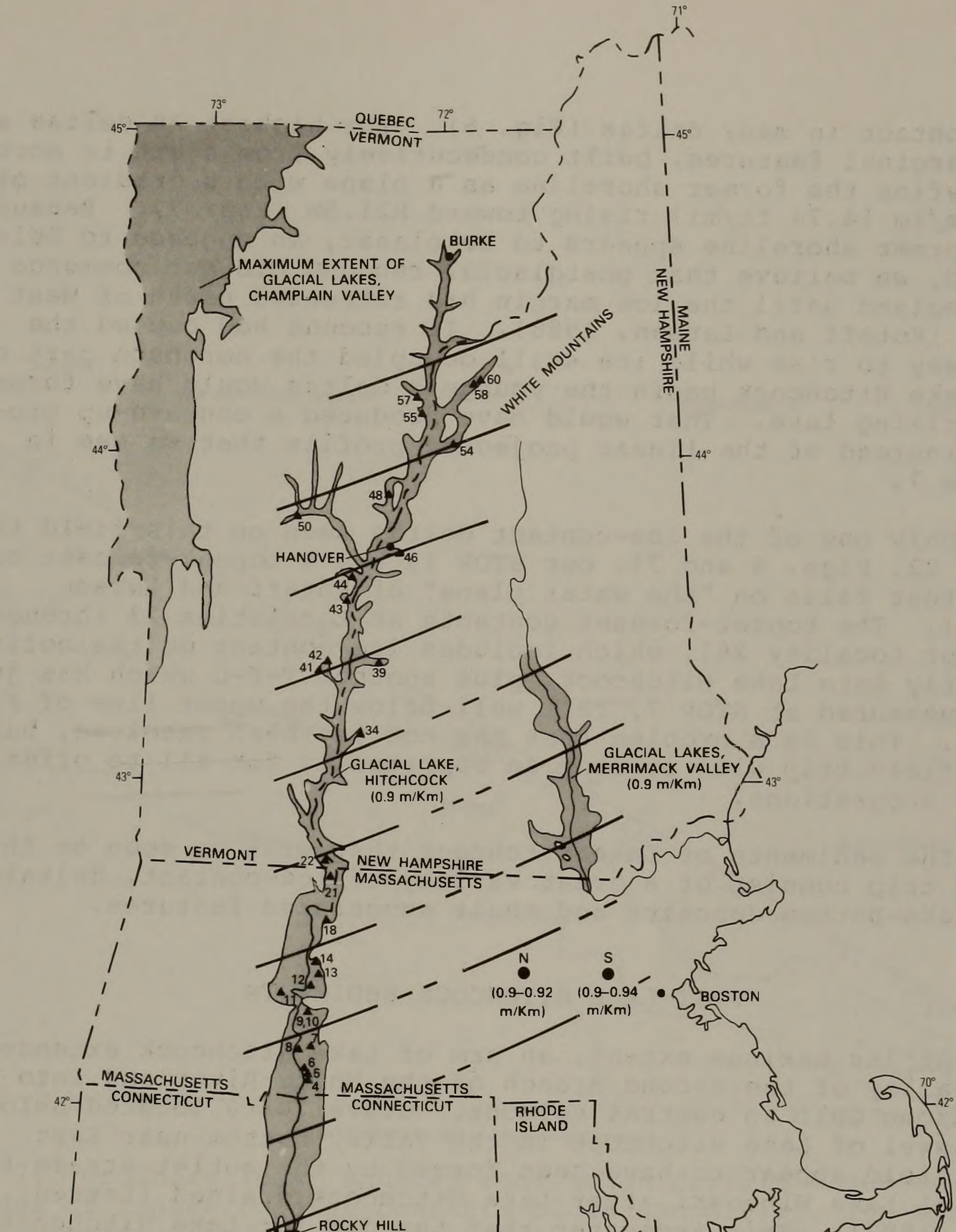

Figure 6. Generalized outline of glacial Lake Hitchcock and selected other glacial lake areas in western New England. (N) glacial Lake Nashua; (S) glacial Lake Sudbury; solid triangles denote location of altitude obtained from unmodified, ice-marginal, or meltwater-derived delta; uplift isobase interval is 25 meters. (Figure from Koteff and Larsen, 1988)

set contact in many deltas (Fig. 6). The highest 28 deltas are ice-marginal features, built consecutively from south to north, and define the former shoreline as a plane with a gradient of 0.90 m/km (4.74 ft/mi) rising toward N21.5W (Fig. 7). Because the former shoreline appears to be planar, as opposed to being curved, we believe that postglacial rebound did not commence in New England until the ice margin had retreated north of West Burke (Koteff and Larsen, 1988). If rebound had caused the spillway to rise while ice still occupied the northern part of the Lake Hitchcock basin the youngest deltas would have formed in a rising lake. That would have produced a concave-up profile instead of the linear projected profile that we see in Figure 7.

Only one of the ice-contact deltas seen on this field trip (Loc. 22, Figs. 6 and 7), our STOP 1, has a topset-foreset contact that falls on "the water plane" of Koteff and Larsen (1988). The topset-foreset contacts at Localities 23 through 30 (except Locality 26), which includes ice-contact deltas built directly into Lake Hitchcock, plus another T-F-C which has just been measured at STOP 7, fall well below the upper line of Figure 7. This is a problem that has not yet been resolved, but this field trip will present an opportunity for all to offer their suggestions.

The sediments of Lake Hitchcock that will be seen on this field trip consist of a great variety of ice-contact, deltaic and lake-bottom deposits and their associated features.

POST-LAKE HITCHCOCK SEDIMENTS

At its maximum extent, an arm of Lake Hitchcock extended up the valley of the Second Branch of the White River and into Williamstown Gulf in central Vermont. Gravel bars located below the level of Lake Hitchcock in the valley bottom near East Brookfield appear to have been formed by the outlet stream from glacial Lake Winooski after Lake Hitchcock drained (Larsen, 1984, 1987). This indicates that the dam for Lake Hitchcock at Rocky Hill had been breached while glacial ice still blocked the northwest-draining Winooski River in Vermont. The draining of Lake Hitchcock has to predate any shell-bearing Champlain Sea deposits and could have occurred around or before 13,000 BP.

Draining of Lake Hitchcock resulted in the erosion of lake-bottom sediments by the Connecticut River, which left wide stream terraces as it cut down below 66 m ASL. A typical stream-terrace deposit consists of 5 to 6 m of yellowish-brown fine to very fine sand over pebble gravel up to a meter thick. These sediments rest disconformably upon lake-bottom deposits. Wind activity was great shortly after Lake Hitchcock drained, as shown by extensive sand-dune deposits that lie southeast of major stream terraces at STOP 8 and STOP 10.

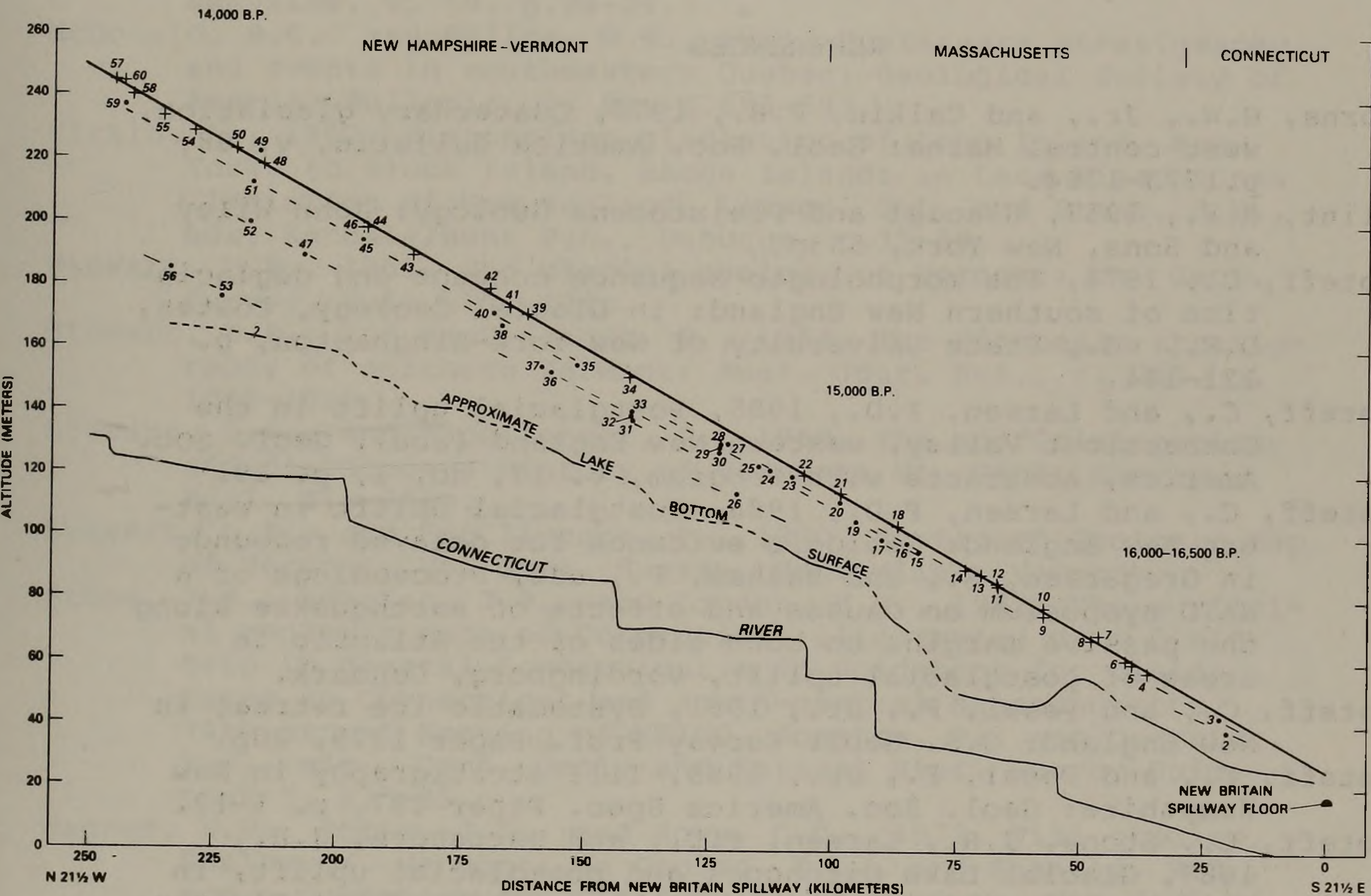

Figure 7. Ordinary least squares regression profile based on altitudes of topset/foreset contacts of 28 unmodified, ice-marginal, or meltwater-derived deltas (+) in glacial Lake Hitchcock. (.) other altitudinal data. Dashed profiles are diagrammatic only. Lake-bottom profile estimated from previous publications and topographic maps. (Figure from Koteff and Larsen, 1988).

ACKNOWLEDGMENTS

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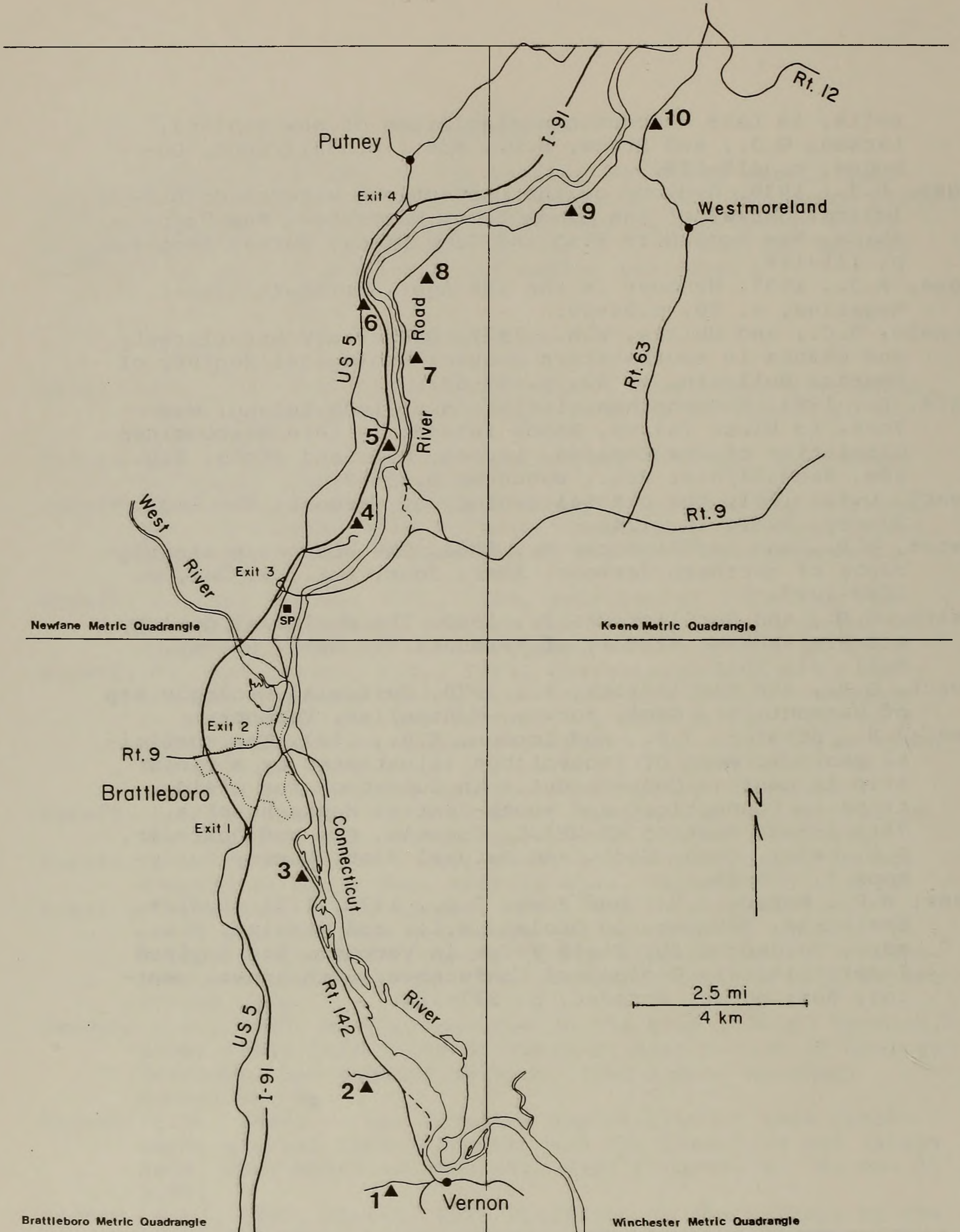

Figure 8. Location of field trip stops.

ROAD LOG

START AT PARKING LOT OF MCDONALD'S RESTAURANT 0.25 MI SOUTH OF THE JUNCTION OF ROUTES 9 AND U.S.5 (NEXT TO EXIT 3 OF I-91) AT THE NORTH END OF BRATTLEBORO.

Mileage

0.0 Leave McDonald's Restaurant, turn left (south) on U.S.5, proceed to the south end of downtown Brattleboro

2.3 Turn left and immediate right on Route 142, proceed south along west side of Connecticut River

4.5 Cersosimo Lumber Yard, site of STOP 3, on right

9.4 Turn right (west) on Pond Road under railroad

9.45 Turn right on West Road, proceed west on stream-terrace deposits cut in Lake Hitchcock bottom sediments

10.00 Pit entrance on left. Reverse direction with caution and park off pavement

STOP 1. GASSETT PIT (Town of Vernon, Vermont): The pit is located in a linear ridge that trends N22W and rises over 120 m ASL (above sea level) on the Brattleboro, Vt-NH, 7.5' x 15' metric quadrangle (1:25,000). The southernmost face is over 280 m south of West Road and has in its upper part 2 to 3 m of pebble-cobble gravel with a matrix of coarse sand and granules. Low-angle crossbeds indicate transport direction to the southwest. About 60 m north of the south face deltaic foresets dip 22 degrees toward S75W. About 15 m further north beds of pebbly coarse sand, fine sand and silt display abrupt change in grain size, cut-and-fill structure, and opposing directions of transport to the northeast and southwest. In July, 1982, collapsed beds of lacustrine fine to medium sand were exposed 75 m north of the latter site. The general aspect of this landform is that of an ice-contact delta fed by meltwater streams issuing along an ice margin that trended north-northwest on the east side of the deposit. In 1982, the elevation of the topset-foreset contact in a former position of the south face was measured to be 119.5 m ASL (Koteff and Larsen, 1988).

Proceed east on West Road, turn left (east) on Pond Road

10.9 Turn left (north) on Route 142 just east of railroad underpass

12.7 Turn left (west) on Tyler Hill Road

12.95 Pit entrance on left

STOP 2. EVANS PIT: Town of Vernon, Vermont; the pit is located on Tyler Hill Road 2.78 km (1.72 mi) N33W of railroad underpass in Vernon (Brattleboro, Vt-NH, metric quadrangle).

The pit is in a ridge that rises toward S33W. About 305 m (1,000 ft) southwest of Tyler Hill Road and at an elevation of about 120 m ASL the ridge joins an irregular plain that slopes gently to the southwest. A small depression is located just southeast of the point where the ridge joins the plain. The southwest face has 1 m of pebble gravel with openwork structure over 1 m of fine to medium sand below which is a thick unit of poorly sorted pebble-cobble gravel with subangular to subrounded boulders. On the east flank of the ridge are younger fine-grained lake sediments with A-type ripple-drift cross-laminations that indicate a transport direction of due south. The sloping ridge is interpreted to be an esker formed by meltwater flowing southwest in a subglacial tunnel. Where the meltwater stream issued from the ice it constructed a large ice-contact delta graded to the level of Lake Hitchcock. The fine-grained lake sediments on the east flank were formed by south-flowing currents in Lake Hitchcock after the ice margin retreated from the head of the delta and the subglacial tunnel was destroyed by melting of the ice.

Proceed east on Tyler Hill Road

13.2 Turn left on Route 142. Proceed north on stream terraces cut by the Connecticut River

15.2 Road descends to the level of the Connecticut River

16.5 Turn left with caution just beyond last building on the left at Cersosimo Lumber Company and park adjacent to Route 142. Walk southwest to exposed sediments

STOP 3. CERSOSIMO LUMBER COMPANY. The site is 2.9 km (1.8 mi) S11E of the junction of Routes 142 and U.S. 5 in downtown Brattleboro (Brattleboro, Vt-NH, metric quadrangle). The exposure extends north-south along the west side of the Cersosimo Lumber Company and faces the Connecticut River about 300 m to the east. Two terrace levels can be seen at the top of the exposure. The north terrace is underlain by 2.9 m of pebble gravel and the south terrace has 2.5 m of pebble gravel capped by 0.9 m of very fine sand. Bedrock is exposed 65 m west of the edge of the north terrace and near Route 142 where the cars are parked.

Under the stream-terrace deposits at the south terrace are 5 m of ice-contact deposits that have been disturbed. A distinctive massive bed with vertical fluting is about 1.5 m thick and consists mainly of medium to coarse sand with granules and small pebbles. The bed has lost its original layering and instead displays a crude banding. At first impression, it appears that the layer represents a grain flow, but no channeling is observed and practically all the other beds show similar internal disruption, including the beds under the north-terrace deposits.

At the north under the stream-terrace deposits are 19.7 m of collapsed ice-contact deposits consisting of pebble gravel, sand and silt in disrupted beds. Lenses of interbedded sand and pebble gravel, flame-like structures of pebble gravel extending upward into massive sand, and zones of silt "clasts" formed by dismemberment of original silt layers all appear to be manifestations of massive disruption of bedded ice-contact deposits. Pebble gravel with cobbles is exposed at the north end of the exposure. The disrupted beds are interpreted to have been originally formed in a subglacial stream environment and to have undergone internal deformation caused by massive collapse by melting of adjacent ice and/or some other process.

Proceed north on Route 142

18.5 Stop sign, turn left and sharp right on U.S. 5. Proceed north through the center of Brattleboro. From MILE 20.0 to 21.0 is the Brattleboro "strip" with many fueling and dewatering possibilities on a major stream terrace

21.0 Cross Route 9, proceed north on U.S. 5

21.6 At the traffic light turn right (east) on Ferry Road

21.8 The open area on the right now occupied by United Parcel Service, baked-goods distributor and C & S Grocery is the site of a former ice-contact delta (a morphosequence) that has been removed almost completely by man

22.2 A partially excavated ice-contact delta (another morphosequence) with foreset bedding exposed is at the left. The deposit formerly covered the lumber yard area

22.4 Turn left (west) opposite asphalt plant into Allard pit.

STOP 4. ALLARD PIT: Near the southeast corner of the Town of Dummerston, Vermont, the pit is 2.3 km (1.4 mi) N45E of the junction of Routes 9 and U.S. 5 at the north end of Brattleboro. The maximum elevation in this pit is over 126 m on the Newfane, Vt-NH, 7.5' x 15' metric quadrangle.

A remnant of the highest part of the landform underlies a solitary pine tree in the northern part of the pit. Under the pine tree are thin flat-lying gravels interpreted to be deltaic topsets below which are foresets that dip to the southwest. Good exposures of foresets are northwest and east of the pine tree. The foresets on the east grade southward into a spectacular exposure of collapsed bottomset beds. Bottomset beds located southwest of the pine tree are not collapsed and ripple-drift cross-lamination in fine sand is well displayed. Just northeast of the pine tree is pebble gravel in fluvial crossbeds 60 cm thick that are interpreted to have been formed in a subglacial tunnel. The deltaic deposits are inferred to have been formed in Lake Hitchcock when the ice margin was located at the north end of the pit area. The elevation of the topset-foreset contact was measured to be 129.8 m (425.87 ft) ASL, which is below "the water plane" of Koteff and Larsen (1988).

Return to Ferry Road and proceed west

23.6 Turn right (north) on U.S. 5. Just north of I-91 are lake-bottom deposits of Lake Hitchcock. The road crosses several bedrock ridges and at Hidden Acres Campground enters an area of collapsed stratified drift with many depressions and ridges

26.0 Turn sharp right on dirt road. Proceed east over gravel ridges (eskers) mantled with lacustrine sediments. A former ice margin position was located 200 to 300 m south of and parallel to the road

26.4 Small borrow pit on the right has thick varves (12 to 50 cm) deposited on the north flank of an ice-contact delta

26.5 "Tornado-like" wind associated with a severe thunderstorm of July 14, 1988, demolished a house trailer at the right opposite the former Moore Farm

26.6 Pass under I-91, bear right and drive up into pit

STOP 5. SIMEONE PIT. The pit is located adjacent to the Connecticut River 4.2 km (2.6 mi) N35E of the junction of Routes 9 and U.S. 5 at the north end of Brattleboro (Newfane metric quadrangle, 1:25,000). The landform is the remnant of an ice-contact delta built directly into Lake Hitchcock. Lake-bottom deposits just west of I-91 indicate that the west side of the delta represents part of the original ice-contact slope. The elevation of the topset-foreset contact was measured to be 127.7m (419 ft) which is below that at the Allard pit (STOP 4) and well below "the water plane" of Koteff and Larsen (1988).

Proceed west

27.9 Turn right proceed north on U.S. 5

28.2 The KOA Campground is on a post-Lake Hitchcock meteoric delta built eastward out onto Lake Hitchcock varved sediment. The road drops into the Salmon Brook valley cut in varved silt and clay, rises onto the same delta (fan) surface as at KOA, and gradually descends to lake-bottom deposits at the Ranney Farm, on the right with four blue silos

29.5 Park on right side of U.S. 5 and walk south and east to clay pit owned by Robert Ranney

STOP 6. CANOE BROOK SECTION. The clay pit is located on the north side of Canoe Brook in the Town of Dummerston and is 2.15 km (1.35 mi) N42E of East Dummerston. The semi-circular pit is about 51 m in diameter and faces south-southwest. The section consists of 21.0 m of thin varves capped by 3.0 m of artificial fill from excavations on I-91. The varves consist of clay-silt couplets 1.0 to 10 cm thick interbedded with fine to very fine sand. Ripple-drift cross-lamination in fine sand dips eastward suggesting a source in the Canoe Brook valley.

On June 29, 1988, Jack Ridge and Fred Larsen counted 640 couplets and discovered brown peat-like organic debris that has been submitted for carbon-14 dating. We hope that a stratigraphic curve showing secular variation of paleomagnetic variation, to be measured by Ridge, plus the carbon-14 date will permit age correlation of Lake Hitchcock varved sediment throughout the Connecticut Valley.

Proceed north on U.S. 5

30.9 Turn right just north of Sunoco station, enter I-91 southbound

32.6 I-91 rises onto stream terrace deposits of the Connecticut River east of the Ranney Farm

34.4 Moore Farm Road passes under I-91

34.5 Simeone pit (STOP 5) on left

35.8 Allard pit (STOP 4) on left

36.0 Top of small ice-contact delta

37.1 Exit right from I-91

37.6 Traffic lights, proceed straight ahead (east) across U.S. 5 and enter Route 9

37.9 Connecticut River with outcrops at river level. The road climbs the flank of a delta on the right and follows the till-stratified contact nearly to the Chesterfield Inn which is on till

40.4 Turn left (north) on Brook Street

41.0 Stop sign, turn left on Main Street which becomes River Road north of the village of West Chesterfield. The road descends a series of small stair-like terraces to the flood plain of the Connecticut River

41.8 Landform west of the Connecticut River is the ice-contact delta of STOP 5

43.3 Park on right at entrance to pit. Just east of River Road are varved silt and clay capped by stream-terrace deposits of the Connecticut River

STOP 7. THOMAS PIT: The pit is located on the south side of the Chesterfield-Westmoreland town line about 350 m east of the Connecticut River on the Newfane, Vt-NH, 7.5' x 15' quadrangle. The pit is in the central part of a landform that is 1.1 km long and 0.45 km wide. The easternmost face has 2 m of topset beds on top of 13 m of southeast- and southwest-dipping foreset beds. The topset-foreset contact was measured to be 131.7 m (432 ft). The projected level of Lake Hitchcock at this site according to Koteff and Larsen (1988) is about 136 m (446 ft).

About 90 m north of the Thomas pit is the Gesmaldi pit with an active pit face about 12.8 m high with 2 to 3 m of topset beds of pebble gravel over foreset beds of sand, pebbly sand, and pebble gravel that dip to the southeast.

The landform is interpreted to be an ice-contact delta that formed directly in Lake Hitchcock between ice on the west and the valley wall on the east. It appears to have been fed, at least in part, by a subglacial stream that also formed an esker, now partially buried by lacustrine sediments about 1 km north-northwest of the Gesmaldi pit.

Extending 1.7 km north of the Gesmaldi pit is an area of post-Lake Hitchcock sand dunes up to 300 m wide. Practically all of the dune area lies below the projected level of Lake Hitchcock. In map pattern the dune sand rests mostly on bottom sediments of Lake Hitchcock and is 5.5 or more meters thick.

Return to cars and proceed north on River Road

43.4 Small pit on right has stream-terrace deposits on lake-bottom sediments on esker gravel

43.7 Coyote Canyon Road on right leads to Gesmaldi pit

44.2 Ridge on right is probable esker covered by Lake Hitchcock bottom deposits

44.5 Small pit at left has 3 m of typical stream-terrace deposits consisting of yellowish-brown fine sand

44.9 Turn right into driveway of white house (Blood residence)

STOP 8. BLOOD PIT: Located in the southwest part of the Town of Westmoreland, New Hampshire, the pit is 3.6 km (2.3 mi) N58E of East Dummerston, Vermont, on the Newfane, Vt-NH, 7.5' x 15' quadrangle. Watch for Mr. Blood's tame partridge.

The pit is in postglacial talus with angular blocks of slatey phyllite probably derived from the Devonian Littleton Formation. Some erratics (possible Cheshire quartzite?) and diamict occur under 3 to 4 m of talus at the base. Bedrock is exposed in the middle and upper parts of the borrow area. The projected level of Lake Hitchcock extends across the upper part of the face. Possibly, the diamict accumulated as subaqueous slide breccia before Lake Hitchcock drained, and the talus accumulated after the lake drained.

From the south end of the pit walk west down gentle slope to base of steeper east-facing slope, 2 to 3 m high. Note lack of stream at base of slope. Climb slope and proceed north and northeast along crest of dunes to small borrow area next to pit-access road. The orientation of sand dunes and wind-abraded bedrock elsewhere in New England suggests that geologically effective winds were from the west and northwest in late-glacial and postglacial time. Canoe Meadows, an extensive terrace cut in fine-grained sediments of Lake Hitchcock, lies immediately to the northwest and probably constitutes the source area for the sand dunes.

45.5 Turn right and proceed north on River Road along the southeast margin of Canoe Meadow, a major stream terrace of the Connecticut River
46.8 Enter Keene metric quadrangle (MAP 5)
48.3 Park in borrow area at right

STOP 9. CHESHIRE COUNTY PIT. The site is located 2.7 km (1.7 mi) N75W of the village of Westmoreland on the Keene, NH-Vt, 7.5' x 15' metric quadrangle. The site offers a mixed bag: (A) from 100 to 150 m northeast along River Road is very compact, probable lower till with iron oxide stain on the joint surfaces, (B) 80 m southwest along the road is a small exposure of varved silt and clay, and (C) in the southwest part of the pit is a large striated erratic of Ascutney syenite, the source for which is located 55 km toward N5E.

Proceed northeast on River Road
49.0 Cheshire County prison on left. After crossing the brook, the road rises to a small terrace then turns 90 degrees to the right and climbs a slope underlain by very compact, oxidized till
49.7 Yield sign, turn left on Route 63
50.1 Park at borrow area on the right

STOP 10. SAND DUNE AREA. The site is on the east side of Route 63, 2.6 km (1.6 mi) N20W of the village of Westmoreland. As at STOP 9, this area is located southeast of a major stream terrace of the Connecticut River, which seems to be a favorite locus for the accumulation of wind-blown sand following the lowering of Lake Hitchcock. The section from the top down consists of: (1) eolian fine sand with buried soil profile, (2) stream-terrace deposits with pebble lag at the base, (3) proximal lacustrine sand with ice-rafted clasts(?), and (4) pebble gravel or till

* To reach Keene, proceed north on Route 63 1.7 miles to Route 12, turn right (southeast) to Keene

* To reach Brattleboro, retrace route on River Road or proceed south on Route 63 to its junction with Route 9, turn right (west) to Brattleboro