1982

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Recommended Citation

Ashley, G.M., Thomas, G., Retelle, M.J., and Hartshorn, J.H. (1982) Sedimentation in a proglacial lake: Glacial Lake Hitchcock, in Guidebook to Field trips in Connecticut and South-Central Massachusetts, New England Intercollegiate Geological Conference 74th Annual Meeting, Storrs, Connecticut. p. 89-102.

Trip Q4

SEDIMENTATION IN A PROGLACIAL LAKE: GLACIAL LAKE HITCHCOCK

BY

Gail M. Ashley*, George M. Thomas**, Michael J. Retelle**, and Joseph H. Hartshorn**

INTRODUCTION

The retreat of continental ice sheets in temperate latitudes produces water in such volumes that a significant proportion of glacial sedimentation is dominated by meltwater related processes. With a shift toward warmer climates during the Late Wisconsinan, huge subcontinent-sized ice sheets began to melt producing sediment charged streams on, within, and under the ice. Meltwater was commonly confined in tunnels whose walls might be ice, drift, and/or rock. Ice contact stratified drift formed as these heavily laden streams drained from the glacier depositing material onto or around stagnating ice. In areas of unobstructed drainage proglacial outwash streams carried sediment away from the ice margin forming valley trains and outwash plains.

Drainage was commonly impeded by topographic barriers composed of ice and/or glacial drift. This resulted in the creation of ponds and lakes in front of the retreating glaciers. Prominent and insignificant glacial lakes were commonplace features of late-glacial time and remnants are still seen in the landscape today as deltas, beaches, spillways and varved clay or other lake-bottom sediments. Lake Agassiz of the western mid-continent and the glacial Great Lakes are known to all geologists, whatever their discipline. Southern New England had many glacial lakes, including those in Cape Cod Bay, the Taunton-Plympton area, the Sudbury-Concord area, the Merrimac Valley, the Nashua Valley, the Quinebaug Valley, the Hoosic-Housatonic drainage, and the largest and longest lived of all, the Connecticut Valley glacial lake: glacial Lake Hitchcock. Figure 1 shows the location of glacial Lake Hitchcock in southern New England.

As melting on the surface of the continental glacier and at its outer margin exceeded the supply of ice moving south, the ice front retreated northward from its outer limits on Long Island to a position north of Middletown. The Middletown readvance took place between about 14,000 and 13,500 years ago, and the ice then melted back to the vicinity of Rocky Hill. There a mile-wide dam of stratified drift was deposited across the valley. Excavations in the dam show that it was deposited as a series of coalescent deltas in a glacial lake (Glacial Lake Rocky Hill, Langer, 1977) at about 135 ft. altitude. This mass of debris acted as a dam for glacial meltwater during the

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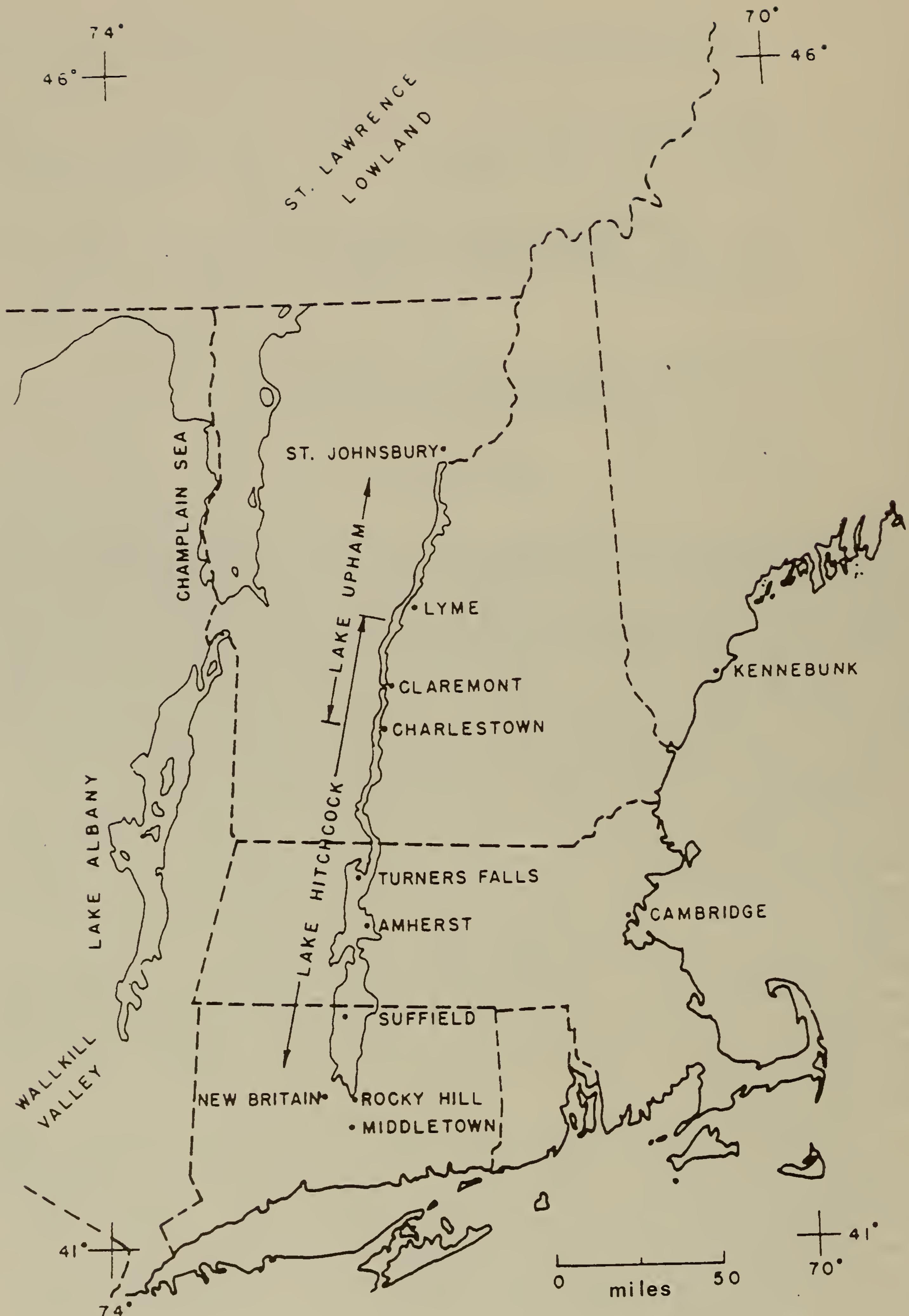

Figure 1 Map of New England showing extent of glacial Lake Hitchcock.

continued ice-front retreat in the Connecticut Valley. The beginning of the lake has been arbitrarily given the date of 13,700 B.P. because it was in the approximate time period of 14-13,500 B.P. that the glacier stood in central Connecticut (Flint, 1956).

Elevations taken from beaches and from topset/foreset contacts in deltas show that Lake Hitchcock had at least three stable lake levels south of the Mt. Holyoke Range (Hartshorn and Colton, 1967). The earliest, and highest, level was a short-lived stage at about 150 ft. This stage drained southwestward across the dam, eventually downcutting into the delta to a temporary base level at about 130 ft. This stage is called the Dividend Brook stage (figure 2). To the west of the Hartford-Rocky Hill divide, a separate lower lake developed. This lake represented the early New Britain stage. As the ice retreated north of the divide that separated the two lakes, the eastern lake drained into the early New Britain stage lake. Thus the lower New Britain spillway (originally at approximately 110 ft.) controlled the water level of the expanding glacial Lake Hitchcock. By the time the ice retreated north of the Mt. Holyoke Range, the outlet at New Britain had apparently stabilized and only one stable water plane is observed for the remaining lake to the north.

The weight of the Laurentide Ice Sheet created a crustal downwarping which increased in magnitude to the north. Due to this isostatic depression, the waters of Lake Hitchcock were always in direct contact with the glacier front. The lake was able to grow northward and still have its level controlled at the southern end by the New Britain spillway. Rapid drainage, and thus the end of the lake, occurred when the dam was breached at Rocky Hill (Schafer and Hartshorn, 1965).

Flint (1956) placed the lake drainage at 10,700 B.P., based on two radiocarbon dates. One date is thought to be pre-lake drainage (10,710 ± 330 B.P.) and the other post-lake (10,650 ± 320 B.P.). The only estimate of lake duration using radiocarbon dating is based on this one date of 10,710 ± 330 B.P. Thus, according to Flint, Lake Hitchcock lasted 3,000 years at most. This is in disagreement with varve counts by Antevs (1922), which suggested a duration of 4,100 years.

GLACIAL LAKE SEDIMENTATION

As the glacier retreated up the Connecticut Valley, the large ice mass became a decreasing influence on the southern portions of the elongate lake. Lake Hitchcock probably was not homogeneous in physical characteristics because of seasonal variations in lake water temperature. Most lacustrine circulation is directly related to thermal conditions within a lake. A well-developed thermocline enhances surface circulation. Fall and spring overturns are dependent upon significant annual fluctuations in lake temperature. Overturns and the thermocline are important factors in temperate lakes but are of less importance in subpolar and polar lakes. Although some lake currents probably existed in all parts of Lake Hitchcock, the best circulation occurred in areas farthest from the glacial front.

Concentration of suspended sediment is the most important factor affecting water density, differences in temperature being negligible by comparison. In glacial lake sedimentation, the absolute density of the lake water is not as important as the density contrast between the lake and the inflowing streams. By analogy with modern glacial streams, streams coming directly from the glacier would have a much higher sediment concentration (i.e., were

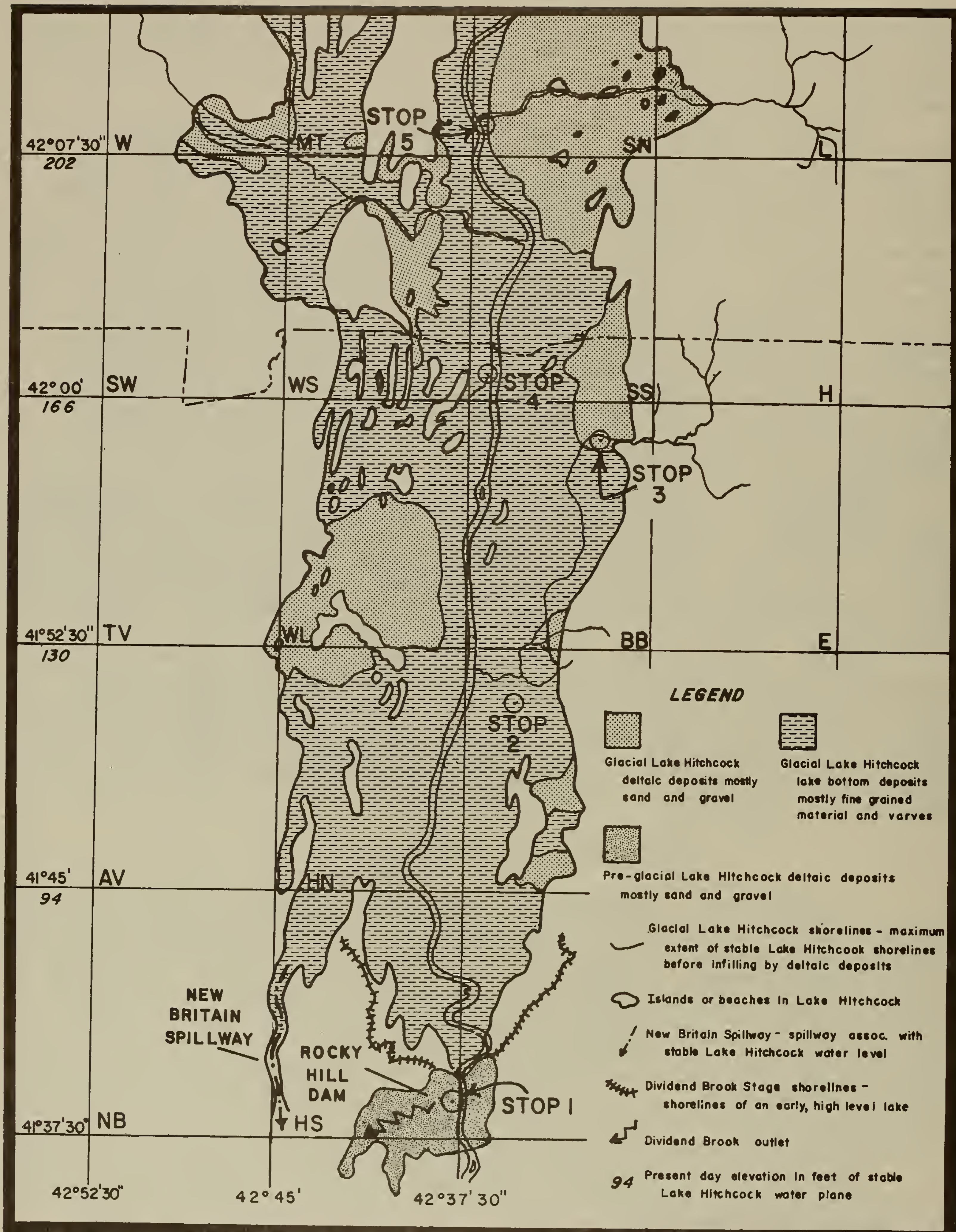

Figure 2 Generalized geologic map of the southern portion of glacial Lake Hitchcock and associated features.

more dense) than streams draining ice-free valleys around the southern end of the lake. Depending upon their relative densities, the major means of sediment distribution would be grouped into underflow, interflow, and overflow.

Using the above suggested limnological conditions as a framework the following mode of deposition is proposed. Sediment was carried to the lake from the glacier or from stagnant ice masses, first directly from the glacier and later by overland streams. Sand and gravel was deposited on the deltas while the finer fraction continued into the lake and flowed at a level determined by its density and that of the lake.

Sediment entered Lake Hitchcock at a number of discrete points. This incoming sediment contained clay that eventually was distributed throughout the lake by currents. The clay settled continuously, unless interrupted by currents, but accumulated in significant amounts only during the winter when coarser material was made less available. The extremely fine-grained winter layer permits the inference that the lake, which was over 60 m deep in some places, was not cleared of suspended sediment during the winter. Thus the clay composing a winter layer does not necessarily represent the same volume of clay brought in during the previous summer. Thickness of the clay layer would be more likely related to concentration of suspended sediment near the lake bottom and length of settling time. Because clay layers tend to be relatively constant in thickness, both of the above factors must have been fairly consistent from year to year.

Most of the sedimentary structures found in the silt layer, such as erosional contacts, crossbedding, and multiple graded beds, are best explained by a bottom current (density underflow). As a stream heavily laden with suspended sediment entered the lake, it flowed down the prodelta slope and out onto the lake floor, depositing sediment as it went. Since streamflow is usually continuous, one can expect that underflow would also be continuous and not like a single-pulse marine turbidity flow. Although flow is continuous, sediment content would certainly vary; multiple graded beds might be explained best by fluctuations in sediment content of the entering stream. Two reasons for these fluctuations could be the diurnal melt cycle or varying runoff due to storms.

During the summer and in succeeding years density flows overlapped and interfingered as deposition occurred on different areas of the deltas, causing bottom currents to flow in a new direction. A flow pattern such as this would tend to fill in low areas and perhaps flow around highs. The summer layer varies greatly in physical characteristics between localities. The clay layer deposited each winter blanketed this complex silt deposit and imprinted a rhythmic nature on the otherwise very diverse sediments.

ROAD LOG for Trip Q4

Assembly Point: Rocky Hill Howard Johnson's Parking lot, southeast of I-91 at exit 24, Rt. 9.

Refer to figure 2, geologic map of southern Lake Hitchcock and figure 3, stop location map with cultural features to locate stops with reference to U.S.G.S. 7½ minute quadrangles. Quadrangles denoted by letter code on figures as follows: AV, Avon; BB, Broad Brook; E, Ellington; G, Glastonbury; H, Hampton; HN, Hartford North; HS, Hartford South; L, Ludlow; M, Manchester; MA, Marlborough; MT, Mount Tom; NB, New Britain; R, Rockville; SN, Springfield

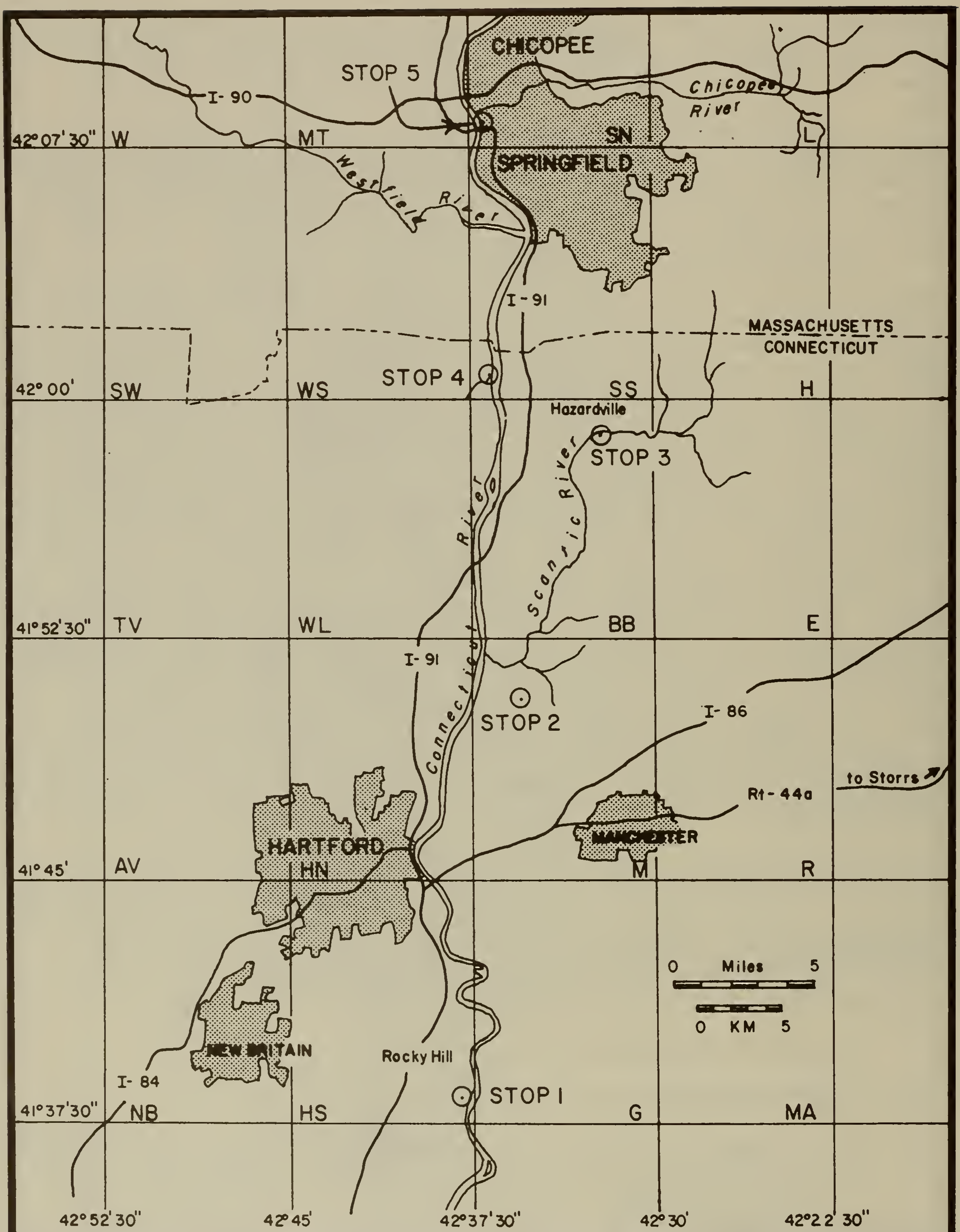

Figure 3 Area of this field trip with stop locations, cultural features and 7½ minute quadrangle locations.

North; SS, Springfield South; SW, Southwick; TV, Tariffville; W, Woronoco; WL, Windsor Locks; WS, West Springfield.

Cumulative mileage

START: HARTFORD SOUTH QUADRANGLE

0.0 Turn right (southeast) on Route 9 from Howard Johnson's parking lot.

0.9 Rocky Hill, is visible on the left as a ridge. It is an outcrop of basalt, with glacial polish, grooves and striations trending about S20°W. Continue past the junction of Route 160 and get in left lane.

1.5 Turn left down Dividend Brook Road. This is a heavily populated area, please go slow.

2.2 Stop sign (Forest St.). There are several abandoned and active gravel pits on the right side. Proceed straight on Dividend Road.

2.4 Second stop sign. We are now on a flat river terrace at around 40 ft.

2.7 Third stop sign at Old Forge St. Proceed straight across onto old gravel road, crossing Dividend Brook. The Dividend Brook valley was utilized as the outlet for an early higher stage of Lake Hitchcock, the Dividend Brook stage.

STOP 1. Enter gravel pit. This pit is located in a large complex kame delta. The delta was deposited into glacial Lake Rocky Hill (Langer, 1977) filling the narrow Connecticut Valley. Once the ice retreated the delta acted as a dam, preventing southward drainage of melt water. Glacial Lake Hitchcock formed between the retreating ice front and the Rocky Hill dam.

Cobble gravel topset beds, gravel foreset beds and sandy foresets have been exposed at various times. The detritus is dominantly reddish-brown indicating the Jurassic-Triassic provenance of the sand and gravel, with the balance comprised of crystalline material from the eastern and western bordering highlands. Variable dip direction of the foreset beds indicates that the dam actually is a complex of coalescing deltaic lobes.

Exit from pit and return to Dividend Road. Watch the three STOP signs.

4.2 Approach Y- intersection of Route 9. Travel north on Route 9, crossing the intersection of Route 160. Continue to Route I-91.

5.5 Get on Route I-91 northbound (right turn). At Putnam exit there is a good view of the present day floodplain of the Connecticut River. The city of Hartford is seen on the left. Stay on I-91.

HARTFORD NORTH QUADRANGLE

11.6 Go through underpass. As you ascend slope on the highway, beware of merging traffic on the right. As you pass exit 34, Route 157, (15.0 miles) get ready for exit in 3/4 mile, to Bissell Bridge (toll). Follow the sign for Route 291, Wilson, South Windsor, Bissell Bridge (16.0 miles) to Exit 35. Turn right at end of ramp on "to Route 159". Cross junction with Route 159. Continue straight ahead. Follow Route 291 to South Winsor and East Hartford.

17.2 Cross Connecticut River, stop and pay toll (35 cents). Sand dunes, some as high as 40 feet (12 m), are visible on the stream terrace deposits in this area. The stream terrace deposits, some of which may be glaciofluvial in origin are up to 20 feet (6 m) thick, overlying as much as 150 feet (45 m) of fine grained glacio-lacustrine sediments. This overlies the Jurassic Portland formation.

19.0 Get in left lane for left turn. Proceed north on Route 5 along postglacial stream terraces.

21.7 Take a right turn at light onto Strong Road, then an immediate left onto Brickwood Lane. Turn right into Kelsey Ferguson Brick Co.

STOP 2. This exposure is in the only active clay pit in glacial Lake Hitchcock and provides a rare glimpse into the bottom sediments. Located 2.6 km from the lake shore and deposited in 14 - 20 m of water, the couplets are composed of a thin silt layer and thicker clay layer. Total varve thickness averages about 100 varves per meter.

Grain-size analyses show that the couplets, on the whole, are extremely fine. The "silt layer" is more than half clay, with a mean grain size between 8.4ϕ and 9ϕ. Clay layers have a mean grain size of 11ϕ. The upper surface of the clay layer is usually uneven, due to burrowing organisms and subsequent filling of the cavities with the overlying silt.

Each couplet shows a color change from bottom to top and thus appears to be a graded bed. However, microscopic examination of impregnated thin sections reveals two distinctive sedimentary units: a thin "silt layer" and a thicker clay layer. The silt was probably carried to the site by density underflows during periods of high runoff. Except for these periodic influxes of silt, sedimentation at this locality was restricted to a slow raining out of clay from suspension. The extremely fine grain size of the clay particles, combined with the platy habit of the clay minerals maintained the particles in suspension for long periods of time. Slow moving lake currents were sufficient to transport the clays far from the original source area. Thus the clays settled from suspension year round.

Return to Route 5 and turn right (north). Again you are travelling over post-glacial Connecticut River terraces.
BROAD BROOK QUADRANGLE

23.6 Junction of Route 191 at Phelps Road.

25.9 Till hill pokes through terrace on right.

26.7 Large till hill, Prospect Hill, cored by Jurassic Portland Formation, is flanked by stream terrace, lacustrine and beach sediments.

27.2 Diagonal right turn following large I-91 signs.

27.5 Swing left to Springfield/Hartford.

27.7 Swing right to Springfield, continue on I-91 north.

32.7 Exit 47E, Route 190 east. At the end of the off ramp take a right (east). Colton (1965) mapped great expanses of this area as sand dune deposits, mantling much of the post-glacial stream terraces. Individual, discrete linear dune ridges up to 6 m high may project above the terrace level

35.1 Take right lane as you approach Enfield Pharmacy for gentle curve to the right. Enter town of Hazardville.

35.4 Right turn on South Maple Street, 100 feet short of Gulf station, proceeding downhill to bridge over Scantic River. Cross bridge.

35.8 Pull off road on left side, below the outcrop

STOP 3. There are two sections to observe at this stop. Figure 4 illustrates a composite measured section for the road side exposure (section A). Section B is exposed on an east-facing cut bank slope to the east of section A. Near the base of section A, a till unit of variable thickness overlies deformed lacustrine silt and sand (varves?). The till is dark reddish brown "valley facies" till of Juro-Triassic provenance which in this section consists of several subunits. Two cobbly till units 10-30 cm thick are each capped by sand and silt graded beds. The till may have originated as: 1) a

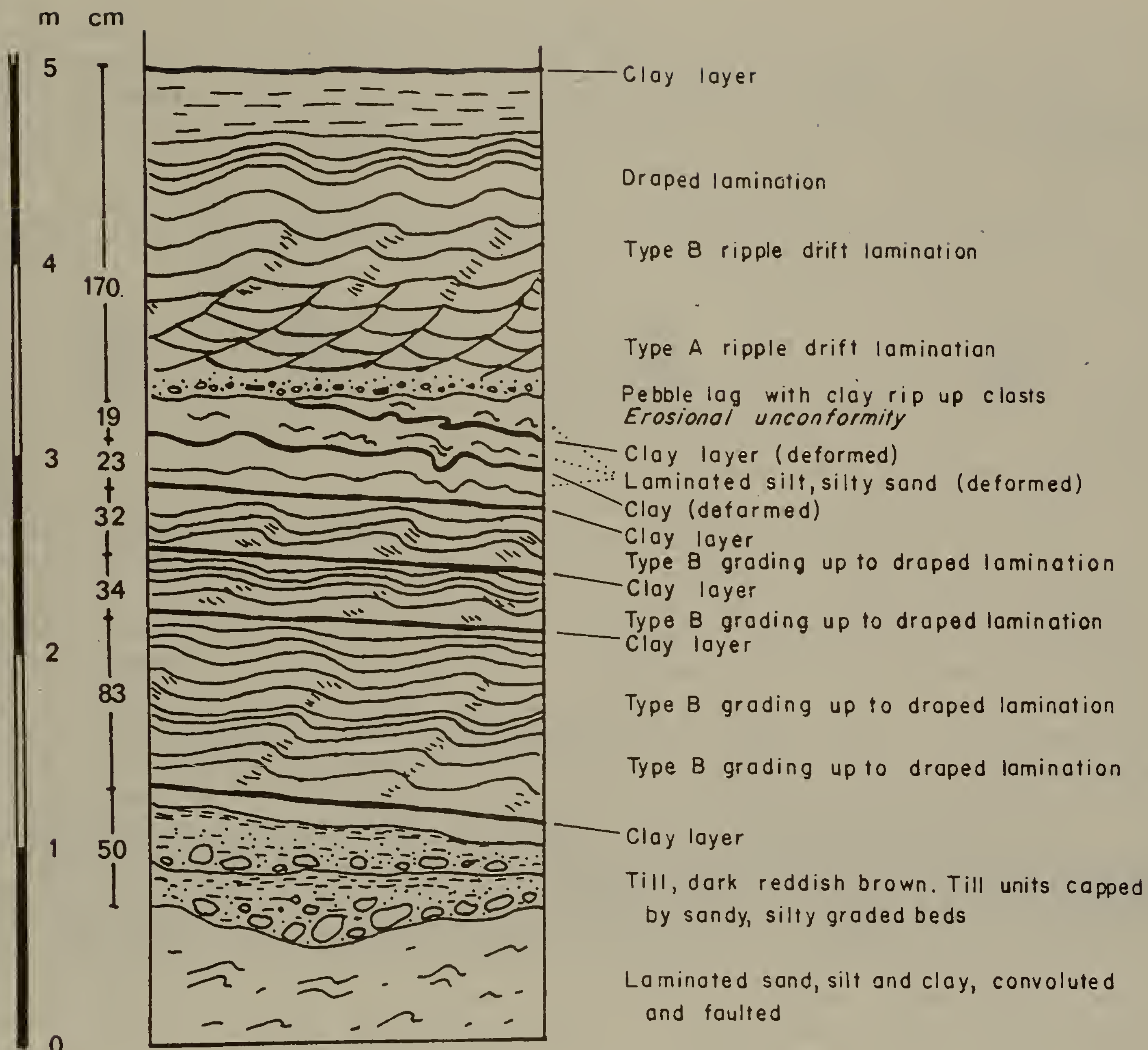

Figure 4 Composite measured section, Scantic River delta Hazardville, Connecticut.

flowtill deposited from local ice or icebergs adjacent to the delta. The graded bedding overlying the till would indicate fines settling from suspension following the main debris flow into the lake down the delta foreslope, 2) till deposited by a readvance pulse of local valley ice. The deformation of the underlying lacustrine silt and sand appears to be greater than that accomplished by instability, loading and dewatering of the fine sediment in the delta foreslope. Moreover, the till unit may possibly be correlated laterally with the dark reddish brown till in section B.

Overlying the till is a section of glaciolacustrine laminated silts and silty sands separated by winter clay layers 0.7 to 2.0 cm thick. This glaciolacustrine section can be divided into two facies, a lower, more distal facies and an upper, more proximal facies.

The lower section consists of silty fine sand with type B ripple drift lamination grading upwards into silty draped lamination (Jopling and Walker, 1968 and Gustavson et al., 1975). At least 5 sequences each overlain by clay layer are represented in the lower glaciolacustrine facies. These ripple drift sequences, indicative of turbid prodelta gravity current deposition, decrease in thickness upsection. This may indicate that the source of these sediments is becoming more distal as the ice front at the apex of the delta is retreating, or that the locus of sedimentation is slowly shifting to another area of the delta foreset.

The lower glaciolacustrine section, which dips approximately 5^{o} to the west is separated from the upper section by a horizontal to sub-horizontal erosional unconformity. A pebbly lag gravel which also contains tabular rip up clasts of clay layers, can be seen along the truncation. The upper glaciolacustrine section consists of medium to coarse sand at the base grading upwards to medium to fine sand and silts. The section is dominated by type A ripple drift lamination grading upward to type B and draped lamination before being capped by a clay layer. The coarser grain size, thicker summer accumulation and appearance of type A ripple drift indicates a higher, energy more proximal sedimentation regime in contrast to that in the lower sequence.

Section B is a thicker section which is stratigraphically comparable to Section A. Section B is found by following the dirt road east along the river from the bridge. At this section, the basal lacustrine unit, approximately 1.7 meters thick, is overlain by 2.6 meters of red till. Above the till, three meters of glaciolacustrine fine sands and silts include undisturbed layers and broken pieces of clay laminae. The section is topped by post-glacial fluvial sands and cobbly gravels under almost one meter of eolian mantle. This is a steep dangerous outcrop. Please be careful and considerate of those people below you.

LUNCH STOP

Turn around. Go back over the bridge and up the hill to the light. Turn left at the light on Hazard Ave.(36.1 miles) and head west. Pass the Texaco station. Stoplight (36.4 miles). Curve to the left as we go past Enfield Pharmacy again. Proceed west on Route 190.

38.6 Junction with I-91. Pass over the highway, continuing west on Route 190. Pass roadcut of Mesozoic redbeds in Enfield.

39.3 Suffield town line, east bank of Connecticut River. Head of canal on left.

Junction 190 and 159. Turn right (north). Pass over top of drumlin and over Rawlins Brook, which exposes lake clays. After crossing Brook, take first right. Stay on River Blvd. Do not cross bridge over Connecticut River.

SPRINGFIELD SOUTH QUADRANGLE

41.7 Park on right side of road, just past small culvert over Deep Brook.

STOP 4. This outcrop is located approximately 125 meters east of River Blvd. and is exposed in a cutbank on the north side of Deep Brook. The stream has cut through the overlying alluvial deposits exposing varved clay and till in the stream bank. The red color of the till (5YR 3/3) reflects its Mesozoic provenance. Note the predominance of striated, red clasts in the stream bed that have eroded from the till.

The outcrop (Figure 5) is capped by approximately 3 meters of fine alluvial sand. The sand appears stratified, however, the stratification is a

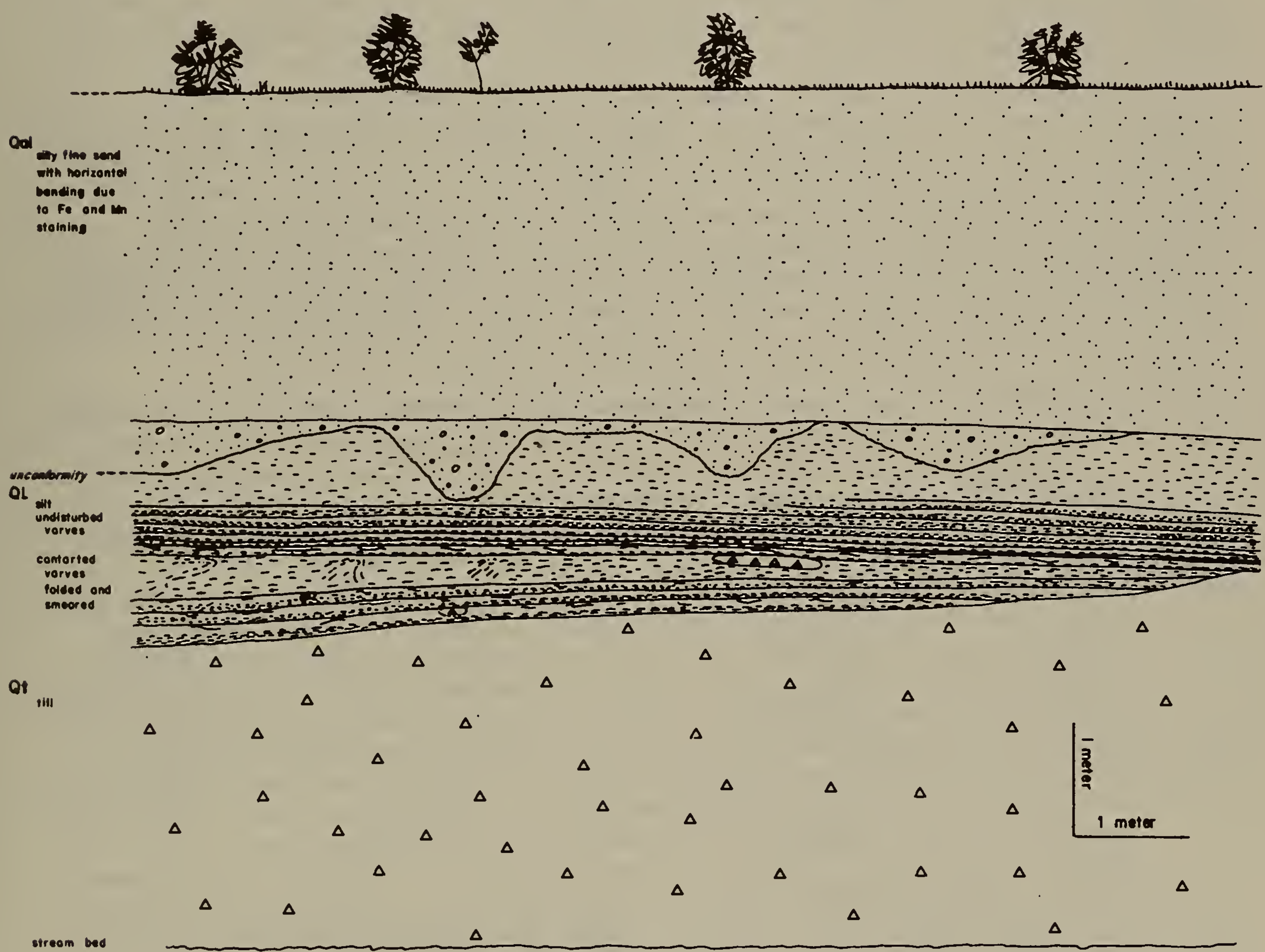

Figure 5 Sketch of outcrop along Deep Brook - stop 4.

result of post-depositional Fe and Mn staining, and not of depositional processes. Conformably below the sand is a highly permeable, heavily stained, coarse sand pebble gravel varying in thickness from 0 to 1 meter. The gravel is an alluvial lag deposited on the former lake bottom by the postglacial Connecticut River. Unconformably below the gravel is a silt layer varying in thickness from 0 to 1 meter. Below the silt there are at least six undeformed varve couplets best exposed at the eastern end of the outcrop. The varves at this locality are relatively thick with the clay layer ranging from 1.8 cm to about 4.5 cm and the silt layer varying in thickness from 2 cm to 15 cm. Each clay layer consists of two parts. The lower part is a dark brown (10YR 3/3) greasy clay with a sharp upper boundary that is sometimes relatively coarse grained (very fine sand to silt). The upper part is a dark reddish brown (5YR 3/3) clay or silty clay that in several varves coarsens upward into the overlying silt. At other varve localities where this bi-colored clay layer is seen it always follows this pattern of red over brown. Size analysis has shown that the dark brown clay is actually 20% silt and 80% clay. The reddish brown clay is slightly coarser: 30% silt and 70% clay, with the clay being consistently coarser than the clay in the brownish layer. The "silt" layer is 85% silt, approximately 15% clay and < 1% sand.

The undeformed varves conformably overlie a minimum of 4 varve couplets that have been severely deformed. The deformation in these varves is indicated by 1) folding of the varves, 2) stringers of reddish clay in the brown clay and visa versa, 3) inconsistent lateral varve thickness, and 4) pods and lenses of till included within the varves. The deformation is thought to have resulted from a minor oscillation of the ice front with a minimum of 4 years between the initial retreat and subsequent overriding by ice. The deformed varves conformably overlie a massive dark reddish brown (5YR 3/3) till. This till contains 57% sand and gravel, 29% silt and 14% clay.

Continue on River Blvd. swinging west to intersection with Route 159.

42.1 Turn right (north) onto Route 159. The highway passes to the west of an elongate till ridge and drumlin. At 42.9 miles, pass Saint Alphonsus College, situated on the drumlin crest.

43.3 Massachusetts-Connecticut state line. Pass Riverside Park on right.

44.3 Stoplight. Proceed straight ahead on Route 159, swinging to the west. Pass over rise to terrace level left and ahead of you. Lower terraces to the right (east) of you are floodplain deposits of the Connecticut River. You are riding over terraces formed by the establishment of post-lake drainage, redepositing sand and gravel of higher delta and outwash terraces over glaciolacustrine silts and clays.

45.5 Pass through the town of Agawam, noting nice old New England houses in the center of town. Cemetery on left. Note the contrast of marble headstones and those made of Portland Formation brownstone.

Junction Route 57. Turn right toward Route 5 (Springfield) to Routes 5-91. Follow signs to I-91. Cross Connecticut River to I-91 North (Springfield/Chicopee signs). Curve left. Pass through Springfield on I-91. A large area below the highway about 25 feet above the river level was flooded during the 1936 and 1938 floods. Floodplain scarp is visible rising to the east (right).

SPRINGFIELD NORTH QUADRANGLE

Note signs for I-391, North--Chicopee.

53.3 Exit to I-391 Chicopee. Road ends 500 feet. At exit 2, turn sharp left (53.9).

Cross to right side under bridge and head south. Outcrop is on the left (east side of road) before bridge over Connecticut River.

STOP 5. The Chicopee Delta, the largest of the Gilbertian deltas fringing Lake Hitchcock, shows varved clay grading into varved deltaic deposits by a gradual thickening of individual layers. At any one site, a prograding delta is shown mainly in the thickening of the coarse layer from 1.5 to 75 cm (occasionally as thick as 1 m). Dimensions of the clay layers remain relatively constant, from 0.75 cm to 1.25 cm.

The basal sediments (not presently exposed) were derived mainly from the glacial lobe within the valley. As the ice receded northward, however, glacial ice on the uplands became the dominant sediment source supplying debris to the major east or west flowing rivers draining into the lake.

Delta growth is reflected in the sedimentary structures occurring in the coarse summer layer. Multiple graded beds are common at the distal portion of the prodelta slope, whereas ripple-drift and draped lamination dominate the proximal portion. These sedimentary structures indicate that during most of delta construction there was abundant sediment and rapid deposition. This, in turn, implies that the bulk of delta building occurred when glacial ice occupied the drainage basin of a particular delta. The nearby ice may have limited the vegetation and thus allowed more sediment to be transported to the lake.

This sequence of varves was deposited as delta foresets in 26-30 m of water. The summer layers are medium to fine silt (7.5Ø mean grain size) coarsening to 5.6Ø at the top. The winter layers are dominantly clay with a mean grain size of 10.7ϕ at the base of the section grading to 9.1ϕ at the top of the section.

A section exposed during construction of an exit ramp to I-95, 400 m directly to the east, revealed 13.7 m of varved deltaic sediments. Figure 6

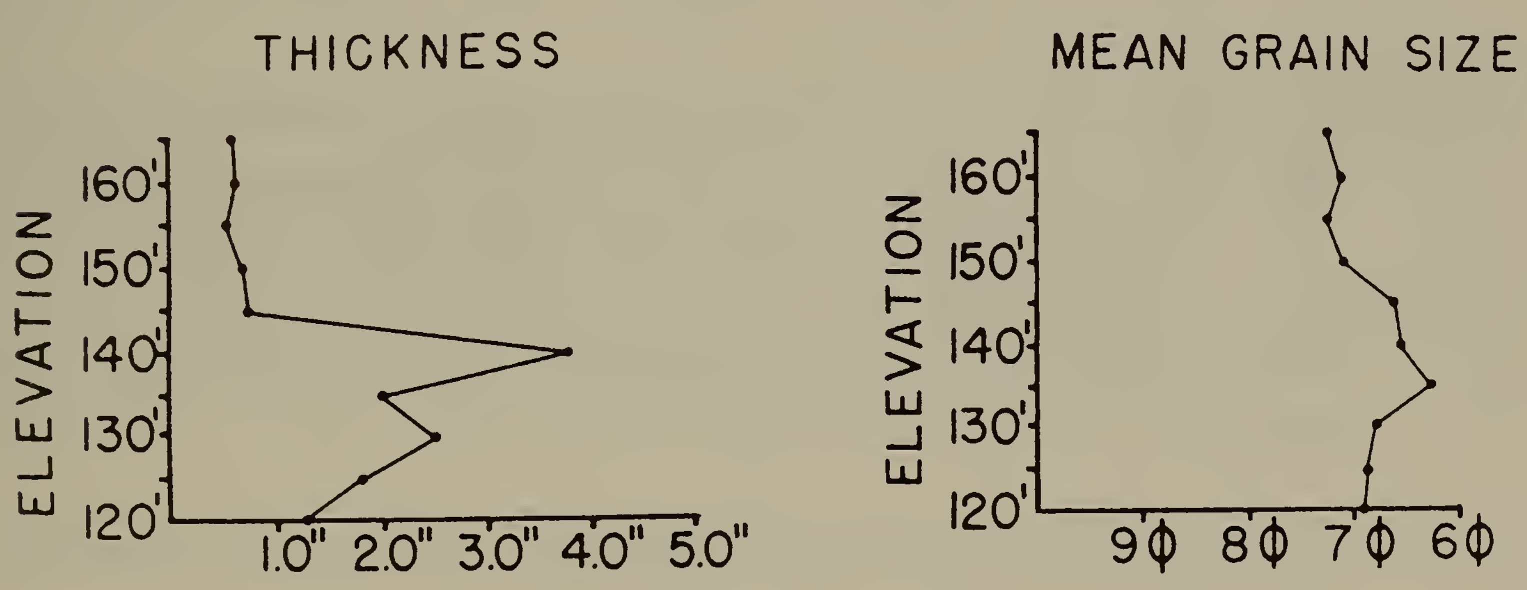

Figure 6 Plot of elevation vs. thickness and elevation vs grain size, for a section just east of stop 5.

illustrates an upsection coarsening of the silt layer and an accompanying increase in thickness, followed by a sharp decrease in thickness and a slight fining of grain size. Although these changes could represent a shift in the delta distributary supplying sediment to the site, it is more likely the result of major diversion of meltwater as deglaciation proceeded northward out of the Chicopee River drainage basin.

To return to I-91, turn around (head north) and follow signs for I-91.

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