

GLACIAL LAKE HITCHCOCK  
AND  
POSTGLACIAL UPLIFT

FRIENDS OF THE PLEISTOCENE  
50th REUNION

Northampton, Massachusetts, May 8-10, 1987

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This guidebook is dedicated to Richard P. Goldthwait  
and  
to the original Friends Of The Pleistocene:  
Richard F. Flint  
J. Walter Goldthwait  
George W. White  
Donald H. Chapman

Open-File Report 87- 329

This report (map) is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards (and stratigraphic nomenclature). (Additional disclaimers where necessary.)

FOREWORD  
FIFTY ANNUAL FIELD REUNIONS OF THE  
FRIENDS OF THE PLEISTOCENE  
1934 TO 1987  
By Richard P. Goldthwait

The founding

Amazing! This is indeed the 50th annual field conference. Actually it took 53 years to get here because World War II effort pre-empted all of our principal characters for four years. The "father" of the idea, Dick Flint of Yale, was working for the U.S. Army Arctic, Desert, and Tropical Information Center.

The "Friends" idea all hatched by letter and phone in the winter of 1934 when Flint wrote to my dad, J. Walter Goldthwait of Dartmouth, that he'd like to see whether a lake similar to that in the Connecticut Valley also existed in the Merrimack Valley of New Hampshire? Or was the glacier ice front melting southward? George White at University of New Hampshire (and I as assistant) were mapping in central New Hampshire so he was co-opted to join. Now White and Don Chapman of UNH had some amazing high marine features around Durham, so they asked Flint to come early on Friday May 25, 1934. Flint obliged and also E. H. Perkins of Maine and Loyd Fisher of Bates College came. After a first day of field discussion Perkins and Fisher seem to have dropped out, but J. W. Goldthwait arrived (I was taking off to Alaska). By Sunday May 27th, Flint, Goldthwait, White, and Chapman had crossed the state northwestward and arrived at Hanover, thinking out loud and arguing all the way.

For the second reunion Flint wrote my dad, "Isn't it about time that the Friends of the Pleistocene meet again?" At that time (1935) this name was unique and even bizarre; since that time the "Friends of everything else" have sprung up. By 1938 (Reunion 5) Flint had copyrighted that name but many found that the university treasurer made us call it a "Pleistocene Field Conference." The word Friends began appearing on pertinent field literature by 1939. As well as a "reunion" or "conference", it has been called a "celebration" (25th) and even "an invasion"!

The non-organization

For many years as numbers grew, Dick Flint was proud of the fact that there was no chairman, no secretary, no treasurer, no dues, and no committees. It had no money or legal or tax status over the 50 years. But, as a matter of fact, there has to be some central spark plug to keep it going. Who puts the finger on some research worker this year to lead the field conference next year? Who keeps some record to know whom to invite next year? There has to be that inner sanctum mailing list. Who tells a desperate leader one month before the reunion, "O.K. to limit the attendees to 100"? Of course Flint did these things from 1934 until he died in 1975, often calling one of us lesser lights to get some backing. He hated that attendance restriction which first had to be exercised in 1966 (29th).

When Joe Hartshorn took over in 1976 there were few records to be had. After Flint's sudden passing, and that of his wife right after, Yale University transferred his records to Steve Porter in Seattle. Anyway a bare-bones list had been made at the 35th (1972) by Art Bloom -- one of Flint's students -- with the help of Ernie Muller at Syracuse and Flint himself. A list of meetings as elaborated from all the 42 field guides I can get up to date (1987) is at the end of this review. (These will be on file at Orton Geological Library, 130 South Oval Mall, The Ohio State University, Columbus, Ohio, 43210).

Where to meet?

Any place is fair game that 100 underpaid northeastern academic and government types will go to willingly for just one weekend to see a field research demonstration. We've been as far north as the marine clays of St. Lawrence Valley at 47 1/2°N (26th), as far south as marine bench deposits in coastal Virginia at 36 1/2°N (29th), as far east as the marine-ice relations near Machias, ME 67 1/2°W (30th), and as far west as the multiple drifts of southwest-central Ohio, 84 1/2°W (15th). At least a dozen reunions were right at sea level, so critically controlled by worldwide glaciation, but another involved a 5-mile walk at 5400 to 6200 feet above sea level where local glaciers were generated.

Please note that 14 states and provinces have been visited over the 50 meetings. If you give half-credit to any two states sharing many stops at one reunion, New York with 14 meetings is easily the leader; within NY the area leading the pack is Finger Lakes (10th, 13th, 35th, and adjacent 23rd). Massachusetts is second with 7, but Connecticut which was the home of Flint rates only 1 and Vermont doesn't rate at all.

States and provinces invaded					
CT	1 1/2	NH	4	PA	3 1/2
DE	1	NJ	2 1/2	QUE	4
MA	7	NY	14	RI	1 1/2
MD	1	OH	1	VA	2
ME	4	ONT	3		

How we dash around.

A caravan of 4 to 30 private cars was endured up until 1960 (1st through 23rd; special short haul bus on 3 occasions). There were breakdowns, out-of-gas dropouts, lost tails of processions, and oh what dust on the back roads of yesteryear. No one could forget "O D" VonEngeln seeing every car out of each of 24 stops to close a gate, then racing by invisibly at 60 mph in a cloud of dust to greet us in the next pit. Wild! Each reunion generally achieved from 100 to 200 miles; then we got left Sunday about 1 PM way out in the sticks somewhere. Leaders soon learned that the fewer the stops the better: 11 to 25 at first, but only 6 to 12 later.

The stops were lengthened when busses came in during the second half of our history. Parking, loading, and instruction were much easier and faster, -- but busses don't get down the lousiest of roads so sometimes walks down logging and pit-access roads were longer. On Dick Flint's last "Friends" one bus even went off a bridge -- slowly, and just one wheel -- but we all crawled out gingerly! In an earlier venture (15th) with vans, one of the vehicles edged off-road into a juicy ditch; it was gloriously lifted out by 80 people. But busses and better highways made long trips feasible. Imagine 294 miles down the full length of Delaware (39th) or 237 miles in the Ridge and Valley Province of PA (38th) all in a day and a half with long stops.

#### Leaders' Headaches.

Biggest is "the guide." Of late the guide has gotten very elaborate, long, and even with a tape binding. It need not be for it is not intended as a publication; if anything it is a progress report. For the first 9 reunions (1934 to 1946) participants were few enough that a sheet of living reservation-eating instructions, plus a list of stops with their particular importance, plus a few hand-outs did the trick. This record is very hard to reconstruct. As numbers passed 50 however, and an increasing number joined late or left early, an actual mileage guide was added and even lists of anticipated attendance (very useful record; "yes" cards returned). When busses became the mode of travel, mileage logs tended to get left out, -- but that makes recapping the stops for sample collection or comparison with your later area impossible. Anyway all are accompanied by an important reference or two, important to get or see ahead. As early as reunion 8 (1941) it was vital to have John Rich's map and bulletin. And then came the 1980's when each guide WAS a bulletin. Nice work if you can get it done and paid for -- but far too much to ask of an enterprising graduate student, who has plenty to show!

The customary routine ever since meeting #1 is for a day and a half only, in May (except 39th in early June). All of the real discussion is at the field stops, -- that's the purpose. Both Saturday and Sunday lunches (Sun. optional) are picnics out-of-doors. For a wonder only 3 or 4 Saturdays have had steady rain to force us under cover; once a church served us lunch! Originally each person brought his own bag lunch, but with busses the trend is to a box lunch in the package deal. Once when Sunday lunch was not available 5 of us heading west of Route 20 headed for Krebs Restaurant. The lady looked at us in field rags and boots, more or less covered with mud, and refused us! But we persisted with \$10 bills flashing, so they set up screens in one corner. Once ushered in quietly we ate them out of house-and-home.

#### Who is a "Friend"?

Now Don Chapman, Charlie Denny and I are the only three of the survivors of the first two meetings who are still alive and kicking in the New England area today. I don't know about Linc Washburn, a student of Flint's then, who

probably made the 3rd meeting; he is very active in Seattle, WA now. My private notations of the 7th reunion on Cape Cod is the earliest list I can find.

Answer to the title is "anyone who wants to be." But it is more than that. To stay on the mailing list you must attend now and then, and especially at first. Retiring leaders do weed out some. As numbers grew a third requirement was expressed: "In keeping with past practice, preference will be given to active workers in the field." Crowding occurred first at the 15th reunion way out in Ohio. It was so far from earlier FOP trips and so expensive to fly that we tried to get everything in Ohio free: opening Friday was "slungullion" and beer at my house, free housing at a geology faculty home first night, free riding in an Ohio State carryall each day, etc. I predicted 30; "yes" cards came from 60; at my house for dinner Friday night we had 90, and WE slept 14 guests!

Oh yes, at the very start and for most years the wives (non-geological) were invited by common consent. Peggy Flint, Mildred White, and Edith Goldthwait all gathered for reunion #2 in 1935 and soon came to look forward to this regular spring outing. Of course they looked at scenery, farms, flowers, and birds at each stop. Peggy came half of the springs until 1975, Edith dropped after 1939 due to health, and Mildred dropped after 1941 when George White moved "way out" to Ohio and Illinois. Most reunions still averaged 3 to 5 wives. The maximum was 10 in 1952 and 18 in 1972 when my wife Kay led a special tour for them on Saturday. Too bad our numbers made this a plan we could not push. And we have added more and more Pleistocene geologist ladies: starting with Althea Smith way back, and then "the Queen of the Pleistocene" Jane Forsyth (1952 on).

At the risk of insulting a few, here are the regular "pros" seen every year or every other year for two decades or more -- based on the only lists published in guides or sent by letter to me. Prizes for the longest-seen friendly faces -- overhalf of the 50 meetings -- go of course to \*Dick Flint of Yale (#1 to #38), Charlie Denny of USGS (#2 to #38 and few since) and Dick Goldthwait of Ohio State (#2 to #43 and few since). Carl Koteff of USGS is about to join this august group (24 from #23 and nearly every one since). close behind him are a dozen "runners-up" who have made it more than 12 times: Art Bloom of Cornell (#23 to 41+), Don Chapman of UNH (#1-12 & 33-36), George Crowl of Ohio Wesleyan (#23 to 41+), John Elson of McGill (#23 to 41+). Joe Hartshorn of U. Mass. (#23 to 50), Ernie Muller of Syracuse (#23 to 33+), Pierre LaSalle of U. Que. (#24 to 41+), Walter Newman of Queens (#24 to 36), Vic Prest of GSC (#10 to 35+), Phil Schafer of USGS (#9-16 & 23-32), \*HTU and/or Althea Smith of U. Mass. (#23-48+), Jan Terasmae of Brock (#23 to 36). These folks always came unless they were out of the East or died.\*

Finally there are at least 25 "party faithful" for a lot of years (6 or more):

Regulars over 6 to 11 years

*Bob Black, U. of Conn.	Louis Peltier, Bethesda, MD
Hal Borns, U. of Maine	Pete Ogden, Ohio Wesleyan &
*Doug Byers, Peabody Fd.	Glenn Prescott, USGS-ME
Ed Ciolkosz, Penn State	Meyer Rubin, USGS
Don Coates, Binghamton	Bill Sevon, PA Geol. Surv.
Gordon Connally, Buffalo	Vic Schmidt, Brockport
Jesse Craft	Les Sirkin, Adelphi U.
Jane Forsyth, Bowling Green	Byron Stone, USGS
Nelson Gadd, GSC	Bob Stuckenrath, Smithsonian
Cal Heusser, NYU	*George White, U. Ill.
Norm Lasca, UW-Milwaukee	Sid White, Ohio State
Bob Leggett, NRC Canada	
*Hulbert Lee, GSC	
Bob Oldale, USGS	*deceased

Over the years we have had a core of these 25 to 35 regulars. In addition we always have another third attracted for the locality where the reunion is held, e.g. Ohio, or Ontario. A few more are attracted some years by the subject emphasized, e.g. glaciomarine, or glaciofluvial, or down-wastage (old), or till stratigraphy, or mountain glaciers.

Always since Reunion #5 there have been a few from closely related sciences: 1 to 3 soils men (Walter Lyford, Jack Tedrow, Ed Ciolkosz), or 1 to 3 palynologists (Cal or Linda Heusser, Jan Terasmae, Jock McAndrews), or 1 or 2 carbon-14 men (Meyer Rubin, Pete Ogden, Bob Stuckenrath), a groundwater specialist (Glenn Prescott, Joe Upson), a botanist (Hugh Raup, John Sanger), and maybe an archeologist (Doug Byers, Dave Sanger). These all added real spice to the arguments. Rarely if ever has any glaciologist set us straight!

The real objective.

From the very start Friends have argued vehemently. Often they flatly deny some conclusions of the leader -- but they always depart friends. Each area visited was in the process of study when we saw it; it is not fully completed research with a final report. Most could benefit by the reunion critique. For a young "pro" as I was (7th and 15th) this can be a fearsome event, but it yielded such a good test of ideas, and a good hunch on further evidence that it proved very worthwhile. These and the 33rd reunion vastly improved my later reports. A second type of meeting has been explored a few times (12th, 18th). The only known evidence for an old unsolved problem was presented by an old pro; the Friends were presumed to solve this by their vote. We saw all the pits relating to Pensauken gravels and were supposed to write its origin. Not one did; after all who would tell Paul MacClintock at Princeton the answer to what he lived on based on a 1 1/2 day tour! The third type of meeting at least 7 times (2, 3, 4, 8, 24, 29, & 36) is when an old pro throws up a "controversial bone" on which he has already made up his mind. Nearly everyone comes with a mind of disbelief; if they go away muttering in their beards he probably lost.

Glacial geology and its related contributing sciences depend mostly upon circumstantial and detached evidence. Although we like to think we have found sure proof we must often work with multiple hypotheses. What we interpret as sure evidence today may prove with later work to apply to a different time or situation. The depth of leaching in Ohio tills, although used with caution for early correlations, proved in one situation at least to be due to different initial carbonate content. What is firm evidence today may indeed be on the scrap heap in a decade or two. Thus comparisons, interrelationships, new kinds of evidence, new arguments or ideas are valuable to us all. It's great to see what the other guy is getting -- and feel that you can debate it all. Debate should be a requirement of every attending "Friend".

#### Why have we come again and again?

What are some of the principal arguments which attracted us over the years? Here are a few with one or two reunions where they were well argued. You can think of more:

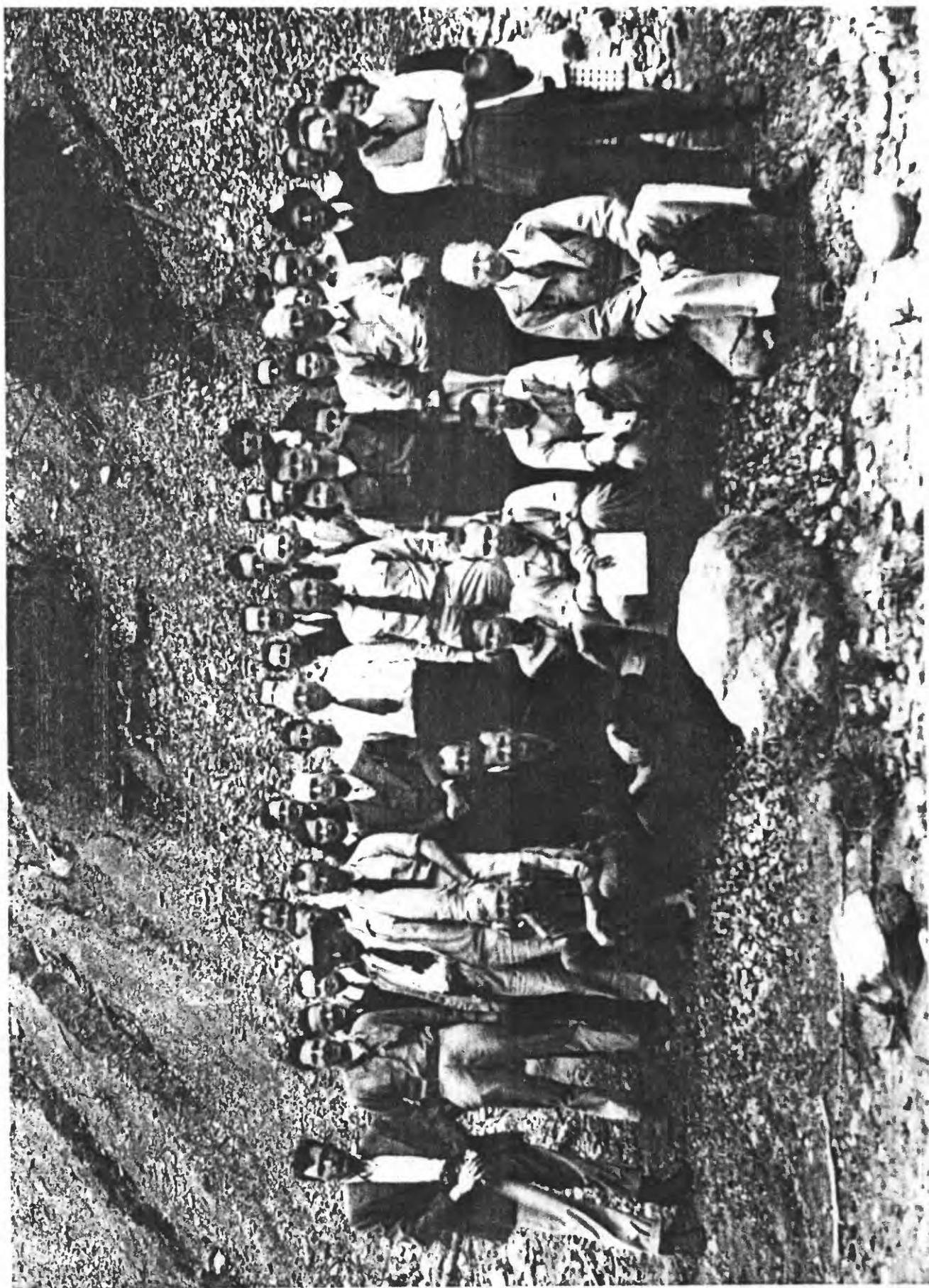
1. Are Antev's varves annual, and correlatable between valleys? (1st)
2. Did the continental ice edge melt back systematically northward? or was it disappearing southward over some areas? (2nd, 32nd)
3. How broad was the thinning, decaying zone of stagnant ice? (4th)
4. Where did land rebound (tilt up) most? and were there hinge lines? (4th)
5. How do you distinguish a truly old drift from most recent ones? (6th & 11th)
6. Do end moraines offer true systematic sequences of deglaciation? (7th & 15th)
7. What was the sequence of mountain vs. continental glaciations? (8th & 33rd)
8. The two-till problem in southern New England (several)
9. What do glacio-lacustrine levels tell us of the changing flow of ice or sequence of retreat? (11th & 18th)
10. What was the periglacial climate really like? and how was it zoned? (14th)
11. Is the "exact" chronology which the radiocarbon revolution introduced consonant with other chronologies? and from area to area? (15th & 22nd)
12. How rapidly did invading ice advance? or retreat? (15th)
13. How can outwashes record significant episodes of retreat? (16th)
14. How many significant minor readvances are recorded in the retreat of the last major glaciation? (22nd)
15. Where was the ice edge when sea first invaded coastal lands? (24th & 30th)
16. When and how high did seas really rise in interglacial times? (29th)
17. Can you rely upon soil development to distinguish different ages of drift? (41st)

FRIENDS OF THE PLEISTOCENE  
ROSTER OF REUNIONS  
1934 to 1987

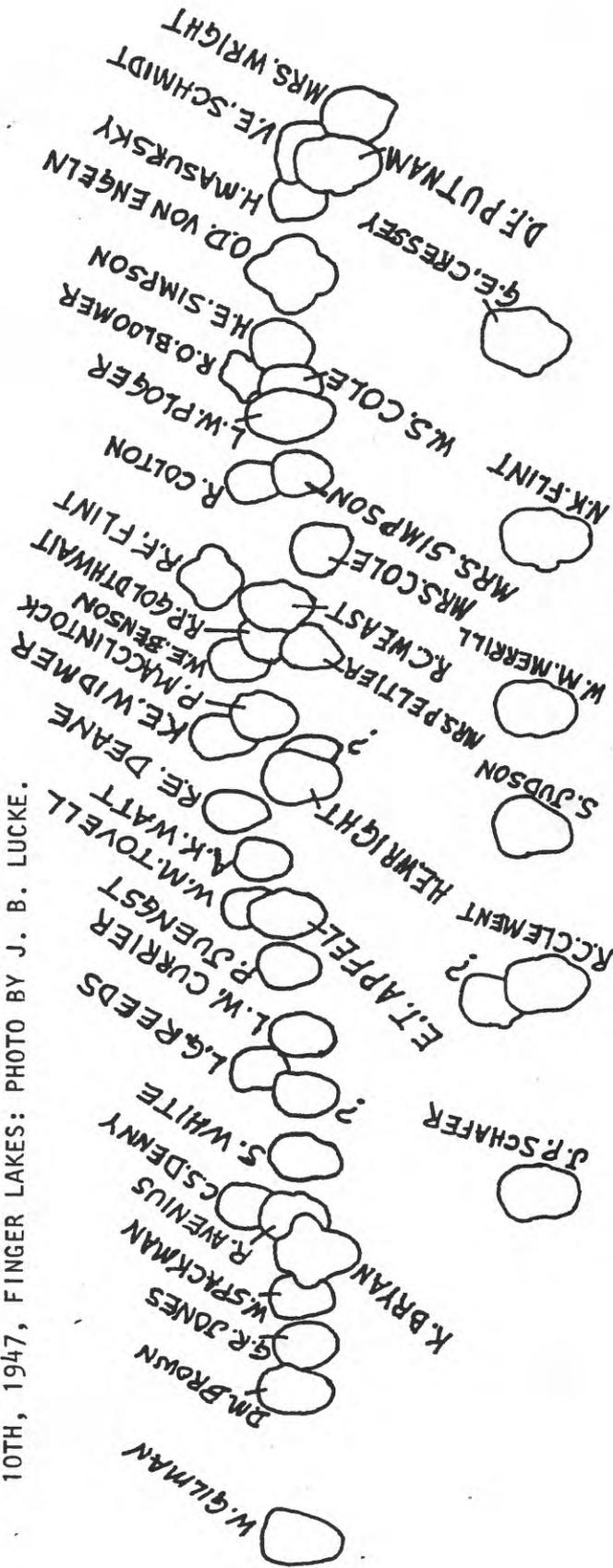
<u>Reunion</u>	<u>Leader(s)</u>	<u>Area</u>	<u>Transport</u> <u>By</u> <u>Miles</u>	<u>Headquarters</u>	<u>Cost</u>	<u>Atten-</u> <u>dance</u>
1. 1934 M25-27	George White & J. Walter Goldthwait	Durham to Hanover, NH	car 140+			
2. 1935	Dick Flint	New Haven to Hartford, CT	car			
3. 1936	Kirk Bryan	S. RI to Cape Cod, MA	car			
4. 1937 M21-23	J. W. & Dick Goldthwait & Dick Lougee	Hanover to Jefferson, NH	car 140+			
5. 1938 M6-8	Charlie Denny & Hugh Raup	Black Rock Forest, NY	cars 14+	Cornwall-on-Hudson	\$3	
6. 1939 M20-21	Paul MacClintock & Meredith Johnson	Drifts, N. NJ	cars 40+	Sussex Inn & Hackettstown	\$2	
7. 1940 M18-19	Kirtley Mather & Dick Goldthwait	W. Cape Cod, MA	cars 90+	Falmouth motels		27
8. 1941 M23-25	John Rich	Catskill Mts., NY	cars 13+	New Saulpaugh & Streeters Hotel		20+
9. 1946 J1-2	Lou Currier & Kirk Bryan	1942-1945 - - - war years - - - Lowell-Westford area, MA	cars 19 stops			
10. 1947 M23-25	Earl Apfel	E. Finger Lakes, NY	cars 110	Lincklaen House, Cazenovia	\$3.50	45
11. 1948 M21-23	D. F. Putnam, Archie Watt, Roy Deane	Toronto to Georgian Bay, ONT	cars 158	Queens Hotel, Barrie		45+
12. 1949 M20-22	Paul MacClintock & John Lucke	'Pensauken' problem, NJ	10 stops cars	Nassau Tavern, Princeton	\$4	32+
13. 1950 M26-28	O. D. Von Engeln	Central Finger Lakes, NY	11 stops cars	Statler Club, Cornell, Ithaca	\$3+	
14. 1951 M26-27	John Hack & Paul MacClintock	Chesapeake soils and stratigraphy, MD	24 stops cars	Waldorf		
15. 1952 M23-25	Dick Goldthwait	Tills, central OH	17 stops vans 195 15 stops	Faculty homes, Columbus; Xenia Hotel	\$5	90+

16. 1953 M22-24	Lou Currier & Joe Hartshorn	Outwash sequences, Ayer quad., MA	cars 109 14 stops			75+
17. 1954 M21-23	Charlie Denny & Walter Lyford	Wellsboro-Elmira- Towanda, PA-NY	cars? 171 11 stops		PennWells Hotel, Wellsboro PA	
18. 1955 M20-23	Paul MacClintock	Champlain lake & sea, NY	bus 108+ 16 stops		Franklin Hotel, Malone	\$5 70+
19. 1956 M25-27	Nelson Gadd	St. Lawrence lowland, QUE	bus 200 8 stops		Manoir Drummond, Drummondville	
20. 1957 M24-26	Paul MacClintock & John Harris	St. Lawrence seaway, NY	bus 120 6 stops		Arlington Inn, Potsdam	
21. 1958 M23-25	John Hack & John Goodlett	Appalachians, Shenandoah, VA	bus 67 8 stops		Belle Meade Motel, Harrisonburg	\$10
22. 1959 M15-17	Alexis Dreimanis & Bob Packer	Lake Erie till bluffs, ONT	cars 191 10 stops		Huron College, Univ. W. Ont., London	
23. 1960 M20-22	Ernie Muller	Cattaraugus Co., W. NY	cars 135 10 stops		Dunkirk Conf. Grounds; Olean Hotel	123
24. 1961 M19-21	Art Bloom	Marine clay & ice margins, SW. ME	bus 121 11 stops		Lafayette Hotel, Portland	\$15 66
25. 1962 M18-20	Cliff Kaye & Phil Schafer	Charlestown moraine & vicinity, RI	bus 150 15 stops		URI, Kingstown	\$4.25 84
26. 1963 M24-26	Hubert Lee	Lower St. Lawrence, QUE	bus 93 13 stops		Hotel St. Louis, Riviere-du-Loup	67
27. 1964 M22-24	Cliff Kaye	Marthas Vineyard, MA	bus 50		The Dunes, Katama	89
28. 1965 M21-23	Joe Upson	Northern Long Island, NY	bus 10 stops		Woodbury Motel, Woodbury	\$15
29. 1966 M20-22	Nick Coch & Bob Oaks	Scarps & stratigraphy, SE. VA	bus		Sunset Manor Motel, Chesapeake	\$17
30. 1967 M19-21	Hal Borns	Marine & moraines, E. ME	bus		Bluebird Motel, Machias	
31. 1968 M24-26	Carl Koteff, Bob Oldale, Joe Hartshorn	E. Cape Cod, MA	bus		Seashore Park Motor Inn, Orleans	\$12
32. 1969 M23-25	Nelson Gadd & Barrie McDonald	Sherbrooke area, QUE	bus 177		Univ. Sherbrooke	82
33. 1970 M22-24	Dick Goldthwait & George Bailey	Mt. Washington region, NH	van 5 walk, & bus 51		AMC Pinkham Notch Camp	\$33 69
34. 1971 M19-21	Gordon Connally	Upper Hudson, Albany NY	bus			104

35. 1972 M19-21	Art Bloom & Jock McAndrews	Central Finger Lakes, NY	bus 52 9 stops	Ithaca College, Ithaca	\$26	105
36. 1973 M18-20	Don Coates & Cuchlaine King	Susquehanna & Oswego Val., NY-PA	bus 124 12 stops	Hinman College, SUNY Binghamton	\$29	92
37. 1974 M17-19	Bill Dean & Peter Duckworth	Oak Ridges-Crawford Lake, ONT	bus 54+	Univ. Toronto		
38. 1975 M9-11	George Crowl, Gordon Connally, Bill Sevon	Lower Delaware Valley, PA	bus 237 11 stops	Penn.Stroud.Hilton, Stroudsburg		67+
39. 1976 J4-6	Bob Jordan & John Talley	Coastal Plain, DE	bus 294 11 stops	Clayton Hall, Univ. Delaware, Newark	\$65	
40. 1977 M20-22	Bob Newton	Ossipee quad., NH	bus 94 11 stops	Red Jacket Motor Inn, Conway		
41. 1978 M5-7	Denis Marchand & Ed Ciolkosz	Central Susquehanna Valley, PA	bus 190 10 stops			
42. 1979 M	Jesse Craft	NE. Adirondack Mts., NY	bus			
43. 1980 M	Bob LaFleur & Parker Calkin	Upper Cattaraugus, Hamburg, NY	bus 83 11 stops			
44. 1981 M	Carl Koteff & Byron Stone	Nashua Valley, MA	bus	Holiday Inn, Leominster		
45. 1982 M	Pierre LaSalle and others	Drummondville, QUE	bus			
46. 1983 M	Woody Thompson & Geoff Smith	Ice margins, central ME	bus	Augusta		
47. 1984 M18-20	Peter Clark & J. S. Street	St. Lawrence lowland, Massena-Malone, NY	bus 180+	Flanders Inn		
48. 1985 M3-5	Ed Evenson and others	Great Valley, NJ-PA	bus 8 stops 10 stops	Americana Great Gorge Hotel, McAfee, NJ		
49. 1986 M23-25	Tom Lowell & Steve Kite	Northernmost ME	bus 117 9 stops	Crocker Hall, U. of Me. Fort Kent		
50. 1987 M7-9	Carl Koteff, Janet Stone, Fred Larsen, Joe Hartshorn	Lake Hitchcock, Conn. Valley, CT-MA	bus 150+	Northampton Hilton, MA	\$50	120?



10TH, 1947, FINGER LAKES: PHOTO BY J. B. LUCKE.



Small photo: 35th, 1972; photo by Dick Gray.  
OLD FRIENDS in Art Bloom's back yard;  
Dick Goldthwait, George White, Dick Flint, Don Chapman.



## BENNETTS BROOK DELTA

GAIL M. ASHLEY and JON C. BOOTHROYD

The Bennetts Brook Delta is located on the west side of the Connecticut River approximately 2 km west of the village of Northfield, Massachusetts. In the early 1970's a south-facing pit wall revealed overlapping lens-shaped sand bodies (Fig.A1). The sand bodies were approximately 75 m long and 10 m high and plunged southward under the floor of the pit. Numerous sequences of ripple-drift cross-lamination had migrated up the west sides of the lenses and down the east sides with little change in the thickness of the ripple-drift units. Paleocurrent directions measured across one of the sand bodies show that turbidity currents flowed eastward approximately parallel to contour lines and in some cases actually flowed upslope (Fig.A2). There is no evidence of structural deformation, thus attitude of the sediments must be considered as primary. The sequences were deposited across previously existing topography, perhaps southward-sloping delta lobes.

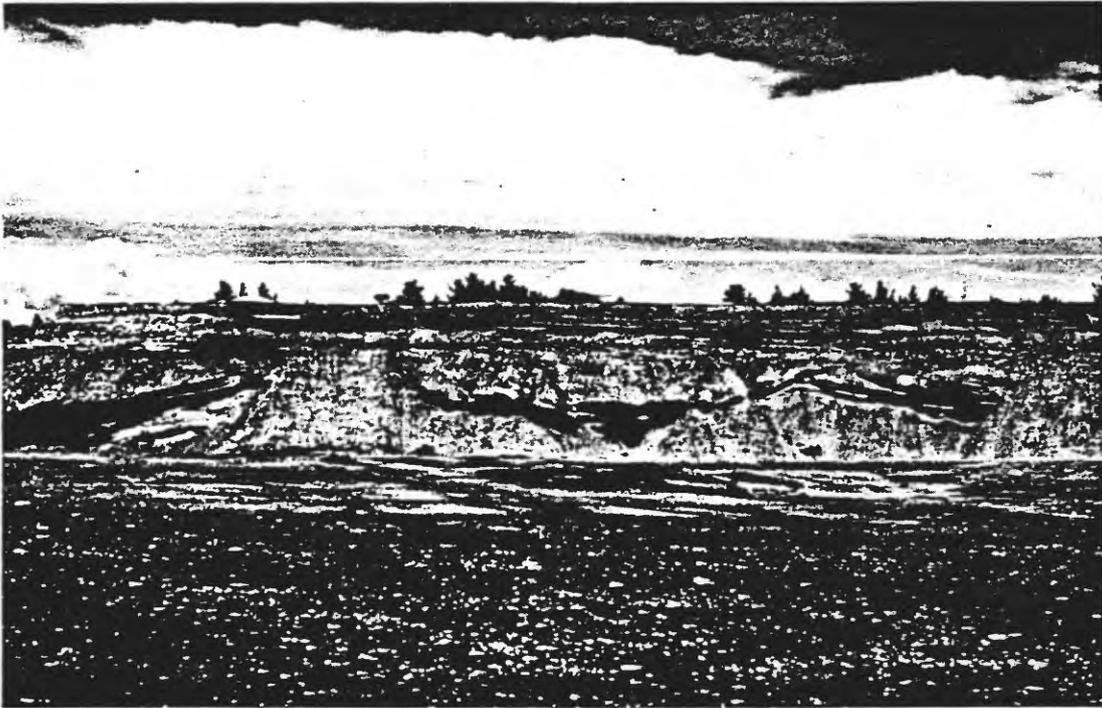
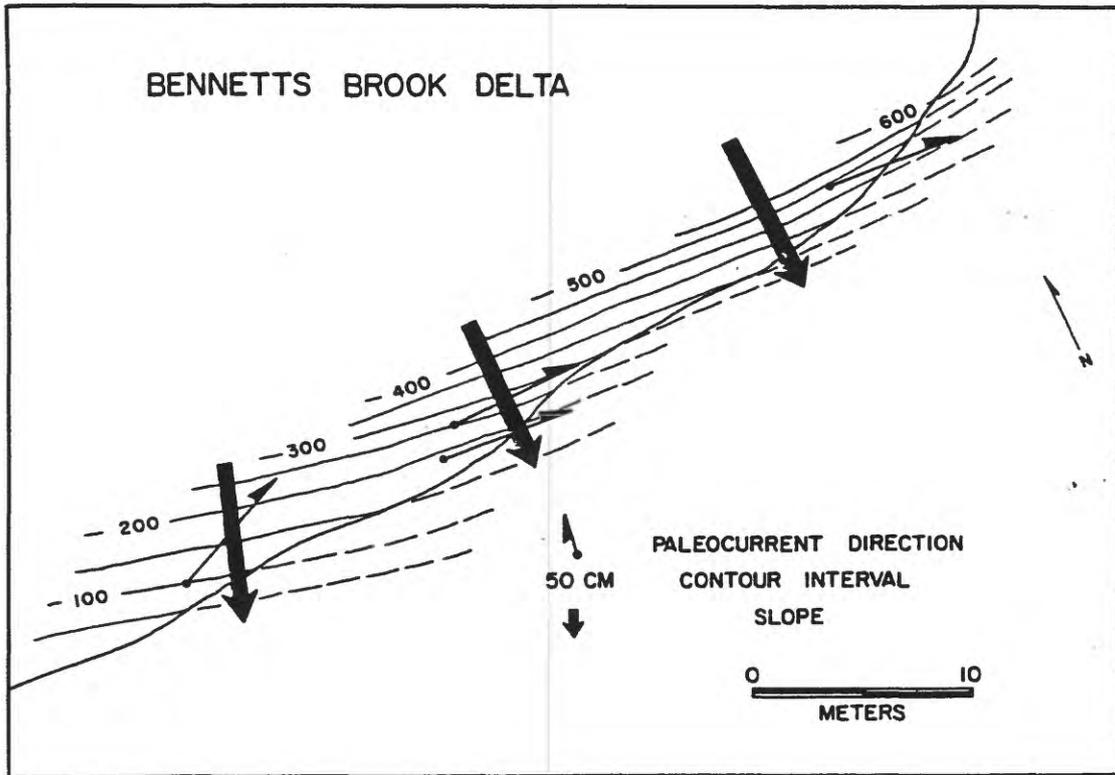


Figure A1. Three south-dipping sand lobes in the Bennetts Brook Delta

Figure A2.



The dominant sedimentary structure within the sequences is ripple-drift: type A (erosional stoss), type B (depositional stoss), and draped lamination. The type produced is related to the relative importance of rate of ripple migration and the rate of bed aggradation (Fig.A3). The ripples climb at some angle  $\theta$  whose tangent is the mean aggradation rate  $V_y$  divided by the downstream migration  $V_x$ .

Figure A3.

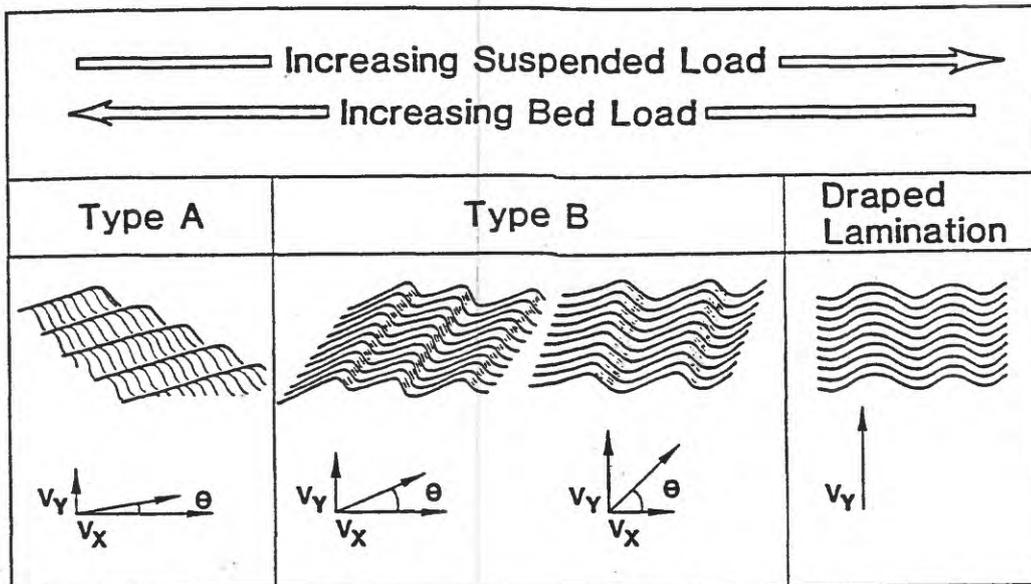
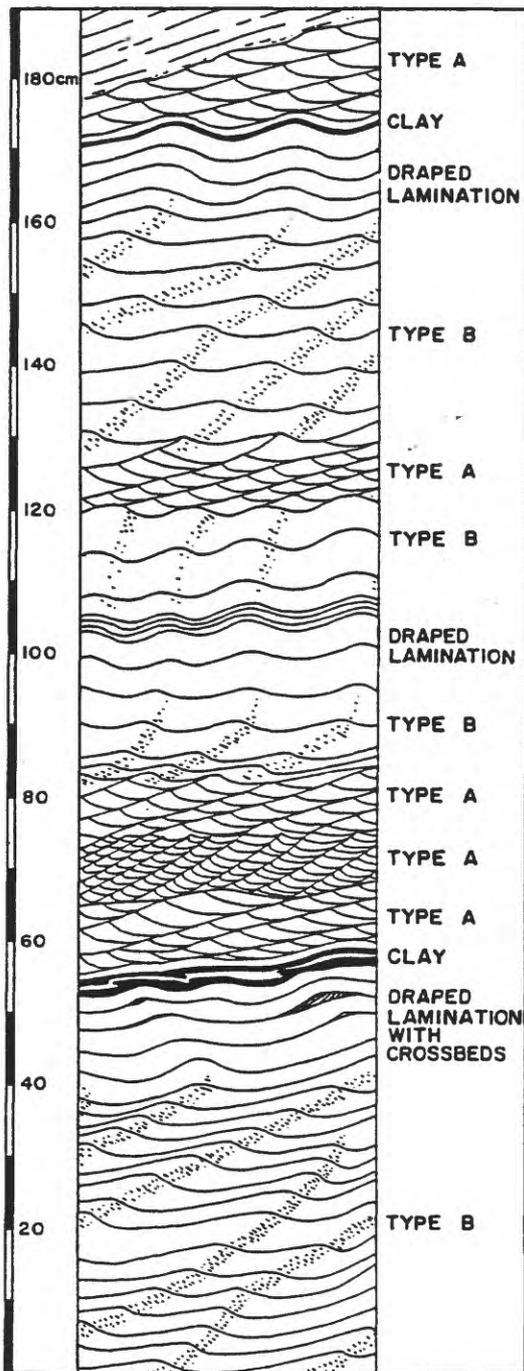


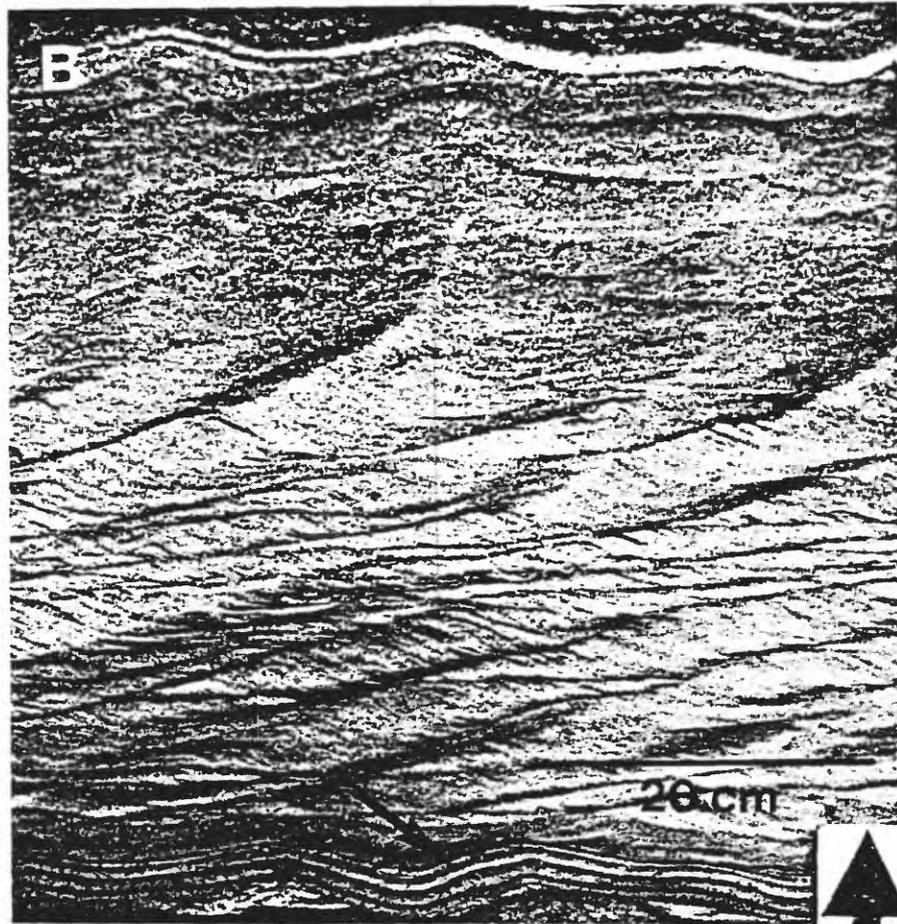
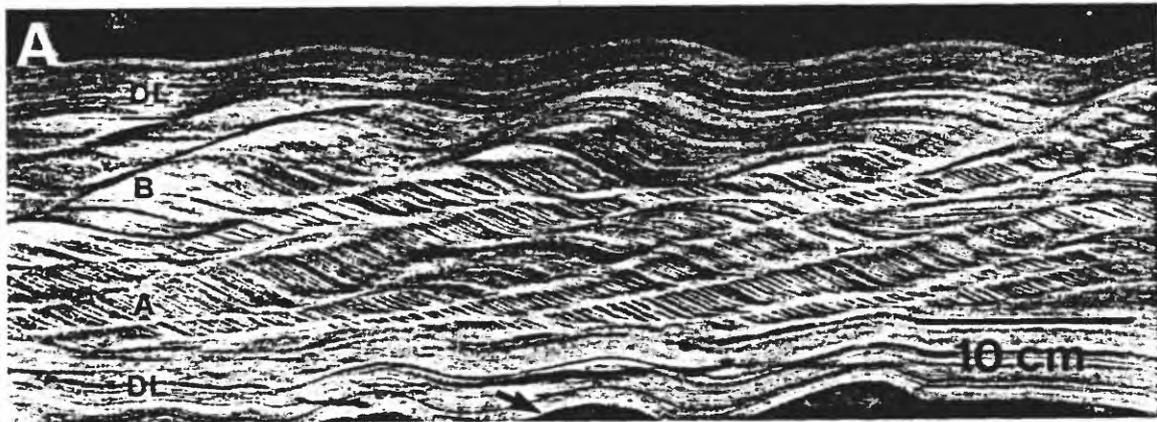
Figure A4.



A measured section 190 cm long taken near the crest of the sand lobe shows type B ripple-drift cross-lamination (Fig. A4). The draped lamination contains a few incipient ripples suggesting periods when bed-load transport was renewed. A slightly deformed clay lamina occurs near the top of the draped lamination. Type A ripple-drift cross-lamination appears next and grades upward into type B, which in turn shows an increasing angle of climb and grades upward into draped lamination. The second unit of draped lamination grades upward into type B ripple-drift cross-lamination, which in turn gives way to type A. This unit of type A grades upward into type B, which, with a gradually increasing angle of climb, grades upward into draped lamination. A thin clay lamina occurs near the top of the parallel lamination.

Flume studies were carried out at the Hydraulic Laboratory at M.I.T. in order to: (1) reproduce some of the characteristic vertical successions of structures found in natural climbing ripple sequences (Fig. A4) and put constraints on parameters (mainly current velocity, rate of aggradation, and time) important in determining the nature of the structures. Figure A5 depicts a comparison of a flume generated (A) and natural (B) ripple drift sequence.

FIGURE A5.



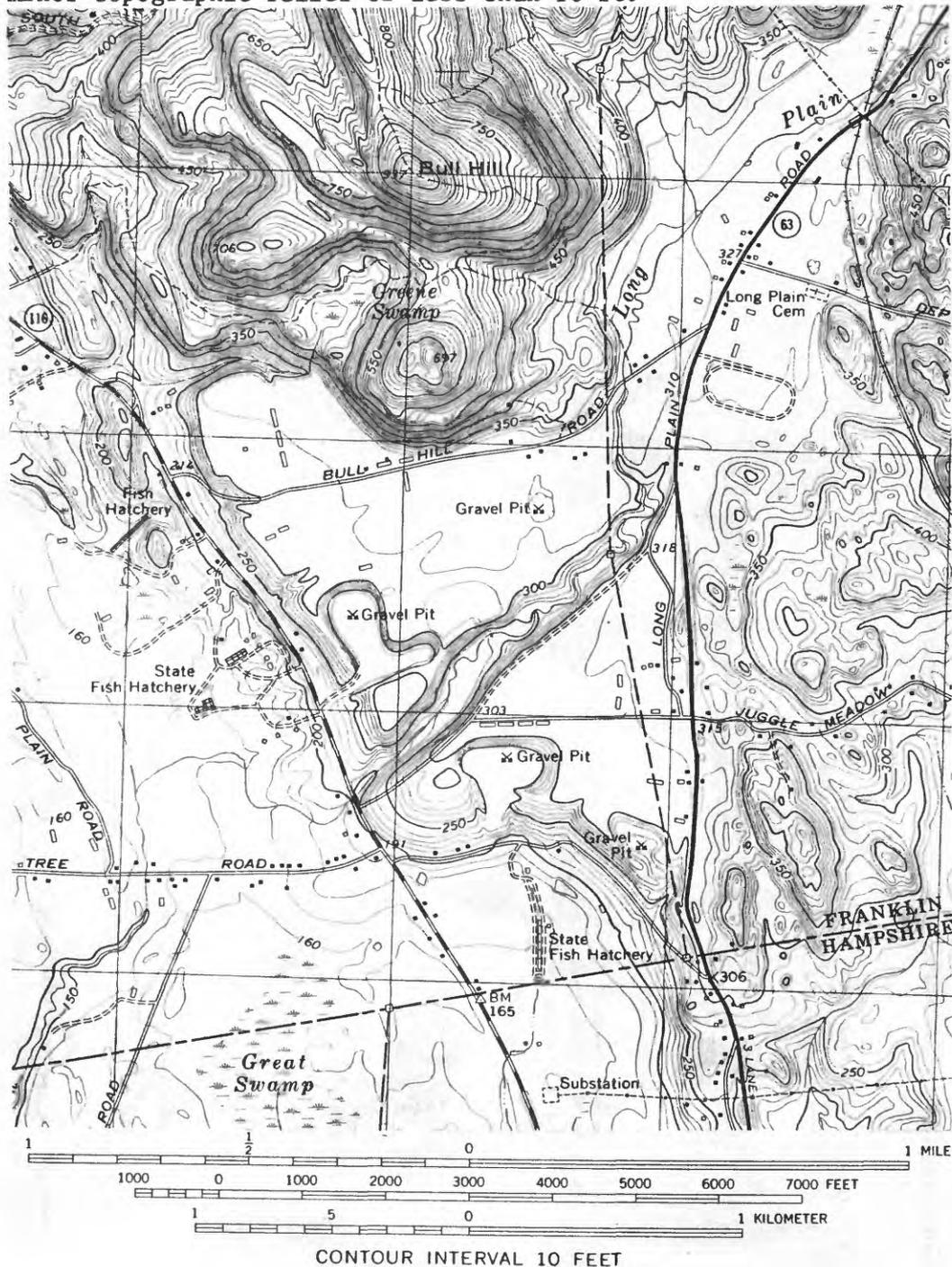
(A) Flume run 8. The run was designed to last 200 min with an asymmetrical velocity curve (maximum velocity = 25 cm sec<sup>-1</sup>) and a symmetrical aggradation-rate curve. Total accumulation was 18 cm. Flow was from left to right. Starting with a train of ripples that had reached equilibrium with an earlier, stronger flow, deposition began (at arrow) with draped lamination (DL) followed by Type A (erosional-stoss) cross-lamination (A), Type B (depositional stoss) cross-lamination (B), and a final blank: of draped lamination.

(B) A climbing ripple sequence exposed in a glaciolacustrine delta (Bennett's Brook Delta, glacial Lake Hitchcock, Massachusetts, USA) exhibits a sequence of sedimentary structures similar to that produced in run 8. Flow was from left to right. The sequence begins by deposition over draped lamination (at arrow). Type A climbing-ripple cross-lamination grades into Type B and finally into draped lamination at the top.

FLUME RUN	VELOCITY (cm/sec) vs. TIME (min)	AGGRADATION RATE (cm/hr) vs. TIME (min)	TIME (min)
8			200

STOP 9A. LONG PLAIN DELTA; town of Sunderland, Mass., Mt. Toby quadrangle. From Rte. 116 turn right (east) on Bull Hill Road. Travel 1.4 mi (2.3 km) up frontal slope and across surface of the delta. Turn right (south) on Rte. 63, travel about 1.0 mi (1.6 km), turn right (west) onto dirt road which goes to 4 tobacco barns and pit on left.

The Long Plain delta is a non ice-marginal delta, fed by meltwater streams that flowed from the ice margin at the head of Long Plain Brook Valley just east of Mt. Toby. It is an ideal morphologic example of a coarse-grained delta, characterized by steeply dipping gravel and sand foreset beds. The surveyed altitude of the T/F contact, 295 ft (89.9 m), is on the projected line of the stable phase of Lake Hitchcock. Jahns (1951) mapped erosional shoreline benches at the 295-ft contour interval on the north and south ends of the delta front. The surface slope of the delta fluvial plain is .0043 (22.5 ft per mile). On the delta surface morphologic elements of braided-stream channels are preserved in minor topographic relief of less than 10 ft.



## INTRODUCTION

It has been fifty years since the Friends last met in the Connecticut River valley, when J. W. Goldthwait, R. P. Goldthwait, and R. J. Lougee described the glacial geology between Hanover, N.H. and Mt. Washington. Two years previous to that, the second meeting was hosted by R. F. Flint in the area between New Haven and Hartford, Conn. In a geographic sense, this 50th reunion picks up from second meeting, covering the Connecticut Valley between Hartford and the northern Massachusetts border (fig. 1). Some aspects of the glacial geology northward toward Hanover and well beyond are presented here, but there isn't time for us to visit this area.

This trip is intended to show the origin and early history of glacial Lake Hitchcock, describe some of the major deglacial events that occurred during retreat of the Laurentide ice sheet in the southern part of the Connecticut River valley, and indicate what the lake and post-lake features suggest to us about the nature of postglacial uplift. We have benefited greatly from a vast amount of work that has been done in this region in the last several decades, which is now being compiled for the new state surficial maps of Connecticut and Massachusetts. These compilations are based primarily on detailed geologic mapping at mainly 7 1/2-minute scale, and most of these maps have been published by the Connecticut Geological and Natural History Survey or the U.S. Geological Survey; there are also many field-trip guides, theses, and other reports available. A separate study to investigate the nature of postglacial uplift has been conducted recently, which also has been able to take advantage of the detailed mapping.

Our present understanding of Lake Hitchcock has benefited not only from the detailed mapping, but especially from ideas and local stratigraphic details that emerged from the state-map compilations. Many statements and observations that seemed contradictory in the past, even from one large-scale map to another, appear to have been successfully resolved at a regional scale. Also, the more concentrated work on postglacial uplift data has provided a model that helps explain quite a few of the earlier contradictions. We hope that this reasoning doesn't appear entirely circular, and no doubt our friends will be glad to assist us on this. Even though the modern work has allowed a more integrated concept for the deglaciation and postglacial uplift of the Connecticut Valley, there remain far too many other questions. Some of these questions are the subject of this meeting. It should be stressed that much of how we presently view things was anticipated by several workers in the past. It has been said that nothing new is really ever discovered, only redefined.

We are indebted to Phil Schafer and Byron Stone who spent much effort in helping us put this guidebook together. Some of their ideas have been incorporated here and they have assisted in reviewing the manuscript.

## EARLY STUDIES

Glacial Lake Hitchcock, which is now thought to have extended well over 200 miles (320 km) from central Connecticut to Burke, Vt. (fig. 2), was given its name by R. J. Lougee (1939) because of Edward Hitchcock's (1818) mention of evidence for lake deposits between the town of Gill and Mt. Holyoke, Mass. Hitchcock's description was somewhat brief and it seems clear that no glacial source was assumed. The name for the lake became firmly established in the 1950's and 1960's during detailed quadrangle studies in Connecticut and Massachusetts where it was accepted by a number of workers.

B. K. Emerson (1898a,b) thought that the glacial sediments in the Connecticut Valley required the presence of ponded water, but he seems to have viewed the lake as more of a "tremendously swollen stream." He gave the names Springfield Lake, Hadley Lake, and Montague Lake for separate areas, mostly in Massachusetts. Later, Emerson (1917) also recognized the effects of postglacial uplift in the region. He stated that "The lakes are bordered by a bench, which is well marked where it cuts into sand beds or drumlins and broadens in great delta flats at the mouth of tributary valleys," and that "As there was almost no southward current in these lakes the beach (bench) must have been nearly horizontal, and the basin in the northern part of the State must subsequently have been elevated nearly 200 feet more than on the south line."

In a paper on the clays and clay industries of Connecticut, G. F. Loughlin (1905) was the first to have recognized several of the most important aspects of Lake Hitchcock that are still valid today. Remarkably, in three rather short paragraphs, he identified the "kames and high gravel plain" at Rocky Hill, Conn., as the dam across the Connecticut River valley, the outlet for the lake near Newington Station (now called the New Britain channel), and a water level at the outlet at or a little above 80 feet. Loughlin also recognized that the southward sloping clay deposits north of the outlet were the result of "depression of the continent to the northward at that time," which is an obvious reference to postglacial uplift.

R. F. Flint (1933) referred to the lacustrine deposits in Connecticut as belonging to the "Hartford lake," continuing the perception that the Connecticut Valley contained several separate glacial lakes. He also referred to the outlet as "the channel at New Britain," although most of the feature, including the apparent threshold, is in Newington. It is not clear why Flint chose the name New Britain in favor of Newington, but his description has been accepted and used for over fifty years.

Lougee (1939), in naming Lake Hitchcock, was the first to consider that the Connecticut Valley was occupied by one intergrated body of water. However, he thought it extended farther south than now placed. He did not recognize the outlet at New Britain, as it was never mentioned in his publications. R. H. Jahns and M. E. Willard (1942) specifically addressed the

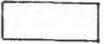
**LAKE HITCHCOCK DELTAS**



Connecticut phase  
(high level)



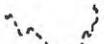
Stable phase  
(82-ft level at NBS)



post-stable phase



Dam for Lake Hitchcock  
at Rocky Hill



Stable Lake Hitchcock  
shoreline



New Britain spillway  
for Lake Hitchcock

• 2

Fieldtrip stop  
location



Area of Figure 3



Figure 1. Glacial Lake Hitchcock and delta deposits in Massachusetts and Connecticut. Ice-marginal deltas record high lake levels as far north as Chicopee, Mass. Northward from there to as far north as Burke, Vermont, ice-marginal deltas record the stable lake level. All stable-level deltas south of Chicopee were built by meteoric water from major tributary valleys such as the Westfield, Chicopee, Farmington and Scantic River valleys.

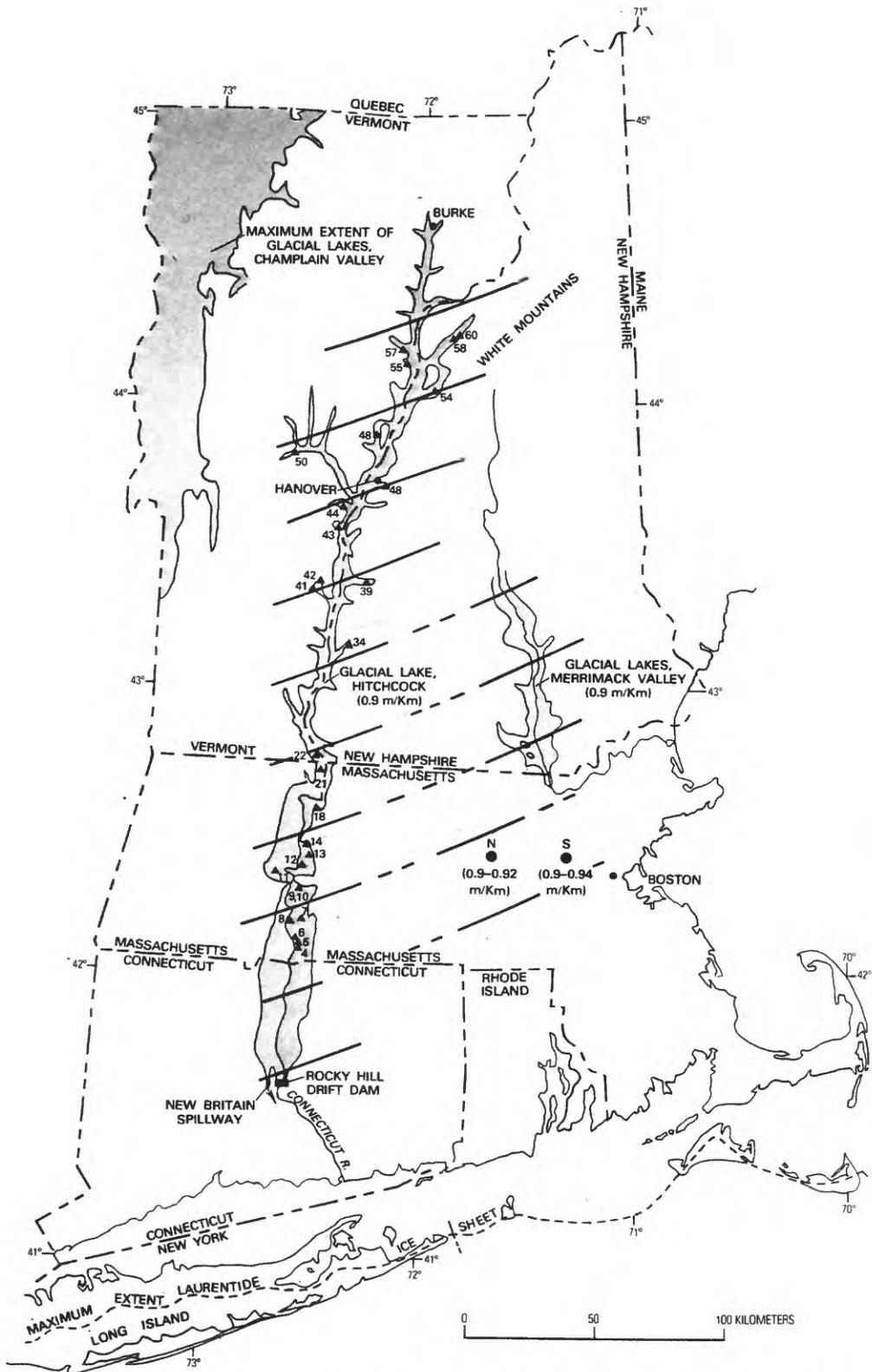


Figure 2. Generalized outline of glacial Lake Hitchcock and selected other glacial lake areas in western New England. (N) glacial Lake Nashua; (S) glacial Lake Sudbury. ( $\Delta_{50}$ ) location of altitude obtained from unmodified, ice-marginal or meltwater-derived delta used in regression analysis described in the text. Uplift isobase interval 25 m. Figure from Koteff and Larsen (in press).

previous notion of separate water bodies in their detailed analysis of the Massachusetts portion of the lake, demonstrating that the lake features defined a single lake, the level of which was controlled by the New Britain channel. This work was done during the initial stages of the detailed mapping program in Massachusetts, and many of their ideas and descriptions of Lake Hitchcock features have been altered only slightly by later studies. Some of Jahns' concepts of sequences and systematic ice retreat were developed here at this time, although he did not include deltas in this original scheme.

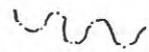
No attempt has been made in this all too brief discussion of the early work to cover all the important contributors (for example Antevs and his varve chronology in 1922, and Flint's first 1930 study). Although these are only a few highlights of how the lake history was first established, it is clear that Lake Hitchcock has been the object of much interest and study dating back to the last century. Also, there have been many workers in recent decades who have contributed a great amount of detail to the geology of the lake, many of whom will be referred to in the discussions at the field stops.

#### INITIATION OF GLACIAL LAKE HITCHCOCK

The inception of Lake Hitchcock really was dependent on the presence of an earlier and higher glacial lake, Lake Middletown (Stone et al., 1982) (fig. 3), in the Connecticut River valley at Middletown and the tributary Mattabesset River valley during retreat of the Connecticut Valley lobe of the Laurentide ice sheet. An extensive deltaic complex controlled by Lake Middletown completely filled the Connecticut River valley and later formed the dam for Lake Hitchcock. Formation of such drift dams in south-draining valleys has been found to be a necessary condition for the creation of many glacial lakes in southern New England. Lake Middletown itself was impounded by a long mass of older meltwater sediments that effectively filled the lower Connecticut River valley southeast of Middletown. Because these deposits extended at least 12 mi (20 km) down the valley, entrenchment of them and consequent lowering of Lake Middletown was relatively slow.

Construction of the deltaic complex began with deposition of successive, contiguous ice-marginal deltas in Lake Middletown in the Cromwell area, which blocked that relatively narrow part of the Connecticut River valley. As the ice margin retreated from the Cromwell deltas, meltwater was impounded behind them at a very slightly higher level than Lake Middletown, and ice-marginal deltas formed in this higher lake near Rocky Hill and on the east side of the Connecticut River in Glastonbury. The waters of this relatively small lake spilled over the Cromwell deposits. A well-developed channel (fig. 6), called the Dividend Brook Spillway (Hartshorn and Koteff, 1968) was carved into the Cromwell delta surface. Together, the Cromwell-Rocky Hill-Glastonbury deltas have been referred to in the past as the drift dam at Rocky Hill.

Ice retreat during the formation of the deltaic complex uncovered, west of the Connecticut River, a bedrock upland that now forms the east-west divide between two tributaries of the Connecticut River, the Mattabesset River to the south and the Park River to the north. The small lake controlled by the

-  LAKE MIDDLETOWN DELTAS
- Mp - Portland
- Mc - Cromwell
- Mn - Newington
- Mw - Western margin
- Me - Eastern margin
- Mh - Hockanum
- Mg - Great Pond
- Mv - Windsorville
  
-  DRIFT DAM FOR LAKE MIDDLETOWN
  
-  DIVIDEND BROOK DELTAS
  
-  LAKE HITCHCOCK DELTAS
- Hc - Connecticut phase
- Hs - Stable phase
- Hp - post-stable phase
  
-  50-FT STREAM TERRACE
  
- NBS  New Britain spillway for Lake Hitchcock
  
- DBS  Dividend Brook Spillway
  
-  Lake Middletown Shoreline
  
-  ice-margin position

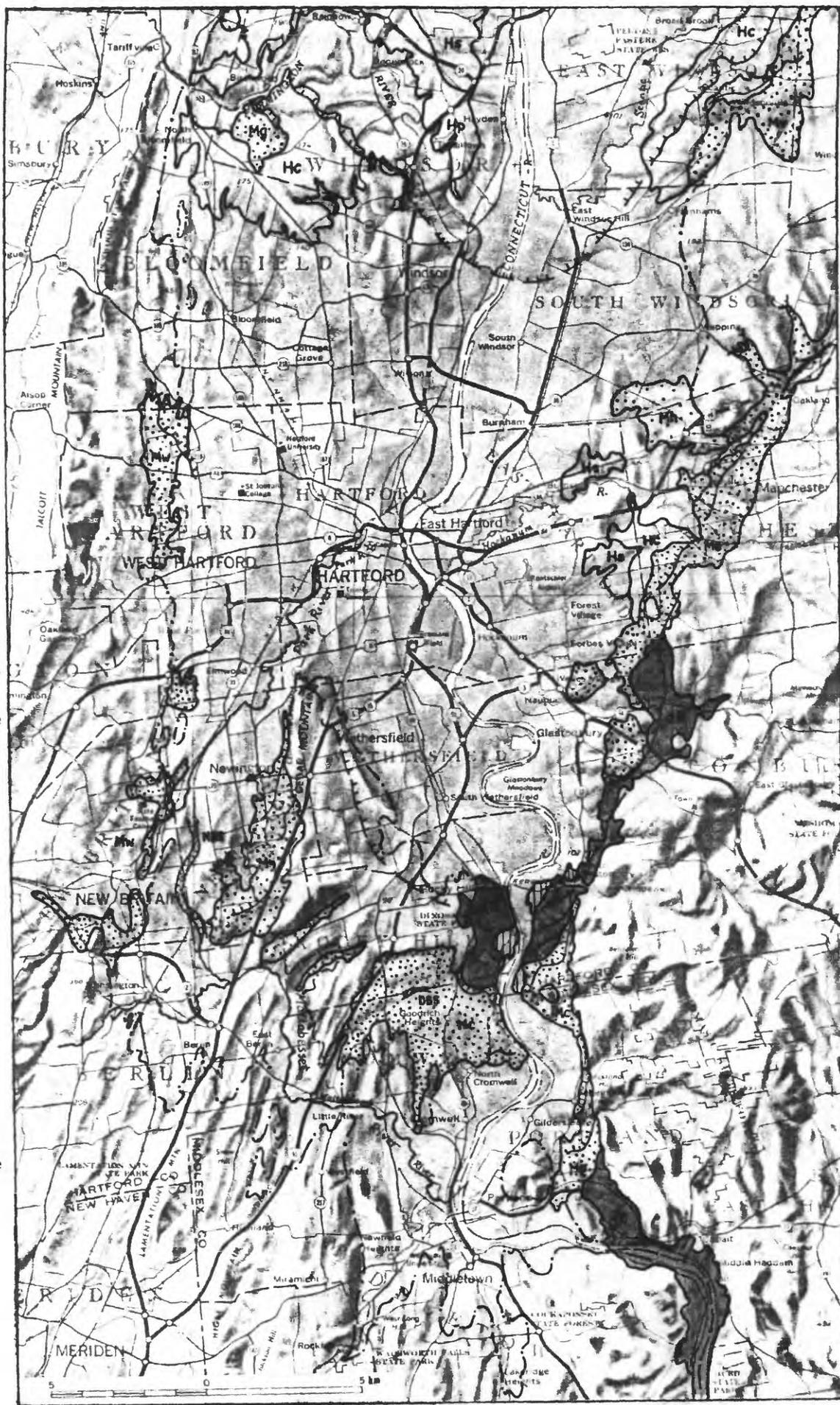


Figure 3. Extent of glacial Lake Middletown.

Dividend Brook spillway expanded northward behind the deltaic complex, east of Cedar Mountain. At the same time, Lake Middletown expanded northward from the Mattabesset basin across a low part of the divide in the New Britain-Newington area, west of Cedar Mountain. As ice retreated from the north end of Cedar Mountain, the lake behind the delta complex dropped and coalesced with Lake Middletown. The Dividend Brook spillway was abandoned and erosion of its channel ceased. The final floor altitude of this spillway was 129 ft, controlled by the level of Lake Middletown into which it drained. The deltaic complex therefore survived to constitute the dam for Lake Hitchcock.

Although Lake Middletown continued to lower slowly by entrenchment of its drift dam, it remained high enough to cover the low part of the divide (no higher than 110 ft (34 m)) in the New Britain-Newington area and the lake was able to expand northward into the Connecticut River basin during ice retreat. Altitudes of deltas on both the east and west side of the basin indicate that Lake Middletown persisted, but with slowly lowering levels, until the ice margin retreated as far north as Windsor.

Further lowering of Lake Middletown allowed emergence of the low divide area at New Britain-Newington, and separated the shrinking Middletown lake to the south and the first phase of glacial Lake Hitchcock to the north. As the ice margin in the Connecticut Valley retreated north, Lake Hitchcock expanded in area although its level gradually lowered because of erosion of till, waterlaid sediments, and weak bedrock in the spillway. Meltwater-derived deltas were constructed successively northward in the lake during stagnation-zone retreat, and their lowering altitudes northward reflect the erosion of the drift at the New Britain channel area. This period of lowering, referred to here as the Connecticut phase of Lake Hitchcock, lasted until the floor of the New Britain channel stabilized on resistant bedrock, preventing further lowering of the lake level, and initiating the stable phase of Lake Hitchcock. By this time, the ice margin may have been as far north as Chicopee, Mass., but its exact position is still unclear.

During its stable phase, Lake Hitchcock continued to expand as the ice margin retreated north from Chicopee through all of Massachusetts and much of New Hampshire and Vermont. Meltwater-derived deltas were successively constructed in the lake probably to about Burke, Vt. The stagnation-zone retreat of the margin was generally systematic, interrupted in places by local readvances such as one at Chicopee (Larsen, 1982). Most of these readvances have been identified only in recent years, and no doubt others will be found as new exposures become available. However, none of them is believed to represent more than local and short-lived events and thus are not correlated regionally.

Lake Hitchcock was once thought to have drained catastrophically when the ice margin had reached just north of Hanover, N.H. (Lougee, 1939, 1957). Recent work by Koteff and Larsen (1985, in press) on postglacial uplift studies, however, has established the longer lake to Burke; also, the presence

-  LAKE MIDDLETOWN DELTAS
- Mp - Portland
- Mc - Cromwell
- Mn - Newington
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- Mv - Windsorville

-  DRIFT DAM FOR LAKE MIDDLETOWN

-  DIVIDEND BROOK DELTAS

-  LAKE HITCHCOCK DELTAS
- Hc - Connecticut phase
- Hs - Stable phase
- Hp - post-stable phase

-  50-FT STREAM TERRACE

-  NBS  
New Britain spillway for Lake Hitchcock

-  DBS  
Dividend Brook Spillway

-  Lake Middletown Shoreline

-  ice-margin position

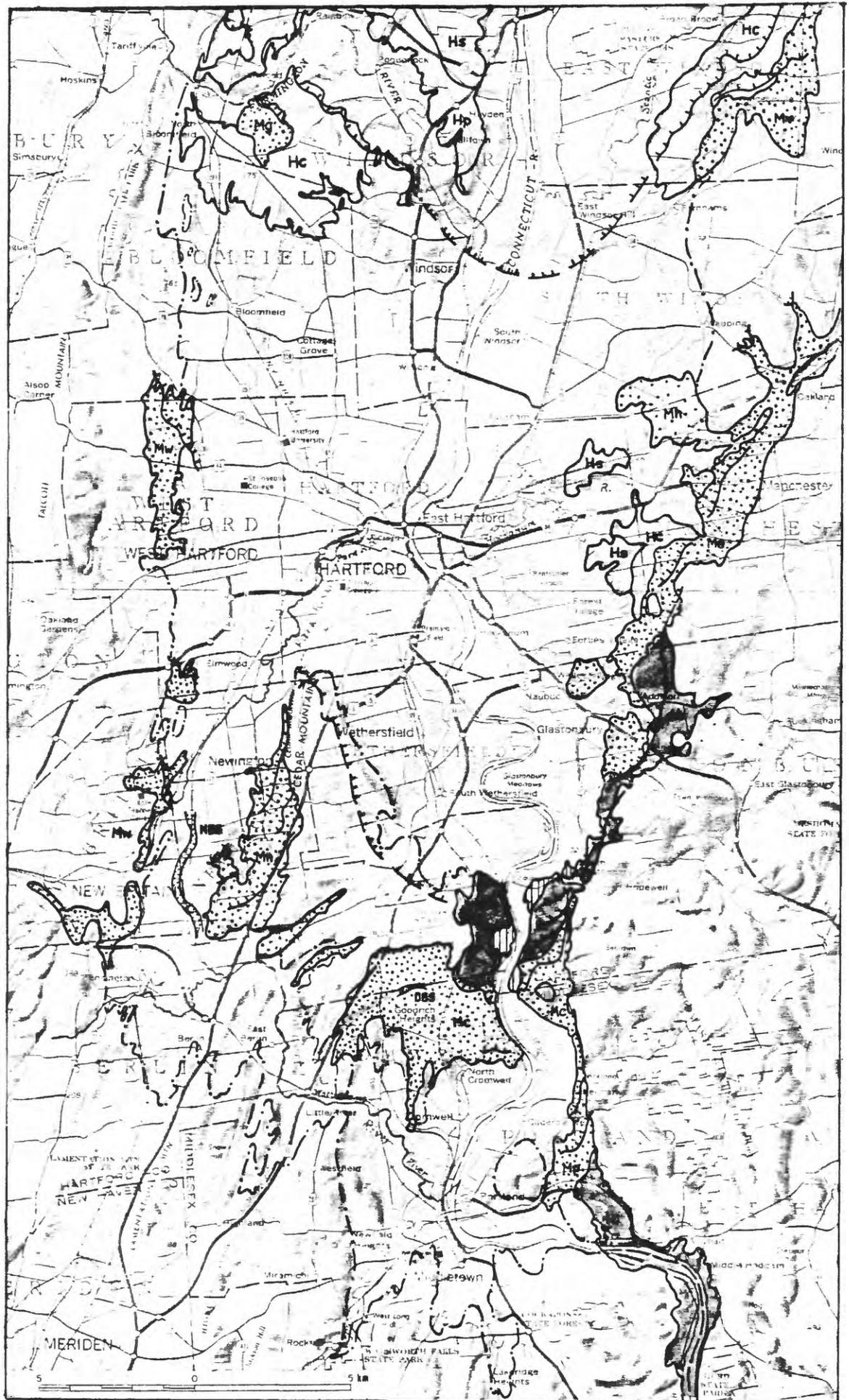


Figure 3. Extent of glacial Lake Middletown.

of postlake stream terraces along the Connecticut River at the Cromwell-Rocky Hill-Glastonbury drift dam only about 30 feet (10 m) below the projected level of Lake Hitchcock indicates a somewhat less dramatic end to the lake.

Dating of the deglacial and postglacial events in the Connecticut Valley is not entirely clear. Stone and Borns (1986) have suggested that the retreating ice margin was in the New Britain channel vicinity about 17,000 years ago, and Antevs (1922) indicated from varve counts that Lake Hitchcock lasted about 4000 years. Flint (1956) believed that the lake drained about 10,700 years ago, based on a radiocarbon date from woody material found at the lower end of the New Britain channel spillway. However, Larsen (1984) feels that evidence in central Vermont indicates that the lake had already drained while the ice sheet was still there, no later than 12,600 years ago. Koteff and Larsen (1985, in press), using radiocarbon dates reported by Davis and Ford (1982) from the White Mountains area of New Hampshire, have suggested that Lake Hitchcock was still in existence, with its level controlled by the New Britain spillway, at least 14,000 years ago. The only thing completely clear from all this is that much more work needs to be done.

#### POSTGLACIAL UPLIFT

Glacial Lake Hitchcock and its related deposits present an unusual opportunity for uplift studies. The lake was lengthy (more than 200 miles [320 km]), lasted for at least 4000 years with a stable outlet for probably half that time, and was located in an area that was deglaciated early. Also, the physical correlation and relative position of most of the deposits are well known because of the detailed mapping of much of the lake area, and we have been able to identify a large number of ice-marginal or meltwater-derived deltas that were successively constructed in Lake Hitchcock during systematic ice retreat. Altitudes obtained from topset/foreset contacts in these deltas now record the postglacial tilt of a once-level water plane. As previously mentioned, the dating of deglacial events in this region is still not sufficient, but those that are available have allowed a broad, fairly reasonable chronologic description of the deglacial history of the region.

Although Loughlin (1905) and Emerson (1917) early on suggested that the area had undergone postglacial uplift, it was Lougee (1939, 1957), who first did any detailed studies. He carefully surveyed altitudes of topset/foreset contacts of Lake Hitchcock deltas and from these reported uplift gradients to the north-northwest of 3.3 ft/mi (0.63 m/km) for Connecticut (and presumably Massachusetts as well), and of 4.6 ft/mi (0.87 m/km) for New Hampshire. Jahns and Willard (1942) also used altitudes of topset/foreset contacts of deltas in Massachusetts and determined the uplift gradient there to be approximately 4.2 ft/mi. Recent studies by Koteff and Larsen (1985, in press), used similar techniques and have arrived at slightly different conclusions. From the recent studies, the uplift gradient indicated for the entire area covered by Lake Hitchcock from central Connecticut to northern New Hampshire and Vermont is 4.74 ft/mi to the N20-21S (fig. 4).

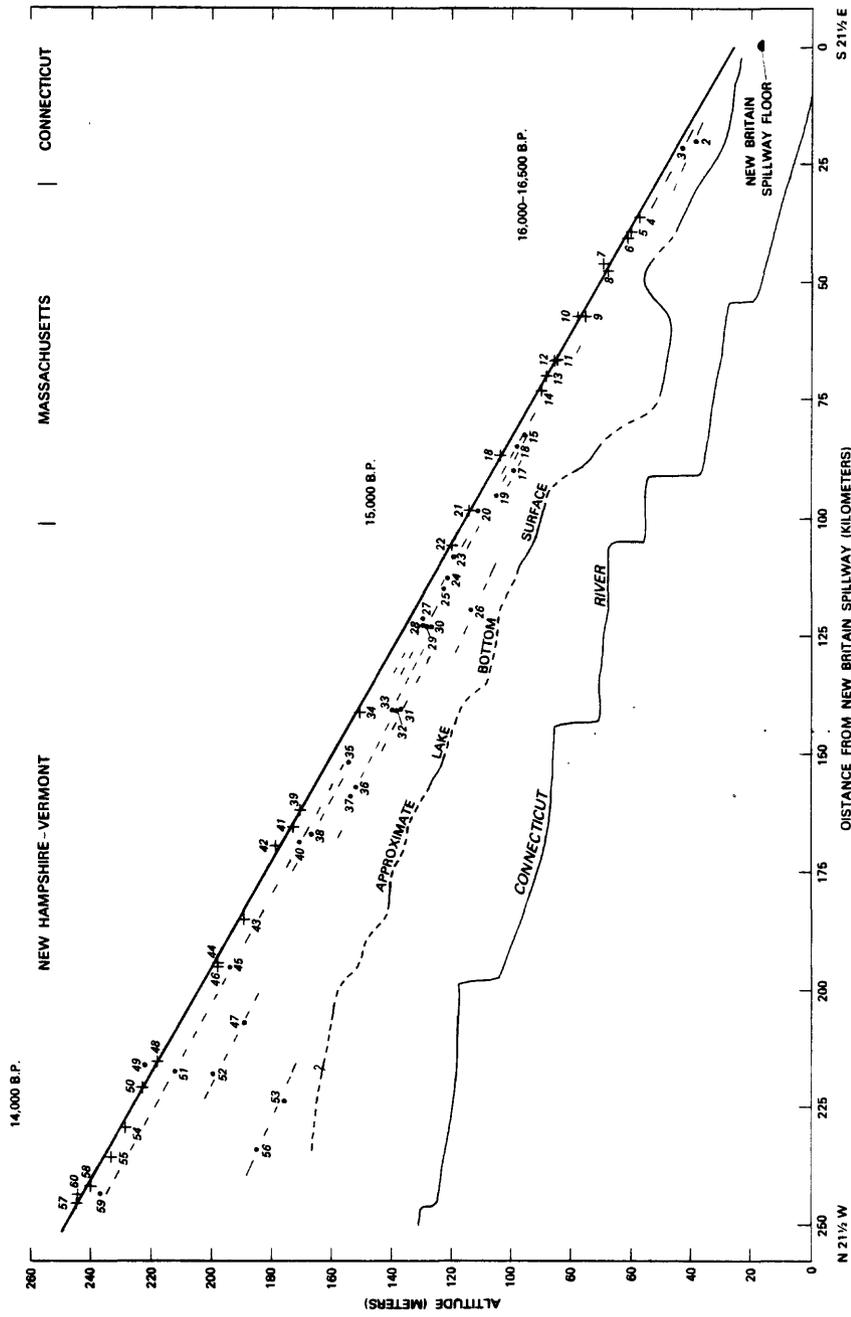


Figure 4. Ordinary least squares regression profile based on altitudes of topset/foreset contacts of 28 unmodified, ice-marginal or meltwater-derived deltas (+) in glacial Lake Hitchcock. (.) other altitudinal data. Dashed profiles diagrammatic only. Lake-bottom profile estimated from previous publications and topographic maps; lake bottom may be higher at delta localities 7 and 8 (STOP 5 discussion). Figure from Koteff and Larsen (in press).

This uplift gradient was established by examination of more than 60 delta localities in Massachusetts, New Hampshire, and Vermont. Delta localities in Connecticut initially were not included because of the complex history of a gradually lowering lake there; by using deltas north of there associated only with the stable phase, a constantly changing variable was excluded from the study. However, some of the Connecticut delta features are addressed at this meeting. Of the 60 delta localities, 28 were selected as representing unmodified deltas resulting from successive meltwater deposition at the ice margin in Lake Hitchcock or from meltwater streams that entered the lake from tributary valleys. The others were considered to be modified by collapse or erosion by later meteoric water, or were constructed in later and lower lake levels after either uplift began or the drift dam at Cromwell-Rocky Hill-Glastonbury, Conn., failed.

Topset/foreset contacts (T/F) of deltas can be a very consistent and accurate estimate of former glacial lake levels, probably to within 3 ft (1 m). This principle has been known for many years (Gilbert, 1890, fig. 15). In our study, deep erosional fluvial channels were avoided; in many of the deltas, the topset beds are 3 ft (1 m) thick or less over foresets. Thus, the water-level error due to erosional scour at the T/F is minimal. Most of T/F altitudes were surveyed with a transit, alidade, or electronic distance meter. In most cases, a permanent bench mark was used for control; in a few other cases, road intersections with elevations located to the nearest foot were used so that the T/F altitude is accurate to within that amount. A few altitudes reported by Jahns and Willard (1942) were used and the accuracy of them is less certain because they did not describe their field methods. However, these altitudes were field checked and found to be reasonable.

Most of the T/F altitudes (fluvial/foreset contacts in some cases) are shown on figure 4. The profile though was originally derived from altitudes of only the 28 unmodified meltwater-related deltas mentioned earlier because they represent the stable level of Lake Hitchcock during deglaciation (our attitude about a few of these at the southern end of the profile has been modified in putting together this trip, to our benefit obviously, and are discussed at the field stops). There is a vertical difference in uplift between the lake spillway at New Britain and the northernmost delta in Vermont of 720 ft (219 m), over a distance of about 152 mi (245 km). The gradient of the profile is thus 4.74 ft/mi (0.9 m/km).

The profile is a best-fit projection based on an ordinary least squares regression of the 28 T/F altitudes. The regression indicates a N20 1/2-21W direction for the projection with error range for the E-W variable of 5% and 0.4% for the N-S variable. Two sigma variation for each altitude is less than 6 ft (2 m). Only two of the delta altitudes are more than 6 ft (2 m) off the fit (one of these, at Chicopee, Mass., may actually represent the last part of the higher Connecticut phase of Lake Hitchcock), and 22 of the altitudes are within 3 ft (1 m). Projection of the profile southward to the lake spillway

indicates that the threshold of stable Lake Hitchcock was about 82 ft (25 m) altitude. Drilling supervised by J. W. Bingham of the USGS Water Resources Division, Hartford, indicates that the bedrock floor at the threshold is about 58 ft (17.7 m) altitude. The water column there is indicated to have been about 24 ft (7 m) in a channel about 700 ft (215 m) wide, and the discharge rate for the lake is calculated to have been about 215,000 ft<sup>3</sup>/s (6100 m<sup>3</sup>/s). Only two modern floods in the basin covered by Lake Hitchcock, recorded in 1936 and 1938, have exceeded this discharge rate, so it seems reasonable that the New Britain spillway could have handled a body of water the size of Lake Hitchcock.

Some of the altitudes reported by Jahns and Willard do not fit well on their generally northward projection of uplift, but do so on the N20 1/2-21W projection. Also, some of the deltas examined by them have now been determined to be later features and not constructed during ice-marginal retreat. Thus, the gradient of 4.2 ft/mi (0.8 m/km), which is an average of all of their data points, is clearly too low. The 3.3 ft/mi (0.63 m/km) uplift gradient reported for Connecticut (and presumably Massachusetts) by Lougee (1939) is no doubt the result of placing the threshold for Lake Hitchcock much farther south than the New Britain spillway. He believed that the uplift projection was about N15W, from which he derived an uplift gradient for New Hampshire of 4.6 ft/mi (0.87 m/km), reasonably close to that of Koteff and Larsen (1985, in press). Lougee explained the different gradients as the result of a hinge line. A N15W projection from the New Britain channel area, however, produces a similar uplift gradient of about 4.6 ft/mi (0.87 m/km) for Connecticut, Massachusetts, and New Hampshire. There is no need to employ hinge lines to describe uplift in this region.

#### DISCUSSION

The nature of the uplift profile (fig. 4) for the Connecticut Valley indicates that the style of postglacial rebound in this region is significantly different than that derived from water bodies in other areas, particularly those that were deglaciated later. The straightness of the uplift profile and the extraordinary closeness of fit of the regression show absolutely no differential warping of the lithosphere. Also, rather than being a time line, the profile is a time-transgressive depiction of ice-marginal or near ice-marginal delta construction in Lake Hitchcock during a systematically northward but increasing rate of ice retreat. As inferred from the correlation of Stone and Borns (1986), the retreating ice margin was in the vicinity of Chicopee, Mass., the southernmost delta locality used for the profile, between 15,000 and 16,000 years ago. Koteff and Larsen (1985, in press) place the ice margin at the northernmost delta about 14,000 years ago. Thus, the profile represents between 1500 and 2000 years of ice retreat. During this time and possibly longer, the stable phase of Lake Hitchcock was maintained at a constant level by the bedrock-floored spillway at New Britain. All of this suggests that postglacial uplift was delayed until the ice was at least in northern New England about 14,000 B.P. If

postglacial uplift was delayed during this period of ice retreat that lasted 1500-2000 years, it is further suggested that uplift was delayed from the beginning of ice retreat from Long Island more than 19,500 years ago (Sirkin, 1982) as well. It seems unlikely that uplift could have been occurring in southern Connecticut and Long Island without affecting any part of glacial Lake Hitchcock during deglaciation there. The entire region appears to have been affected by uplift only after 14,000 B.P., when the ice margin is assumed to be in northern New England. Depending on dating accuracy, a delayed response to uplift of about 5000 years is proposed, from the beginning of ice retreat from Long Island until the ice margin was in northern New Hampshire and Vermont.

Another style of postglacial uplift has been suggested by J. A. Clark (in press) that depicts active uplift at the ice margin from the beginning of deglaciation. Among other things, this model assumes that ice retreat was fairly steady. However, as indicated by Stone and Borns (1986) and Schafer (1979), it is probable that the rate of ice retreat was twice as fast over New Hampshire and Vermont as it was over Connecticut and Massachusetts. Indeed, the rate of retreat may have increased gradually even from the ice position at New Britain. Also, several readvance localities are known in the Connecticut Valley, particularly the southern part, suggesting that ice retreat really was not very steady, although it certainly was systematic. Clark's model also projects a series of time lines from each delta point to the spillway that fall below the straight profile shown in figure 4. Although we can not show this accurately here, this profile is discussed at various places during the trip, particularly at the Chicopee delta. In Clark's model, the best fit of the data from the Connecticut Valley uplift studies also produces a convex up profile, which is about 20 ft (6 m) off the straight-line projection near the center (Groen, Clark, and Koteff, 1986). However, the straightness of the projection (fig. 4) based on the precision of the data seems to preclude a convex up or any curved depiction.

There no doubt are other models of postglacial uplift that differ from the suggestion here that there was a significant delay to the uplift response at the beginning of deglaciation. But it should be stressed that this area is the only one so far that has been studied carefully in a region deglaciated early, before 14,000 B.P. All data for other postglacial uplift studies has been derived from later deglaciated areas. It is hoped that there is evidence here to provoke a healthy discussion.

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STOP 1. MUSTARD BOWL PITS; town of Rocky Hill Conn., Hartford South quadrangle. Turn east from Main St., (Rte. 99) 0.3 mi (0.5 km) south of Cromwell-Rocky Hill town line, onto unimproved road and travel approximately 1 mi (1.6 km) to end of road at southeast corner of southernmost pit scarp (fig. 5).

The pit access road crosses part of the surface of the Cromwell-Rocky Hill-Glastonbury delta complex, which is a series of ice-marginal deltas that completely filled the Connecticut River valley between Rocky Hill and Glastonbury to an altitude of 150-160 ft (46-49 m). This mass of deposits provided the dam for glacial Lake Hitchcock after Lake Middletown had been lowered (see text discussion). The dam is now entrenched by the Connecticut River. Inset against the higher surface is a terrace remnant at 50 ft (15 m) altitude, and was probably cut at the time the dam was breached and Lake Hitchcock drained.

The Cromwell-Rocky Hill-Glastonbury delta complex consists of deposits controlled by two water planes (figs. 5 and 3). The earlier southern deltas were built into open water of Lake Middletown and completely blocked the valley at highest altitudes of 160-170 ft (49-52 m). When the ice margin retreated slightly, but still impinged against Cedar Mountain to the northwest, meltwater was ponded behind the heads of the Lake Middletown deltas and spilled across them through a well-developed channel that straddles the Cromwell-Rocky Hill town line just east of Rte. 3 (fig. 5). This channel, called the Dividend Brook spillway (Hartshorn and Koteff, 1968), was the base-level control for several sequential ice-marginal deltaic deposits that make up the northern part of the Cromwell-Rocky Hill-Glastonbury complex. The spillway was carved into the delta surface from about 150 ft (46 m) down to its present floor altitude of 129 ft (39 m). Deepening of the channel was controlled by the presence of Lake Middletown at its mouth, which had lowered to just under 130 ft (39 m) by the time drainage through the spillway ceased.

The Mustard Bowl pits are cut into the first delta controlled by the Dividend Brook spillway. The topset/foreset contact exposed in this delta is estimated to be 146-149 ft (44-45 m) in altitude. North of the Mustard Bowl kettle and east of Dividend Pond (fig. 5), several pit faces expose about 100 ft (30 m) of ice-marginal and deltaic sediments. At the ice contact northeast part of the deposit, coarse-grained severely collapsed ice-marginal deposits are excavated in the lower pit in the floor of the main pit. The north-facing scarp exposes proximal, interbedded gravel and sand foreset beds on the east and, pebbly sand foreset and bottomset beds to the west. In the lower foreset beds, fine to medium sand beds include ripple-drift cross-laminated units and associated draped lamination, interbedded with planar beds. In the middle to upper foreset beds, pebbly sand, pebbly gravel, medium to coarse sand and silty sand beds dipping 10-15 degrees to the southwest show planar beds and megaripples in transverse bed forms. Fluvial gravel topset beds are exposed best in the farthest west scarps above the 150-ft (46-m) contour. The topset bed sequence is 10-12 ft (3-4 m) thick. The pit centered on the Mustard Bowl kettle shows gentle collapse of delta topset and foreset beds toward the center of the kettle. The surface of the isolated ice block that produced the

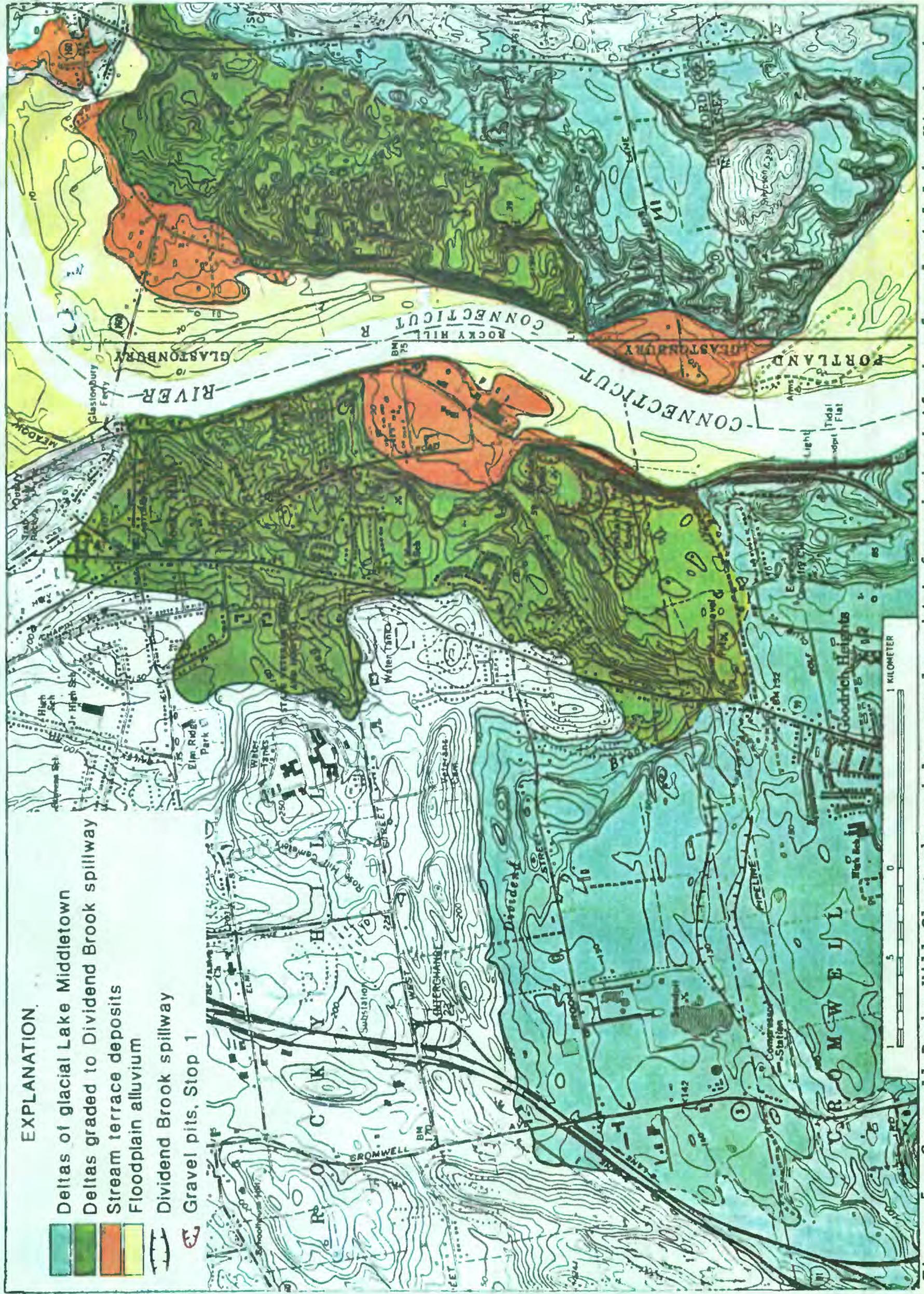


Figure 5. Cromwell-Rocky Hill-Glastonbury delta complex which formed the drift dam for glacial Lake Hitchcock. Base from Hartford South and Glastonbury 7 1/2' topographic quadrangles, 1984 edition.

kettle was at least partly below lake level. By the end of deposition, the ice block was mostly or completely buried by delta sediments derived from meltwater streams issuing from the main ice mass to the northeast.



about 1 km

Figure 6. 1970 aerial photograph of Dividend Brook spillway



Figure 7. New Britain channel (floor shown by shaded area), spillway for glacial Lake Hitchcock New Britain and Hartford South topographic quadrangles, 1946 ed.

erosion; erosional forms downstream along the Brook are appropriate to the Brook itself. The basin of Rockhole Brook is largely occupied by severely collapsed ice-marginal deltas graded to Lake Middletown, with surface elevations of 150-170 ft (46-52 m). Evidently, this delta complex together with extensive bodies of dead ice sufficiently blocked the Rockhole Brook sag, preventing the spillway of Lake Hitchcock from forming there.

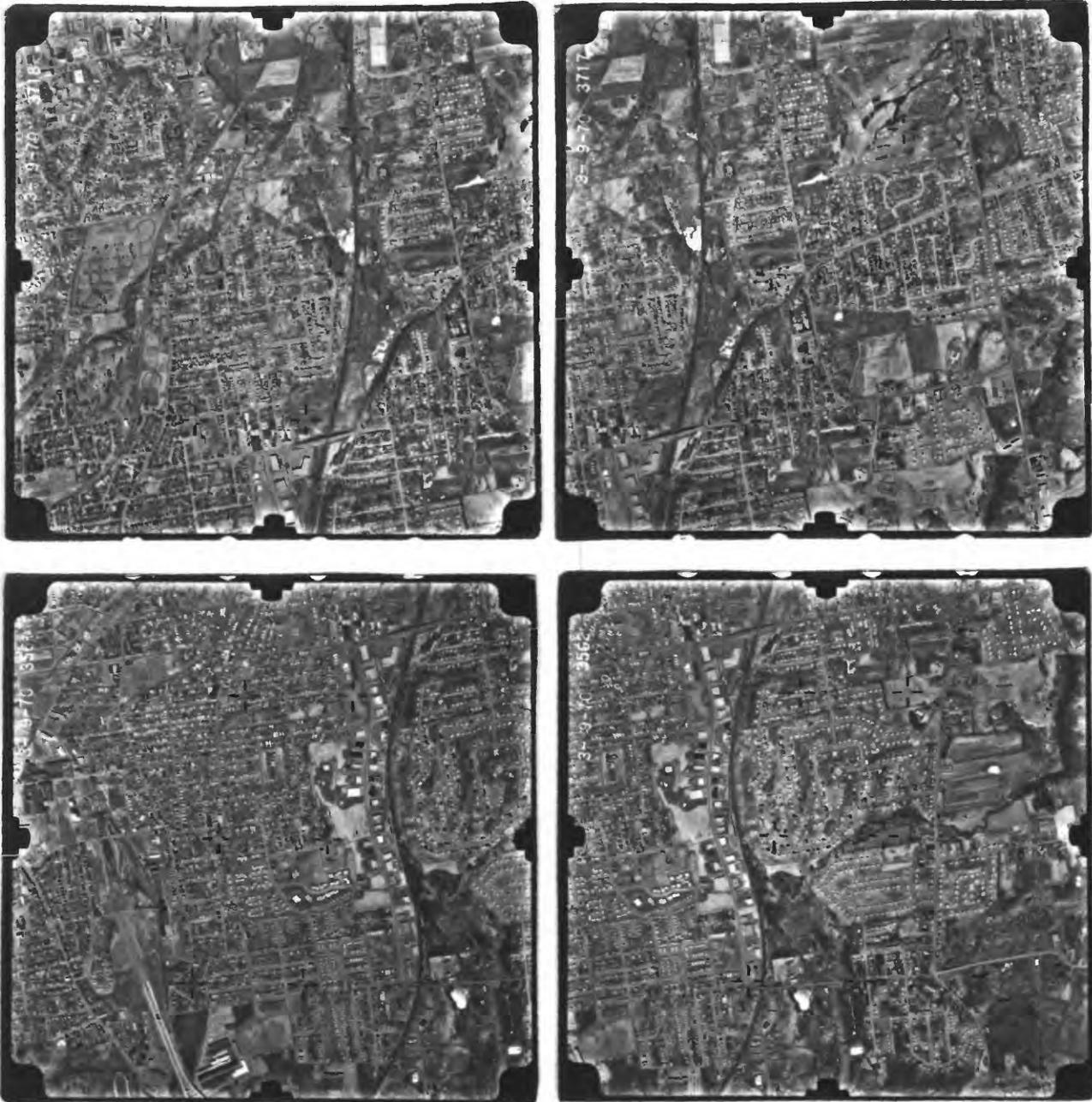
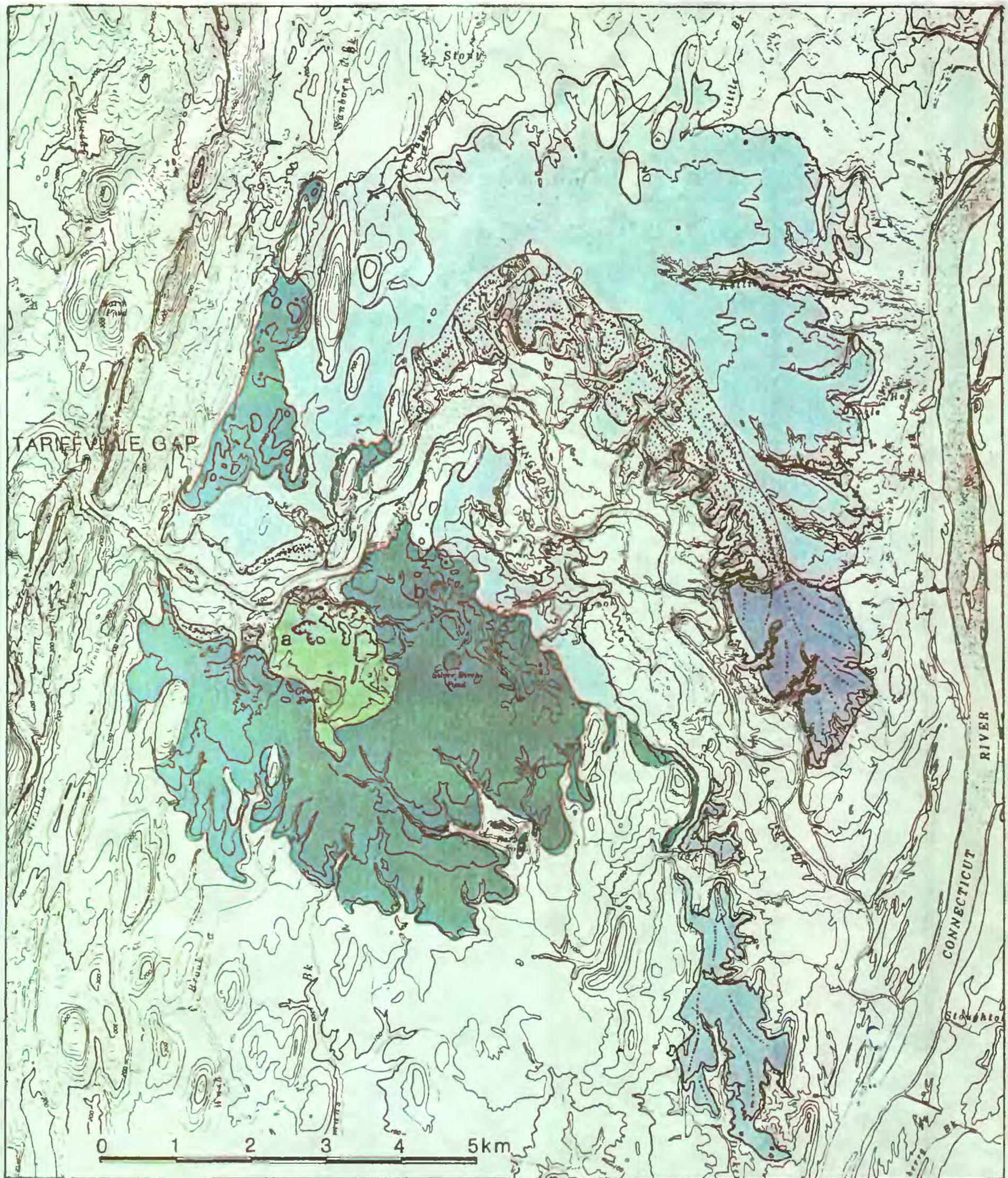


Figure 8. Stereo paired aerial photographs of the New Britain channel spillway area; photographs taken in 1970. Compare with Figure 7.



- Great Pond ice-marginal delta of glacial Lake Middletown
- Windsor ice-marginal delta of glacial Lake Hitchcock, Connecticut phase
- Bradley Field meteoric delta of glacial Lake Hitchcock, stable phase
- Inset fluvial terrace deposits (stippled) and
- Kennedy Road meteoric delta of Lake Hitchcock, post-stable phase
- Gravel pits, STOP 3a, b

Figure 9. Farmington River delta complex.

STOP 3. FARMINGTON RIVER DELTA COMPLEX; town of Windsor, Windsor Locks quadrangle. a) GREAT POND DELTA PIT; Turn north off Prospect Hill Road, 0.15 mi (0.24 km) east of junction with Blue Hills Ave. (Conn. Rte. 187). Travel 0.5 mi (0.8 km) to tobacco barns; continue on dirt road past barns to pit. b) WINDSOR DELTA PIT; Turn north off Prospect Hill Road 1.0 mi (1.6 km) northeast of junction with Day Hill Road, onto Long Road; Turn left onto new development road about 1500 ft from Long Road junction.

The Farmington River delta complex fans out to the north and south in the lower reaches of the Farmington River (fig. 9). The separate deltas of the complex were built into successively lower lake levels and resulted from progradation over a relatively long period of time, from ice-marginal deposition when lake levels were high, through Farmington River meteoric deposition during a long stable phase, to a short post-stable phase.

The Great Pond delta (fig. 9) is the earliest and highest level delta in the Farmington River complex. It prograded southwestward from a NW-trending ice-margin position which marks the west side of the Connecticut Valley ice lobe (figs. 1 and 2). At the time of Great Pond delta deposition, Lake Middletown still covered the New Britain Channel area but at a considerably lowered level; probably just prior to the emergence of the New Britain-Newington divide and the initiation of Lake Hitchcock as a separate lake.

The Windsor delta (fig. 9) was built from an ice margin position about a mile northeast of the head of the Great Pond delta. Progradation of the northern and eastern parts of the delta from the ice margin was in part synchronous with deposition of the western and southern part by distal meltwater entering the lake through the Tariffville Gap (fig. 9). A topset/foreset contact at 178.6 ft measured in the ice-marginal part of the delta (near Stop 3b) projected to the New Britain channel records, a water-level of 117 ft at the spillway threshold. This level, with allowance for a modest depth of water over the spillway, indicates that erosion of the initial 110-115 ft land surface had begun.

The Bradley Field delta (fig. 9) was built northeastward into the lake by water entering the lake through the Tariffville Gap after the ice-margin had retreated from the area north of the present Farmington River. Although deposition in this area probably began while lake levels were still high, the extensive Bradley Field delta was constructed chiefly during the long stable phase of Lake Hitchcock. Altitudes of topset/foreset contacts seen at several construction sites lie on the projected stable-phase lake line. A topset/lacustrine sand contact exposed by backhoe excavation in the northeast part of the delta was surveyed by Stone, Koteff, and Stone at 154 ft; this altitude falls on the stable-phase lake line.

An erosional terrace, inset slightly into the Bradley Field delta is on grade southeastward to delta plains north and south of Farmington River, here called the Kennedy Road delta deposits (fig. 9). These surfaces protrude southeastward from the rest of the delta complex; the fluvial plain of the southern part of this delta is about 10 ft below the Lake Hitchcock stable phase water plane. The base of fluvial sediments in the surface north of the river estimated at 129 ft altitude falls 7-8 ft below the stable lake level.

The relative lowering of lake level recorded by these deposits probably indicates that postglacial tilting had begun at the time of their construction. When the Rocky Hill dam failed and Lake Hitchcock drained the Farmington River cut deeply through the delta complex.

Both pits (3a and b) expose an upward-coarsening sequence of deltaic beds. At the base, several meters of fine-to-medium sand contain laterally extensive beds that are subhorizontal, but in places show dips of less than  $10^\circ$ . Vertical sequences of ripple-drift cross-laminations and draped laminations of white fine sand and red silt record waxing and waning density underflows that flowed on the shallow lake bottom in front of the prograding edge of the delta alluvial plain. In a few places in the pits, sandy foreset beds dip more than  $15^\circ$ - $20^\circ$ . Coarse, pebbly sand, in festooned trough cross-beds, disconformably overlie the lacustrine sand beds. The trough x-beds are overlain by planar-tabular cross-beds of coarse, pebbly sand, and interbedded thin beds of pebble gravel. The trough cross-beds and related gravel beds are interpreted as a coarsening-upward glaciofluvial sequence, related to the prograding braided alluvial plain of the delta.

STOP 4. SCANTIC RIVER DELTA COMPLEX, POWDER HILL ROAD PIT; town of Enfield, Broad Brook quadrangle. From I-91, interchange 47, travel eastward on Hazard Ave. (Rte. 190) 2.4 mi (4 km) through village of Hazardville; turn right (south) on Powder Hill Road; cross Scantic River (rapids over bedrock on left); pit described by Ashley, et al., (1982) on left immediately across River. Continue on Powder Hill Road 0.5 mi (0.83 km) to large pit on left.

Like the Farmington River delta complex, the Scantic River complex records lowering levels of the Connecticut phase and the stable phase of Lake Hitchcock. The early ice-marginal delta south of the Scantic River with surface altitude of 200 ft (fig. 10) was built in front of a NE-trending ice margin into a high level of Lake Hitchcock. A delta surface that reaches 190 ft altitude lies mostly north of the river. Subaqueous beds of this delta, however, extend south of the river along Powder Hill Road and are exposed in the upper section of the Stop 4 pit. This non-ice-marginal delta is at the distal end of a fluvial meltwater terrace which has its ice-marginal head in the Scantic River valley in Massachusetts; it was built into Lake Hitchcock, still in Connecticut phase, but slightly lower than the 200-ft ice-marginal delta. Younger and lower 150-160-ft surfaces lie on the western margin of the delta complex (fig. 10). These surfaces are at the stable-phase Lake Hitchcock level; they were constructed by meteoric water from the Scantic River valley and are probably deltaic although at present there are no pits that display the internal deltaic structure. Thin fluvial sand and gravel beds that are graded to these surfaces underlie the 170-ft terrace surface at Stop 4 and the 150-ft terrace surface above the river bank exposure to the north (fig. 10).



Figure 10. Topographic map of the Scantic River delta complex area.

The sand and gravel pit exposes superposed and contrasting stratigraphic sections of two deltaic morphosequence units, capped by thin fluvial terrace sediment and eolian sand. The lower unit is well exposed in the lower west pit wall where it comprises a coarsening-upward sequence of beds; from top to bottom:

Unit	Thickness	Description
1)	1-2 m	pebble gravel, with abundant poorly sorted coarse sand matrix, in massive beds. Gravel clasts are red sandstone, basalt, and crystalline rocks; coarse sand contains abundant red sandstone rock fragments. This unit thickens in the southern end of the exposure where thin sand beds and disrupted gravel clast fabric shows probable ice-meltant, collapse deformation.
		----- sharp contact -----
2)	0-0.6 m	flowtill; red, compact, matrix supported diamict sediment; unit is lens-shaped in outcrop, about 6 m long; matrix is silty-sand; clasts are chiefly angular red sandstone.
		----- sharp contact -----
3)	1 m	silt and fine sand beds, interbedded with thin lenses, less than 10 cm thick, of compact sandy red flow-till.
		----- covered interval -----
	1-2 m	medium-coarse sand and pebbly sand in thinly bedded and laminated foreset beds; which dip south-southeast.

The lower unit extends across the pit floor to the east wall where red compact, flow till is poorly exposed at the base. Similar beds exposed in lower parts of two sections along the river to the north, described by Ashley et al. (1982), indicate that the top of this unit slopes northward and is the collapsed proximal part of the ice-marginal 200-ft delta.

The upper unit is best exposed in the east pit wall, where it is 3-4 m thick. It is chiefly medium to fine sand in horizontal beds containing cosets of climbing-ripple cross-laminations and related draped laminations. The sand is salt and pepper, quartz and dark heavy-minerals with conspicuous biotite. This unit thickens by way of a downward sloping lower contact to the exposure at the south end of the pit. Here, ripple laminations and intrastratal fluid-escape structures are exposed. The lateral continuity of the beds, the stacked vertical sequences of ripple laminations, and the lack of gravel and cross-bedded coarse sand units indicate that these beds are glaciolacustrine in origin, similar to beds in upper part of stream sections to the north (Ashley et al., 1982). These are delta bottomset beds.

Fluvial coarse pebbly sand and thin pebble-gravel beds disconformably overlie the bottomset sandbeds in the upper part of section. Terrace sediments are overlain by gray-buff (oxidized) massive fine sand of eolian origin (Colton, 1965).

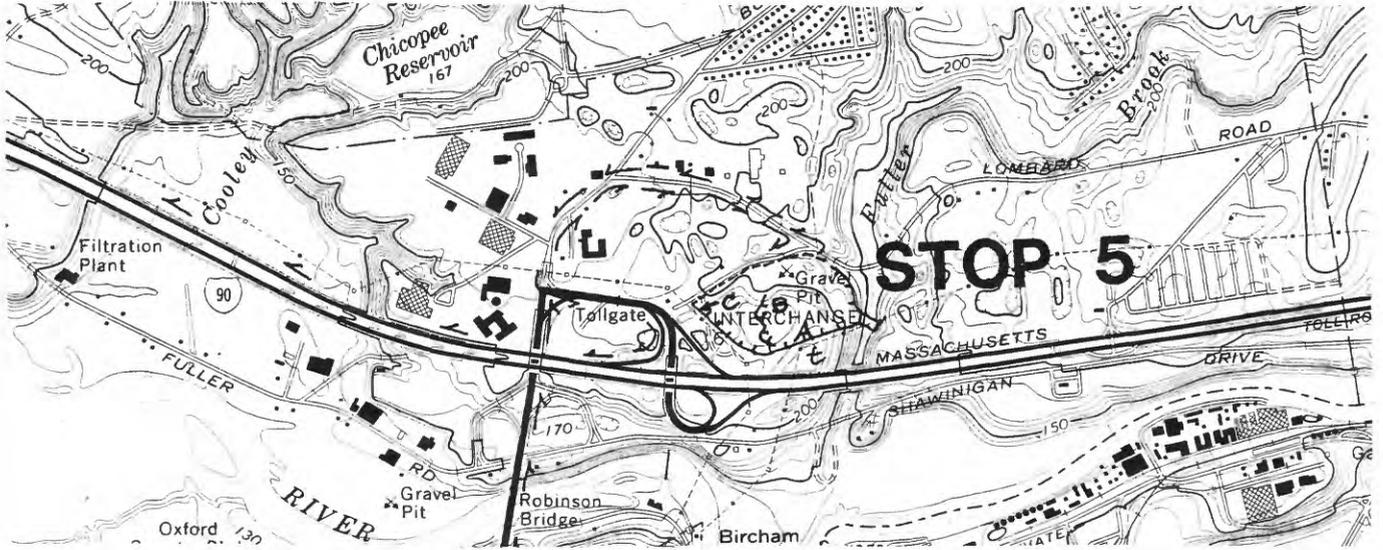


Figure 11.

STOP 5, ZIELINSKI PIT (formerly BASKIN PIT) is located just northeast of, and adjacent to, Exit 6 of the Massachusetts Turnpike, Chicopee, MA. There are three main aspects in this pit: (A) brown till up to 45 ft (14m) thick on the east side of the south wall, (B) low-angle distal foreset beds and proximal bottomsets in an east-facing exposure trending north-south near the middle of the pit, and (C) minor glaciotectonic features associated with the Chicopee readvance at the western end of the pit.

"When first observed in 1977 this pit was less than one-half the size of the present pit. Reddish-brown lodgement till was exposed on the southeast side of the pit. A curved exposure with deltaic beds 9 meters high extended southwest, west, and then northwest from the till. Dune bedding in deltaic topsets indicated transport directions between due west and southwest. No evidence of readvance was noted at that time. By June, 1982, the pit had been expanded nearly to its present size, its growth being limited by powerlines. At the western end of the pit were exposed a series of imbricate thrust faults striking N 70 E and dipping 38 NW. Within the sediments above the thrust faults was a sloping surface marked by pebbles and small lenses of reddish-brown till. I interpret the sloping surface as a gliding plane upon which the margin of the eastern sublobe readvanced a short distance. The readvancing ice was relatively clean as it left little debris on the gliding plane when it melted." (Larsen, 1982, NEIGC Guidebook)

The deltaic beds described above included topsets and foresets (now removed) of a small ice-contact delta that had a surface elevation over 230 ft (70m). It appears that the delta was built to the southwest between a northeast-southwest-trending ice margin on the northwest and the northeast-southwest-trending till ridge on the southeast. Given its surface elevation and the fact that 1.4 mi (2.4km) to the northwest we have a measured topset/foreset contact at 225 ft (68.6 m), we can surmise that

this delta was built into either a lowering phase of Lake Hitchcock or into a drift-dammed lake. In either case, this delta was not built into low, stable Lake Hitchcock.

At present, minor glaciotectonic features at the west end of the pit are still observable. This site is located within the zone of the Chicopee readvance, a 2 to 2.5 mile-wide (3 to 4 km) belt in which exposures of readvance till and other associated glaciotectonic features occur (Larsen, 1982). It is not known whether the ice margin readvanced 2 to 2.5 miles (3 to 4 km) or whether it underwent oscillatory retreat through this zone. In either case, the ice margin was that of an active ice lobe that retreated northward in the Connecticut Valley of Connecticut and Massachusetts.

\* \* \* \* \*

Figure 12.



STOP 6 , MCKINSTRY AVENUE PIT, is located 1.5 miles (2.5 km) N 85 W of Exit 5 of the Massachusetts Turnpike. At the northwest corner of the pit are two fresh exposures. On the east 3 to 4 feet (0.9-1.2m) of pebbly coarse sand overlies 10 feet (3m) of fine sand with ripple crossbedding dipping to the south. At the exposure on the west 5.5 to 6.5 feet (1.7-2.0m) of pebbly coarse and medium sand rest disconformably over 8 to 9 feet (2.4-2.7m) of fine sand with ripple crossbedding dipping to the north. Both planar and trough crossbeds are well displayed in the upper pebbly unit. The average direction of dip from 10 measurements taken in the fluvial crossbeds is S 48.5 W. The upper pebbly unit is interpreted to be a stream-terrace deposit associated with a terrace with an approximate elevation of 215 feet (65.5m) that extends 1.0 mile (1.6km) to the east. The lower fine-sand unit is interpreted to be the bottom deposits of Lake Hitchcock. The upper fluvial unit probably represents stream-terrace deposits left by the early (post-Lake Hitchcock) Connecticut River.

\* \* \* \* \*

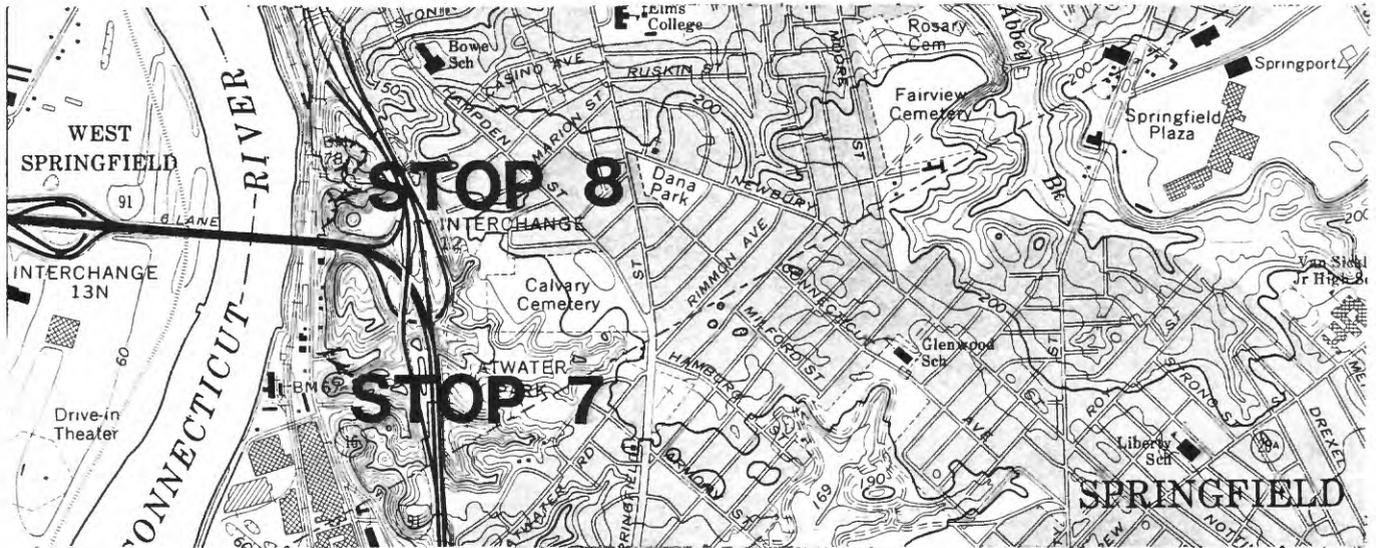


Figure 13.

STOP 7, ENTRANCE TO CENTER AUTO PARTS, is located in the southwest corner of the Springfield North quadrangle. The site is on the east side of Center Street 0.25 miles (0.4 km) south of the I-91 bridge over the Connecticut River. When first studied in 1977, the east-west exposure was 77 ft (24m) long and up to 16.6 ft (5m) high. At present, only 10 per cent of the original exposure is extant and that is in danger of removal. The section measured in 1977 is as follows:

- 0.0-5.9 ft (0.0-1.8 m) undisturbed clay-silt varves
- 5.9-6.1 ft (1.8-1.9 m) brown till
- 6.1-9.6 ft (1.0-2.9 m) sheared and thrust-faulted varves, minor recumbant folds
- 9.6-14.7 ft (2.9-4.4 m) grayish-brown till with lenses of cross-bedded pebbly coarse sand
- 14.7-15.9ft (4.4-4.8 m) deformed varves: gray silty clay, brown silt, minor brown fine sand
- 15.9-16.6ft (4.8-5.1+m) brown till, bottom of till not observed

The section clearly demonstrates readvance of the margin of the Connecticut Valley lobe on the bottom of glacial Lake Hitchcock.

\* \* \* \* \*

STOP 8, PARK WRECKING, is located on the east side of Center Street 0.4 mile (0.64km) north of STOP 7 and 0.15 mile (0.24km) north of the I-91 bridge over the Connecticut River. Two good exposures of Lake Hitchcock bottom deposits are accessible at this site. The clay-silt varves exposed are between 1 and 8 inches (2.5-20cm) in thickness.

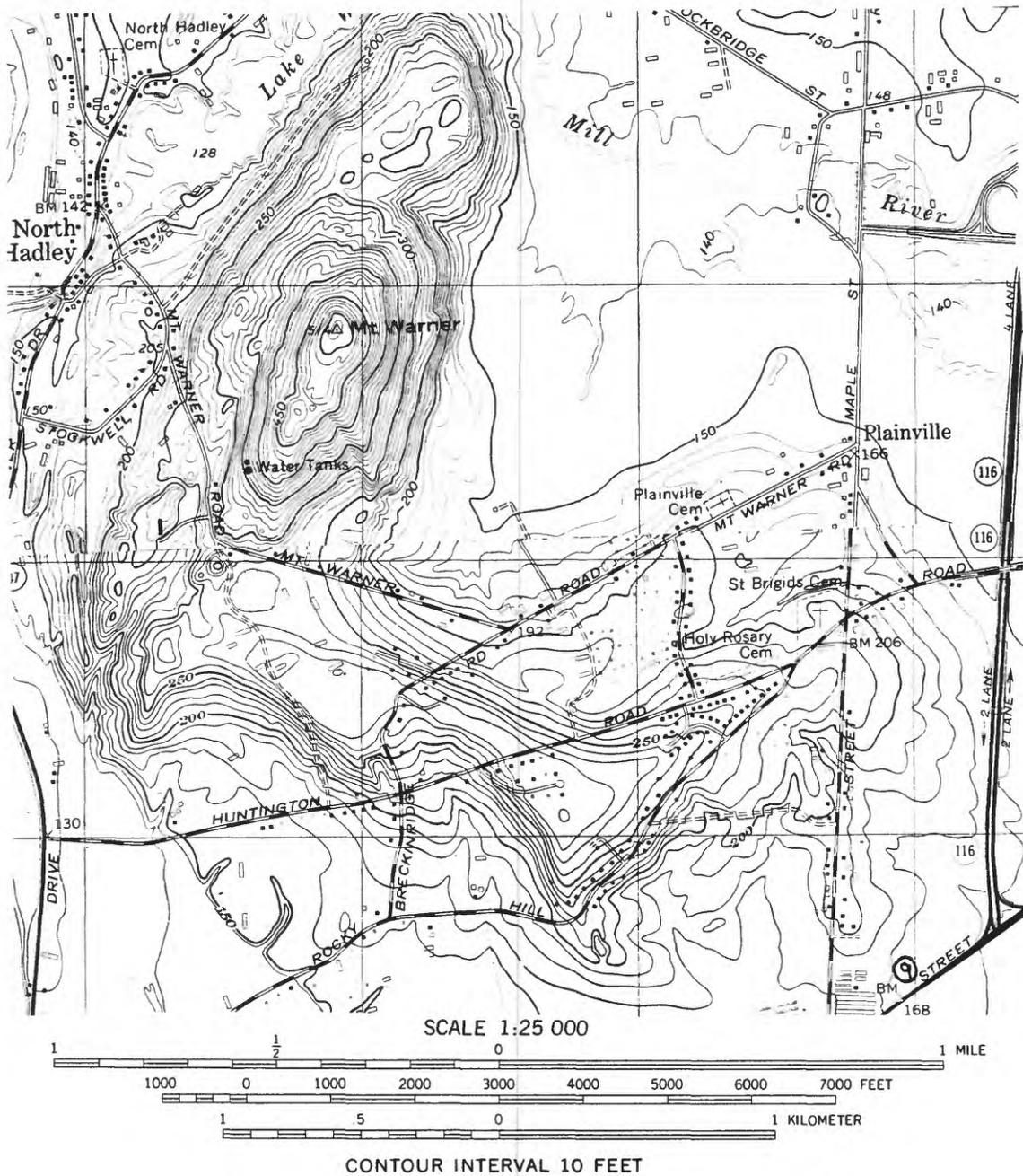


Figure 14. STOP 9. MOUNT WARNER DELTA; town of Hadley, Mass., Mt. Holyoke and Mt. Toby quadrangles. From the junction with I-91 in Northampton east on Rte. 9 for 4.5 mi (7.2 km) to junction with Rte. 116 in Hadley north on Rte. 116 for 0.7 mi (1.1 km) to Rocky Hill Rd., west 0.5 mi (0.8 km) and bear right on Huntington Rd.; west on Huntington Rd., 0.9 mi (1.4 km) to Breckinridge Rd., then north 0.1 mi (0.16 m) to pit entrance.

## STOP 9. MOUNT WARNER DELTA

Some of the description of this deposit is taken from W. A. McIlvride's masters thesis (1982) at UMASS. The Mt Warner delta was deposited directly into Lake Hitchcock from the ice margin and it occupies an area of about 2 mi<sup>2</sup> (5 km<sup>2</sup>) and probably averages 76 m thick. Topset beds are composed of yellowish-brown and reddish-brown sand and pebble to cobble gravel; their thickness increases from less than 2 ft (0.6 m) at the distal end of the delta to as much as 6 ft (2 m) near the center. Bedding in the topsets shows interlayered sand and gravels, cross beds, and scour and fill channel structures. The foreset beds consist of reddish-brown coarse to very coarse sand, with lesser amounts of pebble gravel and fine sand; as much as 50 ft (15 m) of foresets have been exposed. They dip west to southwest from 20 to 25 degrees and even steeper. In the past, the distal foreset slope has been exposed. The northeast facing slope of the delta marks a former ice-marginal position and collapsed beds have been observed there in places. Possible flowtill has been reported by McIlvride to be interlayered with the topsets, but at present time, we are not sure if this exposure is still available. A topset/foreset contact at 278 ft (84.7 m) altitude obtained by Koteff and Larsen from the Mt. Warner delta falls 1 ft (0.3 m) above the profile; in the Florence Street delta in Northampton along the same uplift isobase 5.4 mi (8.6 km) to the WSW, Larsen has obtained a topset/foreset contact altitude of 277 ft (84.4 m), which is exactly on the profile.

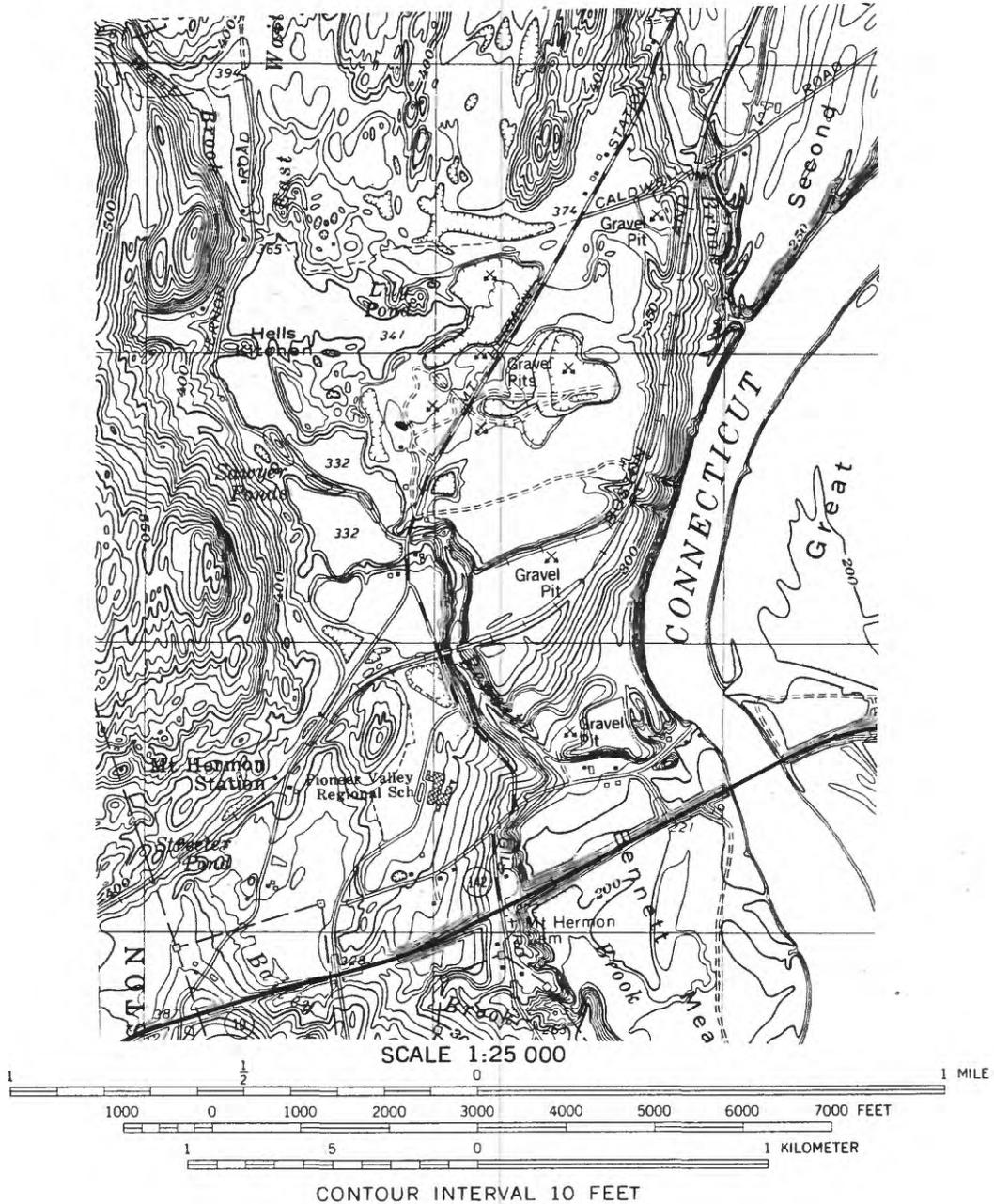


Figure 15. STOP 10. BENNETTS BROOK DELTA; town of Northfield, Mass., Northfield quadrangle. From the junction with I-91 in Bernardston, Mass., east on Rte. 10 approximately 3 mi (4.8 km) to Rte. 142, Gill Rd.; north for a little more than 1 mi (1.6 km) on Gill Rd., to the general area of large gravel pit operations. Excavation at this pit is sporadic, but most accessible part is east of the road.