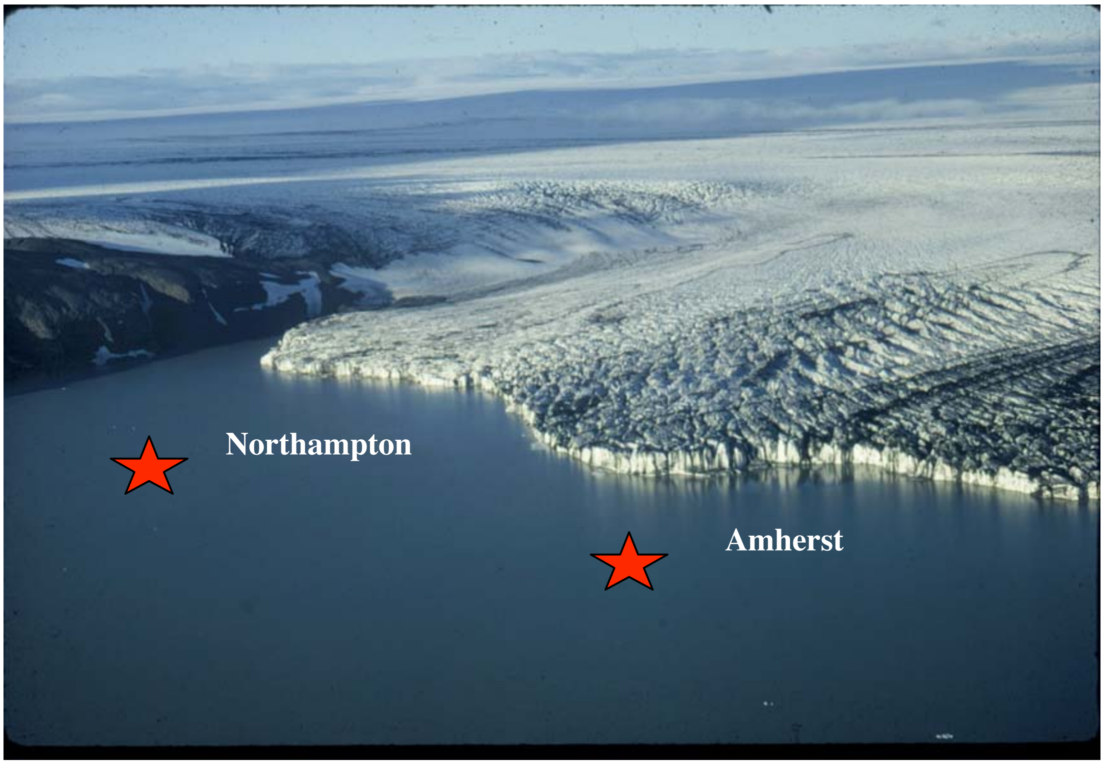
A New Drainage History for Glacial Lake Hitchcock: Varves, Landforms, and Stratigraphy



63rd Annual Reunion of the

North Eastern Friends of the Pleistocene

Field Conference

2-4 June, 2000,

Northampton, MA

Department of Geosciences Contribution No. 73
University of Massachusetts
Amherst, MA 01003-5820
http://www.geo.umass.edu

A New Drainage History for Glacial Lake Hitchcock: Varves, Landforms, and Stratigraphy

63rd Annual Reunion

North Eastern
Friends of the Pleistocene Field Conference

June 2-4, 2000,

The Inn at Northampton, Massachusetts

The trip leaders
Julie Brigham-Grette (UMass-Amherst),
Tammy Rittenour (University of Nebraska),
Janet Stone (USGS – Water Resources Division),
Jack Ridge (Tufts University),
Al Werner, Laura Levy (Mt Holyoke College)
Dena Dincauze, Kit Curran (UMass-Amherst)
Ed Klekowski, (UMass-Amherst),
and Richard Little (Greenfield Community College).

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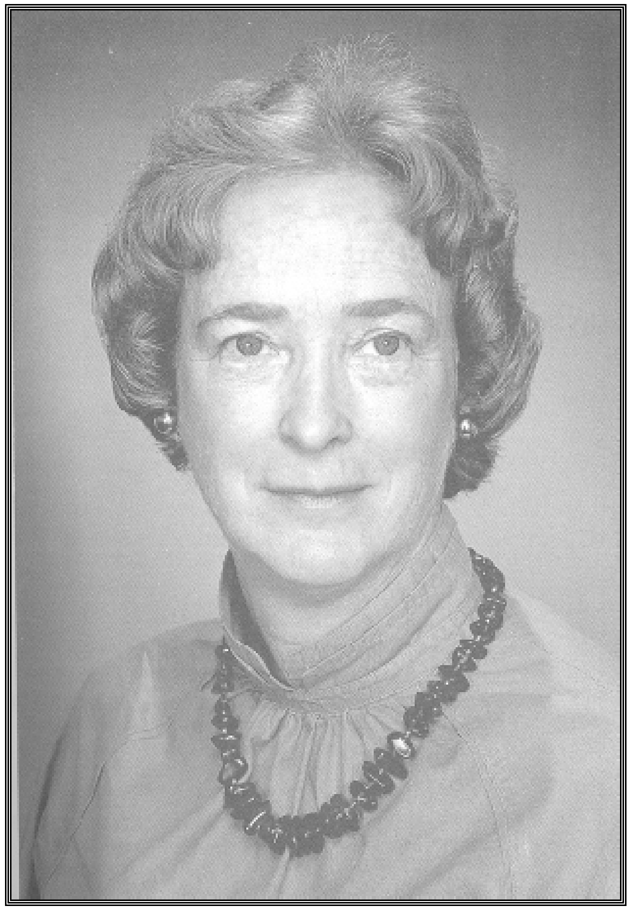
(Cover Photo: Vatnajokull Glacier, Iceland as an analog to the Connecticut Valley region of Central Massachusetts during deglaciation from the Last Glacial Maximum. Photo of Professor Emeritus Joe Hartshorn taken July 1969, archived in the Department of Geosciences, UMass.)

****Dedication****



Professor Dena Dincauze has worked on the archeology of New England nearly all of her professional life. Her name is synonymous with what we know regarding the late glacial/Holocene history of human occupations throughout the region. After working at the Peabody Museum and Department of Anthropology at Harvard and the Anthropology Department at SUNY-Buffalo, Dena came to UMass in the Fall of 1973 to start a 27 year career at UMass-Amherst training and engaging both undergraduate and graduate students in archeology and geoarchaeology. She also assisted the science community at large by serving, for example, as President and President-elect of the Society of Professional Archeologists (1983-1985), as President and President-elect of the Society of American Archaeology (1985-1989), and as editor of *American Antiquity* from 1980-1984, among many other outstanding accomplishments. Her latest book, *Environmental Archaeology: Principles and Practice*, (Cambridge University Press, 350 pgs.), will be out in August, 2000.

Upon the eve of Dena's retirement in December, 2000, we dedicate this FOP volume to her for her friendship and endless dedication to all the dimensions of teaching, research and service to which we can all aspire.

Schedule of FOP Events June 2-4, 2000

Friday June 2

6-10 PM — Welcoming Icebreaker and Registration in the Hampshire Room

The Inn at Northampton (**Trip Headquarters**)
One Atwood Dr. (Interstate 91, Exit 18)
Northampton, MA 01060
Cash Bar available and optional pickup of registration materials

Saturday June 3

7:00-8:00 — Breakfast, pick up registration materials. At the Inn, Coffee is served at 7 AM and buffet breakfast is available at 7:30.

8:15 AM — Field Trip leaves from parking lot at The Inn at Northampton. All participants are expected to ride on the buses provided for the trip (includes restroom facilities). Lots of parking provided for cars at The Inn at Northampton for those driving from elsewhere.

~5:30 PM — Return to the hotel
6:30 PM — Cash Bar
7:30 PM — Buffet dinner, cash bar, and small program

Sunday June 4

7:00-8:00 — Breakfast (. At the Inn, Coffee is served at 7 AM and buffet breakfast is available at 7:30 AM.

8:15 AM — Field Trip leaves from parking lot at The Inn at Northampton All participants expected on the buses provided for the trip (includes restroom facilities)

1:00 PM — Approximate return to Northampton area (trip continues in the Amherst/Northampton area after collecting vehicles after lunch)
3:30 PM — Approximate end of the field excursion. Return to the hotel

Trip Announcement

63rd North East Friends of the Pleistocene
June 2-4, 2000, in the Connecticut Valley
A New Drainage History for Glacial Lake Hitchcock:
Varves, Landforms, and Stratigraphy

This field conference will focus on the classic Late Pleistocene drainage history of Glacial Lake Hitchcock, the large pro-glacial lake system that occupied the length of the Connecticut Valley in central New England. Since 1987 (50th NE FOP), new research by a number of workers has shown that the drainage history was extremely complex and intimately linked to the retreat of the Laurentide Ice Sheet. We will examine evidence that the lake, drained sequentially as a series of subbasins -- a process that likely took thousands of years -- associated with the downcutting of the early Connecticut River through the ancient lake floor as well as through a complex system of ice-contact and meteoric deltas throughout the valley. We will examine the stratigraphy and morphology of glacial, glaciofluvial and lacustrine (varves!) deposits associated with deglaciation along with post-Hitchcock dune complexes. New geochronological control provided by 14C and optically-stimulated luminescence ages shed new light on both the timing of events and gaps in our understanding of the drainage sequence coupled with regional glacioisotatic rebound. The trip headquarters will be at The Inn at Northampton, MA, same site as the 50th FOP.

The trip leaders include Janet Stone (USGS), Jack Ridge (Tufts), Tammy Rittenour (Univ. Nebraska), Julie Brigham-Grette (UMass), and Al Werner (Mt Holyoke College) with cameo appearances by Dena Dincauze (UMass), Ed Klekowski (UMass), and Richard Little (Greenfield CC).

Registration Fee: $65 (includes two lunches, snacks, comfortable buses, guidebook and theme T-shirt): $45 for Students (for the same) DUE APRIL 30th.

Buffet Dinner: $35
(all you can eat)
REGISTER BY MAY 1ST PLEASE

Make checks out to
"Geosciences Fund – 6-30220"
Send registration and dinner fee to
Julie BG-FOP
Department of Geosciences
University of Massachusetts
Amherst, MA 01003
Phone: 413-545-4840 FAX: 413-545-1200

Below is a list of area hotels and *price estimates* for June 2-3. You are **strongly encouraged** to make your lodging arrangements **ASAP** due to other university/college activities in the valley the same weekend. Other area hotels and restaurants are listed at http://virtual-valley.com.

1. **The Inn at Northampton (**Trip Headquarters**)**
   One Atwood Dr. (I/91, Exit 18)
   Northampton, MA 01060
   413-586-1211
   800-582-2929
   email: innoho@javanet.com, http://virtual-valley.com/innatoho
   $119.00 + tax (1-4 people)
   (MENTION "FOP" TO GET THIS SPECIAL RATE UNTIL APRIL 30TH; AFTER THAT NORMAL RATES APPLY)

2. **The Valley Inn- Best Western**
   117 Conz St., Northampton
   413-586-1500
   800-941-3066
   $99.00 + tax (2 people)

3. **Howard Johnsons**
   401 Russell St. /Rte. 9
   Amherst/Hadley
   413-586-0114
   http://virtual-valley.com/hojo
   $115.00 + tax (2 people)

4. **Motel 6**
   State Road / Deerfield
   2 exits north of The Inn at Northampton
   413-665-7161
   nationwide reservations 800-466-8356
   $51.99 + tax (2 people)

5. **Norwottuck Inn**
   208 Russell St. (Rte. 9)
   Hadley, MA
   413-587-9866
   $85.00 + tax (2 people)

6. **Country Belle Motel**
   Rte. 9 / Russell St., Hadley
   413-586-0715
   $75.00 + tax (2 people)

7. **Econo Lodge**
   237 Russell St. (Rte. 9)
   Hadley, MA
   413-584-9816
   $75.00 + tax for 1 Queen or King
   $79.00 + tax for 2 double

Registration Form.

63rd Friends of the Pleistocene

June 2-4, 2000, in the Connecticut Valley

A New Drainage History for
Glacial Lake Hitchcock:
Varves, Landforms, and Stratigraphy

REGISTRATION FORM ------------------------ MUST REGISTER BY MAY 1ST

NAME ____

ADDRESS ____

____

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PHONE:________________________; FAX: ___________________________

EMAIL: ____

Fees: (X those that apply)

________$65 (includes two lunches, snacks, comfortable buses, guidebook and theme T-shirt):
$45 for Students (for the same)

_________Buffet Dinner: $35 (all you can eat)

_________ Total Payment

Make checks out to
"Geosciences Fund - 6-30220"

FAX: 413-545-1200
Phone: 413-545-4840

Send registration and dinner fee to

Julie BG-FOP
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***********Notes ***********

AN INTRODUCTION TO THE NE FOP 2000

Julie Brigham-Grette, Trip Leader

It is the tradition of every FOP trip to provide the faithful followers of this annual field conference with a stimulating look at new research and field data regarding the regional Quaternary history of New England. This year the trip revisits the history of Glacial Lake Hitchcock with a focus on new evidence for the timing of deglaciation, processes influencing lake sedimentation, and factors influencing the drainage sequence and style of Lake Hitchcock. In this context we will also reconsider how the drainage history may be related to the rate and timing of glacio-isostatic rebound. The fundemental challenge of this work is to evaluate changes in sub-basin varve history relative to the sequential incision and evolution of the Connecticut River. New AMS-^{14}C age estimates will be presented to further anchor the Antev's varve chronology. These new ages and revisions to the regional varve sequence provide us with new opportunities for evaluating the varve record as a proxy for high resolution paleoclimate (including teleconnections with El Nino events) in comparison with changes in North Atlantic thermohaline circulation and rapid environmental change over the Greenland Ice Sheet (c.f., Ridge et al., 1999; Rittenour et al., 2000). We have also taken advantage of newer geochronological techniques including the optical luminescence dating of dune complexes on geomorphic surfaces of different relative age. Not to be overlooked is the work of Ed Klekowski and grad student Sean Werle discovering the underwater world of the Connecticut River related to the special habitat offered by eroding submerged varves.

This trip occurs some 12 years after the last FOP in this region which had a similar theme. Though some may have assumed we once had it all figured out based on the work presented at the 1987 FOP, it is the axiom of science that the more we learn, the more we realize just how little we know. The notion that Glacial Lake Hitchcock along its entire length drained as a result of a the erosion of the dam at Rocky Hill has now given way to a new paradigm involving the northward sequential drainage of the lake as a broken series of sub-basins controlled by local dams. Yet the most robust feature of the valley history is the observation that most of the ice-contact deltas all project onto a smooth straight line ("Koteff's curve") suggesting uplift progressed without warping of the regional lake shorelines. The apparent lack of restrained rebound during deglaciation and the need to invoke delayed post-glacial rebound until glacial ice was out of the Connecticut valley is difficult given revisions in lake drainage. What have we overlooked?

I would like to take this opportunity to thank all of the trip leaders for their contributions to this guidebook and to the science presentations at the road stops. I especially want to thank Trent Hayden and Celeste Cosby, two of my current graduate students who were continuously willing to help out with the management of the registration forms, headcounts, envelope stuffing, local arrangements, and more.

Article A. RIDGE ET AL, 1999

Varve, paleomagnetic, and ^{14}C chronologies for Late Pleistocene Events in New Hampshire and Vermont (U.S.A.), Geographie physique et Quaternarie, v, 53, o.1, 79-106

Article B. SPILLWAY GEOLOGY

excerpted from Koteff, Carl, Stone, J.R., Larsen, F.D., Ashley, G.M., Boothroyd, J.C., and Dincauze, D.F., 1988, Glacial Lake Hitchcock, postglacial uplift and post-lake archeology, in J. Brigham-Grette, ed., Field trip Guidebook, American Quaternary Association 1988: University of Massachusetts Department of Geology and Geography Contribution 63, p. 169-208.

Article C. PINGO GEOLOGY

excerpted from Stone, J.R. and Ashley, G.M., 1992, Ice-wedge casts, pingo scars and the drainage of glacial Lake Hitchcock, Trip A-7 *in* Robinson, Peter, and Brady, J.B., eds., Guidebook for fieldtrips in the Connecticut Valley region of Massachusetts and adjacent States, New England Intercollegiate Geological Conference 84th Annual Meeting, Amherst, Mass., Oct. 9-11, 1992: University of Massachusetts, Geology and Geography Contribution 66, vol. 2, p. 305-331

Article D. GLACIAL LAKE HITCHCOCK

excerpted from the Quaternary Geologic Map of Connecticut and Long Island Sound Basin (Stone and others, 1998; U.S. Geological Survey Open File Report OF 98-371)

Glacial Lake Hitchcock existed in the upper Connecticut River basin in Connecticut, Massachusetts, Vermont, and New Hampshire, lengthening to at least 185 mi as the ice retreated northward to the vicinity of Burke, Vt. The Connecticut River valley was dammed to an altitude of l50 to l60 ft in the vicinity of Rocky Hill and Glastonbury by deposits of glacial Lake Middletown (**Mc** and **db**); this mass of stratified drift is often referred to as "the Rocky Hill dam." The spillway for Lake Hitchcock was not over the dam, however, but at the lowest place across the Mattabesset River drainage divide between the Hartford basin and the Middletown-Berlin basin in New Britain. When the ice margin first retreated into the Hartford basin, north of that divide, glacial Lake Middletown water covered the later New Britain spillway location and early ice-marginal deltas in the Hartford basin were controlled by glacial Lake Middletown. Not until glacial Lake Middletown had dropped to below 115 ft could the New Britain spillway area emerge and glacial Lake Hitchcock exist as a separate water body; this occurred at about the time that the ice margin was at Windsor and East Windsor.

During the early life of glacial Lake Hitchcock, the New Britain spillway was eroded into till and older stratified drift so that water levels at the spillway dropped from about 115 ft to 82 ft in altitude (Langer, 1977; Langer and London, 1979). In Connecticut, all ice-marginal and distal meltwater-fed deltas, as well as one small delta built by meteoric water, record lake levels higher than the longer lived stable level. These deltas show a gradual lowering of lake level as the ice retreated northward and the New Britain spillway was incised down to bedrock. Ice-marginal deltas in Windsor (**Hhw**) and East Windsor (**Hhe**) record 110- to 115-ft levels at the spillway. To the north, ice-marginal deltas in Suffield (**Hhr**) and Enfield (**Hhs**) indicate 105- to 110-ft levels at the spillway; still farther north in Suffield and Enfield, Shea Corner (**Hhc**) and Enfield (**Hhn**) deltaic deposits of record levels just below 100 ft at the New Britain spillway. This early phase of glacial Lake Hitchcock is recorded by ice-marginal deltas that are found well into southern Massachusetts and that were built to lake levels between 85 and 95 ft at the spillway. This higher-than-stable-level phase of the lake is referred to as the "Connecticut Phase" (Koteff and others, 1988). It is important to note that deepening of the spillway channel was controlled by conditions 30 to 40 mi to the south, because earlier workers have always considered that the New Britain spillway was an independent control for lake levels. Base level for waters exiting the spillway was controlled by down-cutting in the lower Connecticut River valley and by lowering levels of glacial Lake Connecticut in the Long Island Sound Basin. The Rocky Hill dam area was glacio-isostatically depressed about 145 ft and the New Britain spillway area was depressed about 165 ft more than the area at the mouth of the Connecticut River. In order for the New Britain spillway to lower by 33 ft during the early phase of the lake, glacial Lake Connecticut had to have already lowered to below -82 ft (-25 m) in altitude.

Delta levels in Massachusetts indicate that a stable lake level, 82 ft in altitude, had been reached by the time the ice margin had retreated to just north of the Chicopee River valley; regional correlation of ^{14}C dates (Stone and Borns, 1986) place the ice front in this position at about 15 ka. The 82-ft level indicates that the water flowing through the spillway was about 24 ft deep because its bedrock floor today is at about 58 ft in altitude. Altitudes of topset-foreset contacts of ice-marginal deltas, from southern Massachusetts to the lake's northernmost extent, project to the stable level (82 ft at the New Britain spillway) on a straight line which is tilted up to the north-northwest at a slope of 4.74 ft/mi. The linearity of these projected delta altitudes indicates that the lake level was stable during the time of ice retreat from Chicopee, Mass., to Lyme, N.H., and that postglacial rebound of the land surface did not begin until after all ice-marginal deltas had been built, probably between 14 and 13.5 ka (Koteff and Larsen, 1989). Deltas that were not associated with the ice margin, but rather were built by meteoric water in most river valleys that entered the lake, also project to the stable lake level. In Connecticut, these include unit **Hlh** associated with the Hockanum River, unit **Hls** associated with the Scantic River, and unit **Hlb,** where the Farmington River constructed a large delta northeastward into the lake in the area now surrounding Bradley International Airport. The Bradley International Airport delta covers about 20 mi^2 and the fact that its entire surface (which is tilted up to the N. 21° W. in the amount of 4.74 ft/mi) is graded to the stable 82-ft level provides evidence for the long duration of the stable level and also indicates that the lake was not affected by glacio-isostatic tilting until after nearly all of its deltas had been constructed.

It is important also to note that the New Britain spillway could not have lowered further than the 82-ft level. This is because the 82-ft altitude at the New Britain spillway is equivalent to a -82-ft altitude at the mouth of the Connecticut River when the 164 ft of differential depression between the two localities is taken into account. The base of the channel, through which the paleo-Connecticut River carried water that spilled from glacial Lake Hitchcock, was imposed on bedrock at -89 ft (-27 m) in altitude at the mouth of the present Connecticut River east of Saybrook Point; this point was the actual control for the "Stable Phase" (Koteff and others, 1988) of glacial Lake Hitchcock. The "Stable Phase" of glacial Lake Hitchcock lasted from about 15 ka until about 13.7 ka; during this time, the southern part of the basin (south of the Holyoke Range in Massachusetts) was largely filled with deltaic and lake-bottom sediments. Preserved lake-bottom surfaces in Connecticut are at about 45 ft in altitude in the south and 145 ft in the north; the tilted stable-level paleowaterplane over this area is at 63 ft in altitude at the north edge of the Rocky Hill dam and 172 ft at the Massachusetts border; thus, toward the end of the "Stable Phase" before the dam was breached, water depths in the lake were only 20 to 25 ft. Because the bedrock basin that contained the lake north of the Holyoke Range in Massachusetts is deeper, the lake was not filled with sediment to the extent that it was in the southern basin. North of the Holyoke Range in Massachusetts, preserved lake-bottom surfaces are at 150 ft in altitude, and at the end of the "Stable Phase" water depth was about 150 ft.

Fluviodeltaic deposits (**ft** and **hf**) built southeastward into the lake by the Farmington River record a "Post- stable Phase" (Koteff and others, 1988) of the lake during which levels were lower than the 82-ft level at the New Britain spillway. A topset-foreset contact in the **Hf** deltaic deposits north of the Farmington River is at 127 ft; delta-surface altitudes in the same unit to the south of the river indicate slightly lower water levels. These levels project southward below the New Britain spillway level to 50 to 60 ft in altitude at the Rocky Hill dam and record lowering of lake levels as the dam was entrenched. A preserved 55-ft terrace inset into the Rocky Hill dam sediments on both sides of the present Connecticut River in Rocky Hill and Glastonbury records this "Post-Stable Phase" which was relatively brief in Connecticut. A ^{14}C date 13,540±90 B.P. (Beta-59094, CAMS-4875) on plant debris in lacustrine sands at the top of the lake-bottom section (radiocarbon-dated locality #9) associated with the Farmington River deltaic deposits (**Hf**) delta establish that the time of dam breech was at about 13.5 ka.

The dam most likely was breached by headward erosion of streams on its south side, possibly by ground-water sapping and possibly aided by earthquakes generated by the initiation of postglacial rebound. Regardless of the mechanism by which the dam was breached, glacial Lake Hitchcock could not lower below stable level, much less drain, until its bed was raised by glacio-isostatic tilting. Dam breaching and initiation of isostatic rebound was required in order to establish the lower water-level altitudes recorded in the "Post-Stable Phase" Farmington River deltaic deposits (**Hf**). Once this process began, it proceeded rapidly as the dam was incised from just above 60 ft in altitude (the stable level at the dam) to just above 40 ft; once this 20 ft of lowering was accomplished, glacial Lake Hitchcock, south of the Holyoke Range, was entirely drained and the newly formed Connecticut River began to incise the lake floor (along the terraces of unit **st**) over the 50-mi stretch between the Holyoke Range and the breached dam. Glacial Lake Hitchcock continued to exist north of the Holyoke Range with initial water depths of about 130 ft (lowered from stable level by only 20 ft); continued lowering of the lake was controlled by the rate of rebound, which made it possible for the lake bed south of the Holyoke Range to be incised.

An approximate 4,000-year life span for glacial Lake Hitchcock was indicated by Antevs (1922) through a method of correlating varves in clay pits from Hartford, Conn., to the north end of the lake basin in St. Johnsbury, Vt. This method assumes that the silt-clay varve couplets are annual summer and winter layers and that regional seasonal fluctuations affected the thickness of individual varves over the entire lake basin. Varved silts and clays of glacial Lake Hitchcock were used to construct Antevs' (1922) New England varve chronology between varve-year 3,001 and varve-year 7,000. Recently, Ridge and Larsen (1990) fit a 533-year varve section from Canoe Brook in southern Vermont into the relative varve chronology of Antevs (1922); they also placed the chronology in an absolute time frame with a 12.4 ka ^{14}C date on plant debris in the Canoe Brook section at the position of varve 463 (varve 6,150 in the Antevs chronology). Using this calibration of the varve chronology, lacustrine deposition at the south end of glacial Lake Hitchcock (varve 3,001) began at about 15.5 ka. The early Connecticut phase was followed by the longer stable phase of the lake which lasted until about 13.5 ka (varve 5,050). The post-stable phase of the lake, which lasted only briefly in Connecticut, continued for another 2,000 years north of the Holyoke Range until about 11.5 ka (varve 7,000) (Stone and Ashley, 1992, 1995; Stone, 1999).

POSTGLACIAL CONDITIONS

Postglacial deposits in Connecticut include stream-terrace (**st**), talus (**ta**), dune (**d**), floodplain alluvium (**a**), swamp (**sw**), salt-marsh (**sm**), beach (**b**), fluvial-estuarine channel-fill (**ch**), and marine delta (**md**) deposits; the onset of postglacial conditions was time-transgressive and began several thousand years earlier in the southern part of the State than in the northern parts.

In the Long Island Sound Basin, significant postglacial events include the drainage of the glacial Lake Connecticut and subsequent sea-level rise. The remnant glacial lake was probably completely drained by 15.5 ka and a fluvial channel system (linear scarp symbol on map) was being carved on the lake floor by meteoric streams flowing to the south in coastal Connecticut, and to the north on the north shore of Long Island; these tributary channels joined a major east-west trending trunk channel which also received distal meltwater drainage from the Hudson River valley to the west (Stanford and Harper, 1991). The channel system exited the Basin through the lake- spillway notch in the end moraine at The Race and provided a path through the moraine for transgression of the sea from the south (Lewis and Stone, 1991). Minor fluvial sediments were deposited in the bottoms of the channels during the time that they were occupied by streams. The channels are filled predominantly with estuarine sediment (**ch**) deposited as the early postglacial sea flooded these low-lying areas of the drained lake basin when eustatic sea-level began to rise significantly between 15 and 16 ka (Fairbanks, 1989; Bard and others, 1990) and before glacio- isostatic rebound began.

A major wave-cut marine unconformity (**mu** on seismic section **C-C'**) was cut across the top of the estuarine channel fill and over higher lake deposits as sea level rose. The marine unconformity is present in seismic sections up to altitudes of about -25 m, indicating that sea level probably rose to this height in central Long Island Sound before crustal rebound began.

Figure 7 shows a conceptual relative sea-level curve for central Long Island Sound (highlighted line). The curve was derived by combining the glacio-eustatic sea-level curve from Barbados (Fairbanks, 1989; Bard and others, 1990) with a curve representing the timing and total depth of glacio-isostatic depression in central Long Island Sound. The uplift curve is based on several assumptions (listed on diagram) that are indicated from regional evidence, some of which is presented in this report and in others (Koteff and Larsen, 1989; Stone and Ashley, 1995). The presence of the extensive marine delta (**md**) that records a -40-m relative sea level in central Long Island Sound (Lewis and Stone, 1991; Stone and Lewis, 1991) provides good evidence for the conceptualized relative sea-level curve. The large volume of delta sediment required a significant length of time for construction and the constant -40 m depth of the topset-foreset contact indicates that relative sea level was stable during the deposition of the delta. The only possible source of the great volume of sediment contained within the marine delta was the drained lakebed of glacial Lake Hitchcock in the Connecticut valley to the north. This sediment supply became available only when the stable phase of Lake Hitchcock ended at about 13.5 ka; as previously discussed, glacio-isostatic uplift had to occur in order for glacial Lake Hitchcock to drain. Regional evidence from northern New England (Barnhardt and others, 1995; Koteff and others, 1993; Koteff and others, 1995) also indicates that isostatic rebound began around this time. Thus, the early rapid rate of uplift was balanced with the equally rapid rate of eustatic sea-level rise resulting in a sea-level stand in Long Island Sound at about -40 m for several thousand years (between 13.0 and 9.5 ka). During that time, the marine delta was built and the Connecticut River terrace and floodplain surfaces were incised. Recently obtained ^{14}C dates (9,370±100 Beta-52257, 8,530±80 Beta-52256) on basal organic material beneath the lowest terrace surfaces along the Connecticut River in Massachusetts indicate that most of the postlake

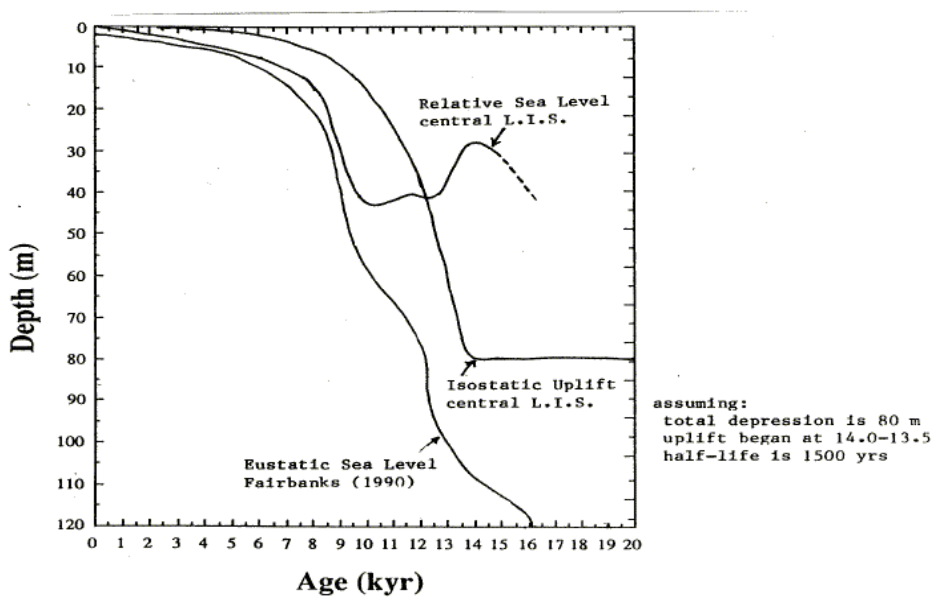

Figure 7. Conceptual relative sea level curve for central Long Island Sound.

incision into the lakebed had been accomplished by ~9.0 ka (Stone and Ashley, 1992). The volume of eroded lakebed sediment, as calculated from the area and depth of incised terraces, is 12 billion m^3; this material now composes the marine delta, the calculated volume of which is 11.5 billion m^3.

As eustatic rise overtook the rate of isostatic rebound, relative sea level in central Long Island Sound rose continuously; the transgression submerged the marine delta and a blanket of marine mud (seismic unit **mm** shown only in section **C-C'**) accumulated over the entire basin. As marine waters deepened, intense tidal-scour conditions developed in eastern Long Island Sound, resulting in the local reworking of marine-delta sediments and the development of a very large sand-wave field in that part of Long Island Sound (Fenster and others, 1990). A record of 4 to 5 m of sea-level rise during the last 4,000 to 5,000 years is preserved in coastal salt-marsh deposits (Bloom and Stuiver, 1963; van de Plassche and others, 1989; Patton and Horne, 1991; van de Plassche, 1991).

In most of mainland Connecticut, postglacial activity consisted predominantly of incision of glacial deposits by meteoric streams along stream-terrace surfaces, followed by the establishment of floodplains at modern levels. Streams had eroded to modern floodplain levels relatively early, in some cases before 12.0 ka (O'Leary, 1975; Stone and Randall, 1978). Postglacial winds were intense and widespread as indicated by the ubiquitous blanket of eolian sand and silt that overlies glacial sediments throughout the State and in which the modern soil is developed. The postglacial climate was severely cold for several thousand years following deglaciation. Paleobotanical studies reveal that treeless, tundra vegetation dominated by dwarf willow (*Salix herbacia*), sedges (*Cyprus* and *Carix*), herbs and shrubs (*Dryas*, *Artemesia*), dated from earlier than 15 ka to about 13 ka, was present in the area (Davis and others, 1980; Gaudreau and Webb, 1985; Jacobson and others, 1987; Thorson and Webb, 1991). Also, wedge- shaped features with a polygonal-ground pattern, interpreted as ice-wedge casts, deform eolian-sand-capped glacial sediments in numerous localities in Connecticut (Schafer and Hartshorn, 1965; Schafer, 1968; O'Leary, 1975; Stone and Ashley, 1992,). These features indicate that permafrost existed locally in areas where substrate conditions were favorable to its formation. The presence of permafrost structures indicates that mean annual temperatures were below 0°C during the early postglacial time interval.

In the upper Connecticut basin, postglacial conditions were dominated by the continued existence of glacial Lake Hitchcock several thousand years after the ice margin retreated from the area. Extensive fields of eolian sand dunes formed in the treeless environment, indicating the continued effects of strong winds. Dunes are present on the relict deltaic and lake-bottom surfaces of glacial Lake Hitchcock. Dunes on deltaic and high-level lake-bottom surfaces were formed by north to north-northeasterly paleowinds; these surfaces were available as early as 15.5 ka. Dunes on stable-level lake-bottom surfaces were formed by northwesterly paleowinds; these surfaces became available at about 13.5 ka as glacial Lake Hitchcock drained. Evidence that severely cold temperatures persisted until the time of glacial Lake Hitchcock drainage exists due to the presence of hundreds of circular to subcircular, rimmed depressions (interpreted as pingo scars) developed in the drained lakebed sediments (Stone and Ashley, 1989; Stone and others, 1991; Stone and Ashley, 1992). Paleobotanical records indicate a warming of the postglacial climate at about 12.5 ka, accompanied by reforestation of the landscape by successive spruce, pine, and hardwood forests from 12.5 to 9 ka (Davis, 1980; Gaudreau and Webb, 1985; Jacobson and others, 1987).

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. Graphical depiction of positions of Lake Hitchcock surfaces and important features south of the Rocky Hill Dam. Upper part
m shows positions as they occur today; lower part of diagram shows positions after differential depression is reconstructed

.

Figure B. Regional Cross-section showing stratigraphy at the Natianuck Avenue site in Windsor, CT, including subsurface extent of gray and red varves as indicated by local test borings, relative position of nearby Antevs (1922) varve locality 4, and lateral continuity with the post-stable stage Farmington River Delta

Article E. ABSTRACTS WITH FIGURES

Stone, J.R. and Ashley, G.M., 1995, TIMING AND MECHANISMS OF GLACIAL LAKE HITCHCOCK DRAINAGE: Geological Society of America Abstracts with Programs, v. 27, no. 1, p. 85.

Glacial Lake Hitchcock (GLH) and its predecessors, Lake Connecticut and Lake Middletown dominated the deglacial history of Long Island Sound Basin and the Connecticut River Valley for thousands of years following ice retreat from the terminal moraines on Long Island. GLH was the longest-lived of these lakes, recorded by a 300-km-long complex of ice-marginal deltas, meteoric-stream-fed deltas, and varved lake-bottom sediments that extends from the drift dam at Rocky Hill and the spillway at New Britain, Conn. to the vicinity of Lyme, N.H. During early high levels of the lake, the spillway channel was incised about 10 m through drift to bedrock. During the long-lived stable stage of the lake, water level at the spillway was at 25 m altitude. Subsequent post-stable stages of the lake existed at lower levels. The post-stable stage lasted only briefly south of the Holyoke Range in Mass., where the stable stage was relatively shallow, and was accompanied by breach of the drift dam and abandonment of the New Britain spillway. A longer post- stable stage existed for about 2,000 years in the northern part of the basin, where the lake was deeper. Water that spilled from the northern basin carved a broad, 75-km-long channel in the drained lake bed to the south and exited the basin through the breached dam. Sediment eroded from the incised lake bed was deposited as an extensive marine delta in central Long Island Sound at a time when relative sea level stood at -40 m. Detailed mapping from marine seismic-reflection profiles in Long Island Sound, Block Island Sound, and the Connecticut River estuary coupled with regional synthesis onland have revealed features significant to the history of GLH, including the buried paleochannel of GLH drainage through the lower Connecticut River valley, across Long Island and Block Island Sounds, and through the terminal moraine. With consideration of glacio-isostatic depression over the entire drainageway south of GLH *(see inserted figure A),* it is evident that this lake never existed independently; levels were always determined by base levels to the south. During the stable stage of GLH, before rebound took place, the stream profile south of the spillway had an extremely low gradient (<0.00005) and was directly connected to sea level in the Connecticut River estuary that stood at a relative altitude only 2 m lower than the lake level to the north. Under these conditions, it was impossible for GLH to lower below the stable level until glacio-isostatic rebound began. The time at which GLH lowered 4-5 m below stable level (and hence the time of initiation of glacio-isostatic rebound in southern New England) is recorded by a new AMS ^{14}C date (13,540+/-90 BP; Beta-59094/CAMS-4875) obtained on plant fragments in lacustrine bottomset beds of the GLH Farmington River post-stable delta at the Matianuck Ave. site in Windsor, Conn. *(see inserted figure B),* described by Stone and Ashley (1992).

Stone, Janet R., 1999, EFFECTS OF GLACIO-ISOSTACY AND RELATIVE SEA LEVEL ON LATE-GLACIAL AND POSTGLACIAL WATER LEVELS IN THE CONNECTICUT RIVER VALLEY AND LONG ISLAND SOUND: Geological Society of America, Abstracts with Programs, v. 31, no. 2, p. 71.

Glacio-isostatic depression and the position of sea level off the continental shelf south of Long Island and in Long Island Sound (LIS) during early retreat of the late-Wisconsinan ice sheet had a profound effect on the water levels of Glacial Lake Hitchcock (GLH). The lake occupied the Connecticut River valley between about 15.5 and 11.5 ka (radiocarbon years), during which time, lake-level altitudes fell from early high levels between 35 and 26 m, through a long stable period at 25 m, to post-stable levels below 25 m after the Rocky Hill dam was breached. Graphical analysis *(see inserted figure A)* of these ancient water levels is based on present altitudes of the New Britain spillway, stable-level deltas, and lake-bottom surfaces, and base-level controls at the mouth of the Connecticut River and notches through the terminal moraines. All altitudes were adjusted for the total (absolute) amount of glacio-isostatic depression, which is defined by a plane sloping 0.9 m/km to the NNW. The total amount of depression is calibrated from the ~80 m required for the construction of a marine delta at -40-m altitude in central LIS as GLH drained. When surfaces across the entire drainage system are restored to the pre-uplift configuration, it is clear that levels of GLH were ultimately controlled by relative sea level far to the south of the New Britain spillway, and that the lake could not drain until postglacial uplift began. The Rocky Hill dam was breached by 13.5 ka, as recorded by a ^{14}C date from bottomset beds of a post-stable delta just north of Hartford, Conn. *(see inserted figure B)*. Restoration of the pre- uplift lake-bottom surface reveals that initial lowering of lake level by only 10-12 m resulted in the complete disappearance of the lake south of the Holyoke Range in Massachusetts, while a deep lake continued to persist in the northern basin until at least 12.4 ka (as recorded by a ^{14}C date at Canoe Brook, Vt). GLH in the northern basin drained across the exposed lake-bottom surface to the south; this surface was entrenched and terraced as uplift progressed, and eroded sediment was deposited as a marine delta in a -40-m relative sea level stand in central LIS.

Most of the total amount of glacio-isostatic depression was recovered by about 9.0 ka, and the ancestral Connecticut River had entrenched into lake sediments down to levels near the modern floodplain by 8.5 ka. A postglacial sea-level curve for central LIS shows that the rate of glacio- eustatic sea-level rise equaled the rate of crustal uplift, resulting in a stable relative sea level stand at -40 m between 13.5 and 9.5 ka. By about 9.0 ka, the rate of eustatic rise began to exceed the rate of uplift, and sea level in LIS rose rapidly from the -40-m stand.

Article F RITTENOUR ET. AL., 2000

ARTICLE G. KLEKOWSKI E., AND WIER, A., 1997

Ice-Age Lake Under Construction *Sport Diver*, Volume 5, No. 4, p. 14-15, August.

Lake Hitchcock, fed by glacial melt water for approximately 3,000 years, disappeared from the New England landscape about 12,000 years ago. Glacial lakes such as Lake Hitchcock formed geological deposits known as varves, each varve is composed of a couplet consisting of a whitish-gray clay layer and a yellowish-brown silty/sandy layer; a couplet represents a single year, the silty/sand deposited in the short summer during ice melt and the clay layer deposited in the long winter when the lake was frozen.

Although Lake Hitchcock disappeared before the first Amerindians entered the Connecticut River Valley, divers can still explore its waters; and that is what we were doing, forty feet under the Connecticut River, exploring a lake that vanished. The river's current had torn a small underwater canyon through a large block of lake sediment. We swam gently down this cleft, the orderly varves were a time warp back to the ice ages. As we descended deeper and deeper, year after year, decade after decade, and, finally, forgotten centuries passed and were lost from view. What events did they chronicle? The birth of a mastodon, the roar of a saber tooth cat, or perhaps something more prosaic but certainly more important -- the survival of the first tree seedling after the ice retreat.

At 60 feet the varve layers abruptly came to an end. With wetsuits streaked with gray glacial clay, we knelt on the bottom and looked up. Surrounding us was an underwater amphitheater of varves with the upper layers disappearing into darkness. Stacks of clay occasionally crumbled and fell, leaving a plume of gray "smoke" as the clay particles dissolved into the water. Bass and other fish were attracted to these small underwater avalanches in hopes of catching the animals inhabiting the varves.

Lake Hitchcock was one of the largest of the glacial lakes in New England. It stretched from mid-Connecticut to northern Vermont, approximately 175 miles. The impoundment resulted from glacial deposits at Rocky Hill, Connecticut that dammed the ice melt as the last glacier retreated northward. The Rocky Hill dam was breached and the lake drained about 12,000 years ago. The Connecticut River generally follows the course of Lake Hitchcock and, in many places, the river has eroded into and sometimes through the lake-bottom sediments. Diving in these portions of the river is, in many respects, like going back in time and exploring the bottom of Lake Hitchcock.

Descending through the river's waters to the lake sediments, the first varves often appear as ghostly white sheets of clay. Closer examination of these clay surfaces reveals a Swiss-cheese-like texture caused by countless burrows of chironomid larvae, an as yet unknown species of the genus Axarus. Chironomids are midges (insects) whose larvae are aquatic, contain hemoglobin, and are an important component of freshwater food webs. Breaking up a piece of clay releases these red worm-like larvae.

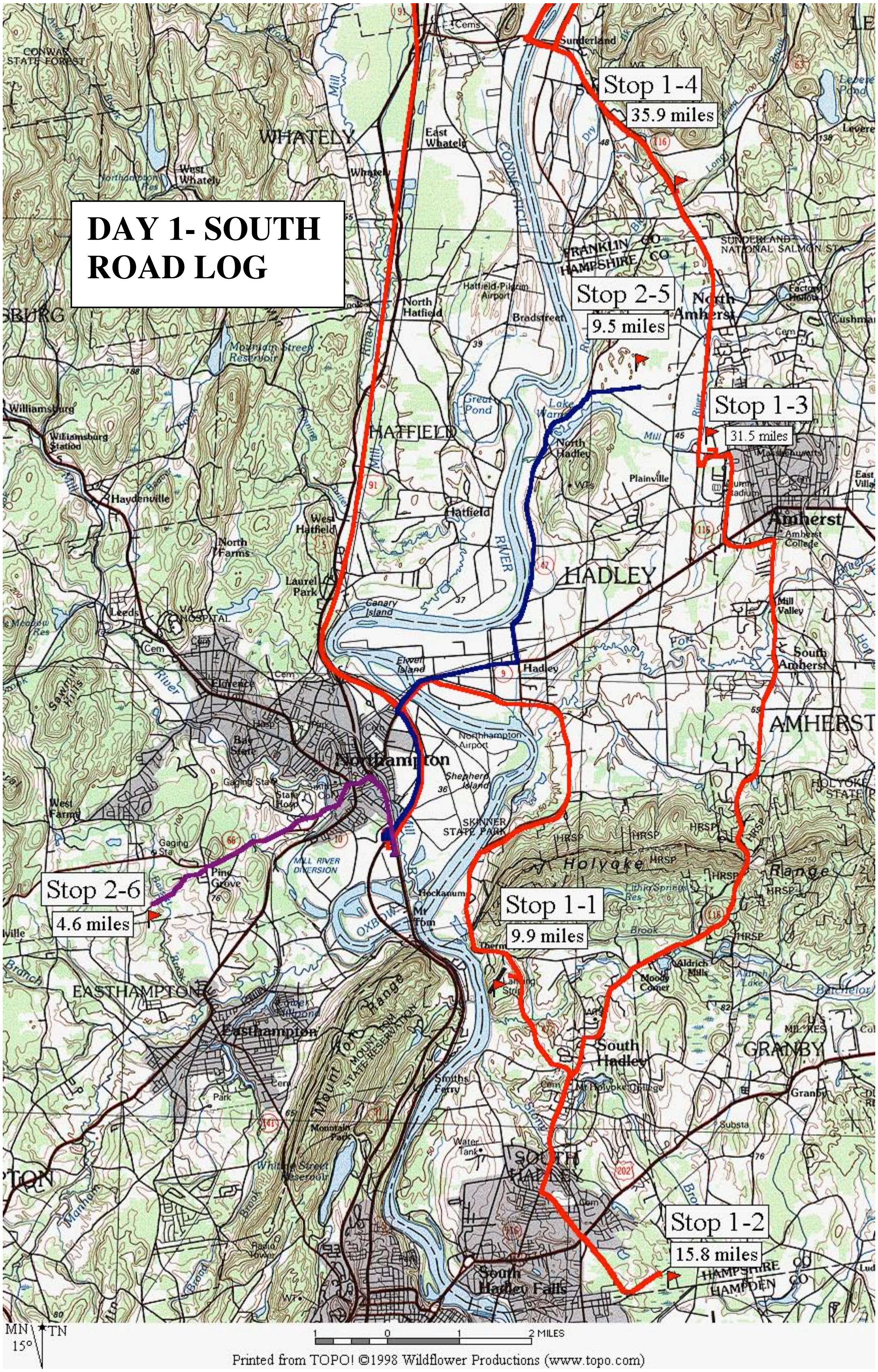
In the deeper part of the river, erosion has cut into the varves and they can be viewed in cross-section. Often the sandy/silty layer of a varve couplet is eroded and undercuts the clay layer. Looking carefully with a dive light into these crevices may reveal a pair of antennae sensing the environment. Looking closer, the diver will find a pair of stalked compound eyes looking back! The Connecticut River crayfish (Orconectes limosus), a solitary bottom dweller, spends its day hiding in crevices or under stones in the river. Its food includes insect larvae (chironomids), smaller crustaceans and dead animal matter. Crayfish are the food of choice for the many carnivorous fish in the river, thus this crustacean's reclusive nature is not surprising.

Very curious concretions of organic matter and carbonate are embedded in the clay portions of the varves and literally carpet the river bottom downstream of exposed and eroding Lake Hitchcock sediments. These concretions are tabular, approximately 6-8 inches across, and resemble puzzle pieces with circular holes punched in them; no two are identical and almost all are very attractive with sensuous, sinusoidal curves. All Lake Hitchcock divers return with a handful as mementos of their visit.

Each varve couplet marks a year; a continuous series of varves is the geological equivalent to the annual growth rings of a very old tree. The thickness of the couplet layers is a record of past environments. The varve couplets beneath the Connecticut River have never been studied and thus may offer new information concerning the rate of ice retreat and climate changes as we exited the last ice age.

In the Northeast the glacier began to retreat about 21,200 years ago. In its wake a series of freshwater glacial lakes were formed. The largest of these was glacial Lake Connecticut, which later became Long Island Sound when sea level rose. Two glacial lakes are traversed by the Hudson River: Lake Hudson in the south and Lake Albany in the north. In New Hampshire the Merrimack River follows the bed of glacial Lake Merrimack. In all of these sites, divers should discover ice age lake sediments similar to those under the Connecticut River.

Check out the Connecticut Valley Web Site organized by Ed at
http://www.bio.umass.edu/biology/conn.river/


DAY 1- SOUTH
ROAD LOG
Stop 1-1
9.9 miles
Stop 1-2
15.8 miles
Stop 1-3
31.5 miles
Stop 1-4
35.9 miles
Stop 2-5
9.5 miles
Stop 2-6
4.6 miles
WHATELY
HATFIELD
HADLEY
AMHERST
Amherst
Northampton
EASTHAMPTON
Easthampton
South Hadley
GRANBY
Holyoke Range
CONNECTICUT RIVER
HAMPSHIRE CO
HAMPDEN CO
FRANKLIN CO
MN
TN
15°
2 MILES
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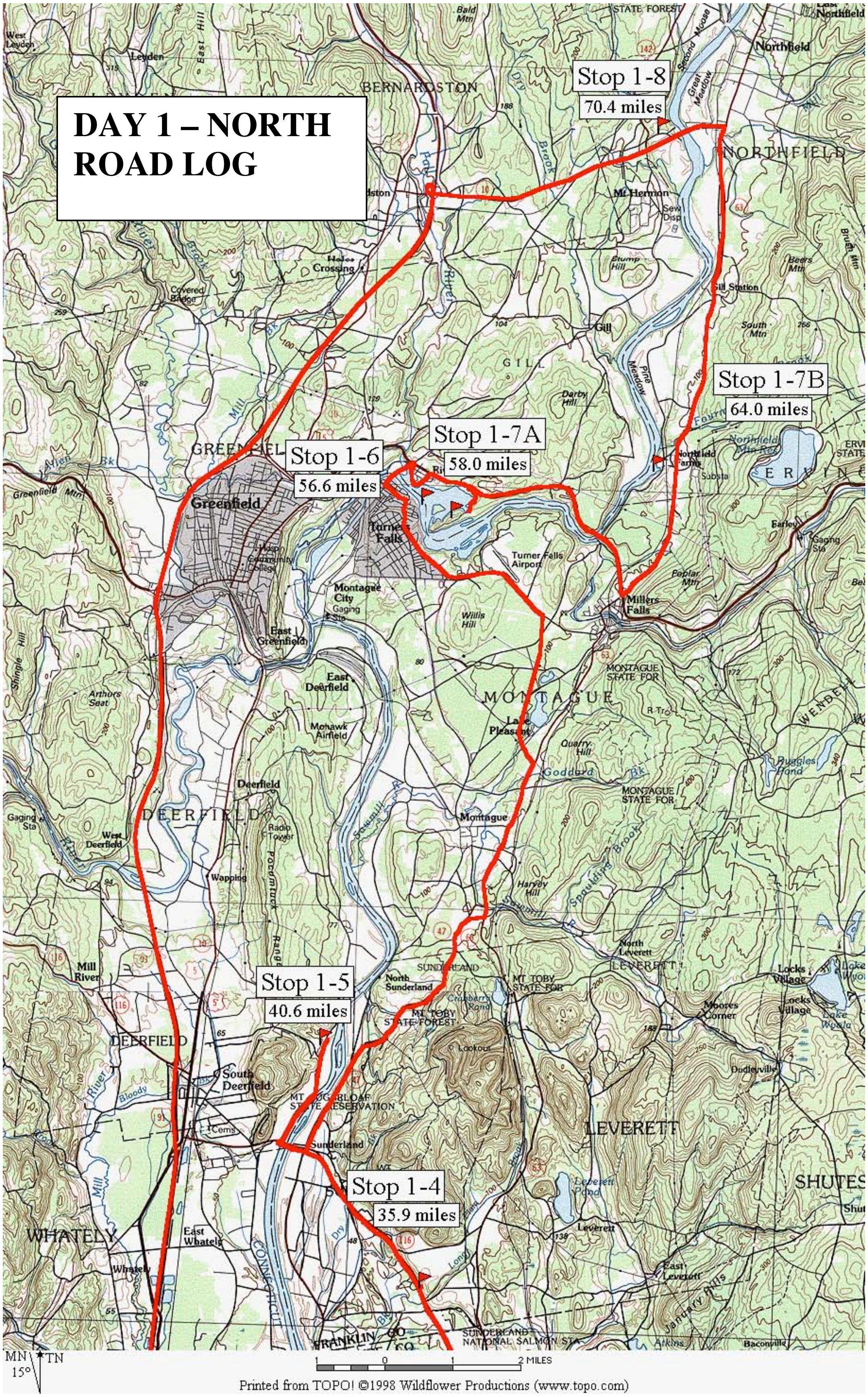
DAY 1 – NORTH ROAD LOG
Stop 1-8
70.4 miles
Stop 1-7B
64.0 miles
Stop 1-7A
58.0 miles
Stop 1-6
56.6 miles
Stop 1-5
40.6 miles
Stop 1-4
35.9 miles
BERNARDSTON
NORTHFIELD
GILL
GREENFIELD
Greenfield
Turners Falls
Millers Falls
MONTAGUE
DEERFIELD
SUNDERLAND
LEVERETT
WHATELY
MN
TN
15°
2 MILES
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