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Post-glacial fluvial terrace remnants as recorders of environmental and baselevel changes and of glacio-isostatic rebound in the Winooski drainage basin, Vermont

A Proposal Presented
by
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to
The Faculty of the Graduate College
of
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for the Degree of Master of Science
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Abstract

I am proposing to develop a dated river terrace chronology for selected rivers in the northern Winooski drainage basin from deglaciation to present. I will be surveying and dating terraces to define the river's altitudinal and lateral positions in space through time. I will then use the chronology to constrain the timing and amount of river incision and to measure the initiation, direction and rate of glacio-isostatic tilting in this area. By comparing the chronology to proxies of climate change, land use change, and baselevel change, I will characterize the timing and cause of terrace formation in the basin.

Introduction

In the time since deglaciation, Vermont has been differentially tilted due to glacio-isostatic rebound (Chapman, 1937; Koteff and Larsen, 1989) and has experienced dramatic climate changes (Lin, 1995 and McDowell et al., 1971). Although these events are interpreted from regional lacustrine records (pro-glacial lake shorelines and pond pollen stratigraphies), there is another important and understudied local record of uplift and climate change: fluvial terraces.

Fluvial terraces are flood plains that have been abandoned through incision or the lowering of the river channel. World-wide studies have shown that these landforms are excellent recorders of tilting (Burnett and Schumm, 1983; Merrits and Vincent, 1989; Merrits et al., 1994) and climate changes (Knox, 1983). Studies of fluvial terraces in two major drainages of the Champlain Basin also have produced successful quantitative results. Treadwell and Kneupfer (1988) measured the domal uplift of the Adirondacks from the terraces of the Ausable River and Brakenridge et al. (1988) interpreted glacio-isostatic rebound and climate changes from the incision history of the Missisquoi River.

The first step in each of these studies was to establish a dated river terrace chronology. Thus, I am proposing to develop a dated river terrace chronology for selected rivers in the northern Winooski drainage basin from deglaciation to present. By surveying and dating terraces, the river's altitudinal and lateral positions will be defined in space through time. I will then use the chronology to constrain the timing and amount of river incision and to measure the initiation, direction and rate of glacio-isostatic tilting in this area. By comparing the chronology to proxies of climate change, land use change, and baselevel change, I will characterize the timing and cause of terrace formation in the basin.

Significance of Study

By mapping, surveying and dating the fluvial terrace remnants, I will develop the first dated river terrace chronology for the Winooski drainage basin. Since the final stage of the deglaciation history is the establishment of the Holocene fluvial systems, I will re-evaluate the deglacial history in the selected river valleys and place the fluvial terraces in the proper geologic context. The incision history of each river will be compared to one another and to previous studies to see if a regional chronology exists and to what extent this chronology reflects environmental, tectonic or baselevel changes. Furthermore, by using the river terraces as a measure of glacio-isostatic tilting in the region, I will be able to make quantitative comparisons to the previous studies in the Northeast.

My hypothesis for river terrace development is as follows (Figure 1): successively lower glacial lakes formed in the river valleys of the Winooski drainage basin as the Laurentide ice sheet retreated from this region. As lower spillways became ice free, these lakes shoaled, and river channels developed in the lacustrine deposits. From the Late Pleistocene through the Holocene, baselevel lowerings, environmental changes, and glacio-isostatic tilting caused the repeated episodes of incision responsible for the flights of fluvial terraces in the Winooski drainage basin.

Terraces that formed prior to and during the period of glacio-isostatic rebound were tilted, and today, they have a gradient equal to initial river gradient ± a component of glacio-isostatic rebound (Figure 2). Since sufficient organic matter, in the form of charcoal and tree remains, is preserved in some terrace deposits and the overlying alluvial fans, the ages of these terraces can be constrained by ^{14}C dates, enabling me to calculate rates of change.

Previous Research

Fluvial Terraces

Conditions for Development of Terraces

Conceptually, fluvial terrace formation is the result of flood plain abandonment. A stress on the river system results in a change of the river dynamics which is accommodated by incision and the establishment of a new, lower flood plain. This stress may be external to the system (changes in climate, baselevel, or human activity) or internal (changes in vegetation or water and sediment yield from hillslopes). Also, it must exceed some intrinsic threshold in the system before incision and terrace formation can occur (Bull, 1991). However, defining or predicting when the threshold will be exceeded is difficult due to the complex interactions and feedbacks among the variables controlling river morphology (channel width, depth, bank strength, slope, etc.) which may differ along reaches or between draianages. Nevertheless, environmental interpretations are possible with a thorough investigation that recognizes and addresses these problems and uncertainties (Schumm and Brakenridge, 1987).

Interpretation of Terrace Remnants as Related to Tilting

River terrace remnants have been utilized to document and measure active and recent tilting at the Mendicino triple junction of California (Merrits and Vincent, 1989; Merrits et al., 1994), the domal uplifts in the lower Mississippi River Valley, (Burnett and Schumm, 1983) and the Adirondacks uplift in the Champlain Basin (Treadwell and Knuepfer, 1988). By surveying river terraces and plotting their longitudinal profiles, these studies have shown that differences in terrace gradients can serve as a means to measure crustal tilting if an initial river profile, often the present river gradient, is assumed.

Interpretation of Terrace Remnants as Related to Environmental Changes

Recent studies suggest that fluvial terraces can successfully record environmental changes as well. Comparisons of fluvial terrace and pollen records in both local (Scully and Arnold, 1981; Brakenridge et al., 1988) and world-wide (Knox, 1983; Arbogast and Johnson, 1994) studies show that the periods of incision or aggradation often occur coincident with climate changes. The new hydrologic and/or sediment transport conditions necessitate an adjustment of the fluvial system such as flood plain abandonment. Deforestation brought about by fires, windstorms, or humans can lead to slope instabilities which increase the sediment load in the rivers. Independent records like local fire histories (Mann et al., 1994) and historical land use provide a means to constrain the influences on the most recent river activity.

Deglaciation and Glacio-isostatic Rebound

Deglaciation of the Champlain and Winooski Basins

The deglacial record of the Champlain and Winooski Basins is one of changing lake levels. As the Hudson-Champlain lobe of the Laurentide ice sheet retreated, proglacial lakes developed in the north-draining valleys and left behind a scattered record of deltas and shorelines. Previous work in the Champlain (Chapman, 1937) and Winooski Basins (Merwin, 1908; MacClintock and Stewart, 1969; Larsen 1972, 1987a, b; and Wagner, 1972) has led to a regional chronology of lake levels (Figure 3). Although these studies lack good age and elevation control, they provide a baseline from which to construct the dated river terrace chronology.

Glacio-isostatic Rebound in the Northeast

The glacio-isostatic rebound pattern has been interpreted across the Northeast from once-level water-line indicators, such as deltas and shorelines, for both coastal and inland regions. Table 1 shows the magnitude, timing and evidence for isostatic rebound from the Vermont to the Maine Coast as reported by several studies.

Field Area

The main trunk Winooski River and several of its tributaries will serve as my field area (Figure 4). In my first field season, I concentrated my efforts on investigating the terraces of the north-flowing Huntington River in order to refine my methods. This coming field season I expect to investigate the Mad River, another north-flowing tributary, and the North Branch, a south-flowing tributary.

Field Work

The goal of the field work is to define the position of fluvial terraces in space through time; therefore, field work involves mapping and surveying fluvial terraces and collecting and dating organic matter.

Terraces and other landforms are mapped on 1:5000 orthophoto quadrangles using stereo aerial photographs and field reconnaissance as control. Surveying is accomplished with a total station by which elevations of terraces can be measured quickly, precisely and accurately. Survey lines, both parallel and perpendicular to the valley centerline, are needed to adequately sample the terraces because of the variability in areal extent of the terraces; past and present meandering patterns of the river control the preservation of terraces. Several measurements are taken to define the terrace surface; the inner and outer edges of each terrace, as defined by the breaks in slope, and several intra-terrace points are measured along profile lines. Survey measurements are referenced to established benchmarks.

For this study, a series of backhoe trenches will be dug on each terrace along a valley cross section line in the Huntington Valley. Stratigraphic relations will be used to interpret the fluvial regime and organic material collected will be ^{14}C dated using both conventional and AMS techniques. These new and previously published dates will provide the chronological control on terrace formation necessary to develop a type terrace chronology. The regional extent of the type chronology will be tested in other valleys using shovel pits to evaluate soil parameters (such as B-horizon development) and additional radiocarbon dates.

Data Interpretation

Interpreting my results will involve several procedures: 1) correlating the terraces to each other and to their respective baselevels; 2) constructing paleo-longitudinal profiles (Figure 5); 3) establishing a dated terrace chronology using the ^{14}C ages of the terraces; 4) calculating the magnitude and direction of glacio-isostatic tilting for each terrace level; 5) calculating incision rates along different reaches (Figure 6); and 6) comparing my terrace chronology to the independent climate (Lin, 1995) and baselevel records (Parent and Occhietti, 1988) to discern which mechanism caused which episode of incision (Figure 7).

Expected Results

I expect to develop the first regional terrace chronology for the Winooski drainage basin. From this chronology and the accompanying survey data, I will interpret the incision history, the glacio-isostatic tilt plane, and the causes for terrace formation in these river valleys. Therefore, by constraining the ages of these landforms and identifying the mechanisms of change, my project will be the first to establish the boundary conditions for geomorphic activity in this basin.

Time Table

January 1995-April 1995:
- defined project
- literature review
- preliminary mapping from air photos and reconnaissance field work
- submitted grant proposals to Sigma Xi and GSA

May 1995-December 1995:
- wrote proposal
- first season of field work
- dated samples
- poster session at GSA National Meeting, New Orleans

January 1996-March 1996
- present thesis proposal
- submit grant proposals to GSA, Sigma Xi
- preliminary mapping from air photos and reconnaissance field work

April 1996-November 1996
- progress report
- second season of field work, other drainages

November 1996-March 1997
- thesis writing
- thesis defense

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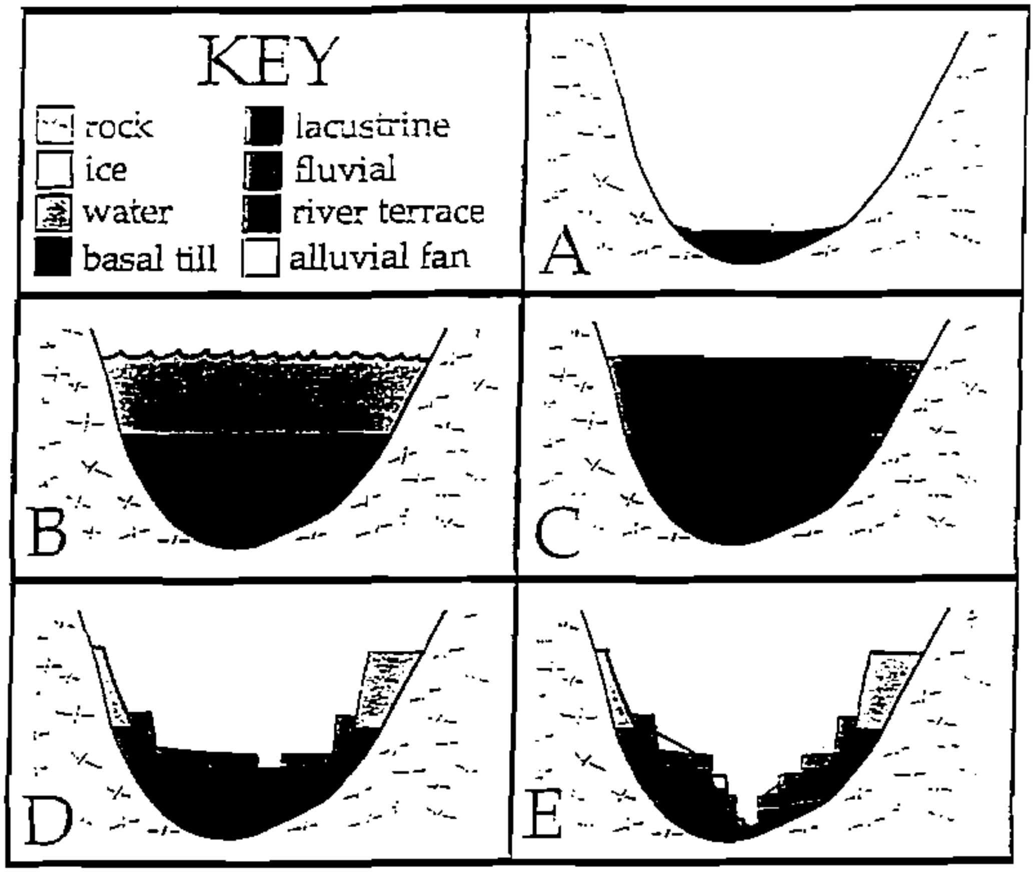

Figure 1: Schematic post-glacial evolution of the river valleys in the Winooski drainage basin. A) The Laurentide Ice deposits a basal till. B) Immediately following deglaciation, pro-glacial lake silts and clays cover the valley bottom. C) As the lake waters recede from the valley, the river aggrades to a stage of Lake Vermont before D) incising the surficial materials and depositing the terrace sequence. E) During the Holocene, river continues to incise and alluvial fans develop.

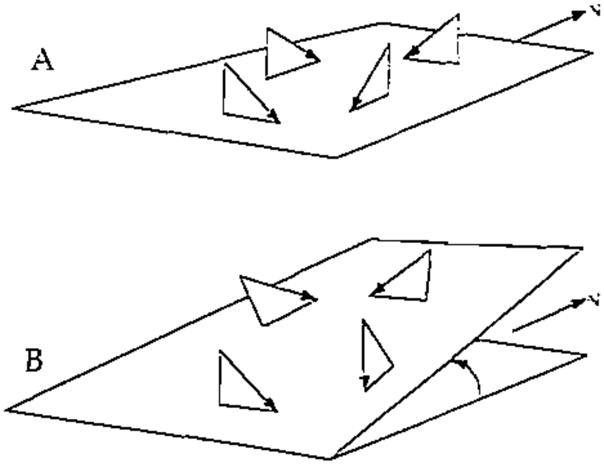

Figure 2: Effect of glacio-isostatic rebound on river terraces. A) The triangles represent the initial river gradient in four drainages of different orientations. If it is assumed that river terraces are formed at the same gradient represented by the triangles, then they will record tilting. B) Once the land is tilted, the gradient of any terraces is equal to its original gradient ± the component of tilting in that direction. Therefore, river terraces perpendicular to the direction of tilting are not tilted and preserve the initial river gradient. In this example, those rivers which flow south will have their terrace gradients steepened while terraces gradients of north-flowing rivers are lessened.

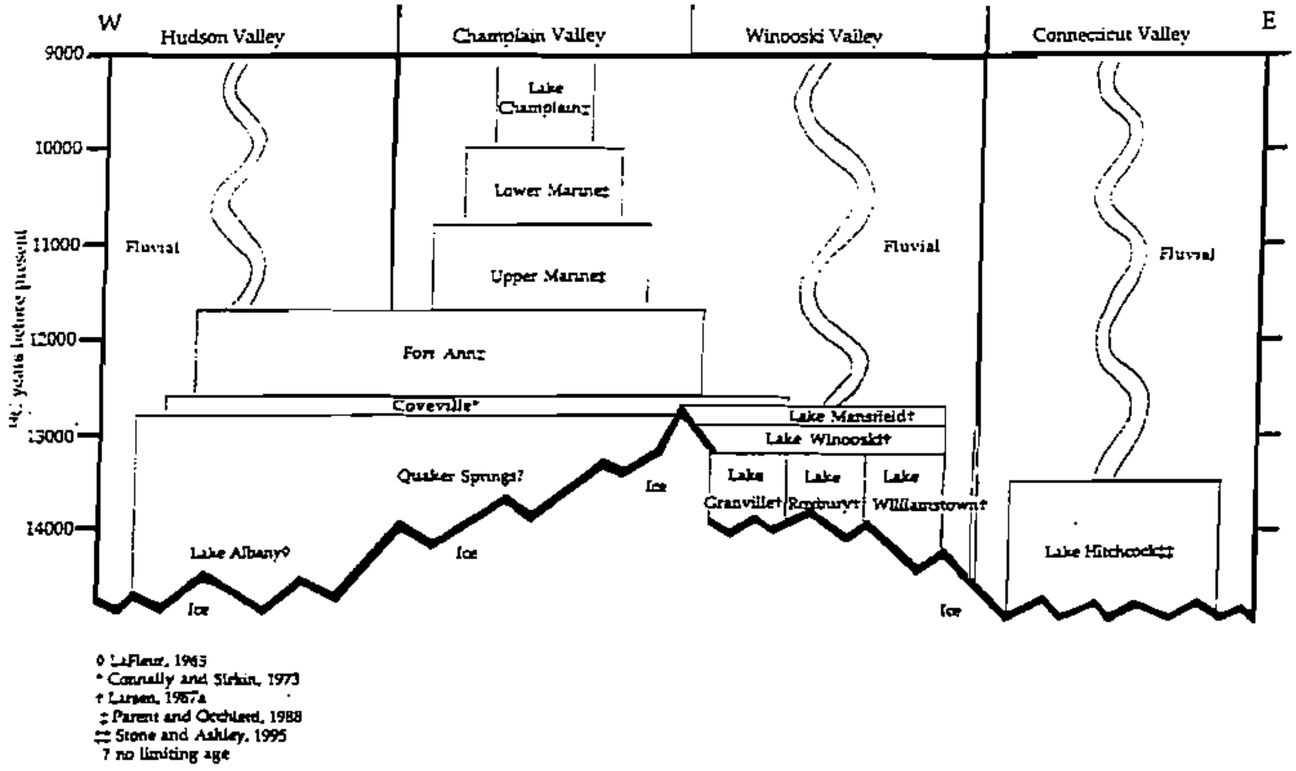

Figure 3: Correlation of post-glacial lake levels from Hudson Valley to Connecticut Valley. The well documented post-glacial lake chronology provides a baseline from which to construct the dated terrace chronology.

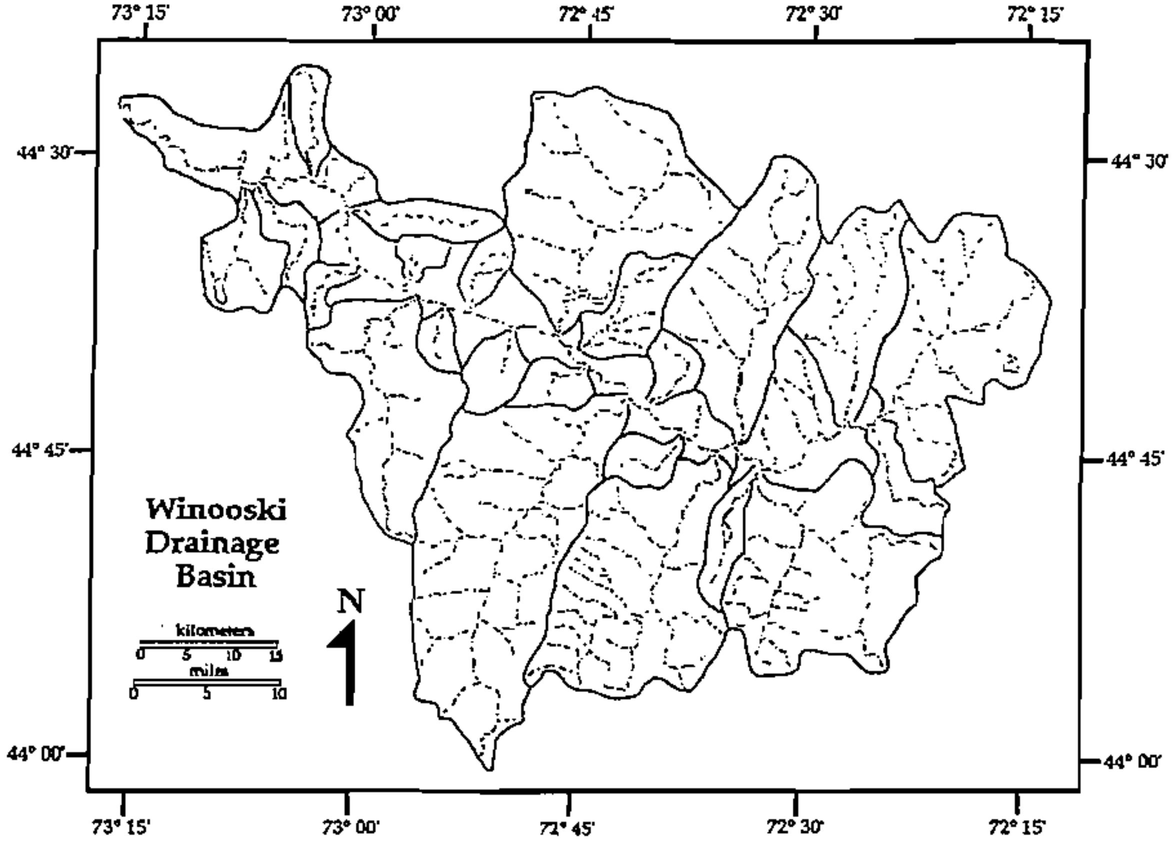

Figure 4: Map of Winooski drainage basin. Outlined valleys have been chosen for this study based on their orientation. By studying valleys of different orientations, it will be possible to solve for their common tilt, the tilt due to glacio-isostatic rebound.

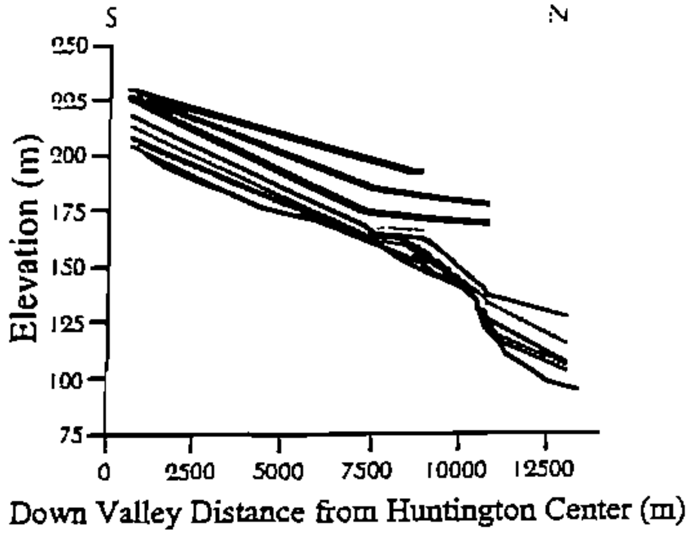

Figure 5: Longitudinal profile of terraces in Huntington Valley. In general, the older terraces in this north-flowing river have a lower gradient which reflects the possible effect of post-glacial tilting. At least two more profiles will be generated in this study and used to measure the glacio-isostatic rebound.

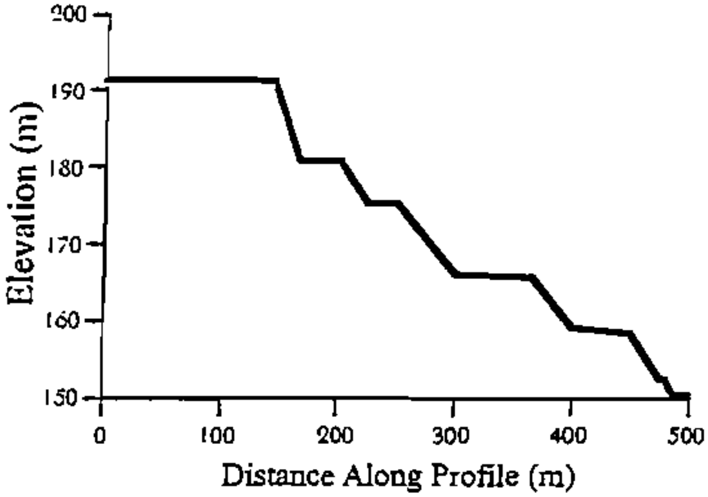

Figure 6: Cross-valley profile of Huntington River. The cross-valley profile will be used to determine the amount of incision by assuming the difference in height between terraces is equal to the incision. Rates are calculated by dividing the difference in height by the difference in terrace ages. In addition, these profiles may be useful for estimating the volume of sediment excavated by the river.

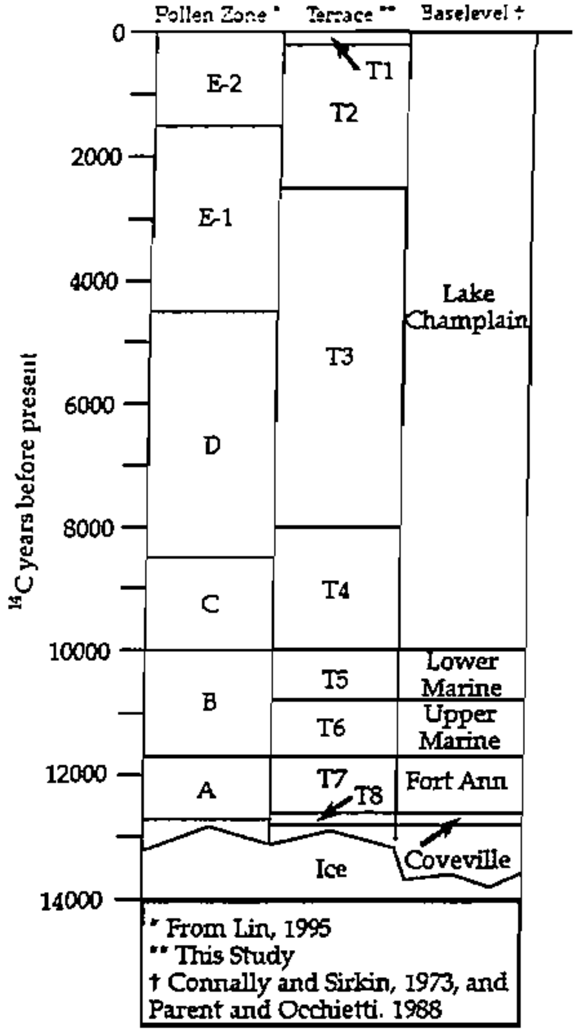

Figure 7: Preliminary comparison of terrace records with pollen and baselevel. At present, the terrace chronology is correlated with the baselevel record before 10.0 ^{14}C ka. The new dates from this study will further constrain the terrace chronology and provide a means to assess the causes of incision.

Table 1: Comparison of Direction, Gradient and Timing of Glacio-isostatic Rebound Across New England

Reference	**Chapman, 1937**	**Brakenridge et al., 1988**	**Koteff and Larsen, 1989**	**Koteff et al., 1993**	**Barnhardt et al., 1995**
Location #	1	1	2	3	4
Region	Lake Champlain Basin	Lake Champlain Basin, Missisquoi River	Connecticut Valley	Coastal central New England	Western Gulf of Maine
Direction	N 21 W	n/a	N 20.5 W-N 21 W	N 28.5 W	n/a
Gradient	~ 1 m/km	n/a	0.9 m/km	0.852 m/km	n/a
Rebound Begins	After Upper Marine	n/a	After 14,000	After 14,000 and before 13.300	Before 13,000
Rebound Ends	Still continuing?	By 8000*	n/a	n/a	n/a

note: all ages are calibrated unless marked with *