A REGIONAL RECORD OF HOLOCENE STORMS FROM TERRIGENOUS LAKE SEDIMENT, NORTHEASTERN USA

A Progress Report Presented

By

Anders J. Noren

To

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The following members of the Thesis Committee have read and approved this document before it was circulated to the faculty:

______________________________ Advisor
Paul R. Bierman, Ph.D.

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Andrea Lini, Ph.D.

______________________________ Chairperson
Leslie-Ann Dupigny-Giroux, Ph.D.

Date Accepted: ________________________

Introduction

To determine when and where Holocene erosive events have affected Vermont and eastern New York, I am investigating whether records similar to the Ritterbush Pond chronology (Brown, 1999) exist in the sediment of other lakes in the northeastern United States. I have retrieved 13 sediment cores from 7 lakes in Vermont, to determine the times at which terrigenous sediment layers were deposited in each lake basin. I have characterized the stratigraphy in the cores with several techniques, including magnetic susceptibility, x-radiography, visual logging, and loss-on-ignition (LOI). I have used radiocarbon to date most of the cores and, in conjunction with the other analytical techniques, to establish a sedimentation chronology for each lake.

I will compare these chronologies to existing records of hillslope erosion to determine whether temporal coherence exists between periods of increased erosion across the northeastern United States. From these observations, I may be able to infer periods of increased storminess, infer trends in Holocene weather patterns, and understand better natural climate variability.

Work Completed to Date

Much of this research has been a collaborative effort with several people, including both graduate and undergraduate students. In particular, I have worked with Josh Galster during core retrieval, and both he and Forrest Janukajtis during lab analyses. Together, we have completed most of the field and lab work for the first batch of 13 lake sediment cores.

Field Work

Before coring, we procured or created detailed bathymetric maps for each of the lakes, and performed initial geomorphic surveys to determine the most suitable coring locations. We chose these locations based on water depth and proximity to sediment sources. During the winter of 1999, we successfully retrieved 13 sediment cores from 7 lakes in Vermont. These cores ranged in length from 4 to 6 m. We cut the cores into 1.5 m sections, capped the sections, and placed each section in refrigerated storage until they were analyzed in the laboratory.

I made several modifications to our percussion coring device (modified after Reasoner, 1993) to increase its reliability and efficiency. They include:

- elimination of the core catcher due to lack of functionality and core barrel space constraints
- use of an additional pulley to reduce friction substantially during core retrieval
- construction of two additional pistons and one additional core head for rapid retrieval of multiple cores

I have also selected and performed initial reconnaissance on 8 lakes in Vermont and New York, for potential coring in the winter of 2000.

Magnetic Susceptibility

Before we opened each core, I used a Bartington Magnetic Susceptibility Meter (MS2) to identify changes in sediment lithology on the basis of differing concentrations of magnetic minerals (Dearing, 1986). Since inorganic terrestrial sediment has a higher susceptibility than gyttja, I use peaks in susceptibility to locate layers of inorganic sediment within each core.

X-Radiography

Prior to opening the cores, we X-radiographed each segment at the University of Vermont Radiation Safety Lab. On X-radiographs, high density represents gyttja; low density represents inorganic sediment. This method yields high-resolution black-and-white images of core stratigraphy, including small features and sedimentary structures not visible to the naked eye (Koivisto and Saarnisto, 1978; Axelsson, 1983).

Visual Logging

We split each core segment lengthwise and immediately photographed the core with 35mm print film and a high-resolution digital camera to record the colors accurately before the sediment began to oxidize. I then logged each core segment in detail, noting color, lithology, and grain size, and other features of interest such as macrofossils.

Sampling

We sampled sediment at 1-cm intervals along the length of each core, and placed each sample in a plastic 20 ml liquid scintillation vial. To each vial we added several milliliters of 0.1N HCl to remove carbonate, and placed the vials in a fume hood for 24 hours. We placed the acidified samples in a freezer for several days. We then loaded the frozen samples into a Labconco Freezone 6 Freeze Dry System, which extracted moisture from the samples. After drying, the samples were sealed and stored.

Loss-on-Ignition

Loss-on-ignition (LOI) is calculated as the percent mass lost when a dried sample is combusted. High LOI values are associated with organic-rich sediments such as gyttja, whereas low LOI values indicate inorganic sediments such as sand, silt, and clay. LOI values for these sediment cores document lithologic changes with depth.

I removed aliquots (each approximately 4 ml) from the dried samples, weighed them, and placed them in 5 ml porcelain crucibles. I combusted batches of 138 samples in an oven at 450°C for 2 hours, allowed the samples to cool for 1 hour, and weighed them again. From these measurements, I calculated the percent mass lost (LOI) for each sample.

Radiocarbon Dating

From each core I removed macrofossils of terrestrial plant material at regular intervals, particularly in and near terrigenous layers. From these samples I selected 35 for radiocarbon (^{14}C) analysis at the Center for Accelerator Mass Spectrometry (AMS) at Lawrence Livermore National Laboratory in Livermore, California. Samples were prepared according to standard procedures, under the supervision of John Southon. Each sample was washed in HCl to remove carbonate, followed by several (1 to 10) washes of NaOH to remove humic acids. The samples were combusted in quartz tubes in the presence of Mg and CuO to produce CO_2 gas, which was isolated on a vacuum line and graphitized. The graphite was packed into targets for AMS analysis. I calibrated the resulting radiocarbon ages with the CALIB program (v. 4.12, Stuiver and Reimer, 1993).

I have used these 35 ^{14}C ages, and their calibrated equivalents, to construct age models for each core analyzed. This was accomplished by fitting regression lines through pairs of successive dates on a graph of age vs. core depth (Fig. 1). The equations for these regression lines allow the determination of ages at any depth throughout the core.

Preliminary Results and Conclusions

In general, I have found that the variability in sediment character, and in particular the character of terrigenous layers, between lakes is significantly higher than I expected. Unlike the sediment of Ritterbush Pond, the sediment of most lakes in this study does not contain many distinct layers of mostly inorganic sediment. Rather, the terrigenous layers in these cores typically exhibit one or more of the following characteristics in contrast to the bulk of the sediment:

- larger than average particle size
- higher abundance of macrofossils from terrestrial plants
- anomalously higher or lower LOI values
- lower-density x-radiographic image
- higher magnetic susceptibility
- anomalously lighter or darker color

Together, the analytical techniques described above allow me to develop a detailed record of the stratigraphy in each of the cores. In turn, I have compared these stratigraphies to their age models to determine the sedimentation chronology for each lake. I have just begun to compare sedimentation chronologies from different lakes (Fig. 2). The lack of uniformity in sediment character between different lakes makes these comparisons difficult, and this initial comparison does not account for these differences. Taken at face value, this comparison indicates little correlation between the timing of terrigenous layer deposition in these lakes. This lack of correlation suggests that events (storms) capable of triggering hillslope erosion were localized rather than regional during the Holocene.

Despite the apparent lack of correlation between these records, it may be possible to determine periods of increased and decreased storminess in this region since deglaciation (Fig. 3).

This preliminary event frequency histogram suggests that storms were less frequent prior to 10,000 yr BP, between 9,000 and 7,500 yr BP, and 5,000 and 3,000 yr BP.

Future Work

I will soon complete lab analyses (LOI and ^{14}C dating) of the Amherst and Emerald cores. I will then use the data sets I have created to develop a methodology that accounts for the differences in lake sediment character. In this manner, I will filter and refine the event chronologies for each lake. I will begin by comparing the results from each lab analysis for individual cores, and use the results to rank the distinctiveness of terrigenous layers in that core. Additionally, I will perform particle size analysis on portions of the cores, to check my own manual determination of particle size during core logging. Since hillslope-clearing wildfires may influence the erodibility of sediment in the lakes' drainage basins, I will also perform charcoal analysis on portions of the cores to determine whether fires coincided with terrigenous layer deposition.

During the winter of 2000, we will retrieve, sample, and analyze additional cores from lakes in Vermont and New York. The records I extract from these additional sedimentary archives will augment the chronologies I have already determined. The location of these additional cores we retrieve will depend on the final results from the first batch of cores, and the number of additional cores will depend on time constraints associated with concurrent core retrieval, sampling, and lab analyses.

Timeline for Completion

Fall 1999

- Present research at GSA Annual Meeting in Denver: October 25-28
- Finish lab analyses on Emerald and Amherst cores
- Use maps and surveying to determine general surficial geology for lake drainage basins
- Develop methodology for filtering chronologies

Winter 2000

- Retrieve, sample, and analyze additional cores from lakes in Vermont and New York

Spring-Summer 2000

- Write thesis

Fall 2000

- Finish writing and defend thesis
- Present research at GSA Annual Meeting in Reno: November 13-16

References Cited

Axelsson, V., 1983, The use of X-Ray radiographic methods in studying sedimentary properties and rates of sediment accumulation. Hydrobiologia 103, 65-69.

Brown, S. L., 1999, Terrestrial sediment deposition in Ritterbush Pond: Implications for Holocene storm frequency in northern Vermont. University of Vermont Master's Thesis, 170 p.

Dearing, J. A., 1986, Core correlation and total sediment influx, in Berglund, B. E., ed., Handbook of Holocene Palaeoecology and Palaeohydrology: New York, John Wiley and Sons, 247-265.

Koivisto, E., and Saarnisto, M., 1978, Conventional radiography, xerography, tomography, and contrast enhancement in the study of laminated sediments; preliminary report. Geographiska Annaler 60A, 55-61.

Reasoner, M. A., 1993, Equipment and procedure improvements for a lightweight, inexpensive, percussion core sampling system. Journal of Paleolimnology 8, 273-281.

Stuiver, M., and Reimer, P.J., 1993, Extended ^{14}C database and revised CALIB 3.0 ^{14}C age calibration program. Radiocarbon 35, 215-230.

Figure Captions

Figure 1

Example of an age model, from Duck Pond.

Figure 2

Comparison of sedimentation chronologies for cores analyzed to date. Larger gray boxes below each of the records indicate the age of the sediment at the bottom of the core; smaller black dashes indicate the timing of terrigenous layer deposition in each record. Note that no thickness is implied by the black dashes; they indicate only the onset of terrigenous deposition at a particular point in time.

Figure 3

Histogram showing frequency of terrigenous layer deposition during the Holocene for lakes analyzed to date. The frequencies are weighted by the inverse of the number of records covering the time interval in question.

Figure 1: Duck Pond Core 1 Age Model

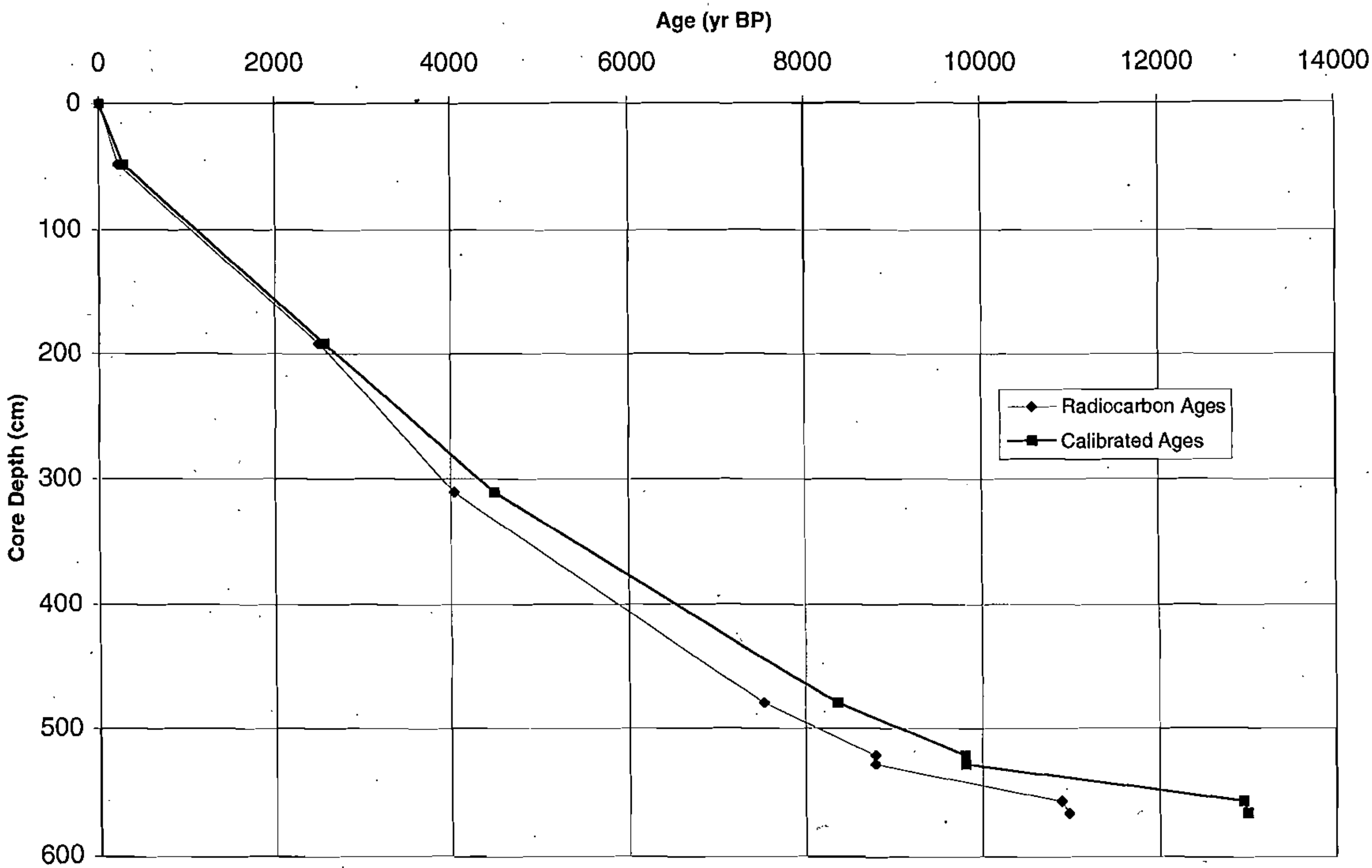

Figure 2: Event Chronology Comparison

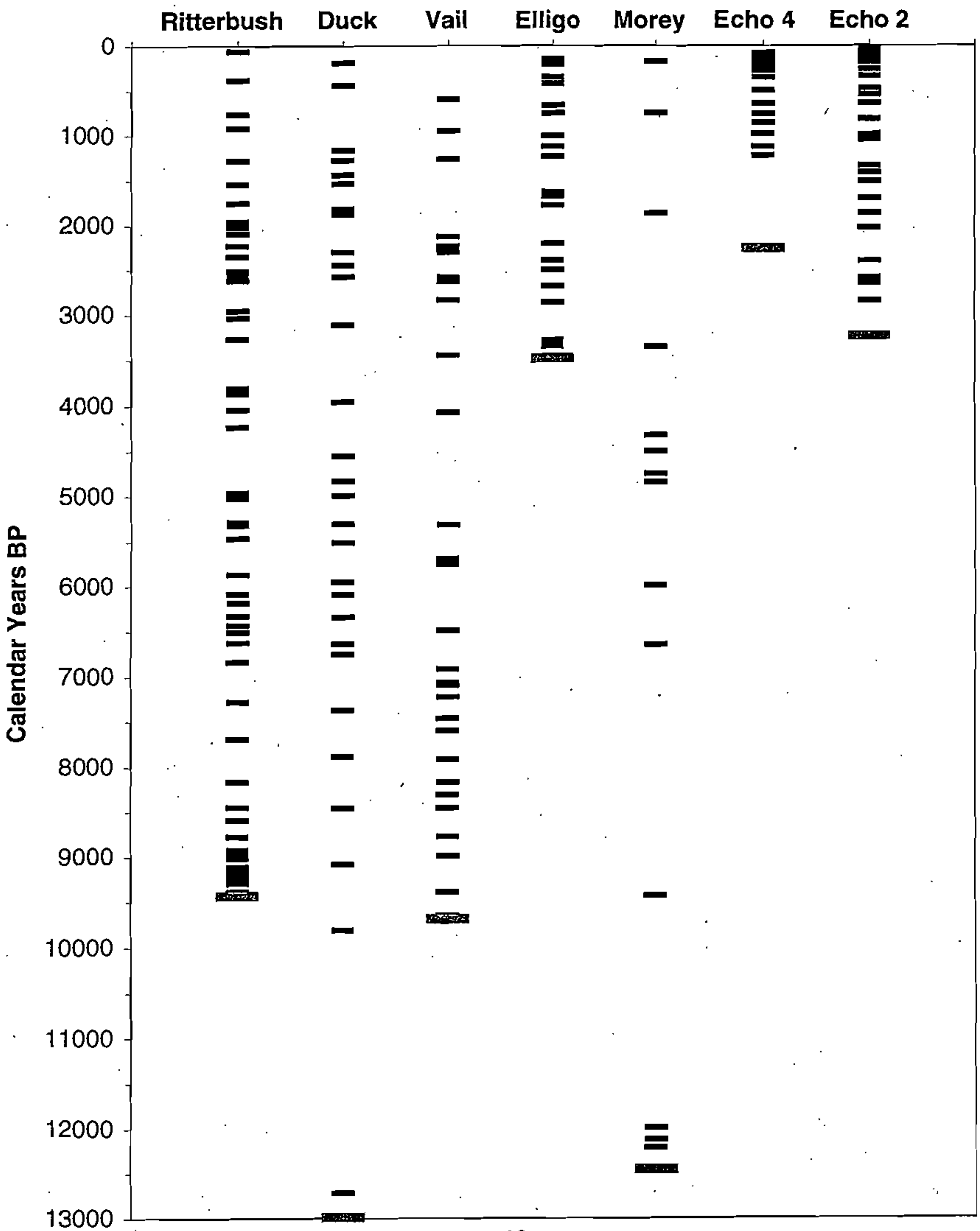

Figure 3: Holocene Event Frequency