Lake Sediment Records in New England:
Indicators of Climate and Hillslope Erosion

A Thesis Progress Report Presented

By

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to

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Introduction

Human influence on climate is not easily distinguished without knowledge of natural climate variability (Stocker and Mysak, 1992). Furthermore, human influence on climate may not be limited to temperature alone, but also may include effects on precipitation (IPCC, 2001). Therefore, studies of natural precipitation patterns contribute to the understanding of natural climate variability and are a prerequisite for distinguishing human-induced changes in precipitation patterns and intensity.

Lake sediment records have been exploited as an archive of paleostorm activity in New England and abroad (Brown et al., 2000; Campbell, 1998; Digerfeldt, 1986; Eden and Page, 1998; Huang et al., 1997; Noren, 2001). Previous research in New England (Brown et al., 2000; Noren, 2001) has increased our ability to elucidate the paleostorm record from lake sediments in the region. Lake sediments, at the very least, provide data that suggest there were times during the Holocene when storms, regardless of their size, happened more often (Brown et al., 2000; Noren, 2001).

Cm-by-cm grain size analysis, a more sensitive analytical method (Bosley et al., 2001; Parris et al., 2001) than the loss-on-ignition and visual logs employed previously, will form the basis of my research. It will make more robust my interpretations of event frequency, and allow me to characterize the storm sediment signature in small, post-glacial lakes.

Research Completed to Date

Core Collection:

Using a modified percussion piston coring device designed by Reasoner (1993), 10 cores from 8 lakes in New Hampshire and in Maine (see Figure 1 and Table 1) were retrieved with the help of Anders Noren, Andrea Lord, Paul Bierman, Andrea Lini, and Leah Morgan. The lakes in New Hampshire and Maine meet the requirements set forth by Brown et al. (2000) and Noren (2001) (see Figure 2 and Table 1). The Reasoner cores were taken as close to the bottom set of the delta as possible (as interpreted by bathymetry) for better detection of storm layers (Campbell, 1999; Parris et al., 2001). Also, in two cases, cores were taken from different deltas within the same lake to distinguish the spatial extent of storm deposits in an individual lake basin (Figure 3). The cores range from 4.5 to 6 meters in length; all of them were divided into 1.5 meter sections for refrigeration then processing.

Since Reasoner cores do not preserve well the historic sediment record, gravity (Glew) cores were obtained from all the lakes with the help of Andrea Lini, Andrea Lord, Leah Morgan, and Nathan Toke. The gravity cores taken from Ogontz Lake and Sandy Pond were taken in conjunction with an undergraduate Geomorphology project by Eric Butler and William Amidon. These cores will be used in an attempt to match the timing of storm layers with historic precipitation records. Hank Hallas, a personal contact with extensive personal background at Sandy Pond, has provided a detailed, historic storm record for that lake from personal observation.

Magnetic Susceptibility:

After retrieving each core, a Bartington Magnetic Susceptibility Meter (MS2) was used to identify changes in sediment lithology where differences in magnetic mineral content exist (Dearing, 1986). Inorganic, terrestrially derived sediment displays a higher Magnetic Susceptibility (MS) than fine grained, organic-rich lake mud (gytta) (Brown et al., 2000; Noren, 2001). Therefore, discreet peaks in susceptibility show the location of inorganic sediment layers in each core (Figure 4).

Splitting, Visual Logging, and Sampling:

Each core section was split lengthwise, and immediately one half of that section was photographed with a high-resolution digital camera under photoflood bulbs to record accurately the visual stratigraphy before the sediment began to oxidize (Figure 4). The other core half was wrapped and sealed in plastic and returned to the refrigerator. A graphical log of each section was created recording changes in color, consistency, the location of macrofossils, and contacts between units of different color. Light brown layers were interpreted to be fine laminations and/or increased amounts of inorganic sediment, and darker brown or black layers were interpreted to be increased amounts of organic material. Grain size was estimated by hand and roughly matched areas with visual changes in color. Samples were collected at 1-cm intervals and freeze dried in 20 mL scintillation vials for use in other analyses. As the core was sampled, macrofossils were collected approximately every 10 centimeters, especially where abundant, and refrigerated until used for radiocarbon dating.

Radiocarbon Dating:

In August of 2001, with the help of John Southon, 49 radiocarbon dates were obtained from macrofossils at Lawrence Livermore National Laboratory. Macrofossils, as opposed to gytta, were used for radiocarbon dating. Dates derived from gytta are commonly offset from macrofossil dates due to the lake reservoir effect or the settling of macrofossils into unconsolidated deposits at the sediment-water interface (Bicrman et al., 1997). Four or five dates for each core were measured in August 2001, and an additional four or five dates for each core will be measured this winter.

Loss-on-Ignition (LOI):

As a proxy measurement of organic carbon content, Loss-on-Ignition (LOI) was performed at cm-resolution down the length of every core with the help of Leah Morgan, an undergraduate from Carleton College and a graduate of the Governor's Institute at UVM. Approximately 250 mg of each dried sample were placed in porcelain crucibles and burned at 450 °C. The resulting mass change was used to estimate LOI.

Field Reconnaissance:

Over the course of the fall and summer of 2001, I re-visited each lake in order to make field observations. I examined the shore of the delta, particularly the surfacc of the delta where it entered the lake to confirm the presence of top-set beds and a steep fore-set. I also observed how far the top-set extended into the lake. I walked each stream, starting from the mouth at the edge of the lake and extending as far upstream into the basin as possible. The primary objective of my fluvial observations was to characterize the stream that fed each delta. For instance, I classified the stream channel as alluvial, colluvial, or bedrock, and tried to identify the primary source of sediment to the delta during floods. As part of Kristen Benchley's Geomorphology class project at UVM, the stream channels from Ogontz Lake and Sandy Pond were survcyed for gradient and slope in order to classify the streams according to Montgomery and Buffington (1997).

Initial Interpretations

Laboratory Analyses

LOI & MS:

Decreases in LOI values distinguish inorganic layers from the organic rieh mud, called *gytta*; the LOI values occur at depths in the cores where MS increases (Figure 4). Both the LOI and MS data indicate that there are depositional layers comprised of inorganic, terrestrial material. These are the layers needed for reconstruction of a paleostorm record. I also consulted these records, as well as the graphical log, to choose which samples to analyze for radiocarbon at Livermore this past August (Figure 4).

Radiocarbon Dating:

For each core, the bottommost macrofossils were dated. Cores extend well baek into the Holocene and late Pleistocene (Figure 5). Macrofossils within the inorganic deposits (as determined by LOI, MS, and graphical log) were chosen wherever possible and directly represent the timing of events (Figure 4). If maerofossils were not found in the inorganic deposits, macrofossils above and below each major inorganic, lighter-colored layer were used to constrain the age of the deposit (Figure 4).

Work to be Completed

Grain Size Analysis (GS):

I will perform GS analysis at cm-resolution for all 9 processed cores. To remove organic material, samples will be soaked in concentrated (30%) H_2O_2 in a sonicating hot bath for 12- 24 hours or until reaction is complete. Then, the samples will be centrifuged, decanted, and rinsed with de-ionized (DI) water, twiee. To remove biogenic silica, the samples will be soaked in NaOH in a sonicating hot bath for 4 hours. The samples will be rinsed twice again and 5mL of dispersant (sodium metaphosphate) will be added as a defloculator until the samples are plaeed in the Coulter Laser Diffraction Unit. Samples will be placed on a sonicator prior to being run in the Coulter machine to mechanically disaggregatc the grains. Twelve replicates of Angela Conlan's (Conlan, 2001) and Andrcw Bosley's (Bosley et al., 2001) samples will be run in order to ensure that the preparation method has sufficient reproducibility.

The Coulter Laser Diffraction Unit provides several statistical paramcters for each grain-size sample, including mean and median grain size, standard deviation, skewness, and kurtosis (Parris et al., 2001; Bosley et al., 2001). It also provides a graphical representation of the percent volume of each grain size in the sample, ranging from 4 to roughly 200 µm. I will determine trends in eaeh statistical parameter independently and then attempt to correlate those trends to storm-related deposition. I will analyze the graphieal results and correlate them to statistical parameters. I have not determined exactly how to treat these data yet, but I will spend much of the spring consulting previous research (e.g., Syvitski et al., 1991) and determining which method best suits laeustrine sediments. Eventually, a log of events as defined by these statistieal and graphical analyses will be created for comparison with other analytical tools sueh as LOI and MS (Noren, 2001; Parris et al., 2001; Bosley et al., 2001).

Event Identification (ID):

I will build on the work done by Noren (2001) by comparing the independent results from each analysis, including Graphical Log, LOI, MS, and GS, to determine a composite record. This composite record of storm events will be comprised of those storm events detected by two or more of the analyses, and therefore, it will be a proxy for the largest storm events in the lake cores.

Event Frequency:

The frequency of storm events, broadly defined as storminess, has been the most illustrative result of lake sediment research in New England (Noren, 2001). I will, in the same fashion as Noren (2001), compare the composite record of each core, with time, to determine periods when storm events occurred more frequently. However, since grain size analysis is a more sensitive measurement of storm-related deposition in lakes, I will compare the grain-size record alone between lakes to attempt to elucidate more detailed trends in the frequency of storms over the Holocene. I will apply spectral analysis to the results examining frequency and compare my results to those of Noren (2001).

Detailed Timeline of Work to be Completed:

December 2001: Set up lake lab for grain size preparation, and run replicate grain-size samples at Rubenstein Ecosystem Laboratory

January 2002: Return to Livermore and complete radiocarbon dating

February- May 2002: Complete age scale models for each core

January- May 2002: Complete laboratory prep of grain size samples and run samples in Coulter Laser Diffraction Unit at Rubenstein Ecosystem Lab

May- September 2002: Statistical analysis of Graphical, LOI, MS and GS results

September- November 2002: Write publication for thesis

December 2002: Defend thesis to UVM faculty

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Figure 1-
Map of core locations in NY, VT, NH and ME. Lake IDs correspond to lake names and physical characteristics in Table 1. Base from Stemer, JHU

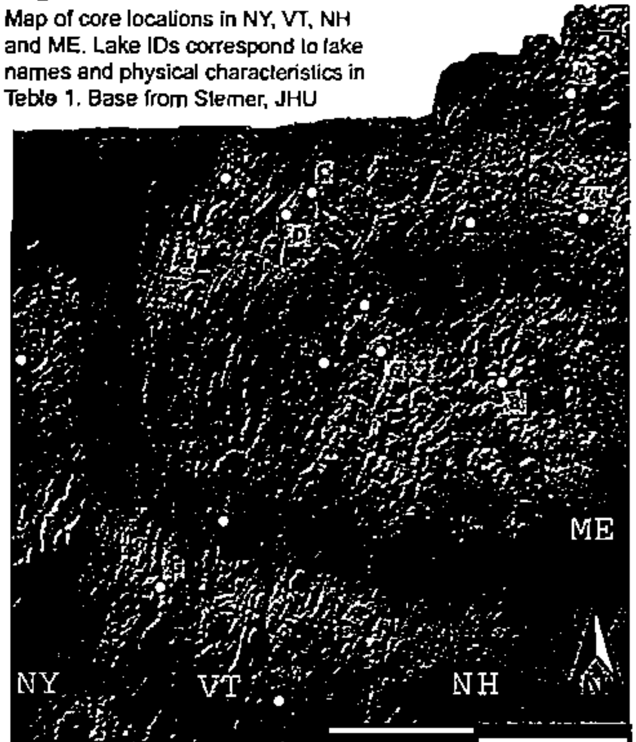

Figure 2-
Lake were selected using the same criteria as Noren (2001) and Brown et al. (2001): a. steep hillslopes, b. available sediment on hillslopes, c. stream capable of supplying sediment to a lake delta, and d. steep perimeter bathymetry (see Figure 3)

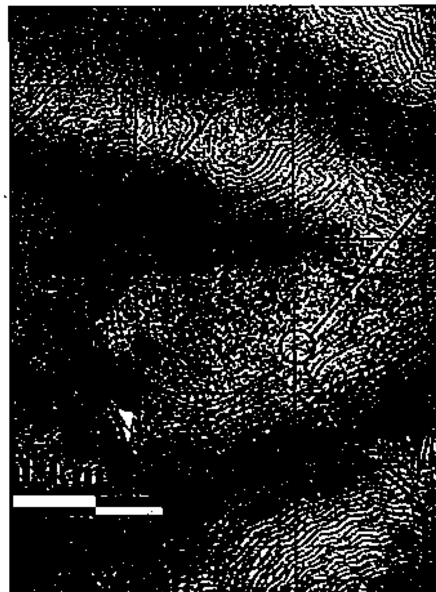

Table 1- Physical characteristics of selected lakes from NY, VT, NH and ME

Lake ID	Lake Name	Surface Area (km^2)	Maximum Depth (m)	Elevation (m)	Drainage Basin Area (km^2)	Drainage Basin Relief (m)
	Maine:					
[illegible]	[illegible] Pond	1.08	15	533	[illegible]	384
[illegible]	[illegible] Pond	1.43	15	174	[illegible]	344
	New Hampshire:					
[illegible]	[illegible]	0.7	27.9	340	[illegible]	427
[illegible]	[illegible]	0.303	22	202	[illegible]	408
[illegible]	[illegible]	1.6	22	396	[illegible]	655
[illegible]	[illegible] Lake	0.38	18	146	[illegible]	353
[illegible]	[illegible] Pond	0.11	12	288	[illegible]	216
[illegible]	Averages:	0.8	18.8	292.0	14.2	399.6
	New York:					
A	Chapel Pond *	0.07	24	485	4.6	925
	Vermont:					
B	Kickerbush Pond ^	0.05	14	317	2.2	293
C	Dobk Pond *	0.03	14	520	0.7	290
D	Vail Pond *	0.06	14	455	0.5	354
E	Lake Morey	2.22	13	327	20.7	414
F	Echo Pond *	0.42	38	323	68.4	678
G	Emerald Pond *	0.11	13	217	[illegible]	713
	Averages:	0.4	17.1	349	35.9	523.9

* Cores collected by Noren (2001) ^ Cores collected by Brown et al. (2000)

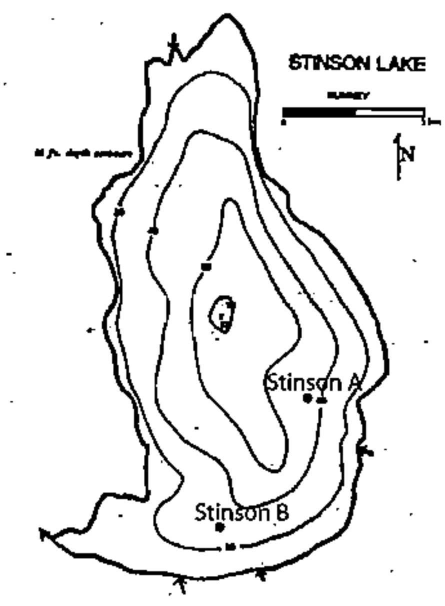

Figure 3-

Bathymetry map of Stinson Lake, showing location of two different cores from two different deltas. These cores will be used to attempt to determine the spatial extent of storms within one lake basin. Comparison of GS results from an individual lake basin will aid my interpretation of what is a consistent sediment source and what is storm-related depositional material. Also, notice the steep bathymetry immediately adjacent to the shore. Cores were taken at the base of the steep bathymetric contours which are interpreted as fore set beds.