LACUSTRINE SEDIMENT RECORDS IN NEW ENGLAND: INDICATORS OF CLIMATE AND HILLSLOPE EROSION

A Thesis Proposal Presented

By

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to

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Abstract:

Holocene hillslope erosion ereates discreet, terrestrially derived, inorganic deposits in lake sediment records. In several locations throughout the world, these deposits have been identified and interpreted as the result of hydrologic events, specifically storms. These deposits are a proxy that represent the timing, frequency, and magnitude of storms. Application of this method has been largely restricted to studies of individual lakes. However, Noren et al. (2000) examined these characteristics in several lakes throughout northern New York and Vermont, finding trends in regional sedimentation which may represent broadly synchronous trends in precipitation intensity and/or duration. I have collected 10 cores from 8 lakes in New Hampshire and Maine, and I will examine the timing, frequency, and magnitude of inorganic deposits in these cores. Radiocarbon dating will be used to constrain the timing of sedimentation. I will use Magnetic Susceptibility and Loss-On-Ignition (LOI) to determine the percentage of terrestrial vs. lacustrine material in each core. I will use a physical test, grain size analysis, to better characterize the frequency and magnitude of sedimentation events. Once a well defined chronology of events exists for each core, I will correlate, statistically, the hydrologic events in the region, in order to infer spatial and temporal trends in sediment delivery and hillslope erosion, and by inference, climate.

Introduction:

Lakes collect and preserve sediments supplied by the surrounding basin. These sediments have two sources: aquatic organisms within the lake and terrestrial material delivered to the lake from hillslope erosion (Meters and Ishiwatari, 1995). The decay of aquatic organisms creates dark, fine-grained mud called *gytta*, rich in organic carbon. Most of the lake sediment record is gytta. In contrast, terrestrial sediment is delivered to the lake during hydrologic events large enough to erode the surrounding hillslopes and transport material to the lake. Terrestrial material may appear in the gytta, as an abrupt, episodic interruption of the lake sediment record (Brown et al., 2000; Campbell, 1998; Eden and Page, 1998; Goslar et al., 1999; Huang et al., 1997; Noren et al., 2000). The same authors suggest that the frequency, thickness, and grain size of inorganic deposits in lake sediments are a primary means of understanding past climate.

Precipitation events of significant duration and/or intensity (i.e. storms alone, or rain on snow events) increase the potential of streams, especially those with high to moderate gradient, to deliver terrestrial sediments to the lake. Therefore, precipitation is often considered the primary cause of terrestrial sediment deposition in lake sediment cores (Brown et al., 2000; Campbell, 1998; Digerfeldt, 1986; Eden and Page, 1998; Huang et al., 1997; Noren et al., 2000).

Previous Work:

Detailed analysis of the timing, frequency, and magnitude of terrestrial sediment layers, and by inference precipitation events, has led to conclusions about climatic variability in many different areas (Brown et al., 2000; Campbell, 1998; Digerfeldt, 1986; Eden and Page, 1998; Huang et al., 1997; Noren et al., 2000). Eden and Page (1998) established a detailed chronology of storms, using inorganic deposits in New Zealand lacustrine sediments. They collected overlapping cores of historic sediment and prehistoric sediment, and were able to identify and to date accurately inorganic deposits in the historic sediment that correlated well with events in historic preeipitation data. By so doing, they were able to confirm that storms were the cause for the inorganic layers in most of their cores. Campbell (1998) examined inorganic deposits in a lake core from British Columbia, using grain size as a non-biogenic means of identifying the deposits, and concluded that an increase in median grain size was due to precipitation, as a result of an increase in the power of streams emptying into the lake. Similarly, Rodbell et al. (1999) studied inorganic deposits in lacustrine sediment as a measure of storm frequency in Ecuador, and Huang et al. (1997) also applied this method to elucidating the frequency of monsoons in the South China Sea.

Until recently, the few reconstructions of past climate in the northeastern United States were based on tree ring widths (Conkey, 1986) or pollen stratigraphy (e. g., Lin, 1996; Jackson and Whitehead, 1991; Spear et al., 1994). Brown et al (2000) examined the presence of inorganic deposits in the lacustrine sediments of Ritterbrush Pond (northern Vermont). They identified intervals of increased inorganic sedimentation during the Holocene, using three important characteristics of the deposits: frequency, timing and magnitude. Defining these parameters for inorganic deposits is crucial to making conclusions about past climate variability. However, previous research has been performed on cores from a single lake. Therefore, trends in the timing of inorganic deposits in lakes across a broader region remain unclear. Noren et al. (2000, unpublished data) was the first to examine inorganic deposits in lake sediments from an entire region, New York and Vermont (see Figure 1 and Table 1). He finds some indication of regional sedimentation trends, which may represent broadly synchronous increases in precipitation intensity and/or duration.

Scope of Current Project:

Objective:

In a similar fashion to Noren et al. (2000, unpublished data), I have collected cores throughout New Hampshire and parts of Maine (see Figure 1 and Table 1). I will identify the timing, frequency, and magnitude of inorganic deposits in the lake sediment cores from this region, using both similar and different analytical techniques then Brown et al. (2000) and Noren et al. (2000, unpublished data).

Both Brown et al. (2000) and Noren et al. (2000, unpublished data) analyzed their sediment cores using techniques capable of distinguishing the amount of carbon in the sediment at high-resolution (1 cm) intervals. However, grain size analysis of lake sediments (Campbell, 1998) is an important test for determining the magnitude of terrestrial sediment deposition in lakes as well. Thus, I will build upon the work of Brown et al. (2000) and Noren et al. (2000, unpublished data) by doing high resolution (1 cm) grain size analysis. I will use the simplest and most illustrative of their techniques, Loss-On-Ignition (LOI) so that our records can be correlated.

Goals & Possible Outcomes:

Goal #1: Quantify depositional events in the lake sediment record

As part of their undergraduate research, A. Bosley et al. (2001) and A. Conlan (2001) analyzed grain size in one of Noren's cores at cm-resolution. Following the work of Campbell (1998), Bosley et al. and Conlan used increases in median grain size as a proxy for depositional events in the lake record, and compared the results with Noren et al.'s tests (2000, unpublished data) for inorganic input (see Figure 2). Bosley et al. and Conlan found major increases in median grain size where Noren's tests detected change in organic carbon content. They also found changes in grains size where no change in organic content was detected. Thus, it appears that grain size is a more sensitive means to detect hydrologic events (see Figure 2).

Possible Outcome: Grain size analysis will detect more sedimentation events than LOI, refining estimates of event frequency and providing a better chronology of events.

Goal #2: Constrain estimates of event magnitude

Event magnitude is influenced directly by precipitation. Campbell (1998) concluded that grain size varies with stream power, the product of the specific weight of water, discharge and slope. Precipitation increases stream power by adding to the volume of water in a channel. As stream power increases, the size of particles carried by a stream also increases, so Campbell (1998) concluded that the variation between grain size and stream power reflects regional trends in precipitation. Brown et al. (2000) used layer thickness as a measure of the magnitude of a depositional event, and concluded that the events occurring before historic times were of greater magnitude.

Possible Outcome: Event magnitude will be better defined by grain size analysis as opposed to LOI because increasing grain size is a direct indication of larger hillslope erosion events.

Significance of Research: Increased attention has been given to human carbon dioxide (CO_2) emission, the concentration of this gas in the Earth's atmosphere (Mahlman, 1997), and the consequent effects on climate. An understanding of natural variability of climate is fundamental to understanding the impact of CO_2 and the effect of anthropogenic emissions (Stocker and Mysak, 1992). A more refined chronology of hydrologic events in lake sediment records across New England will contribute to the understanding of natural climate variability.

Furthermore, Brown et al.'s (2000) conclusions concerning event magnitude are important for understanding the effect of climate change on current landscapes. If the magnitude of prehistoric events was much greater than contemporary events, land managers and engineers must be prepared to develop landscapes and structures accordingly.

Work Plan:

Core Collection: Using a modified percussion piston coring device designed by Reasoner (1993), I worked with Paul Bierman, Anders Noren, Andrea Lord, Andrea Lini, and Leah Morgan to retrieve 10 cores from 8 lakes in New Hampshire and in Maine (see Figure 1 and Table 1). The lakes in New Hampshire and Maine meet the same requirements as set forth by Brown et al. (2000) and Noren et al. (2000, unpublished data) (see Table 1). The cores range from 4.5 to 6 meters in length; all of them have been divided into 1.5 meter sections for processing and are currently in refrigerators for storage.

Magnetic Susceptibility: After retrieving each core, I used a Bartington Magnetic Susceptibility Meter (MS2) to identify changes in sediment lithology where differences in magnetic mineral content exist (Dearing, 1986; see Figure 3). Inorganic sediment displays a higher susceptibility than gytta. Therefore, discreet peaks in susceptibility show the location of inorganic sediment layers in each core.

Remaining Data Collection:

Visual Logging: Each core section will be split lengthwise and immediately photographed to record the colors accurately before the sediment begins to oxidize. I will create a detailed visual log of each section, recording color. Samples will be collected at 1-cm intervals. I will record the location of macrofossils and collect them to use for carbon dating.

Radiocarbon Dating: Macrofossils from each core will be dated at Lawrence Livermore National Laboratory. Macrofossils, as opposed to gytta, will be 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 (Bierman et al., 1997). Macrofossils within the inorganic (or large grain size) deposits will represent the timing of events. If macrofossils are not found in the inorganic deposits, I will date macrofossils above and below each major inorganic or coarse grain layer to constrain the age of the deposit. I estimate that 10 dates will be used for each core. In a similar fashion to Brown et al. (2000) and Noren et al. (2000, unpublished data), I will use the radiocarbon dates to construct an age model for each core. In order to do so, I will extrapolate dates for layers without radiocarbon dates. Careful radiocarbon dating and eonstruction of an age model will allow me to indicate the timing of inorganic deposition in each core, and eorrelate timing between cores, following Noren et al. (2000, unpublished data).

Loss-on-Ignition (LOI): Loss-on-Ignition (LOI) is a measure of carbon content. I will sample and analyze each eore segment at cm intervals in order to distinguish the inorganic layers from the organic rich, gytta.

Grain Size Analysis: High resolution (1 cm interval) grain size analysis will be performed on 5 g dry weight samples treated with 25 mL of 30% H_2O_2 at 90°C for 24 hours to remove organic matter. The grain size analysis will be performed on a Coulter grain size counter at the Rubenstein Lab.

<u>Data Analysis</u>:

The cores range from 4.5- 6 meters in length, so approximately 450 to 600 grain size samples will be analyzed for each core. Sampling at this resolution provides a fixed interval data set, and allows for objeetive statistieal analysis of grain size in each core. Five grain size statistics will be considered: mean, median, standard deviation, skewness and kurtosis. In order to identify an individual layer as a hydrologic event, I will define which, if not all, of these parameters show a statistically significant difference from background characteristics in the core. For instance, a test of variance on an increase in mean grain size may distinguish a layer as an important hydrologie event, or variance in kurtosis or skewness may identify a layer. In any case, a quantitative measurement of the number and timing of significant hydrologic events in each core will be achieved.

LOI at cm level resolution will serve as an independent method for distinguishing significant hydrologic events in the core. I will perform a statistical comparison of LOI and grain size to determine the correlation between the two parameters. Once I identify sedimentation events, I will use the radiocarbon dates to make a detailed chronology of events for each core, which can then be compared to the other cores to find correlation of events throughout the study region. In this fashion, I will better define frequency and timing of depositional and, by inference, hydrologic events.

Timeline for Future Work

Summer 2001

• Core sampling, Splitting, Visual Logging, LOI tests, and travel to Lawrence Livermore National Laboratory for ^{14}C measurements, begin Grain Size Analysis and prepare abstract for Geological Socicty of America Annual Meeting in Boston (poster session).

• Ficld reconnaissance of cored lakes to examine surficial geology and describe basins

Fall-Winter 2001

• September to December: Finish Grain Size Analysis, present findings to date at GSA Annual Meeting in Boston (poster session), present Progress Report to UVM Geology Department

Spring 2002

• Statistical Analysis of Grain Size and LOI results

Summer- Winter 2002

• Write and defend thesis, and present findings at American Geophysical Union (AGU) Annual Meeting, in San Francisco

Figure 1- Map of core locations from Maine and New Hampshire. Selected lakes from Vermont and New York shown for comparison. Numbers correspond to Map Numbers in Table 1.

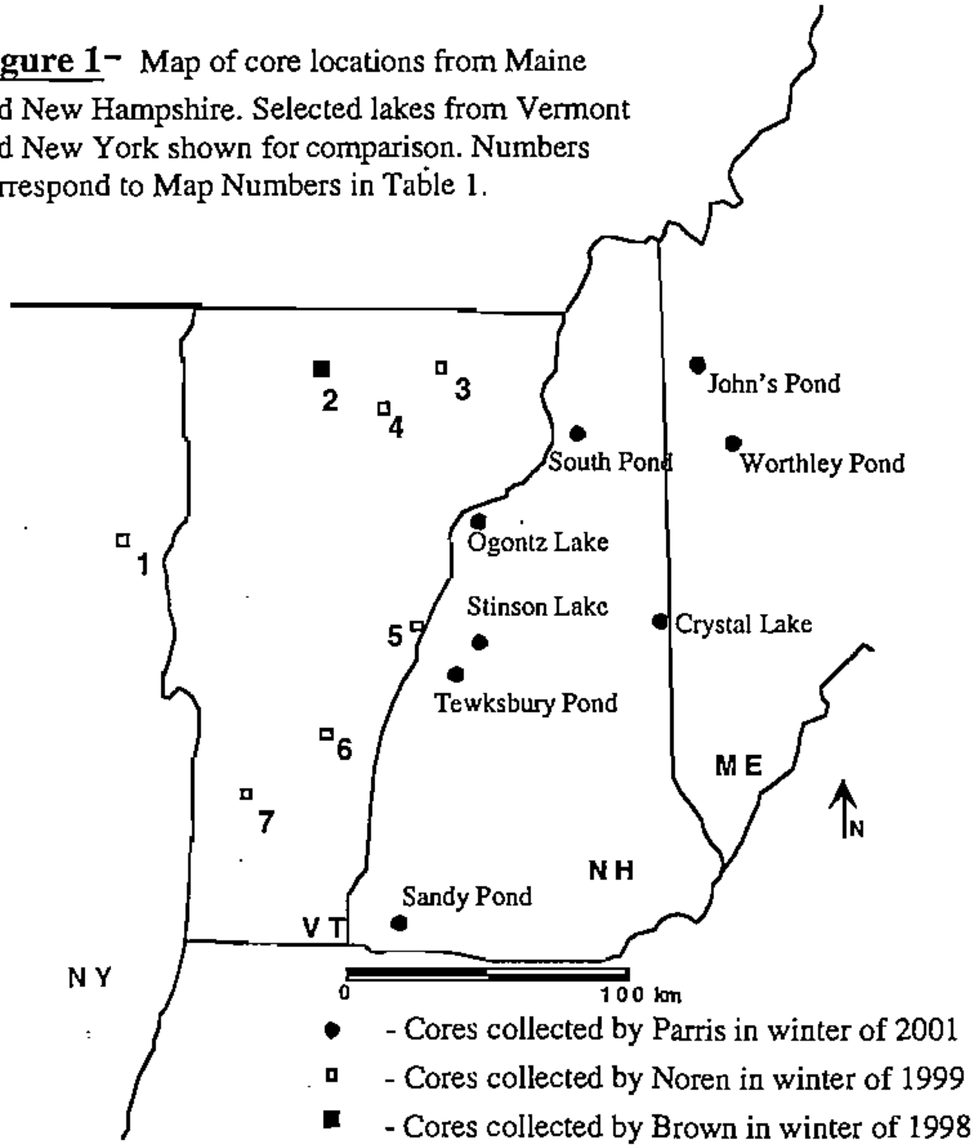


Table 1. Selected physical characteristics of lakes cored in Maine and New Hampshire.

Map #	Lake Name	Surface Area (km)	Maximum Depth (m)	Elevation (m)	Drainage Basin Area (km^2)	Drainage Basin Relief (m)
	Maine:					
	Johns Pond	1.08	15	533	18.2	384
	Worthley Pond	1.43	15	174	13.5	344
	New Hampshire:					
	South Pond	0.7	27.9	340	7.4	427
	Ogontz Lake	0.303	22	202	23.6	408
	Stinson Lake	1.4	22	396	20.7	655
	Crystal Lake	0.38	16	146	15	353
	Tewksbury Pond	0.187	14.9	304	7.4	223
	Sandy Pond	0.11	12	288	1.1	226
	New York:					
1	Chapel Pond*	0.07	24	485	4.6	925
	Vermont:					
2	Ritterbush Pond**	0.05	14	317	2.2	293
3	Duck Pond*	0.03	14	520	0.7	290
4	Elligo Lake*	0.7	30	269	13.1	259
5	Lake Morey*	2.22	13	127	20.7	414
6	Echo Pond*	0.42	28	323	68.1	678
7	Emerald Pond*	0.13	13	217	14.7	713

Sampled in winter 2001. Map numbers correspond to the location of each lake in Figure 1.
* Lakes in New York and Vermont were sampled in winter 1999 by Noren, and are included for comparison.
** Ritterbush Pond was studied by Brown (1999) and is included here for comparison.

Figure 2- (adapted from Bosley, 2001) Log of events for Lake Morey (Fairlee, VT; location shown in Figure 1; physical characteristics in Table 1) determined by filtering of Magnetic Susceptibility (MS), Loss on Ignition (LOI), and Grain Size Data. Grain Size shows the greatest number of events (32) followed by MS (16) and LOI (9). Whereas the grain size log shows a concentration of events (17) between 150-325 cm, only 3 or 4 of these are detected by MS and LOI. I will determine which events, logged by grain size, are statistically significant, and define which logged events represent higher or lower energy deposition. Also, there are logged events that are detected by all three types of analyses: 0-20cm, 120-140cm, and 290-305cm.

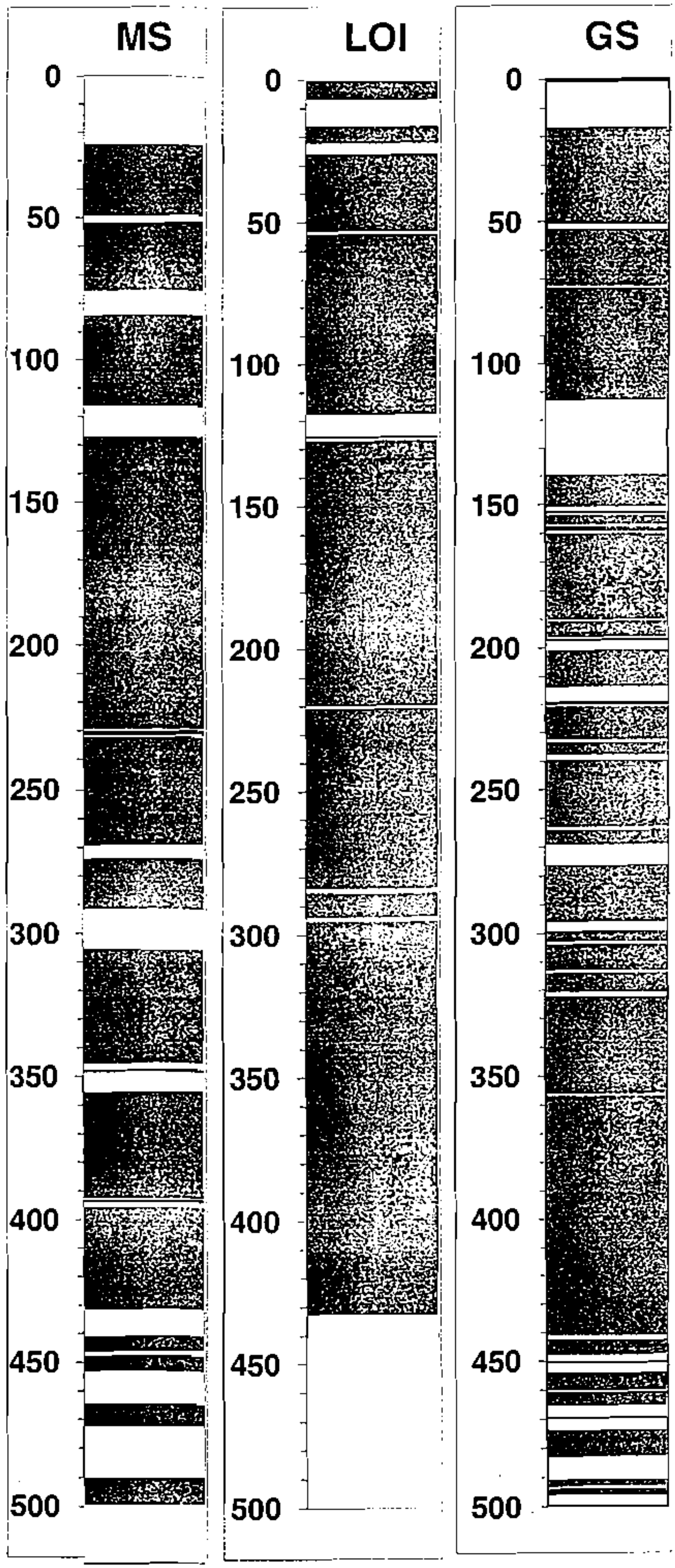
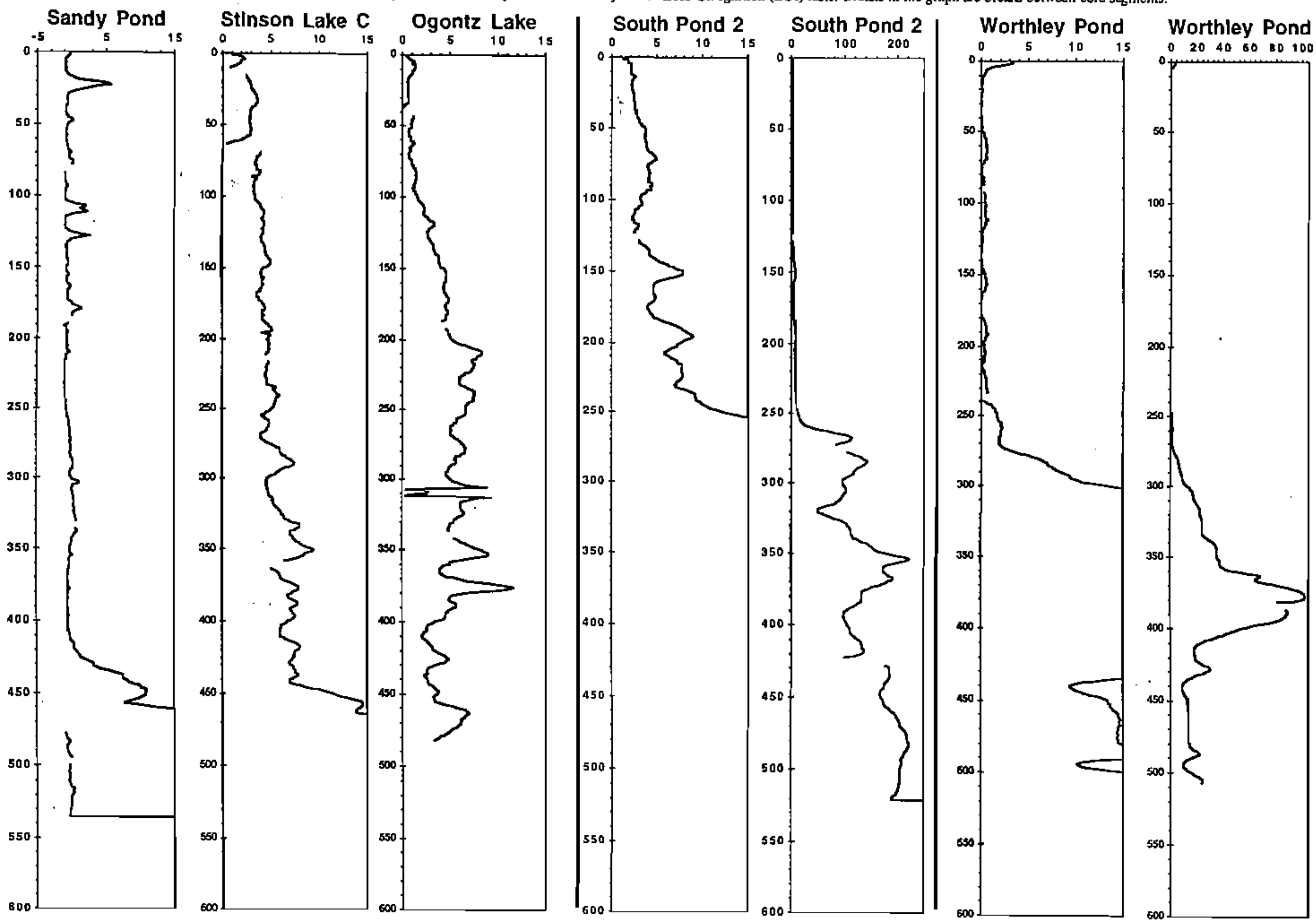


Figure 3- Graphs of Magnetic Susceptibility for 5 cores (locations shown in Figure 1). South Pond and Worthley Pond have been included with two different scales. The larger range shows material with much higher inorganic mineral content characteristic of glacial sediments. The smaller scale is more indicative of gytta, with brief, episodic deposits of inorganic material shown in the spikes to the right on the figure. I will compare the timing, frequency and magnitude of these inorganic deposits with the timing, frequency, and magnitude of inorganic deposits as defined by Grain Size Analysis and Loss-On-Ignition (LOI) tests. Breaks in the graph are breaks between core segments.



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