THE HISTORY OF THE LAURENTIDE ICE SHEET: A DETAILED SEDIMENTARY ANALYSIS OF A BOG, SW OHIO

JOEL BYERSDORFER
Geology Dept., Whitman College
Sponsor: Patrick Spencer

INTRODUCTION

Numerous studies have examined the history of Laurentide ice sheet (Lowell, 1995; Shane1987; and Ekberg et al., 1993). During the last glacial maximum, the ice sheet covered much of North America, advancing as far south as the vicinity of Cincinnati, Ohio.

Much recent study has focused on paleoclimate reconstruction and the relationship between climate and ice sheet dynamics (Broecker and Denton, 1989 and Lowell et al., 1995).

The goal of this study is to establish a record of paleoclimate and ice sheet behavior since the last glacial maximum approximately 20,000 years ago by extracting paleoenvironmental information from a sediment core.

METHODS

Coring sites were selected based on their location relative to the margin of maximum ice sheet advance as well as their suitability for preserving sedimentary records. Ten sets of cores were gathered from ten sites in the area SE of Dayton, Ohio (Fig. 1).

Coring was accomplished using a 2-inch diameter manual piston-coring device. This device allowed the retrieval of fine sediments only; it was not possible to core material coarser than medium to coarse grained sand. Cores were retrieved in approximately 1 meter segments with each thrust. Often, less than one meter was retrieved per thrust. Possibly, sediment from the bottom of the thrust fell into the hole. The most uncertainty resides at the top and bottom of individual core sections. For this reason, two adjacent holes were cored at each site in the hope that by staggering thrusts in each hole, a continuous stratigraphic record could be retrieved. One hole was begun 1 meter below the surface and thrusts taken at successive one meter intervals. The adjacent hole would then begin at 1.5 meters and thrust at 1 meter intervals as well. In theory, cores from each hole fill the gaps from the other.

Detailed descriptions were made for each section, including sedimentary structures, contacts, and color. Magnetic susceptibility readings, grain size measurements and loss on ignition tests measuring carbonate and organic content were taken every 4 cm.

Grain size was calculated by measuring refraction patterns of a laser directed through a sediment suspension of predetermined dilution.

Macrofossil analysis from two core locations per site allowed retrieval of organic material in sufficient quantities to make radiocarbon dating possible.

In order to accurately interpret data, the cores from each site must be correlated with each other in order to obtain absolute stratigraphic depths. To do this one must arbitrarily assign an absolute depth to one section first, and then correlate cores matching contacts and sedimentary structures.

RESULTS AND DISCUSSION

Age Constraints

The two radiocarbon dates in this study are from stratigraphic depths of 4.5 m and just under 8 m. The 8 m date is 16,170±97 yrs BP (19,286±310 yrs BP calibrated, Lab # AA45079), and the 4.5 m date is 13,370±280 yrs BP (16,066±390 yrs BP calibrated, Lab # Beta-158295). The upper date corresponds to the very distinct contact at 4.5 m whereas the bottom date corresponds to date closest to the bog bottom (Fig. 2).

Time represented by this 3.5 m package of sediment is approximately 3000 years. Each centimeter of sediment represents a little less than 10 years. The four centimeter sampling interval used for grain size, loss on ignition, and magnetic susceptibility cannot be expected to yield yearly data trends, but broader trends on the order of fifty, or hundreds of years.

Sedimentology and Sand Anomaly

The top meter of the core, beginning 1.5 m below ground surface, is a dark brown peat unit containing seeds and other organics (Fig. 2). Below, for the next 0.5 m is a banded marl unit containing snail shells. From ~3.3 m to 4.5 m is a banded silt and organic layer, capped at the bottom by a 0.25 m gelatinous gyttja layer. From 4.5 m to 7.5 m is a massive silt layer with occasional darker mottling. The last 0.75 m contains a silt layer above sand layer (more on that later). The bottom 0.1 m of the core is a mix of shell fragments, sand, silt and organics.

This core, 0110, was unique with respect to cores from other sites on this project in that it was the only one containing a coherent layer of sand.

This layer of sand fines upward into gravel just above 8 m. It contains shell fragments and is above a silty layer with organics. Assuming that regional sedimentary processes are dominated by Laurentide Ice Sheet influence, the age of the sand layer is about 20,000 years, which puts it at the same time as maximum glacial advance. At this time, the depositional environment was probably higher energy, compared to silts and clay that dominate most of the sedimentary record.

One possible explanation for the sand layer is that the basin represents an eddy off of a higher energy meltwater channel. Water and sediments were diverted into the basin during high flow where a sudden loss of competency caused deposition. Another possibility is that the basin was initially isolated from meltwater sources. As the outwash level rose and/or the edges of the basin eroded, the basin was exposed suddenly to an influx of moving water and sediment. After the sudden initial influx, the depositional environment transitioned into a lower energy environment. Due to the sharp nature of the contact, the isolated basin seems like the most likely scenario.

Grain size

The sediment column displays an upward fining trend. This makes sense in terms of a retreating ice sheet. There are large mean grain size fluctuations between 4.5 m and 8 m which show a decreasing minimum grain size. These fluctuations could be due to the dynamic nature of braided outwash streams associated with glacial drainage systems. As the ice sheet retreats, the stream becomes less braided and more stable. The grain size trend fluctuates less.

Standard deviation of grain size measurements reflects the sorting of sediment. Higher standard deviation in grain sizes signifies poorer sorting. Thus, a greater degree of reworking would be shown by better-sorted sediment and a lower standard deviation. One might expect to see a pattern of decreasing standard deviation through time as the outwash sediments were reworked and the ice sheet retreated. From 6.5 m and 4 m is a trend of lowering standard deviation. It is not clear whether the large variations in standard deviation are due to experimental uncertainty or environmental conditions.

Magnetic Susceptibility

Magnetic susceptibility measurements (Fig. 2) show high values and large fluctuations at the base of the column, correlating with the sand/gravel layer and proximity to the sediment source. After 7.4 m magnetic susceptibility readings gradually decline up through the sediment column until the present.

Magnetic minerals are generally heavier than non-magnetic. Following this line of reasoning, one would expect magnetic mineral content to decrease with reduced competence and distance from source. The pattern observed in these cores agrees with a signal that might be expected from a retreating source with accompanying lowering competency.

Loss on Ignition

Organic and carbonate content measurements are stable up to approximately 16,000 years ago. At this point, organic content rapidly rises to a higher level accompanied with greater fluctuations (Fig. 2). The most intriguing aspect of the loss on ignition measurements is the manner in which the organic and carbonate graphs are near mirrors of each other throughout the entire sediment column.

A possible explanation for this mirroring involves oxidation associated with increased organic content. As organics increase in the basin, possibly as algae or water plants, oxygen levels decrease via eutrophication. Decay and oxidation of deceased plant matter removes oxygen from the environment. More plants create an oxygen poor environment inhospitable to animals. At many sites, some snail shells made of calcium carbonate are preserved. LOI data from these sites exhibit various degrees of mirroring in carbonate versus organic graphs.

It is reasonable to assume that amount of plant material a given environment supports is related to temperature and aridity. It is likely that when the ice sheet reached its maximum extent, climate was at its coldest. As climate warms, the ice sheet retreats and higher organic and carbonate contents would be expected. However, this trend does not appear in the data. In a regional picture, this trend probably was present, but in an outwash/glaciolacustrine setting, cold water and sediment will continue flowing even after the ice sheet retreats. This might be why the ice sheet retreat signal is far delayed in the carbonate/organic record compared to grain size and magnetic susceptibility measurements.

CONCLUSION

The measurements in this core point to a retreating ice sheet by 16,200 yrs BP. This date represents a minimum age for ice retreat. In all likelihood, retreat began before this date. Also, the severe sedimentologic contrasts at 16,200 and 13,400 yrs BP indicate significant environmental changes. Although the patterns in grain size, loss on ignition, and magnetic susceptibility data display a signature consistent with ice retreat, their variable nature may be indicative of an ice sheet retreating in surges, maybe even with brief periods of advance.

The sand layer probably represents a sudden influx of meltwater into an isolated basin followed by regular sedimentation. This study highlights the importance of differentiating between local environmental changes (sand anomaly) larger scale regional environmental changes, such as those that drive continental glaciations.

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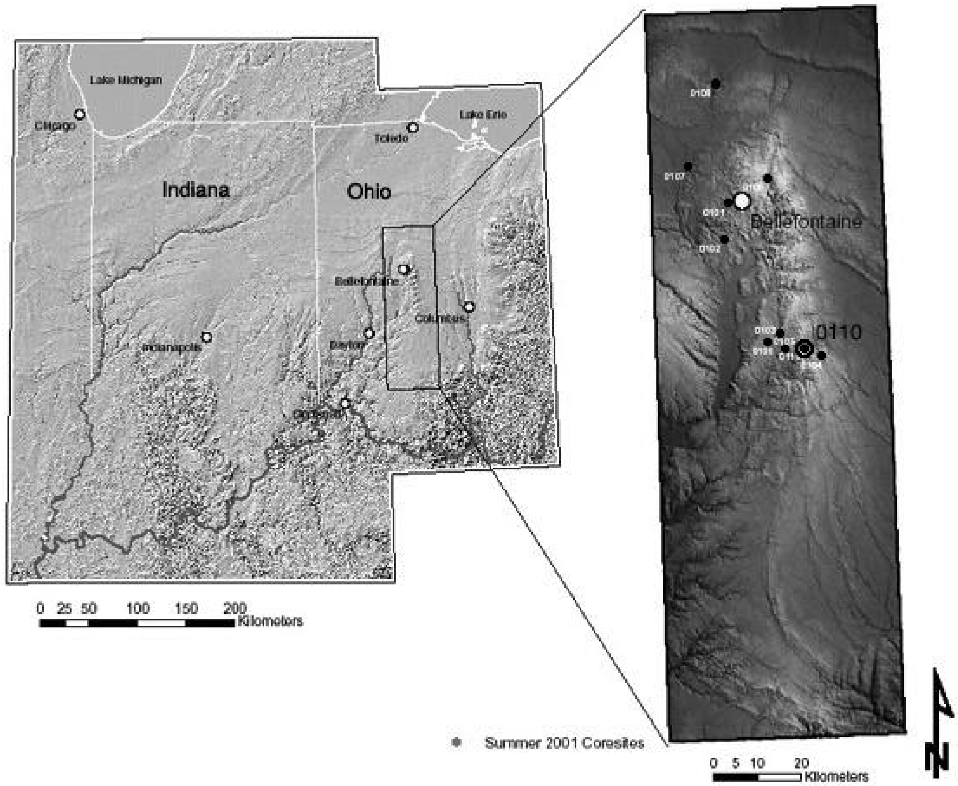

Fig. 1 Location of core sites, 2001 Ohio Keck. Study site indicated by bullseye symbol. Moraine complex of Laurentide Ice Sheet is visible enlarged portion.

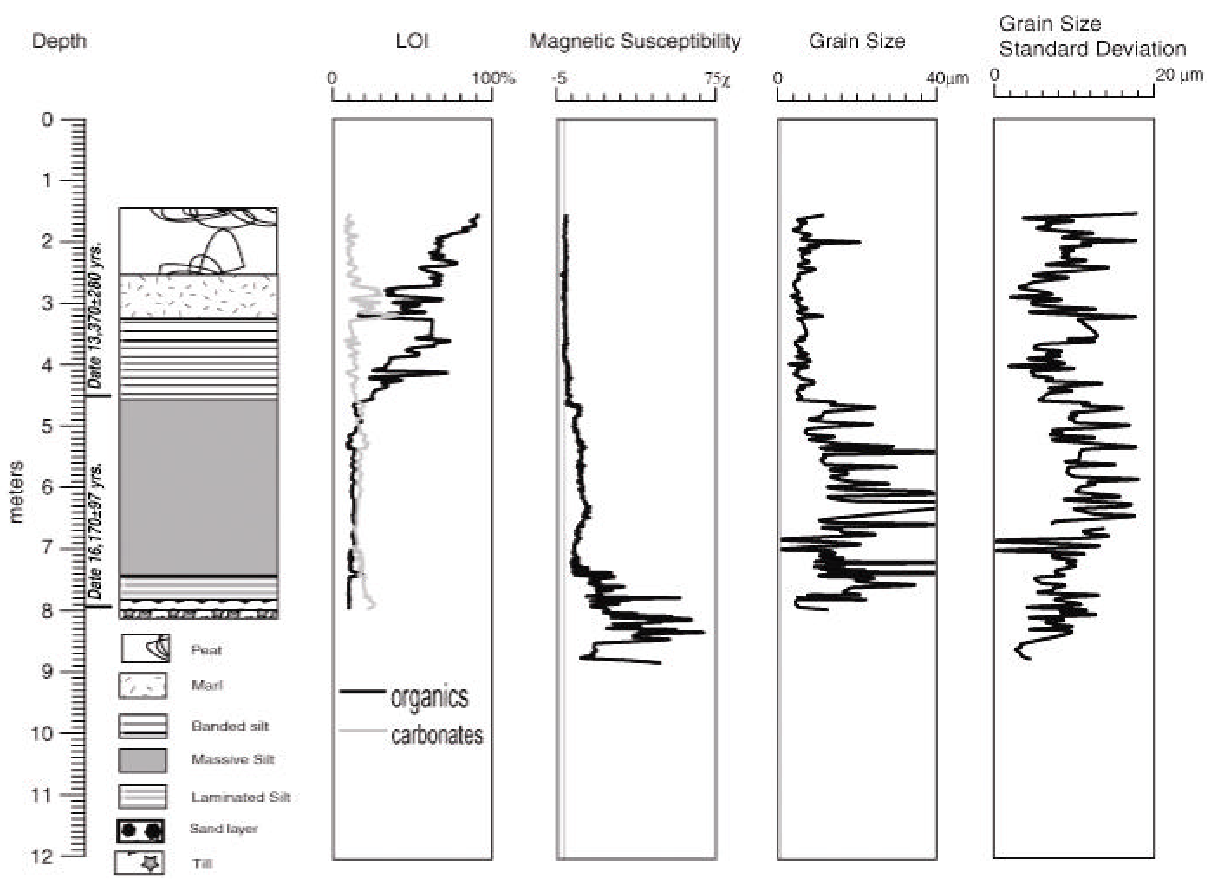

Fig. 2. Data for core 0110. All depths are correlated stratigraphic depths. Left column identifies composition of sediment column. Note mirroring in organic and carbonate content.