PHOTOSYNTHETIC PIGMENTS AND TOTAL ORGANIC CARBON FROM SEDIMENT CORES AS PROXIES FOR HOLOCENE ENVIRONMENTAL CHANGE, UNION CITY, INDIANA

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INTRODUCTION

The interior of North America has provided a limited record of deglacial climate variation (Yu and Wright, 2001). During this time period the retreating Laurentide ice sheet left many topographic depressions. These landforms stored the glacio-fluvial sediments washed off the ice. Sediment cores recovered from these basins provide a good record of climate change during this period of deglaciation (Bradley, 1999).

The purpose of this research was to document the paleoclimate variation that occurred during the last deglaciation. Analyses of the total organic carbon (TOC) and photosynthetic pigments found in the sediment provide a record of biologic productivity within the basin, and have been used as a proxy for climatic variability.

STUDY AREA

Monroe's Bog, site 0209 (Figure 1), is located just north of the Union City moraine. This basin was likely formed as a kettle depression. The Union City moraine is the southernmost end moraine in eastern Indiana, and sediments deposited within this basin provide climate data representative of the time period after the deposition of this end moraine.

METHODS

Field Coring

Three overlapping sediment cores 2" in diameter were recovered using a modified Livingstone piston corer. The sediment was then described noting grain size, color, major contacts, and then covered in plastic wrap and placed in PVC pipe for transport and further analysis.

Initial Laboratory Methods

Once back in the lab, the cores were split down the middle and described in greater detail. The presence of macrofossils was noted, and the core was digitally photographed. The photographs of the three cores were then correlated by aligning the distinct sedimentary beds. Magnetic susceptibility readings were taken at 4cm intervals on three sides of the core using a Bartington MS2 Susceptibility Meter. $1cm^3$ samples were then taken from the second core

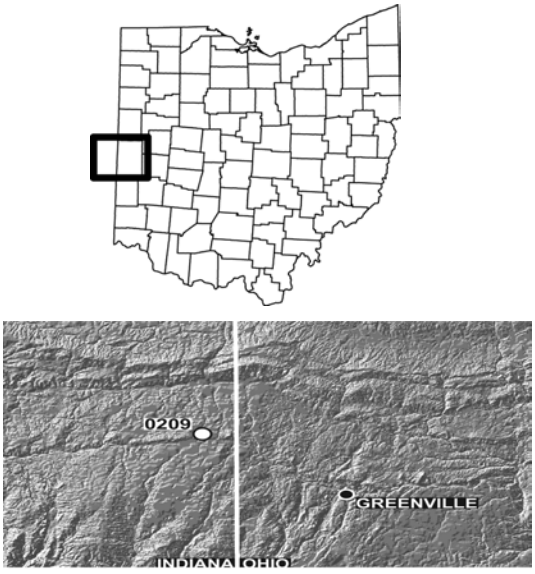

Fig. 1. Map of study area

at 4cm intervals to be used in preliminary loss-on-ignition (LOI) and grain size analysis, using a Spectrex Laser Particle Counter Model PC-2000.

Follow-up Laboratory Methods

Paleoclimate studies by Nesje and Dahl (2000) revealed that the amount of organic matter in lake sediments can be an indicator of Holocene air temperatures. For this reason, high-resolution loss-on-ignition analysis was performed at 1cm intervals on the remainder of the core.

In addition to organic carbon, photosynthetic pigments in sediment cores can be used as indicators for the overall response of the phytoplankton community to climate change (Tani et al., 2002). To gain insight into environmental changes and the origin of the organic carbon, the photosynthetic pigment chlorophyll-a and its degradation product phaeophytin-a were extracted from the sediment using 100% acetone. $1cm^3$ samples were removed from the top 300cm of the core at 5cm intervals, the smaller sample size is due to the lack of organics below this depth as shown in LOI data. The sample was then immersed in 10mL of 100% acetone and homogenized to create maximum surface area for extraction, then wrapped in foil and placed in a 12 degree C refrigerator for 48 hours. After the extraction period the samples were centrifuged and decanted into a separate test tube, all the while making every effort to keep them out of the light. 1 mL samples were placed in quartz cuvettes, and measured for absorbance against a blank of 100% acetone at three wavelengths. The three wavelengths were 662nm, 645nm and 470nm. These represent the peak absorbencies of chlorophyll-a, chlorophyll-b, and carotenoids in 100% acetone, respectively (Lichtenthaler and Wellburn, 1983). One drop of 10% HCl was then added to each cuvette to degrade any remaining chlorophyll-a, and the samples were measured again at each wavelength. The total amount of chlorophyll-a and phaeophytin-a was then calculated for using the equations derived by Lichtenthaler and Wellburn (1983).

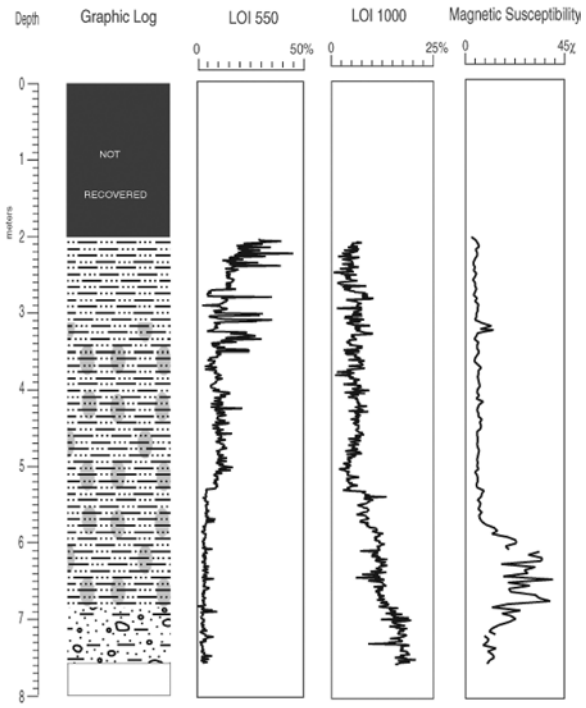

Fig. 2. Core stratigraphy and related LOI and magnetic susceptibility data.

RESULTS AND DISCUSSION

Core Stratigraphy

The combination of the sediments recovered from the three overlapping cores accounts for 200cm to 758cm depth in the basin. High-resolution loss-on-ignition, magnetic susceptibility and core descriptions show four distinct horizons of changing depositional history.

The basal unit is a gray diamicton unit that ranges from 758-685cm (This unit will be referred to as unit 1). It shows very low organic content and magnetic susceptibility, while its carbonate content is the highest in the core, reaching nearly 20%.

Unit 2 ranges from 685-528cm and is composed of mottled silt with a very low organic content, ranging from about 2-4%. Unit 2 is also characterized by its relatively high carbonate content ranging from about 15% at the base to about 5% at the top. This unit also shows the largest variation in magnetic susceptibility from 3-33 SI.

Unit 3 ranges from 528-332cm and is composed of mottled silt. There is a sharp increase in the amount of organics and decrease in the amount of carbonates at the contact between units 2 and 3. The organics

vary from about 8-20% and the carbonates from about 3-8%. Photosynthetic pigments from this horizon show an overall increase in concentration up core and closely parallel the organic carbon trends. This unit shows negligible magnetic susceptibility readings.

Unit 4 ranges from 332-200cm and is a massive silt unit. This unit showed a great spike in organic content at its base, where the measurement doubles in percentage. The overall organics in this unit range from about 10-30%, while the carbonate range remains roughly the same as in unit 3. Chlorophyll-a and phaeophytin-a once again increase up core in this unit and their wide range of values is mimicked in the organic LOI data. Again, magnetic susceptibility readings were negligible.

Interpretation

Studies by Lozano-Garcia and Ortega-Guerrero (1998) signify that low magnetic values were indicators of dry environmental conditions. Research by Tani et al (2002) suggested photosynthetic pigment concentrations can be used as a proxy for environmental conditions, because they indicate the response of the phytoplankton population to climate change. By interpreting relative organic carbon concentrations as a direct sign of Holocene air temperatures (Nesje and Dahl, 2000), and applying the above research to the data from Monroe's Bog, it is possible to reconstruct the environmental conditions during the deposition of the sediments in this basin.

Unit 1

The high carbonate concentration and unsorted nature of the basal unit reveals that it was eroded off of the local limestone bedrock and deposited as a till by the advancing Laurentide Ice sheet.

Unit 2

AMS radiocarbon dating on a piece of wood from the base of this unit suggests ice retreat began in this area at 15,640 +/- ^{14}C yr BP. Based on the above interpretations and the close proximity of the retreating ice sheet, the conditions were very wet during the deposition of unit 2. There was a high amount of sedimentary input into the basin, as seen in the carbonate concentration. The carbonates were eroded off the local bedrock and deposited by glacial outwash. Low organic content in unit 2 indicates that air temperatures were cool enough to repress biologic activity. All of these factors indicate that the climate was warm enough for the onset of increased deglaciation, yet cool enough to prevent biologic activity.

Unit 3

The low magnetic readings and sharp decrease in the amount of carbonates in the sediments of unit 3 suggests drier conditions and less terriginous input to the basin. This unit also has greater overall organic content because of increased local air temperatures. The increase in photosynthetic pigments in unit 3 parallels the increased organics (see Figure 3). This correlation provides evidence that the majority of organic carbon in the basin is actually phytoplankton. The fluctuations in organic content indicate seasonal variation in temperature, while showing an overall warming trend. An AMS radiocarbon date from the top of this unit of 13,690 +/- 100 ^{14}C yr BP indicates about 2000 ^{14}C yrs passed during the deposition of the mottled silt

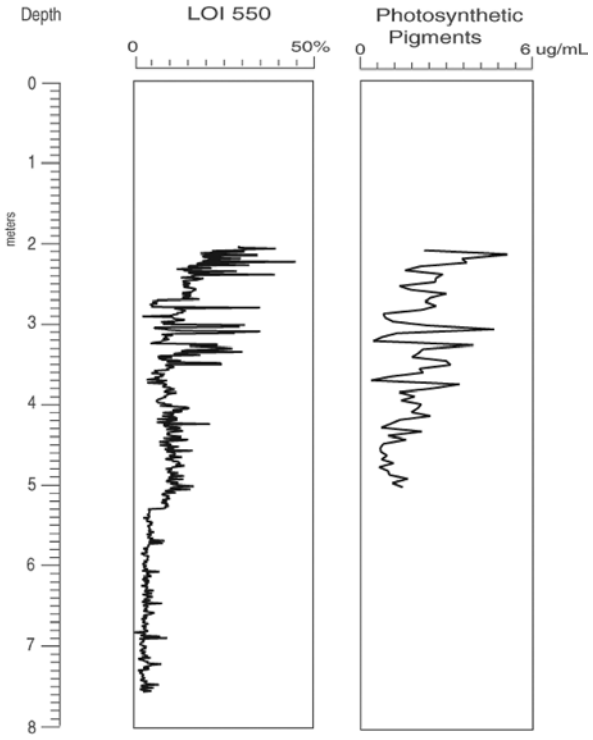

Fig. 3. Organic carbon and photosynthetic pigment concentrations.

horizon.

Unit 4

The youngest radiocarbon date comes from the base of unit 4 and provides and age of 13,505 +/- 78 ^{14}C yr BP for the onset of peak organic activity within the basin. Unit 4 shows the greatest concentration of organic matter, which once again parallels the photosynthetic pigment concentrations. The overall increase in both is interpreted as a warming trend. Within this unit, there are also small sections of core that show low organic content, providing evidence of cool intervals within this warming period.

Origin of Photosynthetic Pigments

The data reveals that the relative amount of photosynthetic pigment in the sediment core follows the same trend as the organic LOI data (Figure 3). The environmental conditions during the deposition of the upper two units are interpreted to be warm and dry, resulting in a low amount of outside input into the basin. For this reason the organic carbon is thought to be composed mainly of phytoplankton. The fact that the majority of the photosynthetic pigments found in the basin are actually phaeophytin-a and not chlorophyll-a reveals that zooplankton was feeding on the phytoplankton causing the degradation of the chlorophyll. This indicates that the total organic carbon in the basin is actually from the fecal pellets of the zooplankton and not allochthonous in origin (Tani et al., 2002). This inference is supported by low magnetic susceptibility values in the upper portion of the core.

CONCLUSIONS

The sediments of Monroe's Bog provide insight into the active climatic cycles that occurred at the beginning of the Holocene. Following ice retreat after 15,640 +/- 97 ^{14}C yr BP cold and moist conditions persisted during the deposition of the basal sediments. A subsequent warming trend resulted in increased organic productivity, reaching its peak some time after 13,505 +/- 78 ^{14}C yr BP. LOI data shows cyclical environmental changes within the sediments deposited during the warming trend and may indicate seasonal variation. The correlation between the photosynthetic pigment concentration and total organic carbon provides support for the interpretation that organics originated within the basin.

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