SEDIMENTOLOGICAL AND GEOCHEMICAL RECORDS OF HOLOCENE ENVIRONMENTAL CHANGE IN SHARPEYE SWAMP, GREENVILLE, OHIO

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INTRODUCTION

Developing a better comprehension of the factors that control climate change is critical for understanding the Earth's history, providing a scientific basis for modeling future climate change, and enabling policymakers to make informed decisions related to global warming. By reconstructing Holocene paleoclimatic changes in Sharpeye Swamp, Greenville, Ohio, this study contributes to a growing body of data about Laurentide Ice Sheet behavior in the southern Great Lakes Region.

Numerous studies of late Wisconsin glacial history make the southern Great Lakes Region, and especially southern Ohio, one of the best-dated records of regional climate change in North America (Wiles et al., 2001). Most of Ohio's surficial quaternary record consists of sediments deposited during the Wisconsinan, the most recent period of glaciation in the southern Great Lakes region (Pavey et al., 1999). Hundreds of radiocarbon dates indicate that the southern margin of the Laurentide Ice Sheet experienced several stages of advance and retreat between 22,000 and 18,000 ^{14}C yrs BP (Eckberg et al., 1993), but subsequent deglaciation in the region has been less-extensively studied.

The Laurentide Ice Sheet advanced to form the Hartwell Moraine 19,000 ± 500 ^{14}C yrs BP. After a subsequent retreat and small re-advance, a major advance at 17,200 ± 400 ^{14}C yrs BP formed the Farmersville Moraine and Arcanum Till Plain. During the Erie Interstade ~16,500-15,500 ^{14}C yrs BP, Ohio was ice-free as the ice retreated to Canada. A readvance at 15,000 ± 500 ^{14}C yrs BP constructed the Mississinewa and Union City end moraines (Dreimanis & Goldthwait, 1973).

Bogs such as Sharpeye Swamp offer high resolution records of continuous deposition over a specific time period and provide both sedimentary and geochemical evidence of variations in local environmental conditions including changing sediment sources.

Geologic Setting

Sharpeye Swamp (Site 0203) is located at 40.1011 N, 84.74445 W in western Darke County, Ohio on Wisconsinan ground moraine south of the ice-marginal Miami Sublobe of the Late Wisconsin Union City Moraine. The site is near a relic glacial discharge channel flowing SW from the Union City Moraine.

METHODOLOGY

Field Methods

A 2-inch diameter modified Livingston piston corer was used to extract two cores one meter apart and staggered in depth starting at 200 and 250 cm below the surface. Together, the two cores provide an almost continuous 950 cm record of sedimentation in the swamp. The cores were removed in meter-long thrusts.

Sedimentology

Each thrust of the two cores was split in half and sedimentologic features were described. Loss on Ignition (LOI), mean grain size, and magnetic suceptibility were measured every 4 cm on Core A, and gaps were filled using correlated sections of Core B.

LOI was measured by heating 1cm^3 plugs in crucibles in a furnace oven at 100°C to evaporate water content, weighing, heating for one hour at 550°C, weighing to determine percent organics removed, heating for one hour at 1000°C, and weighing to determine percent carbonate removed.

Mean grain size was measured by heating 1cm^3 plugs at 100°C to remove water content, grinding in a mortar and pestle to disaggregate clumps, suspending sediment in deionized water, and analyzing on a PC-2000 Spectrex Laser Particle Counter.

Three magnetic susceptibility measurements were taken every 4 cm and averaged. The cores were correlated using visible sedimentologic features and magnetic susceptibility data.

Macrofossils from three intervals were extracted, prepared at the University of Minnesota's Limnological Research Center, and AMS dated at the University of Arizona.

Eleven thin sections were taken from throughout the core.

Geochemistry

66 sections of core, each stratigraphically 1 cm deep, were dried for 12-15 hours at 75°C and shatterboxed.

Bulk Digestion

The bulk geochemistry of 8 of these intervals was analyzed on the ICAP at Middlebury College after preparation at Williams College.

All reagents used were trace metal grade. In Teflon microwave digestion vessels, 1 ml of 35% H_2O_2 was added to 0.1000g of sample for 30 min., then 6 ml of 70% HNO3 was added for 30 min, then 2 ml of concentrated HF and 1 ml of concentrated HCl were added. Vessels were capped and samples were microwave-digested for 9 minutes at 180°C. The subsequent fuming sequence evaporated away the HF and HCl while keeping sediment dissolved: fumed to 0.5ml; added 1.5ml concentrated HCl and fumed to 0.5ml; added 1.5ml concentrated HNO_3 and fumed to 0.5ml. Samples were transferred to 50ml acid-washed centrifuge tubes and brought to 50.00g with 2% HNO_3.

2% HNO_3 Digestion

Five elements (Mn, Sr, Fe, Mg, Ca) showing noteworthy trends from ICAP results were chosen for weak acid digestion analyses. The 66 intervals from Core 0203, as well as loess from 482-486 cm depth of Lowell's Bunnel Core DT5 and 2 cm of till from the top of Core 0202 BT4 (40.09317 N, 84.74343 W), located just south of Core 0203, were analyzed.

0.1000g of sediment and 1 ml of 30% H_2O_2 were added to acid-washed 50-ml centrifuge tubes and left uncapped for 30 minutes. 39g of 2% HNO_3 was added and left for 30 minutes. Samples were capped and put on a shaker for 15 hours, centrifuged at 3,000 rpm for 5 minutes, and the supernatant decanted.

The supernatant was analyzed for Mn, Sr, Fe, Mg, and Ca using flame atomic absorption spectrometry.

RESULTS & DISCUSSION

Radiocarbon Dating

Dates were calibrated with 2-sigma error using CALIB v4.3 (Stuiver & Reimer).

Lab #	Depth (cm)	^{14}C yrs BP	Calibrated calendar yrs BP
AA53417	363-366	post-bomb	n/a
AA53414	603-605	16,090±150	19,907–18,535
AA53425	652-661	16,400±170	20,295–18,850

The two lower dates indicate a sedimentation rate of 58 cm in ~310 ^{14}C yrs, or approximately 0.19 cm/^{14}C yr. It is unlikely that the uppermost macrofossil dated, a stick located at the top of a thrust, was actually deposited at 363-366 cm during the post-bomb era, since it is doubtful that 363 cm have been deposited at the swamp since the 1950s. The stick may have been introduced during the coring process.

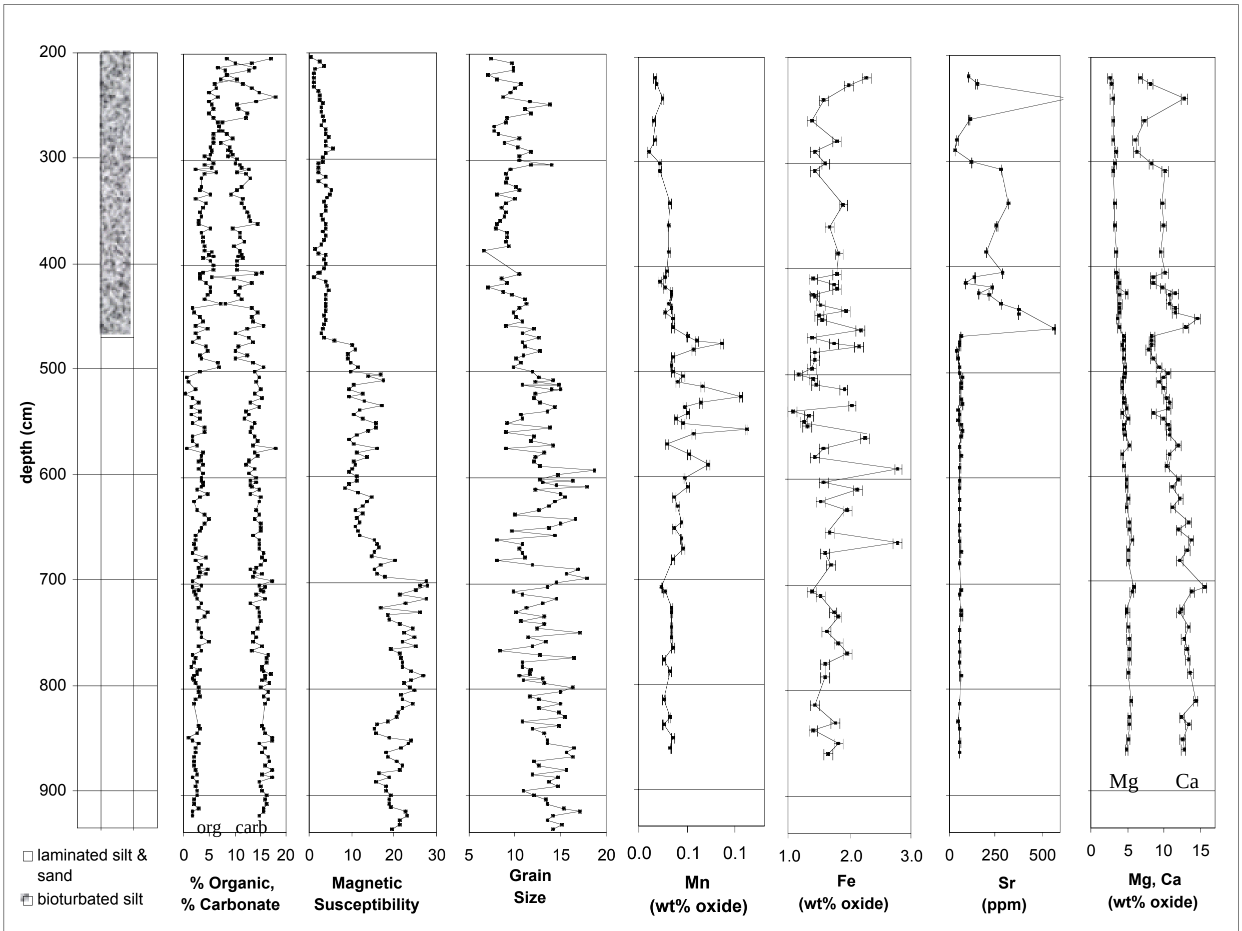

Figure 1. The sedimentologic shift from laminated to bioturbated sediment at 470 cm corresponds with increases in Sr and Ca and decreases in magnetic susceptibility, grain size, and Mn. Mg and Fe trends show no shift at this transition. Geochemical error bars display a 95% CI calculated from standard deviations of 11 replicate standards made from a section of homogonized core.

Sedimentology

Shifts in magnetic susceptibility, organic and carbonate content, and grain size trends correspond with a transition between laminated silt and an overlying package of bioturbated silt at an absolute depth of 465-510cm (Figure 1). Above this transition, average organic composition increases by 2.3%; average carbonate composition decreases by 3.8% and variability increases; average magnetic susceptibility decreases by 14.6 units and variability significantly decreases; and mean grain size decreases by 3.5% and variability decreases. Thin sections reveal graded bedding in the lower part of the core and black horizons rich in organic matter throughout the core.

Magnetic susceptibility shows the most abrupt transition at 468-476cm at the onset of major bioturbation. Large particles tend to have smaller magnetic susceptibility values than small particles of the same source material, since they have less total surface area. The higher magnetic susceptibility of particles in the 500+ cm depth of core thus cannot be attributed to a higher mean grain size. The higher magnetic susceptibility values downcore are thus probably due to a higher percentage magnetic minerals associated with a changed source of clastic sediment input into the basin.

The low organic content of the core, despite a high rate of sedimentation, implies that the laminations are not the result of an oxygen-depleted system.

The general increase in grain size may be related to a receding sediment source, forcing meltwater streams to travel longer distances to reach the basin and larger and/or heavier particles to settle farther from the basin. The major transition around 500 cm was likely caused by a change in sedimentary influx into the Sharpeye Swamp basin.

Geochemistry

Samples processed with 2% HNO_3 leaches indicate changing levels of Mn, Sr, and Ca at the transition from laminated to bioturbated sediment. Sr increases from a stable average of 58 ppm to highly variable concentrations up to 646 ppm. Mn varies less and remains below 0.06 wt% oxide after the transition. Mg and Fe show no significant change around the transition, but Ca increases from 8.0 to 13.3 between 458-466 cm. Ca and Mg both gradually decrease upcore.

The Sr/Ca ratio closely mirrors the Sr trend, and above 470 cm, variations in Ca and Sr are correlated ($R^2 = 0.75$). Although ostracods were found during macrofossil searches, little biogenic calcite was detected in 11 thin sections, containing both allogenic and authigenic carbonate, taken from throughout the core.

Fe and Mn can become soluble in reducing conditions, making it difficult to separate changes in sediment source from basin redox effects. Peaks in the Fe/Mn ratio coincide with peaks in Fe, indicating that Fe and Mn concentrations may be due to changes in catchment supply (Boyle in Last & Smol, 2001).

Till from the base of a nearby core at Site 0202 contains a similar concentration of Sr to the lower portion of Core 0203, indicating that till is a possible sediment source for the 0203 basin until the transition at 470 cm. Loess from Tom Lowell's Bunnel Rd. core contains significantly less Sr than all but a few small horizons in 0203 and provides no evidence that the loess found in the Bunnel Rd. core was present in Core 0203.

CONCLUSIONS

Sedimentologic geochemical trends in Sr, Ca, and Mn at 470 cm in Core 0203 indicate a major environmental change sometime after 16,400 ± 170 ^{14}C yrs BP. Decreased sediment size and magnetic susceptibility upcore of this transition, as well as a dramatic increase in Sr up from lower till-level concentrations, indicate a changed sediment source.

The transition seen at Site 0203 parallels similar shifts at nearby core sites, especially at Site 0204 located to the northeast in the same paleodrainage valley. Both sites show a shift from laminated sand and silt to bioturbated silt accompanied by decreases in magnetic susceptibility, grain size, and % carbonate, and an increase in % organic matter. This transition is constrained to between 16,010 ± 100 and 14,741 ± 96 ^{14}C yrs BP at Site 0204. Similar shifts from laminated to bioturbated sediment along with decreases in magnetic susceptibility and grain size occur at Site 0210 just north of the Miami Sublobe (after 16,220 ± 950 ^{14}C yrs BP) and at Site 0208 near Wooster, Ohio (constrained between 20,930 ± 160 and 12,740 ± 100 ^{14}C yrs BP).

Because such a transition occurs in several of our Ohio study sites, observed sedimentologic changes may be the result of regional environmental changes such as ice sheet retreat during the Erie Interstade. However, the shift is not apparent in all of our sites, indicating that local basin conditions play an important role in basin sedimentation.

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