Report as of FY2007 for 2006MS46B: "Developing a Reliable Method for Identifying Pre-settlement Wetland Sediment Accumulation Rates: 14 C Dating on Bulk Lake Sediments and Extracts"

Publications

Project 2006MS46B has resulted in no reported publications as of FY2007.

Report Follows

Developing a reliable method for identifying pre-settlement wetland sediment accumulation rates: ^{14}C dating on bulk lake sediments and extracts

May 30, 2007

Milestones

1. Cores were collected from Sky Lake in cooperation with the USDA National Sedimentation Laboratory in Oxford, MS and the Yazoo Mississippi Delta Joint Water Management District.

2. Sediment cores were sectioned and dried. Selected intervals were sieved and taken through several chemical treatment steps. Processed samples were combusted and submitted for $\delta^{13}C$ and ^{14}C analyses.

3. Results were obtained for all samples, allowing calculation of sedimentation rates for three open water cores and one wetland core.

4. Preliminary results were presented at the 19th International Radiocarbon Conference in Oxford, England.

5. A manuscript describing the use of ^{14}C from bulk sediment fractions for determining accurate sedimentation rates is in review for publication in *Radiocarbon.*

6. Particle size analyses from samples from one core are currently being processed for completion of a second manuscript detailing the full history of sediment accumulation in an oxbow lake in the Mississippi Alluvial Plain. This manuscript will be submitted in June to the *Journal of Soil and Water Conservation.*

Remaining objectives

1. Submit the second manuscript.

Narrative Summary

Carbon-14 is often used to date specific layers in lake sediments, but there are many problems that can result in erroneous calculated ages. Terrestrial macrofossils are generally the most desirable material to date, but they are often difficult to find. In the absence of macrofossils, pollen may be extracted and dated, but separation is tedious and requires use of toxic chemicals. Bulk sediment fractions contain a mixture of material of various age, and may be subject to reservoir effects that usually add apparent age to samples. A single ^{14}C measurement from a bulk sediment sample is thus unlikely to yield the true age of deposition. If inputs into the system have been relatively constant over an interval of time, however, changes in ^{14}C activity with depth should represent accurate changes in time even if the absolute dates remain uncertain. Knowledge of changes in time and the thickness of sediment accumulated over that interval of time allows calculation of the rate of sediment accumulation.

In this study, three bulk sediment fractions have been compared with three macrofossil (or "subfossil") types.

Bulk sediment
1. untreated silt and clay size fraction, combusted at low temperature (400°C)
2. humic acid leached from silt and clay size fraction
3. undifferentiated organic material (both chemically washed and unwashed) 250-710 μm.

Macro Subfossils
1. twigs representing 1 to 2 years of growth
2. charcoal
3. wood fragments

The ^{14}C activity of all sample types have been compared from a wetland core (Figure 2). The bulk sediment fractions yield highly linear plots with respect to depth, and all yield very similar sedimentation rates (Table 1). The subfossil results are much more scattered and yield slightly lower sedimentation rates. The linearity of the bulk sediment fractions suggests they are more reliable than the subfossil samples for rate determination. This is was an unexpected, but very favorable result.

Samples from three of the cores collected from the open water area were used to test how reproducible calculated sedimentation rates are using a bulk sediment fraction. Since all three bulk sediment fractions from the wetland core produced similar results in the wetland core, only one was chosen for replicate analyses using the open water cores. The untreated silt and clay size fraction was chosen. Data from the three cores (Figure 3) demonstrated a high degree of reproducibility. Data from each core was highly linear, and all three cores show a change of slope, representing a change in sediment accumulation rate, at approximately the same depth. This data shows great promise for the use of biased ^{14}C activity from bulk sediment fractions to accurately estimate sediment accumulation rates.

Additional samples from one open-water core were processed and submitted for ^{14}C analysis to determine the complete sedimentation history of Sky Lake. The results, together with ^{210}Pb and ^{137}Cs data previously acquired, map out the history of this lake from the time it was an active channel of the Mississippi River to the present (Figure 4). Visual stratigraphy within the lake cores divides the sediment into three intervals. The bottom of each core contained coarse sands typical of channel deposits. Above the sands, a transition zone 7 to 15 cm in thickness contains sand, silt and clay. The upper 2 m of sediment are lacustrine silts and clays with no visible layering.

Carbon-14 analyses were performed on sediments within and above the transition zone. The transition zone samples are the lowermost points in Figure 4. The large scatter in ln ^{14}C activity within the transition zone with all values plotting to the left of the overlying points is consistent with an interpretation of these sediments as channel deposits in an actively flowing system. Organic fragments deposited in a stream channel potentially include material that was living a short time earlier along with much older material that may have been exhumed upstream and redeposited at the sampling point.

Within the lacustrine silt and clay, three distinct sedimentation regimes are apparent from the radioisotope data, with steeper slopes representing higher rates of sediment accumulation. The three lacustrine intervals can be characterized, beginning with the lowest, as (1) recently abandoned oxbow with close proximity to the river, frequent flooding, and a relatively high sediment accumulation rate (1.3 mm/yr), (2) migration of the river away from the lake resulting in a reduction in flooding frequency and a much lower sediment accumulation rate (0.2 mm/yr), and (3) clearing of surrounding land for agricultural use resulting in a 50-fold increase in the rate of accumulation (10 mm/yr).

Accumulation rate over the past century was determined based on a combination of ^{14}C, ^{210}Pb and ^{137}Cs data. Changes in ^{14}C activity cannot be used as described here in sediments deposited during the last 50 years because of the large atmospheric influx of anthropogenic ^{14}C introduced by surface testing of nuclear weapons. For these recent deposits, ^{210}Pb and ^{137}Cs are well suited. The slope of excess ^{210}Pb activity vs depth, and the depth of the ^{137}Cs peak both yield a recent sedimentation rate of 10 mm/yr. A line representing changes in ^{14}C activity with an accumulation rate of 10 mm/yr is drawn in Figure 4 and projected to a depth of 110 cm. The uppermost ^{14}C samples, at depths of 79 and 99 cm, fall close to the projected line suggesting that the rate of 10 mm/yr has persisted since the land first began being cleared near the end of the 19th century.

The time interval prior to clearing of surrounding land represents at least 97% of the lake's history. This period lasted upwards of 3600 yr during which time approximately 120 cm of sediment accumulated in the lake. In the last 110 to 120 yr since land began to be cleared, an equivalent mass of sediment has been added, doubling the total sediment thickness. Radioisotope data and recent observations of sediment accumulation over the past 5 years indicate that the 50-fold increase in sediment accumulation rate continues unabated, in spite of improved agricultural practices designed to minimize soil loss.

Table 1 Linearity (r^2), slope (cm depth / ln fraction modern carbon), and calculated sediment accumulation rate based on plots of ln ^{14}C-activity verses depth for each sediment fraction.

Location and sediment fraction		r^2	slope (cm/ln fmc)	sed. rate (mm/yr)
Wetland core (Figure 2)				
twigs		0.76	428	0.52
charcoal		0.89	707	0.86
wood		0.75	506	0.61
710-250 µm (organic debris – pretreated)		0.97	810	0.98
710-250 µm (organic debris – untreated)		0.96	855	1.03
<250 µm, humic acid extract		0.98	849	1.03
<250 µm, low-temperature combustion		0.99	894	1.08
Open water cores (Figure 3)				
all <250 µm, low-temp. combustion				
Core	data points *			
1	upper 4	0.99	170	0.21
2	upper 4	0.999	133	0.16
3	upper 3	0.93	109	0.13
1	lower 2		553	0.67
2	lower 2		1376	1.66
3	lower 3	0.82	791	0.96

* "upper" and "lower" data share the transition point

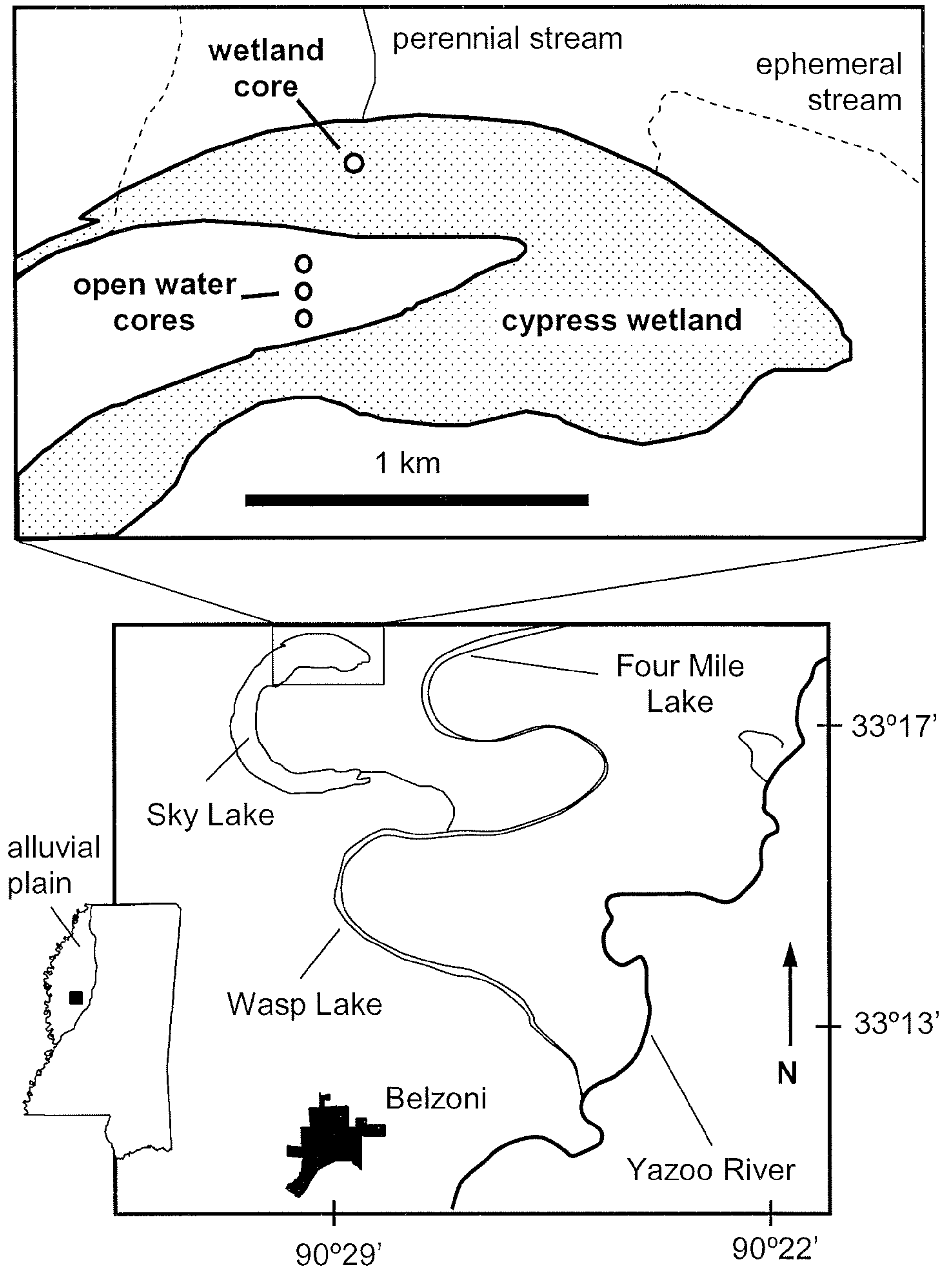

Figure 1. Study Site. The alluvial plain is the ancestral floodplain of the Mississippi-Ohio River system.

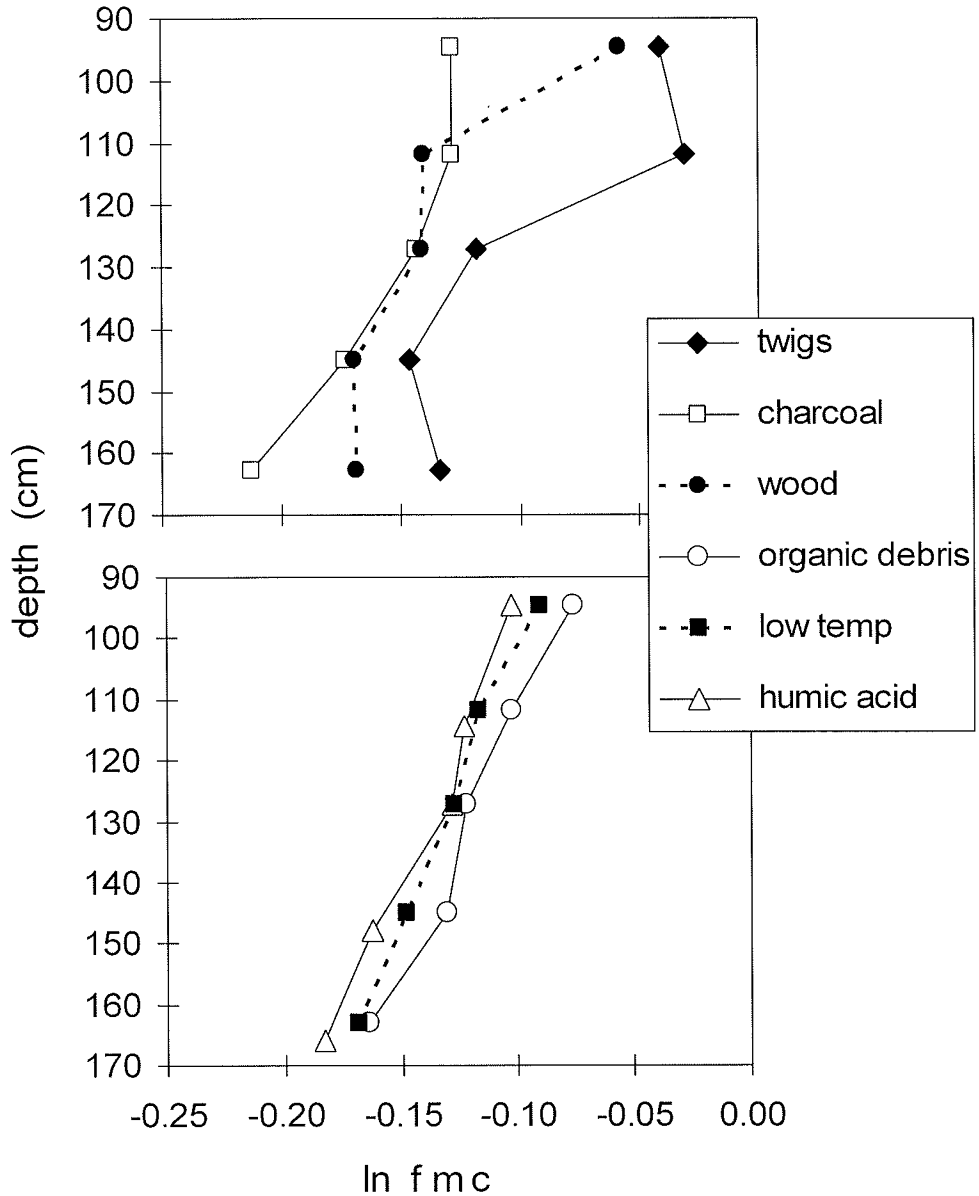

Figure 2. ^{14}C activity of samples from the wetland core (Figure 1). Data is plotted in two separate figures so all data points are visible: discrete samples (twigs, charcoal and wood fragments) are plotted in the upper graph and bulk sediment fractions (250-750 μm fraction – "organic debris"; humic acid extract from <250 μm fraction – "humic acid"; and untreated <250 μm fraction combusted at low temperature – "low temp") are plotted in the lower graph. Pretreated and untreated organic debris were not significantly different, and only the pretreated results are plotted. (ln fmc = natural logarithm of fraction modern carbon)

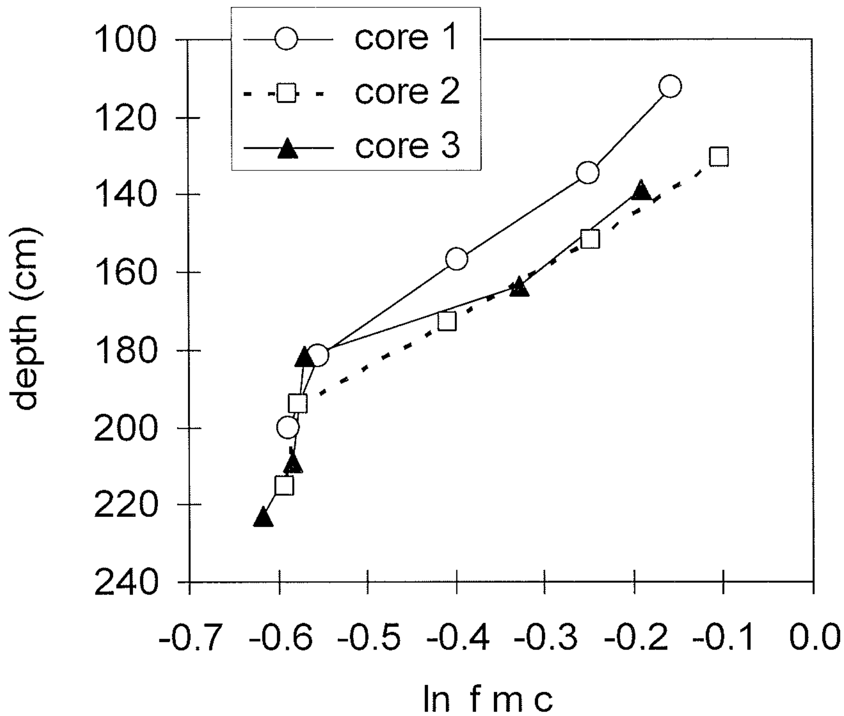

Figure 3. ^{14}C activity of samples from the three open water cores (Figure 1). All data represent the untreated <250 μm fraction combusted at low temperature. ln fmc is the natural log of the fraction modern carbon (^{14}C).

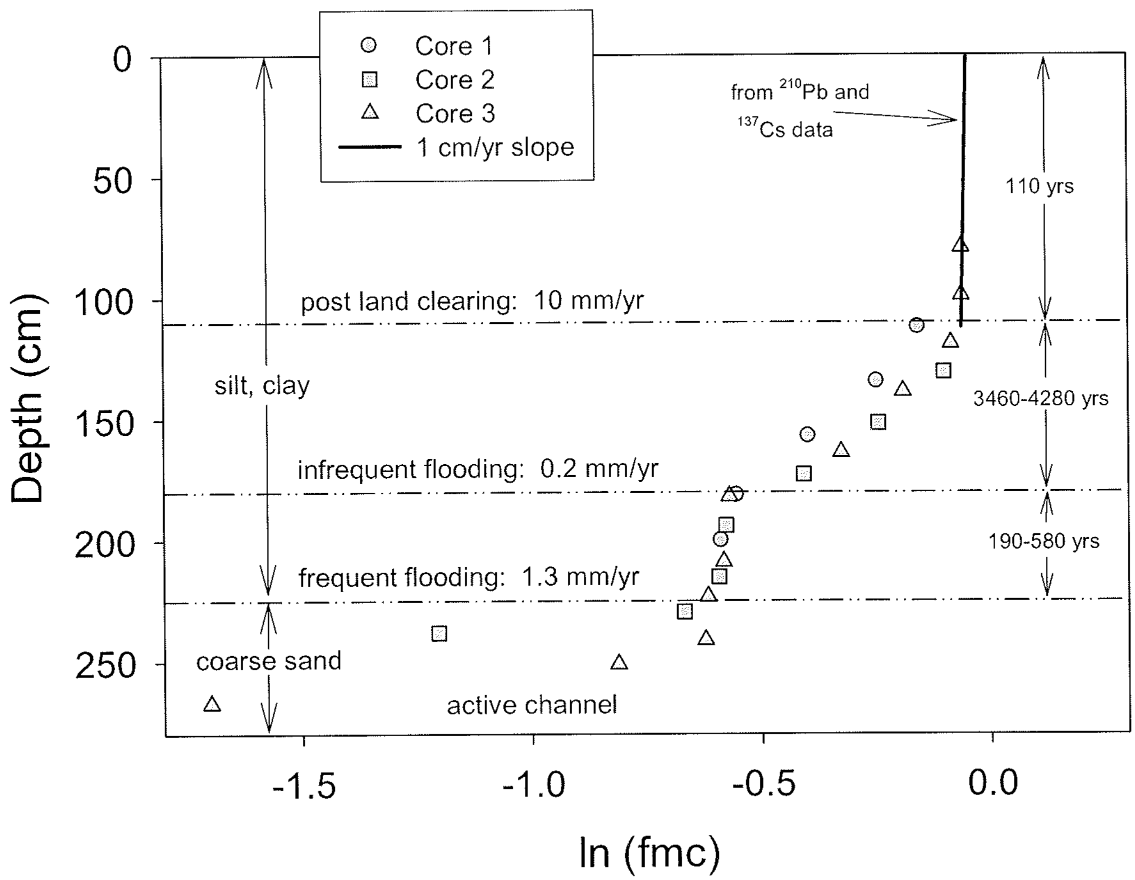

Figure 4. Sediment accumulation history of Sky Lake, Mississippi. ln (fmc) is the natural log of the fraction modern carbon (^{14}C). Sediment accumulation rates are based on the slope of a best fit line through the data for each interval. The duration of each period is based on the thickness of sediment in each interval and the sediment accumulation rate. Large ranges in time are due to uncertainty in the exact breakpoint between intervals and due to variability in interval thicknesses between the three cores.