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Paleoenvironmental Study of Late Holocene, Organic-Rich Deposits Recovered from Pink Beds, A Southern Appalachian Wetland in Western NC

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Abstract

The timing of Holocene climate events is not well constrained for the Southern Appalachians because of a general lack of deposits that preserve a record of environmental change. A wetland site was sampled and processed using a multiproxy approach in order to provide a high resolution temporal reconstruction of environmental changein the Southern Appalachians. Wetland environments in this region generally occupy valleys within mountainous landscapes that are remote and isolated. In this study we use bulk density, percent organic carbon, macroscopic charcoal, C/N ratios, C isotope values, and peat humification analysis to reconstruct past environmental conditions. Pink Beds, the studied wetland site, is located within Pisgah National Forest, (35° 21' 40.45" N 82° 45' 39.91" W) at an elevation of approximately 970.0 m. Classified as a peat accumulating fen, the studied site contains a stream with exposed layers of organic material on the cut banks. The site was probed in order to identify the thickest accumulation of organic matter. A one meter, organic sediment rich core was recovered from the site and a basal radiocarbon age of 730 ± 30 yrs. BP was obtained. Charcoal counts show some variation in fire frequency over the time period studied and C/N ratios reveal that the algal contributions to the sediment pool fluctuate between wet (more algae) and drier (less algae) periods. $\delta^{13}C$ values show that C_3 plants are the dominant source of organic matter to the sediment pool. The Pink Beds site apparently does not record late Holocene climate events such as the Little Ice Age, suggesting that their influence may not have been felt in the Southern Appalachians.

Keywords: Wetlands, Paleoenvironment, Earth Sciences.

1. Introduction:

During the Holocene, which began 11,700 cal yrs. BP, the climate trend around the world is characterized towards warming. Although well defined, there is a deficiency of information on spatial variability[1]. The warming climate trend seen in records around the world began influencing the southern Appalachian Mountain region by 10,000 years BP[2]. The warmest period of time in the southern Appalachian Mountain region during the Holocene is hypothesized to have occurred from 10,000-6,000 years BP[2]. Although detailed information is generally lacking during the general Holocene warming trend, there was a period where climate changed at a dramatic rate around 8,200 years BP. This relatively brief period, known as the 8,200 year event, was characterized by drier and colder winters and wetter summers[3]. Limited data that are available suggests that during the late Holocene the southern Appalachian Mountain region underwent a period of cooling in comparison to the warming in the mid Holocene[2]. Research data point towards a trend of drier and warmer conditions compared to the Pleistocene, with wetter summers, especially between 4,200-3,800 years BP[2,3].

Most terrestrial land masses have experienced increases in temperatures over the past few decades[4]. There are however, a few locations around the world where recorded temperatures have not changed, and in some cases show a cooling trend. One of these temperature anomalies occurs in the Southeastern United States. There are a few hypotheses as to the lack of regional warming trends in this region, such as thermal dispersion by aerosol particles[5] among others. All lack the adequate data to determine if this southeastern “warming hole” is anthropogenic in origin. The primary objective of interest in this study is addressing whether the southeast warmed with the rest of North America during the hypsithermal, or if there was an anomalous “warming hole” by studying proxy records of climate. Historically, a major set-back in studying Quaternary climate in this region is the absence of detailed studies of suitable antiquity in this area. Thus, the secondary objective is to determine if ancient wetland deposits exist in this area. If ancient wetland deposits are found, other well-known Holocene climate events, like the Little Ice Age, may be represented here as well.

Floodplain and wetland soils have been used as climate archives in North America. However, these records have been generally lacking in the Southern Appalachian region. In order to address the research objectives, three local wetland sites were sampled and studied using a multiproxy approach. Use of this approach when studying regional and local climate change, currently an important interdisciplinary problem, is typical. Multiple types of proxy records, which preserve physical characteristics, act as direct measurements and are used to derive paleo-environmental information[6,7]. Ideally, multiple methods that show correlated trends will decrease ambiguity and promote consistency in climate records over the sampled sites. It should be noted that terrestrial records tend to be poorly dated, low-resolution, short duration, and may have discontinuities in sediment accumulation. High-altitude mountainous regions are further complicated by unique local weather conditions, which can create complex feedbacks and cause correlation difficulties between locations.

2. Study Site

The study region is in the Blue Ridge Mountains of North Carolina, with elevations ranging from 653.5 m to 1676.1 m. (Figure 1a) The data collected from the three locations are known as: Pink beds, Alarka, and Speedwell. Panthertown is a previously studied site, with ongoing analysis. (Figure 1b) These investigated sites are best described as Southern Appalachian Bogs[9]. The wetland environments occupy valleys within mountainous landscapes that are remote and isolated. Southern Appalachian Bogs are concentrically zoned, with shrubs that dominate the interior[10]. Often these locations are poorly drained and have alluvial soils rich in organic matter and peat. Their hydrology and fluvial dynamics are poorly understood, and little is known about groundwater seepage[11]. Currently, North Carolina’s temperatures vary with elevation from east to west, with the east coast exhibiting warmer temperatures than central and western North Carolina. The western border of North Carolina shows the coldest temperatures, primarily due to higher elevations (Figure 1b).

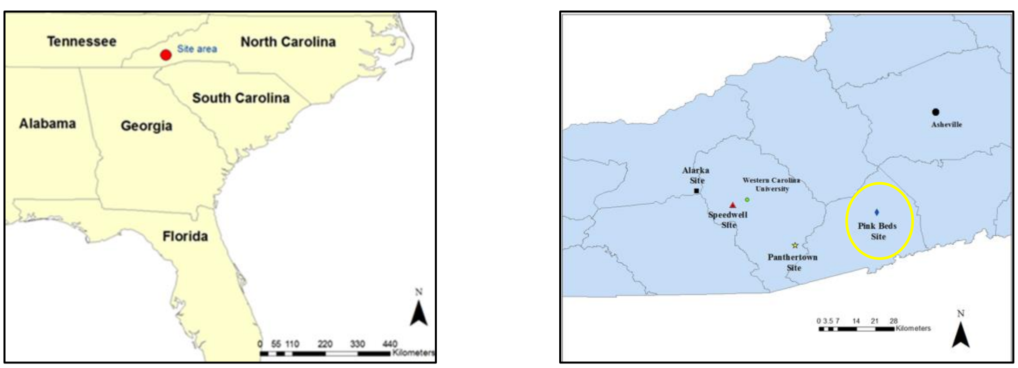

Figure 1: (a) Regional map of the Southeast, red dot denotes the Blue Ridge Mountains of North Carolina. (b) The studied sites, the circle denotes Pink Beds location.

A stream cuts through the deposit at Pink Beds, thus exposing a thick layer of organic material on each side of the river (Figure 2). This exposure along the banks was used to infer the probable location of the thickest accumulation of organic material. The site was then probed along the stream banks to locate the thickest organic accumulations and cored. The core location was recorded for future visits. The core sample taken was 100 cm in depth and sub-sampled in the lab at 1.5cm intervals. A portion of the core, from 86 to 87.5 cm depth, was removed for ^{14}C dating.

Figure 2: The Pink Beds core location, 19.8 m inland from the stream bed and topographic map of the region.

3. Methodology:

A Dutch Auger, which is a type of hand coring device that does not compact sediment, was used for core extraction. After collection, the core was plastic wrapped to preserve the moisture and integrity of the soil. In the lab, Munsell color description and texture identification was performed over the length of the cores, (Figure 3) noting color changes and corresponding texture changes.

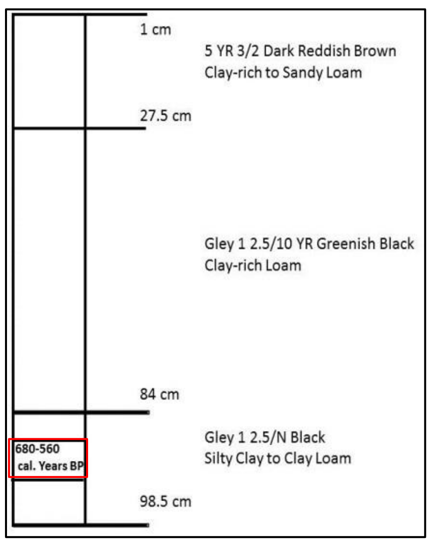

Figure 3: Munsell color description of the 100cm core collected from Pink Beds.

3.1 Multiproxy Methods Used

3.1.1 bulk density:

Sub samples were dried and reweighed. Dry weight was then divided by sample volume to determine bulk density. The volume was estimated using a marked syringe.

3.1.2 carbon and nitrogen analysis:

Carbon and Nitrogen analysis was completed using an elementarVario EL III CNS analyzer. Samples were dried, ground to a fine powder, packaged, weighed and loaded onto the instrument for analysis.

3.1.3 peat humification:

Humic acids were extracted using the standard NaOH technique with percent transmittance measurements taken at 565nm. Bog surface wetness and aridity are recorded by the percent transmittance results, which relate to temperature conditions of the studied site.

3.1.4 macroscopic charcoal analysis:

Approximately 1 to 2.5 cm^3 of soil was used for charcoal analysis. Samples were soaked in 5% Sodium Metaphosphate for 24 hours, then washed through a 125µ sieve and put on a sheet of aluminum foil for drying. Samples were then placed on a grid sheet for counting under a microscope. Total count was divided by sample weight to determine charcoal concentration.

3.1.5 radiocarbon analysis:

A sample near the base of each wetland core was sent to and measured at Beta Analytic (Miami, Florida) for radiocarbon content. Plant remains were isolated and then measured using Accelerator Mass Spectrometry. 14C ages were calibrated using the OxCal v. 4.1.7 and the IntCal09 dataset. Linear interpolation was used for age estimation between dated horizons.

3.1.6 c isotope analysis:

Samples from the core were dried, powdered and sent to the University of North Carolina, Wilmington for isotope analysis. A Costech Elemental Analyzer interfaced to a Thermo Delta V Plus Mass Spectrometer was used to determine isotope ratios.

4. Results:

Data represented (Figure 4) for Pink Beds, NC. The bulk density of the core remains at relatively constant values from 0.38-0.74 g/cm^3 from the present down core to 351 Cal years BP. By 465 Cal years BP, the highest peak of 1.10 g/cm^3 occurs before dropping to baseline levels of 0.75 g/cm^3 at the bottom of the core, near 637 Cal years BP. The percent Carbon begins at 5.4% at the top of the core and increases to its peak of 9.5% at 245 Cal years BP. A steep decrease to 1.8% occurred at 465 Cal years BP and values fluctuate between 2.8% and 4.9% 637 Cal years BP. The C/N ratio steadily increases from values of 12.46 at the top of the core to its highest value of 18.47 at 315 Cal years BP. The C/N ratio then decreases from 465 Cal years BP to a second peak of 18.04 at 567 Cal years BP, and steadily decreases to the bottom of the core.

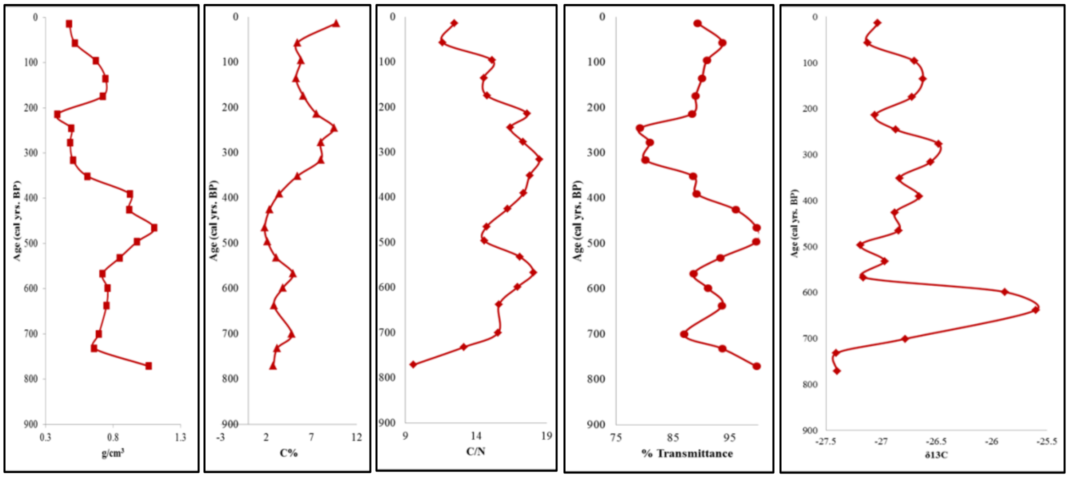

Figure 4: Pink Beds data results: Bulk Density, %C, C/N ratio, % Transmittance, δ13C.

The percent transmittance begins at 93.7% at 56 Cal years BP and dramatically decreases to 79.2% at 245 Cal years BP. It then increases to its peak of 99.7% at 465 Cal years BP and steadily decreases to 86.9% by 700 Cal years BP. δ13C values remain between -27.3‰ to -26.5‰ from the present until 567 Cal years BP. It increases to its peak of -25.8 ‰ at 637 Cal years BP and drastically decreases to -27.1 ‰ by 732 Cal years BP (Figure 4). The charcoal count shows the first peak of 132 pieces at 174 Cal years BP. The count decreases to its lowest level of 4 pieces at 425 Cal years BP and increases to a count of 201 pieces at 531 and 732 Cal years BP (Figure 5).

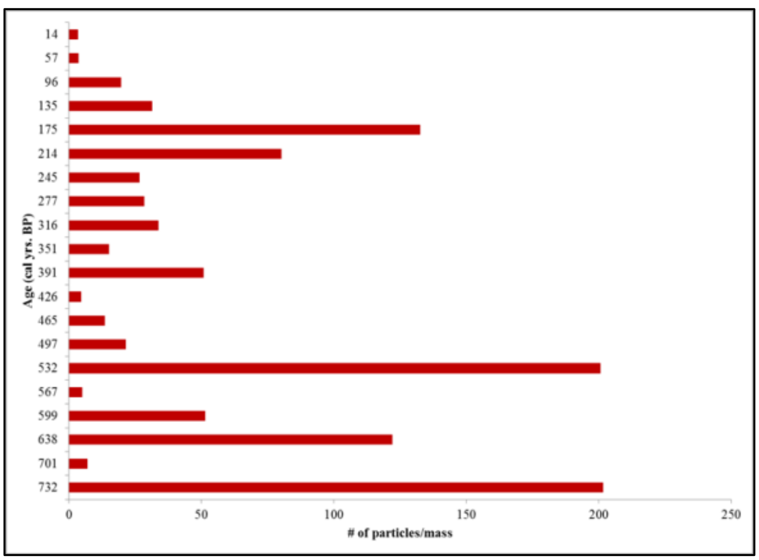

Figure 5: Charcoal count for Pink Beds

5. Discussion:

Based on the soil description, the core had hydric soils since the Munsel color values do not exceed a chromacolor of 2. Some of the colors were on the Gley pages, which is typical of wetland and bog soils. A statistical analysis preformed using a R^2 value chart shows the strongest relationships of the proxies used for analysis. The bolded values show the highest correlated results. (Table 1).

Table 1: The R^2 value chart for Pink Beds data sets.

	Bulk Density	C/N	Carbon %	Charcoal	Transmittance	$\delta^{13}C$
Bulk Density		0.0633	0.7459	0.2997	0.5767	0.0048
C/N	0.0633		0.0333	0.9023	0.3145	0.1675
Carbon %	**0.7459**	0.0333		0.3747	0.6728	1.00E-05
Charcoal	0.2997	**0.9023**	0.3747		0.6688	0.1372
Transmittance	**0.5767**	0.3145	**0.6728**	**0.6688**		0.062
$\delta^{13}C$	0.0048	0.1675	1.00E-05	0.1372	0.062	

Bulk density values show an inverse relationship with the % C data and are typical for a wetland soil, with values ranging between 0.5 and 0.7 g/cm^3.Values correspond with peat bog soils, while soils enriched with minerals would have values of 2.5-3 g/cm^3.

The C/N ratio was at its lowest at 771 BP, indicating a wetter environment and more algal input. Its highest reading was at 315 BP, which indicates dryer conditions, and higher inputs of land plants, to the sediment pool.

The lowest % C at 465 BP, suggests a higher decomposition rate and drier conditions at that time. Its highest % C was at 13 BP. The R^2 values indicate that the transmittance was tracking the %C and that the %C had a high influence on the data.

Charcoal counts show high variation with the lowest counts at 13-56 BP. Low counts of charcoal indicate wetter conditions or less human-set fires over the location site. The highest counts of charcoal occurred at 174, 531 and 732 BP. These spiked counts indicate drier environmental conditions. High counts in general suggest that the area is prone to frequent fires. This could also mean that human-set fires occurred for agricultural purposes, however, the carbon isotope ratios suggest otherwise since maize cultivation, which is what the fire would possibly be used to prepare the land for, would tend to result in elevated values of around -12‰ while values never exceed -25‰ and suggest that maize cultivation was not significant at this location.

The lowest % Transmittance was at 245 BP which indicates a greater amount of humic acids present, heavier decomposition, and thus drier environmental conditions. This correlates with the % C ratios where at the same year there is higher % C which also indicates more decomposition because transmittance and % C are inversely related. The highest % Transmittance was at 771 BP indicating less humic acids, and therefore less decomposition and wetter conditions.

The $\delta^{13}C$ values ranges between -27‰ and -25‰ which indicates more C3 plants than C4 plants at the location site. These plants have different isotopic signatures due to its environmental conditions. C3 plants have a high percentage of CO_2 and H_2O, with lower salinity values and lower temperature variances, like trees, grasses and shrubs. C4 plants have a low percentage of CO_2 and H_2O, with higher salinity values and temperature variances, like corn or maize. Most C4 plants have a δ^{13} C value of -12‰.

6. Conclusion:

The Pink Beds core had a high resolution of data and does not date back to the Hypsithermal, with a radiocarbon date of 680 ± 30 cal yrs. BP. The results suggest that the climate was generally warmer and drier based on the charcoal counts and C/N ratios. The high sedimentation rate of 7.14 cm/yr, suggests that the natural dynamics in the region, possibly from runoff and/or landslides, occurred periodically throughout this time span. There is no definitive data that suggests that Pink Beds was affected by the Little Ice Age, and the absence of a maize signature indicates that this region was not heavily influenced by human activity.

The core from Pink Beds could potentially record the Little Ice Age event. This even occurred from 1500 to 1850 on the European continent and has been suggested to be a regional event. Our data, however, does not show a clear signal of the Little Ice Age. The high charcoal counts do not support the Little Ice Age because higher counts indicate a warmer and drier climate. The C/N ratios, which co-vary with the charcoal data, also suggest that the Little Ice Age did not occur, since the higher C/N ratios during that time suggest wetter conditions.

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