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Isotopic analysis of museum-archived soil samples from archeological sites: A case-study using the Abbott Farm National Historic Landmark, USA

Gregory D. Lattanzi [a,*], Gary E. Stinchcomb [b]

[a] Bureau of Archaeology & Ethnography, New Jersey State Museum, Trenton, NJ 08625, USA
[b] Watershed Studies Institute & Department of Geosciences, Murray State University, Murray, KY 42071, USA

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ABSTRACT

Archived soil samples hold important information for reconstructing ancient environments and can provide data on prehistoric land use, manipulation and changes over time. Archeological investigations at the Abbott Farm National Historic Landmark (NHL) located near Trenton, New Jersey recovered occupations from Paleoindian to Late Woodland periods. Soil samples collected during the 1930s WPA excavations have never been analyzed until now. This paper discusses the results of a carbon isotope analysis of soil organic carbon, $\delta^{13}C_{soc}$, performed on 54 samples from a number of archeological contexts from the Abbott Farm NHL. Data from Early and Middle Woodland pits and associated soils exhibit average $\delta^{13}C_{soc}$ values of $-25.0 \pm 1.0‰$ suggesting that the suite of samples have an isotopic signature that primarily reflects aboveground C_3 vegetation. These values agree with current interpretations of an Early and Middle Woodland that had no maize and a gradual Late Woodland introduction of maize (C_4 plant) into the Lower Delaware River Valley. Assuming these samples have not experienced significant organic matter oxidation in their ~80 years of storage, the Abbott Farm results suggest that preserved archeological feature and soil samples in other collections that have been desiccated and housed in climate controlled facilities serve as an untapped resource for paleoenvironmental reconstruction for sites that either no longer exist or where access is limited. In the case of Abbott Farm NHL, the archeological feature and soil samples provide information on prehistoric site vegetation and paleoenvironment before the beginnings of agriculture in the Delaware Valley.

1. Introduction

The analysis of museum-archived artifacts has added insight to previous archeological studies by often applying a new technology to lithic, bone or just the 3-D scanning of artifacts (Barnes and Thomas, 2006; Hardy, 2009; Kuzminsky and Gardiner, 2012; Pretola, 2001; Siano et al., 2006). To our knowledge, few studies have reexamined soil and sediment samples collected years ago from archeological sites. One study examined macrobotanical items from archived archeological soil samples in addition to samples subjected to flotation (Wymer, 2009). The results of this study helped to identify additional tree species used within Hopewell ceremonial buildings. Another study, while not archeological, looked at changes in isotopic signatures in carbon and nitrogen over forty years within a forest (Billings and Richter, 2006). This study looked at changing stable isotopic values within soil, as they relate to changing ecosystems and forest development. Jones et al. (1987) examined the concentration of metals in soil samples collected from the mid-nineteenth century and noted elevated concentrations of Pb, related to industrial input. In these three examples, the archived soil samples proved to not only yield valuable site-specific information but also helped provide a broader chronological and regional environmental context.

Furthermore, we know of no studies that have examined the concentration and isotopic composition of soil organic carbon ($\delta^{13}C_{soc}$) of archived samples from archeological sites. The lack of such sample reanalysis studies may be due to: (1) the rarity of such samples given the primary focus on artifact collection, and/or (2) near-surface soil and sediment often associated with archeological sites contains labile carbon susceptible to transformation in the presence of oxygen and water:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O. \quad (1)$$

In Eq. (1), soil organic compounds such as glucose, $C_6H_{12}O_6$, are oxidized in the presence of oxygen, O_2, yielding carbon dioxide, CO_2 and H_2O (Vepraskas and Faulkner, 2001). Several studies have shown that organic matter oxidation (Eq. (1)) through heterotrophic (i.e., soil) respiration alters the isotopic composition of carbon, resulting in $\delta^{13}C_{soc}$ enrichment (Balesdent et al., 1993; Dijkstra et al., 2006; Garten et al., 2000; Melillo et al., 1989; Millard et al., 2010; Nadelhoffer and Fry,

* Corresponding author.
E-mail addresses: gregory.lattanzi@sos.nj.gov (G.D. Lattanzi), gstinchcomb@murraystate.edu (G.E. Stinchcomb).

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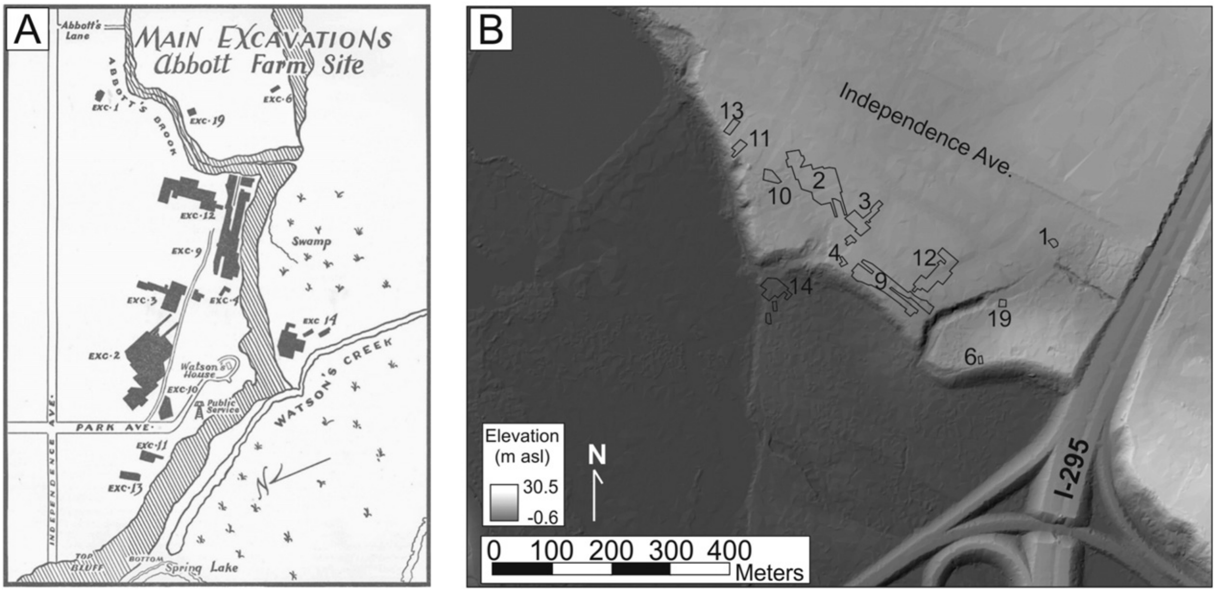

Fig. 1. Abbott Farm study area. (A) Original excavation map from Cross (1956) showing excavation unit locations and other notable geographic features. (B) Approximate locations of main excavations at Abbott Farm carried out by New Jersey State Museum (Cross, 1956) overlain on a 1 m-resolution Lidar digital elevation model and hillshade (Gesch, 2007). Note that the Cross (1956) excavation units are labeled by number and are mentioned in Table 1 and throughout the text. The Interstate 295 highway (I-295) is also labeled.

1988; Von Fischer and Tieszen, 1995). Studies have also shown the moisture content is a primary controlling factor on the soil respiration rate (Brook et al., 1983; Davidson et al., 2000). Assuming samples were desiccated prior to archival and post-archival organic matter transformation is minimal, could archeological soil and feature samples retain meaningful $\delta^{13}C_{soc}$ values that reflect paleoenvironment during occupation?

In April 1939, the archeological site supervisor at the Abbott Farm National Historic Landmark handed out glass vials with cork tops to the excavators (Cross, 1956). These vials were to contain soil samples from the tops and bottoms of pits identified during their excavations. Seventy-five years later, in this study we examine these museum-archived desiccated soil and sediment samples collected from this National Historic Landmark archeological site. We discuss the implications of these results for Middle to Late Woodland cultural and environmental reconstruction at the site, feasibility of examining older untouched collections and protocols to follow for future analyses.

2. Material and methods

2.1. Archeological study area and history

The reanalysis of museum-archived soil samples reported here is focused on the Abbott Farm archeological complex, a National Historic Landmark (NHL) consisting of numerous prehistoric sites both on the Delaware River floodplain and high terrace environments (Stewart, 1994) (Fig. 1).

The site is situated in the Inner Coastal Plain about two miles south of the Fall Line or boarder of the Piedmont and Coastal Plain. Surficial geology of the study area consists of fresh water marsh and estuarine deposits along with Late Wisconsian glaciofluvial deposits. Tertiary and Quaternary gravel deposits in the area serve as a source for tool stone, as well as translocated local cobble stone (Perazio, 1986:18).

Freshwater marshes are located at the base of the bluff which a first-order stream, Abbott's Brook, enters into it. This marshy area is also the headwaters of Watsons Creek, which flows into Crosswicks Creek and then empties into the Delaware River. Most of the marshy area is inundated at high tide. The major soils of the lowlands are alluvial land-freshwater marsh. The uplands (bluff) consist of Galestown–Evesboro soils, which are characterized by deep, excessively drained, nearly level to gently sloping soils that are sandy throughout their depth (Jablonski, 1972:5–6). Aeolian sand and loess deposits have been identified all along the bluff extending in some areas about one mile to the east (Markewich et al., 2015).

Vegetation within the marsh consists of arrow arum and spatterdock while at higher elevation wild rice, arrowhead and pickerelweed are present (Wall et al., 1996a:26–27). On the bluff exist trees such as oak (*Quercus*), hickory (*Carya*) and chestnut (*Castanea*) as well as poplar (*Populus*) and beech (*Fagus*) (Wacker, 1975:112–116; Wall et al., 1996a,b:26). The current climate of the state of New Jersey is continental and shows significant variations between temperatures of winter and summer as well as within each season mainly because of the state's latitude (Robichaud and Buell, 1989:55).

During the first half of the twentieth century, Abbott Farm was one of a few buried, stratified site complexes that scholars used as a basis for reconstructing prehistoric lifeways and establishing cultural historical chronologies in the Middle Atlantic region (Cross, 1941, 1956; Schmitt, 1952; Stewart, 1994:61; Willey and Sabloff, 1993). The Landmark received national attention in 1872 when Charles Conrad Abbott reported finds of "paleolithic man". Scientists from around the world made their way to Abbott Farm to examine the artifacts located in the Trenton gravels (Abbott, 1877, 1881; Spier, 1918).

During the Great Depression interest was refocused on the Abbott Farm, with intensive excavations carried out at many locations within the Abbott Farm NHL. Under the direction of Dr. Dorothy Cross of the New Jersey State Museum, twenty open excavations were completed over a large area of the Abbott Farm complex from 1936 to 1941 (Fig. 1). The excavation results and interpretations were published in a volume devoted solely to the Abbott Farm (Cross, 1956). The Abbott Farm NHL consists of numerous sites over a diverse environmental landscape that includes loess-mantled upland bluffs as well as tidally-influenced lowland estuarine floodplain. Cross (1956) had the excavators collect soil samples from aeolian deposits, pits and excavation units, in addition to charcoal samples from hearths and other features. Although it is not entirely clear why Cross ordered the collection of soil samples, it was her possible foresight that allowed for the examination of these samples using modern analytical techniques.