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Sedimentary proxy evidence of a mid-Holocene hypsithermal event in the location of a current warming hole, North Carolina, USA

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ABSTRACT

A wetland deposit from the southern Appalachian mountains of North Carolina, USA, has been radiocarbon dated and shows continuous deposition from the early Holocene to the present. Non-coastal records of Holocene paleoenvironments are rare from the southeastern USA. Increased stable carbon isotope ratios ($\delta^{13}C$) of sedimentary organic matter and pollen percentages indicate warm, dry early- to mid-Holocene conditions. This interpretation is also supported by *n*-alkane biomarker data and bulk sedimentary C/N ratios. These warm, dry conditions coincide with a mid-Holocene hypsithermal, or altithermal, documented elsewhere in North America. Our data indicate that the southeastern USA warmed concurrently with much of the rest of the continent during the mid-Holocene. If the current "warming hole" in the southeastern USA persists, during a time of greenhouse gas-induced warming elsewhere, it will be anomalous both in space and time.

Introduction

The southeastern USA is one of only a handful of locations globally that did not significantly warm over the 20th century (Alexander et al., 2013). Hypotheses offered to explain this "warming hole" include the influence of irrigation and urbanization (Misra et al., 2012), changes in sea surface temperatures (Robinson et al., 2002), land–atmosphere feedbacks (Pan et al., 2004), internal dynamics (Kunkel et al., 2006), impacts of aerosols and changes in vegetation (Portmann et al., 2009), and the link between high levels of precipitation and damped trends in daily maximum temperature (Portmann et al., 2009). High-resolution, long-term records of Holocene climate change, crucial for addressing these competing hypotheses, are lacking for the southern Appalachian region. The few records that do exist lack complete or continuous Holocene deposition (e.g. Shafer, 1988; McDonald and Leigh, 2011). Thus, as Driese et al. (2008) noted, paleoclimate modelers are forced to base interpretations on extrapolations from other, more distant, study sites within North America.

It is useful to consider the current southeastern USA warming hole in the context of previous continental-scale warm events. Extratropical temperature proxy records show evidence of warmer (than recent decades) conditions for multiple locations around the world in the early to mid-Holocene (Jansen et al., 2007). In North America, proxy records show a "Holocene thermal maximum" peak between 11–9 ka in Alaska and northwest Canada, and about 7–5 ka in northeast Canada (Kaufman et al., 2004). Other continental climate proxy records show a mid-Holocene "altithermal" between 7 and 5 ka in the southwestern and mid-continent regions of the USA (Nordt et al., 1994) and a "hypsithermal" event is present in proxy records from the northeastern USA between about 8.8 and 4.4 ka (Mullins et al., 2011).

Though there is a general lack of continuous Holocene paleoenvironmental records for the Southern Appalachians, much useful paleoenvironmental data are available for the southeastern USA. Leigh (2008) argues for a warm and wet early Holocene on the Atlantic Coastal Plain based on pollen records and reconstructions of stream channel geomorphology. The interpretation of wet early Holocene conditions is generally supported by the pollen data from the Little River site on the upper Coastal Plain of North Carolina (Goman and Leigh, 2004) and also the pollen record from Sandy Run Creek on the upper Coastal Plain of Georgia (LaMoreaux et al., 2009).

Conversely, Otvos (2004, 2006) argues for several early to mid-Holocene "hypsithermal–altithermal" intervals of increased aridity in northwestern Florida, Alabama, and southeastern Louisiana based largely on dune fields (see Goman and Leigh (2006) for an alternative view). Driese et al. (2008) also postulate multiple mid-Holocene

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warming and drying events based on carbon isotope and multi-element data from several southeastern Tennessee floodplain soil profiles. The pollen record from Anderson Pond, TN, also suggests a mid-Holocene warming and drying trend (Delcourt, 1979). However, a later study of the Anderson Pond site suggested that the Holocene portion of the sediment record was either absent or unreliable (Liu et al., 2013). A carbon isotope and organic biomarker record from Lake Tulane in central Florida that covers the last 62,000 years does not provide evidence for mid-Holocene warming (Huang et al., 2006). In a review article, Delcourt and Delcourt (1985) suggest that mid-Holocene warming and drying extended into the mid-latitudes of the Southeast west of the Appalachians, but that warm and wet conditions existed further south and east, in the Southern Appalachian Mountains and the northern Gulf Coastal Plain. It is clear that there is a need for additional data, particularly for the region near the boundary of the inferred warm and dry early to mid-Holocene conditions vs. warm and wet early to mid-Holocene conditions. These data would also be useful for researchers interested in placing the current southeastern “warming hole” in the context of previous Holocene climate changes.

We present a multi-core and multi-proxy record of Holocene environmental change derived from organic-rich sediments from a high elevation wetland site (Panthertown Valley; Fig. 1) in the mountains of western North Carolina, USA. Collected data include bulk C and N content, bulk carbon isotope composition, *n*-alkane distributions, and pollen counts for wetland-specific and upland flora. Although there are challenges to using a multi-proxy approach (Birks and Birks, 2006), many studies have confirmed the benefits of this approach for reconstructing environmental change (e.g. Blundell and Barber, 2005; Davidson et al., 2013), particularly when combined with multi-core analysis (Lejju et al., 2005; Loisel and Garneau, 2010). This comprehensive multi-proxy record from the Panthertown core represents the first of its kind recovered from the Southern Appalachians that nearly spans the entirety of the Holocene.

Location and setting

The Panthertown Valley wetland (35°09.55′N, 83°01.30′W) has a surface area of 4.6 ha and is situated ~1115 m above sea level. The area surrounding the site was logged intermittently from the 1920's to the 1960's, partially planted with white pine shortly thereafter, and transferred to the U.S. Forest Service in 1989 (Kornegay, 2003). The wetland occupies part of a valley and is intersected by Panthertown Creek. The site is underlain by felsic mica gneiss that lies at the core of the Cashiers Antiform (Wickstrom, 1979). The wetland, which hydrologically represents a fen, is an example of the Southern Appalachian bog, typic subtype described by Schafale (2012).

Schafale and Weakley (1990) describe the typical vegetation found within Southern Appalachian bogs as “…a mosaic or zoned pattern of

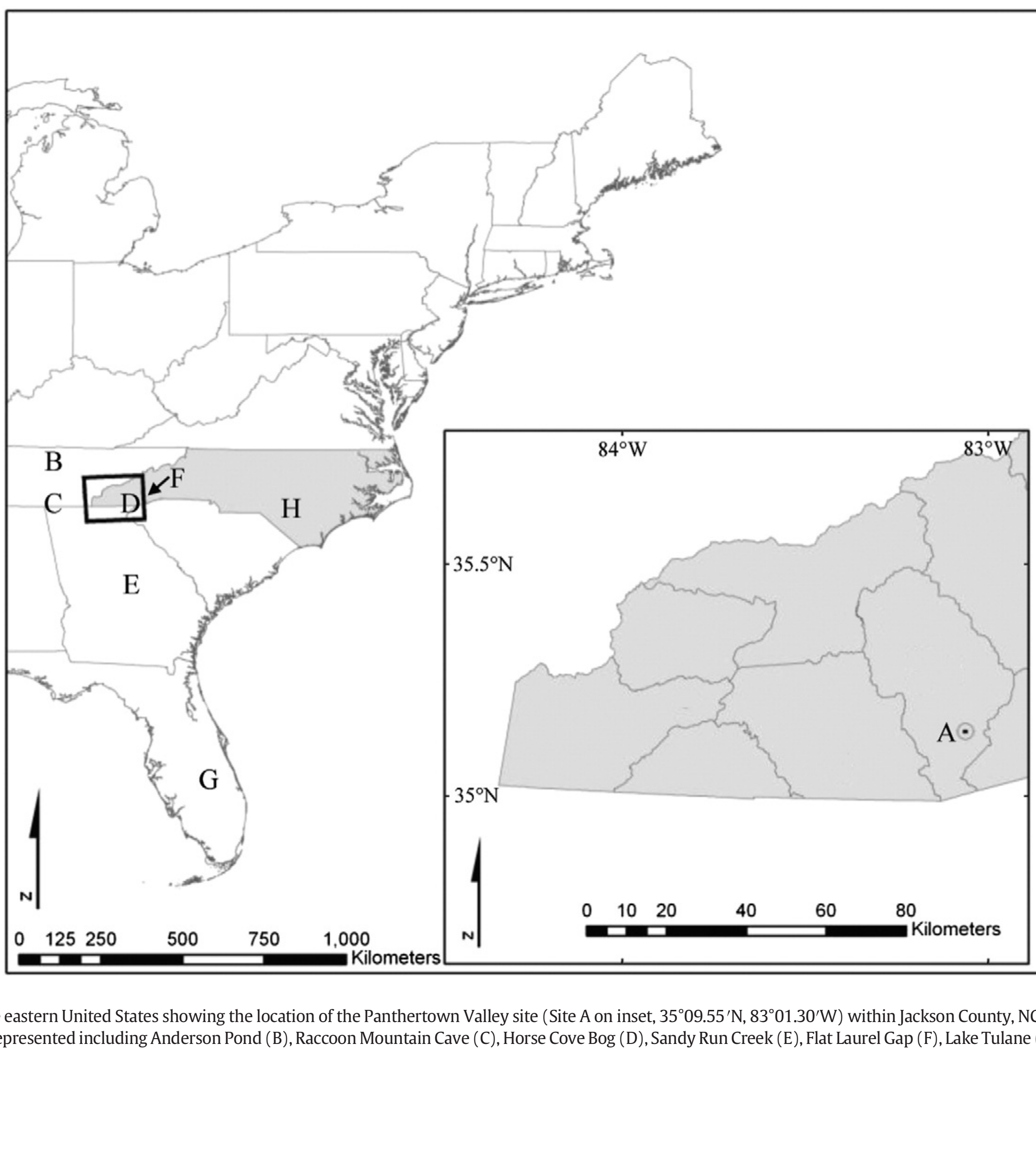

Figure 1. Map of the eastern United States showing the location of the Panthertown Valley site (Site A on inset, 35°09.55′N, 83°01.30′W) within Jackson County, NC. Other sites discussed in the text are also represented including Anderson Pond (B), Raccoon Mountain Cave (C), Horse Cove Bog (D), Sandy Run Creek (E), Flat Laurel Gap (F), Lake Tulane (G) and the Little River Site (H).