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Pollen and *Sporormiella* evidence for terminal Pleistocene vegetation change and megafaunal extinction at Page-Ladson, Florida

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ABSTRACT

Two cores from the Page-Ladson archaeological site, Florida were analyzed for pollen and the dung fungus *Sporormiella*. The cores contained stratified deposits spanning the Pleistocene-Holocene transition: a period characterized by the widespread extinction of Pleistocene megafauna and abrupt changes in vegetation type and distribution. The disappearance of *Sporormiella*, a well-established proxy for large herbivore abundance, by ~12,700 cal BP is consistent with the timing of Terminal Pleistocene megafaunal extinction elsewhere in North America. However, a resurgence of *Sporormiella* between ~10,750–10,200 cal BP suggests an Early Holocene incursion of extant megaherbivores such as bison. Pollen evidence from the site also reflects dramatic vegetation changes, which are likely a response to both changing climate and fluctuating herbivore populations. Prior to 14,500 cal BP, the pollen assemblage reflects a relatively cool and dry climate. Between ca. 14,500–12,600 cal BP, the sediments are characterized by an increase in hardwood forest and mesic plant taxa, indicating an increase in both temperature and precipitation. After 12,600 cal BP, a decrease in arboreal pollen, with the exception of oak, alongside an increase in herbaceous pollen, indicates drier, warmer conditions. These results contextualize changes in human behavior at the onset of the Holocene.

1. Introduction

The Late Quaternary transition from glacial to interglacial climate resulted in drastic changes in plant and animal communities, including the disappearance of over 35 large mammal taxa in North America. The changes that occurred in the terminal Pleistocene are of particular interest to archaeologists to contextualize cultural adaptations of the first Americans. The exact causes, effects, and the precise timing of Plesistocene megafaunal extinction remain unresolved. The Terminal Pleistocene megafaunal extinction in North America by 10,900 B.P. appears to have coincided with the sudden, global transition from Allerød warming to Younger Dryas cooling (Haynes, 2008). Russell et al. (2009) hypothesized that a 'thermal enclave' in the Southeast resulted in a unique mix of tropical and temperate vegetation, which may have enabled Pleistocene megafauna to persist beyond the Allerød-Younger Dryas transition (Webb et al., 2003; Webb, 2006). The present day southeastern United States (hereafter Southeast) is one region where dateable faunal remains are uncommon as a result of poor preservation throughout the region. However, the most current evidence suggests that large herbivores were extinct in the region by the end of the Pleistocene (Halligan et al., 2016).

The lack of paleoenvironmental data has implications for understanding the environmental context of the initial peopling of the Americas because some of the earliest evidence for human occupation of North America has been discovered in the region (e.g., Halligan et al., 2016). Although the available pollen records can provide a foundational understanding of the paleoenvironment, most of them are poorly temporally constrained (e.g. Watts and Hansen, 1994), and provide a rather coarse understanding of the changing vegetation during the late Pleistocene (Watts, 1969, 1975; Watts and Stuiver, 1980; Watts et al., 1992; Watts and Hansen, 1988, 1994). Existing environmental data in Florida (Fig. 1) must be extrapolated over long distances to provide context for early human adaptation because archaeological sites in Florida are often not good candidates for paleoenvironmental study.

Analyses of sediment samples from the Page-Ladson archaeological site resulted in the identification of both pollen and *Sporormiella* dung fungal spores. In 2014, two cores were extracted from the site and capture a nearly continuous terminal Pleistocene-early Holocene sedimentary record constrained by 41 radiocarbon assays

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Fig. 1. Map with Florida pollen studies discussed in the text.

(Table 1, Fig. 2) (Halligan et al., 2016). Excellent organic preservation enables the investigation of environmental proxies, pollen and *Sporormiella* spores, in primary contextual association with radiocarbon-dated materials.

Sporormiella is a genus of coprophilous fungus that has been established as a reliable proxy for large herbivore abundance (Fig. 3) (e.g. Davis,1987; Burney et al., 2003; Burney and Flannery, 2005; Davis and Shafer, 2006; Gill et al., 2009; Baker et al., 2013). The spores are obligate to herbivore dung and can be used as a measure of local herbivore populations (Raper and Bush, 2009; Gill et al., 2013; Baker et al., 2016). Dung fungal spores are discharged from the fruiting bodies within a few centimeters (e.g. Yafetto et al., 2008), and wind can carry the spores up to 100 m (Gill et al., 2013). A low amount of spores (known as "threshold" levels, contributed by small mammals) are also deposited into sediments. Whether transported by wind or runoff, dung fungal spores typically remain local to the dung source (Baker et al., 2016). Thus, this proxy can only reliably infer changes in the large herbivore community at the site and in the immediate vicinity.

It has even been suggested that declines in dung fungi can indicate human colonization, citing evidence that functional extinction events worldwide have followed human settlement into a new area (Burney et al., 2003; Burney and Flannery, 2005; Gill et al., 2009, 2012). However, Fiedel (2016) refutes this idea due to problems in both cultural chronology and inconsistencies between the dung fungi and faunal records. Despite this disagreement, methodologies have become increasingly reliable, and dung fungi have been demonstrated to reflect relative large herbivore abundance and activity in many modern settings (Raper and Bush, 2009; Parker and Williams, 2012; Gill et al., 2013; Baker et al., 2016).

There are factors aside from herbivore abundance that can influence the *Sporormiella* record, such as hydrologic activity. Fluctuating water levels and changes in relative humidity have the potential to skew a *Sporormiella* record (Raper and Bush, 2009; Baker et al., 2013; Wood and Wilmshurst, 2012). Analyzing multiple cores from different locations within the same site, however, can help reduce these potentially misleading signatures caused by increased spore deposition that occurs on the shoreline in comparison to the center of ponds and lakes (Johnson et al., 2015).

2. Study site

2.1. Regional settings

Most of the Southeast was characterized by boreal forests until about 15,000 cal BP, after which warmer temperatures resulted in the emergence of mixed deciduous forests and open park and scrublands (Watts, 1980; Delcourt and Delcourt, 1988; Delcourt, 2002). This period was followed by the Younger Dryas (YD), beginning around 12,900 cal BP, with cooler temperatures across most of North America. An increase in boreal vegetation at lower latitudes, corresponding to the YD, indicates regional cooling in the Southeast (Watts, 1980). For example, *Picea* (Spruce) appeared to flourish as far south as northern Florida at Camel Lake around 12,600 BP (Watts et al., 1992). Other evidence of relatively cool, wet