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An evaluation of fecal stanols as indicators of population change at Cahokia, Illinois

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ABSTRACT

Fecal stanols deposited in sediment provide evidence of trace human waste products and have been proposed as a proxy for measuring population change. Despite its potential to contribute to paleodemographic studies, the method has not been evaluated against conventional archaeological population reconstructions to determine its fidelity in identifying changes in ancient populations nor has it been applied in an environmental setting outside of the Arctic, where low temperatures enhance stanol preservation. We studied sediment cores recovered from a lake adjacent to Cahokia, the largest and most well-studied prehistoric mound center in North America. We found fecal stanol data closely track independently established population reconstructions from multiple sources, confirming the utility of the method and demonstrating its viability in temperate climates.

1. Introduction

Understanding a region's demography is crucial to understanding its history. Population size and density are the consequences of subsistence and settlement strategies and are impacted by the effects of climate change, warfare, disease, migration, famine, and political, social, and economic instability. For example, the impacts of technological advancements and increasing globalization are made clear through the meteoric rise in world population toward the present (Lam, 2011). Indeed, demography is the human story (Tuljapurkar, 2011).

Demographic reconstructions in archaeology frequently rely on indirect evidence, such as summed calibrated date probability distribution of radiocarbon dates (SCDPD), artifact densities, architectural data, or midden volume to infer changes in population (Naroll, 1962; Hassan, 1978; Meindl and Russell, 1998; Peros et al., 2010; Downey et al., 2014). Such proxies, however, are based on generalizations and difficult-to-constrain variables, such as archaeological sampling, the decay of archaeological material, settlement density, settlement duration, and average dwelling occupancy. Fecal stanol analysis is an emergent method in geoarchaeology that provides a relatively direct proxy of population change by identifying variations in the relative amount of trace human waste products retained in the sediment of a specific watershed.

Fecal stanols are recalcitrant organic molecules that persist in sediment for hundreds to thousands of years (Bull et al., 1998). The most prominent human stanol is coprostanol (5β-cholestan-3β-ol), which is formed through microbial degradation of cholesterol in the intestinal tract. Although other mammals, including dogs, donkeys, horses, goats, and cattle, produce coprostanol, only sheep and pigs are known to generate sufficient quantities that could mask changes in human stanol concentration (Leeming et al., 1996; Bull et al., 2002; Prost et al., 2017). Once introduced into the environment as a component of feces, coprostanol is typically buried *in situ* or transported and deposited in a basin, such as a lake or marsh (Fig. 1). With time, coprostanol will degrade to its derivative form, epicoprostanol (5β-cholestan-3α-ol) (Bull et al., 2002). Thus, the abundance of coprostanol and epicoprostanol can be directly linked to the relative size of a population in the environment.

Fecal stanol analysis originated in modern sewage studies (Green et al., 1992), before being employed by archaeologists to identify human presence on a specific landscape (Bethell et al., 1994; Bull et al., 2001; Sistiaga et al., 2014). D'Anjou et al. (2012) were the first to connect changes in the amount of recovered stanols over time to changes in the population of a small settlement north of the Arctic

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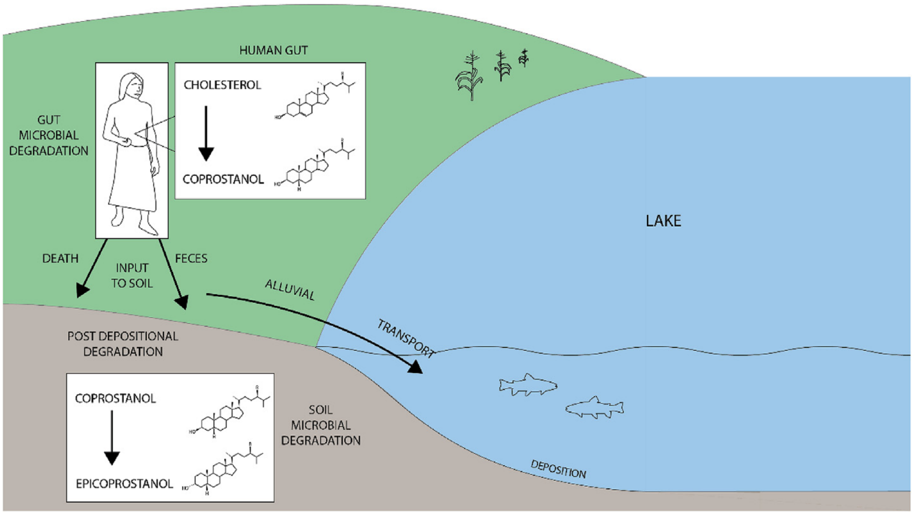

Fig. 1. Schematic depicting the formation, deposition, and degradation of human fecal stanols.

Circle in Norway. Despite the success of D'Anjou et al., the method is yet to be evaluated in an archaeological setting with previous population reconstructions from archaeological studies. Additionally, it remains to be seen if fecal stanol analysis is a viable technique in climates other than those associated with high latitudes, where low temperatures may have enhanced preservation of the stanols.

To evaluate the efficacy of fecal stanols as proxies of human population change relative to other measures, we conducted a blind study on cores from Horseshoe Lake, Illinois, which contains in its watershed the Cahokia Mounds Historic Site (UNESCO No. 198), a massive prehistoric mound center and one of the most intensely studied prehistoric archaeological sites in the United States (Fig. 2) making it especially well-suited for fecal stanol biomarker analysis (Fowler, 1989; Pauketat and Emerson, 1997; Milner, 1998; Pauketat, 1998; Emerson, 2002). First, the site is situated adjacent to a large oxbow lake and coprostanol that was transported or deposited in the lake should be present in lake bottom sediment. Second, Eurasian livestock, notably pigs and sheep, were not introduced into the Americas until the 16th and 17th centuries, roughly two centuries after the abandonment of Cahokia, and therefore elevated pre-contact coprostanol levels are most likely attributable to a human presence (Leeming et al., 1996). Although low levels of coprostanol may derive from wild animals or microbial activity and form a background distribution (Holtvoeth et al., 2016), the large and fluctuating number of humans known to have inhabited the watershed is the best candidate for controlling major changes in the stanol record. Third, considerable effort has been directed toward reconstructing Cahokia's population dynamics, from early estimates conducted in the 19th century (McAdams, 1882) to modern population density calculations (Pauketat, 2003), thus providing multiple population reconstructions for comparison (Pauketat and Lopinot, 1997; Milner, 1986, 1998; Pauketat, 2003).

Existing population reconstructions for Cahokia are based on site architectural data and suggest that Cahokia began emerging as a large population center during the Edelhardt Phase (1000–1050 CE) (Table 1) (Milner, 1998; Pauketat, 2003). According to these reconstructions, the population of the site peaked during the Lohmann Phase (1050–1100 CE), before declining slightly in the Stirling Phase (1100–1200 CE) and declining significantly in the Moorehead Phase (1200–1275 CE). By the Sand Prairie Phase (1275–1350 CE), the region was largely abandoned (Pauketat and Lopinot, 1997), producing one of

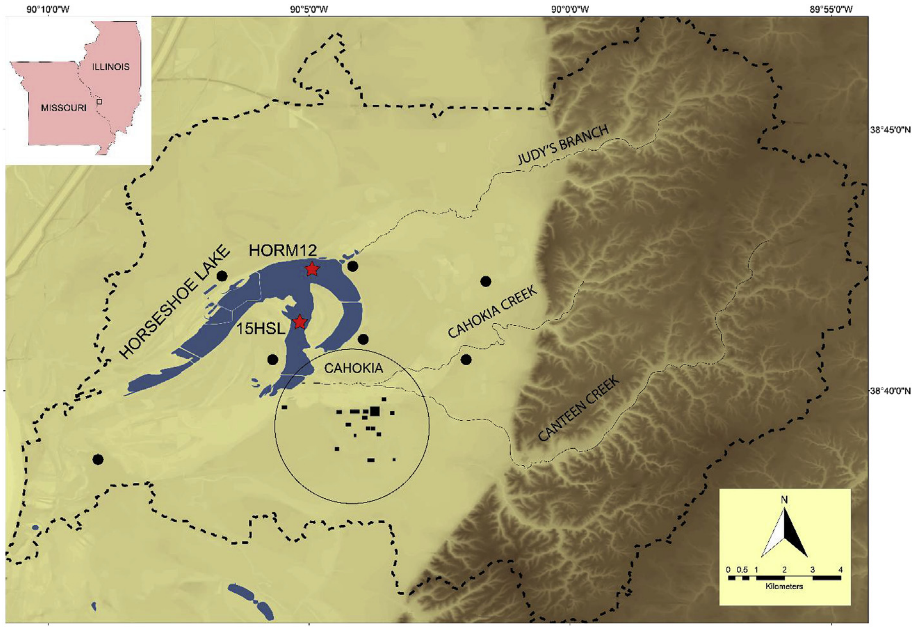

Fig. 2. Cahokia regional vicinity and Horseshoe Lake watershed, shown as the black dashed line. Coring sites are indicated by red stars. Cahokia largely consists of deposits that are within the large circle; black rectangles indicate the location of major Cahokian mounds. Black dots show the locations of small archaeological deposits (< 2 mounds) occupied contemporaneously with Cahokia (approx. 1000–1400 CE; Milner, 1998). Base map elevation data are derived from the National Elevation Dataset (Gesch et al., 2002). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)