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Two Holocene paleofire records from Peten, Guatemala: Implications for natural fire regime and prehispanic Maya land use

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ABSTRACT

Although fire was arguably the primary tool used by the Maya to alter the landscape and extract resources, little attention has been paid to biomass burning in paleoenvironmental reconstructions from the Maya lowlands. Here we report two new well-dated, high-resolution records of biomass burning based on analysis of macroscopic fossil charcoal recovered from lacustrine sediment cores. The records extend from the early Holocene, through the full arc of Maya prehistory, the Colonial, and post-Colonial periods (~9000 cal yr BP to the present). (Hereafter BP) The study sites, Lago Paixban and Lago Puerto Arturo, are located in northern Peten, Guatemala. Results provide the first quantitative analysis from the region demonstrating that frequent fires have occurred in the closed canopy forests since at least the early Holocene (~9000 BP), prior to occupation by sedentary agriculturalists. Following the arrival of agriculture around 4600 BP, the system transitioned from climate controlled to anthropogenic control. During the Maya period, changes in fire regime are muted and do not appear to be driven by changes in climate conditions. Low charcoal influx and fire frequency in the Earliest Preclassic period suggest that land use strategies may have included intensive agriculture much earlier than previously thought. Preliminary results showing concentrations of soot/black-carbon during the middle and late Preclassic periods are lower than modern background values, providing intriguing implications regarding the efficiency of Maya fuel consumption.

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1. Introduction

The prehispanic Maya transformed their environment through agricultural and architectural activities (Dunning et al., 1998; Hansen et al., 2002; Beach et al., 2006; Wahl et al., 2006; Anselmetti et al., 2007; Wahl et al., 2007a,b; Mueller et al., 2010; Estrada-Belli, 2011; Wahl et al., 2013). Fire was an important part of land use practices, arguably the primary tool used to alter the landscape and extract resources. Burning was necessary to open the forest for agriculture and building, and in extraction/production of construction material (Abrams and Rue, 1988; Pohl et al., 1996; Rue et al., 2002). The extensive production of lime plaster for architectural and domestic use also demanded harvesting and burning vast quantities of green wood for lime kiln fuel (Schreiner, 2002). While we understand the fundamental role of fire in Maya land use, very few records of prehispanic biomass burning exist from the Maya lowlands. Consequently, we have only a limited understanding of natural fire regimes and patterns of prehispanic anthropogenic burning in the seasonally dry tropical forests of the Maya lowlands (Murphy and Lugo, 1986; Koonce and González-Cabán, 1990; Cochrane, 2009).

Understanding the role of fire in shaping Neotropical environmental change requires high resolution local and regional scale records of burning aimed at reconstructing the history of both natural and anthropogenic biomass burning regimes. Over the past four decades, a number of studies have focused on fire and human history across the Northern Neotropics. As noted by several scholars (Marlon et al., 2008; Nevle and Bird, 2008; Dull et al., 2010), this growing body of work contains very few high resolution Holocene length records. In the Maya lowlands, existing fire reconstructions are primarily from microscopic charcoal (<125 μm), which records a more regional signal than the macroscopic size fraction (>125 μm) (microscopic: Tsukada and Deevey, 1967; Vaughan et al., 1985; Leyden et al., 1994; Pohl et al., 1996; Dunning et al., 1998; Johnston et al., 2001; Rue et al., 2002; Hillesheim et al., 2005; Wahl et al., 2007b; Rushton et al., 2012; macroscopic: Wahl et al., 2013, Walsh et al., 2014; Schüpbach et al., 2015). In addition, comparison between sites is difficult due to low temporal resolution, methodological differences among the studies, and, in some cases, poor age control.

Here we present two new well-dated, high resolution reconstructions of biomass burning based on macroscopic charcoal. The more local signal recorded by macroscopic charcoal is analyzed in an effort to more precisely characterize the heterogeneity of Maya lowland forest ecosystems. The data cover the early Holocene (~9000 BP) to the present. The following questions are addressed:

- Was fire a part of the seasonally dry tropical forest ecosystem of the Peten prior to the period of agriculture? If so, what was the

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climatically controlled fire regime (number of fire events during a window of time)?
- How did patterns of biomass burning change following the arrival of agriculturalists?
- Can macroscopic charcoal provide information regarding land use practices?

The study sites, Lago Paixban and Lago Puerto Arturo (Fig. 1), are located in the southern Maya lowlands in modern northern Peten, Guatemala. It is here, in what is now a dense, uninhabited seasonally dry tropical forest, that the earliest dynastic Maya empires developed and flourished during the Preclassic period (3500–1700 BP) (Hansen, 1991; Hansen, 2001; Hansen et al., 2002; Estrada-Belli, 2011). The data are presented along with previously published pollen and geochemical data from the sites, and interpreted in the context of existing regional and local paleoenvironmental and archeological records.

2. Background

2.1. Cultural context

The ancient Maya civilization was one of the most advanced to arise in Mesoamerica, indeed, in the ancient world as a whole. For nearly three millennia the Maya dominated a region centered on Guatemala, and extending into southern Mexico, Belize, El Salvador, and Honduras (Sharer and Traxler, 2006). Dynastic empires erected massive architectural projects that are some of the most extensive and sophisticated known from throughout the ancient world in terms of size, symbolism, site design, and architectural techniques (Hansen, 2001; Sharer and Traxler, 2006; Estrada-Belli, 2011). The scale and geographic density of Maya architecture reflect not only a large, well organized population of skilled craftsmen and laborers, but a concurrently large and well organized supporting infrastructure and labor force (Hansen, 2001). Archaeological investigations from the region support the inference of dense urban and rural populations (Abrams and Rue, 1988; Culbert and Rice, 1990; Hansen, 2001; Hansen et al., 2002; Estrada-Belli, 2011). Understanding what system of land use supported these dense populations remains a topic of vigorous debate among scholars (Hansen, 2001; Harrison, 2001; Ford, 2008; Beach et al., 2009; Ford et al., 2009; McNeil et al., 2010; McNeil, 2012; Wahl et al., 2013).

Environmental change, including multi-decadal drought and anthropogenic degradation, has been proposed as a contributing factor in the Terminal Classic abandonment of the southern Maya lowlands. Evidence shows that some areas experienced dramatic, and often abrupt, population declines throughout the prehispanic Maya period (i.e., the Terminal Preclassic and Terminal Classic; Culbert and Rice, 1990; Wahl et al., 2007a). Paleoenvironmental studies have identified significant environmental impacts associated with land use, including rapid and extensive reduction in forest, increased erosion (Rosenmeier et al., 2002; Beach et al., 2006; Wahl et al., 2006; Anselmetti et al., 2007; Wahl et al., 2007a,b; Mueller et al., 2010; Wahl et al., 2013, 2014, 2015) and changes in watershed hydrology (Curtis et al., 1998; Rosenmeier et al., 2002; Beach et al., 2009). Independent paleoclimate records show that climate changed significantly during this same period in the Maya lowlands (Hodell et al., 1995; Curtis et al., 1996; Kennett et al., 2012; Wahl et al., 2013). The challenge has been, and continues to be, drawing a distinction between human induced (through land use) and climatically driven environmental change.

2.2. Human/environment interactions

Changes in biomass burning are controlled by complex interactions of fire, vegetation, climate, and humans (Cochrane, 2009; Whitlock et al., 2010; Bowman et al., 2011). Paleoenvironmental reconstructions

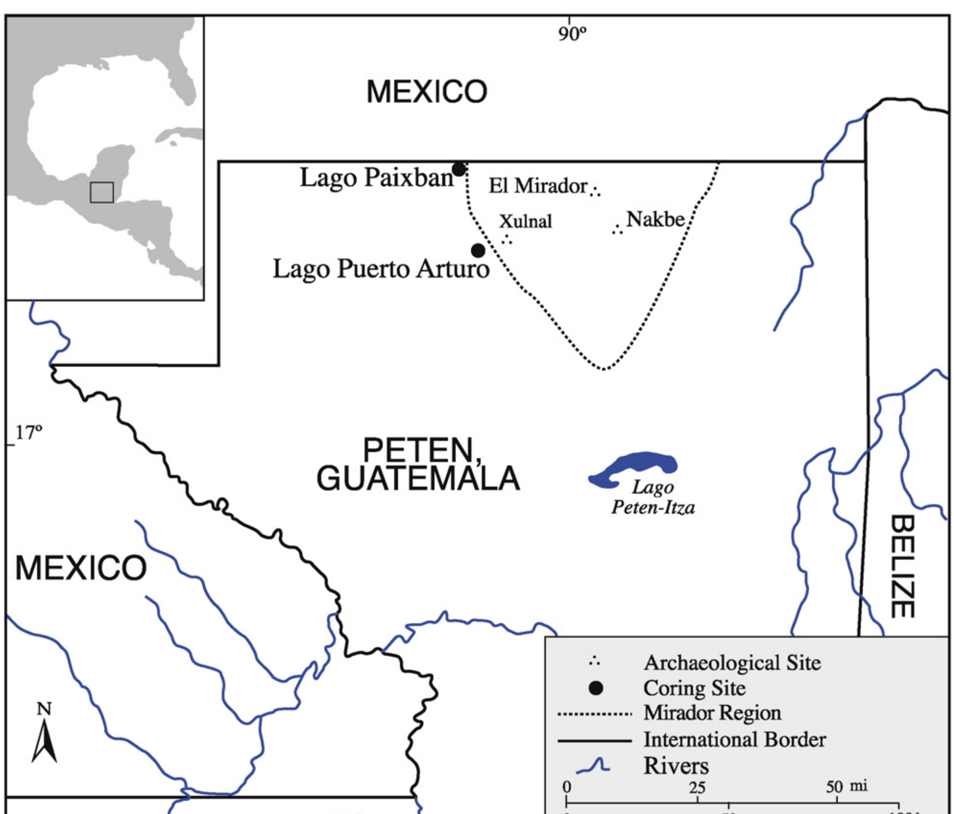

Fig. 1. Map showing coring sites and other archeological and paleoenvironmental records referenced.