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Reprint of: Impacts of Mayan land use on Laguna Tuspán watershed (Petén, Guatemala) as seen through clay and ostracode analysis☆

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ABSTRACT

Most of the cities built by the Mayas in the Petén area, in the Central Yucatán Peninsula, were abandoned 1200 to 1000 years ago. The phenomenon is sometimes un-appropriately called "the collapse of the Maya civilization". Its main causes are still debated, ranging from climatic according to the occurrence of severe or modest droughts, to societal in the form of environmental mismanagement of the environment. In both processes, it is inferred that stress triggered the formation in many Petén lake sediments of erosional clay deposits, known as 'Maya clays'.

This work presents a high resolution, multi-proxy study of 'Maya clays' in lacustrine sediments from Laguna Tuspán, near the archaeological site of La Joyanca. Micropaleontological (ostracodes), mineralogical (clay minerals) and geochemical (bulk elemental composition and stable isotopes in organic carbon) records reveal three different phases of soil erosion throughout the last 5300 years. The oldest phase from 5281 to 2998 cal yr BP (i.e. 3331 - 1048 BC) is characterized by successive natural and moderate soil erosion deposits which follow climatic variations recorded in the American tropical belt. The time interval between 2998 and 1281 cal yr BP (i.e. 1048 BC and AD 661) contains four distinct erosional layers which, according to clay mineralogy, are indicative of both increased erosion of the regolith and strong soil loss. The most recent, also the most massive, deposit of Maya clay ends around 1281 cal yr BP (AD 661), that is some 200 years before the so-called 'Maya collapse' in the Petén area. Recent archeological fieldwork studies indicate that a population mobility took place into the city of La Joyanca from its hinterland by the early Late Classic Period (ca. AD 600), that is, at the end or just after this erosion episode, and well before the occurrence of the Terminal Classic-Postclassic (AD 800-1250) drastic climatic changes. Shifts in environmental management by the local society and timing of urbanization may explain environmental changes better than droughts per se.

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1. Introduction

The past of the ancient Maya civilization is commonly divided into cultural periods spanning from the Early Preclassic Period starting ca. 4000 years ago, to the Postclassic Period ending with the Spanish conquest some 400 years BP. The chronology of the Classic interval (1750-950 yrs BP) is based on the rise and fall of political capitals, and thus slightly varies depending on the location in the Yucatán Peninsula (Fig. 1). For the Petén lowlands, the Terminal Classic period is characterized by the abandonment of most of the cities between 1150 and 950 cal yr BP (AD 800-1000), a process known as the Classic Maya collapse.

Among the various theories attempting to explain this collapse, climatic changes are among the most frequently cited. Several studies on sediment archives collected in cenotes (karstic

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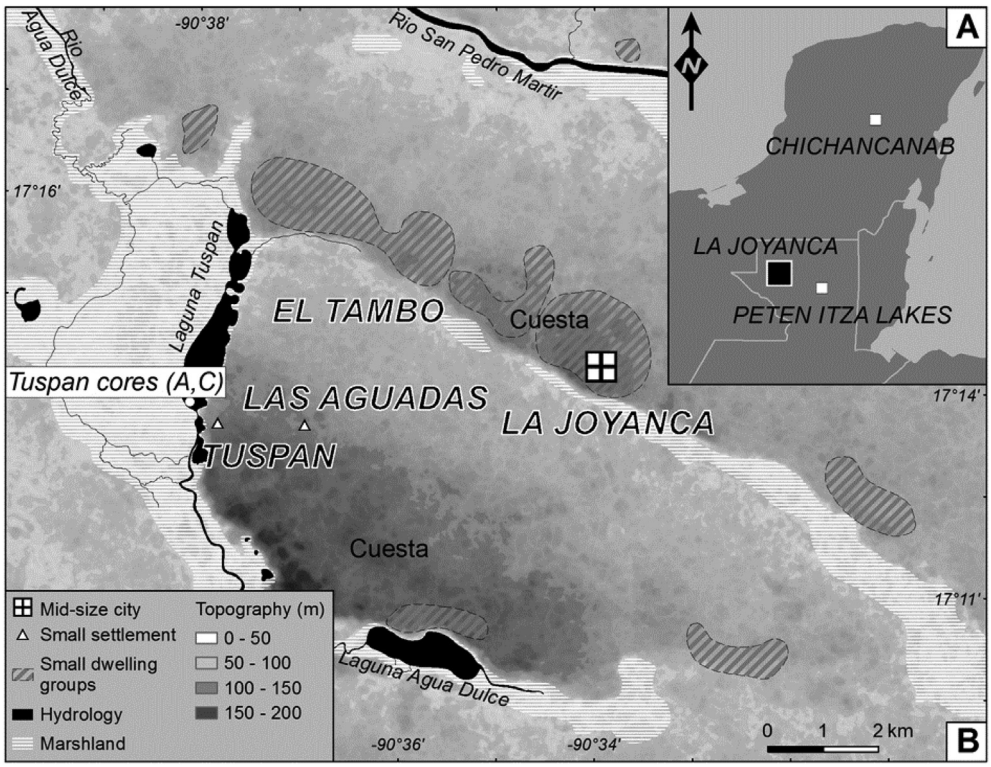

Fig. 1. A: Location of La Joyanca city within the Maya cultural zone, including re-known climatic records location such as Chichancanab lake (Hodell et al., 2005) and Peten Itza lakes (Anselmetti et al., 2007; Mueller et al., 2009). B: Coring locations Tuspan-A and Tuspan-C and Maya settlements in the area, from small dwelling groups to mid-size cities (Carozza et al., 2007; adapted from Galop et al., 2004).

sinkholes) and lakes from the Yucatán Peninsula (Curtis et al., 1996; Hodell et al., 2005; Leyden et al., 1998; Luzzadder-Beach et al., 2012; Whitmore et al., 1996; Wilson, 1980) point to the occurrence of several droughts across the first millennium AD, the most severe occurring toward the end of the Classic Period (Stahle et al., 2011). Medina-Elizalde and Rohling (2012) showed that water resources were reduced by 40% during the Terminal Classic period by studying speleothems from Tecoh Cave, in the northern part of the Yucatán. Another speleothem study by Kennett et al. (2012) indicates that reduced rainfall might have destroyed, or at least fragilized societies and polities of the main cities, which partly, or entirely, depopulated afterwards.

However, some cities located in the northern part of the peninsula, such as Uxmal and Chichén Itza, flourished during the collapse of the lowland cities (AD 800-1000), and lasted until AD 1100. This northern location corresponds to places where water resources are the most dependent on rainfall (Demarest, 2004). Several Northern Belize cities thrived throughout the Postclassic Period until the Spanish conquest. Also limiting the explanatory potential of droughts, several studies showed that the Mayas experienced and survived a series of crises throughout their history (Dunning et al., 2012), the worst of them being the Spanish conquest. Historical facts foster the development of alternative theories calling for severe mismanagement of the environment resulting from sociopolitical interactions. The Mayas conducted extensive deforestation as a way to increase land surface for agriculture (Carozza et al., 2007; Dunning et al., 2012; Galop et al., 2004; McNeil, 2012; Webster, 2002). Such a practice drastically increased soil vulnerability to erosion (Beach et al., 2006, 2009; Cabadas-Baéz et al., 2010). Long-term decreasing productivity of fields, with or without climate changes, might have triggered the abandonment of many Mayan cities.

Yet, the causality and relative role of climatic changes and/or Maya mismanagements of the environment are still debated issues (Aimers and Hodell, 2011). Detailed multiproxy studies have been conducted on numerous lake sediment cores in the Maya lowlands but interpretations are generally hampered by the lack of discrete signals diagnostic of either human impact or climate changes (Leyden et al., 1998).

Major episodes of soil erosion which occurred during periods of extensive agriculture are recorded as thick detrical clay units known as 'Maya clays' (Anselmetti et al., 2007; Brenner, 1994; Deevey et al., 1979; Leyden et al., 1998; Mueller et al., 2009; Rosenmeier et al., 2002). Characteristic of the Preclassic Period, Maya clays are observed in many lake sediment records of the Peninsula as laminated layers (Anselmetti et al., 2007; Leyden et al., 1998). In the well-known Lake Petén Itza, Maya clays are present throughout 5 m of sediment record, spanning 2500 years (Mueller et al., 2009). In the neighboring Lake Salpetén, the 6.5 m thick Maya clays cover roughly 3000 years (Anselmetti et al., 2007). The average time resolution for records from Petén is about 500 years/meter. Such a high temporal resolution allowed Anselmetti et al. (2007) to precisely investigate the chronology of changes in erosion rate. The latter multi-proxies approach concluded in a decoupling between population density and soil erosion rate. The most rapid soil loss occurred early during initial land clearance, suggesting that even low numbers of people can have profound impacts on lowland tropical karst landscapes. This means that, for a relatively long time interval, Maya people had to live with fragile soils. Was this pattern common for the whole Petén area?

Here, we present a 5300 year sediment record from Laguna Tuspán in which several 'Maya clay' horizons are clearly identified. Previous studies conducted on a core extracted nearby indicate that sediments in this area accumulated at an average rate of 0.2 cm/

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