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Research paper

Holocene paleoecology, climate history and human influence in the southwestern Yucatan Peninsula

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ABSTRACT

Centennial resolution pollen analysis of a record from Lake Silvituc, Yucatan Peninsula, provides a 7900 cal yr BP record of vegetation history and climate change in the Maya lowlands. Several droughts occurred during this interval, some of which are evident in other paleoclimatic records from the Caribbean region. We identified taxa that are characteristic of paleoecological change, such as Moraceae, *Ficus* and Asteraceae, among others. *Zea mays* and other taxa reflect the Maya occupation and its impact on the landscape. Droughts, as inferred from vegetational and sedimentary changes, occurred during the intervals of 4700–3600 cal yr BP, 3400–2500 cal yr BP, 2300–2100 cal yr BP, 1900–1700 cal yr BP, 1400–1300 cal yr BP, 730 cal yr BP and 560 cal yr BP. During these periods, tropical forest taxa elements declined (Moraceae, *Brosimum alicastrum*, *Ficus* and Fabaceae) and secondary elements increased (Asteraceae, Mimosoidae-*Acacia*, Chenopodiaceae Vent. and Poaceae), as did local aquatic elements (*Botryococcus*). *Zea mays* appeared 4100 cal yr BP, and other secondary elements, such as Asteraceae, Mimosoideae-*Acacia*, and Chenopodiaceae Vent, increased. The Preclassic abandonment is represented in the record as a shift to drier conditions and a strong decrease in forest taxa.

1. Introduction

The Yucatan Peninsula is an ideal region for analyzing ecological relationships between climate, vegetation, and humans in the past. This study area has high biodiversity, occupies a key biogeographical and climatic position in the tropical–subtropical belt, and has a history of human influence going back more than 4000 yr (Leyden, 2002). The Maya civilization occupied southern Mexico, Guatemala, Belize, El Salvador and Honduras. This culture survived multiple dry events but ended as a polity in the early ninth century (Hodell et al., 1995; Haug et al., 2003). Archaeological evidence suggests early manifestations of drought during the Middle Preclassic (BC 1000–600). Large civic and ceremonial sites of the Central Petén basin, such as Calakmul in Campeche (Domínguez-Carrasco, 1993; Folan et al., 2000), date to this period.

During the last two decades, various methodological tools have provided an understanding of the environmental changes in the Yucatan Peninsula over the past 4000 yr. These techniques include water chemistry as proxy for erosion and aggradation (Beach et al., 2008; Beach et al., 2009), geochemistry and seismology as a proxy for erosion and drought in lakes (Rosenmeier et al., 2002; Anselmetti et al., 2007) and the measurement of isotopes from stalagmites as a proxy for precipitation (Webster et al., 2007; Medina-Elizalde et al., 2010). In addition to multiproxy paleoecological reconstructions related to changes in sea level, the environmental effects on demography, soil stabilization after agricultural abandonment, vegetation and climate history (Wahl et al., 2006; Woller et al., 2007; Müller et al., 2010; Aragón-Moreno et al., 2012) have been analyzed. However, the paleoecological evidence that exists near Lake Silvituc (locally called *Peten Campechano*) is scarce.

Previous paleoecological findings from the Yucatan Peninsula have been based on cores from Lake Cobá (Leyden et al., 1998), which provide evidence of variation in tropical forest composition. Curtis et al. (1996) assessed the high variability in the climate of the Yucatan Peninsula based on cores from Punta Laguna. Islebe and Sánchez (2002) showed that mangrove vegetation and the modern coastline were established in the northwestern part of the Yucatan Peninsula between 3000 and 4000 cal yr BP. Torrescano and Islebe (2006) provided evidence for the establishment of modern sea level at 3800 cal yr BP from the eastern Yucatan coast. Hodell et al. (2005) and Haug et al. (2003) reported data on several droughts that occurred during the Late Holocene, reinforcing the evidence of Classic Maya droughts on a wide regional scale.

Present day climate change discussions focus on how biodiversity will change and how individual species will react under various climate change scenarios (IPCC, 2007). Climate change predictions are based on present day ecological knowledge, and paleoecology can support new insights into and evidence of how biodiversity would react if, for example, precipitation and temperature regimes change drastically. The Late Holocene is a good example of a past period of climate change and could provide how plant communities react to sudden and cyclic changes. The aim of this study is to reconstruct the environmental history of the southwestern Yucatan Peninsula, using fossil pollen as a proxy to

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elucidate past vegetational and climatic changes during the Holocene, based on a centennial-resolution record from Lake Silvituc. Additionally, we searched for evidence of early human occupation in the area. The nature of these changes during the Holocene in the Yucatan Peninsula is expressed as changes in precipitation patterns and vegetation types. Another important aspect of this study is the establishment of a temporal framework based on reliable radiocarbon dates, as many studies lack a well established time control.

1.1. Regional setting

Lake Silvituc (59 m altitude) is located in the southwestern part of the Yucatan Peninsula in the state of Campeche, at 18° 37′ 2″N and 90° 17′ 41.4″W (Fig. 1). The mean annual precipitation in the lake area is 1300 mm/yr (Perez et al., 2011). It is a flat alluvial region with some rivers, lakes and floodplains established on old karst. The central region of the peninsula is varied in elevation and topographic relief and has elevations ranging from 50 to 300 m, while elevations in the rest of the peninsula reach a maximum of 40 m. This complexity has led to the development of a mature karst, caves, greater accumulation of soil, and larger bodies of water in closed depressions (Marín-Stillman et al., 2004). Silvituc is a shallow lake that is 4 km long and 2 km wide and has a maximum depth of 4 m (Fig. 1). The lake is surrounded by vast floodplains and has an island known as Cilvituk with PreHispanic Maya constructions. The region is known for its great cities of the Classic period, including Calakmul, Becán, Chicanná, Balamkú, Xpuhil and Río Bec. According to several archaeological studies, the Maya occupation of the site extends to the Postclassic period. Five Maya settlements have been identified around the lake and near the island (Ojeda-Mas et al., 1996; Alexander, 2000). The dominant vegetation near the lake is medium statured tropical forest (semi evergreen tropical forest) and low tropical forest (low semi-evergreen tropical forest). However, the primary forest has been severely affected by human activities and hurricanes (Sánchez, 2000; Sánchez and Islebe, 2002). This forest type has canopy heights of up to 25 m and typically three well defined layers. The most characteristic arboreal species are *Manilkara zapota* (L.) P. Royen, *Brosimum alicastrum* Sw. and species of the family Fabaceae. Low statured tropical forest in terrain depressions (locally known as *bajos*) is characteristic of this area, and it has a species composition similar to that of the medium statured forest; however, the species have lower canopy heights and are adapted to seasonal flooding. Another forest type that is found in the area consists of what is locally known as "*sabana*" vegetation, an open vegetation type with palms such as *Acoeloraphe wrightii* H. Wendl. Ex Mart., Cyperaceae, Poaceae and low shrubs.

The mean annual temperature is approximately 26 °C (Sánchez and Islebe, 2002). The climate in the study area is seasonal, and most of the precipitation occurs between May and November, which coincides with the northward movement of the Inter-tropical Convergence Zone (ITCZ) and the North Atlantic High (Hoeerling et al., 2001). Cloud features and high sea surface temperatures (SSTs) combine with trade winds cause convection of humid air when they interact with low

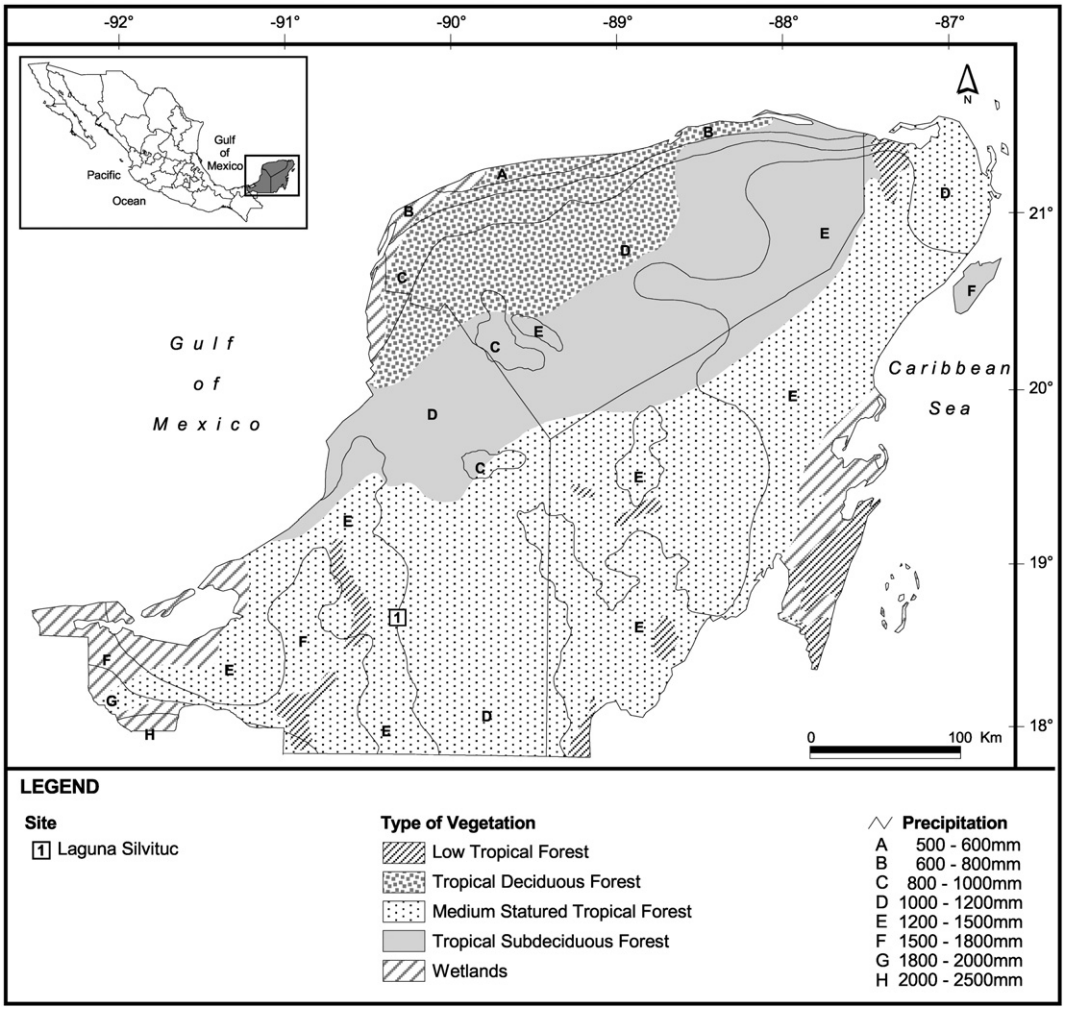

Fig. 1. Map showing the study area and location of core at Lake Silvituc, present day vegetation types and isohyets. Comisión Nacional para la Conservación de la Biodiversidad (CONABIO) was the source of metadata.