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Genesis of hydromorphic Calcisols in wetlands of the northeast Yucatan Peninsula, Mexico

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ABSTRACT

Tropical wetlands are fragile ecosystems controlled by hydrological factors. They are less studied than wetlands of the temperate and subtropical areas, and limited information is available about soil genesis in such systems. Here, we present a soil study of a wetland in the Yalahau region of the northeastern Yucatan Peninsula, in order to assess the properties and understand the genesis of these hydromorphic soils. An east–west transect was established through the wetland to understand differences in soil processes between shallower deposits at the edge of the wetland and thicker deposits at the center of the wetland. Contrary to the central image of peaty and gleyic wetland soils, the dominant soil unit in the wetland examined in the current study is a Calcisol. According to their properties we assume that the Bk horizons of these soils are the product of neoformation, as they consist principally of micritic groundmass. Shells of terrestrial mollusks are also present, and constitute the coarser fractions. The micrite in these soils is proposed to have been synthesized through participation of algae when periodic flooding with waters from karstic geosystems, rich in dissolved carbonates (from limestone dissolution), affects the area. Algae develop intensely on the surface of the flood water, forming periphyton. The algae consume CO_2 dissolved in water through photosynthesis, thus displacing the bicarbonate (soluble)–carbonate (low solubility) equilibrium in favor of carbonate formation. Profiles near the edge of the open wetland show a carbonate-enriched horizon (Bk) overlaying the organic matter-enriched horizon (Ah). We conclude that alternation of horizons enriched with organic material and carbonates reflects the duration of floods: more prolonged flooding promotes algae productivity and carbonate precipitation, while organic matter accumulation is inhibited.

1. Introduction

Karstic landscapes of the Yucatan Peninsula, in southeastern Mexico, exhibit substantial environmental variability along a gradient from the rolling limestone hills of the southern peninsula to the low, flat limestone shelf of the north. In the southern lowlands, about 30% to 40% of the landscape is composed of various forms of wetlands. Recently, these southern wetlands have attracted attention from archeologists and soil scientists in response to evidence that the ancient Maya made use of the wetlands for agricultural production, possibly transforming them through the construction of drainage canals and raised fields. There has, however, been much debate concerning the genesis and nature of these wetland soils, and the degree to which the ancient Maya modified or impacted wetland landscapes of the southern lowlands (Fedick, 1996; Beach et al., 2009).

In contrast to the southern lowlands, the northern Yucatan Peninsula contains few wetlands, the most common type being coastal mangrove swamps (Olmsted, 1993) that have been affected by anthropogenic disturbance for thousands of years (Batllori et al., 1999). Only limited information is available about these coastal wetlands, and in general, most of the studies are concerned with food habitats (Thompson et al., 1992), biodiversity distribution (Rejmankova et al., 1996), ecological models (Mazzotti et al., 2005), groundwater geochemistry (Perry et al., 2002), and hydrogeology (Tulaczyk et al., 1993; Gondwe et al., 2010). Over several decades, extensive soil surveys have been conducted throughout the interior of the northern Yucatan Peninsula, providing information on soil genesis, distribution and classification (e.g., Aguilera, 1959; Bautista et al., 2004, 2005).

It is only in recent years that wetlands of the interior northern lowlands have come to the attention of researchers. At the El Eden Ecological Reserve, located about 35 km from the coast in northern Quintana Roo, Sedov et al. (2008) studied a toposequence from the "upland" forest area to the lowest portions of a wetland, in which the presence of Calcisols (soils with a substantial secondary carbonate accumulation) was reported for the first time. These soils deviate

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considerably from the common product of wetland pedogenesis, which results in the formation of peaty and gleyed soils (soils saturated with groundwater for long enough periods to develop a pattern essentially made up of reddish, brownish or yellowish colors at aggregate surfaces, in combination with grayish/bluish colors inside the aggregates).

For many soils developed on limestones, such as in the Yucatan Peninsula, it has been difficult to identify carbonate that formed in the soil versus carbonate mechanically inherited from the rock. Carbonate formed in the soil has been termed "pedogenic," "secondary" or "authigenic" (Gile et al., 1965; Pal et al., 2000; Monger, 2002). Carbonate mechanically inherited directly from the limestone has been termed "lithogenic," "geogenic" or "primary" (Drees and Wilding, 1987; Doner and Lynn, 1989). Criteria for distinguishing pedogenic from lithogenic carbonates involve both field and laboratory analyses. Field evidence includes differences in the presence of marine fossils (in the limestone) and carbonate macromorphology (nodules, pendants, and laminar caps, which indicate pedogenic processes). Laboratory evidence includes comparing mineralogy, particle size, micromorphology and isotope analyses. The palustrine carbonates result from episodic subaerial expositions and associated pedogenesis of lacustrine mud during lake-level low stands. Thus, palustrine carbonates are characterized by a range of sedimentary features of primary lacustrine deposit and pedogenic features due to later transformation (Freytet, 1973, 1984; Freytet and Verrecchia, 2002; Alonso, 2003).

Here, the results of new research on soils of the wetland at the El Eden Ecological Reserve are presented, in order to better understand the characteristics and genesis of the calcic–hydromorphic soils of the northeast Yucatan Peninsula. Special emphasis is given to studying carbonate accumulation in the wetland environment and associated pedogenetic processes.

2. Regional setting

The study area is located in the northern part of the Yucatan Peninsula, also known as the northern Maya Lowlands. Specifically, the study area is situated in the northeast corner of the peninsula, in the Mexican state of Quintana Roo (Fig. 1). This area represents a distinctive physiographic region within the northern lowlands that is characterized by an extensive freshwater wetland system along with a diversity of other ecosystems that include lagoon and marine environments, coastal dunes, savanna, and semi-deciduous forests (Lazcano et al., 1995). The area is referred to as the Yalahau region, following a phrase in the Yucatec Mayan language that means "source of waters." The Yalahau region receives an unusually high amount of rainfall for the northern lowlands, due to a sea breeze convergence effect (Isphording, 1975). Climate records from the El Eden Ecological Reserve, and from a climatic station in the town of Kantunilkin, about 35 km west–southwest of the El Eden Reserve, report a mean annual temperature of 20 °C and an annual rainfall averaging from 1500 mm

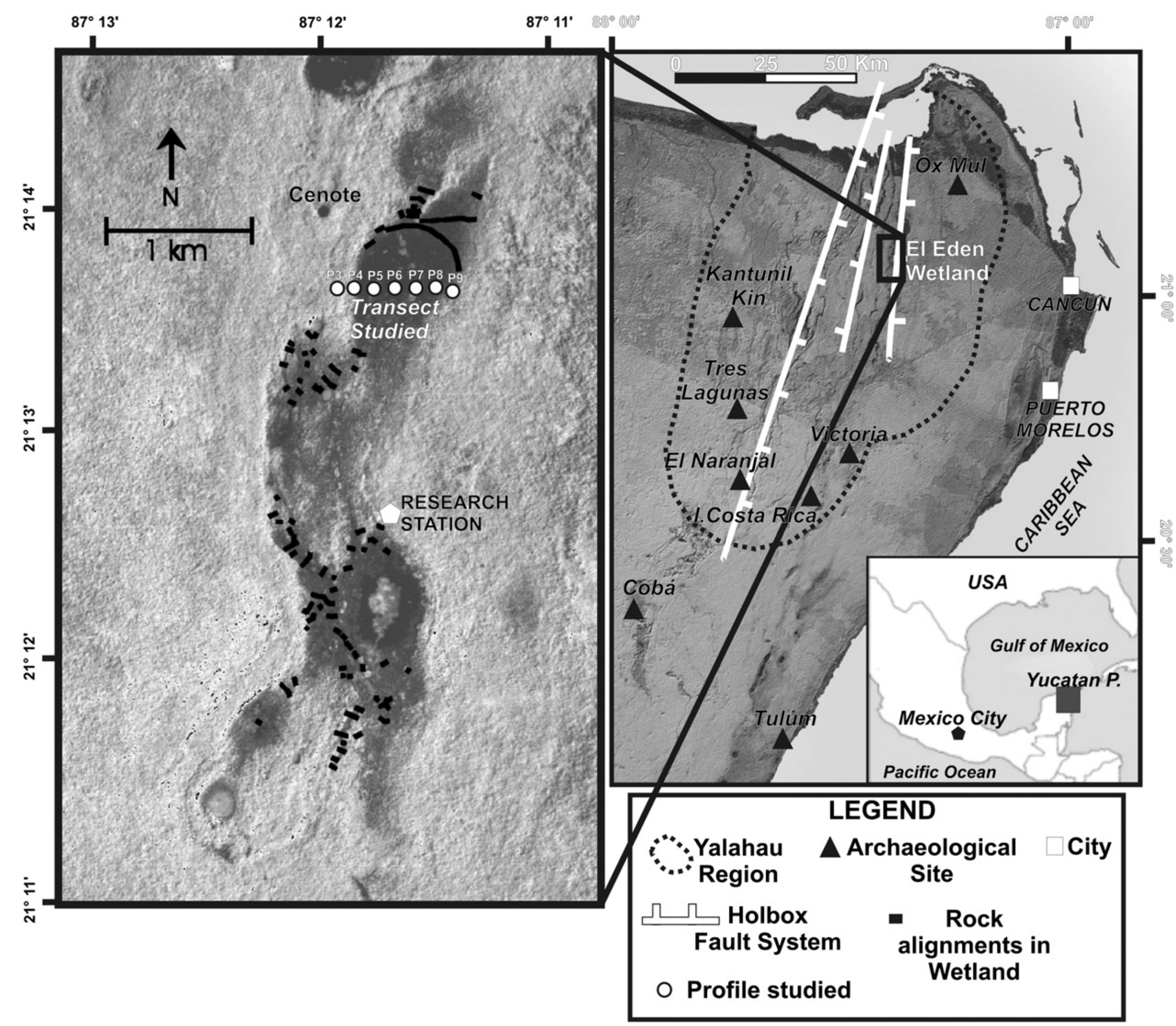

Fig. 1. Location of Yalahau wetland in northeastern Yucatan Peninsula and E–W transect studied.