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Ecological effects of natural hazards and human activities on the Ecuadorian Pacific coast during the late Holocene

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ABSTRACT

The La Tolita archeological site is located in the Province of Esmeraldas in the northwestern part of Ecuador at the border with Colombia. This area comprises one of the world's wettest coastal regions with mangrove and swamps along the coast and has one of the richest tropical rainforest of the planet, extending inland. Today this region is seriously affected by natural hazards including earthquakes, deposition of thick layers of volcanic ash, tsunamis, and El Niño flooding. The region also hosted one of the most important and famous cultures of the late Holocene, the La Tolita–Tumaco, which dominated northern South America between 2900 and 1100 yr BP. With the aim of characterizing the influence on the environment of the different factors of natural hazards, climate changes, and human activities, we drilled a 4-m long sediment core in a swamp close to the La Tolita site. The record dates back to 5000 years BP. Multiproxy analyses of pollen, microcharcoal, XRF-based geochemical data, and geochronology were performed on the sediment to distinguish the different drivers of change. At ~3000 yr BP, an earthquake dramatically modified the landscape, elevating the ground and changing the course of the rivers. In the following two millennia until 1100 yr BP, raised-field agricultural activities dominated the site, providing evidence for an increase in the local population. Human activity progressively declined after 1100 yr BP, with the loss of the regional influence of the Tolita culture. The climate remained permanently moist throughout the sediment record, both the rainforest and the mangrove remained well developed, and marine incursions were short and frequent.

1. Introduction

Life histories of biota are closely linked with environmental changes due to isolation, fragmentation, migration, and re-assemblage that can influence speciation and account for diversification. Tectonic activity and climate variability are the main factors identified as having an impact on genetic and diversity richness with time (Morley, 2000; Hoorn et al., 2010). However, climatic factors related to energy and water availability and productivity account for much of the spatial variation of species richness of widespread species (Willis et al., 2007). High tropical genetic and species biodiversity is generally associated with stable climate areas called refugia or niches (Carnaval and Moritz, 2008).

These refugia have been the focus of study of tropical ecologists and paleoecologists for several decades, and their locations are still subjects of debate within the community. Recently, the introduction of climate models challenged previously proposed locations at broader time and spatial scales, and new proposals for the location of these refugia were proposed (Cowling et al., 2001; Mayle, 2004).

The ecoregion containing the wet forests of Chocó-Darién is considered to be one of the most species-rich lowland areas in the world, with exceptional abundance and endemism over a broad range of taxons including plants, birds, amphibians and butterflies (WWF). The wet forest extends between latitudes 9° to 1°15′ north, and longitudes 79° to 76°15′ west from eastern Panama along almost the entire Pacific coast of Colombia to northern Ecuador. This ecoregion encompasses a strip of land ranging from sea level to an elevation of approximately 1000 m. It is situated between the Pacific Ocean and the western Cordillera of the Andes. The climate of the Chocó, with warm temperatures [mean annual temperature (MAT) is 23.6 °C] and high mean annual precipitation (MAP) from 4000 to more than 9000 mm per year, characterizes one of the few places in the Neotropics with pluvial rainforest

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(Gentry, 1982). The Chocó area was defined as a glacial refugium by Gentry (1982) with high biodiversity endemism and humidity. Five pollen records showed that the region did not undergo any climate changes – at least during the past 4000 years – but was rather subject to strong tectonic activity, which enhanced erosive conditions due to changes in fluvial drainage (Fig. 1). Although the Pacific rainforest of the Chocó is present in all the records, regional differences in the environmental history question the origin of the driving factors behind the small differences in floristic composition at the different sites. The northernmost record located in the Atrato wetlands (6°34′ N, 76°34′ W, 18 m a.s.l.), which is also the most distant from the coast, revealed a succession of dominant species assemblages due to changes in drainage conditions, with the main event dated at 2700 yr BP and a flooding event between 1500 and 500 yr BP (Urrego et al., 2006). Laguna Jataordo (5°48′ N, 76°42′ W, 50 m a.s.l.) has no contact with the coast either and documents the past 4200 yr with a hiatus due to intense erosive conditions recorded between 4000 and 1400 yr (Berrío et al., 2000). More to the south, the pollen record of Caimito (2°32′ N, 77°36′ W, 50 m a.s.l.) spans the last 4000 years with a hiatus between 2700 and 2000 yr (Velez et al., 2001). Caimito exhibited migration of the mangrove belt, which was attributed to tectonic uplift in the coastline and changes in sea level. Close to Caimito, the formation of the lake Laguna Piusbi (1°53′ N, 77°56′ W, 80 m a.s.l.) started at 4400 yr BP, and high precipitation rates appear throughout the record with little human influence on the landscape (Behling et al., 1998). At the southernmost site, the Guandal record (2°13′ N, 78°21′ W, 28 m a.s.l.) started at ~2700 cal yr BP and documents a succession of different dominant floristic assemblages, from pioneer forest to rainforest, depending on the drainage conditions (Urrego Giraldo and Del Valle, 2002). The absence of mangrove taxa indicates that there was no link between the coast and this site.

All these paleoenvironmental records point to a stable climate during the late Holocene and instead to intense tectonic activity, which reinforced changes in the fluvial system and led to reorganization of the landscape and floristic assemblages. Here we present the results of multiproxy analyses of a sediment core collected near the famous archeological site of La Tolita, in the southernmost Chocó area in northern Ecuador. The analyses include data from pollen, charcoal and sediment associated with abundant archeological archives (Valdez, 1987, 2006) and a detailed tectonic study (Dumont et al., 2006) of the area. Our aim was to evaluate the respective influence of changes in sea level, extreme climate events such as El Niño Southern Oscillation (ENSO), tectonic activity and human disturbance on the regional landscape.

2. Study site, climate and vegetation

2.1. Setting of La Tolita coring location

La Tolita is located in the Province of Esmeraldas in northwestern Ecuador at the border with Colombia (Fig. 1). This coastal region is one of the wettest in the world, with mangrove swamps along the coast and tropical forests extending inland. Today the region is strongly affected by natural hazards like earthquakes (including the some of the strongest in South America in the 20th century—1906 Ms 8.7; 1942 Ms 7.9; 1958 Ms 7.8; 1979 Ms 7.9), the deposition of thick layers of volcanic ash, tsunamis, and floods during El Niño events. The core was collected in a coastal brackish swamp behind a beach ridge covered

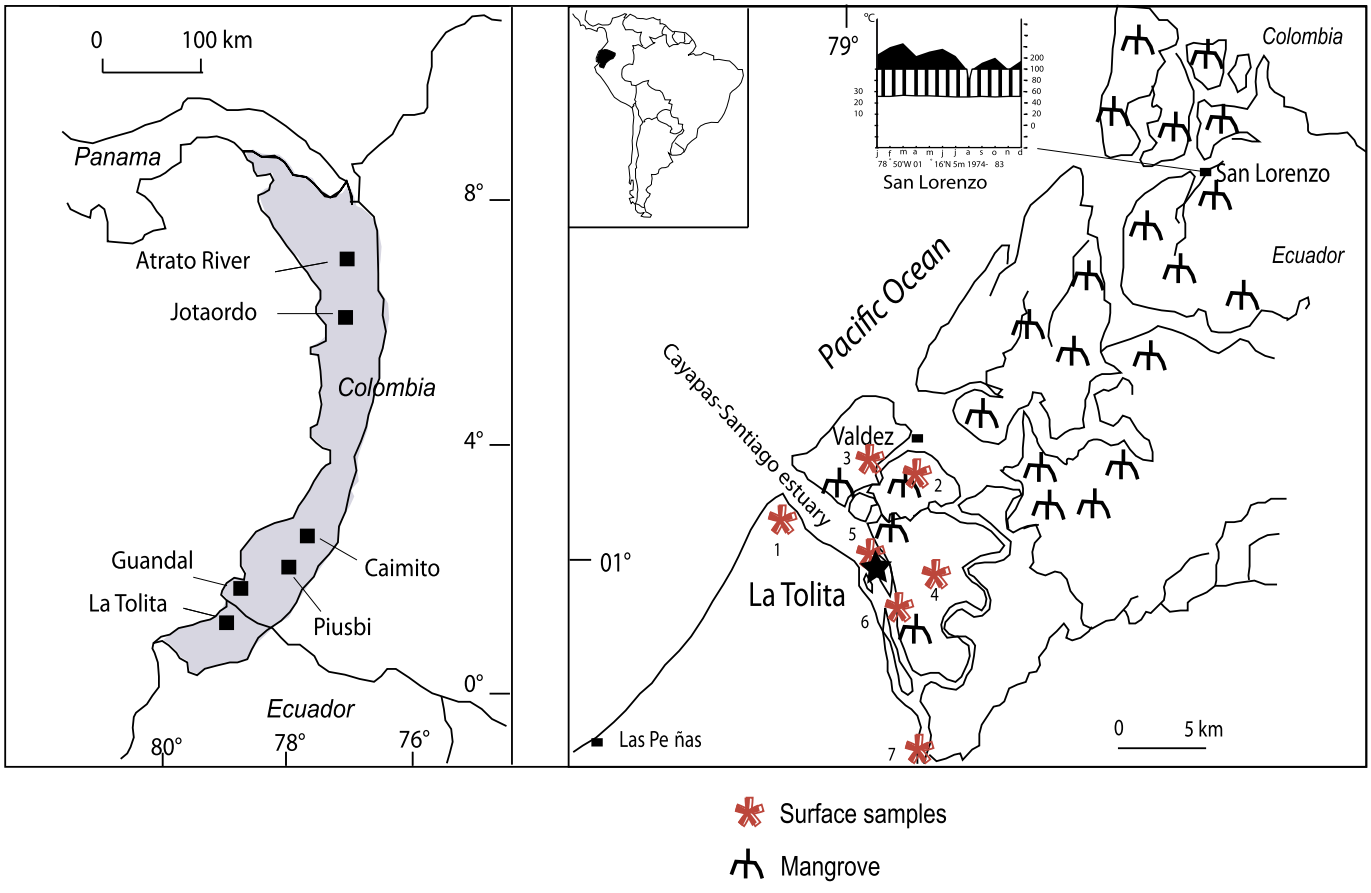

Fig. 1. (a) Map showing the location of the Chocó biogeographic area (gray), the location of the La Tolita site and other pollen records discussed in the text. (b) Location of the surface samples (red star) and distribution of mangrove in the region of La Tolita.