ARTICLE IN PRESS

Palaeogeography, Palaeoclimatology, Palaeoecology xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

Soil phytoliths as indicators of initial human impact on San Cristóbal Island, Galápagos

Fernando J. Astudillo

Department of Archaeology, Simon Fraser University, 8888 University Drive, V5A 1S6 Burnaby, BC, Canada

ARTICLE INFO

Keywords:
Historical ecology
Environmental archaeology
D/P ratio
Colonization
Ecuador

ABSTRACT

I analyzed phytoliths from soil profiles on San Cristóbal Island in the Galápagos Islands to determine whether historical human impact and recent vegetation dynamics are visible in the phytolith record. I extracted phytoliths from soil samples taken from four test pits located at the village, an abandoned field, a forest, and an active agricultural field - all located within the former El Progreso plantation (AD 1860–1920). Changes in the ratio of tree to grass phytoliths with depth in all four samples suggest changes in vegetation composition from forest to open vegetation dominated by grasses, which reflects the removal of forest with colonization and the first permanent human occupation of the archipelago in the middle 19th century. This paper shows that the changes in vegetation brought about by colonization and land clearing for plantations are documented in the soil phytoliths record, and suggests that phytoliths can be used as an indicator of past vegetation change in future work on the historical ecology of the Galápagos archipelago.

1. Introduction

Since its declaration as a World Heritage Natural Site by UNESCO in 1978, the Galápagos Islands have acquired the reputation of being one of the last pristine natural paradises on earth. Thousands of scientists, environmentalists, and tourists from all over the world visit the Islands every year looking for some of the last landscapes not affected by human actions. Local governments and tourism businesses deliberately emphasize the notion that travelling to the Galápagos will transport the visitor to a place where evolution is constantly taking place. Consequently, the archipelago is one of the most visited tourist destinations in the Americas with more than a half a million visitors a year.

However, during the past four centuries the local plant and animal populations have experienced extensive changes caused mainly by anthropogenic activity. After their discovery in 1535, the Galápagos Islands remained sporadically inhabited until 1832 when they were legally incorporated as Ecuadorian territory. For three centuries, the archipelago was visited by pirates and whalers, and was the location of several industrial-size plantations, one prison, and an American army base. Beginning in 1835, the Ecuadorian government provided incentives to colonization which increased the rate of introductions of exotic plants and animals on the islands.

The exploration of the ecological costs of colonialism is an integral part of historical archaeology. The aim of environmental and biological research in historical archaeology is to reconstruct modifications to the landscape and understand the ecological dynamics resulting from imposed socio-political agendas in new settings (Deagan, 2008; Mrozowski, 2006, 2010). In this work, I explore the ecological effects of the initial human presence in the Galápagos archipelago. I present the results of an archaeobotanical study in the agricultural zone of San Cristóbal Island. The overall goal was to investigate the potential of phytolith analysis to explore human impacts on local vegetation; specifically, the ecological impact caused by colonization and human permanent population. Secondary goals were to explore vegetation composition before human arrival, to detect human disturbance, and to evaluate the preservation of phytoliths in local soils.

1.1. Study area and background

The Galápagos are a group of volcanic Islands which formed about three million years ago below the equator in the Pacific Ocean, 1000 km west of the Ecuadorian coast (Between: 01°40′, 01°36′ S and 089°16′ 092°01′ W). The age of the islands increases moving from west to east because of the drift of the Nazca tectonic plate away from the East Pacific Ridge to the southeast over a hotspot (Gromme et al., 2010; McBirney and Williams, 1969; Simkin, 1984). The Galápagos archipelago comprises approximately 128 named islands and islets, but only four are inhabited: Isabela, Floreana, San Cristóbal, and Santa Cruz. This study was located in the southeastern highlands of San Cristóbal; the easternmost, and one of the oldest islands in the Galápagos (Fig. 1).

The structure of the islands is that of coalescent and/or super-posed lava streams in the lower parts and cones of different pyroclastic

E-mail address: fastudil@sfu.ca.

https://doi.org/10.1016/j.palaeo.2017.11.038
Received 19 January 2017; Received in revised form 14 November 2017; Accepted 15 November 2017

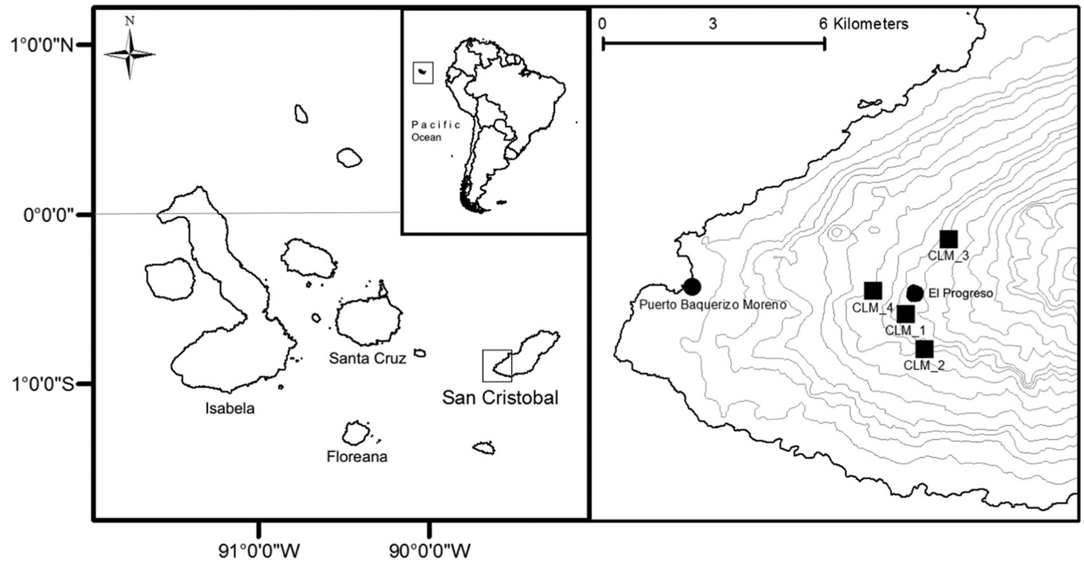

Fig. 1. The Galápagos Islands with location of test pits for phytoliths extraction in the agricultural zone of San Cristóbal Island.

material at higher elevations (Stoops, 2014). Soils are formed after decomposition of lava flow surfaces caused by weathering. The modern landscape is covered with poorly developed black soils; older soils are brown Andisols, and the oldest surfaces show eroded and highly cohesive Red soils (Franz, 1980). Soil pH averages from 6.37 to 6.52 in the humid highlands of San Cristóbal Island (Percy, 2015 pers. comm.).

The islands are situated on the equator; however, they do not have a humid tropical climate due to the influence of two interacting systems: the Inter Tropical Convergence Zone and El Niño Southern Oscillation (Trueman and d'Ozouville, 2010). Local climate is influenced by altitude; the average annual temperature oscillates from 20 to 31 °C, and two seasons are recognized: cool and dry between June and December, and warm and rainy between January and May. The annual precipitation varies from 700 to 3000 mm and on the windward slopes of the mountains a mist, called *garúa*, is responsible for continuous humidity throughout the cool season (Stoops, 2014:2).

In Galápagos, approximately 600 plant taxa exist of which about 32% are endemic. There are seven vegetation zones: the Littoral (or Coastal) zone, the Arid zone, the transition zone, the Scalesia zone, the Zanthoxylum (or Brown) zone, the Miconia zone, and the Pampa (or Fern-Sedge) zone. The latter four zones are moist zones (Wiggins et al., 1971). This study took place in the Scalesia zone, which extends from 200 to 400 m a.s.l. This zone, also called the humid, or agricultural zone is home to a variety of endemic taxa such as *Scalesia pedunculata*, *Psidium galapageium*, *Pisonia floribunda*; and the native trees *Cordia lutea* and *Piscidia carthagenensis* (Lee, 2006; McMullen, 1999; Wiggins et al., 1971). Today, the vegetation is characterized by the presence of invasive tree species such as guava (*Psidium guajava*), blackberry (*Rubus niveus*), plum rose (*Syzygium jambos*), multicolored lantana (*Lantana camara*), and grasses from the genera *Brachiaria*, *Eragrostis*, *Panicum*, and *Pennisetum* (Guézou et al., 2010, 2016).

The Galápagos Islands have a short human history. It is believed that humans did not occupy the archipelago before European discovery. Heyerdahl and Skjølsvold (1974) presented evidence suggesting that pre-Columbian groups from coastal Peru and Ecuador visited the islands, but this proposition is still in dispute (Anderson et al., 2016). The first European to document the archipelago was the Spanish Bishop Tomas de Berlanga in 1535 (de Berlanga, 1884; Vargas, 1986). During the following two centuries, the Islands remained seasonally inhabited by pirates and whalers. In 1832, the Galápagos were incorporated into the new Republic of Ecuador. By the mid 19th century the Galápagos were being colonized by planters to create plantations of sugarcane (*Saccharum officinarum*), coffee (*Coffea arabica* L.), and quinine trees (*Cinchona pubescens*). Ecuadorian businessmen Manuel J. Cobos and José Monroy obtained a long-term concession to plant and export sugar cane and coffee from San Cristóbal Island –formerly named Chatham Island. They created an industrial-scale plantation called El Progreso in the humid highland interior of the island and occupied most of the southwestern portion of the island from 1860s to 1920s (Latorre, 1991, 2002). The ecological consequences of these events are partially documented in palaeoecological and historical records but have been little explored archaeologically.

During the archaeological survey of the agricultural zone of San Cristóbal Island in 2014, a 19th century midden was found in a construction trench a few meters south of the main plantation house; feature labeled as *Carpintero* midden (0°54′28.37″S and 89°33′28.67″W; 332 m. a.s.l.). Charred and uncharred material culture, faunal remains, and wood charcoal constitute the midden. Recovered complete liquor bottles, porcelain fragments, nails, glass, metal fragments, and other pieces of domestic objects were associated with the time CE 1880s–1920s (Jamieson and Astudillo, 2017; LaVainillaFilms, 2016). The soil profile exposed at Carpintero midden showed four distinct horizons: an active soil layer 12 cm thick (Munsell: 5YR 3/3); a 40 cm thick clay-rich, spheroidal- to euhedral-clod A horizon (5YR 3/2) with some dead roots, some charcoal, and some cultural material; a 17 cm cultural midden; and a mineral horizon composed of solid clay that grades from red (2.5YR 3/4) to orange (2.5YR 4/6) in color. The clay is extremely wet with no evidence of organic matter and the pH of soils averages 7.7. Three periods of human occupation were defined from this profile: (1) pre-occupational period, (2) plantation period AD 1880–1920, and (3) post-plantation period 1920s to modern times (Fig. 2) (Astudillo, 2017a).

2. The phytolith record as an indicator of human influences on vegetation

Phytoliths are opaline silica bodies formed when hydrated silicon dioxide is deposited on and between cells of a growing plant. They occur in stems, leaves, roots, fruits, and the inflorescence of certain plants. Their main function in vascular plants appears to be structural support (Strömberg et al., 2016). Phytoliths remain in the soil after plant tissues decay and are incorporated in the soils via the accumulation of organic matter, weathering of the parent material, bioturbation, and other soil-forming processes (Alexandre et al., 1999; Piperno, 2006). The phytolith record has the advantage of relatively high spatial resolution due to the limited dispersal of phytoliths (Fredlund, 2005).