This article appeared in a journal published by Elsevier. The attached copy is furnished to the author for internal non-commercial research and education use, including for instruction at the authors institution and sharing with colleagues.

Other uses, including reproduction and distribution, or selling or licensing copies, or posting to personal, institutional or third party websites are prohibited.

In most cases authors are permitted to post their version of the article (e.g. in Word or Tex form) to their personal website or institutional repository. Authors requiring further information regarding Elsevier’s archiving and manuscript policies are encouraged to visit:

http://www.elsevier.com/copyright
Pre-pottery farmers on the Pacific coast of southern Mexico

Douglas J. Kennett,*, Dolores R. Piperno, John G. Jones, Hector Neff, Barbara Voorhies, Megan K. Walsh, Brendan J. Culleton

Abstract

Large island-like shell mounds along the southern coast of Mexico are the earliest known archaeological sites on the Pacific margin of Mesoamerica. These aceramic deposits date to between 7500 and 3800 cal BP and have been interpreted as locations where foragers, living elsewhere seasonally on the coastal plain, harvested shellfish and other estuarine resources. Based on an accumulation of paleoecological data from elsewhere in the lowland Neotropics of Mesoamerica, southern Central America and South America we pose and provide a first test of an alternative subsistence model: that the Archaic Period populations in this area were slash and burn farmers. Burned maize phytoliths first appear in these sedimentary records at 6500 cal BP in association with macroscopic charcoal and forest disturbance plant taxa. Periodic burning and forest disturbance, consistent with farming activities, are also evident in the macroscopic charcoal record between 6500 and 4700 cal BP. Pollen, phytolith and charcoal records all point to sustained burning, forest disturbance and the cultivation of maize between 4700 and 3800 cal BP. These data suggest that people were slash and burn farming during the Archaic Period prior to the adoption of pottery and the proliferation of Early Formative Period villages and full-fledged agriculture based on near or total reliance on crop plants after ~3800 cal BP.

1. Introduction

The Archaic Period in Mesoamerica is traditionally viewed as a long transitional interval (~9000–3800 cal BP) between a poorly defined Paleoindian big-game hunting tradition and the rise and proliferation of agricultural villages across Mesoamerica starting after 3800 cal BP. Archaeological sites dating to this ~5000 year pre-ceramic period are surprisingly rare. To a certain degree this reflects the demographic and societal realities of the Archaic, but, particularly in the lowlands, it is also a product of the burial (natural and cultural) of older sites or their inundation due to post-glacial sea-level rise in coastal settings. Mesoamerican archaeologists have also placed greater emphasis on later time periods. Domestication, dispersal and experimentation of some key Mesoamerican plant cultigens (maize and squash) are known to have occurred during the Archaic (e.g., Smith, 1997a,b; Piperno and Flannery, 2001; Piperno et al., 2009; Pope et al., 2001; Pohl et al., 2007; Ranere et al., 2009), but a substantial dietary role for these and other cultigens has been generally thought to date to the later Formative Period (after 3800 years ago) when settled village life started becoming well-established (Flannery, 1982; Smith, 2001; Blake et al., 1992a,b; Chisholm and Blake, 2006). Smalley and Blake (2003) have suggested that the low-level use of maize during the Archaic Period, and the reason for its early dispersal from the Balsas region, was its sugary stalk to produce alcohol (and fresh greens), rather than an important dietary staple (also see Blake, 2006). This hypothesis, however, is not supported by the available data on early maize use in its likely area of origin in the Balsas River valley of Mexico (Piperno et al., 2009: 5023).

Voorhies and Kennett have argued previously that the people living along the Pacific coast of southern Mexico during the Archaic were foragers that may have used some domesticated plants at a low level (Voorhies, 1976, 2004; Kennett and Voorhies, 1996; Kennett et al., 2006). This inference is largely based on their work at a series of large shell mounds along the coast (Voorhies, 2004: 32). Voorhies (1976) was drawn to Drucker’s (1948) original...
description of these island-like pre-ceramic shell mounds in the flatwater lagoon systems as evidence for early coastal forager life-ways. Six of these large shell mounds have now been identified and radiocarbon work indicates that they accumulated between ~7500 and 3500 years ago (Voorhies, 2004). Several lines of evidence (see below) indicate that, despite their size, these shell mounds resulted from periodic and repeated visitation to harvest and process marsh clams and other estuarine resources (e.g., fish, shrimp), rather than permanent settlements. More permanent settlements are hypothesized to have been located elsewhere on the coastal plain. However, with one possible latest Archaic exception (Vuelta Limón; see Voorhies, 2004: 100), high sedimentation rates on this flat coastal plain have largely obscured these hypothetical settlements and prevented their detection (Voorhies, 1989; Voorhies and Kennett, 1995). Based on these fragmentary and imperfect data, Voorhies and Kennett have argued that these people were foragers, living in semi-permanent base camps and gathering wild resources from a range of environments logistically, perhaps with some low-level use of domesticated plants (Voorhies, 2004: 396; Kennett et al., 2006: 120). In this paper we present paleoecological data as a first test of an alternative model; that the people living along this stretch of Pacific coast were slash and burn farmers occupying more interior habitats on the coastal plain and periodically visiting the estuarine zone to harvest and process marsh clams and other resources.

The basis for this alternative model is a series of paleoecological studies carried out in the lowland Neotropics during the last twenty years (Neff et al., 2006; Pearshall et al., 2004; Pohl et al., 1996; Piperno and Pearshall, 1998; Pope et al., 2001; Piperno, 2008a; Piperno et al., 2000, 2007, 2009; Ranere et al., 2009). These studies demonstrate that the cultivation of maize (and other domesticates) in slash and burn farming systems was in place well before 3800 years ago in some parts of lowland tropical Mesoamerica, southern Central America and South America. Maize is often the most detectable domesticate used within these slash and burn farming systems, but other cultivars are also in evidence (see Piperno and Pearshall, 1998; Piperno et al., 2000, 2007, 2009). The earliest evidence for slash and burn maize farming in close proximity to the Pacific Coast of southern Mexico comes from the Gulf Coast lowlands of Mexico (7300 cal BP; Pope et al., 2001; Pohl et al., 2007); the central Balsas region of Mexico (7200 cal BP; Piperno et al., 2007), and the Pacific coastal plain of Guatemala by 5500 cal BP (Neff et al., 2006). In this paper we present data from sediment cores (pollen, phytoliths and charcoal) collected in the vicinity of these Archaic Period shellmounds to test the hypothesis that the prehistoric people that deposited them were farmers. Before we present these paleoecological data we provide some background on the archaeological record for the region.

2. Study area

The Pacific coast of Chiapas, Mexico and adjacent Guatemala coast contain one of the longest known archaeological sequences in the lowland Neotropics of Mesoamerica (Fig. 1). At European contact (~ AD 1520) the region, known as the Soconusco, was part of the Aztec Empire and was well known for its agricultural productivity and tropical forest products (Gasco and Voorhies, 1989). The deep and productive alluvial soils of this region, coupled with resource rich wetland environments fostered early settled village life and ceramic manufacture between 3800 and 3600 cal BP (Clark and Cheetham, 2002). A notable increase in coastal agricultural communities occurs after this time and many of these were positioned on the interior margins of the wetland systems along the Pacific coast of Mesoamerica, from Guerrero (Mexico) south to El Salvador (Neff et al., 2006; Kennett et al., 2008). These early villages ultimately provided the social lattice for the first appearance in the Maya region for institutionalized social hierarchies, signaled by the development of larger and more socially and politically important communities governed by higher status individuals or chiefs (Clark and Blake, 1994). Some of these communities grew in size and population density and started monumental building campaigns, and it was in these early cities that some of the first hieroglyphic writing was carved on free-standing stone monuments (Love, 1999, 2002).

Archaeological sites dating prior to 3800 cal BP are rare. The earliest evidence for human occupation of the coastal plain comes from six shell mound sites positioned on the landward edge of an extensive mangrove-estuary system that formed along much of coastal Chiapas, Mexico as sea-level started to stabilize around 7500 cal BP (Voorhies et al., 2002). These shellmounds form artificial islands in these wetlands and range in size from 0.2 to 1.17 hectares and are between 3 and 11 m above the watertable at their centers (Voorhies, 2004). Shell deposits at all locations tested extend well below the modern watertable. The earliest of these sites, Cerro de las Conchas, has shell deposits dating between 7500 and 5500 cal BP (Clark, 1986; Voorhies et al., 2002). It is situated on the inland margin of a large freshwater swamp, but the dominant mollusk species (Polymesoda radiata) indicates that a brackish-water estuary extended to this inland location at the time of initial site formation. The five additional shell mounds are located in the Acapetahua Estuary to the northwest of El Hueyate and date to between ~ 5500 and 3800 cal BP. Deposits of this age at all sites are dominated by the marsh clam P. radiata.

These shell mounds are generally characterized by alternating beds of well-preserved whole and burned fragmented marsh clam shell that suggest periodic rather than continual use of these locations. This interpretation is bolstered by the general absence of house floors, formal hearths and a low diversity of tools and fauna (Voorhies, 2004). Oxygen isotope seasonality studies indicate that for much of the Archaic Period shellfish were harvested throughout the year with a greater emphasis on dry season exploitation (Kennett and Voorhies, 1996; Voorhies et al., 2002). Voorhies (2004); also see Kennett et al., 2006; hypothesized that residential base camps were positioned elsewhere on the coastal plain in forest clearings. Site visibility is a major problem confronting archaeologists working in this region because rivers flowing out of the Sierra Madre seasonally deposit large amounts of sediment across this relatively flat coastal plain. In extreme cases, major tropical storms produce large amounts of rain across the area, resulting in the abrupt burial of modern towns. Locating living surfaces and archaeological sites dating to the Archaic Period has been challenging because of these high sedimentation rates (Voorhies, 1989; Voorhies and Kennett, 1995). The paleoecological data reported in this paper therefore provide an important source of information regarding prehistoric land use, subsistence and settlement during the Archaic Period.

3. Paleoecological methods

Here we report incremental pollen, macroscopic charcoal, and phytolith data from sediment cores taken in close proximity to the five late Archaic Period shellmounds in the Acapetahua region. We used a vibracorer (3.5” tubes) to obtain intact columns of sediment that we split and sampled incrementally for radiocarbon, pollen, phytolith and charcoal analysis. One core was driven in the peri-coastal wetlands within the vicinity of Pijijapan (SOC05-2; UTM 4848656E, 1714546N) and the other was taken in very close proximity to the late Archaic Period shell mounds on the landward edge of the Acapetahua Estuary (SOC05-3; UTM 520258, 1681451N) (see Fig. 1 for core locations). Observations in the field indicated that...
these low-energy wetland environments contained well-preserved paleoecological records that were likely sensitive to anthropogenic alterations of the landscape during the Archaic Period.

3.1. Chronology and age models

Age control for these cores was established with a series of 8 AMS 14C dates on organic-rich sediment and reported in calibrated calendar years. These samples were analyzed at the NSF AMS Facility at the University of Arizona or the National Ocean Sciences Accelerator Mass Spectrometry Facility (NOSAMS; Table 1). At both labs organic-rich sediment (peat) underwent a series of heated acid–base–acid leaches to remove inorganic carbon and mobile organic acid phases. Organic samples were combusted under vacuum to produce CO₂. All 14C dates were calibrated with the Intcal04 atmospheric curve (Reimer et al., 2004) using OxCal 3.10 (Bronk Ramsey, 1995, 2001, 2005). Dates for each core were modeled as a sequence of non-overlapping events, which slightly modified each probability distribution. The weighted average of each decadal probability distribution was used as the central-point estimate to develop the age–depth model (Telford et al., 2004).

The age models for cores SOC05-2 and SOC05-3 were developed using four AMS 14C age determinations each and a date of −55 cal BP for the top sample in each core. Given the small error associated with the AMS dates, the resulting age models were fit with a constrained cubic smoothing spline, suggesting a basal date of 6600 cal BP for core SOC05-2 and 4750 cal BP for core SOC05-3. The age–depth curve for SOC05-2 indicates that sedimentation rate was fairly constant throughout most of the core, except after 600 cal BP when the rate increased rapidly and remained high until present. The age–depth curve for core SOC05-3 indicates that the sedimentation rate was also constant throughout most of the core, except for a period of more rapid deposition between ca. 4100 and 3800 cal BP. Overall these paleoecological sequences cover the last 6600 cal BP and provide a context for evaluating evidence from early archaeological sites.

Table 1

<table>
<thead>
<tr>
<th>Lab #</th>
<th>Provenance</th>
<th>Type</th>
<th>14C Age</th>
<th>Error</th>
<th>Cal BP (2 Sigma)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Range</td>
<td></td>
<td>Weighted average</td>
</tr>
<tr>
<td>OS-53396</td>
<td>Core SOC05-2, 220–222 cmbs</td>
<td>Black Peat</td>
<td>590</td>
<td>30</td>
<td>660–530</td>
</tr>
<tr>
<td>OS-53397</td>
<td>Core SOC05-2, 308–310 cmbs</td>
<td>Black Peat</td>
<td>3710</td>
<td>25</td>
<td>4150–3970</td>
</tr>
<tr>
<td>AA63353</td>
<td>Core SOC05-2, 407–408 cmbs</td>
<td>Wood</td>
<td>5279</td>
<td>44</td>
<td>6190–5930</td>
</tr>
<tr>
<td>AA63354</td>
<td>Core SOC05-2, 467–468 cmbs</td>
<td>Black Peat</td>
<td>5789</td>
<td>44</td>
<td>6720–6470</td>
</tr>
<tr>
<td>AA63355</td>
<td>Core SOC05-3, 308 cmbs</td>
<td>Black Peat</td>
<td>2481</td>
<td>39</td>
<td>2730–2360</td>
</tr>
<tr>
<td>OS-53403</td>
<td>Core SOC05-3, 404–405 cmbs</td>
<td>Black Peat</td>
<td>3520</td>
<td>25</td>
<td>3870–3700</td>
</tr>
<tr>
<td>OS-53398</td>
<td>Core SOC05-3, 505–507 cmbs</td>
<td>Black Peat</td>
<td>3680</td>
<td>35</td>
<td>4150–3900</td>
</tr>
<tr>
<td>AA63359</td>
<td>Core SOC05-3, 565–566 cmbs</td>
<td>Black Peat</td>
<td>4176</td>
<td>34</td>
<td>4840–4580</td>
</tr>
</tbody>
</table>
3.2. Pollen analysis

Sediment samples of 1–5 ml were processed following standard techniques (Erdtman, 1960; Faegri et al., 1989). European Lycopodium spp. spores were added as an exotic tracer. Pollen samples were soaked in sodium hexametaphosphate for 24 h, washed through nested sieves of 250 and 125 μm mesh size, and the residue was transferred into gridded petri dishes and counted under a stereomicroscope. Only charcoal particles >125 μm in minimum diameter were tallied because previous studies indicate that large particles are not transported far from the source and thus are an indicator of local fire activity (Whitlock and Millspaugh, 1996; Clark et al., 1998). Charcoal particles were identified and tallied as either woody or herbaceous (e.g., grass) based on the presence of stomatal openings and comparison to burned reference material (Fig. 2). Where phytolith content was good assemblages usually contained a diversity of arboreal and herbaceous plants characteristic of mature and successional tropical forest growth. Phytoliths were identified through comparison to a modern reference collection of more than 2000 species of Neotropical plants, including domesticated species such as maize and squashes and their closest wild relatives that is housed in Piperno’s laboratory at the Smithsonian Institution. Percentages of phytoliths in each sample are based on counts of at least 100 phytoliths. Frequencies of phytoliths showing evidence of charring, which serve as an index of plant burning, were made independently of the phytolith count.

3.3. Charcoal analysis

Samples of 1 cm³ were taken every 5 cm for macroscopic charcoal analysis as a proxy for fire activity. charcoal samples were soaked in sodium hexametaphosphate for 24 h, washed through nested sieves of 250 and 125 μm mesh size, and the residue was transferred into gridded petri dishes and counted under a stereomicroscope. Only charcoal particles >125 μm in minimum diameter were tallied because previous studies indicate that large particles are not transported far from the source and thus are an indicator of local fire activity (Whitlock and Millspaugh, 1996; Clark et al., 1998). Charcoal particles were identified and tallied as either woody or herbaceous (e.g., grass) based on the presence of stomatal openings and comparison to burned reference material (Fig. 2).

3.4. Weight-loss on ignition

Weight-loss on ignition (LOI) was used to determine changes in the amount of organic material in the sediment (Dean, 1974). Samples analyzed for organics and carbonates were taken approximately every 5 cm. Approximately 1 g of sample was dried, then fired first to 550 °C for one hour, then weighed, then fired to 1000 °C for another hour. The first firing removes all organic carbon, so the percentage weight loss indicates the percentage of organic carbon in the sample. Weight loss between the first and second firing results from CO₂ driven off from carbonate at temperatures above 850 °C. CO₂ percentages are converted to calcite (CaCO₃) percentages.

4. Results

SOC05-2 provides the longest continuous paleoecological sequence for the region, spanning the middle and late Holocene (~6600–200 cal BP). Two major stratigraphic units are visible in the 4.7 m core, a coarse sandy horizon (0–1.8 m) underlain by an organic-rich clay/peat deposit extending to the base of the sequence (1.8–4.7 m). Our age–depth model suggests that the upper stratum was deposited rapidly, perhaps a product of recent landscape modification coupled with a series of catastrophic floods that have impacted the region in recent decades. The deepest deposits date to 6600 cal BP and the uppermost portion of the organic-rich stratum (~1.8 m) dates to 500 cal BP. Accumulation rates were highest (~0.615 mm/yr) in the lower part of the core and slow after 4000 cal BP (~0.349 mm/yr; excluding coarse sandy horizon).

We first present the pollen data because they provide the general paleoecological framework for interpreting the charcoal and phytolith records. Pollen, phytoliths and charcoal are carried and deposited into the sedimentary record in different ways (wind,
water, etc.). Each record is sensitive to a somewhat different set of environmental parameters and the variability in these records is explored in the discussion section within the context of the broader paleoecological and archaeological data for this region.

SOC05-2 is the longer of the two records and well-preserved fossil pollen was found from 180 to 470 cmbs (6600–500 cal BP). Concentration values were generally high throughout the core, and pollen was usually well preserved. Two distinct pollen zones are apparent in this core, based largely on the abundance of red mangrove (*Rhizophora*) pollen in the basal section and disturbance vegetation (e.g., Asteraceae, Cheno-Ams) in the upper zone.

Zone 1 occurs from 470 to 310 cmbs (6600–4100 cal BP), and is marked by high percentages of red mangrove pollen (Fig. 3A). The abundance of salt-tolerant red mangrove pollen indicates that the area was a brackish mangrove swamp. Lesser amounts of sedge (Cyperaceae) and cattail (*Typha*) at intervals hints at the presence of less marine or brackish environments, but these may have been somewhat spatially removed from the coring locality. Both non-mangrove arboreal elements and herbs are significantly reduced in this zone. The few arboreal types encountered in this basal section (pine [*Pinus*], oak [*Quercus*] and Moraceae [probably breadnut]), likely represent types transmitted over significant distances, and they are thought to be non-local in origin.

Zone 2 occurs from 310 to 180 cmbs (4100–400 cal BP), and shows a dramatically different environment. Here we see a significant drop in red mangrove pollen, indicating that the environment had become much less brackish or marine-influenced. At this time, there is a corresponding increase in sedge, cattail, and water lily pollen (*Nymphaea*), as well as a spike in *Salvinia* spores (a floating freshwater aquatic weed), confirming that freshwater now

---

**Fig. 3.** (A) Pollen diagram showing percentages through time of major taxa identified in SOC05-2. Dots indicate presence of taxa. (B) Pollen diagram showing percentages through time of major taxa identified in SOC05-3. Dots indicate presence of taxa.
dominated the region where the core was collected. Forests in the area change from a mangrove forest to arboreal associations characterized by palms, Moraceae, Sapindaceae and other genera. Disturbance vegetation is most noticeable in Zone 2, including pollen from weeds (Asteraceae and Cheno-Ams) and grasses (Poaceae). These types proliferate in disturbed environments including human settlements and agricultural fields. Slight increases in oak and especially pine pollen may also reflect a more open environment, where long-distance pollen can more easily blow into the sediments of the area. Cultigen pollen is poorly represented in this core, and only occurs after 1000 years ago. These include maize (Zea mays) and possibly manioc (Croton/Manioc), although positive identification of the latter is difficult and this grain may simply represent a wild member of the family. The presence of cultigen pollen indicates that farming was taking place in the area. Zea pollen is usually present in low numbers even if fields are close because they are so heavy and poorly dispersed, and other cultivars are poor pollen producers. One would expect percentages of maize and other cultigens to increase with closer proximity to ancient fields. Pollen evidence therefore points to forest clearing consistent with agriculture during the late Archaic (4100–3800 cal BP).

Additional evidence for forest disturbance during the late Archaic Period comes from SOC05-3 (Fig. 3B). This 5.7 m sediment core was drilled 35 km southwest of SOC05-2 in the seasonally inundated wetland surrounding the Acapetahua Estuary. The accumulation of sediment at this location was rapid (~ 1.608 mm/yr) and provides a detailed paleoecological record from 4700 to 2300 cal BP that complements the longer sequence from SOC05-2. Well-preserved fossil pollen was present in most of the SOC05-3 sequence, although sediments above 280 cm (2300 cal BP) were oxidized. In addition, sediments from 328 to 380 cm (2800–3600 cal BP) and from 400 to 416 cm (~3800 cal BP) were largely devoid of fossil grains. Past drying episodes during or shortly after the deposition of sediments from these zones are likely to be responsible for the oxidation of fossil pollen at these times. Concentration values of fossil pollen grains from other portions of the core, however, were generally high, attesting to the excellent state of preservation of these grains. Four distinctive zones are apparent in this pollen record, reflecting past conditions in the coring area.

Zone 1 (564–525 cmbs [4700–4200 cal BP]) is represented by high percentages of sedge (Cyperaceae) and cattail (Typha) pollen, indicating a freshwater or slightly brackish depositional environment. Red mangrove (Rhizophora) pollen is low through this zone, suggesting these plants were present in the area, but somewhat removed from the location where the core was collected. Disturbance indicators through this zone are high, as indicated by Cheno-Ams and Asteraceae grains, consistent with human disturbance in the local area, although cultigen pollen is lacking in the samples.

Zone 2 (525–475 cmbs [4200–3900 cal BP]) is marked by a dramatic, but temporary increase in red mangrove pollen. The environment continues to be dominated by sedge and cattail pollen, suggesting that any changes were largely temporary. Cheno-Am and to a lesser extent Asteraceae pollen are noticeably reduced, and grass (Poaceae) pollen increased in this zone. The initial appearance of Zea mays pollen along with increases in grass pollen occurs at the end of this interval at 3900 cal BP along with a single cotton (Gossypium) pollen grain. The morphological characteristics of this pollen type do not tell us if it was a domesticated or a wild form.

Charcoal concentrations in both SOC05-2 and SOC05-3 complement the pollen record and provide additional information about burning and forest clearing. The charcoal concentrations (# particles/cm³) and the ratio of herbaceous/total charcoal (%) are shown in Fig. 4. Fire activity occurs throughout the SOC05-2

---

**Fig. 4.** Charcoal, LOI, and carbonate data for cores SOC05-2 and SOC05-3.
sequence, but is highest from 1200 to 500 cal BP. The charcoal assemblage through this interval contains high percentages of herbaceous charcoal. Herbaceous charcoal is similar in character to modern maize burned for comparative purposes, but other tropical grasses have similar structures and therefore may have been burned as well. Other periods of very high fire activity occur between ~4300 and 4200 cal BP, 5200 cal BP, and between 5800 and 5600 cal BP. These periods have relatively high herbaceous charcoal values, consistent with the burning of agricultural fields (Walsh et al., 2010). Fire activity in SOC05-3 occurs throughout the sequence, but was highest for a brief period at ~2600 cal BP, and then consistently high between ~4750 and 3800 cal BP, with relatively high percentages of herbaceous charcoal consistent with the clearing of agricultural plots.

The earliest evidence for forest disturbance and maize farming comes from the phytolith record near the base of SOC05-2 and dates to 6500 cal BP (Fig. 5A). Three samples analyzed from the bottom of the core all had well-preserved phytoliths. Numerous diatoms and sponge spicules were also present. In the lowermost sample at 467–469 cmbs there were high concentrations of grasses. Many are from bamboos (e.g., Chusquea, tall saddles), and only a few are from weedy grass varieties (e.g., bilobates representing the Panicoideae and Chloridoideae). No burned or unburned maize phytoliths were observed.

Between 464 and 460 cmbs (6500 cal BP) significant changes take place in the phytolith record. Weedy grasses (e.g., Chloridoideae and Panicoidae) along with Heliconia, an archetypal plant of early successional forests, are dominant in the record, and these phytoliths are commonly burned. Maize leaf and cob phytoliths, including burned examples, were present in the samples, further suggesting deliberate land clearance associated with slash and burn systems. High percentages of Podostemaceae phytoliths, a plant that grows only on rocks in freshwater streams, indicate that the phytolith assemblage originated from interior dryland agricultural fields and arrived in the mangrove swamp via water transport. Phytoliths diagnostic of the ears of teosinte are absent in these and all other sediments examined, further reinforcing the identification of maize phytoliths and also indicating that Zea pollen in these sequences is probably from maize introduced into the area rather than from wild stands of teosinte that may have once existed in the region and are no longer present. The records indicate that by ~6500 cal BP significant landscape modification by maize farmers involving forest clearing and burning occurred in the area.

The phytolith content of SOC05-3 was highly variable (Fig. 5B). Some samples had no phytoliths while others possessed them in high number. Many samples with few phytoliths contained a mass of biogenic silica from diatoms, sponges, and other aquatic organisms. Apparently in these contexts there was no mechanism such as inflowing water to transport terrestrial phytoliths to the coring locale. The samples with a considerable phytolith content show clear evidence for landscape modification for farming, with low frequencies of arboreal phytoliths and high frequencies of weedy grasses and other disturbance taxa (e.g., Heliconia). The phytoliths commonly are burned and maize phytoliths occur in the late Archaic Period deposits by 4100 cal BP.

5. Discussion

Evidence for forest disturbance, burning, and the cultivation of maize extends back to 6500 cal BP (Fig. 6). Weedy grasses, evidence for burning (charcoal and burned phytoliths) and the presence of maize leaf and cob phytoliths in these deposits are all indicative of purposeful land clearing associated with a slash and burn system of cultivation. Teosinte does not grow naturally in this area today and the absence of ear phytoliths of this wild grass throughout the 6600 year sequence indicates that the maize present in the record is a cultigen introduced from outside the area. The dominance of red mangrove in the pollen record in the early deposits coupled with only weak evidence for forest disturbance suggests that these agricultural fields were located some indeterminate distance away from the coring location. The abundance of Podostemaceae phytoliths in this early assemblage suggests that the burned maize phytoliths were carried by water to the coring location from agricultural fields that are now buried somewhere upstream on the coastal plain. Maize pollen was not identified in these earliest levels even with extended counting of multiple pollen slides, a result that conforms with the phytolith data because pollen will not survive as well as phytoliths once eroded from land surfaces and deposited into other sedimentary contexts. We will design future work to target sediments of this age and earlier that are closer to potential agricultural fields.

The high fire activity evident in the charcoal record between 5800 and 5600 cal BP and again at 5200 cal BP is likely of anthropogenic origin and is consistent with forest burning associated with slash and burn agriculture. Fires are triggered by other mechanisms (e.g., lightning) in the tropics (Cardoso et al., 2008; Goldammer, 1990), but the charcoal during these two periods is predominantly herbaceous, rather than arboreal, and its structure is remarkably similar to modern burned maize leaves and not similar to many other known grasses. However, we cannot rule out the possibility that other lowland Neotropical grasses were the source of the charcoal without a more comprehensive comparative collection. Cultigens were not identified during the fire episodes in the pollen record and the phytolith record does not span this interval, but similar patterns of burning associated with cultigens were found to occur to the south along the Pacific coastal plain of Guatemala by 5500 cal BP (Neff et al., 2006). The confluence of data suggests that these fires are related to slash and burn cultivation.

Evidence for maize, forest disturbance, and burning at 6500 cal BP along the Pacific Coast of southern Mexico is consistent with evidence from Central and South America for early dispersal of this domesticate from the Balsas region through the lowland Neotropics (Pearsall et al., 2004; Dickau et al., 2007; Zarillo et al., 2008). Genetic and biogeographic data indicate that maize was domesticated from an annual species of teosinte (Zea mays subsp. parviglumis) that grows in the tropics (Cardoso et al., 2008; Goldammer, 1990), but the charcoal during these two periods is predominantly herbaceous, rather than arboreal, and its structure is remarkably similar to modern burned maize leaves and not similar to many other known grasses. However, we cannot rule out the possibility that other lowland Neotropical grasses were the source of the charcoal without a more comprehensive comparative collection. Cultigens were not identified during the fire episodes in the pollen record and the phytolith record does not span this interval, but similar patterns of burning associated with cultigens were found to occur to the south along the Pacific coastal plain of Guatemala by 5500 cal BP (Neff et al., 2006). The confluence of data suggests that these fires are related to slash and burn cultivation.

Although maize is the only cultigen evident in our Soconusco records, it is likely that a mixture of crops—seed, root, and tree—was being grown in the region by 6500 cal BP. Large labor investments are required to clear forests and burn them and it is unlikely that people would invest this time and effort for a single cultigen. It is also clear that other indigenous Mexican cultigens, such as squashes, were domesticated by 8700 cal BP (Piperno et al., 2009; Smith, 1997a). Many crop plants are difficult to detect in paleoecological records because of poor production and/or taxonomic specificity of their pollen and phytoliths, leading to their under-representation in these kinds of records.

The period from 4700 to 3800 cal BP is when five of the six known shell mounds in the Soconusco region accumulated and this
Fig. 5. (A) Phytolith diagram showing percentages through time of major taxa identified in SOC05-2. Dots indicate presence of taxa. Percentages of burned phytoliths were calculated independently from other phytoliths in the sum. (B) Phytolith diagram showing percentages through time of major taxa identified in SOC05-3. Dots indicate presence of taxa. Percentages of burned phytoliths were calculated independently from other phytoliths in the sum. Phytolith preservation was generally poor in this core.
corresponds in age to the high sustained fire activity evident in our cores. The pollen record indicates forest disturbance and maize phytoliths by \( \sim 4100 \text{ cal BP} \). This is also the same interval that maize phytoliths are first found in the Archaic Period shell mounds (Jones and Voorhies, 2004). Therefore, data from various sources all point to the presence of slash and burn farmers living in close proximity to this seasonally inundated estuarine zone. Clearing forests for cultivating plants implies that crops supplied a significant number of calories to diets and that people had intensified their farming systems beyond simpler forms of “dooryard” horticulture practiced next to residences.

It thus appears that high sedimentation rates on this flat coastal plain have obscured early settlements of people who were practicing slash and burn cultivation. This evidence coincides with intensive exploitation of resources from the coastal estuarine zone. Large shell mounds started accumulating between 7500 and 5500 cal BP along the interior edges of the coastal brackish-water lagoons. Small fish vertebrae recovered during excavations of these shell mounds suggest the use of nets and other sophisticated fishing technology (e.g., weirs; Voorhies, 2004) by these early farmers. Future work will be necessary to determine if the accumulation of these shell mounds at 7500 cal yrs BP directly relates to the adoption of slash and burn agriculture in this area.

Complementary use of slash and burn cultivation and intensive shellfish harvesting persisted in this region until \( \sim 3800–3600 \text{ cal BP} \) when shell mound accumulation ceased. Stable oxygen isotope shellfish harvesting profiles suggest relaxed predation on shellfish populations after \( \sim 4100 \text{ cal BP} \) with the first appearance of maize phytoliths in these shell mounds (Jones and Voorhies, 2004). The cessation of intensive mollusk harvesting after \( \sim 3800 \text{ cal BP} \) occurs with widespread evidence for increases in forest disturbance, burning and a greater reliance upon maize and likely other crops (Neff et al., 2006). Human settlements expanded rapidly along the coast after this time and evidence for the emergence of institutionalized social inequality appears in the archaeological record (Clark and Cheetham, 2002). The abandonment of intensive shellfish harvesting strategies may be more related to these larger societal changes than the adoption of maize at the end of the Archaic as once was hypothesized (Kennett and Voorhies, 1996).

Additional paleoecological records are needed to extend geographically the evidence presented here and determine the overall extent of slash and burn farming systems on this coastal plain during the earlier stages of the Archaic Period. When we started this project it was unclear how deep these peri-coastal sedimentary sequences would extend below the modern ground surface. It turns out that this is highly variable between coring locations and in some instances they extended deeper than the viable range of our coring technology. Additional work with more sophisticated coring technology may extend these records a little earlier than 6600 cal BP, but sedimentary sequences in coastal settings are not likely to extend back beyond 7700 cal BP when sea-level started to stabilize.

6. Conclusions

The paleoecological evidence presented in this paper supports the view that people living along the Pacific coast of southern Mexico employed systems of slash and burn cultivation during the Archaic Period. Episodic burning and forest disturbance together with the remains of maize are all evident in these records between 6500 and 3800 cal BP (and not surprisingly later into the Formative,
Classic and Post-Classic Periods). Future work targeting sediments dating to before 6700 cal BP will be required to determine when slash and burn practices were first established in this region, but the available data conform with evidence from Panama and South America for maize dispersal from the Balsas region of Mexico through the lowland Neotropics during the early stages of the middle Holocene.

These new data alter our view of Archaic Period adaptive strategies along the Pacific coast of Southern Mexico. We now hypothesize that settlements of farmers (i.e., people who were deriving a significant portion of their dietary calories from crop plants) are buried beneath the alluvium on the coastal plain. These settlements were probably more seasonally stable than we once thought, given the labor investments associated with growing and storing maize. These observations will improve our predictive settlement models as the hunt for Archaic Period archaeological sites continues on the coastal plain. The most fertile lands on the coastal plain are not in the peri-coastal wetlands where soils are saline and seasonally inundated. Well-drained alluvial soils are most productive closer to the Sierra Madre where rainfall is more seasonally predictable. The strength and character of the paleoecological signatures reported here suggest that settlements were located some distance away from the wetlands earlier in the Archaic. By the Late Archaic Period the evidence for burning, forest disturbance and maize cultivation suggests that agricultural communities had expanded across the coastal plain and were positioned closer to the wetlands. This is consistent with intensified exploitation of shellfish during the Late Archaic indicated by the increased number of shellfish processing localities. Overall, the combination of slash and burn farming and the exploitation of estuarine resources was a powerful combination that persisted in this area for much of the Archaic Period.

Acknowledgments

This research was funded by the National Science Foundation (BCS-0211215) and the Smithsonian National Museum of Natural History. We thank the two anonymous reviewers for their useful comments. A special thanks goes to John Clark and the New World Archaeological Foundation for their logistical support during our field campaign. The paper was written with fellowship support from the AHRC Centre for the Evolution of Cultural Diversity, Institute of Archaeology, University College London (DJK).

References
