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ARTICLE

South American Maize and Political Economy of the Middle and Late Formative Soconusco Region of Guatemala

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Abstract

We present macrobotanical, starch, and phytolith data from artifacts and sediments from Middle Formative La Blanca (1000–600 cal BC) and Late Formative El Ujuxte (600 cal BC–cal AD 115) in the Soconusco region in Guatemala. Potential economic plants identified included palm (cf. Arecaceae), two varieties of maize (*Zea mays*), guava (*Psidium guajava*), bean (Phaseolus), chili peppers (*Capsicum*), squash (Cucurbitaceae), custard apple (Annonaceae), coco plum (Chrysobalanaceae), lerén (*Calathea*), arrowroot (*Maranta*), and bird-of-paradise (*Heliconia*). The results suggest that control of food production and consumption was critical for the transition from complex chiefdoms during the Middle Formative to the archaic state in the Late Formative. The arrival of a more productive South American variety of maize at El Ujuxte (about 2549 BP) allowed elites to exploit an already existing broad-based economic system and to use the maize-based religious system to increase control over maize agricultural practices and maintain power through ideology and disciplinary power. These data suggest that the arrival of fully domesticated South American maize likely influenced the overall development of Mesoamerican state-level societies.

Resumen

Presentamos datos macrobotánicos, almidón y fitolitos de artefactos y sedimentos del Formativo Medio La Blanca (1000–600 cal aC) y Formativo Tardío El Ujuxte (600 cal aC–115 cal dC), región de Soconusco, Guatemala. Las posibles plantas económicas identificadas incluyen la palma (cf. Arecaceae), dos variedades de maíz (*Zea mays*), la guayaba (*Psidium guajava*), frijol (*Phaseolus*), chiles (*Capsicum*), calabaza (Cucurbitaceae), crema de manzana (*Annonaceae*), la ciruela de coco (Chrysobalanaceae), el lerén (*Calathea*), el arrurruz (*Maranta*) y el ave del paraíso (*Heliconia*). Los resultados demuestran que el control de la producción y el consumo de alimentos fueron fundamentales para la transición de los cacicazgos complejos durante el Formativo medio al estado arcaico en el Formativo tardío. La llegada de una variedad sudamericana de maíz más productiva a El Ujuxte (ca. 2549 AP) permitió a las élites explotar un sistema económico de base amplia ya existente y utilizar el sistema religioso basado en el maíz para aumentar el control sobre las prácticas agrícolas de maíz y mantener el poder mediante la ideología y el poder disciplinario. Estos datos sugieren que la llegada del maíz sudamericano totalmente domesticado influyó en el desarrollo general de las sociedades mesoamericanas estatales.

Keywords: starch; phytoliths; macrobotanical remains; archaeobotany; maize; Formative; Guatamala; Soconusco

Palabras clave: almidón; fitolitos; restos macrobotánicos; arqueobotánica; maíz; Formativo; Guatamala; Soconusco

The origins of social complexity and the shift to intensive maize agricultural systems that characterize Mesoamerican state-level societies remain highly debated (Arnold 2009; Awe et al. 2021; Kennett et al. 2017, 2022; Killion 2013; Nichols 2015:2; Rosenswig 2015). In the Maya region, scholars place the origins of maize agricultural intensification anywhere between the Archaic (9000–3500 BP; Kennett et al. 2022) and the Middle Formative (about 3250 BP; Rosenswig et al. 2015). Yet these debates center largely around when maize becomes productive enough to sustain sedentary populations and cause a shift in diet and social organization. Kennett and colleagues (2022) suggest that Chibchan-speaking peoples migrated into Mesoamerica from Panama around 5600 BP and brought with them more productive South American maize. They hypothesize that the horticultural traditions brought by these peoples resulted in intensified forms of maize agriculture around 4700 BP, more than 1,500 years before other known markers of agricultural intensification. In contrast, Rosenswig and coworkers (2015) suggest that these new intensified maize agricultural systems developed later, during the Middle Formative, at multiple locations around Mesoamerica depending on the environmental and cultural histories of each subregion.

The La Blanca / El Ujuxte project seeks to understand the role of agriculture in the shift from the complex chiefdoms of the Middle Formative to the archaic states of Late Formative Soconusco through a study of data pertaining to foodways: well-contextualized macroremains, phytoliths, and starch grains recovered from site sediments and artifact residues. Our study of multiproxy paleoethobotanical data supports Kennett and colleagues' (2022) hypothesis that South American maize was introduced to Mesoamerica. Our evidence also suggests that (1) maize intensification is not tied to the emergence of social complexity, at least in the Soconusco region; (2) the dramatic social and political changes that are characteristic of the Late Formative, such as the loss of household autonomy, decrease in household rituals, and an increase in public rituals, only developed once more productive varieties of maize became available; and (3) these changes are the result of authority figures exploiting a new resource to consolidate their control over already existing maize-based economic and religious systems.

Background

Subsistence Strategies of Early, Middle, and Late Formative Soconusco

Considerable attention, in the form of macrobotanical, pollen, starch grain, phytolith, and genetic analysis, has been devoted to understanding the origins of agriculture during the Archaic (Dickau et al. 2007; Doebley 2004; Hufford et al. 2012; Piperno and Flannery 2001; Pohl et al. 2007; Ranere et al. 2009; Vallebueno-Estrada et al. 2016, among others). This focus also applies to the Soconusco region where scholars have attempted to find early direct evidence of maize use through the analysis of archaeobotanical data (Blake and Neff 2011; Kennett et al. 2010; Mangelsdorf 1967; Neff et al. 2006; Popper and Lesure 2010; Powis et al. 2007; Rosenswig et al. 2015). Except for recent work by Rosenswig and colleagues (2015), there is little archaeobotanical research on agriculture and the development of complex chiefdoms and the state during the Middle and Late Formative periods.

The development of agriculture in Soconusco is thought to be a gradual process from the Archaic to the Early Formative (Blake and Neff 2011). Populations moved between inland and coastal regions during the Middle and Late Archaic and relied on small-scale horticultural strategies. Cultigens from inland horticultural sites appear to supplement foraging of terrestrial and maritime resources during coastal occupations (Blake and Neff 2011). Legumes appear first in central Soconusco during the Middle Archaic, whereas maize (*Zea mays*), arrowroot (*Maranta arundincacea*), squashes (*Cucurbita*), *achira (Canna*), cotton (*Gossypium*), and other cultigens appear throughout the region during the Late Archaic.

Subsistence strategies of the Early Formative are considered largely continuations of earlier Archaic traditions (Rosenswig et al. 2015). The main difference was the emergence of sociopolitical inequality, sedentism, and two-tiered settlements in the Mazatán region during the Early Formative. Rosenswig and colleagues (2015:91) hypothesize that these trends were due to an increase in maize production toward the end of the Early Formative around 1000 cal BC that set the stage for dramatic changes in the Middle Formative (Lesure et al. 2021). Several important species first appear in the archaeological record of the Early Formative, including avocado (*Persea americana*; Feddema 1993), *jocote* (*Spondias*; Coe and Flannery 1967), tree nuts (Popper and Lesure 2010), and cacao (*Theobroma*; Powis et al. 2007).

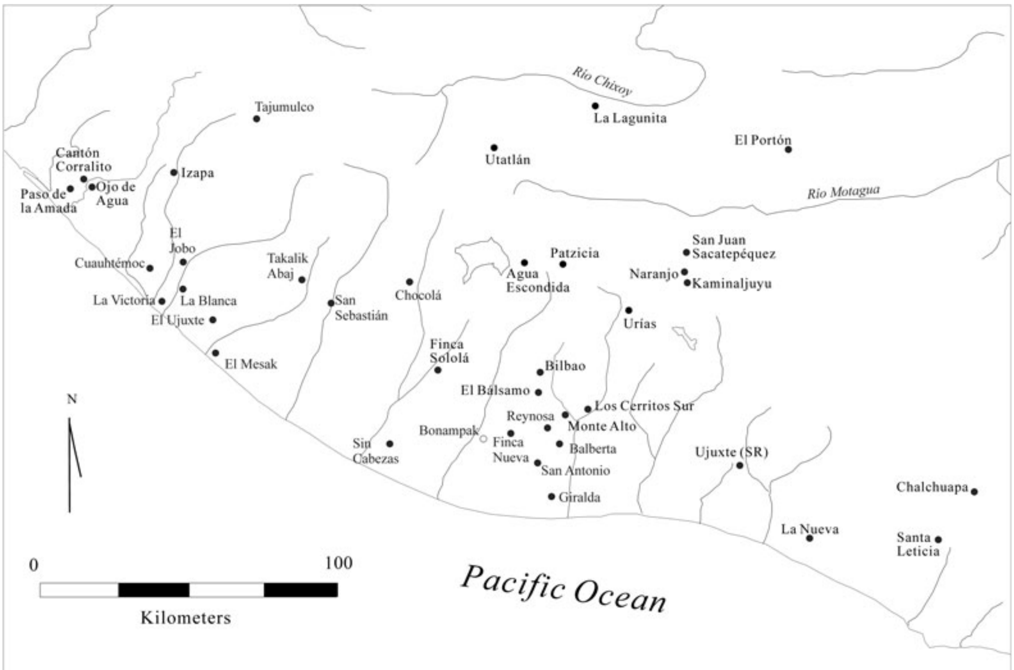

Figure 1. The Pacific coastal plain showing the Formative period sites discussed in the article.

La Blanca, El Ujuxte, and the Emergence of Late Formative Archaic States

The Pacific coastal plain from modern Chiapas, Mexico, to El Salvador (Figure 1) has a rich archaeological record during the entire Formative, making it a key region for understanding the trajectory of early complex societies in Mesoamerica. Trends toward social complexity begin here as early as anywhere in Mesoamerica, and the overall sequence from Early to Terminal Preclassic was characterized by Love (2002) as a series of cycles with an overall trend toward greater complexity. From the Early Formative center of Paso de la Amada to the Late Preclassic cities of El Ujuxte, Izapa, and Takalik Abaj, the region's settlements were among the largest in Mesoamerica. As an important trade corridor from the Archaic period to modern times, the Pacific coastal plain was a place where people of many different origins visited or lived (Love 2012; Love and Guernsey 2011). The zone probably held speakers of several languages, and the moniker "Southern Maya Region" is simplistic.

Although the overall trajectory for the Formative was of increasing complexity, there were multiple cycles of centralization and collapse (Love 2007). Within the Mazatán region of Mexico during the Early Formative, Paso de la Amada was followed in succession by Cantón Corralito and Ojo de Agua. At the beginning of the Middle Formative, population within the Mazatán region declined sharply and, at the same time, surged within the Río Naranjo region of Guatemala. An unprecedented level of aggregation both westward and eastward marked the rise of the La Blanca polity around 1000 cal BC.

La Blanca was about 300 ha in size, with a three-tiered settlement hierarchy covering approximately 350 km^2. Within the settlement, there is marked evidence of social stratification at the household level, manifested in the differential distribution of jade beads and other prestige goods (Love and Guernsey 2011). Soon after 600 cal BC, La Blanca declined to the size of a hamlet, and political power shifted to new cities.

The early city-states of Izapa and El Ujuxte were both, in part, outgrowths of the collapsed La Blanca polity and the economic changes that took place there. El Ujuxte was a planned city about 900 ha in size that was oriented along a north–south axis about 35° east of magnetic north, toward the rising of the star Capella (Love and Rosenswig 2021:155, 157) The five-tiered regional polity covered about 600 km^2 and was at least twice the size of the La Blanca polity. There were at least four secondary centers within the El Ujuxte polity that contained public buildings that were replicas of the larger versions found at El Ujuxte (Love and Rosenswig 2021:161).

Love (2002) characterized the transition as political cycling, in which centralized power had to be reestablished after the La Blanca polity broke up. In that formulation, elites seeking power were viewed as having consciously modified economic and ideological structures of the previous system to enhance their power. In the process they created economic and ideological institutions that gave rise to an early state form of administration.

The Late Formative represented the climax of trends in population growth and nucleation throughout the Pacific coast, piedmont, and highlands (Love 2007; Love and Rosenswig 2021). Izapa and El Ujuxte were part of a network of early city-states that included Kaminaljuyu, Takalik Abaj, Chalchuapa, Chocolá, and Bilbao. These cities were linked by trade networks and intellectual exchanges of art styles, ritual practices, and political ideologies (Love and Guernsey 2011).

The paleoethnobotanical component of the La Blanca / El Ujuxte project seeks to understand subsistence strategies in the Middle and Late Formative and mechanisms that led to the formation of the Late Formative archaic state at El Ujuxte after the collapse of the Middle Formative La Blanca polity (Love 2002:222). Love hypothesizes that changes in economics, ideology, and daily practice at El Ujuxte were key to the reestablishment of political authority after La Blanca collapsed in 600 cal BC: specifically, the loss of individual household autonomy (economics), the development of leadership deriving its power from the larger cosmos rather than more localized earthbound forces (ideology), and the creation of disciplinary power by leadership (daily practice) were instrumental in solidifying more permanent political and social structures. The botanical data presented here supports Love's hypothesis that there was a loss of individual household autonomy (economics) during the Late Formative due, in large part, to the arrival of more productive maize varieties.

Methods

Over a 15-year period, the La Blanca / El Ujuxte project combined regional surveys with excavations at two major centers to investigate the development of social complexity on the Pacific coast of Guatemala during the Middle and Late Formative. Although public areas and monumental constructions were investigated at both sites, the focus was on domestic zones and sampling of households. At both sites, the goal of the excavations was to obtain a cross section of social ranks and to understand how domestic economic and ritual practices changed in the context of increasing political centralization. To date, the project has excavated 20 domestic areas at La Blanca and 14 at El Ujuxte.

To understand economic strategies associated with the emergence of the archaic state, we examined archaeological sediments and artifact residues from both elite and commoner residential contexts for macrobotanical remains, phytoliths, and starch grains. Samples were collected from each excavated level below 50 cm (the presumed depth of the plow zone). Paleoethnobotanical remains reported here include all materials from El Ujuxte (seasons from 1995 to 1997) and materials from the 2003 and 2004 seasons at La Blanca. The work at La Blanca sampled eight house lots, each consisting of a domestic mound and the approximately 400 m^2 around it.

We sampled artifact microfossil residues for artifact types for which a function related to food processing or consumption could be inferred from the form of the artifact, its context, or both. Assumptions about artifact function were derived from ethnoarchaeological studies in the case of metates (Searcy 2011) and the residue analysis of similar artifacts in Mesoamerica (Cagnato and Ponce 2017). Evidence of food production included the presence of maize starch (from the edible portion, the kernel) or cob phytoliths (from inedible tissues associated with kernels) on food-processing artifacts, such as grinding stones, grater and grinding bowl sherds, and cooking vessel sherds. Ceramics likely involved in consumption were sampled from both domestic and ritual contexts.

Our assessment of economic strategies using macroremains was based on plant tissues that became charred, either deliberately through the burning of garbage or fuel, or accidentally—for example, from a cooking mishap or while making a fire—and analyzing their richness and relative abundance. In terms of maize, charred tissues were largely limited to cupules (from the inedible cob) and kernels. Comparing the abundance of these tissues in a ratio (kernel:cupule and kernel:cob) provided insights into whether a site or site area was heavily involved in food production (higher proportion of cupules or cobs) or received prepared foods (higher proportion of kernels; Pearsall 2019:156, 160).

Nineteen artifacts from Ujuxte and 102 artifacts from La Blanca were sampled for phytoliths and starches using the "piggyback" protocol and processed at the University of Missouri Paleoethnobotany Laboratory (Chandler-Ezell and Pearsall 2003). In the piggyback protocol, residues are systematically removed in the reverse order in which they were deposited, thereby ensuring that microfossils contained in the cracks and pores of an artifact are associated with their primary deposition (Hart 2011). Starch slides were counted in their entirety, whereas a diagnostic count (up to 200 count) was conducted for phytoliths. Identifications were made based on the laboratory's neotropical comparative collection and published sources (see Pearsall 2015:254–266).

In addition to sampling artifacts for microfossils, 23 sediment samples from Ujuxte and eight from La Blanca were analyzed for phytoliths. Samples were processed and counted following standard procedures (Pearsall 2015:275–277). Samples collected at La Blanca came from the residential sector in the central and southeast corner of the site, whereas those collected at El Ujxute represented commoner and elite residences, as well as liminal spaces in between.

A total of 6,380 standardized 10-liter samples were collected from La Blanca and processed using machine-assisted flotation, and 1,794 standardized two-liter samples were collected from El Ujuxte and processed using bucket flotation. Sediment sample sizes were measured using a standardized bucket in the field. In addition, 94 handpicked or screen-recovered carbon samples were collected from El Ujuxte. All samples were floated in Guatemala and then shipped to the University of Missouri for analysis (see the tDAR raw data table for more information regarding which specific samples at El Ujuxte were recovered by flotation versus handpicked).

Results

Artifacts

In this article, we use the phrase "economic" to mean "useful" plants. Phytoliths were recovered from almost all La Blanca (91 of 96) and El Ujuxte (18 of 19) artifacts, whereas starches were recovered from about half the artifacts from La Blanca (50 of 102) and about one-third from El Ujuxte (7 of 18 artifacts). Both commoner and elite residents at La Blanca processed and consumed annual crops such as maize (*Zea mays*), squash (*Cucurbita*), and chili peppers (*Capsicum*), as well as root and tuber crops such as *lerén* (*Calathea*) and arrowroot (*Maranta*). Arboreal seed and fruit phytoliths from the soursop (Annonaceae), palm (Arecaceae), coco plum (Chrysobalanaceae), and persimmon (Ebenaceae) families were recovered, and other arboreal indicators were present. Sedge (*Scirpus*, *Cyperus*, and *Carex*) seed phytoliths suggest the use of wetland plant resources (see Supplemental Table 1 for a summary by operation of economic starch and phytoliths recovered from Ujuxte and La Blanca artifacts).

In general, similar combinations of phytoliths and starch grains were recovered from manos, metates, worked stone, and ceramic grinding and grating bowls, indicating that grinding tools were used to process multiple taxa and there was no specialization in terms of artifact types and economic plants. Maize, fruit, and root crop residues were all found on both ceramic and stone grating/grinding/pounding tools, for instance. Thirty-one artifacts from La Blanca also contained burnt epidermal cells, indicating the cooking or processing of cooked foods. Phytolith and starch grain results from El Ujuxte artifacts were similar to those from La Blanca (Supplemental Tables 2 and 3).

Interestingly, bird-of-paradise (*Heliconia*) leaf phytoliths, which do not represent foods, were recovered by sonication from artifact surfaces of both grinding implements and ceramics; they were among the most abundant phytolith types recovered. This indicates a strong association of bird-of-paradise leaves with artifact use.

Sediments

Phytoliths recovered from sediments from La Blanca and El Ujuxte reflect localized anthropogenic landscapes (Supplemental Tables 4 and 5). At La Blanca, cultivated and encouraged plants such as maize, bird-of-paradise, and Marantaceae co-occur with open habitat indicators. Open habitat assemblages include a large proportion of grass, sedge, and herb phytoliths and a limited number of arboreal types. Arboreal phytoliths recovered were mostly from the palm family (Arecaeae). Phytoliths from El Ujuxte samples were similar but also included *lerén* (*Calathea*) tuber phytoliths, sedge seed phytoliths, and squash rind phytoliths. The most common phytolith type at both sites was Podostemaceae, or river-weed. Podostemaceae is a family of mostly submerged, moss-like herbs found in stony rivers (Mabberley 1997; Piperno 2006). The Soconusco plain experiences high sedimentation caused by the seasonal flooding of rivers flowing from the Sierra Madre mountains and by intense tropical storms (Kennett et al. 2010; Voorhies and Kennett 1995). These events are likely to move Podostemaceae phytolith-bearing sediments from rivers over the plain and even into coastal mangroves (Kennett et al. 2010). Sediment phytolith assemblages reflect the dynamic alluvial landscape that Ujuxte and La Blanca peoples inhabited.

Macroremains

The overall macrobotanical assemblages from La Blanca and El Ujxute were quite small, given the large number of samples collected, and they varied considerably among operations (Supplemental Tables 6 and 7). Maize kernels and cob tissues (no cupules), a *Psidium guajava* seed, a *Phaseolus* bean fragment, wood, and unknown seeds, nuts, and fruit rind tissues were recovered from La Blanca. El Ujuxte had a similar plant list, with the addition of Arecaceae (palms) and pigweed (*Trianthema portulacastrum*). Interestingly, in addition to maize kernels, large numbers of maize cupules were recovered from Ujuxte. Most of the material recovered from both sites was charred wood (not identified to taxon).

Discussion

Subsistence, Plant Use, and Agricultural Intensification at La Blanca and El Ujuxte

Comparison of the overall richness of identified taxa and morphotypes at El Ujuxte and La Blanca—the values for macroremains, sediment phytoliths, and artifact residues were calculated separately; see Table 1—reveals that their richness was virtually identical between the two sites and time periods. This suggests that La Blanca and El Ujuxte engaged in broad-based agricultural strategies that were a continuation of Early and Middle Formative practices in the Soconusco region. The results from La Blanca imply that food was being processed and consumed at the household level throughout the Conchas phase (1000–600 cal BC; Love 2018:265). As might be expected given the low counts and low densities of remains, the richness of identified taxa and morphotypes from La Blanca was relatively low ($n = 13$ for macrobotanicals, $n = 14$ for artifacts, and $n = 5$ sediment phytoliths) and highly variable among contexts and the three measures (Table 2; Supplemental Table 8). Commoner contexts (Ops. 31, 34, 35, 36, 38) and elite contexts (Ops. 32, 37) overlapped in the richness of artifact residues and were very similar in terms of phytolith indicators. In terms of macroremains, richness was markedly lower in Operation 37 (elite, $N = 4$) than in most commoner contexts (range, 3–12). Operation 34, a commoner context, had the highest richness for macrobotanicals ($N = 12$), whereas Operation 38, also a commoner context, had the lowest ($N = 3$). Operation 32, an elite context, had the highest richness for artifact residues ($N = 12$), and Operation 36, a commoner context, had the lowest ($N = 4$). Although there are other markers of social inequality at La Blanca, such as construction of large mounds and access to rare minerals (Love and Guernsey 2011), plant food richness and procurement of rare plant foods do not indicate social inequality because of the similar richness of foods in both commoner and elite contexts.

The richness of macrobotanical remains ($n = 16$), artifact residues ($n = 14$), and sediment phytoliths ($n = 10$) at El Ujuxte is similar to that at La Blanca but varied considerably among operations (Table 1; Supplemental Tables 8 and 9). Macrobotanical richness was highest in commoner contexts such as Operations 12, 13, and 17 and at the sole elite context in Operation 18. Macrobotanical richness was the lowest at commoner contexts in Operations 8, 9, 14, and 20. Residue richness was highest ($N = 6$) from surface-collected grinding stones from the 1993 field season. Interestingly, Operation 15, a commoner site, where a high density of macroremains indicated good preservation, had modest richness ($n = 5$) and was dominated by wood. In addition to maize, macroremains of foods recovered from El Ujuxte included bean (*Phaseolus*), two types of palm (Arecaceae), guava (*Psidium guajava*),

Table 1. Richness of Taxa at La Blanca and El Ujuxte.

La Blanca				
Operation	Context	Macrobotanical Richness	Artifact Richness	Phytolith Soil Richness
29	Surface collection	—	—	—
30	Unknown	—	—	—
31	Commoner	—	6	4
32	Elite	—	12	5
34	Commoner	12	8	—
35	Commoner	8	9	—
36	Commoner	6	4	—
37	Elite	4	7	—
38	Commoner	3	10	—
El Ujuxte				
Operation	Context	Macrobotanical Richness	Artifact Richness	Phytolith Soil Richness
1993 Surface	Surface	—	6	—
6	Commoner	4	—	—
7	Commoner	5	2	—
8	Commoner	1	—	—
9	Commoner	2	—	6
11	Commoner	4	4	—
12	Commoner	15	—	9
13	Commoner	10	—	—
14	Commoner	2	—	—
15	Commoner	5	—	4
16	Commoner	—	—	—
17	Commoner	8	—	—
18	Elite	8	—	7
19	Commoner	5	—	—
20	Commoner	2	—	—

and unidentified root/tuber and fruit/nut remains. A few small bean cotyledons were present, potentially representing wild taxa, but most appear to be common bean (*Phaseolus vulgaris*; Supplemental Table 10). Other unidentified dense tissues may represent small pieces of palm meats, beans, dense maize kernels, or unknown fruits/nuts.

An important observation is that there is no reduction in plant food richness at El Ujuxte, indicating that the agricultural system had not narrowed. Narrowing of the subsistence base—for instance, to focus more production capacity on a single crop like maize—is a characteristic of agricultural intensification, as is cropping of land at more frequent intervals, maintaining more open habitats, and so on. Our findings suggest that food production remained broad-based at El Ujuxte.

The occurrence of bird-of-paradise (*Heliconia*) phytoliths directly associated with artifacts at both sites is intriguing. Showy bird-of-paradise flowers are used as ornamentals (Haeckel 2008). However, the broad pliable leaves are used for wrapping food throughout the tropics (Criley and Broschat 1992)

Table 2. Maize Kernel: Cupule Ratio at El Ujuxte.

Operation	Type of Occupation	Period	Maize Kernel Frags	Fused Maize Kernel Mass	Maize Cupules >2mm	Maize Cupules <2mm	Maize Total	Kernel: Cupule Ratio
12	Commoner	Caramelo	12	—	302	20	334	0.04
17	Commoner	Cataluna	—	16	4	—	20	4.00
19	Commoner	Mixed	1	—	1	—	2	1.00
7	Commoner	Pitahaya	2	—	1	3	6	0.50
12	Commoner	Pitahaya	48	1	49	80	178	0.38
18	Elite	Pitahaya	59	—	8	—	67	7.38
19	Commoner	Pitahaya	1	—	1	—	2	1.00
6	Commoner	Sierra	1	—	—	1	2	1.00
13	Commoner	Sierra	2	—	9	12	23	0.10
17	Commoner	Sierra	236	208	1	—	445	444.00
17	Commoner	Sierra or Pitahaya	—	1	25	—	26	0.04
17	Commoner	Mixed	—	1	10	—	11	0.10
Total			362	227	411	116	1,116	

and as coverings for cooking pots (Kress 1990). In Central America, the ethnobotany of *Heliconia* is not well studied, although modern uses of leaves as wrappings for *hallacas*, *tamales*, and *humitas* are widespread and likely reflect older cooking practices (e.g., Díaz-José et al. 2019; Lazos Chaverro and Alvarez-Buylla 1988). In addition to wrappings, the Q'eqchi' Maya use bird-of-paradise leaves to line cooking pots to prevent the burning of steaming tamales, and some species are used as thatch (FLAAR Mesoamerica 2017). *Heliconia* may also be consumed; shoots of several species are harvested for food among the Guayi of Costa Rica (Castaneda Langlois 2004). Several *Heliconia* species are also used medicinally (Balick and Arvigo 2015). The relatively common occurrence of bird-of-paradise phytoliths associated with artifacts in our assemblages suggest several potential uses of leaves in the past as utilitarian, consumable, or medicinal plants.

Types of Maize

Measurements and endosperm characteristics of maize kernels from La Blanca and El Ujuxte indicate that two types of maize were consumed at both sites and that the maize at Late Formative El Ujuxte was generally more productive, in terms of having larger kernels, than that at Middle Formative La Blanca (Supplemental Tables 11 and 12). Both sites had kernels indicative of pop or flint (denser endosperm) and flour (porous endosperm) maize. In addition, maize starch recovered from both sites included granules with smooth surfaces (i.e., without compression facets). Such starch grains are produced by flour (soft) endosperm maize (Piperno and Holst 1998). Although there was overlap in kernel sizes between the Middle and Late Formative datasets, Late Formative maize kernels are clearly larger on average (Av. W × T) than those of the Middle Formative, being both wider (across the face of the kernel, embryo side) and thicker (front to back).

Maize Production and Consumption Patterns

Macrobotanical, sediment phytolith, and artifact residue analysis from La Blanca suggests that maize was processed and consumed at the household level for both elite and commoners during the Conchas phase (1000–600 cal BC). Maize microfossils were commonly recovered from artifacts at La Blanca: of 96, 31 had maize phytoliths and 41 had maize starch. Microfossil concentrations were low, but a diverse array of artifacts—including manos and metates, a ceramic bark beater, ceramic figurine heads, grinding/grating bowl sherds, and other sherds—preserved maize starch and leaf and cob phytoliths (Supplemental Table 2). With the exception of commoner site Operation 34, all site mounds—whether commoner (Ops. 31, 35, 36, and 38) or elite (Ops. 32 and 37)—had a minor maize presence in their macroremains. Operation 34 is unique because it is the only mound to contain any charred cob tissues and sizable kernel fragments.

Kernel:cob and kernel:cupule ratios are useful measures of maize processing and consumption. At the Mississippian site of Cahokia, Illinois, kernel:cob ratios of less than four indicate that household units were shelling their cobs and cooking their own maize kernels, whereas high kernel:cob ratios—those greater than four—indicate that households were being provisioned with shelled maize (Pauketat 1994; Pearsall 2019:156, 160). A similar measure is calculated using kernel:cupule ratios at the Olmec sites of La Joya and Bezuapan, Mexico (VanDerwarkerr 2006:102, 103) and the Mississippian site of Moundville, Alabama (Scarry and Steponaitis 1997:119, 120). Operation 34 at La Blanca contained 14 kernel fragments greater than 2 mm and 6 cob tissues for a kernel:cob ratio of 2.3:1, suggesting that those commoners were shelling and consuming their own maize (Supplemental Table 6).

At El Ujuxte, macrobotanicals indicate that maize was processed for household consumption by both commoners and elites early on during the Caramelo phase (500–300 cal BC), but maize was being provisioned by the end of site occupation during the Sierra phase (cal AD 100–200; Love 2018). A low kernel:cupule ratio (0.37:1) from the top of mound 36 (Op. 12) in Area B, a commoner context, suggests that they were processing and consuming their own maize during the Caramelo phase (500–300 cal BC; Table 3). Almost no charred maize was recovered during the subsequent Cataluña phase (300–100 cal BC) as El Ujuxte grew in size. During the Pitahaya phase (cal 100 BC–AD 100), the elite residence of Mound 46 (Op. 18) had a high 7.38:1 kernel:cupule ratio, indicating that

Table 3. Mean Maize Cupule Width from el Ujuxte, El Gigante, and El Riego.

Site	Period	Dates	Mean Cupule Width (mm) Average	*N*
El Gigante	Late Marcala	4340–4020 cal BP	4.02	8
El Riego	Late Archaic	4250 cal BP	3.47	1
El Riego	Early Formative	3650–3530 BP	3.62	2
El Ujuxte	Late Formative Caramelo	2450–2250 BP	5.39*	18
El Gigante	Estanzuela Late Formative	2350–1820 cal BP	5.08	15
El Riego	Late Formative	2290–1800 cal BP	4.77	4
El Ujuxte	Late Formative Pitahaya	2050–1850 BP	4.76*	17

* Estimate based on 20% shrinkage of kernals during charring

shelled maize was brought in and cooked. This shift from household maize processing and consumption to provisioning continues during the final Sierra phase (cal AD 100–200) and can be seen in Area B, the middle area (Op. 17) between mounds 36 (Op. 12) and 38 (Op. 13). Operation 17 is a commoner context that is radiocarbon dated to cal AD 115 (Love 2018) and had an extremely high kernel: cupule ratio of 444:1 (Table 2). This midden, which could represent a single burning event or the repeated deposition of food waste over time, is an exception. However, the extremely high ratio still suggests that maize was being processed and then redistributed to the community, in this case to a commoner household. This stands in contrast to earlier periods where maize was processed and consumed exclusively at commoner and elite households. Unfortunately, insufficient numbers of maize microfossils were recovered from artifacts or sediments to explore production and consumption patterning further.

Maize in Regional Context

Recently Kennett and colleagues (2017) analyzed well-preserved maize macroremains from the El Gigante site in Honduras. Cobs from the Late Formative component of the cave, dating 2350–980 cal BP, overlap temporally with Ujuxte, suggesting that comparisons would be informative. There is evidence at El Gigante for strong selection for increased yield through local development or the introduction of new varieties outside the range of teosinte (Kennett et al. 2017). Kistler and colleagues (2020) propose that ancient maize genomes from El Gigante are closely related to ancient and modern maize from South America, raising the possibility that El Ujuxte maize (cal AD 115, 1835 BP) might also be descended from South American maize, given the ages of the two sites (Kennett et al. 2017; Love 2018). DNA analysis of desiccated maize from the Estanzuela Late Formative period of El Gigante revealed that they were a combination of local, semidomesticated maize and fully domesticated maize types developed in South America (Kistler et al. 2020).

We compared the size of Late Formative charred maize cupules from El Ujuxte to that of desiccated (uncharred) maize cupules from the same time periods at El Gigante, Honduras, and caves in El Riego, Tehuácan Valley, Mexico (Kennett et al. 2017). To compare charred (El Ujuxte) and desiccated (El Gigante and El Riego) maize cupules, one must take into account the amount of shrinkage that occurs during charring. Charring shrinks cupules about 20%, a middle calculation based on experimental work by Benz (1994). Cupule width was measured from the outside of one cupule wing to the outside of the other wing.

A total of 18 measurable charred cupules were recovered from the beginning of the Late Formative during the Caramelo phase (500–300 cal BC) at El Ujuxte. The average width was 5.39 mm (all measurements were adjusted for 20% shrinkage) with a range of 3.38–7.63 mm. This is larger than the El Gigante Estanzuela Late Formative maize (average width 5.08 mm, $n = 15$) and the Late Formative El Riego maize (average width 4.77 mm, $n = 4$; Kennett et al. 2017:Table S5; see Table 3). Four cupules from El Ujuxte exceed the El Gigante mean, and five exceed the El Riego mean. An additional 17 cupules were recovered from the later Pitahaya phase (cal. 100 BC–AD 100; Love 2018; Supplemental Table 13) during the Late Formative at Ujuxte (average width 4.76 mm, range 4.13–5.95 mm, adjusted for shrinkage) and were close to the same size as maize from Late Formative El Riego.

A paired two-sample *t*-test of unequal variances was conducted between two groups: the Archaic and Early Formative maize at El Gigante and El Reigo versus the Late Formative maize at El Gigante, El Reigo, and El Ujuxte (Caramelo phase, 500–300 cal BC, Pitahaya phase, cal 100 BC–AD 100; Love 2018). Kistler and colleagues (2020) suggest that Archaic and Early Formative maize at El Gigante is descended from maize of South American origin because it is similar in row number and size to the Late Formative maize recovered from the site. Our paired *t*-test ($df = 5$, two-tail $p = 0.002$) reveals that differences in average cupule widths between the earlier and later maize are real. Based on this trait, the Archaic and Early Formative period maize appears to be different from the Late Formative maize. It is likely that El Gigante, El Riego, and El Ujuxte are all the same types of maize descended from varieties developed in and dispersed from South America (see Supplemental Text 1 for a discussion on a hypothesized Pacific coastal dispersion route from South America that contrasts with the overland hypothesis; Kennett et al. 2022).

Conclusions: Maize Political Economy, Religion, and the Archaic State

The paleoethnobotanical component of the La Blanca / El Ujuxte project sought to understand subsistence strategies of the Middle and Late Formative and the mechanisms behind the emergence of archaic states in the Soconusco region. Paleoethnobotanical results support the original hypothesis proposed by Love (2002:223) that shifts in economic strategies and loss of individual household autonomy were instrumental in the development and maintenance of the archaic state at El Ujuxte. Macrobotanical analyses and those of sediment- and artifact-based residues at La Blanca indicate that individual households maintained their autonomy through the control of production and processing of maize and other foods. There is no evidence for agricultural intensification. In contrast, we see decreasing levels of autonomy throughout the Late Formative at El Ujuxte in the form of ever-increasing levels of maize provisioning. Indeed, it is not until the end of the El Ujuxte occupation, the Sierra phase (cal AD 100–200; Love 2018), that we find possible evidence for centralization and control over food (for additional markers of centralization, see Love and Rosenswig 2021).

The keys to understanding the shift at El Ujuxte are establishment of a maize diet and maize ideology during the Early and Middle Formative and the arrival of more productive maize varieties during the Late Formative. Archaeological research at Cuauhtémoc, a lower-tier center west of La Blanca, revealed that maize became increasingly important in both commoner and elite contexts from the Early to Middle Formative, around 1000 cal BC. Increasing quantities of maize macrobotanical remains, the appearance of manos and metates, and the development of maize iconography suggest that maize played an increasingly important dietary and religious role at Cuauhtémoc (Rosenswig et al. 2015). Isotopic analyses of skeletal remains from Early to Middle Formative La Blanca also suggest an increase in maize consumption within the La Blanca polity that coincided with the expansion of food production; for example, an increase in reliance on domesticated dogs (Love 1989). Although the Cuauhtémoc analysis by Rosenswig and colleagues (2015:104) does not provide evidence that the La Blanca polity focused more exclusively on maize production at the expense of other foods (a key marker of agricultural intensification), the data do suggest that maize was central to La Blanca society. Our research has shown that evidence for root/tuber use is present but uncommon at both La Blanca and Ujuxte: no *lerén*, arrowroot, or manioc starch was recovered, and *Calathea* and *Maranta* phytoliths were relatively rare.

South American maize was instrumental in the development and centralization of the maize economy. During the shift from the Middle to Late Formative, the ideology of rulership becomes more grandiose, with rulers likening their actions to those of the maize god at the time of creation (Love 2016). However, the richness of plant taxa at La Blanca and El Ujuxte is virtually identical, suggesting that once maize agricultural systems were established during the Middle Formative, there was no intensification, despite the increasing cultural importance of maize. The more productive South American maize allowed for higher levels of maize productivity without agricultural intensification, such as shortening the fallow period in milpa cycles or constructing agricultural terraces or raised fields. Given the importance of maize in both diet and religion, Late Formative elites could and did exert their authority and control of maize through the production and redistribution of food resources such as those seen at El Ujuxte.

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Data Availability Statement. Data from this study are stored on tDAR, https://core.tdar.org/project/470840/archaeobotanical-data-for-el-ujuxte-and-la-blanca-guatemala-excavations. The collections of the La Blanca and El Ujuxte materials are in the Ceramoteca of the Instituto de Antropología e Historia de Guatemala and in the Salón 3 storage facility. Digital copies of all field records and data are housed at the same institution.

Competing Interests. The authors declare none.

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Supplemental Text 1: South American maize and Pacific coastal trading network hypothesis.

Supplemental Table 1. Summary of Economic Phytolith and Starch Grain Types Found on Different Classes of Artifacts at La Blanca and El Ujuxte.

Supplemental Table 2. Total Phytolith and Starch Counts for Artifacts from La Blanca.

Supplemental Table 3. Total Phytolith and Starch Counts for Artifacts from El Ujuxte.

Supplemental Table 4. Economic Phytoliths from La Blanca Sediments.

Supplemental Table 5. Economic Phytoliths from El Ujuxte Sediments.

Supplemental Table 6. Macrobotanical Remain Totals from La Blanca.

Supplemental Table 7. Macrobotanical Remain Totals from El Ujuxte.

Supplemental Table 8. La Blanca Richness and Density Data.

Supplemental Table 9. El Ujuxte Richness and Density Data.

Supplemental Table 10. Phaseolus Bean Measurements from El Ujuxte.

Supplemental Table 11. Maize Kernel Measurements from El Ujuxte and La Blanca.

Supplemental Table 12. Maize Cupule Measurements from El Ujuxte.

Supplemental Table 13. Maize Kernel/Cupule Ratios at El Ujuxte.

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