MULTI-PROXY ANALYSIS OF PLANT USE AT FORMATIVE PERIOD LOS NARANJOS, HONDURAS

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Paleoethnobotanical analyses of samples excavated at Los Naranjos, Honduras, provide an unprecedented record of the diversity of plants used at an early center with monumental architecture and sculpture dating between 1000 and 500 B.C. and contribute to understandings of early village life in Mesoamerica. Los Naranjos is the major site adjacent to Lake Yojoa, where analysis of an important pollen core suggests very early clearing of the landscape and shifts in the relative prevalence of certain plants over time, including increases in maize. Our results from starch grain, phytolith, and macrobotanical analysis complicate interpretation of previous pollen core dates, suggesting that maize was not as central as expected to the early inhabitants of the settlement. Moreover, with identification of macrobotanical remains recovered from flotation of sediments and extraction of microbotanical remains from adhering sediments and the surfaces of obsidian tools, we can compare the potential of each analysis in interpretations of plant use. No single method would have allowed recovery and identification of all the plants documented across sample types. The presence of botanical residues on the obsidian tools provides direct evidence of processing. Even in the small sample analyzed, we can recognize tools used exclusively for culinary processing, tools used only for non-culinary tasks, and multi-purpose tools.

Estudios paleoetnobotánicos practicados en muestras obtenidas por flotación de suelos y de investigaciones de residuos en artefactos de obsidiana, proveen datos nuevos sobre el uso de plantas en el período Formativo de Mesoamérica, y contribuyen al entendimiento de la complejidad del uso de plantas, la importancia relativa de maíz, y las ventajas del uso de metodologías múltiples para detectar materiales botánicos en sitios arqueológicos. Las muestras vienen de excavaciones en el sitio de Los Naranjos, Honduras, un centro de construcción de arquitectura monumental y de escultura monumental entre 1000 y 500 años A.C. Los Naranjos se localiza en la margen del Lago de Yojoa, donde hace tiempo se obtuvo y analizó una muestra de polen. Con base en los datos de polen y en modelos generales de agricultura mesoamericana, la expectativa de estudios de plantas ha puesto un énfasis sobre el maíz desde 1000 A.C. en adelante. Nuestros datos sugieren algo mas complicado, con la presencia de maíz pero sin calabazas y con muy baja frecuencia de frijoles, añadidos a una muestra amplia de raíces comestibles, productos de arboles, y el uso de plantas para otros fines además de los culinarios. Por lo menos en este caso debemos utilizar modelos más matizados y basados en métodos múltiples, para entender mejor el uso de plantas durante los primeros siglos del desarrollo de las sociedades complejas en Honduras, y probablemente, en otras partes de la región. En particular, señalamos la importancia imprevista de productos de palmas, y el amplio rango de tubérculos procesados con las herramientas examinadas.

Los Naranjos, a multi-component archaeological site located on the north end of Lake Yojoa (Figure 1), was an important community during the Middle Formative period, with monumental architecture and sculpture, use of jade, and some pottery suggesting participation in broader networks linked to the Gulf Coast Olmec (Joyce and Henderson 2010). In their discussion of the Jaral Phase (originally dated 800–400 B.C.), Baudez and Becquelin (1973) noted the development of three earthen platforms up to 20 m tall, whose earliest stages of construction dated to this time (Joyce 2004). Close to Structure IV, a platform that eventually reached 19 m in height and 100-x-75 m in length and width, earlier investigators located basalt sculp-

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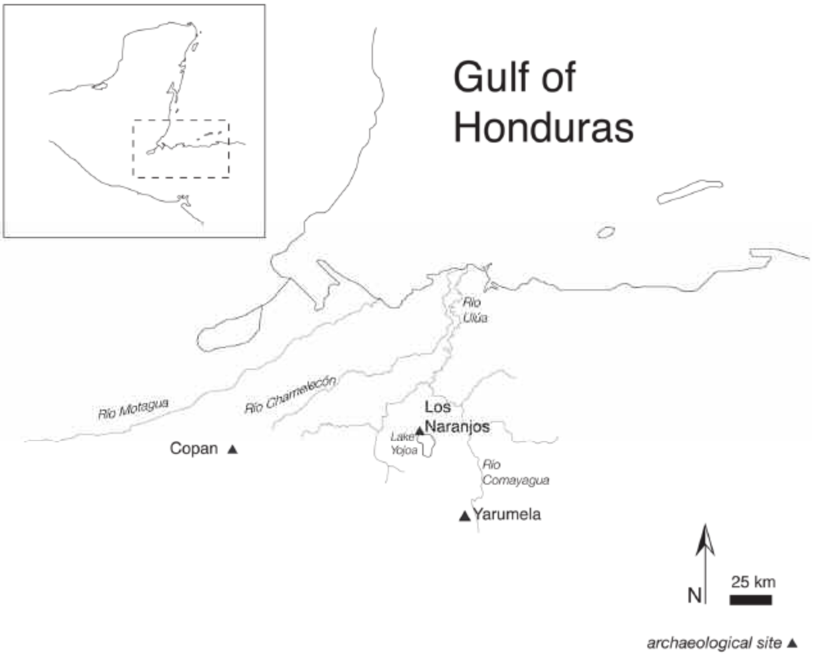

Figure 1. Map of Honduras showing location of Los Naranjos and other sites mentioned in the text.

tures of human figures and zoomorphic creatures (Stone 1934; Strong et al. 1938). These are recognizable today as products of the Middle Formative period, based on subject matter and specific iconography, confirming Los Naranjos as one of the settlements where monumental architecture and sculpture developed at this early period (Joyce and Henderson 2002, 2010). A center of early social complexity, Los Naranjos occupies a special place as one of the easternmost sites known to have either monumental architecture or monumental sculpture during this period, along with Yarumela, Honduras, and Chalchuapa, El Salvador (Dixon et al. 1994; Sharer 1989).

Research of early occupation at this settlement has been complemented by discussions of early landscape modification and transition to agriculture. These discussions have emphasized palynological data recovered from a core of the Lake Yojoa sediments (Rue 1987, 1989). A rise in maize (*Zea*) pollen detected in this core was assigned approximate dates of ca. 2500 B.C., based on one radiocarbon date from the core that shortly preceded the change in pollen profile. More recently, Rue et al. (2002:268) report the calibration of that radiocarbon date to the mid-fourth millennium B.C. and on that basis push back the growth of maize agriculture in the area around Lake Yojoa to ca. 3400 B.C.

Although the lake sediment core provides an excellent index of regional ecology and cultivation near the shores of Lake Yojoa, until now, direct evidence for plant use at the early archaeological site of Los Naranjos has been lacking. In this article, we report on new data from recent macrobotanical and microbotanical analyses that provide the first direct evidence of plant use in Middle Formative Los Naranjos (Morell-Hart 2011). Identified residues included seeds and other large anatomical structures as well as microscopic starch grains and phytoliths. Evidence for maize was limited, beans were scant, and squashes were entirely absent, while a variety of root crops, palms, and other plants were recovered, including some possibly employed for nonculinary purposes. The residues of these plants were extracted directly from sediments and artifacts associated with various contexts and spatial locations and represent the detritus of daily and ritual activity. These data require reconsideration of the assumption that by 800 B.C. the residents of Los Naranjos would have been largely dependent on maize agriculture and underline the importance of considering multiple sources of evidence for human relations with plants.

Early Plant Use in Honduras

The El Gigante rock shelter in southeastern Honduras provides the most robust record of early plant use in the region (Scheffler 2009). There, a stratigraphic sequence with associated calibrated radiocarbon dates from before 9000 B.C. to around 5500 B.C. yielded evidence of plant use in the early and middle Archaic period. Plants identified in levels with dates calibrated between 6500 and 5500 B.C. included *Spondias* (ciruela), *Persea* (avocado), *Agave* (maguey), and examples of both beans *(Phaseolus)* and squashes *(Cucurbita)*. Not evident in these Archaic levels were remains of maize (Neff et al. 2006). Although maize cobs were plentiful (more than 1,000 reported), they were limited to relatively recent strata, the earliest dating between 2000 and 1500 cal. B.C., during the early Formative period (Scheffler 2009).

Pollen data recovered from lake sediment cores, at both Lake Yojoa and near Copan in far western Honduras, appear fairly consistent with the macrofossil, stratigraphic, and radiocarbon evidence from the El Gigante rock shelter. Cores in the Aguada Petapilla suggested that the earliest cultivation of maize in that region dates to around 2600 B.C. (Rue et al. 2002; Webster et al. 2005). McNeil et al. (2010), disputing the obsidian-hydration dating results linked to the chronology of that core, place cultivation of maize to 900–790 cal. B.C at the latest. Regardless of earliest entry to the region, *Zea* pollen appears to increase at the same time as heavy deposits of charcoal, interpreted by all authors as an early signature of human-set fires intended to selectively encourage certain plants. McNeil et al. (2010:1018) even note that this clearing marks "the most dramatic period of deforestation in the past 3,000 years."

Evidence of plant use from all three of these projects has been interpreted to indicate that maize cultivation grew in importance during the Formative period. It has not been possible to clarify the precise timing of the postulated shift to reliance on maize based on the data available from these cores. Rue et al. (2002:268) suggest that the Lake Yojoa core shows that "agriculture intensified around 1000 B.C., after which it remained stable with no 'collapse.'" Evidence from Aguada Petapilla includes a peak in charcoal around 900 B.C., interpreted in a similar way (Rue et al. 2002:269), while McNeil (2010) notes that by 790 B.C. at latest, maize agriculture was firmly established near Copan. At El Gigante, the stratigraphic levels associated with abundant maize macrofossils have associated calibrated radiocarbon dates ranging from 1760 to 800 B.C.

A contrasting point of evidence from the Early Formative is provided by analysis of bone chemistry carried out on human remains recovered in eastern Honduras in the caves of Talgua. There, one sample calibrated to ca. 1400 B.C. shows that the individuals involved "were not consuming substantial quantities of maize" (Herrmann 2002:17). Unfortunately, no data are available from Talgua for the period around 1000 B.C., a time in the Formative period that the other studies have identified as the likely peak of reliance on maize.

The new evidence we report here adds to the existing data by providing the first direct information about plant use at Los Naranjos during the Formative period. It supports an emerging picture that portrays maize as less central to early human plant use in Honduras than previously assumed. It also extends this picture of more diverse plant use, with maize a minor element, somewhat later, into the Middle Formative period after 1000 B.C. The new data from Los Naranjos raise the question of the degree to which plant use in early Honduras should be seen as uniform or subject to more localized patterns.

Plant Use at Middle Formative Los Naranjos

Our research focuses on analysis of samples collected during excavations in 2002 and 2003 in an area immediately adjacent to monumental Structure IV at Los Naranjos. The construction history of Structure IV was first investigated by Claude Baudez and Pierre Becquelin (1973:49–51). Their excavations detected a buried stage of construction, a 6-m-tall platform, dated to the early Middle Formative Jaral phase, to which Baudez and Becquelin (1973) assigned calendar dates of ca. 800–400 B.C. (Unless otherwise indicated, all AMS and radiocarbon dates referenced are calibrated calendar years. Phase estimates are also calendar years, unless the original excavators used uncalibrated radiocarbon years, a practice we do not follow.) This buried construction represents the earliest dated occupation of the site that Baudez and Becquelin recognized. In 2003 and 2004, a Berkeley-Cornell project directed by Rosemary Joyce and John Henderson carried out excavations immediately west of the visible platform of Structure IV, whose latest construction stages date to the Late Formative period (after 400 B.C.). These excavations were intended to provide a more extensive picture of habitation in the area that might have preceded the construction of the Jaral phase platform. The excavations were designed to compare the occupational history of Los Naranjos with the more recently documented site of Puerto Escondido, located in the Ulua River valley to the north, a settlement continuously occupied from before 1600 B.C. through the end of the Middle Formative (Joyce 2007; Joyce and Henderson 2001, 2007, 2010). One pottery type defined at Los Naranjos, Bogran Rugose en Zones, dated to the Jaral phase by Baudez and Becquelin (1973), was indistinguishable from pottery at Puerto Escondido with secure dates between 1100 and 900 B.C. This chronological equivalence suggested that Los Naranjos might have been occupied prior to the building of the earliest known monumental platform at Structure IV by people whose discarded pottery was mixed in construction fill of a later date. The construction of the earliest platforms implied the presence of such a population, and the Lake Yojoa core data suggested that these people would have been long established in the lake shore area when the first stage of Structure IV was built ca. 800 B.C. Understanding regional networks during the transition from the Early Formative period to the Middle Formative period required determining whether the habitation sites of these earlier people could be identified.

Excavations in 2003 and 2004

Ground penetrating radar and magnetometer surveys of an L-shaped area north and west of Structure IV, covering approximately 6,250 m^2 (Tchakirides et al. 2006), provided initial guidance for the placement of excavation units. For the paleoethnobotanical results reported here, the samples came from a block of excavations in an area west of Structure IV, extending 10 m east-west and 14 m north-south. A maximum depth of 1.5 m was excavated in this area, although not all excavated units were carried through to that depth. In those units excavated to 1.5 m, the lowest 25–30 cm appeared to be naturally occurring sediments, mixed gravels, and sand, suggesting that in these areas, at least, excavations reached the original ground surface occupied by the first inhabitants along Lake Yojoa.

The stratigraphy consisted of four distinct units, the two most recent stemming from construction and expansion of the monumental architecture, and the two earlier attributed to the residents who already lived in this location when major construction began. The stratigraphic section likely began with a surface at 1.2 m below modern ground level. On this surface we defined a series of features that are interpreted as the remains of a round-ended structure associated with hearths, sheet midden, and post holes. Included in the materials recovered here were obsidian flakes and blades and ceramics, including large articulated fragments of a bowl related to the Bogran Rugose en Zones type.

This early surface was succeeded by three others, separated by thin lenses of sediment (totaling 10–19 cm between surfaces). The uppermost of these three surfaces was located at approximately 85–90 cm below the modern ground surface. Here, a dense deposit of crumbly, carbon-rich material 19 to 25 cm thick covered sections of in situ burned clay wall bases from rectangular buildings, none completely preserved in outline. In addition to macrobotanical remains, the carbon-rich deposit yielded a large number of obsidian flakes (249) and blades (25).

Immediately above these burned building foundations was the first of two clay fill units extending across the entire excavation area. This 53-cm-thick brown clay fill was heterogeneous in texture and contained localized areas of clays of other colors, as well as very small sherds and obsidian flakes and blades. It was immediately covered by a contrasting 19-cm-thick yellow clay fill with similar texture and color mottling.

The two more recent stratigraphic units are interpreted as construction fills for terraces associated with two stages of the construction of Structure IV. The most recent includes pottery dating after 400 B.C. The earlier brown clay fill lacks specific diagnostic pottery types, but should be associated with the Middle Formative Jaral phase terrace identified by earlier excavators. This stratigraphic sequence implies that both surfaces with identifiable architectural remains predate the first stage of construction of the Jaral structure. The burned house wall bases may be interpreted as products of deliberate demolition at the moment the new building project was initiated. This deliberate activity would account for the continued integrity of the crumbly carbon rich material that extends over the area and underlies the first brown clay fill. The earliest residential features identified likely date to around 1100–900 B.C., based on comparison of the associated pottery with the ceramic sequence from Puerto Escondido (Joyce and Henderson 2007). They presumably represent occupation by villagers prior to the initiation of large-scale construction projects at this location.

The plant remains analyzed by Morell-Hart came from the two surfaces with architectural remains, the more recent from the demolition of house structures in conjunction with the construction of the Jaral phase platform, the older from deeply buried levels dating to ca. 1100–900 B.C. They were produced by sediments subjected to flotation and from obsidian tools sampled for phytolith and starch residues. They thus provide information about the range of plant-related practices carried out by the residents who built the monumental platforms at Los Naranjos, successors of those whose initial land clearing activities more than 1,000 years earlier were detected in the Lake Yojoa pollen core.

Previous Paleoethnobotanical Data from Lake Yojoa

The core from Lake Yojoa revealed variation in plant pollen over time (Rue 1987, 1989). The earliest levels were marked by high percentages of tree species and the absence of cultigens. Markers interpreted by Rue as evidence of early agriculture in the Archaic period included rises in cheno-ams (chenopod or amaranth forms) and maize and low relative percentages of other grasses. Agricultural intensification was inferred from later increases in sunflower family, ragweed, and other disturbed- and fallowed-area plants. From around 1000 B.C., the pollen record evidenced no major vegetation changes, aside from a short period of potential abandonment and reforestation marked by pine tree pollen. However, Rue (1987, 1989) saw no evidence of a period of abandonment marked by depopulation in levels inferred to originate during the end of the Classic period.

The record of pollen recovered from this core must be qualified by the fact that many plants currently in the area are insect-pollinated. Entomophilous pollination results in fewer grains simply dropping into the lake and becoming incorporated into sediment layers. Due to the paucity of insect-borne pollen, the majority of pollen data recovered from the Lake Yojoa core necessarily relates to anemophilous species pollinated through wind-borne grains. Therefore, the pollen record does not provide a complete picture of plant use along the lakeside, nor does it provide direct evidence of plant use at Los Naranjos itself. Cautions have also been issued in the Maya area, where researchers have noted that shifts in pollen signatures may actually reflect fallowing practices (rise in grasses) or the management of forest home gardens (rise in arboreal taxa), rather than shifts in forest succession following human depopulation or abandonment (Ford 2008). In our work, macrobotanical and microbotanical samples were analyzed in an effort to fill in the existing picture of ethnobotanical practice at Lake Yojoa, making use of both sediments and artifacts recovered in excavations at Los Naranjos itself. Such analysis provides more direct evidence of human-plant interactions tied to ancient communities.

Analysis of Plant Remains from Los Naranjos: Sampling Strategy

The paleoethnobotanical data from Los Naranjos encompass six kinds of contexts and were recovered from light fraction macrobotanical samples and microbotanical extractions from obsidian artifacts. Heavy fraction samples were collected but were unavailable for analysis, and remain in Honduras. The selection of artifacts for analysis allowed the identification of plant use associated with specific artifacts and enabled the recovery of complementary botanical data represented at the smallest microscopic level. No ground stone artifacts were recovered from the early levels that are the focus of this study. Obsidian artifacts, however, were abundant in all excavation units and the entire collection was available for sampling.

The analyzed residues come from both Late Early Formative and Early Middle Formative time periods (Table 1) and represent interior surfaces, matrices between surfaces, architectural fill, pit fills, structural collapse matrices, and a high-density midden. Excavators systematically drew bulk samples for macrobotanical analysis from each locus on-site. Morell-Hart carried out microbotanical analysis on the residues extracted from seven of the obsidian artifacts recovered in the course of excavations, including both phytolith and starch grain studies. Both microbotanical and macrobotanical samples were judgmentally selected by Morell-Hart and Joyce for analysis after initial processing (see below). Although this strategy limits representativeness of the samples for the site as a whole, our results are nonetheless notable for the wide array of plants recovered, referencing a broad spectrum of ethnobotanical activities.

The overall diversity of contexts and artifacts was optimal in revealing patterns and anomalies of practice over a variety of micro-landscapes (Morell-Hart 2011). The richness of the data set at Los Naranjos enabled us to ask questions that would have been impossible at data-impoverished sites (usually due to preservation issues) or sites where only one type of data was obtained (usually due to collection or storage issues). The incorporation of multiple lines of archaeobotanical data was augmented by the optimization of methods to maximize recovery of each type of residue.

Methods. Methods for processing and analyzing the macrobotanical light fraction samples and the microbotanical obsidian artifact residues followed protocols well-delineated in contemporary studies (Hastorf 1999; Pearsall 2008; Perry 2004; Piperno 2006; Piperno et al. 2000). Below, we outline the specifics of each method of analysis.

The light fractions of the macrobotanical samples were obtained through flotation processing in the field. A modified SMAP flotation machine (following Watson 1976) was constructed and used onsite for flotation of the bulk sediment samples. In this technique, water was added to each sediment sample and the mixture was agitated. This bucket of material was run through the modified SMAP machine and macrobotanical remains (the "light fractions") were recovered from the material that floated to the surface. After extraneous clays and silts had been removed, the heavy material was collected as a separate fraction and curated. Once the light fractions of each sample were fully dried, they were exported for analysis at the Paleoethnobotany Laboratory at U.C. Berkeley.

In the laboratory, Morell-Hart first scanned the light fraction samples to judge the relative density of charred archaeobotanical remains. Scanning took place under binocular dissecting microscopes, using reflected light from fiber optic light sources, at a range of power between 5X and 30X. Scanning was utilized for an initial overall assessment of the samples, whereas sorting was employed for detailed analysis and identification. During the scanning process, items were not actually removed from the sample, but identified and noted. Macrobotanical samples were then prioritized by Morell-Hart in order of relative density of charred material.

Once the samples were selected by Morell-Hart and Joyce for greater recovery of charred plant remains and to explore specific contexts, the process of sorting began. In this procedure, Morell-Hart divided the light fractions of the floated sediment samples according to particle size, using geological sieves. This size division facilitated and expedited the process of sorting and concentrated a certain range of particle sizes within a certain degree of magnification. Charred materials, and other materials such as bone or snails, were removed from the sample once identified under the microscope. Morell-Hart then performed basic initial identification to designate wood, parenchymous tissue, seeds, and other materials. A variety of tools were employed to aid in this endeavor (probes, dental picks, tweezers, and similar instruments).

After diagnostic specimens were separated for classification, and non-diagnostic specimens were removed for later classification, the identification of charred botanical materials was completed. Morell-Hart used morphological attributes to identify macrobotanical specimens, generally including size, the shape of the macrobotanical specimen's "footprint," surface patterning, and other related morphological characteristics, such as presence or absence of a testa. As is common

Table 1. Taxa, Common Names, Phase(s) When Present, Number of Recovery Instances Based on Type of Sample, and Total Number of Each Taxon Recovered.

Taxon	Common name	EF-MF transition (present)	MF pre-platform (present)	Macrobot LF count	Microbot AS count	Microbot SM count	Total
Amaranthus sp.	amaranth	-	X	2	-	-	2
Annona sp.	custard apple	-	X	1	-	-	1
Arecaceae sp.	(palm family)	X	X	1	3	3	7
Asteraceae sp.	(sunflower family)	-	X	-	1	-	1
Asteraceae sp. 1	(sunflower family)	-	X	2	-	-	2
Asteraceae sp. 6	(sunflower family)	-	X	1	-	-	1
Bromeliaceae sp.	(bromeliad family)	-	X	-	2	1	3
Calathea sp.	leren	-	X	-	1	1	2
Chloridoideae sp.	(grass tribe)	-	X	-	1	-	1
Cyperaceae sp.	(sedge family)	-	X	-	1	-	1
Euphorbiaceae sp.	(spurge family)	-	X	1	-	-	1
Fabaceae sp.	(bean family)	-	X	2	-	-	2
Indigofera sp.	indigo	-	X	1	-	-	1
Ipomoea sp.	sweet potato	-	X	-	4	-	4
Lamiaceae sp.	(mint family)	-	X	4	-	-	4
Lepidium sp.	pepperweed	-	X	1	-	-	1
Manihot sp.	manioc	-	X	-	5	-	5
Marantaceae sp.	(arrowroot family)	X	X	-	1	1	2
Nicotiana sp.	tobacco	-	X	1	-	-	1
Oenothera sp.	evening primrose	-	X	1	-	-	1
Oxalis corniculata	creeping wood sorrel	-	X	1	-	-	1
Panicoideae sp.	(grass tribe)	-	X	-	4	1	5
Panicum sp.	panic grass	-	X	1	-	-	1
Parmentiera aculeata	cucumber tree	-	X	1	-	-	1
Phaseolus sp.	common bean	-	X	-	1	-	1
Poaceae sp.	(grass family)	-	X	2	-	-	2
Poaceae sp. 4	(grass family)	-	X	1	-	-	1
Poaceae sp. 5	(grass family)	-	X	1	-	-	1
Pooideae sp.	(grass tribe)	-	X	-	2	-	2
Rosaceae sp.	(rose family)	-	X	1	-	-	1
Salvia hispanica	chia	-	X	1	-	-	1
Salvia sp.	chia	-	X	1	-	-	1
Scirpus sp.	bulrush	-	X	1	-	-	1
Setaria sp.	bristle grass	-	X	1	-	-	1
Sisyrinchium sp.	blue-eyed grass	-	X	1	-	-	1
UNIDENT seed		-	X	10	-	-	10
UNKN bark?		-	X	4	-	-	4
UNKN druse		-	X	-	1	-	1
UNKN endocarp		-	X	1	-	-	1
UNKN fiber		-	X	-	1	1	2
UNKN fruit		-	X	3	-	-	3
UNKN leaf		-	X	2	-	-	2
UNKN lump		-	X	5	-	-	5
UNKN nutlet		-	X	1	-	-	1
UNKN peduncle		-	X	1	-	-	1
UNKN phyto 1		X	-	-	-	1	1
UNKN phyto 11		-	X	-	-	1	1
UNKN phyto 2		X	X	-	2	2	4
UNKN phyto 3		X		-	-	1	1
UNKN phyto fragment		-	X	-	1	-	1
UNKN phyto scutiform		X		-	-	1	1
UNKN raphide		X		-	1	-	1
UNKN schizocarp 27		-	X	1	-	-	1

Table 1 (continued). Taxa, Common Names, Phase(s) When Present, Number of Recovery Instances Based on Type of Sample, and Total Number of Each Taxon Recovered.

Taxon	Common name	EF-MF transition (present)	MF pre-platform (present)	Macrobot LF count	Microbot AS count	Microbot SM count	Total
UNKN seed 1		-	X	2	-	-	2
UNKN seed 11		-	X	2	-	-	2
UNKN seed 26		-	X	1	-	-	1
UNKN seed 28		-	X	2	-	-	2
UNKN seed 29		-	X	1	-	-	1
UNKN seed 3		-	X	2	-	-	2
UNKN seed 7		-	X	1	-	-	1
UNKN starch		-X	X	-	11	8	19
UNKN starch 1		-	X	-	-	1	1
UNKN storage		-	X	-	-	1	1
UNKN testa		-	X	1	-	-	1
UNKN thorn		-	X	1	-	-	1
UNKN vascular		-	X	-	-	1	1
UNKN woody sp.		X	X	9	6	6	21
Verbena sp.	verbena	-	X	1	-	-	1
Veronica sp.	speedwell	-	X	1	-	-	1
Zea mays	maize	X	X	1	7	4	12

Notes: EF= Early Formative; MF= Middle Formative. LF = Light Fraction of flotation sample; AS = Adhering Sediments of artifacts; SM = Sonicated Material from artifacts. UNKN= unknown; potentially identifiable; UNIDENT = unidentifiable. Total number of flotation samples = 13. Total sediment volume floated = 65 L. Total number of obsidian artifacts analyzed = 7; total number of residue samples = 14.

with archaeobotanical specimens, morphologies were often drastically altered through taphonomic processes, complicating identification (Boardman and Jones 1990; Hubbard and al Azm 1990; Smith and Jones 1990; Stewart and Robertson 1971). For this reason, many remains were left unidentified. Other unknown or unrecognized yet potentially diagnostic specimens were drawn and photographed by Morell-Hart and several undergraduate student assistants, with the expectation that they may eventually be identified.

Morell-Hart compared identifiable specimens with materials in the modern reference collections housed in the UCB Paleoethnobotany Laboratory and with images in books (e.g., Lentz and Dickau 2005; Martin and Barkley 1973) and online in various databases (e.g., Kew Royal Botanic Gardens 2011; United States Department of Agriculture 2011). Once identification was complete, surviving portions of the macrobotanical specimen and taphonomic transformations were noted, for additional clues as to potential processing regimens (Fosberg 1960; Pearsall 2008). After cataloging the macrobotanical specimens, Morell-Hart curated all removed materials in gelatin capsules and boxes, labeled with accompanying site and contextual information.

For the artifact residue extractions, Morell-Hart followed a much different set of protocols. As indicated by studies of stone tools in Australia, starch grains found in surrounding soils are often distinct from those recovered from tools, indicating that the starches found in pores and crevices of artifacts are likely not contaminated by sediment-borne starches (Atchison and Fullagar 1998). Even so, in order to control for potential contamination, Morell-Hart completed two separate extractions for each artifact: a primary wash to remove adhering residues and a secondary sonication to remove embedded materials in fissures and pores. Materials recovered from the adhering sediment were relegated to general "taxa encountered and likely utilized and/or processed," whereas residues sonicated from the artifacts were classified as likely to be associated with actual artifact uses.

For each artifact sampled, the adhering sediment was first removed by rubbing all surfaces of the artifact in distilled water, using powder-free latex examination gloves. Although many researchers use toothbrushes for this procedure, abrasive brushing was avoided, as some of the artifacts may later be analyzed for use wear. Such analyses of wear patterns are complicated by scratching even from the softest of toothbrushes (Hester 1997). Moreover, gloves could be discarded after processing an artifact, eliminating potential contamination through reusing tools like toothbrushes, and eliminating the time required to sterilize toothbrushes between each use. After removal of the adhering residue, Morell-Hart centrifuged each sample at 5,000 rpm for five minutes to concentrate the residue into a small plug at the base of the tube. During this process, the residue extracts were maintained in the processing water to avoid potential damage to starch grains by re-desiccating them.

After removing the adhering matrix as one sample, Morell-Hart placed each artifact in another beaker of distilled water and sonicated it in a Baxter Ultrasonic Cleaner at level 2. Sonication took place for 10 minutes. For each obsidian artifact, the surfaces exhibiting potential wear were immersed in the water, while other surfaces were kept clear. This process extracted the residue embedded within the pores and fissures of each artifact, ideally related to use wear of the lithic tool. As with the adhering residue sample, Morell-Hart concentrated this residue through centrifugation at 5,000 rpm for 5 minutes, maintaining the residue in the original processing water.

The "adhering" and "sonicated" residue samples were mounted on glass slides, using only the distilled water effluvium as mounting medium. Morell-Hart then viewed each sample under a transmitted light Nikkon microscope at different magnifications. Phytoliths and starch grains were counted to 200, or to the maximum available quantity (Piperno 2006), and identified to the smallest possible taxonomic designation. The rest of the slide was then scanned for less common phytoliths and starch grains, and other microremains such as raphides and druses (distinctive crystalline structures present in some plant tissues).

As with the macrobotanical samples, the microbotanical residues extracted from obsidian tools were identified using all means available. Those specimens that were identifiable by Morell-Hart were compared with materials in the modern reference collections housed in the Paleoethnobotany Laboratory and with reference images found in books and online.

Results: Taxa Represented

The taxonomic richness of Formative period samples from Los Naranjos is substantial. We recovered a minimum of 36 and a maximum of 70 distinct taxa (Table 1) from 17 loci at Los Naranjos. This minimum number accounts for the possibility that some taxa were identified through one type of residue analysis (e.g., "Poaceae sp. 4" seed recovered from Light Fraction) but redundant in another type of residue analysis with specimens that were unidentifiable, non-diagnostic, or diagnostic to a different taxonomic clade (e.g., "Panicoideae sp." phytolith recovered from Adhering Sediment). The maximum number of distinct taxa accounts for the possibility that no overlap exists between differentially identified residues. The actual number of recovered taxa is likely somewhere in between these two figures.

We record the total counts of each taxon in the final column of Table 1 to reflect the combined number of instances of each taxon recovered. Sediments adhering to artifacts are likely more representative of surrounding matrices and activities, whereas sonicated materials are likely more representative of actual artifact use (Pearsall 2008; Perry 2004). We calculated final ubiquity values using only the adhering sediments and light fractions of flotation samples (Table 2). This way, each location was counted only once in "overlapping" loci from which both types of samples were taken. Integrating the botanical data in this way also allows us a better overall view of taxon presence across the site, in spite of the fact that each recorded presence might represent a different anatomical part (phytolith, starch grain, fruit, or seed). The most commonly recovered taxa are represented in Table 2, in order of ubiquity.

Plants with Known Edible Uses

Several potential or definitive grain species were identified in the Los Naranjos samples. We recovered maize (*Zea mays)* in the form of phytoliths, starch grains, and a charred kernel from adhering sediments, sonicated material, and one light fraction of a bulk flotation sample. No other

Table 2. Most Frequently Recovered Taxa, by Ubiquity Value (Number of Loci Where Recovered, excluding Sonicated Residues.)

Taxon	Common name	Ubiquity
Zea mays	maize	4
Lamiaceae spp.	mint family	4
Arecaceae spp.	palm family	3
Manihot sp.	manioc	3
Asteraceae sp. 1	sunflower family	2
Ipomoea sp.	sweet potato	2
Salvia sp.	chia	2
(UNKN seed 1)	unknown	2
(UNKN seed 11)	unknown	2
(UNKN seed 28)	unknown	2
(UNKN seed 3)	unknown	2

kernel, cupule, or cob fragments were noted in the flotation samples. If any other maize fragments were present, they lacked diagnostic surface morphology or identifiable gross morphological characteristics. Two amaranth *(Amarantus* sp.) seeds were also recovered from light fraction samples, in addition to several chia (*Salvia* sp.) seeds, perhaps marking the use of chia for food, as has been noted further north in Mexico. The cultivation of such grain species is an expected occurrence in traditional ethnobotanical paradigms for Southeastern Mesoamerica. Cultivation activities could have taken place both in home gardens and in formally defined fields.

Obsidian tools from Los Naranjos also revealed evidence of root crop use through the recovery of starch grains. We identified tuberous roots including leren (*Calathea* sp.), manioc *(Manihot esculenta)*, and sweet potato *(Ipomoea batatas)*. In each of these cases, microbotanical residues were the only means by which we could recover information about underground storage tissues of the species. As with the grain species, plants used for edible underground storage organs could have been cultivated in home gardens, as well as fields.

Other potential staple food species are less well represented at Los Naranjos. The common bean (*Phaseolus* sp.) was recovered only once. Considering its designation as one of the "trinity" of staple species (including squash and maize), and the fact that it has diagnostic starch grains, phytoliths, and macroremains, the low recovery is notable. This paucity may indicate particularities of processing techniques (i.e., rare obsidian tool use; macrobotanical bias toward non-consumable parts of plant), modes of discard, or infrequent actual use. This domesticated species is associated with deliberate cultivation practices, similar to root crops and grain species.

Tree-cropping practices are likely represented by *Annona* and *Arecaceae* species. A recovered custard apple *(Annona* sp.) seed is the lone representative of the taxon. Although a commonly consumed fruit, it is not considered to be a staple crop, so the relatively low frequency ($n = 1$) is unsurprising. The limited recovery may also suggest other non-culinary practices for the species, like those noted in Standley and Steyermark's ethnobotanical study (1946): "[*Annona glabra*] is often utilized along the Atlantic coast of Central America for bottle stoppers and floats for fishing nets and lines. The fruit is insipid and seldom eaten by people but there is a popular belief, perhaps correct, that it is eaten commonly by alligators." We also recovered palm (*Arecaceae)* phytoliths from artifact residues, potentially derived from food species such as cohune (*Attalea cohune)* or coyol *(Acrocomia* sp.).

Recovered residues of herbaceous plants such as tree cucumber (*Parmentiera)* and several unidentified species may also index the consumption of edible fruits or seeds. However, as with many such species, even where identification is possible and additional economic information is available, it is likely that many of the residues are the result of opportunistic ruderals growing in areas disturbed by human activity.

Several species highly anticipated in foodways paradigms of Southeastern Mesoamerica did *not* appear in our Los Naranjos samples. *Cucurbita* (squash) species represent the most prominent absence. The primary economic use of species in this genus is the consumption of the edible flesh and seeds of the squash fruits. However, we recovered no squash remains in phytolith or macrobotanical form. The lack of evidence for squash in the Formative period at Los Naranjos complicates traditional views of widespread high ubiquity of squash for thousands of years. At other sites studied in the region, squashes were recovered only as rind phytoliths in sediment samples, not as macrobotanical remains (Morell-Hart 2011). It may simply be that, due to processing regimens and natural formation processes, mi-

Figure 2. Tobacco (*Nicotiana* sp.) seed recovered from excavation provenience 1-A–14. Longest dimension of fragment = .3 mm.

crobotanical sediment samples provide a better index of the *Cucurbita* genus in this region.

Plants with Known Medicinal Uses

A single tobacco (*Nicotiana* sp.) seed was represented in the samples (Figure 2). This seed was recovered from a matrix located between well-defined deposits, and likely represents accidental incorporation, perhaps through curing practices, as the seeds are not known to have economic uses. As historically recorded, however, the leaves were smoked, rubbed on clothing to ward off snakes, and mixed with water to treat ticks and colmoyote worm (Atran 1993; Heiser 1992; Roys 1965). In the early colonial Yucatec Maya text *Ritual of the Bacabs*, tobacco is recorded as medicine for asthma, bites, stings, bowel complaints, chills, fever, seizures, sore eyes, skin diseases, and urinary complaints. It is also invoked in incantations dealing with “skin eruptions, fever, snake in the abdomen, a worm in the tooth, and the placenta” (Roys 1965). A popular domesticated species from very ancient times through the modern day, tobacco is cultivated in a variety of locations (Goodspeed 1954; Pickersgill 1977).

Several other plants may have had medicinal uses, including grass (*Poaceae*) and sunflower family (*Asteraceae*) species. Representatives of both of these families emerged from the macrobotanical and microbotanical samples. Some herbaceous plants (*Lepidium, Oxalis, Verbena*), recovered as seeds, may also have had medicinal or condiment uses as is recorded for these taxa elsewhere (Lentz 1986; Lentz et al. 1998; Zamora-Martínez and Pola 1992). The ascribed potential medicinal uses of these plants at Los Naranjos, however, are tentative in nature.

Plants with Other Known Uses

We recovered many grass (*Poaceae*) and sunflower family (*Asteraceae*) species from the macrobotanical and microbotanical samples, reinforcing understandings of the general ubiquity of these plants, as identified in pollen from sediments in Lake Yojoa (Rue 1989). Members of the grass family include multiple species potentially used in thatching, bedding, tinder, and for medicinal purposes. Moreover, many of these species may have become incorporated into the archaeological record as components (intentional or otherwise) of clays and sediments used as daub and flooring materials. Grasses grow wild everywhere throughout this region and may have sprung up in nooks throughout the site. Grass seeds can also find their way naturally into the archaeological record, as travelers clinging to clothing and feet, or due to the activities of rodents.

Sunflower family (*Asteraceae*) species were recovered both as microremains and macroremains. Similar to grass species, some may have been used for medicinal purposes, and others as foodstuffs. But overall, as with grasses, these species grow wild quite easily in various places and have the tendency to spread quickly throughout areas, growing without the intervention of people.

Bromeliaceae phytoliths, recovered three times in the course of residue analysis, may correspond with the use of these plants as ornamentals and foodstuffs, although *Tillandsia* species within this family are recorded ethnographically as being used by Lenca peoples in ritual practice (Meluzín 1997).

A large number of taxa had, expectedly, very low recovery rates, including those of *Lepidium, Oenothera, Oxalis, Parmentiera aculeata, Sisyrinchium, Verbena,* and *Veronica*. Perhaps, like the lone indigo plant *(Indigofera* sp.*)* recovered, some of these were used for dyeing purposes. Some may have had edible fruits or seeds that were occasionally consumed, such as the tree cucumber (*Parmentiera)*. Like many other herbaceous plants, some of them may have had medicinal or condiment uses as recorded for these taxa elsewhere (noted above). Some may have been used as ornamentals or home garden privacy screens *(Oenothera)*. Some may have had a role in thatching or matting. Many, however, were probably opportunistic plants growing in disturbed areas, whose residues became naturally incorporated into the recovered archaeobotanical assemblage.

Plant Residues Recovered from Artifacts

We recovered residues of various plant species from obsidian artifacts, either in adhering sediments or sonicated from fissures and pores in the artifact surfaces (Figures 3 and 4). Relative abundances of taxa were quite variable from artifact to artifact. Woody species dominated most assemblages, and *Panicoid* grasses and palm species were also frequently represented, though much less abundant overall than the woody phytoliths. Palm (*Arecaceae)* phytoliths ranged between 5 and 30 percent of each array. *Panicoid* grasses often factored into the assemblages, but never topped more than 3 percent of the assemblage. Relative abundances of all other taxa generally ran between 1 and 5 percent.

Unknown woody species phytoliths were recovered from every artifact at Los Naranjos but one of the obsidian blades. These non-diagnostic arboreal spheres likely index a variety of taxa. However, like the grass species, the ubiquity of wood across artifact types is unsurprising, given the enormous number of practices associated with woody taxa and their wide incorporation into daily life as fuel, implements, and construction materials.

On three of four obsidian blades, there appears to be a much higher relative abundance of maize (12 to 33 percent) and much less wood than in the aggregate of artifacts and plant residues. By comparison, one of the blades had unknown fibers and a high quantity of wood, in addition to unknown starches, but no evidence of maize. This blade may represent an exclusive industrial or workbench "wood and fiber" tool. Another blade had only maize, vascular tissue, and unknown storage tissue, with no wood phytoliths present. This blade may represent an exclusive "food"

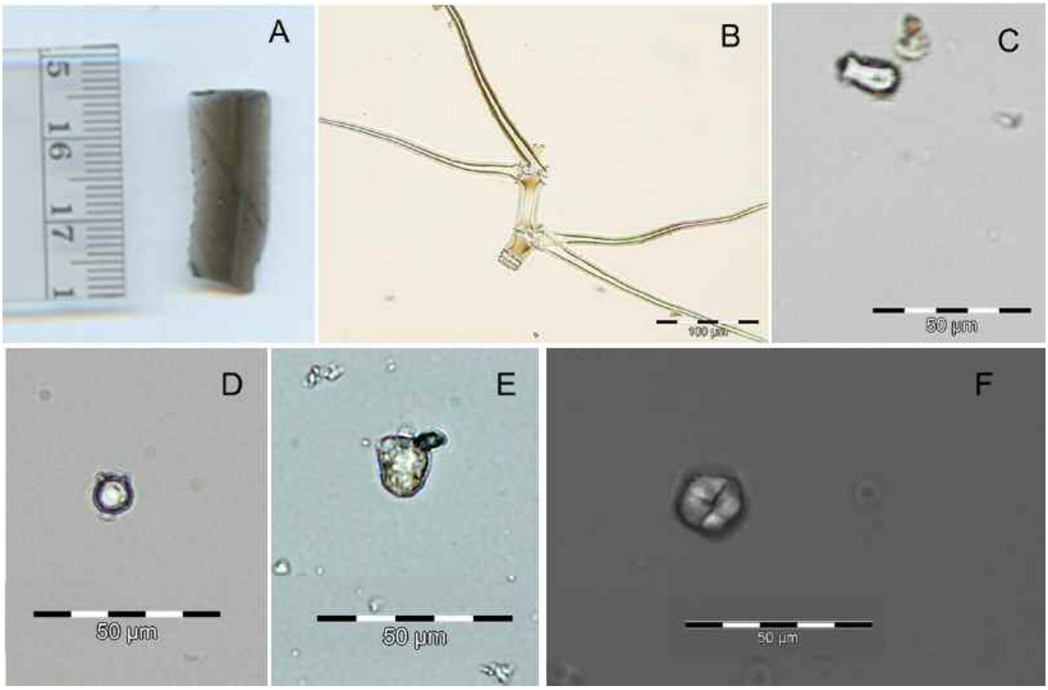

Figure 3. Example of an obsidian artifact and selection of corresponding microfossils recovered from sonicated material: (a) obsidian blade recovered from LN-04-C-11-A; (b) unknown phytolith; (c) unknown starch grain; (d) unknown starch grain; (e) *Bromeliaceae* sp. phytolith; (f) maize (*Zea mays*) starch grain.

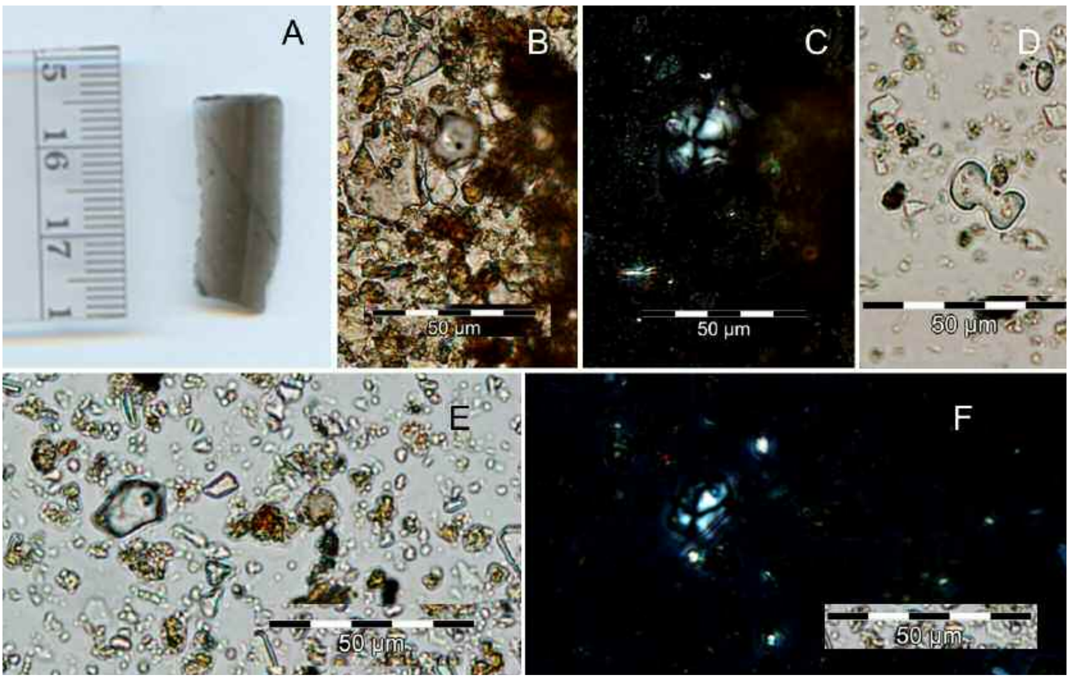

Figure 4. Example of an obsidian artifact and selection of corresponding microfossils recovered from adhering sediment: (a) obsidian blade recovered from LN-04-C-11-A; (b) manioc (*Manihot*) starch grain; (c) same *Manihot* starch grain as in (b), under polarized light; (d) *Panicoid* grass phytolith; (e) unknown starch grain; (f) same unknown starch grain as in (e), under polarized light.

tool. Other blades had a higher diversity of taxa (up to five distinct species) and thus were likely more multipurpose.

The species associated with each artifact reference a myriad of potential activities, from cutting wood with tools to scouring implements with dried maize cobs. We see some discrete uses of obsidian blades, perhaps reserved for particular activities, although food species are represented across most obsidian artifacts. Whatever the particular uses of each artifact, the species collectively recovered from artifacts represent interactions with both domesticated and wild-growing plants.

Discussion

Pollen core data from Lake Yojoa would lead us to expect that by 1000 B.C., maize agriculture, and the accompanying cultivation of beans and squash, would have been well established. This temporal depth of expected agricultural activity does not seem to be indicated by the profile of plants we identified at Los Naranjos: squashes are entirely absent, beans are exceptionally rare, and even maize is present in relatively few samples. What these samples suggest instead is that residents of Los Naranjos between 1000 B.C. and 700 B.C. (the estimated date for construction of the first version of Structure IV) exploited a wide range of plants for subsistence, including both seed and root crops. They likely also made use of products from managed forests and fallowed milpas. Such activities are suggested by scholars working in the nearby Copan area (McNeil 2010) and Belize (Ford 2008), who have linked forest management and milpa fallowing to increases in arboreal and grass pollens.

Many of the plants recovered at Los Naranjos probably served non-culinary purposes. Tobacco is a notable example, known to have been used for medicinal and ritual purposes in later Mesoamerica. Other medicinals are likely included in the variety of plants we identified at the site. A large part of the plant assemblage may represent non-comestible uses of plants: indigo and other plants used in dyes, palms for fiber and thatching, and wood worked into artifacts that are not themselves preserved archaeologically.

From a methodological perspective, the productivity of analysis of even a small number of obsidian artifacts is notable. The plant remains we recovered from these objects, especially those removed through sonication, provide a different kind of evidence for understanding plant use. Whereas flotation samples may only indirectly reflect human actions, as is true also of the pollen core recovered from Lake Yojoa, the obsidian artifacts were primary tools used to process plants. It is noteworthy that one of the tools seems to have been used exclusively for non-culinary activities, while another may have been reserved exclusively for foodstuffs. All other tools analyzed show evidence of multipurpose use.

All the evidence for use of root crops at Los Naranjos originates in the analyses of tools used to process these tubers, whether found in the adhering sediments (less securely associated with artifact use) or sonicated material (more securely associated with artifact use). While maize was present in other samples, the most abundant evidence for this cultigen comes from artifact residues, as does the only detected evidence of beans. Without microbotanical analysis, the significant use of palms would have been underrepresented, and the use of bromeliads (important in traditional Honduran rituals) would have been undetected.

The combination of methods thus provides a richer, more complex picture of human use of plants than any one method alone. We recommended that future researchers interested in human-plant relationships pursue such multi-proxy analysis, from pre-excavation research design through post-excavation subsampling strategy. Complementary methods increase the visibility of taxa difficult or impossible to recover macrobotanically (e.g., leren and sweet potato) or microbotanically (e.g., amaranth and tobacco). Gathering sufficiently large sediment samples for flotation is critical to this endeavor. In semi-tropical areas of Southeastern Mesoamerica, even larger volumes than those analyzed here—a minimum of 10 liters—are recommended. We would also encourage the analysis of heavy fraction samples when available, as this analysis has proven fruitful elsewhere in Mesoamerica (e.g., VanDerwarker and Kruger 2012). Moreover, collecting small (200 g) sediment samples for microbotanical residues enables complementary analyses of activity loci. Maintaining at least a subset of unwashed artifacts is critical, including at least several specimens of chipped stone, ground stone, and ceramics. Such research activities are necessary to obtain a more holistic view of economic plant practices and have already had enormous success across a wide variety of environments and time periods (e.g., Dickau 2010; Hamilakis 1996; Mercader et al. 2003; Zutter 1999).

At the microscale, our study provides a window into daily life of the builders of monumental architecture at Los Naranjos. They enjoyed access to a wide range of plants, both for food and other purposes. Comparison with three neighboring sites suggests that the residents of early Los Naranjos may have enjoyed one of the richest plant assemblages in the region (Morell-Hart 2011). Such contrasts should not be viewed solely in terms of per-sample taxa richness and ecological constraints. Each site studied has unique features, suggesting that when we examine human use of plants at the level of individual practice and intergenerational change, what we will see is much greater complexity than what traditional models suggest. We are also likely to encounter even more unexpected patterns than those already established through previous work demonstrating that cultivation of maize did not go hand-in-hand with early sedentism and social complexity in Honduras (e.g., Herrmann et al. 2002). While social complexity and diversity increase the challenge of generalizing about early human uses of plants, the approach we have elaborated here provides a good snapshot of such activities, identifying places where culturally significant plants first gained an advantage and recognizing the cultural practices that allowed it to happen. Such efforts enrich our understandings of the mosaic of practices linked to domestication in Mesoamerica, as well as other practices that engaged all manner of landscapes from the "wild" to the "domesticated."

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Data Availability Statement. All excavated materials are property of the Instituto Hondureño de Antropología e Historia, which should be contacted for access. It has been the policy of the IHAH to require written confirmation of the excavator's permission; please address requests for letters of support to Rosemary Joyce. Original field records are on file at the Centro Regional of IHAH in La Lima, Cortés, Honduras. Databases resulting from analyses are maintained at Berkeley, and requests for data should be directed to Rosemary Joyce.

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