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I, Angela N Hood , hereby submit this original work as part of the requirements for the degree of Master of Arts in Anthropology.

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Testing the Veracity of Paleoethnobotanical Macroremain Data: A Case Study from the Cerén Site, El Salvador

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Testing the Veracity of Paleoethnobotanical Macroremain Data: A Case Study from the Cerén Site, El Salvador

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Abstract

Archaeological research conducted in 2009 at the Cerén site, a Late Classic Maya village in El Salvador rapidly buried in volcanic ash from the Loma Caldera eruption in A.D. 600, identified intensively cultivated outfields planted in manioc (*Manihot esculenta*) and maize (*Zea mays*) 200 meters south of the habitation area. Ash from Loma Caldera encased plants growing in the outfields when the volcano erupted, and the spaces once occupied by these plants were cast in plaster to reveal an unusually detailed view of an ancient agricultural landscape. A midden comprised of abundant charred paleoethnobotanical macroremains and artifacts was found among these fields. Manioc and maize stems cast in plaster were found to be growing from the midden at the time of the eruption.

This thesis hypothesizes that manioc plant parts would be identified in the midden's assemblage of charred macroremains since the plant's stems grew from the midden. A paleoethnobotanical analysis conducted with the midden assemblage did not identify any manioc plant parts, however. To address the absence of manioc in the form of macroremains, the following questions are posed by this study: Do the plant remains identified from the midden reflect those plants identified in their systemic contexts within the Cerén village and the site's southern agricultural outfields? If the plant remains from the midden and those plants identified in their systemic contexts in the village and outfields are similar, did Cerén's unusual site formation processes contribute to this lack of a preservation bias between the two assemblages? Or does greater parity exist between plant macroremains recovered from the archaeological record and plant resources utilized at ancient Maya sites than archaeologists and paleoethnobotanists currently realize? If the plant remains from the Operation P midden differ from the plants identified in their systemic contexts at Cerén, how can plant use practices, site

formation processes, and recovery/identification biases introduced by archaeologists and paleoethnobotanists contribute to discrepancies between the two assemblages?

This study concludes that the absence of manioc and other plant taxa in the form of carbonized macroremains in the archaeological record does not necessarily preclude their presence and use by the ancient Maya at sites lacking the unique preservation conditions present at Cerén. Incorporating the systematic collection and analysis of both paleoethnobotanical macroremains and microremains into the research designs of archaeological projects in the Maya area will help to bridge the gap between archaeologically invisible plant resources and those used by the ancient Maya.

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First and foremost, I thank the Department of Anthropology at the University of Cincinnati for allowing me to continue my study of anthropology, particularly my committee members, Dr. Vernon L. Scarborough and Dr. Sarah E. Jackson. You have inspired me to read broadly on the ancient Maya, focus on lines of evidence, seek relevance, approach research with creativity, all while keeping the big picture in mind. Your guidance along this journey has been invaluable, and your high standards of academic integrity have set an example that I will follow long after leaving UC.

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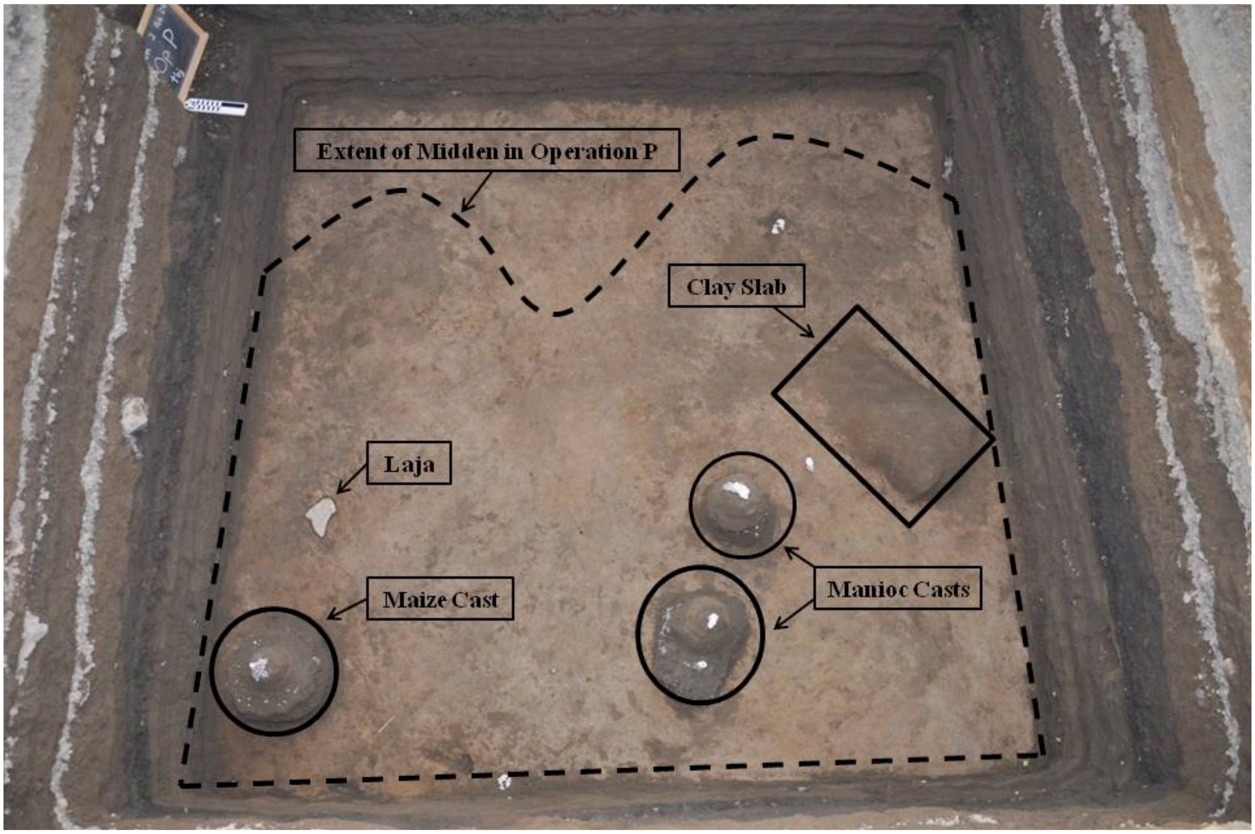
Introduction

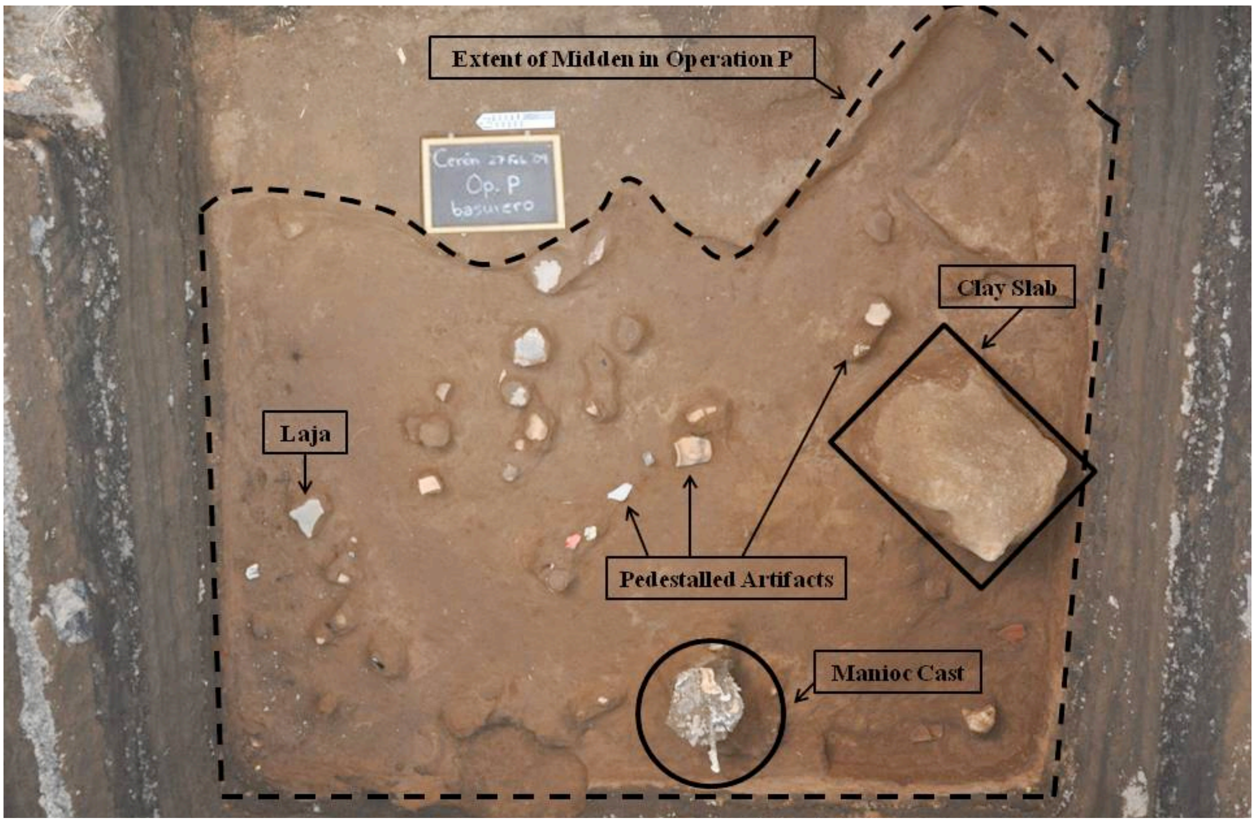
The rapid burial of Cerén in tephra from the Loma Caldera eruption in AD 585-600 (Sheets 1994) preserved plant materials in a manner unprecedented for archaeological sites in the Maya area. Archaeologists have recovered plant remains at Cerén in the form of plaster casts of the hollow impressions left by plants enveloped by tephra at the time of the eruption and as carbonized macroremains, or plant materials large enough to be seen by the unaided eye. The snapshot of plant use practices at Cerén in the minutes preceding the eruption of Loma Caldera has revealed plant resources both commonly found in the paleoethnobotanical assemblages of ancient Maya sites, such as maize (*Zea mays*) and squash (*Cucurbita* spp.), and those rarely found, including malanga (*Xanthosoma violaceum*) and manioc (*Manihot esculenta*) (Lentz and Ramírez-Sosa 2002). This concurrence of common and rare plant remains is starkly exhibited 200 meters south of Cerén's center where intensively cultivated manioc and maize fields were uncovered during the 2009 field season at the site. While investigating the location of a southern boundary for these maize and manioc fields, a 6 cm-thick midden (Figures 1 and 2) was uncovered in Operation P (Figure 3) 6 cm below Cerén's living surface. The Operation P midden contained abundant charred plant remains and artifacts. Manioc and maize stems cast in plaster were found to be growing out of the midden as volunteers when Loma Caldera erupted.

Figure 1. Midden (before excavation) located among manioc and maize fields south of Cerén.



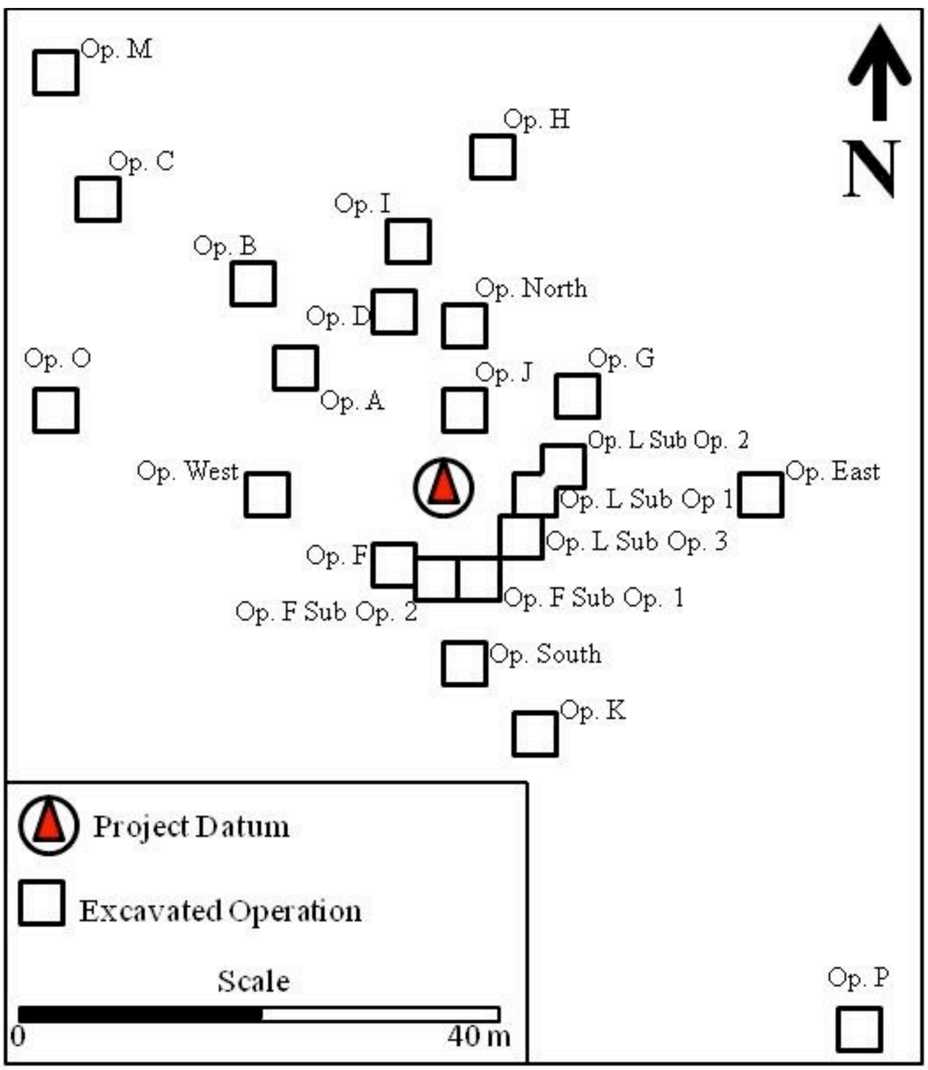
I conducted a paleoethnobotanical analysis of the charred plant remains from the Operation P midden to address the following questions: Do the plant remains identified from the Operation P midden reflect those plants identified in their systemic contexts (Schiffer 1972) within the Cerén village and the site's southern agricultural outfields? If the plant remains from the Operation P midden and those plants identified in their systemic contexts in the village and outfields are similar, did Cerén's unusual site formation processes contribute to this lack of a preservation bias between the two assemblages? Or does greater parity exist between plant macroremains recovered from the archaeological record and plant resources utilized at ancient Maya sites than archaeologists and paleoethnobotanists currently realize? If the plant remains from the Operation P midden differ from the plants identified in their systemic contexts at Cerén, how can plant use practices, site formation processes, and recovery/identification biases introduced by archaeologists and paleoethnobotanists contribute to discrepancies between the two assemblages?

Figure 2. Midden post excavation.



Given that manioc and maize stalks were volunteering from the midden at the time of the Loma Caldera eruption, I approached the analysis of the Operation P midden plant remains with the hypothesis that manioc and maize would be present in the assemblage of the midden itself. I also expected that differences would exist between the plant remains recovered from the Operation P midden and the plants identified in their systemic contexts within the village and outfields. This hypothesis is based on research that finds charred plant remains to be skewed, incomplete sources of evidence for past plant use. Laboratory experiments (Goette et al 1994), comparative studies (Zutter 1999), and ethnoarchaeological research (Jones and Halstead 1995) are often conducted to reconstruct the many causes of these discrepancies. Past plant use practices, as well as cultural and noncultural formation processes have been noted for their distorting effects on the paleoethnobotanical record. Cultural formation processes encompass how human behavior alters plant remains after their actual use (discard, for example) Schiffer 1996:7). Noncultural formation processes are the ways in which the natural environment affects plant remains (Schiffer 1996:7). These variables operate in conjunction to create the assemblages of macroremains that archaeologists collect.

Figure 3. Map of operations excavated during 2009 field season.



Note: Redrawn from Sheets (2009).

Unless plant remains are preserved in arid places, peat bogs, consistently frozen or waterlogged sites (environmental conditions rarely encountered at archaeological sites, especially those in the Maya area), plant macroremains do not preserve unless carbonized (Miksicek 1987:219). Plants become carbonized when heated to 250-500° C in anaerobic or low oxygen environments and before complete combustion reduces them to mineral ash (Braadbaart and Poole 2008:2435). Plant remains in archaeological contexts often become carbonized when burned as fuel, accidentally charred during use/consumption, burned in storage contexts or while in use during an occupational structure fire. A diseased crop might also be purposefully destroyed, among other events (van der Veen 2007:979). Once carbonized, however, plants preserve well under all environmental conditions, although excessive weight or pressure induced by earthquakes and related metamorphic processes can crush remains. Persistent trampling by human agency can significantly alter the integrity of plant remains. Cultural formation processes begin once plant remains are deposited in the archaeological record (via discard, abandonment, etc.) and extend to include the sampling strategies, methods, and analytical techniques employed by archaeologists and paleoethnobotanists to collect and identify these remains. The effects of human activities and noncultural formation processes combine to skew the paleoethnobotanical record toward the preservation of dense plant materials such as wood, nutshells, and cellulose-rich seeds over fleshy fruits, roots, herbs, and oil-rich seeds that generally reduce to ash when burned (Popper 1988:56-57).

The results of the paleoethnobotanical analysis conducted with the Operation P assemblage indicate that significant differences exist between the plant remains recovered from the midden and those found in their systemic contexts within the Cerén village and agricultural outfields. By comparing the two assemblages, this study demonstrates how noncultural and cultural site formation processes, sampling strategies, and identification limitations greatly affect the recovery of plant remains and our interpretations of past plant use practices. A comparison of plant remains from a secondary refuse deposit to plant remains preserved in their systemic contexts by the unusual conditions of rapid burial by volcanic ash also presents a rare opportunity to test the methodological significance and reliability of carbonized macroremains, often the major vestiges of human/plant relationships at archaeological sites.

This study also illustrates the ways in which plant processing techniques and formation processes render some plants invisible in the paleoethnobotanical record. Such a "before and after" glimpse at the plant resources utilized at Cerén is significant because it broadens our understanding of ancient Maya subsistence and plant use practices, one that can be applied to the interpretation of paleoethnobotanical data from other Maya sites and those across Mesoamerica. In this way, Cerén serves as a "laboratory for the testing of assumptions concerning the interpretation of scant remains at sites with a less-informative corpus of plant use data" (Lentz and Ramírez-Sosa 2002:33).

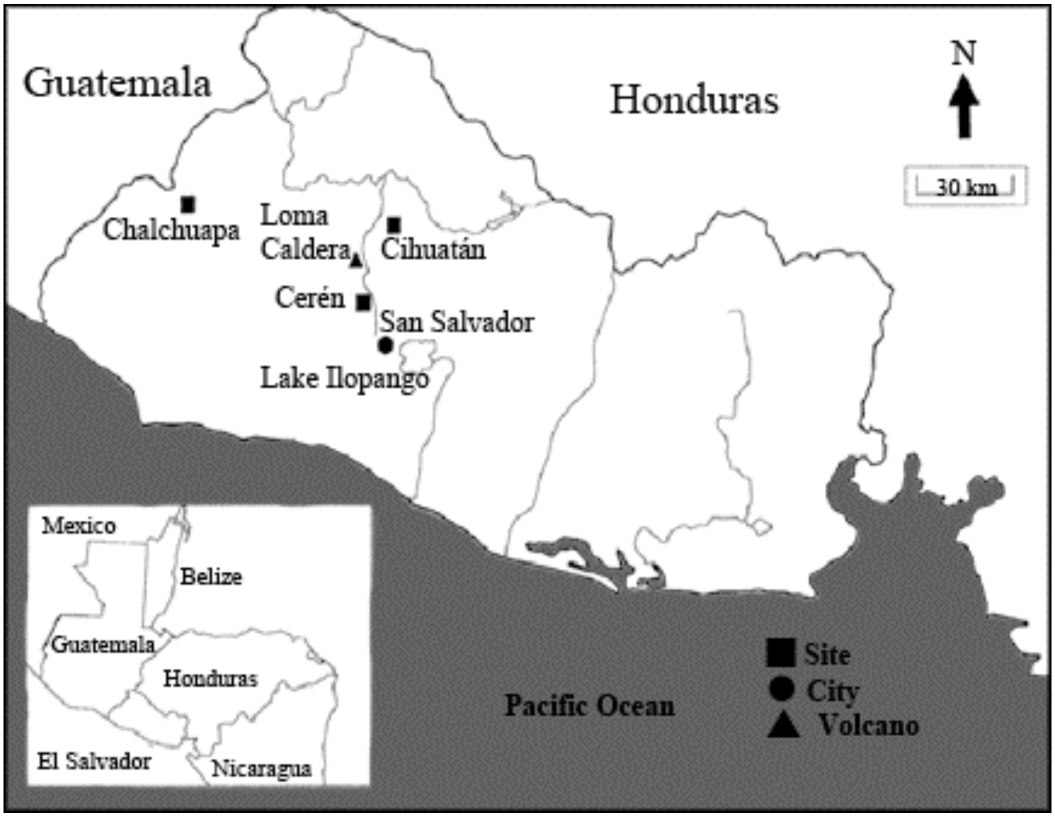
This first chapter focuses on establishing the environmental and cultural setting of the Cerén site, as well as the theoretical context of the research conducted. Chapter 2 discusses the methods and instruments used to recover and analyze paleoethnobotanical remains at Cerén. Results of the paleoethnobotanical analysis conducted with the midden macroremain assemblage are presented in Chapter 3; and Chapter 4 centers on the discussion of these results within the context of the plant remains found in the Cerén village, at other ancient Maya sites, and in Mesoamerica. A concluding chapter summarizes the findings of this study and suggests further work to advance research of past human/plant relationships at Cerén and in the Maya area as a whole. To begin, the following section provides background information about Cerén by describing the environmental setting of the site.

Environmental Setting – Past and Present

Physiographic Setting

Cerén is located in the Zapotitán Valley of north-central El Salvador, adjacent to the town of Joya de Cerén (Figure 4). The Zapotitán Valley lies within a volcanic chain spanning the length of El Salvador, and is bordered by two volcano complexes: Santa Ana to the west and San Salvador to the east (Williams and Meyer-Abich 1955:16). The valley itself, once a Pleistocene lake, is an intermountain basin comprised of tall volcanic peaks surrounding the valley, and the low hills, ravines, and broad plain of the valley floor in which Cerén lies (Black 1983:62). The Río Sucio, so called for the large amount of sediment carried in its waters, flows alongside Cerén and is the principle waterway draining the Zapotitán Valley. Approximately 20 km north of the Zapotitán Valley, the Río Sucio drains into the Río Lempa, which drains all of El Salvador and much of Central America (Daugherty 1969:38).

Figure 4. Map of El Salvador.



Note: Redrawn from Lentz et al. (1996a).

Climate

At an elevation of 450 m asl and a latitude of 14°N, the site is situated within a tropical monsoon climate and annually receives an average of 1,700 mm ±300 mm of precipitation, with 96% of this amount falling between May and October (Sheets 2002:1). The average temperature at Cerén is 24°C (75°F), with lows generally occurring in December dipping down to 22°C (72°F) and the highest temperatures recorded in April at 26°C (79°F) (Sheets 2006:3). The climate in Central America has remained constant over the last 3000 years (Markgraf 1989), so it is reasonable to assume that the current climate is similar to that of the Late Classic Period when Cerén was inhabited.

Flora and Fauna

Large agricultural fields of sugarcane, smallholdings of subsistence crops like maize and beans, stands of fruit trees such as papaya and guava, grasslands, pastures, deciduous brush, and households form the present landscape of the Zapotitán Valley floor (Figure 5). Daugherty (1969) reconstructs the climax vegetation of the Zapotitán Valley floor to be dominated by dense tropical deciduous forest and tropical evergreen forest, with trees such as ramon (*Brosimum alicastrum*), Spanish cedar (*Cedrela odorata*), ceiba (*Ceiba pentandra*), and guanacaste (*Enterolobium cyclocarpum*). Extensive deforestation has left only a few degraded patches of this forest in the valley today. The higher elevations of the volcano complexes in the Zapotitán Valley, between 1,000 m and 2,000 m asl, exhibit small patches of pine and oak, while cloud forest lies above approximately 2,000 m. Like the forests of the valley floor, however, these upland forests have been extensively cleared.

Figure 5. Landscape of the Zapotitán Valley.

Paleoethnobotanical research at Cerén has identified a number of tree taxa that were recovered from household living surfaces as carbonized wood, including fig (*Ficus* sp.), canjuro (*Casearia* sp.), malady (*Aspidosperma* sp.), pine (*Pinus oocarpa*), Spanish cedar (*Cedrela* sp.), aguacatillo (*Nectandra* sp.), escobo (*Prunus* cf. *brachybotra*), and pava (*Cupania dentata*) (Lentz 1996a:Table 1; Lentz and Ramírez-Sosa 2002:Table 4.1). While this combination of deciduous and evergreen tropical species identified within the Cerén village corresponds to Daugherty's reconstruction of the forests that grew in the Zapotitán Valley floor during Precolumbian times, the presence of pine is intriguing. Pine does not grow close to the site today, with closest stands of pine to Cerén located over 10 km away on the upland slopes of the Zapotitán Valley.

The modern landscape of the Zapotitán Valley looks very different from that of the Late Classic period 1,400 years ago, but Precolumbian populations in the Zapotitán Valley also impacted the natural environment around them. In a study of phytoliths extracted from the *tierra blanca joven* (TBJ) living surface of agricultural outfields excavated during the 2009 field season at Cerén, Sheets and colleagues (2011) found samples dominated by grass phytoliths indicating that the area surrounding the site was extensively cleared of forest vegetation. TBJ is the distinctive white ash emitted by the Ilopango volcanic eruption during the Early Classic period (A.D. 400-536) that comprises Cerén's living surface. Phytoliths recovered from clay below Cerén's TBJ living surface show a greater amount of forest indicators (such as Chrysobalanaceae type forms, *Sabal*-type palm, *Heliconia* and *Chusquea*) than those from the TBJ surface, although phytoliths pointing to cleared areas also exist in those earlier samples. In other words, the Preclassic environment of Cerén and its surrounding area was slightly more forested than that of the Late Classic when Cerén was inhabited.

Anthropogenic impacts on plant communities in the Zapotitán Valley also extend to the elimination of savanna habitat. Lentz and colleagues (1996b) identified remains of carbonized perennial grass (*Trachypogon plumosus*) used as thatch roofing atop structures in the village proper, but this grass is no longer evident in the Zapotitán Valley or in El Salvador. *Trachypogon plumosus* likely grew in large quantities within savanna habitats during the Late Classic period in the Zapotitán Valley when Cerén was inhabited, but invasive Old World grass species, agriculture, and overgrazing by livestock has lead to its eradication.

In addition to flora, fauna have been adversely affected by modern deforestation in the Zapotitán Valley. White-tailed deer and peccary remains identified in the Cerén village lack contemporary representatives in the area, although the other mammals recovered from the site – dogs and rodents – have endured (Table 1). Populations of birds have been more resilient through the deleterious effects of modern deforestation (Sheets 2006:7), and the valley is positioned on a main flyway for numerous bird species (Daugherty 1969:94). A duck was found in the storehouse of Household 1, tethered to an interior structural pole with a piece of twine tied to its leg at the time of the Loma Caldera eruption, evidencing the utilization of water fowl by Cerén's inhabitants (Brown 2002:153-154). Unabated pollution emitted into the Rio Sucio upstream from Cerén has completely eliminated a freshwater snail harvested and consumed at Cerén called "jute" (*Pachychilus* sp.) that requires very clean water to survive, a condition that ostensibly existed when the site was occupied (Sheets 2006:39). In addition to freshwater mollusks, marine shells – including spondylus, cowry, and olive shells – were also found at Cerén (Brown 2002:154), likely traded from the Pacific coast and acquired as prestige items by the commoners living at Cerén at markets in nearby Campana San Andrés, the largest site in the Zapotitán Valley and the economic, political, and religious center of the area during the Early and Late Classic (Sheets 2000:221,223).

Table 1. Faunal remains recovered from Cerén.

Mammals	Reptiles	Birds	Mollusks
White-tailed deer (*Odocoileus virginianus*)	Mud turtle (*Kinosternon* sp.)	Duck (Anatidae)	Jute (Freshwater) (*Pachychilus* sp.)
Domesticated dog (*Canis familiaris*)		Unidentified bird	*Spondylus calcifer* (Marine)
Peccary (*Tayassu* sp.)			*Spondylus* sp. (Marine)
Rodent (unidentified)			*Oliva spicata* (Marine)
			Oliva sp. (Marine)
			Cypraea cervinetta (Marine)

Note: Data from Brown (2002)

History of Volcanism

While humans have altered the landscape in the Zapotitán Valley since at least the Preclassic period, volcanic activity has had the greatest effect on the landscape by far, beginning with the Coatepeque volcanic eruption between 40,000 and 10,000 B.C. and continuing into the twentieth century with the Izalco volcano (Table 2). Coatepeque was the first volcanic eruption that may have affected human populations in the Zapotitán Valley, although there is no archaeological evidence to date indicating that the area was inhabited during this Pliocene/Pleistocene period (Sheets 2002:2). The Coatepeque eruption destroyed all plant and animal life within the entire region, but after centuries of weathering, the tephra from this event formed a fertile, clay-rich soil later mined by Cerén's residents for adobe architecture and ceramics (Sheets 2006:9; Zier 1983:134).

Table 2. History of volcanic eruptions in the Zapotitán Valley.

Volcano	Date of Eruption	Effects of Eruption
Coatepeque	40,000-10,000 B.C.	Airfall ash covered region – catastrophic natural disaster; uncertain effects on human populations
Ilopango	A.D. 400-536	Airfall ash covered region – catastrophic natural disaster; all living things within 1,000² km killed
Loma Caldera	A.D. 585-600	Covered 20 km² with 10 m to 10 cm in airfall ash
San Salvador	A.D. 900-1000	Deposited airfall ash in a thick layer in the southeast corner of the Zapotitán Valley, but only 20-30 cm at Cerén
Playón	A.D. 1658	Last airfall ash event, depositing almost 1 m of tephra and covering several square kilometers in lava
San Marcelino	A.D. 1722	15 km² covered in lava
San Salvador	A.D. 1917	Lava flow covered 30 km²
Izalco	A.D. 1770-1965	Continual eruption of lava for nearly two centuries

Like Coatepeque, the next volcanic eruption to affect the Zapotitán Valley, Ilopango, was a regional disaster that decimated plants and animals, and this time human populations as well. Dull and colleagues (2001, 2010) place the Ilopango eruption between the early fifth century A.D. and A.D. 536, when the volcano deposited between 1 m to over 10 m of TBJ in a 25 km radius surrounding the volcano and between 20-50 cm to the northwest, extending beyond El Salvador's border with Guatemala (Dull et al. 2001:Figure 1). The TBJ tephra immediately killed all living things within the 25 km radius of the volcano, while those within approximately 1,000 km² of the volcano were dealt poisonous fumes, contaminated water and food, and a scorched, denuded landscape (Hart and Steen-McIntyre 1983:30). Late Preclassic settlements in western El Salvador experienced complete demographic collapse as a result of the Ilopango eruption, from both the widespread deaths caused by thick TBJ airfall and pyroclastic flows as well as from migration away from the devastated area. Agricultural production would have been impossible for surviving populations living within the 1,000-km^2 surrounding Ilopango volcano. The Zapotitán Valley itself was depopulated after the Ilopango eruption. Black (1983) found no sites dating to the period immediately following the eruption during his survey covering 546 km^2 of the Zapotitán Valley, although 42 Early to Late Classic sites contemporary with Cerén identified during the survey point to communities establishing themselves in the area within a few centuries of the eruption.

Sheets (2006:9) estimates that the Zapotitán Valley was likely abandoned for one or two centuries before human resettlement; in this time the volcanic ash from Ilopango weathered into fertile soil, and plant and animal communities returned to the area. Cerén was one of the first settlements to establish itself in the Zapotitán Valley after the Ilopango eruption, and the site was occupied for approximately one century before Loma Caldera erupted (Sheets 2002:2) in A.D. 585-600 (Sheets 1994). An earthquake, based on large fissures and faults found along the banks of the Río Sucio and within the Cerén village, preceded the ashfall, possibly alerting Cerén's residents to flee the area (Miller 2002:20). After the earthquake, a large fissure opened beneath the Río Sucio 600 m north of Cerén and brought magma into contact with the river, causing a series of explosive eruptions (what volcanologists call hydromagmatic eruptions) that spanned hours or perhaps days, based on comparative studies with historical hydromagmatic eruptions (Miller 2002:15). The ash fell in 14 distinct stratigraphic units at depths ranging between 3-5 m within the Cerén site, collapsing structural elements such as roofs and walls, packing around plants and artifacts, and burying the site completely. Unlike the Coatepeque and Ilopango eruptions, the Loma Caldera event was not a regional disaster and only affected the 20 km^2 surrounding the volcanic vent (Sheets 2006:9).

Subsequent volcanic eruptions depositing airfall ash at Cerén were from the San Salvador and Playón volcanoes. Ash from San Salvador volcano, deposited between A.D. 900-1000, forms the stratum immediately overlying the sequence from Loma Caldera. The present ground surface at Cerén is comprised of ash from the Playón volcano, which has weathered into productive soil for agriculture since deposited in A.D. 1658. The remaining volcanic eruptions in the Zapotitán Valley from San Marcelino, San Salvador, and Izalco volcanoes were lava flows that also occurred in the Post-Conquest era, but these did not impact the Cerén site or the town of Joya de Cerén.

The environmental setting of the Precolumbian Zapotitán Valley was an anthropogenic landscape of forests, grasslands, and gardens that was periodically devastated by volcanic eruptions. While this past was frequently abundant with natural resources, the present Zapotitán Valley has been greatly degraded by industrial pollution, deforestation, and overpopulation. The next section focuses on the social milieu of Cerén and the Zapotitán Valley, as well as unique insights into ancient Maya commoner life imparted by the strong history of archaeological research conducted at Cerén, beginning with a brief summary of Cerén's discovery.

The Cultural Setting

Findings of Archaeological Research at Cerén

Cerén's significance lies in its extraordinary preservation and its ability to inform archaeologists about the everyday lives of commoners who comprised the majority of ancient Maya society. Due to its rapid abandonment and burial in volcanic ash, features of an ancient Maya commoner settlement that generally do not preserve after abandoned endured, such as earthen architecture, artifacts in their systemic contexts, and gardens. When a household is abandoned under less urgent conditions, its residents relocate useful materials before moving elsewhere, and other people in the area often scavenge remaining materials, including architectural elements (Lange and Rydberg 1972). Over time, rain, wind, sedimentation, erosion, wildfires, earthquakes, and other natural events further destroy traces of a household's existence, especially architecture constructed of perishable materials as that found at Cerén. Archaeological research at Cerén has proven so informative because ash from the Loma Caldera eruption froze the village and its environs just as it was 1,400 years ago. Cerén serves as a model for interpreting less well-preserved commoner households and settlements, including those at Chan (Robin et al. 2008) and the Copán Valley (Webster et al. 1997).

A bulldozer operator excavating foundations for a series of grain silos discovered Cerén in 1976. After an archaeologist from El Salvador's National Museum decided that the structural remains were recent, landowners in Joya de Cerén asked Dr. Payson Sheets and his students, who were in the Zapotitán Valley during 1978 conducting an archaeological survey, to examine a structure visible in one of the still-exposed bulldozer cuts. Surprised by the presence of thatch roofing on the structure and the lack of any historic or modern materials therein, Sheets collected some of the thatch for radiocarbon dating to determine the structure's age. The results indicated that it was around 1,400 years old, and Sheets and his students partially excavated two structures at the site before the end of their 1978 field season (Sheets 2006:12-14).

In the years between Cerén's discovery and current research at the site, geophysical surveys have located features of Cerén's Late Classic landscape and guided the placement of excavation operations (Conyers and Spetzler 2002). These geophysical surveys and excavations have uncovered structures belonging to four distinct households, small garden plots and *milpas* (maize fields), a sweat bath, a public building, a religious complex, and intensively cultivated agricultural outfields. The following section gives a brief summary of the structures and landscape features excavated at Cerén to date.

Most structures at Cerén were built upon an adobe platform crafted from the clay-rich deposit lying beneath the site's TBJ living surface. The clay was mixed with grass, constructed into a rectangular platform, and hardened by firing the platform as though it were a large clay brick (Sheets 2006:43). Four adobe columns approximately 1.5 m high were then constructed at each corner of the platform. Walls were added next. Although some structures had solid clay walls (a few household buildings, the sweat bath, and the civic complex), most structures had *bajareque* walls, which are also known as wattle and daub (Sheets 2002:43). In the case of *bajareque* construction, vertical poles were set into the platform at 20 cm intervals. Horizontally oriented vines were then tied to the vertical poles to reinforce the wall; the same clay and grass mixture used to construct the adobe platform was packed around the latticework of poles and vines to finish the walls. The *bajareque* walls abutted the solid adobe columns but were not connected, rendering these structures less vulnerable to total collapse in the case of a strong earthquake (Sheets 2006:44). Thatched roofs were connected to the tops of the vertical poles and further supported with wooden posts attached to the adobe columns. Interior architectural elements varied and included benches (raised adobe platforms within the structure used for sitting, sleeping, and other activities), cornices, niches, and *tabancos* (high shelves).

Household structures are the most common buildings uncovered at Cerén. Based on the spatial distribution and function of individual structures, extramural activity areas, and walkways, four distinct households have been identified at the site (Sheets 2002:43). Household 1, the most thoroughly excavated household at Cerén, is represented by four structures: a domicile (where meals would have been eaten and people would have slept), a ramada (an earthen platform with no walls and a thatched roof), a storehouse, and a kitchen (Beaudry-Corbett et al. 2002:45-51). Extramural spaces surrounding Household 1 include a small maize *milpa* and a kitchen garden growing piñuela (*Bromelia pinguin*), malanga (*Xanthosoma violaceum*), cebadilla (*Schoenocaulon officinalis*), and manioc (Sheets and Woodward 2002:189). All of these plants were identified through the plaster replacement technique that created casts of the plants growing at Cerén when Loma Caldera erupted. Both the *milpa* and kitchen garden were planted upon ridges constructed from the TBJ tephra, and each ridge was flanked on both sides by U-shaped furrows (Figure 6). Based on an abundance of spindle whorls, metates, and other groundstone tools found at Household 1, Beaudry-Corbett and her colleagues (2002) argue that its residents may have produced a surplus of thread, ground maize, and groundstone tools for exchange with other households at Cerén and perhaps as payment for exotic goods at markets in Campana San Andrés or other sites. Surplus thread and ground maize was not found in storage contexts within Household 1, however.

Figure 6. Ridges and furrows of a *milpa* in the Cerén village.

With fewer structures exposed than Household 1, Household 2 comprises a domicile and a storehouse (McKee 2002a:59-64). Two *milpas* were found growing to the east and south of Household 2 in the same planting beds constructed of ridges and furrows observed at Household 1. Paint fragments, hematite, and cinnabar uncovered in the storehouse of Household 2 indicate that the production of painted organic materials (possibly gourds) was a craft specialization undertaken by the household's members (McKee 2002a:70). Household 2 is also in close proximity to a sweat bath, and McKee (2002a) argues that the residents of this household likely built and maintained the structure for themselves and others in the community. This sweat bath is unique in Mesoamerica, as it represents the only adobe sweat bath excavated in this region to date (Sheets 2006:96). The structure's interior contains a fire chamber feature constructed of river cobbles that was likely doused with water when hot to create steam, along with a circular vent in the domed earthen roof to vent smoke from the fire chamber (McKee 2002b:94). Masonry sweat baths have been identified at other sites in the Maya area, including Tikal (Coe 1967), Chichén Itzá (Ruppert 1951), and Piedras Negras (Cresson 1938, Satterthwaite 1952), for example. The interpretation of these buildings as sweat baths derives from ethnographic analogies of sweat baths observed in highland Mexico and Guatemala, which were used for personal hygiene, medicine, and ritual purposes (Redfield 1930).

Households 3 and 4 are only known for their kitchen and storehouse, respectively. The kitchen used by the residents of Household 3 is only partially excavated, but a metate, portions of a hearth, and a large storage vessel strongly support this interpretation of the structure's function (Calvin 2002). The storehouse for Household 4 has been completely excavated, and it was used to store maize within a crib of *bajareque* construction; a metate with cottonseed (*Gossypium hirsutum*) fragments on its surface; and vessels storing more cottonseeds, cacao (*Theobroma cacao*), and chiles (*Capsicum annuum*) (Gerstle and Sheets 2002; Lentz and Ramírez-Sosa 2002:Table 4.1). The ample exterior space sheltered by the storehouse's thatched roof functioned as a workshop producing agave (*Agave* sp.) fiber for rope-making, evidenced by wooden tools tied to the northern end of the structure that were used to extract the useful fibers from agave leaves. Extensive cracks observed in this portion of the clay floor indicate that the wet pulp of the leaf often came into contact with this surface (Sheets 2006:86-87). A plot of approximately 70 agave plants were growing south of the storehouse at the time of the Loma Caldera eruption, further substantiating the inference that agave fiber production occurred at this structure. A row of chile plants growing to the west of the storehouse, a cacao tree to the south, and a guava (*Psidium guajava*) tree were also identified during the structure's excavation (Gerstle and Sheets 2002:79).

The remaining structures identified at Cerén are not domestic buildings, but rather components of a civic complex and a religious complex. The civic complex is comprised of a public building, a storehouse, and a large plaza (Gerstle 2002). The public building is the largest structure to be uncovered at Cerén to date, and its small assemblage of artifacts compared to that of household structures indicates that it was not a domestic space. Two large benches in the public building's front room were likely seats of authority where community elders settled disputes and made decisions for the village (Sheets 2006:96). Only partially excavated, the storehouse associated with the public building contains a turtle carapace and unusual ceramic vessels, and Gerstle (2002) argues that these specialized artifacts may have been in storage for community events that would take place in the plaza.

A structure used as a staging area for community feasts and festivals and a space for divination represent the religious complex. While mostly used for storage, the structure used for feasts and festivals was also a locus for food preparation, as evidenced by a metate, two hearths, faunal remains, and stored maize, beans (*Phaseolus* sp.), and squash (Brown and Gerstle 2002). The ceremonial nature of this feasting is inferred from a deer skull headdress found on an elevated shelf in the building and a well-maintained area of hard-packed TBJ tephra around the structure purposely kept free of artifacts and plants where community rituals likely took place. Associated with this building is a structure that was used for the practice of divination. Based on an artifact assemblage of a female figurine, manos, metates, and spindle whorls, a woman likely practiced divination there (Sweely 1995). Simmons and Sheets (2002) propose that a set of minerals, a pile of beans, and curated obsidian blades found in the structure served a purpose similar to the ritual tools comprised of the same materials used by diviners in Mesoamerica today.

The most recent excavations at Cerén have shifted south of the village proper to investigate whether Cerén's residents maintained agricultural fields beyond this habitation area. In 2007 and 2009, intensively cultivated maize and manioc beds were uncovered in this area. Like the *milpas* and kitchen gardens in the village, the maize and manioc growing in the southern outfields were planted in series of ridges formed with weathered TBJ tephra separated by furrows. The manioc, however, was planted upon ridges seven to ten times larger in size and over a larger total area than those found in the village (Sheets 2009:6). Also, the amount of manioc plants growing in the southern outfields far outnumbers the few manioc plants observed in the village, leading to the realization that manioc was a staple crop at Cerén (Sheets et al. 2011). While manioc has been recovered in the form of macroremains (Miksicek1991:180) and pollen (Pohl et al. 1996:362) from other sites in the Maya area, the plaster casts of manioc at Cerén is the most substantial evidence for the root crop in Mesoamerica to date.

In 2011, research at Cerén continued to explore the extent and organization of maize and manioc agriculture south of the village. While excavating operations to investigate land-use lines between maize and manioc outfields, archaeologists identified a *sacbe* (plural: *sacbeob*), or roadway, along the southern boundary of the Joya de Cerén archaeological park. The feature has an estimated length of 42 m, an average width of 2 m, and an average height of 21 cm (Dixon 2011:64). The *sacbe* was constructed by layering and compacting basket loads of TBJ tephra to create a raised platform (Dixon 2011:67). Two canals extend alongside the eastern and western sides of the *sacbe*, and TBJ tephra was likely removed from these canals to create and maintain the *sacbe*. The canals also functioned as a means of draining water from the *sacbe*.

The discovery of the *sacbe* at Cerén is significant for several reasons. First, the Cerén *sacbe* represents the only evidence of a *sacbe* with a completely earthen construction in the

Maya area (Sheets 2011c:125). *Sacbeob* found in the Maya area generally exhibit a more durable construction of stone and limestone plaster (Folan 1991:222). Also, *sacbeob* had only been found at polity centers (such as Tikal and Caracol) and secondary regional centers until the Cerén *sacbe* was uncovered (Chase and Chase 1996; Sharer and Traxler 2006). The presence of an earthen *sacbe* at a small farming village such as Cerén indicates that such development of the ancient Maya landscape could be accomplished by a small community effort, rather than corvée labor. The presence of a *sacbe* at Cerén demonstrates that *sacbeob* may have been present at other commoner sites in the Maya area. Although it is certain that Cerén's residents used the *sacbe* as a path between their households and outfields, Dixon (2011) points out that the southern orientation of the *sacbe* could lead to Campana San Andrés, the primary regional center of the Zapotitán Valley located 5 km south of Cerén. While this hypothesis requires further investigation, the possibility that ancient Maya commoner communities were connected by *sacbeob* to other small communities, primary and secondary regional centers, and polities renders this underrepresented segment of society as more socially, economically, ideologically, and politically integrated than previously thought.

Now that the findings of archaeological research at Cerén have been presented, discussion will now turn to the broader cultural milieu in which Cerén existed.

The Cultural Context of Cerén

Cerén was one of many settlements in the Zapotitán Valley when the Loma Caldera erupted. Black (1983) estimates that the population of the entire Zapotitán Valley during the late Early Classic/Late Classic period (AD 600-900) ranged between 40,000 and 100,000 people (70-180 people/ km^2) based on his archaeological survey of the area. A variety of sites contemporary with Cerén were identified during the survey, including small to large villages, hamlets, isolated ritual precincts, large villages with ritual construction, secondary regional centers, and the primary regional center of Campana San Andrés (Black 1983:72). The settlement system of the Zapotitán Valley was hierarchical, with Campana San Andrés at the top and the most numerous site-type in the valley – isolated hamlets – at the bottom (Sheets 2002:3). The most populous site in the Zapotitán Valley with a population in the thousands, Campana San Andrés functioned as the political, religious, and economic center of the valley (Sheets 2000:217). An extensive ritual complex with an elevated plaza, pyramidal mounds, and platforms indicates that Campana San Andrés held large-scale religious events that would have involved communities from across the Zapotitán Valley, including Cerén (Black 1983:80; Sheets 2006:11). Campana San Andrés, as mentioned above, was also the economic center of the valley, and elites there organized the trade of exotic items into the area such as the obsidian, jade axes, marine shells, and Copador ceramics found at Cerén. These trade items evidence interaction of some kind between the Zapotitán Valley and the southern highlands in present-day Guatemala (Ixtepeque obsidian), the Motagua Valley of Guatemala (jade source), the Pacific coast (marine shells), and the Copán Valley of Honduras (Copador ceramics) (Sheets 2000:220-222).

There are two Late Classic secondary regional centers, La Virgen and La Cuchilla, in the Zapotitán Valley, and substantial pyramidal architecture, elite residences, and occupational specialists distinguish these sites (Black 1983:79; Sheets 2000:217). Like Campana San Andrés, it is likely that elites at these secondary regional centers played a role in distributing exotic goods to smaller villages and hamlets, evidenced by obsidian implements and debitage indicating the processing of obsidian macrocores by occupational specialists at La Virgen and La Cuchilla (Sheets 1983:215). Since these two sites were discovered with a survey sampling 15% of the Zapotitán Valley, it can be inferred that an actual total of 13 secondary regional centers were contemporaneous with Cerén (Black 1983:77). Sheets (2000) argues that commoners at smaller settlements such as Cerén may have chosen to acquire exotic trade items from the numerous secondary regional centers rather than Campana San Andrés because these peripheral elites may have offered better prices or other social, kin, and economic benefits. Rather than an economic relationship characterized by inequality and exploitation, it appears as though commoners in the Zapotitán Valley had considerable leverage to negotiate the price of trade commodities controlled by elites at Campana San Andrés and secondary regional centers.

Beneath secondary regional centers in the settlement hierarchy of the Zapotitán Valley were large villages with ritual construction (smaller pyramidal architecture), large to small villages, and hamlets (Sheets 2002:3). Cerén itself is characterized as a small village whose population was probably around 100 (Sheets 2000:217). Although a great degree of diversity between commoner communities and households undoubtedly existed during the Late Classic period in the Zapotitán Valley, the extraordinary preservation at Cerén provides a model through which these less extensively excavated commoner sites can be understood. Like Cerén, these villages and hamlets primarily engaged in agrarian activities, cultivating maize, beans, squash, and perhaps manioc. Most material goods were produced within a community, such as architecture, food, groundstone tools, cloth, fiber for rope and net bags, most ceramics, and gourd vessels. With the civic and religious complexes at Cerén as evidence, it is reasonable to argue that commoner villages and hamlets had the autonomy to settle internal disputes and to engage in religious activities distinct from those large-scale events held at Campana San Andrés.

With the environmental and cultural setting of Cerén established, it is important to consider the theoretical framework within which archaeological data from Cerén can be integrated to create and test hypotheses. Household archaeology is the prevailing body of theory employed to interpret archaeological findings at Cerén, and the next section defines household archaeology, discusses its theoretical and methodological antecedents, the current applications of the theoretical framework, and how household archaeology has been employed to research and contextualize the extraordinarily preserved remains of Late Classic village life at Cerén.

The Theoretical Context

The theoretical framework of household archaeology has guided research at Cerén since the site was discovered (Sheets et al. 1990). Household archaeology focuses on households as units of analysis investigated to reconstruct the human behaviors that created the material remains of settlements (Ashmore and Wilk 1988:11). As defined by Wilk and Rathje (1982), a household is comprised of (1) a demographic unit that does not necessarily co-reside in the same dwelling but cooperates socially and economically; (2) the structures, activity areas, and material culture used by the household; and (3) the activities performed by the household members. Specifically, the activities central to a household include the production of food, housing, tools and other materials; the distribution of resources within the household (pooling) and between households (exchange); the transmission of land, property, roles, and rights between generations; and the reproduction of children inculcated in the prevailing cultural norms (Wilk and Rathje 1982:621). Since households were one of the most basic and numerous social units of ancient Maya society, understanding individual households and how they articulate both synchronically and diachronically at varying spatial scales (within a single settlement or across a region, for example) is a means of exploring questions of economic, political, social, and ecological continuity and change.

Household archaeology has its origins in the early days of Maya archaeology, extending back to Edward H. Thompson's excavations of small house mounds around Labná in northern

Yucatán during the late nineteenth century (Thompson 1892). It was settlement archaeology, however, that first integrated studies of small-scale households such as Thompson's with the extensive research on monumental architecture at polity centers to investigate how sites functioned, changed, and related to one another across the ancient landscape. Settlement archaeology itself has roots in cultural ecological anthropology, which emphasized the interplay of ecological processes and cultural change over the stylistic analysis of artifacts stressed by culture-historical archaeology (Steward and Setzler 1938). Gordon Willey, aside from beginning the practice of settlement archaeology with his regional survey of the Virú Valley in Peru (Willey 1953), was the first to apply the methodological approach of settlement archaeology to the Maya area with his settlement survey of the Belize Valley region surrounding Barton Ramie (Willey 1956). Through settlement archaeology, household research in the Maya area took on a processual approach as well as a focus on reconstructing the human behaviors behind the material remains of the archaeological record. Processual approaches to archaeology examine how and why archaeological phenomena change through time (Trigger 1996:314).

To make sense of an often incomplete and poorly preserved record of household life, practitioners of household archaeology in the Maya area have incorporated ethnography, ethnoarchaeology, and ethnohistory to bridge the middle-range theory gap separating perceptible archaeological phenomena from the imperceptible human behavior that created it along with noncultural formation processes (Binford 1977:1-10). Archaeologists excavate houses, not the social units of households, after all (Wilk and Rathje 1982:618). For example, Vogt's (2004) participant-observation research in Chiapas, Mexico with the Zinacantan Maya during the 1950s has been useful to archaeologists seeking analogies for archaeologically unobservable aspects of household and community organization among ancient Maya commoners. Ethnoarchaeology, the study of modern societies' creation, use, and disposal of material culture (including architecture) and how it relates to the explanation of archaeological phenomena, has played an important role in household research in the Maya area. Examples of ethnoarchaeological research include studies testing whether house size correlates to social position, occupation length, or wealth (Wilk 1983), and extrapolating the presence and function of ancient household activity areas through soil chemical signatures on the surfaces of modern Maya houses (Fernández et al. 2002). Chase (1993) compares ethnohistoric descriptions of the spatial distribution of elite and non-elite Maya houses to those excavated at Late Postclassic Santa Rita Corozal and Mayapan and finds that, while a useful data source, ethnohistoric accounts actually minimize the varied social organization exhibited by Precolumbian houses. Practitioners of household archaeology are keenly aware of such normalizing effects; Allison warns that "the diversity of human behaviour [*sic*] in the past is often blurred or even obliterated by use of analogy, even at the level of household activities" (Allison 1999:5). Thus, interpreting ancient households through the lens of modern and historic analogs must be done in a critical manner.

Along with the complementary data sources of ethnohistory, ethnography, and ethnoarchaeology, household archaeology has adopted aspects of the postprocessual theoretical movement within archaeology. Postprocessual archaeologists generally reject positivism (the philosophical system privileging the scientific method for making knowledge claims over methods that do not rely on direct observation) as an objective means of investigating archaeological phenomena and argue that all interpretations of the past are inherently subjective (Trigger 1996:452). Allying themselves with postmodernism, postprocessual archaeologists argue for the existence of multiple truths based on relativism rather than a single narrative. The role of archaeologists, according to postprocessual archaeologist Ian Hodder (1984), is to offer information to individuals so they can construct their own understandings of the past. Postprocessual archaeology also argues against processual archaeologists' emphasis on ecological factors influencing human behavior. Rather, explanations of human behavior should be culture-centric, and the past imbued with a sense that human agency and social realities were driving forces of change.

Instead of flatly renouncing positivism and processual approaches, household archaeology has incorporated the postprocessual movement by pursuing a more "peopled" reconstruction of the past (Robin 2003:309). This has meant shedding more light on ancient Maya commoners, women, slaves, and neighboring non-Maya groups – segments of ancient Maya society that have been historically excluded from the research of archaeological projects in the Maya area focusing on elite temples, palaces, tombs, and other monumental architecture (Sheets 2006:20). To this end, household archaeologists have made use of feminist theory to stress the diversity of actions and social relations within households (Hendon 1996:48) and practice theory (Bourdieu 1977) to analyze how behavioral patterns, beliefs, performance, and everyday actions subvert and perpetuate social structures.

The development of household archaeology in the Maya area has closely followed the historical trajectory of archaeological theory and methods. By integrating aspects of settlement archaeology, cultural ecology, middle range theory, ethnoarchaeology, processual and postprocessual archaeology, and practice theory, among others into the theoretical framework of household archaeology, Mayanists have sought to describe and explain the great heterogeneity observed among households (Marcus 2004:265). The snapshot of daily life offered by the sudden burial and rapid abandonment of Cerén exemplifies this precedent for household diversity observed at sites lacking its unique preservation conditions. Cerén also offers a distinct opportunity to include ancient Maya commoners into narratives of ancient Maya society. Commoners comprised the largest segment of ancient Maya society, but their visibility in the archaeological record is often obscured by the perishable materials used to form their household structures. Robin (2003) points to paleoethnobotany in particular as an important methodological tool for peopling the past and accessing an "invisible-universe dataset" used with other lines of evidence such as architecture and artifacts to create stronger interpretations of household life. For the study of the ancient Maya, household archaeology offers a dynamic body of theory to form and test hypotheses on the social, economic, political, and ecological articulation of *all* ancient Maya households.

Summary

Cerén is a small farming community inhabited during the Late Classic period. The site was rapidly abandoned in approximately AD 600 when a volcanic vent opened beneath the Rio Sucio and buried the village with 3-5 m of tephra. This rapid burial preserved earthen architecture, artifacts, and perishable materials in a manner unprecedented for sites in the Neotropics where the warm, wet climate quickly deteriorates organic materials and adobe structures. The volcanic ash also preserved plants growing at Cerén by encasing them; although the plants themselves decomposed in the years following the Loma Caldera eruption, the negative space they once occupied endured. Plaster casts of the plants growing at the time of the eruption have been made during the many years of research at Cerén, affording a uniquely detailed view of ancient Maya plant use and agricultural practices.

Agricultural outfields intensively cultivated with maize and manioc were discovered 200 m south of the Cerén village in 2007 and 2009, and among these outfields, a midden with large amounts of charred paleoethnobotanical macroremains was uncovered. The study presented in this thesis focuses on the results of a paleoethnobotanical analysis conducted with charred plant remains from the midden and flotation samples taken from excavated portions of the outfields, and their relationship to those plants preserved as plaster casts and the charred plant remains found in the Cerén village. Comparing the charred midden and outfield plant remains to those preserved under unusual conditions across the rest of the site provides as an unparalleled opportunity to test the veracity of paleoethnobotanical macroremain assemblages as representatives of past plant use.

Now that the environmental, cultural, and theoretical settings of Cerén have been discussed, the methods and materials used to collect and analyze the paleoethnobotanical macroremains central to this study will be presented.

Chapter 2
Research Methodology

Field and laboratory methods are vital to both the recovery and analysis of paleoethnobotanical macroremains, and these practices are the focus of this chapter. First, the field methods employed to recover paleoethnobotanical macroremains during the 2009 field season at Cerén will be presented, followed by a description of the laboratory procedures and instruments used for the analysis of the macroremain assemblage. Throughout this discussion of methods, I'll also point out my own contributions to field research at Cerén during my stay in Joya de Cerén from February 22 to March 15, 2009, and my laboratory-based paleoethnobotanical research conducted at the University of Cincinnati.

Field Methods

Research during the 2009 project at Cerén was guided by the geophysical survey and excavations conducted by Dr. Payson Sheets and colleagues in 2007 that initially located the large, intensively cultivated manioc and maize beds 200 m south of Cerén's center. Operations measuring 3 m^2 and oriented due magnetic north were excavated and documented by an exceptional crew of local Salvadoran workers, professors Dr. Sheets and Dr. David L. Lentz, and their students, including myself, Christine Dixon, George Maloof, and Andrew Tetlow. Excavations were located in the area immediately surrounding the manioc beds uncovered during the 2007 field season and at a distance of up to 54 m apart. These operations were excavated to further investigate planting techniques used in these manioc plots, caloric production of manioc per unit area, and agricultural field maintenance practices (Sheets 2009:1). Some operations were expanded with 3 m^2 suboperations to build a better understanding of variability across this agricultural landscape and to locate the extent of individual planting beds.

Operations were excavated stratigraphically, following the well-studied Cerén sequence described by Miller (2002), beginning with Unit 15, a 20-50 cm thick, organic-rich colluvium that comprises the ground surface of the project area. As the 2009 project area is regularly planted in crops, the topsoil was carefully excavated and kept separate to be backfilled last to ensure the fields' continued agricultural productivity. The subsequent stratigraphic units (Units 14 through 4), were excavated with picks and shovels, for these strata of tephra deposited by the Loma Caldera eruption lack archaeological materials. Upon uncovering Unit 3, careful excavation techniques using trowels and whiskbrooms were employed, for this is the stratigraphic unit in which plant cavities have been initially identified at Cerén. When encountered, these cavities were secured with paper plugs to mark their locations and to prevent infill from extraneous tephra or internal collapse. In cases of unusual or potentially significant cavities, a fiber optic proctoscope was used to examine the shape and extent of the cavity and to estimate the amount of dental plaster needed to cast the cavity. A solution of dental plaster and water was poured into cavities and allowed to set for several hours (Figure 7). The plant cavities were then pedestaled as excavation of Units 3, 2, and 1 continued, until the living surface of the TBJ surface of the Cerén occupation was encountered at a depth of approximately 3 m.

Figure 7. Casting cavities in tephra with plaster: (a) pouring plaster into a pedestaled cavity; (b) a partially excavated manioc cast.

The features uncovered across this living surface included planting ridges and furrows, eroded planting beds, level areas cleared of vegetation, platforms, a footpath, and a clay slab possibly used as a field boundary marker. These features were recorded with measurements and photographs. The slope of planting ridges, furrows, and platforms; the distance between the highest point of each planting ridge; the depth of each furrow; and the directional orientation of the planting ridges comprise the standardized set of measurements recorded for each operation. Plant cavities extending beneath these features of the living surface (roots, for example) were also cast in dental plaster. The location of each plant cavity in relation to surrounding features was recorded by assigning each a unique number identifying its position within an operation and by extensively photographing each operation. Once recorded in situ, plant casts were carefully excavated from their tephra matrix with bamboo tools and small paintbrushes.

Carbonized paleoethnobotanical macroremains were collected from Cerén as they were encountered during excavation by all project members and by processing soil samples with water flotation. I conducted flotation processing along with three of the project's Salvadoran crewmembers, with Dr. Lentz's supervision. Along with the 3,687 macroremains collected during excavation, 126 liters of soil from the 2x3 m, 6 cm thick Operation P midden was collected for flotation processing by the Salvadoran crew, Dr. Lentz, and I. Five additional 2-liter soil samples were collected from Operations F, M, and L, for a total of 136 liters of soil processed. A modified Apple Creek water flotation system (Pearsall 2000:15) was employed to process the soil samples (Figure 8). This technique was employed during past paleoethnobotanical studies at Cerén (Lentz et al. 1996a, 1996b; Lentz and Ramírez 2002) because it befits both the limited water supply in Joya de Cerén and the desired retrieval efficacy for macroremains. Each two-liter soil sample was added to a basin containing approximately 6 gallons of water, and the soil was gently agitated by hand to liberate carbonized plant materials from their matrix, or the heavy fraction. A light fraction of charcoal and other carbonized plant remains floated to the water's surface and were collected by pouring water from the basin into a fine mesh screen (150 µm sieve opening). The light fraction of each sample was carefully removed from the screen and dried between several layers of paper. When dry, the carbonized plant remains of the light fraction were placed in paper bags labeled with the samples' provenience information and sealed for transport to Dr. Lentz's Paleoethnobotany Laboratory at the University of Cincinnati for further analysis with stereomicroscopy and environmental scanning electron microscopy (ESEM).

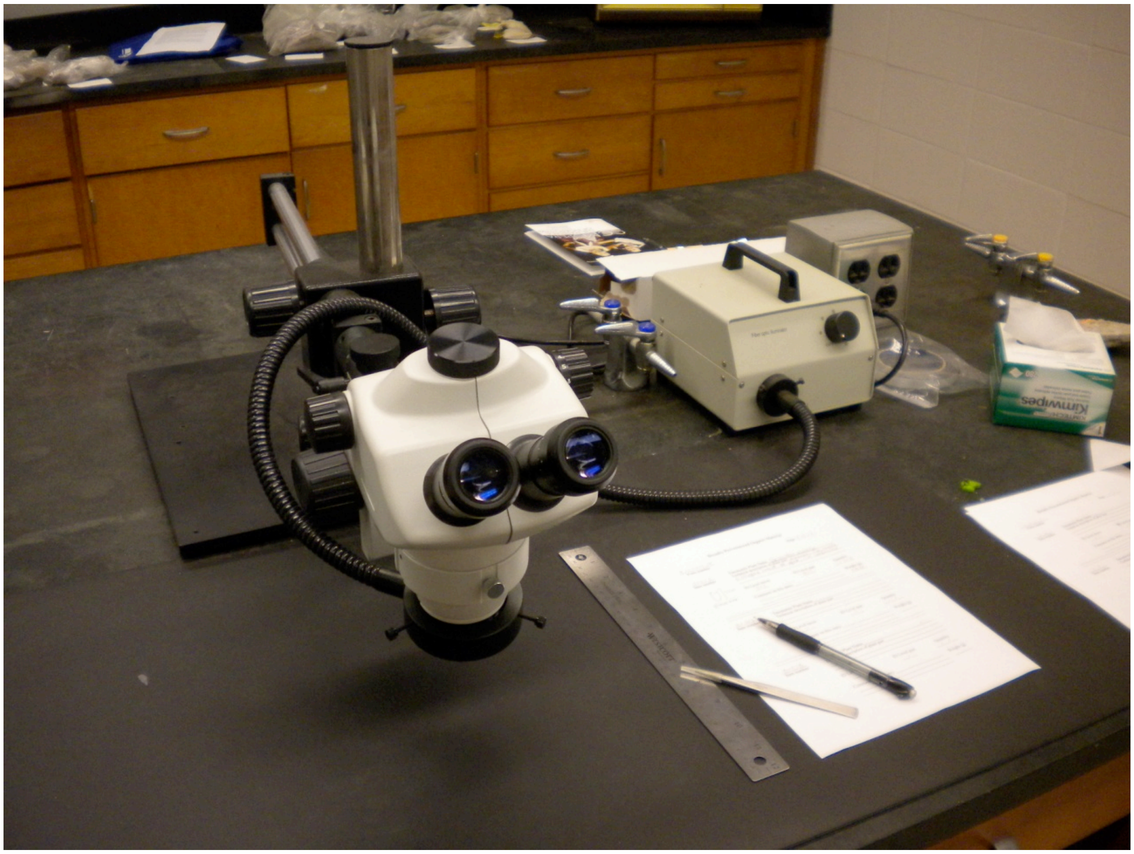
Figure 8. Flotation Procedure: (a) adding 2 liters of a flotation sample to the basin; (b) agitating the sample to separate plant remains from the tephra matrix; (c) pouring light fraction into a 150 μm sieve; (d) light fraction drying between pages of newspaper.

Laboratory Methods

Analyzing Macroremains

Once returned to Lentz's laboratory from El Salvador, I sorted all macroremains based on a broad classification separating wood charcoal, seeds, rinds, and amorphous plant tissue with the aid of a stereomicroscope (8-50X) illuminated by a fiber optic light (Figure 9). I divided wood charcoal into two size fractions with a 2.0 mm geological sieve: wood charcoal larger than 2.0mm was analyzed, while wood charcoal smaller than 2.0 mm was not examined further. I chose this sampling strategy because wood charcoal smaller than 2.0 mm is generally unidentifiable to species, genus, or broader taxonomic categories (i.e. hardwood, pine, or palm) (Pearsall 2000:107; Lentz 1991:272).

Figure 9. Stereomicroscope and fiber optic light used for analysis.



I examined all other macroremains individually with stereomicroscopy for identification. The anatomical and morphological features I used to identify plant remains during analysis are summarized in Table 3. I broke wood charcoal specimens by hand to reveal a fresh transverse section from which to observe features useful for identification, such as vessel arrangement, parenchyma, size and arrangement of rays, resin canals, and vascular bundles. These features permitted the identification of three taxonomic categories: Angiosperms (hardwood), *Pinus* sp. (pine), and Arecaceae (palm). I examined whole and fragmented seeds and noted the color and texture of their seed coats, the amount of endosperm and its position in relation to the embryo, the position and characteristics of the hilum (the attachment scar on a seed from where it was once connected to the ovule), and other features described in Table 3. Roots, stems, and rinds were also broken by hand to examine anatomical structures in transverse section.

Table 3. Anatomical and morphological features used to identify plant remains.

Wood	Seed	Fruit	Roots and Tubers	Leaves and Stems
Vessel size, quantity, and arrangement	Size and shape	Pericarp and endocarp thickness Texture and surface characteristics	Presence/absence, size, shape, and arrangement of leaf nodes	Leaf form, venation, epidermis
Parenchyma arrangement and abundance	Color and texture of seed coat	Attributes of endosperm and embryo	Presence and thickness of periderm	Leaf arrangement on stem
Size and arrangement of rays	Amount/ presence of endosperm and its position relative to the embryo	Presence of attachment scars and sutures	Surface characteristics	Bud type and bud-scale arrangement on stem
Presence of tyloses	Presence and form of hilum	Surface appearance	Stem or leaf base attachment scars	Attachment of stem vascular tissue
Size and position of resin canals	Attachments (spines, awns, bristles, pappus)	Texture of epidermis		
Earlywood and latewood transition	Pollination scar	Cell structure of fruit rind		
	Number of cotyledons	Form of peduncle		

Regardless of plant part, I made scaled sketches of all specimens alongside their taxonomic plant name and a technical description of the plant part. A "confidence rating" ranging between 01 and 03 (01 representing complete confidence in the identification, 02 partial confidence, and 03 no confidence) was assigned to each specimen to gauge how certain I was of the accuracy of my identification. All 02 and 03-rated specimens were kindly reviewed by Dr. David Lentz. In addition to descriptions of plant remains, I also recorded the quantity and weight of specimens on analysis sheets. I weighed specimens with a Mettler BD202 electronic balance with a capacity of 0.01 g to 200 g. Examples of completed analysis forms from this study can be found in Appendix A. Identifications were aided by comparative material in Dr. Lentz's extensive reference collection of plants from Central America. Seed and wood identification manuals and botany textbooks also proved useful for identification purposes, and these resources include Core et al. (1979), Esau (1977), Lentz and Dickau (2005), Martin and Barkley (1961), Pearsall (2000), and Raven et al. (2005). Specimens I considered to be good candidates for further examination with ESEM – plant remains with anatomical features that might indicate their taxonomic family, genus, and/or species – were noted as such on the analysis forms and later prepared for further study. A detailed discussion of ESEM methods and instruments is presented below.

Sorting Flotation Samples

While plant remains recovered from flotation samples were analyzed using the same methods described above for macroremains, the plant remains contained in the light fractions of flotation samples were interspersed with non-cultural materials (small rocks, small pieces of volcanic glass, and insects, for example) and had to be separated. First, I poured an entire bag of light fraction from a 2 liter flotation sample into a 2 mm geological sieve and gently shook it to separate materials > 2 mm from those < 2 mm. I examined these two size fractions separately with a stereomicroscope. I removed all plant materials from the > 2mm size fraction from the non-cultural material and analyzed them, while all plant materials except wood charcoal were removed from the < 2mm size fraction. As discussed above, wood charcoal smaller than 2mm is rarely identifiable even to broad taxonomic categories and was excluded from the assemblage. When I encountered plant remains in a light fraction sample during sorting, I placed them in empty size 00 gelatin capsules using a pair of forceps or a paintbrush and stored in paper bags labeled with the sample's provenience information until the sample was completely sorted. I then individually analyzed each plant remain sorted from the sample following the procedure described above for macroremains.

Environmental Scanning Electron Microscopy (ESEM)

ESEM provides a greater depth of field than that offered by a stereomicroscope to observe features useful for identifying paleoethnobotanical macroremains, and this section describes the methods and instruments used to obtain micrographs of these plant remains. I selected wood charcoal ~ 5mm^3 or larger for ESEM – a size large enough to ensure that both a transverse and tangential section could be acquired from the same specimen, as well as a complete annual growth ring (David L. Lentz, personal communication 2009). I broke pieces of wood charcoal by hand to create flat transverse and tangential sections of interior tissue. Next, I checked each fractured section with a stereomicroscope to ensure that it yielded a surface that exhibited identifiable features. I sprayed the transverse and tangential sections of each wood charcoal specimen with compressed air to remove soil, small fragments of charcoal, and any other materials that would obscure the micrograph.

I used forceps to place 0.5”-wide aluminum specimen mounts into specimen mount holders that accommodate 12 mounts. I labeled each aluminum mount on its underside with a number from 1 through 12 (an extra precaution taken to ensure that provenience information was not separated from plant remains during analysis in the ESEM lab), corresponding to its place in the mount holder, which was also labeled from 1 through 12. Once secured in the mount holder, I covered the aluminum mount in a thin layer of colloidal graphite, a liquid adhesive, using a small wooden probe. With a pair of forceps, I then carefully placed a plant remain onto the colloidal graphite-covered mount with the transverse or tangential section facing up. I labeled the item number of each plant remain on the exterior of the protective plastic case containing the mount holder next to the 1 through 12 label signifying its place within the mount holder. This process was repeated until plant remains were placed on all 12 mounts. I placed additional colloidal graphite around each plant remain with a wooden probe to smooth the sharp angles between the specimen and the mount surface with the goal of reducing charging – a buildup of electrons that deflects the electron beam aimed at the specimen by the microscope (David L. Lentz, personal communication 2009). Charging creates very bright areas on the specimen being examined, and this distorts the micrograph and diminishes the possibility of identifying the plant remain.

Once prepared for ESEM, I took the plant remains to the Department of Chemistry’s Chemical Sensors and Biosensors Laboratory at the University of Cincinnati for imaging. Before loading into the ESEM, all specimens were coated in a thin layer of gold using a Denton Vacuum sputter coater to increase the amount of electrons conducted by the carbonized plant remains, thus reducing incidents of charging. Dr. Necati Kaval operated the sputter coater and the FEI Philips XL30 ESEM (Figure 10). Specimen mounts were removed from their storage containers with forceps and placed into slots on the stage of the specimen chamber. Each slot on the stage had an engraved number next to it ranging sequentially from 1 through 12, and specimen mounts were placed within the slots corresponding to their number within the mount storage case to maintain the plant remains' provenience information during the imaging process. Once secured on the microscope's stage, the specimen chamber was closed and a vacuum pump removed air from the specimen chamber.

Figure 10. ESEM used to image plant remains.

The following description of the ESEM is based on personal communications with Dr. Kaval. The ESEM produces detailed images by aiming an electron gun located at the top of the specimen chamber at a specimen. A beam of high energy electrons focused through a series of magnetic lenses concentrates the electrons on a sample's surface, and scanning coils move the focused beam across the specimen. As the electron beam encounters the surface of the sample, secondary electrons are released from within the sample surface, and a detector collects and converts these secondary electrons into light photons by means of a phosphorescent plate. An amplifier strengthens the signal of secondary electrons coming off of the specimen, and an image of the specimen is composed of the number of secondary electrons released from each area on the specimen's surface converted to light energy. Images of the transverse sections of wood charcoal specimens were taken at both 50x and 100x, while the tangential sections were imaged at 100x. These standardized magnifications ensured that all images of wood charcoal were comparable between specimens and that each image exhibited anatomical features useful for identification.

Dr. Lentz assisted me in the identification of wood charcoal specimens imaged with the ESEM. The Neotropical wood reference collection in the Paleoethnobotanical Laboratory at the University of Cincinnati and a number of Neotropical wood atlases were also used as aides in the identification process, including Chichignoud et al. (1990), Détienne and Jacquet (1983), Kribs (1959), Mainieri and Chimelo (1978), and Uribe (1988).

Digital Microscopy

Images of plant remains exhibiting less detail than ESEM images were taken with a Keyence VHX-1000E digital microscope also housed in the Department of Chemistry's Chemical Sensors and Biosensors Laboratory at the University of Cincinnati and operated by Dr. Kaval. These images were taken to show the overall shape, size, and morphological features of plant remains.

Summary

The paleoethnobotanical macroremains analyzed for this study were collected as they were encountered during excavation and through water flotation processing. Once returned to the Paleoethnobotany Laboratory at the University of Cincinnati, I examined all plant remains (except wood charcoal < 2 mm in size) with stereomicroscopy and identified them with the assistance of Lentz's comparative collection of reference material and published manuals and atlases. Wood charcoal exhibiting a complete growth ring was imaged with SEM for a greater depth of field than that offered by a stereomicroscope for identification purposes.

With the materials and methods used to conduct this study presented, the next chapter will focus on results of this paleoethnobotanical analysis.

Chapter 3

Results

Introduction

This chapter focuses on the analysis of results of the paleoethnobotanical macroremains recovered during the 2009 field season at Cerén. Most of these data were collected from the Operation P midden, but plant remains were also recovered from Operations F, M, and L: excavations that uncovered cultivated manioc beds; an uncultivated area with a possible footpath; and a plot planted in maize and manioc, respectively. Raw count and weight data will be presented first in tabular form, listed in alphabetic order based on family name or a broader classification (i.e., dicot, hardwood, monocot, spermatophyte), a strategy for the presentation of paleoethnobotanical macroremains recommended by Pearsall (2000). A series of more complex quantitative measurements used to interpret frequencies of plant taxa will follow these data tables. The Shannon-Weaver index of diversity is one of these quantitative measurements, and it will be used to compare the plant remains identified from the Operation P midden to those identified from the village proper to test the central research question addressed by this thesis: whether the midden's plant remains reflect those plant taxa preserved in their systemic contexts within the Cerén village. A discussion of each taxon identified in the analysis is the focus of the following chapter.

Paleoethnobotanical Analysis Results

Macroremains

I analyzed a total of 6,916 plant remains from agricultural fields 200 m south of Cerén's, 3,687 of which were recovered as they were encountered during excavation (Table 4). Not all macroremains were identifiable to family, genus, or species due to their small, fragmentary, and/or eroded condition, and these are denoted as unknown amorphous plant tissue. Of the 3,687 macroremains collected, 3,486 or 94% were identifiable. I could not identify some plant remains to family, genus, or species, but in most cases enough anatomical features were present to determine whether the specimen was derived from a moncot, dicot, or spermatophyte. Monocots (or Liliopsida) represent one class of angiosperms or flowering plants (dicots, or Magnoliopsida, are the other major class) and are distinguished by embryos with single cotyledons, stems with scattered vascular bundles, and leaves with parallel venation, among other features (Raven 2005: Table 19-1). Examples of monocots include maize (*Zea mays*) and other grasses, as well as plants in the palm family, Arecaceae. Dicots, on the other hand, have embryos with two cotyledons, stems with vascular bundles arranged in a ring, and leaves with reticulated venation (Raven 2005: Table 19-1). Hardwood trees, beans (*Phaseolus* spp.), and squash (*Cucurbita* spp.) are examples of dicots. The classification of spermatophyte includes all seed-producing plants: angiosperms (both monocots and dicots), gymnosperms, and cycads, among other plants that are not distributed in Central America (Kaufman et al. 1989:313). The Latin abbreviation "cf" precedes tentative identifications, such as that for *Haematoxylon campechianum.*

Table 4. Macroremains collected during excavation.

Taxon	Common Name(s)	Parts	Total Number of Samples	Total Weight of Samples (in grams)	Context
Anacardiaceae					
Spondias sp.	jocote, hogplum	pit	7	0.28	Operation P Midden
Arecaceae	palm family	charcoal	4	0.20	Operation P Midden
Bignoniaceae					
Crescentia sp.	calabash, morro	rind	1	0.01	Operation P Midden

Bombacaceae	balsa family	charcoal	1	0.13	Operation P Midden
Burseraceae					
Protium copal	copal	charcoal	2	0.14	Operation P Midden
Cucurbitaceae					
Cucurbita sp.	squash, ayote	rind	13	0.23	Operation P Midden
Lagenaria siceraria	gourd, tecomate	rind	2	0.01	Operation P Midden
Dicot		charcoal	16	0.05	Operation P Midden
Fungal spore			2	0.02	Operation P Midden
Fabaceae					
Dalbergia sp.		charcoal	1	0.03	Operation P Midden
cf. *Haematoxylon campechianum*	logwood, tinta	charcoal	8	0.58	Operation P Midden
Hymenaea courbaril	palo colorado, guapinol	charcoal	1	0.05	Operation P Midden
Phaseolus sp.	bean, frijol	cotyledon	1159	11.34	Operation P Midden
Phaseolus lunatus	lima bean, frijol de media luna	cotyledon	6	0.15	Operation P Midden
Phaseolus vulgaris	common bean, frijol	cotyledon	135	4.50	Operation P Midden
Hardwood		charcoal	966	19.51	Operation P Midden
Lauraceae					
Persea americana	avocado, aguacate	pit	1	0.20	Operation P Midden
Malpighiaceae					
Byrsonima crassifolia	nance	pit	2	0.03	Operation P Midden
Monocot		charcoal	12	0.18	Operation P

					Midden
		seed	1	0.01	Operation P Midden
Pinaceae					
Pinus sp.	pine, ocote	charcoal	229	2.05	Operation P Midden
Poaceae					
Zea mays	maize, maíz	cob	8	0.23	Operation P Midden
		cupule	54	0.41	Operation P Midden
		kernel	201	3.21	Operation P Midden
		kernels and leaf	1	0.12	Operation P Midden
Sapotaceae	sapodilla family	charcoal	2	20	Operation P Midden
Manilkara sp.		charcoal	1	0.11	Operation P Midden
Spermatophyte		charcoal	643	2.79	Operation P Midden
		charcoal	7	<0.01	Operation L, sub-Op 1
Unknown		amorphous plant tissue	201	1.99	Operation P Midden

The majority of these macroremains were collected from the Operation P midden, which were recovered within one 6 cm stratigraphic unit, as this was the vertical extent of the midden. Hardwood charcoal, *Phaseolus* sp. and *Phaseolus vulgaris* cotyledons, *Pinus* sp. charcoal, and fragments from various parts of *Zea mays* plants were most frequently identified in the set of plant remains hand-collected from the midden. Seven fragments of spermatophyte charcoal were collected from the surface of maize and manioc planting ridges in Operation L, sub Operation 1, the only other context in which macroremains were recovered during excavation.

Flotation Samples

A total of 68 flotation samples, each measuring 2 liters in volume, were taken from excavations south of Cerén. Sixty-three samples were collected from the Operation P midden, three from Operation L, and one sample was collected from both Operations F and M. As is noted in Table 5, a total of 3,229 plant remains were analyzed from the light fraction of flotation samples, 3,185 or 98% of which were identifiable. A number of achenes (a fruit encasing a seed) belonging to the Asteraceae or composite family were found in the soils of all four operations sampled. However, none of these achenes were carbonized; thus they are considered modern intrusions into the strata bearing Cerén's Late Classic occupation. It is possible that burrowing insects or small mammals (faunalturbation), plant roots (floralturbation), or water (aquaturbation) introduced these modern achenes to Cerén's living surface. Also, some seeds may have blown into the operations during excavation and became incorporated into the flotation samples. A corresponding amount of Asteraceae achenes were not identified in the assemblage of macroremains despite their ubiquity in the flotation samples, likely because their small size (no larger than 2 mm^3) precluded them from being seen and collected by excavators.

Table 5. Plant remains recovered from flotation samples.

Taxon	Common Name(s)	Parts	Total Number of Samples	Total Weight of Samples (in grams)	Context
Anacardiaceae					
Spondias sp.	jocote, hogplum	pit	1	0.01	Operation P Midden
Arecaceae	palm family	charcoal	2	<0.01	Operation P Midden

Asteraceae	composite family	modern non-carbonized achene	2169	0.03	Operation P Midden
		modern non-carbonized achene	8	<0.01	Operation F, sub-Op 1
		modern non-carbonized achene	4	<0.01	Operation M, West Wall
		modern non-carbonized achene	15	<0.01	Operation L, sub-Op 1
		modern non-carbonized achene	19	<0.01	Operation L, sub-Op 2
		modern non-carbonized achene	19	<0.01	Operation L, sub-Op 3, furrow between planting ridges 1 and 2
Cucurbitaceae					
Cucurbita sp.	squash, ayote	rind	1	<0.01	Operation P Midden
Lagenaria siceraria	gourd, tecomate	rind	2	<0.01	Operation P Midden
Dicot		charcoal	4	<0.01	Operation P Midden
		charcoal	1	<0.01	Operation L, sub-Op 1
Fabaceae					
Phaseolus sp.	bean, frijol	cotyledon	324	1.83	Operation P Midden

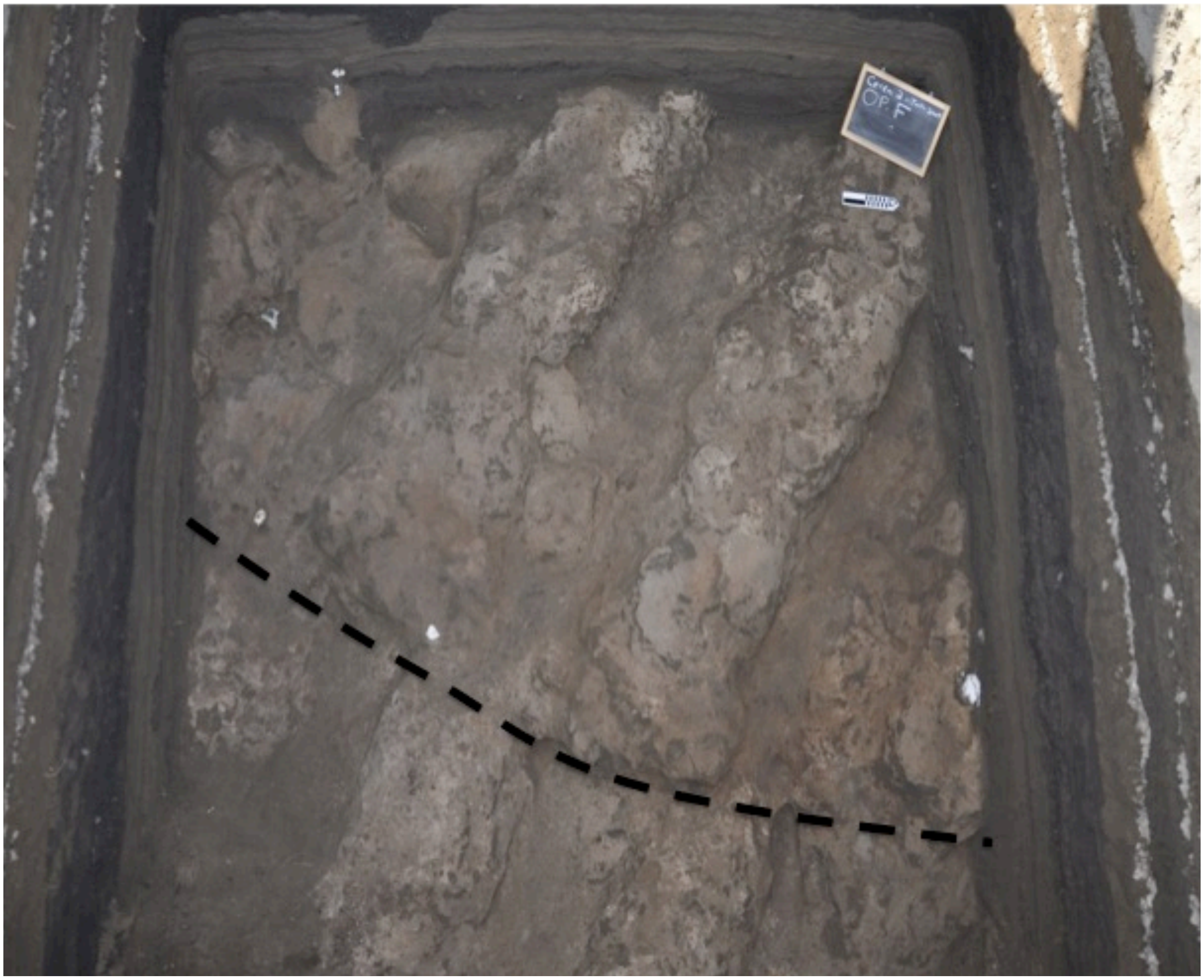
Phaseolus sp.	bean, frijol	cotyledon	1	<0.01	Operation L, sub-Op 2
Phaseolus vulgaris	common bean, frijol	cotyledon	21	0.45	Operation P Midden
Fungal spore			1	<0.01	Operation L, sub-Op 3, furrow between planting ridges 1 and 2
Hardwood		charcoal	164	0.39	Operation P Midden
Lauraceae					
Persea americana	avocado, aguacate	pit	2	<0.01	Operation P Midden
Monocot		charcoal	7	<0.01	Operation P Midden
		bud	1	<0.01	Operation P Midden
Pinaceae					
Pinus sp.	pine, ocote	charcoal	250	0.40	Operation P Midden
Poaceae		modern non-carbonized caryopsis	1	<0.01	Operation P Midden
Zea mays	maize, maíz	cob	1	0.01	Operation P Midden
		cupule	26	0.03	Operation P Midden
		kernel	81	0.40	Operation P Midden
		kernel	1	<0.01	Operation F, sub-Op 1
Spermatophyte		charcoal	57	0.04	Operation P Midden

	charcoal	1	<0.01	Operation L, sub-Op 2
	disseminule	1	<0.01	Operation P Midden
Unknown	amorphous plant tissue	43	0.02	Operation P Midden
	amorphous plant tissue	1	<0.01	Operation F, sub-Op 1

The plant remains most frequently identified from flotation samples taken from the Operation P midden (aside from the modern Asteraceae achenes) include hardwood charcoal, *Phaseolus* sp. and *Phaseolus vulgaris* cotyledons, *Pinus* sp. charcoal, and fragments from various parts of *Zea mays* plants. These findings from the flotation samples reflect those taxa most abundant in the hand-collected set of macroremains. All of the taxa identified in the Operation P midden's flotation samples (excluding uncarbonized modern plant materials) were also identified in the macroremain collection from the midden summarized in Table 4.

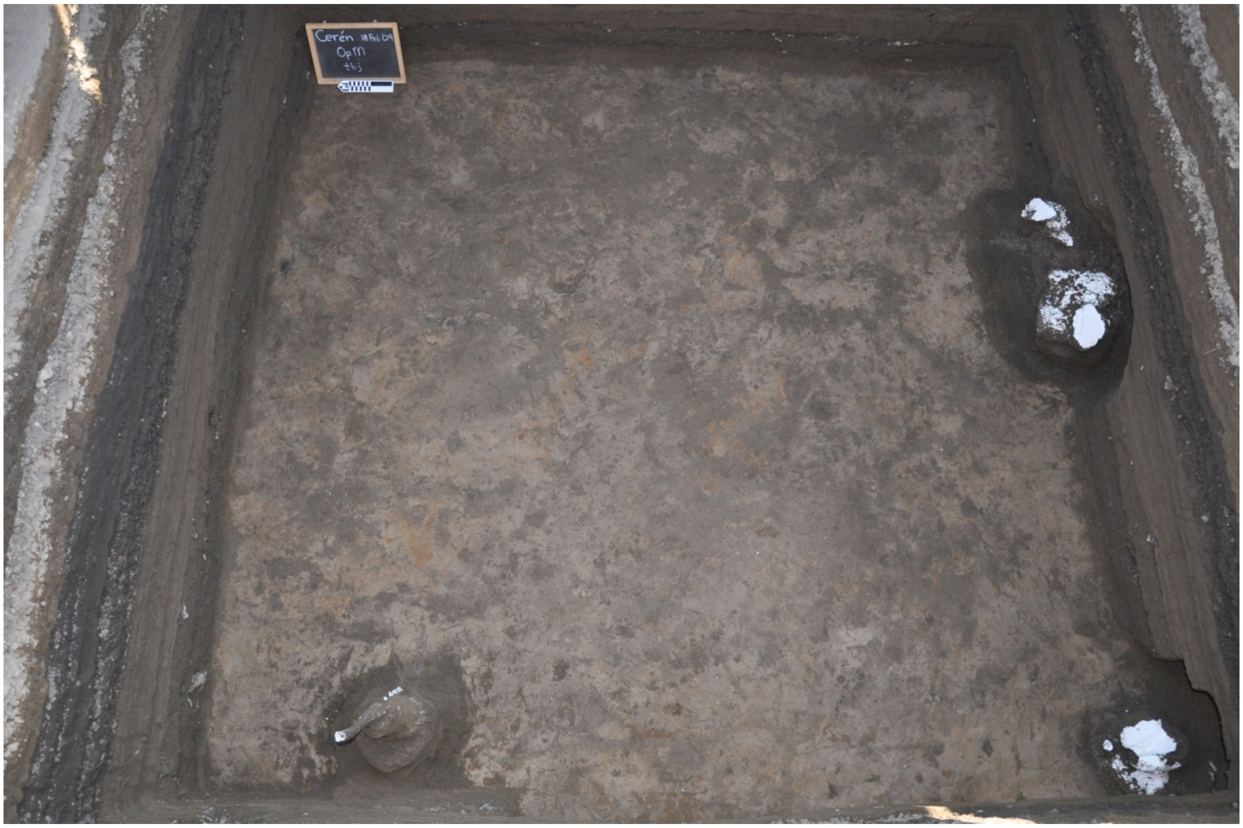
The flotation sample collected from the surface of manioc plots in Operation F-1 yielded eight modern Asteraceae achenes, a carbonized maize kernel, and a charred fragment of unidentifiable plant tissue (Table 5). Also, four plaster casts of manioc roots and stems were prepared and recorded in Operation F-1. Operation F-1 was located between operations that uncovered manioc beds during the 2007 and 2009 projects to investigate the techniques used to construct the large planting ridges and furrows observed in these plots. A boundary between two manioc fields was found in Operation F-1, in which the planting ridges of one plot abut the furrows of another. This boundary is illustrated with a black dashed line in Figure 11. This boundary may delineate separate ownership of the plots or may have been constructed to control soil erosion (Dixon 2009:59).

Figure 11. Boundary between two manioc beds in Operation F-1.



The living surface uncovered in Operation M was a relatively level area not cultivated in crops (Figure 12). A possible footpath extended along the western wall of the operation leading east of magnetic north to Cerén's habitation area, which may have connected the villagers to their outfields to the south (Maloof 2009:42). Two tree trunks and one thin plant unidentifiable to taxon were cast in plaster along the south and west walls of the operation. A flotation sample collected from the TBJ stratum of Operation M's west wall profile did not produce ancient plant remains, but eight modern Asteraceae achenes were identified.

Figure 12. Plan view of Operation M with plaster plant casts in their systemic contexts.



Three flotation samples were collected from Operation L, one from each suboperation excavated to further explore the boundary between large manioc planting beds (similar to the beds uncovered in Operation F) and the significantly more gracile maize beds initially found in Operation G. This transition can be seen in Figure 13, where the ridges planted in manioc (the unexcavated plaster casts which are represented in the figure as cylinders of tephra) on the left side of the excavation are markedly larger than those planted in maize on the right. Fifteen modern Asteraceae achenes and one fragment of dicot charcoal were identified from the flotation sample taken from the TBJ surface of Operation L-1. The flotation sample from Operation L-2, also planted in manioc and maize, yielded 19 modern Asteraceae achenes, one *Phaseolus* sp. cotyledon, and one fragment of spermatophyte charcoal. The flotation sample collected from

Operation L-3 produced 19 modern Asteraceae achenes and one fungal spore, which is also of modern origin.

Figure 13. Manioc and maize plots in Operation L.

Table 6 summarizes the identifiable plant remains from both the macroremain and flotation assemblages presented in Tables 4 and 5. The non-carbonized Asteraceae achenes and fungal spores were not included due to their modern origins. Spermatophyte charcoal is excluded from the list of identified plant remains because the broadly encompassing classification prohibits any conclusions from being drawn regarding its significance to past human/plant relationships. Unidentifiable plant remains designated as "unknown" are also excluded from Table 6. These identified plant remains are examined with quantitative measurements in the next section.

Table 6. Identified plant remains.

Taxon	Common Name(s)	Parts	Total Number of Samples	Total Weight of Samples (in grams)	Context
Anacardiaceae					
Spondias sp.	jocote, hog plum	pit	8	0.29	Operation P Midden
Arecaceae	palm family	charcoal	6	0.20	Operation P Midden
Bignoniaceae					
Crescentia sp.	calabash, morro	rind	1	<0.01	Operation P Midden
Bombacaceae	balsa family	charcoal	1	0.13	Operation P Midden
Burseraceae					
Protium copal	copal	charcoal	2	0.14	Operation P Midden
Cucurbitaceae					
Cucurbita sp.	squash, ayote	rind	14	0.23	Operation P Midden
Lagenaria siceraria	gourd, tecomate	rind	4	0.01	Operation P Midden
Dicot		charcoal	20	0.05	Operation P Midden
		charcoal	1	<0.01	Operation L, sub-Op 1
Fabaceae					
Dalbergia sp.		charcoal	1	0.03	Operation P Midden
cf. *Haematoxylon campechianum*	logwood, tinta	charcoal	8	0.58	Operation P Midden
Hymenaea courbaril	palo colorado, guapinol	charcoal	1	0.05	Operation P Midden
Phaseolus sp.	bean, frijol	cotyledon	1482	13.17	Operation P Midden

		cotyledon	1	<0.01	Operation L, sub-Op 2
Phaseouls lunatus	lima bean, frijol de media luna	cotyledon	6	0.15	Operation P Midden
Phaseolus vulgaris	common bean, frijol	cotyledon	157	4.99	Operation P Midden
Hardwood		charcoal	1129	19.77	Operation P Midden
Lauraceae					
Persea americana	avocado, aguacate	pit	3	0.20	Operation P Midden
Malpighiaceae					
Byrsonima crassifolia	nance	pit	2	0.03	Operation P Midden
Monocot					
		bud	1	<0.01	Operation P Midden
		charcoal	19	0.03	Operation P Midden
		seed	1	<0.01	Operation P Midden
Pinaceae					
Pinus sp.	pine, ocote	charcoal	479	2.45	Operation P Midden
Poaceae					
Zea mays	maize, maíz	cob fragment	10	0.48	Operation P Midden
		cupule	80	0.38	Operation P Midden
		kernels	282	3.54	Operation P Midden
		kernel	1	<0.01	Operation F, sub-Op 1
		kernel and leaf	1	0.12	Operation P Midden
Sapotaceae	sapodilla family	charcoal	2	0.20	Operation P Midden

Manilkara sp.	charcoal	1	0.11	Operation P Midden

Quantitative Measurements

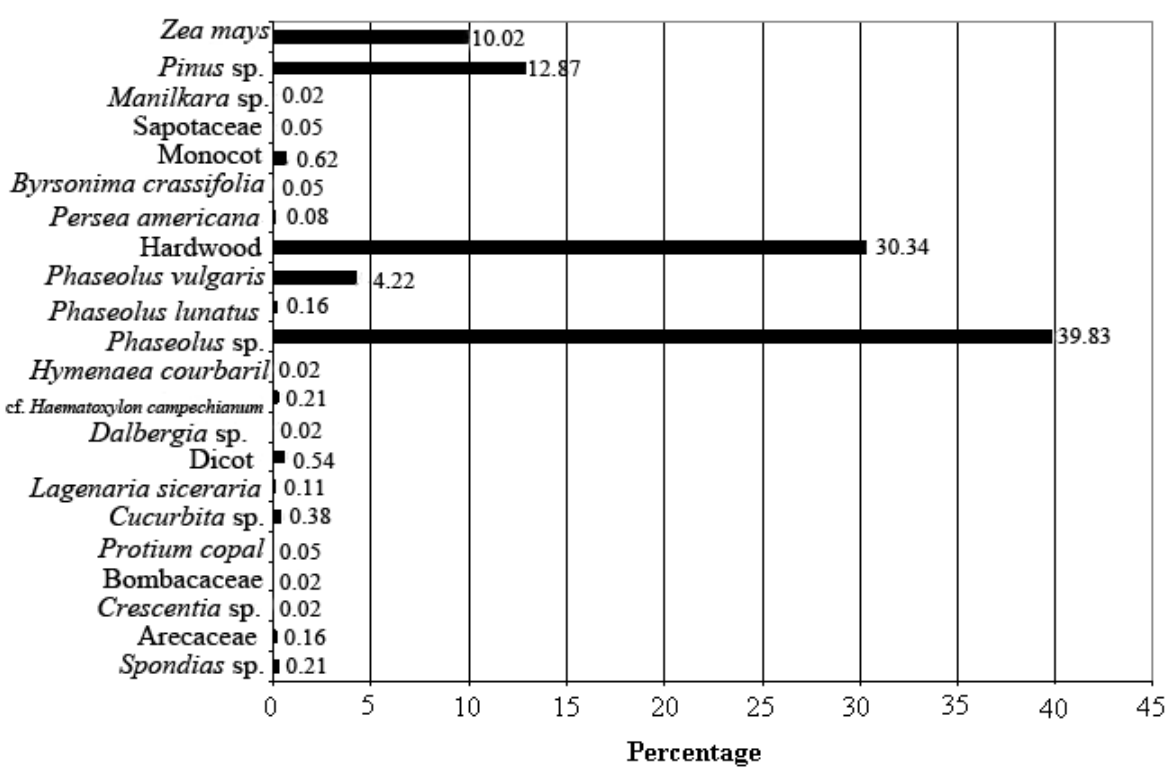
Quantitative measurements in paleoethnobotany are chosen to answer particular research questions (Popper 1988:53), and in this case, quantitative measurements address whether macroremains recovered from a midden reflect those plant resources preserved in their systemic contexts within the Cerén village and its southern outfields. First, the raw count and weight data for identified plant remains presented in Table 6 are reported separately as ratios, a simple statistic expressing the relative abundance of each taxon. For example, the count or weight of one of the identified taxa (i.e., *Spondias* sp.) is the numerator of the ratio and the total number or weight of identified plant remains serves as the denominator (Miller 1988:72). The resulting relative abundance of each taxon is presented as a percentage by multiplying the ratio by 100. The relative abundance of each taxon not only allows taxa in the midden assemblage to be compared to each other based on both count and weight, but it also allows these data to be compared with plant taxa identified in the village using the Shannon-Weaver index of diversity. The Shannon-Weaver index measures the diversity of taxa in an assemblage of plant remains, and it permits quantitative comparisons of multiple paleoethnobotanical assemblages. The relative abundance of identified taxa based on count is presented first.

Relative Abundance by Count

The relative abundance of each taxon based on count is expressed as a percentage in Figure 14. Based on the number of identifiable plant remains collected from agricultural outfields south of Cerén's center, five taxa dominate the assemblage. *Phaseolus* sp. cotyledons are the most abundant plant remain in the assemblage (39.83%), followed by hardwood charcoal

(30.34%); pine charcoal (*Pinus* sp.); (12.87%), maize (*Zea mays*) kernels, cupules, and cob fragments (10.02%); and *Phaseolus vulgaris* cotyledons, common beans with morphological features (hilum and seed leaves) present to securely identify the macroremains to species. None of the other identified plant remains were numerous enough to comprise over one percent of the assemblage, a function of the large total number of plant remains identified and the general homogeneity of the sample. It is difficult to draw meaning from the quantity of plant remains alone, however, for the large numbers of some taxa might be due to the fragmentation of plant parts during carbonization, deposition, and/or collection by excavators. Thus it is necessary to examine the relative abundance of taxa based on weight to control for the distorting effects charring and mechanical damage may have had on the analyzed plant remains.

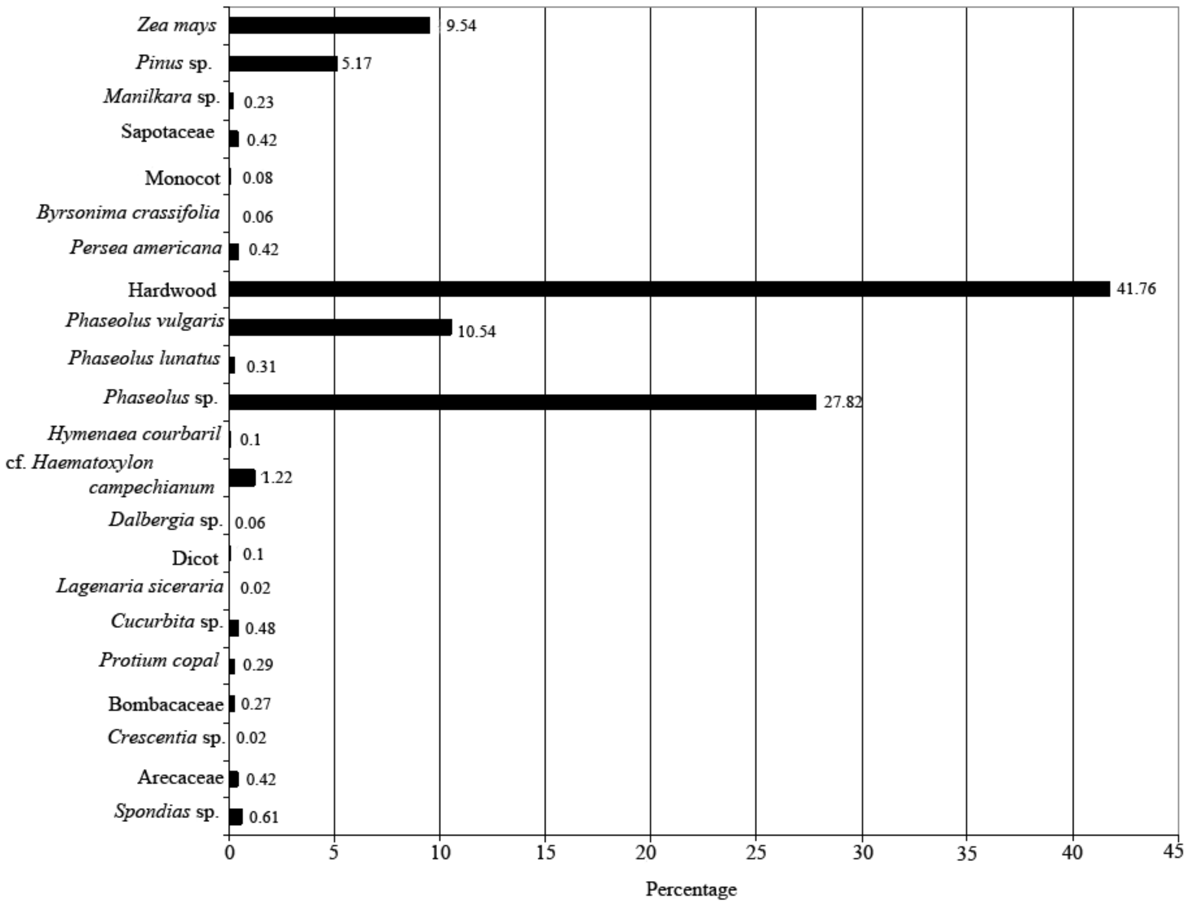
Figure 14. Relative abundance of identified plant remains based on count.



Relative Abundance by Weight

The most abundant taxa based on weight are the same five taxa that are most abundant by count, but their rankings have changed (Figure 15). Hardwood charcoal is the most abundant plant remain based on weight, comprising 41.76% of the assemblage, followed by *Phaseolus* sp. cotyledons (27.82%); *Phaseolus vulgaris* cotyledons (10.54%); maize kernels, cupules, and cob fragments (9.54%); and pine charcoal (5.17%). The reversal of hardwood charcoal and *Phaseolus* sp. cotyledons as the most abundant plant remain by weight as opposed to count is probably best explained as the result of individual pieces of hardwood charcoal weighing more on average than *Phaseolus* sp. cotyledons. Fragments of hardwood charcoal identified in the assemblage varied greatly in size and weight – from > 0.01 g to 0.94 g – whereas the size and weight of *Phaseolus* sp. cotyledons are limited by the plant part's structure and morphology unlike hardwood charcoal, the remains of which potentially could be as large as a tree's trunk.

Figure 15. Relative abundance of identified plant remains based on weight (g).



Phaseolus vulgaris cotyledons, the fifth most abundant plant remain based on count, is the third most abundant by weight. These dissimilar rankings may be attributable to the features required to identify *Phaseolus* cotyledons to species. When identifying *Phaseolus* cotyledons to species, it was necessary for the hilum (scar left by the pollen tube) or seed leaves to be present on the specimen (Kaplan 1956:206-207), resulting in those cotyledons identified as *Phaseolus vulgaris* to be few in number but less fragmentary and therefore greater in weight. By weight, pine charcoal is the fifth most abundant plant remain, while it is the third most abundant based on count. This is likely due to numerous small fragments of pine charcoal, the average weight of which is > 0.01 g, representing the taxon in the assemblage.

Shannon-Weaver Index of Diversity

The Shannon-Weaver index of diversity measures the ability to infer the identity of a randomly selected plant remain from an assemblage (Yellen 1977:107-8; Pearsall 1983:130). If there are a great number of taxa evenly distributed in an assemblage, the chances of predicting the identity of a randomly selected plant remain will be low and the diversity index will indicate great diversity with a high index value. A small number of taxa unevenly distributed in an assemblage will result in a low index value, indicating little diversity in the sample. The Shannon-Weaver index (H) is calculated with the following equation:

$H = - \text{Sum} (N_j/N) \log (N_j/N)$, where N equals the total number of plant remains in the assemblage, and N_j equals the number of a specific taxon in the assemblage (Popper 1988:67). This quantitative measurement was applied to the assemblage of carbonized macroremains identified from the Operation P midden and the plant remains identified from the Cerén village (Table 7) to compare the diversity of taxa identified in these two contexts with such disparate preservation conditions.

Table 7. Shannon-Weaver index of diversity comparing plant remains recovered from the Cerén village and the Operation P midden.

	Cerén Village	Operation P Midden
Acrocomia aculeata endocarps	2	0
Agave sp. fibers, leaf, plant, and stem	34	0
Arecaceae fibers and charcoal	1	6
Aspidosperma sp. charcoal	4	0

Bombacaceae	0	1
Bromeliaceae leaf, stem, and inflorescence	4	0
Byrsonima crassifolia fruit	8	2
Capsicum annuum seeds, peduncles, and stems	17	0
Casearia sp. charcoal	2	0
Cedrela sp.	1	0
Celtis sp. pits	2	0
Crescentia alata fruit and stem	13	0
Crescentia sp.	0	1
Cucurbita moschata seeds	8	0
Cucurbita pepo seeds and peduncle	3	0
Cucurbita sp. rind and seeds	7	14
Cupania dentata charcoal	1	0
Cyperaceae rhizome	1	0
Dalbergia sp. charcoal	0	1
Dicot charcoal, leaf, rind, root, and stem	32	20
Ficus sp. charcoal	2	0
Gossypium hirsutum embryos, fibers, and seeds	6	0
cf. *Haematoxylon campechianum* charcoal	0	8
Hardwood charcoal	7	1129
Hymenaea courbaril charcoal	0	1
Lagenaria siceraria rind	1	4
Manihot esculenta root and stem	11	0

Manilkara sp. charcoal	0	1
Monocot bud, charcoal, fibers, leaf, and stem	10	21
Muntingia calabura seed	1	0
Nectandra sp. charcoal	1	0
Persea americana leaf, cotyledon, and pit	6	3
Pinus sp. charcoal	1	479
Phaseolus lunatus cotyledon	1	6
Phaseolus vulgaris cotyledon	15	157
Phaseolus sp. cotyledon	4	1482
Poaceae stem	5	0
Protium copal charcoal	0	2
Psidium guajava fruit, leaf, and stem	90	0
Rubiaceae stem	4	0
Sapotaceae charcoal	0	2
Solanaceae anther	2	0
Spondias sp. pit	0	8
Tithonia rotundifolia stem	12	0
Theobroma cacao fruit and seed	14	0
Trachypogon plumosus stem	10	0
Xanthosoma violaceum stem and tuber	5	0
Zea mays cob, kernel, stem, prop roots, cupule, and leaf	189	373
Total (N)	537	3721

Diversity Index (H)	1.09	0.65
Mann-Whitney Test, *p* (2-tailed) = 0.009		

Note: Data from Lentz et al. (1996a) and Lentz and Ramírez-Sosa (2002).

The diversity index value for the Cerén village (1.09) is greater than that for the Operation P midden (0.65), indicating that the assemblage of plant remains identified in the village are more diverse than those identified from the Operation P midden. It is not surprising that a more diverse set of plant remains was identified in the Cerén village, given the site's rapid abandonment and burial that preserved plant materials in remarkable detail. The plant remains identified from the midden are much more limited, for their preservation was dependent upon a carbonization event and subsequent deposition into the midden feature. Comparing these two assemblages of plant remains permits an exploration of the natural and cultural formation processes that have rendered certain plant taxa preserved in Cerén's habitation area invisible in the paleoethnobotanical records of the Operation P midden and other sites in the Maya area. These issues are addressed in the following chapter.

Mann-Whitney Test

To address the central question of this thesis (whether carbonized macroremains identified from the Operation P midden reflect the plant resources found in the village proper), the Mann-Whitney statistical test was applied to the two assemblages of plant remains to test whether there are statistically significant differences between the samples. The Mann-Whitney test is a nonparametric statistic chosen for these sets of data because, unlike parametric test such as a *t* test, the Mann-Whitney test does not assume that data are normally distributed (Kinnear and Gray 2009:194). This Mann-Whitney test is especially applicable to archaeological data in general, for its variances are large and unequal due to the formation processes of the archaeological record, often resulting in skewed data distributions (Alan P. Sullivan III, personal communication 2010). As can be seen in Table 7, the p-value for the Mann-Whitney Test is 0.009, which signifies the probability that the differences observed between the assemblage of plant remains from the Operation P midden and the Cerén village are due to chance alone. The threshold for a statistically significant p-value is < 0.05, thus the null hypothesis stating that no significant difference exists between the two assemblages of plant remains at Cerén must be rejected. Quantitative measurements have illustrated that there are significant differences between the plant remains preserved in their systemic contexts within the Cerén village and those found in the secondary refuse deposit of the Operation P midden, and the next chapter explores *why* these differences exist.

Summary

A total of 6,916 paleoethnobotanical macroremains were analyzed from operations excavated during the 2009 field season at Cerén, most of which were collected from the Operation P midden. Slightly over half (53%) were identifiable. Non-carbonized Asteraceae achenes recovered from flotation samples, most likely modern intrusions into the deeply buried stata of Cerén's living surface, represented most of the plant remains deemed unidentifiable. Of the 3,724 identifiable plant remains, 22 taxa are present, five of which were most abundant by the measures of count and weight: *Phaseolus* sp., *Phaseolus vulgaris*, *Zea mays*, hardwood, and *Pinus* sp. (Figures 14 and 15). Although the relative abundance figures calculated for both count and weight measures revealed the same five taxa to be most abundant in the assemblage, their rankings change depending on the measure. Variables contributing to these different rankings based on count and rank include: fragmentation of plant remains during carbonization, deposition, and excavation; identification practices; and the varying sizes and morphology of the plant remains themselves.

When compared to plant remains identified in their systemic contexts within the Cerén village using the Shannon-Weaver index of diversity, carbonized macroremains identified from the Operation P midden assemblage were found to be far less diverse than the plant resources found in the habitation area of the site. A Mann-Whitney statistical test was applied to the two assemblages to assess whether significant differences exist between the two assemblages, and the test found that there is indeed a statistically significant difference. Therefore, the plant resources used by Cerén's residents in the habitation area of the site are not reflected in the Operation P midden. This disparity in plant remains between the two contexts is best understood through the lens of the formation processes that shaped them, a subject addressed in the next chapter.

Chapter 4

Discussion

Introduction

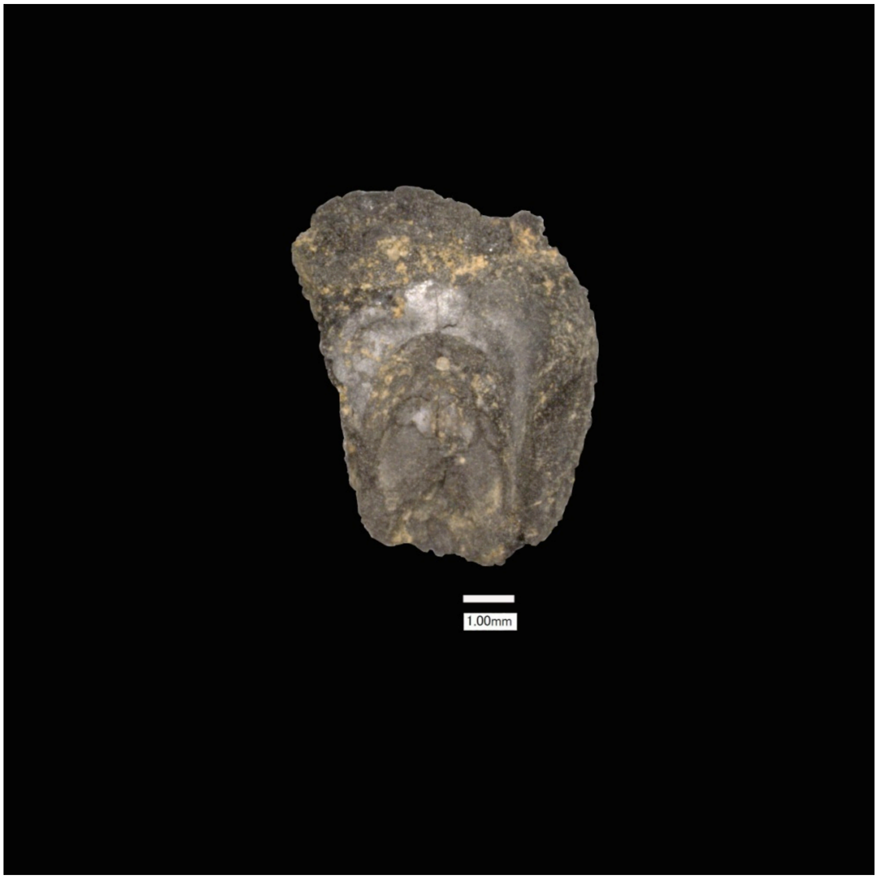
The goal of this chapter is to contextualize paleoethnobotanical analysis results from ancient agricultural outfields 200 m south of Cerén with the plant remains found in the Cerén village and other sites in the Maya area. To begin, the identified plant taxa will be compared and contrasted with plant remains found in the village and at other sites in the Maya area. Included in this discussion will be ancient and modern uses of identified taxa, their modern distribution and habitat, and the formation processes that may have led to their carbonization and deposition into the midden. As van der Veen (2007) points out, reconstructing the daily practices and formation processes that lead to the patterns we see in the paleoethnobotanical record permits us to chart plant use behaviors and changes in these behaviors over time, as well as differences in access to plant resources based on socioeconomic status, ethnicity, and other social factors. Next, variables contributing to the dissonance between the plant resources present in the Cerén village and the midden are addressed. Paleoethnobotanical data from other ancient Maya sites will also be incorporated into this discussion to explore the ways in which differential preservation has affected the record of ancient plant use practices over the entire Maya area. Finally, a research design centered upon mitigating the distorting effects of formation processes on the paleoethnobotanical record to attain a more accurate understanding of the ways in which the ancient Maya utilized plant resources will be offered. The discussion will now focus on the plant taxa identified from the Operation P midden, Operation F, Operation L-1, and L-2.

Identified Taxa – Operations P, F, L-1, and L-2

The Staples: Maize, Beans, and Squash

The major cultigens traditionally thought to have comprised the ancient Maya diet– maize (*Zea mays*), beans (*Phaseolus* spp.), and squash (*Cucurbita* sp.) – are present in the Operation P midden. Figure 16 exhibits a mostly complete maize kernel identified from the Operation P midden. A single maize kernel was also found in the flotation sample collected from the surface of Operation F where the boundary between two manioc fields was uncovered, and a bean cotyledon was also identified in the flotation sample for Operation L-2, which was collected from the surface of a manioc and maize field. These errant maize and bean fragments in Operation F and L-2 were perhaps dropped accidentally by one of Cerén's residents while carrying household refuse to a communal place for disposal such as the Operation P midden. Equally plausible, the plant remains might have been intentionally discarded by someone scattering the overcooked foodstuffs in the large expanse of fields as a means of disposal. Irrespective of how they were deposited, it is clear that these plant remains were charred and discarded in the fields south of the Cerén village before the Loma Caldera eruption, because the remains were not found on the surface of the planting beds during excavation but rather slightly below where flotation sampling extended, as though they were stepped upon and pushed into the TBJ soil.

Figure 16. Digital micrograph of a maize kernel from the Operation P midden.



The prominence of maize in the Operation P midden (comprising 10.02% of the assemblage by count and 9.54% by weight) reflects findings of the plant in the Cerén village. Maize was found there in the kitchen/food preparation area of Household 1 within a storage vessel, where a number of kernels soaked in preparation for grinding (Lentz et al. 1996a:249). Maize was stored in vessels within Structure 10, which functioned as a staging area for village festivals and feasts (Brown and Gerstle 2002). The storehouse for Household 4 contained unshucked maize cobs stored in a crib constructed of wattle and daub (Gerstle and Sheets 2002:75). Maize was also found growing in small *milpas* adjacent to household structures. The presence of complete maize cobs at Cerén saved for posterity as plaster casts has afforded the identification of the type of maize grown at Cerén as the Nal Tel race (Lentz and Ramírez-Sosa

2002:34). Wellhausen and colleagues (1957) describe Nal Tel maize as having 8-16 rows of kernels per cob with smooth, rounded kernels showing little denting – features that were noted for specimens in the Operation P midden. Nal Tel adapts well to varying climates and edaphic conditions, but grows best in warm regions at low elevations. These ideal conditions existed at Cerén.

Maize macroremains have been identified from virtually all sites in the Maya area where programs of paleoethnobotanical research have been pursued. Maize kernels are durable once carbonized and remain easily identifiable. In a series of experiments subjecting maize kernels and cobs to processing techniques (toasting, boiling, and sprouting) and subsequent charring, Goette et al. (1994) found that all kernels retained identifiable features. The plant use behaviors of the ancient Maya that lead to such ubiquity of maize remains are equifinal but almost certainly include accidental charring while toasting, popping, and cooking whole or fragmented kernels. Maize kernels ground into masa harina (maize flour) and incorporated into dishes such as tamales might be difficult to identify once charred, appearing as an unidentifiable mass under a microscope. Tamales are a well-documented use for maize in Classic Maya epigraphy and iconography (Taube 1989:33-34). A Copador bowl found within a niche in the domicile of Household 2 at Cerén contained food residue that might represent atole (Lentz et al. 1996a:251), a gruel made from corn meal, and a charred portion of such a dish may also prove unidentifiable. Kernels considered insufficient for consumption or diseased and therefore undesirable as a seed crop may have been burned as biomass, perhaps along with the entire cob. Ten cob fragments and 80 maize cupules were identified from the Operation P midden, supporting the possibility that maize cobs were indeed burned for fuel at Cerén. Welch and Scarry (1995) consider the presence of maize cupules in paleoethnobotanical assemblages as evidence for the removal of kernels from cobs, a processing method that likely lead to the incorporation of maize cupules into the Operation P midden.

Along with maize, beans also served as a mainstay of the ancient Maya diet (Lentz 1999:5). Common beans (*Phaseolus vulgaris*), lima beans (*Phaseolus lunatus*), and beans lacking the features necessary to make a secure species identification (*Phaseolus* sp.) are dominant in the Operation P midden assemblage (in total comprising 44.21% of the assemblage by count and 38.67% by weight). Two lima bean cotyledons and the hilum (the attachment scar on a seed from where it was once connected to the ovule) characteristic of *Phaseolus vulgaris* seeds are displayed in digital micrographs in Figure 17 and Figure 18, respectively. Considering the large amount of beans identified in the midden, it is possible that a cooking mishap or an intentional burning of diseased seeds preceded their deposition into the Operation P midden. Similar to maize, the events leading to the charring of these beans are equifinal.

Large quantities of beans, including common, lima, and wild relatives, were found mixed together in storage vessels in the Cerén village (Lentz et al. 1996a:253-254). Although abundant at Cerén, beans are generally infrequently found in the archaeological record of ancient Maya sites because their preparation methods, soaking and boiling, rarely lead to carbonization and subsequent preservation (Hammond and Miksecik 1981:268). The paucity of beans recovered from sites throughout the Maya area with well-studied paleoethnobotanical records such as Copán, Aguateca, Chan, and Cuello (Lentz 1991:275; Lentz et al. 2011a; Lentz et al. 2011b; Miksicek 1991:78) underscores the strong effects formation processes and differential preservation have on the taxa recovered from archaeological features like middens, and ultimately our interpretations of past human/plant relationships.

Figure 17. Digital micrograph of lima bean cotyledons from the Operation P midden.

A diet centering upon maize and beans endures in Central America today. The combination of the two plant foods provides complementary nutritional benefits; maize lacks amino acids essential to proper human nutrition (tryptophan and lycene) that beans supply (Gibbon and Ames 1998:56). Beans (along with other legumes) also play an important role in agricultural systems by increasing soil fertility through nitrogen-fixing bacteria present in the plants' roots (Raven et al. 2005:467). Although not observed in the kitchen gardens or outfields of Cerén, *milpas* were likely intercropped or rotated with maize, beans, and squash at sites in the

Maya area to ensure sustained soil fertility and to intensify the subsistence base (Hather and Hammond 1994:330).

Figure 18. The hilum of a *Phaseolus vulgaris* seed from the Operation P midden.

Figure 19. Digital micrograph of a *Cucurbita* sp. rind from the Operation P midden.

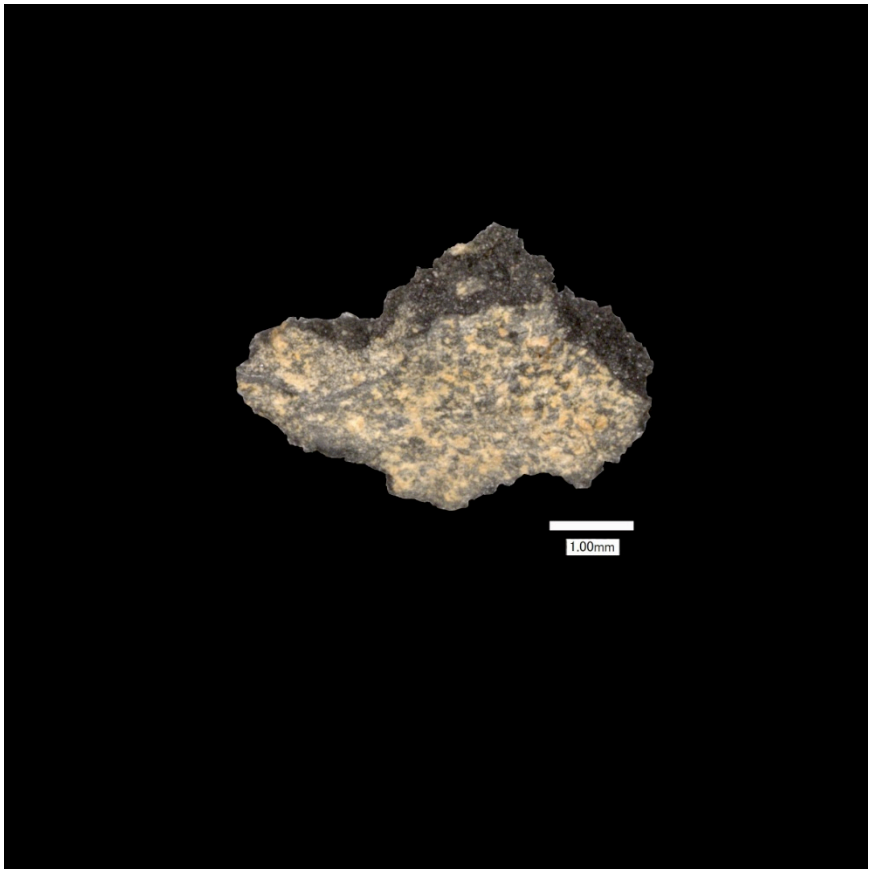
Squash (*Cucurbita* sp.), the third member of the triad of plant foods comprising the ancient Mesoamerican diet, was identified from the Operation P midden as 14 rind fragments (Figure 19). The rind's cellular structure in transverse section is the identifiable feature for this plant part, although it is not possible to distinguish between species of *Cucurbita* without the plant's seeds or peduncles (stem attachment to the fruit) (Cutler and Whitaker 1961:479). Seeds and rinds of *Cucurbita moschata* and *Cucurbita* sp. were found in the village proper at Cerén in the kitchen of Household 1 and in the storehouses for Households 1 and 4 (Lentz et al. 1996a:254). In the kitchen context, *C. moschata* seeds were found on the surface of a metate, indicating that this foodstuff was ground rather than boiled, at least in part, at Cerén. Both preparation techniques leave little chance for carbonization and therefore preservation in the paleoethnobotanical record. However, the peduncles of *Cucurbita* are highly differentiated among its various species. The rinds, although not affording species identification, are also easily identifiable, factors which likely lead to the identification of cucurbits at a wide range of ancient Maya sites such as Copán, Cuello, and Tikal, and prehistoric sites throughout the Americas (Lentz 1991:274; Miksicek 1991:71; Turner and Miksicek 1984:185). Like the inedible parts of maize plants, the rind and peduncle portions of squash fruits may have been burned as fuel in households along with wood and other plant parts and deposited in the Operation P midden. While the plant use practices associated with squash at Cerén are unlikely to result in its carbonization (although other uses and processing methods for squash should not be ruled out), the part of the plant with the most mass – the rind – is easily identifiable when charred, even when in small fragments. This almost certainly contributed to its identification at many sites in the Maya area and beyond.

Bottle Gourd

Four fragments of bottle gourd (*Lagenaria siceraria*) rinds were identified from the Operation P midden (Figure 20). Like squash, bottle gourds are usually identified by the arrangement of cells comprising the plant's rind. In the Cerén village, bottle gourds were found hanging from the walls and rafters of Structure 11, the kitchen for Household 1 (Lentz et al. 1996a:249). The plants' fruits are noted for their wide array of uses as containers and utensils, while their seeds are often eaten like those of related squash species (Cutler and Whitaker 1961:483). A review of the literature returns little in the form of paleoethnobotanical evidence for bottle gourds in the Maya area; the plant's rind has been found at Cerén and Copán (Lentz 1991:274), while phytoliths (silica bodies produced by some living plants that preserve as distinctive forms which are identifiable to species) of the plant were identified from Pulltrouser

Swamp in Belize (Pohl et al. 1996:365-366). The scant evidence for bottle gourds is likely a function of the ways in which the ancient Maya used the plant, uses that likely precluded their carbonization and inclusion in the archaeological record.

Figure 20. Digital micrograph of a *Lagenaria siceraria* rind from the Operation P midden.



Tree Fruits

Arboriculture practiced by the ancient Maya, or the cultivation of trees for subsistence, medicinal products, building materials, and other goods, is a subject that has received much attention (Dahlin 1979; Folan et al. 1979; Gómez-Pompa et al. 1987, 1990; Lange 1971; Lundell 1938; McBryde 1947; McKillop 1994; Miksicek 1990; Netting 1977; Pérez Romero and Cobos Palma 1990; Peters 1983; Puleston 1968, 1982; Sweetwood et al. 2009; Turner and Miksicek 1984; Wilken 1971; Wiseman 1978). Cerén's unique preservation conditions permit a vivid glimpse at not only the types of trees grown by a village of ancient Maya commoners, but also how trees of economic importance were situated in household spaces. Tree fruits such as calabash (*Crescentia alata*), cacao (*Theobroma cacao*), avocado (*Persea americana*), nance (*Byrsonima crassifolia*), guava (*Psidium guajava*), hackberry (*Celtis* sp.), were found on activity surfaces and growing in household courtyards in the Cerén village. These orchards, in addition to small gardens found growing around household structures, indicate that Cerén's residents created a landscape replete with a diverse set of economic species.

Several tree fruits of economic importance were also identified in the Operation P midden, including jocote or hog plum (*Spondias* sp.), avocado (*Persea americana*), nance (*Byrsonima crassifolia*), and calabash (*Crescentia* sp.). The presence of eight *Spondias* pits (Figure 21) is particularly intriguing, for this is the first time the tree fruit has been documented at Cerén, although *Spondias* wood charcoal was identified in the village (David Lentz, personal communication 2012). *Spondias* fruits are eaten fresh and grow in bountiful quantities throughout Central America (Standley and Steyermark 1949:193-194). Given that *Spondias* is ubiquitous throughout the modern Central American landscape, and that the pits are frequently present at sites (Copán and Cuello, for example) that lack the unusual preservation conditions found at Cerén (Lentz 1991:274; Miksicek 1991:72), it is surprising that this tree fruit has remained absent at Cerén until now. Perhaps *Spondias* trees were grown far enough away from the village that their pits did not enter household spaces, or Cerén's residents took diligent care to ensure their removal. In El Salvador today, *Spondias* fruits are in season from July to October (Standley and Steyermark 1949:193-194). Based on the mature state of maize plants growing in the village and outfields at Cerén, Loma Caldera erupted in the middle of the rainy season, which occurs in August in El Salvador (Sheets 2006:37). Thus, *Spondias* was an available food source at Cerén when Loma Caldera erupted. The contribution of *Spondias* fruits to the diet at Cerén is still uncertain based on the paleoethnobotanical evidence, but future research at the site may discern whether the fruits were eaten regularly while in season or only by a few villagers.

Figure 21. Digital micrograph of a *Spondias* sp. pit from the Operation P midden.

In addition to *Spondias* sp., three avocado pits were identified from the Operation P midden (Figure 22). Avocado cotyledons were found on the TBJ surface beneath the eaves of the domicile of Household 2 in the Cerén village, and impressions of the leaf were cast in plaster elsewhere in the habitation area. Evidence of avocado has been documented in the form of macroremains at other ancient Maya sites such as Cuello (Miksicek 1991:72), Copán (Lentz 1991:266), and Pook's Hill in western Belize (Morehart and Helmke 2008:66) and *Persea* pollen was found in the Bladen Branch Region, Southern Maya Mountains, Belize (Abramiuk 2011:264). Although avocado plant parts were not identified in contexts revealing exactly how the fruit was processed and consumed (like the squash seeds found on the surface of a metate), it is reasonable to assume that the fruit was valued for its oil-rich flesh and eaten fresh as it is today. Standley and Steyermark (1949) note that sap extracted from avocado seeds are used in Central America for the indelible stain they produce to mark clothing, and the tree's bark is boiled with textile dyes to prevent the dye from washing away. It is likely that Cerén's residents had varied uses for avocados and the trees bearing them. Seeds and pits (the plant parts most often representing the species in the paleoethnobotanical record) may have become carbonized by being burned as fuel or through a preparation technique that included heating.

Figure 22. Digital micrograph of a *Persea americana* pit from the Operation P midden.

Two nance (*Byrsonima crassifolia*) pits were also identified from the Operation P assemblage. Nance fruits were found in the Cerén village as well. *Byrsonima* sp. and *Byrsonima crassifolia* macroremains have been recovered from other ancient Maya sites such as Cuello (Miksicek 1991:81); the Bronco and Chispas sites in Belize (Hageman and Goldstein 2009:2850); Salitron Viejo, Honduras (Lentz 1989:193); and Copán (Lentz 1991:275). In Central America, nance fruits are eaten fresh, made into a beverage, and added to decoctions administered as baths to relieve asthma and coughs (Roys 1931:306). Trees bearing nance fruit grow at a range of elevations (sea level to 1,800 m amsl) and are indicator species for pine savannas and other grasslands (Bhattacharyaa et al. 2011:117). While it is possible that Cerén's residents collected nance fruits from the uplands along with the pine found at the site, nance trees likely grew closer in grasslands near Cerén. Nance trees are common in modern Maya door gardens, and it is possible that these fruits were collected from such gardens around households at Cerén (David L. Lentz, personal communication 2012). These savanna habitats in the Zapotitán Valley are evidenced by *Trachypogon plumosus* grass used as roof thatch for structures in the Cerén village (Lentz et al. 1996b). Like *Spondias* fruits and avocados, the nance pits found in the Operation P midden were probably charred accidentally or purposefully burned as fuel after the fruit was eaten.

Another tree fruit, *Crescentia* sp. or calabash, was identified from the Operation P midden assemblage. The rind has a distinctive cellular arrangement that is easily observable with a stereomicroscope (Cutler and Whitaker 1961:479). Calabash rinds were also found in the Cerén village within a ceramic vessel stored in the kitchen structure of Household 1 and in the niche of Structure 2, the domicile for Household 2 (Lentz et al. 1996a:256). The calabash found in the niche of Structure 2 was intricately painted and may have been used as a serving container for food or drink (Beaubien 1993:160). Bishop Landa (Gates 1978:103) notes that the Maya also used calabash fruits as containers during the Contact period. Paleoethnobotanical analyses on assemblages of plant remains from Bronco (Hageman and Goldstein 2009:2850) and Pook's Hill (Morehart and Helmke 2008:66) in Belize have also identified calabash macroremains. Considering the contextual evidence from the Cerén village indicating that calabash was used as a container, opportunities for the plant's carbonization and preservation in the archaeological record were likely minimal, which may explain why the plant has been identified at a small number of sites.

The identification of tree fruits from the Operation P midden with extraordinarily well-preserved tree trunks, branches, fruits, stems, and stands of fruit trees in their systemic contexts within household courtyards in the village proper (Lentz and Ramírez-Sosa 2002:38) provides extensive evidence of arboriculture at Cerén. Such vivid details of arboriculture are significant because they contextualize an emerging corpus of paleoethnobotanical data for tree crops at other ancient Maya sites where typical preservation conditions render non-carbonized plant remains virtually invisible. Chan, an ancient Maya farming village in west-central Belize, is such a site, with a diverse set of plant macroremains including numerous tree crops (Lentz et al. 2011b). Remains of avocado cotyledons in outdoor domestic spaces and nance pits recovered from terrace beds indicate that Chan's residents likely planted orchards in household courtyards and further afield in terrace beds, an observation that mirrors the distribution of tree fruits and the trees bearing them in their systemic contexts within the Cerén village, in addition to tree crops such as *Spondias* only documented outside of household areas. Overall, the lush evidence of plant use practices at Cerén provides a useful framework from which to interpret plant macroremains and ancient landscapes throughout the Maya area.

Woods

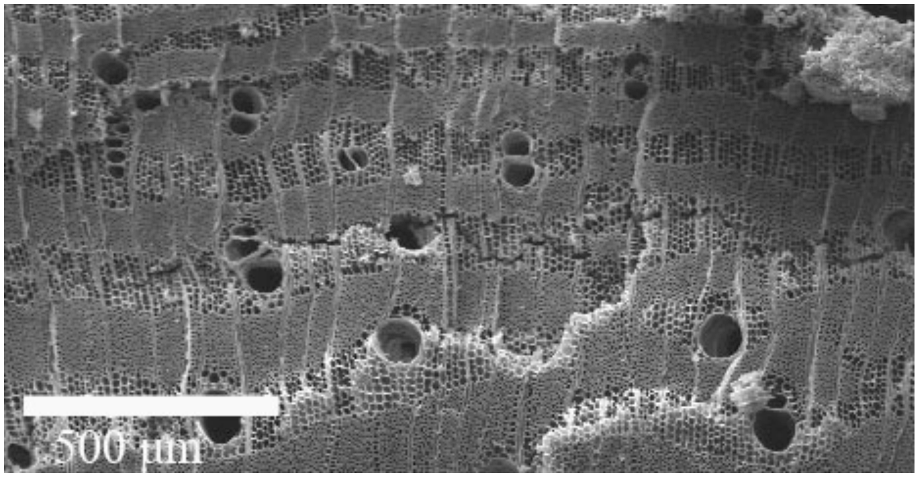
Wood charcoal remains from archaeological sites provide insight into three important aspects of past human/plant relationships: the tree species used by past populations for fuel, construction materials, tools, and other purposes; the composition of past forest communities and landscapes; and the agroforestry practices and foraging behaviors associated with acquiring wood resources (Marston 2009:2192). The following discussion of wood charcoal remains identified from the Operation P midden (no wood charcoal was identified from Operations F, M, or L) focuses on these issues. A total of 16 hardwood specimens representing seven taxa were identified, including cf. *Haematoxylon campechianum*, *Dalbergia* sp., *Hymenaea courbaril*, Bombacaceae, Sapotaceae, *Manilkara* sp., *Protium copal*. None of these taxa have been identified from contexts in the Cerén village by past paleoethnobotanical research at the site. All of these hardwood taxa were identified with the aid of SEM analysis. Pine was also found in the midden assemblage, but none of these specimens were identifiable to species.

It is difficult to isolate the behaviors that led to the carbonization and incorporation of these wood charcoal remains into the Operation P midden since they were recovered from a secondary refuse deposit. However, given the midden's location near a structure that functioned as a domicile or storehouse uncovered during the 2011 field season at Cerén (Sheets 2011a:9), it is likely that the wood remains along with other plant parts recovered from the midden were burned as fuel in a domestic context, perhaps in cooking fires, and discarded in the midden along with the artifacts found therein. Interestingly, wood ash was not present in the midden along with the charred plant remains and artifacts, which might indicate that the residents of Cerén living among extensive manioc and maize outfields were intentionally separating ash from charred plant remains when cleaning out their hearths. Evidence for such activities at Cerén comes from Structure 4, the storehouse-workshop for Household 4, where numerous gourds filled with wood ash were found (Gerstle and Sheets 2002:78). This wood ash would have been mixed with water to create an alkaline solution to soak maize kernels in preparation for grinding, a method for preparing maize practiced by the ancient and modern Maya. Since most charcoal remains from the midden are small in size, fragmentation might have been caused by wood being allowed to burn until nearly all of it combusted and became ash, or perhaps from mechanical damage incurred during the charcoal's removal from hearth features and deposition in the Operation P midden. Although the sources of wood charcoal deposited in the midden are ultimately equifinal, contextual evidence provided by the 2011 excavations at Cerén indicate that at least some of the assemblage was burned as fuel in a domestic setting.

Regardless of the multiple conditions under which wood charcoal from the midden could have been charred, it is certain that Cerén's residents utilized hardwood trees often. Hardwood charcoal was the most abundant plant remain identified in the Operation P midden by weight (Figure 15), and hardwood charcoal was abundant in the village proper as well (Lentz et al. 1996a; Lentz and Ramírez-Sosa 2002). *Haematoxylon campechianum*, also called logwood and tinta, was the hardwood taxon most often identified from the midden assemblage (Figure 23). Macroremains of the species have also been found at Cob and Pulltrouser Swamps in Belize (Pohl et al. 1996:365), and in situ timbers of the tree were identified in palace and temple structures at Tikal (Lentz and Hockaday 2009:Table 2). This species grows abundantly in wetlands and clay-rich soils (Rocas 2003), and it is valued for its durable wood and a dye that is extracted from the wood by the modern Maya to color cotton cloth and other materials (Standley and Steyermark 1946:139-140).

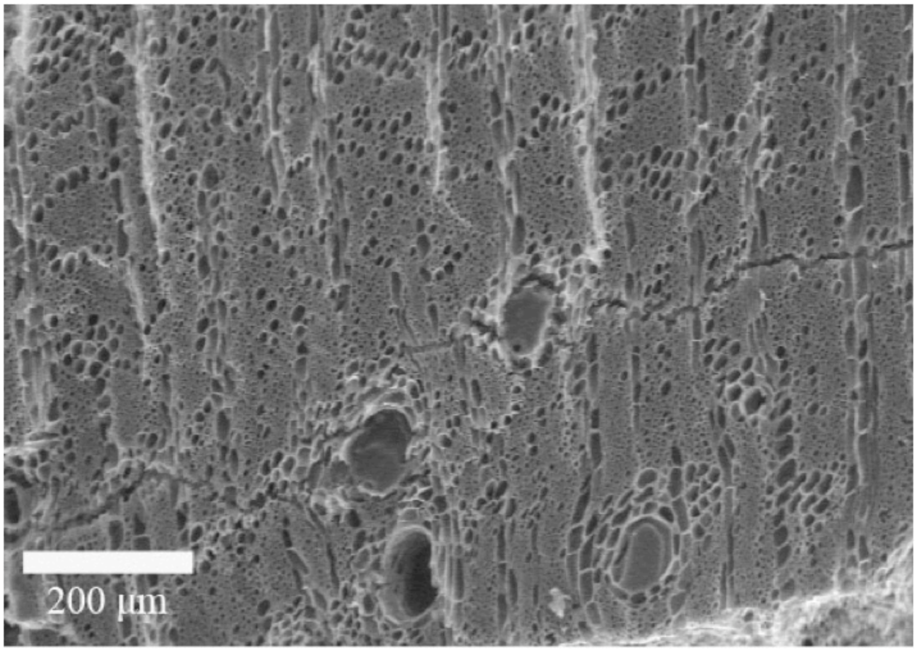
A review of the literature documenting forest communities in El Salvador does not yield information on any historic or modern populations of *H. campechianum* in the country (Carlson 1948; Daugherty 1969; Komar 2003; Standley and Calderon 1926), although extensive deforestation throughout El Salvador may have eradicated the tree from its ancient habitat. David Lentz and I conducted a small-scale vegetation survey around the modern village of Joya de Cerén during the 2009 field season at the site, and we did not note the tree's presence. The wetland environment and clay-rich soils in which *H. campechianum* thrives were conceivably present along the banks of the Río Sucio in the Late Classic period when Cerén was occupied. The clay deposited by the Coatepeque volcano laid below the TBJ living surface of Cerén, and this clay may have comprised the ground surface along the Río Sucio where flooding episodes would have washed away the TBJ. Perhaps the edaphic requirements for *H. campechianum* are not present in the Zapotitán Valley today, given the meters-deep deposits of tephra comprising the soil profile. Also, the extensive deforestation throughout El Salvador may have removed the tree from its Late Classic habitat. The lack of modern counterparts in El Salvador to plant resources used by Cerén's residents 1,400 years ago is not unprecedented, considering the grass species (*Trachypogon plumosus*) used to thatch roofs in the village cannot be found growing in the country today (Lentz et al. 1996b).

Figure 23. Scanning electron micrograph of cf. *Haematoxylon campechianum*, transverse section 50x.



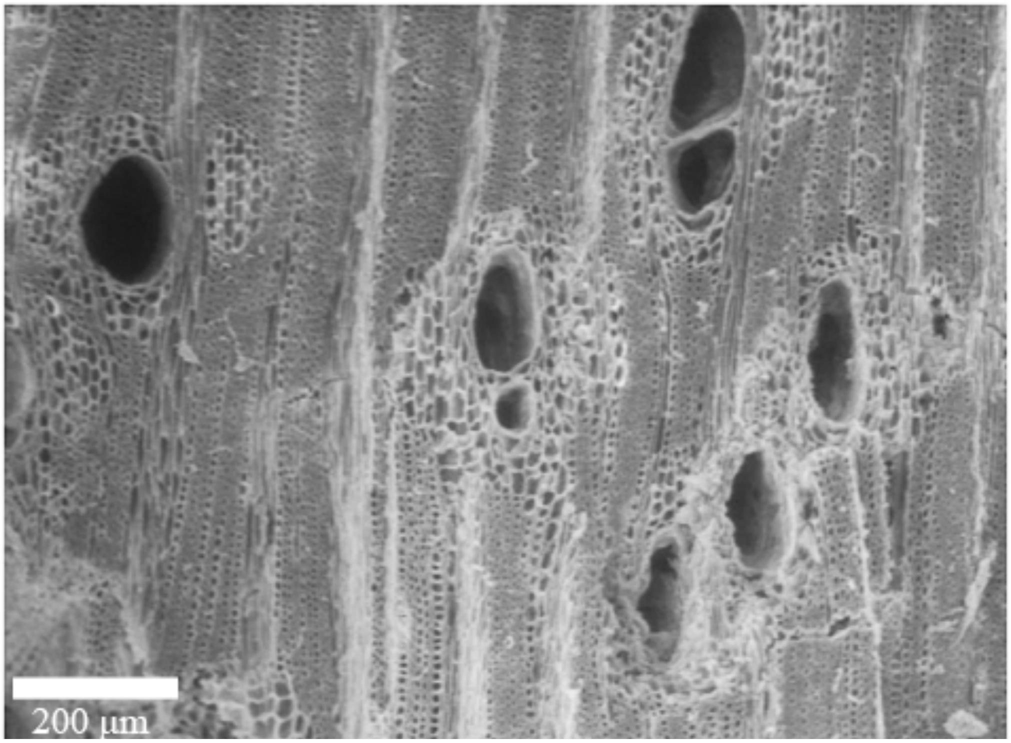
Unlike *H. campechianum*, modern populations of the genus *Dalbergia* sp. (Figure 24) exist in El Salvador. One specimen represents the genus in the Operation P midden, and the taxon's carbonized wood has also been identified in a commoner structure at Copán (Lentz 1991:275-276). The wood from several species of *Dalbergia* is used for fine cabinetwork in Central America (Standley and Steyermark 1946:201-208), and it is possible that the ancient Maya used this tree for crafting structural elements and tools in addition to its use as fuel.

Figure 24. Scanning electron micrograph of *Dalbergia* sp. charcoal, transverse section 100x.



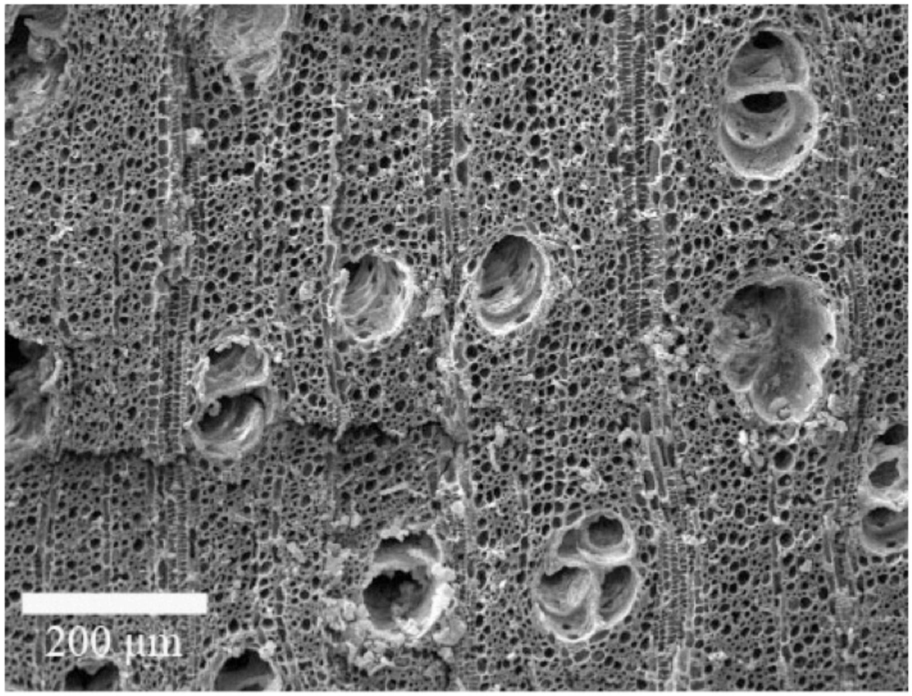
A leguminous tree species like *Dalbergia* sp. and *H. campechianum*, one specimen of *Hymenaea courbaril* charcoal was identified from the midden assemblage (Figure 25). The tree's charcoal was also found at Cuello (Miksicek 1991:71) and Copán in a Bijac phase midden associated with an elite structure (Lentz 1991:275-276). In El Salvador today, the fast-growing tree can be found in a number of diverse habitats, including dry forests, on poor soils, and areas that are regularly inundated (Food and Agriculture Organization of the United Nations 1986:157). Standley and Steyermark (1946) note that the tree has several uses in Central America. The pulp of the tree's fruit is edible and used to flavor atole, and sap is collected from the tree and burned as incense in churches. The wood is also used as a building material. The tree's plastic growing requirements and fast rate of growth likely made it an attractive wood resource for Cerén's residents and the ancient Maya in general.

Figure 25. Scanning electron micrograph of *Hymenaea courbaril* charcoal, transverse section 101x.



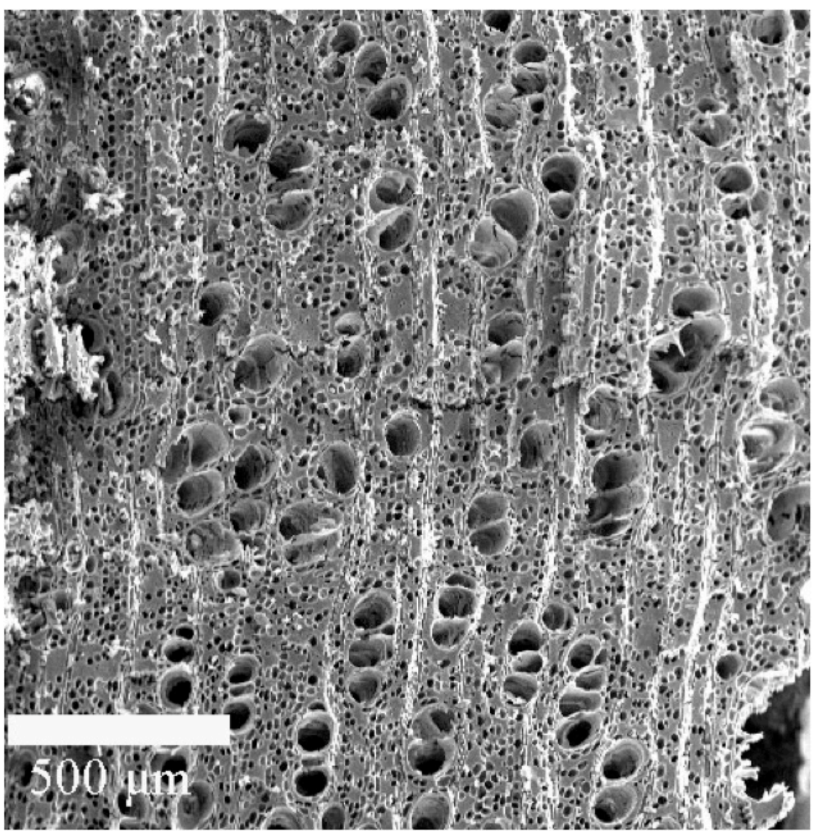
One charcoal specimen from the midden was identified to the Bombacaceae family (Figure 26). The family is widespread in El Salvador and Central America in general (Standley and Steyermark 1949:388-393). In El Salvador, the species *Bombax ellipticum* and the genus *Ceiba* – the sacred tree of life for the ancient Maya (Sharer and Traxler 2006:42) – are common. Daugherty (1969) describes *B. ellipticum* and *Ceiba pentandra* as species characteristic of the tropical evergreen forest of El Salvador, signifying the presence of this forest community in the Zapotitán Valley during the Late Classic period when Cerén was occupied.

Figure 26. Scanning electron micrograph of Bombacaceae charcoal, transverse section 100x.



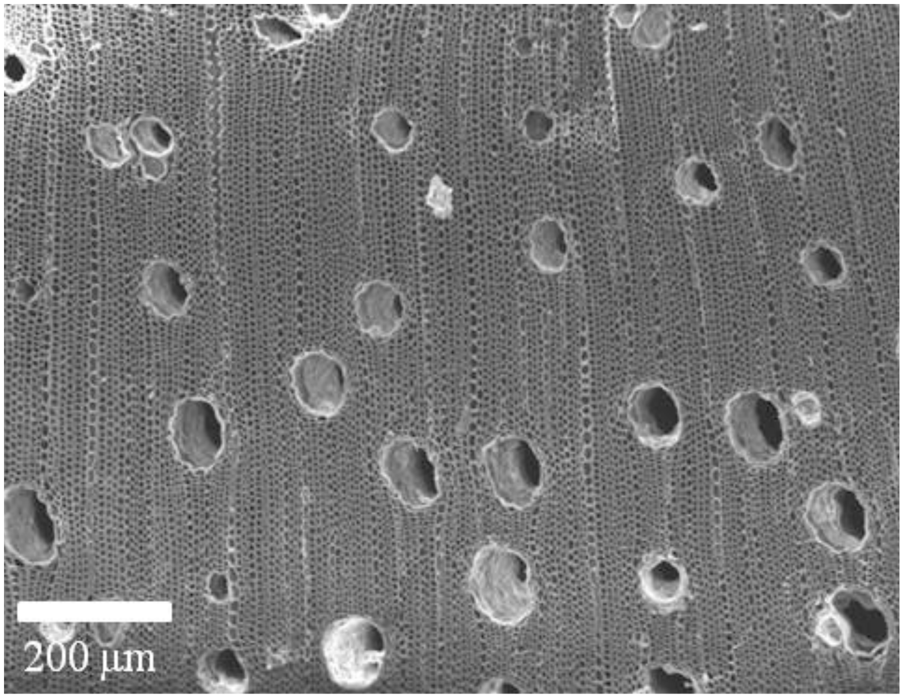
Three wood charcoal specimens belonging to the Sapotaceae family were identified from the Operation P midden. Two of these were unidentifiable beyond the family designation Sapotaceae, and one specimen exhibited enough morphological features to be identified as *Manilkara* sp., also called chicozapote and sapodilla (Figure 27). Several genera belonging to the Sapotaceae family are found in El Salvador today, including *Bumelia*, *Chrysophyllum*, *Manilkara*, *Mastichodendron*, and *Pouteria* (Standley and Williams 1967). Trees in the Sapotaceae family have a wide range of modern economic applications and are valued for their edible fruit, highly durable timber, and latex (collected from *Manilkara zapota*), which for many years was the main ingredient of chewing gum before synthetic forms of latex replaced it. Although plant remains from the Sapotaceae family and the genus *Manilkara* sp. have not been identified at Cerén outside of the Operation P midden, paleoethnobotanical evidence from other sites in the Maya area indicate that the ancient Maya employed materials collected from trees in the Sapotaceae family for purposes similar to their modern uses. Remains from *Manilkara* fruits have been identified at Pook's Hill (Morehart and Helmke 2008:66) and Cuello (Miksicek 1991:71), while wood from *Manilkara zapota* has been identified from tie beams and lintels collected in situ from a large number of temples and palace structures at Tikal (Lentz and Hockaday 2009). Genetic research is currently investigating whether the ancient Maya domesticated *Manilkara zapota* for its timber and fruit (Thompson 2011), and this project's results will have significant bearing on *Manilkara* remains found at Cerén and other ancient Maya sites. *Manilkara zapota* may have been a constituent species of the domesticated forest landscape along with the cacao, avocado, and guava trees that were grown in orchards surrounding the Cerén village.

Figure 27. Scanning electron micrograph of *Manilkara* sp. charcoal, transverse section 50x.



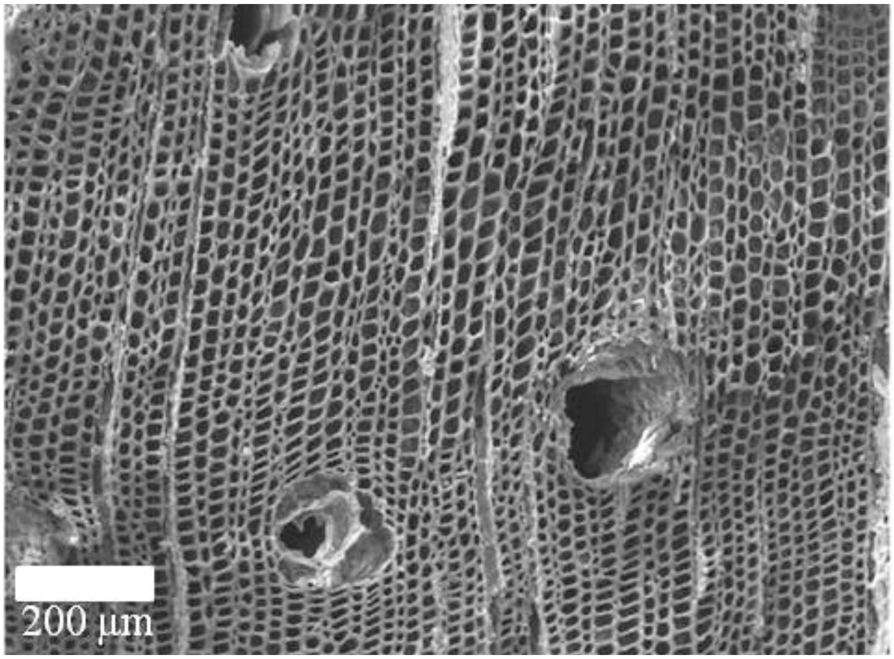
The final hardwood species identified from the midden assemblage is *Protium copal*, commonly referred to as copal or pom (Figure 28). Modern Maya groups extract the fragrant resin from copal trees and burn the substance as incense during religious rituals (Atran et al. 1999:7603). The Q'eqchi Maya collect copal resin by first scoring the trees with machetes and scraping dried resin from the slashes with wooden paddles (Case et al. 2003:191). Elites in the northern Maya lowlands controlled the trade of copal resin during the Contact period, a material whose distribution was incorporated into the ancient Maya political economy as well (Sharer and Traxler 2006:675). While it is possible that Cerén's residents also collected copal and incorporated the burning of its resin into their religious rituals, evidence for such practices has not been found at Cerén to date. Like *H. campechianum*, this Late Classic *Protium copal* lacks historic and modern counterparts in El Salvador (Carlson 1948; Daugherty 1969; Komar 2003; Standley and Calderon 1926). Since it is likely that the *Protium copal* charcoal found in the Operation P midden was burned as fuel, the wood was probably not imported over long distances from the Maya lowlands where it grows plentifully today simply to be used as firewood. More plausibly, *Protium copal* grew closer to Cerén 1,400 years ago where its wood was gathered and burned as a source of fuel and its resin possibly burned as incense during religious rituals.

Figure 28. Scanning electron micrograph of *Protium copal* charcoal, transverse section 98x.



In addition to hardwood taxa, pine was also found in the Operation P midden (Figure 29). A species of pine, *Pinus oocarpa*, was used as a building material in the village. The tree's charcoal was found in roof collapse found in Structure 4, the storehouse-workshop for Household 4 (Lentz et al. 1996a:257). Ethnographic literature offers evidence for modern Maya groups using pine as a building material as well. The Tzotzil (Breedlove and Laughlin 1993:183-184) and Tzeltal Maya (Berlin et al. 1974:299) of Chiapas use pine to construct their houses, as do the Mopan and Kekchi Maya of southern Belize (Thompson 1930:34). In addition to these mundane uses, pine plays a significant role in the ritual lives of the modern Maya. The Tzotzil Maya adorn crosses, shrines, and altars with pine boughs and scatter pine needles across church floors to stand and kneel upon, an act that ensures "proper communication with the supernaturals" (Vogt 1969:393). The Lancandon Maya of Chiapas burn pine resin as incense during rituals and believe that the smoke transforms into a food offering of tortillas for the gods to eat (McGee 1990:44).

Figure 29. Scanning electron micrograph of *Pinus* sp. charcoal, transverse section 99x.



Further evidence exists for the use of pine by the ancient Maya in religious rituals. Pine has been identified from ceremonial contexts at Copán (Lentz 1991:Table 1), Xunantunich (Lentz et al. 2005:579), the El Cajón region of Honduras (Lentz 1989:197), Caracol (Chase and Chase 1998:317), La Milpa (Hammond et al. 2000:43), and Pook's Hill (Morehart 2001:454). Paleoethnobotanical assemblages from cave sites in the Maya area, spaces the ancient Maya considered sacred and used for ritual activities (Pohl and Pohl 1983; Prufer 2002; Turner 1969), are replete with pine remains, further demonstrating the essential quality of pine to ancient Maya ritual practices. For example, pine has been identified from cave sites such as Actun Nak Beh, Laberinto de las Tarantulas, Twin Caves 2, Barton Creek Cave, Actun Halal, Actun Chapat, and Actun Chechem Ha in the Belize River Valley (Morehart 2002); Holomi Baatz, Xba'qe1 Cho'qow, and Sebaleb Xheton caves in the Maya Mountains of Belize (Prufer 2002); and Actun Polbilche (Pendergast 1974), Tiger Bay (Stone 1997:201), Footprint (Graham et al. 1980:169), and Caves Branch (Reents-Budet and MacLeod 1997:58) caves in the Sibun Valley of Belize.

As was discussed in the Environmental Setting section of Chapter 1, the presence of pine in the paleoethnobotanical record at Cerén is unusual, for these trees do not grow close to the site today. The closest stands of pine in the Zapotitán Valley are located on volcanic slopes above 1,000 m asl, over 10 km from the site. Given that the climate has remained essentially the same in Central America since the Late Classic period when Cerén was inhabited, it is unlikely that climatic shifts have rendered a landscape once ideal for pine to an unsuitable one (Markgraf 1989).

There are two possible explanations for how Cerén's residents procured the pine found at the site. First, it is possible that the site's inhabitants walked to the uplands to collect pinewood for fuel, building material, furniture, utensils, and other goods. Evidence for the transportation of pine over several kilometers is not unprecedented in the Maya area. Pine was imported to Xunantunich, San Lorenzo, and Chan Nòohol from the Maya Mountains located over 17 km to the southeast of the area in which the sites are located (Lentz et al. 2005:573). At Cuello, pine was imported 10 km to the southeast and southwest of the site (Miksicek 1991:80). Pine charcoal has also been identified at Dos Pilas (Lentz 1994) and Pulltrouser Swamp (Miksicek 1983:99), sites where pine does not grow today. Analogous to the importation of pine to ancient Maya sites, pine was brought overland to Gordion, an urban settlement in Turkey occupied from the 3rd millennium BCE to the 14th century CE, from a distance of 30 km and used principally as a building material for roofs, while locally available wood taxa were used primarily as fuel (Marston 2009). If pine were imported over a substantial distance from the uplands to Cerén, it is possible that the wood was reserved for its use as a construction material and/or ritually charged item, while trees growing closer to the site were utilized for fuel, as at Gordion. Marston (2009) argues that wood charcoal remains from archaeological sites should be understood in a framework of behavioral ecology (the study of how ecological and social settings affect human behavior) to discern wood acquisition strategies from charcoal assemblages and their contexts. While based on paleoethnobotanical data from a site in the Old World, this example from Gordion is useful for understanding the presence of pine at Cerén and other sites in the Maya area where pine was imported because it imbues the material remains of past plant use practices with a tangible sense of the behaviors and strategies that informed wood resource extraction.

The second explanation for the presence of pine at Cerén places pine in the Zapotitán Valley during the Late Classic period. *Pinus oocarpa*, the species of pine identified from roof collapse in the village, is fire-adapted and grows quickly in recently burned areas, even at elevations as low as Cerén (Perry 1991). As Lentz et al. (1996a) point out, regular burning of the tropical deciduous and evergreen vegetation comprising the Zapotitán Valley floor for *milpas* and other ground-clearing purposes would have created ideal growing conditions for pine. Thus, Cerén's residents may have utilized local stands of the conifer. It is difficult to determine whether the pine identified at Cerén was collected from the Zapotitán Valley floor or imported from the higher elevations of volcano slopes 10 km from the site, but this question might be answered by future research at Cerén. If pinewood was locally sourced, it is possible that the tree grew close to the village or bordering agricultural outfields. Future research at Cerén may be able to determine whether pine was grown locally if a pine tree truck is cast in plaster in its systemic context as other trees and plants have been at Cerén.

Missing Species

As demonstrated by the comparison of plant taxa identified from the Cerén village and the Operation P midden (Table 7), there are significant differences between the plant resources used by past populations and those identified from the archaeological record. Although this finding is not a revelation, it is a unique opportunity to reconstruct these disparate assemblages and the site formation processes, recovery methods, and identification biases that created them. Carbonization is the variable most constraining the preservation of plant remains in the archaeological record of the Maya area. If past use, processing, or discard practices did not expose a plant part to heat in a low oxygen environment (a cooking fire, for example), it is certain that evidence of the plant would decompose in the warm, humid climate of the Neotropics. The absence of plant taxa among the carbonized plant remains like manioc, malanga, chile peppers, guava, and agave in the Operation P midden is clearly linked to the preservation bias favoring the survival of carbonized plants in the archaeological record. The systemic context of cottonseeds upon a metate in the Cerén village (Lentz and Ramírez 2002:37) offers an excellent example of how past plant processing practices – namely grinding – can effectively exclude a plant resource from appearing in the archaeological record of sites with typical preservation conditions.

Recovery methods employed to recover macroremains are another variable that introduces discrepancies between past plant use practices and those plants identified from paleoethnobotanical assemblages. The diverse set of seeds found in the Cerén village (such as chile, squash, cotton, and cacao seeds) was not present in the Operation P midden assemblage. While this is likely due to the behaviors and practices that led to the charring and deposition of a homogeneous set of seeds into the midden, the methods used for recovering plant remains from archaeological contexts could exclude some plant parts such as small seeds. Integrating a plant remain sampling strategy that incorporates both hand-collection of macroremains during excavation and systematic retrieval of flotation samples will help to bridge the gap between the plant remains recovered from archaeological sites and those used in the past. The macroremain sampling strategy for this study was designed to recover small plant remains such as seeds from flotation samples by processing the light fraction through a fine gauge screen. Future paleoethnobotanical research at Cerén would benefit from the analysis of the heavy fraction of flotation samples, or the materials that fail to float on top of the processing basin, in addition to the light fraction. Paleoethnobotanical research at other ancient Maya sites and archaeological sites in general would also be enriched by this research design.

Perhaps more notable than the species present in the Operation P midden is the one species whose absence is most conspicuous: manioc (*Manihot esculenta*). The lack of evidence for manioc in the form of carbonized macrofossils in the midden, despite two manioc stems cast in dental plaster volunteering from the midden and the midden's location 38 meters southeast of the most complex ancient manioc field known in the New World (Tetlow and Hood 2009:14), reflects the problematic conditions surrounding the preservation of manioc in the archaeological record. Manioc is typically propagated vegetatively by planting cuttings from the plant's mature stems in the ground (Cock 1982:756) and not by seeds, eliminating a potential source of evidence for manioc in the archaeological record. Furthermore, manioc roots, along with macroremains of root crops in archaeological contexts throughout the world, preserve poorly and prove difficult to identify even when preserved via carbonization, desiccation, or from waterlogged conditions (Pearsall 2000:153). If modern preparation techniques for manioc – grating, grinding, boiling, and fermentation – mirror those used by Cerén's residents, the probability that manioc root tissue would become carbonized and preserve in archaeological contexts is low.

Having discussed factors deterring the recovery and identification of manioc macroremains, it is important to note that evidence for ancient manioc has been found in the Maya area outside of Cerén. At Cuello, Miksicek identified charred manioc stems, but it is uncertain whether these represent wild or domesticated plants (Miksicek 1991:80). Similar to these macroremains, pollen identified to the genus *Manihot* cannot be differentiated between wild and domesticated forms of manioc. Nonetheless, *Manihot* pollen identified from sediment cores extracted at locations close to ancient Maya sites in Belize (Pohl et al. 1996:362-363) suggest that manioc may have been grown as a cultivar beyond Cerén. Whether manioc was intensively cultivated as a staple crop at other ancient Maya sites as it was 200 meters south of Cerén's center remains unknown.

Despite this seemingly pessimistic outlook on the chances of identifying manioc from sites in the Maya area lacking the unusual preservation conditions at Cerén, archaeologists working in Mesoamerica should be encouraged to incorporate programs of paleoethnobotanical study into their research designs to systematically recover potential macroremains, as well as microremains (pollen, phytoliths, and starch grains) in an effort to broaden our understanding of a botanically as well as culturally diverse region. Microremains are not dependent upon carbonization to preserve in archaeological contexts in the Maya area, making them ideal forms of plants remains for investigating the range of plant resources in use at a site. Pollen and phytolith samples should be collected in the form of soil samples retrieved during excavation of floors, pit features, middens, living surfaces, and other cultural features; from sediment cores; and from artifacts such as ceramics, chipped stone tools, metates, and other groundstone tools (Pearsall 2000). Starch grains are most likely to survive in the tiny fissures of chipped and groundstone tools and ceramics (Pearsall 2000:180), and these artifacts should be systematically sampled. Samples of macro and microremains should be collected from all areas of a site in an effort to mitigate the distorting effects formation processes have on the traces of past plant use.

The difference between small amounts of manioc grown in kitchen gardens within the Cerén village and the intensively cultivated manioc outfields 200 m south of the village provides an excellent example of the ways in which the spatial distribution of a single species can vary within a single site, leading to disparate narratives of plant resource utilization in the past. Before these southern outfields were discovered, it was thought that manioc played a minor role in the diets of Cerén's residents based on the small number of manioc plants found in the village (Lentz and Ramírez-Sosa 2002:35). This interpretation changed after the 2007 and 2009 field seasons at Cerén when it was found that approximately 10 tons of manioc tubers were harvested from the southern outfields in the days preceding the Loma Caldera eruption (Sheets et al. 2011). Clearly, manioc was a staple at Cerén. While these stark contrasts will not be so tangible at sites lacking Cerén's unique preservation, layering multiple lines of evidence for plant use practices from charred macroremains, flotation samples, starch grains, pollen, and phytoliths (Chandler-Ezell et al. 2006) will form the strongest interpretations of the paleoethnobotanical record in Mesoamerica.

Beyond sampling and analyzing multiple forms of plant remains, archaeologically elusive species such as manioc and plant parts such as roots and tubers might be more readily identified as macroremains with the employment of specialized identification techniques such as embedding, transmission electron microscopy (TEM), and scanning electron microscopy. Embedding involves saturating fragile plant tissue in a media that hardens, permitting thin sections of plants' interior anatomical features to be examined for identification with TEM. This technique could be especially useful for the identification of roots and tubers from archaeological sites in Mesoamerica to further explore the roles these plant parts played in ancient subsistence, medicine, and other spheres of life. SEM is also a powerful tool for analyzing plant parts such as roots and tubers that are not easily identified at low magnification, and its use should be expanded in paleoethnobotanical research. The combination of these sampling strategies and identification techniques will not completely reverse the biases due to differential preservation inherent in the paleoethnobotanical record of this Neotropical region, but they will certainly do a great deal for understanding the plant remains that have been preserved.

Summary

The plant remains identified from the Operation P midden, Operation F, Operation L-1, and L-2 represent those taxa common in the paleoethnobotanical record of the Maya area (wood charcoal and maize, for example) and those rarely found as charred remains, such as beans. Beans and wood charcoal dominate this assemblage, with maize, squash, and tree fruits such as avocado, jocote, and nance present in smaller numbers. The hardwood, pine, and palm wood resources identified from the midden indicate that Cerén's residents utilized a diverse set of wood resources in the Late Classic, some of which cannot be found in the Zapotitán Valley today. Without the rich contextual data offered by unusually preserved plant remains in agricultural outfields 200 m south of the Cerén village and the village itself, it would be reasonable to conclude that beans and maize were dietary staples at Cerén supplemented by tree fruits such as jocote, avocado, and nance. As discussed above, however, the paleoethnobotanical record is more an artifact of cultural and noncultural formation processes than a complete inventory of the plants used by past populations. Although intensively cultivated manioc beds surrounded the areas from which this plant remain assemblage was collected and manioc stems cast in plaster were found growing from the Operation P midden, charred manioc remains were not identified. This absence of manioc highlights the preservation bias of the paleoethnobotanical record in Mesoamerica: if the uses, processing techniques, and discard behaviors for a plant resource do not lead to its carbonization, then the plant resource is underrepresented or absent from macroremain assemblages. Archaeologists are fortunate to have sites like Cerén, however, to test our assumptions about plant use practices by the ancient Maya and the methods we use to investigate them. By systematically sampling for and analyzing multiple sources of ancient plant remains with specialized identification techniques at sites across the Maya area, the picture of ancient Maya plant use practices will continue to come into focus.

Chapter 5

Conclusions

Introduction

This chapter synthesizes findings of the paleoethnobotanical analysis conducted with plant remains collected from agricultural outfields 200 m south of the Cerén village while focusing on the study's significance to paleoethnobotanical research in the Maya area, Mesoamerica, and beyond. Suggestions for the direction of future research exploring the ancient human-plant relationship at Cerén and across the Maya area will also be offered.

Research Summary

The research question addressed by this thesis investigates whether the plant macroremains from a midden and the surface of agricultural outfields 200 m south of the Cerén village reflect the plant resources uniquely preserved in their systemic contexts at the site. If these assemblages differ, how can plant use practices, site formation processes, and recovery/identification biases introduced by archaeologists and paleoethnobotanists contribute to differential preservation of plant taxa? To answer these questions, an analysis was conducted on macroremains collected during excavation and from flotation samples. Based on analysis results presented in Chapter 3, the midden, while yielding a range of charred plant remains, did not reflect the diverse set of plants found in the Cerén village (Table 7). The differences between these two assemblages were statistically significant, and while this result is not entirely surprising, it is an unique case study exhibiting just how wide the chasm can be between the plants used by past populations and those identified from the archaeological record.

The causes for such discrepancies between the two assemblages primarily stem from the poor preservation of non-carbonized plant remains at archaeological sites in the warm and humid climate of the Neotropics. Plant use practices and discard behaviors that do not expose plant parts to fire or heat greatly diminish opportunities for preservation. The ubiquity of maize macroremains from Cerén's habitation area and outfields, and from ancient Maya sites in general, compared to the rare occurrence of root crops such as manioc highlight this preservation bias. If modern preparation techniques such as boiling, grinding, fermenting, and grating are analogous to the ways in which Cerén's residents prepared manioc tubers, the chances for the plant part to preserve via carbonization would be few. Maize, unlike manioc tubers, retains identifiable features even when subjected to processing methods like sprouting, toasting, and boiling before carbonization (Goette et al. 1994). Manioc, along with other roots and tubers, still remain difficult to identify when preserved through carbonization (Pearsall 2000:153).

Archaeologists and paleoethnobotanists also introduce biases to the interpretation of the human-plant interaction. By only collecting samples for plant remains that we can see, the chances of reconstructing an accurate a picture of the plant resources in use at sites that are examined from a single set of contexts are extremely low. Although preservation, recovery, and identification problems in paleoethnobotanical studies pose challenges to the study of ancient Maya utilization of plant resources, a research design centered upon the recovery of multiple lines of evidence for plant remains could do a great deal to mitigate these problems. This research design includes systematic sampling of all contexts of a site for both paleoethnobotanical macroremains and microremains, for some plant taxa may remain archaeologically invisible in the form of charred macroremains while appearing as pollen, phytoliths, and/or starch grains. Macroremains should be collected when they are encountered during excavation and by collecting flotation samples from features such as middens, chultuns, and storage pits, as well as surfaces like floors, causeways, and workspaces. Flotation samples should be standardized in volume so that each individual sample is comparable to all others collected for a project. Flotation processing systems, whether modest or elaborate in size and materials, should be designed to recover very small plant parts such as seeds. Both the heavy and light fractions of flotation samples should be analyzed for the most complete picture possible of what plants were being used and becoming carbonized at a site. Specialized analysis techniques such as embedding, TEM, and SEM could help identify fragile and small plant remains, as well as those possessing anatomical and morphological features requiring high magnification for examination. While this research design will not suddenly transform paleoethnobotanical remains recovered from archaeological sites into an exact inventory of the plants utilized there, it will develop a more complete picture of past plant use practices.

Significance

The significance of this study lies in its conclusion that there are substantive differences between the plant taxa found in their systemic contexts within the Cerén village and agricultural outfields 200 m south of the site and those charred macroremains collected from the surfaces of the southern outfields and the Operation P midden. Particularly intriguing is the absence of manioc from this assemblage of charred remains, despite the fact that it was grown as a staple crop in the southern outfields and cast in plaster growing from the midden. This study reveals how even a staple crop can remain archaeologically invisible under normal preservation conditions due to formation processes, methods used to recover plant remains, and identification biases. Such conclusions require a reexamination of the narrative archaeologists and paleoethnobotanists have written for ancient Maya agricultural practices. This reexamination should begin with the adoption of the research design summarized above when paleoethnobotanical studies are pursued at other ancient Maya sites. An emphasis upon the recovery and analysis of multiple lines of plant remain evidence from other ancient Maya sites is the best research strategy to explore whether manioc was present at other sites, or whether the crop was confined to the southeastern periphery of the Maya world.

The findings of this study are applicable to paleoethnobotanical research conducted in other regions of the world, especially those with the poor preservation conditions for non-carbonized macroremains present in the Maya area. This thesis illustrates the importance of understanding the impacts of site formation processes, recovery methods, and identification constraints upon the record of past plant use is an essential research pursuit in itself. Addressing the problem of archaeologically invisible plant taxa with new methods and techniques tailored to geographic regions, individual site conditions, plant taxa, and research questions will serve to strengthen the discipline of paleoethnobotany, as well as broaden archaeologists' reconstructions of past lifeways.

Aside from the methodological significance of this study, understanding the ancient Maya through the "invisible-universe dataset" of plant remains adds rich detail to narratives of a past often dependent upon durable traces of human activity such as stone tools, ceramics, and monumental architecture. More than interesting facts, populating the remote past with plant resources used for subsistence, cordage, fuel, construction materials, furniture, storage containers, medicine, clothing, and ritual activities broadens our reconstructions of ancient Maya agricultural systems, political economy, and socioeconomic status. For example, the plant resources identified at Cerén reveal a Late Classic farming community of commoners in which small kitchen gardens and intensively cultivated outfields alike were planted upon raised beds constructed to suit the crop that would be planted there. The farmers at Cerén were obviously knowledgeable about the crops they raised, creating a landscape replete with economic species.

Based on the amount of crops growing in gardens and outfields, and foodstuffs stored in the village at the time of the eruption, it appears as though Cerén's residents possessed an abundance of diverse food resources. This is not to imply that the villagers never experienced crop failures or food insecurity. However, this image of abundance at an ancient Maya commoner site runs contrary to the stereotype that commoners were impoverished and constantly struggled to make ends meet. Beyond subsistence, Cerén's residents grew cacao and cotton, plants often associated with the political economy of ancient Maya society (Sharer and Traxler 2006:292,634). At Cerén and perhaps other commoner communities in the Maya area, elites did not control the production, consumption, and distribution of these plant resources (Scarborough and Valdez 2009). The possible trade of pinewood from the upland slopes of the Zapotitán Valley to Cerén also expands our notions of trade goods in the Maya area. Trade goods were likely not limited to jade, feathers, obsidian, and marine shells, among other materials, but included plants such as pine with uses both mundane and sacred.

Research examining ancient Maya plant use practices at Cerén also shifts the focus from one of power and prestige that has dominated Maya studies for most of its history to one of everyday household life. Household archaeology is a bourgeoning subfield within Maya studies which sets its sights on understanding the experiences of those in ancient Maya society often overlooked by reconstructions of the past, including commoners, women, children, slaves, and groups living beyond the borders of the Maya world. The paleoethnobotanical research conducted at Cerén portrays the commoner farmers living at the site as actively shaping their environment with household gardens, orchards, and expansive outfields while reaping bountiful returns from them. Their wealth in plant resources, coupled with the large and diverse assemblages of artifacts and architecture encountered during excavations in the village, indicate that Cerén's residents led comfortable lives in the Zapotitán Valley before the Loma Caldera eruption destroyed their village. Imbuing our concepts of ancient Maya commoner lives with the fine details present at Cerén permits us to dispel myths about commoners as a passive underclass – one that arose from an often sparse and incomplete archaeological record of their settlements – in the same way the exquisite preservation of plant remains at Cerén has allowed for the expansion of our understanding of ancient Maya plant use practices.

Future Research

Based on the findings of this thesis, future paleoethnobotanical research at Cerén should continue to seek ways in which archaeologically invisible crops such as manioc could be identified at other sites where preservation conditions are far less optimal. Whether through macro or microremain analysis, residue analysis, obsidian usewear analysis (Sheets 2011b), or other techniques, the detailed view of past plant use practices at Cerén will continue to inform and improve paleoethnobotanical studies at other ancient Maya sites. Exploring the signatures of manioc in particular at other ancient Maya sites is an exciting research track that has the potential to shape our understanding of ancient Maya agriculture, economy, and carrying capacity in the Neotropics.

Future research at Cerén should also continue to examine wood charcoal, not only to identify those taxa used by the site's residents, but also to attempt to reconstruct the constituent species of a forest that has no modern analog. The identification of tree taxa that are no longer present in the Zapotitán Valley such as *Protium copal*, *Haematoxylon campechianum*, and *Pinus* sp. presents the possibility that these trees either grew close to Cerén 1,400 years ago or that their wood was valued enough to be imported to the site. The study of the human-plant interaction at Cerén is so intimately tied to the study of all other aspects of life at the site, due both to the ubiquity of plant remains at the site and the thorough excavation and preservation methods employed there, that any future research at the site will undoubtedly continue to reveal fine details of plant use both unexpected and exciting.

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Appendix A

Analysis Sheet Examples

Macrofossil Cover Sheet

Site Cerén

Operation P-1

Grid

Exact Provenience

Feature Sub tbj midden NW

Date Collected 3/1/09

Collector AWH, DLL

Analyst AWH

Date Analyzed 1/5/10

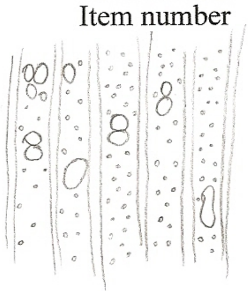
Time

Broadly Provenienced Organic Material

3 / 0 / 0 / 0 / 2
Form number

Page 0 / 1

0 / 0 / 1
Item number



Taxonomic Plant Name Hardwood

Technical description of plant part wood charcoal; multiseriate rays; pores single and in radial chains, diffuse porous, pores abundant; unable to see parenchyma - unsure of its arrangement

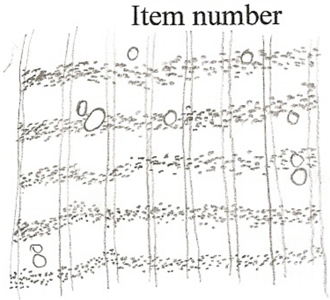
ID Level taxon	ID Level part	Quantity
0 / 1	0 / 1	/ / 1

Comment on this entry: good for SEM

★ Mounted for SEM ★ - SEM taken 1/19/10

Weight (g) 0.19g

0 / 0 / 2
Item number



Taxonomic Plant Name Hardwood

Technical description of plant part wood charcoal; multiseriate rays; diffuse porous, pores single, pores sparse; banded apotracheal parenchyma

ID Level taxon	ID Level part	Quantity
0 / 1	0 / 1	/ / 1

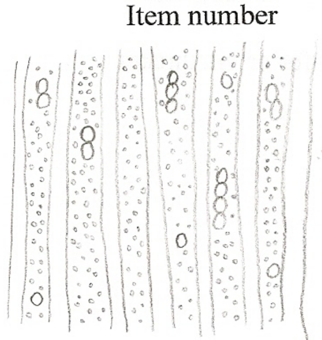
Comment on this entry: good for SEM

SEM taken 1/19/10

★ MOUNTED FOR SEM ★

Weight (g) 0.06g

0 / 0 / 3
Item number



Taxonomic Plant Name Hardwood

Technical description of plant part wood charcoal; multiseriate rays; diffuse porous, pores single and in radial chains; pores abundant; unable to see parenchyma - unsure of its arrangement

ID Level taxon	ID Level part	Quantity
0 / 1	0 / 1	/ / 1

Comment on this entry: good for SEM!!

SEM taken 1/19/10

★ MOUNTED FOR SEM ★

Weight (g) 0.40g

Broadly Provenienced Organic Material

3/0/0/0/7
Form number

Page 0/1

0/0/1
Item number

Taxonomic Plant Name hardwood
Technical description of plant part wood charcoal; multi-seriate rays; pores small, single, in groups of 2 & radial chains, & moderately numerous; diffuse; unable to see parenchyma

ID Level taxon	ID Level part	Quantity
0/1	0/1	/1/1

Comment on this entry:

Weight (g) < 0.01

0/0/2
Item number

Taxonomic Plant Name Phaseolus vulgaris
Technical description of plant part cotyledon; seed leaf present

ID Level taxon	ID Level part	Quantity
0/1	0/1	/1/1

Comment on this entry:

Weight (g) 0.02

0/0/3
Item number

planar view

Taxonomic Plant Name unknown
Technical description of plant part seed? unable to see identifiable features

ID Level taxon	ID Level part	Quantity
0/3	0/2	/1/1

Comment on this entry: *show DLL*

Weight (g) 0.01

Broadly Provenienced Organic Material

3/0/0/0/1
Form number

Page 2/1/4

6/4/0
Item number

Taxonomic Plant Name hardwood
Technical description of plant part wood charcoal; multiseriate rays; unable to see any other features

ID Level taxon 0/1

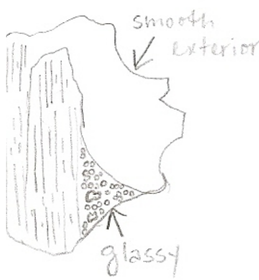
ID Level part 0/1

Quantity / /1

Comment on this entry:

Weight (g) <0.01

6/4/1
Item number



Taxonomic Plant Name Zea mays
Technical description of plant part seed; very shiny; solid, hard texture

ID Level taxon 0/2

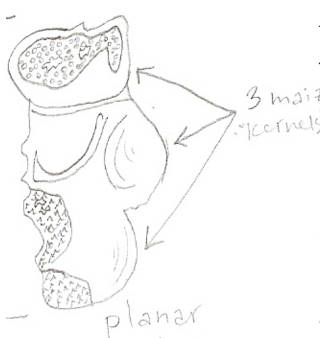
ID Level part 0/2

Quantity / /1

Comment on this entry: * Show DLL *

Weight (g) 0.02

6/4/2
Item number



Taxonomic Plant Name Zea mays → per DLL
Technical description of plant part 3 kernels fused together; glassy, jagged interior texture; exterior seed coat with small, slightly raised oval texture

ID Level taxon 0/2

ID Level part 0/2

Quantity / /1

Comment on this entry: * Show DLL *

Weight (g) 0.07