POLLEN FROM LAGUNA VERDE, BLUE CREEK, BELIZE: IMPLICATIONS FOR PALEOECOLOGY, PALEOETHNOBOTANY, AGRICULTURE, AND HUMAN SETTLEMENT

A Dissertation

by

MCKENZIE LEIGH MORSE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2009

Major Subject: Anthropology

POLLEN FROM LAGUNA VERDE, BLUE CREEK, BELIZE: IMPLICATIONS FOR PALEOECOLOGY, PALEOETHNOBOTANY, AGRICULTURE, AND HUMAN SETTLEMENT

A Dissertation

by

MCKENZIE LEIGH MORSE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Approved by:

Chair of Committee,	Vaughn M. Bryant, Jr.
Committee Members,	David Carlson
	Andreas Holzenburg
	Michael Waters
Head of Department,	Donny Hamilton

August 2009

Major Subject: Anthropology

ABSTRACT

Pollen from Laguna Verde, Blue Creek, Belize: Implications for Paleoecology,
Paleoethnobotany, Agriculture, and Human Settlement. (August 2009)
Mckenzie Leigh Morse, B.A., Grinnell College
Chair of Advisory Committee: Dr. Vaughn M. Bryant, Jr.

This dissertation is a palynological examination of the Mayan archaeological site at Blue Creek, northwestern Belize. This study uncovers more than 4,500 years of environmental and agricultural history of the region, which can be related to human incursion, habitation and plant use, abandonment, and reoccupation of the region.

After an historical and ecological overview of the study site, there follows an explanation of procedures for collecting, sampling, processing, identifying, and counting the fossil pollen from the area. Evidence from archaeology, paleoecology, and physical anthropology is used to construct a model for the first entry of humans into the Maya area. Examinations are made of Archaic Period paleoecology and the cultural developments that set the stage for the advancement of Maya culture.

Next, the physical environment of Blue Creek is explored, and its stability is assessed. This information leads to an assessment of the possibility of drought or soil degradation during the height of Mayan civilization, and contributes to the current understanding of the Maya Collapse at Blue Creek.

Mayan agricultural methodologies are explained, and the changes to traditional production systems that resulted from European colonization are described. A model of agricultural development is proposed.

The plant taxa identified in the Laguna Verde pollen core are listed and described. Finally, the Laguna Verde pollen core is interpreted in terms of the vegetation associations and environmental conditions represented by each stratum.

This study, first, forms a paleoethnobotanical interpretation of pollen samples from the Laguna Verde pollen core by placing the identified taxa in the context of existing research into Maya cultivation, agriculture, and ethnobotany. Second, this study forms an environmental interpretation of the pollen samples by placing the identified taxa in the context of what is known about regional paleoecology and its effects on the history of human occupation. It is concluded that the pollen samples document a mixed signal from local and regional vegetation associations, and that different vegetation associations have fluctuated constantly in dominance throughout the most recent 4,500 years.

ACKNOWLEDGEMENTS

I would like to thank the Texas A&M Anthropology Department; the Texas A&M University Palynology Laboratory; my graduate committee chair, Vaughn Bryant; and my graduate committee members, David Carlson, Andreas Holzenburg, and Michael Waters, for their contributions to my education and to the completion of this project. I offer additional gratitude to Dr. Carlson for his assistance with quantitative methods.

I thank John Jones, Jon Lohse, and the Maya Research Program for sponsoring my travel to Belize for this project, and their contribution to funding my radiometric dating.

I give appreciation to the Texas A&M University Anthropology Department for the Student Travel and Research Grant that funded additional radiometric dating.

Finally, I am grateful to my parents, Colette and Elton Morse; our extended family; and my friends, for enriching my life.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION AND METHODOLOGY

INTRODUCTION AND PROJECT RATIONALE

This dissertation is a palynological examination of the Mayan archaeological site at Blue Creek, northwestern Belize. This study uncovers more than 4,500 years of environmental and agricultural history of the region, which can be related to human incursion, habitation and plant use, abandonment, and reoccupation of the region. In this introductory chapter, the background of this dissertation is given, along with a historical and ecological overview of the study site. Procedures for collecting and sampling, processing, identifying, and counting the fossil pollen from the area are also discussed.

The Maya people are one of few examples of a state-level society to develop in the precolumbian New World. As such, archaeologists want to find out which factors enabled the Maya to achieve a high level of civilization. Chief among these is the Maya's commencement and advancement of agriculture. The Maya's adoption of agriculture was a feat which advanced the Maya beyond their foraging predecessors, enabling the Maya to establish long-term settlements of high population density, where the people could specialize in various occupations and accumulate wealth. This project focuses on the ecological factors that enabled a Maya community to develop and succeed at the site of Blue Creek.

In this project, archaeological palynology (the study of fossilized pollen from archaeological sites) is employed to expand our knowledge of Maya paleoethnobotany (past human-plant interactions) and paleoecology (past physical environment). In addition to the presentation of original pollen data collected at Blue Creek, the present study finds its place in the context of existing research in the realms of Mesoamerican archaeology and ecology through its two lines of inquiry. First, this study forms a paleoethnobotanical interpretation of the pollen samples (i.e. examines the ways in which the plants represented by the pollen in this study might have been used, as through

---

This dissertation follows the style of *American Antiquity*.

agriculture or product manufacture) by placing the identified taxa in the context of existing research into Maya cultivation, agriculture, and ethnobotany. Second, this study forms an environmental interpretation of the pollen samples by placing the identified taxa in the context of what is known about regional paleoecology and its effects on the history of human occupation (i.e. human incursion, habitation, abandonment, and reoccupation) at Blue Creek.

Pollen analysis, combined with a synthesis of the current knowledge of Maya environment and plant use, enable me to make contributions to the existing body of research on the ancient Maya people: Where did they come from, and when? What made the environment at Blue Creek suitable for habitation? What plants did the Maya cultivate extensively or intensively while they were there? What plants did the Maya use, and how did they choose to use those plants? Did any ecological factors contribute to the abandonment of the Blue Creek area during the storied "Maya Collapse," or to subsequent human reoccupation of the area? These questions are addressed during the course of this dissertation.

Purpose of the Present Palynological Investigation

Human presence and activity in an area inevitably leaves a mark on the surrounding natural environment. Paleopalynology (the study of fossil pollen) is a suitable vehicle for investigation of the history of human impact because pollen provides a record of the plants that grow in an area at a given point in time. Pollen can survive thousands of years, even when other evidence of plant life (such as seeds or leaves) has naturally degraded. When correlated with the stratigraphy of the sediment column in which the pollen was deposited, change in the local vegetation community can be observed over time. The purpose of this fossil pollen project is to use pollen to track changes in the environmental record that correlate with, and further explain, human activity in the Blue Creek region.

Various types of ecological change may become evident upon closer examination of a palynological record. Such a study can uncover environmental change at the points of first human incursion into a region and the first local clearing of land. New plants may have been introduced, accidentally or as cultigens, and increases or decreases in numbers of certain native plants may have occurred. During the time of occupation, humans continue to affect their environment through the creation of open areas (as through burning, evidenced in the forms of particulate carbon and an increase in pollen taxa of plants that colonize open or disturbed habitats), the preferential selection of certain plants for economic uses (such as food or firewood), and the preferential destruction of undesirable plants ("weeds"). Changes in a pollen record may give evidence for larger-scale environmental alterations that can affect human societies on a broad scale (e.g. playing a part in the collapse of Maya Civilization in general), and of smaller-scale environmental problems (e.g. the Maya's temporary abandonment of the Blue Creek site during the Terminal Classic Period). This dissertation interprets the environmental significance of the palynological evidence for the full Mayan tenure at Blue Creek.

Chapter Layout

This chapter begins with an introduction to the Maya Research Program, the agency under which the Blue Creek archaeological project is carried out. I move on to locational descriptions relevant to this project, starting with definitions of Middle America, Mesoamerica, and the Maya Area, then zeroing in on the of the Blue Creek archaeological project and the Laguna Verde pollen core site. Next, the theoretical and methodological foundation for this dissertation is established with an introduction to the practice of paleoethnobotany. The direct and indirect forms of evidence paleoethnobotanists use to learn about past environments and agricultural practices are described. The latter portions of this chapter are dedicated to the specific methodologies employed in the Laguna Verde pollen project, including pollen sampling, sample dating, sample processing, pollen identification, and pollen counting.

Maya Research Program

This pollen study was conducted under the aegis of the Maya Research Program (MRP), a not-for-profit research program affiliated with Texas Christian University, Fort Worth, Texas. The aims of the MRP are to understand the Mayan past through excavation, protection, and preservation of Mayan ruins; and to share the resultant knowledge with the public. To this end, the MRP has sponsored the Blue Creek Project (in Blue Creek, Orange Walk District, Belize) since 1992. Annual excavations are ongoing. The Blue Creek Project (BCP) draws together volunteers, field school students, and local Belizeans to work under the direction of archaeological specialists.

The purpose of the BCP is multifold, seeking understanding of the internal structure and temporal and functional dynamics of a particular ancient Mayan city, as well as the broader external social, political, and economic relationships that comprised Mayan society in general (Guderjan 1999:v; Maya Research Program 2002).

Definitions: Middle America, Mesoamerica, and the Maya Area

The Blue Creek site area should be considered in its geographical and cultural contexts. The Blue Creek area is situated within the Middle American geographic region, and within the southern Maya Lowland subdivision of the Mesoamerican culture area. Figure 1 differentiates Middle America from Mesoamerica.

Middle America is geographically defined as the New World land mass stretching from the Rio Grande and the United States-Mexico border, south through the Isthmus of Tehuantepec, to the Panama-Colombia border. This dissertation uses the term “Middle America” to refer to that *geographical* area. Although the focus of this dissertation is the smaller Maya area (delimited below), some consideration of the archaeology and paleoecology of the broader region of Middle America gives context to the environment in which the Mayan culture developed. The bulk of the archaeological work conducted in Middle America has taken place in the country of Mexico, but this paper focuses only on the sites that have been found in the Maya area. No

Figure 1. Mesoamerica and Middle America.

Paleoamerican sites have yet been recorded for the country of El Salvador (Pearson 2002: Chapter V).

Paul Kirchoff (1943) coined the word “Mesoamerica” to describe a culture area contained within, but not itself encompassing, the Middle American geographic region. This dissertation uses the term “Mesoamerica” to refer to that *culture* area. The indigenous peoples of Mesoamerica shared some cultural traits that were absent or rare elsewhere in the New World (Coe 2005:13). These included hieroglyphic writing, books, a calendar, astrological knowledge, a ball game, human sacrifice and self-sacrifice; a diet based on maize, beans, squash, and chili peppers; and a complex pantheistic religion with reference to the “cosmic cycle” and a universe oriented toward the four cardinal directions (Coe 2005:13). Archaeologists largely agree that the complex Mesoamerican cultural elements probably originated among the Olmec, who began to exhibit these traits over 3,000 years ago (Coe 2005:14). Over the years, Mesoamerican elites created and maintained cultural homogeneity throughout the area through the continual exchange of ideas and goods (Coe 2005:14).

The Maya area is a major subdivision of the Mesoamerican culture area. Geographically, it includes the Yucatan Peninsula, Guatemala, Belize, western Honduras, western El Salvador, and parts of the Mexican states of Chiapas and Tabasco (Coe 2005:11). In this area, there is a good fit between the Maya language and Mayan cultural elements (such as shared dietary staples, and the location of Mayan ruins; Coe 2005:11). Mayanist scholars differentiate between the “Maya Highlands” and the “Maya Lowlands,” which differ in terms of geography, biota, and cultural expression. The “highlands” encompass the volcanic montaine areas of Chiapas, southern Guatemala, southwestern Honduras, and El Salvador (Hall & Pérez Brignoli 2003:59). Scholars also divide the Maya area into southern, central, and northern areas, the latter two of which lie entirely within the lowlands. The southern, central, and northern areas, as well as the highlands vs. lowlands, are pictured in Figure 2. The central area was the core of Mayan civilization, with all characteristically Mayan traits present. The true southern lowlands would indicate only a very small area around Copan, Honduras. I

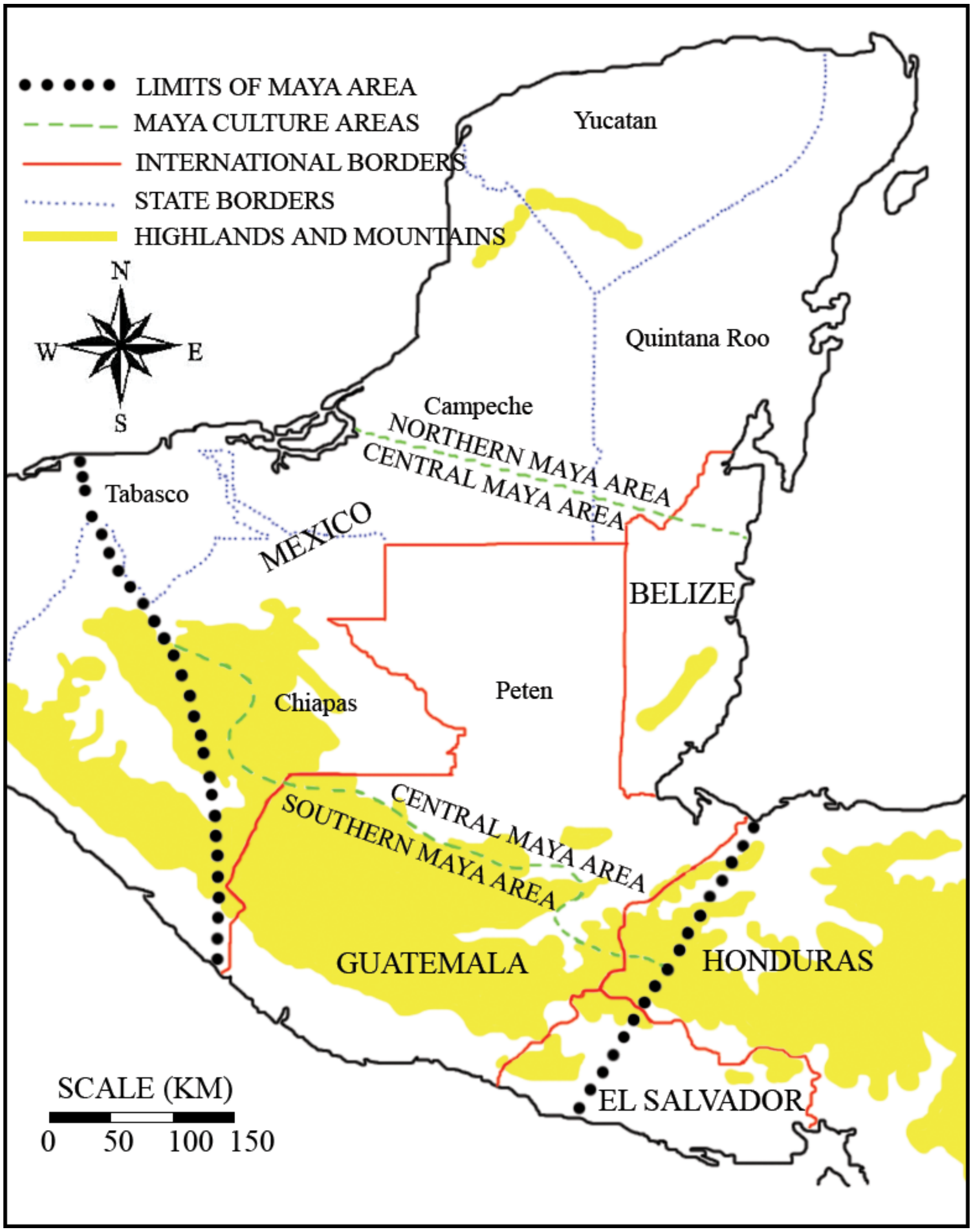

Figure 2. The Maya Area, displaying the northern, central, and southern areas, and differentiating the Maya Highlands from the Maya Lowlands. Redrawn, based on Coe 2005: Figure 1).

(and many others) circumvent the use of the term “central lowlands” by preferring the term “southern lowlands” to indicate all parts of the Maya Lowlands except northern Yucatan. The southern lowlands are thus considered to include Tabasco, the Lacandón Forest of Chiapas, the Petén, and Belize.

Definition of the Blue Creek Area

In both natural and archaeological terms, the Blue Creek area is defined as a 150 km^2 area surrounding the Blue Creek site core, bounded by rivers and canyons. The Maya Research Program holds a permit to conduct archaeological work on over 100,000 acres of land (about 405 km^2; Guderjan et al. 2003:91). In Belize, permits for archaeological work are granted from the Department of Archaeology, Government of Belize, Belmopan. The Maya Research Program permit area is the area of northwestern Belize north of Programme for Belize’s Río Bravo Conservation Area, extending north and west to Belize’s national boundaries with Mexico and Guatemala. In terms of physiographic borders, Booth’s River forms the eastern boundary of the permit area; Río Hondo forms the northern boundary; and Río Bravo and the conservation area form the southern boundary. The area framed by these three rivers is called the “Three Rivers Region,” and is pictured in Figure 3. The Three Rivers Region includes a small part of southern Campeche and the northeastern corner of Petén, though the Maya Research Program permit area is confined to the country of Belize. Geological origins and topographic features are shared throughout the Three Rivers Region (Barrett 2004:86). The ancient Maya who lived within natural boundaries formed by the rivers and canyons are believed to have been the ones responsible for the construction of the monumental architecture in the Blue Creek site core (Guderjan et al. 2003:77). Blue Creek was the only substantial Maya center within its 150 km^2 area, but it was only a medium-sized site compared to others in the Three Rivers Region (Barrett 2004:125; Guderjan 2004:237; Lohse 2003b:7, 12).

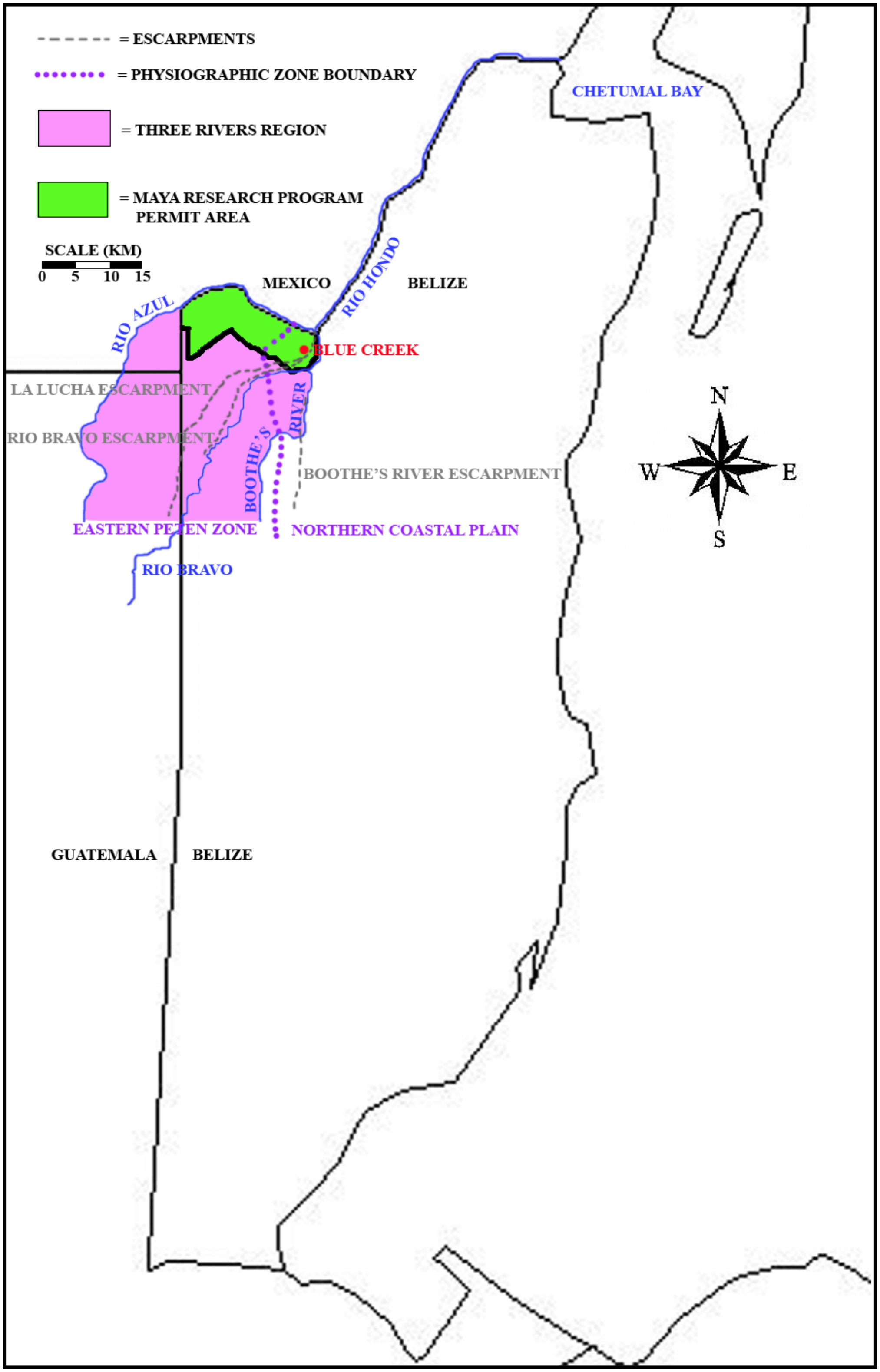

Figure 3. The setting of the Blue Creek site within the Three Rivers Region.

Brief History and Ecological Setting of the Blue Creek Area

To contextualize this study, I offer here a terse introduction to the ecology and history of Blue Creek. The site's setting in the Three Rivers Region is unique for harboring the union of two very different ecological zones, with a 300-foot forested escarpment toward the west, and the Caribbean coastal plain toward the east. Both regions adapt well to agriculture, as the Maya discovered. On top of the escarpment, the uplands are comprised of karstic formations, with well-drained areas conducive to the growth of hardwood lumber and fruit trees, and numerous *bajos* (lowlands) suitable for agriculture (Guderjan & Driver 1999:1). To the east, at the base of the escarpment, is found evidence of raised- and drained- agricultural fields, built by the Late Classic Maya as an adaptation to spring-fed flooding (Guderjan & Driver 1999:1; Lohse 2003a:6). Most of the Three Rivers Region is currently occupied by Mennonite farmers of European descent. Areas within the Blue Creek site are mapped in Figure 4.

The original (pre-Maya) human inhabitants of Blue Creek remain unknown, but the Maya Lowlands were sparsely populated by nomadic hunter-gatherers prior to ca. 7500 B.C. (Coe 2005:26, 44). The ensuing Archaic Period, which lasted until ca. 2000 B.C., saw the development of simple horticulture focused on root crops and fruits, increased sedentarism, and a rising population (Coe 2005:26; Hall & Pérez Brignoli 2003:57; Sanabria 2007:55). The Preclassic Maya moved into the Blue Creek area around 900 B.C., bringing with them the concept of maize-focused village farming and extensive hydraulic works (Guderjan & Driver 1999:1; Lohse 2003a:6; Maya Research Program 2002). Blue Creek became a significant medium-sized political, economic, and ceremonial center during the Late Preclassic or Protoclassic period, and remained such until A.D. 500, during the Early Classic Period (a period which lasted from approximately A.D. 250 to 600; Guderjan 1999:v; Guderjan & Driver 1999:1). During the Late Classic Period (A.D. 8th-9th c.), a combination of rising Maya population, environmental degradation, internal warfare, a breakdown of alliances and trading relationships, and invasion by people from central Mexico (or perhaps Mexicanized Maya; Coe 2005:164-165), lead to widespread decline in Mayan culture and language

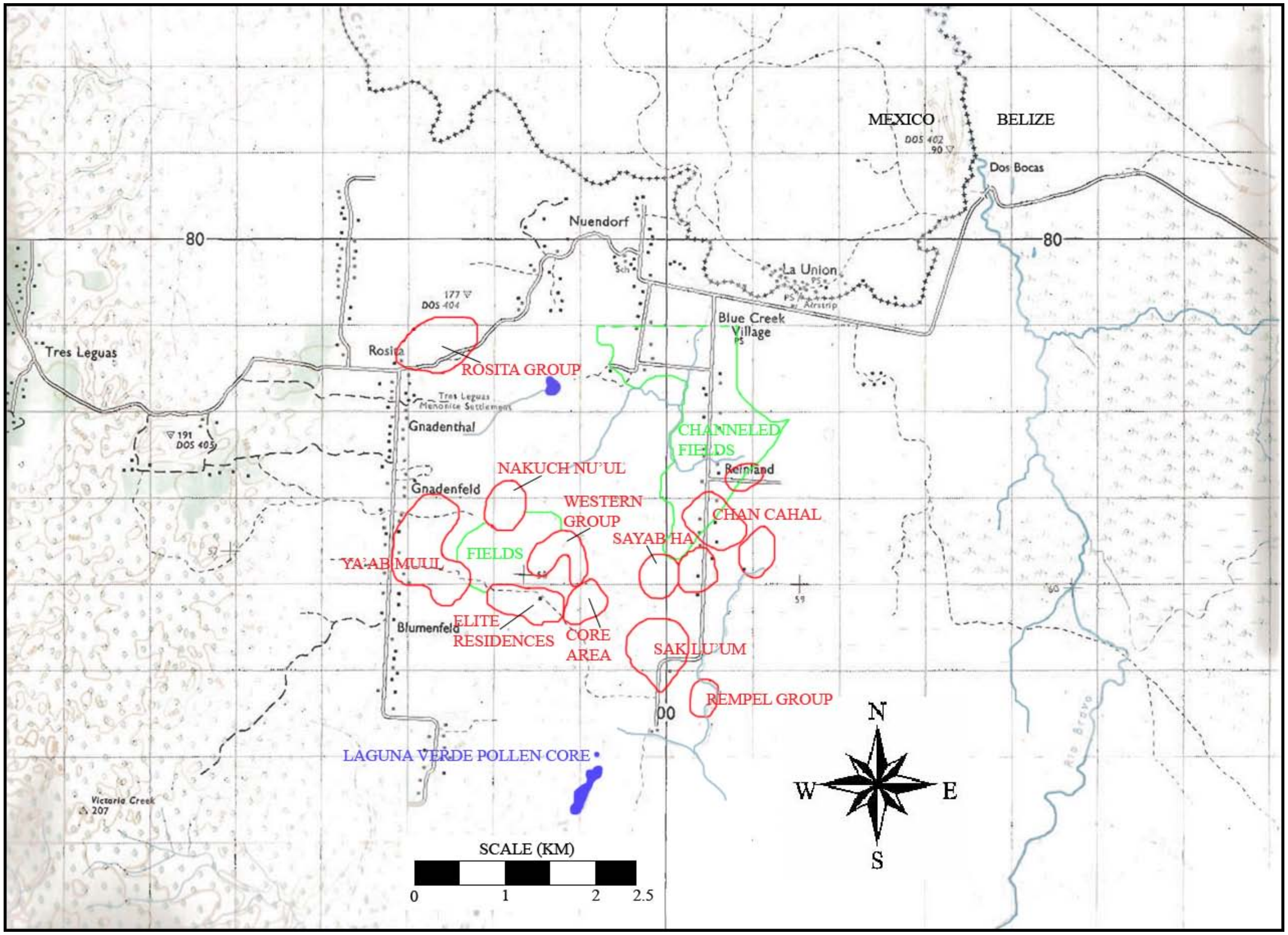

Figure 4. Areas within the Blue Creek site, and location of the Laguna Verde pollen core.

that peaked in the Terminal Classic Period (A.D. 800-925). This decline is termed the "Maya Collapse," and it affected the Maya at Blue Creek, who abandoned Blue Creek around A.D. 900 (Maya Research Program 2002). In the Early Postclassic, the Blue Creek Maya restructured their society, and they established a Postclassic settlement along the Rio Hondo (Guderjan 2006:2).

A complete ecological description, along with an investigation of the Maya Collapse at Blue Creek, is given later in Chapter III. Further details on the initial human settlement of Blue Creek are given in Chapter II.

PALEOETHNOBOTANY

Paleoethnobotanical studies can help fulfill the goals of many types of archaeological investigations, particularly when the project goals include the ability to make statements about human diet and health; social and political systems; past environmental conditions; environmental change; human landscape modification, agricultural practices, and crop use; and plant use and storage. The conduct of a paleoethnobotanical study should include more lines of evidence than plant remains themselves. Each form of evidence has potential benefits and pitfalls, but all can be combined to produce a richer picture of the past. Each line of evidence can support or refute the evidence provided by the others.

The purpose of this section is to introduce the forms of [chiefly paleoethnobotanical] evidence that are used in this dissertation to tell the story of ecological change related to the ancient Maya occupation of Belize. Some of this change was due to natural, climatic factors, while the remainder is attributed to anthropogenic factors, mainly forest clearance for agriculture and intensification of agriculture. In addition to paleoenvironmental change and agricultural development (cultivation methods and plants cultivated), this dissertation is concerned with the uses to which the Maya put food- and non-food (other economic) plants. These matters are explored, in this dissertation and in the literature in general, through the types of evidence addressed in this section. This section emphasizes the means by which scientists have learned about Mayan cultivation methods, plants cultivated, and plant uses. The remainder of this chapter builds on the types of paleoethnobotanical and archaeological data introduced in this section to give further details about the agricultural practices of the Maya and the particular plants grown and/or exploited by the Maya.

Direct vs. Indirect Evidence of Mayan Agricultural Practices

Turner (1985) pointed out that evidence of ancient Mayan agricultural practices comes in both direct and indirect forms. “Direct evidence” includes remains of tools and technologies; Mayan references in art and writing; and botanical remains (Turner 1985:197). Even though direct evidence appears to be the soundest means of investigation, it cannot tell us about such social and political factors as frequency of cropping, division of labor, output levels, etc. These factors may instead be explored through indirect evidence, via ethnographic analogies and “environmental possibilities.” Sixteen lines and subtypes of direct and indirect evidence are considered here, in turn.

When it comes to indicators of diet and health (factors related to agriculture and plant use), the line between direct and indirect evidence is strictly delimited. Direct indicators of human diet and health are obtained from skeletal data (including trace elements and stable isotopes), coprolites, and gut contents. Indirect indicators of human diet and health are food remains and residues, and “implements and activities surrounding the food quest” (Pearsall 2000:499). Indirect indicators of diet and health include soil pollen and phytoliths; macrobotanical remains; tools and cooking vessels; cooking residues; and extra-individual considerations, such as water control features, site size, site location, agricultural features, sediment cores, and other indicators of diet and health with less relation to matters of agriculture and plant use (Pearsall 2000:500). This dissertation is less concerned with matters of individual diet and health than it is with agricultural practices and general plant consumption.

Direct Evidence: Material Remains of Tools and Technologies

Material remains provide direct evidence of ancient agricultural practices, crop cultivation, and plant use. Material remains may take the forms of technological systems, such as terraces, dams, or canals. Other material remains take the form of tools, such as ground-stone handaxes or chipped-stone hoes. Tools sometimes suggest the manner of usage of a particular plant. For example, ground-stone *manos* and *metates* were made and used by people who processed grain; these tools may be tested for the presence of microbotanical remains to discover which particular type of grain that was. Some ceramic vessels have a unique form that suggests a particular function, such as the spouted vessels found at Mayan sites and tombs. Some of these have tested positive for cacao residue, and are believed to have been used in serving a chocolate beverage during the Preclassic and Classic Periods (Henderson et al. 2007; Hurst et al. 2002; Powis et al. 2008, 2002). As the focal point of most surveys and excavations, material remains such as these are at the heart of the archaeological profession.

Direct Evidence: Art and Writing

Written records created by the Maya, and by European explorers who came into contact with them during the early colonial period, provide direct evidence of Mayan agricultural practices, crops, and plant uses. The same type of evidence is provided by Mayan art and iconography, and by illustrations (for example, depicting plant use via drawings of Mayan houses with thatched roofs and wooden structures for storing corn) in some of the European texts.

Written Records of the Maya

Maya hieroglyphic writing and calendar development began during the Late Preclassic Period, perhaps as part of an obsession with recording kings, dynasties, and events surrounding the royal house (Coe 2005:59, 85). The earliest inscribed objects date to about 50 B.C. (Hall & Pérez Brignoli 2003:58). Except for the dates, the very earliest Maya hieroglyphics are still undeciphered (Coe 2005:59).

The calendrical system was important in marking or recording critical political events, celestial motions, and points in agricultural and ceremonial time (Coe 2005:60). The Long Count calendar, which reckons time in units of Great Cycles (probably lasting 5,125 1/4 years and beginning in 3114 B.C.), is found throughout Mesoamerica (Coe 2005:64, 213; Hall & Pérez Brignoli 2003:58). It was first developed by the first century B.C. by people who were under strong Olmec influence, possibly the Mixe-Zoque speakers of Chiapas and the Isthmus of Tehuantepec, where the monuments with the earliest dates have been found (Coe 2005:64). The most ancient object yet uncovered that features a Long Count date is Stela 29 from the site of Tikal, Guatemala; it dates to A.D. 292 (Coe 2005:87; Hall & Pérez Brignoli 2003:58). Writing and the calendar spread from the Pacific Coast into the Maya Highlands, then into the lowlands (Coe 2005:64). The Long Count calendar was later refined by the Maya of the central lowlands (Coe 2005:63). The obsession with hieroglyphic writing and Long Count dates, to document “the life and times of the royal house,” heightened in the Early Classic Period (Coe 2005:85). The Classic Period is defined by the use of the Long Count calendar on the monuments of the lowland Maya (Coe 2005:87). Because dated monuments can be correlated with archaeological dirt and architectural strata, the archaeological sequence of many Classic Maya sites can be closely dated (Coe 2005:87).

The Maya developed a hieroglyphic writing system, though it remains incompletely interpreted by modern scientists. Mostly, the Maya wrote to document matters of religion, ritual, astronomy, and dynastic history; to recognize spiritual alter-egos; and to label items. Fragments of Classic Period bark-paper books or “codices” have been found in a few tombs (Coe 2005:125). Four bark-paper codices have survived into the present from the northern lowland Maya of the Postclassic Period. These deal with religious ritual and rituals related to astronomy (Coe 2005:212). Some of the information in the codices is useful for understanding agricultural matters. For example, two of the codices contain “farmer’s almanac” information about the timing of planting crops (Coe 2005:204).

Most significant among the Mayan texts from the early post-Conquest period are the *Popul Vuh* (by the K'iche' Maya of the southern Guatemalan highlands), the *Annals of the Kaqchikels* (or *Kakchiquels,* or *Cakchiquels,* also of the southern Guatemalan highlands), and the *Books of the Chilam Balam* (or *Bahlam*, by the Yucatec Maya). In the early sixteenth century, these books were transcribed into the Latin alphabet by Spanish explorers, and were thus preserved (Hall & Pérez Brignoli 2003:58). These books combine myth with history, according to the Maya concept of cyclical time, and emphasize religious-ritual behavior. Information on Mayan agriculture and plant use can be gleaned from references to agricultural rituals and beliefs related to plants (See "Mayan Art and Iconography," below.).

Mayan Art and Iconography

Vegetation sometimes figured into ancient Mayan art (including religious iconography), giving us insight into Mayan beliefs and values in general, and the significance of certain plants in particular. For example, even though no material remains of such objects have survived into the present, we know that the Maya blew wooden trumpets because the Bonampak murals (in Chiapas) show musicians blowing "long war trumpets of wood or bark" (Coe 2005:126). That the Pipil, Mexicanized Maya of southern Guatemala, highly esteemed cacao is seen in Pipil carvings, in which the bodies of gods and men spouts fronds and pods of cacao (Coe 2005:176). The Pipil produced cacao for use in drinks and as a currency (Coe 2005:174). The appearance of the mushroom and the water lily (*Nymphaea ampla*) in Maya art ("mushroom stones" and pottery) and iconography; their reference in the *Popul Vuh* and the *Annals of the Kaqchikels* in association with religious activity; and ethnographic analogy with modern Mexican populations, suggested to one researcher that they may have been used psychotropically by the ancient Maya (Dobkin de Rios 1974).

Significant in Maya spirituality and cosmology is the relation between the agricultural cycle and the supernatural world (Coe 2005:211). The Maya conceived of time as cyclical (i.e. non-linear), and the agricultural cycle symbolized the ongoing cycles of creation and destruction of the entire universe (Coe 2005:211). In the creation of the present universe, the resurrected Maize God re-created the stars and “raised a great World Tree” (Coe 2005:214). Religious iconography of the ancient Maya is underlain by agricultural themes surrounding the annual planting and harvest of maize (Coe 2005:65). An important religious text, the *Popul Vuh* of the K’iche’ Maya, tells of a Maize God whose twin sons slay monsters in order to secure his rebirth (Coe 2005:65-66). The K’iche’ carried this story over into their daily lives with the belief that, by planting a seed, a farmer symbolically sent it to its temporary death in the Underworld; with the intervention of the Hero Twins, the maize could be reborn as a young sprout (Coe 2005:66). Colonial-period Maya were thus able to draw parallels between the Maize God and the risen Christ (Coe 2005:66).

In the pantheon of Maya deities, there were patron gods of hunters, fishers, and beekeepers, among others (Coe 2005:217). This suggests that people procuring food were worthy of protection by the gods, and felt a need to ensure success in their pursuits. Maya rulers were sometimes portrayed as the Maize God, who symbolized and celebrated “resurrection and apotheosis” (Coe 2005:173).

Sometimes Maya art and iconography featured plants in a manner that does not suggest a discernable spiritual or symbolic meaning. For example, religious texts and iconography, the Hero Twins slew Wuqub Kaquix or 7 Macaw, the gigantic, bejeweled Principal Bird Deity, when it landed to eat the fruit of the tree *Byrsonima crassifolia* (Coe 2005:66). To me, this suggests only that the Maya recognized the tree.

Mayan tombs are special repositories of information about plant use and plant-related ideologies, as plant remains and pictorial ceramics are sometimes splendidly preserved in the closed, dry tomb environment. Many of the Classic Maya pictorial ceramics served funerary functions, often holding food and drink in the tombs of the royal deceased (like the maize tamales and the cacao beverage that often accompanied the royal dead of the Petén sites; Coe 2005:99, 218). Some ceramics picture the taking of ceremonial enemas, and glyphs indicate that the liquid injected may have been the intoxicating fermented agave beverage, *chih* (Coe 2005:219). At Calakmul, Campeche, the royal corpse of kind “Fiery Claw,” who died in A.D. 700, was found wrapped in “layers of lime, palm, and fine cotton textiles” (Coe 2005:125). This exemplifies some ways in which plants could be used, and proves that cotton was cultivated and textiles were manufactured by the Maya before this time. Among the funerary offerings in the tomb of Fiery Claw was a chocolate vase (Coe 2005:125). At the Yucatan site of Ek’Bahlam was uncovered a rich burial of king Ukit Kan Le’k Tok’, who was buried around A.D. 814 (Coe 2005:173). A stuccoed chocolate vase was found near his head (Coe 2005:173). On the room’s capstone, the king was portrayed as the Maize God (Coe 2005:173).

Written Records of European Explorers

Written records made by the first European explorers of the Mayan realm provide direct evidence of the lifeways of the Maya (including agricultural practices and plant-use habits) at the time of contact. Some of the early Spanish colonizers were Catholic priests or missionaries. Some of them sought to understand the native peoples of the New World, perhaps to facilitate their conversion. Such missionaries filled the role of ethnographer, and much of what we know about the Maya at the time of conquest comes from them (Coe 2005:204).

Sixteenth-century Spanish explorers were simultaneously impressed by the material and artistic accomplishments of the Maya civilization, and horrified by their religious practices, which included human sacrifice (Hall & Pérez Brignoli 2003:6). The most noted of these explorers was Diego de Landa, Franciscan bishop of Yucatan, who wrote *Relación de las Cosas de Yucatan* around A.D. 1560. This was an early ethnographic account, and an attempt to transcribe the Mayan language, number system, and calendar. At the same time, Landa expressed his own religious devotion and his rejection of Mayan religion by burning many of the Maya bark-paper codices (Hall & Pérez Brignoli 2003:58).

In the 18th century, George Henderson, a captain in the [British] West India Regiment, wrote an account of Belize (Hall & Pérez Brignoli 2003:9). In 1773 AD, Bryan Edwards published *History, Civil and Commercial, of the British West Indies*, which contains information about Belize (Hall & Pérez Brignoli 2003:9).

Modern Maya archaeology was initiated by the 1839-1842 explorations by American lawyer John Lloyd Stephens and British artist Frederick Catherwood (Coe 2005:24; Hall & Pérez Brignoli 2003:11, 58). They visited Belize and explored Mayan ruins in Honduras, Guatemala, and Mexico, taking the first measurements and drawing the ground plans of the monuments (Hall & Pérez Brignoli 2003:11). The two were the first Europeans to associate the ruins of Maya cities with the people who still lived near them (Coe 2005:25).

The writings of the earliest European colonizers expose elements of Mayan agricultural practices that left little trace in the archaeological record. For example, the Europeans recorded that the Maya of the Yucatan stored crops in wooden cribs above ground, and also in underground places, perhaps *chultuns* (Coe 2005:204). Some information is also suggested by the elements that are missing from the European record. For example, there is no written record of tortilla production in the pre-conquest Maya Lowlands (Coe 2005:204). Does this mean that tortillas are a novel invention? Although clay griddles were found at the site of Lamanai, Belize, these may have been used to roast cacao beans (Coe 2005:204). Instead of making tortillas, the contact-era Maya made tamales; cornmeal gruel with chili peppers for breakfast; and sourdough was carried into the fields in gourds for lunch (Coe 2005:204). They also cooked stews with meat, peppers and other vegetables, and squash seeds (Coe 2005:205).

Direct and Indirect Evidence: Botanical Remains

Many types of botanical remains, particularly macrobotanical remains, pollen, silica or calcium oxalate phytoliths, and starch grains, show fairly consistent morphology, and often size, within a taxon, so they can often be identified to genus or species. Examination of macro- and micro- botanical remains should be conducted as part of any archaeological project, particularly when the project goals include the ability to make statements about past environmental conditions; environmental change; human landscape modification and crop use; human diet and health; plant use and storage; and social and political systems. Within the project, studies of macro- and micro- botanical remains should ideally be combined, because each can support or refute the evidence provided by the others. In reality, multifaceted analyses are difficult to accomplish because few analysts can become experts in more than one botanical realm, and funding to pay multiple analysts can be tricky to secure. Those are reasons why this dissertation includes only a palynological analysis.

Several classes of botanical remains provide evidence of crop cultivation and plant use by the ancient Maya. This evidence may be of a direct form or an indirect one, depending on the form of the evidence and the context from which it is recovered. For example, sediment samples taken from an ancient agricultural terrace may contain a high relative percentage of pollen of Cucurbitaceae (the squash family). Because cucurbits are pollinated by butterflies and bats, and are thus typically underrepresented in the pollen rain, a high relative percentage of squash pollen in the samples would seem to directly indicate the function of the terrace as a squash field. However, the sediment samples are only indirect indicators of diet; only pollen samples taken from human coprolites or gut contents could prove that squash was part of the human diet and was not grown for another purpose (perhaps for use as storage containers).

The mere presence of any class of botanical remains on an archaeological site may represent human use or consumption of the represented plants, but a list of botanical remains recovered from a site should not be interpreted as a list of plants eaten or used at the site. The remains may have found their way to the site through natural or accidental means. Only botanical remains contained within coprolites and guts are direct evidence of foods consumed (though remains recovered from food-preparation-type vessels and tools may also have a high statistical probability of derivation from food plants). Ethnographic analogies and statistical analyses of patterns observed in botanical data help support interpretations made from botanical data.

Palynology and Paleolimnology

This dissertation explores, palynologically, the types of environmental change that can result from alterations in climate or from anthropogenic causes (namely, clearance of land and introduction and intensification of agriculture). It exemplifies the venues in which palynology allows the exploration of agricultural methods, plants cultivated, and plants consumed. It seeks environmental change related to human settlement, a rising population, and the local clearing of land. These are the types of contributions that palynology can make to any paleoethnobotanical study.

Pollen grains are manufactured by seed-producing angiosperms and gymnosperms. Pollen is produced in the (male) cone or flower anther, and upon maturity is transported by wind, water, insects, or animals to the female part of the plant, whereupon fertilization produces a seed. Any pollen that misses its target is distributed across the landscape by wind and water in a "pollen rain." Pollen grains have very durable outer walls (exines) that can survive for thousands of years, even when other evidence of plant life (such as seeds or leaves) has naturally degraded. Over time, the pollen sequence that builds up in sediments records vegetation at the time of deposition (Pearsall 2000:249). The vegetation record, when considered alongside other factors, is an index of environmental and climatic conditions. Palynologists come to understand this record by extracting pollen grains from sediment and examining them under a microscope. The size, shape, aperturation, and sculptural elements of pollen grains vary from taxon to taxon, enabling the palynologist to identify the taxon from which a pollen grain derived. When correlated with the stratigraphy of the sediment column in which the pollen was deposited, changes in the local vegetation community can be observed over time, indicating any climatic change or anthropogenic effects upon the landscape.

Pollen grains have two special characteristics that assist in the detection of economic plants. First, over time, genetic changes may accrue in a domesticated species that result in changes in the size or morphology of its pollen grains. Such changes can differentiate a wild species from its cultivated form and indicate the point at which domestication came into play. Second, plants differ in their reproductive biology (being dioecious, monoecious, or hermaphroditic) and in the mechanism by which they achieve pollination (via wind, insects, animals, or cleistogamy/self-pollination within a closed flower). Wind-pollinated (or anemophilous) plants (especially dioecious ones) tend to produce much more pollen, and to distribute it over larger areas, than other plants. Anemophilous plants are thus over-represented in the pollen rain. For example, in the Neotropics, only about 2.5 percent of trees are wind-pollinated, but their pollen accounts for around 27 percent of the pollen rain (Bush 1995:594). Therefore, the finding pollen from plants that are not wind-pollinated is generally taken by palynologists to be an indicator of human plant use, because that pollen ordinarily makes up a very small percentage of the natural pollen rain (Pearsall 2000:505). This generalization does not always hold true in the Neotropics, where most plants are pollinated by insects or animals (Bush 1995). It is true that some economic plants, like maize, have an anemophilous pollen syndrome. Still, the general rule is a good starting point for considering the appearance of economic plants in the pollen record. If the pollen of a non-anemophilous plant appears in a pollen sample at a much higher percentage than would be expected based on its reproductive biology and pollination mechanism, human interference is likely indicated.

The palynologist can collect samples for pollen analysis from a variety of locations, depending on the goals of his project. A palynologist interested in documenting environmental change, agricultural development, and plant use may choose any of the following sampling tactics (though these are not the only sampling strategies that palynologists, in general, employ). In addition to these tactics, *control samples* must be taken from outside the target sampling location. Control samples can document the modern pollen rain, and can help the palynologist distinguish significant differences in the pollen record from area to area, and through time.

1. Artifact washes: First, pollen (along with phytoliths and starch grains, types of microbotanical remains addressed below) can be washed off artifacts, such as *manos* and *metates,* ceramic vessels, baskets, and other implements used in processing or preparing food. Pollen demonstrates the presence of flowers, parts of flowers, and other plant parts where plants were used in food or as spices, medicine, or tea. Microbotanical remains can indicate the contents of the storage vessels and the usages of the tools. Crops cultivated (or perhaps obtained through trade) and methods of food storage and preparation are thus suggested.

2. Blanket sampling of an archaeological site: Second, pollen samples can be taken from the sediments in different areas of an archaeological site. This helps to define activity areas, and to discover which crops may have been grown on ancient fields. Special samples should be taken from unique features. For example, samples taken from the area of a burial may indicate the use of flowers in ritual; sediment samples taken from the gut area of an intact burial may contain grains of pollen ingested by the individual.

3. Off-site coring: Finally, off-site cores for pollen (and phytoliths) can document environmental change due to climatic change or to anthropogenic causes. Anthropogenically-induced environmental changes often have root in agricultural processes. A pollen core may reveal “vegetation changes associated with agricultural clearings…[and] help us address not only when crops appear, but when they become important. A record of forest clearing and growth of weeds, succession plants, and crops provides direct information on agricultural activities” (Pearsall 2000:507). The pollen record can detect the adoption and intensification of agriculture through indicators of forest clearance and the presence of crop plants (Pearsall 2000:265).

Off-site cores are usually taken from lakes or swamps because pollen grains are best preserved in permanently-waterlogged environments, where anaerobic conditions prevent decomposition (Pearsall 2000:249). Off-site coring of a swamp was the sampling method chosen for this dissertation, with the goal of documenting both natural and anthropogenic environmental change. Only a few others (Hansen 1990; Jones 1991; Pohl et al. 1996; and Turner & Harrison 1983) have cored swamps in Belize for palynological analysis. More coring for palynological and paleolimnological study has taken place in the Guatemalan Petén, which is home to most of the few lakes in the Maya Lowlands lakes. See the sections “Soil, Anthropogenically-Induced Erosion, and the Maya Clay," "Introduction to Palynological and Paleolimnological Studies Relating to the Late or Terminal Classic Drought," and "Paleolimnological Studies from the Petén" in Chapter III for references and details on the Petén paleolimnological studies. Many of the paleolimnological studies include not only pollen analyses, but also such modalities as stable isotope analysis (from gastropods, ostracods, and lake water), elemental geochemistry (from sediments), magnetic susceptibility, mineralogy, and sediment density. Multi-proxy analyses offer a rich picture of environmental change and an opportunity to support or refute hypotheses through multiple lines of evidence.

Phytolith Analysis

Opaline silica phytoliths form when monosilicic acid obtained through groundwater is deposited within a plant (Pearsall 2000:356). Calcium oxalate phytoliths, instead, form in select plants. Phytoliths accumulate within the cells and in the spaces between the cells of plant flowers, roots, leaves, and stems. The phytoliths can take distinctive shapes, depending upon the part of the plant in which they form, and upon the genus or species, thus enabling the phytolithologist to identify the taxa from which phytoliths derive.

Phytoliths are very durable, even more durable than pollen under many circumstances. Microbes and most flames do not destroy phytoliths, as they do pollen. They can also be obtained from hearths and burned areas, agricultural fields with wetting and drying, and garbage middens, situations which destroy pollen. Because phytoliths are deposited as plants decay in place, they are best-preserved in sheltered environments. Phytoliths may be found in the plant temper of some pottery, and, like pollen, can be extracted from ancient rock. Phytoliths can be found in coprolites; in residues from storage or food preparation vessels; and on stone tools used for food preparation, getting at ancient diet. Isotopic analyses of phytoliths may be used in paleoenvironmental reconstructions (Pearsall 2000:356). Because differences in size and quantity are evident between the phytoliths produced by plants with the carbon-3 vs. carbon-4 (grasses) photosynthetic pathway, phytoliths can indicate different vegetation zones, level of moisture, and the rise of agriculture.

There are some pitfalls to phytolith analysis. Unfortunately, there are few available keys for phytolith identification, and few phytolith experts. Methods of phytolith analysis are not yet standardized. Phytoliths are difficult to identify to genus or species. Morphology and size of phytoliths varies within a species, and even within a single plant. Not all plants produce phytoliths, and some produce more than one type. Thus, plants are not evenly represented in the phytolith record. Multivariate statistical methods must often be applied to the entire phytolith assemblage; because it is difficult to identify phytoliths to the species level, it is usually the patterning that indicates a group of representative plants.

Among Mayanists, phytolith analysis is still in its infancy, and phytolith studies are rare in the literature relevant to this dissertation. However, Steve Bozarth of the University of Kansas has been studying Blue Creek phytoliths and other biosilicates since 1999. He has reported finding phytoliths from maize (*Zea mays*), squash (*Cucurbita* sp.), bottle gourd (*Lagenaria siceraria*), and beans (*Phaseolus* sp.) at Blue Creek (Bozarth & Guderjan 2002, 2004). Inside vessels from ritual caches (possibly associated with ritual bloodletting), he found marine sponge spicules and phytoliths from maize, squash, and other plants with possible economic uses, including *Agave* sp. and the palms of the family Arecaceae (Bozarth & Guderjan 2004).

Starch Grain Analysis

Starch, a form of energy for plant growth, is stored in various parts of plants, including seeds, tubers, roots, and other fleshy parts (Gott et al. 2006:36-40; Pearsall 2000:178). The structure, shape, and size of starch grains vary among species, and these features can sometimes be used to identify the plants from which the starch derived (Gott et al. 2006:40; Pearsall 2000:178). Starch grains (though not always preserved within the structure) can sometimes be used to identify macrobotanical remains, such as seeds, fruits, and tubers.

The preservation and analysis of starch grains, addressed in depth by Huw Barton and Peter Matthews (2006), can be hampered by several factors. Exposure to heat, humidity, oxidation or reduction, and water can cause starch grains to become distorted or lose their structure. Dehydration breaks starch grains, and fungus destroys them. As with phytoliths, morphology and size of starch grains varies within a species, and even within a single plant, making it difficult to determine the taxa from which the starch derived.

Like phytolith analysis, starch grain analysis has more potential for contribution to paleoethnobotanical studies than has yet been achieved. Morphological changes in maize starch grains resulted from genetic changes as the plant underwent domestication; maize starch grains are thus a better indicator of domesticated maize than are the pollen grains of early domesticated maize (Holst et al. 2007). A finding of maize starch could thus confirm the identification of maize pollen. Starch grain analysis is useful in the detection of potential crop plants which do not leave well-preserved macroremains or pollen, such as roots and tubers. Starch grains may be recovered from sediments, or can be washed off artifacts. Studies of archaeological starch grains are still in the pioneering stages, but have proved useful in determining stone tool function and demonstrating human association with the microbotanical remains. So far, starch grains have been collected by washing them off of ground stone tools, particularly the tool crevices (Pearsall 2000:180; Piperno 1998; Piperno et al. 2000).

To my knowledge, no starch grain studies have yet been conducted at Blue Creek.

Macrobotanical Remains Analysis

Macrobotanical remains are plant remains large enough to be visible to the naked eye and to be identified under low-power magnification. These include seeds, fruits and nuts, wood/charcoal, roots and tubers, fibers, leaves, non-woody stems, flowers, and cultivated plant material that served an economic function (e.g. bark paper, palm thatch, cotton cloth).

More so than for pollen grains, phytoliths, or starch grains, the preservation of macrobotanical remains is heavily dependent upon environmental conditions. Pearsall says, "[w]ith the exception of situations of extreme aridity or waterlogging…most macroremains are preserved through human action that led to charring (2000:247)." Charring can provide a direct link between plant remains and human behavior, depending upon the context; instead, charred remains may represent natural forest fires. Archaeological determination of the extent of charcoal should make the distinction. The charring of botanical remains creates specimens that can be used for carbon-14 dating and protects remains from microbial growth. Whole fruits may be found at dessicated or waterlogged sites, but inedible portions of charred fruit are more likely to be found (because the edible portions have presumably been eaten; Pearsall 2000:140). Roots and tubers are occasionally recovered as macroremains, particularly when discarded as spoiled in waterlogged or dessicated settings, when charred during roasting, or when burned as fuel (Pearsall 2000:157, 161). Unfortunately, charring can also distort macroremains, complicating identification.

Macrobotanical remains analysis has a number of potential benefits. The presence of macroremains in an archaeological context could (depending upon the context) indicate which plants were grown, eaten, or otherwise used by site inhabitants, which plants were simply growing in the area, or which non-local plants were obtained through trade. During domestication, plants undergo genetic changes that may manifest as changes in the size, morphology, or anatomical characteristics of plant parts (Pearsall 2000:168). Thus, macrobotanical remains from cultivated populations may sometimes be distinguished from wild populations.

Macrobotanical remains in the form of plants fulfilling an economic purpose have been recovered from Mayan sites, and can tell us about Mayan plant use. For example, at Tikal, plastered rooms of palaces had "sapodilla-wood spanner beams which had only a decorative function" (Coe 2005:124). Morphological features allow wood to be identified to species, which can help determine the location of origin of the wood, the species that grew at the site in ancient times, patterns of firewood selection, and woods chosen for construction or tool manufacture. Softwoods (from conifers) have been used for making paper, while hardwoods have been used for construction (furniture, buildings, etc.)

Economic uses of other macroremains are wide and varied. Bark was used particularly prevalently in precolumbian northeastern United States and in South America in the construction of canoes, longhouses, and roofs. Other macroremains have been discovered in various archaeological contexts around the world. Roots, in addition to their function as food, have been used to make baskets, battle shields, and boat paddles. Flowers and stalks have been used as kindling, arrow points, and dye. Seeds have been used as food and jewelry. Larger seeds and seed husk fibers have been used for life preservers or floats, weaving, kindling, and (in the case of the coconut) to make shoes. Spines have been used in blowguns and as fish hooks, needles, and darts. Willow (*Salix* sp.), jute (*Corchorus* sp.), hemp (*Cannabis* sp.), bamboo (Poaceae), and other long, flexible stems have been used for weaving, whips, and rope. Leaves and other plant parts recovered from archaeological deposits have been used as poisons, hallucinogens, fragrances, and insecticides. These uses may be discovered during macroremains analysis, or in the form of chemical residue. Note that the Maya did not necessarily use plant parts in all of these ways, and that specific details on the Mayan/Mesoamerican uses of the plants represented in the Laguna Verde pollen core are given in Chapter V of this dissertation.

I know of no macrobotanical studies underway at Blue Creek. It is possible that intentionally charred macrobotanical remains could be recovered from the site. Humid environmental conditions rule out the possibility of remains being recovered from permanently arid settings. Permanently waterlogged vegetation exists as peat in the swamps, but it would be difficult to draw a connection between such peat deposits and ancient human activities.

Coprolite Analysis

Coprolites (fossil feces) are good sources of all sorts of faunal and floral (both micro- and macrobotanical) remains, including pollen, phytoliths, plant fibers and cutin, seeds, starch, bone, fur, hair, and so on. The contents recovered from coprolites and mummy gut can provide a direct record of foods ingested. Coprolites can reveal which foods were eaten together and the season of the year when the meal was consumed (e.g. Williams-Dean & Bryant 1975; Reinhard & Bryant 1992:266-268). If foods available at different seasons were eaten together, food storage practices are implicated (Pearsall 2000:520; Reinhard & Bryant 1992:270-272). Coprolites and mummy guts can indicate health status (e.g. parasites, diarrhea, diet composition) or cause of death (hanging or suffocating). Comparisons of latrine deposits in separate locations can indicate differences in diet related to economic status (e.g. Marshall 1999).

Before starting a coprolite project, several caveats are in order. The first possible mistake in coprolite analysis might be to misinterpret an animal coprolite as having a human origin. One should determine whether the coprolite came from a human or from another animal before interpreting its contents! Furthermore, while coprolites can be sources of direct dietary evidence, their interpretive potential must not be overestimated. The natural pollen rain may have introduced non-economic pollen into foods and beverages before they were ingested. It may not be possible or valid to determine the original number of plants or animals (or the caloric intake) represented in a coprolite. Signs of consumption of large game may not be evident at all. Latrine deposits cannot be traced to particular individuals. So, for example, the diet and health status of an individual cannot be determined, and comparisons among group members cannot be made.

Genetic Studies

Genetic studies in archaeobotany are in their infancy. DNA may be preserved in macrobotanical remains. Ancient DNA can be amplified and the nucleotide sequences can be compared to the sequences of known plants to identify the ancient remains. DNA from ancient and even extinct plants has been recovered from amber (e.g. Poinar et al. 1993). Genetic studies have been used to determine the ancestry of domesticated maize (e.g. Hilton & Gaut 1998; Matsuoka et al. 2002; Wang et al. 2005). DNA may also be extracted from coprolites to learn about individuals who deposited coprolites and the plants and animals ingested (e.g. Poinar et al. 2001). As the methodology of this discipline continues to develop, genetic studies of archaeological sediments may someday replace microbotanical analyses (Bryant 2003)!

Molecular Studies

Some paleoethnobotanists have detected the ancient presence of plants at the molecular level, focusing on proteins, lipids, and other compounds found on artifacts or extracted from macrobotanical remains (e.g. Lucquin et al. 2007; Pearsall 2000:183-184). An example of molecular studies that appears in this dissertation involves the detection of theobromine residue in ceramic vessels, which helped archaeologists to determine that the vessels were used as chocolate pots (Henderson et al. 2007; Hurst et al. 2002; Powis et al. 2008, 2002).

Isotopic Analysis and Trace Element Studies

The carbon and nitrogen isotopes in macrobotanical remains (even fragmentary, visually unrecognizable ones) and cooking residues can be studied to determine their photosynthetic pathway (C_3 or C_4/CAM).

Isotopes extracted from skeletal collagen can determine the “relative contributions to diet of marine and terrestrial foods, or of plants of different photosynthetic pathways” (Pearsall 2000:522). Maize is a C_4 crop, while forest plants follow the C_3 pathway, so an enriched carbon signature can indicate reliance on maize agriculture, as opposed to reliance on plants gathered from the forest. In Mesoamerica, maize was the only major source of plant food that followed the C_4 pathway (White et al. 2006:143). A C_4 signature can appear in the bones of people who eat maize or maize-fed animals, and/or marine reef food sources (White et al. 2006:144). The Maya, especially those living in coastal Belize, had access to marine reef foods (White et al. 2006:144). However, physical anthropologists can compare the ratio of carbon and nitrogen isotopes in human skeletons to expose the relative percentages of maize vs. marine foods in the diet (White et al. 2006:144). Isotope studies of skeletal populations can help determine the level to which a population relied on maize agriculture, and can determine whether members of a population had differential access to a maize-based diet.

Isotopic analysis can help identify the location of ancient agricultural fields:

> Organic matter derived from the roots and residual plant materials left in the fields after harvesting of maize crops is enriched in ^{13}C relative to the native forest vegetation…Studies at sites in Belize and Guatemala show that humic matter enriched in ^{13}C occurs only at depths about 60 centimeters in the soil. This is because, after Maya farmers abandoned the soils, wild C_3 vegetation invaded the fields, and bioturbation has presumably translocated this later ^{13}C-depleted humic component downwards…the presence of humic substances, which are enriched in ^{13}C, can indicate that the soil was formerly used for maize agriculture (Schwarcz 2006:319).

Other trace elements can be detected in skeletal populations. Low levels of the periodic elements become incorporated into the human body through ingestion of food, water, and (usually accidentally) soil. “Because foods at different trophic levels and from different environments may contain different concentrations of trace elements, dietary patterns influence the concentrations of trace elements in human tissue” (Pearsall 2000:535). Skeletal hydroxyapatite, tooth enamel, and hair record ingestion of trace elements, such as iron, strontium, barium, zinc, and magnesium. These can be studied to indicate an individual’s trophic level (i.e. reliance on a diet of cereal crops, leafy vegetables, fish, meat, or dairy products).

Indirect Evidence: Ethnographic Analogy, Experimental Archaeology, and Ethnomedicine

Ethnographic analogies make proposals about ancient Mayan agricultural practices and beliefs, based on comparison to historic or modern populations living in the same area, or in a similar area (Turner 1985:196). Because the application of such proposals usually cannot be proven to have applied to the Mayan case, ethnographic analogies are considered to be an indirect form of evidence about the past. Still, ethnographic analogies are sometimes useful in supporting the interpretations made from other types of evidence. For example, ethnographic analogies can help determine the possible uses of plants represented by macro- or micro-botanical remains: which plants were likely used as food vs. fuel? I use ethnographic analogies at various, relevant, points during this dissertation; for example, in Chapter IV, I tell how modern milpa farmers operate in Belize, and suggest that ancient Maya farmers operated in a broadly similar manner.

In addition to offering hints about past agricultural practices, ethnographic analogies may help to reveal the conceptions, ideas, beliefs, spiritual practices, etc. the ancient Maya had regarding agriculture. For example, there are many farming rituals in the modern Yucatan (where soil is thin and rainfall sparse), indicating anxiety about crop success (Coe 2005:251). Yucatan [State] Maya, such as the people of Chan K’om, believe that the gods of nature must be asked to provide favors for man, and must be “repaid through prayers and offerings, including sacred foods and the first-fruits of the harvest” (Coe 2005:25). Rituals include a ceremony to bring rain, and divination through the casting of maize kernels (Coe 2005:251-252). Might Late Classic Period Maya, experiencing environmental stress, have engaged in similar rituals?

Experimentation can be a source of ethnographic analogy, in which archaeologists assess the procedures and probabilities of growing, storing, or cooking a certain plant (e.g. Dering 1999; Puleston 1971, 1977a; Thoms 2008).

Ethnomedicine

The field of ethnomedicine is a major source of the ethnographic analogies in this dissertation. Ethnographic analogy to modern ethnomedical practices suggests ancient Mayan medicinal uses for, and beliefs surrounding, plants.

Ethnomedicine comprises the traditional, culturally-specific healing practices of non-Western (i.e. traditional or indigenous) societies (Sanabria 2007:214). In contrast with Western biomedicine, which focuses on the diagnosis and curing of physical diseases, ethnomedicine often treats culturally-perceived illnesses that may result from an imbalance between humans or between humans and the supernatural (Sanabria 2007:215). Many indigenous peoples do not perceive a separation between mind (or spirit) and body in the same way Westerners do (Sanabria 2007:232-233). This is true among Belizean ethnomedical practitioners, who distinguish physical disease from spiritual disease in a different manner than Western doctors do (Arvigo & Balick 1993:8). In Belize, spiritual health is interconnected with physical health, so a seemingly physical disease may have a supernatural cause (Arvigo & Balick 1993:8-9, 14). To preserve their indigenous identities during the Conquest, many Central Americans combined their traditional ways with the new teachings of Christianity (usually Catholicism; Arvigo & Balick 1993:1). Therefore, many extant ethnomedical practices have roots in both indigenous and Christian beliefs (Arvigo & Balick 1993:1). Ralph Roys' (1931) *The Ethnobotany of the Maya* discusses Conquest-era acculturation via the Mayan usage of both native and European medicinal plants.

Prayer or the burning of incense may be an integral part of the cure for a physical disease (Arvigo & Balick 1993:8-9). Prayers for healing are offered to the Nine Benevolent Maya Spirits (Arvigo & Balick 1993:9). Nine has long been a number sacred to the Maya, symbolizing the connections between heaven and earth (Arvigo & Balick 1993:13-14). Prayers of thanksgiving are offered while the healer collects the plant, so that the healing spirit of the plant will help the patient and not stay in the ground (Arvigo & Balick 1993:10). Other Belizean ethnomedical healing methods include the use of charms, amulets, herbal baths, herbal teas, poultices, powders, tinctures, salves, oils, smoking, massage, chiropractology, and acupuncture (Arvigo & Balick 1993:5-8, 19-22). Mayan ethnomedicine includes almost 200 types of leaves, or *xiv*, used in these types of healing practices (Arvigo & Balick 1993:13).

A healing tradition has been in place in Central America for thousands of years. People may have first discovered the medicinal possibilities of plants when the scent of a plant attracted people to taste the plant, and upon tasting the plant discovered that their symptoms were relieved (Arvigo & Balick 1993:2). Those interested in healing may then have conducted experiments (Arvigo & Balick 1993:2-3). People may also have observed which plants were eaten by sick animals (Arvigo & Balick 1993:3). In Central America, ancient medical schools "taught the role of plants in health care" (Arvigo & Balick 1993:xi). The Maya codices, which were destroyed by Spanish conquistadores, contained information about the medicinal uses of plants (Arvigo & Balick 1993:xi). Modern Belizeans learn home remedies from their parents and grandparents (Arvigo & Balick 1993:4). Some healers learn about healing methods through their dreams of God or the Maya spirits (Arvigo & Balick 1993:4).

Today, individuals turn to ethnomedical practices when they view an illness as having a supernatural cause; when they lack access (e.g. transportation, health insurance) to Western-style health care; and when ethnomedical practitioners (e.g. shamans, grannie healers) share the individual's language and beliefs (Sanabria 2007:222).

Though some plant lore has been preserved orally throughout the centuries, traditional ethnomedicine is now on the decline (Arvigo & Balick 1993:xi, xiv, 5). Traditional healers still play important roles in rural villages, where there is no access to modern Western medicine, and can also provide first aid care (Arvigo & Balick 1993:24). Avenues toward the preservation of ethnomedical knowledge, simultaneously adding to economic development, include "education, agricultural trials with native plants, development of new non-timber forest product industries, seminars and lectures to the lay public, interaction with medical professionals, and ecological- and scientific-based tourism" (Arvigo & Balick 1993:xvii).

Indirect Evidence: Environmental Possibility

The final form of indirect evidence of ancient Mayan agricultural practices and plant uses is "environmental possibility." "Environmental possibility searches the modern environments…for cultivars…that the Maya could have utilized," and reasons how the cultivars could have been produced in ancient times (Turner 1985:196). Environmental possibility is useful for forming hypotheses about practices (like weeding and mulching) that are not archaeologically visible, but were environmentally feasible.

An example of the application of environmental possibility and experimental archaeology comes from archaeologist Dennis Puleston (1971, 1977a). Puleston suggested that the Classic Maya may have been as dependent upon the cultivation of *Brosimum* sp. ("breadnut") as they were upon maize, since breadnut stores well and is often found growing near Maya ruins. However, others believe that breadnut was only famine food for the Maya, and edaphic factors (i.e. disturbed soil) lead the tree to grow near Maya ruins (Coe 2005:21; Lambert & Arnason 1978, 1982; Miksicek et al. 1981). Environmental possibilities are good starting points for experiments or for making hypotheses that can be investigated by other forms of evidence.

METHODOLOGY

Pollen Sampling

The samples considered in this report were collected from a sawgrass (*Cladium jamaicense*) swamp adjacent to a small lake known as Laguna Verde. The swamp was "discovered" during a drive intended to acquaint me with the archaeological sites and ecological zones surrounding Blue Creek as I sought a site for pollen coring. I sought an undisturbed site that was likely to have good pollen preservation, in a location that could have been a catchment area for palynological markers of human activity at, and near, the Blue Creek site. Field personnel were attracted to the Laguna Verde swamp by its sulphurous odor, which indicated that it provided an acidic, reductive, fungistatic, and bacteriostatic environment conducive to the preservation of organic materials, such as pollen (Faegri & Iversen 1989:146). Furthermore, sediment lying beneath the waterline in a swamp provides a permanently moist environment, which favors pollen preservation (as compared to sediments that alternate between moist and arid conditions; Faegri & Iversen 1989:146). The swamp is located approximately 1 km south of the Blue Creek site core area, but is not known to have been part of any archaeological site or wetland agricultural field. It was also free from disturbance by modern human [i.e. agricultural] activity. Therefore, it was considered an appropriate location for taking a sediment core that would provide information about the general environmental history of the Blue Creek region.

Samples for pollen analysis and radiocarbon dating were taken from a single sediment core (UTM Easting 16Q0299504/UTM Northing 1974167, corresponding to Latitude 17°50’45.7441”/Longitude 88°53’31.2349”; see Figure 4). A 3 m long metal pipe with a two-inch diameter was manually driven vertically into the ground. When the bottom of the pipe reached a depth of 261 cm below the water line, the remaining length of pipe was too short for further driving. The excess piping was sawed off. Water was added to fill the top of the pipe, creating a vacuum to prevent loss of sediment during the extraction of the pipe. A rubber cap was applied and secured with duct tape. The pipe was then manually pulled out of the ground, the hole in the ground was marked, and the remaining open end of the pipe was capped. A second, longer pipe was inserted into the same hole until the bottom of the pipe reached a depth of 373 cm below the water line, after which it struck rock and could be driven no further. The same procedures, explained above, were followed to remove and seal this deeper core. Both pipes were appropriately labeled, with top and bottom ends indicated.

To permit comparison of the pollen contents of the core with those of the modern surface, a surface control “pinch” sample was taken at the swamp. An additional modern reference sample representing an open, disturbed environment comes from a modern, plowed cow pasture in the vicinity of Blue Creek.

Areal Vegetation

To enable comparisons between modern and past vegetation, I made notes on the current, modern vegetation I observed both in the herbaceous (sawgrass) swamp, and the nearby (just outside the area dominated by sawgrass) swamp forest. Other (unobserved or unidentified) taxa may exist in this particular herbaceous swamp and swamp forest, and many additional taxa typically grow in those two ecotypes in Belize; the vegetation associations of the local ecotypes are explained fully in the environmental interpretation in Chapter VI. The taxa I observed are listed in Tables 1 and 2, respectively.

Table 1. Herbaceous Swamp Vegetation.

Family	Genus or Species	Common Name
Anacardiaceae	*Metopium brownei*	Chichem
Apocynaceae	Not determined	Frangipani family
Arecaceae	*Acoelorraphe wrightii*	Tasiste palm; palmetto
	Cryosophila stauracantha	Give-and-take palm
Bombacaceae	*Pachira aquatica*	Provision tree
Boraginaceae	*Cordia* sp.	-
Bromeliaceae	Not determined	-
Burseraceae	*Bursera simaruba*	Gumbolimbo
Combretaceae	*Bucida buceras*	Bullet tree
Cyperaceae	*Cladium jamaicense*	Sawgrass
Fabaceae	*Acacia* sp.	Cockspur
	Erythrina sp.	Coral bean
	Other genre of Fabaceae	-
Myricaceae	*Myrica cerifera*	Wax myrtle
Polygonaceae	*Coccoloba* sp.	Bob; wild grape
Polypodiaceae	Not determined	Fern
Rhizophoraceae	*Rhizophora mangle*	Red mangrove

Table 2. Swamp Forest Vegetation.

Family	Genus or Species	Common Name
Annonaceae	*Annona* sp.	Custard apple
Apocynaceae	Not determined	Frangipani family
Arecaceae	*Desmoncus orthacanthos*	Basket tie-tie
Burseraceae	*Bursera simaruba*	Gumbolimbo
Fabaceae	*Erythrina* sp.	Coral bean
Moraceae	*Ficus* sp.	Fig
Pinaceae	*Pinus caribea* var. *hondurensis*	Pine
	Pinus oocarpa	Pine
Sapotaceae	Not determined	Family includes chicle and sapodilla

Pollen Core Stratigraphy

Back at the field station, the pipes were cut into seven shorter segments. The sediments were carefully extruded onto plastic sheeting, and the strata were measured and described. The depth measurements, sediment descriptions, and interpretations of the core are given in Chapter III. There, the strata from the core are also compared with published stratigraphy from local archaeological sites (e.g. Lohse 2003a, Beach & Luzzadder-Beach 2003).

Working within the strata, the columns of sediment were cut one by one, at measured intervals, into sixty-six disks (fifty-nine for pollen sampling, six with potential for radiocarbon dating, and one suitable for both). When possible, the top, center, and bottom of each stratum were sampled. The outer edge of each disk was cut away and discarded to prevent contamination from other levels. Disks were sealed in Whirl-Paks and labeled according to the depth from which they had come. All samples were boxed and transported via personal truck to the United States.

Dating Terminology

This dissertation reports radiometric dates according to the conventions specified by the style guides of the Society for American Archaeology and the American Anthropological Association. The words "before present" are abbreviated as "B.P." for calibrated dates, and as "b.p." for uncalibrated dates and to reference general time periods.

The abbreviation "B.C." is sometimes used in this dissertation to facilitate comparison with other works reporting dates in such terms. Radiometric dates originally reported only as "cal B.C." are given here in that original format.

Most non-radiometric dates of less than two thousand years of age are reported as "A.D." The abbreviation precedes the numeral.

Accelerated Mass Spectrometer Dating

Samples for AMS dating were collected, cut, and stored along with the pollen samples, as described above. Seven samples were noted for their content of relatively large pieces of charcoal, and these were retained for accelerated mass spectrometer (AMS) dating. The Maya Research Program funded the AMS dating of one sample from the lower portion of the sediment core (368-369 cm below the surface of the swamp water, hereafter abbreviated "cmbs"). A Texas A&M University Anthropology Department Travel and Research Grant provided funding for the AMS dating of two additional samples (from 360-361 and 312-313 cmbs). Samples were submitted to Beta Analytic, where they were pretreated with acid/alkali/acid washes to remove carbonates and secondary organic acids. Sample numbers and proveniences, and uncalibrated and calibrated dates are given in Table 3.

Table 3. AMS Dates for the Laguna Verde Pollen Core.

Beta Number	Sample Depth (below water line, in cms)	Measured Radiocarbon Age	2σ Calibrated Date, B.P.	2σ Calibrated Date, B.C.	13c/12c Ratio
176285	368-369	4140±40	cal B.P. 4830 to 4520	cal B.C. 2880 to 2580	$\delta^{13}C$= -25.9 0/00
243498	360-361	4010±40	cal B.P. 4560 to 4550 and 4540 to 4410	cal B.C. 2610 to 2600 and 2590 to 2460	$\delta^{13}C$= -25.6 0/00
243497	312-313	2780±40	cal B.P. 2980 to 2790	cal B.C. 1020 to 840	$\delta^{13}C$= -24.2 0/00

The slight overlap in the confidence interval for the two earliest dates, from the core's two earliest sediment strata, shows that those strata were deposited rapidly. This may account for the low pollen concentration values in samples from those strata.

The significance of the AMS dates is applied throughout this dissertation, particularly in the environmental interpretation of the Laguna Verde pollen core.

Four final samples (from 258-260, 285-287, 290-291, and 343-346 cmbs) have been retained for AMS assays and will allow for an extension and refinement of the chronology, pending funding. This dating will provide *terminus ante quem* dates for additional cultivars. Furthermore, it will provide checks on the sedimentation rate, which is believed to have been great during the height of Mayan land clearance for agriculture (as demonstrated by the 3000-400 b.p. deposition of Maya clay in the Petén) and a period of local water table and ground surface aggradation (during the Late Preclassic through Late Classic Periods; Beach & Luzzadder-Beach 2003:32; Luzzadder-Beach & Beach 2009). It would be interesting to find out whether or not the samples barren of pollen (from 228-229 until 202-203 cmbs) were an artifact of rapid sedimentation during that time, although the samples reserved for dating unfortunately do not bracket the barren segment. The enmeshed issues of water table rise, erosion, and sediment aggradation are further addressed in the "Geology and Soils" section of Chapter III. Finally, further dating may show whether palynological evidence for agriculture reduced around the time of the Maya Collapse (A.D. 900 at Blue Creek).

Pollen Extraction: Initial Processing

Upon arrival in the United States, each sample was assigned a laboratory number. A volume of sediment was measured with an injection syringe, with the tip cut off to form a blunt end. This method of volume sampling is described by geologist Louis J. Maher, Jr. (1981:159-160). The size of most samples in the present study was one cubic cm. However, after it was determined that samples from the range of 219-243 cmbs had low pollen content, larger samples of two or three cubic cm were taken from some of the overlying samples.

After the samples had been measured out, tablets of tracer spores were added to each to check for loss of pollen during processing and for the later calculation of pollen concentration values (number of grains per volume of sediment). Pollen concentration values can help assess the productivity of the depositional environment and the level of post-depositional preservation. Pollen concentration values can be used to compare levels of preservation from site to site, and from different levels of the same site (Bryant & Holloway 1983:208). When geological strata can be dated, tracer spores can be used to estimate pollen influx (number of grains deposited per square cm per year; Maher 1981:153, 188-190). Changes in the concentration value of a single taxon also indicate changes in environment and deposition (Maher 1981:154). Specifically, an increased number of grains of a particular taxon per volume of sediment processed can indicate an increase in the number of plants of that taxon contributing to the depositional environment, or can indicate a slowing of sediment accumulation (Maher 1981:154).

Even though most of the samples were very small in size (one cubic cm), good preservation and high pollen content were expected, so two tablets of *Lycopodium clavatum* tracer spores, each containing 13,500 spores, were added to each sample. Club moss of this species does not grow in modern Belize, although seven species of the family Lycopodiaceae do grow there. Those available for viewing on reference slides (*Huperzia linifolia, Lycopodiella caroliniana,* and *Lycopodiella cernua*) were not similar in appearance to *L. clavatum.* Dr. Vaughn Bryant (personal communication, 2007b) believes that misidentification of spores from naturally-occurring plants as being tracer spores rarely happens. Even in boreal forests, where *Lycopodium* sp. grow with greatest abundance, *Lycopodium* sp. spores do not contribute more than 1-2 percent of the total pollen load.

Later, it was discovered that the use of two tracer spore tablets created an inappropriate ratio of too many tracer spores to too few pollen grains. This meant that many extra hours were required to count the palynomorphs on multiple slides to achieve a 200-grain count for any one sample. Attempts to correct this imbalance were made when some samples were reprocessed (see below): following the recommendation of Maher (1981), only enough spores were added to achieve a 1:1 or 2:1 ratio with the pollen.

The samples were treated with 10 percent hydrochloric acid (HCl) to dissolve the *Lycopodium* tablets and carbonates, and to liberate pollen from any carbonate aggregations. Most of the samples reacted very little with the HCl, thus revealing their low carbonate (high organic) content.

When the reactions stopped, purified water was added to each sample. Samples were "swirled" and passed through 150-micron (μ) screen to separate small (pollen) from large (debris) fractions. The large fraction was discarded, while the supernatant was centrifuged and condensed for pollen extraction.

All samples were dehydrated with glacial acetic acid. To remove unwanted organics, pollen samples were treated with an acetolysis solution (90 percent acetic anhydride, 10 percent sulfuric acid), as recommended by Erdtman (1935, 1960). Acetolysis destroys cellulose by breaking its molecular bonds and binding with the resulting molecules to yield acetic acid and/or simple sugars or short-chain sugar polymers, which are soluble in the acetolysis solution (Marshall 2007). Though the acetolysis procedure removes unwanted organics that would complicate the clear observation of pollen grains during analysis, it leaves intact the sporopollenin that constitutes the basic structure of the pollen grains so that pollen grains can still be observed and identified. Samples were heated in a heating block and stirred for ten minutes. Glacial acetic acid was added to stop the exothermic reaction of the acetolysis; to continue the removal of reactionary byproducts; and to lower the specific gravity of the sulfuric acid.

It was observed that, after acetolysis, some samples in the first batch processed (laboratory numbers 1-24) still had a high organic content. Therefore, they were subjected to 5 percent potassium hydroxide (KOH) to destroy humates and some organics. Dehydration in glacial acetic acid and acetolysis were repeated for all samples in the first batch except those numbered 23 and 24. All samples in the other two batches to be processed were rinsed in KOH before they were acetylated. Some samples (laboratory numbers 29, 30, 33, 34, 35, and 37-41) with particularly high organic content were acetylated twice in an effort to destroy excess organics. Five months after the initial processing, it was determined that some samples still contained so much organic "garbage" that the pollen could not be counted. Some samples (laboratory numbers 3, 5-12, 15-22, 29, 34, 35, 38, 57, and 59) were acetylated yet again.

After acetolysis, samples were centrifuged, decanted, and rinsed several times in purified water. All samples were subjected to heavy density separation with zinc bromide ($ZnBr_2$), specific gravity 2.0. Heavy density separation forces objects to float if they have a specific gravity lower than that of the heavy density liquid, or to sink if they have a higher specific gravity. Pollen has a specific gravity of 1.0-1.5, and will float in

$ZnBr_2$ (specific gravity 2.0), while silicates and other minerals of high specific gravity sink to the bottom of the test tube. Samples were centrifuged at 1,500 rotations per minute (rpm) for one minute, then at 3,000 rpm for six additional minutes. The light fraction containing the pollen was pipetted off for continuing pollen extraction and analysis.

Next, Safranin O was added to stain the pollens' cellulose and protein, and the stain was set with 10 percent ethyl alcohol (EtOH). Samples were again rinsed and dehydrated in EtOH, and were curated in glycerine. One slide was initially made of the pollen from each sample, though some samples later required the making of additional slides to achieve a 200-grain count. This proved problematic. Because the samples had such high content of seemingly indestructible non-pollen organics, and because so many tracer spores had been added to the samples, too much time was expended searching for pollen on the "dirty" slides, and making and examining multiple slides per sample. In preliminary counts of samples 1, 3, and 5, up to 500 *Lycopodium* spores were counted in conjunction with as few as thirty pollen grains (sample 1).

To facilitate the pollen counting, a new processing method was devised and tested on two samples, laboratory numbers 3 and 5. These samples were selected for retreatment because they seemed to be the earliest samples with sufficient pollen to merit counting. One cubic cm of each sample was measured out. Approximately six mL of 5 percent KOH was added to each sample, and the samples were placed in a heating block and stirred for ten minutes. This softened and broke apart the organics. Samples were then rinsed with purified water. *One* tracer spore tablet was added to each sample. Tablets were dissolved with 48 percent hydrofluoric acid (HF). HF would also have destroyed any silicates present, but the samples were observed to have low silicate content anyway. After soaking in HF for approximately twenty-four hours, samples were rinsed thoroughly. The samples were placed into 50 mL Nalgene centrifuge tubes and filled with water mixed with a very small (approximately 1 mL) amount of Amsco Sonic Detergent. This detergent cuts grease and facilitates sonication. Samples were sonicated for approximately 15 seconds to shake apart organics. Next, samples were rinsed through a 150 µ mesh screen, condensed into 12 mL glass centrifuge tubes, and dehydrated with glacial acetic acid. A strong acetolysis solution was prepared to speed hydrolysis and removal of cellulose (Bryant 2006). Samples were placed in a heating block and stirred for ten minutes, then rinsed in glacial acetic acid, followed by water. Finally, the samples were stained and curated in 1 dram vials, as described above.

This new processing method evened out the ratio of pollen grains to tracer spores, and removed unwanted organics. Unfortunately, it was still necessary to prepare multiple slides to achieve a 200-grain count for Sample 5. Sample 3 appeared to contain so little pollen that counting of the reprocessed sample was not attempted. Also, the sonication may have torn some of the palynomorphs; a large number of torn *Lycopodium* spores and loose *Pinus* bladders were observed. Some pollen grains also appeared collapsed or sunken inward, but it is unknown whether this is a result of the processing method. Later, this processing method was honed in a final processing of some samples so that the non-pollen organics could be more successfully destroyed, while the pollen grains remained unharmed.

Pollen Extraction: Final Processing

In September 2004, final processing of the remaining uncountable samples took place. By this time, two years after the samples had been collected in the field, the sediment had dried and hardened, and so could not be measured in cubic cm with the modified syringes. Instead, samples were weighed in grams. Because most samples to be subjected to this final processing were known to have a low pollen concentration, the full remainder of the original sample sediment disks was processed. Varying amounts of sediment remained, and differences in initial water content of the now-dehydrated samples meant that the final sample sizes varied from one another. Since it had been ascertained that most samples had low pollen concentration values, only one *Lycopodium clavatum* tracer spore tablet was added to each sample during the final processing. This was as close as I could come to attaining Maher’s 2:1 tracer spore-to-pollen ratio.

It would have been desirable to make another attempt to reprocess samples with laboratory numbers 3, 5, 7, and 9, but insufficient quantities of sediment remained from previous processing. Samples 3 and 5 had already been processed twice.

The new samples were treated with 10 percent hydrochloric acid (HCl) to dissolve the *Lycopodium* tablets and carbonates, and to liberate pollen from any carbonate aggregations. Following a water rinse, samples were “swirled” and screened through 150 µ screen. The small (pollen) fraction was condensed in 50 mL centrifuge tubes and rinsed again. Hydrofluoric acid (48 percent HF) was added to the tubes and allowed to soak into the samples for one hour. Samples were rinsed once with water, then once with hydrochloric (36 percent HCl) acid to prevent the formation of fluorosilicates. Samples were rinsed three or more times (until the water ran clear), then condensed into 12 mL glass tubes and dehydrated with glacial acetic acid. Samples were heated for 10 minutes in a strong acetolysis solution made from seven parts acetic anhydride and one part sulfuric acid. Next, samples were rinsed once in glacial acetic acid, and then in water until the water ran clear. To oxidize non-reactive unsaturated organic soil colloids (or “humic acids”; Bryant 2006), samples were covered with potassium hydroxide (5 percent KOH) and heated in a heating block for ten minutes. Following one water wash, samples were rinsed once in 36 percent HCl to remove the hemicellulose that had been destroyed by the KOH. Samples were then rinsed in water until the water ran clear. Samples were rinsed once or twice in 36 percent HCl, and again rinsed in water until the water ran clear. Samples were then subjected to heavy density separation with zinc bromide ($ZnBr_2$), specific gravity 2.0, centrifuged at 1,500 rotations per minute (rpm) for one minute, then at 3,000 rpm for nine additional minutes. The light fraction (containing the pollen) was pipetted off, rinsed in water, and dehydrated in 95 percent ethyl alcohol. Pollen was stained with Safranin O, transferred to one-dram vials, and curated in glycerine.

Pollen Identification

The first step in the taxonomic identification of the pollen in this study was familiarizing myself with the most common pollen types of the Neotropics, and with the pollen of the present-day plant taxa that were identified in the area in which samples were collected (listed in Tables 1 and 2). I did this by drawing, measuring, and photographing several hundred reference specimens from the Texas A&M University Anthropology Department Palynology Laboratory reference collection. I also consulted many published light micrographs of pollen grains, and their companion written descriptions. No pollen atlas (a book featuring light micrographs or scanning electron micrographs of pollen grains) has been published for the flora of Belize. Therefore, I consulted atlases from other Neotropical locations with similar florisitic compositions. Particularly useful were *Atlas de las plantas y el polen utilizados por las cinco especies principales de abejas productoras de miel en la región del Tacaná, Chiapas, México* (Martínez-Hernández et al. 1993), *Flora Palinologica de la Reserva de la Biosefera de Sian Ka'an, Quintana Roo, Mexico* (Palacios Chávez et al. 1991), and *Pollen and Spores of Barro Colorado Island* (Roubik & Moreno 1991).

After achieving familiarity with the most significant pollen types from the region, it was possible to make taxonomic identifications of many grains encountered during sample counting, and I was often able to guess correctly the family in which unknown grains might be placed. This procedure led to faster and more precise genus- or species-level identifications.

Whenever possible during sample counting, light micrographs were taken of the polar and equatorial views of at least one grain representing each taxon that was identified. Identifications, even those made by an expert, based only on light micrographs are potentially less accurate than those based on interaction with original palynomorphs. Palynomorphs in light micrographs may appear small or blurred. They cannot be manipulated for observation from multiple angles. Still, it is hoped that these light micrographs will give other palynologists a basis for agreement (or disagreement) with identifications made in this study, and may allow others to help me identify the remaining unidentified grains. Photo plates of the most significant pollen types encountered are given in Appendix A.

Taxonomy

This dissertation follows the taxonomic scheme of the book *Checklist of the Vascular Plants of Belize with Common Names and Uses* (Balick et al. 2000) for its use of generic and specific names, and its grouping of plants into families. Recent genetic evidence has clarified vegetational relationships, enabling plant taxonomists to reclassify some plants into different families (or other taxonomic categories). Significant cases of reclassification are noted below in the section “Taxonomic Discrimination,” and in Chapter V. Out of the necessity to follow a standardized scheme, this dissertation continues to follow Balick et al. even when reclassification could apply.

Taxonomic Discrimination

Some pollen grains are similar in appearance to other pollen grains. Although similar-looking grains are often produced by plants of the same genus or the same family, this is not always the case. This section explains how similar-looking grains were identified, labeled, and in some cases grouped, for this dissertation. Although I may seem to disclose many doubts about the identities of some pollen grains, I am confident in the quality of my work, and believe I had no more doubts or difficulties than any beginning tropical palynologist. The difference is that I am open to discussing these issues if I may thereby contribute to an improved science.

This section covers only the pollen taxa whose identification merits special mention. A complete list of pollen taxa identified in the Laguna Verde core is available in Chapter V. Descriptions and economic uses of all represented plants are also given in Chapter V. An ecological interpretation based on represented taxa is made in Chapter VI.

Acanthaceae: Of the Belizean species of *Bravaisia,* no reference slide or light micrograph was available for the pollen of *B. grandiflora*. The grains and fragments observed closely resembled the pollen of *B. berlandieriana* as published by Palacios-Chavez et al. (synonym *B. tubiflora*; 1991:37, Lamina XVIII).

Anacardiaceae: Some pollen grains were noted that (in terms of the shape and size of apertures, surface ornamentation, and general size) bore similarity to known members of the Anacardiaceae family but could not be identified to genus (perhaps because degradation marred some characteristics). These were tallied under the heading "Anacardiaceae."

In most cases, the *Spondias* sp. pollen grains observed were identified to genus, and 13 grains were thus labeled. It is likely that most of these belonged to the species *S. mombin.* In a few cases, it was possible to easily identify the grains to species. One grain in Sample 13 was identified as *S. mombin*, and one grain in each of Samples 4 and 49 was identified as *S. purpurea.* No grains were labeled as *S. radlkoferi,* though grains from this species may be included under the generic label.

Apiaceae: Several battered pollen grains were tentatively identified as Apiaceae, with one grain counted in Sample 43 and two grains counted in Sample 56. Many Apiaceae (e.g. *Daucus, Coriandrum, Anethum*) produce dumbbell-shaped, tricolporate pollen grains of similar size, and it is difficult to make generic distinctions among them by using standard brightfield microscopy. Therefore, the (possible) Apiaceae grains observed in this study were identified to family level only.

Apocynaceae: Of the four Belizean *Tabernaemontana* species, I was able to view light micrographs or reference slides only of the pollen of *T. alba* and *T. arborea.* Therefore, I identified the grain from Sample 43 to genus-level only. It bore resemblance to the pollen of *T. alba.*

Aquifoliaceae: Three grains of tricolporate, clavate (Colinvaux et al. 1999:192, 251) pollen were identified as *Ilex* pollen during the present study, with one grain counted in each of Samples 19, 30, and 46. I do not have access to light micrographs or reference slides featuring the pollen of the three Belizean *Ilex* species (*I. belizensis, I. guianensis,* and *I. tectonica*; Balick et al. 2000:106), so the observed grains were identified to the genus level.

Araceae/Arecaceae: The Arecaceae produce pollen of two forms, monosulcate and trichotomosulcate (Roubik & Moreno 1991:55-56). The trichotomosulcate grains may easily be mistaken for spores with trilete scars. The smaller monosulcate grains can be fragile and may easily be mistaken for spores, "plant junk," or unidentifiable pollen grains. All three species of Arecaceae palm trees that were observed growing in the vicinity of the Laguna Verde core site (*Acoelorraphe wrightii* and *Cryosophila stauracantha* among the sawgrass swamp vegetation, and *Desmoncus orthacanthos* among the upland swamp forest vegetation) produce monosulcate grains. Therefore, it is possible that more Arecaceae pollen grains were present in the pollen core than could be accurately tallied.

Bactris major produces trichotomosulcate pollen with a baculate exine and perforate tectum (Roubik & Moreno 1991:55) that render it distinguishable from the other Arecaceae grains with which I am familiar.

One battered, reticulate, monosulcate pollen grain was observed in Sample 46. This grain broadly resembled the pollen of Arecaceae or perhaps Araceae.

Aristolochiaceae: In the present study, one grain in Sample 61 was identified as Aristolochiaceae. Light micrographs or reference slides were not available for the pollen of most of the ten Belizean species of this family, but the observed grain bore some resemblance to the pollen of *Aristolochia pilosa* as published in Roubik & Moreno (1991:66, 188).

Asteraceae: Each species within the Asteraceae has a unique pollen morphology, but the very subtle differences among species make grains difficult to identify to species level with standard brightfield light microscopy (Bryant, personal communication, 2008). Palynologists usually divide the Asteraceae into four groups.

The first group, the "high-spine Asteraceae," are mostly produced by the tribe Heliantheae. These plants are mostly pollinated by insects, but also by the wind (Mabberley 2008:210). They may be encountered in the pollen record less often than other types of Asteraceae, and are more likely to have been used economically (Maher

1964). High-spine pollen grains are so called because they are ornamented with echinae that measure longer than 2-3 μ.

The second group, the "low-spine Asteraceae," come mainly from the Ambrosininae, a subtribe of the Heliantheae. Low-spine plants produce large quantities of small, wind-pollinated grains (Bryant, personal communication, 2008). The pollen grains are ornamented with echinae that measure less than 2-3 μ in length.

The third group comes mostly from Lactuceae tribe of Asteraceae. These plants produce fenestrate pollen. Most members are insect-pollinated (Mabberley 2008:210).

The fourth group, identified to genus level, is that of *Artemisia.* Wind-pollinated *Artemisia* plants are common in hot, dry areas (Bryant, personal communication, 2008). No grains of this type were observed during this study.

Betulaceae: One pollen grain identified as *Ostrya* sp. or *Carpinus* sp. (which are mutually indistinguishable by standard brightfield microscopy, if at all) was observed in each of Samples 16 and 60. These trees are usually found in northern temperate regions, but sometimes occur in montaine areas of the tropics. Nevertheless, no member of the family Betulaceae is known to grow in modern Belize. These grains must have arrived at Laguna Verde via long-distance transport.

The pollen of another genus of Betulaceae, *Alnus,* was identified at steady, low levels throughout the core. *Alnus* is purely a high-elevation genus (Bush 1995:600), so the *Alnus* grains must have blown (or washed) into my samples from elsewhere.

Bignoniaceae: Some prolate tricolporate grains were observed that likely came from plants of the family Bignoniaceae. These grains did not exhibit distinguishing features and cannot be identified to genus.

Boraginaceae:Of the 13 Belizean *Cordia* species, I could not access light micrographs or reference slides for the pollen of two species (*C. bullata* and *C. diversifolia*). Though only one pollen grain, in Sample 9, was directly identified to species level, it is believed that most of the *Cordia* grains observed during this study belonged to the species *C. alliodora* and *C. gerascanthus* (the latter resembling the type from a reference slide more than that pictured in Palacios Chavez et al. 1991).

Campanulaceae: One pollen grain from Sample 51 was identified as Campanulaceae. No published light micrographs were available of any of the four Belizean Campanulaceae species. Reference slides were available for the pollen of only one species, *Lobelia cardinalis*. The grain observed in this study did not resemble the pollen of *L. cardinalis.* Instead, it resembled the pollen of several types of *Campanula* and *Phyteuma* (as published in Reille 1999:389-391), genera of Campanulaceae which are not known to grow in modern Belize. This identification is uncertain.

Celastraceae: One pollen grain in Sample 34 was identified as Celastraceae pollen. However, no light micrographs or reference slides were available for some members of the family, and it is possible that the grain has a different identity.

Chenopodiaceae/Amaranthaceae: Recent molecular evidence may reclassify the Chenopodiaceae as a subfamily of the Amaranthaceae. This dissertation follows the older classification scheme (after Balick et al. 2000) that considers the two families to be separate from each other. However, many genera of Amaranthaceae produce periporate pollen that is indistinguishable from that of Chenopodiaceae. The pollen of the two Belizean species of the Chenopodiaceae family is indistinguishable with a light microscope. Together, Chenopodiaceae (*sensu stricta*) and *Amaranthus* sp. pollen grains are identified as “Cheno-Ams.” It is impossible to distinguish pollen of the cultivated forms of Cheno-Ams from that of the wild forms.

Chrysobalanaceae: I lack light micrographs or reference slides of the pollen of many members of this family, but those with which I am familiar bear some common characteristics: they are tricolpate or tricolporate, are suboblate, and have angular or triangular ambs and irregular margins at their apertures. In this study, one grain with these characteristics was observed in Sample 3 and was identified to the family level. Three additional grains, one in each of Samples 7, 28, and 29, were identified as members of the genus *Licania.* Three species of *Licania* (*L. hypoleuca*, *L. platypus*, and *L. sparsipilis*) grow in modern Belize (Balick et al. 2000:81-82). I am unfamiliar with the pollen of *L. sparsipilis.*

Combretaceae/Melastomataceae: Most species within the Combretaceae and Melastomataceae families produce heterocolporate pollen that cannot easily be identified to genus level with a standard brightfield microscope, if at all. In palynological literature, pollen of Combretaceae/Melastomataceae is referred to variably as "Melastomataceae" or "*Terminalia*" (Pohl 1985:61). The pollen of *Bucida buceras* was probably present in the Laguna Verde pollen core, since common swamp forest trees of that species were observed growing in the vicinity.

Laguncularia racemosa (Combretaceae) produces a tricolporate pollen type that is distinguishable from other Combretaceae and Melastomataceae pollen. Three grains of this type were identified to species level.

Corylaceae/Betulaceae: Two pollen grains in Sample 54 of the present study were identified as the pollen of *Corylus* or as similar-looking pollen from the Corylaceae ("hazelnut" family) or Betulaceae ("birch" family). The Angiosperm Phylogeny Group has reclassified the Corylaceae as a subfamily of the Betulaceae, though this dissertation continues to employ the taxonomy of Balick et al. (2000). Neither family is known to grow in modern Belize. These families include trees that produce abundant quantities of anemophilous pollen, so it is probable that the observed pollen grains blew in from a distant or mountainous location.

Cucurbitaceae: Two pollen grains were counted (one grain in each of Samples 28 and 60) that compared favorably with pollen from the family Cucurbitaceae. The pollen grains were medium-large and periporate, with short spines, but could not be identified to genus-level with certainty, perhaps for lack of light micrographs of the corresponding species.

Cupressaceae: One pollen grain in Sample 12 of the present study was identified as "TCT" pollen. TCT pollen includes visually indistinguishable grains from the families Taxodiaceae, Taxaceae, and Cupressaceae. The only species of any of these three families to grow in modern Belize is *Platycladus orientalis* (Cupressaceae), which grows in cultivation (Balick et al. 2000:49). However, the TCT families include trees that produce vast amounts of anemophilous pollen, so the grain under consideration may have blown in from a distant location. *Juniperus* grows in association with pine at elevations above 1500 m in Veracruz, Mexico (Leyden et al. 1993:167), and it is possible that the identified grain blew in from that location.

Cyperaceae: No attempt was made to sort the Cyperaceae by genus or species, but some Cyperaceae grains with "pointy" distal ends were observed. These were the sort produced by *Cladium jamaicense*, the species that dominates the marsh where the core was collected.

Euphorbiaceae: Because I do not have light micrographs or reference slides of the pollen of each of the thirteen Belizean species of *Acalypha*, I identified *Acalypha* grains to genus level.

Due to general similarity of appearance of *Croton* pollen types, the two grains observed were identified to genus level.

Of the three Belizean species of *Sebastiana,* only *Sebastiana adenophora* pollen is pictured in any of my pollen atlases. None of the species are present in the reference slide collection. The *Sebastiana* pollen in my samples looked more like that of *S. fruticosa* (which is not known to grow in modern Belize) than like that of *S. adenophora.* Possibly it was the pollen of *S. confusa* or *S. tuerckheimiana*, which grow in modern Belize but which were not available for viewing.

Fabaceae: I am doubtlessly not familiar with the pollen of all 295 taxa within the Belizean Fabaceae. Many of the unidentified tricolporate pollen grains from this study probably came from insect-pollinated trees of this family.

Three pollen grains resembling *Melilotus* sp. were observed in sample 49. Only one species of *Melilotus,* a cultivar, is known to grow in Belize. The pollen may have come from a taxon that produces pollen that resembles the pollen of *Melilotus* sp.

Light micrographs or reference slides of six *Desmodium* species (*D. barbatum, D. infractum, D. intortum, D. macrodesmum, D. metallicum,* and *D. obtusum*), and of some species of *Senna,* are not available to me. Therefore, *Desmodium* and *Senna* grains were identified by their genera.

Fagaceae: No attempt to identify *Quercus* sp. pollen to the species level was made during the present study.

Flacourtiaceae: In this study, one pollen grain comparing favorably with the pollen of *Banara guianensis* (as described in Roubik & Moreno 1991: 90, 211) was counted in Sample 46. This species is not known to grow in modern Belize. *Banara* has recently been re-classified as a member of the Salicaceae, though this dissertation continues to use the taxonomic scheme of Balick et al. (2000).

Juglandaceae: One pollen grain in Sample 4 was identified as *Carya* pollen. Neither *Carya* nor any member of the Juglandaceae is known to grow in modern Belize. *Carya* spp. is native to temperate regions. It produces large amounts of anemophilous pollen, but the pollen is relatively large and heavy and tends not to travel far upon release (Bryant, personal communication, 2008). Still, it is probable that the grain under consideration here blew into the study site from a distant location.

Lamiaceae: Two stephanocolpate pollen grains in Sample 60 were identified as grains of *Hyptis*, which includes twelve species that grow in modern Belize (Balick et al. 2000:35, 133). Grains of the six species of *Salvia* that grow in modern Belize (Balick et al. 2000:35, 133-134) look similar.

Lentibulariaceae: One grain in Sample 6 of the present study was identified as *Utricularia* pollen. Due to a lack of light micrographs or reference slides featuring the pollen of most of these species, the pollen grain was identified to genus level.

Liliaceae: One pollen grain in Sample 29 was identified as resembling the pollen of *Lilium* sp., though this species is not known to grow in modern Belize. Due to its relatively large size and relatively low production volume, *Lilium* pollen is unlikely to have entered this sample via long-distance transport. Perhaps the grain under consideration came from another member of the class Liliopsida (including 22 Belizean species presently re-assigned to the families Agavaceae, Alstroemeriaceae, Amaryllidaceae, Asteliaceae, Dracaenaceae, or Hypoxidaceae; Balick et al. 2000:3) which does grow in Belize, or perhaps it has been misidentified.

Loranthaceae: Due to the general similarity between the grains of the two genera of Belizean Loranthaceae, and due to the lack of light micrographs or reference slides for some species, Loranthaceae grains were identified to family level.

Malpighiaceae: The two species of Belizean *Byrsonima* bear similar-looking pollen (Palacios Chavez et al. 1991:96). Therefore, *Byrsonima* pollen was identified to genus level.

Four pollen grains in Sample 13 closely resemble the pollen of *Bunchosia lindeniana*, though other periporate grains of the Malpighiaceae are also similar.

Malvaceae: One pollen grain that appeared to belong to the Malvaceae was noted in Sample 24. Though periporate and long-spined like many grains from the Malvaceae family, the observed grain was fragmented and so could not be identified to genus- or species-level. Although I would like to believe that this grain represented *Gossypium* sp. (wild or cultivated "cotton"), this cannot be verified. Since *Gossypium* sp. is insect-pollinated, its pollen is most likely to be found where its flowers have fallen directly on the ground. The pollen of cultivated cotton cannot be distinguished, by standard brightfield microscopy, from the pollen of wild cotton or other members of the family (Pohl 1985:38). Furthermore, the Malvaceae includes non-economic plants that produce pollen that looks much like that of cultivated *Gossypium* sp., such as *Sida* sp. An additional (complete) grain of Malvaceae pollen was found in the reference sample from a modern cow pasture.

Meliaceae: In this study, eight pollen grains (most with tetracolporate apertures) had an ambiguous appearance that could have matched the pollen from the species of multiple genera. These, including three grains in Sample 4, two grains in Sample 12, and one grain in each of Samples 1, 31, and 54, were labeled by the family name.

A type of tetracolp(or?)ate grain, resembling grains of *Swietenia macrophylla* but having unusually indistinct pores, was found in Samples 9 (five grains) and 12 (24 grains). This type was tallied separately from the grains that more convincingly came from *S. macrophylla.*

One grain of *Trichilia hirta* pollen was noted in Sample 9. I have light micrographs or reference slides of five of the nine Belizean *Trichilia* species. It is possible that the grain I observed was not from *T. hirta* but instead came from one of the four species (*T. breviflora, T. erythrocarpa, T. minutiflora,* or *T. moschata*) whose pollen I have not seen.

Moraceae and Cecropiaceae/Urticaceae: A new clade, called the "urticalean rosids," has been established on the basis of recent genetic studies. It includes Moraceae, Ulmaceae, Celtidaceae, Cannabaceae, and Urticaceae. *Cecropia* sp., once believed to belong to the Moraceae or Cecropiaceae, are now placed in the Urticaceae. This dissertation continues to consider members of the forementioned families as classified by Balick et al. (2000). For example, Balick et al. consider the Cecropiaceae to be a family of its own (2000:29, 58).

Some palynologists (e.g. Bush 1995; Bush 2002; Dunning et al. 1998b) do not distinguish between the pollen of Moraceae and that of Urticaceae. I believe that this distinction can be made (because the pore morphology differs), as long as the Moraceae pollen is not too degraded.

In three samples, a diporate grain was observed that bore resemblance to other Moraceae grains, but could not be positively identified as *Brosimum* pollen; nor could this type be identified as *Trema* (Ulmaceae) pollen, which is also diporate and similar in size to *Brosimum.* Three of these grains were counted in Sample 31, and one grain was counted in each of Samples 9 and 13. These grains were tallied under the label "Moraceae, diporate." These may instead have been Urticaceae.

A triporate form of Moraceae pollen was observed in the deeper half of my core, with two grains occurring in each of Samples 12 and 23, and one grain in each of Samples 3, 7, 11, 15, 16, 21, 24, and 25. This may have been the pollen of *Castilla elastica, C. tunu, Maclura tinctoria,* or *Poulsenia armata.* All four types of trees bear globular triporate pollen and grow in modern Belize. Though the pollen of these species could be differentiated by size, species-level identification was not attempted during the present study.

No reference slides or light micrographs were available for the genus *Pseudolmedia.*

Myricaceae: The pollen of *Myrica* sp. resembles that of *Casuarina* sp. (Casuarinaceae). I did not become familiar with *Casuarina* pollen until late in my counting. Fortunately, *Casuarina* sp. has only recently been introduced to Belize, and its pollen should not be expected to have been present in most of my samples. Two species of *Casuarina* grow in modern Belize (Balick et al. 2000:61). *C. equisetifolia* is a relatively recent introduction from Australia or southeastern Asia, planted as an ornamental shade tree and timber source. The species was not introduced into the United States until the 20th century, whereupon it became an invasive in the subtropical states (Bryant, personal communication, 2008).

Myristicaceae: I have been unable to access light micrographs or reference slides of the pollen of the three species of Belizean Myristicaceae (*Compsoneura sprucei, Virola koschnyi,* and *V. multiflora*), but two pollen grains from Sample 24 compare favorably with light micrographs and reference slides of *Compsoneura debilis* and *Virola sebifera.* These grains have therefore been identified to family level.

Myrtaceae: Some of the Belizean Myrtaceae (*Eugenia* sp., *Myrcianthes fragrans, Pimenta dioica,* and *Myrcia* sp., the latter being distinct from *Myrica* sp. of the family Myricaceae) produce a small, syncolporate type of pollen that was observed during this study and identified to family level.

While syncolpate Myrtaceae pollen was observed at low levels throughout my column, a few grains of tricolporate Myrtaceae pollen were also observed. These were distinguishable from the pollen of Loranthaceae, which can resemble syncolpate Myrtaceae pollen but lack the “polar triangle” characteristic of most Myrtaceae pollen. Two grains of tricolporate Myrtaceae pollen, with no observable polar triangle, were counted in Sample 9. Several genera of Myrtaceae produce grains of this sort, so they have been placed under the heading “Myrtaceae, tricolporate.”

Orchidaceae: Several Orchidaceae grains were tentatively identified during this study, with one grain counted in Sample 24, three grains counted in Sample 26, and four grains counted in Sample 45. Orchidaceae grains have unusual elongated, inaperturate forms, and occur in groups (pollinarium) of two, four, or eight pollen sacs (pollinia), each containing millions of pollen grains. With pollen grains trapped in pollinia to be transported by insects, the chances of pollen grains entering the general pollen rain or falling into lake sediments is very small (Bush 1995:602-603). Pieces of plant matter resembling pollinia were identified as Orchidaceae pollen. Upon further consideration, these may not be Orchidaceae pollen because they are probably too small in size. The smallest dimension of any Orchidaceae pollinia featured in any of my available atlases is atlas is .2 mm, or 200 μ (featured in Roubik & Moreno 1991). Not only were the identified grains much smaller than 200 μ, but all pollen samples in this study were passed through a 150 μ mesh screen during processing, which should have prevented any Orchidaceae pollen from entering the samples that were finally analyzed. Certainly the pollen of every one of the 297 Belizean orchid species is not featured in the atlases; smaller forms could exist.

Piperaceae: Because pollen grains of both Belizean Piperaceae genera (*Peperomia* and *Piper*), are very small (12 μ or less in diameter), it is difficult to observe their details with a light microscope. The grains could easily be mistaken for fungal spores, and ignored. Therefore, it is possible that more Piperaceae grains were present in the Laguna Verde core than were properly identified. In spite of their small size, it is possible to differentiate the pollen of the two genera because grains of *Peperomia* are inaperturate, while grains of *Piper* are monosulcate (Roubik & Moreno 1991:128-130). One pollen grain in Sample 34 was identified as *Piper.*

Poaceae: During the identification and counting phase, I noted the approximate long axis diameters of the observed Poaceae grains. Although there is much overlap in the size ranges of the pollen of different Poaceae species, size can help to discriminate between the pollen of wild vs. cultivated grasses. For reporting in this dissertation, measured grains were sorted into four size categories. The smallest size category, containing grains with long axis measurements of less than 50 μ, are assumed to have come from wild grasses. The largest size category, containing grains measuring greater than 100 μ, are assumed to have come from *Zea mays*. The intermediate size categories, containing grains of 50-69 μ and 70-100 μ, may contain grains derived from wild grasses, *Zea mays* or primitive maize, or other non-maize cultivars. For example, the pollen of *Saccharum officianarum* ("sugar cane") measures 51-56 μ in diameter (Roubik & Moreno 1991:44-45), and may account for some of the Poaceae pollen in the upper (postcolumbian) portion of the Laguna Verde column. More information about the characteristics of Poaceae pollen may be found in Chapter IV.

Polygonaceae: Due to lack of reference slides or light micrographs of the pollen of some Belizean Polygonaceae, grains bearing a similarity of appearance to pollen of that family were identified to family level only.

Rubiaceae: Several species of *Spermacoce*, such as *S. densiflora* and *S. verticillata,* produce pollen grains with 7-9 colpi and a circular amb measuring approximately 25 μ in diameter. It was this pollen type that was most often observed during this study. One smaller grain of that compared favorably with *S. assurgens,* which sometimes has as few as four colpi, was noted in Sample 23.

One *Faramea* grain was noted in Sample 4. I have not been able to access a light micrograph or reference slide of the pollen of one of the three Belizean species of *Faramea* (*F. brachysiphon*), so the grain was identified to genus level.

Three grains of the genus *Psychotria* were counted in each of Samples 13 and 46. Light micrographs or reference slides of some Belizean species of *Psychotria* were unavailable, so grains were identified to genus level.

Rutaceae: In spite of the relatively easy generic distinction of Rutaceae pollen, the *Zanthoxylum* grains observed during this study could not be identified to the species level due to a lack of light micrographs or reference slides for two (*Z. petenense* and *Z. riedelianum*) of the seven Belizean species. *Zanthoxylum* pollen can be easily distinguished from the [known] pollen of other genera in the Rutaceae family. Unlike psilate *Amyris* pollen, *Zanthoxylum* pollen has a reticulate exine. Unlike large, tetracolporate *Citrus* pollen, *Zanthoxylum* pollen is small and tricolporate. *Zanthoxylum* pollen is smaller and has different proportions (being oblate to subprolate, rather than subprolate to prolate) than pollen of *Esenbeckia pentaphylla belizensis* and *Pilocarpus racemosus.* I lack light micrographs or reference slides of the pollen of *Casimiroa tetrameria* and *Triphasia trifolia.*

Sapindaceae: One pollen grain in Sample 9 was found to resemble *Thinouia myriantha.* This species is not known to grow in modern Belize (Balick et al. 2000:116). Two plants with similar generic names, *Thinouia tomocarpa* and *Thouinia paucidentata,* do grow in modern Belize (Balick et al. 2000:116), but I have not been able to access a light micrograph or reference slide of the pollen of either. Why taxonomists would give two genera of the same family such similar names (“inou” vs. “ouin”) is beyond me.

Sapotaceae: Light micrographs or reference slides of the pollen of some of the 23 species of Sapotaceae were unavailable, so some grains were identified to family level.

Solanaceae: Many Solanaceae produce tricolporate, spheroidal to prolate-spheroidal pollen grains with thick psilate exines and transverse pores, and many closely overlap in their range of sizes. It may be possible to identify these grains to genus- or species-level, but with a high error rate. Therefore, grains were identified to the family level. Four grains were identified as Solanaceae during the present study, with one grain counted in each of Samples 2 and 28, and two grains counted in Sample 43.

Three grains of *Physalis* pollen were counted during this study. Pollen grains of this genus have shorter transverse pores with more equatorial constriction than other Solanaceae that otherwise have similar descriptive characteristics. Four species of *Physalis* grow in modern Belize: *P. angulata, P. gracilis, P. pubescens,* and *P. philadelphica,* the last of which grows in cultivation (Balick et al. 2000:125, 127). Of these, I was unable to obtain light micrographs or reference slides of the pollen of *P. gracilis,* but the observed grains may have come from any of the remaining three species and were therefore identified to genus level.

Typhaceae: According to Balick et al. (2000:38, 176), only one genus (one species) of Typhaceae, the cattail family of perennial marsh herbs (Mabberley 1997:733-734), is native to Belize. This native species is *Typha domingensis,* called “southern cattail” or “elephant grass,” and 203 grains of its pollen were observed throughout my core. However, Standley & Record (1936:67) list *Typha angustifolia*, the “narrowleaf cattail,” as the sole native species of Typhaceae in Belize. In this study, 63 grains of *T. angustifolia* pollen were observed, dispersed throughout the column. It is possible that some monoporate spores could have been mistaken for grains of *T. angustifolia* pollen. However, the pollen of *T. domingensis* is distinctive from the pollen of *T. angustifolia*, so there would have been no cross-misidentification of the two in this study. It is not certain why Balick et al. and Standley & Record would have recognized in Belize the presence of mutually exclusive species. It is possible that human impact on the Belizean landscape has caused *T. domingensis* to become more prevalent since the advent of agriculture (see Rejmánková et al. 1995 and Pope et al. 2005), but as both agriculture and the first occurrence of this pollen type existed in pre-European times, this process must have begun even before the colonial times in which Standley & Record were writing. Only *T. domingensis* is listed in *Flora Mesoamericana* (a comprehensive database listing the flora of Mesoamerica; Davidse et al. eds., 1995), shoring up the possibility that it is the only species of Typhaceae to grow in Belize. On the other hand, Jones (1991:114) observed both *T. angustifolia* and *T. domingensis* growing at Cobweb Swamp, Belize.

Additionally, one tetrad grain of *Typha latifolia* (“broadleaf cattail”) pollen was observed in each of Samples 4 and 19, and eleven additional grains were counted in the cow pasture surface sample. Since it is unlikely that these grains were blown long distances to Belize from their native grounds in more temperate climes, it is possible that spore tetrads resembling the pollen of *Typha latifolia* were misidentified here.

Ulmaceae: One species of Belizean Ulmaceae, *Ampelocera hottlei*, was not identified during this study; no light micrograph or reference slide featuring this pollen type was available. A SEM light micrograph of *A. cubensis* is found in Zavada & Crepet 1981:926. The grain has 4-5 pores (Zavada & Crepet 1981:925), but appears to have a granulate texture like that of *Celtis* grains, rather than a rugulate exine like that of *Ulmus* grains. No such grain was observed during the present study.

Urticaceae: Some palynologists (e.g. Bush 2002; Rue 1987) do not distinguish between the pollen of Moraceae and that of Urticaceae, or group those types together ("Urticales," including Urticaceae, *Ficus* sp., *Brosimum* sp., *Trema* sp., *Cecropia* sp., and other species) when forming their environmental interpretations. I believe that the morphological distinction can be made (due to differences in pore morphology), as long as the pollen is not too degraded. The formation of an Urticales category erroneously groups indicators of distinct environmental conditions. For example, *Ficus* sp. and *Brosimum* sp. are climax species, while *Trema* sp. and *Cecropia* sp. are successional species (Rue 1987:286).

Most Urticaceae pollen grains are small and fragile, and bear small pores, so these grains may be mistaken for spores. Furthermore, I do not have light micrographs or reference slides featuring the pollen of all of the Belizean Urticaceae. It is therefore possible that more Urticaceae grains were observed during the present study than were accurately counted. In this study, one Urticaceae pollen grain was noted in Sample 33, and seven more were counted in the modern cattle pasture reference sample, and were identified to family level. The observed grains were triporate and measured approximately 15 μ in diameter, resembling the pollen of *Pouzolzia obliqua*.

Verbenaceae: *Lippia nodiflora* was only found toward the bottom of my core, with two grains occurring in each of Samples 3 and 5, and 18 grains occurring in Sample 6. It is possible that other *Lippia* grains were observed early during my study and were mistaken for grains of *Protium.*

Violaceae: In this study, seven pollen grains comparing favorably with the pollen of *Rinorea squamata* (as described in Roubik & Moreno 1991:151, 248) were counted, including one grain in Sample 16, four grains in Sample 17, and two grains in Sample 46. *R. squamata* is not known to grow in modern Belize. Three species of this genus (*R. deflexiflora*, *R. guatemalensis*, and *R. hummelii*) do grow in modern Belize (Balick et al. 2000:73), but I have not been able to access light micrographs or reference slides featuring the pollen of these species.

Vitaceae: One grain of *Cissus* pollen was counted in Sample 59. This grain was identified to genus level because light micrographs or reference slides featuring the pollen of three of the Belizean *Cissus* species (*C. biformifolia, C. cacuminis,* and *C. verticillata*) were unavailable. Of the three species (*C. erosa, C. gossypiifolia,* and *C. microcarpa*) for which light micrographs or reference slides were available, the observed pollen grain resembled *C. gossypiifolia* and *C. microcarpa* more closely than it resembled *C. erosa.*

Pollen Counting

A standard 200-grain count, as recommended by Barkley (1934:287-288), was attempted for all sixty-two pollen samples taken from the Laguna Verde core and surface samples. A count above 200 grains usually discovers very few new major taxa, and does little to alter the relative percentages of grains counted (Barkley 1934; Dimbleby 1957:14), although it may reveal some new minor taxa (Jones & Bryant 1998). In some cases, the 200-grain mark was inadvertently overshot during joyous, rare hours of zealously counting well-preserved or high-concentration value samples. In other cases, poor preservation and low concentration values rendered the completion of a 200-grain count impossible or worthless due to statistical invalidity.

Only pollen grains were included in the 200-grain count. That is, *Lycopodium* tracer spores were counted under their own separate tally. No additional fern or fungal spores were counted, though many were observed.

Pollen grains degraded beyond recognition were tallied in a category of “unidentifiable/indeterminate” grains. Pollen grains that appeared to be in adequate condition, but that could not be identified with available resources, were recorded as “unidentified/unknown.” Both categories were included in the 200-grain counts. Relative percentages of grains assigned to these categories, and further quantitative methods, are discussed in greater depth in Chapter VI.

CHAPTER II

THE FIRST PEOPLE OF THE MAYA AREA

CHAPTER INTRODUCTION

Before the questions of human impact on the environment of Blue Creek can be addressed, it is necessary to address some preliminary questions: Where did the first human inhabitants of the Maya area come from? When did they arrive? Who were the first inhabitants of Belize, and when did they arrive? Was a population that was already identifiably Mayan the first to inhabit Belize, or was there continuity between pre-Mayan populations and the Maya? The answers to these questions help us understand human habitat selection and the development of the subsistence strategies that would later play key roles in the success and failure of the Mayan empire.

The first section of this chapter focuses on the first Paleoamericans to enter what would later become the Maya area. It aims to use evidence from archaeology, paleoecology, and physical anthropology to construct a model for the first entry of humans into the Maya area. Stages of early tool technology in the Maya area are defined. Some of the earliest archaeological sites in the area are evaluated in terms of their stratigraphy and dating, and judgments are made regarding the authenticity of the artifacts excavated from those sites. Because an understanding of paleoenvironment is necessary for the development of hypotheses regarding the suitability of a region for human habitation at a given point in time, paleoecological studies have been summarized for every site from which such studies were available. Additionally, a summary of the paleoecology of the Middle American region is given. A brief introduction is made to Middle American/Paleoamerican physical anthropological studies. Finally, this evidence is combined in the proposition of a model for the first peopling of the Maya area.

The second section of this chapter narrows the focus to Belize, examining the Archaic Period cultural developments that set the stage for the advancement of Maya culture. Archaic Period technologies, modes of subsistence, and settlement patterns are noted. The means by which Maya culture evolved in Belize is discussed. Finally, the Archaic Period paleoecology of the Maya Lowlands is examined.

SECTION ONE: THE FIRST MIDDLE AMERICANS

Paleoindians and Paleoamericans

Physical anthropological evidence supports the hypothesis that modern American Indians are not the direct descendants of the first Americans. To uphold this idea, I use the term “Paleoamericans” to refer to the earliest human populations to enter Middle America. Most Paleoamericans practiced a culture oriented toward the gathering of vegetative resources and the hunting of big game prior to the end of the Pleistocene, and these people are the focus of this section of this chapter. However, to maintain consistency with the terminology in published literature, the term “Paleoindian” is herein employed to refer to the lithic stages and time periods with which the Paleoamericans were concerned.

Site Evaluations

Before a model for the earliest human colonization of the New World can be developed, archaeologists must identify the sites that provide definitive evidence of human occupation at an early date. Whether this evidence comes in the form of authentic man-made objects or remains of human bodies themselves, it must be encountered in a firm stratigraphic context, within which pieces of evidence can be firmly associated with each other and with absolute dates. If the validity of an artifact cannot be proven; if context is suspect or absent; or if no method of absolute dating is applied, naysayers will negate the validity of a supposedly-early site, and may deny the possibility of a pre-Clovis occupation of the New World (Waters 2004).

In this chapter, I set out to evaluate a number of supposedly-early archaeological sites in the Maya area in terms of their validity, stratigraphy, and dating. In some cases, too little information is known for such assessments to be made. Where available, information on the paleoecology of each site is presented for the relevant time period(s),

Figure 5. Archaeological sites with "First Middle Americans" or "Early Plant Domestication" components, discussed in the text.

so that the reader may understand any implications that the natural environment may have had on the suitability of a location for its function as a human habitat, and on human subsistence and technological innovation. Notes are made about the cultural implications of the tool technologies and paleoenvironment.

Archaeological sites discussed in this chapter are mapped in Figure 5.

Stages of Paleoindian Tool Technology

This chapter examines evidence for the human occupation of the Maya area during the Pleistocene and Early Holocene (pre-ceramic, pre-Maya) eras. Much of this evidence for early human occupation lacks proper stratigraphic context and absolute dating. Such evidence would ordinarily be considered necessary to the development of a model for the peopling of the New World regarding the timing of human entry into the Maya area. It is difficult to find archaeological sites associated with the earliest occupants of the Maya area because the open sites have been obscured by vegetation and geological factors, and because there are few caves or rock shelters suitable for human habitation (Coe 2005:41). It is therefore useful to devise a scheme by means of which the ages of undated sites can be estimated, as well as a framework into which adequately-dated sites can be sorted. On the basis of variations in environment, subsistence, and particularly technology, archaeologists have subdivided this time period into several units. There is, however, some disagreement as to how the period can best be divided; compare, for example, the Archaeolithic and Cenolithic stages presented by Lorenzo & Mirambell (1999:483-490) to the Lithic and Archaic stages presented by MacNeish & Nelken-Terner (1983:71-77). These two classification schemes can be combined to produce a rough timeline with four stages of technological developments by the earliest humans to enter Middle America and the Maya area. The first three stages can be broadly grouped into a “Paleoindian” occupation, while a gradual transition to an “Archaic” occupation was made during the fourth stage. The Archaic Period of Belize is discussed elsewhere in this dissertation.

Although one might question the methodology by which archaeologists have delimited the four tool technology stages, they do provide a method useful for sorting undated archaeological sites and artifacts. Below, brief descriptions of each of the four tool technology stages are given, followed by the delineation of the archaeological sites in the Maya area that represent each technological stage.

Lithic Stage One

The earliest stage, beginning with the entrance of human beings into the Maya area perhaps 30-40,000 years ago or earlier, should be characterized simply by chopping tools (MacNeish & Nelken-Terner 1983:71). No absolute presence of such a stage has been established in the Maya area, but the site of El Bosque in Nicaragua, and possibly early sites in Mexico (San Isidro in Nuevo León, the Diablo complex of Tamaulipas, and the earliest deposits at Tlapacoya in Distríto Federal), bracket the Maya area on both sides (MacNeish & Nelken-Terner 1983:71, 72).

Lithic Stage Two

A second technological stage, partially overlapping the first, is represented by archaeological sites that date from approximately 30,000 to 14,000 years ago. In this chapter, sites are assigned to “stage two” rather than “stage one” when they are found to contain tools other than simple choppers. Artifacts typical of sites from this period are unifacial (including choppers, points, burins, scrapers, and wedges), often associated with extinct fauna, and sometimes with worked bone (MacNeish & Nelken-Terner 1983:72). Artifacts dating up to 14,000 years ago are large and crude, and there exists some doubt as to whether most were authentically made by humans (Lorenzo & Mirambell 1999:483). Most sites representing the second lithic stage are in Mexico (MacNeish & Nelken-Terner 1983:72-73): the earliest strata at several locations in Valsequillo (Puebla); Tlapacoya and Santa Lucia (Distríto Federal); and possibly Rancho La Amapola and El Cedral (San Luis Potosí), earliest Santa Marta Rockshelter (Chiapas), and Loltún Cave (Yucatan). The latter two of these sites are found in the

Maya area; I do not address the central Mexican sites in depth in this chapter because they lie well outside the Maya area. The only possible "stage two" site discovered outside Mexico was at Richmond Hill, Belize.

Richmond Hill, Orange Walk District, Belize: Crude, unifacial chert tools at the Richmond Hill chert outcrop were found without associated ceramics, so Richmond Hill has been labeled an "Early Man" site (Hammond et al. 1979:99; Puleston 1975:522, 529). In spite of the seemingly local origin of the chert, no unworked chert nodules were found at the site (Puleston 1975:531). This fact could make one skeptical that the stones were "tools" and not a natural formation. Circular rises on the ground may have been platforms for relatively permanent shelters for a Pleistocene human population (Puleston 1975:531), as the site's stratigraphy does not appear to result from natural gilgai formation. Buried pits may have been household hearths (Puleston 1975:532). If these features and artifacts are indeed of anthropogenic origins, this would be the oldest archaeological site known from Belize.

Santa Marta Rockshelter, Chiapas, Mexico: In Santa Marta Rockshelter, a few unifacial tools were found (MacNeish & Nelken-Terner 1983:73). A radiocarbon date from an overlying stratum dated to 9000 B.P., indicating the older age of the tools (MacNeish & Nelken-Terner 1983:73). Overlying strata harbored tools representing lithic stage three.

Loltún Cave, Yucatan, Mexico: Norberto Gonzales found unifacial tools in association with bones of extinct fauna such as horse and mammoth, suggesting a Pleistocene date for the site (MacNeish & Nelken-Terner 1983:73).

Lithic Stage Three

The third Paleoindian technological stage in Middle America, lasting roughly from 20,000 to 9,000 years ago, saw the introduction of projectile points, most of which were leaf-shaped (e.g. the Lerma type) or bifacially fluted (e.g. Clovis lanceolate, Clovis waisted, and fishtail types in Middle America; Lorenzo & Mirambell 1999:483, 490; MacNeish & Nelken-Terner 1983:73; Ranere & Cooke 1991:238). Clovis points in

Mexico are nearly 12,000 years old, and appear to be the oldest of the three fluted types (Lorenzo & Mirambell 1999:490). Stratification indicates that lanceolate Clovis points pre-dated waisted Clovis points, and that fishtail points came last of all (Haynes 2002:27; Ranere & Cooke 1991:241). Fishtail points seem to have been produced in greatest numbers between 11,000 and 9,000 years ago (MacNeish et al. 1980). Other stone tools typical of "stage three" are stemmed projectile points, prismatic blades, burins, and polyhedral cores, end scrapers, and blade scrapers, all produced by direct percussion (Lorenzo & Mirambell 1999:484; MacNeish & Nelken-Terner 1983:74).

The development of new hunting technology suggests that new methods of hunting were evolving. Most evidence for a Paleoamerican occupation in Middle America belonged to the "Early Hunters," who, with the aid of fluted projectile points, pursued big-game herbivores in the period spanning from 11,500 to 9,000 years ago (Ranere & Cooke 1991:238). The nomadic hunters followed herds of animals such as mammoth, mastodon, horse, camel, and bison, as they crossed the grasslands of both North and South America (Coe 2005:43). Indeed, fluted points have many times been found in association with the remains of now-extinct large game animals (Haynes 2002:92).

Fluted Clovis spear points have been found in Mexico, as far south as Costa Rica and Panama, and throughout the Maya area (Coe 2005:43), often as surface finds lacking stratigraphic context. Most of the locations in the Maya area where fluted points have been found have *not* been excavated; only the "stage four" sites of Los Tapiales, Guatemala, and Los Grifos, Chiapas, Mexico, have been thoroughly excavated from archaeological sites with dated stratigraphic contexts (Pearson 2002; Ranere & Cooke 1991:238, 239). The stage three sites in the Maya area include pre-ceramic Copan, Honduras; the next-to-earliest levels at Santa Marta Rockshelter in Chiapas; and Huehuetenango, Guatemala (Longyear 1948:248-249; MacNeish & Nelken-Terner 1983:72, 74). Some Guatemalan and Belizean surface finds may also date to this period. Differences between assemblages from highland Guatemala and lowland Belize suggest that a highland-lowland dichotomy in tool technology was developing during this time, perhaps related to the availability of different natural resources in the two areas (MacNeish & Nelken-Terner 1983:74). Other “stage three” sites are known from central Mexico.

Copan, Honduras: There may have been a pre-Maya deposit at Copan, Honduras (Longyear 1948:248-249). Buried about half a meter beneath Archaic Period deposits, and bedded between two layers of sterile river clay was a 10 cm layer containing charcoal, broken bones of small animals, and more than 170 chips of flint and obsidian (but no definite tools; Longyear 1948:248). This may represent an old beach deposit with natural burning, or an anthropogenic hearth deposit (Longyear 1948:248-249). This site was probed before the common usage of radiocarbon dating, so the age of the “site” is unknown, and its place in the “stage three” category is uncertain.

Santa Marta Rockshelter, Chiapas, Mexico: This site produced a flaked- and ground-stone and bone tool assemblage that produced radiocarbon dates in the 9300 B.P. range (Ranere & Cooke 1991:240). Projectile points found at Santa Marta Rockshelter were not fluted, but were instead leaf-shaped (Ranere & Cooke 1991:240). Only modern fauna were found at this site (Ranere & Cooke 1991:240).

Huehuetenango, Guatemala: An “early hunter” site, near Huehuetenango in Guatemala, was excavated by Herbert Alexander in 1977 (Coe 2005:44). Now-extinct Pleistocene megafauna were butchered there (Coe 2005:44). I have been unable to find a detailed or original report on this site.

Guatemalan Surface Finds: Because they have no secure dates, the Guatemalan surface finds of the Fishtail Point tradition may be considered to belong to either lithic stage three or stage four. Most fishtail points are believed to have been produced between 11,000 and 9,000 years ago (MacNeish et al. 1980), a period that includes terminal “stage three” and initial “stage four”. Most evidence of Paleoamerican occupation of Guatemala has come from surface finds, beginning with the A.D. 1722 report *Historia Natural del Reino de Guatemala*, in which historian Francisco Ximénez wrote about two fluted lanceolate points from Guatemala (Bray 1978:457, 458; 1980:168). In 1960, Michael Coe reported a child’s find of an obsidian fluted point eroding out of a hill near San Rafael, near Guatemala City, Guatemala (Coe 1960:412). Coe described the point as having “ears” (like a “fishtail” point), but with a flute on only one side (Coe 1960:412). Other Paleoindian finds in Guatemala include a fluted point from Los Tapiales; the basal portion of an obsidian fluted fishtail point from the Quiché Basin (in the west-central Guatemalan highlands) site of Santa Rosa Chujuyub, which compares favorably with the San Rafael specimen reported by Coe; and an almost-complete basalt fluted point from the Quiché Basin site of Chajbal (Bray 1978:457-458; 1980:169; Brown 1980:317, 318; Gruhn & Bryan 1977; Pearson 2002: Chapter V). The Chajbal point seems to be similar to the one described by in the eighteenth century (Bray 1978:459).

Other Paleoindian surface finds resulted from the Quiché Basin Archaeological/ Ethnohistorical Project surveys that were conducted in highland Guatemala in the late 1970s. The survey recorded at least 117 surface sites estimated, on the basis of artifact typology, to date to the Paleoindian and Archaic periods (Brown 1980:313, 315). The authors define three site types in all: chipping stations or workshop sites, base camps, and limited-resource camps (Brown 1980:321). Some are workshop sites associated with outcrops of the fine-grained grey basalt from which many of the artifacts are made (Brown 1980:317). Most of the sites lacked projectile points, but other lithic artifacts included bifaces, scrapers, cleavers, burins, gravers, cores, and flakes (Brown 1980:315, 318-321). No certain base camps were established for the Paleoindian sites, so Paleoamericans were probably more nomadic, smaller groups than Archaic-period peoples, who later left behind a greater range of tool and material types and activity areas (Brown 1980:322).

No paleoecological studies were conducted in conjunction with these surface finds. However, pollen samples from Guatemalan lakes tell about the Guatemalan regional paleoenvironment in the Paleoindian period. A summary of these studies published by Ranere & Cooke tells of the presence of savannas, with herbaceous and aquatic pollen dominating, prior to 10,750 B.P. (1991:245). Conditions must have been warmer and wetter during this time. From 10,750 to 8500 B.P., the pollen record shows the spread of juniper scrub, which requires cooler and drier conditions than found in the Guatemala today (Ranere & Cooke 1991:245).

Belize: Ladyville and Lamanai Surface Finds: All evidence for the earliest human activity in Belize lacks stratigraphic context, and no radiocarbon assays have been published. The oldest evidence may be the stemmed, fluted fishtail point encountered by archaeologists Georges Pearson and Peter Bostrom on the banks of the New River Lagoon, near the site of Lamanai (Pearson & Bostrom 1998). The estimated age of the point is 11,000 years (Pearson 2004). Pearson suggested that this point could have been used as a knife, rather than as a projectile point (Pearson 2004).

Two fluted points were collected as surface finds at the Ladyville site, near Belize City, during the Colha Project and the later Belize Archaic Archaeological Reconnaissance surveys (Hammond 1982:355; Hester 1981; Pearson 2002: Chapter V).

Lithic Stage Four

The fourth and final stage probably began just after 10,000 years ago and continued until ceramic technology developed locally. The period from approximately 11,000 to 4,500 years ago (or 9000 to 2500 B.C.) is referred to as the Archaic Period in the Mayan area (Hammond & Miksicek 1981:261; MacNeish et al. 1980:47). Further details on the Archaic Period of Belize are given in a later section of this chapter. Early in this period, global warming contributed to the extinction of the Pleistocene megafauna, and a transition toward an Archaic Period subsistence pattern began. This entailed an increasing focus on plant collection, and incipient cultivation of economic plant species. Lithic technology became much more specialized, perhaps as people made more specific regional adaptations to certain environmental zones (MacNeish & Nelken-Terner 1983:73). Clovis and Lerma points were still in use, but were joined by specialized bifacial projectile point types, including leaf-shaped points with stems and ears, as well as points of the Agate Basin, Plainview, Golondrina, Madden Lake, Scottsbluff, Eden, and Plano types (MacNeish & Nelken-Terner 1983:73, 76). Other lithic tools, including choppers, scrapers, perforators, denticulates, and burins were produced by percussion and also by pressure flaking during this period (Lorenzo & Mirambell 1999:484). Tools of ground and polished stone, such as mullers, mortars, and grinding stones, were used to process seeds and leaves (MacNeish & Nelken-Terner 1983:73, 76). The diversity of tool types in use during this period suggests that people were adapting to their local environments and pursuing subsistence strategies in addition to, or instead of, big-game hunting (MacNeish & Nelken-Terner 1983:76).

Adequately-excavated and adequately-dated “stage four” sites are found in relative abundance across Middle America. In the Maya area, the Llanoid-Cordilleran tradition (“Llanoid” indicates influences from the western United States, while the “Cordilleran” tradition is native to western Mexico and Pacific Guatemala) is represented at the sites of Los Tapiales and La Piedra del Coyote in the Quiché Basin of Guatemala. The Fishtail Point tradition is represented by surface finds in the Quiché Basin of Guatemala (discussed above, under “Lithic Stage Three”) and near Esperanza, Honduras; Lowe Ranch and the Lowe-ha Complex of Belize; and Los Grifos, Mexico (MacNeish & Nelken-Terner 1983:75).

Los Tapiales and La Piedra del Coyote, Quiché Basin, Guatemala: In 1977, Ruth Gruhn and Alan Bryan explored two Quiché Basin sites that radiocarbon-dated between 11,000 and 7000 b.p. (Brown 1980:314, 315). While these “stage three” sites are significant, it should be noted that I have not had the opportunity to view the original site reports. Los Tapiales and La Piedra del Coyote each held a wide variety of tool types made from three raw material types, perhaps signifying that these sites were base camps (Brown 1980:322). However, the sites were very small and were situated on steep alpine meadow-pine forests, which probably had limited resources, and so may have been occupied only seasonally (Brown 1980:317, 322).

At the site of La Piedra del Coyote, Gruhn and Bryan dug test pits that revealed retouched flakes and an end scraper (Ranere & Cooke 1991:240). Radiocarbon dates place the site between 10,650±1350 B.P. (note the wide standard error) and 9430±120 B.P. (Ranere & Cooke 1991:240).

Only two km from La Piedra del Coyote, Gruhn and Bryan excavated the site of Los Tapiales. There, they uncovered approximately 100 artifacts from the base of a shallow weathered volcanic ash unit (Stross et al. 1977:115). These included the base of one Clovislike fluted point, bifaces, unifacial points, burins, gravers, scrapers, blades, and retouched flakes (Ranere & Cooke 1991:240; Stross et al. 1977:115). Fourteen Lerma points were also found at the site (MacNeish & Nelken-Terner 1983:77).

Most of the Los Tapiales artifacts were made from basalt, but 20 percent were made from obsidian and 4 percent from chalcedony (Stross et al. 1977:115). Neutron activation analyses were applied to determine the chemical composition of sources of obsidian artifacts from Los Tapiales, and to trace the raw materials to their source (Stross et al. 1977:114). Three sources were detected from an area 50-75 km from the site (Stross et al. 1977:115), perhaps indicating the mobility of the Paleoamericans who visited Los Tapiales. The tools were bracketed by radiocarbon dates 8810±110 b.p. and 11,170±200 b.p., with densest occupation at 9860±185 b.p. (Ranere & Cooke 1991:240).

Esperanza Surface Finds, Honduras: Surface finds of fishtail points in the Honduran highlands were reported by Bullen & Plowden (1963).

Lowe Ranch Site, Belize: The earliest abundant evidence for human occupation in Belize comes from the period known as the Lowe-ha phase, which lasted from 9000 to 7500 B.C. (Hammond 1982:354). During this “stage four” period, terminal Paleoindian hunter-gatherers were “drawn to the orchard-savanna environment of northern Belize by the edible wild plants and the game food potential of Ice Age herbivores” (Zeitlin 1984:361). The people were most likely hunters of large game, including horse and giant sloth (Hammond 1982:354). The artifacts that constitute the Lowe-ha Complex include fishtail and Plainview points, scrapers, blades, and choppers (Hammond 1982:354). The long chert spear tip known as the Lowe Point is an “index fossil” for the Early Archaic of northern Belize (Coe 2005:47).

A site with an assemblage typical of the Lowe-ha phase is Lowe Ranch, where artifacts recovered during excavation include a Plainview-type lanceolate point fragment, eleven fishtail points, and end scrapers (Zeitlin 1984:362). Lowe Ranch is located on a pine ridge, where little sediment has accumulated during the Holocene era, so the artifacts could not be stratigraphically provenienced, and no suitable material was available for radiocarbon dating (Zeitlin 1984:361-362).

Los Grifos, Chiapas, Mexico: A formal excavation that produced radiocarbon dates was conducted at the Los Grifos site in Chiapas. There, two fishtail points and one Clovis-waisted point were found in association with modern (i.e. post-Pleistocene) fauna only (Lorenzo & Mirambell 1999:490; Ranere & Cooke 1991:240). Bracketing dates on associated organic material were 8930±150 b.p. and 9460 b.p. (Ranere & Cooke 1991:240). An older occupation layer was radiocarbon dated to 9540±150 B.P. and obsidian-hydration dated to 9300 years of age (Ranere & Cooke 1991:240).

Pleistocene-Early Holocene Paleoecology of the Maya Area

The following outline of the paleoenvironment of the Maya area during the late Pleistocene-early Holocene transition is chiefly based on several summaries of primary research written by other archaeologists.

Because water was bound up in glaciers during the Pleistocene era, sea levels were lower then, so the coastlines of the Maya area extended some distance beyond their current locations (Pearson 2002: Chapter IV). During the Pleistocene, alpine glaciers existed on the highest volcanic peaks in Middle America, particularly in the transverse volcanic axis near Mexico City (Pearson 2002: Chapter IV). Archaeologist Georges Pearson writes, “Although glacial advances may have raised water levels in the Basin of Mexico, pluvial lakes were not present in Middle America when humans first arrived” (Pearson 2002: Chapter IV). The last glacial advance in Mexico probably took place between 13,000 and 11,000 radiocarbon years ago (Pearson 2002: Chapter IV). The sites discussed in this chapter are not in alpine locations, and thus would not have been directly affected by glacial activity. They would, however, have supported different vegetational and faunal regimes than they do today. Overall, the climate across the Maya area during the Pleistocene was cooler and drier than today. There was a 600-900 m downward displacement of vegetation, in comparison to modern times (Ranere &

Cooke 1991:245). In other words, plants that tolerate cooler and drier conditions grew at lower elevations than they do today, so the paleoclimate must have been cooler and drier (but not arid).

Evidence from pollen cores and plant macrofossils from packrat middens allowed Pearson to make the following generalizations about Pleistocene vegetation (Pearson 2002: Chapter IV). Around 18,000 b.p., most of Mexico south of the Tropic of Cancer, including the Isthmus of Tehuantepec and the Yucatan Peninsula, along with Guatemala, Belize, and El Salvador, were thorn scrub and wooded savanna. From 18,000 to 14,000 b.p., this area was cooler and drier than today. Vegetation included pine-oak forest, with alder, juniper, and zones of brush and grass. After 14,000 b.p., the climate became moister, and cover by pine forest increased. The ensuing period must have been very dry, since Lake Texcoco in central Mexico “dried up completely between 14,000 and 6140 ^{14}C yr B.P. and suffered from considerable erosion” (Pearson 2002: Chapter IV). Most of Honduras, and all but the Pacific side (which was thorn scrub and wooded savanna) of Nicaragua, Costa Rica, and Panama were moist forest with some montane taxa.

Paleobotanical data indicates that Middle America was predominantly forested, with savannas occupying discontinuous patches, from 10,000 to 11,500 b.p. (Ranere & Cooke 1991:246). Fluted points have been found in various forested locations; it is uncertain whether the people predominantly occupied the tropical forests, or whether they predominantly occupied the savannas but exploited forest resources (such as lithic material; Ranere & Cooke 1991:247). An early Holocene cooling began between 10,000 and 8500 b.p. (Pearson 2002: Chapter IV). Modern plants and animals were in place between 9,000 and 10,000 years ago (Ranere & Cooke 1991:247). Early Holocene vegetation patterns may have been a result of the disappearance of the megaherbivores, rather than the cause of their disappearance, based on analogues in modern Africa and Asia (Ranere & Cooke 1991:246). Megafauna can tolerate short-term climatic fluctuations, and as adults are little impacted by non-human predators (Ranere & Cooke 1991:246). The activities of megafauna can transform woodlands into more open grasslands (Ranere & Cooke 1991:246). I believe this to be true. If grazing or browsing fauna is removed from an area, taller plants grow in and shade out shorter ones.

Evidence from Physical Anthropology

Evidence from physical anthropology relevant to the study of the peopling of the New World can include comparisons of physical traits, blood types, and DNA samples among populations of the past, and between populations of the past and those of the present. All these types of evidence are not available in abundance for Paleoamericans from the Maya area; only one blood group test, and no DNA tests, are known to have been conducted in Middle America (Pearson 2002: Chapter V). The remains of but few Paleoamericans have been recovered from Middle American archaeological sites, and in fact all of these were found in Mexico. Nevertheless, given that the Maya area seems to have been bracketed on its southern and northern borders by human populations since the time of lithic stage one, there exists some chance that the first humans to enter Mexico were related to the first humans that occupied the Maya area. Therefore, the physical anthropological evidence from Mexico is relevant to the question of the peopling of the Maya area.

Head shape has been used as evidence of biological relationships among populations. Crania with long and narrow measurements are called “dolichocephalic,” and those with short, broad measurements are termed “brachicephalic.” “Mesocephalic” crania have measurements that fall in an intermediate range. The Mexican skeleton with the earliest date is Peñon III (found in Mexico City), with an AMS date of 10,755±75 B.P. (Gonzalez et al. 2003:381, 383). This 25-year-old female was dolichocephalic, like many other Paleoamericans, including Browns Valley Man of Minnesota and Confins Man of Brazil (De Terra et al. 1949:142; Gonzalez et al. 2003:381, 383). An incomplete human skull was found out of stratigraphic context somewhere at Tlapacoya I Beta (in Distríto Federal) in 1968; it was AMS dated to 10,200±65 B.P., and it, too, was dolichocephalic (Gonzalez et al. 2003:381, 385; Lorenzo & Mirambell 1999:489).

The head shapes of Peñon III and Tlapacoya I indicate that the earliest humans in Mexico had long, narrow heads, and were of “nonmongoloid affinity” (Gonzalez et al. 2003:386). Instead, their heads were probably more similar to early people of Australia and Africa (Gonzalez et al. 2003:386). Another dolichocephalic skull, from San Vicente Chicoloapan (found in the Basin of Mexico, near Mexico City), suggests that the dolichocephalic population continued to occupy Mexico until at 4410±50 B.P. (Gonzalez et al. 2003:386). However, crania with intermediate dates also varied in head shape. A cranium from Texcal Cave (found in Valsequillo, Puebla, Mexico), which had an intermediate date of 7480±55 B.P., was brachicephalic (Gonzalez et al. 2003:386). At Tlapacoya XVIII, a brachicephalic cranium was found within a stratum dated at 9920±250 B.P. (Lorenzo & Mirambell 1999:489).

The final [possibly] Paleoamerican skeleton from Mexico, the undated Tepexpan Man (found in the Basin of Mexico, north of Mexico City), has been called mesocephalic (De Terra et al. 1949:142). It has also been called Mongoloid (De Terra 1947:43; Field 1948:17-18). This may indicate that it had different ancestry from the other skeletons which are known to truly date to Paleoindian times. Furthermore, various formulations were applied to the Tepexpan skeleton to estimate a stature of 167-200 cm (De Terra et al. 1949:98-100, 102). Interestingly, this would have been taller than average precolumbian males (160 cm) and modern Mexican males (162 cm). The Tepexpan skeleton did not, however, seem to differ significantly from Archaic-period burials at other Mexican sites (El Arbolillo, Zacatenco, and Ticoman; De Terra et al. 1949:117). Tepexpan Man was tested for blood type, and was found to have “tentative evidence…for the presence of group substance A” (De Terra et al. 1949:135). Attempts were made to compare the blood type of Tepexpan man to that of Aleutian mummies and two postcolumbian Native American skeletons from Oregon yielded inconsistent results (De Terra et al. 1949:135). Still, cranial measurements and height indicate discontinuity of Tepexpan Man with earlier Paleoamericans; perhaps Tepexpan Man was an intrusive burial from a later time period.

Recently, Arturo González and Carmen Rojas Sandoval have painstakingly excavated three skeletons from the now-submerged cave systems along the coast of Quintana Roo, near the site of Tulum (Largent 2005). Dates on bone collagen and associated charcoal have ranged from 10,000 to 13,000 B.P. I have been unable to access any report comparing the morphology or DNA of these finds to that of other human remains.

Model for the Peopling of the Maya Area

When did the first humans arrive in the Maya area? Where did they come from? How did they get to the Maya area? These, of course, are very complex questions. If one deems credible the evidence for the site of El Bosque, Nicaragua (a "lithic stage one" site), and Tlapacoya, Mexico (a "lithic stage one" site, here discussed only in the physical anthropology section), the first humans in Middle America left behind their traces as long ago as 35,000 b.p. More definite evidence of human presence, including stone tools that are authentic beyond doubt, is found from the "stage three" sites after 20,000 b.p.

I believe in multiple waves of early human colonization of North America by members of Asian populations via the Bering Land Bridge, and possibly in colonization of South America via a water route from southeastern Asia. Multiple waves of colonization would account for the variation in the early American skeletons. It is possible that the very first Paleoamericans interbred with, or were replaced by, later arrivals.

After crossing into the New World, how did people get to the Maya area? Some archaeologists have suggested that the first people to reach the Maya area did so by traveling south along coastlines, first along the Pacific coastline, and later along the Atlantic and Caribbean coasts (Sanabria 2007:71; Dillehay 2000). Colonization of Middle America by a direct water route from African or Australia could explain the similarity of some of the oldest New World crania to those of modern Africa and Australia, but that is the only line of evidence to hint at the possibility of such a scenario.

The coasts would have presented fewer barriers to movement than an inland route, and would have offered access to abundant marine resources (Sanabria 2007:71). A water route would have been open for travel at any time during the Pleistocene, even when no ice-free corridor was open for passage in the North American landmass. Archaeological evidence of coastal occupation of the Maya area during the Pleistocene is lacking, although Pleistocene-age sites may now be submerged due to sea level changes. Archaic Period coastal sites are known from Belize (MacNeish & Nelken-Terner 1983:79-82, 84).

Some people arrived in the Maya area by a land route, as well. Paleoecological evidence indicates that much of Middle America was covered with montane forest during the late Pleistocene era, when the first migrations probably occurred. Some archaeologists view the tropical forest as impenetrable; it could have served as a barrier for southward expansion of Paleoamericans coming from North America, unless some kind of grassland corridor, similar to the Great Plains of modern North America, existed in Middle America (Ranere & Cooke 1991:247). Most Paleoindian sites in Middle America are in the forested highlands. This fact may result from archaeologists' preferences for working in highland locations, or from better natural conditions for preservation of archaeological materials in the highlands. On the other hand, the highland location of many Paleoindian sites may indicate that Paleoamericans entered by a highland route and remained adapted to the highlands for a long period of time (Ranere & Cooke 1991:248). They could have come south along the Rocky Mountains and the Sierra Madre, or north along the Cordillera de los Andes. The last glacial advance in Middle America probably took place between 13,000 and 11,000 radiocarbon years ago (Pearson 2002: Chapter IV). In Middle America, glaciers were confined to high mountain peaks, and so would not necessarily have impeded human migration (Pearson 2002: Chapter IV).

The fact that so little evidence remains of the Paleoamerican entrada may be related to the scarcity of natural resources in tropical montane forests. Because resources would have been sparse, the human population must have been very small, very dispersed, and highly mobile (Ranere & Cooke 1991:247). Thus, site numbers and site sizes are small (Ranere & Cooke 1991:248). On the other hand, Paleoamericans were hunters, and presence of game animals may have been more important to their choice of location/migration patterns than the vegetation itself (Ranere & Cooke 1991:247). Thus, Paleoamerican remains have been found in every ecological zone in Middle America that has been identified for the late Pleistocene and Early Holocene (Ranere & Cooke 1991:247).

The specifics of the timing of these multiple migrations, and further migrations south (or even north) into the Maya area are open to question. Evidence from tool technologies can provide hope for answers. Some humans, who did not use Clovis-type technologies, were doubtlessly living in the Maya area before Clovis times. Some archaeologists think a fluted point tradition arose among foragers in south-central North America and spread southward and northward, since fluted points in Canada and the Arctic date later, and since fishtail points in South America predate the Clovis era (Ranere & Cooke 1991:239; Snarskis 1979:136). A Clovis-related migration would have been a secondary migration of people who were already living in North America. This scenario is more likely than an initial migration into the Americas by big-game hunters who already possessed fluted-point technology (Snarskis 1979:136). Fishtail points may have come to the Maya area through migration or diffusion from South America, or could have been independently invented in the Maya area as Paleoamericans adapted their technologies to suit their local environments (Ranere & Cooke 1991:239).

Summary and Conclusions

This chapter has, so far, incorporated evidence from archaeology, paleoecology, and physical anthropology to construct a model for the first entry of humans into the Maya area. Along the way, the earliest archaeological sites known from the Maya area have been evaluated in terms of their stratigraphy, dating, and artifact authenticity. Paleoecological and physical anthropological evidence has been provided that supports a model in which the earliest humans to arrive in the Maya area may have traveled via a highland route from North or South America (or both), and/or by water along the coastlines, as early as 35,000 years ago. They were hunters of large game, and as such lived in very small, mobile groups that left behind little evidence for modern archaeologists to ponder.

SECTION TWO: THE BELIZEAN ARCHAIC PERIOD, AND THE PLATFORM FOR MAYA CULTURE

Archaic Period Overview

Above, the section on lithic stage four introduced the transition from the Paleoindian Period to the Archaic Period in the Maya area. The Archaic Period in the Maya area extended from approximately 9000 to 2500 B.C. (Hammond & Miksicek 1981:261; MacNeish et al. 1980:47) or 7500 to 2000 B.C. (Coe 2005:26). By 7000 B.C., the Pleistocene glaciers were in full retreat, and modern plants and animals were (more or less) in their present places (Coe 2005:44; Ranere & Cooke 1991:247). The Pleistocene megafauna were killed off by a combination of the desertification of the grasslands caused by the hotter, drier weather, and over-hunting by humans (Coe 2005:44).

The death of the megafauna heralded the onset of the Archaic cultural period, focused on the collection and the first cultivation of wild plant foods, began in the Mayan area (Coe 2005:44). Lithic technology became more specialized as people adapted to different environmental zones in the region (MacNeish & Nelken-Terner 1983:73). The archaeological record of the Archaic Period shows a decline in abundance of projectile points and an increased number of tools (such as grinding stones) particular to non-hunting subsistence strategies (MacNeish & Nelken-Terner 1983:76, 77). This indicates a shift in food procurement strategies away from hunting, toward collection and preparation of food plants.

In addition to the exploitation of a broadened resource base, characteristics of this period include increased sedentarism; a rising population; invention of pottery; and the rise of complex, chiefdom-level societies (Sanabria 2007:55). Coe (2005:10) places some of these developments in the Early Preclassic Period, not the Archaic Period, but the timing is approximately the same.

These environmental and material-cultural conditions applied to the Maya area in general. Because the remainder of this dissertation deals with environmental and cultural conditions of people in one, smaller, locale within the Maya area, the focus of this chapter must now turn to the Archaic Period in Belize. To provide the material-cultural and paleoecological setting out of which the Maya culture later developed, a summary is given here of the Archaic Period developments in Belize. The Blue Creek area of Belize, which is the focus of this dissertation, was first settled during the Archaic Period, so the little that is known about the pioneers is covered at the end of this section.

Early Archaic Culture in the Lowlands of Belize

Toolkits from the **Lowe-Ha Phase** (9000-7500 B.C.) of the early Archaic Period indicate that the subsistence economy of Belize focused on hunting (MacNeish et al. 1980:55). Hunters pursued such large game as wild horse and giant sloth, but they were probably the last Belizeans to do so before these animals became extinct (Hammond 1982:354; Zeitlin 1984:361). Most inhabitants of Orange Walk District lived inland, practicing seasonal hunting and seasonal plant collecting, as demonstrated by the milling stones and mullers for seed grinding that are now part of the archaeological record (MacNeish & Nelken-Terner 1983:78).

Coastal Belize was occupied, as well. The Belize Archaic Archaeological Reconnaissance Survey noted that most preceramic sites seem to have been located in proximity to sources of water (such as rivers, seasonal tributaries, or occasionally *chultuns*) or on former river terraces (MacNeish et al. 1980:9-27). This survey may have been biased toward finding sites that were located along watercourses because much of the survey was conducted by boat. However, other archaeologists have made note of coastal occupations during the Archaic Period. From 9500 to 8000 b.p. (or 7500 to 5500 B.C., according to Hammond & Miksicek 1981:261), people practicing the **Sand Hill** culture in coastal Belize were adapted to maritime conditions (MacNeish & Nelken-

Terner 1983:78). The artifact complex was used to butcher, work skins, and work wood and hard materials, and seems to show less emphasis on hunting and more emphasis on seed collecting than artifacts of the Lowe-Ha complex (MacNeish et al. 1980:42). The people left behind macroblades, gouges, and end scrapers that seem to have been used in boat-building (MacNeish & Nelken-Terner 1983:78; MacNeish et al. 1980:42). They also used pestles and mullers for grinding seeds (MacNeish et al. 1980:42). Sand Hill sites are small "microband" camps, and the variety of environments in which the sites were found suggests that the people migrated in response to the wet and dry seasons (MacNeish et al. 1980:55). The size of social groupings may have varied seasonally, as well, with larger groupings occurring "at the end of the dry and the beginning of the wet season when game is plentiful around higher sink holes and river terraces. Fishing in the latter case would be possible…" and ripened wild fruits would be available (MacNeish et al. 1980:57). At the end of the wet season, people may have broken into microbands for hunting "near the now-flowing higher tributaries" (MacNeish et al. 1980:57). During the dry season, people moved downriver and sometimes onto islands to exploit marine and estuarine resources (MacNeish et al. 1980:57).

Coastal and inland occupations persisted through the ensuing **Belize Phase**, which existed from 5500 to 4200 B.C. (Hammond & Miksicek 1981:261) or 7000 to 6000 b.p. (MacNeish & Nelken-Terner 1983:81). The Belizean Tradition that may have extended from coastal Belize southwest to coastal Veracruz, Mexico (MacNeish & Nelken-Terner 1983:81). Settlements were patterned as "macroband" camps or hamlets, which may indicate intensification of resource exploitation (MacNeish et al. 1980:43, 57). Diagnostic artifacts of the Belize complex are ground-stone mortars, plates, and large stone bowls, with milling stones and pestles also common (MacNeish et al. 1980:43). Few projectile points or end scrapers were found, suggesting an increasing cultural emphasis on the exploitation of plant resources (MacNeish et al. 1980:43). Although stone bowls and grinding stones were among their possessions, there is no evidence that the people of Belize were yet cultivating plants (MacNeish & Nelken-

Terner 1983:81). Plants exploited may have included wild savanna grasses and acorns (MacNeish et al. 1980:58).

Highland-Lowland Archaic Dichotomies and Preclassic Cultural Transmission

At the same time, the highland-lowland cultural dichotomy was building. This dichotomy was first hinted at by the exploitation of different tool technologies in different altitudinal environments during Paleoindian times. At this point in the Archaic Period, highland Mesoamericans settled into village life, invented their first ceramics, and experimented with agriculture (MacNeish & Nelken-Terner 1983:81). Between 5000 and 3500 B.C., local plant domestication occurred (MacNeish & Nelken-Terner 1983:79). Knowledge regarding plant cultivation diffused, and soon plants such as "amaranth and corn; common, tepary, and runner beans; moschata and mixta squash; pumpkins, avocados, [and] black and white zapotes" were common cultivars across central Mexico (MacNeish & Nelken-Terner 1983:81).

An Archaic Period "Desert Culture," based on intensified collection of wild plant foods and the hunting of smaller game, arose in the southwestern United States and throughout highland Mexico (Coe 2005:44). The people of the Desert Culture of Mexico may have been the first to domesticate maize, beans, squash, and chili peppers, and to share the practice of cultivation with the people of the Maya area (Coe 2005:44). A Desert Culture rockshelter in Chiapas, Mexico, called Santa Marta, contained *manos* and *metates* and other food-processing tools (Coe 2005:45). Santa Marta Rockshelter is discussed as a "stage two" and "stage three" lithic site in the Paleoamerican section of this chapter, and the Archaic Period/Desert Culture occupation there continued until approximately 3500 B.C. (Coe 2005:45). The people of Santa Marta may have acted as cultural translators between the Desert Culture of the north and the people of Guatemala. Perhaps the people of Santa Marta shared with, or brought to, the people of Guatemala both the proto-Maya language and knowledge of maize cultivation (Coe 2005:45).

The suggestion that highland culture was transmitted to the lowlands finds support in ceramic evidence. The earliest pottery in the Maya Lowlands, dating to the

Middle Preclassic Period, lacks the early horizon markers typical of Mexican and Honduran pottery, suggesting that lowland pottery did not have a long early development in situ (Andrews V et al. 1990:572). For example, the ceramic types of the Swasey Phase, the first ceramic phase in the Maya Lowlands, do not seem to have a heritage among the Early Formative ceramics of the Maya Lowlands (Hammond et al. 1979:107). Thus, the first lowland pottery may have been introduced from the highlands after highland pottery had achieved a more sophisticated level of development. Lack of unity in the pottery styles at the different sites suggests that they did not have a long history of development in situ, but rather that the "original settlers of the lowlands entered from different areas and at slightly different times, perhaps from the northern highlands of Guatemala and eastern Chiapas" (Andrews V et al. 1990:580). The Pasión drainage of Guatemala has been suggested as a possible place of origin for the type of pottery most similar to that of the Swasey ceramic phase, the earliest ceramic phase of northern Belize (Andrews V et al. 1990:572).

Late Archaic Culture in Belize

The agricultural advancements of the highlands can be compared with the slower pace at which plant cultivation was adopted in the lowlands. Although the Archaic Period of the lowlands is poorly known, it seems that lowlanders were living in sedentary communities, but were still dependent upon marine resources, rather than agricultural products (MacNeish & Nelken-Terner 1983:82). In Belize, people of the **Melinda Phase** lived in sedentary, non-agricultural, marine-dependent villages on the Caribbean Coast between 6000 and 5000 b.p. (MacNeish & Nelken-Terner 1983:84) or 4200 and 3300 B.C. (Hammond & Miksicek 1981:261). The longer duration of the settlements may indicate further intensification of resource exploitation (MacNeish et al. 1980:43, 57).

During the ensuing **Progreso Phase** (between 5000 and 4000 b.p. according to MacNeish & Nelken-Terner 1983:84, or between 3300 and 2500 B.C. according to Hammond & Miksicek 1981:261), Belizeans still depended upon coastal and riverine resources, but had finally begun to practice agriculture. Most Progreso-phase sites were situated near rivers or the sea, "where floodplain soils would have been attractive to early farming villages" (MacNeish et al. 1980:50, 64). Manos and metates suggest the utilization of plant resources (MacNeish et al. 1980:50).

The Progreso Phase, and the Archaic Period, came to an end in Belize around 2500 B.C., when pottery first came into use there (MacNeish et al. 1980:54). The first pottery-producing sedentary villages in northern Belize were established around 1000 or 900 B.C., during the (Maya) Middle Preclassic Period (Coe 2005:47). While it cannot be proven that the Archaic people were Maya, there seems to be no discontinuity between the Archaic sites and the later, pottery-producing, maize-farming, Maya speakers (Coe 2005:47).

The First Inhabitants of the Blue Creek Area

The first people to settle the Blue Creek area arrived during the Archaic Period. The earliest AMS date supporting human occupation and maize cultivation in the Blue Creek area comes from my own pollen core at Laguna Verde (earlier maize pollen has been reported from Cob Swamp, Belize; Pohl et al. 1996:360). Charred material at the bottom of the core (3.68 to 3.69 m below the surface water level) dated between 4830 and 4520 B.P. (2880 to 2580 B.C.). Definite maize pollen was identified in the sample I took immediately above this one, at 3.67 to 3.68 m below the surface level. Further evidence for a pre-ceramic Archaic occupation comes from a wetland core taken by Steve Bozarth and Sheryl Beach (Guderjan 2006:1). The bottom of the core contained maize pollen radiocarbon dating to 4500 B.P. (Guderjan 2006:1).

Another Archaic Period radiocarbon date was obtained from a paleosol buried at a depth of 3.5 m in a collapsed sinkhole. It contained charcoal and lithics, and dated between 2475 and 2195 cal B.C. (Beach & Luzzadder-Beach 2003:31). Ceramics stop above the latter paleosol (Beach & Luzzadder-Beach 2003:31), indicating the true pre-ceramic age of the paleosol.

These dates provide evidence for early, Archaic Period occupation of the Blue Creek area, and indicate the practice of maize farming in the area. People living in the Maya Lowlands at this time were hunters and simple horticulturalists (Coe 2005:26), but the development of more intensive agriculture was just on the horizon.

The medium-sized Maya center (in a political, religious, and economic sense) of Blue Creek was first occupied around 900 B.C., during the Early Preclassic Period (Guderjan 2004:235). By the Middle Preclassic Period (800-300 B.C.), the people of the Blue Creek area were intensive agriculturalists living a sedentary village life. The first true cities hosting monumental architecture and inscriptions were settled throughout the Maya area during the Middle Preclassic, and the Blue Creek area was no exception. The sites of Blue Creek and nearby Chan Cahal were the first in the area to exhibit public architecture, around 800 B.C. (Lohse 2003b:8-9). Also in the Middle Preclassic, forest clearance for agriculture began near the sites of Dos Hombres and La Milpa. Channeled agricultural fields east of the Blue Creek site dated between 2350 and 1880 B.P., or 1300 and 820 B.C. (Beach & Luzzadder-Beach 2003:30, 31). Intensive agriculture was in full swing, and the settlers now fully exhibited the traits that we identify as belonging to Mayan culture.

Archaic Period Paleoecology

In light of the pre-ceramic, pre-Mayan human presence in the Blue Creek area, it is worthwhile to reflect on the environment of the Maya Lowlands at that time. This section focuses on the paleoenvironment beginning in the early Holocene and extending through the Archaic Period (7500-2000 B.C.). This information is a good lead-up to the environmental interpretation of the Laguna Verde pollen core, which (beginning between 2580 and 2880 cal B.C.) dates to the late Archaic Period.

Much of our knowledge of this paleoenvironment comes from palynological and paleolimnological studies, most taking place in the Guatemalan Petén. Pollen from a 36,000 year long sediment record from Lake Quexil, Guatemala, showed that the tropical rain forest familiar in modern times did not exist during the Pleistocene (Brenner et al. 2002:146; Leyden et al. 1993:169-170, 1994). During the Pleistocene, temperatures were 6.5-8 °C below the present level, and the climate was relatively dry because the “seasonal insolation difference at 10'N was reduced and the [Interpropical Convergence Zone] occupied a southerly position on average” (quote from Curtis et al. 1998:152; also Brenner et al. 2002:146; Leyden et al. 1993:165, 176). The late Pleistocene vegetation was thorn scrub, followed by sparse temperate oak forest (Leyden et al. 1993:171). The early Holocene became warmer and wetter: “Hodell *et al.* (1991) suggested that increased precipitation in the Neotropics during the early to middle Holocene was a consequence of greater intensity of the annual cycle, which was driven by changes in seasonal insolation forced by the earth’s precessional cycle” (Curtis et al. 1998:153). This resulted in increased precipitation, but also increased runoff and erosion in the Petén (Curtis et al. 1998:153). Increased precipitation facilitated the colonization of the Petén by tropical rain forest around 10,500 b.p. (Brenner et al. 2002:146; Leyden et al. 1993:169, 171). The lowland Neotropical rain forest is therefore quite young.

A multi-proxy analysis (using pollen, stable isotope geochemistry, etc.) of a sediment core from Lake Peten-Itza, Petén, Guatemala, assessed environmental change and human influence on the regional environment throughout the Holocene (Curtis et al. 1998). Before 9000 radiocarbon years ago, the climate was relatively dry (Curtis et al. 1998:139, 150). Around 9000-8000 years ago, the greatest seasonality occurred, with the wettest years of the Holocene leading to the filling of Lake Peten-Itza and other lakes in the Petén and the Yucatan Peninsula (Brenner et al. 2002:149; Curtis et al. 1998:139, 151). Wetter conditions prevailed for about 5000 years (Brenner et al. 2002:149). At Lake Peten-Itza, conditions were moist enough to support high semi-deciduous lowland forest between 8600 and 6800 b.p. Moraceae and Urticaceae dominated the pollen record (Curtis et al. 1998:139, 146, 151). Moister conditions prevailed from 6800 to 5780 b.p., after which decline in lowland forest taxa began (probably due to human disturbance; Curtis et al. 1998:139). Between 5780 and 2800 b.p., forest clearance and soil erosion accelerated; deposition of soil into the lake increased (Curtis et al. 1998:139, 152).

A study of Laguna Tamarindito, Petén, provided a 10,000-year-long climate record (Dunning et al. 1998b). The Laguna Tamarindito pollen core was dominated by *Pinus* pollen ten thousand years ago (Dunning et al. 1998b:145). From about 7500 until after 4000 b.p., the climate was moist, and the pollen showed the presence of an undisturbed tropical forest that included Moraceae, Combretaceae, and Burseraceae (Dunning et al. 1998b:145).

The Archaic Period climatic sequence may have been similar in Belize, though dates and vegetation types differed. Early pollen zones at Cobweb Swamp noted the presence of a cattail and sedge swamp or open water savanna (Jones 1991). This was replaced by principal-growth forest sometime between 8061 and 6417 B.P. (Jones 1991:73, 77-78). After this time, a rising sea level may have caused an increase in swamp salinity and an increasing abundance of salt-tolerant taxa, such as *Rhizophora*.

After this time, in the late Archaic Period and into the Preclassic Period, a drying trend began in the Maya Lowlands (Brenner et al. 2002:149). This may be accounted for by "reduced seasonality, caused by reduced annual north-and-south migration of the Intertropical Convergence Zone" (Brenner et al. 2002:149). Palynological markers of anthropogenic disturbance and land clearance for agriculture greatly increased throughout the Maya Lowlands (Curtis et al. 1998:140; Cowgill et al. 1966; Deevey 1978; Deevey et al. 1979; Dunning et al. 1998b:145; Leyden 1987; Vaughan et al. 1985:80-81).

CONCLUDING REMARKS

A chapter summary is here provided with a brief, synoptic return to the questions presented at its outset.

1. Q: From where did people come to the Maya area, in general? When did they arrive? A: Multiple waves of migration took place from the Old World into the New World. Upon reaching the New World, Paleoamericans may have travelled to the Maya

area via the coastlines, first following the Pacific coast, and later the Atlantic and Caribbean coasts; or they may have followed a land route to the Maya area, perhaps preferring to occupy highland areas and travelling south along the Rocky Mountains and the Sierra Madre, or north along the Cordillera de los Andes. The first Paleoamericans may have arrived in the Maya area as long as 35,000 years ago, with a definite presence established after 20,000 years ago.

2. Q: Who were the first people to come to Belize, in particular? When did they arrive? A: There has been little speculation in the literature as to the location of origin of the first Belizeans, but one may point to the general model for the peopling of the Maya area for clues. The oldest possible archaeological site is the undated Richmond Hill site, with a primitive, unifacial, "lithic stage two" assemblage. Surface finds of fishtail points may date to 11,000 years ago. The earliest Belizeans were big game hunters during the Pleistocene, and exploiters of marine resources.

3. Was a population that was already identifiably Mayan the first to inhabit Belize, or was there continuity between pre-Mayan populations and the Maya? A: Once the human population was well-established, during the late Archaic Period, the people of northern Belize began to receive cultural influences from elsewhere, namely from highland Guatemala via Chiapas, as is suggested by the ceramic evidence. No discontinuity is seen between late Archaic Belizeans and later Belizean Maya, suggesting that elements of culture diffused while the same human population remained, more or less, place. Ongoing interactions (e.g. speech, trade) between the people of Blue Creek and others in the region created and maintained a cultural complex that became identifiably Mayan.

The stage has now been set for an examination of the development of the subsistence strategies that would later play key roles in the success and failure of the Mayan empire.

CHAPTER III
THE ECOLOGICAL SETTING OF BLUE CREEK

CHAPTER INTRODUCTION

Why did the Maya choose to settle in the Blue Creek region? Given the long history of low population and low population density in Belize, was the Blue Creek area even suitable for long-term habitation by a settled human community (namely that of the Maya from the Preclassic through Postclassic Periods)? Or did environmental factors doom any who would settle the region to an occupation period that could only have been brief and turbulent? Testable questions assess the availability and quality of the factors necessary for human survival, as well as the strength of the infrastructure and its ability to support a relatively large (compared to bands of nomadic foragers) group of sedentary people. Factors essential to human survival include food and water, as well as raw materials facilitating the procurement of food and water (such as toolstone, and clay for pots), and raw materials for building fires and constructing shelter. Infrastructural support includes the human knowledge and leadership required to make use of, or distribute, the essentials for human survival to meet the needs of a large, sedentary population. This may entail the mobilization of labor, the development of agricultural technologies, and the building of external alliances for defense or for trade for non-local goods.

Assessment of these factors is the purpose of this chapter, with the goal of evaluating the *physical* environment in the Blue Creek area in terms of its ability to provide the essentials for human life, and also in terms of its resource stability. I demonstrate in this dissertation that particular combinations of some aspects of the physical environment, such as soil type and moisture regime, result in the growth of particular plant communities; and changes over time in local or regional vegetation, indicated by the pollen spectrum, are used to make suggestions about changes in soil quality and moisture availability. Because the ultimate purpose of this dissertation is to display the ecological changes through time, revealed by variations in the pollen spectrum, the focus is never on strictly sociopolitical factors, but on human interactions with the environment and on anthropogenically-caused environmental change. Sociopolitical aspects and infrastructural support, such as the quality of the local leadership and the comportment of trade relationships, are considered as they relate to the physical environment.

The information presented here should be considered in conjunction with other studies that have focused on the sociopolitical aspects of life at Blue Creek (e.g. Barrett 2004; Clayton 2003; Driver 2003; Guderjan et al. 2003; Lohse 2003a, 2003b). It can be generally assumed that local leadership existed at Blue Creek, and that they were capable of running a long-term settlement, as by coordinating agriculture and trade and by organizing labor. If the local leaders were to lose such capacities, societal downfall might be expected. In fact, we know there were kings at Blue Creek, the first having been installed around A.D. 100 (Guderjan 2004:235, 240-241, 247). The ruling lineage seems to have remained intact until the Late Classic Period, at which point the lineage seems to have been undermined by outsiders (Guderjan 2004:242, 247). After this, the site was abandoned. It can be seen that the quality of the local leadership was unquestionably important in shaping the population's interactions with the environment (e.g. ordering land clearance for large-scale construction projects; organizing community-wide efforts in hydraulic agriculture) and with outsiders (e.g. coordinating extra-polity trade that required a local increase in agricultural production). If the leadership was unstable, so would the society be, regardless of the stability of the physical environment.

A stable, high-quality physical environment can help a community buffer negative effects of outside forces, such as climate change and regional warfare. Although the physical environment is not the sole force to control every cultural variable, its characteristics can spur on human adaptations and innovations, and can influence the direction taken by interpersonal and intersocietal relationships. We can expect that the essentials for human life were present in Blue Creek at the time its first human occupants arrived, but we should question whether those same factors remained stable through the waxing and waning of the Mayan civilization. Stability, or lack thereof, has implications for human adaptations at the infrastructural level.

An example of successful adaptation to environmental instability comes from the Maya living in northern Yucatan during the Late Classic Period, explained by Bruce Dahlin in an article on climate change (2002). In the Late Classic Period, Yucatan Maya society flourished, while those living in some other parts of the Maya Lowlands may have suffered from drought. Low rainfall and high moisture loss through the porous limestone bedrock make northwestern Yucatan State the part of the Maya Lowlands that is the most deficient in available water for agriculture. Because Maya living in northwest Yucatan State were most accustomed to living under drought conditions, it is possible that they developed the most effective mechanisms to cope with the Terminal Classic drought. For example, rather than dedicating themselves solely to farming, they may have effectively cushioned their losses by exploiting diverse marine, estuary, swamp, and savanna resources. Rather than counting on agricultural self-sufficiency, the people relied on external trade -an infrastructural issue- to meet their needs. The northern Maya may have fared well because they were able to make use of a broader resource base and different adaptive strategies (including those in the ideological, political, economic realms –again infrastructural issues) than Maya elsewhere. People in the southern Maya Lowlands may have failed to make adaptations (such as capital or labor improvements) to the Terminal Classic drought because their political leaders accepted drought as a fate predestined by the calendar cycle. It would have been possible for the southerners, instead, to use this prediction of drought as an advance warning to start planting drought-tolerant crops; to intensify their labor to produce and store more food; or to make “large-scale capital improvements such as construction of public reservoirs, storage facilities, and centralized terracing or irrigation systems that are paid for by taxes, tribute, and labor service” (Dahlin 2002:333). People could also share the burden of their losses by improving networks with kin and trading partners living elsewhere.

It can be seen that not only the ongoing presence of adequate natural resources, but also the population's ability to cope with changes in resource availability (i.e. sociopolitical factors, both internal and external to a society), have impacts on the long-term success of a community. This chapter, then, explores the physical environment and natural resources upon which the Blue Creek regional infrastructure was built. Factors including soil conditions, climate, water sources, local raw materials, and trade for non-local goods are explained. Finally, the possibility is considered of a coalescence of instability in these physical characteristics, combined with sociopolitical instability, in the form of the Maya Collapse.

GEOLOGY AND SOIL

An examination of soils is important in a paleoethnobotanical study because variations in soil, along with variations in topography and/or geology, and rainfall, account for the development of different flora in different locations (Standley & Record 1936:10). Soil characteristics, topography, and rainfall work together to produce "soil suites with different properties of fertility, permeability, and erodability" (Rice et al. 1985:91). Not only do soils influence regional vegetational associations, but soils also have impact on "the food production capabilities of populations, on the characteristics of standing water resources, and on the character of natural and human-induced perturbations in resources" (Rice et al. 1985:91). For example, low capacity of a soil to retain moisture can inhibit crop growth, especially during the dry season (King et al. 1992:23). Because soils with different properties have different ecological consequences, a region that holds a variety of soil types provides a human population with an increased number of subsistence options. A greater number of subsistence options is a hallmark of economic and ecological stability. During times of environmental stress, whether of anthropogenic or natural origins, "[landscape] heterogeneity may have been the most important factor in ensuring a population's ability to successfully adapt and survive" (Barrett 2004:51). Below, it is explained that the Blue Creek site is located in an ecotone, which provided the site's inhabitants with benefits from an available assortment of natural resources, including various types of arable soils.

“Good Soil”

It has long been assumed that tropical soils are “universally infertile,” so that, under cultivation, they “cannot retain key nutrients needed for crop production” (Johnston 2003:131). This assumption was founded upon a conventional model of tropical ecology, which is now known to be erroneous (Johnston 2003:131). The traditional model of tropical ecology states the following about tropical agriculture: Nutrients are concentrated not in tropical forest soils, but in the forest vegetation; slash-and-burn cultivation releases the nutrients from the vegetation and deposits it, as ash, in the soil (Johnston 2003:131). Nutrients may then be lost from the soil via percolation into the subsoil or via surface runoff and topsoil erosion (Johnston 2003:131). “Weeds invade cultivated fields because they are better adapted to nutrient-poor environments” than crops are (Johnston 2003:132). After the second year of cultivation, depletion of nutrients causes declining crop yields (Johnston 2003:132). Fields must then be fallowed to permit reforestation and nutrient restocking (Johnston 2003:132).

A new model of tropical ecology has been developed; it states that the traditional model exaggerates nutrient loss (Johnston 2003:133). Fields abandoned after two years of cultivation usually reforest rapidly, which would not be possible if the soils were so nutrient-depleted (Johnston 2003:133, 143). The new model holds that system nutrients are stored both in the vegetation, *and* in the soil (Johnston 2003:133). Because weeds are better adapted to disturbed habitats than cultivars, and because “soil seed banks contain abundant weed seeds,” weeds outcompete cultivars; weeds absorb and sequester a progressively greater portion of the field’s total nutrient stocks” (Johnston 2003:133). Therefore, crop yield declines are caused not by nutrient loss, but by outcompetition by weeds (Johnston 2003:133, 143, 144).

With the knowledge that tropical soils are not infertile as was once believed, we may ask what constitutes good agricultural soil in northern Belize. Twentieth-century farmers living in Corozal District, Belize, classify soils as "*boshluum* (good black soil which is preferred for milpa), *zacluum* (white, stony soil), *kyanluum* (a yellow soil bad for corn and beans but good for tree crops such as mango, coconut and plantain" (Hazelden 1975:186). As noted below, deep, dark, calcareous clays and clayey colluvium are preferred as agricultural soils (Hazelden 1975:186; King et al. 1992:2; Standley & Record 1936:11-12). These soils are suitable for the growth of most of the plants used by the Maya, though they are not without problems. During periods of high rainfall, these soils are subject to problems with wetness and drainage; during the dry season, shallower soils can become too dry (Hazelden 1975:186).

The lands with the greatest agricultural value in northern Belize are on floodplains, such as those along Spanish Creek and the Belize River. Those areas are not as limited by lack of available water as other land systems in northern Belize, though they may be subject to flooding (King et al. 1992:175-182). However, periodic flooding may help replenish soil nutrients. Most of these agriculturally-ideal land systems have deeper soil than is found in other systems, and (with some exceptions in the Upper Belize Floodplains) they do not lack soil nutrients (King et al. 1992:175-182).

The Blue Creek area is not situated on such a floodplain, which calls into question the nature of the soil in the Blue Creek area at the time of Maya settlement and Classic Period population growth. The present section of this chapter provides hard evidence for soil quality and diversity in the Blue Creek area, beginning with an explanation of the geological background upon which the soils are based. Details are then presented on the topography of northern Belize. The next section describes the soil types present in the Blue Creek area today, and offers an assessment of their potential for farming. Because many of the non-vegetative natural resources of the Blue Creek area are of mineral origin, the ensuing section introduces the raw materials of the area, and offers details on inter-regional trade for raw materials unavailable locally. Due to a history of natural and anthropogenic interference, the soils of today are not the same as they were when the first Maya arrived in the Blue Creek area. Therefore, the penultimate portion of the "Geology and Soils" section considers soil change (e.g.

aggradation, erosion, redeposition) during the Maya period. Such consideration reveals the impacts people have had on the soil, and permits speculations regarding the implications that soil change may have had for the social stability of the Classic Period Maya. Finally, the geological events revealed in the stratigraphy of the Laguna Verde pollen core and in other geoarchaeological studies at Blue Creek are explained.

Geology of the Yucatan Peninsula

The metamorphic “basement rocks” of Belize and northern Central America were laid down more than 200 million years ago, during the Paleozoic era (Hall & Pérez Brignoli 2003:12). Belize, like the rest of the Yucatan Peninsula, began to be formed when marine deposits formed limestone beds during the Eocene epoch (Turner & Harrison 1983:12). The limestone peninsula emerged from the Caribbean Sea sometime during the Oligocene or Miocene epochs (Turner & Harrison 1983:12). The isthmus that is now Central America formed, connecting North and South America, 3-4 million years ago, in the Pliocene epoch (Hall & Pérez Brignoli 2003:13). Quaternary age volcanoes, formed within the last two million years, line the Pacific coast of Central America (i.e. the Maya Highlands; Hall & Pérez Brignoli 2003:12-13). There are no volcanoes in Belize or the Yucatan Peninsula (i.e. the Maya Lowlands). During the Pleistocene, the limestone bed of the Yucatan Peninsula emerged further from the Caribbean Sea, and tilted in a westward and northwestward direction (Turner & Harrison 1983:12). Postemergence erosion followed, creating modern topography and soils (Turner & Harrison 1983:12).

Geology and Topography of Northern Belize

The Belize River divides Belize north from south. This paper focuses on northern Belize, where the Blue Creek archaeological ruins are sited (See Figure 3 in Chapter I.). The northern portion of Belize is chiefly a plain that slopes from west to east, with the highest elevation being about 400 ft (Standley & Record 1936:9). Miocene folding created the west-east running central Maya Mountains (which are comprised of Upper Carboniferous slates), formed the synclinal plains of northern and southern Belize, and submerged the northern plain (Standley & Record 1936:10, 11). Tertiary and Quaternary folding built the drainage systems of the northern coastal plain and led to the re-emergence of the limestone foundation of northwestern Belize, especially to the west of the fault line at Booth's River, where Blue Creek is located (Standley & Record 1936:10).

The limestone of Belize is known as Río Dulce Limestone, named after a Guatemalan gorge (south of Belize) in which the limestone is exposed (Standley & Record 1936:11). This thick, hard, white limestone covers most of the Yucatan and nearby Caribbean islands (such as Cuba, the Cayman Islands, Jamaica, and Haiti) below 2,500 ft in elevation (Standley & Record 1936:11). When the limestone goes into solution during drainage, it weathers to form hills and caves; this is known as *karst* topography (King et al. 1992:17; Standley & Record 1936:11; Turner & Harrison 1983:16). Karst topography began to develop in the Yucatan Peninsula during the emergence of the peninsula from the Caribbean Sea in the Late Miocene (Turner & Harrison 1983:16). When unconsolidated limestone is deposited as clastic sediment (dirt or soil), it is called *sascab* or *sahcab* (Turner & Harrison 1983:16). When unconsolidated limestone is deposited as clay, it is often called *marl.* Used correctly, *marl* refers to freshwater calcareous clay, but it is often uncertain whether the limestone parent material of the clay was deposited under freshwater or marine conditions, leading to some misapplications of the term (Turner & Harrison 1983:16). Marl need not be derived solely from limestone; degraded flint and quartzite veins also create marls that overlie the limestone beds in northern Belize (Standley & Record 1936:11). A key feature shared by these marls is their high content of calcium carbonate.

Topography of the Blue Creek Area: Escarpments, Physiographic Zones, and the Ecotone

The most prominent feature in the topography of the Blue Creek area is the Bravo Escarpment, which continues north to form an extension of the Booth's River

Escarpment. East of the Bravo Escarpment, La Lucha Escarpment runs almost parallel to the Bravo Escarpment; the two meet just south of the Blue Creek site. The escarpments are post-Eocene fault lines that run north-south through the area (Guderjan 1991:3; King et al. 1992:32). Freshwater spring seeps emerge at the bases of the escarpments (Lohse 2003a:3, 5). Río Bravo and Boothe's Rivers lie at the bases of the escarpments and meet at Boothe's Swamp (Guderjan 1991:3).

The fault lines mark an important ecotonal division between two significant geological, vegetative, and cultural/political/economic (see Lohse 2003a and 2003b) zones. The Blue Creek site is located in an ecotone (called the Escarpment Ecotone) between these zones. The boundaries of these physiographic zones, or "land regions," were defined by geographers King et al. (1992:33) by grouping together land systems with "similar topography, lithology, soils, vegetation and hydrology". The Northern Coastal Plain Zone (also locally called the Escarpment Ecotonal Corridor) sits east of (or below) the Bravo Escarpment. The land west of (or above) the escarpment rises up to an elevation of about 120 m, where the Bravo Hills mark the beginning of the Eastern Petén Zone (also called the Upland Hill and *Bajo* Corridor; Guderjan 2004:235; King et al. 1992:17; Lohse 2003a:2).

Land at the bottom of the Bravo Escarpment, on the Northern Coastal Plain, is flat and swampy, with a few low terraces, ranging from sea level to 40 m above sea level (Guderjan 2004:235-236; King et al. 1992:35). However, there are many microenvironments that can host "dense populations of biological organisms including plant and animal life", and these organisms are key resources in this zone (Lohse 2003a:6). "Most of the Plain is underlain by Cenozoic limestone", which supports the growth of semi-deciduous broadleaf forest (King et al. 1992:35). Where there are soils made from Pleistocene alluvium, pine forests and orchard savannas grow (King et al. 1992:35). Additional details on the soils of the Northern Coastal Plain are given below. Mean annual rainfall on the Northern Coastal Plain is 1300-2000 mm (King et al. 1992:35).

Land at the top of the escarpment, in the Eastern Petén Zone, is marked by the presence of well-drained flat lowlands, *bajos*, and rolling karstic hills that average 40 to 60 m above sea level, and reach as high as 200 m or more (Guderjan 2004:235-236; Guderjan et al. 2003:81). The Bravo Hills region of the Eastern Petén Zone lies immediately west of the Bravo Escarpment, and is the portion of the Eastern Petén Zone in which the Blue Creek site is located. Most of the Bravo Hills region is "underlain by faulted hard Cretaceous and early Palaeogene limestones" (King et al. 1992:35). Semi-deciduous broadleaf forest grows there (King et al. 1992:35). Mean annual rainfall in the Bravo Hills is 1500 mm (King et al. 1992:35). Areal resources of the Eastern Petén Zone include chert outcrops and arable soils (Lohse 2003a:4). Craft specialization in lithics is known from this zone, but not from the Northern Coastal Plain, reflecting a difference in resources that may have implications for differences in sociopolitical organization between the two zones (Lohse 2003a:5, 10; 2003b:12,15). Particularly fertile soils are found in the *bajos* and *rejolladas* of the Eastern Petén Zone (discussed below, under the subheading "Blue Creek Area Soil Types").

Archaeological sites within the permit area of the Maya Research Program exist both above and below the escarpment. The Blue Creek site core lies atop the escarpment. The Laguna Verde pollen core was taken from a point at the bottom of the escarpment, just below the rise in altitude. Whether good fortune or good sense led the ancient Maya to occupy the Blue Creek area cannot be known, but the site's location in the Escarpment Ecotone provided the people with access to the resources of two different ecological zones, with increased diversity in the area of gradation between the two zones. Ecotonal locations offer "higher biotic diversity as well as higher biotic mass than either of the merging ecological zones", as well as "access to a very diverse set of environmental niches" (Guderjan *et al* 2003:78). The ecotonal situation provided the farmers with "diverse soils and farming conditions that therefore [diversified] risk and [provided] stability to production systems" (Guderjan et al. 2003:78).

Blue Creek Area Soil Types

We turn now to a delineation of the soil types in the Blue Creek area today, and an assessment of their potential for farming. It shall be demonstrated that there exist a variety of soil types in the Blue Creek area, which would have increased the number of subsistence possibilities for the ancient Maya. Some of the soil types were suitable for agriculture, while others provided the types of forest products that were necessary for Maya subsistence.

There are three main soil settings near the Blue Creek site and along the Río Bravo, the course of which runs south and east of the site. These are discussed in turn below. Soils in the Blue Creek area are mainly inceptisols, including gleysols, fluvisols, or aquepts (Hall & Pérez Brignoli 2003:20). The inceptisol soil order consists of moist soils of recent origin, with weakly developed horizons derived from parent materials. Inceptisols are periodically renewed when major rivers flood, and can be fertile when properly managed (Hall & Pérez Brignoli 2003:20). Inceptisols sometimes require artificial drainage to accommodate human settlements and farming (Hall &Pérez Brignoli 2003:20).

Upland Soils of the Eastern Petén Zone and the Bravo Hills

The first of three soils settings is found in the uplands, where calcareous soils derived from Eocene limestone exist (Guderjan 1991:3). Soils derived from, “or associated with, calcareous parent materials, [tend to be] fertile, usually supporting high forest” (King et al. 1992:2). The upland portions of the Eastern Petén Zone originally hosted mesic forests and cohune ridges, and now contain “some of the best agricultural soils found in northern Belize” (Guderjan et al. 2003:81, King et al. 1992). They could have been farmed in ancient times without need for ditching or terracing, because the land drains naturally as rainwater percolates through the porous karst topography to the water table. However, valuable soil nutrients may be lost through this same drainage system (Barrett 2004:80).

In some places, particularly in the Bravo Hills region, upland soils are “stony or rocky shallow dark clays” (King et al. 1992:2). Some sands and sandy loams in northern Belize also contain abundant flint, and can be too acidic for agriculture (Hazelden 1975:186). Stones may be an impediment to agriculture, but modern Mennonite farmers grow maize, sorghum, and sugar cane, and also pasture animals, in the region (King et al. 1992:35).

Within the Bravo Hills land region, the Maya Research Program archaeological sites are scattered across three subunits of a land system known as the Gallon Jug Rolling Plain with Hills (King et al. 1992:38, 179). This rolling landscape is built of early Tertiary limestone (King et al. 1992:44). Karst hills are broken by the steep fault scarps, mentioned above (King et al. 1992:44). Some parts of the Gallon Jug Rolling Plain with Hills appear to be quite fertile and are under cultivation today. In other parts, particularly along the fault scarps, the agricultural potential is limited by erosion, workability, and moisture availability (King et al. 1992:179). The same was true during ancient Maya times.

Bajo and Rejollada Soils of the Eastern Petén Zone

The second soil setting is found in the shallow depressions (known as *bajos*), that pit the uplands of the Eastern Petén Zone/Upland Hill and *Bajo* Corridor. In the *bajos*, soils are thick, wetland deposits of black or brown calcareous clay, silt, and loam (Guderjan 1991:3; Standley & Record 1936:11). Deep, dark clays are the preferred agricultural soils in northern Belize (Hazelden 1975:186; King et al. 1992:2; Standley & Record 1936:11-12). The relatively deep soil of the *bajos* supports the growth of a range of vegetation associations. Guderjan et al. (2003:81) report that “a variety of seasonal wetlands are located in the bajo depressions, with at least seven different vegetation associations.” These include high forest dominated by *Attalea cohune* (“cohune palm”), and scrub swamp dominated by sedge and sawgrass (Standley & Record 1936:11-12).

Soils in the *bajos* are fertile (Guderjan 2004:236), but the ancient Maya found that the *bajo* soils could become saturated during the wet season, and sometimes required artificial drainage (i.e. drainage channels) so they could be farmed during the dry season. The ditched agricultural fields at Blue Creek occur mostly in a low-lying area dominated by cohune palm forest and marsh (Barrett 2004:85). Modern farmers in the Petén are reported to use most of the *bajo* niches without making landscape modifications (Guderjan et al. 2003:81). Most modern farmers choose not to exploit the *bajos*, but sugar plantations have been situated on the northern “cohune cays” since the seventeenth century (Standley & Record 1936:14). Eight km west of the Blue Creek site is a 40 km-square, agriculturally productive *bajo* known as the Dumbbell Bajo for its shape (Guderjan 2004:237; Guderjan et al. 2003:77). Modern farmers have converted much of the Dumbbell Bajo into rice fields and cattle pasture (Barrett 2004:122).

Nutrient-rich, moisture-retaining, deep sediment also collects in shallow sinkholes, called *rejolladas*. *Rejolladas* provide some of the best farmland in the drier parts of the northern Yucatan Peninsula (Guderjan et al. 2003:80). *Rejolladas* are found along the Bravo Escarpment, including three immediately adjacent to (southwest) the Blue Creek site core (Guderjan et al. 2003:80). The *rejolladas* may have attracted early comers to settle and farm in the area (Guderjan et al. 2003:80).

Soils of the Northern Coastal Plain

The third soil setting is found northeast of the Río Bravo, in the Northern Coastal Plain Zone. This is a band of siliceous, sandy soils deposited as clastic sediments derived from the Maya Mountains, which aggraded on a previous shoreline of the Caribbean Sea (Guderjan 1991:3). Some soils near the Río Bravo are fertile (Guderjan 1991:3). In places, a black or red soil supports forest dominated by *Swietenia macrophylla* (“mahogany”) and *Manilkara zapota* (“sapodilla”; Standley & Record 1936:12). These are considered important timber crops today, and could have been exploited by the ancient Maya for wood and fruit, respectively. However, high fertility is not the general rule for soils across the Northern Coastal Plain. Northern Coastal Plain topsoils overlying soft limestone or marl tend to be shallow, subject to flooding, high in acidity, low in natural fertility, and otherwise difficult to farm (Guderjan

2004:236; King et al. 1992:2; Standley & Record 1936:11). In some places, including locations at the base of the Bravo Escarpment, the soil is sandy and will support only pine and "dry grass savanna" (Standley & Record 1936:11). There are, however, niches in the Northern Coastal Plain that contain arable soils, through the landscape may first require anthropogenic modification.

The Maya Research Program archaeological sites are scattered across two land systems within the Northern Coastal Plain land region, each with different ecological characteristics (King et al. 1992). These subunits are the Shipyard Plain and the Sibal Swamps. The Shipyard Plain is flat, arable land currently under use for milpa farming, pasture, and production of sorghum and sugar cane (King et al. 1992:175). The Shipyard Plain could have been farmed by the ancient Maya, as well. The Sibal Swamps is a savanna plain; due to its wetness, the land is not currently used (King et al. 1992:175). The main soil problem in the Sibal Swamps, and in the western part of the Northern Coastal Plain in general, is wetness. The karst topography of the Eastern Petén Zone permits surface water to drain into the water table. The water flows underground and downslope to the Northern Coastal Plain, emerging at the base of the Bravo Escarpment, where it forms springs, marshes, and shallow lakes (Barrett 2004:83). Thus, ancient Mayan farmers had to adapt to the dampness of the Sibal Swamps by developing wetland agricultural practices. The channeled agricultural fields found east of the Blue Creek site center were created as an adaptation to swampy terrain that was subject to inundation by spring water (Lohse 2003a:6). The Laguna Verde pollen core was taken from a Sibal Swamps setting, but close to its border with the Bravo Hills-Gallon Jug Rolling Plain with Hills land system.

Soil, Anthropogenically-Induced Erosion, and the Maya Clay

The Maya were the first people to establish densely populated, permanent cities in the Maya Lowlands, including northern Belize. This dense population was the first to remove natural vegetation on a large scale, to clear the land for building structures and to plant crops. That modern soil surfaces are not the same ones encountered by the ancient

Maya can be assumed by “reference to causes now in operation” (Lyell 1835), and is solidly demonstrated by a number of studies in the Petén department of northern Guatemala, where most paleobotanical and paleolimnological studies of the Maya Lowlands have taken place (Beach & Dunning 1995; Binford 1983; Brenner 1983, 1994; Brenner et al. 1990, 2002; Cowgill & Hutchinson 1966; Cowgill et al. 1966; Curtis et al. 1998; Dahlin et al. 1980; Deevey 1978; Deevey et al. 1979, 1983; Dunning et al. 1997, 1998b; Hansen et al. 2002; Islebe et al. 1996; Leyden 1984; Popenoe de Hatch et al. 2002; Rice et al. 1985; Rosenmeier et al. 2002; Tsukada 1966; Vaughan et al. 1985; Wiseman 1985; and others). The Petén is topographically and floristically similar to northern Belize (particularly to the Eastern Petén Zone of northwestern Belize; Balick et al. 2000:1), though differences in soil conditions recommend some caution in using the Petén as an analog to northern Belize. Most of the Petén is blanketed by mollisols (calcimorphic rendzinas; Curtis et al. 1998:142), which are rich in humus that developed under grassland conditions. The moderately-developed mollisols of the Petén contrast with the less-developed inceptisols of the Blue Creek area, which are more similar to the soils of the Yucatan Peninsula to the north. Mollisols support tropical lowland dry forest (Curtis et al. 1998:142), whereas the forests are moister near Blue Creek. Still, much of the Petén vegetation is similar to that of the Yucatan, with many members of the Moraceae, Meliaceae, Sapotaceae, Fabaceae, and Lauraceae families growing in both places (Curtis et al. 1998:142). At the present time, the paleolimnological and palynological studies from the Petén remain the best predictors of ancient conditions in northwestern Belize, until more work can be completed at the latter location.

Studies from the Petén demonstrate soil change during the Mayan era. For example, excavations and pedological analysis of *bajo* soils in the Mirador Basin of northernmost Petén revealed the consistent presence of a buried paleosol (Hansen et al. 2002:281), and a layer of “Maya clay” (explained below) immediately underlay the paleosol. Isotope analysis demonstrated that the paleosol contained a higher abundance of plants following the C4 photosynthetic pathway (grasses), while overlying sediments contained a higher abundance of C3 plants (forest plants; Hansen et al. 2002:281). The paleosol had features consistent with soils deposited in existing marshlands, suggesting "that it was formed in a more humid, marshy environment" that may have existed during the Maya Preclassic Period, between 500 B.C. and A.D. 0 (Hansen et al. 2002:281). This was more likely to have been the "primary agricultural surface for the ancient Maya" than the soils of the modern *bajos* (Hansen et al. 2002:281). This is but one example to demonstrate the anthropogenically-caused changes to the soil that occurred during the Mayan era.

Such changes continued as the human population grew and Maya farmers intensified their production. Removal of vegetation in the uplands led to erosion of upland soil, which was redeposited in places of lower elevation, such as the *bajos.* "In general, high soil losses follow a cycle of deforestation, decomposition of forest humus, soil structure degeneration, and surface compaction…[leading to] overland flow and soil piping" (Dunning et al. 1998b:142).

In the Petén, soil erosion was caused primarily by anthropogenic factors, with some studies suggesting regional drying as a secondary factor. The soil that eroded in the uplands was redeposited in lakes and *bajos,* as revealed by a common pattern that shows up in the stratigraphy of lake and *bajo* sediment cores. "Sediment cores taken from ten lakes by the Central Petén Historical Ecology Project in the 1970s exhibit the following standard pattern: a pre-Maya layer of organic muck overlying bedrock, a thick layer of inorganic 'Maya clay,' and post-Maya organic muck" (Dunning et al. 1998b:142). Palynological studies of sediment cores from Lakes Quexil, Sacnab, and Macanche (pictured in Figure 6) with other Guatemalan sites mentioned in the text) revealed an almost-complete absence of arboreal pollen in the Maya clay, while younger and older organic zones contain much (arboreal) tropical forest pollen (Vaughan et al. 1985:75). The Maya clay is thus indicative of a period of high erosion and extensive forest clearance (Dunning et al. 1998b:142; Vaughan et al. 1985:75). Typically, the Maya clay consists of inorganic (montmorillonite, or silicate), fine-grained, clay-rich colluvium, with increasing proportions of limestone toward the top of the section (Brenner et al. 2002:146; Curtis et al. 1998:141; Rice et al. 1985:95). Although the

Maya clay accumulated from 3000 and 400 years B.P., the rate of deposition varied (Brenner et al. 2002:146; Curtis et al. 1998:141, 154). At Lakes Quexil and Sacnab, clay deposition and agricultural indicators picked up strongly between the Early and Late Classic Periods (Vaughan et al. 1985:76-77). The Maya clay varied in thickness from 1.6 m in Lake Quexil to 6.3 m in Lake Yaxha (Brenner et al. 2002:146; Curtis et al. 1998:141, 154; Vaughan et al. 1985:74).

For Classic Period Maya farmers, the consequences of this erosion may have turned out to be devastating. "As population density increased through the Preclassic and Classic periods deforestation steadily progressed, soil erosion and sedimentation increased exponentially, sediments became increasingly inorganic, and phosphate levels rose abruptly" (Dunning et al. 1998b:142). Reduced organic content and increased phosphate levels meant that sediments were less nutrient-rich and less suitable for farming. Because "soil erosion...removes nutrients like phosphorous and nitrogen, runoff carrying eroded soil is rich in these nutrients and these often lead to many nutrient loading and biological pollution problems in waters that receive eroded soil" (Luzzadder-Beach & Beach 2008:225). Therefore, when infertile sediments with inappropriate nutrient compositions were redeposited in *bajos* and were transported via water to both upland and lowland sites, those locations also lost potential as suitable sites for wetland agriculture.

Moreover, the Maya clay sometimes formed an impenetrable layer that sealed away the groundwater below (Rice et al. 1985:95). At Lake Yaxha, the thick hardness of the clay prevented a coring apparatus from penetrating it (Rice et al. 1985:95). If a clay layer like this were deposited on a wetland agricultural field, it would have prevented the field from draining properly.

Even as upland milpa farmers were losing their soil to erosion, the wetland fields of the lowlands were also declining in cultivability. Thus, an inability to feed the burgeoning, densely-settled population of the Late and Terminal Classic Periods may have undermined the authority of the local leadership, leading to warfare, and (along with other factors) to the abandonment of Maya cities that has been heralded as the great

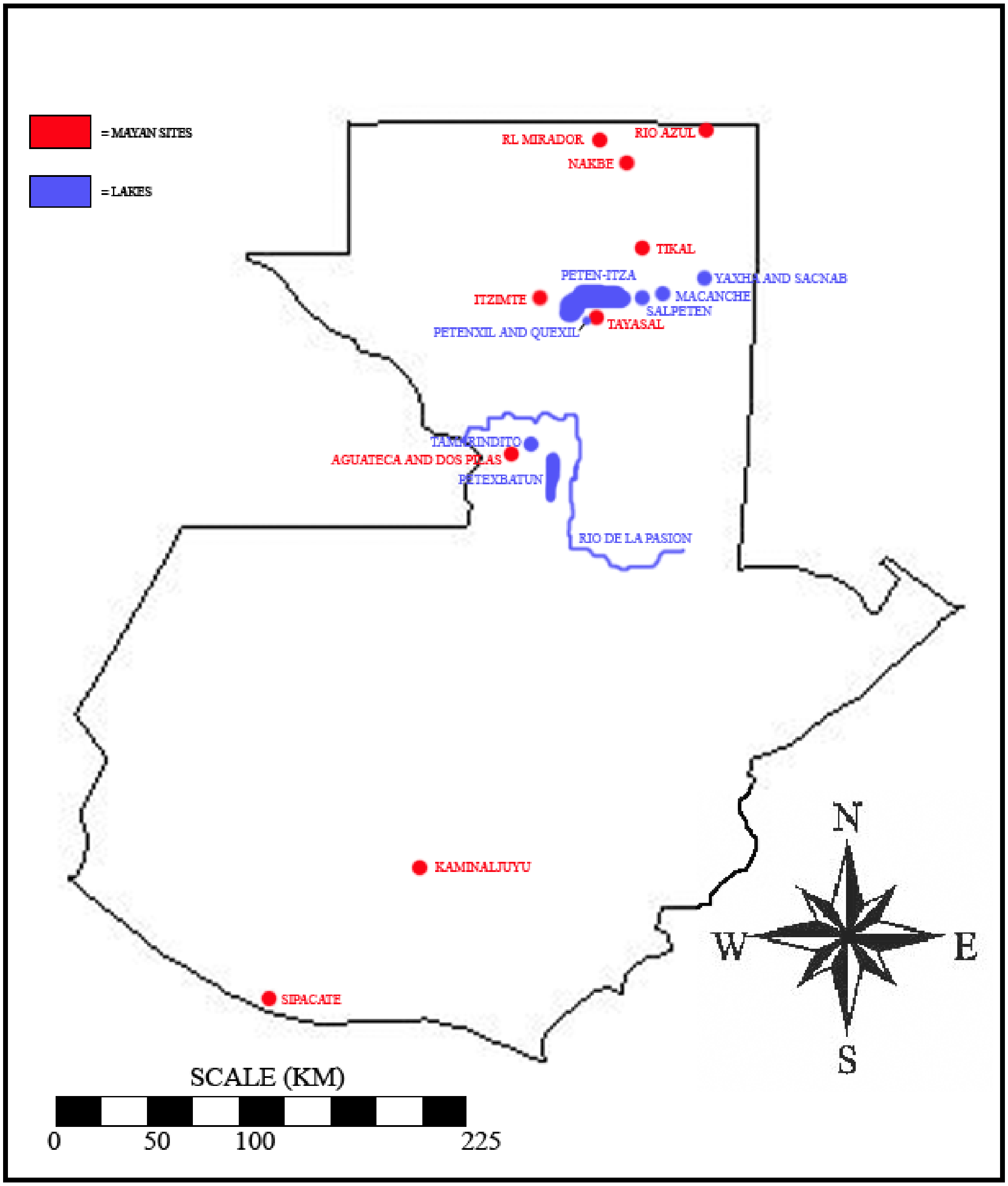

Figure 6. Guatemalan archaeological sites and locations discussed in the text.

"Maya Collapse" (Coe 2005:161-162; Gunn et al. 2002:80; Sanabria 2007:64). See the section "Drought and the Maya Collapse," below in the hydrology section, for additional details on the issue.

Sea Level Rise and Sedimentology in Northern Belize

Immediately below in the discussion of Blue Creek stratigraphy, and in the "Drought" section later in this chapter, sea level rise is implicated as the probable main cause of sediment influx and soil degradation at Blue Creek during the Late Preclassic through Late Classic Periods. Background information on sea level rise and its relationship to sedimentology is provided in this section.

Lee High (1975) was an influential pioneer in the study of sea level change along the Belize coast, which he undertook as part of a study of geomorphology and sedimentology. He concluded that the most important factor in the formation of the Belizean coastline was the marine transgression (sea level rise) that resulted from post-Pleistocene glacial melting (High 1975:93). High's findings were later refined by other researchers, including Gischler & Hudson (2004) and Toscano & Macintyre (2003). High discussed sea level rise, but did not publish a sea level curve.

Sea level curves can be based on radiocarbon dates on mangrove peat from the intertidal zone (e.g. Halley et al. 1977, Purdy 1974, Shinn et al. 1982, Toscano & Macintyre 2003), or on radiocarbon dates and biological characteristics of coral obtained from reef cores (e.g. Gischler & Hudson 2004, Toscano & Macintyre 2003). Those based on coral are more reliable because it is certain that the evidence (i.e. coral) comes from a primary context (Westphall 1986:69).

Pohl et al. (1996) undertook a program of coring and excavations across northeastern Belize and into Chetumal Bay to investigate ancient Maya wetland agriculture and the issue of sea level rise. They used radiocarbon dates on organic carbon, charcoal, and waterlogged wood obtained from a highly organic regional paleosol to create a sea level curve (Pohl et al. 1996:364). The curve shows a steep 4 m rise between approximately 6000 and 4000 B.C., followed by surface stability that lasted until 1500 B.C. The sea level dropped less than half a meter around 1000 B.C., and has since risen about one meter. The reef core-based sea level curves published by Gischler & Hudson (2004:230) and Toscano & Macintyre (2003:266, 267) do not show these details. However, the three studies agree that there has been a sea level rise of 3 m during the last 7,000 years, including a rise of 1 m during the most recent 3,000 years; and sea level rise is ongoing in the present day.

Rising Water Table

What effects would a rising sea level have had on inland hydrology and geology? High (1975) proposed that the rising sea level resulted in a rise in the water table inland. As explained by Pohl et al. (1996:365), "The freshwater aquifer in northern Belize, as elsewhere in the Yucatán Peninsula...is floating on seawater. Any change in sea level would therefore cause groundwater levels in the interior to rise or fall." Thus, the sea level rise of 3 m during the last 7,000 years corresponds to a 3 m rise in the inland water table (Pohl et al. 1996:365).

Although other factors may influence groundwater levels, sea level seems to be the most important factor. Possible explanations of groundwater rise include two anthropogenic models: "accelerated erosion-induced aggradation of clays that perched the water table...and deforestation-induced water table rise because of reduced regional transpiration" (Luzzadder-Beach & Beach 2009:21). Three natural models have also been proposed: "climatically induced upland erosion, sea-level rise-induced water table rise, and [unlikely and unknown] tectonic-induced water table rise" (Luzzadder-Beach & Beach 2009:21). Erosion is certainly known to have occurred in some locations, including Blue Creek (e.g. Beach et al. 2006), but evidence favors marine transgression as the main factor in water table rise (e.g. High 1975; Gischler & Hudson 2004; Toscano & Macintyre 2003).

Sea level change has impacted the water tables across the Northern Coastal Plain, to a point at least 70 km inland from the coast of the Caribbean Sea, and reaching Blue Creek. On the eastern side of the site, at "the base of the Río Bravo Escarpment, (8-10 msl)...the water table currently resides near the modern surface" (Luzzadder-Beach & Beach 2008:219). The high water table there has implications for agriculture: water is available during the dry season, but may cause waterlogging to the roots of intolerant plants; and the high concentration of dissolved nutrients in the water table may (harmfully) increase the salinity of soil when water evaporates (Luzzadder-Beach & Beach 2008:219).

Water Chemistry and Sediment Aggradation

Sea level rise and concomitant groundwater rise have impacted the chemistry of surface water in Belize since the Preclassic Period (Luzzadder-Beach & Beach 2008:211), causing changes in sedimentation. Bloom et al. (1983) showed that the waters are nearly saturated with calcium carbonate, and also have a high gypsum content. The dissolved minerals tend to precipitate during the dry season (Bloom et al. 1983:419), creating mineral-rich sediment. This fact was exemplified by Julie Stein's (1990) study of the geoarchaeology of the site of San Antonio Río Hondo, Albion Island, northern Belize. She found that the Río Hondo and the groundwater sometimes became supersaturated with dissolved gypsum and carbonates, which precipitated out of solution and led to the aggradation of one meter of mineral-rich sediments on the ancient agricultural fields at the site (Stein 1990:329, 335-336).

Geoarchaeologists Sheryl Luzzadder-Beach and Timothy Beach (2008, 2009) have conducted several studies of soil, soil chemistry, and water chemistry in the Three Rivers Region, and have created a model for groundwater rise and sediment aggradation at Blue Creek. In the Archaic Period, the water table was approximately .8 to 1.7 m lower than it is today (Luzzadder-Beach & Beach 2009:21). Through the first half of the Preclassic Period, the regional soil surfaces were 1-2 m lower than they are today. During the latter half of the Preclassic Period, water tables rose, creating wetlands. Around 2000 b.p., wetland sediments began to aggrade because of flooding, peat accumulation, and gypsum precipitation. "[Water] table rise is the main driver [of sediment aggradation in] the wetlands of the coastal plain because the aggraded sediments here are dominantly composed of gypsum, in which the groundwater is saturated" (Luzzadder-Beach & Beach 2009:1). The ground surface level rose by approximately 1.2 m between 350 B.C. and A.D. 900. Although river flooding, local erosion, and human activity caused some of this aggradation, the chief factor was precipitation of gypsum and calcium carbonate "from a rise in a water table nearly saturated in calcium and sulfate ions" (Luzzadder-Beach & Beach 2009:1, 20-21). This precipitation would have occurred seasonally, due to evaporation and transpiration during the warmer and drier months (Luzzadder-Beach & Beach 2009: 20).

The Stratigraphic Profile of the Laguna Verde Pollen Core, and Blue Creek Stratigraphy

The stratigraphic profile of the Laguna Verde pollen core is described in Table 4. Column one, "Stratigraphic Zone," lists zone numbers utilized in the remainder of this dissertation to refer to the strata. Column two, "Depth of Stratum," gives the measurement (in cm) below the surface of the swamp water of the upper and lower facies of each stratum. It should be noted that Zone 0 consisted only of water, and the upper surface of Zone 1 began 174 cm below the surface of the water. Column three, "Type of Sediment," describes the character of the sediment within each zone.

Table 4. Laguna Verde Pollen Core Stratigraphy.

Stratigraphic Zone	Depth of Stratum (below water line, in cm)	Type of Sediment
0	0-174	Water; no sediment
1	174-193 (top of core)	Fibric peat
2	193-201	Clayey calcareous ooze
3	201-243	Organic-rich calcareous ooze
4	243-272	Highly decomposed sapric peat; occasional gypsum nodules; rocky; granular; probably indicates ongoing Late Preclassic/Early Classic erosion and rising water table
5	272-283	Mineral-rich marl; some organic content; probably indicates the onset of Late Preclassic/Early Classic erosion and rising water table
6	283-289	Woody fibric peat
7	289-291 (bottom of first pipe)	Organic-rich marl
7	291-301 (top of second pipe)	Organic-rich marl
8	301-310	Calcareous marl; high organic content; gooey
9	310-329	Decomposed sapric peat; gooey; very dark
10	329-334.5	Marl with organics

Table 4, Continued.

Stratigraphic Zone	Depth of Stratum (below water line, in cm)	Type of Sediment
11	334.5-362	Poorly decomposed fibric peat; bands of marl, particularly in lower section; 346-362 cm very dark with charcoal content
12	362-373 (bottom of core)	Marl with organics and charcoal

We can see how sea level rise, water table rise, and mineral precipitation and sediment aggradation shaped the stratigraphy near the Blue Creek site. Human hands, in the forms of anthropogenically-caused erosion and the manipulation of the water supply to agricultural fields, also impacted the stratigraphy. In their extended study of the soil and stratigraphy of the channeled agricultural fields east of the Blue Creek site center, geoarchaeologists Tim Beach and Sheryl Luzzadder-Beach found evidence for changes in sedimentation during the Mayan era. Their work can be combined with other archaeological data to fill in the picture of anthropogenically-caused soil change through time, and to look at the ways in which soil change reflected on human society.

Stratigraphic profiles of “polygonal features” (i.e. surfaces of channeled fields) identified a buried paleosol as extending from a depth of approximately 1.1 m to 1.5 m (Beach & Luzzadder- Beach 2003:30, 31). This “buried paleosol is termed the Eklu’um Paleosol, and is a regional occurrence” (Lohse 2003a:6). The Eklu’um Paleosol was rich in organics and could be productively farmed without further modifications (Beach & Luzzadder-Beach 2003:32). It was deposited sometime between 1000 B.C. and A.D. 80, during the Preclassic Period (Beach & Luzzadder-Beach 2003:31-32; Lohse 2003a:6). The Eklu’um Paleosol was the dry, stable ground surface during the Middle Preclassic Period (800-300 B.C.), the time of initial settlement of Blue Creek and nearby sites, and the time of the beginnings of forest clearance near the Three Rivers Region sites of Dos Hombres and La Milpa (Lohse 2003a:10).

Soil stability ended during the Late Preclassic Period (300 B.C.-A.D. 300), when sediment began to bury the paleosol, and the upland *bajos* began to receive sedimentation (Beach & Luzzadder-Beach 2003:31; Lohse 2003a:10). The situation was similar to that in the Petén. Then, during the Early Classic Period (A.D. 300-600), the site of Blue Creek experienced major growth, causing erosion in the uplands at the same time ditched fields began to be constructed in the wetlands (Beach & Luzzadder-Beach 2003:32; Lohse 2003a:10). As sea-level rise led the local water tables to rise between approximately A.D. 80 and 450, erosion, “together with the precipitation of carbonates and other minerals present as dissolved solids in ground water, contributed to the in-filling and aggradation of low-lying wetlands” (Beach & Luzzadder-Beach 2003:32; Lohse 2003a:6). Where the sediment overlying the Eklu’um Paleosol had not been disturbed by modern plowing and pasturing, layers of gypsum-rich marl, striated with “minor flood deposits of limestone sand, and sediments (like gypsum and calcium carbonate) precipitated out of groundwater”, and covered the paleosol (Beach & Luzzadder-Beach 2003:31-32). The constantly-changing landscape may have been seasonally productive for agriculture, but could have posed long-term difficulties (Beach & Luzzadder-Beach 2003:32). As sand and silt built up on a field, it would have buried any rich mulch, and the growing surface would then have become too permeable to hold moisture throughout the dry season (Wilk 1985:50).

During the Classic and Late Classic Periods (between approximately A.D. 450 and 850), as the population peaked and many new upland/hinterland settlements were established, aggradation continued, and the water table rose as much as 150 cm above the Eklu’um Paleosol (Beach & Luzzadder-Beach 2003:32; Lohse 2003a:7, 10). “Maya farmers responded by digging canals to help drain crop lands. These canals gradually in-filled with sediment and were cleaned out again and again; “canal muck” tossed onto adjacent fields provided fertilizer and nutrients for crops” (Beach & Luzzadder-Beach 2003:32). Channeled fields were in widespread use, and fields were terraced on the slopes near residences at Blue Creek and at the nearby sites of La Milpa and Dos Hombres (Guderjan et al. 2003:80, 81; Lohse 2003a:10). This type of intensive farming probably required a heavy labor input. It may also eventually have had diminishing returns. To the east of the Three Rivers Region, at the site of San Antonio Río Hondo, northern Belize, canalization of wetland fields was shown to have caused salt accumulation in the soil; this resulted in sodium accumulation that may have hindered the growth of salt-sensitive crops like maize and beans (Bloom et al. 1985:21, 29, 30).

The stratigraphy of the Laguna Verde pollen core (Table 4) did not include a layer of Maya clay, like the Petén lakes have. Nor did it include an Eklu'um Paleosol. These differences in the character of the Laguna Verde sediments are probably due to the differences in the local depositional environment of the swamp. Any erosive soil from outside the laguna would have been deposited in tandem with carbonaceous sediment derived from the detritus of the endemic swamp vegetation; the high organic content of the peat that formed would have masked the presence of any inorganic clay. The stratum from 283 to 272 cm below water level was richer in mineral content than other strata. The overlying stratum, from 272 to 243 cm below water level, consisted of highly decomposed sapric peat, with occasional gypsum nodules, and an overall rocky and grainy texture. These two strata probably represent the period of upland erosion, rising water levels and periodic flooding, and mineral precipitation that took place in the Blue Creek area during the Late Preclassic and Early Classic Periods, as noted by Beach & Luzzadder-Beach (2003; above).

While the strata from 243 to 221 cm and from 221 to 201 cm below water level were rich in both organic matter and in calcareous minerals, most of these zones (from 225 to 202 cm) contained only a statistically insignificant quantity of pollen. This barren pollen stratum can be compared to the barren pollen strata concomitant with the deposition of Maya Clay at Lakes Quexil, Sacnab, and Macanche. At Laguna Verde, the barren pollen stratum may signal continuing upland erosion along with rapid accumulation of vegetative detritus in a reductive environment that was not conducive to pollen preservation. The period in which these strata accumulated may have been the same Late Classic Period span for which Beach & Luzzadder-Beach noted ongoing aggradation and heavy farming. Further radiometric dating of samples from the Laguna Verde core could confirm this correlation. Unfortunately, the pollen record was unable to demonstrate a peak in the pollen of cultigens at that time.

These strata were followed by the deposition of a third stratum of low organic content, this time clayey and calcareous, extending from 201 to 193 cm below water level. Strata with low organic content can indicate rapid sedimentation rates (Cowgill et al. 1966:19), deposition in a plant-free environment (unlikely in this swamp), or deposition in an environment that was destructive to organic matter. If the environment were relatively dry at the time of deposition of this stratum, vegetative matter may have fallen onto exposed surface sediment and weathered away, instead of being preserved in the anoxic underwater environment of the wet swamp of today. Pollen samples from this stratum show a reduction in some of the relatively mesic types (such as *Typha*, *Myrica cerifera*, and rain forest taxa), and peak abundances of types that may indicate a dry or open savanna environment (such as Poaceae and Asteraceae; but see Bush 1995 and Bush 2002). Could this stratum represent a drought during the Terminal Classic Period? Additional radiometric dating could help to answer this question by proving the age of the stratum. Later in this chapter, a study of Blue Creek hydrology investigates the possibility of drought.

RAW MATERIALS AND EXTERNAL TRADE

For the Blue Creek site to have been suitable for long-term occupation by a dense population, it must have provided the Maya with local access to the means of production of necessary and desirable goods. Furthermore, trade with non-local communities from which locally unavailable materials and goods could be obtained must have been possible. Both points prove true, as this section demonstrates. The trade system is briefly introduced, and a short survey is made of both the locally-available (non-vegetative) raw materials, and the raw materials that were acquired through trade external to the Three Rivers Region.

The Riverine and Coastal Trade System

The situation of the Blue Creek site near three rivers is important not only because it offered access to the river water itself, but also because the rivers were trade routes for the ancient Maya. Items that did not occur naturally in the local environment had to be obtained through trade. The Blue Creek site is situated at the terminus of a riverine and coastal trade system that extended from western Belize along Río Azul and Río Hondo, to the Caribbean coast. Because Blue Creek is located at the westernmost navigable point along the Río Hondo, trade goods may have been transported overland from Blue Creek to inland Belize and to the Petén (Barrett 2004:296). Blue Creek has a stone dock, weir system, and dam feature on the Río Azul that could have been employed as a port facility or for trade purposes (Barrett 2004:75, 99-100; Guderjan et al. 2003:88).

Through the riverine and coastal trade system, inhabitants of Blue Creek obtained stone tools, granite, obsidian, jade, marine shell, basalt, and other items, offering agricultural products and forest products in exchange (Guderjan et al. 2003:88-90). Agricultural products were probably produced for export in the expansive ditched fields near the Chan Cahal residential cluster at the base of the Bravo Escarpment (Guderjan et al. 2003:87, 88). Other exports may have included non-food products reaped from the upland forests, like mahogany, copal, animal products such as pelts and feathers, and wild or cultivated cacao (Barrett 2004:132, 294; Guderjan et al. 2003:87).

Archaeologist and lithicist Jason Barrett felt that the deficiency in critical material resources at Blue Creek, combined with the site’s strategic position on the riverine and coastal trade route, gave Blue Creek a strong need to integrate into regional exchange networks. The site’s ability to “draw resources in substantial quantity from distant source zones” served to integrate the site into the circum-Caribbean exchange network, and gave the site importance in that system (Barrett 2004:296). The maintenance of these networks required a high level of intra- and inter-regional elite interaction (Barrett 2004:131). However, not only elites, but also individuals with entrepreneurial interest, probably participated in the trade network (Barrett 2004:293-294).

Details on locally-available and imported mineral resources are given below, in the section “Mineral Resources.” The issue of trade is further addressed in the section “Adaptations to Drought.”

Mineral Resources

While some mineral resources occurred naturally in the Blue Creek area, others were imported from outside the region. Easily quarried and nearly ubiquitous, limestone was the primary construction material of the Maya (Coe 2005:22). At Blue Creek, consolidated limestone for use in building construction was available above the Bravo Escarpment, but was found only in limited locations below the escarpment, “possibly lending to the general lack of masonry architecture among settlements below the escarpment” (Barrett 2004:90). This issue exemplifies the resource diversity (which could, in this case, be perceived as a disparity) within one sociopolitical community scattered across an ecotone, and also demonstrates that locally-available environmental resources influence the development of material culture. At Blue Creek, the local limestone was also used for making ground stone tools, such as *manos, metates,* bark beaters, and stucco polishing stones (Barrett: 2004:108; Guderjan 1991:49). Some of these ground stone tools were also made from local dolomite and quartzite, while others were made from imported basalt and granite (Barrett 2004:108). Granite was obtained through trade from its source in the Maya Mountains of central Belize (Coe 2005:22; Guderjan 1991:49; Yaeger 1991:92).

Chert, for manufacturing flaked stone tools, ranked high in importance among the locally-available raw materials. No sites of chert procurement or intensive stone tool production have yet been identified in the Northern Coastal Plain portion of the Maya Research Program permit area (Lohse 2003a:5, 2003b:12, 15). However, chert deposits are found outcropping from their limestone beds in the Eastern Petén Zone, which has “an abundance of sites reflecting intensive, perhaps specialized, lithic craft production”

(Lohse 2003a:10; Coe 2005:22). A number of chert outcrops exist near the Rosita settlement cluster and near the Dumbbell Bajo (Barrett 2004:396). Tool-quality chert also occurs naturally in some of the local waterways, including Chan Chich Creek (=upper Río Bravo), Río Bravo itself, and intermittent streams near the site of La Milpa (Lindeman & Guderjan 1991:95). The chert found within the Blue Creek settlement zone is coarse-grained and therefore of less-than-ideal quality for use in tool manufacture; the chert would have required thermal alteration before it could be worked, and the resulting tools would not have had sharp or durable edges and would have been difficult to recycle (remanufacture) into new forms (Barrett 2004:132, 292). Better, fine-grained chert and chalcedony can be found further afield, in the *bajos* west of Blue Creek, and in the northern Belize chert-bearing zone east of New River (Barrett 2004:59, 292). Additional chert could have been procured from the savannas of southern Belize, where there are large outcrops of chert, with which debitage and stone tools have been found (Hammond & Miksicek 1981:264). Archaeologist Jason Barrett's survey of outcrops in the Maya Research Program permit area, combined with his study of lithic materials recovered from the Blue Creek site, led him to conclude that Blue Creek obtained more than half of its stone tools through trade (Barrett 2004:130-131, 297).

Clay for ceramic production may have been harvested from the *bajos* near Blue Creek (Clayton 2003:82).

In addition to basalt, granite, chert, and chalcedony, other mineral resources were imported into Blue Creek, including obsidian, salt, and jade. Obsidian was sought from the volcanic areas of the Maya Highlands (Coe 2005:22). Salt was panned in the lagoons of the north coast of the Yucatan Peninsula and at the inland mineral springs near the Pacific Coast (Coe 2005:23), and may have been imported into Blue Creek. Green jade, a sumptuary good, "occurs as pebbles and boulders in the river deposits" of Río Motagua in the highlands of southern Guatemala (Coe 2005:23). Items carved from jade have been recovered from Blue Creek, in both elite and (less frequently) commoner contexts. That commoners possessed this sumptuary good indicates that the people of

Blue Creek were probably well-to-do, at least until jade imports nearly ceased during the 6th century A.D. (Barrett 2004:130, 132).

Gold and silver have no natural source in the Maya Lowlands, and they were unknown there until A.D. 800 (Coe 2005:22).

Non-Mineral Resources and Imports

Blue Creek imported some other raw materials that were not of mineralogical origin. In addition to jade (mentioned above), important sumptuary articles for Maya elites included marine shells and, possibly, feathers. Marine shells and sponges were imported into Blue Creek from the lagoons along the Caribbean Sea, 100 km downstream on the Río Hondo (Guderjan 2004:238; Coe 2005:23). This example demonstrates Blue Creek's participation in long-distance trade. Tail feathers from the quetzal bird may have been sought from the southern highlands, until the bird was hunted to near-extinction by the 9th century A.D. (Coe 2005:23), although no quetzal feathers have been recovered from Blue Creek.

Copal, a resin derived from the tree *Protium copal*, was produced in large quantities on the southern coast of Quintana Roo, Mexico (Guderjan 1991:45). The tree also grows at Blue Creek, so copal could have been produced and even exported from the site. Copal nodules were found at Chan Chich, a large center approximately 50 km southwest of Blue Creek along the Río Bravo (Guderjan 1991:45).

HYDROLOGY

Water is a resource crucial to sustaining human life, not only for drinking, but also for watering crops, navigating trade routes, obtaining marine or riverine resources, and (hopefully) bathing. Throughout the Maya Lowlands, there are few permanently flowing rivers or other means of surface drainage (Coe 2005:17; Hall & Pérez Brignoli 2003:58; Sanabria 2007:42). Lakes are rare, rainfall is unreliable, and the temperatures run hot (Coe 2005:17). Thus, thirst can be a serious problem (Coe 2005:17). Lacking modern plumbing systems, the ancient Maya must have sought to establish their settlements in proximity to a good water source that could be used to suit multifold human purposes. In times of dense human populations, people probably exploited all areas located near sources of potable water (Brenner et al. 2002:151). People would not prefer to establish a long-term settlement in a place where insufficient water was available or where they were not able to use water to meet their needs.

This chapter addresses the water budget of the Blue Creek Maya. The purpose of this section is to demonstrate that the hydrological regime of Blue Creek made an important contribution to the habitability and cultivability of the site; changes in the stability of the hydrological regime may have caused significant problems for ancient Mayan society. First, the local climate is addressed, to get at moisture input in the form of rainfall, and to note aspects of potential instability in the climatic and hydrological regimes. Next, output of the hydrological system is addressed, beginning with a discussion of permanent rivers in the Blue Creek area. The subsurface drainage system of karst topography is then explained. Sources of standing water used, or constructed, by the Maya (including *aguadas, bajos, cenotes, chultuns,* and *civales*) are defined. The notion of a Terminal Classic Period drought is considered as a factor contributing to the Maya Collapse. Finally, strategies for water management employed by ancient Maya farmers are considered, along with adaptations of the leadership to drought.

Where Does the Water Come From? The Climate of Blue Creek

If the Blue Creek area were suitable for long-term occupation by a dense human population, aspects of the climate must have been favorable for settlement and for agriculture. Any disruptions in some element of the local climate (e.g. fire, drought, hurricane) could have failed to support a group's relatively long-term settlement; could have made the location dangerous for people; or could have undermined the agricultural system too frequently or made agriculture impossible. Here, the stability (or instability) of the climate of Blue Creek is examined. "Climate" includes such factors as precipitation, humidity, temperature, winds, and general weather patterns. The focus in this section is placed on inputs to the areal water budget.

The risk of a catastrophic natural disaster striking Belize is relatively low, with hurricanes providing the greatest risk. From June through November is the season during which tropical storms and hurricanes strike Belize (International Travel Maps 2004; Hall & Pérez Brignoli 2003:18). Belize City has been destroyed by hurricanes, most recently in 1931 and 1961 (Hall & Pérez Brignoli 2003:24). Flooding of the Northern Coastal Plain sometimes results from hurricanes (Luzzadder-Beach & Beach 2009:21). A flood during the Late Preclassic Period caused 9 cm of sediment aggradation in the Three Rivers Region, and this may have been caused by a hurricane strike (Luzzadder-Beach & Beach 2009:21).

On a scale of 1 (minimum) to 5 (maximum), the Blue Creek area has an earthquake or seismic risk of 2 (Hall & Pérez Brignoli 2003:25). No major earthquakes are known to have struck Belize (Hall & Pérez Brignoli 2003:25). No active volcanoes exist in Belize (Hall & Pérez Brignoli 2003:25).

The Northeast Trades are the prevailing winds in Belize and the rest of Central America (Hall & Pérez Brignoli 2003:18). They bring precipitation to the Caribbean slope (Hall & Pérez Brignoli 2003:18). Over the long term, the Maya area passes through climatic macrocycles that bring varied levels of hot or cool temperatures, and of wetness or dryness (Gunn et al. 2002:80). Each year of drought can be accompanied by different events, such as plagues of locusts that eat milpa crops and urban ornamental plants (Gunn et al. 2002:80). Each long period of cool temperatures impacts the length and timing of the growing season, as well as the nature of pollen production and dispersal (Gunn et al. 2002:80). Though the entire Maya area has a tropical climate, average temperature and land use change with altitudinal zones (Hall & Pérez Brignoli 2003:19). For example, tropical crops like bananas, cotton, and cacao are grown near sea level; subtropical crops like coffee are grown in the intermontane valleys; and temperate crops like wheat and potatoes are grown in the cooler lands in the mountains (Hall & Pérez Brignoli 2003:19). All parts of the Maya area typically receive enough rain to support unirrigated agriculture for at least part of the year (Hall & Pérez Brignoli 2003:18).

Annually, the Maya area also passes through climatic macrocycles that bring wet and dry seasons. Belize has a subtropical climate, with alternating wet and dry seasons. The amount of rainfall, and the onset and duration of the wet season, is highly variable in northern Belize (King et al. 1992:2). The dry season, driven by the Bermuda-Azores high pressure system, generally lasts from February through May (Balick et al. 2000:1; Standley & Record 1936:12). Winds, usually coming from the southeast, are strongest during the dry season; they stir up lots of pollen, aggravating allergies, at the beginning of the dry season (Hall & Pérez Brignoli 2003:18). The hottest months arrive during the dry season and continue into the wet season, lasting from March through September (International Travel Maps 2004). The double-peaked wet season generally lasts from June through October, and light rains continue until January (International Travel Maps 2004; King et al. 1992:21). Winds come mainly from the east during the wet season. During the winter, "Northers," or cold, wet air streams originating in the Arctic, sometimes accompany heavy showers, and these can be damaging to crops (King et al. 1992:20).

In the Maya area, rainfall decreases from south to north and west (Coe 2005:18). Within the country of Belize, annual precipitation is greater to the south of the central Maya Mountains than to the north, and greater inland than on the Caribbean Coast (Balick et al. 2000:1; Standley & Record 1936:12-13). The rainfall differential impacts the vegetation: south of the Maya Mountains, the forests grow taller and support a greater number of evergreen species (Balick *et al*. 2000:3). However, no area within Belize is too dry or too cold to support plant life (Hall & Pérez Brignoli 2003:26). Far northern Belize, the location of the Blue Creek site and point of origin of the Laguna Verde pollen core, is the driest part of the country, receiving between 1300 and 2000 mm (less than 70 in) of annual precipitation (Cubola Productions 1990:25; King et al. 1992:35).

Northern Belize, along with 75 percent of Central America, is considered to be humid (as opposed to arid; Hall & Pérez Brignoli 2003:23). Belize has an average humidity of 75-80 percent (International Travel Maps 2004). The mean relative humidity in Orange Walk District is higher, at 80-88 percent (King et al. 1992:23).

"Net gain (storage) of groundwater occurs in the wet season…whereas net loss (depletion) occurs in the dry season" as groundwater is drawn off by the rivers and by evaporation (Turner & Harrison 1983:17). Having addressed the input into the water budget as an aspect of climate, we now turn to the system output.

Where Does the Water Go? Permanent Rivers

Some of the water input of a system is always lost to evaporation. That which remains on, or in, the ground must move somewhere else (generally toward and ocean, or deeper into the ground), or be stored in place. Although there is little surface drainage in most places in the Maya Lowlands (Hall & Pérez Brignoli 2003:58; Sanabria 2007:42), "northern Belize is characterized by surface, as well as subsurface, drainage" (Turner & Harrison 1983:17). First, surface drainage is addressed here. Fortunately, unlike other places in the Maya Lowlands (such as the more arid northern Yucatan), Belize has several major rivers. Rivers are among the strategic resources of the Blue Creek area, providing access not only to water but also functioning as routes for trade and transportation. Northern Belize is geologically folded, and the rivers flow along asymmetrical synclines (Hammond & Miksicek 1981:261). Blue Creek (as pictured in Figure 3, Chapter I) is located in what has been called the "Three Rivers Region" after the three rivers that form its boundaries (Río Azul, Río Hondo, and Río Bravo; Clayton 2003:81). The site center is situated near the confluence of the Río Bravo and the Río Hondo (Neivens 1991:51). The waterway that gives its name to the site (i.e. Blue Creek) joins Río Bravo to become the Río Hondo, which flows into Chetumal Bay on the Caribbean Sea. Along its way to Río Bravo, Blue Creek runs through several deep canyons, including one where the river crosses the Bravo Escarpment (Guderjan 2004:235-236). Vestiges of the population that abandoned the Blue Creek site (and many other sites in the Three Rivers Region) during the Late and Terminal Classic

Periods resettled along the Río Hondo during the Postclassic Period (Clayton et al. 2005:120; Guderjan 2006:2).

Other water sources proximate to the Blue Creek site include a chain of five lakes 4 km to the southeast; a natural spring (arising from the base of the Bravo Escarpment) and an *aguada* .5 km to the east; and a *cenote* (now dry) .5 km to the southwest (Neivens 1991:51). A ramp was artificially constructed for the transport of water from the *cenote* to the site's center (Neivens 1991:51). *Aguadas, cenotes,* and other water sources available in the Maya Lowlands are discussed below.

Where Does the Water Go? Subsurface Drainage and *Cenotes*

In the karst topography of Belize, Petén, and the Yucatan Peninsula as a whole, water eats its way through the limestone bedrock, causing the limestone to go into solution, and creating a cavelike subsurface drainage system. When a section of limestone and overlying sediment collapses, a basin is created for the permanently-exposed water table. This is called a *cenote*. Thus, *cenotes* are circular, perennially-filled sinkholes. In addition to *bajos, cenotes* are the most important sources of standing water in the Yucatan Peninsula.

Because the Yucatan is dry and stony, it was important for the ancient Maya to locate their settlements near *cenotes* so they could obtain water for drinking and bathing (Coe 2005:17, 194). *Cenotes* have always "served as focal points for native settlement" (Coe 2005:17). Examples of archaeological sites located near *cenotes* include many Mayan sites in Cayo District (Healy et al. 1983:400). At Postclassic Period Chichen Itza, the cult of the Sacred Cenote, or Well of Sacrifice, was alive; people and objects were ceremonially thrown into *cenotes* as sacrifices to the Rain God (Coe 2005:188-189). Several *cenotes* have been found near Blue Creek, including Crocodile Lake near the Rosita settlement cluster; Blue Lake 3.5 km south of the site center; and *cenotes* west and east of the site core (both above and below the escarpment; Barrett 2004:84). A dry *cenote* was also located half a kilometer southwest of Blue Creek (Neivens 1991:51), and final *cenote* was found near the Sak Lu'um residential cluster to the southeast (Guderjan et al. 2003:87).

Standing Water: *Bajos* and *Civales*

Bajos and *cenotes* (above) are the main sources of standing water in the Yucatan Peninsula. Both lack surface drainage outlets. Near the Blue Creek site, large *bajos* (such as the Dumbbell Bajo, northwest of the site) are found west of the Bravo Escarpment, in the Eastern Petén Zone of northwestern Belize. To the east, at the bottom of the Bravo Escarpment, are ditched agricultural fields and small *bajos* that may have also been used for agriculture (Guderjan 2004:237).

Bajos are broad wetland depressions that fill in summer, but often dry out during the dry season. More technically, *bajos* are "perched depressions lined with residual, partly alluvial clays and are only inundated during the rainy season" (Rice et al. 1985:91). In this case, "perched" means that the *bajos* drain very slowly into an underground aquifer. The dominant plant taxa within a *bajo* may vary from that of the surrounding uplands. For example, in the Mirador Basin of northern Guatemala, forest height in the *bajos* is lower than in the surrounding uplands, and the dominant species is *Haematoxylon campechianum* (logwood; Hansen et al. 2002:277).

Some believe that the *bajos* were once perennial wetlands, known as *civales,* but ongoing sedimentation related to Maya occupation from Early Classic through Terminal Classic times converted the *civales* into seasonally-inundated depressions, or *bajos* (Lohse 2003a:4). Richard Hansen and colleagues studied the *civales* that occur in some of the *bajos* of the Mirador Basin, and found evidence in favor of this hypothesis. They noted that *civales* (defined as "treeless, wet areas of herbaceous vegetation") stay wet during the dry season, while other areas in the *bajos* dry out two months after the end of the rainy season (Hansen et al. 2002:277). This study suggests that the Mirador Basin used to be dominated by "a major, mature lacustrine system consisting of wetland marshes" because the most humid areas of the *bajos* today contain stands of plants typically associated with larger lacustrine systems, *Bravaisia tubiflora* and *Pachira aquatica* (Hansen et al. 2002:280).

Many natural water holes are found in the Mirador Basin *civales,* so the *civales* may have been attractive to Preclassic settlers, who made use of the permanent water sources, wildlife, fiber sources, organic soils, and defensive functions they provided (Hansen et al. 2002:277-278). The Mirador Basin *civales* underwent heavy sedimentation at the end of the Late Preclassic (ca. A.D. 150; Hansen et al. 2002:287). Production of lime and stucco may have caused deforestation in the uplands, causing upland soil and clay to erode and be redeposited on the *civales,* burying the suitable agricultural surface and leading to the depopulation of the area (Hansen et al. 2002:287-288). A large storm or hurricane could also have contributed to the infilling (Hansen et al. 2002:288). Today, the forest-type vegetation of the *bajos* seems to be encroaching on the Mirador Basin *civales*, "suggesting an evolutionary sequence of change from marsh to forest as the *civales* become filled by sediments" (Hansen et al. 2002:278). The process seems to be in place today (Hansen et al. 2002:289), suggesting that people continue to affect their environment by causing erosion that contributes to the in-filling of the *civales*.

Not every archaeologist believes that *bajos* are, essentially, silted-in lakes. In the 1960s archaeologist Ursula Cowgill, who studied the Petén lakes with palynologist Matsuo Tsukada, took issue with that idea, but most other palynologists and paleolimnologists disagree with Cowgill (Pohl 1985:5).

The ancient Maya are believed to have planted dry-season crops in the *bajos.* This idea is further explored in Chapter IV.

Standing Water: *Aguadas*

Seasonally-inundated depressions smaller than *bajos* are called *aguadas* (Coe 2005: 17; Dunning et al. 1998b:142). These can be natural or artificial, and sometimes served as reservoirs or water holes for the ancient Maya. A drawback to the use of the *aguadas* as reservoirs is their potential to harbor bacteria. In the Mirador Basin *aguadas,* "[as] the water recedes during the dry periods, the concentrations of coliform and *Escherichia coli* become significant" (Hansen et al. 2002:275).

Some archaeological sites suggest uses of *aguadas* by the ancient Maya. For example, pollen from *Zea,* and other grasses, from an artificially-constructed *aguada* near the site of Nakbe (in the northern Petén) suggested that the area was cleared and used for agriculture between A.D. 680 and 840 (Hansen et al. 2002:283). A plaza at the major ceremonial center site of El Posito (in northern Belize) was located near an *aguada* (Pring 1975:Figure 6.1), though no agricultural (or other) use of the *aguada* was suggested in the report. There is also an *aguada* in the middle of the Cuello site, also in northern Belize (Wilk 1975: Figure 8.2).

Seasonally flooded land along the margins of *aguadas* and lakes, known as lacustrine wetlands, provide an ecological niche that could have been farmed in the dry season by the ancient Maya without archaeologically-visible modifications (Guderjan et al. 2003:81).

***Chultuns*: Artificial Reservoirs?**

What could the ancient Maya do when lakes, rivers, and *cenotes* were inaccessible or insufficient to store fresh water for the community? Sometimes they built a *chultun* (pluralized as *chultuns, chultunob,* or *chultunes*). *Chultuns* are bottle-shaped chambers or pits dug out of limestone marl floors or surfaces (Coe 2005:56). *Chultuns* are found throughout the Maya area. In the northern Maya area, some occurred naturally (as part of the karst topography) and functioned as deep cisterns. These were attractive to the ancient Maya as water-storage facilities.

Most *chultuns* did not occur naturally, but were artificially excavated into the limestone bedrock, dug out with stone tools (Puleston 1965:24; 1971:322-324). In the northern Maya area, some *chultuns* were lined with stones and plastered walls, and could have been used for water storage (Puleston 1971:322-324). The Puuk Maya of the Yucatan built their *chultuns* to collect drinking water during the dry season (Coe 2005:166).

In the southern Maya area, *chultuns* had as many as nine lateral chambers and platforms, and only occasionally were modified with stone-lined and plastered walls and floors (Puleston 1965:24; 1971:322-324). The southern-style *chultuns* were probably not used to store water, since they were abundant in areas that already had other water sources, their shapes were not conducive to water collection, and most were unplastered and therefore not water-tight (Puleston 1965:29; 1971:325). At Blue Creek, at least one *chultun* was constructed in the southern fashion (Driver 2003:71).

What purposes could the *chultuns* have served, if they were not used to store water? Beyond water storage, the functions of the *chultuns* for the ancient Maya are uncertain, and there has been much speculation on this subject (Puleston 1965:24). By the time of the first ethnographic reports mentioning the *chultuns* were written in the 19th century, no living Mayas were using the *chultuns* (Puleston 1971:322). A small percentage of archaeologically-explored *chultuns* have been used to house human burials (Clayton 2003:87; Puleston 1965:29). *Chultuns* at Blue Creek were used as tombs at the end of the Late Preclassic Period (Guderjan 2004:247).

Chultuns may have served as places to store food. In the Yucatan, crops are known to have been stored in wooden cribs above ground, and also in underground places, perhaps *chultuns* (Coe 2005:204). The high humidity inside the *chultuns* would have promoted food spoilage (Puleston 1971:329). Experimental archaeologist Dennis Puleston (1971) observed that foods most foods, with the exception of ramón seeds, went bad when stored in *chultuns.* The ramón may have survived because its naturally low moisture content made it resistant to attack by fungi in the humid environment (Puleston 1971:332). Charles Miksicek and his co-workers later repeated Puleston's experiment and also found that, while most stored food spoiled in a few weeks, ramón seeds were still edible after being stored in *chultuns* for five months (Miksicek et al. 1981:918; Pohl & Miksicek 1985:14). Miksicek also found that maize and tubers (including *Xanthosoma*, *Dioscoria*, and *Manihot*) were edible after storage (Pohl & Miksicek 1985:14).

Alternative functions of *chultuns* may have included housing sweat baths; storing non-food objects; and caching (Coe 2005:56). The limestone excavated from the pits could have been used in construction (Coe 2005:56).

Archaeological findings demonstrate the variety of uses of *chultuns.* From Late Preclassic Cuello, Belize, came two sealed *chultuns* containing carbonized plant remains (Hammond & Miksicek 1981:267). One was used for food storage (or perhaps for the disposal of charred food remains) and was later converted to a water cistern, and finally was filled with trash (Hammond & Miksicek 1981:268). At Tikal, Guatemala, more than 280 *chultuns* were found, perhaps one for every household unit (Puleston 1965:26). Most were sealed with limestone covers, and many entrances were surrounded by post molds, suggesting that they were covered with structures, perhaps to keep out vermin and rain (Puleston 1965:26). These must have been used for storage.

Two *chultuns* were found at the site of La Milpa, which was explored by the Río Bravo Archaeological Project in the late 1980s (Guderjan 1991:25). One had a masonry wall separating an interior room from the main chamber, and small niches dug into a bedrock wall; it was probably used for mortuary purposes (Guderjan 1991:25). The other was constructed in the “northern” fashion, and was probably used to store water (Scarborough et al. 1995:109). La Milpa had a comprehensive water management system, including four drainages, several reservoirs, and numerous check dams to carry water away from the core site and to retain soil moisture (above the dams) to increase agricultural productivity (Guderjan 1991:25; Scarborough et al. 1995).

Five *chultuns* are known from the site of Chan Chich, which is situated on the Río Bravo not far from Blue Creek (Guderjan 1991:35). Its location is pictured in Figure 7 of this chapter, along with the locations of other Belizean archaeological sites mentioned in the text. Chan Chich has multiple water sources, including the river, a seasonal creek, two *aguadas*, and *bajos* (Guderjan 1991:35).

Southwest of the Blue Creek site center, a *chultun* was located at the center of the courtyard at a settlement cluster called U Xulil Beh (Driver 2003:65, 71). The *chultun* “had been constructed in typical Southern Lowland style”, with an oval entrance shaft,

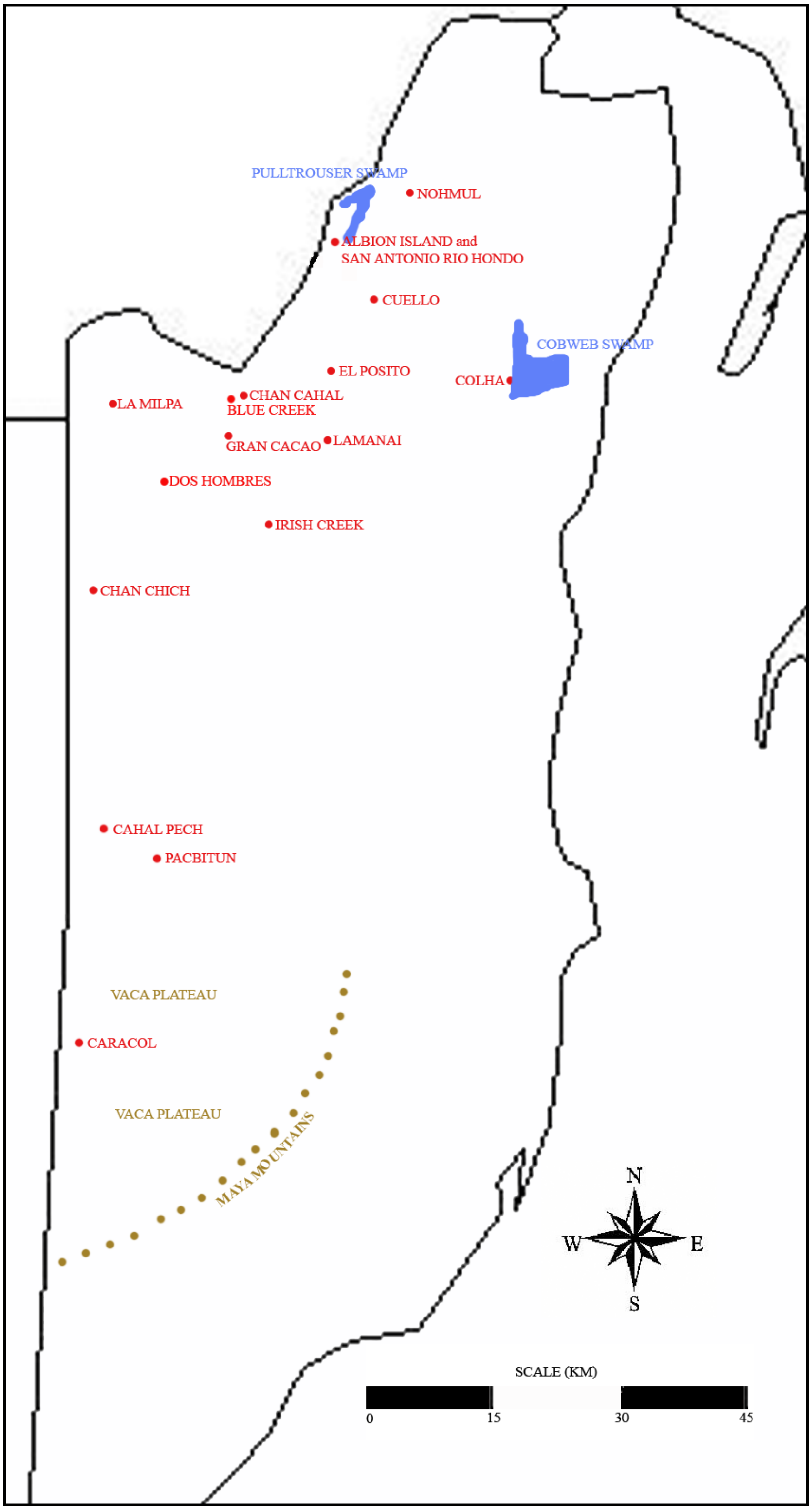

Figure 7. Belizean archaeological sites and locations discussed in the text.

an entrance chamber, and a lower main chamber (Driver 2003:71). It was partially filled with soil and redeposited structural fill, but contained no artifacts in their primary contexts (Driver 2003:71). At Rosita, northwest of the Blue Creek site center, another *chultun* was found (Clayton 2003:87). It had a deliberately-created entranceway and an inner edge lined with medium-sized boulders, but no certain artifacts (Clayton 2003:87). The *chultun* was too humid inside to have been used for food storage, unless deliberate fermentation was desired (Clayton 2003:87).

DROUGHT, SOIL DEGRADATION, AND THE MAYA COLLAPSE

The purpose of this section is to define the "Maya Collapse" and to assess the role drought and soil degradation may have played in this process. I question whether there was environmental stability in the Blue Creek area throughout time, and whether human adaptations to any environmental instability were likely to have contributed to the abandonment of the Blue Creek site. Finally, I seek factors, beyond drought, for the Maya Collapse throughout the Maya area and at Blue Creek in particular.

The "Maya Collapse"

The process by which Mayan civilization lost its dominance and prevalence in parts of the Maya area is called the "Maya Collapse." The grand downfall of Maya civilization took place during the Terminal Classic Period, which lasted roughly from A.D. 800 to 925 (The term "Late Classic" refers to the period from A.D. 600 to 900, and "Terminal Classic" refers to the final 100 years of that period.).

Mayan archaeological sites figuring into the discussion of the Maya Collapse, as well as the remainder of this dissertation, are mapped in Figures 6, 7, and 8. The Maya Collapse seems to have affected most strongly the people who lived in the humid southern Maya Lowlands, including eastern Tabasco, the Lacandón Forest of Chiapas, southern Campeche, southern Quintana Roo, the Petén, and parts of Belize; much of coastal and northern Belize remained unaffected (Hall & Pérez Brignoli 2003:58; Johnston 2003:142). During the first half of the 9th century A.D., the southern Maya are

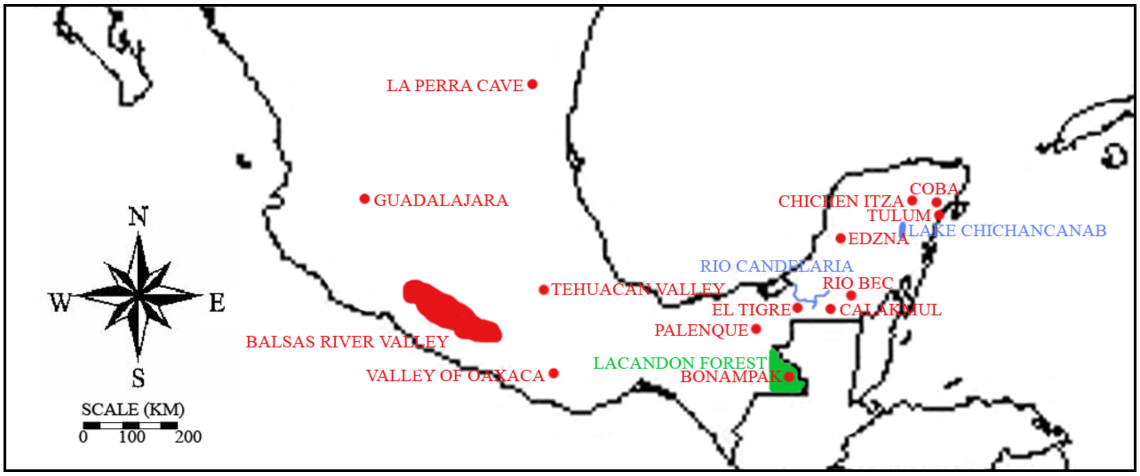

Figure 8. Mexican archaeological sites and locations discussed in the text.

believed to have suffered from drought, warfare, demographic decline, and a loss of cultural complexity (Dahlin 2002:327). During the Collapse, the Maya population is thought to have been reduced by as much as 90 percent (Johnston 2003:142). Resulting from the Collapse, cultural elements (such as special knowledge, mythology, and ritual) of the royalty and elite scribes were lost for all time (Coe 2005:163). Archaeological evidence of population losses or movements, such as cessation of construction, termination rituals, and abandonment of cities, is particularly strong.

The people who survived the collapse of the southern lowlands mostly moved out of the cities, instead wandering and camping in the forests (Coe 2005:163). Some of the people may have moved north into the Yucatan, or south into the Chiapas highlands, though this is uncertain (Coe 2005:164). Not all the Lowland Maya centers suffered decline or abandonment; cities like Tayasal (in Petén) and Lamanai (in Belize) were founded and/or expanded after the Collapse (Coe 2005:199). Some house-groups at Copan, Honduras, also survived (Barrett 2004:51).

Meanwhile, Maya influence increased on the Gulf Coast and in the central highlands of Mexico (Coe 2005:161). There was no decline or abandonment in the northern lowlands (i.e. the northern Yucatan Peninsula), where invasion by Toltec warriors from central Mexico ushered in the Postclassic Period in A.D. 987 (Coe 2005:161, 166). The Toltec took over the Yucatan and established their capital city at Chichen Itza (Coe 2005:173, 179). Maya settlements on the northern plains of the Yucatan and in the Puuc hills grew and flourished under the empire of Chichen Itza until A.D. 950-1100 (Dahlin 2002:327). The sites of Cobá and Tulum (in Quintana Roo) were founded during the same time (Coe 2005:161). Chichen Itza was abandoned in A.D. 1224, and the Toltec seem to have disappeared (Coe 2005:192).

During the Postclassic Period, the main Maya settlements were in the northern lowlands and in the highlands (including most of Chiapas, southern Guatemala, southwestern Honduras, and El Salvador; Hall & Pérez Brignoli 2003:58-59). The southern lowlands were never significantly repopulated by the Maya or by the Spanish *conquistadores*; much of the southern lowlands remained unoccupied for nearly a thousand years after the Collapse (Hall & Pérez Brignoli 2003:59; Johnston 2003:142).

The Collapse at Blue Creek

During the Early Classic Period, Blue Creek was a politically independent city ruled by its own local dynasty (Guderjan 2004:242, 247). The erection of monumental architecture was at its height, and wealth and power were displayed through the accumulation of elite goods (Guderjan 2004:242). By the Late Classic Period, things had changed. The population continued to grow, as indicated by the proliferation of non-elite housemounds above the Bravo Escarpment, expansion of elite courtyards in the site core, and conversion of civic-ceremonial space into residential space in the site core (Barrett 2004:118; Guderjan 2004:242). However, there were few large-scale constructions (Guderjan 2004:242), perhaps signifying that the local rulers were no longer able to command the labor of their citizens. Possible termination rituals were conducted at some elite residences and at a pyramid known as Structure 3 during the Terminal Classic Period (Guderjan 2004:248). Blue Creek was abandoned around A.D. 900 A.D. (Guderjan 2004:235, 248).

Changes in the settlement patterns in the Blue Creek the Three Rivers Region were afoot during the Late Classic Period, with alterations in which sites and residential clusters experienced growth vs. stagnation and the establishment of many new upland/hinterland settlements (Lohse 2003a:10, 2003b:14). Perhaps new settlements were placed so as to provide easier access to land open for agriculture. Channeled agricultural fields were in widespread use during the Late Classic, and fields were terraced on the slopes near La Milpa and Dos Hombres (Lohse 2003a:10), suggesting that there was a need for agricultural intensification at that time. In addition to Blue Creek, other sites in the Three Rivers Region were abandoned. Gran Cacao, a center nearly as large as Blue Creek, was occupied from the early Middle Preclassic until abandonment in the Late Classic or Early Postclassic (Lohse 2004). Chan Cahal, the hinterland settlement with the longest continuous occupation of a residential cluster in the region, was occupied from the Middle Preclassic (1000-800 B.C.) until abandonment in the Late Classic (A.D. 750 to 830 or 850; Guderjan et al. 2003:86).

It is evident that the people of Blue Creek experienced some forms of stress during the Late Classic Period. The origin of that stress may lie in population growth and the need to extract resources to support a dense population; a breakdown of exchange relationships; interpolity conflicts (perhaps even submission to a neighboring kingdom); and perhaps from drought, erosion, and soil dgradation problems similar to those known from the Petén at this time. The issue of drought is the subject of the end of this chapter; the sociopolitical factors of exchange and interpolity hegemony are briefly discussed here. Barrett (2004:132) noted that the volume of imported goods decreased sharply during the 6th century A.D., and hypothesized that fundamental alterations in the long-distance exchange networks caused “sites to adapt to new social and economic realities.” This “trade entropy” may have resulted from decreased infrastructural support for long-distance trade, or from political fluctuations (Barrett 2004:295-296). Political fluctuations may have resulted from attempts by the large polities of Tikal and Calakmul to incorporate outlying polities into their respective hegemonic states (Barrett 2004:126). Tikal lies only 100 km southwest of Blue Creek, and Calakmul lies 100 km northwest of Blue Creek. Although there is no evidence that either polity ever controlled Blue Creek, their influence was felt throughout the Maya Lowlands during the Classic and Late Classic Periods. Tikal and Calakmul forced the establishment of alliances and exacted military support and other tribute from those they conquered, meanwhile competing and conducting warfare against each other (Barrett 2004:126, 128). Tikal dominated from the early 5th- through mid-6th- centuries. Calakmul took over as the dominating force until the end of the 7th century, after which Tikal resumed its supreme position (Barrett 2004:127). The breadth of influence by Tikal and Calakmul, and the level of warfare between the two powers, reached its climax at the end of the 8th century A.D. (Barrett 2004:126).

There is no evidence that any other polity ever controlled Blue Creek, but the influence of both extra- and intra-regional hegemonic powers was felt in the Three Rivers Region. The Three Rivers Region site of Rio Azul is known to have allied with Tikal (Barrett 2004:128, 130). Within the Three Rivers Region, the site of La Milpa was the dominant power during the Late Classic Period (Barrett 2004:131). Because a site's ability to attain and maintain a hegemonic position depends upon its ability to manipulate power relationships and resource distribution patterns (Barrett 2004:131), political fluctuations may have caused the breakdown of trade relations and the turbulence in settlement patterns which are visible at Blue Creek. In other words, the emergence of the first regional political economy may appear in the archaeological record as an instance of "Maya Collapse."

Blue Creek society was restructured during the Early Postclassic Period (Guderjan 2006:2). The site itself was not formally reoccupied; neither architectural remains, nor diagnostic ceramics of the Postclassic have been discovered (Barrett 2004:120). The people seem to have abandoned the site, but not the region. A new Postclassic settlement was established along the Río Hondo (Guderjan 2006:2). The hinterland settlement of Akab Muclil, which had been occupied from the Early Classic through the Terminal Classic Periods, was reoccupied during the Early Postclassic Period. Akab Muclil is the only hinterland settlement near Blue Creek known to have been occupied during the Early Postclassic (Maya Research Program 2005:3). The Birds of Paradise ditched agricultural fields, south of the Río Bravo and close to the site of Gran Cacao, date to the Postclassic Period (Maya Research Program 2005:4-5), indicating that the area was still suitable for farming after the Collapse.

The overarching question here is, “What caused the stress experienced by the people of the Blue Creek area during the Late Classic Period?” Were the problems chiefly sociopolitical; is there evidence for environmental instability; or were there other troubles at that time? Because environmental instability can be explored through palynology, I focus first on the problem of drought, and then secondarily consider other problems of the Late Classic Period that cannot be explored palynologically.

Drought

This section addresses drought, a form of environmental instability believed to have plagued the Maya area at the time of the Collapse. The incidence and the extent of the drought are addressed. In Chapter VI, I examine the palynological and sedimentary records from the Laguna Verde pollen core to judge whether or not drought may have been a factor in the Collapse in the Blue Creek area.

Most Mayanists agree that “climatic processes played a significant role in the cultural changes that occurred in at least some parts of the Maya area from the Preclassic…to Postclassic periods. In particular, a number of studies suggest that the decline of Maya civilization in the Terminal Classic Period was greatly influenced, if not caused, by a prolonged drought” (Gunn et al. 2002:79). Most significant among those studies are Folan et al. (1983), a correlation of moisture availability, climate change, and culture change; Gunn et al. (2002), climate change models; Gunn & Adams (1981), relationships between global temperatures and local rainfall; and Hodell et al. (2001), solar forcing and drought. Important paleoecological studies that have led most current Mayanists to believe that climate change had some impact on the Maya in some locations (particularly in Petén, Guatemala) include Covich & Stuiver (1974), Yucatan; Dahlin et al. (1980) and Dahlin (1983), El Mirador, Petén; Deevey et al. (1979), Lakes

Yaxha and Sacnab, Petén; Hodell et al. (1995), oxygen isotope evidence for drought at Lake Chichancanab, Yucatan; Leyden (1987), Lake Salpeten, Petén; Vaughan et al. (1985) and Wiseman (1985), Lake Quexil, Petén. Combined evidence suggests that droughts plagued the Maya Lowlands from A.D. 800 to 1050 (Coe 2005:163). This period was driest in the Holocene at various sites, and coincided with the Maya Collapse (Brenner et al. 2002:150).

Details from specific paleolimnological and palynological studies documenting the extent and duration of the drought (or, conversely, its absence) are given below. Ironically, although the northern Yucatan underwent the greatest amount of climatic drying, society there was relatively unaffected by the drought, probably because they were able to make use of a broader resource base and different adaptive strategies than Maya elsewhere (Dahlin 2002:327). However, not even all of the northern Maya kingdoms survived drought (Dahlin 2002:337). Even if the drought primarily affected the northern Yucatan Peninsula, there is widespread evidence for Terminal Classic drying from Mexico to the Bolivian and Peruvian Andes (Curtis et al. 1998:155).

Some studies (Dahlin 2002; Gunn et al. 2002; Hodell et al. 2000; Hodell et al. 2001) have implicated the annual movement of the Intertropical Convergence Zone, which moves with changes in global temperatures, as an explanation for annual variation in rainfall in the Maya area ("Southward movement means dry, and northward means wet, conditions"; Gunn et al. 2002:81). In the case of the Terminal Classic Period drought, "the North Atlantic high-pressure system was displaced to the southwest" (Dahlin 2002:331-332). The drought must have affected not only the northern Maya area, but other parts of Mesoamerica as well, because the entire southern North Atlantic region was subject to the same atmospheric-circulation changes that caused large-scale environmental conditions (Dahlin 2002:331; Hodell et al. 2000:26). The concept of Global Energy Balance accounts for large-scale climatic patterning by correlating climate, global temperature, and precipitation (Hansen et al. 2002:288). This model indicates that, "the lower the global temperature, the smaller the amount of precipitation that falls in the tropical lowlands of Mesoamerica" (Hansen et al. 2002:288). Periods of maximal global cooling at A.D. 100 and 815 (the latter toward the beginning of the Terminal Classic Period) were associated with minimal precipitation and minimal discharge rates of the Candelaria River, the major drainage of the Mirador Basin of northern Petén (Hansen et al. 2002:288). Interestingly, the opposite may have been the case in Belize, where the water level in some rivers rose, perhaps as a response to a rising sea level, during the Late Preclassic through Late Classic Periods (e.g. Beach & Luzzadder-Beach 2003:32; Hansen et al. 2002:288; Luzzadder-Beach & Beach 2009; Pohl 1990:189). See the section “Sea Level Rise,” earlier in this chapter, for further details on this matter.

Introduction to Palynological and Paleolimnological Studies Relating to the Late or Terminal Classic Drought

Palynological and multi-proxy paleolimnological records from the Maya Lowlands document changes in vegetation through time, getting at climate- and human-induced changes in the landscape, and thereby indicating the state of the environment at the time of the Maya Collapse. Pollen records throughout the Maya Lowlands suggest a pattern in which “the Maya converted tropical lowland forest into an agricultural, savanna-like landscape, probably during a period of regional climatic drying. The modern forest represents vegetation that “recovered,” following a reduction in anthropogenic stress, sometime after the Collapse in the ninth century A.D.” (Brenner et al. 2002:145). This pattern has been found at Petapilla Swamp, Honduras (Rue 1987:285-286); Laguna de Cocos on Albion Island, Belize (Hansen 1990); Lake Cobá, Yucatan (Leyden et al. 1998:111, 116); and the following lakes in Petén, Guatemala: Lake Quexil (Wiseman 1985:68;Vaughan et al. 1985:83); Lake Salpeten (Leyden 1987:407); Lake Sacnab (Deevey et al. 1979; Vaughan et al. 1985:83); Lake Macanche (Vaughan et al. 1985:83); Lake Peten-Itza (Curtis et al. 1998:139, 146, 151-156; Islebe et al. 1996:265, 269-270); and Laguna de Petenxil (Wiseman 1985:68). The pattern was different in the Pasión drainage of the Petén (including Laguna Tamarindito), where an Early Classic Period population decline allowed for the growth of mature forest before land clearance resumed during the Late Classic Period (Brenner et al. 2002:146). At Cobweb Swamp, Belize, there was palynological evidence for forest clearance and agricultural disturbance, but not for drought nor for a Postclassic return to climax forest (Jones 1991).

Pertinent details from some of these studies, and from other studies with interpretations bearing on the drought, are given below. Combined evidence suggests that land clearance for agriculture, combined with a drought, led to erosion and degradation of soil quality. These factors, combined with the sociopolitical factors discussed below, compounded to cause the Maya Collapse in at least some parts of the lowlands. However, many researchers working in the Maya Lowlands have found evidence against the occurrence of a Late Classic drought. In some cases, sociopolitical factors seem to have been more significant than drought in causing the Maya Collapse.

Paleolimnological Studies from the Yucatan Peninsula

To study climate change, Mark Brenner and colleagues (2002) took sediment cores in Lakes Chichancanab and Punta Laguna in the eastern Yucatan Peninsula. This study focused on moisture availability throughout the past 2,600 years (Brenner et al. 2002:141). The abundance of isotope oxygen-18 in ostracods (marine crustaceans) in the lake sediments was measured to assess the ratio of evaporation to precipitation (Brenner et al. 2002:144-145, 149-151). It was concluded that droughts inspired by solar forcing occurred cyclically, every 208 years or so, with the driest period occurring between A.D. 800 and 1000 (Brenner et al. 2002:141). This was the time of the abandonment of the southern Maya Lowlands and the Puuk cities in the north (Coe 2005:32). The drought, combined with anthropogenic degradation of the environment, seems to have caused too many successive years of crop loss, preventing the people from continuing to live in high concentrations (Coe 2005:32).

An assay of a pollen core from Lake Cobá published by Leyden et al. (1998) was one of few studies that failed to find evidence for a Late Classic Period drought in the Yucatan. At Lake Cobá, human disturbance seems to have muffled any climatic signal

(Leyden et al. 1998:111). Leyden et al. (1998:111, 120) suggested that variable rainfall may have been responsible for the Collapse. This would have endangered the maize crop without affecting native vegetation. However, maize pollen was present throughout the core, suggesting that people never completely abandoned the area or gave up cultivation altogether (Leyden et al. 1998:116).

Palynological Studies from Honduras

Palynologist David Rue reported the pollen sequences from Petapilla Swamp and Lake Yojoa, near the site of Copan, Honduras (Rue 1987:185). Rue interpreted the sequence as showing a high level of ecological stability, "with no evidence of vegetational changes congruent with the ~ AD 900 Late Classic Collapse", with only a slight increase in *Pinus* and Meliaceae pollen hinting at post-Collapse reforestation (Rue 1987:285-286). The human population in the region may have remained stable throughout this time (Rue 1987:286). Furthermore, Rue did not credit environmental change as playing a role in the pollen stratigraphy. He wrote, "There is no palynological evidence for any significant late Holocene climatic change in the present or previous Central American sequences, thus allowing the assumption that all vegetational changes are human-induced" (Rue 1987:285). This conclusion was similar to that made by Leyden et al. (1998) for Lake Cobá, Yucatan.

Paleolimnological Studies from the Petén

As noted above, many paleolimnological studies from the Petén have documented the widespread presence of agricultural savanna in a period of climatic drying around the time of the Collapse. Several researchers have, however, found evidence *against* the occurrence of a drought in the Petén during the Terminal Classic Period. For example, stable isotope analysis at Lake Peten-Itza did not show evidence for a Terminal Classic drought (Curtis et al. 1998:155). This was inexplicable to the authors of the study, unless the drought primarily affected the northern Yucatan

Peninsula and did not penetrate into the southern lowlands, which the authors recognized as improbable (Curtis et al. 1998:155).

Matsuo Tsukada (1966) and Urusula Cowgill and colleagues (1966) studied two pollen cores from Laguna de Petenxil, in the Central Lakes District of the Petén. They found no climatic evidence that could explain the downfall of the Maya Empire: "There has been no significant climatic change over the past four millennia, nor has the erosion rate increased to any extent that could be interpreted as disastrous. Though man has been agricultural in the region…there has been no indication…that population pressure ever became great enough to cause serious disturbances. There is…clear evidence of great variation in the extent of human activity…that would suggest marked oscillations in the local population" (Cowgill et al. 1966:126). In other words, the major features of the pollen records from Laguna de Petenxil were caused by human disturbance of vegetation, not by climatic changes (Deevey et al. 1979:302). Forest disturbance and agricultural practice by the Maya are indicated, but evidence is lacking for the disastrous soil erosion and drought that is typically seen in pollen records from the Maya Lowlands (Brenner et al. 2002:142-145).

Frederick Wiseman (1985) conducted additional pollen studies at Laguna de Petenxil and Lake Quexil. Rather than blaming climatic change, Wiseman saw that humans had a hand in environmental degradation that must have factored into the Maya Collapse. Wiseman (1985:68) notes that the maximum abundance of *Zea* pollen at Laguna de Petenxil and Lake Quexil occurred around the time of the Maya Collapse, so extreme intensification of maize agriculture may have led to ecological and agricultural collapse. The ensuing decline in human population and maize agriculture led to reclamation of the area by swamp and upland forest (Wiseman 1985:68).

A paleolimnological study of Laguna Tamarindito (in the Petexbatun region, south of the Central Lakes District) provides a 10,000-year-long climate record, demonstrating the occurrence of two dry periods around 6500 and 4900 b.p. (but not during the time of the Maya Collapse; Dunning et al. 1998b:147). During the Late Classic Period, between A.D. 600 and 800, sedimentation slowed as the Maya employed agricultural terracing and check-dams as erosion controls (Dunning et al. 1998b:139, 141). The Maya seem to have been employing technological adaptations to prevent the type of ecological disaster, resulting from overfarming, which was suggested for the Central Lakes District. The Late Classic was the period of greatest population density in the Petexbatun region; at the end of this period, intersite conflicts were associated with abrupt population decline, followed by site abandonment (Dunning et al. 1998b:141). Deforestation did *not* occur in the hypothesized manner; it did *not* increase steadily from Preclassic through Late Classic times, as it did elsewhere in the Petén (Dunning et al. 1998b:147). Intersite conflicts seem to have played a more important role than drought in the Collapse here.

Soil Degradation

Many archaeologists believe that the Maya Collapse was precipitated by the intensification of milpa agriculture via the reduction of the fallow period; consequentially, nutrients were leached from the soils, weeds and insects invaded the fields, and topsoil eroded (Johnston 2003:141). Even a relatively sustainable cultivation-lengthening program (such as slash/mulch agriculture) would have suffered from weed encroachment and nutrient loss eventually. Some paleolimnological and palynological evidence suggests that land clearance for agriculture, combined with a drought, led to erosion and degradation of soil quality. That ecological changes did occur in the southern lowlands during the Late Classic Period is supported by paleoecological evidence of deforestation (seen in the paleoenvironmental record as a replacement of forest species by grasses), soil nutrient loss, the sequestration of nutrients (such as nitrogen and phosphorous) in lacustrine deposits, and increased topsoil erosion visible as the “Maya clay” (Johnston 2003:141). These anthropogenic changes increased in severity in parallel to the increase in human population size and density (Johnston 2003:141). Thus, overpopulation and resultant soil degradation may have led to a food crisis and thus to the Maya Collapse in some parts of the Maya Lowlands.

Other Causes of the Maya Collapse

In other parts of the Maya Lowlands, including at Blue Creek, evidence for drought is lacking, or the drought is not believed to have been severe enough to play a primary role in the Collapse. It is therefore worthwhile to consider other, non-climatic, factors that may have led to the Maya Collapse, and to unite climatic causes with sociopolitical ones.

Reasons for the Maya Collapse in the southern lowlands have included epidemic disease, foreign invasion from Mexico, social revolution from within the Maya population, a lowered water table, hurricanes, and earthquakes (Coe 2005:161). Other reasons for the Maya collapse include overpopulation resulting in food shortages, and a shift from slash-and-burn to more intensive (and ecologically damaging) agriculture (Sanabria 2007:64). In addition to drought, the strongest factors in the Maya collapse were "endemic internecine warfare" and "overpopulation and accompanying environmental collapse" (Coe 2005:162).

By considering Maya history during the Late Classic, we see the buildup of "endemic internecine warfare." Between A.D. 751 and 790, "long-standing alliances began to break down, interstate trade declined, and conflicts between neighboring city-states increased" (Coe 2005:161). Intersite conflict began. The problem of warfare was significant in the Petexbatun region in southern Petén, at such sites as Dos Pilas and Aguateca, by the late 8th century (Coe 2005:162). Archaeologist Arthur Demarest commented that, during this time, there was a "devolution from cities involved in regional alliances, to warring centers, to minor sites, to tiny villages" (Coe 2005:162). Elites competed against each other, developing extravagant architecture and hosting "senseless" wars (Coe 2005:162), alienating the commoners and probably exacting tribute that led to agricultural intensification and environmental devastation.

Between A.D. 790 and 830, the death rate was greater than the birth rate (Coe 2005:162). After A.D. 830, construction stopped in most of the southern lowlands (Coe 2005:162). Monumental construction halted. The last Maya date known to have been carved during the Terminal Classic Period was found at Itzimte, in the Petén, and dates to January 15, A.D. 910 (Coe 2005:162).

When people encountered agricultural shortfalls, there may have been rebellions: Eric Thompson suggested that the frustrated commoners revolted when they saw that the elites could no longer "call down the rains from Chaak [the rain god]" because they had lost "the mandate of heaven" (Coe 2005:163).

Whether because of drought, the exacting of tribute, the disruptions caused by warfare, overpopulation, or environmental collapse, or all of the above, an inability to feed the burgeoning, densely-settled population of the Late and Terminal Classic Periods may have undermined the authority of the local leadership, leading again to warfare, and (along with other factors) to the abandonment of Maya cities (Coe 2005:161-162; Gunn et al. 2002:80; Sanabria 2007:64) and what we know as the Maya Collapse.

Adaptations to Drought and Soil Degradation

A successful community must have adequate infrastructural support if it is to sustain a large and/or dense population for an extended period of time. In the realm of hydrology, infrastructural support must include the knowledge and leadership necessary to exploit and, when necessary, conserve water resources. Such leadership could have been crucial during the annual dry season, and in times of scarce or unpredictable rainfall, like the time of the prolonged drought that is thought to have had a hand in causing the Maya Collapse. In some places, the leadership could have helped implement community-wide adaptations to drought that could have buffered its potential negative effects on the population. Some adaptations, such as changes in ideology, are less visible than others in the archaeological record, but may have been of importance (Dahlin 1983; Scarborough 1998:149). Iconographic evidence suggests that some Maya elite held an ideology that "ritually [approximated] the everyday and mundane activities associated with water by the sustaining population, [and the] elites used high-performance water ritual…to further centralize control" (Scarborough 1998:135). This section focuses on Mayan strategies for water management and archaeologically-visible adaptations to drought, with evidence from archaeological sites in Belize; some attention is given to soil conservation strategies.

First, the situation of the site in an ecotone can be perceived as a buffer against environmental stressors, even if the site's first settlers were unaware of this fact. The Blue Creek Maya had local access to the natural resources of swamp and riverine environments and upland forests. Access to such a variety of resources helped prevent overdependence on any single resource, diminishing risk in the event of single-resource failure. The site of Lamanai and some parts of Copan survived the Maya Collapse, possibly because of the quality and diversity of natural resources there (Barrett 2004:51).

Water management and soil conservation strategies included the construction of dams and terraces. Dams were constructed on creeks at Mayan sites in Cayo District "in order to protect valuable freshwater springs and to help preserve their scarce water sources" (Healy et al. 1983:400). Dams were sometimes constructed to hold water in reservoirs (e.g. Beach & Dunning 1997:20; Scarborough 1998), making the water supply a strategic, defensible resource. Check dams controlled water supply to the fields (Pohl & Miksicek 1985:11). Sometimes check dams were constructed in conjunction with terracing systems. Terraces functioned to control soil erosion, to prevent runoff, to maintain moisture levels during the dry season, and to distribute rainwater evenly over a hillslope (Pohl & Miksicek 1985:11; Wilk 1985:48). Terraces helped prevent the channeling of water as it flowed down hillsides, thus providing a more even water distribution to the agricultural fields (Healy et al. 1983:405).

At the site of Caracol, in Cayo District, a six-hectare hillslope was terraced (Healy et al. 1983). All the terraces were built contemporaneously, and were probably the result of much planning and coordination, rather than representing individual family-level efforts (Healy et al. 1983:402). Strong leadership is indicated accordingly.

Although methods of hydraulic (or irrigated) agriculture are discussed in more detail in Chapter IV, it can be noted here that the Blue Creek Maya used various methods to control the water supply to their fields. Check dams, terraces, and both raised and channeled (drained) agricultural fields are all known from the Blue Creek area. These were constructed to manage excess water and were not forced adaptations to drought. In fact, Blue Creek's wetland fields and canals, which date between the Late Preclassic and Terminal Classic Periods, were probably adaptations to water inundation: "This prehistoric effort was to improve water quality for crops to drain low quality water away and leach excess gypsum in otherwise fertile organic soil" (Luzzadder-Beach & Beach 2008:225). Dams are found on the western backslope of the Bravo Escarpment (Guderjan et al. 2003:80). A few terraced fields are associated with the elite residences near the upper rim of the Bravo Escarpment, and more are found near residences in the Bravo Hills ecological zone, including some near Rosita (Guderjan et al. 2003:80, 81, 86). Raised fields, first observed from the air, exist near Irish Creek, east of Boothe's River (Guderjan et al. 1991:55). These are the only known raised fields in the area (Guderjan et al. 1991:55). The channeled agricultural fields below (or east of) the Bravo Escarpment (especially near the Chan Cahal residential cluster) were created as an adaptation to terrain subject to inundation by spring water (Guderjan et al. 2003:86-87; Lohse 2003a:6). The channels permitted drainage of excess water from the fields, creating additional cultivable space. The Birds of Paradise ditched agricultural fields, south of the Río Bravo and close to the site of Gran Cacao, hold straight canals (some more than 200 m in length), and have produced dates from the Postclassic Period (Maya Research Program 2005:4-5). This may mean that the area was still suitable for farming during the Postclassic, and that local leadership persisted through the Maya Collapse and subsequent population movements in the Blue Creek area.

In addition to the construction of dams, terraces, and raised and channeled fields, the ancient Maya knew how to conserve soil moisture by "mulching, sowing cover crops, and interplanting" (Wilk 1985:48). Mulching, importation of rich agricultural soil, and transplantation of canal muck to field surfaces can sometimes be observed in the stratigraphy of ancient fields (Dunning et al. 2002:276). Mulching protected the soil from erosion and renewed soil fertility.

Mayan adaptations to drought could have included increased use of *chultuns* (underground cisterns) and water-storage vessels; greater cultivation of xeric-adapted agricultural plants; and exploitation of seasonally-inundated *bajos* for agriculture (Brenner et al. 2002:154). Cultivation in the *bajos* is more thoroughly addressed in Chapter IV.

Trade may have been external recourse for dealing with the effects of drought. Successful leaders sometimes relied upon their relationships with trading partners who lived outside the drought-impacted region to provide goods needed for survival, as well as exotic luxury items. Trade relationships are visible in the archaeological record not only through the presence of artifacts of non-local origin, but also through features that suggest a trade-related function. For example, there may have been a Classic Mayan port or jetty on the Río Hondo, 3.7 km from the site of Nohmul (Pring & Hammond 1975:116-127). Platforms there secondarily came to house burials, so their function as facilities of trade, fish landing, lading of trade goods, etc., is suggested but cannot be proven. A port feature is also found at Blue Creek. Above, in the section "The Collapse at Blue Creek," a disruption in trade relationships, possibly resulting from the interference of a neighboring hegemonic polity, is implicated in the Collapse at Blue Creek.

Given the number of water sources available at Blue Creek, and the diversity of water and soil conservation measures and adaptations to drought that the Maya (both in Blue Creek, and nearby) are known to have employed, a water shortage may not have been a problem for the Blue Creek Maya. Although the site may have experienced some stress from population growth during the Classic and Late Classic Periods, this chapter has shown that the local environment was provident enough, and the people were capable of employing sufficient adaptive strategies, to avoid a crisis situation related to water shortage. As suggested for the Petexbatun region of the Petén by Dunning et al. (1998b), the implementation of some methods of irrigated agriculture at Blue Creek may not have been intended as agricultural intensification so much as it was intended for conservation of water resources and of the landscape. At Blue Creek, the development of channeled fields began during the Middle Preclassic Period (Beach & Luzzadder-Beach 2003); elsewhere in the southern Maya Lowlands, terraced fields and raised fields began to be used during the Preclassic Period, predating the hypothesized Terminal Classic Period drought and also predating the highest levels of Classic Period population pressure and soil degradation. At Blue Creek, methods were implemented to deal with excess water, and were not forced adaptations to drought; inability to deal with drought conditions was probably not the primary cause of site abandonment. Even if a Terminal Classic Period drought did impact the Blue Creek area, water shortage was probably not the most significant problem experienced in Blue Creek at the time of site abandonment. Population growth, erosion of agricultural soils, disruptions in trade relationships, and political disturbances were probably more important problems during the Terminal Classic Period. Thus, sociopolitical factors must always be considered in conjunction with environmental ones.

CHAPTER IV
MAYAN PLANT CULTIVATION

CHAPTER INTRODUCTION

This chapter begins with an explanation of the process of the independent invention of plant cultivation in Middle America from its beginnings during the Archaic Period. Following that is a description of the cultivation methods employed by the ancient Maya of Blue Creek and other sites in the Maya Lowlands, as known from the types of direct and indirect evidence introduced in Chapter I. Focus is given to the most important of the Mayan cultivars, squash, maize, and beans. Finally, an explanation is given of the changes to traditional Mayan production systems that resulted from contact with European colonists.

INTRODUCTION TO THE ORIGINS AND DEVELOPMENT OF AGRICULTURE IN MIDDLE AMERICA

The popular stereotype of precolumbian Native Americans as “backward” and “primitive” is overthrown by consideration of the independent agricultural achievements of the indigenous peoples. Archaeological and palaeoethnobotanical evidence demonstrate that the people of Middle America were among the earliest in the New World to implement agricultural innovations. This paper provides a general overview of the origination and spread of agriculture in Middle America. Locations of origin, important crops and the earliest dates from which they are known, potential sources of bias in data interpretation, and models for the development of agriculture in Middle America are considered. A special section on maize highlights the most important Mayan (indeed, Middle American) crop.

As explained in Chapter I, and as pictured in Figure 1 (Chapter I), *Mesoamerica* is defined as the cultural area that includes southern Mexico, Guatemala, El Salvador, Belize, and the western part of Honduras, Nicaragua, and Costa Rica (Kirchoff 1943). In this chapter, some attention is given to portions of Middle America lying outside of

Mesoamerica proper, including central and northern Mexico and Panama. Therefore, the term *Middle America* is generally used to indicate the region under consideration. North of Mesoamerica, hunting and gathering (rather than agriculture) predominated in prehistoric times, while the region to the immediate southeast remained marginal in terms of plant domestication (McClung de Tapia 1992:144, 145). Early developments in New World agriculture are known from South America, but they are beyond the scope of this work.

Locations of Earliest Cultivation

Middle America encompasses a number of climatic regimes, each with its own characteristic natural vegetation. Although most areas are suitable for rain-fed (non-hydraulic) agriculture, local climatic variations may have spurred the development of certain subsistence adaptations. For example, irrigation agriculture developed in some arid areas (McClung de Tapia 1992:144-146).

An issue of current debate is whether Middle American plant cultivation first took place in the cooler, drier tropical highlands, or in the warmer tropical lowlands. Traditional models hold that agriculture originated in the highlands prior to 7,000 b.p.[1] and spread to the lowlands much later on (Pohl et al. 1996:355). In the past, some scientists have been biased against the possibility of agricultural origins in the lowland tropics, in part because of the difficulty of recovering organic remains from archaeological sites there, and in part because lowland tropical soils were thought to be too poor to support agriculture (Sanabria 2007:57-58). A newer model of tropical ecology now recognizes that tropical soils are not inherently nutrient-depleted, but that many of the nutrients stored within tropical ecosystems are bound up in the vegetation (Johnston 2003; see the "soils" section of Chapter III for further details). It is now generally realized that there are *some* naturally fertile soils in the Neotropics (such as those on floodplains and in *bajos*), and that agricultural methods (such as slash/mulch agriculture) could have been employed in the long-ago past to increase soil fertility in

---

[1] For the sake of continuity within this section, all conventional dates reported as "B.C" have been converted to "b.p." by adding two thousand years.

niches with less rich soils. In refuting the bias against tropical lowland agriculture, one must also consider that intensive agriculture and a broad resource base would have been necessary to support the large, complex societies that developed in some areas of the lowland tropics. Indeed, "some of the earliest Mesoamerican archaeological sites pointing to sedentism, large populations, and cultural complexity are in lowland areas. These sites furthermore display evidence of primary state formation," developing from non-state societies, as the Olmec and Maya did (Sanabria 2007:58). Newer studies also take into account information from forms of microbotanical remains (such as pollen, starch grains, and phytoliths) that are able to survive the rigors of the wet tropical climate (Bryant 2003). New interpretations suggest that forest destruction, probably due to clearance of fields for cultivation, began in Panama near the beginning of the Holocene (Piperno 1998; Pohl et al. 1996), and by the Early Preclassic Period in the Maya area. Early dates for some crops, such as *Zea mays*, are nearly contemporaneous in the highland and lowland zones (see Table 5). Thus, plant cultivation (in general) in the highlands probably did *not* long predate cultivation in the lowlands, and indeed cultivation may have begun around the same time at multiple locations within both ecological zones (Pohl et al. 1996:356).

In addition to this dating evidence, scientists opposing an origin in the arid highlands cite ecological evidence. The first cultivated foods were probably root crops and fruits (Hall & Pérez Brignoli 2003:57). Harris (1972:185) places the hearthland of New World vegeculture (root crop agriculture) in the tropical lowlands, intermediate between the hot deserts and rain forests, where a dry season would allow root crops to thrive. Pohl et al. (1996:356) propose an origin in the "warmer, wetter, midlatitude habitats of the Pacific slope of southwestern Mexico." There, the climate and environment better meet the requirements of such cultigens as maize, beans, and squash. Genetic data and phytolith analyses support southwestern Mexico as the hearthland of domesticated maize, since it most closely resembles the wild teosinte (the probable maize progenitor) endemic to that region (Pohl et al. 1996:356-357).

It is best to conclude that all crops were not first domesticated at a single center of origin, from which they spread to all other sites. Centers of diversity do not necessarily indicate centers of origin (Heiser 1979:323). Local variations *do* exist as to which crops were first cultivated at specific locations, as is demonstrated in Table 5. Locations mentioned in Table 5 and in the remainder of this chapter are pictured in Figure 5 (Chapter II).

Timing of Early Agriculture in Middle America

In the early Holocene, Middle Americans earned their subsistence via hunting and gathering wild plants. Increasingly deliberate human interference with plants, leading to genetic and morphological changes, began in Middle America by 9000-8000 b.p. (Piperno & Pearsall 1998:4, 167). Habitation sites were initially occupied on a seasonal and short-term basis (Piperno & Pearsall 1998:167). Year-round, settled village life, accompanied by more complex agriculture, began in the northern part of the Middle American isthmus around 6000 b.p., and in the southern part around 4500 b.p. (Hall & Pérez Brignoli 2003:57). Maize pollen began to appear regularly in the sediments of archaeological sites from Guatemala through Panama during the time span between 4700 and 4200 b.p. (Blake 2006:60). During the Preclassic Period, between 4000 and 1750 b.p., maize and squash agriculture took hold (Andrews V et al. 1990; Hammond & Miksicek 1981; Hammond et al. 1979; Hall & Pérez Brignoli 2003:57). The Maya began their sedentary lifeways in permanent villages, where they produced ceramic vessels in greater quantities than they had previously. The first pottery-producing sedentary villages in northern Belize were established between 3000 and 2900 b.p. (Coe 2005:47). Pottery-producing farmers were not known to the Petén until about 3000 b.p. (Coe 2005:46). The villages soon became densely-settled cities with ceremonial buildings and monuments, and people invented new agricultural technologies to intensify production.

Table 5. Dates and Locations of Early Plant Domestication in Middle America.

Date (Range), years b.p.	Event	Location	Reference
12000	Late Pleistocene climate variation resulted in ongoing extinction of large game animals; nomadic hunting and gathering	Tehuacán Valley	McClung de Tapia 1992:157
12000 (12000-4000)	Burning to increase disturbance vegetation (tubers, fruits, and other seasonally scarce carbohydrate sources); widespread deforestation	Panama	Pohl et al. 1996:358, 367
10000 (10750-9840)	First domestication of *Cucurbita pepo* (squash)	Guila Naquitz Cave, Valley of Oaxaca	Smith 2005:9444, 2001:1326, 1997:934; McClung de Tapia 1992:148, 154
10000 (10000-8000)	Initial low-level human interference with vegetation		Piperno 1998:421
10000 (10000-8000)	Pollen, phytolith, and starch evidence for growth of tubers, tree fruits, and seed plants	Central Panama	Piperno 1998:438
10000 (10000-7000)	Pollen, phytolith, and starch evidence of human manipulation of squash, *Zea mays* (maize), *Maranta arundinacea* (arrowroot), *Calathea allouia* (leren), and probably *Manihot* (manioc)	Lower Central America	Piperno 1998:395
9970	First cultivated *Lagenaria siceraria* (bottle gourd)	Guila Naquitz Cave, Valley of Oaxaca	Smith 2005:9444
9400 (9400-8700)	First pollen evidence for *Zea mexicana* (teosinte)	Valley of Oaxaca	McClung de Tapia 1992:149
9200 (9200-7200)	First cultivated *Persea americana* (avocado), *Capsicum annuum* (annual pepper), *Amaranthus* sp. (amaranth), and *Gossypium hirsutum* (cotton)	Tehuacán Valley	Harris 1967:102; McClung de Tapia 1992:149
9000 (9000-7000)	Increase in plant collecting	Tehuacán Valley	McClung de Tapia 1992:157
9000 (9000-7000)	First cultivation of *Setaria geniculata* (foxtail)	Tehuacán Valley	McClung de Tapia 1992:154
9000 (9000-7000)	Phytolith evidence of first cultivation of leren and arrowroot	Panama	Piperno 1998:440
9000	First macrobotanical evidence of *Capsicum annuum*, domesticated by 6121 b.p.	Tamaulipas and Tehuacán Valley	Harris 1967:101; McClung de Tapia 1992:149-151, 154
8700	Starch and phytoliths of cultivated *Zea mays*	Balsas Valley, Mexico	Piperno et al. 2009
8000 (8000-4700)	Dry climate may have caused scarcity of natural resources, encouraging cultivation	Panama	Pohl et al. 1996:367
7960	First cultivated *Cucurbita pepo*	Tehuacán Valley	Smith 2005:9444

Table 5, continued.

Date (Range), years b.p.	Event	Location	Reference
7300	*Zea mays* phytoliths and pollen	San Andres, Tabasco	Pohl et al. 2007
7250	First evidence of *Lagenaria siceraria* (bottle gourd)	Tehuacán Valley	Smith 2005:9444
7200 (7200-5400)	*Diospyros ebenaster* (black sapote), *Casimiroa edulis* (white sapote), and controversially *Cucurbita moschata* appear	Tehuacán Valley	Harris 1967:102, but see conflict with Smith 2001, 2005, below*
7200 (7200-4000)	First domestication of amaranth, *Chenopodium* sp., and *Secharia* sp. (chayote)	Basin of Mexico	McClung de Tapia 1992:149
7000	First domestication of *Zea mays*	Central Balsas region, Mexico	Smith 2001:1326
7000 (7000-6000)	Appearance of maize in lower Central America	Central Panama	Pohl et al. 1996:358, 368
7000 (7000-4200)	Pollen evidence for destruction of natural vegetation, plant manipulation, and slash-and-burn agriculture with maize	Lowland tropical forest (central Panama; Belize; Mexican Gulf Coast)	Piperno 1998:419-421, 441
7000 (7000-4800)	Pollen evidence for domesticated *Manihot esculenta* (manioc), maize, and squash	Belize and Panama	Piperno 1998:423
7000 (7000-5400)	Decrease in hunting activity and increase in cultivation and domestication; first appearance of maize, replacing cultivated foxtail	Tehuacán Valley	De West et al. 1975:101; Harris 1967:102; McClung de Tapia 1992:157
7000	Appearance of *Acrocomia mexicana* (coyol), a palm fruit requiring irrigation during the dry season	Tehuacán Valley	McClung de Tapia 1992:155
6490	First cultivated *Lagenaria siceraria* (bottle gourd)	Tamaulipas	Smith 2005:9444
6360	First cultivated *Cucurbita pepo*	Tamaulipas	Smith 2005:9444
6305-6015	AMS date for earliest maize cobs at Guila Naquitz Cave	Valley of Oaxaca	Piperno & Flannery 2001:2102
5500 (5500-3000)	Adoption of maize in humid lowlands and arid highlands		Pohl et al. 1996:358
5400 (5400-3500)	Reliable subsistence agriculture; semisedentarism; appearance of pottery	Tehuacán Valley	McClung de Tapia 1992:157
5400	Possible pollen evidence of domesticated *Manihot* sp.	Cob Swamp, Belize	Pohl et al. 1996:362
5000 (5000-4200)	Continued spread of slash-and-burn agriculture with maize throughout Mesoamerica	Mesoamerica	Piperno 1998:441
4500	Ongoing forest decimation likely led to competition for resources	Maya Lowlands	Pohl et al. 1996: 367-368

Table 5, continued.

Date (Range), years b.p.	Event	Location	Reference
4500 (4500-4000)	Palynological, macrobotanical, and bone isotope analysis of the presence of maize, avocado, and *Acrocomia vinifera* and other palms	Cost Rica; western Honduras; and Tabasco, Mexico	Pohl et al. 1996:357
4000	Reliable subsistence agriculture; permanent villages	Valley of Oaxaca	Smith 2001:1326
4000	Domesticated maize began to replace cultivated foxtail	Tamaulipas	De West et al. 1975:101
4000	First occurrence of maize pollen	Peten, Guatemala	McClung de Tapia 1992:159
4000 (4000-3000)	First occurrence of maize phytoliths and macroremains	Cuello, Belize	Pearsall 1982:866
3900-3500	Theobromine reside in ceramic vessels indicates use of *Theobroma cacao* (cocoa)	Gulf Coast, Mexico	Powis et al. 2008
3500 (3500-historic period)	Full-time agriculture and irrigation; small permanent villages	Tehuacán Valley	McClung de Tapia 1992:157
3500	Additional cultigens in place, including amaranth, *Helianthus annuus* (sunflower), and *P. lunatus* (lima bean)	Tamaulipas	Harris 1967:101-102
3400 (3400-500)	*Phaseolus acutifolius* (tepary bean), *Canavalia ensiformis* (jack bean), *Phaseolus coccineus* (runner bean), *Arachis hypogaea* (peanut), *Lycopersicon esculentum* (tomato), *Psidium guajava* (guava), and lima bean cultivated	Tehuacán Valley	Harris 1967:102
3100	Theobromine reside in ceramic vessels indicates use of cacao	Puerto Escondido, Honduras	Henderson et al. 2007
3000	Sedentary villages	Panama	Pohl et al. 1996:357
3000 (3000-2000)	First pollen, phytolith, and macrobotanical evidence of cultivated *Phaseolus* sp. (beans) and maize	Sitio Sierra, Panama	McClung de Tapia 1992:160; Piperno 1984
3000 (3000-2000)	Period of agricultural intensification throughout tropical lowlands	Tropical lowlands	Pohl et al. 1996:358
3000 (3000-1500)	Palm (Arecaceae) pollen recovered from agricultural field	Colha, Belize	Jones 1994:209
2900 (2900-2200)	First evidence of manioc (tissue in coprolites)	Tehuacán Valley	McClung de Tapia 1992:155
2800	First evidence of *Cucurbita moschata*	Tamaulipas	Smith 2005:9444
2600-1750	Theobromine residue in ceramic vessels indicates use of cacao	Colha, Belize	Hurst et al. 2002
2400 (2400-1700)	First occurrence of maize macroremains	Chalchuapa, El Salvador	Sheets 1982:102
2380	Earliest archaeological evidence of *Phaseolus vulgaris*	Coxcatlan Cave, Tehuacán Valley	Smith 2001:1325, 2005:9444
2115	First macroremains of *Cucurbita argyrosperma* (=*C. mixta*)	Tehuacán Valley	Smith 2005:9444

Table 5, continued.

Date (Range), years b.p.	Event	Location	Reference
2000	Early agriculture at many sites	Honduras; Costa Rica; Panama	McClung de Tapia 1992:152
2000	Earliest macrobotanical remains of domesticated maize and beans	Panama	McClung de Tapia 1992:160
1850	First pollen evidence of cultivated manioc and sweet potato	Panama	McClung de Tapia 1992:155
1400 (1400-1100)	Macroremains indicate fruit collection and first known maize cultivation	Honduras	McClung de Tapia 1992:159
1400 (1400-1100)	Iconographic evidence and remnant stands suggest cultivation of *Theobroma cacao* (cacao)	Northern Yucatan	Gómez-Pompa et al. 1990
1270	First evidence of *Phaseolus vulgaris*	Tamaulipas	Smith 2005:9444

* New AMS radiocarbon dates and sample reanalysis may call into question some of the dates reported from the Mexican dry cave sites (Smith 2001, 2005).

Early Species Cultivated in Middle America

Although phytolith and starch grain analyses have posited that the cultivation of root crops had begun at an even earlier date (especially in southern Middle America and northern South America; e.g. Piperno 1998; Piperno & Pearsall 1998:163-164, 204, 292), it was the maize-beans-squash triumvirate that became the foundation of the Middle American agriculturalist diet. Of all the crops domesticated in Precolumbian Middle America, none has received as much attention, or has been the focus of so much scientific study, as have *Zea mays* (maize), *Phaseolus vulgaris* (common bean), and *Cucurbita pepo* (squash). This agricultural combination has been named the "maize-beans-squash complex," and the "three sisters." Many researchers have looked into the ancestry, geographic origin, and processes of domestication of these crops.

Squash is one of the first plants known to have been domesticated in Middle America, with dates of domestication as early as 10,000 b.p. from Guilá Naquitz Cave in the Valley of Oaxaca (Piperno 1998:395, 440; Piperno & Flannery 2001:2101; Smith 1997:934; Smith 2001:1325, 1326). At these early dates, the first people to plant and harvest squash in the Valley of Oaxaca were likely hunter-gatherers. The ancestry of wild *Cucurbita* is uncertain. Cultivated squash (*Cucurbita pepo*) may have descended from wild populations of *C. texana* or *C. fraterna* (sometimes called *C. pepo* ssp. *fraterna*) in Texas or northeastern Mexico (respectively; Decker 1988:9). Alternatively, modern populations of *C. texana* and *C. fraterna* may have descended from *C. pepo* plants that escaped from cultivation (Decker 1988:9). Smith (2001:1325) recommends searching for the "wild progenitor" in the southern highlands of Mexico, where the oldest macrobotanical remains of the plant (in both cultivated and unidentified wild forms) have been found. Piperno & Pearsall (1998:233) suggest that other varieties of squash developed on the Pacific and Atlantic slopes of Mexico. For example, *C. argyrosperma* may have originated in the Balsas Valley, where its wild ancestor *C. sororia* grows today.

The first people to domesticate maize (around 7000 b.p., probably in the central Balsas region of Mexico) had already been growing squash for one thousand years

(Smith 2001:1326). Early "cultivated" maize was a descendent of a wild grass, which thrived in an "improved" (human-disturbed) habitat (Mangelsdorf et al. 1964:543). Once domesticated, the practice of maize cultivation spread like wildfire; the crop was commonly cultivated throughout Middle America by 4200 b.p.

The people who first domesticated beans (several thousand years later, probably near Guadalajara, Jalisco, Mexico) may have already been growing squash, maize, and probably other crops for some time (Smith 2001:1325, 1326). Based on their content of S-type phaseolin seed protein, a population of wild *Phaseolus vulgaris* growing near Guadalajara has been identified as the progenitor of cultivated beans (Gepts 1998; Smith 2001:1325). The most ancient evidence of wild *Phaseolus* sp. comes from 10700-8700 b.p. at Guilá Naquitz Cave in the Valley of Oaxaca, with larger beans growing in Mexico by 9000 b.p. (McClung de Tapia 1992:149). Cultivated beans are thought to have grown as early as 7000 b.p., but the earliest directly AMS dated cultivated *Phaseolus vulgaris* specimens (found at Coxcatlán Cave in the Tehuacán Valley) date to only 2380 b.p. (Kaplan & Lynch 1999; McClung de Tapia 1992:149; Smith 2001:1325). Beans were not widely cultivated in Middle America until at least 3500 b.p. An improvement of storage methods may have facilitated bean domestication; beans were protected from consumption by feral animals, "thereby permitting natural selection to operate on the existing polygenic system (McClung de Tapia 1992:153)."

A fourth crop plant has figured prominently in the agriculture of Middle America: *Capsicum* sp., or "chili pepper." The genus *Capsicum* includes approximately 30 species; of the five that are cultivated, *C. annuum* is the most popular (Oyama et al. 2006:554). In early colonial times, European explorers of the Maya area noted the importance of chili peppers in the Mayan diet, claiming that nothing was consumed without the inclusion of the fruit (Cichewicz & Thorpe 1996:65). The plant frequently appears among Mayan ethnomedicinal remedies, and has been demonstrated by modern science to have antimicrobial properties (Cichewicz & Thorpe 1996). Wild peppers are often an understory component of the tropical deciduous forests of the Maya area (Oyama et al. 2006:554). Southern Mexico has been suggested as the location of earliest cultivation of the chili pepper (Oyama et al. 2006:560). The earliest macrobotanical remains of chili pepper are known from the Tehuacán Valley of Mexico, and date to the period between 9200 and 7200 b.p. (Harris 1967:102; McClung de Tapia 1992:149).

In all, the maize-beans-squash complex took about six thousand years to develop (Smith 2001:1326). By around 5400-3500 b.p., village-based farming economies were established in Mexico and much of Middle America, and crops could contribute significantly to the diet (McClung de Tapia 1992:157; Smith 2001:1326). Given the high economic and ideological significance maize had for Middle Americans, a special section on the geographic origin, ancestry, and processes of domestication of maize follows.

THE SIGNIFICANCE OF MAIZE: AN INTRODUCTION TO ITS GEOGRAPHIC ORIGIN, ANCESTRY, AND EVOLUTION

Maize (*Zea mays* ssp. *mays*) is the world's third most important food crop, following only wheat and rice. Taking into account all the maize that is fed to the domesticated animals that contribute to the human diet in the forms of dairy products and meat, maize is "the principal food plant of the Western world" (Beadle 1980:112). It was the staple crop of the ancient Maya. Given the significance of this plant of the Poaceae family, it is interesting to consider the geographic origin, ancestry, and related evolutionary history of corn. Indeed, these issues are some of the most pressing questions asked by Mesoamerican archaeologists. This section offers a brief introduction to archaeological, paleoethnobotanical, and genetic evidence for two competing theories on the development of maize. First, the question of the geographic origin of cultivated maize is introduced. Next, two competing theories, the Teosinte Theory and the Tripartite Theory, are summarized. Details on the plants figuring into these theories are then given. The problem of the uncertain ancestry of maize is introduced. Macrobotanical, microbotanical, archaeological, and genetic evidence is presented in support or refutation of the key theories. A model for the process of the development of maize agriculture is offered. It is concluded that the Teosinte Theory is the more plausible of the two theories under consideration.

The Geographic Origin of Maize

Maize was domesticated in the New World, although some have argued otherwise. No living wild grass with the same morphological properties as cultivated maize has ever been discovered, anywhere. As explained in this paper, evidence from archaeological, paleoethnobotanical, and genetic investigations situates cultivated maize and its wild ancestors solidly in the New World, and most probably in the Balsas Valley of southwestern Mexico.

Before the development of modern genetic studies, the New World ancestry of maize was incredibly difficult to trace. Theoretically, if the wild ancestor of the modern crop continued to grow, uncultivated, in its native habitat(s), geneticists would know to look to that wild population to trace its links to the modern cultivar. However, no wild plant in the New World bears a close morphological resemblance to cultivated maize (Beadle 1980:112). Because of the lack of morphological similarities, New World scientists working before the development of modern genetic studies (discussed below) could not be certain which wild plant was the ancestor of cultivated maize; the homeland of any modern wild plant could not be named the location in which maize was first domesticated, based on morphology alone. The lack of close resemblance to a modern wild plant, and the unknown “hearthland” of first cultivation, complicated the search for the ancestors of maize, and made the ancestry and evolution of maize all the more intriguing to curious scientists. This section enquires into the possible ancestors of maize and the possible locations of its early cultivation.

Within the New World, maize is thought to have been domesticated first somewhere in Mesoamerica. Mesoamerica, with its diversity of plant habitats differing in elevation, temperature, and amount and timing of rainfall, supports a wide range of natural vegetation (Mangelsdorf 1983:244). This natural vegetation could have included the ancestor(s) of cultivated maize. Moreover, the variety of natural environments could somewhere have provided a suitable habitat for maize cultivation (McClung de Tapia 1992:144).

Early scholars like Sylvanus Morley believed that the Maya were the first people to domesticate *Zea mays* (Coe 2005:44). A great many varieties of maize grow in modern Guatemala; the level of diversity suggested to some that Guatemala may have been the early center of maize cultivation (Coe 2005:45). But the idea of maize development of in the Maya area is at odds with the fact that most of the earliest-known macrobotanical remains of maize have been recovered from the dry caves in the Tehuacán Valley of Puebla and Oaxaca, Mexico—outside the Maya area. The discovery of these remains led some researchers to believe that this valley was the site of first maize cultivation around 7,000 years ago (Eubanks 2001). The rising interest in studies of microbotanical remains (pollen, phytoliths, and starch grains) has demonstrated the early cultivation of some crops (especially root crops) in the humid lowland Neotropics (e.g. Piperno et al. 2000). While the lowlands may have been the location of the first plant cultivation in the New World (in general), microbotanical evidence has not yet proven that the presence of cultivated maize in the lowlands (or in the Maya area) predates the macrobotanical remains from central Mexico. New genetic research, explained later in this paper, pushes the probable place of origin of cultivated maize in the opposite direction, to the west of the dry cave sites, into the Central Balsas Valley of Guerrero, Mexico.

Two Theories

Many researchers have challenged themselves to answer the questions of the geographic origin, ancestry, and evolution of maize, and two main theories (with variations) have emerged. The more parsimonious of the two is called the “Teosinte Theory.” The Teosinte Theory simply states that, through human selection 8,000 to 15,000 years ago, a wild annual teosinte (probably *Zea mays* ssp. *parviglumis*) became the direct ancestor of cultivated maize (Beadle 1980:112; Mangelsdorf 1983:216). According to the Teosinte theory, through hybridization and backcrossing of teosinte populations, teosinte evolved into cultivated maize (McClung de Tapia 1992:148). Major proponents of this theory, and its variations, have been botanist and cytogeneticist George Beadle (1939, 1980, 1981); botanists Walton Galinat, Hugh Iltis, and John Doebley; and dry caves-site archaeologist Richard MacNeish.

The second major theory, created by plant geneticist and botanist Paul Mangelsdorf and his colleague Robert Reeves (e.g. Mangelsdorf & Reeves 1939; Mangelsdorf et al. 1978), is called the "Tripartite Theory." Part one of the Tripartite Theory states that the ancestor of cultivated maize was not teosinte, but instead a form of wild maize pod-popcorn (McClung de Tapia 1992:148). This pod corn ancestor no longer exists because it was "swamped out of existence" by later cultivated strains (Beadle 1980:112). Part two of the Tripartite Theory originally stated that teosinte derived from the hybridization of maize and the wild grass *Tripsacum.* However, Rafael Guzman's 1976 discovery of perennial diploid teosinte, *Zea diploperennis*, led to the revised statement that teosinte is the product of hybridization of maize and *Zea diploperennis* (Iltis 1982:200; Iltis et al. 1979; Mangelsdorf 1983:233). The third part of the Tripartite theory states that "many modern varieties of corn have undergone genetic introgression from teosinte or *Tripsacum* or both" (Mangelsdorf 1983:217). This interbreeding would account for shared characteristics among the species, and would lend hybrid vigor to highly inbred cultivated maize. However, botanists Garrison Wilkes and George Beadle, among others, have argued that teosinte and *Tripsacum* do not hybridize under natural conditions, and that teosinte cannot be a hybrid derivative of maize (McClung de Tapia 1992:148).

The remainder of this maize section evaluates the archaeological and paleoethnobotanical evidence that supports or refutes these theories.

The Plants

Maize

Comprehension of the Teosinte Theory and the Tripartite Theory, and judgments in favor or rejection of either, must have a basis in an understanding of the taxonomy, morphology, and reproductive characteristics of the plants concerned. Knowledge of plant morphology is useful in interpreting the macrobotanical record of an archaeological site. Therefore, this brief introduction to the traits of maize and its relatives may prove useful in understanding the archaeological evidence that supports or refutes theories regarding the history of maize.

Modern cultivated maize, *Zea mays* ssp. *mays*, is perhaps the most recently-evolved grass of the Poaceae family (Iltis 1981:7). Its common name, “maize,” originated among the Arawak-speaking Taino Indians of the Bahamas and Greater and Lesser Antilles, to whom it meant “life-giving seed” (Sanabria 2007:254-255). Maize is an annual grass, and has ten chromosomes in its haploid form (Iltis 1981:7). Cultivated maize has developed some characteristics with beneficial properties, including seeds that are tightly affixed to a cob that is completely enclosed in a husk, which protects the seeds from predators and facilitates harvesting by humans. Characteristics like this likely result from a high degree of inbreeding within the subspecies. Inbreeding also has had some negative effects; for example, the husk acts to limit natural effective seed dispersal (Mangelsdorf et al. 1964:538). Hybridization with other Poaceae, namely teosinte and *Tripsacum* spp., lends “hybrid vigor” to cultivated maize by downplaying some of the negative effects of inbreeding through, for example, increasing resistance to disease; developing a strong, tall stalk and a good root system; and producing ears with many kernels (Beadle 1980:119).

The morphology of the maize plant, itself, is evidence of a long history of human interference with the plant’s reproduction. Maize in Mexico has been dependent on humans for its reproduction for at least 4,500 years (Benz & Long 2000:460). The reproduction of maize is facilitated by wind-pollination and the production of copious quantities of pollen. However, because the inflorescence with the seeds (i.e. the ear) is completely encased in the husk, maize has no way of dispersing its seeds without human assistance (Mangelsdorf et al. 1964:538). Without human help, new “daughter” plants would establish themselves so close to their “mother” that all would compete for water and soil nutrients; perhaps none would survive (Beadle 1980:112). Wild maize (if such a thing existed), or the ancestor of cultivated maize, must have had a more effective way of dispersing its seeds. The question then arises, how was the ancestor of cultivated maize different from modern cultivated maize? Scientists are interested in answering this question, and in the identification of the plants that were ancestral to cultivated maize.

Teosinte

The main plant that is considered to be ancestral to cultivated maize is commonly known as “teosinte.” The word “teosinte” comes from the Aztec/Nahuatl *teocentli*, which means “God’s ear of corn.” In parts of modern Mexico, teosinte is called *madre de maiz*, meaning “mother of maize,” or *maicillo,* “little corn” (Beadle 1980:119; Iltis 1982:194). Some interpret this folk etymology as underlying indigenous knowledge that teosinte and maize are related, supporting the Teosinte Theory. Mexican farmers are known to say that teosinte growing in cornfields is “good for the corn,” and experiments by university-affiliated researchers have shown that cross-pollination of maize by teosinte does indeed produce maize that has hybrid vigor (Beadle 1980:119).

In the literature, the name “teosinte” has been applied to various annual wild grasses of the genus *Zea*, including *Z. mays* ssp. *mexicana* (=*Z. mexicana*), *Z. mays* ssp. *parviglumis*, *Z. luxurians*, and five additional, unspecified “taxa of wild grasses that are closely related to maize” (Benz 2006:9, 11, 12, 13). The taxonomy of the genus was defined by botanists John Doebley and Hugh Iltis (Doebley & Iltis 1980; Iltis & Doebley 1980). Recent genetic evidence has identified *Z. mays* ssp. *parviglumis* as the ancestor of cultivated maize.

The fact that teosinte grows wild in the same regions where maize was hypothesized to have originated led some early botanists to wonder if teosinte might be the ancestor of maize (Beadle 1980: 113), as those who follow the Teosinte Theory continue to believe. Wild teosinte is native to Guatemala, Honduras, and southern and western Mexico, places where temperatures are warm, and daylight does not exceed 12-13 hours per day (Beadle 1980:112, 114; Coe 2005:45). Geographic ranges and ecological preferences of species within the genus *Zea* are given in Doebley & Iltis 1980 and Iltis & Doebley 1980. Today, teosinte populations have been reported from as far south as northern Nicaragua (Horn 2006:368). It should not be automatically assumed that precolumbian teosinte had the same range as modern teosinte, since people (and the grazing cattle introduced to the New World by European colonists) have caused environmental modifications that could have caused plants to change their ranges (Horn 2006:369). Nevertheless, the present-day central Balsas River Valley of Mexico is the habitat of *Z. mays* ssp. *parviglumis,* the annual teosinte which has recently been identified as the genetic ancestor of cultivated maize (Smith 2001:1324), and the Balsas River Valley is the best guess as to the area where teosinte cultivation began.

Over the years, there has been some resistance in the scientific community to the notion that human involvement with teosinte resulted in cultivated maize. Before the advent of recent genetic studies, the great morphological differences between teosinte and maize made a close relationship between the two plants seen untenable. Mangelsdorf created the Tripartite Theory because he believed that some combination of popcorns and podcorns would have produced a plant more similar to the macrofossils of early cultivated maize, than would have evolved if teosinte were the sole ancestor (Mangelsdorf et al. 1964:538). Even George Beadle (1980:112-113) noted the morphological differences between teosinte and cultivated maize: Teosinte has several thinner stalks growing from its base, and triangular seeds, each enclosed in a hard individual fruit case or husk. Maize has only one thick stalk, and one husk surrounding all the seeds. In teosinte, all seeds are arranged in a single row of 6-10 seeds, and multiple “female spikes” of seeds grow on each stalk. Maize, in contrast, produces only one or several ears per stalk. When teosinte reaches maturity, the individual fruit cases open and break off the spike, so the seeds can be easily disseminated. As noted above, maize disseminates its seeds poorly.

More resistance to the idea of teosinte having been ancestral to maize stemmed from the idea that teosinte could neither have been grown as a crop, nor could have been prepared as a nutritious food for humans. Could a plant that was itself an unsuitable crop have been the ancestor of one of the leading food plants of modern times? This question has led some scientists to re-examine the possibilities for teosinte cultivation and consumption. It is true that, because teosinte seeds separate freely from their stems, teosinte grains would have been difficult for early humans to harvest (Mangelsdorf 1983:235). Teosinte grains are nutlike and hard-shelled; each kernel is encased in a shell comprised of cellulose and lignin, which is too tough for people to chew (Beadle 1980:117; Mangelsdorf 1983:235). The shells are very difficult to separate from the kernels, and the kernels inside the shells are very small, so a person would have to eat an awful lot of teosinte to get sufficient nutrition (Mangelsdorf 1983:235). But perhaps early teosinte cultivators were not focused on consuming the grains. Iltis (1982:196) pointed out that it is possible for humans to chew on teosinte stems, in the same manner as one might chew on sugarcane. Ethnographic evidence shows that Mexican children still do this, and quids of chewed stems were recovered from Richard MacNeish’s archaeological excavations at La Perra Cave in Tamaulipas and at the caves of Tehuacán Valley, Oaxaca, Mexico (Iltis 1982:196; Mangelsdorf 1983:235). Some modern Mexicans use teosinte stalks to brew beer, or eat the nutritious leaves (Blake 2006:68-69). Moreover, if early teosinte cultivators were interested in consuming the grains, they could have found an efficient means of doing so. Immature teosinte kernels and their cases are edible on their own (Beadle 1981:891). Experiments by Beadle revealed that, even without ceramics, teosinte grains can be popped on fire embers or heated rocks or sand, and eaten like modern movie popcorn (1980:117). There is no evidence that Native Americans ever popped teosinte, but there *is* evidence of popped *maize* at the archaeological site of Bat Cave, New Mexico (Mangelsdorf 1983:235). Teosinte grains can also be eaten like porridge, after they have been dried and ground with *mano* and *metate* (which have been known archaeologically for about 8,000 years) and the husks have been floated away in water (Beadle 1980:117; 1981:891).

With the preceding arguments and new genetic insight, the old resistance to the notion of teosinte cultivation has broken down. Blake (2006:68-69) suggested the following model for teosinte cultivation. It is possible that humans were initially interested in teosinte not for its grains, but for its stalks and leaves. As teosinte varieties with larger cobs evolved, people may have found the seeds (grains) easier to collect, transport, and plant, even if their primary interests were in the stalks and leaves. Once domesticated teosinte varieties began to lose their seed casings, the grain itself became more accessible for human consumption. Such a model supports the Teosinte Theory.

Tripsacum

Another plant genus that was once important in theories on the development of maize is *Tripsacum*. *Tripsacum* is the genus of the Poaceae family most closely related to *Zea* (Iltis 1981:5). *Tripsacum* has nine species spread geographically from the lowlands of central and northern South America, all the way up to Massachusetts in the United States (Mangelsdorf 1983:233). Although *Tripsacum* grows wild in the same region in which maize is thought to have originated, proponents of the Tripartite Theory no longer believe that it is ancestral to maize. However, *Tripsacum* has some of the same morphological characteristics (e.g. individual kernels encased in individual husks) and positive traits as teosinte (stronger root system and stronger stalks than maize; and resistance to drought, excessive moisture, insect damage, and disease; Mangelsdorf 1983:233). It was once believed that *Tripsacum* (along with teosinte) contributed these characteristics to modern cultivated maize through introgression (Mangelsdorf 1983:233).

The nail in the coffin of the portion of the Tripartite Theory that had identified *Tripsacum* as an ancestor of cultivated maize came from a line of evidence relevant to this dissertation: palynology. Botanist John Rowley was one of the first to study pollen of the grass family via phase contrast microscopy, Scanning Electron Microscopy (SEM), and Transmission Electron Microscopy (TEM; e.g. Rowley 1960, 1976). Rowley posited that the exine structure of pollen grains from cultivated grasses differed from that of wild grasses, though the differences later proved to be unquantifiable. In 1972, Umesh Banerjee and Elso Barghoorn made Scanning Electron Micrographs (SEM) of the pollen grains of maize, teosinte, and *Tripsacum* (Mangelsdorf 1983:223).

Teosinte and *Tripsacum* are the only New World grasses with pollen that cannot be distinguished from that of *Zea mays* by simple axis measurements (all have long axis measurements greater than 45 μs) and pore-axis ratios (all of which can exceed 5.7; Irwin & Barghoorn 1965:39). Using phase contrast microscopy, *Tripsacum* can be seen to have three levels of phase retardation; *Zea mays* has two levels; and teosinte falls somewhere in between. (Irwin & Barghoorn 1965:39). The SEM images published by Banerjee and Barghoorn demonstrated that pollen grains of both maize and teosinte have evenly-distributed spinules on their exines, while the spinules on the exines of *Tripsacum* are clumped (Irwin & Barghoorn 1965:42; Mangelsdorf 1983:223). With this palynological evidence, Mangelsdorf agreed that he had been wrong: a hybridization of maize and *Tripsacum* did not yield teosinte (Iltis 1982:197). Instead, Mangelsdorf became convinced, teosinte resulted from a hybridization of maize with the newly-discovered *Zea diploperennis.*

Introduction to the Evidence for the Ancestry of Cultivated Maize

Evidence for the support or rejection of the two major theories of maize origin, ancestry, and evolution through cultivation can be sought in the archaeological and paleoethnobotanical records and in genetic studies. Here, the archaeological and paleoethnobotanical evidence that has been most frequently cited in discussions of the Mesoamerican origins of maize is introduced. The relevant evidence is found mainly in the form of preserved plant remains (both macro- and micro-botanical remains), but also in the form of artistic representations. These lines of evidence benefit from mutual support by genetic studies. In combination, the forms of evidence can help to answer the question of whether teosinte existed before maize, or vice-versa, thus pointing to the most likely ancestor of cultivated maize. The question of whether or not teosinte predated maize is an important one; Mangelsdorf (e.g. Mangelsdorf et al. 1978:237, 249-250) believed that wild maize had existed long before the domesticated form. It the remains of cultivated maize appeared in the archaeological record before teosinte appeared, there would be support for the idea that cultivated maize evolved in situ from a wild maize (Tripartite Theory), rather than from teosinte (Teosinte Theory).

Sources of bias exist in the archaeological and paleoethnobotanical records which can be mitigated by consideration of genetic evidence. Archaeological evidence for ancestry of cultivated maize is limited by poor preservation, due in part to human processing prior to deposition (if maize were ground prior to consumption, remaining evidence would be sparse or difficult to identify) and, possibly, undiscovered sites. Phytolith and pollen evidence shows that maize was used in southern Central America and northern South America between 7000 and 5000 b.p., but carbonized macrobotanical remains and bones (for use in isotope analyses) from before 3000 b.p. are poorly preserved in the tropical lowlands (Piperno 1998:427). It is important to note that much of the archaeological evidence for the development of this complex comes from only five dry caves in three regions of Mexico (Tamaulipas, Tehuacán Valley, and the Valley of Oaxaca; Smith 1997:932; Smith 2001:1325-1326). These areas of most intense excavation do not include Guadalajara or the Balsas River Valley, where, based on genetic evidence, beans and maize are (respectively) thought to have originated. Thus, based on archaeological evidence, it is difficult to ascertain whether maize arose out of crosses between wild maize and teosinte, or any other way (McClung de Tapia 1992:153). We can turn to genetic evidence to resolve the question. The archaeological and paleoethnobotanical evidence remains useful for identifying the first appearances of cultivated maize in different locations, and at different times.

Macrobotanical Evidence

Macrobotanical remains are the best form of evidence for researching the domestication and spread of maize because they readily display morphological changes indicative of domestication, and because they can be directly dated by AMS. Macrobotanical evidence relevant to this discussion includes various maize, teosinte, and *Tripsacum* plant parts, among them whole cobs, cob fragments, roots, stalks, leaves, husks, kernels, and quids of chewed stalks and husks. At archaeological sites, these are usually found in a charred context or under conditions of dessication. Due to preservational conditions of macrobotanical remains, it is easier to trace the northward spread of cultivated maize than it is to trace the southward spread, from the Balsas River Valley into the Maya area (Dull 2006:358).

Macrobotanical evidence for the early domestication of plants is known from a limited number of Mesoamerican archaeological sites, mostly in arid Mexico. Much of the important work in the investigation of the origins of plant domestication in Mesoamerica has come from the 1960s excavations led by archaeologist Richard MacNeish (McClung de Tapia 1992:143, 147). MacNeish led investigations in the caves (Coxcatlán, Purron, San Marcos, Tecorral, and El Riego) at the margins of the Tehuacán Valley of Puebla and Oaxaca (MacNeish 1971, 1972; Mangelsdorf et al. 1964:539). Also significant were Kent Flannery's (1986) excavations at Guilá Naquitz Cave, also in Oaxaca.

Possibly the oldest known maize cobs come from these Tehuacán Valley sites, so some scientists, like Mangelsdorf, have used them as evidence that cultivated maize replaced its wild ancestor at these sites first. Could wild maize have grown in the Tehuacán Valley? Although the valley is arid and mainly supports xerophytic vegetation, it does contain perennial springs (Mangelsdorf et al. 1964:539). Anyway, wild maize would have been an annual plant, so it would not have had to survive the winter drought; most of the rain in the Tehuacán Valley comes between April and October, when the annual wild maize would have been growing (Mangelsdorf et al. 1964:539).

The earliest-known directly AMS dated maize macroremains (6305-6015 cal B.P. or 5400 b.p.) come from Guilá Naquitz Cave in Oaxaca, a site that also produced the earliest-known remains of *Cucurbita pepo* (Benz 2001; Piperno & Flannery 2001:2101-2102; Smith 1997). These early maize cobs are primitive in appearance, show teosinte ancestry, and probably do not represent cultivated specimens (Piperno & Flannery 2001:2102-2103; Perhaps, then, they should be called "teosinte" instead of "maize"!).

The earliest ‘early cultivated’ maize cobs come from San Marcos Cave, and were directly AMS dated to 4700 b.p. (5500 cal B.P.; Long et al. 1989; Benz & Long 2000; Mangelsdorf et al. 1964:541). This cave faces a broad alluvial plain that may have supported maize agriculture, and that could have a good habitat for wild maize (Mangelsdorf et al. 1964:541). The alluvial terraces near San Marcos cave were artificially irrigated, so they were likely the site of agricultural fields, *replacing* the natural habitat of the wild maize (Mangelsdorf et al. 1964:542). This evidence may support the Tripartite Theory.

Other early maize macroremains were found at Coxcatlán Cave, and were radiocarbon dated to between 5200 and 3400 B.C. The cobs were found with remains of bottle gourd, squash, tepary beans, chili peppers, amaranth, avocado, and zapote, so it is reasonable to believe that there was *some* cultivation or agriculture happening in the Tehuacán Valley by this time (Mangelsdorf et al. 1964:544).

The AMS dates reported here are based on reanalyses and updates of radiocarbon dates. These new AMS dates on maize macroremains fall into the same time range in which teosinte is first thought to have appeared. The earliest undisputed evidence of teosinte comes from 3000 B.C. in the Tehuacán Valley (Mangelsdorf 1983:237). Dating evidence, therefore, cannot conclude that maize predated teosinte.

Keeping in mind the important question of whether teosinte appeared before cultivated maize, archaeologist Gloria Caddell did a survey of evidence (pollen and macroremains) for teosinte, maize, and hybrids at eight archaeological sites from Panama to New Mexico dating between 8000 B.C. and A.D. 1000 (Mangelsdorf 1983:236). Only at the site of Zohapilco, in the Valley of Mexico, did teosinte appear before maize, but this evidence is disputed (Mangelsdorf 1983:236-237). The dispute arises from the fact that two teosinte fruit cases were found in the strata dating between 6000 and 4500 B.C., possibly as old as the earliest maize pollen, *but* these teosinte fruit cases appear to be modern contaminants (Mangelsdorf 1983:238). Following this chronology, maize predated teosinte, so the Tripartite Theory is supported by this evidence.

Of incidental interest, the oldest Belizean maize macroremains of which I am aware were found at the site of Cahal Pech, and dated to 2730±130 B.P. (Lawlor et al. 1995:158).

Palynological Evidence

Although macrobotanical remains of ancient maize are probably the best evidence for the process by which maize became domesticated and spread from its original habitat in the Balsas River Valley, macrobotanical remains are rarely preserved in the humid tropical areas of Mexico and Central America, where the earliest maize is believed to have originated (Bryant 2007a:19659). Pollen is more likely to survive over thousands of years in such environments, so pollen has much to teach us about the onset and dispersal of maize cultivation.

Pollen Morphology: A significant problem in the palynology of maize domestication is that it is often difficult to determine whether a pollen grain came from domesticated maize, or from another grass (Bryant 2007a:19659). Poaceae pollen is very plain in appearance via light microscopy, and the palynologist must always be careful not to confuse maize pollen with the similar-looking pollen of other grasses, aquatic grasses, or bamboos (Horn 2006:368). Palynologists have attempted to use grain dimensions to separate maize pollen from that of other Poaceae. The pollen of early domesticated maize, teosinte, and *Tripsacum* all exhibit a substantial overlap in size ranges (Dull 2006:358). Most palynologists feel that the comparison of long axis measurements is still the best method for differentiating between fossil teosinte and maize pollen (Dull 2006:358). Maize, teosinte, and *Tripsacum* all have long-axis measurements greater than 45 μ (Irwin & Barghoorn 1965:39) Early maize (before 6000 b.p.) produced pollen grains of approximately the same size range (50-90 μ) as modern teosinte pollen (Barghoorn et al. 1954:230-231; Dull 2006:358-359; Mangelsdorf et al. 1978:242). However, maize pollen grains tend to have the largest dimensions (Dull 2006:358-359).

In addition to long axis diameter, palynologists attempting to define the pollen of cultivated maize (vs. that of wild grasses) have considered grain size, pore diameter, level of phase retardation, ratio of pore diameter to grain diameter, and surface (or exine) structure and texture (Barghoorn et al. 1954:232; Bryant 2007a:19659-19660; Grant 1972; Irwin & Barghoorn 1965; Kurtz et al. 1960; Mangelsdorf et al. 1978:240-242; Rowley 1960, 1976; Tsukada & Rowley 1964). Many of the studies have concluded that there is substantial overlap among the characteristics of the pollen of maize, teosinte, and *Tripsacum.*

There has yet been no resolution to the problem of differentiating fossilized cultivated maize pollen from ancient teosinte pollen (Bryant 2007a:19660). This problem abates as one examines later (i.e. not the very earliest) cultivated maize pollen, because the grain diameter eventually came to (reliably and greatly) exceed the size of other grass pollen. As maize cob size evolved, so did the size of maize pollen grains. At archaeological sites where both maize macrofossils and maize pollen have been found, increasing cob size has been correlated with an increase in pollen size (Dull 2006:358; Galinat 1961:322-323, 325; Grant 1972:182; Mangelsdorf et al. 1978:243). Only maize pollen grains exceed 92 μ in length (Dull 2006:359).

Clues to Identifying Maize Pollen: Although it can be difficult to differentiate between the pollen of wild and early cultivated maize, archaeological palynologists can identify geological strata indicative of agricultural practice by looking for clues that accompany maize pollen in the sediment. These clues include fine charcoal, indicating burning to clear land for agriculture; pollen of other possible cultivars; and a shift in the pollen spectrum from dominance by forest plants to dominance by plants that prefer open or disturbed habitats (including agricultural weeds, such as other grasses, Amarathaceae, and Asteraceae’ Dull 2006:359; Horn 2006:369). For example, Bartlett et al. (1969) associated early (7000 b.p.) cultivated maize from a core in the Gatun Basin of Panama with fine charcoal; pollen of *Manihot esculenta* (cassava) and *Ipomoea* (sweet potato); abundance of pollen of Poaceae, *Ambrosia*-type Asteraceae, and other herbaceous weeds (such as *Borreria*); and scarcity of tree pollen. Bloom et al.

(1983:418), in a study of wetland agriculture at San Antonio Río Hondo, Albion Island, Belize, noted that the percentage of tree pollen (such as *Quercus* and Moraceae) "was the lowest that has been found in an archaeological context in northern Belize. This is a probable indication of extensive forest clearance and suggests that the Maya used wetland agriculture in conjunction with wet-season swidden on uplands like many lowland cultivators today."

Finally, one can consider the context from which a pollen sample was collected, and the time period to which it dated, as clues to the identification of the Poaceae grains in a sample. Maize has an anemophilous pollen syndrome, but its grains are large and heavy, and are therefore unlikely to travel far (more than 60 m) from the parent plant (Horn 2006:369). Islebe et al. (1996) believed that maize pollen would not be common in lake sediments unless the maize crop was grown on the lakeshore. Therefore, a sample collected from an agricultural context (such as a ridge-and-furrow field or a terrace) could reasonably contain maize pollen. In a similar line of reasoning, a 65 µ Poaceae grain could more easily represent maize if collected from a 4000-year-old stratum than if collected from the modern surface.

Dates for Early Maize Pollen: Directly dated macrofossil remains consistently yield younger dates than indirectly dated microbotanical remains (Blake 2006:56). Maize pollen from the 70-m-deep Bellas Artes geological core in Mexico City was, with some dispute, formerly believed to be the very oldest maize pollen (McClung de Tapia 1992:147). In 1954, Barghoorn et al. reported five grains of large Poaceae pollen from the bottom of the 80,000-year-old core, claiming that the pollen represented the ancestor of maize that was "neither teosinte, nor *Tripsacum,* nor a cross between the two" (McClung de Tapia 1992:147). However, George Beadle and others disputed Barghoorn's interpretation: the grains were "too large to represent a hypothetical wild maize," as pollen diameter is correlated with cob size, and early cobs are known from the archaeological record to have been very small (McClung de Tapia 1992:147). The grains were later judged to be contaminants from a later date, or victims of thermallygenerated genetic mutations (Beadle 1981:891; Benz 2006:10; McClung de Tapia 1992:147).

The earliest known *Zea* pollen comes from San Andrés, Tabasco (7300 B.P.; Pohl et al. 2007). The earliest maize pollen from Belize was reported from Cob Swamp (4610±60 b.p.; Pohl et al. 1996:360-361). This was the point when maize agriculture seems to have become common in the Maya area. Blake (2006:60) was struck by his observation that "the most common dates for [the appearance of maize pollen in] lake or swamp core sample locations is in the 4200 to 4700 B.P. range: Sipacate, Guatemala; Cob Swamp, Belize; Lake Yojoa, Honduras; Laguna Martínez, Costa Rica; and La Yeguada, Panama", suggesting "an expansion of maize planting during this period." The Laguna Verde core starts during this period, with the first grain of cultivated maize pollen recovered from at stratum dating between 4830 and 4520 B.P.

Phytolith and Starch Grain Evidence

Like pollen grains, phytoliths and starch grains may be recovered from contexts in which macrobotanical evidence, and even pollen, has been destroyed. Some researchers believe that it may be more reliable to examine phytoliths and starch grains to differentiate between the presence of cultivated maize and that of other grasses, than it is to rely on pollen for such evidence (Holst et al. 2007). Still, the use of phytoliths in identifying the presence of ancient maize remains controversial (e.g. Dull 2006). Microbotanical remains, especially phytoliths, are difficult to date accurately because it is difficult to determine whether or not they were recovered from their original context of deposition. The reliability of dates for phytoliths increases when they are tied to residues in cooking pots or dentition in skeletons (Blake 2006:63).

The earliest maize phytoliths (accompanied by *Zea* pollen) come from the Aguadulce Rockshelter on the Pacific coastal plain of Panama, dating between 7800 and 6200 b.p. (Piperno et al. 1985; Piperno & Pearsall 1998:Chapter 4; Benz 2006:18). Pohl et al. (2007) used phytolith data to document the origin of domesticated maize 7,300 years ago in southwestern Mexico. In the Maya area, the earliest indirect dates on samples associated with *Zea* phytoliths come from Sipacate, Guatemala (4600 b.p.; Blake 2006:64-65).

Microbotanical specialist Dolores Piperno and her colleagues have shown that starch grains and phytoliths can differentiate between wild teosinte and domesticated maize, because morphological differences in those types of remains resulted from the genetic changes caused by human intervention (Bryant 2007a; Holst et al. 2007). In some cases, they have recovered starch grains from maize and various tubers from the surfaces of ground stone tools, demonstrating human association with the microbotanical remains (e.g. Piperno 1998, Piperno et al. 2000, 2009). They have confirmed that pollen is *not* a good indicator of very early domesticated maize: morphological features of the pollen of cultivated maize and wild teosinte are virtually identical, with measurements that widely overlap. Piperno and colleagues put these facts together in a three-pronged study of pollen, phytoliths, and starch grains in the Balsas Valley of Mexico, the probable site of the initial divergence of cultivated maize from wild teosinte (Piperno et al. 2007). This study showed a connection between anthropogenic burning, land clearance, and pollen from maize or its ancestral teosinte, around 7000 B.C. More recently, Piperno and colleagues uncovered nearly 9,000 years of occupation at the Xihuatoxtla rock shelter, also in the Balsas Valley (Piperno et al. 2009; Ranere et al. 2009). Although the site was poor in pollen and macrobotanical remains, phytoliths and starch grains were recovered from sediments and from the surfaces of ground stone tools. Microbotanical remains bearing the traits of cultivated *Zea* (rather than teosinte) were found below charcoal that was radiocarbon dated to 8700 B.P.

Artistic Representations in the Archaeological Record

An interesting complement to macro- and micro-botanical evidence for the ancestry and evolution of maize is found in artistic representations of maize on ancient artifacts, as explained in Mangelsdorf’s 1974 book *Corn: Its Origin, Evolution, and Improvement*. For the state-level societies in the precolumbian New World, including the Maya of Mesoamerica and the Aztec of Mexico, maize was important not only as a food, but as “the subjects of solemn rites and ceremonies in which various deities concerned with cereals and their production were worshipped” (Mangelsdorf 1974:187). Maize was a religious or sacred object. As such, it made its appearance in various art forms. The artistic representations do not provide evidence for the Tripartite Theory over the Teosinte Theory, or vice-versa, but they do give insight into the evolution of maize.

In Mexico, wherefrom most of the art comes, it was created primarily in the stone and ceramic modalities. When correlated with dates from archaeological strata, these artistic representations can give insight into the morphology or ‘race’ of the plant at any given time, even in the absence of macroremains. Even where macroremains are present, the artistic representations provide a complementary view because the preserved cobs no longer have intact kernels. The artistic representations allow scientists to determine when certain steps in maize evolution occurred. Scientists actually try to identify the race of maize depicted in this art. Although interpretation of art does not sound like a very scientific method, the photographs in Mangelsdorf’s book show very convincing, obvious distinctions among different types of maize as depicted in art. Mangelsdorf says that it is possible to determine which artistic representations were intended by the artist to be realistic, vs. which are stylized, because real maize has paired rows of paired kernels; stylized representations often have no paired rows and alternating kernels.

Examples of “maize art” include Zapotec ceramic funerary urns from Monte Alban, Oaxaca. One urn dating to A.D. 600-800 features Nal-Tel maize in a figure’s headdress, and another has maize hung on a figure’s necklace. An unprovenienced Mexican rain god (complete with goggles) “idol” figure wears Nal-Tel near its neck and shoulders. Other “idols” and sherds feature dent corn. Completely different races of maize are featured on Peruvian narrow-mouthed ceramic vessels.

Genetic Evidence

Scientists want to know how evolution operated on the ancestors of maize to cause change over time. It has been debated whether plant domestication is a biological or genetic process within the plants, vs. a cultural process resulting from human adaptations to their natural environment (McClung de Tapia 1992:156). Perhaps maize was domesticated through biological *and* cultural processes, especially if the plant was domesticated contemporaneously in several locations with different environmental circumstances and different cultivation practices.

Recent advances in genetics have filled in some details about the relationships between maize, its wild relatives, and its hypothetical ancestors, but have not resolved all controversies. A genetic study published by Mary Eubanks (2001) fell in favor of the Tripartite Theory, promoting the idea that maize was descended from a cross between teosinte and *Tripsacum*, because a genomic comparison found that maize had some polymorphisms in common with teosinte (inherited by maize from a teosinte ancestor) and others in common with *Tripsacum* (inherited by maize from a *Tripsacum* ancestor). Another genetic study (Hilton & Gaut 1998) found the opposite, stating that maize did not result from "a hybridization between a member of the genus *Zea* and *Tripsacum*" (Benz 2006:13).

The most conclusive and widely-accepted recent genetic study (Matsuoka et al. 2002) identified an annual teosinte, *Zea mays* spp. *parviglumis,* as the closest wild relative (or the immediate predecessor) of maize. Matsuoka et al. suggested that the basal (i.e. of a cladogram) races of teosinte from which maize developed are native to locations above 1900 m above sea level. They placed the cradle of earliest maize domestication in the Balsas River Valley in the highlands of the southwestern Mexican state of Guerrero (Matsuoka et al. 2002:2082). The modern range of *Zea mays* spp. *parviglumis* is centered on this area. Matsuoka et al. believed that maize originated from a single cultivation episode in highland southern Mexico and diversified before spreading to the lowlands (2002:2080).

Matsuoka et al. also used genetics to predict the time period in which the earliest maize cultivation may have occurred. To answer questions “about the length of time humans have intervened in teosinte populations” and to get at the timing of the divergence of maize from teosinte, gene sequencing comparisons have been conducted to identify population bottlenecks (Benz 2006:12). This enables scientists to calculate the founder plant population size based on a given duration of the bottleneck (Benz 2006:12). The size and duration of the bottleneck must also have been dependent upon selection intensity (Benz 2006:14). This type of “bottleneck study” led Matsuoka et al. (2002) to conclude that maize diverged from *Zea mays* ssp. *parviglumis* around 9188 b.p. (Benz 2006:13). Likewise, genetic studies by Wang et al. (2005) show that *Zea mays* diverged from *Zea mays* ssp. *parviglumis* between 5000 and 15,000 b.p. (Benz 2006:14).

The best of the genetic evidence, then, falls solidly in favor of the Teosinte Theory, and even suggests the date and location for the earliest cultivation of maize.

Model for the Earliest Cultivation of Maize

Once ancient Mesoamericans recognized the utility of the plant, they became involved with it in such a way as to cause the morphological and genetic changes that eventually resulted in the large, sweet-kerneled cobs we eat today. Here, a model for the origins of maize cultivation and agricultural development is in order. Hugh Iltis (1982:193) suggests a scenario specific to the Mesoamerican domestication of maize. After eating the Pleistocene megafauna into extinction, humans in the ancient Americas had to rely on hunting smaller game animals and collecting wild plant foods. Population pressure may have forced humans to occupy arid areas, where fewer wild plants and animals were available for collection (Iltis 1982:193). Humans living in these marginal areas had to find a way to supply themselves with food, and agriculture was born (Iltis 1982:193).

I do not necessarily agree with Iltis that population pressure was a major factor in human habitat choice in Archaic Period Mesoamerica. The Archaic peoples, probably living in the highlands of the Balsas River Valley (where the ancestral maize plant was endemic), are likely to have recognized the function of the plant as a food. They may have consumed the stalks and leaves of the plant, rather than the mature grains. The people would then, perhaps unknowingly, have taken steps toward incipient cultivation, including protecting the plant from wild animals and birds, and collecting and storing seeds for future plantings. The crop evolved as people removed competing vegetation from the plant’s natural habitat. People gradually became more and more dependent on the cultivated grain, and relied less on the gathering of wild plants for food. Only later did people clear large tracts of land to serve as agricultural fields. Later still, maize production was intensified through such means as irrigation.

As people produced this food crop, they created morphological changes in the plant. A study of maize macrofossil morphology from the Tehuacán Valley suggests that early maize was directionally selected by humans, first for an increased number of grains per cob, then for increased grain size, and finally (after 2500 B.C.) for an increased number of cobs per stalk (Benz & Long 2000:463-464).

Because archaeologists have not found a large quantity of maize remains at the early maize-bearing dry cave sites, it is assumed that, maize did not become an important part of the human diet instantly after it had been fully domesticated and subjected to intense selection for desirable traits (as indicated by bottleneck estimates indicating rates of morphological change; Benz 2006:16). Yet, once brought under cultivation, maize spread more quickly than cultivated squash or beans (Smith 2001:1326). Maize was widely cultivated by no later than 4200 b.p. (Blake 2006:60; Pohl et al. 1996:363). This was possibly due to the development of new methods of cooking maize, or “possibly because [maize] became highly desired as a feasting beverage” (Piperno 1998:427-428).

By the time of Columbus’ arrival in the New World, there were 200-300 varieties of maize under cultivation, from central Chile northward to the mouth of the St. Lawrence River in Canada (Beadle 1980:112). Native Americans had taken it from its homeland and selected for characteristics that helped the corn adapt to local tropical and temperate environments (Beadle 1980:112).

Conclusion

This special maize section has offered a brief introduction to archaeological, paleoethnobotanical, and genetic evidence for two competing theories on the development of maize. The geographic origin, ancestry, and history of cultivation were briefly outlined, and two competing theories, the Teosinte Theory and the Tripartite Theory, were summarized. Evidence was presented in support or refutation of these theories. Although the Teosinte Theory is much simpler, there are no pollen samples or macrobotanical remains that can prove that teosinte predated maize. Instead of accepting this fact as proof that teosinte could not have been the ancestor of maize, we can call upon genetic studies to prove the close ancestral relationship of teosinte to maize. It can be concluded that the Teosinte Theory is more plausible than the Tripartite Theory. As archaeologists, palynologists, botanists, plant geneticists, and other scientists continue their research into this issue, a new, even more complete, or more precise theory for the geographic origins, ancestry, and evolution may well emerge.

SOURCES OF BIAS IN THE PALEOETHNOBOTANICAL RECORD

To interpret the information above, and to understand the debates over the location of the first cultivation, one must take into account potential sources of bias in the data. As noted above, the available palaeoethnobotanical evidence is geographically limited. Much of the evidence for early agriculture in Middle America comes from the arid highlands of Mexico. In fact, the most frequently-cited archaeological evidence for early maize, squash, and beans comes only from dry caves in three regions of Mexico (Tamaulipas, Tehuacán Valley, and the Valley of Oaxaca; McClung de Tapia 1992:147; Smith 1997:932; Smith 2001:1325-1326). Again, these areas of most intense excavation do not include Guadalajara or the Balsas River Valley, where beans and maize (respectively) are thought to have originated (Pohl et al. 1996:357). Fewer excavations have been conducted in other Middle American locations, or in areas thought to have been the sites of original domestication (McClung de Tapia 1992:156). Therefore, it is likely that the sites of earliest domestication have not yet been located. More excavations, and excavations in a greater variety of ecological zones, are needed.

In addition to its geographical limitations, the available data is also a product of preservation bias resulting from the effects of each site's local environment. It is of note that, in his search for the origin of maize, Richard MacNeish expanded upon his excavations in the Tehuacán Valley and in Oaxaca by conducting tests in Guatemala and Honduras; however, no evidence was recovered (Mangelsdorf et al. 1964:539). The aridity of the Mexican dry cave sites makes them especially conducive to the preservation of botanical remains. Conversely, humid tropical environments are not conducive to the preservation of botanical macroremains (although pollen, phytoliths, and charcoal may be recovered from perennially wet environments in the tropics; Piperno 1998:434; Pohl et al. 1996:356).

Also, some types of remains from certain species are underrepresented in the archaeological record, either due to low natural production or to poor preservation. For example, the pollen of *Manihot esculentum* is rarely encountered, "since its flowering is unnecessary for propagation and cultivation, and its means of pollen dispersal limits the number of grains produced by the plant" (Jones 1994:208). *Phaseolus* sp. self-pollinates within its closed flowers, and thus little to no pollen evidence of *Phaseolus* is known from archaeological sites (Bush 1995:605; J. Jones, personal communication, 2001, 2002). The tissue of many tuber crops is rarely preserved, in part due to methods of pre-depositional processing by humans (Pearsall 2000). Identification of *Capsicum* remains to the species level often requires the recovery of intact stems, which are rare in the archaeological record (McClung de Tapia 1992:154). However, *Capsicum* starch grains can be recovered from ancient stone tools that were used in food processing (Perry et al. 2007). These can be identified to the genus level, and the size of the grains is indicative of domestication (Perry et al. 2007:986). Cu*curbita* is also poorly represented in the archaeological record; its flesh is not found, and its seeds are likely to have been consumed (McClung de Tapia 1992:153). While features of the stem (the peduncle) are the most reliable indicators of *Cucurbita* cultivation, peduncles are rarely found (McClung de Tapia 1992:153). However, it has recently been discovered that the size and morphology of *Cucurbita* phytoliths can also indicate domestication (Piperno & Pearsall 1998:188-196; Piperno et al. 2009:5022).

Bias can also result from the interpretation of the data. Due to the potential for intraregional variation, individual excavations cannot necessarily be used to document the sequence of events (i.e. the order in which particular crops came under domestication) for a larger region (McClung de Tapia 1992:147). Many palaeoethnobotanical samples are very small, or lack supporting evidence that can indicate provenience or confirm domestication (McClung de Tapia 1992:147). Even when sufficiently large samples of botanical remains are recovered, it may not be possible to determine the exact point at which the represented plants came under cultivation. Although seeds, pollen, and phytoliths may all be shown to have increased in size over time, it is difficult to determine at what point along the growth curve cultivation actually began. For example, an increase in seed size indicates bean domestication, but other morphological changes (such as "increased seed permeability, which reduced the amount of soaking required for cooking"; McClung de Tapia 1992:153) are not always apparent in the archaeological record.

To overcome these potential biases, an overview of agricultural development should not merely include data from the earliest known example of each domesticated crop, or from one type of botanical remains. It should instead include all available forms of data from multiple locations, as does Table 5 of this chpater; this approach gives a broader perspective on agricultural development across the entire region.

MODELS FOR THE DEVELOPMENT OF AGRICULTURE IN MIDDLE AMERICA

In spite of the potential for bias, scientists seek to integrate the information they have collected on the origin and spread of domesticated plants. Scientists have developed models for both the general trajectory of plant domestication, and for the more specific development of agricultural systems in Middle America. Outlines of several of these models are given below.

First, an outline of the general trajectory of plant domestication defines concepts essential to the understanding of agricultural origins. The earliest stages of human interaction with a wild plant may include collecting, toleration, and occasional care (McClung de Tapia 1992:156, 162). Some plants, often considered to be *weeds,* thrive in human-disturbed habitats, and these are often the plants destined to become *cultivars* (De West et al. 1975:99, 102). *Cultivation* occurs at a stage of greater human involvement, with increased care, some selection, the realization that seeds are the mechanism of plant genesis, and perhaps some uprooting and transplant of desirable seedlings (Hirst 2008; McClung de Tapia 1992:156). Simple collecting and sowing do not necessarily lead to plant domestication because harvesting selects for ‘wild’ characteristics in the remainder of the breeding population (De West et al. 1975:102). *Domestication* requires that more careful selection and manipulation take place over a number of generations, so that genotypic (and sometimes phenotypic) alterations may sometimes result (De West et al. 1975:99, 103). The species evolves so as to magnify those traits most useful to its human domesticators. The domesticated species becomes dependent upon human involvement in its life cycle (De West et al. 1975:99; Harris 1972:185; McClung de Tapia 1992:156). Domesticated plants will only survive as long as their disturbed habitat is maintained, and as long as the plants continue to be propagated by humans (De West et al. 1975:99, 100). For example, “[m]aize will survive at most two generations, even in a cultivated field, if not harvested and replanted by man” (De West et al. 1975:100). Some plants used by humans never undergo the biological changes indicative of domestication; therefore, a plant may be cultivated without ever becoming domesticated (De West et al. 1975:99; McClung de Tapia 1992:162).

Harris (1972) integrated these general principles into an ecosystemic explanation of the origin of plant domestication. In Harris’ model, complex ecosystems, such as those of the tropics, were good starting points for domestication because the many wild plants and animals available there were already attractive for humans searching for their subsistence (1972:194). The early inhabitants of areas with complex resources were probably generalized in their use of resources, so, in comparison to the inhabitants of simple ecosystems, they were able to live in small groups that traveled less far and less frequently in search of food (Harris 1972:184). As the mobility of the foragers declined, the foragers became intimately acquainted with local resources, based on seasonal scheduling and sometimes ritual involvement (Harris 1972:194). Decreased mobility also created disturbed or open areas within the human habitat (Harris 1972:185). Plant domestication was the eventual result (Harris 1972:184, 194).

It is worthwhile to note that, while sedentarism and domestication co-evolve in Harris' model, this may not have been the case in Middle America. The development of agriculture in the New World was *not* an Old World-style "Neolithic revolution." Piperno (1998:440), in accord with Harris' model, found phytolith evidence demonstrating that, before 7000 b.p., food production systems in Panama and northwestern South America were "characterized by a simple kind of horticulture practiced largely in house gardens (no significant clearing of the forest for larger-scale agricultural plots yet)." Conversely, archaeological evidence from some Middle American areas shows that plant domestication began early in the Holocene, while sedentary living, coupled with the use of ceramics, began closer to 4000 b.p. (McClung de Tapia 1992:148; Piperno & Pearsall 1998:8). Agriculture at Tehuacán and Tamaulipas was not closely associated with village life, pottery, or polished-stone artifacts (Harris 1972:180; 1967:103). Of interest in this dissertation, maize agriculture began near Blue Creek by 4500 b.p., while the village was not settled until 2900 b.p., also the approximate starting period of the local ceramic sequence. Furthermore, New World agriculture could not have begun as a response to population pressure, as the human population at the sites of earliest cultivation was very low (Piperno & Pearsall 1998:9, 12-13).

Harris' model applies important concepts to explain *how* plants come under domestication, but it does not explain *why* people domesticate plants. Of course, reasons for domestication vary from place to place and from plant to plant. Different techniques for plant domestication develop in different places, and at different times. Several models for the development of agricultural systems in Middle America apply the general principles of domestication to try to explain why people became farmers. These explain the origins of agriculture as an economic buffering strategy, or as a "strategy to manipulate social relationships in the context of emerging political hierarchies" (Pohl et al. 1996:367). Either explanation, or both, may apply to an individual case of agricultural development (i.e. a single archaeological site). Two of the traditional models for the reasons behind the origins of agriculture in Middle America are described below, as summarized by McClung de Tapia (1992). The models were developed by Richard MacNeish and Kent Flannery, respectively, largely based on evidence from the Mexican dry cave sites mentioned above. When considering these (and other) models, it is important to take into account all of the sources of potential bias, given above.

MacNeish explained agriculture as an economic buffering strategy. In MacNeish's model, "major changes in human adaptation occurred when they did because human populations had accumulated enough ecological and subsistence knowledge to readapt to new environmental conditions" (McClung de Tapia 1992:161). MacNeish (1971 and 1972, as reported in McClung de Tapia 1992:156) proposed that cultivation began in the Tehuacán Valley as hunting-and-gathering people returned to the same area, year after year, to collect the same plants. This led to weeding and clearing of the land, creating a disturbed habitat that would favor the growth of certain plants (e.g. digging aerated the soil; burning the landscape inadvertently encouraged the growth of edible seed plants), and sometimes causing genetic changes in the plants. Meanwhile, the late Pleistocene climate variation caused environmental changes, including the deaths of many of the animals upon which the human hunters had preyed. In an effort to stabilize resource availability in times of uncertainty, people began to transport seeds from one area to another, intentionally planting them, and establishing a horticultural system. At first, the new farmers may have planted a great variety of crops and made seasonal use of non-cultivated food resources. As agriculture became more intensified, farmers adopted increasingly sedentary lifeways, focusing on a smaller variety of crops and non-cultivated (i.e. gathered, wild) resources. Pohl et al. (1996:357, 363) pointed out that, even after the onset of agriculture, farmers in Mexico and northern Belize continued to rely on aquatic resources, including fish, turtle, and mollusks, as well as hunting (mostly small mammals). Continued reliance on non-cultivated food sources supplemented dietary needs, and provided some protection against crop failure.

Like MacNeish, Flannery saw agriculture as "a consequence of human adaptation to the unpredictable availability of subsistence resources during the gradual replacement of late Pleistocene vegetation by Holocene floral communities" (McClung de Tapia 1992:161). As the Pleistocene megafauna died out, hunters had to make a shift in subsistence resources (termed the "Broad Spectrum Revolution") to widen their resource base to include small game and more plant foods. Flannery also reflected on the social impact of agriculture. Flannery (1968 and 1986, as reported in McClung de Tapia 1992:160-161) took a systems approach to explain the "positive feedback" mechanisms that led to the development of agriculture in the central highlands of Mexico. Under this "cybernetic" model, naturally occurring genetic changes in maize and beans made those plants easier to harvest and/or prepare for consumption, making them more attractive to human consumers. Human involvement with the plants led to further favorable genetic changes. As cultivation intensified, it became necessary for people to schedule spring planting and fall harvesting of crops, reducing their ability to pursue other food resources (such as certain seasonal plants, or seasonal hunting) at those times of the year. As the population rose, the people changed their use of resources and developed new technologies. Population increase and an increase in social complexity were indicative of the "Neolithic Revolution." Agriculture continued, not as a last-resort attempt to deal with population increase, but as a way of ensuring resource stability, possibly with surplus production used to symbolize prestige.

Several of the social aspects of Flannery's model are supported by the research of other scientists, conducted at sites other than the Mexican dry caves. For example, rising populations led early agriculturalists in Belize to experiment with raised field agriculture (Jones 1994:209). Also, in Panama, forest decimation after 4500 b.p. may have led to competition for resources (Pohl et al. 1996: 367-368). Cropping may have caused competition for land, as well as political manipulations (Pohl et al. 1996:367).

Models like these may satisfactorily describe the origins of agriculture at individual sites or over small regions, and they may be adapted for application at other sites so that interregional comparisons can be made. However, no single general model absolutely characterizes all instances of the onset of plant cultivation and agriculture in Middle America. As this section has shown, the reasons for the development of agriculture, as well as the processes involved in that development, vary from location to location. This consideration of archaeological and palaeoethnobotanical data from multiple zones has provided a broad overview of the origins of agriculture in Middle America.

CULTIVATION METHODS

This section discusses the agricultural methods employed by the Maya, most of which are known to have been employed at Blue Creek or in the Three Rivers Region. First, methods of dry-field cultivation (including milpa, slash/mulch, kitchen gardening, tree cropping, and root cropping) are explained. Second, hydraulic and irrigated agriculture are differentiated, and the method of terracing and the usage of dams and weirs are covered. Third, methods of wetland-field cultivation (including the construction of channeled or drained fields and raised fields, and the dry-season cultivation of riverbanks and lakeshores) are described. Pest control and miscellaneous cultivation practices are touched upon. Finally, postcolumbian agriculture is described, including plantation agriculture and agroforestry. Multiple cultivation methods were usually practiced contemporaneously within each Mayan community, and even within each work group.

It shall be seen that the Maya were innovators who agroengineered a variety of cultivation practices that could be adapted to suit local environments and the requirements of local populations. Ethnographic analogy to modern peoples in the Maya area shows wide variety in agricultural practices, and because they had less external contact with alien populations than modern people, it must be assumed that the ancient Maya were even more "diverse and locally adapted…to widely varying environments and to changing social and economic circumstances" (Wilk 1985:47). For one farmer, or a single farming community, to employ a variety of agricultural strategies is to minimize risk of crop loss (Wilk 1985:54); the people of Blue Creek enjoyed the added benefits of their living situation in an ecotone, where they were not only able to employ a variety of agricultural strategies, but did so in a variety of microenvironments (discussed in Chapter III).

A movement away from a diversification of agricultural strategies could have been a step toward the Maya Collapse. Adoption of a single farming strategy is usually a result of entrance into a marketing system, in which case risk is minimized through the storage of cash or goods by the individual or the state (Wilk 1985:54). For the Lowland Maya, this process may have begun during the Early Classic Period (Wilk 1985:54). During the Classic Period, the Maya intensified their production of maize, but they appear to have continued to practice other forms of agriculture. With so many agricultural possibilities, it may well be that the Classic Period Maya population was higher than would have been expected if the people had relied exclusively on milpa cultivation (Coe 2005:22). Higher agricultural production may have freed some people from the pursuit of food to engage in other occupations, but the combination of production intensification and high population may have had implications for the Maya Collapse (Coe 2005:22). For example, the farm fields may have become barren, leading to trade disruptions, revolts of starving commoners, and interpolity raids. The issues of population, agricultural intensification, and related implications for the Maya Collapse are explored later in this chapter.

Information regarding the locations, at the Blue Creek site and in the Three Rivers Region, of the application of some methods of agriculture (especially as pertaining to water conservation measures) was given in Chapter III.

Dry-Field Cultivation: Milpa

The dry-field cultivation methods (milpa, slash/mulch, tree cropping, kitchen gardening, and root cropping) are distinguished from the hydraulic and wetland agricultural methods, discussed below, in that they generally did not require artificial irrigation, and relied on rainwater as their main moisture source.

Milpa refers to slash-and-burn ("swidden") agriculture, in which maize is the primary crop. The word "milpa" is also used to refer to the maize fields, themselves (Coe 2005:16). Milpa cultivation of the uplands was the predominant mode of food production for the ancient Maya, and remains the most widespread farming technique of the modern Maya (Healy et al. 1983:398; Pohl & Miksicek 1985:13). Modern milpa farmers clear small forest plots, which they cultivate for a few years and abandon upon soil exhaustion; in contrast, the ancient Maya developed more intensive forms of milpa, in which they cultivated larger fields "in bottom lands or on terraced slopes of the highlands" (Schwarcz 2006:319). These, and other, intensification methods are discussed later in this chapter.

The Process of Milpa Cultivation

Around A.D. 1500, the approximate time of first European contact, the Mayan milpa system was practiced as described below (Hall & Pérez Brignoli 2003:62, unless noted). At the beginning of the dry season, trees and undergrowth were felled and allowed to dry out, before burning at the end of the dry season. Seeds were planted in May, just before the onset of the rainy season. Religious ceremonies were conducted to ensure a bountiful harvest. Prayers for rain were offered to the gods (Coe 2005:19). Maize crops were weeded until they ripened by September, when "each stalk was bent double to enable the grain to dry and harden without damage by the rain" (Hall & Pérez

Brignoli 2003:62). Maize was harvested in October. With irrigation, or in the warmer and wetter areas of the Maya area, two maize crops might have been produced each year. Sometimes secondary crops were interplanted with the corn. Beans grow well in milpa fields, where they are free from the dampness in which they fall prey to fungal diseases. Bean vines like to climb up maize stalks (Hall & Pérez Brignoli 2003:155). In the Maya Lowlands, milpas are usually only fertile for two years of continuous cultivation, after which they must lie fallow for 4-20 years, depending upon local soil and rainfall conditions (Coe 2005:19-20).

Judy Cusick (1991) published an ethnographic study of contemporary *milperos* (milpa farmers) living in the Río Bravo area. I offer this information for comparison to the early-European-contact record, and as a reflection of possible farming conditions for the ancient Maya in the Three Rivers Region. In 1990, there were six *milperos* in the area; four were full-time farmers (Cusick 1991:99, 101). Each worked on 10-15 acres of land (Cusick 1991:99). A 10-acre plot of land could provide enough food for 3-4 people, sometimes with a surplus that could be sold for cash (Cusick 1991:100-101). Plots of land were selected to open for cultivation once the vegetation had achieved a high level of regeneration (Cusick 1991:99). Vegetation was cut (by axe or machete) for new milpa*s* in January, and allowed to dry out before burning at the end of the dry season (Cusick 1991:99). New milpas were difficult to clear, but had the best soil fertility and also provided sources of firewood (Cusick 1991:99). The first planting of maize, using a dibble stick, usually took place in May for an October harvest, and a second crop could be planted in November (Cusick 1991:100). A milpa could be planted for 2-4 years, after which soil fertility decreased and weed encroachment became problematic, so the plot was then allowed to lie fallow for another 2-4 years (Cusick 1991:100). Modern fertilizers, insecticides, and herbicides permit less fallow time than was previously possible (Cusick 1991:100). In the Río Bravo area, none of the milpas had an irrigation system; that is, fields were watered by rainfall alone (Cusick 1991:101). The milperos grew crops in addition to maize, including okra, peppers, plantains, sweet potato, watermelon, cucumbers, squash, beans, bananas, coconuts, tomatoes, pineapple, and papaya (Cusick 1991:100). The farmers also eat "bush" foods, such as fowl, fish, eggs, "wild cherry" (possibly *Pseudolmedia spuria* [Moraceae] or *Pouteria reticulata* [Sapotaceae]) and *mora* (possibly mulberry [*Morus* sp., Moraceae] or blackberry [*Rubus* sp., Rosaceae]; Cusick 1991:100). Some keep domesticated animals (Cusick 1991:101).

Variations on Milpa Cultivation

Variations on milpa practices have existed throughout time and place. In the Maya highlands, terms of continuous field use are shorter and fallow periods longer with increasing altitude and decreasing precipitation (Coe 2005:16). In modern highland milpas, several kinds of maize are planted at different times of the year; the fields are furrowed; and hillocks are built around the sprouts to protect the sprouts and to retain soil moisture (Coe 2005:16). More than two dozen precolumbian ridge-and-furrow fields have been discovered in El Salvador, and others have been found elsewhere in Mesoamerica and in the New World in general (Dull 2006:362). At the site of Merliot Milpa in the highlands of central El Salvador, archaeologists discovered a series of three "fossil maize fields buried under volcanic tephra" (Dull 2006:362). The fields were of the ridge-and-furrow sort, with "10- to 15-centimeter high ridges spaced roughly one meter apart" (Dull 2006:362). The fields had deeper ditches for drainage (Dull 2006:363). Impressions of maize plants were found on two of the fields, and plaster casts were molded from some of the impressions (Dull 2006:362). The fields dated between 2780 B.P. and 1290 B.P. (roughly Middle Preclassic through Late Classic Periods), making them the earliest New World maize fields with in situ macrofossil impressions (Dull 2006:362-363).

In the Maya Lowlands, milpas have been planted in the dry uplands, but they are also found on terraced hillslopes, and on drained fields in the bottomlands or *bajos*. Milpa (usually a dry-field method) can thus be combined with hydraulic and wetland cultivation methods. An example comes from the site of Cuello, northern Belize. There, the canals of channeled- and raised- maize fields have produced shells of snails, oysters, and scallops show that marine mollusks were brought to the site by the Maya for food or so their shells could be used (Hammond & Miksicek 1981:265-266). By the Middle Preclassic Period, pollen, phytoliths, marine mollusks, and charred plant remains provide evidence for the cultivation of at least three types of maize, which were produced in small patches for long-fallow milpa cultivation cleared from the relatively undisturbed monsoon forest (Hammond & Miksicek 1981:265).

In both the highlands and the lowlands, secondary crops (such as beans, squash, and manioc) are sometimes interplanted with the maize (Coe 2005:16).

Benefits and Limitations of Milpa Cultivation

The greatest benefit milpa cultivation had for the ancient Maya was its ability to support a large, sedentary population. When combined with other farming techniques and economic strategies, milpa could have freed some people from the pursuit of food, enabling them to work at other occupations (Coe 2005:22).

Milpa cultivation probably posed some problems for the ancient Maya. For the modern Maya, milpa does not reliably produce a food surplus, and requires that some land always lie in fallow, thus reducing the effective carrying capacity of the land (Healy et al. 1983:398). The same situation may be projected into the past, when total dependence on swidden cultivation would have imposed limits on settlement density, settlement size, and settlement stability (Puleston 1977a:37).

It is implicit that the large Classic Maya ceremonial centers, with high population densities, may not have been able to rely solely upon milpa cultivation to feed their people (Healy et al. 1983:398). Instead, they may have turned to more intensive cultivation methods, creating terraces and raised or drained fields, and turning to other methods of cultivation (such as tree cropping and root cropping), to overcome the limitations imposed by the necessity of a fallowing period (Healy et al. 1983:398; Johnston 2003; Puleston 1977a:37).

The widespread employment of milpa cultivation had ecological consequences. The system required the clearing of much forest land, as indicated by the regional pollen record (Pohl & Miksicek 1985:13), which shows a decreasing abundance of the pollen of forest taxa concomitant with an increase in maize pollen and other agricultural indicators (This is not clear for the Laguna Verde pollen core.). Milpa cultivation also caused soil change. For example, in parts of the Corozal Project area in southern Belize, grey and black topsoil was common at archaeological sites where the ancient Maya had practiced agriculture, probably because "the 'slash and burn' system of agriculture has released much more carbon on these sites…" (Hazelden 1975:184). Throughout the tropics, if fallow periods are insufficient, soils "permanently deprived of their forest cover quickly decline in fertility and become quite unworkable as a lawyer of brick-like laterite develops on the surface" (Coe 2005:18-19). Thus, the overworking of the soil could have had long-term consequences for the ecology and economy (i.e. declining agricultural productivity; reduced access to forest resources) of the ancient Maya.

Dry-Field Cultivation: Cultivation Lengthening Through Slash/Mulch Agriculture

It has long been assumed that pre-industrial agrarian societies that, like the Classic Maya, lack plows, draft animals, and chemical fertilizers, or that do not irrigate or employ intensive wetland agriculture, can only intensify production by shortening and then eliminating the fallow period (Johnston 2003:126, 137). Most archaeologists seem to believe that the Maya intensified milpa production by reducing and eliminating the fallow period. These assumptions are founded upon a conventional model of tropical ecology, which is now known to be erroneous (see the section "Good Soil" in Chapter III for details; Johnston 2003:131).

Rather than resorting to fallow elimination, production can be intensified in a more productive and sustainable manner by "cultivation lengthening," a process that increases the number of years a field can be cultivated before fallowing. This usually occurs by means of intensive weeding and mulching (Johnston 2003:126, 130). Johnston (2003) shows that short-fallow milpa could not have produced enough food to sustain ongoing growth of the Classic Maya population, and proposes that the Maya therefore must have employed a variety of cultivation methods, especially cultivation lengthening with intensive weeding and mulching, to meet their needs.

Under more extensive, long-fallow cultivation regimes, weeding was probably not practiced at all (Boserup 1965). Weeding was, however, part of more intensive agricultural regimes (such as slash/mulch agriculture), when it was necessary to keep the cultivated plot free of unwanted vegetation for many successive years. Crop yield can be improved by weeding (which "enables cultigens to absorb nutrients that otherwise would be sequestered in weeds"), followed by weed mulching (or other forms of mulching, which returns weed nutrients to the soil; Johnston 2003:133). Weeding and mulching must *both* be applied to facilitate cultivation lengthening, this system could be termed "slash/mulch agriculture" (Johnston 2003:147, 148).

To be most effective, weeds must be pulled or dug out by the roots before they seed (Johnston 2003:134, 145). Weeding is labor-intensive, but can increase the length of time a field can be cultivated before fallowing to seven or eight years (contrasting with only 2-4 years in a short-fallow swidden system; Johnston 2003:145).

Using the pulled weeds as mulch on the fields restores nutrients from the weeds to the soils, and mulching prevents erosion (Johnston 2003:146, 147). Aside from weeds, mulch may come from other plant material cut down from the field; plant matter transported from other locations; green manures (plants -especially legumes- intentionally cultivated for use as mulch); human waste; animal manure; and transported mud and fertile soil (Johnston 2003:148-149). Mulches are most effective "when applied at the start of the rainy season, during the earliest stages of crop growth…the same season during which aggressive weeding has comparably beneficial impacts on crop production" (Johnston 2003:146-147). Mulching agricultural fields is a better means of maintaining soil nutrients than the ash fertilizer that results from slash-and-burn cultivation (Johnston 2003:143). Ash dissolves rapidly, or washes away before it can be absorbed by the crops (Johnston 2003:143).

Weeding and mulching practices leave little evidence in the archaeological record. For example, the Maya of the dry, riverless northern Yucatan Peninsula left little evidence of intensive agricultural practices, but they likely weeded their crops and mulched the fields to retain moisture (Dahlin 2002:331; Johnston 2003). Slash/mulch systems are used in modern times by low- to moderate-density populations, and are less labor-intensive than the short-fallow swidden most archaeologists believe to have been practiced by the Classic Period Maya (Johnston 2003:148). We can imagine that the ancient Maya, likewise, found slash/mulch agriculture to be ecologically sustainable and feasible in terms of labor cost, and to provide greater crop yields than other intensification strategies (Johnston 2003:149-150). Slash/mulch agriculture may not have been employed in places where agriculture had been intensified by means of raised- or drained- field technology (Johnston 2003: 151).

Dry-Field Cultivation: Tree Cropping and Kitchen Gardens

In addition to milpa cultivation, tree cropping and the keeping of “kitchen gardens” were dry-field methods that provided the ancient Maya with food and vegetable materials. Although the Maya made use of wild tree fruits and natural forest products, they found it convenient (and perhaps necessary) to keep gardens close to their homes in which vegetables and fruit trees were raised. From at least Preclassic times, tree crops were planted near houses to provide shade in addition to food (Pohl & Miksicek 1985:14, 15). Groves of fruit trees were scattered near settlements (Coe 2005:205). The growth of tree crops was also encouraged on the milpa fields (Pohl & Miksicek 1985:14).

The Maya kept cacao orchards for commercial and elite use (Pohl & Miksicek 1985:14). Iconography depicting the tree and the fruit *Theobroma cacao* (“cacao”) prove its significance to the ancient Maya. Ceramic evidence, in the form of spouted vessels that functioned as chocolate beverage pots (some containing theobromine residue from ancient cacao), shows one use of the cacao bean. Cacao beans were also used as currency (Coe 2005:205). The only commercially-produced crop of the Maya in precolumbian times, cacao was grown mostly in Soconusco and part of Guatemala (Hall & Pérez Brignoli 2003:63). There, cacao was sown in nurseries, then transplanted into orchards to grow in the shade of other trees (Hall & Pérez Brignoli 2003:63).

Beyond cacao, there is little direct archaeological evidence that possible tree crops were actually put to use by the Maya. Some *indirect* evidence exists. Macrobotanical remains of the sort most frequently recovered from archaeological sites, such as charcoal, are indirect evidence that the plants actually served economic purposes. Pollen is another form of indirect evidence, and pollen can be a poor indicator of the presence of tree crops. Most tree crops have entomophilous pollination and are underrepresented in the pollen record (Ford 2008; Pohl & Miksicek 1985:15), so their pollen is significant when it appears. The absence of pollen from probable tree crops should not be interpreted as a sign of environmental mismanagement or deforestation (Ford 2008). In 1981, Frederick Wiseman took pollen samples from soil beneath actively flowering trees on a modern cacao plantation in Belize, and he found no cacao pollen in his samples (Pohl & Miksicek 1985:15). Palynological evidence of intensive tree cropping may be masked by pollen from nearby weedy fallow zones or from bordering ecotypes that contain anemophilous plants that produce and release pollen in greater quantities (Wiseman 1985:67).

Additional indirect evidence of Mayan use of tree crops comes from ethnographic analogies to modern people, and from the persistent presence of the trees and their remains on archaeological sites today. Ethnographic parallels to modern people tell us which trees produce fruit that is edible, and enjoyable, to humans, and which trees produce other useful raw materials. Fruit trees can today be found growing at many Mayan archaeological sites in disproportionately greater abundances relative to their numbers in the surrounding forest. Ford (2008) found that modern Maya farmers near El Pilar (on the Belize-Petén border) actively manage the forests near their homes to include a high percentage of economically-useful species. These include *Mangifera indica* (“mango”), *Cocos nucifera* (“coconut”), *Ananas comosus* (“pineapple”), *Musa paradisiaca* (“banana”), and many other trees and herbs of local importance. Gasco (2008) found similar results for the “homegardeners” of the Soconusco region of Chiapas. Corzo Márquez & Schwartz (2008) report that home gardening constitutes as much as 15 percent of household income of the people of the modern Petén, and improves their nutritional status.

These ethnographic analogies suggest, but do not prove, that the ancient Maya also had a special interest in home gardening and tree cropping. At some archaeological sites, the presence of botanical remains speaks to the ancient presence of certain plants; but it is usually difficult to demonstrate connections between ancient plants and their possible human cultivators. For example, seeds of *Celtis* sp. ("hackberry") have been found at some archaeological sites, but it is uncertain whether or not the edible fruits were actually enjoyed by the ancient Maya (Pohl & Miksicek 1985:15). *Celtis* is "a common early successional species in recently cleared areas" (Pohl & Miksicek 1985:15), and rather than having been intentionally cultivated by the Maya, the trees may have colonized archaeological sites after site abandonment. A similar situation applies to *Brosimum* sp. (ramón), which grows on archaeological sites today, but has only on two occasions been recovered (in macroremain form) from archaeological strata at Mayan sites (Miksicek et al. 1981:917). *Brosimum* is pre-adapted to growing in disturbed places (Miksicek et al. 1981:917).

Charcoal and/or charred seeds of the following potential tree crops have been recovered from many Mayan archaeological sites, including Pulltrouser Swamp, San Antonio Río Hondo, and Cuello, Belize; Copan, Honduras; and Tikal and Kaminaljuyu, Guatemala (Coe 2005:21-22, 205; Pohl & Miksicek 1985:15). These tree crops are *Annona* sp. (sweetsop, cherimoya, or custard apple), *Byrsonima crassifolia* (nance), *Chrysophyllum* sp. (star apple), *Cordia dodecandra* (siricote), *Crescentia* sp. (calabash tree), *Manilkara zapota* (sapodilla), *Persea americana* (avocado), *Pouteria sapota* (mamey zapote), *Protium copal* (copal), *Psidium guajava* (guava), *Spondias* sp. (hogplum), *Theobroma cacao* (cacao), and possibly also *Brosimum* sp. (breadnut), *Carica papaya* (papaya) and *Pimenta dioica* (allspice).

Dry-Field Cultivation: Root Cropping

Root crops, or tubers, were among the vegetables grown in the kitchen gardens (Coe 2005:21-22). Written records from the period of Spanish contact note that the Maya successfully cultivated root crops on both dry upland fields *and* on wetland fields (Pohl 1985:38; Pohl & Miksicek 1985:15).

We have little archaeological evidence to indicate which root crops were grown at particular archaeological sites. Plant macroremains tend to be poorly preserved in the soils of the humid Neotropics (Bryant 2003:1030). Due to the methods by which they are cooked, tubers seldom become carbonized and thereby enter the archaeological record, but occasional root crop fragments are found at archaeological sites (Pohl & Miksicek 1985:15). Many root crops are insect-pollinated and produce pollen in small amounts, so the palynologist seldom encounters evidence of root crops. Most root crops produce no phytoliths, produce too few phytoliths for likely encounter in the archaeological record, or only produce phytolith forms that are found in both domesticated and wild varieties of the plant and are therefore poor indicators of cultivation (Piperno & Clary 1984:90-91, 101; Piperno & Holst 1998:765).

However, starch grains (microscopic granules within which a plant's energy is stored) from tubers can be recovered from ancient soils, and have been recovered from stone tools at archaeological sites in Panama (Piperno & Holst 1998). Panama is not located in the Maya area, but it has a humid lowland tropical environment similar to that of much of the Maya area. That environment, with marked dry seasons and areas with wet soils, is one in which tubers grow well (Bryant 2003:1030; Piperno & Clary 1984:101). Tubers also fare well on land that has been recently cleared of its tropical forest cover (Bryant 2003:1030), such as that of kitchen garden plots. The presence of starch grains from tubers on food-processing implements has led to the suggestion that tubers were the first plants to have been cultivated in the New World. Because tubers can be "stored" underground by remaining unharvested until they are needed, humans could have returned to gather tubers as needed without losing their residential mobility

(Piperno & Fritz 1994:639). No high-level sociopolitical organization or advanced technology would have been required for this method of proto-cultivation.

What root crops were grown by the Maya? Possibilities include *Dioscorea* spp. (“yam”), *Ipomoea batatas* (“sweet potato”), *Manihot esculenta* (“manioc”), *Maranta arundinaceae* (“arrowroot”), and *Xanthosoma* sp. (“otoe”). *Manihot esculenta* produces phytoliths, but in quantities too small for likely recovery from archaeological soils (Piperno & Clary 1984:90-91). *Maranta arundinaceae* may produce phytoliths that can be found in the archaeological record, but evidence was inconclusive (Piperno & Clary 1984). *Dioscorea* spp., *Ipomoea batatas,* and *Xanthosoma* sp. produce no phytoliths (Piperno & Clary 1984:91). Starch grains from *Dioscorea* spp., *Manihot esculenta,* and *Maranta arundinaceae* were found at archaeological sites in Panama (Piperno & Holst 1998:765).

Irrigation Agriculture

Types of Irrigation Agriculture; Distinction of Irrigation, Rain-Fed, and Wetland Agriculture

Management of water for crops was obviously an important matter for ancient Mayan farmers, and this management assumed different directions in accordance with the farming environment and with sociopolitical factors. “Irrigation” refers to the process of artificially applying water to soil to improve the growth of crops. Reliance on the artificial application of water is the factor that distinguishes irrigation agriculture from the types of rain-fed cultivation discussed above. Irrigation agriculture is distinguished, by the types of locations in which it is practiced, from the types of wetland agriculture discussed later in this chapter: irrigation usually takes place in relatively dry, upland settings, while wetland cultivation takes place in moist, seasonally-inundated wetlands such as swamps, *bajos,* and riverbanks. Wetland agriculture usually requires that water be drained away from the fields, rather than being artificially applied. However, because the large-scale creation of channeled and raised fields in wetland areas necessitates water management strategies, these are sometimes referred to as forms of *hydraulic* agriculture. Varieties of wetland agriculture practiced by the Maya are discussed later in this chapter.

Anthropologist Karl Wittfogel (1957) divided irrigation agriculture into two types, depending upon the scale and organizational level on which it is conducted. Wittfogel referred to small-scale irrigation agriculture performed by an individual or small community as “hydroagriculture.” Large-scale irrigation agriculture that required the cooperation of a larger group, and which could have been related to social, political, and/or economic oppression, was termed “hydraulic agriculture.” Types of irrigation agriculture discussed in this paper are terracing and the construction of weirs or dams. These were used by the ancient Maya at both hydroagricultural and hydraulic scales. This issue is expanded upon in the section “Cultural Implications of Terracing.”

Irrigation Agriculture: Terraced Fields

Why Build Terraces?

Hillside terracing was one of the important agricultural advancements made by the ancient Maya (Hammond & Miksicek 1981:259). Some ancient Maya were aware (if not scientifically so) of the nutrient depletion associated with soil erosion, and took steps to prevent erosion through such means as terrace construction (Brenner et al. 2002:146). Terraces functioned to distribute rainwater evenly over a hillslope, to prevent runoff, retaining soil moisture; and to maintain moisture levels during the dry season (Healy et al. 1983:405; Pohl & Miksicek 1985:11; Wilk 1985:48). Terraces control, but do not prevent, soil loss; they “slow runoff velocity and decrease rate of sediment transport by reducing slope length and gradient (Johnston 2003:138). That terracing was an effective means of erosion control can be seen on the hillsides of Cayo District, Belize, where those hillsides that were terraced by the ancient Maya still hold thick soil, while the unterraced hillsides have only thin, unfertile, eroded soil (Healy et al. 1983:400).

How to Terrace

Construction techniques for agricultural terraces include linear terracing on dry slopes; the irregular construction of terraces in a "spider's web" pattern; and terracing with check dam features to control water supply to the fields (Pohl & Miksicek 1985:11). Stones were placed so as to form terrace walls, and dirt was often transported to form a level field surface. At the site of Caracol, Belize, terraces were constructed through the careful placement of limestone boulders, without stone trimming or the use of mortar (Healy et al. 1983:402). The inclusion of small stones helped prevent erosion during periods of heavy rainfall (Healy et al. 1983:404-405).

The benefits of terracing may have been enhanced through combination with other agricultural techniques. For example, in addition to terracing, soil moisture can be retained by "mulching, sowing cover crops, and interplanting" (Wilk 1985:48).

The types of crops grown on the ancient terraced fields remain uncertain. Recovery of pollen, phytoliths, and macrobotanical remains from terraces has been poor (Pohl & Miksicek 1985:11). Maize pollen was reported from the terraces at Caracol, but it is possible that the pollen blew onto the terraces from nearby upland fields (Pohl & Miksicek 1985:11). Terraces may have been continually cropped, because unwanted vegetation could have destroyed the terraces if permitted to grow during fallow periods (Pohl & Miksicek 1985:11).

Where to Terrace

Terraces have been found at both lowland and upland sites, in northern Belize, Petén, Campeche, and Quintana Roo (Lambert & Arnason 1978:33). Outside Belize, terraces have been reported from Río Bec, southern Yucatan (Turner 1978, 1983b). Many have been reported from Guatemalan Petén, such as those at Petexbatun region (Beach & Dunning 1995; Dunning & Beach 1994; Dunning et al. 1997); in rural areas southeast of Tikal (Turner 1978); south of Lake Petén-Itzá (Rice 1993); along the Río de la Pasión (Brenner et al. 2002:146; Dunning et al. 1997; White et al. 1993:347); and elsewhere in Petén (Turner 1979).

Ancient Mayan agricultural terraces are unevenly distributed in Belize, and it is difficult to estimate the amount of surface area they cover (Pohl & Miksicek 1985:11). Many of the terraces are located in the upper Belize River region, on the Vaca Plateau and the western slopes of the Maya Mountains (Chase & Chase 1998; Dunning et al. 1998a; Healy et al. 1983; Pohl & Miksicek 1985:11; Turner 1979; White et al. 1993:347). Others have been found north of the Maya Mountains, in the Three Rivers Region, at the site of La Milpa (Dunning et al. 2002); near the elite residences at Blue Creek; and near the Rosita settlement cluster northwest of Blue Creek (Guderjan et al. 2003:80-81, 86). Terraces located near residences may have been used for "kitchen gardens" (Guderjan et al. 2003:81, 86).

Construction of agricultural terraces began in the Maya Lowlands during the Preclassic Period (Johnston 2003:140). Most terraces in Belize were constructed between the Early and Late Classic Periods (Pohl & Miksicek 1985:11), a time of population growth.

Cultural Implications of Terracing

The deployment of agricultural terraces by the ancient Maya has implications in the sociopolitical, economic, and ecological realms, and indicates stratification in those realms. Like other methods of agricultural intensification, terracing may have originated as a response to a need to increase production to meet the increasing demands of a growing human population (White et al. 1993:348). Population pressure is implied by the fixed-field nature of the stone-walled terraces, which contrasts with the shifting-field nature of the milpa cultivation that is best employed when the population is relatively low and more land is available *per capita*.

Alternatively, rather than beginning as a response to a burgeoning population, methods of agricultural intensification (such as terracing) may have been the cause of population growth; or intensification and population growth could have had continuous, mutual inspiration in the form of a feedback loop. Terracing, as an intensive agricultural method, is believed to have had a high labor cost. People may have been willing to pay this cost in exchange for the benefits of being able to live at a higher population density. High-density living under a productive, intensive, agricultural regime could have freed some people from the need to work in the food-production sector. Those liberated individuals could have instead worked, for example, at the construction of monumental architecture, or even at the construction of the terraces. This occupational differentiation, because it contributed to ongoing economic, social, and political stratification, could be interpreted as oppressive to some member of Maya society (after Wittfogel 1957). Large terrace systems, as forms of hydraulic agriculture, could not have been built by independent operators. For example, all agricultural terraces at the site of Caracol, which cover more than six hectares, were built contemporaneously; they were probably the result of much planning and coordination, rather than representing individual family-level efforts (Healy et al. 1983:402). The coordination of work groups implies the existence of strong political leaders, who could direct such efforts.

Terracing, like so many other human actions, had ecological, economic, and social consequences. An example comes from the terraces of Caracol. During the period in which they were used agriculturally, heavy clay built up on the terraces there, so the soil became more difficult to work (Healy et al. 1983:406). The clay was impervious to air, water, and root growth, and it hardened and cracked during the annual dry season (Healy et al. 1983:406). Water would have puddled on the terraces, or simply flowed away without absorption, when the rains came (Healy et al. 1983:406). Certain minerals could have built up to a toxic level and caused a decline in crop yields (Healy et al. 1983:407). Declining crop yields would have failed to support a large population. At Pacbitun, Belize, the failure of the agricultural terraces to meet the needs of a growing population may have been a reason for the abandonment of the site (White et al. 1993:348, 366-367, 370).

Irrigation Agriculture: Dams and Weirs

Where to Dam

Places: Dams have been reported from Mayan sites (or regions) at Cayo District, Belize (Healy et al. 1983); La Milpa, Belize (Guderjan 1991; Scarborough et al. 1995); Laguna Tamarindito, Petén (Beach & Dunning 1997; Dunning et al. 1998b); Tikal, Petén (Scarborough 1998); and Candelaria River, Campeche (Siemens et al. 2002).

Situations: Dams were built in particular situations, depending upon their intended purpose (discussed below in the section "Why to Dam"). Most were situated on the margins of reservoirs, on hillsides and terraced agricultural fields, or on creeks and rivers.

Why to Dam

The overarching purpose of the construction of dams was to control water. The need (or desire) to control water may have arisen as a conservation measure (See the section "Adaptations to Drought" in Chapter III.); as a means of agricultural intensification; as a political strategy; or even (according to Siemens et al. 2002:115) "as fairly desperate expedients in the face of climate change." Following are reasons why the Maya constructed dams.

1. To hold water in reservoirs: Dams were constructed to hold water in reservoirs (e.g. Beach & Dunning 1997:20; Scarborough 1998). The collection of water in reservoirs helped prevent erosion during the wet season (Scarborough et al. 1995:98, 115). Water stored in reservoirs could be released in a controlled fashion (which sometimes involved the use of artificial channels and diversion weirs) during seasonal droughts (Scarborough et al. 1995:98, 115).

2. To provide a water source close to residences: Sometimes reservoirs were constructed in proximity to residences. They were convenient sources of water storage to people who lived nearby. Containment in a small body (reservoir) made water a strategic, defensible resource, which was extra valuable during the population growth and warfare of the Late Classic Period (Beach & Dunning 1997:20, 26).

3. To control the water supply to agricultural fields: Check dams were constructed to control release of water from reservoirs and to control the downslope movement of water. Sometimes check dams were constructed in conjunction with terraced-field systems; these dams controlled water release and slowed erosion. The dams retained soil moisture in the fields above the dams, thereby increasing agricultural productivity (Guderjan 1991:25). Dams could also help maintain water levels in wetland fields (Siemens et al. 2002:115, 120).

4. To prevent erosion: By employing dams to control the release of water, erosion was prevented (or at least slowed) during the wet season (Dunning et al. 1998b:139, 141; Scarborough et al. 1995:98, 115). This helped prevent loss of richer soils from the uplands, and sedimentation or in-filling of low-lying areas.

5. To protect springs: Freshwater springs emerge from the bases of hills and escarpments and on some creeks in the Maya Lowlands. Dams were constructed in the uplands and on creeks to control erosion and the resulting pollution or burying of these valuable water sources (Beach & Dunning 1997:27-28; Healy et al. 1983:400).

6. To drain the core site: Dams were sometimes part of systems that functioned to drain water away from places where people lived, worked, and conducted ceremonial activities. This was the case at the site of La Milpa, Belize (Guderjan 1991:25).

7. To facilitate canoe travel on rivers: Dams could be constructed on rivers to maintain a sufficient water level for canoe travel to take place. This was the case along the Candelaria River in Campeche (Siemens et al. 2002:115, 120).

How to Dam

This section presents data from archaeological surveys and excavations to exemplify a few dam construction techniques of the ancient Maya. Some ancient Maya dams may have included wooden gates or other timber structures that are not part of the archaeological record. Features that archaeologists find are mostly constructed of earth, rubble, and limestone boulders. For example, the dams on the Candelaria River, Campeche, “seem to be elaborations or imitations of the numerous natural barriers already in the stream" (Siemens et al. 2002:115). The dams were built by placing "rounded rocks transverse to the current" (Siemens et al. 2002:120).

Another example comes from La Milpa, Belize, where the water management system included a series of 18 possible check-dam terraces along the steep slope of a drainage channel (Scarborough et al. 1995:102-103). The check-dam terraces were constructed with deliberately-created vertical walls, and were reinforced by carefully-placed small limestone boulders. The water management system at La Milpa also included a stone dam 17.5 m in length, which functioned to hold water in a reservoir (Scarborough et al. 1995:103). The dam had a rubble foundation, and may have had a timber superstructure (Scarborough et al. 1995:104). Another dam, at least 1.6 m in height and more than 40 m wide, consisted of a berm built of earthen fill. There, buried plaster floors may have been "landings from which access to the sluices controlling the release of the water were made" (Scarborough et al. 1995:107).

Introduction to Wetland Agriculture

As noted above, wetland agriculture takes place in moist, seasonally-inundated wetlands such as swamps, *bajos,* and riverbanks. Ten percent of the land area in Central America can be classified as wetlands (Darch 1988:87), and conducting agriculture in the wetlands is a means by which people can intensively produce food in what would otherwise be considered "wasted" land area. Seasonally-inundated land can be considered an ecotone. It is an area of transition between two floral/faunal communities, one permanently wet, and the other *terra firma* (Siemens et al. 2002:119). An ecotone has "edge effect": a greater number of species and a higher species density than the non-transitional areas surrounding the ecotone. The Maya exploited the birds, fish, mollusks, and vegetation that were endemic to the wetlands. Wetlands have high rates of primary productivity, and can provide suitable space for productive agriculture even without the use of artificial fertilizers (Darch 1988:87, 92).

In modern times, wetlands have been viewed as severely limited in agricultural potential because they are so wet (Darch 1988:87). Nevertheless, "a variety of seasonal wetlands are located in the bajo depressions, with at least seven different vegetation associations...modern farmers in the Petén use most of these niches for agricultural purposes without any modifications" (Guderjan et al. 2003:81). Unmodified wetland fields are often suitable for dry-season agriculture, when the uplands are too dry for rain-fed farming. Dry-season wetland farming enables the production of a second annual crop. The rich soil bordering the wetland fields can also be cultivated, with maize planting timed so that it matures as the wetlands progressively dry out during the winter dry season (Coe 2005:21). Unmodified wetland agricultural systems may also help preserve wetland ecological habitats, permitting recolonization by native plants once agricultural fields are abandoned (Darch 1988:87, 92).

Unmodified wetland fields are difficult to identify archaeologically. However, evidence exists that the Maya permanently modified some wetland fields, by either digging channels to drain water away from the fields, or by building the fields above the waterline. The deployment of wetland agriculture is also suggested by the micro- and macrobotanical records of some archaeological sites. At San Antonio Río Hondo, high percentages of pollen from cultigens and low percentages of pollen from arboreal species suggest that the Maya practiced dry-season wetland cultivation in combination with forest clearance for wet-season upland agriculture by the time of the transition from Early to Middle Preclassic Periods (Bloom et al. 1985:26). At Cuello, flotation samples of marine mollusks show that mollusks were brought to the site, possibly from the canals of the wetland fields (Hammond & Miksicek 1981:267).

Construction of drained (or channeled) and raised fields began in the Maya Lowlands during the Preclassic Period (Johnston 2003:140), and continued at some sites into the Classic Period. Agriculture at many wetland sites was abandoned during the Classic Period.

Wetland Agriculture: Channeled Fields

Why to Ditch

Many agricultural fields located in wetlands or places of permanent or seasonal inundation were channeled (or ditched) around their margins. Some upland (non-wetland) fields were also channeled to facilitate irrigation. The channels drained excessive water during the rainy season, and possibly provided irrigation during the dry season (Turner & Harrison 1983:3). Channeled fields are distinguished from raised fields because, although both appeared to consist of field surfaces surrounded by "moats," the surfaces of the latter were built up above the water level to control drainage and irrigation. Channeled and raised fields can both be recognized in the archaeological record by their checkerboard or ladderlike arrangement as seen from an aerial view, or by groups of ditches and embankments (Darch 1988:89). Raised fields are discussed in more detail below.

The field channels had functions beyond drainage and irrigation. At the Terminal Preclassic site of Edzna, Campeche, the large hydraulic system included 14 miles of canals that radiated out from the city center (Coe 2005:84). In addition to draining the agricultural fields, the canals there provided habitats for game birds and marine food animals (Coe 2005:84). For example, shells of snails, oysters, and scallops show that marine mollusks were brought to the site of Cuello, northern Belize, by the Maya for food or so their shells could be used (Hammond & Miksicek 1981:265-266). These would have thrived "in the canals of channeled- and raised-field complexes" (Hammond & Miksicek 1981:267). Fishing was possible at sites where channeled fields were constructed on riverine floodplains; fish enriched the soil by making nitrogen contributions (Puleston 1977a:38, 39, 42; Turner 1983a:46). Finally, channels could have been used for canoe transportation (Puleston 1977a:38, 39; Turner 1983a:46); at Edzna, the channels were used to transport people and goods into the city (Coe 2005:84).

How to Ditch

Channeled fields were constructed by digging canals on the edges of swamps or floodplains to drain off excess water (Darch 1988:89, 90). Like the ditches separating raised field surfaces, these channels were periodically cleared of muck, and the muck was replaced of the field's surface to act as fertilizer (Darch 1988:90). Evidence of canal clearing appeared in the pollen record at Pulltrouser Swamp, where the pollen of *Nymphaea* sp. ("water lily," an aquatic plant) appeared in the sediments of the agricultural fields (Darch 1988:90).

Local variations in field size and arrangement were adapted to suit local hydrological conditions (Darch 1988:89-90). Field channels may have held different amounts of water, depending upon their size, placement (i.e. in relation to a river or source of water or drainage), and elevation (Siemens & Puleston 1972:233). As observed in modern times, the surface of one ancient field might be underwater, while there is little or no water in the channels of a field on a neighboring site (Siemens & Puleston 1972:233). In such a case, it is possible that the fields were not used contemporaneously, and that there was a major change in the level of the water table between the times the two fields were constructed (Siemens & Puleston 1972:233, 234).

Some of the canals in the Mayan channeled field systems may have been as large as those of the *chinampas* of central Mexico (Puleston 1977a:38). Examples of total cultivated area, individual field area, and canal depth, width, and length come from the sites of San Antonio Río Hondo and Pulltrouser Swamp in northern Belize, and from the Candelaria River Basin sites in Campeche. *Total cultivated area:* At Pulltrouser Swamp, individual field platforms were arranged into various patterns with other fields, separated by ditches, to cover a larger total area, ranging between .225 and 3.575 square km (22.5 and 357.5 ha; Turner 1983a:30). The average size was 447.2 square m (Turner 1983a:46). Raised fields in the Candelaria River Basin of southeastern Campeche cover only about 2 square km (Siemens & Puleston 1972:233). *Field size:* At Pulltrouser Swamp, the size of each individual quadrilateral (or multi-sided and angular) field ranged between 10 and 30 m per side (Turner 1983a: 30-31, 33). At San Antonio Río

Hondo, channeled fields measured 12 to 20 m per side (Bloom et al. 1985:26). *Canal depth:* At Pulltrouser Swamp, the maximum vertical distance from the bottom of a canal to the top of a field was 2.50 m or farther (Turner 1983a:46). At San Antonio Río Hondo, ditches ranged from .5 to 1.0 m deep (Bloom et al. 1985:26). *Canal width and length:* At Pulltrouser Swamp, ditches varied in width between 1 and 10 m or more (Turner 1983a:33). Several major ditches of 100 to 200 m or longer in length led to the New River (Turner 1983a:33).

Where to Ditch

Canals have been found at both lowland and upland sites, in northern Belize, Petén, Campeche, Quintana Roo, and on the dry Pacific slope of the Maya area (Hall & Pérez Brignoli 2003:62-63; Lambert & Arnason 1978:33). Drained fields in *bajos* were found south of Tikal (Culbert et al. 1996; Kunen et al. 2000) and in Quintana Roo (Harrison 1978, 1982). Examples of Mayan archaeological sites with channeled fields include El Tigre, Campeche (Puleston 1977a:38, 1977b:450); Edzna, Campeche (Coe 2005:84; Matheny 1978); the Río Candelaria area, Campeche (Siemens & Puleston 1972); Pulltrouser Swamp, Belize (Darch 1988; Turner 1983b); San Antonio Río Hondo, Belize (Puleston 1977a:37); Lamanai, Belize (Lambert et al. 1984:67, 82); Gran Cacao, Belize (Maya Research Program 2005:4-5); and Blue Creek, Belize (Beach & Luzzadder-Beach 2003).

Channeled Fields at Blue Creek

Numerous wetlands exist in the Blue Creek area, and at least five channeled field complexes were established east of the site core (Guderjan et al. 2003:79). Ceramic evidence suggests, but does not prove, that these fields were established during the Late Classic Period (Guderjan et al. 2003:79).

In 2003, geoarchaeologists Tim Beach and Sheryl Luzzadder-Beach studied the soil and stratigraphy of the polygonal features, thought to be channeled agricultural fields with linear canals, east of the Blue Creek site (Beach & Luzzadder-Beach

2003:29). Stratigraphic profiles of the polygonal features identified a buried paleosol at extending from a depth of approximately 1.1 m to 1.5 ms, the upper portion of which had been previously dated (elsewhere) to the Middle Preclassic Period, between 2350 and 1880 b.p. or 1300 and 820 B.C. (Beach & Luzzadder-Beach 2003:30, 31).

During the Classic and Late Classic Periods, as the population peaked, between approximately A.D. 450 and 850, aggradation continued, and the water table rose as much as 150 cm above the Eklu'um Paleosol (Beach & Luzzadder-Beach 2003:32; Lohse 2003a:7). "Maya farmers responded by digging canals to help drain crop lands. These canals gradually in-filled with sediment and were cleaned out again and again; "canal muck" tossed onto adjacent fields provided fertilizer and nutrients for crops" (Beach & Luzzadder-Beach 2003:32). This type of intensive farming probably required a heavy labor input. It may also eventually have had diminishing returns. Elsewhere, at the site of San Antonio Río Hondo, northern Belize, canalization of wetland fields was shown to lead to salt accumulation in the soil, causing sodium accumulations that may have hindered the growth of salt-sensitive crops like maize and beans (Bloom et al. 1985:21, 29, 30).

Crops Grown on Channeled Fields

Written records from the period of Spanish contact note that the Maya successfully cultivated root crops (such as *Manihot esculentum*) not only on dry upland fields, but also on wetland fields (Pohl 1985:38; Pohl & Miksicek 1985:15). Pollen and macrofossil remains on archaeological fields suggest that the crops grown on drained fields included *Zea mays, Amaranthus* sp., and *Gossypium* sp. (Darch 1988:91; Miksicek 1983; Wiseman 1983). Other possible drained field cultivars include *Cucurbita moschata, Theobroma cacao, Persea americana, Capsicum* sp., and *Celtis* sp. (Darch 1988:91).

Wetland Agriculture: Raised Fields

Raised agricultural fields (like the better-known Aztec *chinampas*) were distinct from *channeled* (or ditched) fields, because the former were built up above a swamp's water level. This was accomplished by digging up mud and soil from the swamp's surface and piling it onto a central platform. A fill material was laid down, and the mud and soil were replaced to serve as the planting medium (Darch 1988:90). The platforms, which appeared to be separated by canals, were usually constructed about one m above the average water level (Darch 1988:89). Periodically, the canals were cleaned out, and new muck was dumped onto the central field, renewing the fertility of the planting surface, and enabling the field to be cultivated year after year (Hall & Pérez Brignoli 2003:63). This system controlled drainage and irrigation in inundated areas (Rice et al. 1985:101; Turner & Harrison 1983:3). The construction of raised planting surfaces was, like the channeling of wetland fields, allowed the Maya to increase the amount of land surface area that could be cropped. Because (unlike upland milpa fields) the wetlands could be cropped during the dry season, raised fields allowed for an increase in the number of crops that could be produced each year (Rice et al. 1985:101). Raised fields were also beneficial in that the planting platforms could have taken a variety of shapes that permitted aeration or temperature control (Turner & Harrison 1983:1).

In the Maya Lowlands, channeled fields seem to have been constructed more frequently than raised fields were. However, where sites have become covered with silt (such as results from anthropogenic soil erosion), raised fields are difficult to detect in the archaeological record (Deevey et al. 1979:299), so it is possible that more raised fields once existed than we can observe today. Alfred Siemens and Dennis Puleston (1972) were the first archaeologists to note raised fields, when they observed the narrow rectangles in *bajos* and on seasonally-flooded land bordering rivers. These were located in the Candelaria River Basin of southeastern Campeche, Mexico (Siemens & Puleston 1972:229). Raised fields were built in flat, low-lying, wet places where systems of irrigation agriculture (such as terracing) could have served little purpose, and "where water levels vary little through the annual cycle" (Coe 2005:20; Deevey et al. 1979:299).

To date, raised fields of Mayan construction have been found in Campeche, Quintana Roo, and Belize (Coe 2005:20; Deevey et al. 1979:299; Gliessman et al. 1983; Harrison 1993), and at Río Azul, Petén (Culbert et al. 1998). In some parts of Belize, raised fields cluster around bajos (Coe 2005:20; Deevey et al. 1979:299). For example, raised and channeled fields were constructed in a depression containing a sawgrass swamp at Pulltrouser Swamp (Turner 1983a). Raised fields were also constructed on the riverbanks at Albion Island, Belize (Pohl 1990; Turner & Harrison 1983:19). In the Three Rivers Region, the only known raised fields (first observed from the air) exist near Irish Creek, east of Boothe's River (Guderjan et al. 1991:55); and near La Milpa (Dunning et al. 2002).

Estimates based on aerial photography and limited surface survey concluded that raised fields cover more than 40,000 has in northern Belize and southern Quintana Roo (Turner & Harrison 1983:2). However, such estimates should be confirmed with more meticulous fieldwork to prevent mistakes. Adams (1983) used radar imagery to infer the presence of raised-field systems along the Río de la Pasión, but later field testing showed the features to be non-agricultural (Dunning et al. 1997:258-259).

Raised field agriculture dates to the Late Preclassic (before A.D. 250) and coincided with an increase in human population (Coe 2005:20-21). It does not seem that the raised fields were still in use by the Classic Maya (Coe 2005:21).

Wetland Agriculture: Dry-Season Cultivation of Riverbanks

The third and final type of wetland agriculture practiced by the ancient Lowland Maya was the dry-season cultivation of riverbanks. This system, like other methods of wetland agriculture, allowed an extra crop to be produced during the dry season.

Riverbank cultivation may have been one of the first cultivation methods developed by the ancient Maya. It is possible that this system developed even earlier than long-fallow milpa in the uplands (Dunning et al. 1998b:148; Wilk 1985:55). This is evidenced, for example, by the lack of the types of stone tools that could have been used for clearing land for milpa in the assemblages of Early and Middle Preclassic Cuello, Belize (Wilk 1985:55). During the same periods, the first known raised fields were being constructed on low-lying banks of the Río Hondo at the site of San Antonio Río Hondo on Albion Island, Belize (Pohl & Miksicek 1985:12, 21-22).

Elsewhere in northern Belize, raised fields were constructed on the low-elevation banks of the low-gradient New River near Pulltrouser Swamp, beginning in the Early Classic Period (Turner & Harrison 1983). Dry-season cultivation may also have taken place in the lacustrine wetlands of the Eastern Petén Zone of Belize and Guatemala. The lacustrine wetlands consist of seasonally-inundated land at the margin of lakes and *aguadas.* Lacustrine wetland landscapes are not known to have been modified for agriculture in the Maya Lowlands, but they may have been farmed during the dry season without modification (Guderjan et al. 2003:81).

The construction of raised fields on the riverbanks may have been an adaptation of farmers (already farming the riverbanks) to a sea level rise and accompanying increase in sedimentation that took place from approximately 3500 to 2500 B.P. (1500-500 B.C.; Turner & Harrison 1983:19). Alternatively, the proposed raised fields at San Antonio Río Hondo and Pulltrouser Swamp may have been *natural* products (rather than anthropogenic ones) of increased sedimentation caused by sea level rise and overbank flooding; but canals for draining the riverbank fields were likely manmade (Antoine et al. 1982; Piperno & Pearsall 1998:306; Turner & Harrison 1983:19).

Other Mayan Agricultural Practices

In addition to the types of dry-field, irrigated, and wetland agriculture discussed above, the Maya must have employed other agricultural practices. Some of these practices were not commonplace throughout the Maya Lowlands and are known from only a few sites. For example, the construction of aqueducts (including a sub-structural aqueduct; Coe 2005:130) is, to the best of my knowledge, unique to the site of Palenque.

Other hypothesized agricultural practices are not evident in the archaeological record. There has been little archaeological exploration of the impacts of plant diseases, predators, and pests on Mayan crops (Pohl 1985:6). Lime was sometimes scattered on the fields to drive away ants. It is possible that intercropping and crop rotation strategies served as methods of pest control (Pohl 1985:39-40) or rendered many pest control methods unnecessary, since it is most often in large monocropped plots that pests become specialized on specific crops. Where weeds were allowed to grow on agricultural fields, they may have distracted potential herbivorous insects from preying on the crops (Pohl 1985:39-40). Weeds steal nutrients from crops, but some crops intended to be used as mulch were planted near fields (Johnston 2003:148-149).

The ancient Maya may have applied natural fertilizers to their fields. Pre-industrial agrarian societies are known to have used ash (from burning unwanted vegetation), animal manure and human waste, vegetative garbage and recycled weeds (or "mulch"), and transported marl to refresh the soil (Boserup 1965). At Preclassic Nakbe, terrace surfaces were mulched with "nutrient-rich mucks mined from *bajos*" (original sources Dunning et al. 2002; Hansen 2000; Martinez et al. 1999; quoted from Johnston 2003:139). Fertilizers and mulches may be difficult to observe in the archaeological record.

Finally, little is known about the social and political factors that governed the Mayan agricultural system. In the age of European contact, Landa wrote that Mayan lands were communally owned and worked by groups of twenty men (Coe 2005:204). It may be more accurate to say that property was inherited patrilineally; each patrilineage held title to its own lands; and individual farmers held portions of this land in usufruct, but members of a patrilineage were obligated to help each other (Coe 2005:208). Division of agricultural labor based on sex and age is uncertain, although Linda Neff (2004) offered suggestions as to the sexual division of labor based on ethnographic evidence and the ability of each sex to wield the tools necessary for various agricultural tasks.

POSTCOLUMBIAN AGRICULTURE, PLANTATIONS, AND LOGGING

Introduction: Postcolumbian Political History of Belize

An understanding of the colonial history of Belize is important because 400 years of colonial rule established the economic, political, and social structures that remain in place today. These factors have also shaped the character of the modern agricultural systems in Belize. A discussion of postcolumbian and modern agricultural practices in the Maya Lowlands is relevant to this dissertation for two key reasons. First, contact between the populations of the New and Old Worlds resulted in a "Columbian exchange" of cultivars and methods for producing them. The introduction of new vegetation may be apparent in the pollen record, as may be the shift in emphasis from the Mayan interplanting system to the European-style plantation-based mono-cropping (or cash cropping) system. Second, the landscapes of the Americas transformed in response to European colonization, as indigenous land use strategies collided with European ones (Sanabria 2007:44). Depopulation of indigenous societies impaired their ability to sustain cultivation in the traditional manner (Sanabria 2007:44). In some places, where the natives had created grasslands and savannas through cutting and burning the natural tropical forest as part of slash-and-burn agriculture, natural forest began to regenerate (Sanabria 2007:44). Later, some of this land was again deforested and planted with crops or converted to pasture land (Hall & Pérez Brignoli 2003:15; Sanabria 2007:44). These types of landscape change may be evident in the pollen record.

To show the factors underlying the Columbian exchange and the postcolumbian landscape transformations of Belize, I begin with a statement about the Post-Collapse political situation. I move on to an explanation of the postcolumbian political history of Belize, including the Spanish and British colonial periods in Central America. I then turn to remarks on the changes to the traditional Mayan production systems that resulted from European contact. Finally, I give details on the postcolumbian agricultural systems instituted in the Maya area, including the logging industry and cash cropping plantation systems.

The Political Situation of the Post-Collapse Maya

After the Maya Collapse, the southern lowlands (including Belize) were never significantly repopulated by the Maya (Hall & Pérez Brignoli 2003:59). During the Postclassic Period, the main Maya settlements were in the highlands and in the northern lowlands of the northerly Yucatan Peninsula (Hall & Pérez Brignoli 2003:59). Beginning around the time of the Collapse and continuing into the period of European contact, the Maya were influenced by warriors and traders from central Mexico, to the west. The last to arrive in the Maya area were the Aztecs, "who by the 15th and early 16th centuries [had established] a tributary province in Soconusco and developed a vast trading network along both coasts of the isthmus" (Hall & Pérez Brignoli 2003:57).

At the time of first European contact, in the 16th century A.D., the Maya were organized into relatively small city-states, some of which were loosely confederated (Sanabria 2007:64). Some researchers claim that this form of political organization worked against the Spanish *conquistadores*, because they could not form larger-scale alliances that would help them to conquer greater numbers of Maya (Sanabria 2007:64, 84). Other researchers disagree, believing that the subdivision of the Maya into relatively small polities enabled the Spaniards to subdue one group at a time, and use each group as an ally in subduing its enemy groups (Hall & Pérez Brignoli 2003:66). Either way, the Maya showed resistance to Spanish colonization from the very first, often building their cities atop hills, where they could be more easily defended from attack by Spanish *conquistadores* (Coe 2005:200-201).

Spanish Colonialism

European involvement in the Maya area began with the A.D. 1494 Treaty of Tordesillas. This agreement between Spain and Portugal allowed Spain to take colonial power over Central America, as well as most of North and South America (Hall & Pérez Brignoli 2003:30). Central America was "discovered" by a voyage of Spaniard Rodrigo de Bastidas in 1501 (Hall & Pérez Brignoli 2003:66). Over the next 50 years, other Spaniards explored and conquered much of Central America (Hall & Pérez Brignoli

2003:66). In A.D. 1517, Yucatan was “discovered” by Hernández de Córdoba (Coe 2005:202). In A.D. 1519, Hernán de Cortes explored the Grijalva area (in Chiapas, Tabasco, and Campeche, Mexico; Coe 2005:202). Nine years later, Francisco de Montejo initiated the Spanish Conquest of the northern Maya (Coe 2005:202). In A.D. 1542, the Spanish established their capital city at Mérida (Coe 2005:202). Pedro de Alvarado worked at conquering the Maya in Guatemala from A.D. 1523 until 1541 (Coe 2005:203). This “Early Conquest” period was a time of violent suppression of the indigenous people (Coe 2005:243). The Spaniards did not set out to kill off the conquered people, but to convert them to Christianity and to exploit their labor and produce (Hall & Pérez Brignoli 2003:76). To this end, those Maya who lived in locations convenient for the Spanish were herded into towns, where they could be converted and controlled (Coe 2005:243). Many Indians died as a result of contact with the Spaniards, mostly from European diseases to which they had no natural immunity (Coe 2005:243; Hall & Pérez Brignoli 2003:76-77). In the Maya area, the native population declined sharply between A.D. 1500 and 1600, and did not begin to rise again until the 18th century (Hall & Pérez Brignoli 2003:77). Even today, most of the remaining native Maya live in the Maya Highlands, where the population was most numerous at the onset of Spanish contact (Hall & Pérez Brignoli 2003:77).

Most early Spanish colonial settlements, in the 15th and 16th centuries, were in the islands of the Caribbean and the Caribbean coast of mainland Central America (Hall & Pérez Brignoli 2003:30). When the Spanish, in the 1520s and 1530s, discovered the large indigenous civilizations and metallurgic resources of Mexico and Peru, they moved their focus to those areas for the remainder of the colonial period (Hall & Pérez Brignoli 2003:30), and ignored Belize while doing so.

The ensuing “Colonial Indian Period,” which endured from end of 16th century through the first quarter of the 18th century, was noted for its entrenchment of Spanish bureaucracy in the New World colonies. For administrative purposes, the Spanish had already divided their colonial holdings in Central America into viceroyalties. Viceroyalties were further subdivided into *audiencias* with judiciary and military functions (Hall & Pérez Brignoli 2003:32). Belize, with northern Central America, belonged to the viceroyalty of New Spain (Hall & Pérez Brignoli 2003:32). Belize belonged to the Audiencia of Mexico from 1538 until 1543 and then the Audiencia de los Confines from 1543 until 1564, rejoining the Audiencia of Mexico from 1564 until 1570, and finally becoming part of the Audiencia of Guatemala from 1570 until independence in 1821 (Hall & Pérez Brignoli 2003:32). *Audiencias* were further subdivided into provinces and other small units (Hall & Pérez Brignoli 2003:33).

Within these smaller units, *encomienda* systems were instituted. The *encomienda* system permitted Spaniards to own land in the colonies. In exchange for promising to convert the native people to Catholicism, Spanish landowners were permitted by the Spanish crown to force the indigenes to pay tribute and/or work on Spanish plantations. Until the second half of the 18th century, the Catholic friars were the only legal Spanish residents of most Indian villages, so it was they who were responsible for maintaining law and order and ensuring Indian participation in the *encomienda* (Hall & Pérez Brignoli 2003:74). No *encomiendas* were granted in Belize, which had no long-term Spanish settlement. The *encomienda* system was finally abolished in A.D. 1724.

During the 17th century, the Spanish colonial empire achieved its maximal extent. From A.D. 1672 to 1678, Dominican friars and missionaries made the first *entrada* (expedition into unconquered territory) into Belize (Hall & Pérez Brignoli 2003:74). The close of the 17th century saw the collapse of the last remaining Maya capital, at Tayasal, Petén. Tayasal resisted Spanish conquest until A.D. 1697 (Hall & Pérez Brignoli 2003:59).

British Colonialism

In the 17th and 18th centuries, Spain was forced to turn most of its globe-wide colonial holdings over to England, France, and the Netherlands (Hall & Pérez Brignoli 2003:31). Neither France nor the Netherlands sought to establish colonies in Central America, but British colonists began to settle in Belize in the 1630s (Hall & Pérez

Brignoli 2003:142-143). Concurrently, Spain's imperial power was weakened from within, as *criollos* of mixed indigenous and Spanish descent sought to gain political and economic power as they developed their identities in stratified colonial society (Hall & Pérez Brignoli 2003:31). By the Treaty of Versailles in 1783 and the Convention of London in 1786, the British were permitted to maintain their small settlement in Belize, and after a series of colonial wars with Spain, Belize was formally colonized by the British in 1862 (Hall & Pérez Brignoli 2003:33, 35, 37, 146-147). The boundaries of modern Belize were established by the Anglo-Guatemalan Treaty of 1859 and the Anglo-Mexican Treaty of 1893 (Hall & Pérez Brignoli 2003:44-45, 48). However, from the late 19th century through most of the 20th century, Mexico and Guatemala continued to dispute their borders with Belize, with Guatemala especially desiring access to the Caribbean Sea via watercourses that pass through Belize (Hall & Pérez Brignoli 2003:48). In 1933, Guatemala claimed sovereignty over Belize, and Belize did not achieve independence until 1981 (Hall & Pérez Brignoli 2003:48).

Belize was never fully occupied by the Spanish, and had relatively sporadic contact with the Spanish, and therefore does not show as much Spanish influence as other Middle and Central American countries (Hall & Pérez Brignoli 2003:4, 69). Even British colonists were less interested in Belize than they were in the lands to the south that could provide a route across the isthmus between the Pacific Ocean and the Caribbean Sea (Hall & Pérez Brignoli 2003:45). British colonists filled in settlement gaps left by the Spanish, probably forming the first British settlements in Belize around A.D. 1638 (Hall & Pérez Brignoli 2003:36). The British were quick to exploit the Belizean hardwoods, initially cutting logwood for use as a dyestuff (Hall & Pérez Brignoli 2003:34, 36). When the A.D. 1786 Convention of London was signed, Spain recognized British settlement in Belize, and gave the British permission to cut mahogany for furniture and construction (Hall & Pérez Brignoli 2003:34, 36, 147). The British formed alliances with the few remaining natives against the Spanish (Hall & Pérez Brignoli 2003:34, 36). Most of the Belizean coast became populated by the British and their African slaves (Hall & Pérez Brignoli 2003:36). The remaining Maya lived farther inland and had little contact with the British until the 19th century (Hall & Pérez Brignoli 2003:36). Flight into the forest was a form of resistance to colonialism, both by the Maya and by the escaped African slaves, who had been brought to the New World by European colonists (Sanabria 2007:98-99).

Independence and Colonial Influences

The territory of Belize existed as the colony of British Honduras from 1862 until 1981 (becoming an official Crown Colony in 1871), though local citizens sometimes protested against British rule (Hall & Pérez Brignoli 2003:35, 218-219, 238, 261). Beginning in the 1880s and continuing into present times, struggles have continued between Maya who desire independence and the national governments of modern nations located in the Maya area, which have attempted to force the Maya to give up their communal lands to labor for slave wages on cash-crop plantations. In Mexico, remote Maya villagers have only begun to accept the rule of the national government during the last few decades (Coe 2005:203). Recently, since 1994, some Maya have formed the Zapatista National Liberation Army to challenge Mexican authority (Coe 2005:203).

Belize achieved internal self-governance in 1964 and complete independence in 1981 (Hall & Pérez Brignoli 2003:45). Belize has a population of approximately 256,000 (United Nations 2002).

Today, Belize continues to show British influence. English is the country’s official language. Belize is “an independent member of the British Commonwealth,” with a British-style parliamentary government and the British monarch as the chief of state (Central Intelligence Agency 2008; Hall & Pérez Brignoli 2003:4-5, 45, 219). However, the country has some characteristics in common with the Central American countries that were more heavily colonized by the Spanish, not the least of which is the peoples’ shared indigenous roots. The majority of indigenous people living in modern Belize, Guatemala, and southeastern Mexico are of Mayan descent (Hall & Pérez Brignoli 2003:58). Also, in spite of the fact that British influence in Belize was stronger than Spanish influence, most of Belize’s Christians are Catholics (in the Spanish tradition), rather than Protestants (in the British tradition; Hall & Pérez Brignoli 2003:99). Population movements have strengthened the ties between citizens of different countries in the region. In the aftermath of the Caste War of 1847-1901 (in Yucatan, Mexico), rebelling Maya on the northwestern border of Belize engaged in guerilla warfare against the Mexican government (Hall & Pérez Brignoli 2003:45, 99). As a result, Spanish-speaking mestizos and Maya moved from Mexico into Belize; mestizos still constitute about one-third of Belize’s population (Hall & Pérez Brignoli 2003:99). Later, after the civil wars of the 1980s, thousands of Salvadorans and Guatemalans (many indigenous people) migrated to Belize, bringing their Hispanic-American cultures with them (Hall & Pérez Brignoli 2003:273).

Changes to Traditional Production Systems

The section “The Process of Milpa Cultivation” (above) gives details on the type of farming practiced by Postcolumbian and modern Maya farmers in Belize. This system came into being through a combination of traditional Mayan farming practices with production systems, animals, and crops introduced by European colonists. The two-way flow of plants and animals between the Old World and the New World is known as the Columbian exchange (Crosby 1972). Spanish *conquistadores* introduced to the Maya cattle, pigs, chickens, citrus trees, watermelon, sugarcane, and coffee (Coe 2005:244). They also brought to the New World wheat, bananas, olives, grapes, rice, horses, and goats (Sanabria 2007:84, 256-258). In turn, New World crops such as maize, beans, manioc, potatoes, and chili peppers found their way to Europe (Sanabria 2007:85). The Europeans also introduced new tools, such as steel axes and other steel implements (Coe 2005:204). These replaced the copper axes the Maya had acquired from Mexico during the Postclassic Period, and some of the traditional simple farming implements, “such as hoes and digging sticks made from wood and bone” (Hall & Pérez Brignoli 2003:62; Coe 2005:204).

Social factors influenced the choice of Europeans to plant certain crops in the New World. Sometimes, Europeans in the New World sought to replace indigenous crops with the Old World crops with which they were more familiar (Sanabria 2007:256). Wheat, for example, was the only grain recognized by the Roman Catholic Church for use in the Holy Eucharist, so Catholic Europeans preferred wheat to the endemic maize (Sanabria 2007:256). The Spanish introduced wheat farming to the cool, dry highlands (Hall & Pérez Brignoli 2003:155). Catholic friars sometimes tried to outlaw food associated with “pagan” practices (Sanabria 2007:256).

Economic factors played a stronger role than social factors in the choice of crops and introduction of production methods. At the time of the conquest, Maya farmers in the Yucatan exported cotton as a cash crop (Coe 2005:205). They also exported honey, cotton mantles, and slaves. The only commercially-produced crop was cacao, which was grown mostly in Soconusco and part of Guatemala (Hall & Pérez Brignoli 2003:63). However, most agriculture in the Maya area has been for local consumption, in part because of the difficulty of long-distance transportation of food crops (Hall & Pérez Brignoli 2003:62, 154). Maize has been the leading subsistence crop for thousands of years. In colonial times, Europeans introduced to the Maya area new systems of agricultural production that were not oriented toward subsistence and local consumption, but toward profit to be gained from intensive (mass) production, export, and sale on the world market. Much land was cleared for the establishment of large plantations (or *haciendas*) for cash crops, and for pasturing livestock. The new logging industry took timber for profit. Other natural resources, such as salt and ores of silver, gold, and iron, began to be exploited at alarming rates (Hall & Pérez Brignoli 2003:158-159).

Indigenous Maya had relied on beans to be their main source of dietary protein, supplemented by the consumption of fish and wild game (Hall & Pérez Brignoli 2003:155). Profit-minded Spanish introduced livestock rearing to Central America in the 16th century, razing forests to clear land for pasture through the 17th century (Hall & Pérez Brignoli 2003:155, 156). Livestock rearing eventually caught on in Belize.

Cattle, pigs, and bees are raised today (International Travel Maps 2004; King et al. 1992:5-6).

Agroforestry

In early colonial times, logwood (*Haematoxylon campechianum*) and mahogany (*Swietenia macrophylla*) were Belize’s chief exports (Hall & Pérez Brignoli 2003:156). Logwood grows best in the marshy coastal and riverine forests of the Yucatan Peninsula, including eastern Belize (Hall & Pérez Brignoli 2003:160). The tree was exploited by the Maya for the red and purple dyes that could be produced from it (Hall & Pérez Brignoli 2003:160). The Spanish noticed logwood in the 16th century, and began to fell logwood in Campeche in the 16th and 17th centuries (Hall & Pérez Brignoli 2003:160). Forest resources drew British colonists to Belize in the mid-17th century (Standley & Record 1936:17-18). Logwood trees were felled at about ten years of age; then the deep red heartwood was cut into sticks and sent to Europe, where the sticks were ground into a powder that was used in dye production (Hall & Pérez Brignoli 2003:26, 160). Vegetable dye from logwood became one of Central America’s most valuable exports (Hall & Pérez Brignoli 2003:26, 160).

The value of logwood and the rights to exploit it caused struggles between Spanish and British colonists. By the early 18th century, British settlers in Belize bought black slaves to do the hard labor in the lumber camps (Hall & Pérez Brignoli 2003:160). As production and export of logwood by the British increased, prices for logwood fell (Hall & Pérez Brignoli 2003:160). This angered the Spanish, but they failed to evict the British lumbermen and eventually granted them rights to continue their activities via the 1763 Treaty of Paris (Hall & Pérez Brignoli 2003:160). However, prices for logwood continued to fall even as the most accessible stands were depleted, and in the 1770s the British turned their attention to mahogany production (Hall & Pérez Brignoli 2003:160). In Europe, the mahogany was turned into furniture, pianos, church interiors, railway carriages, and ships (Hall & Pérez Brignoli 2003:177).

In later (20th century) colonial times, the Belizean economy still depended upon agroforestry, with three-quarters of the country's exports consisting of forest products (Standley & Record 1936:17). In addition to logwood and mahogany, the trees *Cedrela odorata* ("cedar"), *Dalbergia stevensonii* ("rosewood"), *Manilkara zapota* ("sapodilla"), and *Pinus caribea hondurensis* (pine) were heavily exploited (Standley & Record 1936:17). Important secondary timbers were *Virola koschnyi* ("palo de sangre"), *Calophyllum brasiliense rekoi* ("santa maria"), and *Vochysia hondurensis* ("white mahogany"; Standley & Record 1936:34-36).

Deforestation has become a significant problem in post-colonial Middle America. The amount of Middle American land covered by forests decreased (from 52 to 34 percent) while the amount of pasture land increased (from 19 to 28 percent) between 1970 and 1990 (Hall & Pérez Brignoli 2003:242). Obviously, the increased production of beef cattle was linked to forest clearance. In Petén, Guatemala, half the forest cover has disappeared since the 1960s (Sanabria 2007:305). Once a heavily forested region populated sparsely by swidden farmers and chicle tappers, the area has been inundated by corporations and wealthier people who want to invest in cattle ranching, logging, and exploration for minerals and petroleum (Sanabria 2007:305). Fortunately, Belize has not suffered the widespread deforestation that has plagued other Middle American countries (Hall & Pérez Brignoli 2003:274). In the late 20th century, Middle American governments began to realize the need to set aside forest reserves, national parks, and protected Indian lands (Hall & Pérez Brignoli 2003:95). By the 1960s, the Belizean economy was reoriented from forestry to agriculture (Hall & Pérez Brignoli 2003:240). This shift in focus is the subject of the following section.

Plantations, Commercial Agriculture, and the Modern Economy

As noted above in the section "Spanish Colonialism," many indigenous people in Central America were enjoined to labor for Spanish agriculturalists as part of the *encomienda* system, prior to its abolition in A.D. 1724. Native labor on the *haciendas* of Central America continued under different conditions after that time. The need to supply the plantations with additional labor led to the importation of African slaves (Sanabria 2007:85). The Spanish profited from intensive production of tropical plants such as cacao, indigo, and logwood (Hall & Pérez Brignoli 2003:31). Throughout colonial times and into the present, the relative importance of different export commodities has shifted. After the Spanish discovered cacao, they continued to produce it, and it remained a major export of the Audiencia of Guatemala through the 16th century (Hall & Pérez Brignoli 2003:63). In the 17th century, indigo became the most important export crop; and in the 19th century, coffee and bananas dominated (Hall & Pérez Brignoli 2003:155). At the turn of the 20th century, large plantations of henequen and sisal (*Agave* spp., cacti used to manufacture strong twine) were established in the Yucatan Peninsula (Sanabria 2007:42, 96). Tobacco was grown in warm, moderately rainy parts of Central America; salt was produced; and silver, gold, and iron ores were mined (Hall & Pérez Brignoli 2003:158-159).

None of this is known to have taken place in Belize, a land largely ignored by the Spanish. In the late 1930s, most Belizean agriculture was still described as "shifting" and "primitive." The indigenous people of Belize have long employed shifting cultivation to meet personal needs, sometimes producing a salable surplus (Standley & Record 1936:14, 15). Because people were able to meet their personal needs, Agricultural Officer H.P. Smart, writing in *The Forests and Flora of British Honduras*, supposed that people would not adopt modern agricultural methods until population pressure made this necessary (Standley & Record 1936:15). At the time of his writing, much agriculture was confined to narrow (quarter-mile wide) riverside strips of clayey soil, bordered on one side by a river and on the other side by a low-lying swamp (Standley & Record 1936:14). There, vegetable crops were produced on a small scale. These included maize or corn (*Zea mays*), beans (*Phaseolus* spp.), cassava (*Manihot* spp.), yams (*Dioscorea* spp.), cocoyam (*Xanthosoma* spp.), sweet potato (*Ipomoea batatas*), rice (*Oryza sativa*), plantain (*Musa paradisiaca*), and "cowpeas" (no Latin binomial specified; Standley & Record 1936:15-16). Preference of the individual farmer, and not necessarily demands of the market, played a role in the choice of crops to be produced: *Zea mays* and *Phaseolus* spp. were in 1936 grown by native Maya; *Manihot* spp. and *Dioscorea* spp. were grown by people of Carib extraction; and "the Creole planter [grew] a little of all" (Standley & Record 1936:16).

Commercial agriculture was not developed in Belize until the 20th century, late in the British colonial period. Commercial agriculture in Belize expanded in the 1920s and 1930s, when an economic depression and concurrent depletion of accessible timber resources followed World War I (Standley & Record 1936:13). These problems and global trade stagnation called for a reduction in dependence on foreign imports of foodstuffs (Standley & Record 1936:13). The British colonial government encouraged the cultivation of corn, rice, and beans by constructing two rice mills and two drying kilns (Standley & Record 1936:16). Modern agricultural methods were also promoted in Belize by people who came from the West Indies to farm (Standley & Record 1936:15).

The cultivation of cash crops in Belize has not always proven to be profitable. Most fruit companies encountered problems such as plant disease, soil exhaustion, lack of availability of modern transportation, the need to clear and drain land, and the need to construct ports, railroads, villages, and other colonial infrastructure (Hall & Pérez Brignoli 2003:94). Colonists mistakenly assumed that all land was suitable for farming and that the natural vegetation was an obstacle rather than an economically valuable renewable resource (Hall & Pérez Brignoli 2003:95). Eventually, the British colonial administration became aware of these problems, and attempted to remedy them by conducting in-depth surveys of the land and creating such publications as potential land use maps. In 1958, for example, the British Directorate for Overseas Surveys classified the land in Belize according to the uses to which the land could potentially be put (Great Britain Directorate of Overseas Surveys 1958b). "Potential land use" means something like "land capability," being the sort of use that can be sustained over time without damaging the natural environment (as by erosion). Land slope, water availability, and land fertility were also considerations in potential land use classification schemes (Hall & Pérez Brignoli 2003:26). Suggestions were made as to the suitability of certain districts for success in certain types of crop cultivation, for use as pasture land, or for conservation, etc. As yet, most of Belize has not been commercially or agriculturally developed, and less than 5 percent of the country’s land area is under cultivation (about 15 percent of arable land; Central Intelligence Agency 2008), so the accuracy of the suggested land uses cannot be rated. Still, the potential land use ratings show that people were interested in promoting and increasing commercial agricultural production, and exemplify the potential for human agency in landscape change.

Over time, the importance of agriculture to the Belizean economy has increased. Today, agriculture accounts for 69 percent of foreign earnings, but only 21.3 percent of the GDP (Central Intelligence Agency 2008; International Travel Maps 2004). In 2005, 22.5 percent of Belizeans were employed in the agricultural sector (Central Intelligence Agency 2008). Yet in the 1990s, most food crops in northern Belize were still grown on a “modified ‘milpa’ system,” with a short-term fallow period between crops (King et al. 1992:3). The use of legumes or mixed cropping to refresh the soil was infrequent (King et al. 1992:3). Most farms are small, with most Belizean farmers hold only 5-50 acres, “but a greater total area of land is held by those farming more than 50 [acres]” (King et al. 1992:3). This system may seem primitive, but it requires only about 15 percent of suitable agricultural land to be in active use, leaving 60 percent of Belize forested (Central Intelligence Agency 2008; International Travel Maps 2004).

Sugar, citrus, bananas, and cocoa are the most important cash crops for Belize (International Travel Maps 2004). Each is discussed in turn here. Sugar cane (*Saccharum officinarum*) cultivation was introduced to Central America in the 17th century. The Spanish widely cultivated sugar cane in Central America (Hall & Pérez Brignoli 2003:155). They found sugar cane relatively easy to produce, since it is ecologically tolerant, can withstand extensive production, and can survive neglect (Hall & Pérez Brignoli 2003:240; King et al. 1992:3). It can be grown casually alongside crops that require more tending; for example, sugar cane was fodder for the oxen that pulled carts on the Spanish coffee plantations (Hall & Pérez Brignoli 2003:155, 194). As the demand for sugar quickly rose on the world market, African slaves and laborers from the East Indies [islands] were imported to work on the sugar plantations (Standley

& Record 1936:14). As a British colony, Belize was able to export sugar in the 19th and early 20th centuries, until “primitive” (extensive) cultivation methods proved unprofitable (Standley & Record 1936:14). A diversification program was initiated in the mid-1980s, but its efforts abated when sugar prices subsequently rose (King et al. 1992:4). Today, sugar cane is the basis of the rural economy of northern Belize (King et al. 1992:3). It is also produced on the well-drained clay soils of southern Belize (Standley & Record 1936:14). Belizean sugar and molasses are mostly exported to the United Kingdom (Hall & Pérez Brignoli 2003:240).

Of the citrus fruits, grapefruit (*Citrus paradisi*) was the first to become an important export crop. Grapefruits were introduced in the Stann Creek District in A.D. 1913, and in 1924 were produced in sufficient quantity for the commencement of export sales (International Travel Maps 2004; Standley & Record 1936:16). Citrus fruits are grown in northern Belize (King et al. 1992:4-5).

Banana (*Musa* spp.) production had a rocky early history in Belize. North American fruit companies attempted the cultivation of bananas on plantations in Stann Creek District between A.D. 1908 and 1941 (Hall & Pérez Brignoli 2003:94, 205). After a devastating outbreak of Panama disease, the cultivation of bananas for export was temporarily abandoned (Hall & Pérez Brignoli 2003:205; Standley & Record 1936:15). Production has since resumed in southern Belize (International Travel Maps 2004).

Cacao (*Theobroma cacao*) has been a popular foodstuff at least since Maya times, but only recently has Belizean cacao become economically important, because West African cacao is cheaper on the world market (International Travel Maps 2004; Standley & Record 1936:15). Only Cayo District receives enough rainfall to support the growth of *T. cacao* (King et al. 1992:4).

Other plants have been commercially produced in Belize during the 20th and 21st centuries. Coconut (*Cocos nucifera*) production saw a major increase after A.D. 1910, and today most of the coconuts and copra are produced for export (Standley & Record 1936:15). Coconuts are cultivated in the sandy soil of the Caribbean coast and the cays of Belize (Standley & Record 1936:14). Pineapples (*Ananas comosus*), which came to Belize from Brazil, are cultivated and “more or less naturalized” in modern Belize (Standley & Record 1936:90). Some species of yam (*Dioscorea* sp.), both wild endemics and introduced cultivars, grow in Belize (Balick et al. 2000:154-155; Standley & Record 1936:95). Marijuana (*Cannabis sativa*) is illicitly cultivated “around Orange Walk”, and Belize is becoming increasingly involved in the South American drug trade (Central Intelligence Agency 2008; International Travel Maps 2004). Red kidney beans (*Phaseolus vulgaris*) are the most-commonly-cultivated legume in Belize (King et al. 1992:4). In addition to bananas, mangoes (*Mangifera indica*), and rice (*Oryza sativa*) are cultivated in southern Belize (International Travel Maps 2004). Like citrus fruits, mangoes are grown in northern Belize (King et al. 1992:4-5). Cashew (*Anacardium occidentale*) and coffee (*Coffea* spp.) are cultivated in modern Belize (King et al. 1992:5). Trials for carambola (*Averrhoa carambola*) and yellow passion fruit (*Passiflora edulis flavicarpa*) agriculture were in progress in the early 1990s, and Sea Island cotton (*Gossypium barbadense*) was tried in Orange Walk District (King et al. 1992:4-5); these may become more important cash crops in the future.

Changes wrought to Middle American agriculture as a result of European contact have had serious consequences for the native people. By the 20th century, commercial production of bananas, coffee, cotton, sugar, and beef resulted in deforestation (and associated problems with drainage and erosion), devastation of flora and fauna, and the use of ineffective and unhealthful chemical fertilizers and pesticides (Hall & Pérez Brignoli 2003:241). Land distribution and distribution of wealth are major problems. Peasants or small farmers can afford to conduct their subsistence agriculture on only a very small percentage of each country’s arable land, while commercial producers hold the majority of the land (Hall & Pérez Brignoli 2003:242-243). With a recent population explosion and the movement of people away from farms and into urban areas (in search of employment and access to social services), Middle America now must import much of its food (Hall & Pérez Brignoli 2003:243, 248).

CHAPTER V

LIST AND DESCRIPTIONS OF LAGUNA VERDE POLLEN CORE TAXA

This chapter lists the plant taxa represented in the Laguna Verde pollen core. Brief descriptions of the represented plants are given. Written evidence from Postclassic Mayan texts and from early European travelers to the Maya Lowlands, combined with ethnographic analogies to recent Belizeans and other Mesoamericans, suggest possible usages for plants with economic value. I explain such uses for the plants represented palynologically in the Laguna Verde core. When relevant, I give the sample number or depth in the core at which pollen grains of the represented taxa were observed; additional details of this type are given in the "Taxonomic Discrimination" section of Chapter I.

KEY SOURCES FOR PLANT USES

Although many sources were consulted during the description of plant uses given in this chapter, three sources were particularly helpful. The first helpful source originated with colonial agroforestry. The Forest Department of British Honduras was established in 1922, during British colonial rule, to promote systematic commercial forestry (Standley & Record 1936:25). Field Museum of Natural History botanist Paul C. Standley worked with Samuel J. Record to facilitate the Department in identifying the botanical resources it was responsible for managing (Standley & Record 1936:7). The eventual result was their 1936 publication of *The Forests and Flora of British Honduras*, which describes Belize in terms of its geography, geology, climate, agricultural history, and forest types, and lists (in some cases keying and describing) its woody and herbaceous plants. This was the earliest significant publication of its kind for Belize.

The second helpful source was *Checklist of the Vascular Plants of Belize with Common Names and Uses*, published by botanist Michael Balick and colleagues in 2000. This book lists the 3,408 species of plants that grow in Belize, and gives their common names, growth habits, and local and regional uses. Thirty-eight percent of the flora is reported to be economically useful (Balick et al. 2000:1).

The third significant source consulted for this section was *Rainforest Remedies: One Hundred Healing Herbs of Belize,* written by Balick and physician Rosita Arvigo during the 1990s. This book gives a primer on ethnomedicine, before illustrating the medicinal plants of Belize and explaining their curative functions.

LIST OF PLANTS REPRESENTED IN THE LAGUNA VERDE POLLEN CORE

The list headings in Table 6 indicate the types of pollen that were identified during my study of the Laguna Verde pollen core. Pollen grains were identified to various taxonomic levels, from family to species. In cases where pollen grains were identified to family level, the name of the family (in capital letters) is followed by "(Family)".

Table 6. Taxa Represented in the Laguna Verde Pollen Core.

ACANTHACEAE
    Bravaisia sp.
    Justicia campechiana
ANACARDIACEAE
    Anacardium occidentale
    Mangifera indica
    Metopium brownei
    Spondias mombin
    Spondias purpurea
    Spondias sp.
APIACEAE (Family)
APOCYNACEAE
    Tabernaemontana sp.

Table 6, Continued.

AQUIFOLIACEAE
    Ilex sp.
ARACEAE/ARECACEAE (Families)
    Bactris-type
ARISTOLOCHIACEAE (Family)
ASTERACEAE
    High-spine
    Low-spine
    ASTERACEAE/AMARANTHACEAE, fenestrate type
BETULACEAE
    Alnus sp.
    Ostrya sp./*Carpinus* sp.
BIGNONIACEAE (Family)
BOMBACAEAE
    Pachira aquatica
BORAGINACEAE
    Cordia alliodora
    Cordia sp.
BURSERACEAE
    Bursera sp.
    Protium sp.
CAMPANULACEAE (Family)
CELASTRACEAE (Family)
CHENOPODIACEAE/AMARANTHACEAE (Families)
CHRYSOBALANACEAE (Family)
    Licania sp.
COMBRETACEAE/MELASTOMATACEAE (Families)
    Laguncularia racemosa (COMBRETACEAE)

Table 6, Continued.

COMMELINACEAE
    Commelina sp.
CORYLACEAE/BETULACEAE (Families)
CUCURBITACEAE (Family)
CUPRESSACEAE
    Platycladus orientalis
CYPERACEAE (Family)
DILLENIACEAE
    Curatella americana
ERYTHROXYLACEAE
    Erythroxylum sp.
EUPHORBIACEAE (Family)
    Acalypha sp.
    Alchornea sp.
    Croton sp.
    cf *Gymnanthes lucida* or *Chamaesyce hirta*
    Sebastiana sp.
FABACEAE (Family)
    Andira inermis
    Bauhinia divaricata
    Bauhinia herrarare
    cf *Cassia=Senna* sp.
    cf *Dalbergia brownei*
    Desmodium sp.
    cf *Lonchocarpus* sp.
    cf *Machaerium seemanii*
    cf *Melilotus* sp.
    Mimosoideae cf *Acacia* sp.

Table 6, Continued.

- *Mimosa* sp.
- *Swartzia* sp.

FAGACEAE

- *Quercus* sp.

FLACOURTIACEAE

- *Banara guianensis*

HAMAMELIDACEAE

- *Liquidambar styraciflua*

HIPPOCRATEACEAE

- *Hippocratea volubilis*

JUGLANDACEAE

- *Carya* sp.

JUNCACEAE

- *Juncus marginatus*

LAMIACEAE

- *Hyptis* sp.

LENTIBULARIACEAE

- *Utricularia* sp.

LILIACEAE

- *Lilium* sp.

LORANTHACEAE (Family)

MALPIGHIACEAE (Family)

- *Byrsonima* sp.
- cf *Heteropterys laurifolia*

MALVACEAE (Family)

MELIACEAE (Family)

- *Cedrela* sp.
- *Swietenia* sp.

Table 6, Continued.

- *Trichilia hirta*

MORACEAE (Family) and CECROPIACEAE

- *Cecropia* sp.
- cf *Brosimum* sp.
- *Ficus* sp. (diporate)
- MORACEAE triporate
- Other diporate (Possibly URTICACEAE)

MYRICACEAE

- *Myrica* sp.

MYRISTICACEAE (Family)

- *Virola* sp.

MYRTACEAE (Family)

- MYRTACEAE syncolpate
- MYRTACEAE tricolporate

NYMPHACEAE (Family)

ORCHIDACEAE? (Family)

PIPERACEAE

- *Piper* sp.

PINACEAE

- *Pinus* sp.
- *Tsuga* sp.

POACEAE

- POACEAE<50 μ
- POACEAE, 50-69 μ
- POACEAE, 70-100 μ
- POACEAE>100 μ

PODOCARPACEAE

- *Podocarpus guatemalensis*

Table 6, Continued.

POLYGONACEAE (Family)
    Coccoloba sp.
RHAMNACEAE
    Colubrina arborescens
RHIZOPHORACEAE
    Rhizophora mangle
RUBIACEAE (Family)
    Borreria laevis=Spermacoce assurgens (species distinctive)
    Borreria sp. or *Spermacoce* sp.
    Faramea sp.
    Psychotria sp.
RUTACEAE
    Zanthoxylum sp.
SAPINDACEAE (Family)
    Exothea diphylla
Sapindus saponaria or RHAMNACEAE
    Talisia sp.
    Thinouia myriantha
SAPOTACEAE (Family)
    cf *Chrysophyllum mexicanum*
    Pouteria sp.
    cf *Pouteria stipitata* (Species does not grow in modern Belize)
    *Pouteria uniloculari*s*=P. reticulata*
SCROPHULARIACEAE (Family)
SIMAROUBACEAE
    Picramnia antidesma
SOLANACEAE (Family)
    Markea sp.

Table 6, Continued.

- *Physalis* sp.
- SYMPLOCACEAE
    - cf *Symplocos martinicensis*
- TILIACEAE (Family)
    - *Corchorus hirsutus*
    - *Heliocarpus americanus*
    - cf *Trichospermum grewiifolium*
- TYPHACEAE
    - *Typha angustifolia*
    - *Typha domingensis*
    - *Typha latifolia*
- ULMACEAE
    - *Celtis* sp.
    - *Trema* sp.
    - *Ulmus* sp.
- URTICACEAE (Family)
- VERBENACEAE
    - *Lantana* sp.
    - *Lippia* sp. (=*Phyla* sp.)
- VIOLACEAE
    - *Rinorea squamata*
- VITACEAE
    - *Cissus* sp.
    - *Vitis tiliifolia*

DESCRIPTIONS AND USES OF PLANTS REPRESENTED IN THE LAGUNA VERDE POLLEN CORE

This section provides brief descriptions of the plants represented in the Laguna Verde pollen core, and gives possible usages for plants with economic value based on sources explained at the outset of this chapter.

Acanthaceae

Bravaisia sp.
Justicia campechiana

The family Acanthaceae includes 18 genera and 47 species, plus three cultivated species, which grow in modern Belize (Balick et al. 2000:35, 136-138). The pollen of two genera was observed during the present study. The first was that of *Justicia campechiana*, an herb or subshrub commonly known as "white chilar" and "wild pepper" (Balick et al. 2000:137). Three grains of *Justicia campechiana* pollen were counted in Sample 4.

The second genus represented was *Bravaisia*, two species of which grow in modern Belize (Balick et al. 2000:136). Both *B. berlandieriana* and *B. grandiflora* grow as shrubs or trees (Balick et al. 2000:136). *B. berlandieriana* is used in modern Mesoamerica for medicine, ritual, and miscellaneous products; no economic use is suggested by Balick et al. for *B. grandiflora* (Balick et al. 2000:136). One grain (or distinctive fragment) of *Bravaisia* pollen was counted in each of Samples 3, 13, 21, and 56.

Anacardiaceae

Anacardium occidentale
Mangifera indica
Metopium brownei
Spondias mombin
Spondias purpurea

Spondias sp.

Eight genera and ten species of Anacardiaceae grow in modern Belize (Balick et al. 2000:34, 116-117). This family includes such well-known plants as cashew, pistachio, mango, poison ivy, and sumac. The pollen of five Anacardiaceae species was observed during the present study. Most of the Belizean representatives of this family grow as trees, and three grow also as shrubs (Balick et al. 2000:116-117).

Anacardium occidentale is commonly known as "cashew" or "marañon," and the seeds (nuts) and fruits of this tree are used as food in Belize and elsewhere in the world (Balick et al. 2000:116). The fruit is also processed into juice and wine (Standley & Record 1936:43). This plant is used elsewhere in Mesoamerica for miscellaneous products, medicine, poison, construction, and oil (Balick et al. 2000:116). One grain of pollen from *Anacardium occidentale* was discovered in Sample 28 of this study.

Mangifera indica, commonly known as "mango," produces a fruit that is eaten in Belize and elsewhere in the world (Balick et al. 2000:117). This tree is also used elsewhere in the tropical world for medicine (antibacterial for tooth abcesses, antidiarrheal, antifungal, antivenom for snake bites), miscellaneous products, beverages, and poison (Balick et al. 2000:117). One pollen grain from *Mangifera indica* was observed in each of Samples 28 and 41.

Metopium brownei is commonly known as "chechem" or "black poison wood." Like other members of the Anacardiaceae, it produces a skin-irritating sap known as "urushiol." The shrub or tree is used in modern Belize for miscellaneous products (such as cutlery handles and "articles of turnery"), poison, blistering gum that can be used medicinally, railroad ties, and house construction (Balick et al. 2000:117; Standley & Record 1936:37, 45). It is also used elsewhere in Mesoamerica for medicine and forage (Balick et al. 2000:117). Pollen of this type was observed at steady, low levels throught the Laguna Verde pollen core.

Three species of *Spondias* grow in modern Belize (Balick et al. 2000:34, 117). *Spondias mombin*, a tree commonly known as "hog plum," is used in the Neotropics for food (rarely cultivated), ornamentation, construction, beverages, medicine (antiinflammatory for eyes, antidiarrheal, venereal disease treatment), and miscellaneous products (Balick et al. 2000:117). *S. purpurea*, a shrub or tree known as "jocote," is widely cultivated in the tropics for its fruit. It is used in modern Mesoamerica for food, ornamentation, construction, medicine, beverages, and miscellaneous products (Balick et al. 2000:117). *S. radlkoferi*, another tree known as "hog plum," is used in Belize for medicine, construction, and food (Arvigo & Balick 1993:125; Balick et al. 2000:117). Identification of *Spondias* sp. pollen is discussed in the "Taxonomic Discrimination" section of Chapter I.

Apiaceae (Family)

Four genera and five species, plus five additional cultivated species, of Apiaceae grow in modern Belize (Balick et al. 2000:34, 120). This family of herbs includes popular food plants commonly known as "cilantro," "dill," "celery," "carrot," and "parsley" (Balick et al. 2000:120). Identification of Apiaceae pollen is discussed in the "Taxonomic Discrimination" section of Chapter I. Such grains were observed in very low numbers in the upper third of the core.

Apocynaceae

Tabernaemontana sp.

Twenty-one genera and 36 species, plus four cultivated species, of the family Apocynaceae grow in modern Belize (Balick et al. 2000:34, 121-123). Members of this "dogbane" family grow as vines, shrubs, and trees, some of which produce an economically-useful gum or latex (Balick et al. 2000:121-123). *Tabernaemontana* sp. pollen was identified in this study. Four species of *Tabernaemontana* grow in modern Belize: *T. alba*, *T. amygdalifolia*, *T. arborea*, and *T. divaricata* (Balick et al. 2000:122-123). The last grows only in cultivation (Balick et al. 2000:123). *T. alba* is an evergreen shrub or tree used in modern Belize for medicine, products, and gum; no use is suggested for the other species (Balick et al. 2000:123). In the present study, one grain of *Tabernaemontana* sp. pollen was identified in Sample 43.

Aquifoliaceae

Ilex sp.

The only genus within the Aquifoliaceae is *Ilex*, and three species of *Ilex* grow in modern Belize (Balick et al. 2000:33, 106). Members of the "holly" genus grow as shrubs or trees (Balick et al. 2000:106). *I. guianensis* is used medicinally in modern Belize (Balick et al. 2000:106), and holly is mildly toxic when ingested by humans. One grain of *Ilex* sp. pollen was counted in each of Samples 19, 30, and 46 of the present study.

Araceae/Arecaceae (Families)

Bactris-type

Twenty-four genera and 39 species and subspecies, plus four cultivated species, of Arecaceae grow in modern Belize (Balick et al. 2000:39-40, 194-196). All grow as palms (Balick et al. 2000:194-196). Most Arecaceae are used economically, serving in Belize and elsewhere in Mesoamerica as provisioners of food, medicine, construction materials, miscellaneous products, beverages, forage, oil, fuel, fiber, ornamentation, and/or poison, or serving a ritual purpose (Balick et al. 2000:194-196).

Pollen identified as *Bactris major* was chiefly found at the top of my core and in the surface sample, with two grains being counted in Sample 57, one grain in each of Samples 58 and 59, four grains in Sample 60, and three grains in the surface sample (Sample 61). Only one grain, in Sample 26, was found deeper in the core. *B. major* is a spiny palm that is used in modern Belize for food, medicine, beverage, fiber, and forage, and is used elsewhere in Mesoamerica for miscellaneous products (Balick et al. 2000:194).

Four additional pollen grains in the present study (one trichotomosulcate in Sample 12, two monosulcates in Sample 43, and one monosulcate in Sample 59) were identified as belonging to the palm family. Palms of possible interest are discussed here. *Cryosophila stauracantha* grows on-site in the upland swamp forest at Laguna Verde, and is generally found in moist upland and lowland forests (Arvigo & Balick 1993:109).

This palm is known as “give and take” because its spines can give a stinging cut, but the “inside part of the sheath and petiole is pink, cotton-like and sticky”, and “is applied to fresh wounds to staunch bleeding, prevent infection, and alleviate pain” (Arvigo & Balick 1993:109). Its leaves can be dried and tied together to make brooms for sweeping (Arvigo & Balick 1993:109).

The palms *Attalea cohune* and *Sabal* sp. are of possible interest for their economic uses. *A. cohune*, “cohune palm,” is used for construction, thatch, furniture, oil, and food (Standley & Record 1936:39, 45). Experiments in the commercial plantation of cohune were conducted in colonial Belize (Standley & Record 1936:34-39). *Sabal mauritiiformis*, a “palmetto,” produces leaves for thatching and wood for house posts and piling (Standley & Record 1936:46). The genus is the source of the food “heart of palm.”

One pollen grain in this study was identified that broadly resembled the pollen of Arecaceae or perhaps Araceae, a family dominated by herbs and vines, some of which are epiphytes (Balick et al. 2000:171-173). The family includes the “calla lily” and the “elephant ear.” Nine genera and 45 species, plus four cultivated species, of Araceae grow in modern Belize (Balick et al. 2000:38, 171-173). Balick et al. do not suggest an economic use for most species of Araceae, though four species are cultivated and some can be eaten (Balick et al. 2000:171-173).

Aristolochiaceae (Family)

In the present study, one grain in Sample 61 was identified as Aristolochiaceae. One genus, *Aristolochia*, and ten species of the family Aristolochiaceae grow in modern Belize (Balick et al. 2000:29, 55). These grow as herbs, vines, lianas, shrubs, and trees in forests and riversides in undisturbed locations (Arvigo & Balick 1993:83, Balick et al. 2000:55). Some are used for food, medicine, poison, and as ornamentals in modern Belize and Mesoamerica (Balick et al. 2000:55). *A. trilobata* is a popular herbal remedy in modern Belize; it is drunk as a tea or infusion to treat flu, colds, and a variety of digestive and cardiovascular complaints, among other health conditions (Arvigo &

Balick 1993:83). In this study, one pollen grain bore some resemblance to the pollen of *Aristolochia pilosa* as published by Roubik & Moreno (1991:66, 188). This plant grows as a vine; no economic purpose is suggested by Balick et al. (2000:55).

Asteraceae

High-spine
Low-spine
Asteraceae/Amaranthaceae, fenestrate type

Asteraceae pollen was frequently observed in the present study, often in relative percentages of ten to twenty percent. Eighty-six genera and 153 species and subspecies, plus four cultivars, of Asteraceae grow in modern Belize (Balick et al. 2000:36-37, 148-154). Most grow as herbs; some are shrubs or have other growth habits (Balick et al. 2000:148-154). The family includes plants commonly known as “wormwood,” “sunflower,” “ragweed,” “Jerusalem artichoke,” “globe artichoke,” “lettuce,” and “safflower.”

The most common economic purpose of the plants of this family is medicinal, though some plants have other uses (Balick et al. 2000:148-154). *Critonia morifolia* is important for its many uses in Belizean traditional medicine (Arvigo & Balick 1993:115). *Chromolaena odorata* is also used in herbal baths and teas to cure various conditions (Arvigo & Balick 1993:121). *Neurolaena lobata* is used to kill parasites, insects, and fungus (Arvigo & Balick 1993:129). *Tagetes erecta*, or “marigold,” is used as a tea or bath for various ailments, to cancel evil spells, and to expel evil spirits (Arvigo & Balick 1993:143). Mayan priests wash themselves in a marigold decoction so as to facilitate better communication with the spirits (Arvigo & Balick 1993:143). *Sphagneticola trilobata* also has medicinal purposes (Arvigo & Balick 1993:171).

Betulaceae

Alnus sp.

Ostrya sp./*Carpinus* sp.

This family of deciduous trees and shrubs is not known to grow in modern Belize. Pollen of *Alnus* sp. ("alder") and *Ostrya* sp./*Carpinus* sp. ("hop-hornbeam"/"hornbeam") was observed during this study, and must have arrived at the core location via long-distance transport. Their economic uses are not relevant to this project. The identification of Betulaceae pollen is further addressed in the section "Taxonomic Discrimination" in Chapter I.

Bignoniaceae (Family)

Three grains of Bignoniaceae pollen were counted in each of Samples 25 and 38, two grains in each of Samples 18 and 46, and one grain in each of Samples 11, 19, and 23. The Bignoniaceae number 26 genera and 45 species and subspecies, plus three cultivars, which grow in modern Belize (Balick et al. 2000:35-36, 138-140). Many species grow as lianas, but some grow as woody vines, shrubs, or trees (Balick et al. 2000:138-140; Standley & Record 1936:356). No economic purpose is suggested by Balick et al. for most species, but economic purposes are given for some species (2000:138-140). The wood of *Tabebuia pentaphylla* ("mayflower") has been used for making cattle yokes and truck parts (Standley & Record 1936:46, 364). The family includes *Crescentia cujete*, "calabash tree," which was a Mayan tree crop.

Bombacaceae

Pachira aquatica

Seven genera and ten species of Bombacaceae grow in modern Belize (Balick et al. 2000:30, 68). Most Belizean members of this family of large tropical trees have several economic uses (Balick et al. 2000:68). Some of the trees, like "balsa," produce soft wood with commercial value (Bryant, personal communication, 2008). Two grains of *Pachira aquatica* pollen were counted in Sample 44. This tree is used in modern

Belize for its edible seeds and for construction, and is additionally used elsewhere in Mesoamerica for dye (Arvigo & Balick 1993:167; Balick et al. 2000:68). In traditional Belizean medicine, the bark or fruit is boiled in water, and the tea is drunk to build the blood; to treat anemia, exhaustion, low blood pressure, and kidney pain; and as a tonic (Arvigo & Balick 1993:167). In the lumber camps of colonial British Honduras, bark tea was used as a food substitute when supplies ran low (Arvigo & Balick 1993:167).

Boraginaceae

Cordia alliodora

Cordia sp.

Six genera and 33 species of Boraginaceae grow in modern Belize (Balick et al. 2000:35, 129-131). Of the "borage" or "forget-me-not" family, only the pollen of one genus, *Cordia*, was identified during the present study. Thirteen species of *Cordia* grow in modern Belize (Balick et al. 2000:35, 129-130), and the pollen of two of these (*C. alliodora* and *C. gerascanthus*) was observed at very low levels throughout the Laguna Verde pollen core. *C. alliodora* and *C. gerascanthus* grow as shrubs or trees, and some species are commonly known as "laurel" (Balick et al. 2000:129-130).

The tree *Cordia alliodora* has been used in modern Belize for logging truck parts, piling, boat decking, railroad ties, lining furniture and chests, musical instruments, medicine, and construction; it is additionally used elsewhere in Mesoamerica for food ("manjack" fruit) and spice (Balick et al. 2000:129; Standley & Record 1936:44, 336). The wood is sometimes used as a substitute for mahogany or teak. No economic use is suggested for the large tree *C. gerascanthus* (Balick et al. 2000:130; Standley & Record 1936:337).

Burseraceae

Bursera sp.

Protium sp.

Three genera and seven species of Burseraceae, the “torchwood” or “frankincense and myrrh” family of tropical trees, grow in modern Belize (Balick et al. 2000:34, 116). Pollen grains from one of the three genera, *Tetragastris* (represented in Belize by one species, *T. panamensis*), were not observed in any samples from the present study.

Bursera simaruba is the only species representative of its genera that grows in modern Belize (Balick et al. 2000:116). Pollen of this type was observed at steady, low levels throughout the Laguna Verde pollen core. This tree with shaggy red bark is commonly known as “gumbolimbo.” *B. simaruba* is sometimes grown as living fence posts, because its severed limbs can take root and regenerate (Arvigo & Balick 1993:119; Standley & Record 1936:199). It is used in Belize for medicine (in tiger balm for muscle pain, and in preparations described below), beverages, and construction, and is additionally used elsewhere in Mesoamerica for miscellaneous products such as varnish and resin, fuel, ritual, poison, and as an ornamental (Balick et al. 2000:116). The aromatic red sap is tapped for use in mending dishes and coating canoes to protect them from insect damage (Standley & Record 1936:199). In Belizean traditional medicine, gumbolimbo bark is boiled in water, and the water is used as an antidote to skin irritations, such as those caused by poisonwood sap, insect bites, and sunburn (Arvigo & Balick 1993:119). A similar preparation is drunk as a tea to cure kidney problems, anemia, urinary tract problems, colds, flu, and other ailments (Arvigo & Balick 1993:119). Undertakers and others who handle the dead wash their hands in this liquid to guard against the tainting of crops planted by those same hands (Arvigo & Balick 1993:119). The forehead can be wrapped with gumbolimbo leaves to cure headache, and a steam bath with the leaves is said to help fight typhoid (Arvigo & Balick 1993:119).

Five species of *Protium* grow in modern Belize (Balick et al. 2000:34, 116). All are forest trees, and all but *P. glabrum* are commonly known as “copal” (Balick et al. 2000:116). *Protium* pollen was found only at the top and the bottom of the Laguna Verde pollen core. *P. costaricense* is used in modern Belize for resin and medicine (Balick et al. 2000:116). No economic use is suggested by Balick et al. for *P. glabrum, P. multiramiflorum,* or *P. schippii* (2000:116). *P. copal* has more economic uses than the other species of its genus. The ancient Maya used the resin of the copal tree for rubber, chewing gum, and incense (Coe 2005:206). They burned copal incense when saying prayers to ward off the evil eye (Arvigo & Balick 1993:17, 85). In modern Belize, the tree is used for resin, ritual, medicine, and poison; elsewhere in Mesoamerica, it is additionally employed for miscellaneous products and as an ornamental (Balick et al. 2000:116; Standley & Record 1936:46). The resin has traditionally been used to treat tooth cavities (Arvigo & Balick 1993:85). Powdered bark is applied medicinally to wounds and sores (Arvigo & Balick 1993:85). The bark can be boiled to make a tea that is said to soothe stomach complaints and to clear out intestinal parasites (Arvigo & Balick 1993:85).

Campanulaceae (Family)

Two genera and four species of the family Campanulaceae grow in modern Belize (Balick et al. 2000:36, 141). All four grow as herbs, many with blue flowers (Balick et al. 2000:141). The identification of a single Campanulaceae pollen grain in this study is uncertain.

Celastraceae (Family)

Six genera and eleven species of Celastraceae grow in modern Belize (Balick et al. 2000:33, 105-106). Most Belizean Celastraceae grow as trees or shrubs; a few species are used economically for medicine or miscellaneous products (Balick et al. 2000:105-106). In the present study, one pollen grain resembled that of *Elaeodendron xylocarpum,* a shrub used medicinally in Mesoamerica (Balick et al. 2000:105). The identification of Celastraceae pollen is further addressed in the section "Taxonomic Discrimination" in Chapter I.

Chenopodiaceae/Amaranthaceae (Families)

Cheno-Am pollen was counted at regular, low levels throughout the Laguna Verde pollen core. Two genera and two species of wild Chenopodiaceae grow in modern Belize (Balick et al. 2000:30, 61). This family includes plants commonly known as "goosefoot," "quinoa," "spinach," and "beet," the latter two of which have been recently introduced (as cultivars) to Belize from the Old World (Balick et al. 2000:61). Of the two wild species, no economic use is suggested for the herb *Salicornia bigelovii* (Balick et al. 2000:61). *Chenopodium ambrosioides* grows as a weedy herb or subshrub (Arvigo & Balick 1993:100; Balick et al. 2000:61). It is used as a food ("epasote") and poison in Mesoamerica (Balick et al. 2000:61). In traditional Belizean medicine, *C. ambrosioides* leaves are brewed as a tea to create a sedative; tea from the roots cures hangover (Arvigo & Balick 1993:101). Juice of mashed leaves is drunk to kill intestinal parasites (Arvigo & Balick 1993:101). The leaves are also eaten raw or added to other foods for their flavor and antiflatulent properties (Arvigo & Balick 1993:101).

Amaranthaceae (*sensu stricta*) occurs in ten genera and 24 species in modern Belize (Balick et al. 2000:30, 62). The family contains weeds and ornamentals, including plants commonly known as "amaranth" and "tumbleweed." *Amaranthus* encompasses six species in modern Belize (Balick et al. 2000:62). The seeds are eaten as a spice (Arvigo & Balick 1993:37; Balick et al. 2000:62) and can be cooked as a grain. Amaranth leaves or leaf juice are used medicinally as a food, tea, or bath to treat anemia, tiredness, constipation, and poor nutrition, and to cleanse wounds and sores (Arvigo & Balick 1993:37; Balick et al. 2000:62). The leaves of these herbs are eaten in Belize in salads and soups (Arvigo & Balick 1993:37). Elsewhere in Mesoamerica, *A. caudatus* is grown ornamentally, and *A. spinosus* is used for poison (Balick et al. 2000:62).

Written records from the Spanish contact period note the cultivation and usage of "amaranth" by the Maya in Yucatan state (Pohl 1985:38-39). The grain was used to strengthen and dye cloth, and its ashes were used for soap (Pohl 1985:38-39).

Some plants of the Amaranthaceae (*sensu stricta*) produce a distinctive fenestrate form of pollen. These were noted separately from the other Cheno-Ams during the present study. Among Belizean plants producing this type of pollen, seven species of *Alternanthera* and three species of *Iresine* predominate (Balick et al. 2000:62). *Alternanthera* species all grow in herbal forms; *A. sessilis* grows semi-aquatically (Balick et al. 2000:62). Some species of *Alternanthera* serve medicinal and ornamental purposes in modern Belize and elsewhere in Mesoamerica (Arvigo & Balick 1993:111; Balick et al. 2000:62). *Iresine* includes shrubs and trees, and also the herb *I. diffusa,* which is used in Belize as forage and medicine (Balick et al. 2000:62). One additional species of *Alternanthera* (*A. bettzickiana*) and one additional species of *Iresine* (*I. herbstii*) are purposely cultivated in modern Belize (Balick et al. 2000:62).

Chrysobalanaceae (Family)

Licania sp.

Four genera and nine species of Chrysobalanaceae grow in modern Belize (Balick et al. 2000:32, 81-82). The Belizean Chrysobalanaceae grow as shrubs and small trees and have a variety of economic uses, including food (fruit) and forage (Balick et al. 2000:81-82). The pollen observed in this study compared favorably with the pollen of *L. hypoleuca,* a tree that is used in modern Belize and elsewhere in Mesoamerica for construction purposes (Balick et al. 2000:81). The identification of Chrysobalanaceae pollen is further discussed in the section "Taxonomic Discrimination" in Chapter I.

Combretaceae/Melastomataceae (Families)

Laguncularia racemosa (Combretaceae)

Pollen of the families Combretaceae and Melastomataceae was a major constituent in the Laguna Verde core, accounting for at least 5 percent (and often more than 20 percent) of the pollen in most samples, and at maximum, 74.4 percent in Sample 58 (180-181 cm). In Belize, the Melastomataceae have a greater presence than the Combretaceae. Twenty genera and 96 species and subspecies of Melastomataceae grow in modern Belize (Balick et al. 2000:33, 99-103). They assume various habits: herb, liana, epiphytic shrub, shrub, small tree, and tree (Balick et al. 2000:99-103). Balick et al. (2000:99-103) do not suggest and economic use for most species, though many produce edible fruits (Standley & Record 1936:286).

Five genera and nine species, plus one cultivar, of Combretaceae grow in modern Belize (Balick et al. 2000:33, 103-104). These occur as lianas, woody vines, shrubs, or trees (Balick et al. 2000:103-104). The Combretaceae have more economic uses than the Melastomataceae, and are used in Belize for miscellaneous products, construction, medicine, fuel, and elsewhere in Mesoamerica are additionally used in tanning and for dye, oil, and poison (Balick et al. 2000:103-104). For example, the wood of *Bucida buceras* is used for charcoal, fuel, and railroad ties (Standley & Record 1936:44).

Laguncularia racemosa (Combretaceae) produces a distinctive form of pollen. Grains of this type are tricolporate (rather than stephanocolporate), and have transverse pores that constrict at the colpi. *L. racemosa*, a shrub or tree known as “white mangrove,” is used in Belize for fuel and elsewhere in Mesoamerica is used for miscellaneous products, construction, dye, medicine, and tanning (Balick et al. 2000:103).

Commelinaceae

Commelina sp.

Six genera and 21 species and subspecies of Commelinaceae -all herbs- grow in modern Belize (Balick et al. 2000:39, 178-179). Some are grown as ornamentals. In the present study, two pollen grains resembling the pollen of *Commelina erecta angustifolia* (as featured in Martínez-Hernández *et al.* 1993:38-39) were counted in Sample 11. *C. erecta* is used in modern Belize and Mesoamerica for medicinal purposes (Balick *et al.* 2000:178-179). The plant can be ground into a balm to treat muscle soreness.

Corylaceae/Betulaceae (Families)

In the present study, several grains were identified as the pollen of *Corylus* or as similar-looking pollen from the Corylaceae ("hazelnut" family) or Betulaceae ("birch" family). Neither family is known to grow in modern Belize. The sourcing of pollen of these families is addressed in Chapter I.

Cucurbitaceae (Family)

The Cucurbitaceae grains observed during this study (one grain in each of Samples 28 and 60) could be identified to family level only. This family includes some of the earliest cultivars known from the Neotropics. Sixteen genera and 25 species, plus four cultivated species, of Cucurbitaceae grow in modern Belize (Balick et al. 2000:31, 74-75). Most species grow as herbaceous vines (Balick et al. 2000:74-75; Standley & Record 1936:391). *Cucurbita pepo* ("squash") was one of the first New World cultivars, having been domesticated in Mexico as long ago as 10,750 b.p. (McClung de Tapia 1992:148, 154; Smith 1997:934, 2001:1326, 2005:9444), and in Belize between 7000 and 4800 b.p. (Piperno 1998:423). Many other species produce edible gourds or melons, such as the cultivars *Cucumis sativus* ("cucumber") and *Citrullus lanatus* ("watermelon"). Other species produce gourds with other economic purposes, such as *Lagenaria siceraria* ("bottle gourd," which mysteriously came to the New World from Africa in precolumbian times) and *Luffa cylindrica* ("sponge gourd"; Balick et al. 2000:75).

Cupressaceae

Platycladus orientalis

One pollen grain in Sample 12 of the present study was identified as “TCT” pollen. Cupressaceae is the “cedar” family. It produces a type of pollen that is indistinguishable from the pollen of two other families, Taxaceae and Taxodiaceae, neither of which is known to grow in Belize. The only species of Cupressaceae to grow in modern Belize is *Platycladus orientalis*, which grows as a cultivar introduced from Asia (Balick et al. 2000:49). However, the the trees of all three families produce vast amounts of anemophilous pollen, so the pollen under consideration here may have blown in from a distant location.

Cyperaceae (Family)

Cyperaceae pollen was abundant throughout the Laguna Verde pollen core, reaching a peak relative abundance of 36.6 percent in Sample 32 (277-278 cm). Cyperaceae is the “sedge” family. Twenty-one genera and 146 species and subspecies of Cyperaceae grow in modern Belize (Balick et al. 2000:39, 180-185). All grow as herbs (Balick et al. 2000:180-185). No economic use for most of the Cyperaceae is given by Balick et al.¸ though economic uses are suggested for some species (2000:180-185). Most of the Cyperaceae pollen counted during this study probably came from *Cladium jamaicense*, the sedge that dominates the swamp at Laguna Verde. This species is used for the manufacture of miscellaneous products in modern Belize, and is also used elsewhere in Mesoamerica for poison, medicine, and fiber (Balick et al. 2000:180).

Macrobotanical remains show that the Maya of Middle Preclassic Cuello collected razorgrass (*Scleria bracteata*) from swamps and brought it to their site, perhaps for use as roof thatching (Hammond & Miksicek 1981:266).

Dilleniaceae

Curatella americana

Five genera and nine species and subspecies of Dilleniaceae grow in modern Belize (Balick et al. 2000:30, 64). All are lianas, with the exception of the tree *Curatella americana*, and it was the pollen of this species that was observed during this study. *C. americana* is used medicinally in modern Belize, and its leaves work as fine-grained sandpaper (Balick et al. 2000:64; Standley & Record 1936:44). This tree is additionally used for miscellaneous products, food, fuel, spice, tanning, and construction elsewhere in Mesoamerica (Balick et al. 2000:64). This pollen type was observed only in the deepest third of my core, with two grains counted in each of Samples 6 and 10, and one grain counted in each of Samples 15 and 18.

Erythroxylaceae

Erythroxylum sp.

One genus (*Erythroxylum*) and four species of Erythroxylaceae grow in modern Belize (Balick et al. 2000:33, 112). Stimulating coca tea and the drug cocaine are produced (outside Belize) from a plant of this genus. *Erythroxylum* sp. plants grow as shrubs or trees (Balick et al. 2000:112). *E. rotundifolium* is used medicinally in modern Mesoamerica; no economic use is suggested by Balick et al. for the other Belizean species (2000:112). One grain of *Erythroxylum* sp. pollen was counted in each of Samples 6 and 18, and two grains were counted in each of Samples 12 and 59.

Euphorbiaceae (Family)

Acalypha sp.

Alchornea sp.

Croton sp.

cf *Gymnanthes lucida* or *Chamaesyce hirta*

Sebastiana sp.

Thirty-one genera and 104 species of the Euphorbiaceae, or “spurge,” family grow in modern Belize (Balick et al. 2000:33, 106-111). The pollen of five genera of Euphorbiaceae was identified in this study. Additionally, pollen grains that bore some resemblance to the Euphorbiaceae grains with which I am familiar, but that could not be identified with certainty, were tallied as “Other Euphorbiaceae.” With the exception of the grains resembling the pollen of *Gymnanthes lucida* or *Chamaesyce hirta*, the observed grains were identified to the genus level.

Thirteen species of *Acalypha* grow in modern Belize (Balick et al. 2000:33, 106-107). *Acalypha* species grow as herbs, shrubs, small trees, and trees in disturbed sites such as old fields and yards (Arvigo & Balick 1993:63; Balick et al. 2000:106-107). Four of the thirteen species are used medicinally in Belize or elsewhere in Mesoamerica, and are commonly termed “yerba del cancer” (Balick et al. 2000:106-107). *Acalypha* is used by traditional healers in modern Belize in a powder, tea, or bath to treat many skin conditions (such as rashes, blisters, and itching) and for stomach and urinary complaints (Arvigo & Balick 1993:63). *A. mortoniana* is used in Belize for construction, fiber, and miscellaneous products (Balick et al. 2000:107). *A. polystacha* is used in Mesoamerica for food (Balick et al. 2000:107). *Acalypha* sp. pollen was found in low frequencies throughout the Laguna Verde pollen core, especially in the lower two-thirds of the core.

Alchornea latifolia is the only species of this genus that grows in modern Belize (Balick et al. 2000:107). This tree is used in Mesoamerica for construction, miscellaneous products, and for ornamental and fumitory purposes (Balick et al. 2000:107). *Alchornea* sp. pollen was counted in low numbers in the lower two-thirds of the Laguna Verde pollen core.

Twelve species of *Croton* grow in modern Belize (Balick et al. 2000:33, 108). *Croton* species grow as herbs, subshrubs, shrubs, and trees (Arvigo & Balick 1993:181; Balick et al. 2000:108). Balick et al. do not suggest an economic use for nine of the *Croton* species, but four species (*C. cortesianus*, *C. niveus*, *C. schiedeanus*, and *C. xalapensis*) are used medicinally in Belize and elsewhere in Mesoamerica (Balick et al. 2000:108). In traditional Belizean medicine, *Croton* leaves are prepared as a bath, stem bath, or tea to help with fever, aches, menstruation, and uterine problems, and to assist healing and prevent infection after childbirth (Arvigo & Balick 1993:181). *C. niveus* is also used elsewhere in Mesoamerica as a spice, beverage, and fuel source (Balick et al. 2000:108). *C. schiedeanus* is used in Mesoamerica in construction (Balick et al. 2000:108). One grain of *Croton* sp. pollen was identified in each of Samples 4 and 9, toward the bottom of the Laguna Verde pollen core.

I cannot distinguish the pollen of *Gymnanthes lucida* from that of *Chamaesyce hirta*. Grains of this type were identified in the lower half of the Laguna Verde pollen core, and were most abundant near the bottom of the core. *G. lucida,* a shrub or tree, is used in Mesoamerica for medicine and miscellaneous products (Balick et al. 2000:109). *Chamaesyce* is sometimes considered to be a subgenus of *Euphorbia,* a genus that includes the “poinsettia.” *C. hirta* is an herb used in Mesoamerica as a medicine and a poison (Balick et al. 2000:107).

Three species of the genus *Sebastiana* grow in modern Belize. *S. adenophora* is an herb; Balick et al. (2000:110) do no suggest an economic use for this plant. *S. confusa* and *S. tuerckheimiana* grow as shrubs or trees, and are commonly known as “white poison-wood”; no economic use is suggested by Balick et al. for either species (2000:110-111). Grains of *Sebastiana* sp. pollen were present in low numbers throughout the Laguna Verde pollen core.

Fabaceae (Family)

Andira inermis
Bauhinia divaricata
Bauhinia herrarare
cf *Cassia=Senna* sp.
cf *Dalbergia brownei*
Desmodium sp.
cf *Lonchocarpus* sp.
cf *Machaerium seemanii*

cf *Melilotus* sp.
Mimosoideae cf *Acacia* sp.
Mimosa sp.
Swartzia sp.
Mimosa sp.

The Fabaceae *sensu lata* of modern Belize includes 80 genera and 295 species and subspecies (Balick et al. 2000:32, 82-95).

Mimosoideae

The subfamily Mimosoideae includes 20 genera and 77 species and subspecies (Balick et al. 2000:32). Two types of Mimosoideae pollen grains were identified in the present study. The first type, a small tetrad, belongs to the genus *Mimosa.* Thirteen species of *Mimosa* and two subspecies (for a total of 14 taxa; don't get confused by the math) grow in modern Belize (Balick et al. 2000:32, 84-85). These grow in various habits: small trees, shrubs, subshrubs, herbs, vines, and lianas (Balick et al. 2000:84-85). While no economic function is suggested for most species, some species are used within Belize for the manufacture of miscellaneous products, medicine, and poison, and are also used elsewhere in Mesoamerica in construction and as ornamentals (Balick et al. 2000:84). One grain of *Mimosa*-type pollen was counted in each of Samples 4, 7, 16, 22, 27, 31, 59, 60, and 61 (the modern "pinch" sample from the swamp) of the Laguna Verde pollen core; two grains were counted in Sample 30; and four grains were counted in the modern cow pasture sample.

The second type of Mimosoideae identified in the present study is the *Acacia* type; some pollen grains of the genus *Inga* resemble the pollen of *Acacia* and may be included in this category. There are ten species of *Acacia* in modern Belize, and twelve species of *Inga* (Balick et al. 2000:32, 82-84). *Acacia* grows as a shrub or tree, often thorny and pod-bearing (Arvigo & Balick 1993:75, Balick et al. 2000:82). Some species are used in modern Belize for construction, tanning, miscellaneous products, or food (Balick et al. 2000:82). The plant's pods contain edible seeds, enjoyed by children

(Arvigo & Balick 1993:75). *Acacia* bark can be chewed and applied as a poultice to treat snakebites in an emergency (Arvigo & Balick 1993:75). Tea made from *Acacia* bark is traditionally used to treat male impotency and to counteract bad luck and envy (Arvigo & Balick 1993:75). In Mexico, Tzotzil and Tzeltal Maya use *A. angustissima* (which has mild antibacterial properties) to treat toothache, rheumatoid arthritis, skin cuts, and digestive tract problems. *A. angustissima* is additionally used elsewhere in Mesoamerica for forage (high-protein seeds), and in the Mexican beverage *pulque* (Balick et al. 2000:82). *A. farnesiana* has an extraordinary number of regional uses, including fuel, miscellaneous products, ornamentation, medicine, forage, dye, gum, poison, and tanning (Balick et al. 2000:82). *Inga* species grow as shrubs or trees (Balick et al. 2000:83-84). No economic use is reported for most species, but some are used in Belize as food and medicine (Balick et al. 2000:83-84). *I. edulis* has edible seeds that are said to taste like vanilla ice cream. In the uplands of Middle America, *Inga* trees are often planted to provide shade for coffee plantations (Standley & Record 1936:161). Two grains of *Acacia*-type pollen were counted in each of Samples 7 and 51; three grains were counted in Sample 60; nine grains were counted in Sample 61 (the modern "pinch" sample from the swamp); and 13 grains were counted in the modern pasture sample.

Papilionoideae

The subfamily Papilionoideae includes 47 genera and 163 species and subspecies that grow naturally in modern Belize, plus 12 cultivars (Balick et al. 2000:32, 95). Seven pollen types of this subfamily were observed during this study. First, three pollen grains resembling *Melilotus* sp. pollen were observed in Sample 49. *Melilotus alba* is the only species of this genus growing in modern Belize, and it is an introduced cultivar (Balick et al. 2000:95). The pollen may have come from a related genus that produces pollen similar to that of *Melilotus* sp.

Second, two grains of *Andira inermis* pollen were observed in Sample 31. This tree is used in Belize for construction and miscellaneous products, such as the wooden parts of logging trucks, wheels, and rolling stock parts (Balick et al. 2000:89; Balick et al. 2000:43). It is also used elsewhere in Mesoamerica for medicine (as a vermifuge and purgative), poison (in large doses), forage, and as an ornamental (Balick et al. 2000:89; Standley & Record 1936:179).

Third, six grains of *Machaerium seemannii* pollen were observed in Sample 59. This vine is used for medicine in Mesoamerica (Balick et al. 2000:93).

Fourth, pollen resembling that of *Dalbergia brownei* was noted, with one grain occurring in Sample 10 and two grains occurring in Sample 24. Balick *et al*. (2000:90) do not suggest an economic use for this shrub or tree, though Standley & Record (1936:181) note that the timber can be used for cabinetry, furniture, and turnery. Although I was unable to find a reference specimen or light micrograph featuring the pollen of *Dalbergia stevensonii*, that closely-related tree is worthy of mention. *Dalbergia stevensonii* (“rosewood”) is an important timber crop in Belize. Its wood is exported from Belize to the United States to be made into marimba and xylophone bars (Standley & Record 1936:32-33, 182-183). It is also exported to other countries, and is used in building construction and turnery (Standley & Record 1936:33, 44, 182).

The fifth type of Papilionoideae pollen observed in this study was of the *Lonchocarpus* genus. Three grains were found in Sample 11, and six were found in Sample 59. The observed grains probably came from *L. pentaphyllus*, *L. rugosus*, or *L. xuul*, all of which are similar in size and appearance. All three are trees (Balick et al. 2000:92). *L. rugosus* is used in Belize for fuel, and is used elsewhere in Mesoamerica for construction (Balick et al. 2000:92). A related tree, *L. longistylus* or *L. violaceus*, produces bark that was used to flavor Yucatec Mayan *balche’* (a mead; Coe 2005:206; Leyden et al. 1998:112).

The sixth type of Papilionoideae pollen observed in this study was that of the genus *Swartzia*, probably *S. cubensis*. This tree with red sap is used for medicinal purposes in modern Belize (Balick et al. 2000:94). Three grains were observed in Sample 1 of the Laguna Verde pollen core; one grain was observed in each of Samples 4 and 13.

The seventh type of Papilionoideae pollen observed during this study was that of the *Desmodium* genus. Five *Desmodium* grains were counted in Sample 30; three grains were counted in each of Samples 35 and 60; two grains were counted in Sample 41; and one grain was counted in each of Samples 42, 58, and 59. Twelve species and three subspecies (for a total of 14 taxa; don't get confused by the math) of *Desmodium* grow in modern Belize (Balick et al. 2000:90-91). Most *Desmodium* taxa grow as herbs, but some take the habit of vines, subshrubs, or shrubs (Balick et al. 2000:90-91). Some fulfill medicinal purposes in Belize and elsewhere in Mesoamerica (Balick et al. 2000:90-91). *D. adscendens* is used in traditional Belizean medicine to cure backaches, muscle spasms, headaches, joint aches, muscle aches, and other problems (Arvigo & Balick 1993:201). Pollen grains resembling *D. tortuosum* and *D. incanum* were observed during this study and were identified to genus. *D. incanum,* an herb or subshrub commonly known as "strong back," serves medicinal purposes in modern Belize and elsewhere in Mesoamerica (Balick et al. 2000:91). *D. tortuosum*, an herb or shrub, is used in Belize for forage and elsewhere in Mesoamerica has medicinal purposes (Balick et al. 2000:91).

The Papilionoideae include beans, members the genus *Phaseolus.* Although beans were doubtlessly an important food for the ancient Maya, no *Phaseolus* pollen was observed during the present study. This does not necessarily mean that beans were not grown or eaten at Blue Creek. It is interesting to note that no remains of beans were found by Hammond & Miksicek (1981:268) during their macrobotanical study at Cuello, northern Belize. They suggest that, even in the unlikely event that beans become carbonized, their cotyledons are too fragile to survive in the [lowland tropic] archaeological record (Hammond & Miksicek 1981:268). There remains the outside possibility that "absence of beans *could* reflect adequate animal protein, from hunting, fishing, and [marine mollusks]" (Hammond & Miksicek 1981:268).

Caesalpinioideae

The subfamily Caesalpinioideae includes 13 genera and 55 species and subspecies that grow in modern Belize, plus five cultivars (Balick et al. 2000:32, 86-88). Three types of Caesalpinioideae pollen were observed during the present study. The first was that of the genus *Senna*, which is represented by 17 species in modern Belize (Balick et al. 2000:9132, 87-88). Most species take the habit of shrub, but also occur variously as vines, lianas, herbs, subshrubs, and trees (Balick et al. 2000:87-88). Few economic uses are suggested by Balick et al. for most species (2000:87-88). It is believed that the types recognized during this study were, or resembled, *S. atomaria, S. pallida,* and *S. reticulata.* These were identified to genus level. One grain of *Senna* sp. pollen was counted in each of Samples 1 and 30; two were counted in Sample 58; and three grains were counted in each of Samples 59 and 60. *S. atomaria* is a shrub or tree used for dye, medicine, and construction in Mesoamerica (Balick et al. 2000:87). *S. pallida* grows as a shrub or tree and is used in construction in Mesoamerica (Balick et al. 2000:88). *S. reticulata* is a shrub or small tree and has medicinal purposes in modern Belize and elsewhere in Mesoamerica (Balick et al. 2000:88).

The other two types of pollen from the Caesalpinioideae subfamily observed during this study were those of *Bauhinia divaricata* and *Bauhinia herrarae. B. divaricata* is a shrub or tree used medicinally in Belize, and it is used also for fiber and miscellaneous products elsewhere in Mesoamerica (Balick et al. 2000:86). One grain of this type was noted in Sample 9 of the present study. *B. herrarae* is a woody “cowfoot” vine that grows near roadsides and in gaps and disturbed areas of forests (Arvigo & Balick 1993:88-89). One grain of this type was counted in Sample 13. *B. herrarae* is used for construction, fiber, and cordage in Mesoamerica (Arvigo & Balick 1993:89; Balick et al. 2000:86). The Yucatec Maya use the vine to tie the crossbars and roof timbers of their houses (Arvigo & Balick 1993:89). Belizeans traditionally drink tea made from the bark or leaves of *B. herrarae* to staunch diarrhea, excessive menstrual bleeding, and hemorrhage; and to cure headaches (Arvigo & Balick 1993:89). The tea used to be drunk as a birth control method, but since it was said to cause irreversible infertility, it has largely fallen out of use for this purpose (Arvigo & Balick 1993:89). A similar concoction is used to wash wounds (Arvigo & Balick 1993:89).

Fagaceae

Quercus sp.

Quercus sp. pollen was found in low numbers (less than 5 percent per sample) in most samples of the Laguna Verde pollen core. One genus (*Quercus*) and eight species of Fagaceae grow in modern Belize (Balick et al. 2000:30, 59-60). All are "oak" trees; *Quercus sapotifolia* also occurs as a shrub (Balick et al. 2000:59-60). *Q. sapotifolia* (an evergreen "red oak") has medicinal uses in Mesoamerica; no other economic purpose is suggested for this family by Balick et al. (2000:59-60). Standley & Record (1936:46) tell that the wood of some *Quercus* spp. is (or was) used for truck parts and charcoal, and the bark is used for tanning.

Flacourtiaceae

Banara guianensis

Eleven genera and 23 species, plus one cultivated species, of Flacourtiaceae grow in modern Belize (Balick et al. 2000:30, 71-72). They grow as shrubs and trees (Balick et al. 2000:71-72). Approximately one-quarter of Belizean Flacourtiaceae species have economic uses (Balick et al. 2000:71-72). One pollen grain comparing favorably with the pollen of *Banara guianensis* (as described in Roubik & Moreno 1991: 90, 211) was observed in Sample 46 of this study. This species is not known to grow in modern Belize.

Hamamelidaceae

Liquidambar styraciflua

One genus (one species) of Hamamelidaceae grows in modern Belize; this is *Liquidambar styraciflua*, or "sweetgum" (Balick et al. 2000:29, 56). This tree is used in modern Mesoamerica for miscellaneous lumber products, ornamentation, medicine, and ritual purposes (Balick et al. 2000:56). Ancient Mexicans mixed the gum or resin with tobacco for smoking. The gum is also used medicinally (to treat sciatica and other nerve problems) and commercially in some parts of Middle America and Europe (Standley & Record 1936:147). One pollen grain of this type was counted in Sample 22 of the Laguna Verde pollen core.

Hippocrateaceae

Hippocratea volubilis

Five genera and five species of Hippocrateaceae grow in modern Belize (Balick et al. 2000:33, 106). These grow primarily as lianas, but also as woody vines, shrubs, and trees (Balick et al. 2000:106). Only the woody vine *Hippocratea volubilis* has an economic use; it is used for fiber in modern Mesoamerica (Balick et al. 2000:106). Three grains of *H. volubilis* pollen were counted during this study, with one grain occurring in each of Samples 4, 43, and 57.

Juglandaceae

Carya sp.

The Juglandaceae includes hickory, walnut, and pecan trees (Mabberley 1997:373). No members of the family are known to grow in modern Belize. The sourcing of this pollen is discussed in Chapter I.

Juncaceae

Juncus marginatus

One genus (one species) of Juncaceae grows in modern Belize; this is *Juncus marginatus* (Balick et al. 2000:39, 180). This plant is an herb or “rush” (Balick et al. 2000:180). No economic purpose for this plant is suggested by Balick et al. (2000:180). Three grains of *J. marginatus* pollen were observed in Sample 33, two grains were counted in each of Samples 1 and 35, and one grain was counted in each of Samples 2, 9, 12, 38, and 61.

Lamiaceae

Hyptis sp.

Nine genera and 27 species, plus two cultivated species, of Lamiaceae grow in modern Belize (Balick et al. 2000:35, 132-134). These members of the "mint" family grow as herbs and subshrubs, several of which have culinary, medicinal, or other economic uses (Balick et al. 2000:132-134). Two pollen grains in Sample 60 of this study were identified as belonging to *Hyptis* sp. ("oregano"), or perhaps *Salvia* sp. ("sage"). The two genera produce similar-looking pollen grains, but *Hyptis* sp. is more abundant in Belize, with twelve species, compared to *Salvia*'s six species (Balick et al. 2000:35, 133-134).

Hyptis suaveolens is used for food, medicine, poison, and beverages (Arvigo & Balick 1993:131; Balick et al. 2000:133-134). *Hyptis verticillata* ("verbena") was sold in government commissaries in colonial British Honduras as medicine, and its leaves are used by the Caribs to drive vermin from hens' nests (Standley & Record 1936:345).

Lentibulariaceae

Utricularia sp.

Fifteen species of *Utricularia* grow in modern Belize (Balick et al. 2000:36, 140-141). These are terrestrial, subaquatic, and aquatic herbs (Balick et al. 2000:140-141). The genus, commonly known as "bladderwort," consists of carnivorous plants. No economic use is suggested by Balick et al. (2000:140-141) for any of the *Utricularia* species. One pollen grain of this type was discovered in Sample 6, toward the bottom of the Laguna Verde pollen core.

Liliaceae

Lilium sp.

One pollen grain in Sample 29 of the present study was identified as resembling the pollen of *Lilium* sp., though this species is not known to grow in modern Belize.

Perhaps the grain under consideration came from another member of the class Liliopsida (including 22 Belizean species presently re-assigned to the families Agavaceae, Alstroemeriaceae, Amaryllidaceae, Asteliaceae, Dracaenaceae, and Hypoxidaceae; Balick et al. 2000:3) which does grow in Belize, or perhaps it has been misidentified. The Liliopsida include plants commonly known as “lily,” “garlic,” “onion,” and “agave.” Of relevance to this dissertation, the ancient Maya made fermented agave into a beverage known as *chih* or *pulque* (Coe 2005:206).

Loranthaceae (Family)

Four genera and nine species of Loranthaceae, the “mistletoe” family, grow in modern Belize (Balick et al. 2000:32, 104). Pollen from this family was observed in low numbers throughout the Laguna Verde pollen core, particularly in the lower two-thirds of the core. The Loranthaceae pollen counted during this study was that of the genera *Psittacanthus* and *Struthanthus.* The three Belizean *Psittacanthus* species are hemiparasitic vines or shrubs (Balick et al. 2000:104). *P. mayanus* is used in modern Belize for medicine; no economic use is suggested by Balick et al. for the other two species (2000:104). The three Belizean *Struthanthus* species are also hemiparasitic vines or shrubs (Balick et al. 2000:104). *S. cassythoides* and *S. orbicularis* are used in Belize and elsewhere in Mesoamerica for medicinal purposes (Balick et al. 2000:104).

Malpighiaceae (Family)

Byrsonima sp.

cf *Heteropterys laurifolia*

Ten genera and 36 species of the family Malpighiaceae grow in modern Belize (Balick et al. 2004:33-34, 112-113). Of these, the most ubiquitous Malpighiaceae pollen type in the current study was that of the genus *Byrsonima. Byrsonima* sp. pollen occurred at a relative frequency of .5 to three percent in most samples. Two species of the genus, *B. bucidifolia* and *B. crassifolia,* grow in modern Belize (Balick et al. 2000:34, 112). Both species, which grow as shrubs or trees, are commonly known as "craboo" and "nance." Their fruits are eaten raw, pickled, or otherwise prepared as food in modern Belize (Balick et al. 2000:112; Standley & Record 1936:44, 206). *B. crassifolia* is also used in Belize for medicine, and is additionally used elsewhere in Mesoamerica for construction, fuel, beverages, forage, miscellaneous products, tanning, poison, and dye (Balick et al. 2000:112). *Byrsonima* fruits were eaten by the ancient Maya, and their macrobotanical remains were recovered from a platform excavation at Middle Preclassic Cuello, Belize (Hammond & Miksicek 1981:266).

One pollen grain of the liana *Heteropterys laurifolia* was observed in Sample 3 of this study. This plant is used in modern Belize for fiber and construction (Balick et al. 2000:112).

In Sample 13, four grains of periporate pollen resembling that of *Bunchosia lindeniana* was identified to family level. *B. lindeniana* grows as a shrub or small tree (Balick et al. 2000:112). Balick et al. do not suggest an economic use for this species (2000:112).

Malvaceae (Family)

Nineteen genera and 44 species and subspecies, plus four cultivated species, of Malvaceae grow in modern Belize (Balick et al. 2000:30-31, 68-71). The Belizean Malvaceae grow as herbs, subshrubs, shrubs, and trees (Balick et al. 2000:68-71). The family includes two species of *Gossypium,* or "cotton," which is "cultivated worldwide for its fiber" (Balick et al. 2000:69). Indigenous Middle Americans grew cotton (particularly in the hot, dry Pacific lowlands) in pre-colonial times, and European colonists followed their lead (Hall & Pérez Brignoli 2003:155, 158). Few Europeans could afford to have clothing imported from Europe, so they made their own cloth from cotton or wool (from the sheep they raised; Hall & Pérez Brignoli 2003:155). Frederick Wiseman has recovered *Gossypium* pollen from ancient wetland agricultural fields (Pohl & Miksicek 1985:16).

Also included in this family are *Abelmoschus esculentus,* "okra," the pods of which are cultivated for food; and eight species and two subspecies (for a total of nine taxa; don't get confused by the math) of *Hibiscus*, some of which are cultivated as ornamentals (Balick et al. 2000:69, 71).

One grain of Malvaceae pollen was identified (to the family level) in Sample 24, from the bottom third of the Laguna Verde pollen core. An additional grain of Malvaceae pollen was discovered in the modern comparative sample taken from a present-day cattle pasture.

Meliaceae (Family)

Cedrela sp.
Swietenia sp.
Trichilia hirta

Six genera and 16 species of Meliaceae grow in modern Belize (Balick et al. 2000:34, 117-118). All grow as trees or shrubs (Balick et al. 2000:117-118). This family includes trees commonly known as "cedar" and "mahogany" (Balick et al. 2000:117-118).

Three types of Meliaceae pollen were identified in the present study. The first type of Meliaceae pollen recovered in this study came from *Swietenia macrophylla*. *S. macrophylla* pollen was observed in the lower half of the Laguna Verde pollen core. This tree, commonly known as "mahogany," has been the primary timber crop of Belize since the second quarter of the 18th century (Standley & Record 1936:30). When the first Forest Department of British Honduras was established in 1922, one of its chief goals was to increase mahogany production for export (Standley & Record 1936:25). Residents of the United Kingdom and United States imported the wood for construction and veneers (Standley & Record 1936:30). *Swietenia macrophylla* trees, along with *Cedrela odorata* trees (below), were soon over-exploited and their stands depleted, so the Forest Department sponsored a regeneration program in the 1920s (Standley & Record 1936:26-27, 31-32). The regeneration program involved planting desirable seedlings, cutting out the competition in the canopy and underbrush, and removing lianas (Standley & Record 1936:27). This managed forestry is a good illustration of the impacts human interference can have on vegetational composition. *S. macrophylla* is used for medicine (to improve blood circulation and erectile dysfunction) and construction in modern Belize (Balick et al. 2000:118). It is also used in the manufacture of miscellaneous products elsewhere in Mesoamerica (Balick et al. 2000:118).

The second type of Meliaceae pollen recovered in this study came from *Cedrela odorata* (=*Cedrela mexicana*). The *C. odorata* tree is commonly known as “cedar,” “red cedar,” or “Spanish cedar” (Balick et al. 2000:117). Cedar has been an important timber crop in modern Belize; exports began by A.D. 1825 (Standley & Record 1936:26, 31-32). Its durable, insect-resistant wood is used in modern Belize for construction, furniture and chests, dugout canoes, boat planking, and shingles (Arvigo & Balick 1993:67, Balick et al. 2000:117; Standley & Record 1936:32, 44). Cedar is exported for use as resin and in boat-building, as well as for the construction of miscellaneous products such as cabinets and cigar boxes (Balick et al. 2000:117; Standley & Record 1936:32, 44). Modern Maya follow the traditions of their ancestors in using cedar wood to build altars, chairs, and likenesses of idols for ceremonial or religious purposes (Arvigo & Balick 1993:67). Traditional healers in modern Belize use an infusion of grated cedar bark in water to treat bruises, injuries, pains, and excess mucus; the infusion also works as a tonic and a female contraceptive (Arvigo & Balick 1993:67). Regular sniffing of cedar bark is said to cure nosebleeds (Arvigo & Balick 1993:67). Seven grains of *C. odorata* pollen were counted, with three grains coming from Sample 4, two grains from Sample 42, and one grain from each of Samples 21 and 29.

The third type of Meliaceae pollen grain observed in this study resembled the pollen of *Trichilia hirta*. One grain of this pollen type was noted in Sample 9. Nine species of *Trichilia* grow in modern Belize. *T. hirta* is a shrub or tree commonly known as “red cedar” (Balick et al. 2000:118). It is used in modern Belize in construction and medicine, and is used in other parts of Mesoamerica for miscellaneous products, poison, and oil (Balick et al. 2000:118).

Moraceae (Family) and Cecropiaceae/Urticaceae

Cecropia sp.

cf *Brosimum* sp.

Ficus sp. (diporate)

Moraceae (triporate)

Other diporate (Possibly Urticaceae?)

Eight genera and 36 species representing the family Moraceae grow in Belize today (Balick et al. 2000:29). Well-known plants from this family include “mulberry,” “osage orange,” and “fig.” Three additional genera encompassing four species of the closely-related family Cecropiaceae are found in modern Belize (Balick et al. 2000:29). Of these, the pollen of *Cecropia* and *Ficus;* a diporate type comparing favorably with *Brosimum*; and a triporate type were identified during this study.

Ficus species, commonly known as “figs,” grow as trees or hemi-epiphytes, often along riversides (Arvigo & Balick 1993:105; Balick 2000:57). In addition to the 22 feral species, two species (*F. carica* and *F. elastica*) are cultivars introduced from the Old World (Balick et al. 2000:58). Some species are used in Belize and elsewhere in Mesoamerica for food (fruit), forage, and medicine (Arvigo & Balick 1993:105; Balick et al. 2000:57-58). *Ficus* bark was used by ancient Central Americans to manufacture paper and clothing (Standley & Record 1936:112). In Belizean traditional medicine, the white sap of *F. maxima* is applied to skin fungus, ringworm, and boils (Arvigo & Balick 1993:105). The latex is made into a poultice to cure backaches, and is used to help remove bad teeth (Arvigo & Balick 1993:105). A “leaf bath” is taken to improve circulation (Arvigo & Balick 1993:105). The Lacandon Maya apply chewed fig leaves as a poultice for snakebites. Fig flowers are considered to be symbols of good luck (Arvigo & Balick 1993:105). One grain of *Ficus* sp. pollen was counted in each of Samples 33 and 37 of the Laguna Verde pollen core, and two grains were noted in Sample 60.

The preponderance of Moraceae pollen identified in this study compared favorably with the pollen of the genus *Brosimum,* three species of which (*B. alicastrum*

alicastrum, B. guianense, and *B. lacenscens*) grow in modern Belize (Balick et al. 2000:56-57). All three are trees commonly known as "ramón" or "breadnut" (Balick et al. 2000:56-57). *Brosimum* sp. pollen was found throughout the Laguna Verde pollen core, but was most abundant in the lower two-thirds of the core. It achieved a peak relative abundance of 32 percent in Sample 6. *B. guianense* is used in construction (Balick et al. 2000:57). *B. alicastrum* ssp. *alicastrum* is used in Mesoamerica for food (fruit and seeds), medicine, construction, and forage (Balick et al. 2000:56; Standley & Record 1936:44, 110). Early Mayan explorer C.L. Lundell noted that the *Brosimum alicastrum* ripens between March and May, the growing season for maize in the upland wet season swidden agricultural system of the uplands (Pohl 1985:3). Its edible nut could therefore have been an important food for the Maya in times of seasonal food shortages. Lundell also suggested that the present-day distribution of *B. alicastrum* trees (on abandoned ruins) was caused by prehistoric manipulation of the forest by humans (Pohl 1985:3). However, some archaeologists have suggested that ramón was never more than famine food for the Maya, and that the trees colonized Mayan ruins after abandonment by the human inhabitants (Lambert & Arnason 1982:298-299; Marcus 1982:250; Pohl & Miksicek 1985:14), because it is a "disclimax species with poorly dispersed fruits" (Miksicek et al. 1981:917). Lambert & Arnason studied the vegetation associations at Lamanai, Belize, and concluded that there was nothing unique about the ruin-associated vegetation (1978:40). Some taxa grow well atop ruins because they are naturally well-drained, have a high pH, and because abundant calcium and magnesium are available from the limestone of the structures (Lambert & Arnason 1982:298). Pollen records from northern Belize and central Petén show that high levels of *Brosimum* pollen vary inversely with disturbance indicators (Pohl & Miksicek 1985:14), meaning that this tree is more likely to flourish in undisturbed locations. Still, in a survey of 110 modern Mayan kitchen gardens in Belize and eastern Petén, researchers found only one *Brosimum* tree, and concluded that this plant never served as more than famine food for the ancient Maya (Miksicek et al. 1981:916-917).

The pollen of the two Belizean *Trophis* species (*T. mexicana* and *T. racemosa*) is similar in aperturation, size, and general appearance to *Brosimum* pollen. *Trophis* has slightly larger pores (Roubik & Moreno 1991:119-121), but this difference is difficult to perceive with a light microscope, and during this study no attempt was made to distinguish between the pollen of the two genera. *Trophis* shrubs or trees are, like *Brosimum,* known as “breadnut” or “ramón” (Balick et al. 2000:58). *T. racemosa* is used in Belize for food, forage, and medicine; elsewhere in Mesomerica, it is also used for fuel (Balick et al. 2000:58; Standley & Record 1936:47).

A triporate form of Moraceae pollen was observed in this study that may have been the pollen of the trees *Castilla elastica, C. tunu, Maclura tinctoria,* or *Poulsenia armata. C. elastica* yields rubber (Standley & Record 1936:44, 110). *Maclura tinctoria* is used for food and spices, beverages, construction, dyestuff, medicine, tanning, and miscellaneous products such as cabinets (Balick et al. 2000:58; Standley & Record 1936:44, 111).

Two naturally-occurring genera of Belizean Moraceae have not been addressed. Three species of *Dorstenia*, an herb, grow in Belize (Balick et al. 2000:29, 57). These bear distinctive periporate pollen that was not observed during this study. Finally, three species of *Pseudolmedia*, a tree, grow in Belize (Balick et al. 2000:29, 58). *Pseudolmedia* produces a cherry-like edible fruit, and its wood is used for railway ties (Standley & Record 1936:46, 117).

Three genera and four species of Cecropiaceae grow in modern Belize (Balick et al. 2000:29, 58). No economic use is suggested for *Pourouma bicolor* (Balick et al. 2000:58). The pollen of *Coussapoa oligocephala* was not observed during the present study. The remaining three species of tree produce pollen that looks similar from one species to the others, and no attempt at species-level distinction was made. *Cecropia obtusifolia* is used in Mesoamerica for miscellaneous products, ritual functions, medicine, food, forage, and fumitory purposes (Balick et al. 2000:58). *Cecropia peltata* is used in Belize for miscellaneous products and medicinal and fumitory purposes (Arvigo & Balick 1993:209; Balick et al. 2000:58). *Cecropia* is commonly known as "trumpet," and its stems are said to have been used by Central American natives for manufacturing musical instruments of that name (Standley & Record 1936:111). This pollen type was found at low frequencies throughout the lower two-thirds of the Laguna Verde pollen core, and reached its peak relative abundance of 11.5 percent in Sample 39.

Myricaceae

Myrica sp.

Myrica cerifera is the only representative species of Myricaceae in Belize (Balick et al. 2000:30, 59). This lowland shrub is commonly known as "myrtle" or "bayberry". It has medicinal uses in Belize, and is used for miscellaneous products, ritual purposes, and tanning elsewhere in Mesoamerica (Balick et al. 2000:59). *Myrica* sp. pollen was found throughout the Laguna Verde pollen core, and was most abundant in the lower two-thirds of the core.

Myristicaceae (Family)

Virola sp.

Two genera and three species of Myristicaceae, the "nutmeg" familiy, grow in modern Belize (Balick et al. 2000:29, 50-51). These species are *Compsoneura sprucei*, *Virola koschnyi*, and *V. multiflora*. In this study, some pollen grains were identified as belonging to the genus *Virola*, while others compared favorably with published light micrographs of the pollen of *Compsoneura debilis* and *Virola sebifera* and were identified to family level because these species are not known to grow in Belize. Very few of each type were found in the core.

Of the Belizean Myristicaceae, *C. sprucei* is a red-sapped shrub or tree (Balick et al. 2000:50; Standley & Record 1936:139). The *Virola* species are trees, and *V. koschnyi* is an important secondary timber crop in Belize (Standley & Record 1936:34, 140). It is used in Belize for construction and for miscellaneous products elsewhere in Mesoamerica (Balick et al. 2000:50-51; Standley & Record 1936:34, 47). It is exploited for veneer wood, furniture, and the construction of dories (Standley & Record 1936:35).

Myrtaceae (Family)

Myrtaceae (syncolpate)

Myrtaceae (tricolporate)

Myrtaceae pollen was found throughout the Laguna Verde pollen core, and was most abundant at the very top and bottom of the core. Well-known plants of the Myrtaceae family include “eucalyptus,” “clove,” and “guava.” Four species of the family are endemic to Belize (Balick et al. 2000:4). However, most of the Myrtaceae are native to southern Asia and Australia, and were restricted to their native habitats until the 19th century. Recently, many species have been exported to the tropical and semi-tropical regions of the world as ornamentals or timber trees (Bryant, personal communication, 2008). Today, ten genera and 58 species, plus three cultivated species, of Myrtaceae grow in Belize (Balick et al. 2000:32-33, 96-99). A few of economic significance are described here. Thirty-one species of *Eugenia* (one of which is endemic) grow in modern Belize (Balick et al. 2000:4, 32, 97-98). All grow as shrubs or trees (Balick et al. 2000:97-98). No economic use is suggested for most species, but some are used in Belize for medicine, miscellaneous products, fuel, forage, food, and also regionally for beverages, construction, and ornamentation (Balick et al. 2000:97-98). Two species of *Myrcia* (not to be confused with *Myrica* of the family Myricaceae) grow in modern Belize (Balick et al. 2000:32, 98). Both grow as shrubs or trees (Balick et al. 2000:98). *M. splendens*, the “pigeon plum,” produces a fruit that is eaten in Mesoamerica (Balick et al. 2000:98). *Myrcianthes fragrans* is a shrub or tree that is used in Mesoamerica for fuel, construction, and medicine (Balick et al. 2000:98). *Pimenta dioica*, or “allspice,” is a forest or backyard tree that is used in Belize for spicing stews, cereals, and liquors (Arvigo & Balick 1993:31). Its leaves are brewed to make tea (Arvigo & Balick 1993:31, Balick et al. 2000:98). The plant is traditionally used for various medicinal purposes, in which it is used as a tea, poultice, bath, tincture, or paste to cure digestive upsets, gas, infant colic, rheumatism, exhaustion, menstrual cramps, foot fungus, or toothache (Arvigo & Balick 1993:31). Finally, *P. dioica* is used regionally for its aromatic essential oil (Balick et al. 2000:98; Standley & Record 1936:45).

Nymphaceae (Family)

One genus (*Nymphaea*) and three species of Nymphaceae grow in modern Belize (Balick et al. 2000:29, 55). All three species are aquatic herbs (Balick et al. 2000:55), commonly known as "water lily." *Nymphaea ampla* is used medicinally and grown as an ornamental in modern Mesoamerica (Balick et al. 2000:55). Ten grains of *N. ampla* pollen were counted during this study, with four grains in Sample 3 and one grain in each of Samples 5, 21, 37, 40, 46, and 60.

Orchidaceae (Family)

The Orchidaceae have the second-highest number of species (279) of any plant family in modern Belize, and four of the 22 largest genera belong to Orchidaceae (Balick et al. 2000:3, 37-38). Although the presence of large Orchidaceae pollen in the Laguna Verde pollen samples is debatable, their abundance in Belize (especially in moist forests) is undisputable. This family of herbs, including many epiphytes, is noted for its beautiful flowers. Perhaps the most famous of the orchids is the producer of the vanilla bean. Identification of this pollen type is further discussed in Chapter I.

Pinaceae

Pinus sp.
Tsuga sp.

Two trees of the family Pinaceae grow in modern Belize. These are the "pine" trees *Pinus caribea hondurensis* and *Pinus oocarpa* (Balick et al. 2000:29, 49; Standley & Record 1936:67). *Pinus* sp. pollen was abundant throughout the Laguna Verde pollen core. Because the genus is wind-pollinated and produces large quantities of pollen, its presence in the Laguna Verde core greatly exaggerates the actual presence of the trees. It is thus a poor indicator of paleoenvironmental conditions and past ecotypes.

The ancient Maya used pine wood in construction, and pine resin to fuel their torches (Hammond & Miksicek 1981:266). Inhabitants of the Middle Preclassic site of Cuello traveled beyond the site to secure this resource Hammond & Miksicek 1981:266).

As of 1936, much Belizean pine was privately grown and milled for local use and small-scale regional export (Standley & Record 1936:33-34). During colonial times (in the 1920s), the Forest Department of British Honduras actively protected some pine stands from fire to encourage their regeneration (Standley & Record 1936:27-28). It was hoped that larger-scale commercial production, including rosin and turpentine manufacture, could be achieved (Standley & Record 1936:33-34). Today, *P. oocarpa* is used regionally in construction (Balick et al. 2000:49; Standley & Record 1936:67). *P. caribea hondurensis* is a much-planted timber crop (Mabberley 1997:558, Standley & Record 1936:33-34, 67). It is used in modern Belize for carpentry, pilings, railroad ties, fuel, and medicinal purposes (Balick et al. 2000:49; Standley & Record 1936:45). Elsewhere in the Mesoamerican region, this subspecies is also tapped for its resin (Balick et al. 2000:49).

The genus *Tsuga* ("hemlock") is not known to grow in modern Belize, so its pollen must have arrived at Laguna Verde via long-distance transport.

Piperaceae

Piper sp.

Two genera (*Peperomia* and *Piper*) and 45 species, plus one cultivated species, of Piperaceae grow in modern Belize (Balick et al. 2000:29, 52-55). In this study, one pollen grain was identified as *Piper* sp. This is the genus to which the spice "black pepper" belongs. Most *Piper* species grow as shrubs or small trees; some are used in medicine, ritual, or in other ways (Balick et al. 2000:53-54; Standley & Record 1936:102).

Poaceae

Poaceae<50 μ

Poaceae, 50-69 μ

Poaceae, 70-100 μ

Poaceae>100 μ

Seventy-four genera and 248 species and subspecies, plus five cultivated species, of Poaceae grow in modern Belize (Balick et al. 2000:39, 185-194). All are grasses (Balick et al. 2000:185-194). Around the world, many are cultivated as food grains. Balick et al. do not suggest an economic use for most species, but some are used for medicine, ornamentation, poison, forage, ritual, miscellaneous products, food, and fiber (Balick et al. 2000:185-194). *Phragmites australis* has an unusual number of economic uses in Mesoamerica, including construction, fiber, food, forage, gum, medicine, and miscellaneous products (Balick et al. 2000:192). The five modern Belizean cultivars, used as human food, are *Cymbopogon citrates* ("lemon grass"), *Oryza sativa* ("rice"), *Saccharum officinarum* ("sugar cane"), *Sorghum bicolor* ("sorghum"), and *Zea mays mays* ("maize" or "corn"; Balick et al. 2000:193-194). The Spanish introduced rice to Central America, but it did not take hold as a staple food until the 19th and 20th centuries (Hall & Pérez Brignoli 2003:155). Lemon grass was introduced from India, and sorghum from northern Africa, late in the colonial period.

Sugar cane was also introduced during the colonial period, and came under widespread cultivation in the area. Today, a large sugar cane plantation operates in the vicinity of the Laguna Verde swamp. The plantation is located perhaps twenty miles (or more) away from the swamp. Tower Hill Sugar Refinery, which handles all of Belize's sugar cane processing, is located in Orange Walk Town. Orange Walk Town is known as "Sugar City." Orange Walk Town is about 30 miles northeast of Laguna Verde, where my core was taken. Sugar cane is the primary crop of Orange Walk District. Sugar cane pollen likely comprises some of the Poaceae pollen in the upper (postcolumbian) portion of the Laguna Verde pollen core; the identification of Poaceae pollen is further addressed in the section "Taxonomic Discrimination" in Chapter I.

Zea mays ssp. *mays* grows exclusively under cultivation, and is used primarily to feed humans and livestock. Poaceae pollen identified as *Zea mays* pollen (with a diameter of 100 µ or larger) was found in small amounts throughout the Laguna Verde pollen core, with one grain counted in each of Samples 3, 11, 15, 45, 50, 51, 58, and 59, and two grains counted in each of Samples 23 and 60 . Although maize tortillas are an important food in the Maya area today, there is no written record of tortilla production in the pre-conquest Maya Lowlands (Coe 2005:204). Although clay griddles were found at the site of Lamanai, Belize, these may have been used to roast cacao beans (Coe 2005:204). Instead of making tortillas, the Maya made tamales; cornmeal gruel with chili peppers for breakfast; and sourdough was carried into the fields in gourds for lunch (Coe 2005:204). They also cooked stews with meat, peppers and other vegetables, and squash seeds (Coe 2005:205). Maize kernels can be dried, ground, and brewed like coffee (Arvigo & Balick 1993:87). In their traditional medicine, Belizeans boil maize kernels or silk in water, and drink the resulting beverage to cure measles, cleanse the lymphatic system, and fix various conditions of the urinary system (Arvigo & Balick 1993:87). *Z. mays* is a religious symbol in Mesoamerica. Some Mesoamericans believe that the gods created people from corn, or that maize is the food of the gods and was shared with humans as a special blessing (Arvigo & Balick 1993:87). See also the special maize section in Chapter IV.

Podocarpaceae

Podocarpus guatemalensis

One genus (one species) of Podocarpaceae grows in modern Belize; this is *Podocarpus guatemalensis* (Balick et al. 2000:29, 49; Standley & Record 1936:67). This coniferous tree, commonly known as “cypress,” is used for house construction, boat building, and railroad ties in modern Belize and elsewhere in Mesoamerica (Balick et al. 2000:49; Standley & Record 1936:46). Pollen of *P. guatemalensis* was observed only in the bottom half of the Laguna Verde core, with two grains counted in each of Samples 4 and 7, and one grain counted in each of Samples 8, 10, 15, 30, and 32.

Polygonaceae (Family)

Coccoloba sp.

Four genera and 19 species of Polygonaceae grow naturally in modern Belize (Balick et al. 2000:30, 63-64). Fourteen of these species belong to the genus *Coccoloba* (Balick et al. 2000:30, 63). These are shrubs or trees commonly known as "wild grape," so called after their sometimes-cultivated, edible fruit (Balick et al. 2000:63; Standley & Record 1936:44). Some *Coccoloba* species are used in Belize for forage, medicine, food (fruit and preserves), beverages, construction materials, and fuel; *Coccoloba uvifera* is additionally used elsewhere in Mesoamerica for its sap and for tanning and miscellaneous products (Balick et al. 2000:63; Standley & Record 1936:126). Pollen of *Coccoloba* sp. was identified throughout the Laguna Verde pollen core, and was slightly more abundant in the uppermost strata.

Rhamnaceae

Colubrina arborescens

Five genera and six species of Rhamnaceae, the "buckthorn" family, grow in modern Belize (Balick et al. 2000:33, 111). The pollen of one species, *Colubrina arborescens,* was observed deep within the Laguna Verde core; one grain was counted in each of Samples 6, 7, 9, 11, 12, and 28, and two grains were counted in Sample 10. *C. arborescens* grows as a tree or shrub, and is used in beverages (including a Caribbean soft drink called "Mauby"), construction, medicine, and miscellaneous products in modern Mesoamerica (Balick et al. 2000:111).

Rhizophoraceae

Rhizophora mangle

Two genera and two species of Rhizophoraceae grow in modern Belize (Balick et al. 2000:32, 104). No grains resembling *Cassipourea guanensis* were observed during the present study, but grains of *Rhizophora mangle* were present throughout most of the column, reaching peaks at Sample 15 and Sample 29. This swamp forest tree, known as "red mangrove," is most common in saline coastal marshes; this fact accounts for the relatively low percentages of *R. mangle* pollen at Laguna Verde, as compared to its higher percentages in pollen studies from eastern Belize (e.g. Jones 1991). However, *R. mangle* can also grow in brackish and fresh water, and was observed growing on-site at Laguna Verde. The plant is hermaphroditic, and can be self- or wind-pollinated.

Wood of this tree is used in Belize for miscellaneous products, fuel, charcoal, and tanning, and is additionally used elsewhere in Mesoamerica for food, construction, and dye (Arvigo & Balick 1993:175; Balick et al. 2000:104; Standley & Record 1936:46). In traditional Belizean medicine, the bark of *R. mangle* is boiled, and the hot water is used to bathe sores, swellings, leprosy, and other skin conditions (Arvigo & Balick 1993:175).

In modern times, the law regulates increasing mangrove clearance to prevent coastal erosion, hurricane damage, and depletion of marine food resources (King et al. 1992:3).

Rubiaceae (Family)

Faramea sp.

Psychotria sp.

Spermacoce sp. or *Borreria* sp.

Spermacoce assurgens=*Borreria laevis* (species distinctive from others of these genera)

Fifty genera and 142 species of Rubiaceae, plus six cultivars, grow in modern Belize (Balick et al. 2000:36, 141-148). Rubiaceae is the "coffee" family. Four

Rubiaceae pollen types were identified during the present study. Two types belonged to the genus *Spermacoce*, and one of these types (*S. assurgens*) was identified to species level. "*Borreria*" is an old pseudonym for *Spermacoce* that sometimes appears in the palynological literature. Twelve species of *Spermacoce* grow in modern Belize (Balick et al. 2000:36, 147). All of these grow as herbs, and several are used medicinally (Balick et al. 2000:147). The herb *S. assurgens* is used medicinally in Mesoamerica (Balick et al. 2000:147). The pollen of *Spermacoce* sp. or *Borreria* sp. was identified throughout the Laguna Verde pollen core, and was most abundant in the upper third of the column and in the lowermost samples.

The third type of Rubiaceae pollen observed in this study was that of *Faramea.* One *Faramea* sp. grain was noted in Sample 4. Two species of *Faramea* grow in modern Belize (Balick et al. 2000:36, 142). Both *Faramea* species grow as shrubs or trees, and no economic use is suggested for either (Balick et al. 2000:142). The grain observed in this study compared favorably with the pollen of *F. occidentalis.*

The final type of Rubiaceae pollen identified in this study was that of the genus *Psychotria.* Three grains of this type were counted in each of Samples 13 and 46. Thirty-nine species of *Psychotria* grow in modern Belize, the largest genus in the Rubiaceae family (Balick et al. 2000:36, 144-146; Standley & Record 1936:385). The observed grains fit the descriptions of *P. marginata* and/or *P. uliginosa* given by Roubik & Moreno (1991:137-138), being inaperturate, approximately 30 μ in diameter, and baculate or gemmate. *P. marginata* is a shrub used medicinally in modern Belize (Balick et al. 2000:145). *P. uliginosa* is a subshrub that is used medicinally in Belize and elsewhere in Mesoamerica (Balick et al. 2000:146).

Rutaceae

Zanthoxylum sp.

Rutaceae is the "citrus" family. Most are native to the Middle East and Africa, but were exported to the New World during colonial times to produce fruit (Bryant, personal communication, 2008). Seven genera and 20 species, plus two cultivated species, of Rutaceae grow in modern Belize (Balick et al. 2000:34, 118-119). All Belizean plants in this family grow as trees or shrubs (many thorny), and many produce edible citrus fruits such as the orange, grapefruit, lime, and lemon (Balick et al. 2000:118-119).

The pollen of only one Rutaceae genera, *Zanthoxylum,* was observed during the present study. All seven of the Belizean *Zanthoxylum* species grow as trees (Balick et al. 2000:119). No economic use is suggested by Balick et al. for most species, but *Z. caribaeum* is used in Belize for medicine and is also used elsewhere in Mesoamerica in construction, and *Z. juniperum* is used in Belize for fuel and medicine (Balick et al. 2000:119). One grain of *Zanthoxylum* sp. pollen was counted in each of Samples 6, 27, 29, 30, 36, 41, and 56, and two grains were counted in each of Samples 57 and 59.

Sapindaceae (Family)

Exothea diphylla
Sapindus saponaria or Rhamnaceae
Talisia oliviformis
Thinouia myriantha

Fourteen genera and 37 species and subspecies, plus two cultivated species, of Sapindaceae grow in modern Belize (Balick et al. 2000:34, 114-116). Sapindaceae is the “soapberry” family, and its famous members include the delicious Asian fruits “lychee,” “rambutan,” and “longan.”

Most of the pollen grains in this study that were grouped under the label “Sapindaceae” were triporate, tricolporate, or tetracolporate grains with a distinctive triangular or quadrangular outline when examined in polar view, like many grains of the genera *Allophylus*, *Cupania, Paullinia,* and *Serjania. Allophylus* and *Cupania* species grow as shrubs and trees, while *Paullinia* and *Serjania* species grow as vines and lianas (Balick et al. 2000:114-116). Plants of these four genera have various economic uses (Arvigo & Balick 1993:113; Balick et al. 2000:114-116). The caffeinated fruit “guarana” comes from a species of *Paullinia*.

In the present study, 21 pollen grains in Sample 4 and one grain in each of Samples 11 and 16 were identified as the pollen of the shrub or small tree *Sapindus saponaria. S. saponaria* is used in Belize for miscellaneous products, medicine, and construction (Balick et al. 2000:115). The pulp of the fruit is sometimes used as a substitute for soap (Standley & Record 1936:235), and the seeds can be crushed to make soap.

The pollen of another tree species, *Exothea diphylla,* was also observed, with one grain counted in each of Samples 10 and 13. No economic use is suggested for this species by Balick et al. (2000:115).

Pollen of *Talisia oliviformis* was also observed, with one grain noted in Sample 4. This evergreen tree is used in modern Belize for miscellaneous products and forage, and is used elsewhere in Mesoamerica for food (Balick et al. 2000:116).

One grain from Sample 9 was found to resemble the pollen of *Thinouia myriantha.* This species is not known to grow in modern Belize (Balick et al. 2000:116).

Sapotaceae (Family)

cf *Chrysophyllum mexicanum*
Pouteria sp.
cf *Pouteria stipitata* (Species does not grow in modern Belize)
Pouteria unilocularis=P. reticulata

Five genera and 23 species of Sapotaceae grow in modern Belize (Balick et al. 2000:31, 77-79). Most Sapotaceae grains observed during the present study had smaller, tricolporate forms, resembling the pollen of *Chrysophyllum mexicanum, Pouteria reticulata,* or *Pouteria stipitata.* The latter type is known from light micrographs in Roubik & Moreno (1991:243) and is not known to grow in modern Belize.

One grain of *Chrysophyllum* sp. pollen was counted in Sample 49. Three species of *Chrysophyllum* trees grow in modern Belize (Balick et al. 2000:77). *C. cainito* is a tree that produces the fruit “star apple,” which is eaten in Belize and elsewhere in Mesoamerica. It is used in beverages and construction, and for miscellaneous products, medical purposes (to treat diabetes and rheumatism, and as a tonic), and latex (from the fruit's skin) in Mesoamerica (Balick et al. 2000:77). *C. mexicanum* serves as food in Belize and elsewhere in Mesoamerica is also used for miscellaneous products, medicine, latex, construction, and beverages (Balick et al. 2000:77). *C. mexicanum* is used in Belize and elsewhere in Mesoamerica for medicine, food, gum, construction, and forage (Balick et al. 2000:77). *C. venezuelense* is used in Mesoamerica for food (Balick et al. 2000:77).

Eight species and two subspecies (for a total of nine taxa; don't get confused by the math) of *Pouteria* trees grow in modern Belize (Balick et al. 2000:31, 78). Many of the Sapotaceae pollen grains observed during this study resembled those of *P. reticulata.* This tree is commonly known as "wild cherry," and it produces a fruit eaten in Mesoamerica (Balick et al. 2000:78). *Pouteria* sp. produce a heavy wood that is used in naval construction (e.g. dock pilings) in modern times, but the wood would have been too heavy for the Maya to work by hand in ancient times.

Some larger, 4- and 5-colporate pollen grains were observed during this study and were identified as "Sapotaceae" or as "*Pouteria* sp." Grains thus identified probably included representatives of *Manilkara zapota*, *Pouteria sapota* (=*P. mammosa, =Calocarpum mammosum*), and *P. campechiana. Manilkara zapota* is a tree commonly known as "sapote," "chicle," and "sapodilla" (Balick et al. 2000:78). This has been an important commercial timber crop in colonial and modern Belize, and is noted for its production of latex used in chewing gum (Standley & Record 1936:26, 39, 311). Supplies of this tree were depleted in the 1920s due to unregulated tapping (Standley & Record 1936:40, 43). The products of *M. zapota* are used in Belize and elsewhere in Mesoamerica for food; medicine; tool handles; and construction of house beams, lintels, and pilings (Balick et al. 2000:78; Standley & Record 1936:43). *P. sapota,* a large tree commonly known as "sapote," is used in modern Belize for food, medicine, oil, and timber for house frames, and is also used elsewhere in Mesoamerica in construction and for latex, miscellaneous products, and poison (Balick et al. 2000:78; Standley & Record 1936:44, 312). This evergreen tree is cultivated in Middle America for its sweet fruit, and it is considered an attractive ornamental. *P. campechiana* is exploited for food, miscellaneous products, medicine, forage, and latex in modern Belize (Balick et al. 2000:78).

One pollen grain identified as "*Pouteria*" or "Other Sapotaceae" was identified in each of Samples 4, 5, 12, 25, 26, and 49, mostly in the lower half of the Laguna Verde pollen core.

Scrophulariaceae (Family)

One pollen grain from Sample 1 was assigned to the family Scrophulariaceae. Modern Belizean Scrophulariaceae includes 15 genera and 28 species, plus two cultivated species (Balick et al. 2000:35, 134-135). The Scrophulariaceae grow as herbs, subshrubs, and shrubs (Balick et al. 2000:134-135). No economic purpose is suggested by Balick et al. (2000:134-135) for most species, though some are used medicinally.

Simaroubaceae

Picramnia antidesma

Four genera and four species (one with two subspecies, for a total of five taxa) of Simaroubaceae grow in modern Belize (Balick et al. 2000:34, 117). All grow as shrubs or trees (Balick et al. 2000:117). The pollen of one species, *Picramnia antidesma,* was observed during this study, with one grain counted in Sample 13 and two grains counted in Sample 46. Two subspecies, *P. antidesma antidesma* and *P. antidesma fessonia,* grow in modern Belize (Balick et al. 2000:117). The pollen observed here was that of the former species, which produces pollen that is much larger than that of the latter species (Palacios Chavez et al. 1991: 124). *P. antidesma antidesma* is used for food and medicine in modern Belize and elsewhere in Mesoamerica (Balick et al. 2000:117).

Solanaceae (Family)

Markea sp.

Physalis sp.

Thirteen genera and 57 species, plus nine cultivated species, of the family Solanaceae grow in modern Belize (Balick et al. 2000:35, 124-127). The Solanaceae grow variously as vines, lianas, herbs, subshrubs, shrubs, and trees (Balick et al. 2000:124-127). Among these are popular food plants, including those commonly known as “chili pepper,” “tomatillo,” “tomato,” “eggplant,” and “potato.” The tobacco plant, *Nicotiana tabacum*, is also a member of this family. The Solanaceae family is high in alkaloids and can be toxic to humans in large doses. Four Solanaceae grains were identified to the family level during the present study, with one grain counted in each of Samples 2 and 28, and two grains counted in Sample 43.

In three cases (Samples 7 and 12, and the modern “pinch” sample), I was able to identify to genus level grains of the genus *Physalis*. Four species of *Physalis* grow in modern Belize, and all four grow as herbs and are used as food (Balick et al. 2000:125, 127). *P. angulata* and *P. philadelphica* are commonly known as “tomatillo” (Balick et al. 2000:125, 127). Other uses of *Physalis* in modern Belize and Mesoamerica are in the realms of medicine (to treat sore throats), and spice (Balick et al. 2000:125).

The pollen of the epiphytic shrub *Markea neurantha* is distinctive from other Solanaceae pollen, having three markedly aspidate, vestibulate pores. Four grains of, or resembling, *Markea* pollen were counted in Sample 15 of the present study. No economic use for *M. neurantha* is suggested by Balick et al. (2000:125).

Symplocaceae

cf *Symplocos martinicensis*

One genus (one species) of Symplocaceae grows in modern Belize; this is *Symplocos martinicensis*, a tree (Balick et al. 2000:31, 79). In this study, one grain of *S. martinicensis* pollen was noted in each of Samples 16 and 28. Balick et al. do not suggest an economic purpose for this plant (Balick et al. 2000:79).

Tiliaceae (Family)

Corchorus hirsutus

Heliocarpus americanus

cf *Trichospermum grewiifolium*

Eight genera and 14 species, plus two cultivated species, of Tiliaceae grow in modern Belize (Balick et al. 2000:30, 67). The Tiliaceae grow as shrubs and trees (Balick et al. 2000:67).

Three types of Tiliaceae pollen grains were identified to species level in this study. First, grains were identified as having come from *Heliocarpus americanus*. This tree is used in modern Belize for manufacturing miscellaneous products and fiber (Balick et al. 2000:67; Standley & Record 1936:241). Two grains of this type were counted in Sample 2, and one grain was counted in each of Samples 13 and 52.

The second type of Tiliaceae pollen identified in this study was that of *Trichospermum grewiifolium.* Two grains of this type were counted in Sample 15. This common forest tree, popularly known as “balsa wood,” is used in modern Belize and elsewhere in Mesoamerica for construction, fiber (e.g. bast for cordage), and miscellaneous products (Balick et al. 2000:67; Standley & Record 1936:43, 240).

The final type of Tiliaceae pollen identified in this study compared favorably with the pollen of *Corchorus hirsutus.* This particular species is not known to grow in modern Belize (Balick et al. 2000:67). However, one grain of pollen comparing favorably with that of *C. hirsutus* was observed in each of Samples 8, 13, and 34. The only species of the *Corchorus* genus known to grow wild in modern Belize is *C. siliquosus* (Balick et al. 2000:67), a weedy shrub which produces pollen that is much larger than that of *C. hirsutus. C. olitorius* grows in cultivation in Belize (Balick et al. 2007:67). The genus produces the fiber “jute.”

Typhaceae

Typha angustifolia

Typha domingensis

Typha latifolia

Typhaceae is the “cattail” family of perennial marsh herbs. Pollen of the cattails *Typha angustifolia, T. domingensis,* and *T. latifolia* was observed during this study. Members of this genus are high in starch, and the rhizomes and unusually carbohydrate-rich pollen can be eaten as famine food (Mabberley 1997:734). Cattail fluff was used as tinder by some ancient Native American groups.

T. domingensis is used for food and miscellaneous products in Belize and elsewhere in Mesoamerica (Balick et al. 2000:176). *T. angustifolia* leaves are used for matting in Mesoamerica, and cattail fluff makes a soft stuffing (Standley & Record 1936:67). *T. latifolia* is not known to grow in modern Belize, and a fungal spore may have been mistaken for a pollen grain from that species.

Typhaceae pollen was observed throughout the Laguna Verde pollen core, occurring in a relative abundance of .5 to 3 percent in most samples and reaching a peak abundance of 18.3 percent in Sample 59.

Ulmaceae

Celtis sp.

Trema sp.

Ulmus sp.

Ulmaceae is the “elm” family. Although elm (*Ulmus* sp.) pollen was identified in significant quantities during this study, trees of that genus are not known to grow in modern Belize. This tree, common in temperate regions, is wind-pollinated, and it produces large amounts of pollen that could have arrived at Laguna Verde via long-distance transport.

Taxonomists disagree about the family assignments of other so-called Ulmaceae. The Angiosperm Phylogeny Group places *Celtis* sp. and *Trema* sp. in the Cannabaceae, but this dissertation follows the classification scheme of Balick et al. (2000) in placing these species in the Ulmaceae.

Three genera encompassing five species and two subspecies (for a total of six different taxa; don't get confused by the mathematics) of the Ulmaceae grow in modern Belize (Balick et al. 2000:29, 56). The pollen of one species, *Ampelocera hottlei,* was not identified during this study. The remaining modern Belizean taxa are *Celtis iguanea, Celtis schippii, Trema integerrima, Trema micrantha floridana,* and *Trema micrantha micrantha* (Balick et al. 2000:56). In this study, pollen of the genera *Celtis* sp. and *Trema* sp. were identified in significant quantities; no attempt was made to make species- or subspecies-level identifications. Pollen of the *Celtis/Trema* type was abundant throughout the Laguna Verde core, occurring in relative abundances of 4 to 10 percent in most samples, and reaching a peak abundance of 13.9 percent in Sample 11. The fruit ("wild cherry" or "hackberry") of the shrub or tree *Celtis iguanea* is used in modern Belize for food (Balick et al. 2000:56). *Celtis* sp. seeds have been found at some archaeological sites, but it is uncertain whether or not the edible fruits were actually enjoyed by the ancient Maya (Pohl & Miksicek 1985:15). In modern Mesoamerica, *Celtis iguanea* is used as medicine and as poison (Balick et al. 2000:56). It functions dually as a curative and a poison.

Balick et al. give no economic uses for the tree *Celtis schipii* or for *Trema integerrima* (2000:56). *Trema micrantha floridana* is used in Belize for construction, food, and forage; elsewhere in Mesoamerica it is additionally used for fiber, medicine, and miscellaneous products (Balick et al. 2000:56). *Trema micrantha micrantha* is used in modern Belize for construction, food, forage, and fiber; elsewhere in Mesoamerica it is also used for fuel (Balick et al. 2000:56). All three of the *Trema* varieties occur as shrubs or trees (Balick et al. 2000:56).

Urticaceae (Family)

Eight genera and 21 species of Urticaceae, the "nettle" family, grow in modern Belize (Balick et al. 2000:29-30, 59). All grow as herbs, shrubs, or trees, some producing painful stings (Balick et al. 2000:59; Standley & Record 1936:120). No economic purpose is suggested for most species by Balick et al. (2000:59) or Standley & Record (1936:118-120). One grain of Urticaceae pollen was identified in Sample 33 of the present study, and seven grains were noted in the modern cattle pasture reference sample.

Verbenaceae

Lantana sp.

Lippia (=*Phyla* sp.)

Sixteen genera and 40 species, plus four cultivars, of Verbenaceae grow in modern Belize (Balick et al. 2000:35, 131-133). Two Verbenaceae pollen types were observed during the present study. The first was that of *Lantana.* Four species of *Lantana*, all shrubs, grow in modern Belize (Balick et al. 2000:35, 131-132). The grain observed in Sample 12 of this study probably came from *L. camara.* Wild *L. camara* is common in thickets and widely distributed in Middle America, and is often considered a weed, but it is also a "cultivated shrub common in gardens, old fields, roadsides, [and] trails" (Arvigo & Balick 1993:223; Standley & Record 1936:342). It is used in modern Belize for food (berries), ornamentation, and beverages, and is additionally used elsewhere in Mesoamerica for miscellaneous products (like furniture and brooms) and poison (Balick et al. 2000:131). In traditional Belizean medicine, powdered or infused leaves are used to relieve itching (Arvigo & Balick 1993:223).

The second type of Verbenaceae pollen observed during this study was that of *Lippia nodiflora* (=*Phyla nodiflora*). This herb is used in modern Mesoamerica for medicine and forage (Balick et al. 2000:132). *L. nodiflora* pollen was only found toward the bottom of my core, with two grains occurring in each of Samples 3 and 5, and 18 grains occurring in Sample 6.

Violaceae

Rinorea squamata

Five genera and twelve species of Violaceae grow in modern Belize (Balick et al. 2000:31, 72-73). The Belizean Violaceae grow variously as lianas, herbs, shrubs, and trees (Balick et al. 2000:72-73). The family contains the familiar flowers "violet" and "pansy." The only species used economically is *Rinorea hummelii*, which is used in modern Belize for medicine and forage, and is used elsewhere in Mesoamerica in construction (Balick et al. 2000:73). In this study, seven pollen grains comparing favorably with the pollen of *Rinorea squamata* (as described in Roubik & Moreno 1991:151, 248) were counted, including one grain in Sample 16, four grains in Sample 17, and two grains in Sample 46.

Vitaceae

Cissus sp.

Vitis tiliifolia

Vitaceae is the "grape" family, most members of which grow as lianas with tendrils (Bryant, personal communication, 2008). Two genera and seven species of Vitaceae grow in modern Belize (Balick et al. 2000: 33, 111-112). Six of the species belong to the genus *Cissus* (Balick et al. 2000:111). All grow as lianas, and five species are used medicinally (for healing tendons, ligaments, and broken bones; and as a balm for treating arthritis and osteoarthritis) in modern Belize or elsewhere in Mesoamerica (Balick et al. 2000: 111). *C. verticillata* is additionally used for poison and miscellaneous products in Mesoamerica (Balick et al. 2000: 111). One grain of *Cissus* sp. pollen was identified in Sample 59 of the Laguna Verde core.

One species representative of the second Belizean genus of Vitaceae grows in modern Belize: this is *Vitis tiliifolia* (Balick et al. 2000:111-112). This liana, commonly known as "wild grape," is used in modern Belize for medicine and food, and is also used elsewhere in modern Mesoamerica for beverages and miscellaneous products (Balick et al. 2000:111-112). One grain of *V. tiliifolia* pollen was identified in each of Samples 4, 14, and 46, and two grains were counted in Sample 16.

CHAPTER VI

CONCLUSIONS AND ENVIRONMENTAL INTERPRETATION OF THE LAGUNA VERDE POLLEN CORE

CHAPTER INTRODUCTION

By examining the ways in which the plants represented in the pollen spectrum group together, the palynologist is able to reconstruct the environmental conditions that were in place at the sampling site (or region) at the time of sample deposition. In order to achieve such an environmental interpretation, a palynologist must understand the composition of local and regional plant communities, or vegetation associations. The vegetation association that can be supported in an area depends on such factors as hydrology (i.e. moisture availability) and soils (including mineral availability, the capacity of the soil to hold moisture, and soil depth). Areas with unusual soil or drainage characteristics, and areas altered by humans, can have vegetation dominated by a single species of tree or a particular species composition. Mangrove swamps in moist gulfs and lagoons, and stands of *Pinus caribea* on poor sandy soils, are examples (Hall & Pérez Brignoli 2003:20). Such factors allow the palynologist to reveal not only past vegetation, but also additional aspects of the paleoenvironment.

In order to determine the vegetation association that was probably present at the time of sample deposition, the palynologist compares the pollen spectrum to the vegetational communities known to exist near the sample site in modern times. In implementing this procedure, a few notes of caution are in order. First, modern vegetational communities may not offer a fair comparison for pollen samples from pre-Holocene (i.e. Ice Age, or geological) times, when now-extinct vegetation grew, and/or when vegetation communities existed that have no modern analog. This truth does not pose a problem for this dissertation. However, a second and similar problem can arise from anthropogenic disturbance. When a pristine ecosystem (such as that of pre-Maya Belize) first becomes inhabited by humans, humans alter the vegetation through such means as selection for cultivation and vegetation clearance. Even if the disturbed ecosystem is later abandoned (as during the interval between the Maya Collapse and initial European colonization) and allowed to recover, the secondary climax state it achieves may not match its primary, pristine state. Fortunately, the pollen record usually allows for the detection of a secondary climax state.

A third complex problem arises during the interpretation of paleopalynological samples. Namely, there is not a 1:1 correlation of plants to pollen grains. This comes closer to the truth only if all species in the pollen spectrum are similar in terms of pollen productivity and pollen transport efficiency (Faegri 1966:139). One might like to assume that each pollen grain could represent a certain acreage of ground cover, but this is impracticable because the pollen production of each species may vary according to climate and other factors, and because different species have different levels of efficiency of pollen transport (Faegri 1966:138). Some plants are over-represented in the pollen spectrum, while others are seldom represented. To get around this problem, calculations called "R-values" may be applied. An R-value consists of a species' pollen percentage in a sample, divided by the percentage of the vegetation in the sampling environment identified as the same species (Davis 1963:898). Knowledge of R-values helps to correct for the fact that some taxa "over-produce" or "under-produce" pollen, causing the relative percentage of pollen of a given taxon in a sample to misrepresent the true vegetation cover by that taxon (Davis 1963:898-899, 904-905). Thus, true estimations of the most- and least-dominant taxa in the original vegetation can be made (Davis 1963:910). However, most archaeological palynologists do not calculate R-values because they are specific to place and time. They require extensive trapping of pollen from the anthers or cones of all modern plants in all vegetation associations expected to have contributed to the fossil pollen samples. The dearth of available time and money almost always makes such studies impossible. This fact does not obviate a consideration of the accuracy of a species' representation in the pollen spectrum; the palynologist can (and should) still consider such factors as a species' reproductive biology (e.g. flower structure, potential for self-pollination, etc.) and its pollination mechanism (e.g. wind, insects, animals, etc.). Although palynologists watch for the appearance of the pollen of “indicator” taxa that prefer a narrow habitat range, the presence or absence of such grains ultimately depends upon the plants’ reproductive biology and pollination syndrome. An excellent article on this topic, *Neotropical Plant Reproductive Strategies and Fossil Pollen Representation,* was published by botanist Mark Bush in 1995. Bush explains that, although taxa with an anemophilous pollination syndrome comprise only 2.5 percent of Neotropical trees, their pollen constitutes 27 percent of the sedimentary pollen record. Bush ranks 162 common lowland pollen taxa based on their reproductive strategies and pollination mechanisms, amounting to a ranking of their likelihood of being over- or under-represented in the pollen record. This dissertation takes such information into account in its paleoenvironmental interpretation.

This chapter provides an environmental interpretation of the Laguna Verde pollen core. It begins with a discussion of modern vegetation associations within northern Belize in general, and at Blue Creek and near the coring site in particular. Pollen/vegetation studies from northern Belize and the Petén are introduced. The Laguna Verde pollen diagram is presented, and is interpreted in light of the probable vegetation associations of each stratum and a comparison to the literature.

MODERN VEGETATION ASSOCIATIONS OF NORTHERN BELIZE

Belize, the Petén, and nearby Mexico share a Yucatan/Petén flora of North American (“Nearctic”) origin. This flora can be contrasted with the “Neotropic” vegetation of South American origin, which is found in southern Middle America, and to which the Yucatan/Petén flora bears little resemblance (Hall & Pérez Brignoli 2003:20; Standley & Record 1936:9). The endemic Yucatan/Petén flora is more similar to that of the region of Middle America stretching from Guatemala to Panama, than to that of southern Mexico or the Greater Antilles (Estrada-Loera 1991:687-697). This is true even though the Yucatan Peninsula was connected with Mexico even before southern Middle America first collided with North America during the late Miocene, probably because the geographical barriers between southern Middle America and the Yucatan Peninsula are less formidable (Estrada-Loera 1991:689-690).

Ecologist Leslie Holdridge created a life-zone classification system for Middle America that takes into account "ecological variations caused by latitude and altitude" (Hall & Pérez Brignoli 2003:22). The life-zones system classifies locations by considering the sum of the effects of annual precipitation, mean annual biotemperature suitable for plant growth, and the potential evapotranspiration ratio (Hall & Pérez Brignoli 2003:22). The Holdridge scheme classifies northern Belize as a subtropical moist forest life zone in the basal (i.e. non-montane) altitudinal belt of a subtropical land region (Balick *et al*. 2000:2; Hall & Pérez Brignoli 2003:22-23). As compared to a tropical land region, a subtropical land region supports the growth of fewer arboreal species, and the vegetation attains less height (Hall & Pérez Brignoli 2003:22).

Within the subtropical moist forest life zone of northern Belize, there exist a number of vegetation associations, the development of which is dependent upon such factors as underlying geology and soil, moisture regime, altitude, frequency of forest fires; and anthropogenic disturbance. These vegetation associations have been classified and described according to various schemes. For this dissertation, schemes consulted included one of forest types (Standley & Record 1936); a land resource assessment and agricultural potential assay (King et al. 1992); vegetation classifications published by the Great Britain Directorate of Overseas Surveys (1958a, 1976); and a classification of the ecosystems of Belize (Meerman & Sabido 2001a, 2001b). Major vegetation associations by these schemes usually include mangrove forest; pine forest; and various types of savanna and deciduous rain forest. The remainder of this section describes the major vegetation associations within those types.

Mangrove Forest

Mangrove forest grows in brackish water along the Caribbean coast; in tidal lagoons, swamps, and saline depressions that were once the site of tidal lagoons; and on tidal flats and along the drainage channels that run through the tidal flats (Standley & Record 1936:19). *Rhizophora mangle,* or "red mangrove," is the dominant species

(Standley & Record 1936:19). Areas of lower salinity are favored habitats for Combretaceae (Jones 1991:21-22).

Pine Forest

Soils derived from siliceous rocks favor the growth of *Pinus caribaea* (Standley & Record 1936:20-21). Large stands of pine trees are found at higher elevations on the Mountain Pine Ridge and along other isolated ridgetops (Standley & Record 1936:20-21). Pine grows in association with grasses, sedges, and herbs, including those of the genera *Crotalaria, Drosera, Panicum, Paspalum, Polygala,* and *Utricularia* (Standley & Record 1936:21). In places of higher elevation, pines are found in association with *Byrsonima crassifolia, Curatella americana,* and *Quercus* spp. (Standley & Record 1936:20). In the moister soils of the low-elevation coastal plain, and in southern Belize, pine grows in association with those trees listed above, and also with *Acoelorraphe wrightii, Crescentia cujete,* and *Chrysobalanus icaco* (Hammond & Miksicek 1981:263). Pine savanna provides a refuge for white-tailed deer, and so may have served as a hunting preserve for the ancient Maya (Hammond & Miksicek 1981:263).

Savanna

Standley & Record (1936:19-20) identified three types of savannas in Belize. First, brackish (saline) water savannas replace mangrove forests in the dark silty soils that lie above the flood line of coastal areas. Cyperaceae dominate the vegetation.

Second, fresh water savannas form on inland lagoons and along the streams and rivers of the coastal plain. They are fed by fresh water and are periodically flooded by rainfall, but are subject to dry-season fires. The vegetation is dominated by Cyperaceae and *Panicum* spp. (Poaceae).

Finally, in northern Belize, inland savannas form in shallow sandy soil atop marl beds. In depressions, which are moister and contain shallower soil, Cyperaceae and associated vegetation are prevalent. In places with deeper soil and better drainage, Poaceae and associated vegetation dominate.

Savannas are dominated by graminoid vegetation, but often contain clumps of shrubs or trees. Typical tree taxa are *Byrsonima* sp., *Curatella americana, Pinus* sp., and *Quercus* sp. (Balick et al. 2000:2).

Savannas and coniferous forests in Belize are more adapted to fire than deciduous forests are (Meerman & Sabido 2001a:20). "[Natural] savannahs would be much smaller in extent and not burnt so often as is presently the case" (Meerman & Sabido 2001a:20). Most fires in the Northern Coastal Plain today are caused by arson or by escaped milpa fires (Meerman & Sabido 2001a:19-20, 22). Savannas are therefore anthropogenically expanded.

High Rain Forest: Montane Forest

The chief ecotype in the Blue Creek area is the subtropical moist forest, or rain forest, and its variants. Standley & Record (1936) identified five subtypes of high rain forest: the montane forest, swamp forest, intermediate forest, advanced forest, and secondary forest. The montane forest is confined to the Maya Mountains and the higher elevations of central Belize. The montane forest represents an intermediate successional stage between the grasslands and pine forests of higher elevation, and the advanced forests downslope (Standley & Record 1936:23). Jones (1991:23) reports that the "constituent taxa are essentially identical to the intermediate forest type."

High Rain Forest: Swamp Forest

Swamp forest develops in areas of standing fresh or brackish water. Near the coastline of the Caribbean Sea, and on the river levees of the coastal plain, a mangrove association develops, dominated by *Avicennia nitida* ("black mangrove"), *Laguncularia racemosa* ("white mangrove"), and *Rhizophora mangle* ("red mangrove"; Standley & Record 1936:21). When this tidal levee forest reaches a more advanced stage, it also plays home to *Chrysobalanus icaco, Conocarpus erecta, Pachira aquatica,* and *Pterocarpus officinalis* (Standley & Record 1936:21). In northern Belize, swamp forests are home to many palms, such as *Acoelorraphe wrightii, Bactris* sp., and *Sabal* *mauritiiformis* (Meerman & Sabido 2001b:43; Standley & Record 1936:22). Brackish swamp forests of northern Belize also contain *Bucida buceras, Calophyllum brasiliense* var. *rekoi, Chrysobalanus icaco,* and *Manilkara zapota*; (Standley & Record 1936:22). Freshwater swamp forests of northern Belize contain *Cameraria latifolia, Chrysobalanus icaco,* and *Crescentia* spp. (Standley & Record 1936:22).

High Rain Forest: Intermediate Forest

Pine and swamp forests pass through an intermediate forest stage on their way to becoming advanced rain forest (Standley & Record 1936:22). Intermediate forests retain the vegetation of the earlier stage, but some new species achieve prevalence. In northern Belize, the intermediate forest association includes *Acosmium panamense, Bucida buceras, Bursera simaruba, Calophyllum* spp., *Gliricidia sepium, Pouteria belizensis, Pseudolmedia* spp., *Simarouba glauca, Swietenia macrophylla, Vochysia hondurensis*, and *Xylopia frutescens* (Standley & Record 1936:22). A subtype of this association is characterized by the prevalence of the palms *Cryosophila stauracantha* and *Sabal* spp., plus *Manilkara zapota, Metopium brownei,* and *Pouteria belizensis* (Standley & Record 1936:22).

High Rain Forest: Advanced Forest

The advanced, or climax, rain forest is distinctly stratified, with tall trees in heterogeneous association forming the canopy (Standley & Record 1936:24). The advanced forest often has a dense subcanopy of *Attalea cohune* ("cohune palm"), almost to the exclusion of other species (Standley & Record 1936:23). Shrubs and ferns may otherwise form the subcanopy (Standley & Record 1936:24). The understory may include lianas, epiphytic orchids, bromeliads, aeroids, and cacti (Hammond & Miksicek 1981:262; Standley & Record 1936:24). Species in an advanced forest include survivals from earlier successional stages, as well as *Calophyllum* spp., *Castilla elastica, Ceiba pentandra, Ficus* spp., *Pouteria sapota, Spondias mombin, Terminalia* spp., *Vochysia hondurensis*, and *Zanthoxylum* spp. (Standley & Record 1936:24). On the limestone-derived soils of northern Belize are found *Brosimum* spp. and *Cedrela odorata* (Standley & Record 1936:24).

High Rain Forest: Secondary Forest

Some land that was cultivated during Mayan times has now grown up again to an advanced-stage (pre-climax or climax) secondary rain forest (Standley & Record 1936:24). The climax forest probably took 50 to 100 years to develop after the Maya first abandoned their farm fields (Hammond & Miksicek 1981:263). However, the high rain forests have recently seen significant disturbances, due to two centuries of commercial logging and vegetation clearance for modern agriculture. Reforestation begins as cultivated fields are abandoned, then re-seeded by trees that had continued to grow on uncultivated ridgetops and swamps. Some of these surviving trees were cohune palms that survived ring barking during forest clearance for milpa or 20th-century logging, or that were allowed to stand in the farm fields (Guderjan 1991:3; Hammond & Miksicek 1981:262; Standley & Record 1936:21, 24). Some sectors became so dominated by cohune palm as to be called “cohune palm forests.” Stands of cohune palms are sometimes signs of ancient farm fields.

Early stages of secondary rain forest growth are characterized by temporary, transitional species that do not persist in significant numbers into later stages of secondary growth (Standley & Record 1936:25). Post-agricultural-clearance pioneer plants include grasses, forbs, composites, “vine-like legumes, morning-glory and passion-flower” (Hammond & Miksicek 1981:263). Shrubs begin to establish themselves after about a year, along with nightshades (*Solanum* spp.) and chile (*Capsicum annuum*; Hammond & Miksicek 1981:263). In moister areas, such as filled-in *bajos*, shrubs are substituted with sedges, *Acacia cookii*, and *Bactris major* (Hammond & Miksicek 1981:263). Five to fifteen years after farm field abandonment, short trees grow, including *Trema micrantha*, *Guazuma ulmifolia*, *Cornutia pyramidata*, *Cecropia peltata*, *Lysiloma latisiliquum*, and *Cochlospermum vitifolium* (Hammond & Miksicek 1981:263).

After cultivation has been abandoned for 24 to 35 years, a closed *ramonal* forest sometimes develops (Hammond & Miksicek 1981:262-263). *Ramonal* forests contain a high proportion of plants that are suitable for human use. At Tikal, Cuello, and other sites, *ramonal* is found near site ruins, leading some archaeologists to believe that this is an artificial vegetation association resulting from Mayan forestry or cultivation habits. *Ramonal* is dominated by *Brosimum alicastrum* ("ramón"), which is especially common on calcareous soils (Standley & Record 1936:25). Other common plants include *Manilkara zapota, Castilla elastica, Pimenta dioica, Talisia oliviformis, Pouteria sapota, Spondias mombin,* and *Ficus* species.

Other transitional species characteristic of the secondary rain forests of northern Belize area *Cecropia obtusifolia, Ceiba pentandra, Cordia alliodora, Heliocarpus americanus, Inga* spp., *Miconia* spp., *Ochroma pyramidale, Schizolobium parahyba, Trema* spp. and *Trichospermum grewiifolium* (Standley & Record 1936:25).

MODERN VEGETATION ASSOCIATIONS OF THE BLUE CREEK AREA

This section uses the vegetation classification schemes introduced above to provide greater detail about the vegetation associations in the Blue Creek site area and at the Laguna Verde pollen core site.

Maya Research Program principal archaeologist Thomas Guderjan (1991:3) identified five major types of vegetation in the Río Bravo area of the Three Rivers Region; these are upland broadleaf forest (high rain forest), covering 63% of the land area; swamp forest, 20%; palm forest (a variety of rain forest), 8%; savanna, 2%; and marsh (a variety of wet savanna), 7 percent. The high rain forest is found mostly west of the Bravo/Boothe's escarpment system, in the Eastern Petén physiographic zone. The swamp forests, savannas, and marshes occur east of the escarpment.

Much of the Blue Creek site area (matching up to the site locations mapped in Guderjan 2004:238) is in permanent cultivation via mechanized agriculture (Great Britain, Directorate of Overseas Surveys 1976; Meerman & Sabido 2001b). On the agricultural lands, the natural vegetation associations have been substantially disrupted.

The remainder of the area, especially west of the escarpment, is blanketed by a type of high rain forest that is thoroughly described as a "tropical evergreen seasonal broadleaf lowland forest over calcareous soils: Tehuantepec-Petén variant" ecosystem (Meerman & Sabido 2001b). Common trees[1] include *Attalea cohune* (Arecaceae), *Brosimum alicastrum, Bursera simaruba, Cedrela odorata, Cupania belizensis* (Sapotaceae), *Cryosophila stauracantha* (Arecaceae), *Ficus* sp., *Lonchocarpus castelloi, Manilkara zapota, Matayba apetala* (Sapotaceae), *Metopium brownei, Pimenta dioica* (Myrtaceae), *Pouteria reticulata, Protium copal, Sabal mauritiiformis* (Arecaceae), *Spondias mombin, Swietenia macrophylla, Talisia oliviformis, Trichilia minutiflora,* and *Trophis racemosa.* The understory includes *Malvaviscus arboreus* (Malvaceae), *Piper jacquemontianum* (Piperaceae), Poaceae, and *Psychotria pubescens.*

Other vegetation associations are found in the Blue Creek area. Mangrove swamps are found on the west side of the bend in the road that runs south from Blue Creek Village, past Reinland. However, it is the escarpment ecotone (directly south, southeast, and east of the Blue Creek site area) that hosts the greatest variety of ecotypes, each occupying a relatively small land area. Areal ecotypes include the "short-grass savanna with shrubs," "tropical evergreen seasonal broadleaf alluvial forest," "tropical lowland tall herbaceous swamp," "tropical evergreen seasonal broadleaf lowland swamp forest: high variant," and "broad-leaved lowland shrubland: leguminous variant," as defined by Meerman & Sabido (2001b).

East of the escarpment and south of the Blue Creek village farming area is "short-grass savanna with shrubs," a fire-vulnerable lowland savanna. It is a "species poor but highly specialized ecosystem" (Meerman & Sabido 2001a:64). The savanna consists of scrublands or grasslands with dense clumps of small trees or shrubs. Cyperaceae is the dominant graminoid; other sedges and grasses are also common. Frequent woody taxa include *Acoelorraphe wrightii* (Arecaceae), *Calyptranthes* sp. (Myrtaceae), *Chrysobalanus icaco, Clidemia* sp. (Melastomataceae), *Curatella americana. Erythroxylum guatemalense, Hippocratea excelsa, Metopium brownei,*

---

[1] This section lists only vegetation represented in the Laguna Verde pollen core. Additional taxa characteristic of each ecotype are listed in the original sources.

Miconia sp. (Melastomataceae), *Mimosa albicans, Pinus caribaea,* and *Quercus oleoides.* Herbs, including *Borreria* sp., are frequent.

South of the savanna, and scattered in small patches in the general vicinity, is "tropical evergreen seasonal broadleaf alluvial forest." This is a seasonally-flooded riparian rain forest, found along the banks of the Río Bravo, along other rivers, and in lagoons (Meerman & Sabido 2001b:42). Frequent vegetation includes *Aristolochia grandiflora, Bactris* sp. and other Arecaceae, *Bucida buceras* (Combretaceae), *Cassia grandis* and other Fabaceae, *Cecropia peltata, Cordia gerascanthus, Ficus* sp., *Inga affinis, Inga vera, Licania platypus, Lonchocarpus guatemalensis, Pachira aquatica, Rinorea* sp., *Trichospermum grewiifolium,* and *Trophis racemosa. Attalea cohune* (Arecaceae) and *Bambusa vulgaris* (the introduced Poaceae, "bamboo") form dense patches.

South of the alluvial forest is a long strip of "tropical lowland tall herbaceous swamp." Vegetation associations are those of the wet inland savanna or the swamp forest. Frequent vegetation includes Poaceae and/or Cyperaceae (especially *Cladium jamaicense*, *Cyperus* sp., *Scirpus* sp., and *Scleria* sp.), a variety of herbs, and shrubs like *Bucida buceras* (Combretaceae) and *Acoelorraphe wrightii* (Arecaceae). *Typha latifolia* and palmettos are also found (Hammond & Miksicek 1981:263). Where such swamps occur in forested areas and have no drainage channel, they are locally known as 'sibals'" (Meerman & Sabido 2001b:72). The Laguna Verde pollen core was taken from a sibal swamp setting (see Chapter III).

Small patches in the Blue Creek area are the habitat of "tropical evergreen seasonal broadleaf lowland swamp forest: high variant." This is a low swamp forest that includes deciduous trees. It occurs on poorly-drained soils east and south along the escarpment, and in the *bajos* of the Eastern Petén Zone. Herbs and sedges grow in areas where the tree canopy is broken (Meerman & Sabido 2001b:43). Sometimes thick woody vines are found. Frequent tree species include *Bactris* sp., *Bucida buceras* (Combretaceae), *Coccoloba* sp., *Croton* sp., *Metopium brownei, Manilkara zapota, Sabal mauritiiformis* (Arecaceae), and *Swietenia macrophylla.*

Also found in small patches along the escarpment and in the Eastern Petén Zone, and sometimes occurring in association with the foregoing high-variant swamp forest, is the “broad-leaved lowland shrubland: leguminous variant.” The broad-leaved lowland shrubland is a low deciduous rain forest. Frequent vegetation includes *Acoelorraphe wrightii* (Arecaceae), *Bucida buceras* (Combretaceae), *Byrsonima bucidifolia, Chrysobalanus icaco, Coccoloba reflexiflora, Croton* spp., *Erythroxylum guatemalense, Eugenia rhombea* (Myrtaceae), *Manilkara zapota, Metopium brownei, Myrica cerifera, Swietenia macrophylla,* and abundant epiphytes.

Modern Vegetation Associations of the Laguna Verde Core Site

The Laguna Verde pollen core was extracted from a patch of the sibal swamp variant of the tropical lowland tall herbaceous swamp (see above). This swampy patch was situated in an area dominated by tropical evergreen seasonal broadleaf lowland forest (see above). Near the core site are areas characterized as swamp forest, inland savanna, and cohune palm forest (Great Britain Directorate of Overseas Surveys 1958a). At the time of pollen core extraction, the vegetation in the herbaceous swamp and surrounding swamp forest were surveyed, as described in Chapter I.

LITERATURE REVIEW OF POLLEN-VEGETATION STUDIES IN BELIZE AND THE PETÉN

A review of paleolimnological and palynological studies relating to the Late (or Terminal) Classic Period drought was given in Chapter III. Some of the same studies (Cowgill et al. 1966; Deevey 1978; Deevey et al. 1979; Islebe et al. 1996; Tsukada 1966; Vaughan et al. 1985) and others (Curtis 1998; Goman & Byrne 1998; Jones 1991; Leyden 1987) provide pollen sequences to contribute to the record of environmental change surrounding the Mayan era. Some of the studies (Leyden et al. 1998; Wiseman 1985) provide modern pollen-vegetation correlations so that certain pollen types can be used as indicators of past ecotypes. This section is a summary of those studies.

Holocene Pollen Sequence of the Petén, Guatemala

The most comprehensive pollen sequence for the Maya area comes from the Petén, where many paleolimnological studies have been conducted in the Lake District (See also Chapter III.). Vaughan et al. (1985:80-83) offered a good synthesis of the Petén Lake District pollen sequence, which is combined here with information from the other sources noted above.

Pre-Maya

A pre-Maya zone of aquatic and forest pollen dated to 7000 B.C. The abundant aquatic pollen included examples of pond weeds and cat-tails. Moraceae (*Brosimum* and *Ficus*) pollen was especially abundant. The high rain forest was represented by *Bombax, Manilkara, Sapium,* and *Thouinia.* The forest trees were mostly insect-pollinated and under-represented in the pollen record.

Early and Middle Preclassic Periods

A pollen zone representing an undisturbed open forest extended from approximately the late 3rd millennium B.C. until the 3rd century B.C., spanning the Early and Middle Preclassic Periods. Forest genera (*Bombax, Bursera, Coccoloba, Liquidambar,* and *Podocarpus*) were present in high absolute frequencies, indicative of a slow sedimentation rate. However, there were also high relative frequencies of herbaceous and grass pollen, showing that the extent of open, unforested land was also great. Pollen of trees that grow in clearings or open savanna (*Byrsonima, Cecropia,* Melastomataceae, *Quercus*) was common. The climate was probably similar to that of today.

Maya Zones

Deposition of pollen indicative of significant human disturbance occurred between the beginning of the Late Preclassic Period (3rd c. B.C.) and the Terminal Postclassic Period in the 17th century A.D. These "Maya Zones" were marked by indicators of extensive deforestation. Markers included clay-rich sediments; an increase in grassland or weedy types (C-4 plants) like Poaceae, high-spine Asteraceae, Cyperaceae, and Chenopodiaceae-*Amaranthus* pollen; and a corresponding decrease in arboreal pollen (C-3 plants) to less than 30 percent of total pollen. The amount of open, unforested land increased during this time, as there was little evidence of tropical forest taxa (such as Moraceae).

Coverage by savanna-type taxa increased during periods of relative dryness. Savanna trees and shrubs (such as *Byrsonima* and the Melastomataceae) and *Cecropia* reached their maxima during the Late Preclassic Period.

All grassland pollen types, except the low-spine Asteraceae, increased during the Early Classic Period. *Zea mays* was the only certain crop plant to leave traces in the pollen record, and its cultivation reached its maximum extent during the Classic Period. The low-spine Asteraceae increased during the Late Classic and Postclassic Periods. The Late Classic Collapse probably took place in “the minimum between two maxima of Ambrosiae [=*Ambrosia* and low-spine Asteraceae]” (Vaughan et al. 1985:86).

Late Classic Period Collapse

No dramatic changes in the pollen spectrum were noted at the time of the Maya Collapse. Prevalent taxa were Poaceae, herbs, savanna trees, and low-spine Asteraceae. Even though the vegetation was open, there was an interruption of the spread of agricultural weeds. Slight rises in *Cecropia* and other Moraceae indicate some temporary reforestation, which was temporarily reversed during the Postclassic Period.

Post-Maya Reforestation

The pollen of indicators of openness (*Ambrosia*, Poaceae, *Quercus*) decreased during the Postclassic Period. Meanwhile, forest taxa (Moraceae, *Terminalia*, *Zanthoxylum*) increased, indicating reforestation after the Maya Collapse. Once the area was depopulated, the rain forest probably returned to an advanced (secondary) stage within two centuries, recapitulating the synthesis of rain forest from savanna that occurred in the early Holocene.

Holocene Pollen Sequence of Belize

Fewer studies have concerned themselves with the pollen sequence of the Maya Lowlands outside the Petén. One that has came from palynologist John Jones, who wrote his doctoral dissertation (1991) about the pollen of Cobweb Swamp, Belize. Cobweb Swamp is located approximately 50 km east of Blue Creek.

Pre-Maya

In samples dated between 6612 and 4468 B.C., Jones found no tree pollen and an increased abundance of open- or disturbance-associated taxa (Asteraceae, Cheno-Ams, and Poaceae) in strata thought to represent a cattail and sedge swamp or open freshwater savanna. Sometime prior to 4468 B.C., the first forest in the area began to develop, as demonstrated by the appearance of Moraceae/*Brosimum* sp. pollen, representing "undisturbed, principal-growth forest" or incipient tropical lowland forest (Jones 1991:77-78). Around 4468 B.C., the pollen of Cyperaceae, Moraceae, *Typha*, and disturbance taxa all decreased in abundance; forest taxa dominated. Around 4462 B.C., swamp salinity increased, possibly due to a rising sea level. Salt-tolerant taxa, like *Rhizophora* (red mangrove), increased, though white mangrove (Combretaceae) was present throughout.

Early and Middle Preclassic Period

At Cobweb Swamp, human settlement began around 2462 B.C. Near this time, *Rhizophora* and Moraceae pollen (tree pollen) decreased. As in the Petén, the area was open. Disturbance indicators, including the weed *Borreria*, Cheno-Ams, and particulate carbon (charcoal), increased. The first possible cotton pollen appeared.

Between 1681 and 400 B.C., the water in Cobweb Swamp was deeper, sedimentation was faster, and marl was deposited (Jones 1991:82). Human clearance of trees could have increased water runoff into the swamp (Jones 1991:82). The first *Zea mays* pollen appeared at this time (Jones 1991:83).

Late Preclassic Period through Present Times

After 400 B.C., pollen of disturbance-indicating Cheno-Ams decreased, while *Myrica* (tree) pollen increased, possibly indicating site abandonment (Jones 1991:83). By A.D. 1414, the red mangrove/sawgrass swamp regenerated. Later, *Rhizophora* pollen declined, while Combretaceae and Malpighiaceae pollen increased, possibly reflecting colonial-era logging practices.

A history of forest clearance during Mayan times is corroborated by a study of the lake islands and uplands between Colha and Chetumal Bay, northern Belize. This study by Thomas Hester and his team from The University of Texas is known only through a secondary report (Coe 2005:46-47), as the original report was not cited completely and may not have ever been published. It was found that pollen dated between 3500 and 1900 B.C. demonstrated widespread forest clearance. Maize and manioc were cultivated at the margins of swamps. From 1500 to 900 B.C., forest clearance continued as agriculture intensified.

INDICATOR TAXA

Palynologists look for combinations of plant taxa to indicate the type of ecosystem that was probably present at the time of sample deposition. This procedure, with its potential pitfalls, is covered in the chapter introduction. This section uses the palynological literature (especially Bush 1995; Goman & Byrne 1998; Islebe et al. 1996; Jones 1991; Lambert & Arnason 1978, 1982; Leyden et al. 1998; Vaughan et al. 1985; and Wiseman 1985) to establish the categories of indicator taxa that were used in making the environmental interpretation of the Laguna Verde pollen core. Categories are dependent upon the habitat preference or ecological significance of the grouped plants. Consultation of the palynological literature was important in addition to the notation of the modern vegetation associations of Belize and of the Blue Creek area (covered earlier in this chapter) because the palynological literature makes apparent which taxa tend to be under-represented in the pollen spectrum. Furthermore, by using categories of indicator taxa similar to those of other palynologists, I enable the comparison of environmental change at Laguna Verde to environmental change elsewhere in the Maya Lowlands in the environmental interpretation at the end of this chapter. This section discusses only taxa represented in the Laguna Verde pollen core; some researchers have identified the pollen of additional taxa that represent the same ecotype, but which were not found at Laguna Verde.

Indicators of Active Agricultural Plots

In the Laguna Verde pollen core, *Zea mays* pollen is a certain indicator of active agricultural plots. Other possible indicators are Cucurbitaceae, Malvaceae, *Physalis*, and *Saccharum officianarum.*

Chapter I explains the difficulties in identifying the pollen of many members of the Cucurbitaceae (melon and squash family) and the Malvaceae (cotton family) to the generic level. The pollen identified from these families may have come from agricultural plots or gardens growing cucumber, melon, or cotton, though it is improbable that entomophilously-dispersed pollen from off-site locations would have reached Laguna Verde. More likely, the pollen came from wild relatives of known cultivars. The earlier grain of Cucurbitaceae pollen could have come from a wild plant that was casually exploited for its fruit. Several species of Malvaceae have swamp or mangrove associations and may have fared well at Laguna Verde, while others grow as weeds in disturbed areas (Balick et al. 2000:68-71). Many of the non-economic Malvaceae that produce pollen that looks much like that of cultivated cotton are "secondary successional plants which are highly correlated with other agricultural indicators" (Wiseman 1983:116). Even if the observed pollen did not come from cultivated cotton, it may be indicative of agricultural practice in the area. The pollen of Cucurbitaceae and Malvaceae did not appear in pollen samples until after the Maya settled at Blue Creek, so the identification of these types as cultivars is not unreasonable.

The observed *Physalis* pollen may likewise have come from cultivated tomatillo or a wild (or casually exploited) relative. *Physalis philidelphica* is hermaphroditic and insect-pollinated. It cannot self-pollinate, so isolated plants will not fruit. This argues in favor of the plant's growth among others of its species, whether in a garden or in a wild stand.

Saccharum officianarum, "sugar cane," is the leading crop in present-day Orange Walk District. The pollen of this cultivated grass is medium-sized, measuring 51-56 μ in diameter (Roubik & Moreno 1991:44-45), and its appearance could not be distinguished from other Poaceae grains in the samples. Still, sugar cane pollen should account for some of the Poaceae pollen in the upper (postcolumbian) portion of the Laguna Verde column.

Open Environment/Disturbance Indicators

In the Laguna Verde pollen core, the following taxa are considered to be disturbance indicators: Asteraceae, *Borreria, Cecropia, Celtis,* Cheno-Ams, Poaceae, Solanaceae, *Trema,* and Urticaceae. Some of these plants (Asteraceae, *Borreria* , Cheno-Ams, Poaceae, and Solanaceae) are herbs or weeds that are quick to colonize agricultural fields and their margins, yards, roadsides, and other open areas (Arvigo & Balick 1993:100; Balick et al. 2000:61; Dunning et al. 1998b:144-145; Goman & Byrne 1998; Islebe et al. 1996:265, 267, 269; Jones 1991:71, 81; Leyden 1987:407, 409, 411; Vaughan et al. 1985; Wiseman 1985:69). Cheno-Ams, in particular, are not found in forests, suggesting that "Cheno-Ams are quickly replaced in a regenerating forest" (Jones 1991:81). The Poaceae are generally accepted as indicators of open environments because they need sunlight to grow, while growing close to the ground. However, Poaceae are pandemic and grow in nearly all habitats. The Poaceae are wind-pollinated and produce large amounts of pollen, but "[m]ost grass pollen is dispersed close to the ground and thus does not become airborne over great distances" (Bryant, personal communication, 2008). Caution must be applied when using Poaceae to indicate openness or aridity, because its pollen signal is easily distorted when the local flora is comprised primarily of plants with either an anemophilous *or an entomophilous* pollen syndrome (Bush 2002).

The other disturbance taxa (*Cecropia, Celtis, Trema,* and Urticaceae) are "pioneer" trees, or early successional trees that are quick to colonize recently opened or disturbed areas (Arvigo & Balick 1993:209; Balick et al. 2000:58; Bush 1995:596, 602; Pohl & Miksicek 1985:15). They are also found in forest gaps, forest margins, and the edges of riparian forests (Bush 1995:596, 602; Meerman & Sabido 2001a:6). These trees are fast colonizers because they have an anemophilous pollen syndrome, produce large amounts of pollen, and have a high pollen dispersal capacity (Bush 1995:596, 602; Bush 2002:9; Domínguez-Vázquez et al. 2004).

Some of the disturbance taxa have unusual environmental tolerances. For instance, *Celtis* is drought-tolerant, and many of the Cheno-Ams are halophytes, growing in salty soils. Characteristics such as these contribute to the ability of the disturbance taxa to colonize locations that are unsuitable for other plants.

Croton, a frequent swamp forest taxon, can also be a disturbance indicator. Because its growth is dependent upon high levels of sunlight, it grows best in open areas.

Pollen samples from disturbed environments are also marked by an increased abundance of particulate carbon (charcoal), which often results from anthropogenic burning of vegetation to clear land for agricultural production.

Indicators of Inland (Dry) Savanna

Savannas are dominated by graminoid vegetation (usually Poaceae and/or Cyperaceae), along with herbs such as *Borreria*. However, dry savannas often contain clumps of shrubs or trees, and can grade into a dry forest subtype of high forest. Typical tree taxa are *Byrsonima*, *Curatella americana,* Fabaceae, *Erythroxylum guatemalense, Mimosa*, *Pinus*, and *Quercus*. *Hippocratea* is also found. Tree taxa shared with other ecotypes defined here are Arecaceae, *Alchornea,* Melastomataceae, *Metopium brownei,* Myrtaceae, and Sapotaceae.

Some inland savanna trees are also commonly found in pine-dominated forests, as both ecotypes are relatively dry. *Curatella americana* is frequent in pine forests, as is *Byrsonima. Byrsonima crassifolia* grows, often in large stands, in the open pine forests and savannas below 1800 m altitude in the tropics and subtropics of the New World. The trees are highly drought-tolerant.. *Quercus* is native to the northern hemisphere, but grows from cold latitudes through the tropics, in deciduous and evergreen forms. In Belize, *Quercus* is found in savannas and montane forests, and is a good indicator of an open environment, especially when found in conjunction with Poaceae pollen (Dunning et al. 1998b:145).

In contrast to most tropical rain forest trees, which are insect-pollinated and produce little pollen, more trees of the inland savanna and montane forest (discussed below) are wind-pollinated and produce large amounts of pollen. These trees tend to be over-represented in the pollen record, and the presence of their pollen could mistakenly give the impression that a forest was once present at the site of pollen deposition, when in fact the pollen arrived at an open (unforested) savanna via long-distance transport.

Indicators of Montane (or Temperate) Forest

Montane/temperate forest does not occur in the modern Three Rivers Region. However, taxa characteristic of such a forest are found at higher elevations in the Maya Mountains to the south, and in neighboring Mexico and Guatemala. Many temperate forest taxa produce large quantities of pollen that may have been transported by wind to arrive at Laguna Verde. The temperate/montane forest is indicated by *Alnus*, *Carya*, Cupressaceae, *Ostrya*/*Carpinus*, *Podocarpus, Quercus, Tsuga*, and *Ulmus.* Temperate forest taxa shared with other ecotypes are *Celtis, Myrica,* Myrtaceae, *Pinus,* and *Quercus*. *Pinus* is, of course, also the dominant taxa in pine forests, such as that of the August Pine Ridge northeast of Blue Creek.

Indicators of Open Water or Wet Savanna

Some taxa in the Laguna Verde pollen core can be considered indicators of the presence of open water in the swamp. Certain herbaceous taxa are indicators of wet savanna; for this dissertation, those indicators are Cyperaceae, *Juncus, Lippia nodiflora,* Nymphaceae, *Typha angustifolia, T. domingensis, T. latifolia,* and *Utricularia.*. Poaceae, some Asteraceae, and other herbs are also frequent in wet savannas (Cowgill et al. 1966:12; Meerman & Sabido 2001b), but in the location in question, pollen from those families will show a stronger signal when its origin is instead from an open, disturbed area or dry savanna. Wet areas that are home to clumps of trees or forests are considered "swamp forest," a separate category discussed below. Because the ecotypes grade into one another, some tree taxa (Arecaceae, Combretaceae/Melastomataceae, *Laguncularia racemosa, Myrica cerifera,* and *Rhizophora mangle*) overlap the two categories. Finally, while not generally characteristic of wet savannas, *Acacia*, *Bursera simaruba, Coccoloba,* and Fabaceae can be considered as secondary indicators of wet savanna, since I observed these taxa growing in the Laguna Verde swamp.

Cyperaceae pollen was extremely abundant in the Laguna Verde pollen core, outranked only by Combretaceae/Melastomataceae pollen. This is no wonder, given that they area where the core was driven is currently a sedge (*Cladium jamaicense*)-covered swamp.

Sedges are wind-pollinated, but do not produce pollen in large amounts (Bryant, personal communication, 2008). Sedge pollen is dispersed close to the ground, and therefore tends not to be widely dispersed (Bryant, personal communication, 2008). Sedges have centers of diversity in the tropics, but are widely distributed. They grow mostly in nutrient-poor areas and in wetlands. Because they require so much water, they are most often found "in and around marshes, bogs, along river banks, and along the edges of lakes" (Bryant, personal communication, 2008). In a pollen sample not directly extracted from a sedge swamp, the presence of Cyperaceae pollen can indicate open land or anthropogenic disturbance (Dunning et al. 1998b:145).

Typhaceae is a family of perennial plants of wet habitats. Members of the genus *Typha* are all known as “cattails.” They grow “along the edges of swamps, rivers, marshes, bogs, and lakes” (Bryant, personal communication, 2008). All are wind-pollinated, but because the genus is aquatic, the occurrence of *Typha* in a pollen record is indicative of local, as opposed to regional, conditions (i.e. conditions near the lake or swamp from which pollen samples were collected; Dunning et al. 1998b:145). *Typha angustifolia* grains are fragile and are rapidly destroyed in alkaline environments, so they are not often found far from their production source (Bryant, personal communication, 2008). Pollen of *T. lagifolia* degrades rapidly in warm, microbial, and comparatively aerobic circumstances, but can be well-preserved when deposited in peat bogs (Sandster & Dale 1961:38-39, 43, 1964:437, 448). Of the *Typha* species, grains of *T. domingensis* were the most commonly observed in the Laguna Verde core.

Observing the present, ongoing increase in marshes dominated by *T. domingensis* over other marsh types, Rejmánková et al. (1995) studied freshwater marshes in northern Belize. They proposed that, after climatic changes (i.e. warming) caused higher water levels and increased salinity, the Maya abandoned wetland agriculture (Rejmánková et al. 1995:29). The freshwater marsh plant communities that followed cultivation could have been dominated either by *Cladium jamaicense* (Cyperaceae; “sawgrass”), *Eleocharis cellulosa* (Cyperaceae; “rush”), or *Typha domingensis* (Typhaceae; “cattail”). It was determined that marshes with nutrient enrichment caused by erosion or human settlement upland were more likely to be dominated by *C. jamaicense* or *T. domingensis* (Rejmánková et al. 1995:34). Which plant became prevalent depended on nutrient availability, hydroperiod, and frequency of fires (Rejmánková et al. 1995:34). An increase in salinity, “related to changes in climate, sea level, or ditching and clearing wetland fields, would have favored [*C. jamaicense*] or [*E. cellulosa*]” (Rejmánková et al. 1995:34). Human disturbance may thus be responsible for the creation of the Laguna Verde sawgrass swamp, though it is not clear that the relative abundances of the pollen of Cyperaceae and *T. domingensis* increased as regional agricultural production was intensified.

In a palynological study at Laguna Tamarindito, Petén, Guatemala, *Typha* pollen was found to increase with the rate of sedimentation during the Mayan Classic period, a time of high erosion (Dunning et al. 1998b:145). There, *Typha* probably also contributed much to the organic content of the sediment (Dunning et al. 2002:145).

In a study of the habitats of malaria vector mosquitoes in northern Belize, Pope et al. (2005) found that marshes adjacent to agricultural fields (particularly those growing sugar cane) had higher soil phosphorous, probably coming from agricultural runoff, and had a higher percentage of cover by *T. domingensis* than "unimpacted" marshes bordered by forest or scrub. However, present land use (i.e. scrub or forest vs. agricultural land) accounted for only 5-20 percent of the variance in the distribution of *T. domingensis*, so other [unstated] factors must also have impact (Pope et al. 2005:1231). Pope et al. concluded that agricultural runoff may cause an increase in coverage by *T. domingensis* in places where it already grows, but "will have less influence in marshes that lack *Typha domingensis* to begin with" (Pope et al. 2005:1231). For the Laguna Verde study, this information means that a correlation may be sought between an increase in the relative abundance of *T. domingensis* pollen and proximity (Note: The buffer zones considered in the study of Pope et al. included land to 100 m from the edge of present-day swamp; 2005:1229) to agricultural land. An increase in *T. domingensis* pollen would particularly be expected in marshes in proximity to sugar cane fields after the introduction of sugar cane agriculture in the 17th century.

Juncus sp. is found in all wet areas of the world, but is rare in the tropics. For its pollen to have been present in the Laguna Verde core, the plant may have had a substantial presence in the swamp.

Nymphaea has a cosmopolitan distribution, but it cannot compete with marsh graminoids because of its high light requirements. Therefore, it is most characteristic of open swamps (without a closed canopy; Wiseman 1983:110).

Utricularia species are terrestrial, subaquatic, and aquatic herbs (Balick et al. 2000:140-141). The genus is found worldwide, growing in fresh water and wet soil. It grows well in soils poor in dissolved minerals. *Utricularia* sp. is self-pollinated or has an entomophilous pollination syndrome, so its pollen can be expected to be rare in the record.

Indicators of Swamp Forest

Swamp forests are home to a greater abundance of arboreal taxa than are wet savannas (which are dominated by herbaceous taxa). However, as noted above, some of the same tree taxa may be found in both ecotypes or on their shared margin. Indicators of swamp forest in this dissertation are *Bactris* (and other Arecaceae), *Bravaisia, Croton, Metopium brownei,* Myrtaceae, *Pachira aquatica,* Sapotaceae, and *Swietenia macrophylla*. *Tabernaemontana* can represent advanced swamp forest. Tree taxa also found in the wet savanna are Arecaceae, *Coccoloba*, Combretaceae/Melastomataceae, *Laguncularia racemosa, Myrica cerifera,* and *Rhizophora* mangle. *Bursera simaruba* can be found in the swamp forest, but is a better indicator of high forest. Secondary indicators of swamp forest are Apocynaceae, *Desmoncus orthacanthos, Ficus*, *Pinus caribaea hondurensis,* and *Pinus oocarpa*, which grow in the Laguna Verde swamp today.

Palms of the family Arecaceae are abundant in Belize, forming impenetrable thickets in the swamp forest and serving as a major component of the understory of the high forest (Jones 1991:23; Standley & Record 1936:80). Many palms have economic significance (oil, construction, food), so it is likely that palms were “spared by the Maya and allowed to grow alongside the crops” (Jones 1991:88). Standley & Record (1934) opined that the forests regenerated rapidly after the Maya abandoned cultivation because they allowed palms to remain in the fields (Jones 1991:88). Modern farmers allow economically-significant trees to stand (Jones 1991:88). Although milpa farmers seem to spare palms, palm pollen is seldom found in pollen cores in the Petén Lakes District (Vaughan et al. 1985:82). Only 17 grains of Arecaceae pollen were found in the Laguna Verde pollen samples, in spite of the fact that live palm trees were observed in the modern swamp. Jones (1991) found Arecaceae pollen at relative frequencies less than five percent at Cobweb Swamp. Members of the family are insect-pollinated, though their fossil pollination does not rank particularly low among Neotropical plants (Bush 1995:605). This means that the relative frequency at which Arecaceae pollen appears in fossil pollen samples should not be unduly swamped out by other pollen-producers. Arecaceae pollen grains appear to be thin-walled and fragile (personal observation), so perhaps they are apt to be destroyed relatively soon after deposition, and therefore not found in fossil pollen samples in an abundance representative of their presence in Belizean swamp forest, wet savanna, and high forest.

Croton species are a frequent component of swamp forest (Meerman & Sabido 2001b), but can also indicate disturbance. *Croton* grows well in clearings, on roadsides, and at forest margins (Arvigo & Balick 1993:181; Balick et al. 2000:108).

Metopium brownei is abundant in karst limestone hills, on acidic savannas, in flat lowlands over limestone (particularly in northern Belize), and generally in calcareous soils (Meerman & Sabido 2001a:6; Standley & Record 1936:37). It is found in swamp forest and intermediate forest, and in thickets in open areas (Standley & Record 1936:37, 226). This tree is often found in association with *Manilkara zapota* (Sapotaceae; Standley & Record 1936:37).

Pachira aquatica grows in swamp forests, but is also found along watercourses and in fields (Arvigo & Balick 1993:167; Standley & Record 1936:250).

Swietenia macrophylla is most abundant on limestone soils, but “is not strictly dependent on these and its abundance tends to reflect past disturbance history” (Meerman & Sabido 2001a:6).

The Apocynaceae are pandemic in the tropics, and most species are insect- or animal-pollinated (Bryant, personal communication, 2008). *Tabernaemontana alba* is “frequent in thickets or forest; widely distributed in tropical America” (Standley & Record 1936:329), but it is moth-pollinated and hermaphroditic, and therefore underrepresented in the pollen record (Bush 1995:607).

Indicators of High Forest/Lowland Tropical Rain Forest

For this dissertation, the chief indicators of high forest, or lowland tropical rain forest, are *Acalypha, Alchornea,* Anacardiaceae, *Brosimum alicastrum, Bursera simaruba, Cedrela odorata, Cordia*, Euphorbiaceae, Fabaceae, Flacourtiaceae, *Heliocarpus, Ilex, Licania*, *Lonchocarpus*, some Malpighiaceae, Meliaceae, Moraceae, some Rubiaceae, Sapindaceae, *Spondias, Talisia oliviformis, Thouinia, Trichilia minutiflora,* Urticaceae, *Virola,* and *Zanthoxylum.* Most of these are arboreal species. Representative of the understory are herbaceous taxa from the Malvaceae and Piperaceae, and *Psychotria*. High forest taxa also found in the wet savanna or swamp forest are *Acacia*, Arecaceae, Burseraceae, *Bursera simaruba, Cecropia,* Combretaceae/Melastomataceae, *Ficus*, *Metopium brownei*, Myrtaceae, *Pouteria reticulata* and other Sapotaceae, and *Swietenia macrophylla*. High forest taxa also found in the dry savanna are *Alchornea*, *Byrsonima, Hippocratea,* and *Mimosa*.

Some of these taxa, along with a few others, are characteristic of particular subtypes of high forest. The “alluvial forest” subtype is indicated by *Aristolochia, Cassia* and other Fabaceae, *Inga*, *Licania, Rinorea*, and *Trichospermum grewiifolium*, in addition to the above-mentioned *Bactris* and other Arecaceae, Combretaceae, *Cecropia peltata, Cordia gerascanthus, Ficus*, *Lonchocarpus, Pachira aquatica,* and *Trophis racemosa.* In the understory, *Attalea cohune* (Arecaceae) and *Bambusa vulgaris* (the introduced Poaceae, “bamboo”) form dense patches (Meerman & Sabido 2001b).

Some high forest taxa are also found in disturbed sites, such as old fields and yards; these are *Acalypha, Bursera simaruba,* and Urticaceae (Arvigo & Balick 1993:63, 119; Balick et al. 2000:106-107; Domínguez-Vázquez et al. 2004). The Urticaceae thrive in open areas, and farmers consider them to be pesky weeds (Bryant, personal communication, 2008). Because they are explosively wind-pollinated and produce a large number of small pollen grains that can be blown far from their source of origin, they easily colonize disturbed areas and the forested margins of riparian areas (Bryant, personal communication, 2008; Bush 1995:602). *Bursera simaruba* is an element of primary as well as secondary vegetation, and is often associated with disturbed sites

(Domínguez-Vázquez et al. 2004). The tree grows quickly, and often appears as a pioneer species during reforestation. It has adapted to tolerate habitats that include strong winds and salty and calcareous (but not soggy) soils. However, *B. simaruba* is most strongly characterized as a tropical deciduous forest tree, and its presence in a pollen record represents forested (as opposed to open or savanna-like) environments (Dunning et al. 1998b:145). *Bursera* pollen may be found in conjunction with the pollen of other forest trees, such as Combretaceae and Moraceae (Dunning et al. 1998b:145). *Bursera* is insect-pollinated, and produces a small quantity of pollen that may not be representative of the true abundance of the tree (Tsukada 1966:63).

Though not common in disturbed areas, the [dry-]seasonally-deciduous tree *Cedrela odorata* has greater distribution in early-stage secondary rain forest than it has in advanced high rain forest (Standley & Record 1936:25).

Good indicators of high forest are *Brosimum* and other Moraceae, Combretaceae, and *Cordia*. Some species of *Cordia* are often found in the high forest, but they may be underrepresented in the pollen record (Standley & Record 1936:335, 337). *Cordia* spp. are hermaphroditic and have “deep-throated” flowers, and so must rely on long-tongued pollinators (rather than wind, for example) for their reproduction (Bush 1995:597, 606). *Cordia* pollen is thus most likely to be found in a sedimentary pollen record when flowers fall, or are washed, into the body of water from which a pollen core was extracted (Bush 1995:597). The Moraceae are tropical deciduous forest trees, and their presence in a pollen record often represents forested environments (Dunning et al. 1998b:145). *Brosimum* is insect-pollinated, but produces large quantities of pollen (Bush 1995:602). Pollen records from northern Belize and central Petén show that high levels of *Brosimum* pollen vary inversely with disturbance indicators (Pohl & Miksicek 1985:14), meaning that this tree is more likely to flourish in undisturbed locations. Likewise, dry savanna types like *Byrsonima* and *Quercus* increase when Moraceae decrease (Vaughan et al. 1985).

Indicators of Secondary Forest

Certain taxa are particularly common in successional scrub and secondary forest. These are *Acacia, Brosimum* and other Moraceae, *Cassia, Cecropia, Croton,* Piperaceae, Sapotaceae, *Trema,* and *Zanthoxylum.* *Bursera simaruba* and *Cedrela odorata* may also be found. With the exception of Piperaceae, each of these taxa has already been mentioned as an indicator of at least one other ecotype. For this dissertation, a pollen sample could be considered to represent secondary forest when it has a high proportion of these taxa, or when it was preceded in the column by disturbance indicators. However, because representation by rain forest taxa occurred at very low levels throughout the Laguna Verde pollen core, the identification of secondary forest was not useful.

Piperaceae has a pantropical distribution, and is a common component of the understory of the high forest. The family includes edible and ornamental peppers, so some members (like the genus *Piper*) are spread anthropogenically and are considered to be an invasive problem.

THE LAGUNA VERDE POLLEN DIAGRAM

Figure 9 is a pollen diagram that displays the relative abundances of significant taxa identified in 50 of the 62 samples from the Laguna Verde pollen core. The diagram is based on the counts of pollen taxa represented in the Laguna Verde pollen core (Appendix B) and the conversion of those counts to relative percentages of grains counted in each sample (Appendix C). Pollen samples containing a statistically-insignificant amount of pollen were excluded from the diagram (Figure 9). These samples contained less than 150 pollen grains and had a pollen concentration value of less than 1,000 grams/gm or 2,500 grains/cc of sediment. Samples excluded were from the depths 202-203, 206-207, 210-211, 214-215, 219-220, 221-222, 224-225, 260-261, 370-371, and 372-373 cm below the surface of the swamp water. Two samples from the modern surface were also excluded because they may not have been deposited contiguously with the top sample from the column.

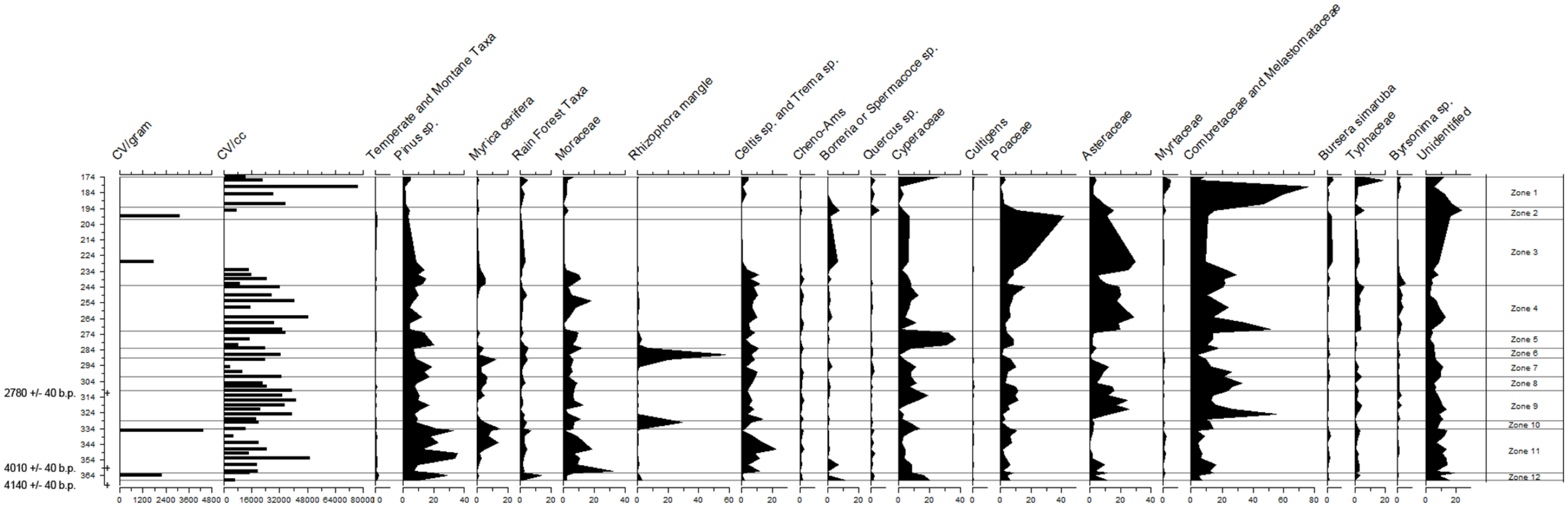

Figure 9. Laguna Verde pollen diagram.

The y-axis of the diagram labels samples according to their depths (in cm) below the surface of the swamp water. Stratigraphic Zones 1-12 are identified. These correspond to the stratigraphy given in Chapter III, except that the strata from 243-201 cm are considered as a single unit, and the strata 291-289 cm and from 289-283 cm (containing similar sediment but collected at the ends of different pipes) are united in the diagram. The first two x-axes plot the concentration values of the samples in grains/gm or grains/cc, depending upon the unit of measurement of each sample. Concentration values range from 1,774 to 4,375 grains/gm, and from 3,902 to 77,400 grains/cc.

The relative abundances of nineteen significant pollen taxa are then plotted for each sample. The category "unidentified" encompasses both pollen grains that could not be identified due to their degradation, and grains that were adequately preserved but could not be identified with available resources. The relative abundance of unidentified grains ranged from 2.9 percent in the sample from 249 to 250 cm, to 23.4 percent in the sample from 195-196 cm. Three variables are groups of taxa, within which each taxa occurred infrequently but had significance when considered as part of a group. The first, "Temperate and Montane Taxa," includes *Alnus, Carya,* Corylaceae/Betulaceae, Cupressaceae, *Ostrya/Carpinus, Podocarpus, Tsuga,* and *Ulmus.* These pollen grains are likely to have had a distant origin. *Quercus* and *Pinus* can also have temperate or montane affiliations, but they are locally present, and are frequent components of inland savanna vegetation. They are therefore considered as separate variables in the diagram. The second group, "Rain Forest Taxa," includes the pollen of many taxa typically present in Belizean rain forests. These are *Acalypha*, *Alchornea*, *Anacardium occidentale,* Anacardiaceae, cf *Andira inermis,* Aristolochiaceae, cf *Banara guianensis*, cf *Bauhinia divaricata, Bauhinia herrarae*, *Cedrela odorata*, *Cordia*, *Cordia alliodora,* Euphorbiaceae cf *Gymnanthes lucida* or *Chamaesyce thymifolia*, Other Euphorbiaceae, *Exothea diphylla*, Fabaceae cf *Lonchocarpus*, *Heliocarpus americanus*, *Ilex*, *Licania*, Malpighiaceae cf *Heteropterys laurifolia*, Other Malpighiaceae, *Mangifera indica*, Meliaceae, Myristicaceae, *Piper*, cf *Psychotria*, cf *Rinorea squamata*, cf Rubiaceae, Sapindaceae, *Sapindus saponaria*, *Spondias* sp., *Spondias mombi*n, cf *Spondias* *purpurea*, *Talisia oliviformis*, cf *Thinouia myriantha*, *Trichilia hirta*, cf *Trichospermum grewiifolium*, Urticaceae, and *Zanthoxylum*. Because many of these taxa have an entomophilous pollen syndrome and produce only small quantities of pollen, but share significance as rain forest taxa, they are diagrammed together as a single variable. The third group, "Cultigens," includes pollen of cultivars or possible cultivars. These are Cucurbitaceae, Malvaceae, *Physalis*, and Poaceae (100 μ diameter or larger).

THE ARBOREAL/NON-ARBOREAL/AQUATIC POLLEN SUM

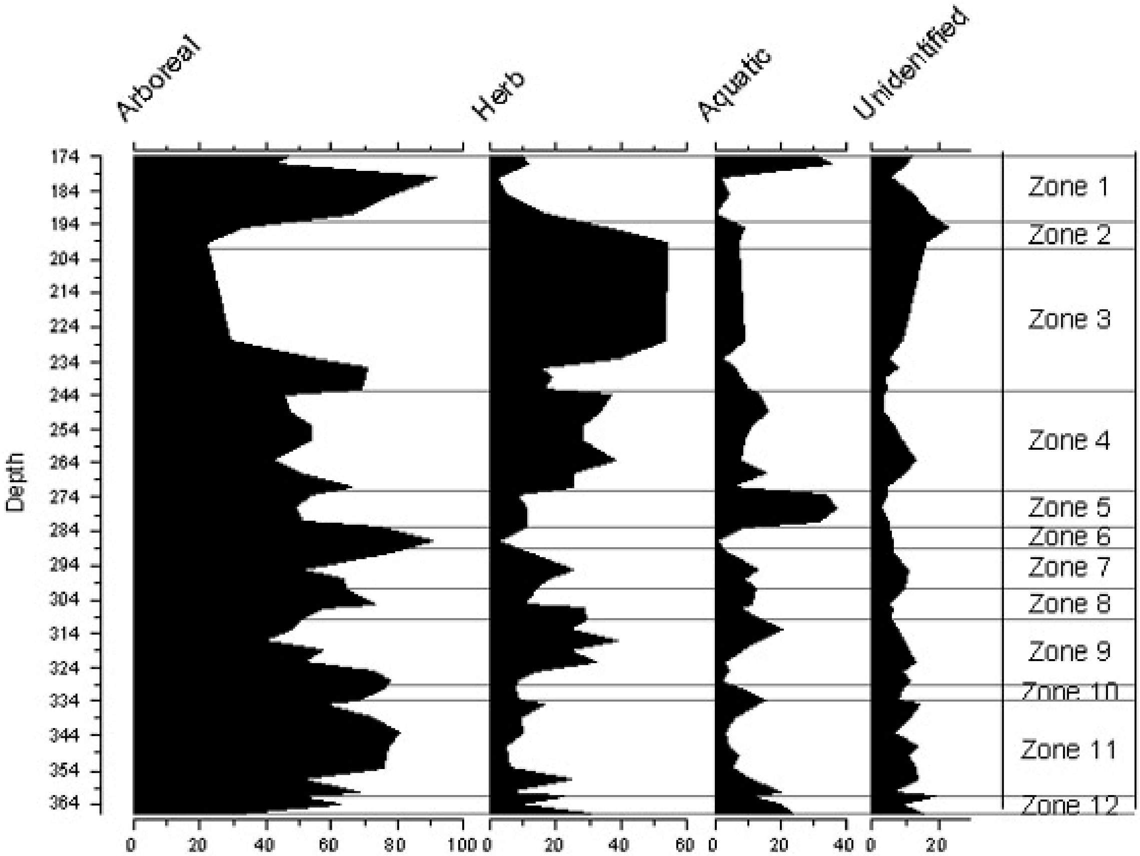

Figure 10. Arboreal/non-arboreal/aquatic pollen diagram.

Figure 10 displays shifts in the relative percentages of all arboreal, non-arboreal, and aquatic taxa. The fourth category ("Unidentified") combines indeterminate and unknown grains, to round out the pollen sum. Unlike the pollen diagram (Figure 9), which includes only the taxa with greatest representation in the core, Figure 10 includes all taxa that were observed. Taxa assigned to the "non-arboreal" category are Amaranthaceae, Apiaceae, Aristolochiaceae, Asteraceae, *Bauhinia herrarae*, *Borreria* sp. or *Spermacoce* sp., *Borreria laevis=Spermacoce assurgens,* cf Campanulaceae, Cheno-Ams, *Cissus* sp., *Commelina* sp., *Croton* sp., cf Cucurbitaceae, *Desmodium* sp., Fabaceae cf *Machaerium seemanii* and cf *Melilotus* sp., *Hippocratea volubilis,* Lamiaceae cf *Hyptis* sp., *Lantana* sp., cf *Lilium* sp., Loranthaceae, Malvaceae, cf *Markea* sp., cf Orchidaceae, *Physalis* sp., *Piper* sp., Poaceae, Scrophulariaceae, Solanaceae, and cf *Vitis tiliifolia.* Taxa assigned to the "aquatic herb" category are Cyperaceae, *Justicia campechiana, Juncus marginatus*, Nymphaceae, *Phyla nodiflora=Lippia nodiflora,* all three *Typha* sp., and *Utricularia* sp. All other taxa identified in the Laguna Verde pollen core are included in the "arboreal" category.

QUANTITATIVE STUDIES OF THE LAGUNA VERDE POLLEN CORE

A survey of the literature in my personal collection shows that most palynologists do not apply non-parametric or multivariate statistics to their work. Perhaps a lack of mathematical inclination among archaeological palynologists who approach palynology from an anthropological background leads to the frequent absence of statistical support in the palynological literature. This is a shame, because the advances in computing and software during the last 30 years (or so) have virtually eliminated the need for making difficult calculations by hand. The archaeological palynologist needs only to know which methods can appropriately applied to his data; check to make sure the data satisfies any assumptions of the tests; and correctly interpret the results. Palynologists should confirm that their subjective conclusions are mathematically "real" before publishing dramatic results. As archaeological palynologists continue to build a scientific and objective discipline, we should not be afraid to attempt to use quantitative methods in our work. Collaboration with applied statisticians can help us in our efforts. Indeed, many methods for statistical applications in stratigraphic palynology have been developed by applied statisticians in collaboration with paleoecologists (e.g. Birks 2005; Birks & Gordon 1985), rather than by the paleoecologists themselves.

To fortify the subjective conclusions that can be drawn from examination of the pollen diagram, quantitative and statistical methods (including descriptive statistics, Pearson correlation, and ANOVA regression) are used here to analyze data from the Laguna Verde pollen core. SPSS software was used to perform the calculations. Samples included in the statistical analyses were the same statistically-valid samples used in the creation of the pollen diagrams (as explained above, in the section “The Laguna Verde Pollen Diagram”), unless otherwise noted. That is, the two surface samples were excluded, because they were not part of the stratigraphic column; and the ten samples with very low concentration values and pollen sums were also excluded. Before statistical analysis could proceed, it was necessary to transform the data so it would approach the normal distribution as closely as possible. To eliminate the problem of zero values, “1” was added to the relative percentage of each taxon. The natural log of each relative percentage was then taken to reduce the problem of skewness.

Pollen Preservation

Descriptive statistics, 2-tailed Pearson correlation, and regression were used to assess the preservation status of pollen grains from the Laguna Verde core. Degraded pollen grains assigned to an “unidentifiable/indeterminate” category constituted 0-23.3 percent of each sample, with a median value of 6.35 percent. Pollen grains that appeared to be in adequate condition, but that could not be identified with available resources, were recorded as “unidentified/unknown.” These grains constituted 0-15.9 percent of each sample, with a median value of 1.5 percent. In the pollen diagram and the arboreal/non-arboreal/aquatic diagram, these two categories are combined into a single "unidentified" category. In the statistics that follow, only degraded "unidentifiable" grains were included.

To determine whether depth of a sample was related to the preservation status of pollen, I used linear regression. Depth was plotted as the independent variable, and the log of the percentage of unidentifiable grains was plotted as the dependent variable. The correlation coefficient r was .081, and the significance was .578. These results are not significant at the .05 level; there were comparatively high and low percentages of unidentifiable grains at all depths.

Concentration values can be important in determining the level of preservation of grains in a pollen sample. A low concentration value, low pollen count, the presence of many degraded grains, low taxa diversity, and a high percentage of grains that are easily identified even when degraded can (together or in some combination) indicate that the content of a pollen sample may be a poor representation of a past ecotype. To check for this possibility, linear regression and 2-tailed Pearson correlation were applied, with depth plotted as the independent variable, and concentration value (per cc) as the dependent variable. Four samples with concentration values measured in grams were excluded from this analysis. The resulting correlation coefficient .182, with a 2-tailed significance of .225, is not significant at the .05 level, meaning that relative depth does not explain the variability in concentration values. It should be noted that samples with very low pollen sums or poor concentration values were pre-excluded from this analysis (as explained in the section "The Laguna Verde Pollen Diagram"); many of the excluded samples came from stratigraphic Zone 3.

Stratigraphic Zone 3, unique within the column for its near total composition of fine-grained minerals, had a high number of pollen samples with pollen concentration values so low as to preclude them from most of the statistical analyses presented here. Based on the geoarchaeological evidence discussed in Chapter 3, I believe that this stratum was deposited rapidly during the Late Preclassic and Classic Periods. To determine whether or not pollen was well-preserved in this rapid-deposition context, I compared the means and standard deviations of (untransformed) relative percentages of unidentifiable (degraded) pollen in all twelve of the samples taken from Zone 3, to those from all fifty of the other samples analyzed for this project. Even those samples excluded from other statistical analyses were included here. The mean relative percentage of unidentifiable grains in Zone 3 samples was 8.81±8.37, while the mean for all other samples was 7.71±4.83. A 2-tailed Student's t-test (two-sample equal variance) returns a t-statistic of .5459. For 60 degrees of freedom and a 2α confidence interval, the statistic on the T table is 2.0. Because the computed (observed) value is smaller than the tabulated value, the null hypothesis should be accepted: the mean relative percentage of unidentifiable grains in Zone 3 is not different from that of the other stratigraphic zones. It cannot, then, be said that pollen is not well-preserved in a rapid-deposition context, even though pollen grains are less abundant per unit volume samples (i.e. concentration values are lower). This might be useful knowledge for future palynologists.

Low concentration values, in combination with high relative percentages of unidentifiable grains, can signal poor preservation. I used a 2-tailed Pearson correlation to check for an association between concentration values (per cc) and raw (untransformed) relative percentages of unidentifiable grains. The results were not statistically significant (r=.104, 2-tailed p=.491); there were both high and low relative percentages of unidentifiable grains in samples with both high and low concentration values.

Alongside the consideration of concentration values and relative percentages of indeterminate grains, taxonomic diversity (the number of taxa identified within a sample) is a measure of pollen preservation. If only a few types of easily-identifiable grains are found in a sample, sample preservation is probably too poor to gauge paleoenvironmental conditions. For the Laguna Verde pollen core, a diversity plot (Figure 11) shows the number of taxa identified in each sample (dependent variable) plotted against the total number of pollen grains identified in the sample (independent variable). In general, more taxa were identified in samples with higher pollen sums (line of best fit: $y=.0874x + 8.3558$; $R^2=.4919$). This is to be expected, because higher counts are more likely to discover the presence of rare taxa (e.g. Colinvaux et al. 1999, Mosimann 1965). For most of the Laguna Verde samples, samples, between 200 and 240 grains were counted, and between 15 and 37 taxa were identified.

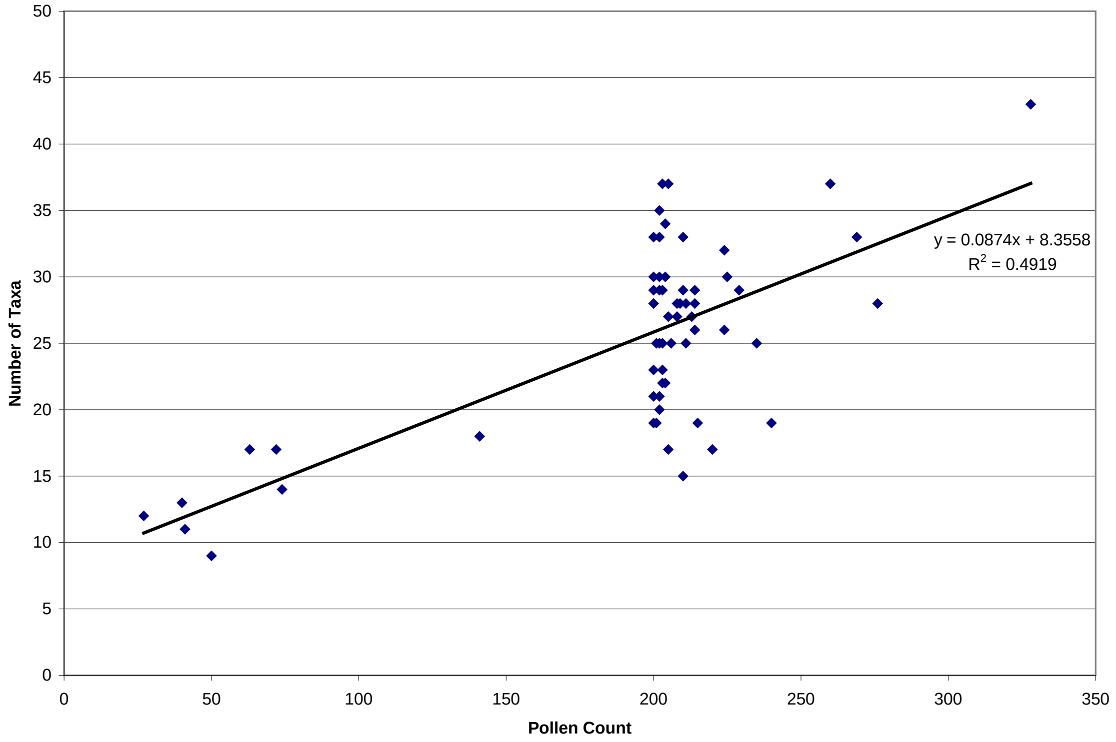

Figure 11. Taxonomic diversity rises as the pollen sum increases. Image credit: David Carlson

As final check on the relationship between diversity and grain preservation, the number of taxa identified in each sample was plotted as the dependent variable, and the relative percentage of indeterminate grains was plotted as the independent variable. The relationship between the two variables was insignificant, so it cannot be concluded that fewer taxa were identified in samples with higher percentages of indeterminate grains.

Depth-Based Changes in Relative Abundances of Taxa

The Laguna Verde pollen diagram (Figure 9) displays changes in relative abundances of major taxa from sample to sample. The curve for each taxon has a “sawtoothed” appearance, as it fluctuates in relative abundance. Such fluctuation can obscure a true shift in the relative abundance of a taxon through time or depth. Furthermore, analysis of the diagram can be considered a semi-quantitative, or even subjective, means of analysis. Analysis of depth-based shifts in relative abundance of taxa can be strengthened through the application of linear regression to the data. Regression was, therefore, applied, with depth plotted against the normalized relative abundances of major taxa.

Some taxa showed statistically-significant changes through time: *Celtis/Trema* (r=.312, p=significance=.027), Moraceae (r=.4, p=.004), *Pinus* (r=.684, p=.000), rainforest taxa (r=.344, p=.014), and temperate taxa (r=.542, p=.000) decreased through depth (or time), while *Byrsonima* (r=-.32, p=.023) and Combretaceae/Melastomataceae (r=-.375, p=.007) increased. The remaining taxa (Asteraceae, *Borreria/Spermacoce*, Cheno-Ams, Poaceae, *Quercus*, Cyperaceae, Typhaceae, *Myrica*, Myrtaceae, *Rhizophora*, *Bursera*, cultigens) showed no significant net change. It should be noted that this test measures overall change through depth, so any lack of net (or linear) change in relative abundance does not mean that there were never fluctuations in the abundance of a particular taxon. The regressions indicate the constant presence of non-arboreal and aquatic taxa, and an overall decrease in the abundance of most arboreal taxa through time. This indicates that the landscape near Laguna Verde is more open today than it was when the oldest core sediments were deposited, approximately 4,600 years ago.

Principal Components Analysis and Cluster Analysis

Exploratory principal components analysis has been performed on the Laguna Verde pollen core data. The purpose of principal components analysis is to reduce complex data to a few variables. These are displayed on a multidimensional scatterplot, making it possible to visualize major trends in the data. Principal components analysis can be used to compare modern and fossil pollen samples along several dimensions. Sample similarity is measured by the proximity of points in the scatterplot. Samples can be then grouped with similar samples; for example, fossil pollen samples grouped with modern pollen samples may represent similar ecotypes. However, it can be difficult to classify fossil pollen samples that fall between groups of modern samples (Liu & Lam 1985).

I used the natural log of relative percentages of all variables (taxa) from 50 samples with adequate concentration values (as noted above) to do principal components analysis. Seven components accounted for 66.26% of the variation in the variables; 29.79% of the variation is attributed to the first two principal components. I then made two scatterplots featuring Principal Component 1 as the independent variable, and Principal Component 2 as the dependent variable. In the first scatterplot (Figure 12), cases were labeled by their depth within the stratigraphic column. In the second scatterplot (Figure 13), cases were labeled by the stratigraphic zone from which the sample derived. It is apparent in Figures 12 and 13 that samples generally cluster most closely with stratigraphically-adjacent samples.

Dr. David Carlson assisted me in exploring the botanical drivers (i.e. plant taxa) that are strongest in defining the principal components. He used software from the R Project for Statistical Computing to test for fluctuations in my data. First, 60 taxa were identified as being represented in at least four samples; these were reduced to presence/absence scores (1/0). Next, a runs test was applied to the ubiquity data, to see if any of the 60 taxa were found in consecutive (stratigraphically adjacent) samples. Few runs of two, three, or more are random, and the runs test identifies which taxa occur in runs more often than would be expected by random chance. Fifteen taxa occurred in more runs than expected ($p<.05$); these were Arecaceae, Low-spine Asteraceae, *Byrsonima*, *Cecropia*, *Colubrina*, *Desmodium*, Fabaceae, Loranthaceae, *Mimosa*, triporate Moraceae, *Quercus*, Sapindaceae, Sapotaceae, *Trema*, and *Typha*. Three taxa occurring in more runs than expected, but at weaker levels of significance ($.05<p<.058$), were included in the remainder of the analysis; these were *Myrica*, Myrtaceae, and

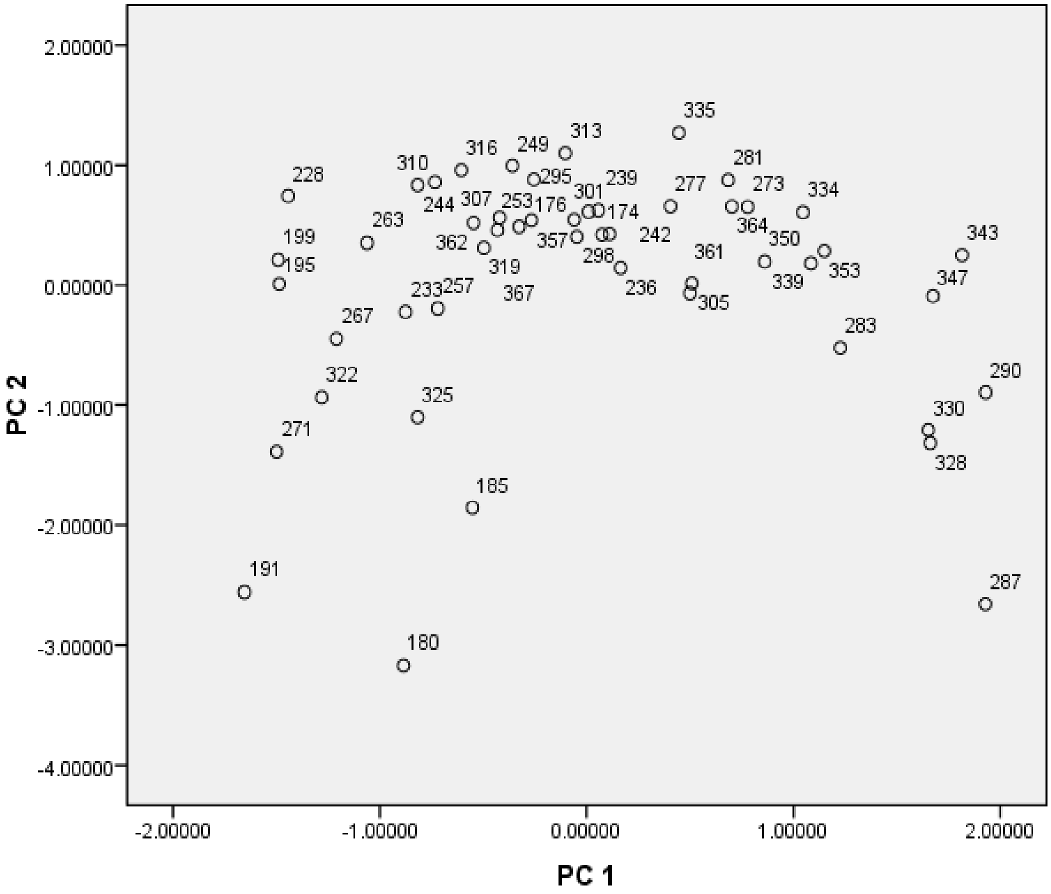

Figure 12. Principal components 1 and 2, with cases labeled by sample depth.

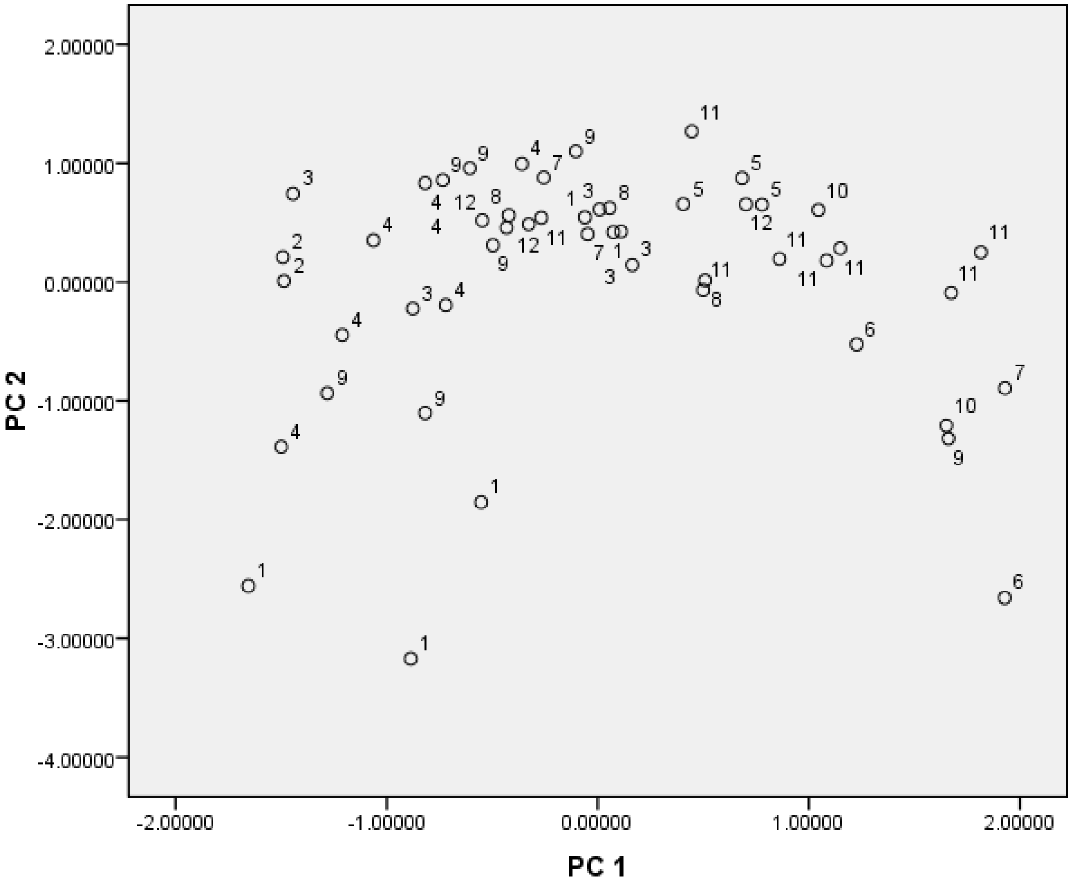

Figure 13. Principal components 1 and 2, with cases labeled by stratigraphic zone.

Poaceae<50 µ. Principal components analysis was applied to these 18 taxa to see if the runs coincided (which is to say, if some of the same taxa made runs of some of the same samples), and seven principal components were identified. Scatterplots were made of each principal component (as the dependent variable) plotted against depth (as the independent variable), and these were fitted with best-fit lines. All show non-linear variability. Cluster analysis of relative percentages of the most-ubiquitous taxa in the core grouped samples differently than did cluster analysis based on the seven principal components identified from the results of the runs test. However, samples clustered more closely with stratigraphically-adjacent samples than would be expected by chance.

The principal components analysis indicates that different groups of taxa covaried in different directions, at different points in time. Further cluster analysis based on normalized relative percentages of the most-ubiquitous taxa can be used to suggest which groups of taxa covaried. However, these groups were not necessarily ecologically meaningful, with (for example) typical "dry savanna" taxa clustering with typical "high rainforest" taxa, and omnipresent *Pinus* dominating all. Thus, principal components analysis and cluster analysis support my general hypotheses of a mixed signal of local and regional pollen; environmental fluctuations; and a lack of strong unidirectional environmental change.

INTERPRETATION OF THE LAGUNA VERDE POLLEN CORE

The pollen diagram of the Laguna Verde pollen core does not show strong evidence of major unidirectional environmental shifts over time, but has a sawtoothed appearance indicative of frequent changes in the dominance of different vegetation associations. The lack of strong natural pollen zonation may result from the stability of the Laguna Verde swamp as a mesic environment throughout the time period represented by the pollen core. Continual presence of typical "wet savanna" taxa at the core site (as demonstrated by the statistical analysis above) may mask any shifts in dominance of other vegetation associations in the region. However, this idea is not necessarily supported by the arboreal/non-arboreal/aquatic pollen diagram (Figure 10), which shows constant fluctuations in the relative abundances of taxa in all categories. It is not feasible to exclude the relative percentages of wet savanna taxa from the pollen diagram because the number of pollen grains in each sample would be too low to accurately represent regional environments. Instead, we can accept the wet savanna local environment as a constant, and can consider the pollen of other vegetation associations to represent the other ecotypes present in the region contributing to the pollen rain.

Below, the shifts in prevalence of the vegetation association are considered alongside the social and agricultural developments of the Maya. AMS dates, sediment stratigraphy, and comparisons to other palynological studies conducted in the Maya Lowlands are included in the discussion. The discussion proceeds in order of the stratigraphic zones identified on the right side of the pollen diagram, beginning at the bottom of the pollen core with Zone 12. The stratigraphy of these zones is described in Table 4, Chapter I.

Zone 12

The bottom stratum of the core extended from 373 to 362 cm below the surface of the swamp water. The earliest AMS date for the core was taken from this stratum, with a sample from 368-369 cm dating between 2880 and 2580 cal B.C., or 4830 to 4520 B.P. Taxa showing the strongest presence in this stratum were *Pinus, Quercus,* Poaceae, Asteraceae, *Borreria/Spermacoce,* and Cyperaceae, and the rain forest group. All but the latter form a common combination in inland (dry) savanna environments. Jones (1991) documented a similarly open landscape at Cobweb Swamp, Belize, around 2462 B.C.

The group of temperate and montane taxa achieved its greatest abundance during this period, suggesting that coverage by these taxa at some external location was greatest during this time. That unknown location may have been cooler than today, as well, with taxa that normally grow at higher elevations being vertically displaced (i.e. migrating downslope) and thereby occupying a larger land area.

The Maya are not known to have lived at Blue Creek until 900 B.C. (Guderjan & Driver 1999:1; Lohse 2003:6; MRP 2002). However, the earliest *Zea mays* pollen came from this stratum (367-368 cm), predating local Mayan settlement by approximately 1,600 years. Inert charcoal appeared for the first time in the same sample, suggesting an anthropogenic cause for burning.

Because maize can be propagated only with human assistance, and because maize pollen does not travel far from its source of origin, it seems that the plant and its human cultivators must have been present in the Blue Creek area at a date earlier than expected. At this time, in the Archaic Period, the maize cultivators in the Blue Creek area would not yet have evolved the full suite of traits characteristic of the Mayan ethnicity. Instead, they were mobile band-level hunters and simple horticulturalists. The presence of maize pollen exposes an Archaic Period presence of maize-cultivating humans in the Blue Creek area. The early date thus enables me to trace the agricultural and ecological developments from the Archaic Period forward, as simple horticulture became intensified agriculture and the Maya civilization unfolded.

Zone 11

The Zone 11 stratum extended from 362 to 334.5 cm. An AMS date between 2460 and 2610 cal B.C. (4410-4560 B.P.) was obtained from a sample at 360-361 cm. This date range slightly overlaps the date from Zone 12, probably indicating rapid sedimentation. The greatest relative abundances of pollen in Zone 11 came from *Pinus,* Moraceae, *Celtis*, and *Trema*. Cyperaceae, Asteraceae, Combretaceae and Melastomataceae were initially abundant, but declined in abundance as time progressed, while Poaceae fluctuated in abundance. Although arboreal pollen was more frequent in Zone 11 than in Zone 12, the olio of common taxa sends a mixed signal. *Pinus* can be present in pine forest, inland savanna, and swamp forest, but is often over-represented in pollen records. Moraceae is typically found in high rain forest. Combretaceae and Melastomataceae are found in wet savanna or swamp forest. The other taxa are common in open and disturbed environments. The overall picture is one of progressively larger patches of arboreal coverage. Although tropical rain forest taxa were present in their greatest relative abundance near Laguna Verde when Zone 12 was deposited (13.7 percent in the sample from 357-358 cm), the type of undisturbed tropical rain forest documented in the Petén before 4,000 b.p. (Dunning et al. 1998b:145; Vaughan et al. 1985:75) was not locally intact.

Agriculturally, maize pollen was present at 343-344 cm, and pollen of the possible cultivar *Physalis* was found in samples from 357-358 cm and 339-340 cm. Particulate carbon was observed in about half of the samples, suggesting that the human presence and plant cultivation were intermittent.

Zone 10

Aside from over-represented *Pinus,* the most abundant taxa in narrow Zone 10 (334.5-329 cm) were *Myrica cerifera,* Cyperaceae, and Combretaceae and Melastomataceae. Pollen of *Rhizophora mangle* also began an ascent to its very significant secondary maximum. Pollen of Moraceae, *Celtis,* and *Trema* temporarily declined to very low levels in this zone. The dominant taxa were, therefore, those of the swamp forest and of open environments. The environment may have been relatively moist and saline, so as to support the swamp forest trees and the halophytic *Rhizophora mangle*. Maize pollen occurred in Zone 10, at 330-331 cm.

Zone 9

A band of highly decomposed peat was deposited from 329 to 310 cm below the surface of the swamp water. The upper end of this stratum (312-313 cm) was AMS dated between 1020 and 840 cal B.C., or 2980-2790 B.P. It was at this point during the Middle Preclassic Period that Blue Creek was first occupied by an identifiably Mayan population, with the first settlement of the Chan Cahal residential cluster. Geoarchaeological evidence notes that the Eklu'um Paleosol began to be deposited at this time, forming a stable surface for farming (Beach & Luzzadder-Beach 2003; Lohse 2003a).

However, the water level of the Caribbean Sea was rising at this time (1500-500 B.C.), bringing more water to the inland waterways of Belize, and increasing sedimentation rates in some locations. Higher water levels are demonstrated in the Laguna Verde pollen core by the increase in swamp forest taxa in Zone 9. The pollen diagram shows that the pollen of Combretaceae/Melastomataceae hit secondary maxima during deposition of this stratum, as pollen of *Rhizophora mangle* declined from its secondary maximum in Zone 10. Typhaceae pollen increased in relative abundance. The stratum shows a strong swamp forest component, with swamp trees overshadowing low-growing Cyperaceae and Poaceae until the end of the period. By the end of the period, Cyperaceae, Poaceae, and Asteraceae pollen increased in abundance, as pollen of

Combretaceae/Melastomataceae and *Rhizophora mangle* made sharp declines. Figure 10 shows the relative decrease in arboreal pollen and increases in non-arboreal and aquatic pollen at this point. Charcoal was present in all samples. An increase in environmental disturbance and canopy openness seems to have been concomitant with the settlement of Blue Creek. Similar disturbance and forest clearance were demonstrated for the Middle Preclassic Period in the Petén (Curtis et al. 1998; Cowgill et al. 1996; Deevey 1978; Deevey et al. 1979; Leyden 1987; Vaughan et al. 1985).

Zone 8

A narrow band of calcareous marl with high organic content was deposited from 310 to 301 cm below the water level. The pollen diagram shows dips, followed by small increases, in the relative abundances of the pollen of various tree taxa, including *Myrica cerifera,* Moraceae, *Celtis* and *Trema,* and Combretaceae/Melastomataceae. Zones 6-8 show a hump in the abundances of pollen of *Myrica cerifera,* Cyperaceae, and Combretaceae/Melastomataceae, demonstrating a small peak in coverage by swamp forest during this period. Figure 10 shows that arboreal pollen remained dominant during this time. However, levels of Moraceae pollen in Zone 8 were about half as high as they had been during the depositions of Zones 12, 11, and 10, perhaps indicating an overall decline in the coverage of high rain forest.

The agricultural weed *Borreria/Spermacoce* remained present at steady, low levels. Malvaceae pollen was present in the sample from 305-306 cm, possibly representing a cultivar or a disturbance-associated weed. All samples contained charcoal.

It was during the Middle Preclassic Period, between 800 and 300 B.C., that more sites in the Three Rivers Region were settled by Mayan farmers, and forest clearance took place at the sites of Dos Hombres and La Milpa (Lohse 2003a:10). The varied pollen spectrum in Zone 8 seems to represent an environment in flux.

Zone 7

Continued sawtoothing of the pollen diagram shows ongoing vegetational fluctuations during the deposition of Zone 7 (301-289 cm). The most noteworthy occurrence was the increase in pollen of Asteraceae and Poaceae, and concomitant decrease in pollen of Combretaceae/Melastomataceae, by the end of the period. Pollen of *Myrica cerifera* hit a peak near the top of Zone 7. Again, all samples contained charcoal. Cucurbitaceae pollen was present in the sample from 291-290 cm. Ongoing high levels of land clearance for agriculture are suggested.

Zone 6

Narrow Zone 6, a woody peat deposited between 289 and 283 cm below the water level, saw the relative abundance of *Rhizophora mangle* pollen soar to 57.5 percent (287-288 cm). The woodiness of the peat, together with the *Rhizophora mangle* pollen, indicates the on-site presence of a significant number of red mangrove trees. Pollen of *Myrica cerifera* declined from its peak. This expansion of high swamp forest taxa masked any pollen signal from the regional vegetation. To the west, the Mirador Basin experienced a period of increased marshiness between 500 B.C. and 0 A.D. (Hansen et al. 2002:281) which may be correlated with this one at Laguna Verde, pending further radiometric dating.

Zone 5

As explained in the section on the pollen core stratigraphy, the mineral-rich marl between 283 and 272 cm was probably deposited during the onset of an interval of increasing erosion and a rising water table during the Late Preclassic Period and Early Classic Period. The pollen diagram shows a sharp decline in pollen of *Rhizophora mangle.* Red mangrove was quickly replaced in dominance by pollen of Cyperaceae, which achieved its maximum of 36.6 percent in the sample from 277-278 cm. Figure 10 shows that aquatic pollen was unusually prevalent in Zone 5. Representation of Moraceae doubled, while rain forest taxa showed a small increase in Zones 6 and 5.

Zone 4

The stratum deposited between 272 and 243 cm below the surface of the water probably represents erosion and a rising water table, ongoing since Zone 5. During the Late Preclassic Period, the population of Blue Creek grew, and channeled fields were created to facilitate agriculture in areal wetlands. During deposition of Zone 4, pollen of swamp forest taxa like *Myrica cerifera* and *Rhizophora mangle* maintained very low levels, though pollen of Combretaceae/Melastomataceae conversely showed a temporary major peak early in the stratum. Pollen of disturbance-associated Asteraceae dominated. Other disturbance- or openness-associated taxa, like *Byrsonima*, *Celtis/Trema,* and *Borreria/Spermacoce*, continued to be present at low levels. Figure 10 shows the dominance of non-arboreal (herb) pollen in Zone 4. Charcoal was present in all samples. The regional environment evidently increased in openness during deposition of Zone 4, as agriculture expanded. A similar situation applied in the Petén.

Zone 3

Zone 3, extending from 243 to 201 cm below the surface of the water, consisted of an oozy sediment rich in both organics and minerals. Early in the zone, the pollen spectrum was similar to that described for Zone 4. Figure 10 shows that the pollen of non-aquatic herbs was dominant in Zone 3. This could be associated with widespread land clearance, probably for agricultural purposes. However, very little pollen was recovered from the seven samples taken between 225 and 202 cm. This zone likely represents the Middle Classic Period, a time of regional sediment aggradation caused by a rising water table. Erosion was also caused by heavy farming near Blue Creek. Rapid sedimentation evidently resulted in very low pollen influx rates. Maize pollen was noted in the sample taken from 233-234 cm.

Zone 2

Statistically-valid pollen levels resumed near the beginning of Zone 2, 201 to 193 cm below the surface of the water. High levels of disturbance-associated Asteraceae, Poaceae, and *Borreria/Spermacoce* pollen were immediately present. Wet savanna taxa Cyperaceae and Typhaceae showed a smaller presence, but Combretaceae/Melastomataceae pollen began a major increase. Moraceae pollen was present, but pollen representing the rain forest group was found at levels much-reduced from those of Zone 3, suggesting that the high rain forest component of the regional vegetation was very small. Figure 10 shows that non-aquatic herbs had a significant presence in Zone 2, but they yielded to arboreal taxa in Zone 1. The low organic content of the clayey sediment of Zone 2, combined with the presence of dry savanna/open space taxa, lead to the speculation that the environment was relatively dry during deposition of Zone 2. Further radiometric dating may establish a correlation between Zone 2 and the Terminal Classic drought experienced in other parts of the Maya Lowlands, though a full-on drought is not implicated for northern Belize by any line of evidence.

Zone 1

The most recent zone of the Laguna Verde pollen core extended from 193 to 174 cm below the surface of the water. It represents vegetation from the Colonial Period through the present day. The strongest contributors to the pollen spectrum are taxa that are known to grow at Laguna Verde today, including Cyperaceae, Typhaceae, and (most significantly, comprising 75.8 percent of the pollen in the sample from 180-181 cm) Combretaceae/Melastomataceae. Pollen in a “pinch” sample taken from the surface of the non-submerged sediment at the core site likewise showed the major ongoing presence of the pollen of Cyperaceae, Combretaceae/Melastomataeae, and Asteraceae. Thus, Zone 1 represents the type of ecological setting -a sawgrass swamp- that can be witnessed at Laguna Verde today, with a high relative percentage of aquatic plants, some arboreal taxa, and few non-aquatic herbs.

DISCUSSION AND CONCLUSION

Lack of strong natural pollen zonation in the Laguna Verde pollen core reveals constant shifts in the dominance of various vegetation associations since the beginning of the core, over 4,500 years ago. A human presence, with land clearance and maize cultivation, was present near Blue Creek from that time forward. Most strata in the core were dominated by pollen representing either the wet savanna and swamp forest on-site at Laguna Verde, or else by taxa representative of openness or disturbance in the region. The relative importance of swamp forest arboreal taxa, versus low wet or dry savanna vegetation, shifted at various points in time.

The most interesting questions that can be asked of the Laguna Verde pollen core regard changes to the Blue Creek environment during the heavy farming of the Classic Period, and during the ensuing Maya Collapse. Evidence from the pollen core suggests rapid sediment influx into Laguna Verde during the Classic Period, followed by a period of dryness. Although no certain drought is believed to have impacted Blue Creek, it is possible that heavy erosion in the area uplands and related influx of sediment in the lowlands led to a decline in the quality of agricultural soils. Because we know that the erection of monumental architecture at Blue Creek slowed during the Late Classic Period, and there were termination rituals in the Main Plaza of Blue Creek during the Terminal Classic Period, we know that the Blue Creek site was abandoned around 900 A.D. However, the pollen spectrum does not show certain evidence of human abandonment of the area. Stratigraphic Zone 2 must extend well into the Postclassic Period, but the pollen of that zone does not show the significant regeneration of rain forest-type vegetation that occurred in the Petén after the Maya abandoned agriculture there. Petén lakes sediments contain large quantities (30 percent or more) of arboreal rain forest pollen, both before and after the deposition a band of Maya Clay (which represented high levels of erosion and forest clearance during the Preclassic and Classic Periods) containing far lower levels of rain forest pollen. In contrast, the Laguna Verde pollen core showed the presence of moderate amounts (10-20 percent) of rain forest pollen throughout most of the core. Although the highest percentages of rain forest pollen types like Moraceae and the rain forest group were achieved early in the core (in Zones 12 and 11), those percentages did not slacken off substantially until the deposition of the barren pollen zone (Zone 3) and later (Zones 2 and 1). Figure 10 shows that arboreal pollen dominated most of the Laguna Verde core, except for barren Zone 3 and uppermost (modern) Zone 1. Still, the Laguna Verde pollen core never showed the high levels of rain forest pollen known from the Petén. The reason for this may be that the local wet savanna and swamp forest vegetation had relatively greater importance at Laguna Verde, or that pollen representing those vegetation associations effectively masked the pollen signal from other vegetation in the region. On the other hand, the moderately low levels of rain forest-type pollen before, during, and after the Mayan era may result from continuous human disturbance in the area. The pollen core shows that early settlers of the area were already cultivating maize. Because the Blue Creek area was resettled during the Early Postclassic area, and because people continue to live and farm in the area, the landscape has never had an opportunity to recover from human disturbance.

Further research relating to this project should include additional radiometric dating for a chronological refinement, and additional palynological sampling outside a swamp zone to provide a balanced regional picture. This dissertation has interpreted the paleoethnobotanical and environmental significance of the palynological evidence for the full Mayan tenure at Blue Creek, incorporating evidence from lines of inquiry ranging from archaeology to geology. Such a comprehensive project is a good starting point for our understanding of the environmental history of the Blue Creek site and the Three Rivers Region.

REFERENCES CITED

Adams, Richard E.

1983 Ancient Land Use and Culture History in the Pasión River Region. In *Prehistoric Settlement Patterns: Essays in Honor of Gordon R. Willey*, edited by E.Z. Vogt and R.M. Leventhal, pp. 319-336. University of New Mexico Press, Albuquerque.

Andrews V, E. Wyllys and Norman Hammond

1990 Redefinition of the Swasey Phase at Cuello, Belize. *American Antiquity* 55(3):570-584.

Antoine, P.P., R.L. Skarie, and Paul R. Bloom

1982 The Origin of Raised Fields near San Antonio, Belize: An Alternative Hypothesis. In *Maya Subsistence: Studies in Memory of Dennis E. Puleston*, edited by Kent V. Flannery, pp. 227-236. Academic Press, New York.

Arvigo, Rosita and Michael J. Balick

1993 (1998) *Rainforest Remedies: One Hundred Healing Herbs of Belize*, 2nd edition. Lotus Press, Twin Lakes, Wisconsin.

Balick, Michael J., Michael H. Nee, and Daniel E. Atha

2000 *Checklist of the Vascular Plants of Belize with Common Names & Uses*. New York Botanical Gardens Press, New York.

Barghoorn, Elso S., Margaret K. Wolf, and Kathryn H. Clisby

1954 Fossil Maize from the Valley of Mexico. *Botanical Museum Leaflets, Harvard University* 16:229-240.

Barkley, F.A.

1934 The Statistical Theory of Pollen Analysis. *Ecology* 15:283-289.

Barrett, Jason Wallace

2004 Constructing Hierarchy Through Entitlement: Inequality in Lithic Resource Access Among the Ancient Maya of Blue Creek, Belize. Ph.D. dissertation, Anthropology Department, Texas A&M University, College Station.

Bartlett, Alexandra S., Elso S. Barghoorn, and Rainer Berger

1969 Fossil Maize from Panama. *Science* 165 (3891):389-390.

Barton, Huw, and Peter J. Matthews

2006 Taphonomy. In *Ancient Starch Research,* edited by Robin Torrence and Huw Barton, pp. 75-94. Left Coast Press, Walnut Creek, California.

Beach, Timothy, and Nicholas Dunning

1995 Ancient Maya Terracing and Modern Conservation in the Petén Rain Forest of Guatemala. *Journal of Soil and Water Conservation* 50:138-145.

1997 An Ancient Maya Reservoir and Dam at Tamarindito, El Petén, Guatemala. *Latin American Antiquity* 8(1):20-29.

Beach, Timothy, Nicholas Dunning, Sheryl Luzzadder-Beach, D.E. Cook, and John Lohse

2006 Impacts of the Ancient Maya on Soils and Soil Erosion in the Central Maya Lowlands. *Catena* 65:166-178.

Beach, Timothy, and Sheryl Luzzadder-Beach

2003 Geological Investigations at Blue Creek, 2003. In *Blue Creek Regional Political Ecology Project 2003 Season Summary-Project Overview*, edited by Jon C. Lohse, pp. 29-32. Maya Research Program, Texas Christian University, Fort Worth, Texas.

Beadle, George W.

1939 Teosinte and the Origin of Maize. *Journal of Heredity* 30:245-247.

1980 The Ancestry of Corn. *Scientific American* 242:112-119.

1981 Origin of Corn: Pollen Evidence. *Science* 213 (4510):890-892.

Benz, Bruce F.

2001 Archaeological Evidence of Teosinte Domestication from Guilá Naquitz, Oaxaca. *Proceedings of the National Academy of Sciences USA* 98 (4):2104-2106.

2006 Maize in the Americas. In *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize*, edited by John E. Staller, Robert H. Tykot, and Bruce F. Benz, pp. 9-20. Elsevier, Burlington, Massachusetts.

Benz, Bruce F., and Austin Long

2000 Prehistoric Maize Evolution in the Tehuacán Valley. *Current Anthropology* 41(3):459-465.

Binford, Michael W.

1983 Paleolimnology of the Peten Lake District, Guatemala. *Hydrobiologia* 103:199-203.

Birks, H.J.B.

2005 Fifty Years of Quaternary Pollen Analysis in Fennoscanda 1954-2004. *Grana* 44:1-22.

Birks, H.J.B., and A.D. Gordon

1985 *Numerical Methods in Quaternary Pollen Analysis*. London: Academic Press.

Blake, Michael

2006 Dating the Initial Spread of *Zea mays.* In *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize,* edited by John E. Staller, Robert H. Tykot, and Bruce F. Benz, pp. 55-72. Elsevier, Burlington, Massachusetts.

Bloom, Paul R., Mary D. Pohl, Cynthia Buttleman, Frederick Wiseman, Alan Covich, Charles Miksicek, Joseph Ball, and Julie Stein

1983 Prehistoric Maya Wetland Agriculture and the Alluvial Soils Near San Antonio Rio Hondo, Belize. *Nature* 301:417-419.

Bloom, Paul R., Mary D. Pohl, and Julie Stein

1985 Analysis of Sedimentation and Agriculture Along the Río Hondo, Northern Belize. In *Prehistoric Lowland Maya Environment and Subsistence Economy*, edited by Mary D. Pohl, pp. 21-33. Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, Massachusetts.

Boserup, Esther

1965 *The Conditions of Agricultural Growth.* Chicago: Aldine Publishing Company.

Bozarth, Steven R. and Thomas H. Guderjan

2004 Evidence of Agriculture and Ceremonies Based on Biosilicate Analysis. In *The Blue Creek Project: Working Papers from the 1998 and 1999 Seasons,* edited by Thomas H. Guderjan and R.J. Lichtenstein, pp. 101-115. Maya Research Program, Forth Worth, Texas.

Bray, Warwick

1978 An Eighteenth Century Reference to a Fluted Point from Guatemala. *American Antiquity* 43(3) 457-460.

1980 Fluted Points in Mesoamerica and the Isthmus: A Reply to Rovner. *American Antiquity* 45(1):168-170.

Brenner, Mark

1983 Paleolimnology of the Peten Lake District, Guatemala. *Hydrobiologia* 103:205-210.

1994 Lakes Salpeten and Quexil, Peten, Guatemala, Central America. In *Global Geological Record of Lake Basins,* vol. 1, edited by E. Gierlowski-Kordesch and K. Kelts, pp. 377-380. Cambridge University Press, U.K.

Brenner, Mark, Barbara Leyden, and Michael W. Binford

1990 Recent Sedimentary Histories of Shallow Lakes in the Guatemalan Savannas. *Journal of Paleolimnology* 4:239-251.

Brenner, Mark, Michael F. Rosenmeier, David A. Hodell, and Jason H. Curtis

2002 Paleolimnology of the Maya Lowlands: Long-term Perspectives on Interactions Among Climate, Environment, and Humans. *Ancient Mesoamerica* 13:141-157.

Brown, Kenneth L.

1980 A Brief Report on Paleoindian-Archaic Occupation in the Quiche Basin, Guatemala. *American Antiquity* 45(2):313-324.

Bryant, Vaughn M.

2003 Invisible Clues to New World Plant Domestication. *Science* 299:1029-1030.

2006 Pollen Extraction Procedure with Emphasis on Forensic Samples. Unpublished manuscript on file, Palynology Laboratory, Texas A&M University, College Station.

2007a Microscopic Evidence for the Domestication and Spread of Maize. *Proceedings of the National Academy of Sciences USA* 104(50):19659-19660.

2007b Personal communication.

2008 Personal communication.

Bryant, Vaughn M. and Richard G. Holloway

1983 The Role of Palynology in Archaeology. In *Advances in Archaeological Method and Theory*, Vol. 6, pp. 191-224. Academic Press, San Diego.

Bullen, Ripley P., and William W. Plowden, Jr.

1963 Preceramic Archaic Sites in the Highlands of Honduras. *American Antiquity* 28(3):382-385.

Bush, Mark B.

1995 Neotropical Plant Reproductive Strategies and Fossil Pollen Representation. *The American Naturalist* 145 (4):594-609.

2002 On the Interpretation of Fossil Poaceae Pollen in the Lowland Humid Neotropics. *Palaeogeography, Palaeoclimatology, Palaeoecology* 177:5-17.

Central Intelligence Agency

2008 Belize. In *The World Factbook*. Electronic document, https://www.cia.gov/library/publications/the-world-factbook/geos/bh.html#Econ, accessed September 2008.

Chase, A.F., and D.Z. Chase

1998 Scale and Intensity in Classic Period Maya Agriculture: Terracing and Settlement at the "Garden City" of Caracol, Belize. *Culture and Agriculture* 20(2/3):60-77.

Cichewicz, Robert H., and Patrick A. Thorpe

1996 The Antimicrobial Properties of Chile Peppers (*Capsicum* species) and Their Uses in Mayan Medicine. *Journal of Ethnopharmacology* 52:61-70.

Clayton, Sarah C.

2003 Investigations at Rosita, 2003: Toward Understanding the Sociopolitical Landscape of the Blue Creek Region, Northwestern Belize. In *Blue Creek Regional Political Ecology Project 2003 Season Summary-Project Overview*, edited by Jon C. Lohse, pp. 81-88. Maya Research Program, Forth Worth, Texas.

Clayton, Sarah C., W. David Driver, and Laura J. Kosakowsky

2005 Rubbish or Ritual? Contextualizing a Terminal Classic Problematical Deposit at Blue Creek, Belize. A response to "Public Architecture, Ritual, and Temporal Dynamics at the Maya Center of Blue Creek, Belize" by Thomas H. Guderjan. *Ancient Mesoamerica* 16:119-130.

Colinvaux, Paul, Paulo Eduardo De Oliviera, and Jorge Enrique Moreno Patino

1999 *Amazon Pollen Manual and Atlas*. Overseas Publishers Association, Amsterdam, Netherlands.

Coe, Michael D.

1960 A Fluted Point from Highland Guatemala. *American Antiquity* 25(3):412-413.

2005 *The Maya*, seventh ed. New York: Hudson & Thames.

Corzo Márquez, Amilcar R., and Norman B. Schwartz

2008 Traditional Home Gardens of Petén, Guatemala: Resource Management, Food Security, and Conservation. *Journal of Ethnobiology* 29(2):290-304.

Covich, Alan, and Minze Stuiver

1974 Changes in Oxygen-18 as a Measure of Long-Term Fluctuation in Tropical Lake Levels and Molluscan Populations. *Limnology and Oceanography* 19:682-691.

Cowgill, Ursula M., and G. Evelyn Hutchinson

1966 La Aguada de Santa Ana Vieja: The History of a Pond in Guatemala. *Archiv für Hydrobiologie* 62:335-372.

Cowgill, Ursula M., G. Evelyn Hutchinson, A.A. Raček, Clyde E. Goulden, Ruth Patrick, and Matsuo Tsukada

1966 The History of Laguna de Petenxil, a Small Lake in Northern Guatemala. *Memoirs of the Connecticut Academy of Arts and Sciences* 17:1-126.

Crosby, A.W.

1972 *The Columbian Exchange: Biological and Cultural Consequences of 1492*. Greenwood Press, Westport, Connecticut.

Cubola Productions

1990 *Atlas of Belize*, 16th ed. Cubola Productions, Belize.

Culbert, T. Patrick

1998 The Collapse of Classic Maya Civilization. In *The Collapse of Ancient States and Civilizations*, edited by Norman Yoffee and George Cowgill, pp. 69-101. University of Arizona Press, Tucson.

Culbert, T. Patrick, L. Levi, B. McKee, and J. Kunen

1996 Investigaciones Arqueológicas en el Bajo la Justa Entre Yaxha y Nakum. In *IX Simposio de Investigaciones Arqueológicas en Guatemala*, edited by J.P. Laporte and H.L. Escobedo, pp. 51-57. Instituto Nacional de Antropología e Historia, Guatemala City, Guatemala.

Curtis, Jason H., Mark Brenner, David A. Hodell, Richard A. Balser, Gerald A. Islebe, and Henry Hooghiemstra

1998 A Multi-Proxy Study of Holocene Environmental Change in the Maya Lowlands of Petén, Guatemala. *Journal of Paleolimnology* 19:139-159.

Cusick, Judy M.

1991 Milpero Culture in the Río Bravo Area. In *Maya Settlement in Northwestern Belize: The 1988 and 1990 Seasons of the Río Bravo Archaeological Project*, edited by Thomas H. Guderjan, pp. 99-101. Maya Research Program, Forth Worth, Texas.

Dahlin, Bruce H.

1983 Climate and Prehistory on the Yucatan Peninsula. *Climatic Change* 5:245-263.

2002 Climate Change and the End of the Classic Period in Yucatan: Resolving a Paradox. *Ancient Mesoamerica* 13:327-340.

Dahlin, Bruce, John Foss, and M.E. Chambers

1980 *Project Alcalches: Reconstructing the Natural and Cultural History of Seasonal Swamp in El Mirador*. New World Archaeological Foundation Papers, Vol. 45. Provo, Utah.

Darch, Janice P.

1988 Drained Field Agriculture in Tropical Latin America: Parallels from Past to Present. *Journal of Biogeography* 15(1):87-95.

Davidse, G., M. Sousa A., A.O Chater, and S. Knapp, eds.

1995 *Flora Mesoamericana*. Universidad Nacional Autónoma de México, México, D.F. Also available as an electronic document, http://www.mobot.org/MOBOT/fm/ .

Davis, Margaret B.

1963 On the Theory of Pollen Analysis. *American Journal of Science* 261:897-912.

Decker, Deena

1988 Origin(s), Evolution, and Systematics of *Cucurbita pepo* (Cucurbitaceae). *Economic Botany* 42(1):4-15.

Deevey, Edward S.

1978 Holocene Forests and Maya Disturbance Near Quexil Lake, Petén, Guatemala. *Polskie Archiwum Hydrobiologii/Polish Archives of Hydrobiology* 25:117-129.

Deevey, Jr., Edward S., Don S. Rice, Prudence M. Rice, H. H. Vaughan, Mark Brenner, and M.S. Flannery

1979 Maya Urbanism: Impact on a Tropical Karst Environment. *Science* 206 (4416):298-306.

Dering, J. Philip

1999 Earth-Oven Plant Processing in Archaic Period Economies: An Example from a Semi-Arid Savannah in South-Central North America. *American Antiquity* 64(4):659-674.

De Terra, Helmut

1947 Preliminary Note on the Discovery of Fossil Man at Tepexpan in the Valley of Mexico. *American Antiquity* 13(1):40-44.

De Terra, Helmut, Javier Romero, and T.D. Stewart

1949 *Tepexpan Man*. Viking Fund Publications in Anthropology No. 11. Johnson Reprint Corporation, New York.

De West, J.M.J., and J.R. Harlan

1975 Weeds and Domesticates: Evolution in the Man-Made Habitat. *Economic Botany* 29:99-107.

Dillehay, Thomas D.

2000 *The Settlement of the Americas: A New Prehistory*. Basic Books, New

York.

Dimbleby, G.W.

1957 Pollen Analysis of Terrestrial Soils. *New Phytologist* 56(12):12-28.

Dobkin de Rios, Marlene

1974 The Influence of Psychotropic Flora and Fauna on Maya Religion. *Current Anthropology* 15(2):147-164.

Doebley, John F., and Hugh H. Iltis

1980 Taxonomy of *Zea* (Gramineae). I. A Subgeneric Classification with Key to Taxa. *American Journal of Botany* 67(6):982-993.

Domínguez-Vázquez, G., G.A. Islebe, and R. Villanueva-Gutiérrez

2004 Modern Pollen Deposition in Lacandon Forest, Chiapas, Mexico. *Review of Palaeobotany and Palynology* 131(1-2):105-116.

Driver, W. David

2003 Inter-community Architectural Variation: Excavations Conducted in the Blue Creek Settlement Zone. In *Blue Creek Regional Political Ecology Project 2003 Season Summary-Project Overview*, edited by Jon C. Lohse, pp.53-80. Maya Research Program, Forth Worth, Texas.

Dull, Robert A.

2006 The Maize Revolution: A View From El Salvador. In *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize,* edited by John E. Staller, Robert H. Tykot, and Bruce F. Benz, pp. 357-365. Elsevier, Burlington, Massachusetts.

Dunning, Nicholas P., and Timothy Beach

1994 Soil Erosion, Slope Management, and Ancient Terracing in the Maya Lowlands. *Latin American Antiquity* 5(1):51-69.

Dunning, Nicholas P., Timothy Beach, P. Farrell, and Sheryl Luzzadder-Beach

1998a Prehispanic Agroecosystems and Adaptive Regions in the Maya Lowlands. *Culture and Agriculture* 20(2/3):87-101.

Dunning, Nicholas P., Timothy Beach, and David Rue

1997 The Paleoecology and Ancient Settlement of the Petexbatun Region, Guatemala. *Ancient Mesoamerica* 8:255-266.

Dunning, Nicholas P., S. Luzzadder-Beach, Timothy Beach, John G. Jones, V. Scarborough, and T. Patrick Culbert

2002 Arising from the *Bajos*: The Evolution of a Neotropical Landscape and the Rise of Maya Civilization. *Annals of the Association of American Geographers* 92(2): 267-283.

Dunning, Nicholas P., David J. Rue, Timothy Beach, Alan Covich, and Alfred Traverse

1998b Human-Environment Interactions in a Tropical Watershed: The Paleoecology of Laguna Tamarindito, El Petén Guatemala. *Journal of Field Archaeology* 25(2):139-151.

Erdtman, Gunnar

1935 Investigation of Honey Pollen. *Svensk Botanisk Tidskrift* 29:79-80.

1960 The Acetolysis Method: A Revised Description. *Svensk Botanisk Tidskrift* 54(4):34-37.

Estrada-Loera, Enrique

1991 Phytogeographic Relationships of the Yucatan Peninsula. *Journal of Biogeography* 18 (6):687-697.

Eubanks, Mary W.

2001 The Mysterious Origin of Maize. *Economic Botany* 55(4):492-514.

Faegri, Knut

1966 Some Problems of Representativity in Pollen Analysis. *Palaeobotanist* 15:135-140.

Faegri, Knut, and Johs Iversen

1989 *Textbook of Pollen Analysis*. Blackburn Press, Caldwell, New Jersey.

Field, Henry

1948 Early Man in Mexico. *Man* 48:17-19.

Flannery, Kent V.

1968 Archaeological Systems Theory and Early Mesoamerica. In *Anthropological Archaeology in the Americas*, edited by B. Meggers, pp. 67-87. Anthropological Society of Washington, Washington, D.C.

Flannery, Kent V., editor

1986 *Guilá Naquitz: Archaic Foraging and Early Agriculture in Oaxaca, Mexico*. Academic Press, New York.

Folan, William J., Joel Gunn, Jack D. Eaton, and Robert W. Patch

1983 Paleoclimatological Patterning in Southern Mesoamerica. *Journal of Field Archaeology* 10(4):453-468.

Ford, Anabel

2008 Dominant Plants of the Maya Forest and Gardens of El Pilar: Implications for Paleoenvironmental Reconstructions. *Journal of Ethnobiology* 29(2):179-199.

Galinat, Walter S.

1961 Corn's Evolution and Its Significance for Breeding. *Economic Botany* 15:320-325.

Gasco, Janine

2008 'Le da Alegría Tener Flores': Homegardens in the Soconusco Region of Chiapas, Mexico. *Journal of Ethnobiology* 29(2):259-277.

Gepts, Paul

1998 What Can Molecular Markers Tell Us About the Process of Domestication in Common Bean? In *The Origins of Agriculture and Crop Domestication*, edited by A.B. Damania, J. Valkoun, G. Willcox, and C.O. Qualset. ICARDA, Aleppo, Syria. Electronic document, http://www.ipgri.cgiar.org/Publications/HTMLPublications/47/index.htm, accessed November 21, 2008.

Gischler, Eberhard, and J. Harold Hudson

2004 Holocene Development of the Belize Barrier Reef. *Sedimentary Geology* 164:223-236.

Gliessman, S.R., Billie L. Turner II, F.J. Rosado May, and M.F. Amador

1983 Ancient Raised Field Agriculture in the Maya Lowlands of Southeastern Mexico. In *Drained Field Agriculture in Central and South America*, edited by J.P. Darch, pp. 90-110. BAR International Series No. 189.

British Archaeological Reports, Oxford, U.K.

Goman, Michelle, and Roger Byrne

1998 A 5000-Year Record of Agriculture and Tropical Forest Clearance in the Tuxtlas, Veracruz, Mexico. *The Holocene* 8(1):83-89.

Gómez-Pompa, A., J.S. Flores, and M.A. Fernández

1990 The Sacred Cacao Groves of the Maya. *Latin American Antiquity* 1(3):247-257.

Gonzalez, Silvia, José Concepción Jiménez-López, Robert Hedges, David Hoddart, James C. Ohman, Alan Turner, and José Antonio Pompa y Padilla

2003 Earliest Humans in the Americas: New Evidence from Mexico. *Journal of Human Evolution* 44 (3): 379-387.

Gott, Beth, Huw Barton, Delwen Samuel, and Robin Torrence

2006 Biology of Starch. In *Ancient Starch Research,* edited by Robin Torrence and Huw Barton, pp. 35-46. Left Coast Press, Walnut Creek, California.

Grant, C.A.

1972 A Scanning Electron Microscopy Survey of Some Maydeae Pollen. *Grana* 12:177-184.

Great Britain, Directorate for Overseas Surveys

1958a British Honduras Natural Vegetation Map. Tolworth, Surrey, U.K.

1958b British Honduras Potential Land Use Map. Tolworth, Surrey, U.K.

1976 Belize 1:50,000. Tolworth, Surrey, U.K.

Gruhn, Ruth, and Alan L. Bryan

1977 Los Tapiales: A Paleoindian site in the Guatemalan Highlands. *Proceedings: American Philosophical Society* 121(3)235-273.

Guderjan, Thomas H.

1999 Introduction: The Status of Excavations and Research at Blue Creek. In *The Blue Creek Project: Working Papers from the 1997 Season,* edited by W. David Driver, Helen R. Haines, and Thomas H. Guderjan, pp. v-ix. Maya Research Program, St. Mary's University, San Antonio, Texas.

2004 Public Architecture, Ritual, and Temporal Dynamics at the Maya Center of Blue Creek, Belize. *Ancient Mesoamerica* 15:235-250.

2006 *Preliminary Blue Creek Field Report*. Maya Research Program, Texas Christian University, Forth Worth, Texas.

Guderjan, Thomas H., editor

1991 *Maya Settlement in Northwestern Belize: The 1988 and 1990 Seasons of the Río Bravo Archaeological Project*. Maya Research Program, St. Mary's University, San Antonio, Texas.

Guderjan, Thomas H., Jeffrey Baker, and Robert J. Lichtenstein

2003 Environmental and Cultural Diversity at Blue Creek. In *Heterarchy, Political Economy, and the Ancient Maya: The Three Rivers Region of the East-Central Yucatan Peninsula,* edited by Vernon L. Scarborough, Fred Valdez, Jr., and Nicholas P. Dunning, pp. 71-91. University of New Mexico Press, Albuquerque.

Guderjan, Thomas H. and W. David Driver

1999 Chapter 1. Architecture and Ritual at Blue Creek. In *The Blue Creek Project: Working Papers from the 1997 Season*, edited by W. David Driver, Helen R. Haines, and Thomas H. Guderjan, pp. 1-11. Maya Research Program, St. Mary's University, San Antonio, Texas.

Guderjan, Thomas H., Michael Lindeman, Ellen Ruble, Froyla Salam, and Jason Yaeger

1991 Archaeological Sites in the Río Bravo Area. In *Maya Settlement in Northwestern Belize: The 1988 and 1990 Seasons of the Río Bravo Archaeological Project*, edited by Thomas H. Guderjan, pp. 55-88. Maya Research Program, St. Mary's University, San Antonio, Texas.

Gunn, Joel D., and Richard E.W. Adams

1981 Climatic Change, Culture, and Civilization in North America. *World Archaeology* 13(1):87-100.

Gunn, Joel D., Ray T. Matheny, and William J. Folan

2002 Climate-Change Studies in the Maya Area: A Diachronic Analysis. *Ancient Mesoamerica* 13:79-84.

Hall, Carolyn and Héctor Pérez Brignoli

2003 *Historical Atlas of Central America*. University of Oklahoma Press, Norman.

Halley, R.B., E.A. Shinn, J.H. Hudson, and B. Lidz

1977 Recent and Relict Topography of Boo Bee Patch Reef, Belize. In *Proceedings of the Third International Coral Reef Symposium, Miami. Volume 2. Geology*, pp. 29-35.

Hammond, Norman

1982 The Prehistory of Belize. *Journal of Field Archaeology* 9(3):349-362.

Hammond, Norman, and Charles H. Miksicek

1981 Ecology and Economy of a Formative Maya Site at Cuello, Belize. *Journal of Field Archaeology* 8(3):259-269.

Hammond, Norman, Duncan Pring, Richard R. Wilk, Sara Donaghey, Frank P. Saul, Elizabeth S. Wing, Arlene V. Miller, and Lawrence H. Feldman

1979 The Earliest Lowland Maya? Definition of the Swasey Phase. *American Antiquity* 44(1):92-110.

Hansen, Barbara C.S.

1990 Pollen Stratigraphy of Laguna de Cocos. In *Ancient Maya Wetland Agriculture: Excavations on Albion Island, Northern Belize*, edited by Mary D. Pohl, pp. 155-186. Westview Press, Boulder, Colorado.

Hansen, Richard D.

2000 The First Cities: The Beginnings of Urbanization and State Formation in the Maya Lowlands. In *Maya: Divine Kings of the Rainforest*, edited by N. Grube, pp. 50-68. Konemann, Cologne, Germany.

Hansen, Richard D., Steven Bozarth, John Jacob, David Wahl, and Thomas Schreiner

2002 Climatic and Environmental Variability in the Rise of Maya Civilization: A Preliminary Perspective from Northern Petén. *Ancient Mesoamerica* 13:273-295.

Harris, D.R.

1967 New Light on Plant Domestication and the Origins of Agriculture: A Review. *Geographical Review* 57(1):90-107.

1972 The Origins of Agriculture in the Tropics. *American Scientist* 60:180-193.

Harrison, Peter D.

1978 Bajos Revisited: Visual Evidence for One System of Agriculture. In *Prehispanic Maya Agriculture*, edited by Peter D. Harrison and Billie L. Turner II, pp. 247-254. University of New Mexico Press, Albuquerque.

1982 Subsistence and Society in Eastern Yucatán. In *Maya Subsistence: Studies in Memory of Dennis E. Puleston*, edited by Kent V. Flannery, pp. 119-130. Academic Press, New York.

1993 Aspects of Water Management in the Southern Maya Lowlands. In *Economic Aspects of Water Management in the Prehispanic New World*, edited by Vincent Scarborough and B. Isaac, pp. 71-122. Research in Economic Anthropology Supplement 7. JAI Press, Greenwich, Connecticut.

Haynes, Gary

2002 *The Early Settlement of North America: The Clovis Era*. Cambridge University Press, U.K.

Hazelden, John

1975 Further Notes on the Soils and Rocks of Northern Belize. In *Archaeology in Northern Belize*, edited by Norman Hammond, Chapter 10, pp. 184-189. British Museum-Cambridge University Corozal Project 1974-5 Interim Report. Centre of Latin American Studies, University of Cambridge, U.K.

Healy, Paul F., John D.H. Lambert, J.T. Arnason, and Richard J. Hebda

1983 Caracol, Belize: Evident of Ancient Maya Agricultural Terraces. *Journal of Field Archaeology* 10(4):397-410.

Heiser, C.B.

1979 Origins of Some Cultivated New World Plants. *Annual Review of*

Ecological Systems 10:309-326.

Henderson, John S., Rosemary A. Joyce, Gretchen R. Hall, W. Jeffrey Hurst, and Patrick E. McGovern

2007 Chemical and Archaeological Evidence for the Earliest Cacao Beverages. *Proceedings of the National Academy of Sciences USA* 104(48):08937-18940.

Hester, Thomas R.

1981 A Fluted Projectile Point from Belize. Center for Archaeological Research, University of Texas at San Antonio, Texas.

High, Lee R., Jr.

1975 Geomorphology and Sedimentology of Holocene Coastal Deposits, Belize. In *Belize Shelf: Carbonate Sediments, Clastic Sediments, and Ecology,* edited by K.W. Wantland and W.C. Pusey III, pp. 53-96. American Association of Petroleum Geologists, Tulsa, Oklahoma.

Hilton, Holly, and Brandon S. Gaut

1998 Speciation and Domestication in Maize and Its Wild Relatives: Evidence from the Globulin-1 Gene. *Genetics* 150(2):863-872.

Hirst, K. Kris

2008 Deep Origins of Agriculture. About.com: Archaeology. Electronic document, http://archaeology.about.com/b/2008/09/28/deep-origins-of-agriculture.htm?nl=1, accessed October 2, 2008.

Hodell, David A., Mark Brenner, and Jason H. Curtis

2000 Climate Change in the Northern American Tropics and Subtropics Since the

Last Ice Age: Implications for Environment and Culture. In *Imperfect Balance: Landscape Transformations in the Precolumbian Americas,* edited by David L. Lentz, pp. 13-38. Columbia University Press, New York.

Hodell, David A., Mark Brenner, Jason H. Curtis, and Thomas Guilderson

2001 Solar Forcing of Drought Frequency in the Maya Lowlands. *Science* 292(5520):1367-1370.

Hodell, David A., Jason H. Curtis, and Mark Brenner

1995 Possible Role of Climate in the Collapse of Classic Maya Civilization. *Nature* 375:391-394.

Hodell, David A., Jason H. Curtis, Glenn A. Jones, Antonia Higuera-Gundy, Mark Brenner, Michael W. Binford, and Kathleen T. Dorsey

1991 Reconstruction of Caribbean Climate Change Over the Past 10,500 Years. *Nature* 352(6338):790-793

Holst, Irene, J. Enrique Moreno, and Dolores R. Piperno

2007 Identification of Teosinte, Maize, and *Tripsacum* in Mesoamerica by Using Pollen, Starch Grains, and Phytoliths. *Proceedings of the National Academy of Sciences USA* 104 (45):17608-17613.

Horn, Sally P.

2006 Pre-Columbian Maize Agriculture in Costa Rica: Pollen and Other Evidence from Lake and Swamp Sediments. In *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize,* edited by John E. Staller, Robert H. Tykot, and Bruce F. Benz, pp. 367-380. Elsevier, Burlington, Massachusetts.

Hurst, W. Jeffrey, Stanley M. Tarka Jr., Terry G. Powis, Fred Valdez Jr., and Thomas R. Hester

2002 Cacao Usage by the Earliest Maya Civilization. *Nature* 418:289-290.

Iltis, Hugh H.

1981 The Catastrophic Sexual Transmutation Theory (CSTT): From the Teosinte Tassel Spike to the Ear of Corn. Paper presented at the XIII International Botanical Congress, Sydney, Australia.

1982 Corn (*Zea mays*) in Relation to Its Wild Relatives. *Desert Plants* 2(4):193-202.

Iltis, Hugh H., and John F. Doebley

1980 Taxonomy of *Zea* (Gramineae). II. Subspecific Categories in the *Zea mays* Complex and a Generic Synopsis. *American Journal of Botany* 67(6):994-1004.

Iltis, Hugh H., John F. Doebley, Rafael Guzman M., and Batia Pazy

1979 *Zea diploperennis* (Gramineae): A New Teosinte from Mexico. *Science* 203:186-188.

International Travel Maps

2004 Belize. International Travel Maps, Vancouver, Canada.

Irwin, Henry and Elso S. Barghoorn

1965 Identification of the Pollen of Maize, Teosinte and Tripsacum by Phase Contrast Microscopy. *Botanical Museum Leaflets, Harvard University* 21(2):37-56.

Islebe, G.A., H. Hooghiemstra, M. Brenner, J.H. Curtis, and D.A. Hodell

1996 A Holocene Vegetation History from Lowland Guatemala. *The Holocene* 6:265-271.

Johnson, William C.

1983 The Physical Setting: Northern Belize and Pulltrouser Swamp. In *Pulltrouser Swamp: Ancient Maya Habitat, Agriculture, and Settlement in Northern Belize*, edited by Billie L. Turner II and Peter D. Harrison, pp. 8-20. University of Texas Press, Austin.

Johnston, Kevin J.

2003 The Intensification of Pre-Industrial Cereal Agriculture in the Tropics: Boserup, Cultivation Lengthening, and the Classic Maya. *Journal of Anthropological Science* 22:126-161.

Jones, Gretchen D. and Vaughn M. Bryant, Jr.

1998 Are All Counts Created Equal? In *New Developments in Palynomorph Sampling, Extraction, and Analysis*, edited by Vaughn M. Bryant and J.H. Wrenn, pp. 115-120. American Association of Stratigraphic Palynologists Foundation, Contributions Series Number 33.

Jones, John G.

1991 Pollen Evidence of Prehistoric Forest Modification and Maya Cultivation in Belize. Doctoral dissertation, Texas A&M University, College Station.

1994 Pollen Evidence for Early Settlement and Agriculture in Northern Belize. *Palynology* 18:205-211.

2001 Personal communication.

2002 Personal communication.

Juggins, Stephen

2007 C2 Version 1.5. Software for Ecological and Paleoecological Data Analysis and Visualization. Newcastle University, Newcastle upon Tyne, U.K.

Kaplan, Lawrence, and Thomas F. Lynch

1999 *Phaseolus* (Fabaceae) in Archaeology: AMS Radiocarbon Dates and Their Significance for Pre-Columbian Agriculture. *Economic Botany* 53(3):261-272.

King, R.B., I.C. Bailie, T.M.B. Abell, J.R. Dunsmore, D.A. Gray, J.H. Pratt, H.R. Versey, A.C.S. Wright, and S.A. Zisman

1992 Land Resource Assessment of Northern Belize. *Natural Resources Institute Bulletin* 43 (2 volumes).

Kirchoff, Paul

1943 Mesoamerica. *Acta Americana* 1:92-107.

Kunen, Julie L., T. Patrick Culbert, Vilma Fialko, Brian McKee, and Liwy Grazioso

2000 Bajo Communities: A Case Study from the Central Petén. *Culture and Agriculture* 22(3):15-31.

Kurtz, Edwin B., James L. Liverman, and Henry Tucker

1960 Some Problems Concerning Fossil and Modern Corn Pollen. *Bulletin of the Torrey Botanical Club* 87:85-94.

Lambert, John D.H., and J. Thor Arnason

1978 Distribution of Vegetation on Maya Ruins and Its Relationship to Ancient Landuse at Lamanai, Belize. *Turrialba* 28(1):33-41.

1982 Ramón and Maya Ruins: An Ecological, not an Economic, Relation.

Science 216(4543):298-299.

Lambert, John D.H., A.H. Siemens, and J. Thor Arnason

1984 Ancient Maya Drained Field Agriculture: Its Possible Application Today in the New River Floodplain, Belize, C.A. *Agriculture, Ecosystems and Environment* 11:67-84.

Largent, Floyd B.

2005 Early Humans South of the Border: New Finds from the Yucatán Peninsula. *Mammoth Trumpet* 20(3):8-11.

Lawlor, Elizabeth J., Amy J. Graham, and Scott L. Fedick

1995 Preclassic Floral Remains from Cahal Pech, Belize. In *Belize Valley Preclassic Maya Project: Report on the 1994 Field Season,* edited by P.F. Healy and J.J. Awe, pp. 150-172. Trent University, Occasional Papers in Anthropology No. 10. Peterborough, Ontario, Canada.

Leyden, Barbara W.

1984 Guatemalan Forest Synthesis After Pleistocene Aridity. *Proceedings of the National Academy of Sciences USA* 81(15):4856-4859.

1987 Man and Climate in the Maya Lowlands. *Quaternary Research* 28:407-414.

Leyden, Barbara W., Mark Brenner, and Bruce H. Dahlin

1998 Cultural and Climatic History of Cobá, a Lowland Maya City in Quintana Roo, Mexico. *Quaternary Research* 49:111-122.

Leyden, Barbara W. Mark Brenner, David A. Hodell, and Jason H. Curtis

1993 Late Pleistocene Climate in the Central American Lowlands. In *Climate*

Change in the Continental Isotopic Records, edited by P.K. Swart, K.C. Lohmann, J.A. McKenzie, and S. Savin, pp. 165-178. Geophysical Monograph No. 78. American Geophysical Union, Washington, D.C.

1994 Orbital and Internal Forcing of Climate on the Yucatan Peninsula for the Past ca. 36 ka. *Palaeogeography, Palaeoclimatology, Palaeoecology* 109:193-210.

Lindeman, Michael, and Thomas H. Guderjan

1991 Notes on Stone Procurement and Consumption. In *Maya Settlement in Northwestern Belize: The 1988 and 1990 Seasons of the Río Bravo Archaeological Project*, edited by Thomas H. Guderjan, pp. 95-97. Maya Research Program, St. Mary's University, San Antonio, Texas.

Lohse, Jon C.

2003a *Blue Creek Regional Political Ecology Project 2003 Season Summary – Project Overview*, pp. 1-14. Maya Research Program, Texas Christian University, Fort Worth, Texas.

2003b *Blue Creek Regional Political Ecology Project: Understanding Ancient Maya Socio-Political Process and Resource Use in Upper Northwestern Belize – 2003 Season*. Maya Research Program, Texas Christian University, Fort Worth, Texas.

2004 *The Blue Creek Project 2004 Season Summary*. Maya Research Program, Texas Christian University, Fort Worth, Texas.

Long, Austin B., Bruce F. Benz, D.J. Donahue, A.J.T. Tull, and L.J. Toolin

1989 First Direct AMS Dates on Early Maize from Tehuacán, Mexico. *Radiocarbon* 31:1035-1040.

Longyear III, John M.

1948 A Sub-Pottery Deposit at Copan, Honduras. *American Antiquity* 8(3):248-249.

Lorenzo, José Luis and Lorena Mirambell

1999 The Inhabitants of Mexico During the Upper Pleistocene. In *Ice Age Peoples of North America: Environments, Origins, and Adaptations of the First Americans*, edited by Robson Bonnichsen and Karen L. Turnmire, pp. 482-496. Center for the Study of the First Americans, Corvallis, Oregon.

Lucquin, Alexandre, Ramiro Javier March, and Serge Cassen

2007 Analysis of Adhering Organic Residues of Two "Coupes-á-socles" from the Neolithic Funerary Site "La Hougue Bie" in Jersey: Evidences of Birch Bark Tar Utilisation. *Journal of Archaeological Science* 34:704-710.

Luzzadder-Beach, Sheryl, and Timothy Beach

2008 Water Chemistry Constraints and Possibilities for Ancient and Contemporary Maya Wetlands. *Journal of Ethnobiology* 28(2):211-230.

2009 Arising from the Wetlands: Mechanisms and Chronology of Landscape Aggradation in the Northern Coastal Plain of Belize. *Annals of the Association of American Geographers* 99(1):1-26.

Lyell, Charles

1835 *Principles of Geology: Being an Inquiry How Far the Former Changes of the Earth's Surface are Referable to Causes Now in Operation*, 4th ed. John Murray, London.

Mabberley, D.J.

1997 *The Plant-Book*. Cambridge University Press, U.K.

2008 *Mabberley's Plant-Book*, 3rd ed. Cambridge University Press, U.K.

MacNeish, Richard S.

1971 Speculation about How and Why Food Production and Village Life Developed in the Tehuacán Valley, Mexico. *Archaeologi* 24(4):307-315.

1972 The Evolution of Community Pattern in the Tehuacán Valley of Mexico and Speculations about the Cultural Processes. In *Man, Settlement and Urbanism,* edited by P. Ucko, R. Tringham, and George Dimblely, pp. 67-93. Duckworth, London.

MacNeish, Richard S., and Antoinette Nelken-Terner

1983 The Preceramic of Mesoamerica. *Journal of Field Archaeology* 10(1):71-84.

MacNeish, Richard S., S. Jeffrey K. Wilkerson, and Antoinette Nelken-Terner

1980 First Annual Report of the Belize Archaic Archaeological Reconnaissance. Robert F. Peabody Foundation for Archaeology, Andover, Massachusetts.

Maher, Louis J.

1964 Ephedra Pollen in Sediments of the Great Lakes Region. *Ecology* 45:391-395.

1981 Statistics for Microfossil Concentration Measurements Employing Samples Spiked with Marker Grains. *Review of Paleobotany and Palynology* 32:153-191.

Mangelsdorf, Paul C.

1974 *Corn: Its Origin, Evolution, and Improvement*. Cambridge, Massachusetts: Belknap Press of Harvard University Press.

1983 The Mystery of Corn: New Perspectives. *Proceedings of the American*

Philosophical Society 127(4):215-247.

Mangelsdorf, Paul C., Elso S. Barghoorn, and Umesh C. Banerjee

1978 Fossil Pollen and the Origin of Corn. *Botanical Museum Leaflets, Harvard University* 26:238-255.

Mangelsdorf, Paul C., Richard S. MacNeish, and Walton C. Galinat

1964 Domestication of Corn. *Science* 143(3606):538-545.

Mangelsdorf, Paul C., and R.G. Reeves

1939 The Origin of Indian Corn and Its Relatives. Texas Agricultural Experiment Station, Bulletin 574. College Station, Texas.

Marcus, Joyce

1982 The Plant World of the Sixteenth- and Seventeenth-Century Lowland Maya. In *Maya Subsistence*, edited by K.V. Flannery, pp. 239-273. Academic Press, New York.

Marshall, Dawn M.

1999 Pollen Analysis of Late 1800s Privy Deposits from Houston, Texas. M.A. thesis. Texas A&M University, College Station, TX.

2007 Ethnopalynological Applications in Land and Water Based Archaeology. Ph.D. dissertation, Anthropology Department, Texas A&M University, College Station.

Martinez, G., Richard D. Hansen, John Jacob, and W.K. Howell

1999 Nuevas Evidencias de las Sistemas de Cultivo del Preclasico en la Cuenca Mirador. In *XII Simposio de Investigaciones Arqueologicas en Guatemala*, edited by J.P. Laporte, H.L. Escobedo, and A.C.M. de Wasnaver, pp. 327-

336. Museo Nacional de Arqueología y Historia and Asociacion Tikal, Guatemala City, Guatemala.

Martínez-Hernández, Enrique, José Ignacio Cuadriello-Aguilar, Oswaldo Téllez-Valdez, Elia Ramírez-Arriaga, María Susana Sosa-Nájera, Julia Eva María Melchor-Sánchez, Margarita Medina-Camacho, and María del Socorro Lozano-García

1993 *Atlas de las plantas y el polen utilizados por las cinco especies principales de abejas productoras de miel en la región del Tacaná, Chiapas, México*. Universidad Nacional Autónoma de México, México, D.F.

Matsuoka, Yoshihiro, Yves Vigouroux, Major M. Goodman, Jesus Sanchez G., Edward Buckler, and John Doebley.

2002 A Single Domestication for Maize Shown by Multilocus Microsatellite Genotyping. *Proceedings of the National Academy of Sciences USA* 99(9): 6080-6084.

Matheny, Ray T.

1978 Northern Maya Lowland Water-Control Systems. In *Prehispanic Maya Agriculture*, edited by Peter D. Harrison and Billie L. Turner II, pp. 185-210. University of New Mexico Press, Albuquerque.

Maya Research Program

2002 Electronic document, http://www.mayaresearchprogram.org/index.html, accessed September 2002. Texas Christian University, Fort Worth, Texas.

2005 Maya Research Program 2005 Season Highlights in Blue Creek, Belize. Electronic document, http://www.mayaresearchprogram.org, accessed December 2005. Texas Christian University, Fort Worth, Texas.

McClung de Tapia, Emily

1992 The Origins of Agriculture in Mesoamerica and Central America. In *The Origins of Agriculture*, edited by C. Wesley Cowan and Patty Jo Watson, pp. 143-171. Smithsonian Institution Press, Washington, D.C.

Meerman, J.C. and W. Sabido

2001a Central American Ecosystems Map, Volume 1. Programme for Belize, Belize City.

2001b Central American Ecosystems map, Volume 2. Programme for Belize, Belize City.

Miksicek, Charles H.

1983 Macrofloral Remains of Pulltrouser Swamp: Settlements and Fields. In *Pulltrouser Swamp: Ancient Maya Habitat, Agriculture, and Settlement in Northern Belize*, edited by Billie L. Turner II and Peter D. Harrison, pp. 94-104. University of Texas Press, Austin.

Miksicek, Charles H., R. McK. Bird, Barbara Pickersgill, S. Donaghey, J. Cartwright, and Norman Hammond

1981 Rethinking Ramón: A Comment on Reina and Hill's Lowland Maya Subsistence. *American Antiquity* 46(4):916-919.

Mosimann, J.E.

1965 Statistical Methods for the Pollen Analyst: Multinomial and Negative Multinomial Techniques. *Biometrika* 49:65-82.

Neivens, Mary

1991 Operations at the Site of Blue Creek. In *Maya Settlement in Northwestern Belize: The 1988 and 1990 Seasons of the Río Bravo Archaeological*

Project, edited by Thomas H. Guderjan, pp. 51-54. Maya Research Program, St. Mary's University, San Antonio, Texas.

Oyama, Ken, Sergio Hernández-Verdugo, Carla Sánchez, Antonio González-Rodríguez, Pedro Sánchez-Peña, José Antonio Garzón-Tiznado, and Alejandro Casas

2006 Genetic Structure of Wild and Domesticated Populations of *Capsicum annuum* (Solanaceae) from Northwestern Mexico Analyzed by RAPDs. *Genetic Resources and Crop Evolution* 53:553-562.

Palacios Chávez, Rodolfo, Beatriz Ludlow-Wiechers, and Rogel Villanueva G.

1991 *Flora Palinologica de la Reserva de la Biosefera de Sian Ka'an, Quintana Roo, Mexico*. Centro de Investigactiones de Quintana Roo, Chetumal, Quintana Roo, Mexico.

Pearsall, Deborah M.

2000 *Paleoethnobotany: A Handbook of Procedures*. 2nd ed. Academic Press, San Diego, California.

1982 Phytolith Analysis: Applications of a New Paleoethnobotanical Technique in Archaeology. *American Anthropologist* 84(4):862-871.

Pearson, Georges A.

2002 Pan-Continental Paleoindian Expansions and Interactions as Viewed from the Earliest Lithic Industries of Lower Central America. Ph.D. dissertation, Department of Anthropology, University of Kansas, Lawrence, Kansas.

2004 Stemmed Fluted 'Fishtail' Point. Electronic document, http://www.people.ku.edu/~ftgap/pearson/PEARSON.htm, accessed Spring 2004, but no longer available online. Department of Anthropology, University of Kansas, Lawrence, Kansas.

Pearson, Georges A., and Peter A. Bostrom

1998 A New Fluted Stemmed Point from Belize and Its Implication for a Circum-Caribbean Paleoindian Culture Area. *Current Research in the Pleistocene* 15:55-56.

Perry, Linda, Ruth Dickau, Sonia Zarrillo, Irene Holst, Deborah M. Pearsall, Dolores R. Piperno, Mary Jane Berman, Richard G. Cooke, Kurt Rademaker, Anthony J. Ranere, J. Scott Raymond, Daniel H. Sandweiss, Franz Scaramelli, Kay Tarble, and James A. Zeidler

2007 Starch Fossils and the Domestication and Dispersal of Chili Peppers (*Capsicum* spp. L.) in the Americas. *Science* 315:986-988.

Piperno, Dolores, and Karen H. Clary

1984 Early Plant Use and Cultivation in the Santa Maria Basin, Panama: Data from Phytoliths and Pollen. In *Recent Developments in Isthmian Archaeology: Advances in the Prehistory of Lower Central America,* edited by Frederick W. Lange. BAR International Series No. 212. British Archaeological Reports, Oxford, U.K.

Piperno, Dolores, Karen H. Clary, Richard G. Cooke, Anthony J. Ranere, and Doris Weiland

1985 Preceramic Maize in Central Panama: Phytolith and Pollen Evidence. *American Anthropologist* 87(4):871-878.

Piperno, Dolores, and Kent Flannery

2001 The Earliest Archaeological Maize (*Zea mays L.*) from Mesoamerica: New Accelerator Mass Spectrometer Dates and Their Implications. *Proceedings of the National Academy of Sciences USA* 98:2101-2103.

Piperno, Dolores, and Gayle J. Fritz

1994 On the Emergence of Agriculture in the New World. *Current Anthropology* 35(5):637-643.

Piperno, Dolores, and Irene Holst

1998 The Presence of Starch Grains on Prehistoric Stone Tools from the Humid Neotropics: Indications of Early Tuber Use and Agriculture in Panama. *Journal of Archaeological Science* 35:765-776.

Piperno, Dolores, and Deborah Pearsall

1998 *The Origins of Agriculture in the Lowland Neotropics*. Academic Press, San Diego.

Piperno, Dolores R.

1984 A Comparison of Differentiation of Phytoliths from Maize and Wild Grasses: Use of Morphological Criteria. *American Antiquity* 49(2):361-383.

1998 Paleoethnobotany in the Neotropics from Microfossils: New Insights into Ancient Plant Use and Agricultural Origins in the Tropical Forest. *Journal of World Prehistory* 12(4):393-449.

Piperno, Dolores R., J. Enrique Moreno, J. Iriarte, Irene Holst, M. Lachniet, John G. Jones, Anthony J. Ranere, and R. Castanzo

2007 Late Pleistocene and Holocene Environmental History of the Iguala Valley, Central Balsas Watershed of Mexico. *Proceedings of the National Academy of Sciences USA* 104(29):11874-11881.

Piperno, Dolores R., Anthony J. Ranere, Irene Holst, and Patricia Hansell

2000 Starch Grains Reveal Early Root Crop Horticulture in the Panamanian

Tropical Forest. *Nature* 407:894-897.

Piperno, Dolores R., Anthony J. Ranere, Irene Holst, Jose Iriarte, and Ruth Dickau

2009 Starch Grain and Phytolith Evidence for Early Ninth Millennium B.P. Maize from the Central Balsas River Valley, Mexico. *Proceedings of the National Academy of Sciences USA* 108(13):5019-5024.

Pohl, Mary, Dolores R. Piperno, Kevin O. Pope, and John G. Jones

2007 Microfossil Evidence for Pre-Columbian Maize Dispersals in the Neotropics from San Andrés, Tabasco, Mexico. *Proceedings of the National Academy of Sciences USA* 104:6870-6875.

Pohl, Mary D., editor

1985 *Prehistoric Lowland Maya Environment and Subsistence Economy*. Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, Massachusetts.

1990 *Ancient Maya Wetland Agriculture: Excavations on Albion Island, Northern Belize*. Westview Press, Boulder, Colorado.

Pohl, Mary D., and Charles H. Miksicek

1985 The Development and Impact of Ancient Maya Agriculture. In *Prehistoric Lowland Maya Environment and Subsistence Economy*, edited by Mary D. Pohl, pp. 9-20. Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, Massachusetts.

Pohl, Mary D., Kevin O. Pope, John G. Jones, John S. Jacob, Dolores R. Piperno, Susan D. DeFrance, David L. Lentz, John A. Gifford, Marie E. Danforth, and J. Kathryn Josserand

1996 Early Agriculture in the Maya Lowlands. *Latin American Antiquity* 7:355-372.

Poinar, Hendrik N., Raul J. Cano, and George O. Poinar, Jr.

1993 DNA from an Extinct Plant. *Nature* 363:677.

Poinar, Hendrik N., Melanie Kuch, Kristin D. Sobolik, Ian Barnes, Artur B. Stankiewicz, Tomasz Kuder, W. Geofferey Spaulding, Vaughn M. Bryant, Alan Cooper, and Svanted Paabo

2001 A Molecular Analysis of Dietary Diversity for Three Archaic Native Americans. *Proceedings of the National Academy of Sciences U.S.A.* 98(8):4317-4322.

Pope, Kevin, Penny Masuoka, Eliška Rejmánková, John Grieco, Sarah Johnson, and Donald Roberts

2005 Mosquito Habitats, Land Use, and Malaria Risk in Belize from Satellite Imagery. *Ecological Applications* 15(4):1223-1232.

Popenoe de Hatch, Marion, Erick Ponciano, Tomás Barrientos Q., Mark Brenner, and Charles Ortloff

2002 Climate and Technological Innovation at Kaminaljuyu, Guatemala. *Ancient Mesoamerica* 13:103-114.

Powis, Terry G., W. Jeffrey Hurst, María del Carmen Rodríguez, Ponciano Ortíz C., Mickael Blake, David Cheetham, Michael D. Coe, and John G. Hodgson

2008 The Origins of Cacao Use in Mesoamerica. *Mexicon* 30:35-38.

Powis, Terry G., Fred Valdez Jr., Thomas R. Hester, W. Jeffrey Hurst, and Stanley M. Tarka Jr.

2002 Spouted Vessels and Cacao Use Among the Preclassic Maya. *Latin American Antiquity* 13(1):85-106.

Pring, Duncan

1975 Excavations at El Posito. In *Archaeology in Northern Belize,* edited by Norman Hammond, Chapter 6, pp. 128-131. British Museum-Cambridge University Corozal Project 1974-5 Interim Report. Centre of Latin American Studies, University of Cambridge, U.K.

Pring, Duncan, and Norman Hammond

1975 Investigation of a Possible Port Installation at Nohmul. In *Archaeology in Northern Belize,* edited by Norman Hammond, Chapter 5, pp. 116-127. British Museum-Cambridge University Corozal Project 1974-5 Interim Report. Centre of Latin American Studies, University of Cambridge, U.K.

Puleston, Dennis E.

1965 The Chultuns of Tikal. *Expedition* 7(3):24-29.

1971 An Experimental Approach to the Function of Classic Maya Chultuns. *American Antiquity* 36(3):322-335.

1975 Richmond Hill: A Probable Early Man Site in the Maya Lowlands. *Actos y Memorias, XLI Congreso Internacional de Americanistas* 1:522-533.

1977a Experiments in Prehistoric Raised Field Agriculture: Learning From the Past. *Journal of Belizean Affairs* 5:36-43.

1977b The Art and Archaeology of Hydraulic Agriculture in the Maya Lowlands. In *Social Process in Maya Prehistory: Studies in Honour of Sir Eric Thompson*, edited by Norman Hammond, pp. 449-467. Academic Press, London.

Purdy, E.G.

1974 Karst-Determined Facies Patterns in British Honduras: Holocene Carbonate Sedimentation Model. *American Association of Petroleum Geologists Bulletin* 58:825-855.

Ranere, Anthony J., and Richard G. Cooke

1991 Paleoindian Occupation in the Central American Tropics. In *Clovis Origins and Adaptations*, edited by Robson Bonnichsen and Karen L. Turnmire, pp. 237-253. Center for the Study of the First Americans, Corvallis, Oregon.

Ranere, Anthony J., Dolores R. Piperno, Irene Holst, Ruth Dickau, and José Iriarte

2009 The Cultural and Chronological Context of Early Holocene Maize and Squash Domesticaion in the Central Balsas River Valley, Mexico. *Proceedings of the National Academy of Sciences USA* 106(13):5014-5018.

Reille, Maurice

1999 *Pollen et Spores d'Europe et d'Afrique du Nord*. Second edition. Laboratoire de Botanique Historique et Palynologie, Marseille, France.

Reinhard, Karl J., and Vaughn M. Bryant, Jr.

1992 Coprolite Analysis: A Biological Perspective on Archaeology. In *Archaeological Method and Theory,* edited by Michael B. Schiffer, pp. 245-288. University of Arizona Press, Tucson.

Rejmánková, Eliška, Kevin O. Pope, Mary D. Pohl, and Jose M. Rey-Banayas

1995 Freshwater Wetland Plant Communities of Northern Belize: Implications for Paleoecological Studies of Maya Wetland Agriculture. *Biotropica* 27(1):28-36.

Rice, Don S.

1993 Eighth-Century Physical Geography, Environment, and Natural Resources in the Maya Lowlands. In *Lowland Maya Civilization in the Eighth Century A.D.*, edited by Jeremy Sabloff and J. Henderson, pp. 11-64. Dumbarton Oaks, Washington, D.C.

Rice, Don S., Prudence M. Rice, and Edward S. Deevey

1985 Paradise Lost: Classic Maya Impact on a Lacustrine Environment. In *Prehistoric Lowland Maya Environment and Subsistence Economy*, edited by Mary D. Pohl, pp. 91-105. Peabody Museum Papers 77. Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, Massachusetts.

Rosenmeier, Michael F., David A. Hodell, Mark Brenner, Jason H. Curtis, and Thomas P. Guilderson

2002 A 4000-Year Lacustrine Record of Environmental Change in the Southern Maya Lowlands, Petén, Guatemala. *Quaternary Research* 57:183-190.

Roubik, David W. and Jorge Enrique Moreno

1991 *Pollen and Spores of Barro Colorado Island*. Missouri Botanical Garden, St. Louis.

Rowley, John R.

1960 The Exine Structure of “Cereal” and “Wild” Type Grass Pollen. *Grana Palynologica* 2(2):9-15.

1976 Observation of One Pollen Grain by SEM, TEM, and Light-Microscopy. *Acta Botanica Academiae Scientarum Hungaricae* 22(3-4):449-461.

Roys, Ralph

1931 (1976) *The Ethnobotany of the Maya*. Pennsylvania: Institute for the Study of Human Issues, Philadelphia.

Rue, David J.

1987 Early Agriculture and Early Postclassic Maya Occupation in Western Honduras. *Nature* 326:285-286.

Sanabria, Harry

2007 *The Anthropology of Latin America and the Caribbean*. Pearson Education, Boston.

Sangster, A.G., and H.M. Dale

1961 A Preliminary Study of Differential Pollen Grain Preservation. *Canadian Journal of Botany* 39(1):35-43.

1964 Pollen Grain Preservation of Underrepresented Species in Fossil Spectra. *Canadian Journal of Botany* 42:437-449.

Scarborough, Vernon L.

1998 Ecology and Ritual: Water Management and the Maya. *Latin American Antiquity* 9(2):135-159.

Scarborough, Vernon L., Matthew E. Becher, Jeffrey L. Baker, Garry Harris, and Fred Valdez, Jr.

1995 Water and Land at the Ancient Maya Community of La Milpa. *Latin American Antiquity* 6(2):98-119.

Schwarcz, Henry P.

2006 Stable Carbon Isotope Analysis and Human Diet: A Synthesis. In *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize*, edited by John E. Staller, Robert H. Tykot, and Bruce F. Benz, pp. 315-321. Elsevier, Burlington, Massachusetts.

Sheets, P.D.

1982 Prehistoric Agricultural Systems in El Salvador. In *Maya Subsistence: Studies in Memory of Dennis E. Puleston*, edited by K. Flannery, pp. 99-

118. Academic Press, New York.

Shinn, E.A., J.H. Hudson, R.B. Halley, B. Lidz, and D.M. Robbin

1982 Geology and Sedimentological Accumulation Rates at Carrie Bow Cay, Belize. In *Atlantic Barrier Reef Ecosystem at Carrie Bow Cay, Belize. 1. Structure and Communities,* edited by K. Rutzler and I.G. Macintyre, pp. 63-75. Smithsonian Contributions to Marine Science 12. Smithsonian Institution, Washington, D.C.

Siemens, Alfred H., José Angel Soler Graham, Richard Hebda, and Maija Heimo

2002 "Dams" on the Candelaria. *Ancient Mesoamerica* 13:115-123.

Siemens, Alfred H., and Dennis E. Puleston

1972 Ridged Fields and Associated Features in Southern Campeche: New Perspectives on the Lowland Maya. *American Antiquity* 37:228-239.

Smith, Bruce D.

1997 The Initial Domestication of *Cucurbita pepo* in the Americas 10,000 Years Ago. *Science* 276:932-934.

2001 Documenting Plant Domestication: The Consilience of Biological and Archaeological Approaches. *Proceedings of the National Academy of Sciences USA* 98(4):1324-1326.

2005 Reassessing Coxcatlan Cave and the Early History of Domesticated Plants in Mesoamerica. *Proceedings of the National Academy of Sciences USA* 102(27):9438-9445.

Snarskis, Michael J.

1979 Turrialba: A Paleo-Indian Quarry and Workshop Site in Eastern Costa Rica. *American Antiquity* 44(1):125-138.

Standley, Paul C. and Samuel J. Record

1934 *The Forests and Flora of British Honduras.* Field Museum of Natural History. Publication 350. Botanical Series Vol. XII.

1936 *The Forests and Flora of British Honduras*. Field Museum Press, Chicago.

Stein, Julie K.

1990 Sedimentation and Maya Agriculture Along Rio Hondo, Belize. In *Ancient Maya Wetland Agriculture: Excavations on Albion Island, Northern Belize,* edited by Mary D. Pohl, pp. 323-337. Westview Press, Boulder, Colorado.

Stross, F.H., H. V. Michel, F. Asaro, and R. Gruhn

1977 Sources of Some Obsidian Flakes from a Paleoindian Site in Guatemala. *American Antiquity* 42(1):114-118.

Thoms, Alston V.

2008 The Fire Stones Carry: Ethnographic Records and Archaeological Expectations for Hot-Rock Cookery in Western North America. *Journal of Anthropological Archaeology* 27:443-460.

Toscano, M.A., and I.G. Macintyre

2003 Corrected Western Atlantic Sea-Level Curve for the Last 11,000 Years Based on Calibrated ^{14}C Dates from *Acropora palamata* Framework and Intertidal Mangrove Peat. *Coral Reefs* 22:257-270.

Tsukada, Matsuo

1966 The Pollen Sequence. In *The History of Laguna Petenxil, A Small Lake in Northern Guatemala,* edited by Ursula Cowgill and G. Evelyn Hutchinson, pp. 63-66. Memoirs of the Connecticut Academy of Arts and Sciences 17.

Tsukada, Matsuo, and John R. Rowley

1964 Identification of Modern and Fossil Maize Pollen. *Grana Palynologica* 5:406-412.

Turner, Billie L. II

1978 Ancient Agricultural Land Use in the Central Maya Lowlands. In *Prehispanic Maya Agriculture*, edited by Peter D. Harrison and Billie L. Turner II, pp. 163-183. University of New Mexico Press, Albuquerque.

1979 Prehispanic Terracing in the Central Maya Lowlands: Problems of Agricultural Intensification. In *Maya Archaeology and Ethnohistory,* edited by Norman Hammond and Gordon R. Willey, pp. 103-115. University of Texas Press, Austin.

1983a The Excavations of Raised and Channelized Fields at Pulltrouser Swamp. In *Pulltrouser Swamp: Ancient Maya Habitat, Agriculture, and Settlement in Northern Belize*, edited by Billie L. Turner and Peter D. Harrison, pp. 30-51. University of Texas Press, Austin.

1983b *Once Beneath the Forest: Prehistoric Terracing in the Rio Bec Region of the Maya Lowlands*. Westview Press, Boulder, Colorado.

1985 Issues Related to Subsistence and Environment Among the Ancient Maya. In *Prehistoric Lowland Maya Environment and Subsistence Economy*, edited by Mary D. Pohl, pp. 195-209. Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, Massachusetts.

Turner, Billie L. II and Peter D. Harrison, Editors

1983 *Pulltrouser Swamp: Ancient Maya Habitat, Agriculture, and Settlement in Northern Belize*. University of Texas Press, Austin.

United Nations

2002 World Population 2002 (Data Sheet). Electronic document, www.un.org/esa/population/publications/wpp2002/POP-R2002-DATA_Web.xls, accessed 2002.

Vaughan, Hague H., Edward S. Deevey, Jr., and Sam E. Garrett-Jones

1985 Pollen Stratigraphy of Two Cores from the Petén Lake District. In *Prehistoric Lowland Maya Environment and Subsistence Economy*, edited by Mary D. Pohl, pp. 73-89. Peabody Museum Papers 77. Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, Massachusetts.

Wang, Huai, Tina Nussbaum-Wagler, Bailin Li, Qiong Zhao, Yves Virouroux, Marianna Faller, Kirsten Bomblies, Lewis Lukens, and John F. Doebley

2005 The Origin of the Naked Grains of Maize. *Nature* 436:714-719.

Waters, Michael R.

2004 The Role of Geoarchaeology in the Search for the First Americans. In *New Perspectives on the First Americans,* edited by Bradley T. Lepper and Robson Bonnichsen, pp. 187-192. Texas A&M University Press, College Station, Texas.

Westphall, Michael J.

1986 *Anatomy and History of a Ringed-Reef Complex, Belize, Central America.* M.S. Thesis, Rosentiel School of Marine and Atmospheric Sciences, University of Miami, Florida.

White, Christine D., Paul F. Healy, and Henry P. Schwarcz

1993 Intensive Agriculture, Social Status and Maya Diet at Pacbitun, Belize. *Journal of Anthropological Research* 49(4):347-375.

White, Christine D., Fred J. Longstaffe, and Henry P. Schwarcz

2006 Social Directions in the Isotopic Anthropology of Maize in the Maya Region. In *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize*, edited by John E. Staller, Robert H. Tykot, and Bruce F. Benz, pp. 143-159. Elsevier, Burlington, Massachusetts.

Wilk, Richard R.

1975 Superficial Examination of Structure 100, Colha. In *Archaeology in Northern Belize*, edited by Norman Hammond, pp. 152-173. British Museum-Cambridge University Corozal Project 1974-5 Interim Report. Centre of Latin American Studies, University of Cambridge, U.K.

1985 Dry Season Agriculture Among the Kekchi Maya and Implications for Prehistory. In *Prehistoric Lowland Maya Environment and Subsistence Economy*, edited by Mary D. Pohl, pp. 47-57. Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, Massachusetts.

Williams-Dean, Glenna, and Vaughn M. Bryant, Jr.

1975 Pollen Analysis of Human Coprolites from Antelope House. *The Kiva* 41(1):97-111.

Wiseman, Frederick M.

1983 Analysis of Pollen from the Fields at Pulltrouser Swamp. In *Pulltrouser Swamp: Ancient Maya Habitat, Agriculture, and Settlement in Northern*

Belize, edited by Billie L. Turner II and Peter D. Harrison, pp. 105-119. University of Texas Press, Austin.

1985 Agricultural and Vegetation Dynamics of the Maya Collapse in Central Petén, Guatemala. In *Prehistoric Lowland Maya Environment and Subsistence Economy*, edited by Mary D. Pohl, pp. 63-71. Papers of the Peabody Museum of Archaeology and Ethnology No. 77. Harvard University, Cambridge, Massachusetts.

Wittfogel, Karl A.

1957 *Oriental Despotism: A Comparative Study of Total Power*. Yale University Press, New Haven.

Yaeger, Jason H.

1991 Preliminary Report of the Gallon Jug Settlement Survey. In *Maya Settlement in Northwestern Belize: The 1988 and 1990 Seasons of the Río Bravo Archaeological Project*, edited by Thomas H. Guderjan, pp. 89-93. Maya Research Program, St. Mary's University, San Antonio, Texas.

Zavada, Michael S. and William L. Crepet

1981 Investigations of Angiosperms from the Middle Eocene of North America: Flowers of the Celtidoideae. *American Journal of Botany* 68(7): 924-933.

Zeitlin, Robert N.

1984 A Summary Report on Three Seasons of Field Investigations into the Archaic Period Prehistory of Lowland Belize. *American Anthropologist*, New Series, 86(2):358-369.

APPENDIX A

PHOTO PLATES

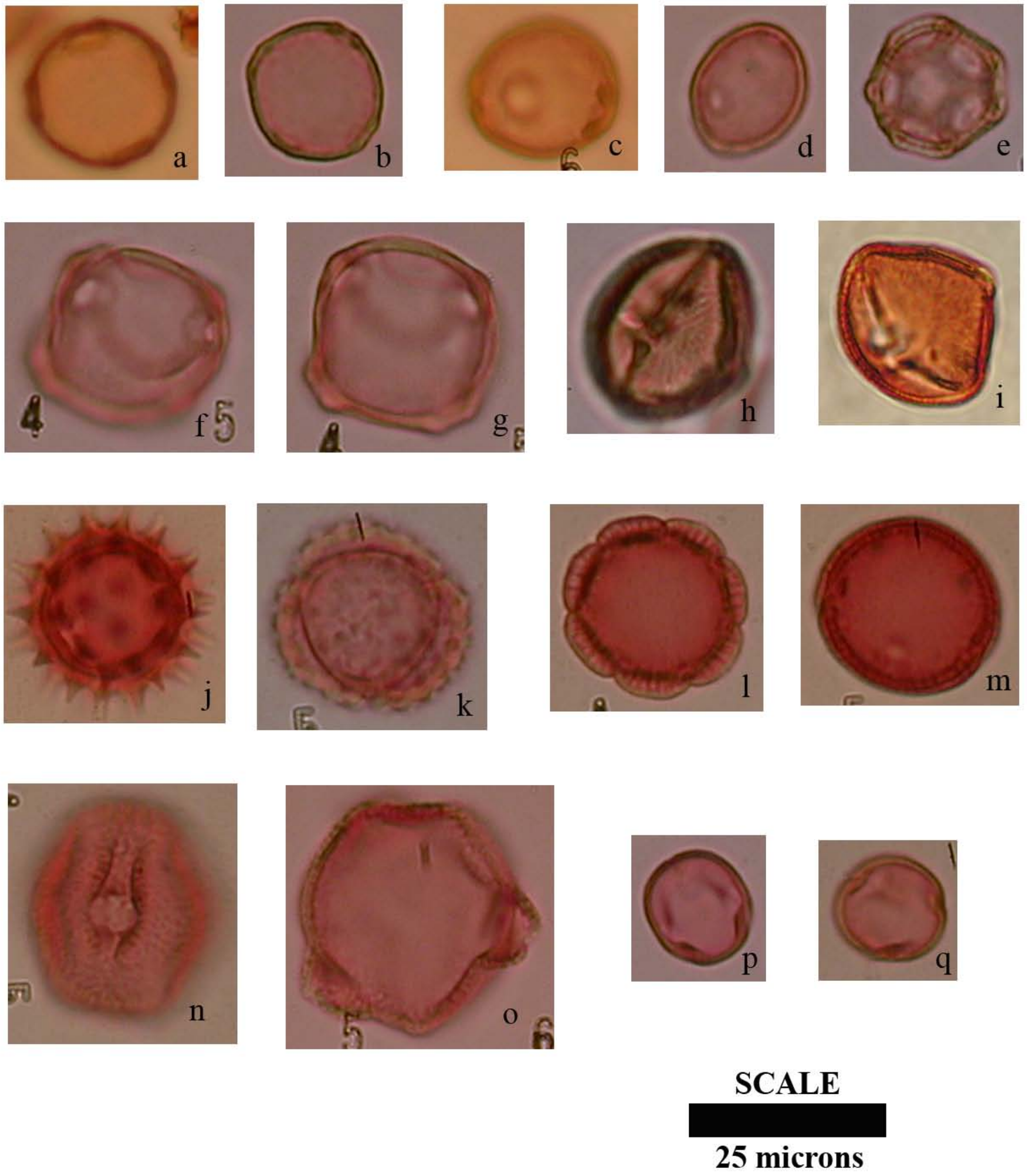

Figure A-1. a-d, *Acalypha*; e, Amaranthaceae; f-g, *Alnus*; h-i, Anacardiaceae; j, Asteraceae, high-spine; k, Asteraceae, low-spine; l-m, *Borreria* or *Spermacoce*; n-o, *Bursera simaruba*; p-q, *Byrsonima*.

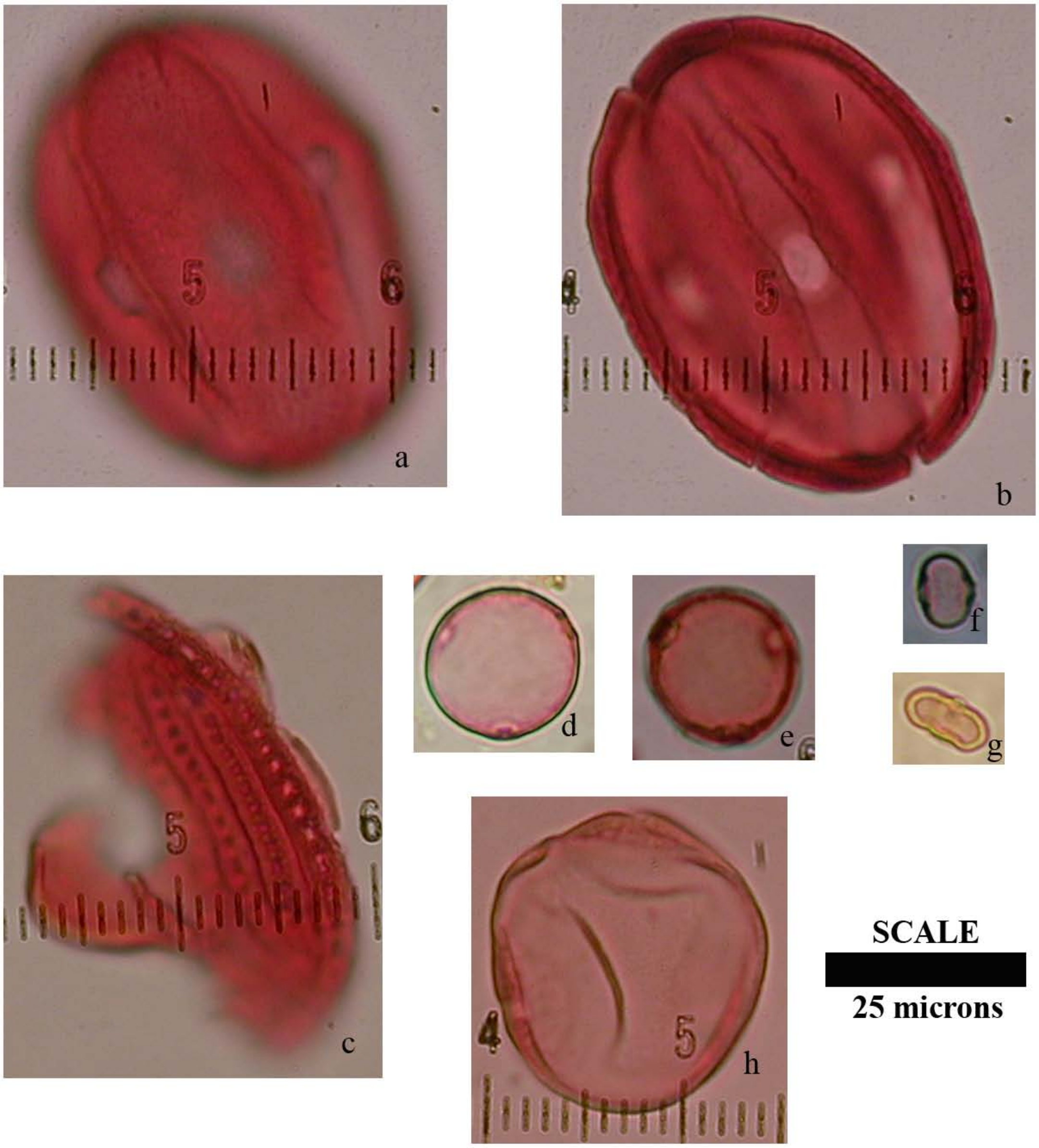

Figure A-2. a-b, *Bauhinia herrarae*; c, *Bravaisia* (fragment); d, *Cannabis* or *Celtis*; e, *Celtis*; f-g, *Cecropia*; h. *Carya*.

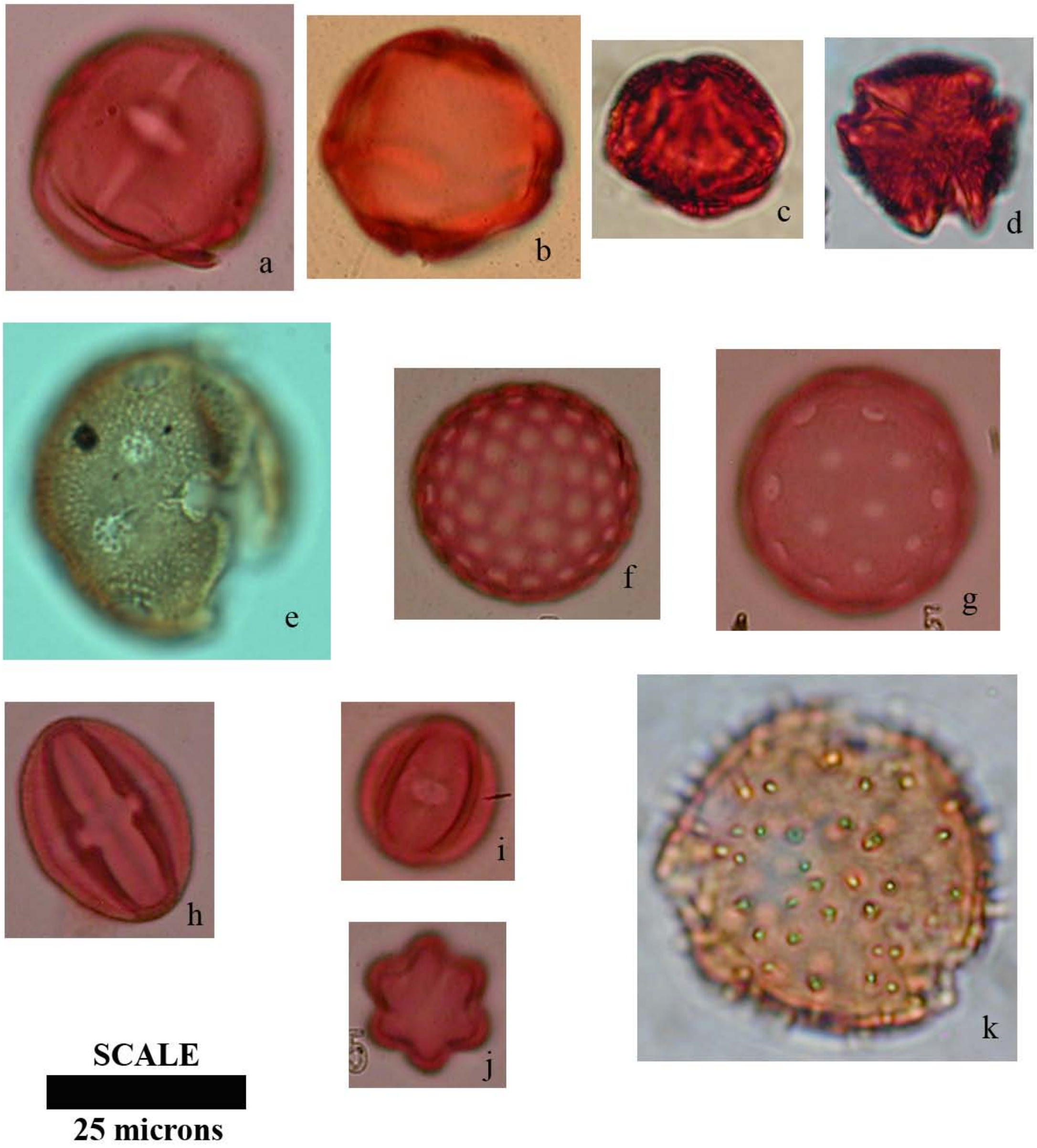

Figure A-3. a-b, *Cedrela odorata*; c-d, Celastraceae; e-g, Chenopodiaceae-Amaranthaceae; h, *Corchorus hirsutus*; i-j, Combretaceae-Melastomataceae; k, Cucurbitaceae.

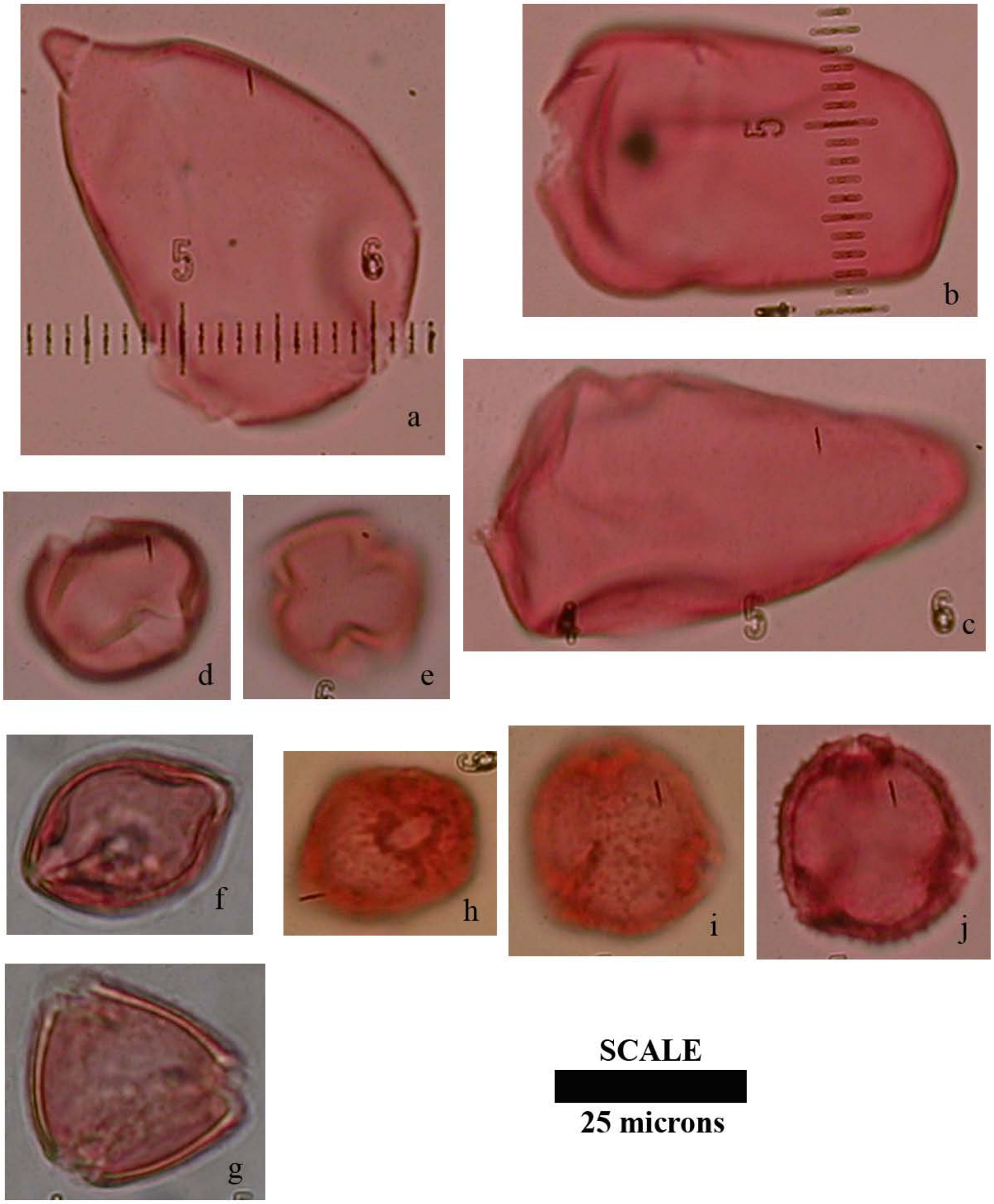

Figure A-4. a-c, Cyperaceae; d-e, cf *Dalbergia brownei*; f-g, *Desmodium*; h-j, *Exothea diphylla*.

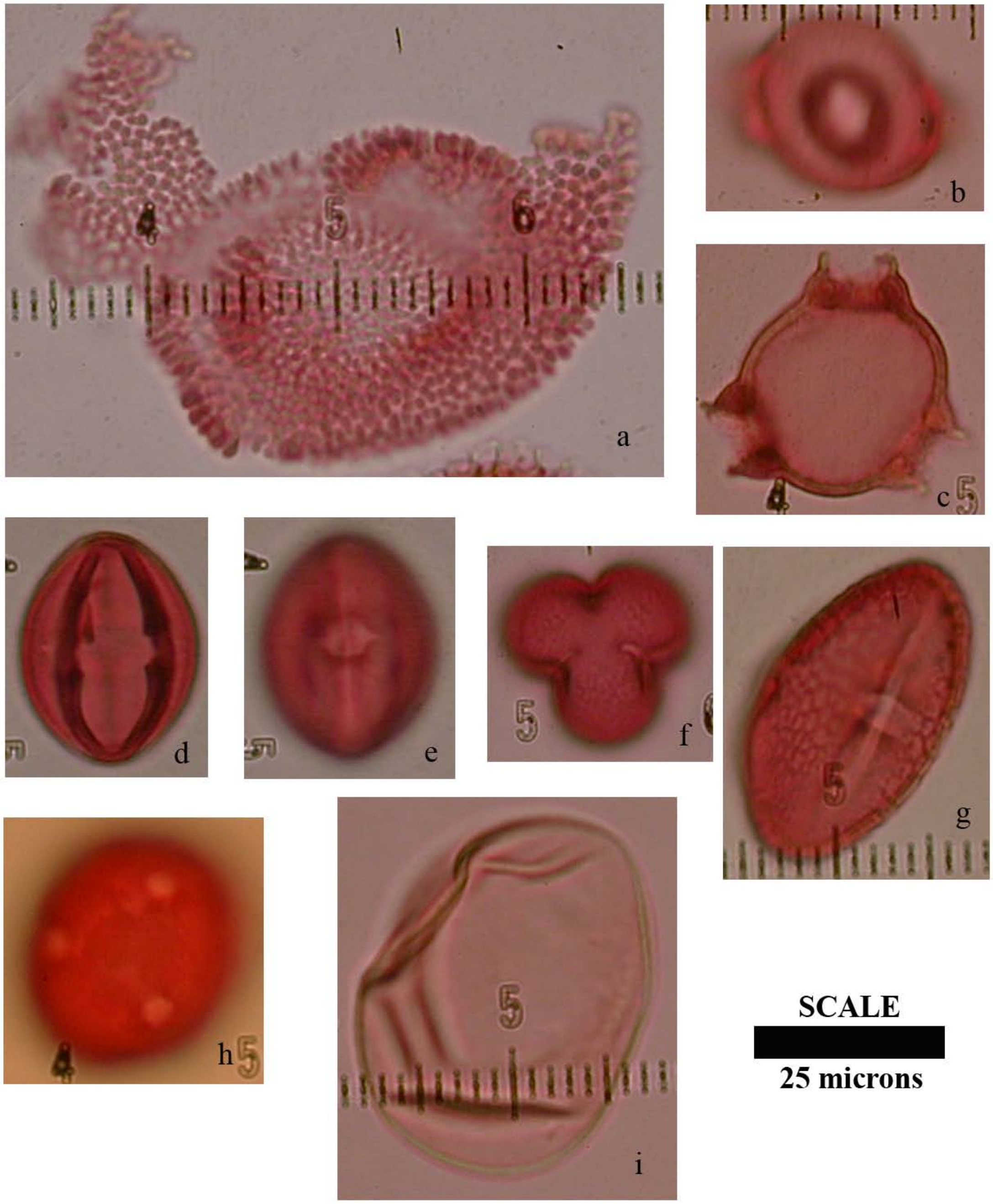

Figure A-5. a, Euphorbiaceae (fragment); b-c, *Faramea*; d-f, cf *Gymnanthes lucida* or *Chamaesyce thymifolia*; g, *Heliocarpus donnell-smithii*; h, *Heteropterys*; i, *Juncus*.

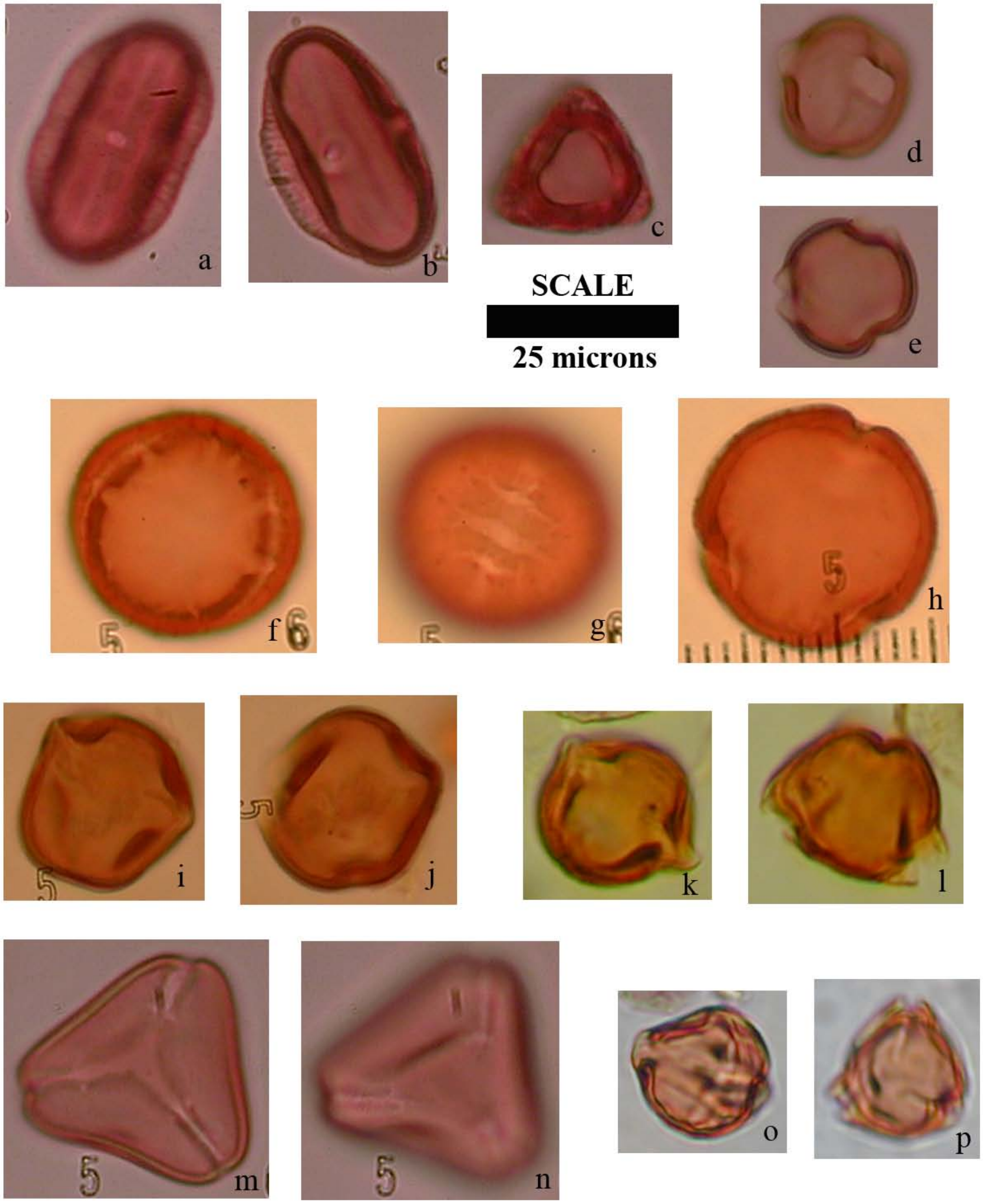

Figure A6. **a-c, *Justicia campechiana*; d-e, *Laguncularia racemosa*; f-h, *Lantana*; i-j, cf *Licania*; k-l, *Lonchocarpus*; m-n, Loranthaceae; o-p, cf *Markea*.**

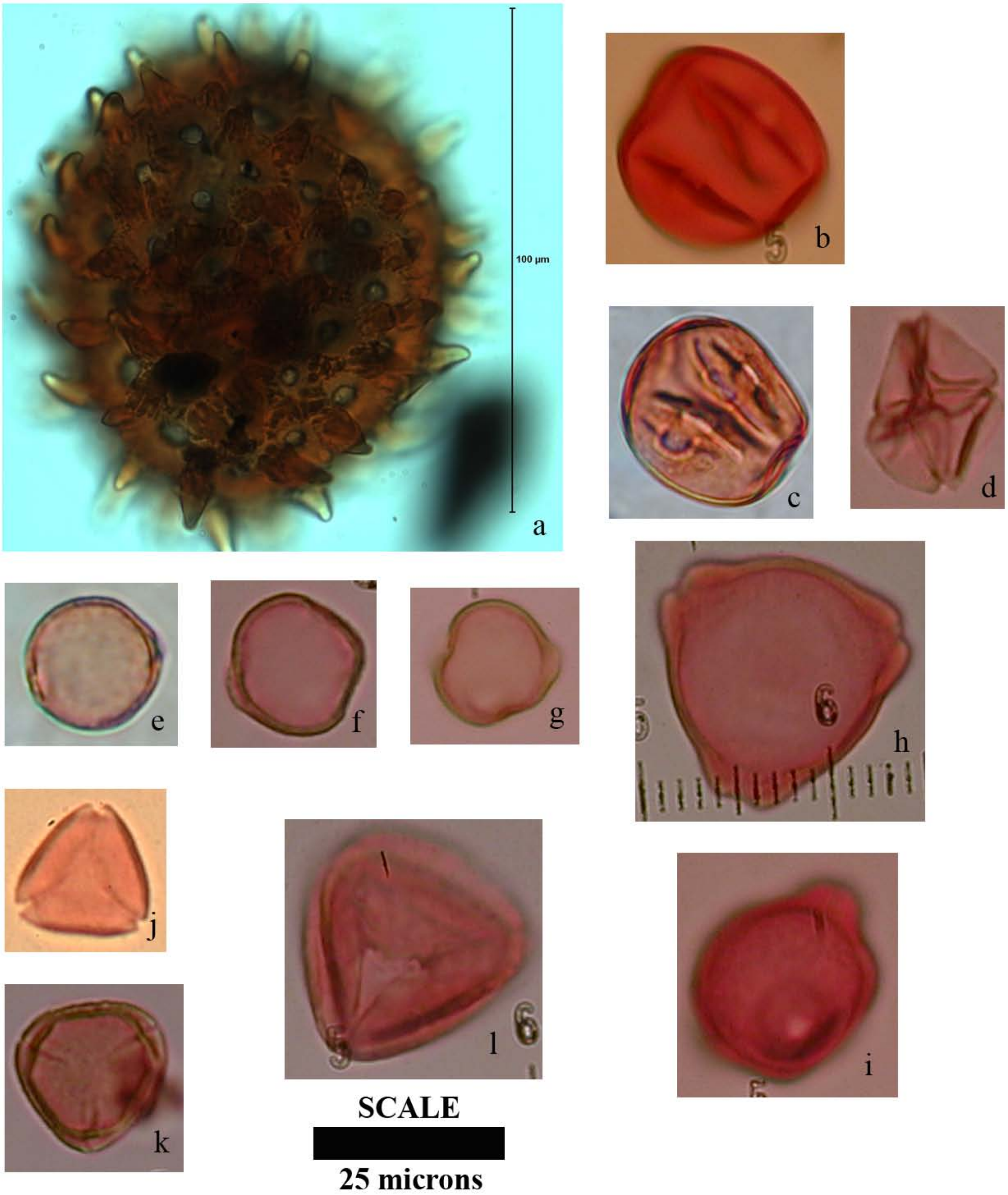

Figure A-7. a, Malvaceae; b-c, Meliaceae; d, Mimosa; e, Moraceae, *Brosimum* type; f, Moraceae, diporate; g, Moraceae, triporate; h-i, *Myrica*; j, Myrtaceae, *Eugenia* type; k, Myrtaceae, tricolporate.

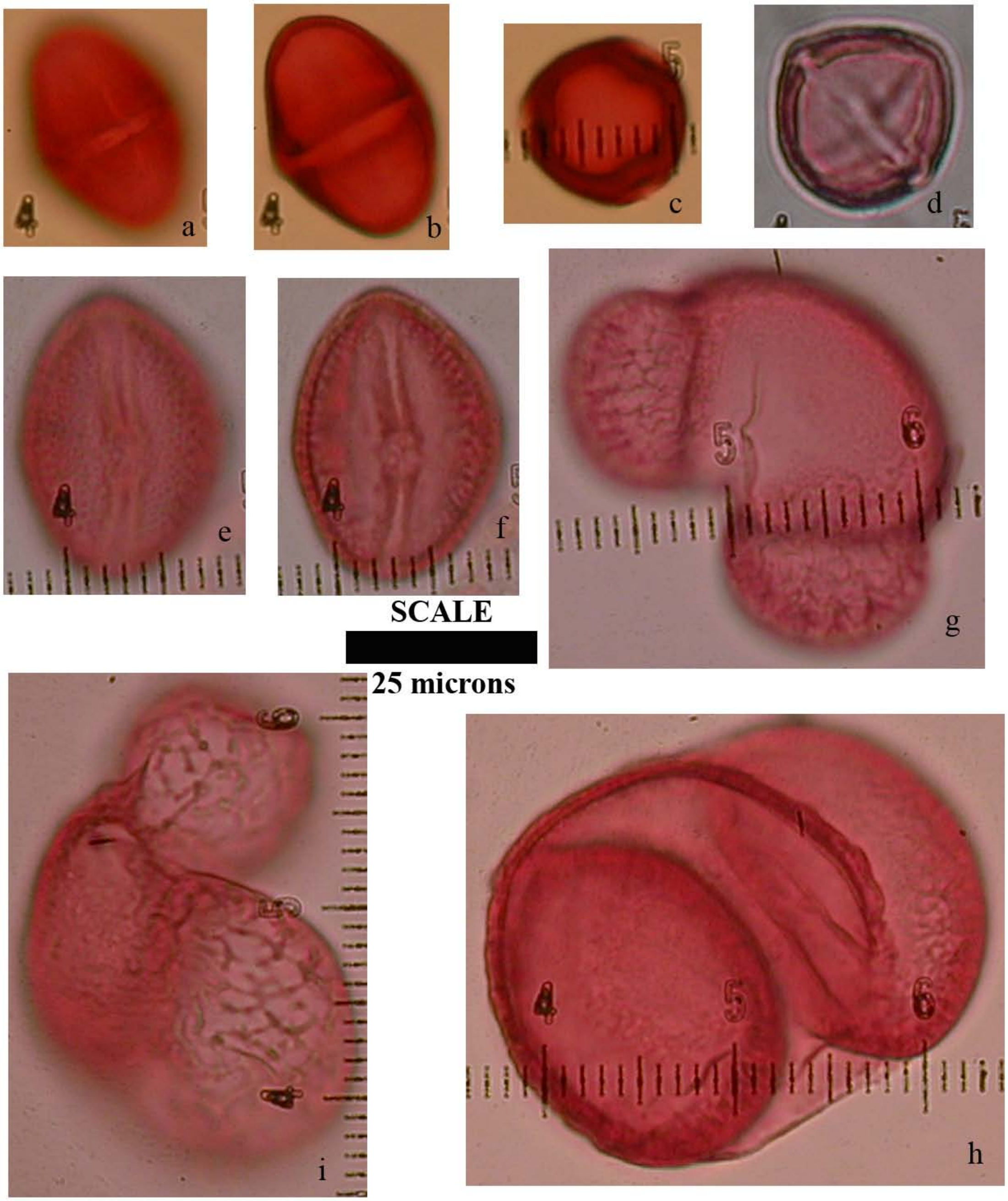

Figure A-8. a-c, *Phylla*; d, *Physalis*; e-f, *Picramnia antidesma*; g-h, *Pinus*; i, *Podocarpus*.

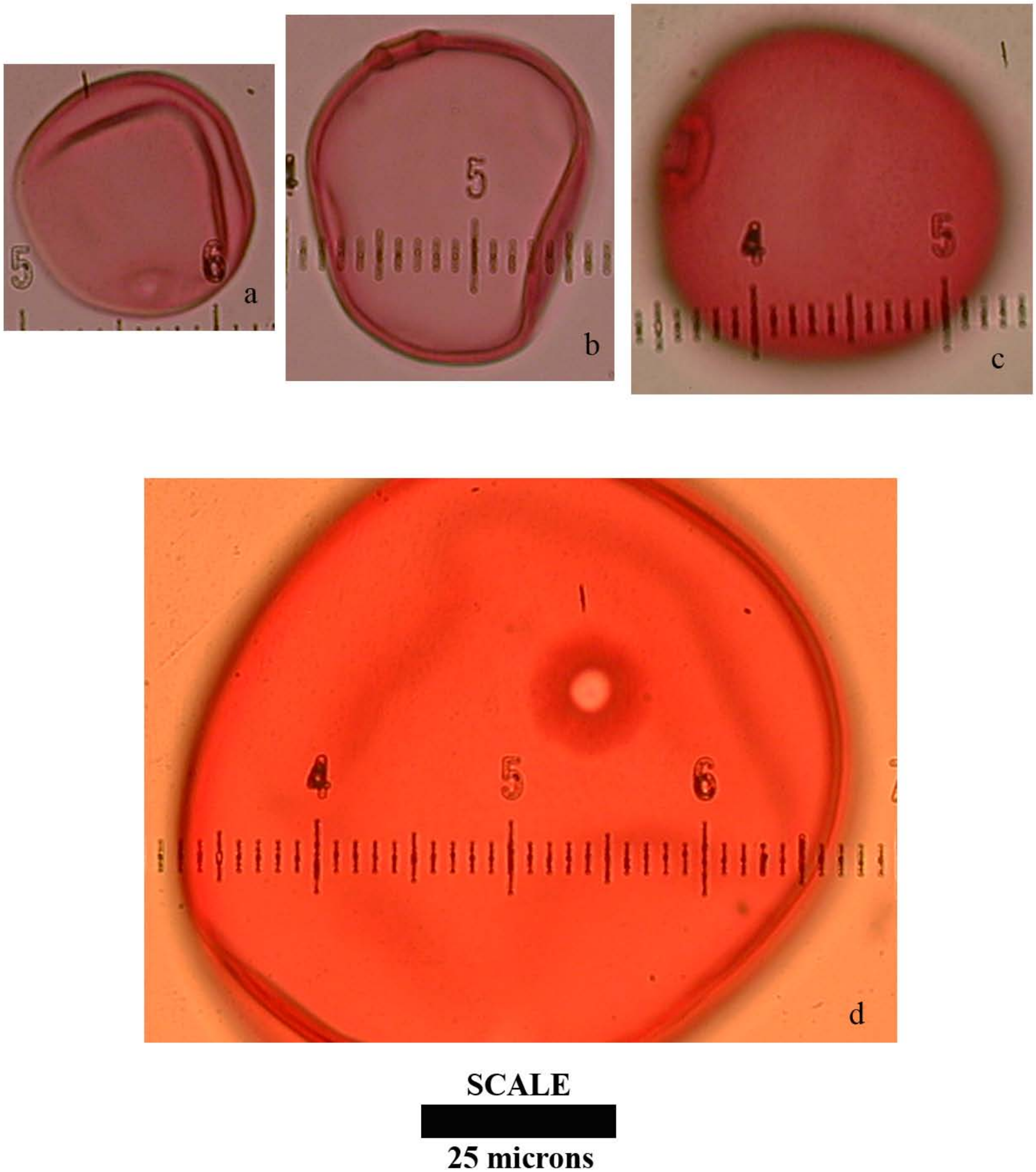

Figure A-9. a, Poaceae, ~35 microns; b-c, Poaceae, ~50 microns; d, *Zea mays*.

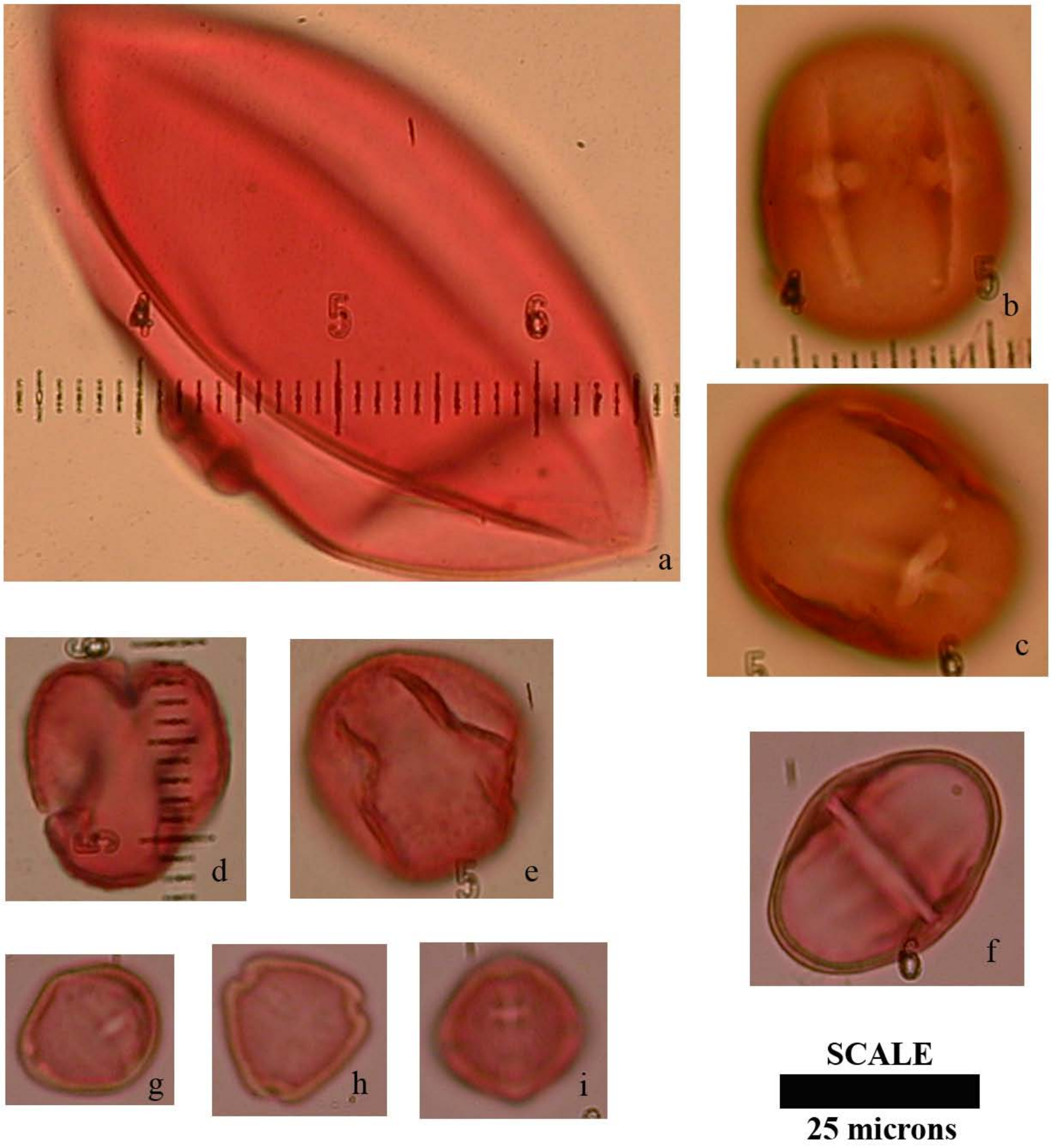

Figure A-10. a, *Zea mays*; b-c, cf *Pouteria mammosa*; d-e, *Quercus*; f, *Protium*; g-i, cf *Sapindus saponaria* or Rhamnaceae.

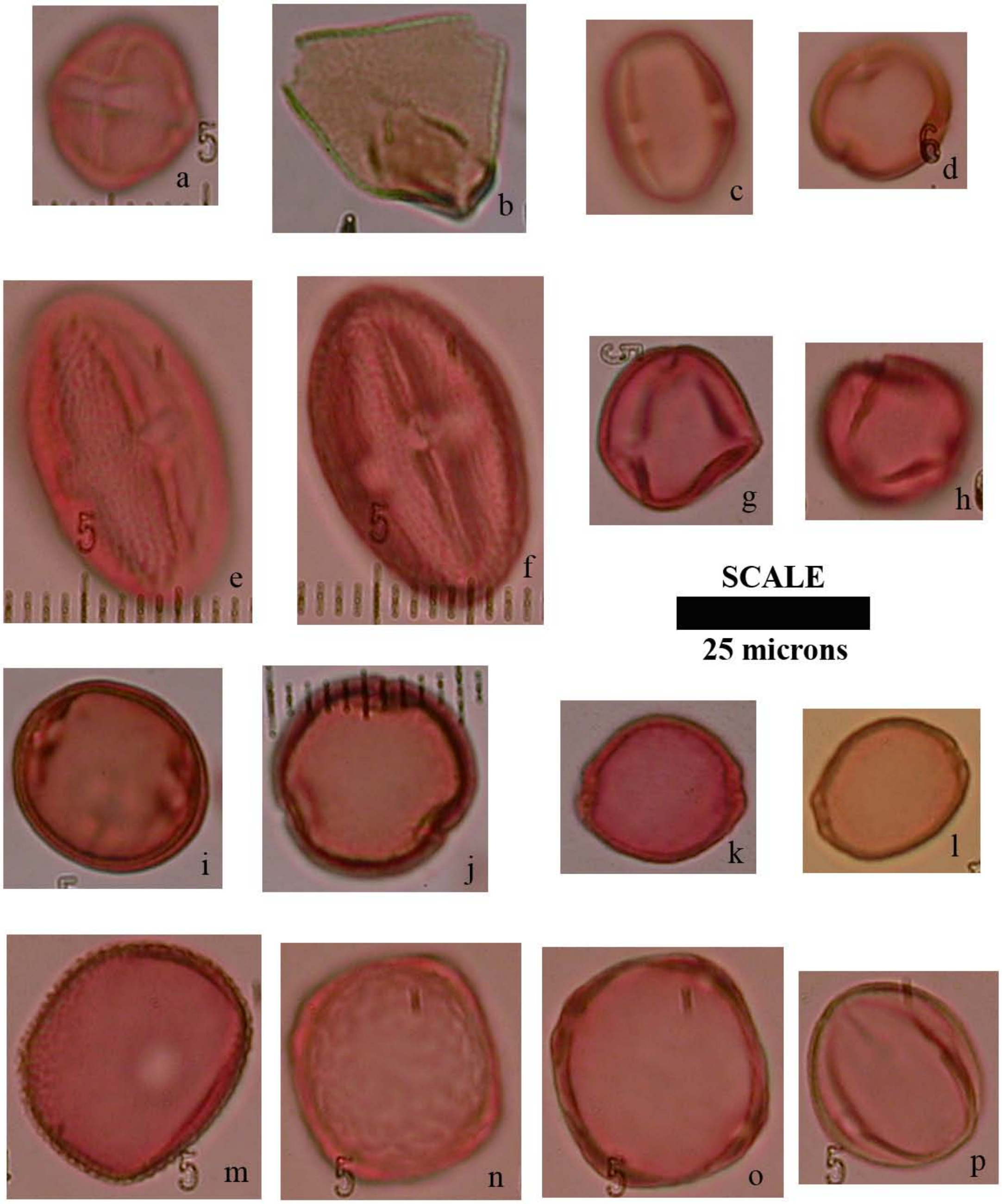

Figure A-11. a, *Rhizophora*; b, Sapindaceae; c-d, Sapotaceae; e-f, *Spondias*; g-h, *Swartzia*; i-j, *Thouinia myriantha*; k-l, *Trema*; m, *Typha domingensis*; n-o, *Ulmus*; p, *Vitis*.

APPENDIX B

COUNTS OF POLLEN FROM TAXA REPRESENTED IN THE LAGUNA VERDE POLLEN CORE

Sample Number (Lab Number)	**372-373 (1)**	**370-371 (2)**	**367-368 (3)**	**364-365 (4)**	**362-363 (5)**	**361-362 (6)**	**357-358 (7)**
Taxon							
Acalypha sp.	0	1	0	0	0	0	0
Alchornea latifolia	0	0	0	0	1	0	0
Alnus sp.	0	0	1	1	3	0	0
Amaranthaceae, fenestrate	0	0	0	0	2	0	0
Anacardium occidentale	0	0	0	0	0	0	0
Anacardiaceae	1	0	0	0	0	0	1
cf *Andira inermis*	0	0	0	0	0	0	0
Apiaceae	0	0	0	0	0	0	0
Araceae or Arecaceae	0	0	0	0	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	0	0	0
Arecaceae, other	0	0	0	0	0	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	0	0	12	1	3	3	0
Asteraceae, Low-spine	0	0	11	7	21	3	20
cf *Banara guianensis*	0	0	0	0	0	0	0
cf *Bauhinia divaricata*	0	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0	0
cf Bignoniaceae	0	0	0	0	0	0	0
Borreria sp. or *Spermacoce* sp.	0	5	23	0	2	0	14
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0	0
Bravaisia sp.	0	0	1	0	0	0	0
Bursera simaruba	0	0	2	2	1	0	1
Byrsonima sp.	0	0	0	1	1	0	0
cf Campanulaceae	0	0	0	0	0	0	0
Carya sp.	0	0	0	1	0	0	0
Cecropia sp.	0	0	0	0	1	0	5
Cedrela odorata	0	0	0	3	0	0	0
Celastraceae	0	0	0	0	0	0	0
Celtis sp.	0	0	1	0	0	3	2
Cheno-Ams	0	0	3	3	1	0	2
cf Chrysobalanaceae	0	0	1	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	1	1	0	0	1	0	1
Colubrina arborescens	0	0	0	0	0	1	1
Combretaceae/Melastomataceae	5	1	14	14	30	23	32
Commelina sp.	0	0	0	0	0	0	0
Corchorus hirsutus	0	0	0	0	0	0	0
Cordia sp.	0	0	0	0	2	4	0
Cordia alliodora	0	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0	0
Croton sp.	0	0	0	1	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	0
Curatella americana	0	0	0	0	0	2	0
Cyperaceae	9	7	41	53	18	17	17
Desmodium sp.	0	0	0	0	0	0	0
Erythroxylum sp.	0	0	0	0	0	1	0
Euphorbiaceae cf *Gymnanthes lucida or Chamaesyce thymifolia*	1	4	0	14	0	0	0
Other Euphorbiaceae	0	0	0	2	0	0	0
Exothea diphylla	0	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	1	0	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	0	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	0	0	0	2
Other Fabaceae	0	0	0	0	0	0	0
Faramea sp.	0	0	0	1	0	0	0
Heliocarpus americanus	0	2	0	0	0	0	0
Hippocratea volubilis	0	0	0	1	0	0	0
Ilex sp.	0	0	0	0	0	0	0
Justicia campechiana	0	0	0	3	0	0	0
Juncus marginatus	2	1	0	0	0	0	0
Laguncularia racemosa	0	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	0	0	0
Licania sp.	0	0	0	0	0	0	1
cf *Lilium*	0	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0	0
Loranthaceae	0	0	0	1	0	0	0
Malpighiaceae cf *Heteropterys laurifolia*	0	0	1	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0
Mangifera indica	0	0	0	0	0	0	0
cf *Markea* sp.	0	0	0	0	0	0	0
Meliaceae	0	0	1	3	0	0	0
Metopium brownei	0	0	0	0	0	0	0
Mimosa sp.	0	0	0	1	0	0	1
Moraceae cf *Brosimum* sp.	0	2	3	7	15	64	17
Moraceae cf diporate *Ficus* sp.	0	0	0	0	0	0	0
Moraceae, other diporate	0	0	0	0	0	0	0
Moraceae, triporate	0	0	1	0	0	0	1
Myrica cerifera	1	2	0	3	0	0	2
Myristicaceae	0	0	0	0	0	0	0
Myrtaceae, syncolpate	0	0	0	2	3	1	0
Myrtaceae, tricolporate	0	0	0	0	0	0	0
Nymphaceae	0	0	4	0	1	0	0
Orchidaceae?	0	0	0	0	0	0	0
Ostrya/Carpinus	0	0	0	0	0	0	0
Pachira aquatica	0	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	2	0	2	18	0
Physalis sp.	0	0	0	0	0	0	1

Sample Number (Lab Number)	**372-373 (1)**	**370-371 (2)**	**367-368 (3)**	**364-365 (4)**	**362-363 (5)**	**361-362 (6)**	**357-358 (7)**
Taxon							
Picramnia antidesma	0	0	0	0	0	0	0
Pinus sp. whole	16	14	7	67	19	3	9
Pinus sp. bladder	2	0	8	12	17	7	7
Pinus sp. body and one bladder	1	0	1	8	0	3	1
Pinus sp. body	1	0	4	5	4	1	3
Piper sp.	0	0	0	0	0	0	0
Poaceae<50 microns	0	1	13	9	18	3	13
Poaceae, 50-69 microns	1	1	0	5	0	0	0
Poaceae, 70-100 microns	0	0	0	0	0	0	0
Poaceae>100 microns	0	0	1	0	0	0	0
Podocarpus guatemalensis	0	0	0	2	0	0	2
Polygonaceae	0	0	0	1	0	0	0
cf *Pouteria* sp.	0	0	0	0	0	0	0
cf *Pouteria stipitata*	0	0	0	0	1	0	0
Pouteria unilocularis=P. reticulata	0	0	0	1	0	0	0
Protium sp.	0	0	0	12	0	0	3
cf *Psychotria* sp.	0	0	0	0	0	0	0
Quercus sp.	1	5	3	7	2	0	2
Rhizophora mangle	1	2	7	6	0	0	2
cf *Rinorea squamata*	0	0	0	0	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	0	0	0	0	0	0	1
Sapindus saponaria	0	0	0	21	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	0	0	1	0	0	0	0
Scrophulariaceae	1	0	0	0	0	0	0
Sebastiana sp.	0	0	0	0	0	2	0
Solanaceae	0	1	0	0	0	0	0
Spondias sp.	0	0	1	0	1	0	0
Spondias mombin	0	0	0	0	0	0	0
cf *Spondias purpurea*	0	0	0	1	0	0	0
Swartzia sp.	3	0	0	1	0	0	0
Swietenia macrophylla	0	0	0	0	0	0	0
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0	0
Tabernaemontana sp.	0	0	0	0	0	0	0
Talisia oliviformis	0	0	0	1	0	0	0
TCT	0	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0	0
Trema sp.	0	3	3	2	2	20	7
Trichilia hirta	0	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	1	0
Typha angustifolia	0	0	0	0	0	5	5
Typha domingensis	0	0	0	10	1	0	0
Typha latifolia	0	0	0	1	0	0	0
Ulmus sp.	0	0	1	3	0	0	0
Urticaceae	0	0	0	0	0	0	0
Utricularia sp.	0	0	0	0	0	1	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	1	0	0	0
Zanthoxylum sp.	0	0	0	0	0	1	0
Unidentified/Unknown	10	5	14	3	16	4	3
Additional special abundant unknown	0	0	0	0	0	0	0
Unidentifiable/Indeterminate	5	14	17	24	24	9	25
Total	63	72	203	328	213	200	204
Lycopodium	419	327	421	250	194	274	287
Charcoal	Absent	Absent	Present	Present	Present	Present	Present
Depth in cmbs	372-373	370-371	367-368	364-365	362-363	361-362	357-358
Volume/Weight of Sample	8 gm	7 gm	1 cc	8 gm	1 cc	1 cc	1 cc
Number of *Lycopodium* tablets added	1	1	1	1	1	2	2
Concentration Value	254 grains/gm	424 grains/gm	6510 grains/cc	2214 grains/gm	14822 grains/cc	19708 grains/cc	19098 grains/cc

Sample Number (Lab Number)	**353-354 (8)**	**350-351 (9)**	**347-348 (10)**	**343-344 (11)**	**339-340 (12)**	**335-336 (13)**	**334-335 (14)**
Taxon							
Acalypha sp.	3	1	4	0	1	0	1
Alchornea latifolia	1	0	1	0	0	0	1
Alnus sp.	1	0	0	0	0	0	0
Amaranthaceae, fenestrate	0	1	0	0	0	0	0
Anacardium occidentale	0	0	0	0	0	0	0
Anacardiaceae	0	0	1	0	1	1	0
cf *Andira inermis*	0	0	0	0	0	0	0
Apiaceae	0	0	0	0	0	0	0
Araceae or Arecaceae	0	0	0	0	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	0	0	0
Arecaceae, other	0	0	0	0	1	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	2	2	0	0	1	4	2
Asteraceae, Low-spine	1	1	0	0	1	2	2
cf *Banara guianensis*	0	0	0	0	0	0	0
cf *Bauhinia divaricata*	0	1	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	1	0
cf Bignoniaceae	0	0	0	1	0	0	0
Borreria sp. or *Spermacoce* sp.	0	1	2	1	1	2	0
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	1	0
Bursera simaruba	3	2	1	0	5	3	1
Byrsonima sp.	0	2	2	1	0	0	1
cf Campanulaceae	0	0	0	0	0	0	0
Carya sp.	0	0	0	0	0	0	0
Cecropia sp.	2	0	0	0	0	0	1
Cedrela odorata	0	0	0	0	0	0	0
Celastraceae	0	0	0	0	0	0	0
Celtis sp.	2	1	3	0	4	0	0
Cheno-Ams	1	1	5	1	2	6	1
cf Chrysobalanaceae	0	0	0	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	0	0	0	0	1	0	2
Colubrina arborescens	0	1	2	1	1	0	0
Combretaceae/Melastomataceae	12	14	11	9	17	8	30
Commelina sp.	0	0	0	2	0	0	0
Corchorus hirsutus	1	0	0	0	0	1	0
Cordia sp.	0	0	1	1	1	0	0
Cordia alliodora	0	1	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0	0
Croton sp.	0	1	0	0	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	0
Curatella americana	0	0	2	0	0	0	0
Cyperaceae	8	9	8	4	6	26	28
Desmodium sp.	0	0	0	0	0	0	0
Erythroxylum sp.	0	0	0	0	2	0	0
Euphorbiaceae cf *Gymnanthes lucida or Chamaesyce thymifolia*	0	1	0	0	0	5	0
Other Euphorbiaceae	0	0	0	0	0	1	0
Exothea diphylla	0	0	1	0	0	1	0
Fabaceae cf *Cassia=Senna* sp.	0	0	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	1	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	3	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	0	0	0	0
Other Fabaceae	1	0	0	0	0	0	0
Faramea sp.	0	0	0	0	0	0	0
Heliocarpus americanus	0	0	0	0	0	1	0
Hippocratea volubilis	0	0	0	0	0	0	0
Ilex sp.	0	0	0	0	0	0	0
Justicia campechiana	0	0	0	0	0	0	0
Juncus marginatus	0	1	0	0	1	0	0
Laguncularia racemosa	0	0	0	0	1	2	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	1	0	0
Licania sp.	0	0	0	0	0	0	0
cf *Lilium*	0	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0	0
Loranthaceae	0	0	0	0	0	0	0
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	4	0
Malvaceae	0	0	0	0	0	0	0
Mangifera indica	0	0	0	0	0	0	0
cf *Markea* sp.	0	0	0	0	0	0	0
Meliaceae	0	0	0	0	2	0	0
Metopium brownei	0	0	0	0	0	0	1
Mimosa sp.	0	0	0	0	0	0	0
Moraceae cf *Brosimum* sp.	22	13	37	26	16	0	13
Moraceae cf diporate *Ficus* sp.	0	0	0	0	0	0	0
Moraceae, other diporate	0	1	0	0	0	1	0
Moraceae, triporate	0	0	0	1	2	0	0
Myrica cerifera	5	3	9	27	15	24	31
Myristicaceae	0	0	0	0	0	0	0
Myrtaceae, syncolpate	2	1	1	2	4	0	0
Myrtaceae, tricolporate	0	2	0	0	0	0	0
Nymphaceae	0	0	0	0	0	0	0
Orchidaceae?	0	0	0	0	0	0	0
Ostrya/Carpinus	0	0	0	0	0	0	0
Pachira aquatica	0	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0	0

Sample Number (Lab Number)	**353-354 (8)**	**350-351 (9)**	**347-348 (10)**	**343-344 (11)**	**339-340 (12)**	**335-336 (13)**	**334-335 (14)**
Taxon							
Physalis sp.	0	0	0	0	1	0	0
Picramnia antidesma	0	0	0	0	0	1	0
Pinus sp. whole	22	10	5	8	7	62	16
Pinus sp. bladder	22	48	13	22	13	13	13
Pinus sp. body and one bladder	15	11	4	10	10	9	14
Pinus sp. body	12	12	2	6	6	3	3
Piper sp.	0	0	0	0	0	0	0
Poaceae<50 microns	7	4	2	12	12	20	10
Poaceae, 50-69 microns	1	0	0	3	1	5	3
Poaceae, 70-100 microns	0	0	1	0	0	4	0
Poaceae>100 microns	0	0	0	1	0	0	0
Podocarpus guatemalensis	1	0	1	0	0	0	0
Polygonaceae	0	0	0	0	0	0	0
cf *Pouteria* sp.	0	0	0	0	1	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0	0
Protium sp.	0	1	0	0	0	0	0
cf *Psychotria* sp.	0	0	0	0	0	3	0
Quercus sp.	1	5	0	3	0	5	0
Rhizophora mangle	1	0	0	1	1	0	5
cf *Rinorea squamata*	0	0	0	0	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	0	0	0	0	0	0	0
Sapindus saponaria	0	0	0	1	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	0	0	0	0	0	0	0
Scrophulariaceae	0	0	0	0	0	0	0
Sebastiana sp.	9	0	6	5	0	0	0
Solanaceae	0	0	0	0	0	0	0
Spondias sp.	0	1	0	0	0	0	2
Spondias mombin	0	0	0	0	0	1	0
cf *Spondias purpurea*	0	0	0	0	0	0	0
Swartzia sp.	0	0	0	0	0	1	0
Swietenia macrophylla	0	0	5	5	0	0	1
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	5	0	0	24	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0	0
Tabernaemontana sp.	0	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0	0
TCT	0	0	0	0	1	0	0
cf *Thinouia myriantha*	0	1	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0	0
Trema sp.	22	16	41	28	11	2	4
Trichilia hirta	0	1	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	0	0
Typha angustifolia	0	1	1	0	0	0	0
Typha domingensis	3	3	0	2	5	8	4
Typha latifolia	0	0	0	0	0	0	0
Ulmus sp.	0	1	0	1	1	0	1
Urticaceae	0	0	0	0	0	0	0
Utricularia sp.	0	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	0	0	0	1
Zanthoxylum sp.	0	0	0	0	0	0	0
Unidentified/Unknown	6	8	5	5	10	4	7
Additional special abundant unknown	10	0	13	0	0	16	0
Unidentifiable/Indeterminate	12	14	9	9	14	18	9
Total	211	203	200	202	205	269	208
Lycopodium	115	379	218	272	255	166	442
Charcoal	Present	Absent	Present	Absent	Absent	Present	Present
Depth in cmbs	353-354	350-351	347-348	343-344	339-340	335-336	334-335
Volume/Weight of Sample	1 cc	1 cc	1 cc	1 cc	I cc	5 gm	1 cc
Number of *Lycopodium* tablets added	2	2	2	2	2	1	2
Concentration Value	49539 grains/cc	14462 grains/cc	24770 grains/cc	20051 grains/cc	5507 grains/cc	4375 grains/gm	12705 grains/cc

Sample Number (Lab Number)	**330-331 (15)**	**328-329 (16)**	**325-326 (17)**	**322-323 (18)**	**319-320 (19)**	**316-317 (20)**	**313-314 (21)**
Taxon							
Acalypha sp.	2	1	0	0	0	0	0
Alchornea latifolia	3	0	0	0	0	2	0
Alnus sp.	0	0	0	0	0	0	1
Amaranthaceae, fenestrate	0	0	0	0	1	0	0
Anacardium occidentale	0	0	0	0	0	0	0
Anacardiaceae	0	1	0	0	0	0	0
cf *Andira inermis*	0	0	0	0	0	0	0
Apiaceae	0	0	0	0	0	0	0
Araceae or Arecaceae	0	0	0	0	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	0	0	0
Arecaceae, other	0	0	0	0	0	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	1	0	2	2	4	6	3
Asteraceae, Low-spine	5	2	23	50	30	43	21
cf *Banara guianensis*	0	0	0	0	0	0	0
cf *Bauhinia divaricata*	0	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0	0
cf Bignoniaceae	0	0	0	2	1	0	0
Borreria sp. or *Spermacoce* sp.	1	2	0	0	1	0	2
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	0	1
Bursera simaruba	0	1	0	1	1	1	1
Byrsonima sp.	0	3	1	0	5	0	5
cf Campanulaceae	0	0	0	0	0	0	0
Carya sp.	0	0	0	0	0	0	0
Cecropia sp.	0	2	0	2	3	2	0
Cedrela odorata	0	0	0	0	0	0	1
Celastraceae	0	0	0	0	0	0	0
Celtis sp.	0	0	1	2	0	2	1
Cheno-Ams	1	4	0	2	2	5	2
cf Chrysobalanaceae	0	0	0	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	1	2	0	1	0	0	0
Colubrina arborescens	0	0	0	0	0	0	0
Combretaceae/Melastomataceae	27	19	113	55	32	26	27
Commelina sp.	0	0	0	0	0	0	0
Corchorus hirsutus	0	0	0	0	0	0	0
Cordia sp.	0	0	1	0	0	0	0
Cordia alliodora	0	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0	0
Croton sp.	0	0	0	0	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	0
Curatella americana	1	0	0	1	0	0	0
Cyperaceae	16	4	7	0	8	24	38
Desmodium sp.	0	0	0	0	0	0	0
Erythroxylum sp.	0	0	0	1	0	0	0
Euphorbiaceae cf *Gymnanthes lucida or Chamaesyce thymifolia*	0	0	0	0	0	0	0
Other Euphorbiaceae	0	0	0	0	0	0	0
Exothea diphylla	0	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	0	0	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	0	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	0	0	0	0
Other Fabaceae	0	0	0	0	0	0	0
Faramea sp.	0	0	0	0	0	0	0
Heliocarpus americanus	0	0	0	0	0	0	0
Hippocratea volubilis	0	0	0	0	0	0	0
Ilex sp.	0	0	0	0	1	0	0
Justicia campechiana	0	0	0	0	0	0	0
Juncus marginatus	0	0	0	0	0	0	0
Laguncularia racemosa	0	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	0	0	0
Licania sp.	0	0	0	0	0	0	0
cf *Lilium*	0	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0	0
Loranthaceae	1	1	0	0	0	0	0
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0
Mangifera indica	0	0	0	0	0	0	0
cf *Markea* sp.	4	0	0	0	0	0	0
Meliaceae	0	0	0	0	0	0	0
Metopium brownei	0	0	0	0	0	0	0
Mimosa sp.	0	1	0	0	0	0	0
Moraceae cf *Brosimum* sp.	14	19	8	0	22	12	12
Moraceae cf diporate *Ficus* sp.	0	0	0	0	0	0	0
Moraceae, other diporate	0	0	0	0	0	0	0
Moraceae, triporate	1	1	0	0	0	0	1
Myrica cerifera	10	4	0	1	0	1	9
Myristicaceae	0	0	0	0	0	0	0
Myrtaceae, syncolpate	2	0	0	0	0	0	1
Myrtaceae, tricolporate	0	0	0	0	0	0	0
Nymphaceae	0	0	0	0	0	0	1
Orchidaceae?	0	0	0	0	0	0	0
Ostrya/Carpinus	0	1	0	0	0	0	0
Pachira aquatica	0	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0	0

Sample Number (Lab Number)	**330-331 (15)**	**328-329 (16)**	**325-326 (17)**	**322-323 (18)**	**319-320 (19)**	**316-317 (20)**	**313-314 (21)**
Taxon							
Physalis sp.	0	0	0	0	0	0	0
Picramnia antidesma	0	0	0	0	0	0	0
Pinus sp. whole	7	10	8	6	12	4	4
Pinus sp. bladder	9	6	5	9	13	10	11
Pinus sp. body and one bladder	2	1	1	4	4	3	4
Pinus sp. body	1	2	1	4	5	2	2
Piper sp.	0	0	0	0	0	0	0
Poaceae<50 microns	2	5	3	10	10	21	16
Poaceae, 50-69 microns	1	0	0	1	0	3	2
Poaceae, 70-100 microns	0	1	0	1	0	0	2
Poaceae>100 microns	1	0	0	0	0	0	0
Podocarpus guatemalensis	1	0	0	0	0	0	0
Polygonaceae	0	0	0	0	0	0	2
cf *Pouteria* sp.	0	0	0	0	0	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0	0
Protium sp.	0	0	0	0	0	0	0
cf *Psychotria* sp.	0	0	0	0	0	0	0
Quercus sp.	3	1	0	1	1	0	1
Rhizophora mangle	65	35	0	0	1	0	1
cf *Rinorea squamata*	0	1	4	0	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	1	0	0	0	1	0	0
Sapindus saponaria	0	1	0	0	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	0	0	0	0	0	0	0
Scrophulariaceae	0	0	0	0	0	0	0
Sebastiana sp.	3	1	0	0	1	2	2
Solanaceae	0	0	0	0	0	0	0
Spondias sp.	1	0	0	0	1	0	0
Spondias mombin	0	0	0	0	0	0	0
cf *Spondias purpurea*	0	0	0	0	0	0	0
Swartzia sp.	0	0	0	0	0	0	0
Swietenia macrophylla	0	14	0	0	0	0	0
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	1	0	0	0	0	0
Tabernaemontana sp.	0	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0	0
TCT	0	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0	0
Trema sp.	14	27	7	14	9	12	9
Trichilia hirta	0	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	2	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	0	0
Typha angustifolia	0	0	1	5	7	0	0
Typha domingensis	1	0	1	1	1	2	3
Typha latifolia	0	0	0	0	1	0	0
Ulmus sp.	0	1	0	0	1	0	0
Urticaceae	0	0	0	0	0	0	0
Utricularia sp.	0	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	2	0	0	0	0	0
Zanthoxylum sp.	0	0	0	0	0	0	0
Unidentified/Unknown	6	8	0	3	6	8	5
Additional special abundant unknown	0	0	0	0	0	0	0
Unidentifiable/Indeterminate	14	15	18	24	15	11	11
Total	224	200	205	203	200	202	202
Lycopodium	303	286	141	258	153	131	162
Charcoal	Present	Present	Present	Present	Present	Present	Present
Depth in cmbs	330-331	328-329	325-326	322-323	319-320	316-317	313-314
Volume/Weight of Sample	1 cc	1 cc	1 cc	1 cc	1 cc	1 cc	1 cc
Number of *Lycopodium* tablets added	2	2	2	2	2	2	2
Concentration Value	19960 grains/cc	18881 grains/cc	39255 grains/cc	21244 grains/cc	35294 grains/cc	41633 grains/cc	33666 grains/cc

Sample Number (Lab Number)	**310-311 (22)**	**307-308 (23)**	**305-306 (24)**	**301-302 (25)**	**298-299 (26)**	**295-296 (27)**	**290-291 (28)**
Taxon							
Acalypha sp.	0	1	3	0	0	0	2
Alchornea latifolia	0	0	0	0	0	0	1
Alnus sp.	0	1	0	0	0	0	0
Amaranthaceae, fenestrate	0	0	0	0	0	0	0
Anacardium occidentale	0	0	0	0	0	0	1
Anacardiaceae	0	0	1	0	0	0	0
cf *Andira inermis*	0	0	0	0	0	0	0
Apiaceae	0	0	0	0	0	0	0
Araceae or Arecaceae	0	0	0	0	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	1	0	0
Arecaceae, other	0	0	0	0	0	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	4	10	1	7	7	4	0
Asteraceae, Low-spine	29	22	8	10	11	22	2
cf *Banara guianensis*	0	0	0	0	0	0	0
cf *Bauhinia divaricata*	0	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0	0
cf Bignoniaceae	0	1	0	3	0	0	0
Borreria sp. or *Spermacoce* sp.	2	3	2	0	0	5	1
Borreria laevis=Spermacoce assurgens	0	1	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	0	0
Bursera simaruba	1	0	1	4	2	1	0
Byrsonima sp.	2	2	2	3	1	2	1
cf Campanulaceae	0	0	0	0	0	0	0
Carya sp.	0	0	0	0	0	0	0
Cecropia sp.	3	6	2	1	1	0	4
Cedrela odorata	0	0	0	0	0	0	0
Celastraceae	0	0	0	0	0	0	0
Celtis sp.	1	0	4	2	1	1	3
Cheno-Ams	1	2	2	4	4	1	1
cf Chrysobalanaceae	0	0	0	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	1	2	2	1	0	2	2
Colubrina arborescens	0	0	0	0	0	0	1
Combretaceae/Melastomataceae	49	60	69	46	53	27	20
Commelina sp.	0	0	0	0	0	0	0
Corchorus hirsutus	0	0	0	0	0	0	0
Cordia sp.	0	0	0	0	0	0	1
Cordia alliodora	0	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0	0
Croton sp.	0	0	0	0	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	1
Curatella americana	0	0	0	0	0	0	0
Cyperaceae	24	16	24	18	16	23	8
Desmodium sp.	0	0	0	0	0	0	0
Erythroxylum sp.	0	0	0	0	0	0	0
Euphorbiaceae cf *Gymnanthes lucida or Chamaesyce thymifolia*	0	0	0	0	0	0	2
Other Euphorbiaceae	0	0	0	0	0	0	0
Exothea diphylla	0	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	0	0	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	2	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	0	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	0	0	0	0
Other Fabaceae	0	0	0	0	0	0	0
Faramea sp.	0	0	0	0	0	0	0
Heliocarpus americanus	0	0	0	0	0	0	0
Hippocratea volubilis	0	0	0	0	0	0	0
Ilex sp.	0	0	0	0	0	0	0
Justicia campechiana	0	0	0	0	0	0	0
Juncus marginatus	0	0	0	0	0	0	0
Laguncularia racemosa	0	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	0	0	0
Licania sp.	0	0	0	0	0	0	1
cf *Lilium*	0	0	0	0	0	0	0
Liquidambar styraciflua	1	0	0	0	0	0	0
Loranthaceae	0	3	0	2	1	0	3
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0	0
Malvaceae	0	0	1	0	0	0	0
Mangifera indica	0	0	0	0	0	0	1
cf *Markea* sp.	0	0	0	0	0	0	0
Meliaceae	0	0	0	0	0	0	0
Metopium brownei	0	0	1	0	0	0	0
Mimosa sp.	1	0	0	0	0	1	0
Moraceae cf *Brosimum* sp.	7	9	16	5	11	10	9
Moraceae cf diporate *Ficus* sp.	0	0	0	0	0	0	0
Moraceae, other diporate	0	0	0	0	0	0	0
Moraceae, triporate	0	2	1	1	0	0	0
Myrica cerifera	4	8	12	14	5	5	25
Myristicaceae	0	0	2	0	0	0	0
Myrtaceae, syncolpate	0	0	1	0	0	1	2
Myrtaceae, tricolporate	0	0	0	0	0	0	0
Nymphaceae	0	0	0	0	0	0	0
Orchidaceae?	0	0	1	0	3	0	0
Ostrya/Carpinus	0	0	0	0	0	0	0
Pachira aquatica	0	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0	0

Sample Number (Lab Number)	**310-311 (22)**	**307-308 (23)**	**305-306 (24)**	**301-302 (25)**	**298-299 (26)**	**295-296 (27)**	**290-291 (28)**
Taxon							
Physalis sp.	0	0	0	0	0	0	0
Picramnia antidesma	0	0	0	0	0	0	0
Pinus sp. whole	3	5	6	16	10	18	7
Pinus sp. bladder	14	8	8	15	11	12	8
Pinus sp. body and one bladder	1	1	4	2	3	7	4
Pinus sp. body	1	3	1	5	4	2	0
Piper sp.	0	0	0	0	0	0	0
Poaceae<50 microns	21	16	6	9	7	20	13
Poaceae, 50-69 microns	3	6	1	0	3	1	1
Poaceae, 70-100 microns	0	0	0	0	0	0	0
Poaceae>100 microns	0	2	0	0	0	0	0
Podocarpus guatemalensis	0	0	0	0	0	0	0
Polygonaceae	0	0	0	0	0	0	0
cf *Pouteria* sp.	0	0	0	1	1	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0	0
Protium sp.	0	0	0	0	0	0	0
cf *Psychotria* sp.	0	0	0	0	0	0	0
Quercus sp.	0	3	0	1	4	3	0
Rhizophora mangle	0	0	1	0	0	2	40
cf *Rinorea squamata*	0	0	0	0	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	0	2	1	4	0	2	1
Sapindus saponaria	0	0	0	0	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	0	1	0	0	0	5	0
Scrophulariaceae	0	0	0	0	0	0	0
Sebastiana sp.	0	0	1	1	0	0	5
Solanaceae	0	0	0	0	0	0	1
Spondias sp.	1	0	0	0	2	0	0
Spondias mombin	0	0	0	0	0	0	0
cf *Spondias purpurea*	0	0	0	0	0	0	0
Swartzia sp.	0	0	0	0	0	0	0
Swietenia macrophylla	1	0	2	0	0	0	4
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0	1
Tabernaemontana sp.	0	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0	0
TCT	0	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0	0
Trema sp.	14	12	10	18	19	4	14
Trichilia hirta	0	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0	0
Tsuga sp.	0	1	0	0	0	0	0
Typha angustifolia	0	2	0	10	2	1	0
Typha domingensis	5	0	0	0	0	3	0
Typha latifolia	0	0	0	0	0	0	0
Ulmus sp.	0	0	0	0	0	0	0
Urticaceae	0	0	0	0	0	0	0
Utricularia sp.	0	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	0	0	0	0
Zanthoxylum sp.	0	0	0	0	0	1	0
Unidentified/Unknown	3	0	0	6	7	2	0
Additional special abundant unknown	0	0	0	0	0	0	7
Unidentifiable/Indeterminate	9	14	11	15	13	21	6
Total	206	225	210	224	203	209	204
Lycopodium	141	246	252	182	515	1446	230
Charcoal	Present	Present	Present	Present	Present	Present	Present
Depth in cmbs	310-311	307-308	305-306	301-302	298-299	295-296	290-291
Volume/Weight of Sample	1 cc	1 cc	1 cc	1 cc	1 cc	1 cc	1 cc
Number of *Lycopodium* tablets added	2	2	2	2	2	2	2
Concentration Value	39446 grains/cc	24695 grains/cc	22500 grains/cc	33231 grains/cc	10643 grains/cc	3902 grains/cc	24065 grains/cc

Sample Number (Lab Number)	**287-288 (29)**	**283-284 (30)**	**281-282 (31)**	**277-278 (32)**	**273-274 (33)**	**271-272 (34)**	**267-268 (35)**
Taxon							
Acalypha sp.	1	6	1	0	3	1	0
Alchornea latifolia	1	1	1	0	1	0	0
Alnus sp.	0	0	0	0	0	0	0
Amaranthaceae, fenestrate	0	0	0	1	1	0	0
Anacardium occidentale	0	0	0	0	0	0	0
Anacardiaceae	0	0	0	0	0	0	0
cf *Andira inermis*	0	0	2	0	0	0	0
Apiaceae	0	0	0	0	0	0	0
Araceae or Arecaceae	0	0	0	0	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	0	0	0
Arecaceae, other	0	0	0	0	0	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	0	6	2	0	1	0	5
Asteraceae, Low-spine	1	3	2	3	5	39	33
cf *Banara guianensis*	0	0	0	0	0	0	0
cf *Bauhinia divaricata*	0	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0	0
cf Bignoniaceae	0	0	0	0	0	0	0
Borreria sp. or *Spermacoce* sp.	0	0	0	2	0	1	0
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	0	0
Bursera simaruba	3	1	1	2	0	0	0
Byrsonima sp.	3	1	1	0	3	4	5
cf Campanulaceae	0	0	0	0	0	0	0
Carya sp.	0	0	0	0	0	0	0
Cecropia sp.	2	6	1	1	4	2	0
Cedrela odorata	1	0	0	0	0	0	0
Celastraceae	0	0	0	0	0	1	0
Celtis sp.	0	3	1	2	0	0	3
Cheno-Ams	1	4	3	0	1	3	4
cf Chrysobalanaceae	0	0	0	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	0	1	4	1	0	1	2
Colubrina arborescens	0	0	0	0	0	0	0
Combretaceae/Melastomataceae	8	35	23	27	30	103	71
Commelina sp.	0	0	0	0	0	0	0
Corchorus hirsutus	0	0	0	0	0	1	0
Cordia sp.	0	1	1	0	0	0	0
Cordia alliodora	0	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0	0
Croton sp.	0	0	0	0	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	0
Curatella americana	0	0	0	0	0	0	0
Cyperaceae	1	16	71	74	69	1	23
Desmodium sp.	0	5	0	0	0	0	3
Erythroxylum sp.	0	0	0	0	0	0	0
Euphorbiaceae cf *Gymnanthes lucida or Chamaesyce thymifolia*	0	0	0	0	0	0	0
Other Euphorbiaceae	0	0	0	0	0	0	0
Exothea diphylla	0	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	0	1	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	0	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	0	0	0	0
Other Fabaceae	0	1	0	0	0	0	0
Faramea sp.	0	0	0	0	0	0	0
Heliocarpus americanus	0	0	0	0	0	0	0
Hippocratea volubilis	0	0	0	0	0	0	0
Ilex sp.	0	1	0	0	0	0	0
Justicia campechiana	0	0	0	0	0	0	0
Juncus marginatus	0	0	0	0	3	0	2
Laguncularia racemosa	0	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	0	0	0
Licania sp.	2	0	0	0	0	0	0
cf *Lilium*	1	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0	0
Loranthaceae	1	1	0	0	0	0	0
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0
Mangifera indica	0	0	0	0	0	0	0
cf *Markea* sp.	0	0	0	0	0	0	0
Meliaceae	0	0	1	0	0	0	0
Metopium brownei	1	0	0	1	1	0	0
Mimosa sp.	0	2	1	0	0	0	0
Moraceae cf *Brosimum* sp.	6	18	9	16	15	0	1
Moraceae cf diporate *Ficus* sp.	0	0	0	0	1	0	0
Moraceae, other diporate	0	0	3	0	0	0	0
Moraceae, triporate	0	0	0	0	0	0	0
Myrica cerifera	2	8	1	0	3	0	0
Myristicaceae	0	0	0	0	0	0	0
Myrtaceae, syncolpate	1	0	0	0	0	0	0
Myrtaceae, tricolporate	0	0	0	0	0	0	0
Nymphaceae	0	0	0	0	0	0	0
Orchidaceae?	0	0	0	0	0	0	0
Ostrya/Carpinus	0	0	0	0	0	0	0
Pachira aquatica	0	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0	0

Sample Number (Lab Number)	**287-288 (29)**	**283-284 (30)**	**281-282 (31)**	**277-278 (32)**	**273-274 (33)**	**271-272 (34)**	**267-268 (35)**
Taxon							
Physalis sp.	0	0	0	0	0	0	0
Picramnia antidesma	0	0	0	0	0	0	0
Pinus sp. whole	10	3	22	19	12	1	1
Pinus sp. bladder	5	7	15	9	7	4	6
Pinus sp. body and one bladder	0	2	7	3	7	4	2
Pinus sp. body	1	2	2	4	4	0	0
Piper sp.	0	0	0	0	0	1	0
Poaceae<50 microns	2	1	18	11	7	7	5
Poaceae, 50-69 microns	0	3	1	5	1	0	1
Poaceae, 70-100 microns	0	0	0	1	1	0	0
Poaceae>100 microns	0	0	0	0	0	0	0
Podocarpus guatemalensis	0	1	0	1	0	0	0
Polygonaceae	0	0	0	0	0	0	0
cf *Pouteria* sp.	0	0	0	0	0	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0	0
Protium sp.	0	0	0	0	1	0	0
cf *Psychotria* sp.	0	0	0	0	0	0	0
Quercus sp.	2	2	0	1	1	0	0
Rhizophora mangle	123	14	3	5	2	0	1
cf *Rinorea squamata*	0	0	0	0	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	1	0	0	0	0	0	0
Sapindus saponaria	0	0	0	0	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	0	0	0	0	0	0	1
Scrophulariaceae	0	0	0	0	0	0	0
Sebastiana sp.	4	8	5	3	1	0	1
Solanaceae	0	0	0	0	0	0	0
Spondias sp.	0	0	0	0	0	0	1
Spondias mombin	0	0	0	0	0	0	0
cf *Spondias purpurea*	0	0	0	0	0	0	0
Swartzia sp.	0	0	0	0	0	0	0
Swietenia macrophylla	3	6	0	1	0	0	0
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0	0
Tabernaemontana sp.	0	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0	0
TCT	0	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0	0
Trema sp.	13	19	13	3	18	10	7
Trichilia hirta	0	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	0	0
Typha angustifolia	0	0	0	0	0	7	6
Typha domingensis	0	1	2	1	0	1	0
Typha latifolia	0	0	0	0	0	0	0
Ulmus sp.	0	0	0	0	1	0	0
Urticaceae	0	0	0	0	1	0	0
Utricularia sp.	0	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	0	0	0	0
Zanthoxylum sp.	1	1	0	0	0	0	0
Unidentified/Unknown	1	3	0	2	0	1	0
Additional special abundant unknown	0	0	0	0	0	0	5
Unidentifiable/Indeterminate	12	8	12	3	9	7	14
Total	214	202	229	202	214	200	203
Lycopodium	177	229	718	360	164	161	189
Charcoal	Present	Present	Present	Present	Present	Present	Present
Depth in cmbs	287-288	283-284	281-282	277-278	273-274	271-272	267-268
Volume/Weight of Sample	1 cc	1 cc	1 cc	1 cc	1 cc	1 cc	1 cc
Number of *Lycopodium* tablets added	2	2	2	2	2	2	2
Concentration Value	32644 grains/cc	23816 grains/cc	8611 grains/cc	15150 grains/cc	35396 grains/cc	33540 grains/cc	29000 grains/cc

Sample Number (Lab Number)	**263-264 (36)**	**260-261 (37)**	**257-258 (38)**	**253-254 (39)**	**249-250 (40)**	**244-245 (41)**	**242-243 (42)**
Taxon							
Acalypha sp.	1	0	1	1	0	0	0
Alchornea latifolia	0	0	1	0	0	0	0
Alnus sp.	0	0	0	0	0	1	0
Amaranthaceae, fenestrate	0	0	0	0	0	0	0
Anacardium occidentale	0	0	0	0	0	0	0
Anacardiaceae	0	0	0	0	0	0	0
cf *Andira inermis*	0	0	0	0	0	0	0
Apiaceae	0	0	0	0	0	0	0
Araceae or Arecaceae	0	0	0	0	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	0	0	0
Arecaceae, other	0	0	0	0	0	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	11	0	7	16	28	22	16
Asteraceae, Low-spine	47	1	38	19	14	23	6
cf *Banara guianensis*	0	0	0	0	0	0	0
cf *Bauhinia divaricata*	0	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0	0
cf Bignoniaceae	0	0	3	0	0	0	0
Borreria sp. or *Spermacoce* sp.	5	0	1	3	2	1	0
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	0	0
Bursera simaruba	0	0	1	0	2	2	0
Byrsonima sp.	1	0	8	4	6	3	11
cf Campanulaceae	0	0	0	0	0	0	0
Carya sp.	0	0	0	0	0	0	0
Cecropia sp.	2	0	3	23	4	0	0
Cedrela odorata	0	0	0	0	0	0	2
Celastraceae	0	0	0	0	0	0	0
Celtis sp.	2	0	2	0	2	1	1
Cheno-Ams	1	0	1	3	4	0	2
cf Chrysobalanaceae	0	0	0	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	0	0	3	0	1	0	4
Colubrina arborescens	0	0	0	0	0	0	0
Combretaceae/Melastomataceae	27	1	50	33	21	48	44
Commelina sp.	0	0	0	0	0	0	0
Corchorus hirsutus	0	0	0	0	0	0	0
Cordia sp.	0	0	1	0	0	1	0
Cordia alliodora	0	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0	0
Croton sp.	0	0	0	0	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	0
Curatella americana	0	0	0	0	0	0	0
Cyperaceae	8	1	14	16	26	19	16
Desmodium sp.	0	0	0	0	0	2	1
Erythroxylum sp.	0	0	0	0	0	0	0
Euphorbiaceae cf *Gymnanthes lucida or Chamaesyce thymifolia*	0	0	0	0	0	0	0
Other Euphorbiaceae	0	0	0	2	9	0	0
Exothea diphylla	0	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	0	0	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	0	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	0	0	0	0
Other Fabaceae	0	0	0	0	0	0	0
Faramea sp.	0	0	0	0	0	0	0
Heliocarpus americanus	0	0	0	0	0	0	0
Hippocratea volubilis	0	0	0	0	0	0	0
Ilex sp.	0	0	0	0	0	0	0
Justicia campechiana	0	0	0	0	0	0	0
Juncus marginatus	0	0	1	0	0	0	0
Laguncularia racemosa	0	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	0	0	0
Licania sp.	0	0	0	0	0	0	0
cf *Lilium*	0	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0	0
Loranthaceae	0	0	0	0	4	2	0
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0
Mangifera indica	0	0	0	0	0	1	0
cf *Markea* sp.	0	0	0	0	0	0	0
Meliaceae	0	0	0	0	0	0	0
Metopium brownei	0	0	0	0	1	1	0
Mimosa sp.	0	0	0	0	0	0	0
Moraceae cf *Brosimum* sp.	5	0	13	13	7	8	13
Moraceae cf diporate *Ficus* sp.	0	1	0	0	0	0	0
Moraceae, other diporate	0	0	0	0	0	0	0
Moraceae, triporate	0	0	0	0	0	0	0
Myrica cerifera	0	0	0	0	1	5	11
Myristicaceae	0	0	0	0	0	0	0
Myrtaceae, syncolpate	0	0	1	0	0	0	0
Myrtaceae, tricolporate	0	0	0	0	0	0	0
Nymphaceae	0	1	0	0	1	0	0
Orchidaceae?	0	0	0	0	0	0	0
Ostrya/Carpinus	0	0	0	0	0	0	0
Pachira aquatica	0	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0	0

Sample Number (Lab Number)	**263-264 (36)**	**260-261 (37)**	**257-258 (38)**	**253-254 (39)**	**249-250 (40)**	**244-245 (41)**	**242-243 (42)**
Taxon							
Physalis sp.	0	0	0	0	0	0	0
Picramnia antidesma	0	0	0	0	0	0	0
Pinus sp. whole	8	2	1	4	7	8	12
Pinus sp. bladder	16	2	7	9	9	6	5
Pinus sp. body and one bladder	0	2	1	1	4	3	9
Pinus sp. body	1	1	0	0	1	0	0
Piper sp.	0	0	0	0	0	0	0
Poaceae<50 microns	12	4	11	12	13	27	6
Poaceae, 50-69 microns	1	2	1	3	4	9	3
Poaceae, 70-100 microns	0	0	0	0	0	1	0
Poaceae>100 microns	0	0	0	0	0	0	0
Podocarpus guatemalensis	0	0	0	0	0	0	0
Polygonaceae	0	0	0	0	0	0	0
cf *Pouteria* sp.	0	0	0	0	0	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0	0
Protium sp.	0	0	0	0	0	0	0
cf *Psychotria* sp.	0	0	0	0	0	0	0
Quercus sp.	0	1	2	1	1	0	2
Rhizophora mangle	0	0	2	2	1	0	1
cf *Rinorea squamata*	0	0	0	0	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	0	0	0	0	0	0	0
Sapindus saponaria	0	0	0	0	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	0	0	0	0	0	0	0
Scrophulariaceae	0	0	0	0	0	0	0
Sebastiana sp.	2	0	0	0	0	0	2
Solanaceae	0	0	0	0	0	0	0
Spondias sp.	0	0	0	0	0	0	0
Spondias mombin	0	0	0	0	0	0	0
cf *Spondias purpurea*	0	0	0	0	0	0	0
Swartzia sp.	0	0	0	0	0	0	0
Swietenia macrophylla	0	0	0	0	0	0	0
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0	0
Tabernaemontana sp.	0	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0	0
TCT	0	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0	0
Trema sp.	18	0	12	15	20	18	23
Trichilia hirta	0	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	0	0
Typha angustifolia	5	0	3	2	0	0	0
Typha domingensis	2	0	1	4	6	14	5
Typha latifolia	0	0	0	0	0	0	0
Ulmus sp.	0	0	0	0	0	0	0
Urticaceae	0	0	0	0	0	0	0
Utricularia sp.	0	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	0	0	0	0
Zanthoxylum sp.	1	0	0	0	0	1	0
Unidentified/Unknown	1	2	2	2	0	2	2
Additional special abundant unknown	0	0	0	0	0	0	0
Unidentifiable/Indeterminate	25	6	16	12	6	6	7
Total	202	27	208	200	205	235	204
Lycopodium	112	223	366	133	199	197	578
Charcoal	Present	Present	Present	Present	Present	Present	Present
Depth in cmbs	263-264	260-261	257-258	253-254	249-250	244-245	242-243
Volume/Weight of Sample	1 cc	6 gm	1 cc	1 cc	1 cc	1 cc	1 cc
Number of *Lycopodium* tablets added	2	1	2	2	2	2	2
Concentration Value	48696 grains/cc	272 grains/gm	15344 grains/cc	40601 grains/cc	27814 grains/cc	32208 grains/cc	9529 grains/cc

Sample Number (Lab Number)	**239-240 (43)**	**236-237 (44)**	**233-234 (45)**	**228-229 (46)**	**224-225 (47)**	**221-222 (48)**	**219-220 (49)**
Taxon							
Acalypha sp.	0	0	2	1	0	0	0
Alchornea latifolia	0	0	0	0	0	0	0
Alnus sp.	1	0	0	0	0	0	0
Amaranthaceae, fenestrate	0	0	1	0	0	0	0
Anacardium occidentale	0	0	0	0	0	0	0
Anacardiaceae	0	0	0	0	0	0	0
cf *Andira inermis*	0	0	0	0	0	0	0
Apiaceae	1	0	0	0	0	0	0
Araceae or Arecaceae	0	0	0	1	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	0	0	0
Arecaceae, other	2	0	0	0	0	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	6	6	27	8	0	0	0
Asteraceae, Low-spine	7	5	27	75	0	0	7
cf *Banara guianensis*	0	0	0	1	0	0	0
cf *Bauhinia divaricata*	0	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0	0
cf Bignoniaceae	0	0	0	2	0	0	0
Borreria sp. or *Spermacoce* sp.	4	0	2	17	0	0	1
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	0	0
Bursera simaruba	4	1	0	9	0	0	0
Byrsonima sp.	6	3	2	1	0	0	0
cf Campanulaceae	0	0	0	0	0	0	0
Carya sp.	0	0	0	0	0	0	0
Cecropia sp.	0	2	0	0	0	0	0
Cedrela odorata	0	0	0	0	0	0	0
Celastraceae	0	0	0	0	0	0	0
Celtis sp.	1	1	0	0	0	0	0
Cheno-Ams	5	1	2	0	0	0	0
cf Chrysobalanaceae	0	0	0	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	7	5	10	0	0	0	1
Colubrina arborescens	0	0	0	0	0	0	0
Combretaceae/Melastomataceae	45	61	48	25	0	0	6
Commelina sp.	0	0	0	0	0	0	0
Corchorus hirsutus	0	0	0	0	0	0	0
Cordia sp.	0	1	0	0	0	0	0
Cordia alliodora	0	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0	0
Croton sp.	0	0	0	0	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	0
Curatella americana	0	0	0	0	0	0	0
Cyperaceae	14	11	5	17	0	0	1
Desmodium sp.	0	0	0	0	0	0	0
Erythroxylum sp.	0	0	0	0	0	0	0
Euphorbiaceae cf *Gymnanthes lucida or Chamaesyce thymifolia*	0	0	0	0	0	0	0
Other Euphorbiaceae	0	0	0	0	0	0	0
Exothea diphylla	0	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	0	0	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	0	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	3
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	0	0	0	0
Other Fabaceae	0	0	0	0	0	0	0
Faramea sp.	0	0	0	0	0	0	0
Heliocarpus americanus	0	0	0	0	0	0	0
Hippocratea volubilis	1	0	0	0	0	0	0
Ilex sp.	0	0	0	1	0	0	0
Justicia campechiana	0	0	0	0	0	0	0
Juncus marginatus	0	0	0	0	0	0	0
Laguncularia racemosa	0	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	0	0	0
Licania sp.	0	0	0	0	0	0	0
cf *Lilium*	0	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0	0
Loranthaceae	1	2	2	0	0	0	0
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0
Mangifera indica	0	0	0	0	0	0	0
cf *Markea* sp.	0	0	0	0	0	0	0
Meliaceae	0	0	0	0	0	0	0
Metopium brownei	3	2	0	0	0	0	0
Mimosa sp.	0	0	0	0	0	0	0
Moraceae cf *Brosimum* sp.	23	19	3	2	0	0	0
Moraceae cf diporate *Ficus* sp.	0	0	0	0	0	0	0
Moraceae, other diporate	0	0	0	0	0	0	0
Moraceae, triporate	0	0	0	0	0	0	0
Myrica cerifera	11	9	4	3	0	0	0
Myristicaceae	0	0	0	0	0	0	0
Myrtaceae, syncolpate	0	0	0	1	0	1	3
Myrtaceae, tricolporate	0	0	0	0	0	0	0
Nymphaceae	0	0	0	1	0	0	0
Orchidaceae?	0	0	4	0	0	0	0
Ostrya/Carpinus	0	0	0	0	0	0	0
Pachira aquatica	0	2	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0	0

Sample Number (Lab Number)	**239-240 (43)**	**236-237 (44)**	**233-234 (45)**	**228-229 (46)**	**224-225 (47)**	**221-222 (48)**	**219-220 (49)**
Taxon							
Physalis sp.	0	0	0	0	0	0	0
Picramnia antidesma	0	0	0	2	0	0	0
Pinus sp. whole	14	13	18	1	0	0	0
Pinus sp. bladder	8	5	9	14	0	0	0
Pinus sp. body and one bladder	8	2	3	2	0	0	0
Pinus sp. body	1	0	0	7	0	0	0
Piper sp.	0	0	0	0	0	0	0
Poaceae<50 microns	7	17	17	45	0	0	3
Poaceae, 50-69 microns	5	1	1	1	0	0	0
Poaceae, 70-100 microns	0	0	1 (100 µ)	0	0	0	0
Poaceae>100 microns	0	0	0	0	0	0	0
Podocarpus guatemalensis	0	0	0	0	0	0	0
Polygonaceae	0	0	0	0	0	0	0
cf *Pouteria* sp.	0	0	0	0	0	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0	0
Protium sp.	0	0	0	0	0	0	0
cf *Psychotria* sp.	0	0	0	3	0	0	0
Quercus sp.	0	0	0	0	0	0	2
Rhizophora mangle	0	0	1	0	0	0	0
cf *Rinorea squamata*	0	0	0	2	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	0	0	0	0	0	0	0
Sapindus saponaria	0	0	0	0	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	1
Other Sapotaceae (not *Pouteria* sp.)	0	0	1	0	0	0	2
Scrophulariaceae	0	0	0	0	0	0	0
Sebastiana sp.	2	1	2	0	0	0	0
Solanaceae	2	0	0	0	0	0	0
Spondias sp.	0	1	0	0	0	0	0
Spondias mombin	0	0	0	0	0	0	0
cf *Spondias purpurea*	0	0	0	0	0	0	1
Swartzia sp.	0	0	0	0	0	0	0
Swietenia macrophylla	0	0	0	0	0	0	0
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0	0
Tabernaemontana sp.	1	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0	0
TCT	0	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0	0
Tiliaceae	0	0	3	0	0	0	0
Trema sp.	10	22	8	2	0	0	0
Trichilia hirta	0	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	0	0
Typha angustifolia	0	0	0	0	0	0	0
Typha domingensis	2	1	1	7	0	0	0
Typha latifolia	0	0	0	0	0	0	0
Ulmus sp.	0	0	0	0	0	0	1
Urticaceae	0	0	0	0	0	0	0
Utricularia sp.	0	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	1	0	0	0
Zanthoxylum sp.	0	0	0	0	0	0	0
Unidentified/Unknown	1	4	0	9	0	0	0
Additional special abundant unknown	0	0	0	0	0	0	0
Unidentifiable/Indeterminate	7	13	10	15	0	0	8
Total	210	211	214	276	0	1	40
Lycopodium	230	354	395	300	0	79	38
Charcoal	Present	Present	Present	Present	Present	Present	Present
Depth in cmbs	239-240	236-237	233-234	228-229	224-225	221-222	219-220
Volume/Weight of Sample	1 cc	1 cc	1 cc	14 gm	16 gm	1 cc	15 gm
Number of *Lycopodium* tablets added	2	2	2	1	1	2	1
Concentration Value	24652 grains/cc	16093 grains/cc	14627 grains/cc	1774 grains/gm	N/A	N/A	947 grains/gm

Sample Number (Lab Number)	**214-215 (50)**	**210-211 (51)**	**206-207 (52)**	**202-203 (53)**	**199-200 (54)**	**195-196 (55)**	**191-192 (56)**
Taxon							
Acalypha sp.	0	0	0	0	0	0	0
Alchornea latifolia	0	0	0	0	0	0	0
Alnus sp.	0	0	1	0	0	0	0
Amaranthaceae, fenestrate	0	0	0	0	0	0	1
Anacardium occidentale	0	0	0	0	0	0	0
Anacardiaceae	1	0	0	0	0	0	0
cf *Andira inermis*	0	0	0	0	0	0	0
Apiaceae	0	0	0	0	0	0	1
Araceae or Arecaceae	0	0	0	0	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	0	0	0
Arecaceae, other	0	0	0	0	0	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	1	0	2	0	7	16	9
Asteraceae, Low-spine	6	10	21	5	17	15	11
cf *Banara guianensis*	0	0	0	0	0	0	0
cf *Bauhinia divaricata*	0	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0	0
cf Bignoniaceae	0	0	0	0	0	0	0
Borreria sp. or *Spermacoce* sp.	1	1	1	1	3	15	7
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	0	1
Bursera simaruba	0	0	1	0	6	0	0
Byrsonima sp.	0	0	0	0	0	0	0
cf Campanulaceae	0	1	0	0	0	0	0
Carya sp.	0	0	0	0	0	0	0
Cecropia sp.	0	0	0	0	0	0	0
Cedrela odorata	0	0	0	0	0	0	0
Celastraceae	0	0	0	0	0	0	0
Celtis sp.	0	0	0	0	0	0	0
Cheno-Ams	0	0	1	0	0	2	0
cf Chrysobalanaceae	0	0	0	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	0	0	0	0	0	2	19
Colubrina arborescens	0	0	0	0	0	0	0
Combretaceae/Melastomataceae	4	4	5	0	22	30	102
Commelina sp.	0	0	0	0	0	0	0
Corchorus hirsutus	0	0	0	0	0	0	0
Cordia sp.	0	0	0	0	0	0	0
Cordia alliodora	0	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	2	0	0
Croton sp.	0	0	0	0	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	0
Curatella americana	0	0	0	0	0	0	0
Cyperaceae	0	3	5	8	15	6	0
Desmodium sp.	0	0	0	0	0	0	0
Erythroxylum sp.	0	0	0	0	0	0	0
Euphorbiaceae cf *Gymnanthes lucida or Chamaesyce thymifolia*	0	0	0	0	0	0	0
Other Euphorbiaceae	0	0	0	0	0	0	0
Exothea diphylla	0	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	0	0	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	0	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	2	0	0	0	0	0
Other Fabaceae	0	0	0	0	0	0	0
Faramea sp.	0	0	0	0	0	0	0
Heliocarpus americanus	0	0	1	0	0	0	0
Hippocratea volubilis	0	0	0	0	0	0	0
Ilex sp.	0	0	0	0	0	0	0
Justicia campechiana	0	0	0	0	0	0	0
Juncus marginatus	0	0	0	0	0	0	0
Laguncularia racemosa	0	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	0	0	0
Licania sp.	0	0	0	0	0	0	0
cf *Lilium*	0	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0	0
Loranthaceae	0	0	0	0	0	0	3
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0
Mangifera indica	0	0	0	0	0	0	0
cf *Markea* sp.	0	0	0	0	0	0	0
Meliaceae	0	0	0	0	1	0	0
Metopium brownei	0	0	0	0	0	0	1
Mimosa sp.	0	0	0	0	0	0	0
Moraceae cf *Brosimum* sp.	0	1	0	0	1	6	0
Moraceae cf diporate *Ficus* sp.	0	0	0	0	0	0	0
Moraceae, other diporate	0	0	0	0	0	0	0
Moraceae, triporate	0	0	0	0	0	0	0
Myrica cerifera	0	0	3	2	0	2	1
Myristicaceae	0	0	0	0	0	0	0
Myrtaceae, syncolpate	0	0	0	0	0	3	0
Myrtaceae, tricolporate	0	0	0	0	0	0	0
Nymphaceae	0	0	0	0	0	0	0
Orchidaceae?	0	0	0	0	0	0	0
Ostrya/Carpinus	0	0	0	0	0	0	0
Pachira aquatica	0	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0	0

Sample Number (Lab Number)	**214-215 (50)**	**210-211 (51)**	**206-207 (52)**	**202-203 (53)**	**199-200 (54)**	**195-196 (55)**	**191-192 (56)**
Taxon							
Physalis sp.	0	0	0	0	0	0	0
Picramnia antidesma	0	0	0	0	0	0	0
Pinus sp. whole	0	3	2	6	3	2	0
Pinus sp. bladder	3	2	10	6	2	5	1
Pinus sp. body and one bladder	1	0	0	0	0	1	2
Pinus sp. body	1	0	5	1	2	0	0
Piper sp.	0	0	0	0	0	0	0
Poaceae<50 microns	13	19	53	12	87	20	5
Poaceae, 50-69 microns	0	4	0	5	0	1	0
Poaceae, 70-100 microns	0	0	0	0	0	0	0
Poaceae>100 microns	1	1	0	0	0	0	0
Podocarpus guatemalensis	0	0	0	0	0	0	0
Polygonaceae	0	0	1	0	1	0	0
cf *Pouteria* sp.	0	0	0	0	0	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0	0
Protium sp.	0	0	1	0	0	2	0
cf *Psychotria* sp.	0	0	0	0	0	0	0
Quercus sp.	0	0	1	0	0	11	0
Rhizophora mangle	0	0	0	0	0	0	0
cf *Rinorea squamata*	0	0	0	0	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	0	0	0	0	0	0	0
Sapindus saponaria	0	0	0	0	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	1	0	1	0	7	3	16
Scrophulariaceae	0	0	0	0	0	0	0
Sebastiana sp.	0	0	0	0	0	0	0
Solanaceae	0	0	0	0	0	0	0
Spondias sp.	0	0	0	0	0	0	1
Spondias mombin	0	0	0	0	0	0	0
cf *Spondias purpurea*	0	0	0	0	0	0	0
Swartzia sp.	0	0	0	0	0	0	0
Swietenia macrophylla	0	0	0	0	0	0	0
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0	0
Tabernaemontana sp.	0	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0	0
TCT	0	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0	0
Trema sp.	0	1	0	0	0	0	0
Trichilia hirta	0	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	0	0
Typha angustifolia	0	0	0	0	0	?	0
Typha domingensis	0	3	0	0	0	12	0
Typha latifolia	0	0	0	0	0	0	0
Ulmus sp.	0	0	0	0	0	0	0
Urticaceae	0	0	0	0	0	0	0
Utricularia sp.	0	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	0	0	0	0
Zanthoxylum sp.	0	0	0	0	0	0	1
Unidentified/Unknown	0	2	3	2	11	0	0
Additional special abundant unknown	0	0	0	0	0	0	0
Unidentifiable/Indeterminate	8	17	23	2	23	47	38
Total	41	74	141	50	210	201	220
Lycopodium	275	467	279	273	112	364	167
Charcoal	Absent	Present	Present	Present	Present	Present	Present
Depth in cmbs	214-215	210-211	206-207	202-203	199-200	195-196	191-192
Volume/Weight of Sample	14 gm	13 gm	16 gm	7 gm	8 gm	2 cc	1 cc
Number of *Lycopodium* tablets added	1	1	1	1	1	2	2
Concentration Value	144 grains/gm	165 grains/gm	426 grains/gm	353 grains/gm	3164 grains/gm	7455 grains/cc	35569 grains/cc

Sample Number (Lab Number)	**185-186 (57)**	**180-181 (58)**	**176-177 (59)**	**174-175 (60)**	**Surface 1 (61)**	**Cowfield (62)**
Taxon						
Acalypha sp.	0	0	0	1	0	0
Alchornea latifolia	0	0	0	0	0	0
Alnus sp.	0	0	0	0	2	0
Amaranthaceae, fenestrate	0	0	0	0	0	0
Anacardium occidentale	0	0	0	0	0	0
Anacardiaceae	0	0	0	2	4	0
cf *Andira inermis*	0	0	0	0	0	0
Apiaceae	0	0	0	0	0	0
Araceae or Arecaceae	0	0	0	0	0	0
Arecaceae, *Bactris*-type	2	1	1	4	3	0
Arecaceae, other	0	0	1	0	0	0
Aristolochiaceae	0	0	0	0	1	0
Asteraceae, High-spine	1	3	7	4	10	3
Asteraceae, Low-spine	3	1	2	5	5	44
cf *Banara guianensis*	0	0	0	0	0	0
cf *Bauhinia divaricata*	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0
cf Bignoniaceae	0	0	0	0	0	0
Borreria sp. or *Spermacoce* sp.	0	0	0	0	2	0
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	0
Bursera simaruba	2	0	8	9	5	0
Byrsonima sp.	1	5	2	5	0	0
cf Campanulaceae	0	0	0	0	0	0
Carya sp.	0	0	0	0	0	0
Cecropia sp.	0	0	0	0	0	0
Cedrela odorata	0	0	0	0	0	0
Celastraceae	0	0	0	0	0	0
Celtis sp.	0	1	3	2	2	2
Cheno-Ams	1	0	0	2	0	6
cf Chrysobalanaceae	0	0	0	0	0	0
Cissus sp.	0	0	1	0	0	0
Coccoloba sp.	6	2	6	7	1	0
Colubrina arborescens	0	0	0	0	0	0
Combretaceae/Melastomataceae	120	163	10	21	31	1
Commelina sp.	0	0	0	0	0	0
Corchorus hirsutus	0	0	0	0	0	0
Cordia sp.	2	1	1	0	0	0
Cordia alliodora	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0
Croton sp.	0	0	0	0	0	0
cf Cucurbitaceae	0	0	0	1	0	0
Curatella americana	0	0	0	0	0	0
Cyperaceae	6	1	34	68	46	51
Desmodium sp.	0	1	1	3	0	0
Erythroxylum sp.	0	0	2	0	0	0
Euphorbiaceae cf *Gymnanthes lucida or Chamaesyce thymifolia*	0	0	0	0	0	0
Other Euphorbiaceae	0	0	0	0	0	0
Exothea diphylla	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	0	2	3	3	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	6	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	6	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	3	9	13
Other Fabaceae	0	0	3	4	0	0
Faramea sp.	0	0	0	0	0	0
Heliocarpus americanus	0	0	0	0	0	0
Hippocratea volubilis	1	0	0	0	0	0
Ilex sp.	0	0	0	0	0	0
Justicia campechiana	0	0	0	0	0	0
Juncus marginatus	0	0	0	0	1	1
Laguncularia racemosa	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	2	0	0
Lantana sp.	0	0	0	0	0	0
Licania sp.	0	0	0	0	0	0
cf *Lilium*	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0
Loranthaceae	1	0	0	0	0	0
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	1
Mangifera indica	0	0	0	0	0	0
cf *Markea* sp.	0	0	0	0	0	0
Meliaceae	0	0	0	0	0	0
Metopium brownei	0	2	0	0	0	0
Mimosa sp.	0	0	1	1	1	4
Moraceae cf *Brosimum* sp.	4	4	5	17	1	2
Moraceae cf diporate *Ficus* sp.	0	0	0	2	0	0
Moraceae, other diporate	0	0	0	0	0	0
Moraceae, triporate	0	0	0	0	0	0
Myrica cerifera	0	0	2	1	2	0
Myristicaceae	0	0	0	0	0	0
Myrtaceae, syncolpate	1	9	9	2	3	0
Myrtaceae, tricolporate	0	0	0	0	0	0
Nymphaceae	0	0	0	1	0	0
Orchidaceae?	0	0	0	0	0	0
Ostrya/Carpinus	0	0	0	1	0	0
Pachira aquatica	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0

Sample Number (Lab Number)	**185-186 (57)**	**180-181 (58)**	**176-177 (59)**	**174-175 (60)**	**Surface 1 (61)**	**Cowfield (62)**
Taxon						
Physalis sp.	0	0	0	0	1	0
Picramnia antidesma	0	0	0	0	0	0
Pinus sp. whole	1	1	4	3	12	8
Pinus sp. bladder	2	0	4	4	2	4
Pinus sp. body and one bladder	0	1	1	4	0	0
Pinus sp. body	0	0	1	1	1	4
Piper sp.	0	0	0	0	0	0
Poaceae<50 microns	2	0	6	6	5	11
Poaceae, 50-69 microns	1	0	0	0	2	0
Poaceae, 70-100 microns	0	1 (100 µ)	0	1	0	0
Poaceae>100 microns	0	0	1	2	0	0
Podocarpus guatemalensis	0	0	0	0	0	0
Polygonaceae	0	0	0	0	0	0
cf *Pouteria* sp.	0	0	0	0	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0
Protium sp.	0	1	2	12	8	0
cf *Psychotria* sp.	0	0	0	0	0	0
Quercus sp.	4	0	5	0	8	1
Rhizophora mangle	0	0	0	1	2	0
cf *Rinorea squamata*	0	0	0	0	0	0
cf Rubiaceae	1	0	0	0	0	0
Sapindaceae	0	0	0	0	0	0
Sapindus saponaria	0	0	0	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	1	0	0	0	0	0
Scrophulariaceae	0	0	0	0	0	0
Sebastiana sp.	2	0	0	2	0	0
Solanaceae	0	0	0	0	0	0
Spondias sp.	0	0	0	0	0	0
Spondias mombin	0	0	0	0	0	0
cf *Spondias purpurea*	0	0	0	0	0	0
Swartzia sp.	0	0	0	0	0	0
Swietenia macrophylla	0	0	0	0	0	0
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0
Tabernaemontana sp.	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0
TCT	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0
Trema sp.	6	0	5	9	4	0
Trichilia hirta	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	0
Typha angustifolia	0	0	0	0	0	0
Typha domingensis	3	3	37	13	1	30
Typha latifolia	0	0	0	0	0	11
Ulmus sp.	0	0	0	0	1	0
Urticaceae	0	0	0	0	0	7
Utricularia sp.	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	0	0	0
Zanthoxylum sp.	2	0	2	0	0	0
Unidentified/Unknown	0	0	3	1	4	3
Additional special abundant unknown	0	0	5	11	0	0
Unidentifiable/Indeterminate	25	12	12	19	20	33
Total	201	215	202	260	200	240
Lycopodium	191	75	330	550	69	246
Charcoal	Absent	Not noted	Present	Present	Present	Present
Depth in cmbs	185-186	180-181	176-177	174-175	Surface	Surface
Volume/Weight of Sample	1 cc	1 cc	1 cc	1 cc	10 gm	2 cc
Number of *Lycopodium* tablets added	2	2	2	2	1	2
Concentration Value	28413 grains/cc	77400 grains/cc	22261 grains/cc	12764 grains/cc	3913 grains/gm	6585 grains/cc

APPENDIX C

RELATIVE PERCENTAGES OF TAXA REPRESENTED IN THE LAGUNA VERDE POLLEN CORE

Sample Number (Laboratory Number)	372-373 (1)	370-371 (2)	367-368 (3)	364-365 (4)	362-363 (5)	361-362 (6)	357-358 (7)
Taxon							
Acalypha sp.	0	0.014	0	0	0	0	0
Alchornea latifolia	0	0	0	0	0.005	0	0
Alnus sp.	0	0	0.005	0.003	0.014	0	0
Amaranthaceae, fenestrate	0	0	0	0	0.009	0	0
Anacardium occidentale	0	0	0	0	0	0	0
Anacardiaceae	0.0161	0	0	0	0	0	0.005
cf *Andira inermis*	0	0	0	0	0	0	0
Apiaceae	0	0	0	0	0	0	0
Araceae or Araceae	0	0	0	0	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	0	0	0
Arecaceae, other	0	0	0	0	0	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	0	0	0.059	0.003	0.014	0.015	0
Asteraceae, Low-spine	0	0	0.054	0.021	0.099	0.015	0.098
cf *Banara guianensis*	0	0	0	0	0	0	0
Bauhinia divaricata	0	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0	0
cf Bignoniaceae	0	0	0	0	0	0	0
Borreria sp. or *Spermacoce* sp.	0	0.069	0.113	0	0.009	0	0.069
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0	0
Bravaisia sp.	0	0	0.005	0	0	0	0
Bursera simaruba	0	0	0.01	0.006	0.005	0	0.005
Byrsonima sp.	0	0	0	0.003	0.005	0	0
cf Campanulaceae	0	0	0	0	0	0	0
Carya sp.	0	0	0	0.003	0	0	0
Cecropia sp.	0	0	0	0	0.005	0	0.025
Cedrela odorata	0	0	0	0.009	0	0	0
Celastraceae	0	0	0	0	0	0	0
Celtis sp.	0	0	0.005	0	0	0.015	0.01
Cheno-Ams	0	0	0.015	0.009	0.005	0	0.01
cf Chrysobalanaceae	0	0	0.005	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	0.016	0.014	0	0	0.005	0	0.005
Colubrina arborescens	0	0	0	0	0	0.005	0.005
Combretaceae/Melastomataceae	0.079	0.014	0.069	0.043	0.141	0.115	0.157
Commelina sp.	0	0	0	0	0	0	0
Corchorus hirsutus	0	0	0	0	0	0	0
Cordia sp.	0	0	0	0	0.009	0.02	0
Cordia alliodora	0	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0	0
Croton sp.	0	0	0	0.003	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	0
Curatella americana	0	0	0	0	0	0.01	0
Cyperaceae	0.143	0.097	0.202	0.162	0.085	0.085	0.083
Desmodium sp.	0	0	0	0	0	0	0
Erythroxylum sp.	0	0	0	0	0	0.005	0
Euphorbiaceae cf *Gymnanthes lucida* or *Chamaesyce thymifolia*	0.016	0.056	0	0.043	0	0	0
Other Euphorbiaceae	0	0	0	0.006	0	0	0
Exothea diphylla	0	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	0.016	0	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	0	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	0	0	0	0.01
Other Fabaceae	0	0	0	0	0	0	0
Faramea sp.	0	0	0	0.003	0	0	0
Heliocarpus americanus	0	0.028	0	0	0	0	0
Hippocratea volubilis	0	0	0	0.003	0	0	0
Ilex sp.	0	0	0	0	0	0	0
Justicia campechiana	0	0	0	0.009	0	0	0
Juncus marginatus	0.032	0.014	0	0	0	0	0
Laguncularia racemosa	0	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	0	0	0
Licania sp.	0	0	0	0	0	0	0.005
cf *Lilium* sp.	0	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0	0
Loranthaceae	0	0	0	0.003	0	0	0
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0.005	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0
Mangifera indica	0	0	0	0	0	0	0
cf *Markea* sp.	0	0	0	0	0	0	0
Meliaceae	0	0	0.005	0.009	0	0	0
Metopium brownei	0	0	0	0	0	0	0
Mimosa sp.	0	0	0	0.003	0	0	0.005
Moraceae cf *Brosimum* sp.	0	0.028	0.015	0.021	0.07	0.32	0.083
Moraceae cf diporate *Ficus* sp.	0	0	0	0	0	0	0
Moraceae, other diporate	0	0	0	0	0	0	0
Moraceae, triporate	0	0	0.005	0	0	0	0.005
Myrica cerifera	0.016	0.028	0	0.009	0	0	0.01
Myristicaceae	0	0	0	0	0	0	0
Myrtaceae, syncolpate	0	0	0	0.006	0.014	0.005	0
Myrtaceae, tricolporate	0	0	0	0	0	0	0
Nymphaceae	0	0	0.02	0	0.005	0	0
cf Orchidaceae	0	0	0	0	0	0	0
Ostrya/Carpinus	0	0	0	0	0	0	0
Pachira aquatica	0	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0.01	0	0.009	0.09	0
Physalis sp.	0	0	0	0	0	0	0.005

Sample Number (Laboratory Number)	**372-373 (1)**	**370-371 (2)**	**367-368 (3)**	**364-365 (4)**	**362-363 (5)**	**361-362 (6)**	**357-358 (7)**
Taxon							
Picramnia antidesma	0	0	0	0	0	0	0
Pinus sp. whole	0.254	0.19	0.034	0.204	0.089	0.015	0.044
Pinus sp. bladder	0.032	0	0.039	0.037	0.08	0.035	0.034
Pinus sp. body and one bladder	0.016	0	0.005	0.024	0	0.015	0.005
Pinus sp. body	0.016	0	0.02	0.015	0.019	0.005	0.015
Piper sp.	0	0	0	0	0	0	0
Poaceae<50 microns	0	0.014	0.064	0.027	0.085	0.015	0.064
Poaceae, 50-69 microns	0.016	0.014	0	0.015	0	0	0
Poaceae, 70-100 microns	0	0	0	0	0	0	0
Poaceae>100 microns	0	0	0.005	0	0	0	0
Podocarpus guatemalensis	0	0	0	0.006	0	0	0.01
cf Polygonaceae	0	0	0	0.003	0	0	0
cf *Pouteria* sp.	0	0	0	0	0	0	0
cf *Pouteria stipitata*	0	0	0	0	0.005	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0.003	0	0	0
Protium sp.	0	0	0	0.037	0	0	0.015
cf *Psychotria* sp.	0	0	0	0	0	0	0
Quercus sp.	0.016	0.069	0.015	0.021	0.009	0	0.01
Rhizophora mangle	0.016	0.028	0.034	0.018	0	0	0.01
cf *Rinorea squamata*	0	0	0	0	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	0	0	0	0	0	0	0.005
Sapindus saponaria	0	0	0	0.064	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	0	0	0.005	0	0	0	0
Scrophulariaceae	0.016	0	0	0	0	0	0
Sebastiana sp.	0	0	0	0	0	0.01	0
Solanaceae	0	0.014	0	0	0	0	0
Spondias sp.	0	0	0.005	0	0.005	0	0
Spondias mombin	0	0	0	0	0	0	0
Spondias purpurea	0	0	0	0.003	0	0	0
Swartzia sp.	0.048	0	0	0.003	0	0	0
Swietenia macrophylla	0	0	0	0	0	0	0
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0	0
Tabernaemontana sp.	0	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0.003	0	0	0
TCT	0	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0	0
Trema sp.	0	0.042	0.015	0.006	0.009	0.1	0.034
Trichilia hirta	0	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	0.005	0
Typha angustifolia	0	0	0	0	0	0.025	0.025
Typha domingensis	0	0	0	0.03	0.005	0	0
Typha latifolia	0	0	0	0.003	0	0	0
Ulmus sp.	0	0	0.005	0.009	0	0	0
Urticaceae	0	0	0	0	0	0	0
Utricularia sp.	0	0	0	0	0	0.005	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	0.003	0	0	0
Zanthoxylum sp.	0	0	0	0	0	0.005	0
Unidentified/Unknown	0.159	0.069	0.069	0.009	0.075	0.02	0.015
Additional special abundant unknown	0	0	0	0	0	0	0
Unidentifiable/Indeterminate	0.079	0.19	0.084	0.073	0.113	0.045	0.123
Percentage Total	1.002	0.992	1.001	0.996	1.002	1	1.004
Total Number of Grains	62	72	203	328	213	200	204
Lycopodium	419	327	421	250	194	274	287
Charcoal	Absent	Absent	Present	Present	Present	Present	Present
Depth in cmbs	372-373	370-371	367-368	364-365	362-363	361-362	357-358
Volume/Weight of Sample	8 gm	7 gm	1 cc	8 gm	1 cc	1 cc	1 cc
Number of *Lycopodium* tablets added	1	1	1	1	1	2	2
Concentration Value	250 grains/gm	424 grains/gm	6510 grains/cc	2214 grains/gm	14822 grains/cc	19708 grains/cc	19098 grains/cc

Sample Number (Laboratory Number)	353-354 (8)	350-351 (9)	347-348 (10)	343-344 (11)	339-340 (12)	335-336 (13)	334-335 (14)
Taxon							
Acalypha sp.	0.014	0.005	0.02	0	0.005	0	0.005
Alchornea latifolia	0.005	0	0.005	0	0	0	0.005
Alnus sp.	0.005	0	0	0	0	0	0
Amaranthaceae, fenestrate	0	0.005	0	0	0	0	0
Anacardium occidentale	0	0	0	0	0	0	0
Anacardiaceae	0	0	0.005	0	0.005	0.004	0
cf *Andira inermis*	0	0	0	0	0	0	0
Apiaceae	0	0	0	0	0	0	0
Araceae or Araceae	0	0	0	0	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	0	0	0
Arecaceae, other	0	0	0	0	0.005	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	0.009	0.01	0	0	0.005	0.015	0.01
Asteraceae, Low-spine	0.005	0.005	0	0	0.005	0.007	0.01
cf *Banara guianensis*	0	0	0	0	0	0	0
Bauhinia divaricata	0	0.005	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0.004	0
cf Bignoniaceae	0	0	0	0.005	0	0	0
Borreria sp. or *Spermacoce* sp.	0	0.005	0.01	0.005	0.005	0.007	0
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	0.004	0
Bursera simaruba	0.014	0.01	0.005	0	0.024	0.011	0.005
Byrsonima sp.	0	0.01	0.01	0.005	0	0	0.005
cf Campanulaceae	0	0	0	0	0	0	0
Carya sp.	0	0	0	0	0	0	0
Cecropia sp.	0.009	0	0	0	0	0	0.005
Cedrela odorata	0	0	0	0	0	0	0
Celastraceae	0	0	0	0	0	0	0
Celtis sp.	0.009	0.005	0.015	0	0.02	0	0
Cheno-Ams	0.005	0.005	0.025	0.005	0.01	0.022	0.005
cf Chrysobalanaceae	0	0	0	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	0	0	0	0	0.005	0	0.01
Colubrina arborescens	0	0.005	0.01	0.005	0.005	0	0
Combretaceae/Melastomataceae	0.057	0.069	0.055	0.045	0.083	0.03	0.144
Commelina sp.	0	0	0	0.01	0	0	0
Corchorus hirsutus	0.005	0	0	0	0	0.004	0
Cordia sp.	0	0	0.005	0.005	0.005	0	0
Cordia alliodora	0	0.005	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0	0
Croton sp.	0	0.005	0	0	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	0
Curatella americana	0	0	0.01	0	0	0	0
Cyperaceae	0.038	0.044	0.04	0.02	0.029	0.097	0.135
Desmodium sp.	0	0	0	0	0	0	0
Erythroxylum sp.	0	0	0	0	0.01	0	0
Euphorbiaceae cf *Gymnanthes lucida* or *Chamaesyce thymifolia*	0	0.005	0	0	0	0.019	0
Other Euphorbiaceae	0	0	0	0	0	0.004	0
Exothea diphylla	0	0	0.005	0	0	0.004	0
Fabaceae cf *Cassia=Senna* sp.	0	0	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0.005	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	0.015	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	0	0	0	0
Other Fabaceae	0.005	0	0	0	0	0	0
Faramea sp.	0	0	0	0	0	0	0
Heliocarpus americanus	0	0	0	0	0	0.004	0
Hippocratea volubilis	0	0	0	0	0	0	0
Ilex sp.	0	0	0	0	0	0	0
Justicia campechiana	0	0	0	0	0	0	0
Juncus marginatus	0	0.005	0	0	0.005	0	0
Laguncularia racemosa	0	0	0	0	0.005	0.007	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	0.005	0	0
Licania sp.	0	0	0	0	0	0	0
cf *Lilium* sp.	0	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0	0
Loranthaceae	0	0	0	0	0	0	0
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0.015	0
Malvaceae	0	0	0	0	0	0	0
Mangifera indica	0	0	0	0	0	0	0
cf *Markea* sp.	0	0	0	0	0	0	0
Meliaceae	0	0	0	0	0.01	0	0
Metopium brownei	0	0	0	0	0	0	0.005
Mimosa sp.	0	0	0	0	0	0	0
Moraceae cf *Brosimum* sp.	0.104	0.064	0.185	0.129	0.078	0	0.019
Moraceae cf diporate *Ficus* sp.	0	0	0	0	0	0	0
Moraceae, other diporate	0	0.005	0	0	0	0.004	0
Moraceae, triporate	0	0	0	0.005	0.01	0	0
Myrica cerifera	0.024	0.015	0.045	0.137	0.073	0.089	0.149
Myristicaceae	0	0	0	0	0	0	0
Myrtaceae, syncolpate	0.009	0.005	0.005	0.01	0.02	0	0
Myrtaceae, tricolporate	0	0.01	0	0	0	0	0
Nymphaceae	0	0	0	0	0	0	0
cf Orchidaceae	0	0	0	0	0	0	0
Ostrya/Carpinus	0	0	0	0	0	0	0
Pachira aquatica	0	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0	0

Sample Number (Laboratory Number)	**353-354 (8)**	**350-351 (9)**	**347-348 (10)**	**343-344 (11)**	**339-340 (12)**	**335-336 (13)**	**334-335 (14)**
Taxon							
Physalis sp.	0	0	0	0	0.005	0	0
Picramnia antidesma	0	0	0	0	0	0.004	0
Pinus sp. whole	0.104	0.049	0.025	0.04	0.034	0.23	0.077
Pinus sp. bladder	0.104	0.236	0.065	0.109	0.063	0.048	0.063
Pinus sp. body and one bladder	0.071	0.054	0.02	0.05	0.049	0.033	0.067
Pinus sp. body	0.057	0.059	0.01	0.03	0.029	0.011	0.014
Piper sp.	0	0	0	0	0	0	0
Poaceae<50 microns	0.033	0.02	0.01	0.059	0.059	0.074	0.048
Poaceae, 50-69 microns	0.005	0	0	0.015	0.005	0.019	0.014
Poaceae, 70-100 microns	0	0	0.005	0	0	0.015	0
Poaceae>100 microns	0	0	0	0.005	0	0	0
Podocarpus guatemalensis	0.005	0	0.005	0	0	0	0
cf Polygonaceae	0	0	0	0	0	0	0
cf *Pouteria* sp.	0	0	0	0	0.005	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0	0
Protium sp.	0	0.005	0	0	0	0	0
cf *Psychotria* sp.	0	0	0	0	0	0.011	0
Quercus sp.	0.005	0.025	0	0.015	0	0.019	0
Rhizophora mangle	0.005	0	0	0.005	0	0	0.024
cf *Rinorea squamata*	0	0	0	0	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	0	0	0	0	0	0	0
Sapindus saponaria	0	0	0	0.005	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	0	0	0	0	0	0	0
Scrophulariaceae	0	0	0	0	0	0	0
Sebastiana sp.	0.043	0	0.03	0.025	0	0	0
Solanaceae	0	0	0	0	0	0	0
Spondias sp.	0	0.005	0	0	0	0	0.01
Spondias mombin	0	0	0	0	0	0.004	0
Spondias purpurea	0	0	0	0	0	0	0
Swartzia sp.	0	0	0	0	0	0.004	0
Swietenia macrophylla	0	0	0.025	0.025	0	0	0.005
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0.025	0	0	0.117	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0	0
Tabernaemontana sp.	0	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0	0
TCT	0	0	0	0	0.005	0	0
cf *Thinouia myriantha*	0	0.005	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0	0
Trema sp.	0.104	0.079	0.205	0.139	0.054	0.007	0.063
Trichilia hirta	0	0.005	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	0	0
Typha angustifolia	0	0.005	0.005	0	0	0	0
Typha domingensis	0.014	0.015	0	0.01	0.024	0.03	0.019
Typha latifolia	0	0	0	0	0	0	0
Ulmus sp.	0	0.005	0	0.005	0.005	0	0.005
Urticaceae	0	0	0	0	0	0	0
Utricularia sp.	0	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	0	0	0	0.005
Zanthoxylum sp.	0	0	0	0	0	0	0
Unidentified/Unknown	0.028	0.039	0.025	0.025	0.049	0.015	0.034
Additional special abundant unknown	0.047	0	0.065	0	0	0.059	0
Unidentifiable/Indeterminate	0.057	0.069	0.045	0.045	0.068	0.067	0.043
Percentage Total	0.999	1.002	1	1.008	0.998	1.001	1.003
Total Number of Grains	211	203	200	202	205	269	208
Lycopodium	115	379	218	272	1005	166	442
Charcoal	Present	Absent	Present	Absent	Absent	Present	Present
Depth in cmbs	353-354	350-351	347-348	343-344	339-340	335-336	334-335
Volume/Weight of Sample	1 cc	1 cc	1 cc	1 cc	I cc	5 gm	1 cc
Number of *Lycopodium* tablets added	2	2	2	2	2	1	2
Concentration Value	49539 grains/cc	14462 grains/cc	24770 grains/cc	20051 grains/cc	5507 grains/cc	4375 grains/gm	12705 grains/cc

Sample Number (Laboratory Number)	**330-331 (15)**	**328-329 (16)**	**325-326 (17)**	**322-323 (18)**	**319-320 (19)**	**316-317 (20)**	**313-314 (21)**
Taxon							
Acalypha sp.	0.009	0.005	0	0	0	0	0
Alchornea latifolia	0.013	0	0	0	0	0.01	0
Alnus sp.	0	0	0	0	0	0	0.005
Amaranthaceae, fenestrate	0	0	0	0	0.005	0	0
Anacardium occidentale	0	0	0	0	0	0	0
Anacardiaceae	0	0.005	0	0	0	0	0
cf *Andira inermis*	0	0	0	0	0	0	0
Apiaceae	0	0	0	0	0	0	0
Araceae or Araceae	0	0	0	0	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	0	0	0
Arecaceae, other	0	0	0	0	0	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	0.004	0	0.01	0.01	0.02	0.03	0.015
Asteraceae, Low-spine	0.022	0.01	0.112	0.246	0.15	0.213	0.104
cf *Banara guianensis*	0	0	0	0	0	0	0
Bauhinia divaricata	0	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0	0
cf Bignoniaceae	0	0	0	0.01	0.005	0	0
Borreria sp. or *Spermacoce* sp.	0.004	0.01	0	0	0.005	0	0.01
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	0	0.005
Bursera simaruba	0	0.005	0	0.005	0.005	0.005	0.005
Byrsonima sp.	0	0.015	0.005	0	0.025	0	0.025
cf Campanulaceae	0	0	0	0	0	0	0
Carya sp.	0	0	0	0	0	0	0
Cecropia sp.	0	0.01	0	0.01	0.015	0.01	0
Cedrela odorata	0	0	0	0	0	0	0.005
Celastraceae	0	0	0	0	0	0	0
Celtis sp.	0	0	0.005	0.01	0	0.01	0.005
Cheno-Ams	0.004	0.02	0	0.01	0.01	0.025	0.01
cf Chrysobalanaceae	0	0	0	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	0.004	0.01	0	0.005	0	0	0
Colubrina arborescens	0	0	0	0	0	0	0
Combretaceae/Melastomataceae	0	0.095	0.551	0.271	0.16	0.129	0.137
Commelina sp.	0	0	0	0	0	0	0
Corchorus hirsutus	0.121	0	0	0	0	0	0
Cordia sp.	0	0	0.005	0	0	0	0
Cordia alliodora	0	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0	0
Croton sp.	0	0	0	0	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	0
Curatella americana	0.004	0	0	0.005	0	0	0
Cyperaceae	0.071	0.02	0.034	0	0.04	0.119	0.188
Desmodium sp.	0	0	0	0	0	0	0
Erythroxylum sp.	0	0	0	0.005	0	0	0
Euphorbiaceae cf *Gymnanthes lucida* or *Chamaesyce thymifolia*	0	0	0	0	0	0	0
Other Euphorbiaceae	0	0	0	0	0	0	0
Exothea diphylla	0	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	0	0	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	0	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	0	0	0	0
Other Fabaceae	0	0	0	0	0	0	0
Faramea sp.	0	0	0	0	0	0	0
Heliocarpus americanus	0	0	0	0	0	0	0
Hippocratea volubilis	0	0	0	0	0	0	0
Ilex sp.	0	0	0	0	0.005	0	0
Justicia campechiana	0	0	0	0	0	0	0
Juncus marginatus	0	0	0	0	0	0	0
Laguncularia racemosa	0	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	0	0	0
Licania sp.	0	0	0	0	0	0	0
cf *Lilium* sp.	0	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0	0
Loranthaceae	0.004	0.005	0	0	0	0	0
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0
Mangifera indica	0	0	0	0	0	0	0
cf *Markea* sp.	0.018	0	0	0	0	0	0
Meliaceae	0	0	0	0	0	0	0
Metopium brownei	0	0	0	0	0	0	0
Mimosa sp.	0	0.005	0	0	0	0	0
Moraceae cf *Brosimum* sp.	0.063	0.095	0.039	0	0.11	0.054	0.045
Moraceae cf diporate *Ficus* sp.	0	0	0	0	0	0	0
Moraceae, other diporate	0	0	0	0	0	0	0
Moraceae, triporate	0.004	0.005	0	0	0	0	0.005
Myrica cerifera	0.045	0.02	0	0.005	0	0.005	0.045
Myristicaceae	0	0	0	0	0	0	0
Myrtaceae, syncolpate	0.009	0	0	0	0	0	0.005
Myrtaceae, tricolporate	0	0	0	0	0	0	0
Nymphaceae	0	0	0	0	0	0	0.005
cf Orchidaceae	0	0	0	0	0	0	0
Ostrya/Carpinus	0	0.005	0	0	0	0	0
Pachira aquatica	0	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0	0

Sample Number (Laboratory Number)	**330-331 (15)**	**328-329 (16)**	**325-326 (17)**	**322-323 (18)**	**319-320 (19)**	**316-317 (20)**	**313-314 (21)**
Taxon							
Physalis sp.	0	0	0	0	0	0	0
Picramnia antidesma	0	0	0	0	0	0	0
Pinus sp. whole	0.031	0.05	0.039	0.03	0.06	0.02	0.02
Pinus sp. bladder	0.04	0.03	0.024	0.044	0.065	0.05	0.054
Pinus sp. body and one bladder	0.009	0.005	0.005	0.02	0.02	0.015	0.02
Pinus sp. body	0.004	0.01	0.005	0.02	0.025	0.01	0.01
Piper sp.	0	0	0	0	0	0	0
Poaceae<50 microns	0.009	0.025	0.015	0.049	0.05	0.104	0.079
Poaceae, 50-69 microns	0.004	0	0	0.005	0	0.015	0.01
Poaceae, 70-100 microns	0	0.005	0	0.005	0	0	0.01
Poaceae>100 microns	0.004	0	0	0	0	0	0
Podocarpus guatemalensis	0.004	0	0	0	0	0	0
cf Polygonaceae	0	0	0	0	0	0	0.01
cf *Pouteria* sp.	0	0	0	0	0	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0	0
Protium sp.	0	0	0	0	0	0	0
cf *Psychotria* sp.	0	0	0	0	0	0	0
Quercus sp.	0.013	0.005	0	0.005	0.005	0	0.005
Rhizophora mangle	0.29	0.175	0	0	0.005	0	0.005
cf *Rinorea squamata*	0	0.005	0.02	0	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	0.004	0	0	0	0.005	0	0
Sapindus saponaria	0	0.005	0	0	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	0	0	0	0	0	0	0
Scrophulariaceae	0	0	0	0	0	0	0
Sebastiana sp.	0.013	0.005	0	0	0.005	0.01	0.01
Solanaceae	0	0	0	0	0	0	0
Spondias sp.	0.004	0	0	0	0.005	0	0
Spondias mombin	0	0	0	0	0	0	0
Spondias purpurea	0	0	0	0	0	0	0
Swartzia sp.	0	0	0	0	0	0	0
Swietenia macrophylla	0	0.07	0	0	0	0	0
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	0.005	0	0	0	0	0
Tabernaemontana sp.	0	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0	0
TCT	0	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0	0
Trema sp.	0.063	0.135	0.034	0.069	0.045	0.059	0.059
Trichilia hirta	0	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	0.009	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	0	0
Typha angustifolia	0	0	0.005	0.025	0.035	0	0
Typha domingensis	0.004	0	0.005	0.005	0.005	0.01	0.015
Typha latifolia	0	0	0	0	0.005	0	0
Ulmus sp.	0	0.005	0	0	0.005	0	0
Urticaceae	0	0	0	0	0	0	0
Utricularia sp.	0	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0.01	0	0	0	0	0
Zanthoxylum sp.	0	0	0	0	0	0	0
Unidentified/Unknown	0.027	0.04	0	0.015	0.03	0.04	0.025
Additional special abundant unknown	0	0	0	0	0	0	0
Unidentifiable/Indeterminate	0.063	0.075	0.088	0.118	0.075	0.054	0.054
Percentage Total	0.994	1	1.001	1.002	1	0.997	1.005
Total Number of Grains	224	200	205	203	200	202	202
Lycopodium	303	286	141	258	153	131	162
Charcoal	Present	Present	Present	Present	Present	Present	Present
Depth in cmbs	330-331	328-329	325-326	322-323	319-320	316-317	313-314
Volume/Weight of Sample	1 cc	1 cc	1 cc	1 cc	1 cc	1 cc	1 cc
Number of *Lycopodium* tablets added	2	2	2	2	2	2	2
Concentration Value	19960 grains/cc	18881 grains/cc	39255 grains/cc	21244 grains/cc	35294 grains/cc	41633 grains/cc	33666 grains/cc

Sample Number (Laboratory Number)	**310-311 (22)**	**307-308 (23)**	**305-306 (24)**	**301-302 (25)**	**298-299 (26)**	**295-296 (27)**	**290-291 (28)**
Taxon							
Acalypha sp.	0	0.004	0.014	0	0	0	0.01
Alchornea latifolia	0	0	0	0	0	0	0.005
Alnus sp.	0	0.004	0	0	0	0	0
Amaranthaceae, fenestrate	0	0	0	0	0	0	0
Anacardium occidentale	0	0	0	0	0	0	0.005
Anacardiaceae	0	0	0.005	0	0	0	0
cf *Andira inermis*	0	0	0	0	0	0	0
Apiaceae	0	0	0	0	0	0	0
Araceae or Araceae	0	0	0	0	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	0.005	0	0
Arecaceae, other	0	0	0	0	0	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	0.019	0.044	0.005	0.031	0.034	0.019	0
Asteraceae, Low-spine	0.141	0.098	0.038	0.045	0.054	0.105	0.01
cf *Banara guianensis*	0	0	0	0	0	0	0
Bauhinia divaricata	0	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0	0
cf Bignoniaceae	0	0.004	0	0.013	0	0	0
Borreria sp. or *Spermacoce* sp.	0.01	0.013	0.01	0	0	0.024	0.005
Borreria laevis=Spermacoce assurgens	0	0.004	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	0	0
Bursera simaruba	0.005	0	0.005	0.018	0.01	0.005	0
Byrsonima sp.	0.01	0.009	0.01	0.013	0.005	0.01	0.005
cf Campanulaceae	0	0	0	0	0	0	0
Carya sp.	0	0	0	0	0	0	0
Cecropia sp.	0.015	0.027	0.01	0.004	0.005	0	0.02
Cedrela odorata	0	0	0	0	0	0	0
Celastraceae	0	0	0	0	0	0	0
Celtis sp.	0.005	0	0.019	0.009	0.005	0.005	0.015
Cheno-Ams	0.005	0.009	0.01	0.018	0.02	0.005	0.005
cf Chrysobalanaceae	0	0	0	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	0.005	0.009	0.01	0.004	0	0.01	0.01
Colubrina arborescens	0	0	0	0	0	0	0.005
Combretaceae/Melastomataceae	0.238	0.267	0.329	0	0.261	0.129	0.098
Commelina sp.	0	0	0	0	0	0	0
Corchorus hirsutus	0	0	0	0.205	0	0	0
Cordia sp.	0	0	0	0	0	0	0.005
Cordia alliodora	0	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0	0
Croton sp.	0	0	0	0	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	0.005
Curatella americana	0	0	0	0	0	0	0
Cyperaceae	0.117	0.071	0.114	0.08	0.079	0.11	0.039
Desmodium sp.	0	0	0	0	0	0	0
Erythroxylum sp.	0	0	0	0	0	0	0
Euphorbiaceae cf *Gymnanthes lucida* or *Chamaesyce thymifolia*	0	0	0	0	0	0	0.01
Other Euphorbiaceae	0	0	0	0	0	0	0
Exothea diphylla	0	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	0	0	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0.01	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	0	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	0	0	0	0
Other Fabaceae	0	0	0	0	0	0	0
Faramea sp.	0	0	0	0	0	0	0
Heliocarpus americanus	0	0	0	0	0	0	0
Hippocratea volubilis	0	0	0	0	0	0	0
Ilex sp.	0	0	0	0	0	0	0
Justicia campechiana	0	0	0	0	0	0	0
Juncus marginatus	0	0	0	0	0	0	0
Laguncularia racemosa	0	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	0	0	0
Licania sp.	0	0	0	0	0	0	0.005
cf *Lilium* sp.	0	0	0	0	0	0	0
Liquidambar styraciflua	0.005	0	0	0	0	0	0
Loranthaceae	0	0.013	0	0.009	0.005	0	0.015
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0	0
Malvaceae	0	0	0.005	0	0	0	0
Mangifera indica	0	0	0	0	0	0	0.005
cf *Markea* sp.	0	0	0	0	0	0	0
Meliaceae	0	0	0	0	0	0	0
Metopium brownei	0	0	0.005	0	0	0	0
Mimosa sp.	0.005	0	0	0	0	0.005	0
Moraceae cf *Brosimum* sp.	0.034	0.04	0.076	0.022	0.054	0.048	0.044
Moraceae cf diporate *Ficus* sp.	0	0	0	0	0	0	0
Moraceae, other diporate	0	0	0	0	0	0	0
Moraceae, triporate	0	0.009	0.005	0.004	0	0	0
Myrica cerifera	0.019	0.036	0.057	0.063	0.025	0.024	0.123
Myristicaceae	0	0	0.01	0	0	0	0
Myrtaceae, syncolpate	0	0	0.005	0	0	0.005	0.01
Myrtaceae, tricolporate	0	0	0	0	0	0	0
Nymphaceae	0	0	0	0	0	0	0
cf Orchidaceae	0	0	0.005	0	0.015	0	0
Ostrya/Carpinus	0	0	0	0	0	0	0
Pachira aquatica	0	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0	0

Sample Number (Laboratory Number)	**310-311 (22)**	**307-308 (23)**	**305-306 (24)**	**301-302 (25)**	**298-299 (26)**	**295-296 (27)**	**290-291 (28)**
Taxon							
Physalis sp.	0	0	0	0	0	0	0
Picramnia antidesma	0	0	0	0	0	0	0
Pinus sp. whole	0.015	0.022	0.029	0.071	0.049	0.086	0.034
Pinus sp. bladder	0.068	0.036	0.038	0.067	0.054	0.057	0.039
Pinus sp. body and one bladder	0.005	0.004	0.019	0.009	0.015	0.033	0.02
Pinus sp. body	0.005	0.013	0.005	0.022	0.02	0.01	0
Piper sp.	0	0	0	0	0	0	0
Poaceae<50 microns	0.102	0.071	0.029	0.04	0.034	0.096	0.064
Poaceae, 50-69 microns	0.015	0.027	0.005	0	0.015	0.005	0.005
Poaceae, 70-100 microns	0	0	0	0	0	0	0
Poaceae>100 microns	0	0.009	0	0	0	0	0
Podocarpus guatemalensis	0	0	0	0	0	0	0
cf Polygonaceae	0	0	0	0	0	0	0
cf *Pouteria* sp.	0	0	0	0.004	0.005	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0	0
Protium sp.	0	0	0	0	0	0	0
cf *Psychotria* sp.	0	0	0	0	0	0	0
Quercus sp.	0	0.013	0	0.004	0.02	0.014	0
Rhizophora mangle	0	0	0.005	0	0	0.01	0.196
cf *Rinorea squamata*	0	0	0	0	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	0	0.009	0.005	0.018	0	0.01	0.005
Sapindus saponaria	0	0	0	0	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	0	0.004	0	0	0	0.024	0
Scrophulariaceae	0	0	0	0	0	0	0
Sebastiana sp.	0	0	0.005	0.004	0	0	0.025
Solanaceae	0	0	0	0	0	0	0.005
Spondias sp.	0.005	0	0	0	0.01	0	0
Spondias mombin	0	0	0	0	0	0	0
Spondias purpurea	0	0	0	0	0	0	0
Swartzia sp.	0	0	0	0	0	0	0
Swietenia macrophylla	0.005	0	0.01	0	0	0	0.02
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0	0.005
Tabernaemontana sp.	0	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0	0
TCT	0	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0	0
Trema sp.	0.068	0.053	0.048	0.08	0.094	0.019	0.069
Trichilia hirta	0	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0	0
Tsuga sp.	0	0.004	0	0	0	0	0
Typha angustifolia	0	0.009	0	0.045	0.01	0.005	0
Typha domingensis	0.024	0	0	0	0	0.014	0
Typha latifolia	0	0	0	0	0	0	0
Ulmus sp.	0	0	0	0	0	0	0
Urticaceae	0	0	0	0	0	0	0
Utricularia sp.	0	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	0	0	0	0
Zanthoxylum sp.	0	0	0	0	0	0.005	0
Unidentified/Unknown	0.015	0	0	0.027	0.034	0.01	0
Additional special abundant unknown	0	0	0	0	0	0	0.034
Unidentifiable/Indeterminate	0.044	0.062	0.052	0.067	0.064	0.1	0.029
Percentage Total	1.004	0.997	1.007	0.996	1.001	1.002	1.004
Total Number of Grains	206	225	210	224	203	209	204
Lycopodium	141	246	252	182	515	1446	230
Charcoal	Present	Present	Present	Present	Present	Present	Present
Depth in cmbs	310-311	307-308	305-306	301-302	298-299	295-296	290-291
Volume/Weight of Sample	1 cc	1 cc	1 cc	1 cc	1 cc	1 cc	1 cc
Number of *Lycopodium* tablets added	2	2	2	2	2	2	2
Concentration Value	39446 grains/cc	24695 grains/cc	22500 grains/cc	33231 grains/cc	10643 grains/cc	3902 grains/cc	24065 grains/cc

Sample Number (Laboratory Number)	**287-288 (29)**	**283-284 (30)**	**281-282 (31)**	**277-278 (32)**	**273-274 (33)**	**271-272 (34)**	**267-268 (35)**
Taxon							
Acalypha sp.	0.005	0.03	0.004	0	0.014	0.005	0
Alchornea latifolia	0.005	0.005	0.004	0	0.005	0	0
Alnus sp.	0	0	0	0	0	0	0
Amaranthaceae, fenestrate	0	0	0	0.005	0.005	0	0
Anacardium occidentale	0	0	0	0	0	0	0
Anacardiaceae	0	0	0	0	0	0	0
cf *Andira inermis*	0	0	0.009	0	0	0	0
Apiaceae	0	0	0	0	0	0	0
Araceae or Araceae	0	0	0	0	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	0	0	0
Arecaceae, other	0	0	0	0	0	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	0	0.03	0.009	0	0.005	0	0.025
Asteraceae, Low-spine	0.005	0.015	0.009	0.015	0.023	0.195	0.163
cf *Banara guianensis*	0	0	0	0	0	0	0
Bauhinia divaricata	0	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0	0
cf Bignoniaceae	0	0	0	0	0	0	0
Borreria sp. or *Spermacoce* sp.	0	0	0	0.01	0	0.005	0
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	0	0
Bursera simaruba	0.014	0.005	0.004	0.01	0	0	0
Byrsonima sp.	0.014	0.005	0.004	0	0.014	0.02	0.025
cf Campanulaceae	0	0	0	0	0	0	0
Carya sp.	0	0	0	0	0	0	0
Cecropia sp.	0.009	0.03	0.004	0.005	0.019	0.01	0
Cedrela odorata	0.005	0	0	0	0	0	0
Celastraceae	0	0	0	0	0	0.005	0
Celtis sp.	0	0.015	0.004	0.01	0	0	0.015
Cheno-Ams	0.005	0.02	0.013	0	0.005	0.015	0.02
cf Chrysobalanaceae	0	0	0	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	0	0.005	0.017	0.005	0	0.005	0.01
Colubrina arborescens	0	0	0	0	0	0	0
Combretaceae/Melastomataceae	0.037	0.173	0.1	0.137	0.14	0.515	0.35
Commelina sp.	0	0	0	0	0	0	0
Corchorus hirsutus	0	0	0	0	0	0.005	0
Cordia sp.	0	0.005	0.004	0	0	0	0
Cordia alliodora	0	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0	0
Croton sp.	0	0	0	0	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	0
Curatella americana	0	0	0	0	0	0	0
Cyperaceae	0.005	0.079	0.31	0.366	0.322	0.005	0.113
Desmodium sp.	0	0.025	0	0	0	0	0.015
Erythroxylum sp.	0	0	0	0	0	0	0
Euphorbiaceae cf *Gymnanthes lucida* or *Chamaesyce thymifolia*	0	0	0	0	0	0	0
Other Euphorbiaceae	0	0	0	0	0	0	0
Exothea diphylla	0	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	0	0.005	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	0	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	0	0	0	0
Other Fabaceae	0	0.005	0	0	0	0	0
Faramea sp.	0	0	0	0	0	0	0
Heliocarpus americanus	0	0	0	0	0	0	0
Hippocratea volubilis	0	0	0	0	0	0	0
Ilex sp.	0	0.005	0	0	0	0	0
Justicia campechiana	0	0	0	0	0	0	0
Juncus marginatus	0	0	0	0	0.014	0	0.01
Laguncularia racemosa	0	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	0	0	0
Licania sp.	0.009	0	0	0	0	0	0
cf *Lilium* sp.	0.005	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0	0
Loranthaceae	0.005	0.005	0	0	0	0	0
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0
Mangifera indica	0	0	0	0	0	0	0
cf *Markea* sp.	0	0	0	0	0	0	0
Meliaceae	0	0	0.004	0	0	0	0
Metopium brownei	0.005	0	0	0.005	0.005	0	0
Mimosa sp.	0	0.01	0.004	0	0	0	0
Moraceae cf *Brosimum* sp.	0.028	0.089	0.039	0.079	0.07	0	0.005
Moraceae cf diporate *Ficus* sp.	0	0	0	0	0.005	0	0
Moraceae, other diporate	0	0	0.013	0	0	0	0
Moraceae, triporate	0	0	0	0	0	0	0
Myrica cerifera	0.009	0.04	0.004	0	0.014	0	0
Myristicaceae	0	0	0	0	0	0	0
Myrtaceae, syncolpate	0.005	0	0	0	0	0	0
Myrtaceae, tricolporate	0	0	0	0	0	0	0
Nymphaceae	0	0	0	0	0	0	0
cf Orchidaceae	0	0	0	0	0	0	0
Ostrya/Carpinus	0	0	0	0	0	0	0
Pachira aquatica	0	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0	0

Sample Number (Laboratory Number)	**287-288 (29)**	**283-284 (30)**	**281-282 (31)**	**277-278 (32)**	**273-274 (33)**	**271-272 (34)**	**267-268 (35)**
Taxon							
Physalis sp.	0	0	0	0	0	0	0
Picramnia antidesma	0	0	0	0	0	0	0
Pinus sp. whole	0.047	0.015	0.096	0.094	0.056	0.005	0.005
Pinus sp. bladder	0.023	0.035	0.066	0.045	0.033	0.02	0.03
Pinus sp. body and one bladder	0	0.01	0.031	0.015	0.033	0.02	0.01
Pinus sp. body	0.005	0.01	0.009	0.02	0.019	0	0
Piper sp.	0	0	0	0	0	0.005	0
Poaceae<50 microns	0.009	0.005	0.079	0.054	0.033	0.035	0.025
Poaceae, 50-69 microns	0	0.015	0.004	0.025	0.005	0	0.005
Poaceae, 70-100 microns	0	0	0	0.005	0.005	0	0
Poaceae>100 microns	0	0	0	0	0	0	0
Podocarpus guatemalensis	0	0.005	0	0.005	0	0	0
cf Polygonaceae	0	0	0	0	0	0	0
cf *Pouteria* sp.	0	0	0	0	0	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0	0
Protium sp.	0	0	0	0	0.005	0	0
cf *Psychotria* sp.	0	0	0	0	0	0	0
Quercus sp.	0.009	0.01	0	0.005	0.005	0	0
Rhizophora mangle	0.575	0.069	0	0.025	0.009	0	0.005
cf *Rinorea squamata*	0	0	0	0	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	0.005	0	0	0	0	0	0
Sapindus saponaria	0	0	0	0	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	0	0	0	0	0	0	0.005
Scrophulariaceae	0	0	0	0	0	0	0
Sebastiana sp.	0.019	0.04	0.022	0.015	0.005	0	0.005
Solanaceae	0	0	0	0	0	0	0
Spondias sp.	0	0	0	0	0	0	0.005
Spondias mombin	0	0	0	0	0	0	0
Spondias purpurea	0	0	0	0	0	0	0
Swartzia sp.	0	0	0	0	0	0	0
Swietenia macrophylla	0.014	0.03	0	0.005	0	0	0
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0	0
Tabernaemontana sp.	0	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0	0
TCT	0	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0	0
Trema sp.	0.061	0.094	0.057	0.015	0.084	0.05	0.034
Trichilia hirta	0	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	0	0
Typha angustifolia	0	0	0	0	0	0.035	0.03
Typha domingensis	0	0.005	0.009	0.005	0	0.005	0
Typha latifolia	0	0	0	0	0	0	0
Ulmus sp.	0	0	0	0	0.005	0	0
Urticaceae	0	0	0	0	0.005	0	0
Utricularia sp.	0	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	0	0	0	0
Zanthoxylum sp.	0.005	0.005	0	0	0	0	0
Unidentified/Unknown	0.005	0.015	0	0.01	0	0.005	0
Additional special abundant unknown	0	0	0	0	0	0	0.025
Unidentifiable/Indeterminate	0.056	0.04	0.052	0.015	0.042	0.035	0.069
Percentage Total	1.003	1.004	0.984	1.005	1.004	1	1.004
Total Number of Grains	214	202	229	202	214	200	203
Lycopodium	177	229	718	360	164	161	189
Charcoal	Present	Present	Present	Present	Present	Present	Present
Depth in cmbs	287-288	283-284	281-282	277-278	273-274	271-272	267-268
Volume/Weight of Sample	1 cc	1 cc	1 cc	1 cc	1 cc	1 cc	1 cc
Number of *Lycopodium* tablets added	2	2	2	2	2	2	2
Concentration Value	32644 grains/cc	23816 grains/cc	8611 grains/cc	15150 grains/cc	35396 grains/cc	33540 grains/cc	29000 grains/cc

Sample Number (Laboratory Number)	**263-264 (36)**	**260-261 (37)**	**257-258 (38)**	**253-254 (39)**	**249-250 (40)**	**244-245 (41)**	**242-243 (42)**
Taxon							
Acalypha sp.	0.005	0	0.005	0.005	0	0	0
Alchornea latifolia	0	0	0.005	0	0	0	0
Alnus sp.	0	0	0	0	0	0.004	0
Amaranthaceae, fenestrate	0	0	0	0	0	0	0
Anacardium occidentale	0	0	0	0	0	0	0
Anacardiaceae	0	0	0	0	0	0	0
cf *Andira inermis*	0	0	0	0	0	0	0
Apiaceae	0	0	0	0	0	0	0
Araceae or Araceae	0	0	0	0	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	0	0	0
Arecaceae, other	0	0	0	0	0	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	0.054	0	0.034	0.08	0.137	0.094	0.078
Asteraceae, Low-spine	0.233	0.037	0.183	0.095	0.068	0.098	0.029
cf *Banara guianensis*	0	0	0	0	0	0	0
Bauhinia divaricata	0	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0	0
cf Bignoniaceae	0	0	0.014	0	0	0	0
Borreria sp. or *Spermacoce* sp.	0.025	0	0.005	0.015	0.01	0.004	0
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	0	0
Bursera simaruba	0	0	0.005	0	0.01	0.009	0
Byrsonima sp.	0.005	0	0.038	0.02	0.029	0.013	0.054
cf Campanulaceae	0	0	0	0	0	0	0
Carya sp.	0	0	0	0	0	0	0
Cecropia sp.	0.01	0	0.014	0.115	0.02	0	0
Cedrela odorata	0	0	0	0	0	0	0.01
Celastraceae	0	0	0	0	0	0	0
Celtis sp.	0.01	0	0.01	0	0.01	0.004	0.005
Cheno-Ams	0.005	0	0.005	0.015	0.02	0	0.01
cf Chrysobalanaceae	0	0	0	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	0	0	0.014	0	0.005	0	0.02
Colubrina arborescens	0	0	0	0	0	0	0
Combretaceae/Melastomataceae	0.137	0.037	0.24	0.165	0.102	0.204	0.216
Commelina sp.	0	0	0	0	0	0	0
Corchorus hirsutus	0	0	0	0	0	0	0
Cordia sp.	0	0	0.005	0	0	0.004	0
Cordia alliodora	0	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0	0
Croton sp.	0	0	0	0	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	0
Curatella americana	0	0	0	0	0	0	0
Cyperaceae	0.04	0.037	0.067	0.08	0.127	0.081	0.078
Desmodium sp.	0	0	0	0	0	0.009	0.005
Erythroxylum sp.	0	0	0	0	0	0	0
Euphorbiaceae cf *Gymnanthes lucida* or *Chamaesyce thymifolia*	0	0	0	0	0	0	0
Other Euphorbiaceae	0	0	0	0	0.044	0	0
Exothea diphylla	0	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	0	0	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	0	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	0	0	0	0
Other Fabaceae	0	0	0	0	0	0	0
Faramea sp.	0	0	0	0	0	0	0
Heliocarpus americanus	0	0	0	0	0	0	0
Hippocratea volubilis	0	0	0	0	0	0	0
Ilex sp.	0	0	0	0	0	0	0
Justicia campechiana	0	0	0	0	0	0	0
Juncus marginatus	0	0	0.005	0	0	0	0
Laguncularia racemosa	0	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	0	0	0
Licania sp.	0	0	0	0	0	0	0
cf *Lilium* sp.	0	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0	0
Loranthaceae	0	0	0	0	0.02	0.009	0
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0
Mangifera indica	0	0	0	0	0	0.004	0
cf *Markea* sp.	0	0	0	0	0	0	0
Meliaceae	0	0	0	0	0	0	0
Metopium brownei	0	0	0	0	0.005	0.004	0
Mimosa sp.	0	0	0	0	0	0	0
Moraceae cf *Brosimum* sp.	0.025	0	0.063	0.065	0.034	0.034	0.064
Moraceae cf diporate *Ficus* sp.	0	0.037	0	0	0	0	0
Moraceae, other diporate	0	0	0	0	0	0	0
Moraceae, triporate	0	0	0	0	0	0	0
Myrica cerifera	0	0	0	0	0.005	0.021	0.054
Myristicaceae	0	0	0	0	0	0	0
Myrtaceae, syncolpate	0	0	0.005	0	0	0	0
Myrtaceae, tricolporate	0	0	0	0	0	0	0
Nymphaceae	0	0.037	0	0	0.005	0	0
cf Orchidaceae	0	0	0	0	0	0	0
Ostrya/Carpinus	0	0	0	0	0	0	0
Pachira aquatica	0	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0	0

Sample Number (Laboratory Number)	**263-264 (36)**	**260-261 (37)**	**257-258 (38)**	**253-254 (39)**	**249-250 (40)**	**244-245 (41)**	**242-243 (42)**
Taxon							
Physalis sp.	0	0	0	0	0	0	0
Picramnia antidesma	0	0.074	0	0	0	0	0
Pinus sp. whole	0.04	0.074	0.005	0.02	0.034	0.034	0.059
Pinus sp. bladder	0.079	0.074	0.034	0.045	0.044	0.026	0.025
Pinus sp. body and one bladder	0	0.037	0.005	0.005	0.02	0.013	0.044
Pinus sp. body	0.005	0	0	0	0.005	0	0
Piper sp.	0	0	0	0	0	0	0
Poaceae<50 microns	0.059	0.148	0.053	0.06	0.063	0.115	0.029
Poaceae, 50-69 microns	0.005	0.074	0.005	0.015	0.02	0.038	0.015
Poaceae, 70-100 microns	0	0	0	0	0	0.004	0
Poaceae>100 microns	0	0	0	0	0	0	0
Podocarpus guatemalensis	0	0	0	0	0	0	0
cf Polygonaceae	0	0	0	0	0	0	0
cf *Pouteria* sp.	0	0	0	0	0	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0	0
Protium sp.	0	0	0	0	0	0	0
cf *Psychotria* sp.	0	0	0	0	0	0	0
Quercus sp.	0	0.037	0.01	0.005	0.005	0	0.01
Rhizophora mangle	0	0	0.01	0.01	0.005	0	0.005
cf *Rinorea squamata*	0	0	0	0	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	0	0	0	0	0	0	0
Sapindus saponaria	0	0	0	0	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	0	0	0	0	0	0	0
Scrophulariaceae	0	0	0	0	0	0	0
Sebastiana sp.	0.01	0	0	0	0	0	0.01
Solanaceae	0	0	0	0	0	0	0
Spondias sp.	0	0	0	0	0	0	0
Spondias mombin	0	0	0	0	0	0	0
Spondias purpurea	0	0	0	0	0	0	0
Swartzia sp.	0	0	0	0	0	0	0
Swietenia macrophylla	0	0	0	0	0	0	0
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0	0
Tabernaemontana sp.	0	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0	0
TCT	0	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0	0
Trema sp.	0.089	0	0.058	0.075	0.097	0.077	0.113
Trichilia hirta	0	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	0	0
Typha angustifolia	0.025	0	0.014	0.01	0	0	0
Typha domingensis	0.01	0	0.005	0.02	0.029	0.06	0.025
Typha latifolia	0	0	0	0	0	0	0
Ulmus sp.	0	0	0	0	0	0	0
Urticaceae	0	0	0	0	0	0	0
Utricularia sp.	0	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	0	0	0	0
Zanthoxylum sp.	0.005	0	0	0	0	0.004	0
Unidentified/Unknown	0.005	0.074	0.01	0.025	0	0.009	0.01
Additional special abundant unknown	0	0	0	0	0	0	0
Unidentifiable/Indeterminate	0.124	0.222	0.077	0.055	0.029	0.026	0.034
Percentage Total	1.005	0.999	1.003	1	1.002	1.002	1.002
Total Number of Grains	202	27	208	200	205	235	204
Lycopodium	112	223	366	133	199	197	578
Charcoal	Present	Present	Present	Present	Present	Present	Present
Depth in cmbs	263-264	260-261	257-258	253-254	249-250	244-245	242-243
Volume/Weight of Sample	1 cc	6 gm	1 cc	1 cc	1 cc	1 cc	1 cc
Number of *Lycopodium* tablets added	2	1	2	2	2	2	2
Concentration Value	48696 grains/cc	272 grains/gm	15344 grains/cc	40601 grains/cc	27814 grains/cc	32208 grains/cc	9529 grains/cc

Sample Number (Laboratory Number)	**239-340 (43)**	**236-237 (44)**	**233-234 (45)**	**228-229 (46)**	**224-225 (47)**	**221-222 (48)**	**219-220 (49)**
Taxon							
Acalypha sp.	0	0	0.009	0.004	0	0	0
Alchornea latifolia	0	0	0	0	0	0	0
Alnus sp.	0.005	0	0	0	0	0	0
Amaranthaceae, fenestrate	0	0	0.005	0	0	0	0
Anacardium occidentale	0	0	0	0	0	0	0
Anacardiaceae	0	0	0	0	0	0	0
cf *Andira inermis*	0	0	0	0	0	0	0
Apiaceae	0.005	0	0	0	0	0	0
Araceae or Araceae	0	0	0	0.004	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	0	0	0
Arecaceae, other	0.01	0	0	0	0	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	0.029	0.028	0.126	0.029	0	0	0
Asteraceae, Low-spine	0.033	0.024	0.126	0.272	0	0	0.175
cf *Banara guianensis*	0	0	0	0.004	0	0	0
Bauhinia divaricata	0	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0	0
cf Bignoniaceae	0	0	0	0.007	0	0	0
Borreria sp. or *Spermacoce* sp.	0.019	0	0.009	0.062	0	0	0.025
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	0	0
Bursera simaruba	0.019	0.005	0	0.033	0	0	0
Byrsonima sp.	0.029	0.014	0.009	0.004	0	0	0
cf Campanulaceae	0	0	0	0	0	0	0
Carya sp.	0	0	0	0	0	0	0
Cecropia sp.	0	0.009	0	0	0	0	0
Cedrela odorata	0	0	0	0	0	0	0
Celastraceae	0	0	0	0	0	0	0
Celtis sp.	0.005	0.005	0	0	0	0	0
Cheno-Ams	0.024	0.005	0.009	0	0	0	0
cf Chrysobalanaceae	0	0	0	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	0.033	0.024	0.047	0	0	0	0.025
Colubrina arborescens	0	0	0	0	0	0	0
Combretaceae/Melastomataceae	0.214	0.288	0.224	0.091	0	0	0.15
Commelina sp.	0	0	0	0	0	0	0
Corchorus hirsutus	0	0	0	0	0	0	0
Cordia sp.	0	0.005	0	0	0	0	0
Cordia alliodora	0	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0	0
Croton sp.	0	0	0	0	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	0
Curatella americana	0	0	0	0	0	0	0
Cyperaceae	0.067	0.052	0.023	0.062	0	0	0.025
Desmodium sp.	0	0	0	0	0	0	0
Erythroxylum sp.	0	0	0	0	0	0	0
Euphorbiaceae cf *Gymnanthes lucida* or *Chamaesyce thymifolia*	0	0	0	0	0	0	0
Other Euphorbiaceae	0	0	0	0	0	0	0
Exothea diphylla	0	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	0	0	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	0	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	0.075
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	0	0	0	0
Other Fabaceae	0	0	0	0	0	0	0
Faramea sp.	0	0	0	0	0	0	0
Heliocarpus americanus	0	0	0	0	0	0	0
Hippocratea volubilis	0.005	0	0	0	0	0	0
Ilex sp.	0	0	0	0.004	0	0	0
Justicia campechiana	0	0	0	0	0	0	0
Juncus marginatus	0	0	0	0	0	0	0
Laguncularia racemosa	0	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	0	0	0
Licania sp.	0	0	0	0	0	0	0
cf *Lilium* sp.	0	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0	0
Loranthaceae	0.005	0.009	0.009	0	0	0	0
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0
Mangifera indica	0	0	0	0	0	0	0
cf *Markea* sp.	0	0	0	0	0	0	0
Meliaceae	0	0	0	0	0	0	0
Metopium brownei	0.014	0.009	0	0	0	0	0
Mimosa sp.	0	0	0	0	0	0	0
Moraceae cf *Brosimum* sp.	0.11	0.09	0.014	0.007	0	0	0
Moraceae cf diporate *Ficus* sp.	0	0	0	0	0	0	0
Moraceae, other diporate	0	0	0	0	0	0	0
Moraceae, triporate	0	0	0	0	0	0	0
Myrica cerifera	0.052	0.042	0.019	0.011	0	0	0
Myristicaceae	0	0	0	0	0	0	0
Myrtaceae, syncolpate	0	0	0	0.004	0	0	0.075
Myrtaceae, tricolporate	0	0	0	0	0	0	0
Nymphaceae	0	0	0	0.004	0	0	0
cf Orchidaceae	0	0	0.019	0	0	0	0
Ostrya/Carpinus	0	0	0	0	0	0	0
Pachira aquatica	0	0.009	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0	0

Sample Number (Laboratory Number)	**239-340 (43)**	**236-237 (44)**	**233-234 (45)**	**228-229 (46)**	**224-225 (47)**	**221-222 (48)**	**219-220 (49)**
Taxon							
Physalis sp.	0	0	0	0	0	0	0
Picramnia antidesma	0	0	0	0.007	0	0	0
Pinus sp. whole	0.067	0.061	0.084	0.004	0	0	0
Pinus sp. bladder	0.038	0.024	0.042	0.051	0	0	0
Pinus sp. body and one bladder	0.038	0.009	0.014	0.007	0	0	0
Pinus sp. body	0.005	0	0	0.025	0	0	0
Piper sp.	0	0	0	0	0	0	0
Poaceae<50 microns	0.033	0.08	0.079	0.163	0	0	0.075
Poaceae, 50-69 microns	0.024	0.005	0.005	0.004	0	0	0
Poaceae, 70-100 microns	0	0	0.005	0	0	0	0
Poaceae>100 microns	0	0	0	0	0	0	0
Podocarpus guatemalensis	0	0	0	0	0	0	0
cf Polygonaceae	0	0	0	0	0	0	0
cf *Pouteria* sp.	0	0	0	0	0	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0	0
Protium sp.	0	0	0	0	0	0	0
cf *Psychotria* sp.	0	0	0	0.011	0	0	0
Quercus sp.	0	0	0	0	0	0	0.05
Rhizophora mangle	0	0	0.005	0	0	0	0
cf *Rinorea squamata*	0	0	0	0.007	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	0	0	0	0	0	0	0
Sapindus saponaria	0	0	0	0	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	0.025
Other Sapotaceae (not *Pouteria* sp.)	0	0	0.005	0	0	0	0.05
Scrophulariaceae	0	0	0	0	0	0	0
Sebastiana sp.	0.01	0.005	0.009	0	0	0	0
Solanaceae	0.01	0	0	0	0	0	0
Spondias sp.	0	0.005	0	0	0	0	0
Spondias mombin	0	0	0	0	0	0	0
Spondias purpurea	0	0	0	0	0	0	0.025
Swartzia sp.	0	0	0	0	0	0	0
Swietenia macrophylla	0	0	0	0	0	0	0
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0	0
Tabernaemontana sp.	0.005	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0	0
TCT	0	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0	0
Tiliaceae	0	0	0.014	0	0	0	0
Trema sp.	0.048	0.104	0.037	0.007	0	0	0
Trichilia hirta	0	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	0	0
Typha angustifolia	0	0	0	0	0	0	0
Typha domingensis	0.01	0.005	0.005	0.025	0	0	0
Typha latifolia	0	0	0	0	0	0	0
Ulmus sp.	0	0	0	0	0	0	0.025
Urticaceae	0	0	0	0	0	0	0
Utricularia sp.	0	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	0.004	0	0	0
Zanthoxylum sp.	0	0	0	0	0	0	0
Unidentified/Unknown	0.005	0.019	0	0.033	0	0	0
Additional special abundant unknown	0	0	0	0	0	0	0
Unidentifiable/Indeterminate	0.033	0.061	0.047	0.054	0	0	0.2
Percentage Total	1.004	0.996	0.999	1.004			1
Total Number of Grains	210	212	214	276	0	1	40
Lycopodium	230	354	395	300	0	79	38
Charcoal	Present	Present	Present	Present	Present	Present	Present
Depth in cmbs	239-240	236-237	233-234	228-229	224-225	221-222	219-220
Volume/Weight of Sample	1 cc	1 cc	1 cc	14 gm	16 gm	1 cc	15 gm
Number of *Lycopodium* tablets added	2	2	2	1	1	2	1
Concentration Value	24652 grains/cc	16093 grains/cc	14627 grains/cc	1174 grains/gm	N/A	N/A	947 grains/gm

Sample Number (Laboratory Number)	214-215 (50)	210-211 (51)	206-207 (52)	202-203 (53)	199-200 (54)	195-196 (55)	191-192 (56)
Taxon							
Acalypha sp.	0	0	0	0	0	0	0
Alchornea latifolia	0	0	0	0	0	0	0
Alnus sp.	0	0	0.007	0	0	0	0
Amaranthaceae, fenestrate	0	0	0	0	0	0	0.005
Anacardium occidentale	0	0	0	0	0	0	0
Anacardiaceae	0.024	0	0	0	0	0	0
cf *Andira inermis*	0	0	0	0	0	0	0
Apiaceae	0	0	0	0	0	0	0.009
Araceae or Araceae	0	0	0	0	0	0	0
Arecaceae, *Bactris*-type	0	0	0	0	0	0	0
Arecaceae, other	0	0	0	0	0	0	0
Aristolochiaceae	0	0	0	0	0	0	0
Asteraceae, High-spine	0.024	0	0.014	0	0.033	0.08	0.041
Asteraceae, Low-spine	0.146	0.135	0.149	0.1	0.081	0.075	0.05
cf *Banara guianensis*	0	0	0	0	0	0	0
Bauhinia divaricata	0	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0	0
cf Bignoniaceae	0	0	0	0	0	0	0
Borreria sp. or *Spermacoce* sp.	0.024	0.014	0.007	0.02	0.014	0.075	0.032
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	0	0.005
Bursera simaruba	0	0	0.007	0	0.029	0	0
Byrsonima sp.	0	0	0	0	0	0	0
cf Campanulaceae	0	0.014	0	0	0	0	0
Carya sp.	0	0	0	0	0	0	0
Cecropia sp.	0	0	0	0	0	0	0
Cedrela odorata	0	0	0	0	0	0	0
Celastraceae	0	0	0	0	0	0	0
Celtis sp.	0	0	0	0	0	0	0
Cheno-Ams	0	0	0.007	0	0	0.01	0
cf Chrysobalanaceae	0	0	0	0	0	0	0
Cissus sp.	0	0	0	0	0	0	0
Coccoloba sp.	0	0	0	0	0	0.01	0.086
Colubrina arborescens	0	0	0	0	0	0	0
Combretaceae/Melastomataceae	0.098	0.054	0.035	0	0.105	0.149	0.462
Commelina sp.	0	0	0	0	0	0	0
Corchorus hirsutus	0	0	0	0	0	0	0
Cordia sp.	0	0	0	0	0	0	0
Cordia alliodora	0	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0.01	0	0
Croton sp.	0	0	0	0	0	0	0
cf Cucurbitaceae	0	0	0	0	0	0	0
Curatella americana	0	0	0	0	0	0	0
Cyperaceae	0	0.041	0.035	0.16	0.071	0.03	0
Desmodium sp.	0	0	0	0	0	0	0
Erythroxylum sp.	0	0	0	0	0	0	0
Euphorbiaceae cf *Gymnanthes lucida* or *Chamaesyce thymifolia*	0	0	0	0	0	0	0
Other Euphorbiaceae	0	0	0	0	0	0	0
Exothea diphylla	0	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	0	0	0	0	0	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0	0	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0	0	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0.027	0	0	0	0	0
Other Fabaceae	0	0	0	0	0	0	0
Faramea sp.	0	0	0	0	0	0	0
Heliocarpus americanus	0	0	0.007	0	0	0	0
Hippocratea volubilis	0	0	0	0	0	0	0
Ilex sp.	0	0	0	0	0	0	0
Justicia campechiana	0	0	0	0	0	0	0
Juncus marginatus	0	0	0	0	0	0	0
Laguncularia racemosa	0	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0	0	0	0
Lantana sp.	0	0	0	0	0	0	0
Licania sp.	0	0	0	0	0	0	0
cf *Lilium* sp.	0	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0	0
Loranthaceae	0	0	0	0	0	0	0.014
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0
Mangifera indica	0	0	0	0	0	0	0
cf *Markea* sp.	0	0	0	0	0	0	0
Meliaceae	0	0	0	0	0.005	0	0
Metopium brownei	0	0	0	0	0	0	0.005
Mimosa sp.	0	0	0	0	0	0	0
Moraceae cf *Brosimum* sp.	0	0.014	0	0	0.005	0.03	0
Moraceae cf diporate *Ficus* sp.	0	0	0	0	0	0	0
Moraceae, other diporate	0	0	0	0	0	0	0
Moraceae, triporate	0	0	0	0	0	0	0
Myrica cerifera	0	0	0.021	0.04	0	0.01	0.005
Myristicaceae	0	0	0	0	0	0	0
Myrtaceae, syncolpate	0	0	0	0	0	0.015	0
Myrtaceae, tricolporate	0	0	0	0	0	0	0
Nymphaceae	0	0	0	0	0	0	0
cf Orchidaceae	0	0	0	0	0	0	0
Ostrya/Carpinus	0	0	0	0	0	0	0
Pachira aquatica	0	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0	0

Sample Number (Laboratory Number)	**214-215 (50)**	**210-211 (51)**	**206-207 (52)**	**202-203 (53)**	**199-200 (54)**	**195-196 (55)**	**191-192 (56)**
Taxon							
Physalis sp.	0	0	0	0	0	0	0
Picramnia antidesma	0	0	0	0	0	0	0
Pinus sp. whole	0	0.041	0.014	0.12	0.014	0.01	0
Pinus sp. bladder	0.073	0.027	0.071	0.12	0.01	0.025	0.005
Pinus sp. body and one bladder	0.024	0	0	0	0	0.005	0.009
Pinus sp. body	0.024	0	0.035	0.02	0.01	0	0
Piper sp.	0	0	0	0	0	0	0
Poaceae<50 microns	0.317	0.257	0.376	0.24	0.414	0.1	0.023
Poaceae, 50-69 microns	0	0.054	0	0.1	0	0.005	0
Poaceae, 70-100 microns	0	0	0	0	0	0	0
Poaceae>100 microns	0.024	0.014	0	0	0	0	0
Podocarpus guatemalensis	0	0	0	0	0	0	0
cf Polygonaceae	0	0	0.007	0	0.005	0	0
cf *Pouteria* sp.	0	0	0	0	0	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0	0
Protium sp.	0	0	0.007	0	0	0.01	0
cf *Psychotria* sp.	0	0	0	0	0	0	0
Quercus sp.	0	0	0.007	0	0	0.055	0
Rhizophora mangle	0	0	0	0	0	0	0
cf *Rinorea squamata*	0	0	0	0	0	0	0
cf Rubiaceae	0	0	0	0	0	0	0
Sapindaceae	0	0	0	0	0	0	0
Sapindus saponaria	0	0	0	0	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	0.024	0	0.007	0	0.033	0.015	0.072
Scrophulariaceae	0	0	0	0	0	0	0
Sebastiana sp.	0	0	0	0	0	0	0
Solanaceae	0	0	0	0	0	0	0
Spondias sp.	0	0	0	0	0	0	0.005
Spondias mombin	0	0	0	0	0	0	0
Spondias purpurea	0	0	0	0	0	0	0
Swartzia sp.	0	0	0	0	0	0	0
Swietenia macrophylla	0	0	0	0	0	0	0
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0	0
Tabernaemontana sp.	0	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0	0
TCT	0	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0	0
Trema sp.	0	0.014	0	0	0	0	0
Trichilia hirta	0	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	0	0
Typha angustifolia	0	0	0	0	0	0	0
Typha domingensis	0	0.041	0	0	0	0.06	0
Typha latifolia	0	0	0	0	0	0	0
Ulmus sp.	0	0	0	0	0	0	0
Urticaceae	0	0	0	0	0	0	0
Utricularia sp.	0	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	0	0	0	0
Zanthoxylum sp.	0	0	0	0	0	0	0.005
Unidentified/Unknown	0	0.027	0.021	0.04	0.052	0	0
Additional special abundant unknown	0	0	0	0	0	0	0
Unidentifiable/Indeterminate	0.195	0.23	0.163	0.04	0.11	0.233	0.172
Percentage Total	0.997	1.004	0.997	1	1.001	1.002	1.005
Total Number of Grains	42	74	141	50	210	201	221
Lycopodium	275	467	279	273	112	364	167
Charcoal	Absent	Present	Present	Present	Present	Present	Present
Depth in cmbs	214-215	210-211	206-207	202-203	199-200	195-196	191-192
Volume/Weight of Sample	14 gm	13 gm	16 gm	7 gm	8 gm	2 cc	1 cc
Number of *Lycopodium* tablets added	1	1	1	1	1	2	2
Concentration Value	144 grains/gm	165 grains/gm	426 grains/gm	353 grains/gm	3164 grains/gm	7455 grains/cc	35569 grains/cc

Sample Number (Laboratory Number)	**185-186 (57)**	**180-181 (58)**	**176-177 (59)**	**174-175 (60)**	**Surface 1 (61)**	**Cowfield (62)**
Taxon						0
Acalypha sp.	0	0	0	0.004	0	0
Alchornea latifolia	0	0	0	0	0	0
Alnus sp.	0	0	0	0	0.01	0
Amaranthaceae, fenestrate	0	0	0	0	0	0
Anacardium occidentale	0	0	0	0	0	0
Anacardiaceae	0	0	0	0.008	0.02	0
cf *Andira inermis*	0	0	0	0	0	0
Apiaceae	0	0	0	0	0	0
Araceae or Araceae	0	0	0	0	0	0
Arecaceae, *Bactris*-type	0.01	0.005	0.005	0.015	0.015	0
Arecaceae, other	0	0	0.005	0	0	0
Aristolochiaceae	0	0	0	0	0.005	0
Asteraceae, High-spine	0.005	0.014	0.035	0.015	0.05	0.0125
Asteraceae, Low-spine	0.015	0.005	0.01	0.019	0.025	0.183
cf *Banara guianensis*	0	0	0	0	0	0
Bauhinia divaricata	0	0	0	0	0	0
Bauhinia herrarae	0	0	0	0	0	0
cf Bignoniaceae	0	0	0	0	0	0
Borreria sp. or *Spermacoce* sp.	0	0	0	0	0.01	0
Borreria laevis=Spermacoce assurgens	0	0	0	0	0	0
Bravaisia sp.	0	0	0	0	0	0
Bursera simaruba	0.01	0.018	0.04	0.035	0.025	0
Byrsonima sp.	0.005	0.023	0.01	0.019	0	0
cf Campanulaceae	0	0	0	0	0	0
Carya sp.	0	0	0	0	0	0
Cecropia sp.	0	0	0	0	0	0
Cedrela odorata	0	0	0	0	0	0
Celastraceae	0	0	0	0	0	0
Celtis sp.	0	0.005	0.015	0.008	0.01	0.008
Cheno-Ams	0.005	0	0	0.008	0	0.025
cf Chrysobalanaceae	0	0	0	0	0	0
Cissus sp.	0	0	0.005	0	0	0
Coccoloba sp.	0.03	0.009	0.03	0.027	0.005	0
Colubrina arborescens	0	0	0	0	0	0
Combretaceae/Melastomataceae	0.6	0.744	0.05	0.081	0.155	0.004
Commelina sp.	0	0	0	0	0	0
Corchorus hirsutus	0	0	0	0	0	0
Cordia sp.	0.01	0.005	0.005	0	0	0
Cordia alliodora	0	0	0	0	0	0
cf Corylaceae or Betulaceae	0	0	0	0	0	0
Croton sp.	0	0	0	0	0	0
cf Cucurbitaceae	0	0	0	0.004	0	0
Curatella americana	0	0	0	0	0	0
Cyperaceae	0.03	0.005	0.168	0.262	0.23	0.213
Desmodium sp.	0	0.005	0.005	0.012	0	0
Erythroxylum sp.	0	0	0.01	0	0	0
Euphorbiaceae cf *Gymnanthes lucida* or *Chamaesyce thymifolia*	0	0	0	0	0	0
Other Euphorbiaceae	0	0	0	0	0	0
Exothea diphylla	0	0	0	0	0	0
Fabaceae cf *Cassia=Senna* sp.	0	0.009	0.015	0.012	0	0
Fabaceae cf *Dalbergia brownei*	0	0	0	0	0	0
Fabaceae cf *Lonchocarpus* sp.	0	0	0.03	0	0	0
Fabaceae cf *Machaerium seemanii*	0	0	0.03	0	0	0
Fabaceae cf *Melilotus* sp.	0	0	0	0	0	0
Fabaceae/Mimosoideae cf *Acacia* sp. (not *Mimosa*)	0	0	0	0.012	0.045	0.054
Other Fabaceae	0	0	0.015	0.015	0	0
Faramea sp.	0	0	0	0	0	0
Heliocarpus americanus	0	0	0	0	0	0
Hippocratea volubilis	0.005	0	0	0	0	0
Ilex sp.	0	0	0	0	0	0
Justicia campechiana	0	0	0	0	0	0
Juncus marginatus	0	0	0	0	0.005	0.004
Laguncularia racemosa	0	0	0	0	0	0
Lamiaceae cf *Hyptis* sp.	0	0	0	0.008	0	0
Lantana sp.	0	0	0	0	0	0
Licania sp.	0	0	0	0	0	0
cf *Lilium* sp.	0	0	0	0	0	0
Liquidambar styraciflua	0	0	0	0	0	0
Loranthaceae	0.005	0	0	0	0	0
Malpighiaceae cf *Heteropterys laurifolia*	0	0	0	0	0	0
Malpighiaceae, other	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0.004
Mangifera indica	0	0	0	0	0	0
cf *Markea* sp.	0	0	0	0	0	0
Meliaceae	0	0	0	0	0	0
Metopium brownei	0	0.009	0	0	0	0
Mimosa sp.	0	0	0.005	0.004	0.005	0.017
Moraceae cf *Brosimum* sp.	0.02	0.018	0.025	0.065	0.005	0.008
Moraceae cf diporate *Ficus* sp.	0	0	0	0.008	0	0
Moraceae, other diporate	0	0	0	0	0	0
Moraceae, triporate	0	0	0	0	0	0
Myrica cerifera	0	0	0.01	0.004	0.01	0
Myristicaceae	0	0	0	0	0	0
Myrtaceae, syncolpate	0.005	0.041	0.045	0.008	0.015	0
Myrtaceae, tricolporate	0	0	0	0	0	0
Nymphaceae	0	0	0	0.004	0	0
cf Orchidaceae	0	0	0	0	0	0
Ostrya/Carpinus	0	0	0	0.004	0	0
Pachira aquatica	0	0	0	0	0	0
Phyla nodiflora=Lippia nodiflora	0	0	0	0	0	0

Sample Number (Laboratory Number)	**185-186 (57)**	**180-181 (58)**	**176-177 (59)**	**174-175 (60)**	**Surface 1 (61)**	**Cowfield (62)**
Taxon						0
Physalis sp.	0	0	0	0	0.005	0
Picramnia antidesma	0	0	0	0	0	0
Pinus sp. whole	0.005	0.005	0.02	0.012	0.06	0.033
Pinus sp. bladder	0.01	0	0.02	0.015	0.01	0.017
Pinus sp. body and one bladder	0	0.005	0.005	0.015	0	0
Pinus sp. body	0	0	0.005	0.004	0.005	0.017
Piper sp.	0	0	0	0	0	0
Poaceae<50 microns	0.01	0	0.03	0.023	0.025	0.046
Poaceae, 50-69 microns	0.005	0	0	0	0.01	0
Poaceae, 70-100 microns	0	0.005	0	0.004	0	0
Poaceae>100 microns	0	0	0.005	0.008	0	0
Podocarpus guatemalensis	0	0	0	0	0	0
cf Polygonaceae	0	0	0	0	0	0
cf *Pouteria* sp.	0	0	0	0	0	0
cf *Pouteria stipitata*	0	0	0	0	0	0
Pouteria unilocularis=P. reticulata	0	0	0	0	0	0
Protium sp.	0	0.005	0.01	0.046	0.04	0
cf *Psychotria* sp.	0	0	0	0	0	0
Quercus sp.	0.02	0	0.025	0	0.04	0.004
Rhizophora mangle	0	0	0	0.004	0.01	0
cf *Rinorea squamata*	0	0	0	0	0	0
cf Rubiaceae	0.005	0	0	0	0	0
Sapindaceae	0	0	0	0	0	0
Sapindus saponaria	0	0	0	0	0	0
Sapotaceae cf *Chrysophyllum mexicanum*	0	0	0	0	0	0
Other Sapotaceae (not *Pouteria* sp.)	0.005	0	0	0	0	0
Scrophulariaceae	0	0	0	0	0	0
Sebastiana sp.	0.01	0	0	0.008	0	0
Solanaceae	0	0	0	0	0	0
Spondias sp.	0	0	0	0	0	0
Spondias mombin	0	0	0	0	0	0
Spondias purpurea	0	0	0	0	0	0
Swartzia sp.	0	0	0	0	0	0
Swietenia macrophylla	0	0	0	0	0	0
cf *Swietenia* sp. or cf *Fraxinus* sp.	0	0	0	0	0	0
cf *Symplocos martinicensis*	0	0	0	0	0	0
Tabernaemontana sp.	0	0	0	0	0	0
Talisia oliviformis	0	0	0	0	0	0
TCT	0	0	0	0	0	0
cf *Thinouia myriantha*	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0
Trema sp.	0.03	0	0.025	0.035	0.02	0
Trichilia hirta	0	0	0	0	0	0
cf *Trichospermum grewiifolium*	0	0	0	0	0	0
Tsuga sp.	0	0	0	0	0	0
Typha angustifolia	0	0	0	0	0	0
Typha domingensis	0.015	0.014	0.183	0.05	0.005	0.125
Typha latifolia	0	0	0	0	0	0.046
Ulmus sp.	0	0	0	0	0.005	0
Urticaceae	0	0	0	0	0	0.029
Utricularia sp.	0	0	0	0	0	0
cf *Vitis* sp. (*Vitis tiliifolia*)	0	0	0	0	0	0
Zanthoxylum sp.	0.01	0	0.01	0	0	0
Unidentified/Unknown	0	0	0.015	0.004	0.02	0.013
Additional special abundant unknown	0	0	0.025	0.042	0	0
Unidentifiable/Indeterminate	0.124	0.055	0.059	0.073	0.1	0.138
Percentage Total	1.004	1.004	1.005	1.004	1	1.0005
Total Number of Grains	201	219	202	260	200	240
Lycopodium	191	75	330	550	69	246
Charcoal	Absent	Not noted	Present	Present	Present	Present
Depth in cmbs	185-186	180-181	176-177	174-175	Surface	Surface
Volume/Weight of Sample	1 cc	1 cc	1 cc	1 cc	10 gm	2 cc
Number of *Lycopodium* tablets added	2	2	2	2	1	2
Concentration Value	28413 grains/cc	774000 grains/cc	22261 grains/cc	12764 grains/cc	3913 grains/gm	6585 grains/cc

VITA

Name:	Mckenzie Leigh Morse
Address:	Department of Anthropology, Texas A&M University MS 2354 College Station, TX 77843
E-mail address:	mmorse@neo.tamu.edu
Educational background:	B.A., Anthropology and Linguistics, Grinnell College, 1998 Ph.D., Anthropology, Texas A&M University, 2009