PALEOENVIRONMENTAL INVESTIGATIONS NEAR HATTIEVILLE, CENTRAL BELIZE: IMPLICATIONS FOR ANCIENT MAYA SALT PRODUCTION

By

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PALEOENVIRONMENTAL INVESTIGATIONS NEAR HATTIEVILLE, CENTRAL BELIZE: IMPLICATIONS FOR ANCIENT MAYA SALT PRODUCTION

Abstract

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Analysis of three sediment cores collected from central Belize in 2007 reveals a complex history of past environmental change, including evidence for coastal instability and subsidence. Coupled with archaeological evidence from the region, we now are beginning to see a clearer picture of past human activities in the area. Changing lagoonal salinity is indicated by changing mangrove assemblages, which offers further insight into past salt-making efforts in the region.

The three samples were taken in conjunction with major research being conducted by the XARP (Xibun Archaeological Project). The area chosen for palynological testing is close to salt-production refuse mounds (Wits Cah Ak'al) that date to the Late Classic to Terminal Classic eras. Further palynological analysis, in conjunction with radiocarbon testing, has confirmed that the Maya may have been producing salt in this area prior to the Late Classic.

Several radiocarbon dates were obtained for sediment Cores 2 and 3, dating to approximately 4435 $\pm$ 37 years B.P. and 3562 $\pm$ 36 years B.P. Pollen from plants which grow in brackish conditions (mangrove) is present around the radiocarbon date of 4435 $\pm$ 37 years B.P. for Core 2, and sometime after 3562 $\pm$ 36 years B.P. for Core 3. Analysis has concluded that

brackish conditions were present within this area well before the Preclassic. Additionally, salt production was likely practiced well before the Late/Terminal Classic, as charcoal concentration values performed for Core 3 indicate. Charcoal concentration values near the base of Core 3 suggest natural forest fire. However, later charcoal counts indicate human use of fire within this area, which otherwise appears to have not been a permanent habitation site.

This thesis argues that palynological data can indicate environmental change, as well as helping to provide indicators for discerning salt production. In cooperation with radiocarbon and charcoal data, I have suggested that the Maya may have indeed produced salt using the *sal cocida* method of salt production prior to the Late/Terminal Classic near the Wits Cah Ak'al mounds in central Belize.

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Chapter One: Introduction

This thesis investigates salt production in the Maya lowlands prior to the Maya Late Classic period (A.D. 600-800). The data used in this analysis are palynological and will contribute significantly to our current knowledge concerning salt production among the ancient Maya. Currently, it is believed that the salt production occurred at the Wits Cah Ak'al site in central Belize. Due to the onset of brackish conditions as a result of coastal subsidence, salt production would have been possible near the Wits Cah Ak'al mounds as well. In correlation with radiocarbon dates and charcoal data, this thesis indicates that the Classic Maya (A.D. 250-600) could have produced salt near the Wits Cah Ak'al site, after utilizing the nearby area for slash and burn agriculture prior to the rise in water table level.

Chapter one is a general introduction and outlines my thesis. Chapter two supplies relevant background information. Chapter three presents a scientific context for the topic of salt, its biological components, and its effect on humans, and provides past evidence for the production of salt in this region. Chapter four describes a general methodology for pollen analysis, including processing and microscope analysis. Chapter five contains the results of the palynological analysis used in this thesis. Chapter six elaborates upon the results discussed in Chapter five. Chapter seven concludes this thesis, noting significant findings and suggesting directions for future research.

Central Belize has long been an area of interest for researchers of ancient history as well as for archaeologists. Central Belize is part of the region known as the Maya Lowlands. This environment, lushly composed of tropical forests, pine ranges, and savanna, contains many

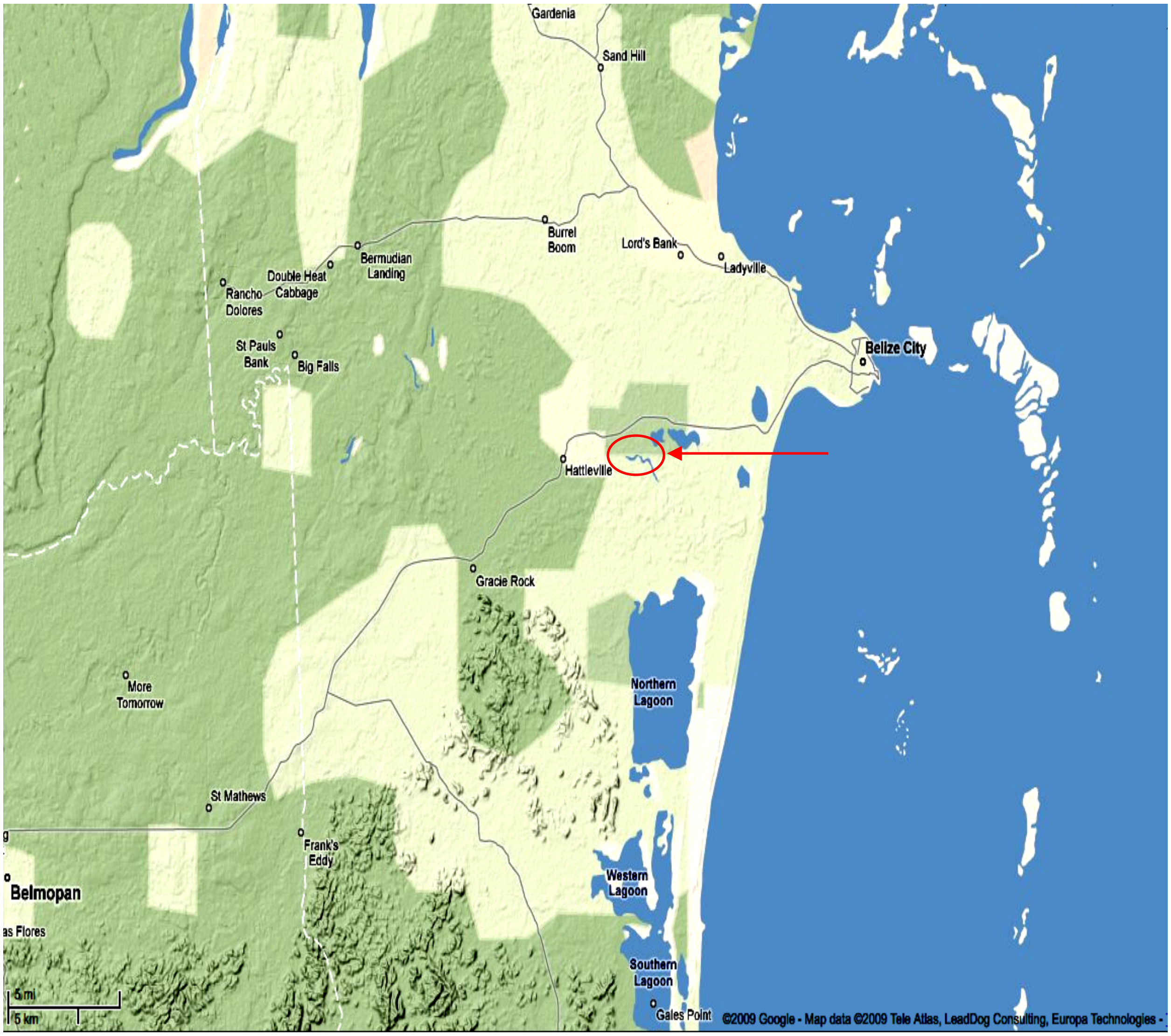

Figure 1. Overview map of Belize with approximate coring location outlined, taken from Google Maps.

archaeological sites, such as Altun Ha. Belize is a geographically diverse region; much of its diversity coming from the abundant coral reefs and sea life that line the coast (Figure 1). The majority of southern and central Belize is composed of tropical rainforests, mangrove formations, and wetlands while Northern Belize has a drier climate, forests, plains, and swamplands (Nations 2006).

The vast majority of archaeological studies of the ancient Maya in central and northern Belize has focused on large population centers, Maya trade, and interaction with other cultures. The paleoenvironment in the Maya Lowlands during the Preclassic through the Postclassic periods is not well understood. While some paleoenvironmental studies have been conducted (Jones 1994), specific analysis of pollen or other paleoenvironmental praxis for the Maya Lowlands has not been prominent among researchers.

Further analysis of the paleoenvironment of central Belize may help illustrate the daily routines of life for the ancient Maya within the Maya Lowlands (Figure 2). Of primary interest to this study is the role of trade between the coastal areas of Belize, inland central Belize, and other, more well-known cultural spheres, such as the Petén. Researchers have speculated that “peripheral” areas, such as the Lowlands, may have obtained most of their goods from "core" areas, or even from around the Gulf of Mexico (Andrews 1983; Rathje 1971). Although the argument that core areas were the main loci for cultural development is primarily a view held during earlier phases in the history of archaeology, and has since been debated by those who argue for the self-sufficiency of the lowland Maya (Bell and Eaton 1972; Dornstreich 1972; Lange 1971; Marcus 1973; McKillop 2002), the argument has not yet dissipated (Murata 2008).

Figure 2. Map of Belize with political boundaries, cultural regional labels, and approximately outlined coring locations (Taken from the University of Texas Libraries).

To better understand what interaction people of the Maya Lowlands with their environment, and what effects this interaction may have had on their economy and subsistence during the time of the ancient Maya, a paleoenvironmental study was conducted in central Belize. Archaeologically, central Belize has not been well studied. An archaeo-environmental study conducted in Central Belize would contribute to the corpus of knowledge about the Maya Lowlands. Additionally, not only will a paleoenvironmental study allow researchers to better understand the specific ecology of Central Belize, but will also indicate what natural resources Maya in this area had available for trade or other uses.

Recent research into ancient Maya salt production (Graham 1987; Graham and Pendergast 1989; MacKinnon and Kepecs 1991; McKillop 2002) has led to an increased interest in understanding how salt was produced and distributed within the Maya Lowlands and throughout the greater Maya area. A paleoenvironmental study can indicate whether the environment is saline or not, as well as the feasibility of salt production. With these objectives in mind, this research consists of a paleoenvironmental study in which pollen from three sediment cores taken near Hattieville, Belize, in February 2007, were processed and analyzed.

The cores were taken with the express purpose of performing pollen analysis, in accordance with the Xibun Archaeological Research Project (XARP), under the direction of Dr. Patricia McAnany of Boston University. The samples were collected near archaeological mounds that have a known association with Late Preclassic to Late Classic salt production (Jones and Hallock 2007). It was hoped, prior to analysis that pollen from saline-tolerant plants would be found within the cores. For example, if salt-tolerant plants, such as *Rhizophora* (red mangrove), we discovered during analysis, this would support the hypothesis that the Lowland Maya had the opportunity to pursue salt production within this area of central Belize.

Pollen from salt-tolerant plants, such as *Rhizophora* (red mangrove) were discovered during analysis and subsequently dated. From this study it is apparent that the Lowland Maya had the opportunity to pursue salt production within this area of central Belize. Additionally, analysis of charcoal concentration values helps determine what form of salt production the Maya may have utilized. The two basic methods of salt production known throughout the Maya region are *sal cocida* and *sal solar*.

Sal solar is the production of salt by evaporation, a method unlikely to leave any trace in the archaeological record. *Sal cocida* consists of cooking brine to obtain salt contained in the solution, and this method does leave traces in the archaeological record. Ceramic pieces from the broken brine pots are often taken as evidence that the *sal cocida* method was utilized. Further, the presence of charcoal in addition to ceramic "briquetage" would lend further support to the proposal that the *sal cocida* method was employed, as wood would be burned in order to boil the brine in the pots. "Briquetage," in this case, indicates the broken ceramic refuse left after brine is boiled in pots during the *sal solar* method of salt production. Charcoal as the sole evidence for salt production is not convincing, but when paired with palynological evidence, it indicates that the *sal cocida* method of salt production was likely.

By correlating palynological, radiocarbon, and charcoal evidence, this thesis presents convincing evidence that the ancient Maya were producing salt using the *sal cocida* method before the Late Classic period. By providing this information, this study contributes to our knowledge of the ancient Preclassic and Classic Maya. Specifically, this research contributes new information to the existing body of knowledge on the ancient Maya and their subsistence systems, economy, trade, and environmental features through paleoenvironmental research.

Chapter Two: Study Area and Background Information

The Maya occupied an area of land in Central America which can be divided into Highlands and Lowlands regions. The Highlands encompass both a southern and a northern region. The southern highlands "lie in an east-west band between, on the south, the belt of volcanic cones that parallels the Pacific coast and on the north, the great rift-valley system" (Sharer 1994:27). The northern highlands are "north of the continental rift marked by the Motagua and Grijalva valleys...to the west are the Chiapas highlands of Mexico and the Altos Cuchumatanes of northwestern Guatemala and eastern Chiapas, followed by the Sierra de Chuacus in central Guatemala and the Sierra de las Minas that extends eastward almost to the Caribbean" (Sharer 1994:30).

The lowlands, extending northeast from the northern highlands, are also divided into southern, central, and northern zones. The southern highlands include what is now modern Chiapas, Mexico, as well as the "northern portions of Huehuetenango, El Quiche, Alta Verapaz, and Izabal, in Guatemala…as well as the southern boundary of modern Belize and the floodplains and coastal areas of northwestern Honduras" (Sharer 1994:35).

The central lowlands are comprised of the Petén in Guatemala, the southern Yucatan, and modern-day Belize, while the northern lowlands are located in the "northern half of the Yucatan peninsula" (Sharer 1994:40). The highland regions in the Maya sphere are better known archaeologically than the lowlands. However, this dearth of knowledge is not always the case in lesser-studied areas, such as eastern and central Belize. Lack of interest in lowland sites has traditionally resulted from a bias, primarily illustrated by an emphasis on elaborate manifestations of ceremonies found on the landscape, such as large temples and ballcourts. Another bias researcher's hold is the belief that the Maya Lowlands were not as complex as other areas. Belize has been ignored to a greater degree than other areas in the lowlands in many studies, some researchers rationalizing this oversight by stating that there seems to be no prominent stela cult in the area, which would indicate less cultural complexity (Willey 1987).

Paleoenvironmental studies can correct for this bias, by studying the Maya Lowlands, specifically Belize, in greater detail, and by helping to reconstruct the complex picture of early settlement and land use in the area. Some archaeologists have mentioned that Archaic sites are difficult to find, and thus to study because the "settlement may be ephemeral," and because "macrobotanical remains are rarely preserved in humid tropical environments" (Pohl et al. 1996:356). Others believed that pollen research is unlikely to produce reliable results for a variety of reasons. Theories that dismiss the usefulness of pollen research posit various reasons for this position, including the rationale that many plants in the subtropics are pollinated by insects and so there would be less pollen; that the diversity in plants would create a pollen rain too difficult to interpret and identify; and because the history was "too stable" to make it worth the effort (Leyden 2002:87). However pollen analysis (along with phytolith and macrobotanical analysis) has disproven these excuses repeatedly.

Indeed, micro-botanical analysis seems especially well suited to answering questions about early settlements in the humid, tropical Maya Lowlands. Micro-botanical analysis has frequently been used to support or disprove hypotheses about the origin of agriculture in Mesoamerica and can again be used to address a troubling assumption present in earlier work on this geographical region. The assumption is that agriculture in Mesoamerica could not have originated in the Lowlands. Until recently, many believed that the Highlands were the birthplace of agriculture in this region, beginning around 5000 B.C. with the increasing use of horticultural techniques (Coe and Flannery 1964; MacNeish 1964). In fact, maize does not appear in the Highlands until around 3500 B.C. (Pohl et al. 1996).

The origin of agriculture now seems to have occurred in the mid-latitude habitats of the Pacific slope of southwestern Mexico (Pohl et al. 1996; Pope et al. 2001). Maize is genetically descended from teosinte in the Rio Balsas drainage of Guerro (Pohl et al. 1996), although its point of domestication has not yet been determined. The use of domesticated maize seems to have followed a trajectory of warm moist lowland climates within Mesoamerica. In Panama, maize is in use as a "seed crop" between 5000 and 4000 B.C. (Pohl et al. 1996:357). However, other neighboring regions, such as the Pacific coast of Chiapas, were slower to adopt maize (Pohl et al. 1996).

Dominant crops such as maize appear in Tabasco, Mexico, along the Grijalva River delta around 5000 B.C. (Pope et al. 2001). By 5100 B.C., forest clearance and the cultivation of maize were occurring along the Gulf Coast of Mexico. Sedentary villages which relied on the cultivation of maize, beans, and aquatic resources were prominent in Tabasco between 2250 and 1750 B.C. (Pohl et al. 1996). In the Lowlands region of Mesoamerica, massive forest disturbance occurred between 10,000 and 6000 B.C. In Northern Belize, at Cob Swamp, manioc pollen has been found which dates to 3400 B.C., while cotton and sunflower appear by 2500 B.C. (Pope et al. 2001). Maize pollen grains found at Cob Swamp have been dated to around 2400 B.C. Cobweb Swamp, also in Northern Belize, apparently had maize by 2500 B.C.

Interestingly, nearby Pulltrouser and Douglas Swamps do not appear to have been using maize until 890 B.C. and 520 B.C. (Pohl et al. 1996).

Zea pollen found prior to 2500 B.C. is of a smaller size and different morphology, and could be of a type displaced by varieties that came to dominate later. Smaller maize found at Cob Swamp dating to 2400 B.C. may indicate that the Maya in the Lowlands independently domesticated maize, as larger *Zea mays* grains are found elsewhere in Mesoamerica at this time (Pohl et al. 1996). After 2500 B.C., small *Zea* pollen disappears (Pope et al. 2001). The trend seems to be that around 2000 B.C. areas were obviously being cleared for farming. Closely following these developments, sedentary villages appear around 1000 B.C.

A Chronology of Ancient Belize

The archaeology of Belize prior to the Early Preclassic (2000-1000 B.C.) is not well known (Table 1). In fact, there is scant evidence of human occupation prior to 3400 B.C. (Lohse et al. 2006). The Terminal Pleistocene period in Central America occurred 11,000-13,000 years ago. After this era, came the chronologically defined Paleoindian or Archaic era (10,000 years ago).

Archaeological evidence supports the assertion that humans in this region survived by adopting a hunting and gathering lifestyle, mainly pursuing mega-fauna during the Archaic period (9000-4000 B.C.). They practiced subsistence ways similar to those practices found among the Native Americans in North America at this time (Lohse et al. 2006). Evidence of a hunting and gathering tradition includes fishtail points and lanceolate points. Fishtail points and

Table 1: Maya Cultural Timeline

Era/Period	Time/Chronology	Ceramic/Lithic Complex
Late Postclassic	A.D. 1200-1500	Waterbank
Early Postclassic	A.D. 900-1200	
Terminal Classic	A.D. 800-900	Samana
Late Classic	A.D. 600-800	Tepeu
Early Classic	A.D. 250-600	Tzakol
Protoclassic/Terminal Preclassic	A.D. 100-250	
Late Preclassic	400 B.C.-A.D. 100	Chicanel, Tulex, Sarstoon Lopez, Mamon, Freshwater Floral Park, Cocos
Middle Preclassic	1000-400 B.C.	
Early Preclassic	2000-1000 B.C.	Swasey, Blanden, Xe
Archaic	9000-4000 B.C.	**Lithics**: Belize, Melinda, Sandhill, Progresso, Lowe-Ha

three fluted lanceolate points have been found in Belize, although these are usually from surface finds (Lohse et al. 2006).

The chronological categorizations for the Archaic are inconsistent, as many archaeologists have used their own titles and dates when referring to this era. Further, many chronological designations overlap, adding to the disorganization. Lohse et al. (2006) have used an Early and Late Archaic classification, which overlaps with an Early and Late Preceramic classification, as well as the Early Preclassic. New pollen evidence refutes previous studies that placed the development of agriculture in Mesoamerica in the Highlands. Previous studies assumed that maize was cultivated in the Highlands by 5000 B.C. and that the lowlands did not have agriculture until much later (Coe and Flannery 1964; MacNeish 1964).

However, additional pollen studies helped determine that agriculture did not appear in the highlands until 3500 B.C. (Pohl et al. 1996). Finding Archaic and early Paleoindian sites is frequently difficult, primarily due to poor preservation, as the Lowlands are characterized by a humid climate (Pohl et al. 1996). However, despite the difficulties inherent in understanding the development of agriculture in the Lowlands, pollen analysis has shown that by 10,000 B.C., there was significant forest disturbance in Panama. However it was not until 3500 B.C. that maize is shown to have spread to the Lowlands. The Belize Archaic, according to this timescale, lasted from 8000-3400 B.C. Pollen analysis indicates that the water table rose along with the sea level in this area around 6000-4000 B.C., "creating mangrove swamps and later freshwater lagoons in depressions and floodplains" (Pohl et al. 1996).

During the Late Archaic (3400-900 B.C.), people practiced horticulture and lived in temporary settlements, such as rock shelters. They also constructed stone tools, made of materials such as chert (Lohse et al. 2006). Lowe and Sawmill points are the main material objects that help define the Late Archaic period. Sedentism, likely in the form of small-scale semi-sedentary horticulture, was occurring in the Lowlands during this time period.

Sea- level rise stabilized around 3000 B.C. and dropped by 1000 B.C. Farmers could then begin to use the organic-rich soil to grow crops. However, not all sedentary settlements adopted maize agriculture simultaneously (Pohl et al. 1996). Forest disturbance in the Lowlands of Belize occurred by 2500 B.C. (Pohl et al. 1996), and possibly as early as 3000 B.C. Studies done at Cobweb Swamp, near the lithic production site of Colha, indicate that there is "clear evidence of early human forest modification, disturbance, and domesticated plant cultivation around 2500 B.C." (Jones 1994:207). A field had been constructed and dates from between 2500-1000 B.C. Along with red and white mangrove pollen (*Rhizophora* and Combretaceae), a single manioc pollen grain was found in samples taken from this site (Jones 1994).

By 2400 B.C., maize was cultivated at Cob Swamp in Belize. The pollen found at Cob Swamp is of a different variety than modern maize, and is very similar to early maize pollen found at Colha (Pohl et al. 1996). However, the Lowe point found in Pulltrouser Swamp in association with an early maize grain indicates that the pre-Maya or Maya were still living a hunting/gathering/fishing lifestyle during this time. The point dates to 2210 B.C. (Pohl et al. 1996).

The Early Preclassic (2000-1000 B.C.) and Late Preceramic are usually described as a time of increasing social complexity and settled communities, although the increasing number of people on the landscape are not yet considered "Maya." However, forest disturbance and the introduction of maize agriculture indicate that the Yucatec Maya were beginning to move into the area, perhaps introducing maize agriculture to local communities (Pohl et al. 1996). The various cities or settlements dominant during this time do not appear to have a complex system of government which ruled through dynasties and sought prestige and the control of other city-states. There was also no writing at this time. However, maize agriculture was being practiced, a claim based upon the presence of maize pollen from the Petén which dates to this time period (2000 B.C.) (Willey 1987). Deforestation and intensive agriculture occur broadly across the Lowlands between 2000-1000 B.C. (Pohl et al. 1996). Other pollen evidence that corroborates this claim for the introduction of agriculture includes archaeological investigations done at Cuello. These studies show that the early Maya settled in the Lowlands as early as 1200 B.C. (Jones 1994).

At Cobweb Swamp, an agricultural field dates to between 1000-500 B.C. Pollen from this field indicates that the Maya were growing cotton, maize, chilies, and palms, and that massive forest clearance was underway (Jones 1994). Other evidence of early cultivation of plants comes from the Cob, Pulltrouser, and Douglas Swamps. At Pulltrouser, maize was found which has been dated to 890 B.C.; and at Douglas to 520 B.C. (Pohl et al. 1996). Water level rose again around 1300 B.C., leading to the construction of canals (Douglas swamp) and ditches (Cob Swamp) (Pohl et al. 1996).

Prior theories concerning early Lowland Maya subsistence options suggested that root foods, such as jicama and yucca, were dominant. However, pollen investigations have not borne out this theory (Bronson 1966). The rationalization for the argument that root foods were the main foodstuff utilized included that the Lowland regions were not productive enough for intensive agriculture, and so could not support a large population. As a result of this limitation, maize would have been a "luxury" item for the elite, and root crops would have been common food for the poor (Bronson 1966:270). However, this theory has been refuted by recent paleoenvironmental research (Piperno and Pearsall 1998).

Research indicates that pottery production occurred by 1000 B.C., in the Eastern Lowlands, and Cuello, a northern Belizean settlement, was occupied by 1020 B.C. (Willey 1987). Stone tools, such as oval bifaces, constricted unifaces, macroblades, large flakes, and ground stone were being constructed in the Lowlands at this time (Lohse et al. 2006).

During the Middle Preclassic (1000-400 B.C.), people within the Maya Lowlands region were interacting with peoples from outside the core area. Specifically, the Maya were interacting with the Olmec to the north on some level. Whether this was of a military or trading nature is not conclusively known (Sharer 1994). The Olmec at this time (1200 B.C.) were ruled by a theocratic chiefdom and practiced significant extension of trade and, thus, influence in some regions of the Maya Highlands. The great Olmec city of San Lorenzo reached its peak during this time, around 1150 B.C. (Sharer 1994).

The Middle Preclassic is thought to be the period in which colonization (or invasion) by the Maya began. This era is further chronologically classified by the Xe Ceramic Complex of the Usumacinta drainage (900-700 B.C.), Mamom Ceramic Complex (700-400 B.C.), and the Swasey Complex of northern Belize (1000-500 B.C.). It was a time of increasing population and expansion into the forests, as people moved away from previously populated water-ways (Sharer 1994). Swidden, or slash-and-burn agriculture, was practiced in these forested areas (Sharer 1994) and some Maya peoples may have begun the practice of raiding local villages for extra labor and sacrifice (Sharer 1994:68). An example of a settlement occupied during the Middle

Preclassic era, Cuello, has evidence of hearths, stone tools, and Swasey Complex pottery, as well as mano and metate fragments, and a plastered platform (Sharer 1994). There has been some debate within the archaeological community whether ceramics were introduced into the Maya Lowlands by the "classical Maya" (Willey 1987:62).

During the Late Preclassic, in the Central Lowlands, the Chicanel Ceramic Complex became prominent (400 B.C.-A.D. 100) and increasing social stratification was evident in elaborate ritualistic burials (Sharer 1994). Trade in luxury items was also occurring (Willey 1987). Around 400 B.C.-A.D. 250 fields in the Lowlands were abandoned when the water rose too high for the feasible production of crops (Pohl et al. 1996). Late Preclassic settlements relevant to this study include Lamanai and Cerros, both found in modern Belize. There is evidence of an elaborate platformed structure at Lamanai, indicating increasing social complexity. Cerros was a fishing village, located on the coast of Belize. By 50 B.C., this settlement had become a "small regal center" with an elaborate temple and ballcourts. Cerros was eventually abandoned and/or no longer used as a "regal/ritual" center, as evidenced by the burning and smashing of ritual articles (Sharer 1994:118).

The term Protoclassic period is sometimes used to designate this period in time (50 B.C.-A.D. 250). During this time, in Belize, the Floral Park ceramic complex became prominent, especially along the border of the Petén. During the Early Classic Period (A.D. 250-600), the Nuevo-Tzakol ceramic complex took over primacy from Floral Park's red-and-black-on-orange polychromes (Willey 1987).

Sites at Ambergis Cay, such as Marco Gonzalez, in Belize, testify to the continuing occupation and thriving nature of coastal Belizean sites, even in the Late and Postclassic eras.

Marco Gonzalez was occupied from at least the Late Preclassic until the Postclassic period. Salt production occurred here from the Late Classic, until approximately A.D. 800 (Graham and Pendergast 1989). However, it was not until the mid 1100's A.D. that construction and use of buildings greatly intensified. Buk type ceramics are present at Marco Gonzalez, the style originating at Lamanai, a site further west and inland from Marco Gonzalez. Clearly trade was occurring between these sites (Graham and Pendergast 1989). Studies performed in the Stann Creek District, Belize, provide details on lifestyles practiced by the Lowland Maya in eastern Belize during the Late Classic and Postclassic (Graham 1994). Studies in the Stann Creek District indicate that the coastal southern Lowland Maya engaged in subsistence trade and processed seafood, as well as ceramics. It is likely that they were not only in contact with inland communities, but also may have facilitated trade farther up the coast.

A Brief Review of the Environmental Adaptations of the Maya within Belize and the Maya Lowlands

The Maya Lowlands is a rich ecological area, full of natural resources. Prior to the development of agriculture, the Late Archaic peoples relied upon foraging and fishing in estuarine environments (Neff et al. 2006a). Little is known concerning the primary reason for the movement of peoples into the Lowlands, but some researchers have theorized that the Yucatec Maya moved into the Lowlands in order to take advantage of the strategic location of rivers which would facilitate trade (Voorhies 1982). Other research indicates that the warm and moist environment in the Maya Lowlands facilitated early maize agriculture, and thus was appealing to early Maya farmers (Pohl et al. 1996).

Previous research (Bronson 1966; Rathje 1971) underestimated the actual power that the Lowland Maya had over their landscape. These researchers believed that the Maya Lowlands were ecologically impoverished, and as a result, suffered from low population density due to the inability of the land to produce surplus food. Many of these researchers have stressed the importance of the Highlands as a source of food items for the resource-poor Lowlands (Voorhies 1982). Some of these researchers posit that a complex trade network might have developed, wherein the Lowland Maya would trade utilitarian objects they produced for exotic items from the Highlands (Voorhies 1982).

More recent research has emphasized that the Lowland Maya intensively cultivated wetlands by utilizing canals and raised bed fields (Fedick and Ford 1990; Willey 1987). Agricultural practices would have varied depending on the particular environmental niche in which a farmer lived. Other agricultural practices included crop rotation, kitchen-gardens, mulching, and cultivation of diverse crops (Lange 1971; Netting 1977; Willey 1987).

The Maya also had complex systems in place for securing water. Water was obtained from caves. Ladders were utilized to obtain the water (Matheny 1982: 160). Stone receptacles were used at Actun Spukil near Oxkintok to collect water as well (Matheny 1982). Open cenotes, a result of karstic geography, especially characteristic of the Yucatan, could provide abundant fresh water (approximately 30 meters) to parched areas (Matheny 1982:160).

In addition to cenotes, stone receptacles, and cave collection, water could also be obtained from wells, chultuns (underground storage caverns often used for liquid), aguadas, reservoirs, and canals (Voorhies 1982). Chultuns, constructed as early as the Late Preclassic, could store up to 86,000 liters of water (Voorhies 1982:164). Thus, some of these water sources could provide for large populations, suggesting that the Maya Lowlands need not have been a desolate, under-populated area.

Research in northern Belize has uncovered many raised- bed systems that used local water to produce more crops. Typically, these raised beds were constructed in wetlands, which are composed of floodplains, lake margins, and swampland (Siemens 1982). Areas as far north as Quintana Roo likely had artificially raised fields (Siemens 1982). In Belize, terraces have been found throughout the "entire northwest corner of the flank lands of the Maya Mountains between Belize and the Xibun Rivers" (Turner II 1978:168). As further evidence of their agricultural skill, the Maya would have had to institute ways of maintaining and repairing damage to raised fields and terraces caused by natural disaster and animal disturbance (Siemens 1982). As evidenced by their utilization of the environment for agriculture, the Maya had a great mastery of many natural resources.

With their skills, the Maya grew squash, chili peppers, manioc and other root crops, cotton, agave, palms, Amaranth, tobacco, tomatoes, and Ramon. Many of these items provided significant nutritional value while others supplied materials to meet other needs. For example, the squash "supplied carbohydrates, vitamins A and B, niacin, pantothenic acid, calcium, and potassium" (Lentz 1999:5). Chili peppers contained many vitamins and were nutritious. Cotton was used in the manufacture of clothing and its seeds could be used for oil (Lentz 1999:11). Agave supplied fiber (Lentz 1999). Palms were widely useful for oil and they also provided vitamins A, D, E, and K (Lentz 1999). The Maya also created tree orchards that provided them with avocados, cacao and cashew nuts (Lentz 1999). Unfortunately, many of these plants are not preserved in the archaeological record. For example, only seeds of squash have been found at Ceren, but the presence of these seeds indicates that this vegetable was consumed by people living in the area (Lentz 1999). Other plants that likely played an important role in the culture of the Maya but which are poorly preserved archaeologically include avocado, tomato, jicama, manioc and other root plants.

Other natural resources available in the Maya Lowlands included minerals and rocks. The Maya could have trekked up the Maya Mountains for useful lithic material. However, it was likely easier for the Maya to use boats or rafts to transport such material from the mountains downstream (Graham 1987). Although some rivers, such as the Sittee, were abundant in materials including slate and shale, not all rivers would have served good collection sites for material for tool construction or trade (Graham 1987). In northern Belize, outcrops of granite would have been a valuable trade item for use in tool construction or raw building materials (Graham 1987).

Non-domesticated plants were also readily available for the Lowland Maya to use. Many ethnographic accounts list medicinal and gastronomical uses the modern Maya have for native plants. This knowledge is passed down from the pre-Columbian Maya through oral traditions and historical documentation. In addition, many wild plants native to the Maya Lowlands are also found in other areas of the Maya sphere. It can be assumed, then, that ethnographic evidence of uses of native wild plants that originate outside of the Lowlands, but within the general Maya region, can be considered applicable for understanding uses in the Lowlands as well.

The Itza Maya, in the Petén, utilize Combretaceae (*Bucida buceras*), to provide housewood for floors, and to create a poultice or patch for skin eruptions (Atran et al. 1993:656). *Zanthoxylum carribaeum*, or prickly ash, is used to calm "possessed children", and as a decoration (Atran et al. 1993). The various species of Moraceae (*Brosimum alicastrum*) have been used for fence wood, to produce a drink for pregnant women, to reduce swelling, as an emergency water source, for fiber, for wheels, and for fodder (Atran et al. 1993). Some species of Sapindaceae possess an edible covering, or are used as firewood or floor panels (Atran et al. 1993). Other species of Sapotaceae have been used for firewood, torches, housewood, and to adulterate chicle (Atran et al. 1993). This list presents only a partial inventory of the uses available to the Maya, but furnishes the reader with a general sense of the utility of local plants.

A Review of Environmental Conditions of Belize and Past Climatic Variation

The central zone of the Maya Lowlands is located along northern Guatemala or the Petén and east into Belize and the southern Yucatan. Throughout the Petén, swamps, forests, karstic landscapes, and savannahs are prominent (Sharer 1994). Belize is “a coastal strip some 174 miles long and about 70 miles broad at its widest point, lying on the eastern seaboard of Central America between 15 degrees 54’ and 18 degrees 29’ North Latitude, and 88 degrees 11’ and 89 degrees 13 ½’ West Longitude” (Waddell 1961:57). In western Belize, the Maya Mountains border the Petén. East of the Maya Mountains many streams flow towards the Caribbean (Waddell 1961). The Belize River flows northeast and exits into the Caribbean, while the Rio

Hondo and the New River flow north and northeast, exiting into Chetumal Bay (Sharer 1994; Waddell 1961).

The Sibun or Xibun River, near the location where the cores for this study were taken, “rises in the easterly side of the southerly hills near the Belize River, and then reaches the sea 10 miles south of Belize (City)” (Waddell 1961:58). The general landscape of Belize shifts from north to south. Southern Belize is characterized by a narrow coastal plain, bordered by the Maya Mountains which rise as high as 3000 feet and plateaus to the west. The remainder of the southern portion of Belize is dotted with limestone and shale deposits (Waddell 1961). The northern portion of Belize is a “flat low-lying coastal plain, frequently swampy,” bordered by coastal plateau about “500 feet in height," and pine forests (Waddell 1961:57). Eastward along the coast, a barrier reef extends 200 km from the “Mexican border in the north to the Sapodilla Cays in the Gulf of Honduras,” and is in places very close to the shore (Nations 2006:228).

Rainfall is abundant throughout Belize, however, not as much falls in the central lowlands as in the southern lowlands. Rainfall patterns in the southern lowlands can be varied and unpredictable (Waddell 1961; Sharer 1994). The rainy season lasts from May until January, while the dry season occurs from February until May. Temperatures also vary, depending on seasonal humidity. “Average [temperatures] are in the 'tierra caliente' [tropical] range, although dry-season daytime temperatures often rise above 38 degrees Celsius or 100 degrees Fahrenheit” (Sharer 1994:38). The mean monthly humidity is comparatively high and can vary from 78 percent to 91 percent (Waddell 1961). The climate is generally drier to the north gradually becoming moister toward the south (Nations 2006).

The Maya rainforest, of which much of Belize is composed, is home to many species of animals including rodents such as pacas, and agoutis, deer, jaguar, monkeys (such as the Central American Spider Monkey), tapir, coatimundis, otter, and peccaries. Avian species include the harpy eagle and the parrot. Reptiles such as hemotoxic vipers, crocodiles, and iguanas, and insects such as the botfly and leaf cutter ants complete the range of fauna (Nations 2006:51).

The plant life in Belize and other areas of the Maya Lowlands is also diverse. Examples of common plants include the *amate* or fig tree, its inner bark used to produce paper, allspice bushes, which provide berries used for seasoning, and the *Bayal* vine, sometimes used to weave baskets. Trees are another well-utilized resource: ramon trees supply nuts, cacao trees provide a source for chocolate, *chicozapote* trees provide chicle, logwood trees give wood and colored dyes, and *Piper* species are occasionally used medicinally or in cooking (Nations 2006: 93). Indeed, this list of species cannot do the Lowlands justice, as its scope is necessarily quite limited.

Climate Trends Within the Maya Lowlands

The pollen of some of the plants listed above can be used to trace climate patterns. By correlating examples of climate change in the Maya Lowlands, and specifically in Belize, with pollen data from the Hattieville study, a more complete climate sequence is designed for the time period in which the ancient Maya lived and, that particular region, the Maya Lowlands. Pollen can be employed to uncover the climates of eras past, as well as the subsistence practices of cultures embedded in those eras. For this study, it is important to note that climate change at a local level can occur as a result of local environmental features and atmospheric circulation. For example, "tropical cells, jet streams, and baro-clinic zones can interact with mountain ranges, coast lines, and inland waters to modify the regional climate" (Storch and Floser 1999:35).

From 34,050-22,050 B.C., the climate in the region of the Maya Lowlands was moist, but still rather dry, with mesic temperate forests (Leyden 2002). During the last glacial maximum, between 22,050 and 12,050 B.C., temperature declined "from 6.5 degrees Celsius to 8 degrees colder than today(s) (average temperature)" (Leyden 2002:88). Pollen is scarce in samples from this period. During the late glacial onset (12,050-8050 B.C.), halophytic plants and mesic temperate forests dominated the landscape. However, during the Early Holocene (8050-4050 B.C.), there is evidence of a warmer climate, likely due to "orbital forcing of solar insolation, ocean-atmosphere interactions, and variations in solar activity" (Leyden 2002). At this time, charcoal becomes more abundant in the record, and arboreal pollen taxa increase.

Lakes Quexil and Salpeten, in the Yucatan, enjoyed warm, moist climates around 8,000-6,000 B.C. Rising sea levels filled Lake Coba and Cenote San Jose Chulchaca, and Coba becomes swampy around 6400-6200 B.C. (Leyden 2002). The sea level reached its maximum height around 5100-4300 B.C. After this zenith, a drying trend can be seen in the pollen record during the Early Preclassic (1800 B.C.) (Leyden 2002). South in the Petén, a drier climate and more open areas became more prominent around 4500 B.C. After 2000 B.C., the forest was drastically reduced (Leyden 2002).

Palynological data has been used in other areas of known Maya influence in order to better understand past environments. Samples were taken from Manchon Swamp, Guatemala, to study climate and its possible effects on settlement and subsistence patterns. At Manchon, occupation began around 1500 B.C., during the Locona phase. Mangrove pollen appears reduced around 3000 B.C., and is followed by an increase in charcoal and disturbance pollen around 1500-1000 B.C. (Neff et al. 2006b). This same pattern is reflected in the Lower Rio Naranjo sample. Prior to 2700 B.C., this area was heavily forested with mangroves. However, from 2700-2600 B.C., there appears increased charcoal and evidence of forest modification (Neff et al. 2006b). Humans were in the area by 2700 B.C. at Lower Rio Naranjo. By 1500 B.C., humans were manipulating the environment at Manchon.

The Holocene thermal maximum ended in 3000 B.C., later, leading to drier conditions after 2000 B.C. With drought and "declining returns," humans may have intensified their horticultural efforts through the utilization of new plant types that would generate satisfactory output within such dry conditions (Neff et al. 2006b:306). The end of the thermal maximum may have exacerbated an already drying climate, but the clearing of forests, a practice indicated by increasing charcoal concentrations, probably heightened this trend. On the other hand, the two signatures (deriving from natural climate change and humans) could be confused. "Clearing of forests increases the representation of herbaceous taxa and increases the distances that pollen can be transported by the wind from other plant associations….thus replicating an arid environment [in the pollen record]" (Leyden 2002:93).

Palynological environmental studies done in Northern Belize indicate that sea level rose between 6000 and 4000 B.C., followed by a period of stabilization at 3000 B.C. (Pohl et al. 1996). After this period of stability, sea level dropped between 3000 and 1000 B.C. (Pohl et al. 1996). This is the main period when maize agriculture became dominant for many communities within the Maya Lowlands. Farmers took advantage of the fertile wetlands environment caused by the rise and then fall of the water table. However, by 1300 B.C., the water table rose again, this time inundating fields, which were subsequently abandoned between 400 B.C. and A.D. 250 (Pohl et al. 1996).

Chapter Three: Salt

To place in context the data and conclusions derived from this study, it is necessary to describe what salt is, how crucial it is for the human body, and how it can be produced. Followed by these discussions, some examples of salt production in the Maya Lowlands are given. Salt is a necessary mineral component of the human body. This substance is a crystal-like mineral found naturally within the landscape, and has been used throughout history to preserve food products.

The average human needs 500 mg of salt per day to regulate muscles and nerves and osmotic pressure (Mannino 1995). A lack of salt can lead to confusion, delirium, unhealthy kidneys, dehydration, and death (Andrews 1983; McKillop 2002). This constellation of effects is also known as salt deficient syndrome, which is characterized by nausea, upset stomach cramps and upset water metabolism (Keslin 1964). However, excessive sodium can lead to hypertension which is "…a disorder for which genetic material sets the stage; excessive sodium precipitates it and perpetuates it. Extra salt makes all forms more rapidly progressive and accelerates the onset of terminal events; extra potassium is everywhere protective" (Meneely and Battarbee 1976:768).

The body continually balances salt intake through osmosis, maintaining equilibrium between the extracellular and intracellular environment (Laszlo 2001; Meneely and Battarbee 1976). When ingesting salty foods, the intracellular environment must balance itself with the saltier extracellular environment to maintain health. Excess salt is exuded through the kidneys and if the body is in need of surplus salt, such as when experiencing stress or excess movement, it is stored (Laszlo 2001; McKillop 2002). In tropical regions, the body may need more salt, due to increased sweat secretion resulting from the hot climate, which leads to salt loss (Andrews 1983; McKillop 2002). The human body can satisfy most or all of its salt needs, depending upon its environment and mode of subsistence, through dietary sources. Meat and fish consumption inherently leads to salt ingestion, and such a diet may negate the need for supplementary salt (Adshead 1992; Keslin 1964). However, people who rely primarily upon a plant-based diet frequently need more sodium chloride than plants alone can provide (Keslin 1964).

Humans adapt to diverse environments, in a variety of ways, including through their diet. In a tropical environment, such as the Maya Lowlands, where meat from wild game is less abundant and plants are readily available, salt ingestion may be low since plants contain less sodium than do animals (Andrews 1983). Marcus (1984) has contested this, claiming that there is a difference between salt appetite and salt requirements. While Andrews claims that the Maya would have needed 8 g of sodium per day to *survive* due to the tropical climate, others claim that only 0.5 to 0.9 g per day would be necessary (Andrews 1983; Marcus 1984; Meneely and Battarbee 1976). Most domesticated plants that the Maya would have had access to, such as maize, beans, and squash, lack sufficient salt to support the human body (without any additional sources of salt). If only 0.7 g of salt per day were required for survival, then it would take up to 154 lbs of maize, squash, and beans to obtain the necessary sodium per day (Keslin 1964:12). However, a diet based on wild or domesticated game would provide the necessary amount of sodium with the consumption of only 2.5 lbs of lean meat (Keslin 1964).

The Prehistoric and Historic Production of Salt in Mesoamerica

Ash from burned palms has been a source of salt for the people of the Maya Lowlands in the past (McKillop 1996). However, some researchers have wondered how sustainable this venture would be for long-term consumption (Andrews 1983; Andrews 1984; Marcus 1984). Andrews (1984) has suggested that burning palms is a very labor-intensive process which would produce very little salt. It would have been more feasible to produce salt or obtain it in another, less destructive fashion rather than to decimate many palms. Salt can be obtained by exploiting natural salt mounds, mining sodium deposits in the earth, exploiting brine springs, evaporating sea water, and boiling brine.

Since there were no natural salt mines or mounds within the Maya Lowlands, the Maya produced salt by the *sal solar* and *sal cocida* methods. The method for obtaining salt by boiling brine is known as *sal cocida*, while the method for obtaining salt by evaporating sea water is known as *sal solar*. The *sal cocida* method consists of using ceramic pots to boil brine, leaving a salt cake. The brine was often pretreated by using *sal solar* methods or by passing the brine through salty earth to soak up additional sodium prior to using the *sal cocida* method (McKillop 2002). Evidence for past use of the *sal cocida* method includes ceramic sherds called briquetage (Adshead 1992; McKillop 2002) and salt mounds, or *tlateles* (Charlton 1969; Nunley 1967). Sherds are produced as a direct result of using the *sal cocida* method because salt cakes on the inside of ceramic pots, requiring the pot to be broken to obtain the salt. This process is described by Dillon et al. (1988:50):

After 10 days of continuous boiling, crystallized salt forms a domed crust inside of the pot…and brine beneath keeps boiling. It can break a vessel unless it is broken up…at the end is a salt cake….partially permeating its sidewalls and adhering to the inner surface, so the pot must be broken….the result are tlateles, or salt mounds.

If the process of producing salt and breaking ceramic pots to obtain it continues, then *tlateles* will result. *Tlateles* are characterized by broken ceramic sherds. It was thought at one time that *tlateles* were habitation sites or a type of chinampa, having been built up through years of use (Nunley 1967). An early explanation of one such collection describes it as a "mound(s) composed of sherd layers and mud" (Nunley 1967:518). However, later studies confirmed that they are, in fact, byproducts of salt production (Charlton 1969; Dillon et al. 1988). Charlton noted that modern salt production techniques by native inhabitants around Lake Texcoco also left "large piles of leached earth" (Charlton 1969:75). He also noted that ceramic pots might have been purposely made thin so that they would more easily break when the time came (Charlton 1969).

Sal solar was the primary method of salt production in the Yucatan. Salt was simply collected along the great salt beds lining the coast of the Yucatan Peninsula. The saltwater naturally would evaporate and dry along the shore. Though not a technically sophisticated method, this method remains popular today: "The most widespread method used today (in the Yucatan*)* is solar evaporation, whereby salt water from coastal estuaries is collected in shallow pans and allowed to evaporate by solar action until only salt, [the method] known as *sal solar*, remains" (Andrews 1983:16). Clearly, the *sal solar* technique has not changed significantly since Pre-Columbian times.

Several studies investigate ancient Maya salt production, most focusing on mass production using the evaporation method in the Yucatan peninsula salt flats (Andrews 1983), and recently, studies have investigated salt production using the *sal cocida* method along the Belizean coast (McKillop 2002). Andrew's model (1983) places the main salt production hub north, in the Yucatan, and utilizes data on population and salt demand as support for Yucatan dominance of the salt trade. According to the study, because the lowland population was larger than its salt resources could support, the society must have relied upon Yucatan sources, importing the salt they desired (Andrews 1983).

The only salt production site mentioned by Andrews within the Lowlands were Ambergis Cay and Salinas de los Nueve Cerros, which, according to Andrews, only could produce about 400 tons of salt annually and could likely produce only enough salt for 137,000 people (Andrews 1983:46; Andrews 1984:827). Since Andrews was aware only of Ambergis Cay and Salinas de los Nueve Cerros at the time as salt production sites within the Lowlands, he surmised that additional salt would have had to be imported. The Yucatan Peninsula is historically linked to large production levels, and so even with little archaeological evidence, he was able to ethnohistorically and historically make a convincing case for large-scale salt production at the Yucatan Peninsula which in turn was subject to large-scale trade (Marcus 1984).

Additional research has focused on several Belizean coastal sites, where cylindrical ceramic pieces were found (MacKinnon and Kepecs 1989). These objects were identified as likely to be parts of *sal cocida* salt-production pots. As a result of this find and interpretation, new salt production centers in the lowlands became apparent. During the Point Placencia

Archaeological Project on the southern Belizean coast, ten sites were located dating to the Late and Terminal Classic periods; three of these were identified as salt-production sites (MacKinnon and Kepecs 1989). These sites are associated only with coastal lagoons not inland sites, and with mounds (*tlateles*), which are thought to be the remains of salt production (MacKinnon and Kepecs 1989). For example, Guzman Mound, located on the south coast of Guatemala along the Mexican border, consists of a salt mound bordered by salt flats (Nance 1992). Excavation revealed that the mound at one time was 1.3 m. high, and was created by refuse from salt production. Nance (1992:29) reports that the

> …refuse consisted of reddish-brown to black midden, at times mixed with ash and charcoal and containing daub and great quantities of potsherds. Interbedded with these layers of midden were deposits of grey loam which we interpreted as desalinated tailings from the salt-making process, originally excavated or scraped from the surrounding salt flat.

Unlike the majority of coastal Belizean salt mounds which date to the Classic Period, Guzman Mound was in use as a salt production area as early as the Late Preclassic (400 B.C. to A.D. 100), as evidenced by similarities in sherds found there to Microflores pottery, Kaminaluyu, and Crucero Red ceramic types (Nance 1992). The site would have been a salt flat by 200 B.C., as a leaf impression of the salt tolerant *madre sal* tree *Avicennia nitida* indicates (Nance 1992). Ceramic evidence further indicates that the *sal cocida* method of salt production was practiced (Nance 1992). Salt production ended by the Postclassic, after which the mound was likely farmed as evidenced by soil profiles (Nance 1992).

Not completely refuting Andrews's (1983) theory of a dominant Yucatan salt trade, MacKinnon and Kepecs have argued that the coastal Lowland Maya did produce their own salt, but that it was inferior to Yucatan salt (MacKinnon and Kepecs 1989:531). The lowland Maya elite would have engaged in long-distance trade with the Yucatan in order to obtain the costlier high-quality white salt, while the commoners would have had to accept the dirtier but cheaper local salt of Point Placencia (MacKinnon and Kepecs 1989). MacKinnon and Kepecs came to this conclusion by testing the *sal cocida* method using Point Placencia soil and then performing blind tests with Yucatan salt as a comparison. Participants in the blind taste tests preferred the Yucatan salt (MacKinnon and Kepecs 1989:530).

Problems with this innovative test, however, run from varying cultural preferences for taste to alteration of the soil over time. Many modern peoples, after becoming accustomed to uniform, white salt, have recently begun clamoring for dirty "peasant" salt, impurities and all (Kurlansky 2002:444). Clearly there are similarities in the situation described and the difference between white "high-quality" Yucatan salt and brown "inferior-quality" Point Placencia salt. It is hard to account and predict for preference and taste. Further, salt manufactured by the Lowland Maya with soil obtained during the Last Classic period was compared to salt created using contemporary soil, two sources distinct enough to introduce difference in taste.

Another source of salt in the interior Maya Lowlands was Salinas de los Nueve Cerros (Dillon et al. 1988). Andrews mentioned this site as one of the only sources of lowland salt production in his 1983 study. He concluded that salt produced at Salinas de los Nueve Cerros would have been used only locally (Andrews 1983). The location of Salinas de los Nueve Cerros, along the junction of the Chixoy/Salinas River, Pasion, and Lacantun rivers (which transition into the Usumacinta River), was ideal for the monopolization of local salt production (Dillon et al. 1988). Salt was produced from the Tortugas salt dome at least as early as the Preclassic era, as the pottery found in the refuse mound indicates (Dillon et al. 1988). The rainy season would have been the most conducive time for salt production at Salinas de los Nueve Cerros. During this season, salty water drains from lakes on top of the mound, gradually diluting into brine during the rainy season (Dillon et al. 1988).

Further work has been done to better understand overall production and output for the *sal solar* and the *sal cocida* methods of salt production. Experiments performed at the Salinas de los Nueve Cerros mound investigated the production potential for solar evaporation salt production. An estimated 18,000 to 24,000 metric tons of salt could have been produced annually through the *sal solar* method, well outpacing Andrews's conclusion that Salinas de los Nueve Cerros and Ambergis Cay combined would produce only 400 tons of salt annually (Andrews 1983:46; Andrews 1984:827; Dillon et al. 1988:42). However, production would have taken up to nine days, due to the crystallization process. As a result, salt production likely occurred only during the dry season, three or four two-week periods per year (Dillon et al. 1988). During the wet season, from June to October, workers would have utilized the *sal cocida* method (Dillon et al. 1988).

Recently, McKillop (2002) suggested that the Belizean coast has been overlooked as a viable place for salt production due to coastal subsidence. Researchers might assume that the Belizean coast would not be an ideal spot for industrial activity because it would appear that it was not stable, as the land was continuously encroached upon by the sea as it subsided. However, McKillop argues that salt was produced using the *sal cocida* method at several coastal settlements. Production was likely a locally controlled, but standardized cottage industry with production areas at places such as Punta Ycacos Lagoon, rather than a state-controlled salt production “factory.” Production would have satisfied local needs, and there would have been enough surplus to trade to local inland cities or settlements, such as Lubaantun (McKillop 2002).

Physical evidence for salt production along coastal Belize includes inland trade goods found at salt workshops (traded for salt), along with salt-cooking devices that were standardized for bulk production (McKillop 2002). Perhaps, production of salt would have occurred in the dry season, the work performed by either gender or both (McKillop 2002). The location and number of salt-production localities would likely have been dictated by the availability of fuel (wood) for the *sal cocida* method (McKillop 2002). In this model, independent salt production specialists could have obtained some benefits from inland elites, by trading salt inland, thus gaining exotic goods and perhaps even marriage alliances (McKillop 189). Further, the demand for salt may have increased with the intensification of *Zea mays* cultivation, perhaps used as a seasoning for cooked maize.

Prior work discusses salt production occurring in the northern Yucatan region (Andrews 1983), as well as Guatemala (Nance 1992) and other inland Maya lowland sites (Dillon et al. 1988). Recent research has included the Belizean coast as a location for ancient Mayan salt production (McKillop 2002). This study will add to the knowledge already obtained concerning the salt production within the Maya Lowlands. However, unlike other studies conducted recently in Belize (McKillop 2002), the Wits Cah Ak'al site and the location of the coring sites for the subsequent palynological study are located in Central Belize, and are not directly located upon the modern Belizean coast. The coring locations represent a former tropical forested area, which due to coastal subsidence, developed into a brackish and marshy environment. This new environment, although not conducive to farming, was ideal for the purposes of salt production, a process which is evidenced by the salt refuse mounds of Wits Cah Ak'al. Beyond demonstrating that the Maya likely produced salt in this area, this study more importantly demonstrates the adaptability of the Maya to new environmental circumstances.

Chapter Four: Methods

Included in Chapter four is information on the methodology used in this study, including location of the pollen coring units, the method of collection, lab processing methods, and explanation of the analysis. Lastly, the lab location, samples and cores chosen, and radiocarbon dates are listed.

As part of a study being conducted by the Xibun River Archaeological Research Project (XARP), three sediment cores were collected from a lagoon approximately six miles from the Belizean coast, in February 2007 (Figure 3). The area where the samples originated are in close proximity to Hattieville, Belize (Table 2).

The decision to collect sediment cores from this area stems from a recognition that more study needs to be completed in this area. Compared to other more thoroughly studied areas within the Maya Lowlands, further study is needed near coastal Belize in order to learn more about human interaction with the local environment. The samples were collected near mounds which have a known association with Late Preclassic to Terminal Classic Salt Production (Jones and Hallock 2007).

Table 2: Coordinates of the Belize 2007 Cores taken from UTM Zone 16 N, North American Datum 1927

Sediment Core #	Meters East	Meters North
1	357462	1932784
2	357812	1933868
3	358164	1931049

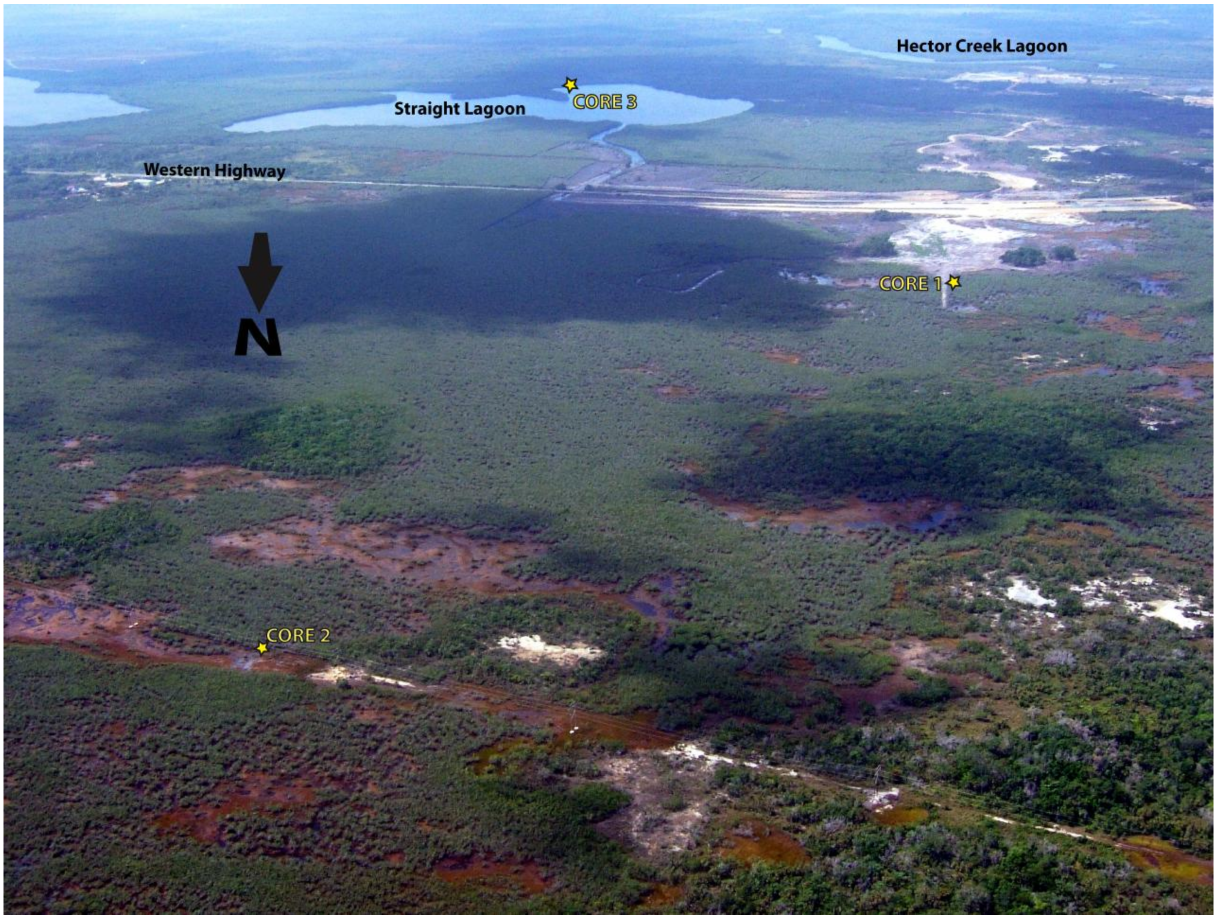

Figure 3. Aerial photograph showing coring locations near Hattieville, Belize, discussed in this thesis. Photo courtesy of Satoru Murata.

It was unknown at the time of collection whether the samples collected would shed further light on salt production in the area. However, results have not only indicated that this region of Belize was conducive to salt production, but they also illuminate other characteristics of the environment at this time.

All three sediment cores were collected by Dr. John G. Jones using a manually-driven apparatus. In the field laboratory, the samples were carefully extracted from the cores, sampled at every 5 cm, and placed in airtight bags marked by their 5 cm intervals. Samples were ultimately transported to Washington State University and placed in cold storage.

Recognizing that the environmental conditions in Belize are often not favorable for pollen production, a conservative pollen extraction technique was followed. Pollen is an organic compound and although very durable, is susceptible to bacterial, fungal and mechanical degradation. Natural cycles of wetting and drying produce an environment favorable for the growth of pollen-destroying bacteria and fungi. Under these conditions, pollen grains are likely to have suffered some adverse affects, and thus would be expected to be present, if at all, in a weakened state of preservation. With this in mind, weaker bases and acids were selected for use in extraction, particularly excluding those chemicals which have been documented to act harshly towards poorly preserved fossil grains.

The volumes of each sample were first quantified (1-3cc's), placed in sterile beakers, and a known quantity of exotic tracer spores was added to each sample. Here, European *Lycopodium* spp. spores were chosen as an exotic, because these spores are unlikely to be found in the actual fossil pollen assemblages from this region. Tracer spores are added to samples for two reasons. First, by adding a known quantity of exotic spores to a known quantity of sediment, fossil pollen concentration values can be calculated. Second, in the event that no fossil pollen is observed in the sediment sample, the presence of *Lycopodium* tracer spores verifies that processor error was not a factor in the pollen loss (Benninghoff 1962; Stockmarr 1971).

Following the addition of the tracer spores, the samples were washed with 10% hydrochloric acid. This step removed carbonates and dissolved the bonding agent in the tracer spore tablets. The samples were then rinsed in distilled water, sieved through 150 micron mesh screens, and swirled to remove the heavier inorganic particles. Next the samples were consolidated, and 50% Hydrofluoric Acid was added to the residues to remove unwanted silicates. After the silicates had been removed, the residues were rinsed thoroughly in distilled water, and were then washed in 1% KOH to remove alkaline soluble humates.

Next, the samples were dehydrated in Glacial Acetic Acid, and were subjected to an acetolysis treatment (Erdtman 1960) consisting of 9 parts Acetic Anhydride to 1 part concentrated Sulfuric Acid. During this process, the samples were placed in a heating block for a period not exceeding 8 minutes. This step removed most unwanted organic traces including cellulose, hemi-cellulose, lipids and proteins, and converted these materials to water-soluble humates. The samples were then rinsed in distilled water until a neutral pH was achieved.

Following this treatment, the samples were next subjected to a heavy density separation using Zinc Chloride (Sp.G. 2.00). Here, the lighter organic fraction was isolated from the heavier minerals. After this treatment, the lighter pollen and organic remains were collected and rinsed thoroughly in water. The residues were then dehydrated in absolute alcohol, and transferred to a glycerine medium for curation in glass vials.

Permanent slides were prepared using glycerine as a mounting medium, and identifications were made on a Nikon compound stereomicroscope at 400-1250x magnification. Identifications were confirmed by using the Palynology Laboratory's extensive pollen reference collection. Minimum 200-grain counts of fossil pollen, standard among most palynologists (Barkeley 1934), were made for each sample when pollen was preserved in the sediments. 200-grain counts are thought to be fairly reflective of past vegetation and paleoenvironmental conditions.

Concentration values were calculated for all sediment samples. Hall (1981) and Bryant and Hall (1993) note that concentration values below 2,500 grains/ml of sediment may not reflect past conditions well, and usually record a differentially preserved assemblage. As a result, counts with low concentration values should be viewed with caution.

Pollen concentration values were calculated for each sample once the counting was complete (Appendix B, C). The volume of soil chosen for processing varied, depending on the sediment types and anticipated pollen concentrations (Tables 3, 4, 5). With the exception of five problematic samples, all counts were calculated to have a concentration value in excess of 2500 grains/cc of sediment, a value usually considered to be sufficient for accurate pollen interpretations (Hall 1981). The problematic samples were near the bottom of all cores. The deepest five samples from Cores 1 and 2 contained no pollen. The absence of pollen within these samples is due to poor preservation, as they were taken from the oldest part of the core.

Overall, Core 3 was more problematic than the other cores, as samples taken at 160 cm, 180 cm, and 195 cm bs (below surface), all had counts of fewer than 200 grains. Interestingly, samples taken at 185 and 190 cm bs were in good condition and pollen counts consistently met

Table 3: Core 1 Pollen Provenience and Preservation Status Organized by Depth

Lab/Sample #	Depth	Volume	Preservation
1	60 cm	1 cc	Good
25	65 cm	1 cc	Good
2	70 cm	1 cc	Good
26	75 cm	1 cc	Good
3	80 cm	1 cc	Good
27	85 cm	1 cc	Good
4	90 cm	1 cc	Good
28	95 cm	1 cc	No Pollen
5	100 cm	2 cc	No Pollen
6	120 cm	3 cc	No Pollen
7	140 cm	3 cc	No Pollen
8	160 cm	3 cc	No Pollen

Table 4: Core 2 Pollen Provenience and Preservation Status Organized by Depth

Lab #	Depth	Volume	Preservation	Lab#	Depth	Volume	Preservation
9	90 cm	1 cc	Good	34	155 cm	1 cc	Good
29	95 cm	1 cc	Good	15	160 cm	1 cc	Good
10	100 cm	1 cc	Good	35	165 cm	1 cc	Good
30	110 cm	1 cc	Good	16	170 cm	1 cc	Good
11	120 cm	1 cc	Good	36	175 cm	1 cc	Good
31	125 cm	1 cc	Good	17	180 cm	1 cc	Poor
12	130 cm	1 cc	Good	18	190 cm	1 cc	No Pollen
32	135 cm	1 cc	Good	19	200 cm	1 cc	No Pollen
13	140 cm	1 cc	Good	20	214 cm	1 cc	No Pollen
33	145 cm	1 cc	Good	21	225 cm	2 cc	No Pollen
14	150 cm	1 cc	Good	22	235 cm	2 cc	No Pollen

Table 5: Core 3 Pollen Provenience and Preservation Status Organized by Depth

Lab #	Depth	Volume	Preservation	Lab #	Depth	Volume	Preservation
1	85 cm	1 cc	Good	32	160 cm	2 cc	Good->200 g.
25	90 cm	1 cc	Good	8	165 cm	2 cc	Good
2	95 cm	1 cc	Good	33	170 cm	2 cc	Good
26	100 cm	1 cc	Good	9	175 cm	1 cc	Good
3	105 cm	1 cc	Good	34	180 cm	2 cc	Good->200 g.
27	110 cm	1 cc	Good	10	185 cm	1 cc	Good
4	115 cm	1 cc	Good	35	190 cm	2 cc	Good
28	120 cm	1 cc	Good	11	195 cm	1 cc	Poor->200 g.
5	125 cm	1 cc	Good	36	200 cm	2 cc	Poor
29	130 cm	2 cc	Good	12	205 cm	1 cc	No Pollen
6	135 cm	1 cc	Good	13	215 cm	1 cc	No Pollen
30	140 cm	2 cc	Good	14	225 cm	1 cc	No Pollen
7	145 cm	1 cc	Good	15	235 cm	1 cc	No Pollen
31	150 cm	2 cc	Good	16	240 cm	1 cc	No Pollen
23	155 cm	1 cc	Good	24	260 cm	1 cc	No Pollen

Table 6: Calibrated Radiocarbon Dates for Belize Cores 2 and 3

Sample ID	Material	14 C age BP
BZE07-C2-140CM	Peat	4435 ± 37
BZE07-C3-195CM	Wood	3562 ± 36
BZE07-C3-195CM	Wood	3518 ± 35

the 200-grain minimum. The problems encountered with deeper samples likely stems from poor soil conditions, which led to poor preservation of the pollen grains.

Radiocarbon samples from Cores 2 and 3 were obtained from the Arizona AMS Laboratory (Table 6). Three radiocarbon dates were obtained from Cores 2 and 3. For Core 3 we obtained two radiocarbon dates. The calibrated and corrected radiocarbon dates indicate that Cores 2 and 3 date to at least the Archaic and the Early Preclassic Maya periods. The time period indicated here is well before the expected dates, which should have been dated to the Late Classic period.

However, the samples used for radiocarbon dating were taken near the base of the cores, and therefore they date the origin of the span of time that the sediment cores represent. Further analysis indicates that the cores represent a lengthy span of time, one in which the environment completely changed well after the dates collected near the base. In conjunction with data attained from the nearby Wits Cah Ak'al mounds, this likely places the more recent undated surface samples from the core close to the Late Classic period. This correlation, along with other pollen data, will be presented at greater length in the next chapter.

Chapter Five: Results

This chapter presents the results of the analysis discussed in Chapter four. The method used to divide each core is explained and the pollen found within each zone is listed. Trends in pollen data, such as the appearance or disappearance of specific pollen taxa in relation to depth, are also described. Chapter six discusses the results described in this chapter.

Pollen zones were established by using a stratigraphically constrained sum of squares analysis, using a program intrinsic to the pollen diagram generating program. This program, called Tilia Graph, uses CONISS to establish a dendrogram based on similarities with other samples in a stratigraphic column. CONISS is a multivariate statistical technique that discerns any dissimilarities between samples. Generally, these zones are readily apparent to the analyst based on variations in key taxons.

A pollen concentration formula from Davis (1969) was used to derive the concentration values assigned to total pollen counts found in the slides. Pollen counts indicate that there are 47 pollen types for all three cores. The pollen types have been separated broadly into four categories. For all three cores there are two mangrove types, five aquatic types, nine herbaceous types, and twenty-nine non-mangrove arboreal pollen represented. The total counts for each sample of Cores 1, 2, and 3 are organized by sample number in Table 7 and in Appendix B and C.

The results from all three cores are presented individually below. Following this chapter, all data presented in the results will be clarified and a cohesive account of the local environment(s) that each core represents will be discussed.

Table 7

Pollen Counts and Percentages from BZE-2007 Core 3

	Sample Number			
Pollen Taxa	**1**	**2**	**3**	**4**
Arecaceae				5 (2.4)
Asteraceae High Spine	4 (1.7)	2 (0.9)	5 (2.4)	6 (2.9)
Asteraceae Low Spine	3 (1.2)	3 (1.4)		
Chaetoptelea				
Cheno-Am				
Combretaceae	87 (37.5)	125 (59.2)	123 (61.1)	74 (36.5)
Convolvulaceae				
Fabaceae				
Moraceae				
Myrtaceae				
Poaceae	5 (2.1)			6 (2.9)
Polygonaceae				1 (0.4)
Sedge		2 (0.9)		
Sapotaceae				
Solanaceae	12 (5.2)			
Verberaceae				
Borreria				4 (1.9)
Bravasia				
Bursera	3 (1.2)			
Cassia		3 (1.4)		

Coccoloba	3 (1.2)	1 (0.4)		1 (0.4)
Gymnopodium	1 (0.4)	8 (3.7)	2 (0.9)	1 (0.4)
Hirea	1 (0.4)	4 (1.8)	10 (4.9)	3 (1.4)
Ilex				
Machaerium				
Metopium				
Myrica	12 (5.1)	2 (0.9)	2 (0.9)	16 (7.9)
Pinus	12 (5.1)	7 (3.3)	15 (7.4)	18.5 (9.1)
Quercus	48 (20.6)	28 (13.2)	15 (7.4)	25 (12.3)
Rhizophora	4 (1.7)	9 (4.2)	19 (9.5)	8 (3.9)
Sebastiana	2 (0.8)	5 (2.3)		2 (0.9)
Typha	1 (0.4)	3 (1.4)	5 (2.4)	
Zanthoxylum	2 (0.8)			
Indeterminate	19 (8.1)	2 (0.9)		27 (13.3)
Unknown	13 (5.6)	9 (4.2)	3 (1.4)	5 (2.4)
Total	**232 (100)**	**211 (100)**	**201 (100)**	**202.5 (100)**
Tracer Spores	188	53	70	1028
Concentration Value (Grains/ml)[1]	30,954	99,862	72,026	4,941

[1] Samples 12-16 and 24 are not listed as no pollen was found.

Table 7

Pollen Counts and Percentages from BZE-2007 Core 3, Continued

	Sample Number			
Pollen Taxa	**5**	**6**	**7**	**8**
Arecaceae				1 (0.4)
Asteraceae High Spine	16 (7.9)	9 (4.5)		
Asteraceae Low Spine		1 (0.5)	3 (1.4)	
Chaetoptelea				
Cheno-Am				
Combretaceae	32 (15.9)	14 (7.0)	16 (7.9)	20 (9.8)
Convolvulaceae	1 (0.4)			
Fabaceae				
Moraceae				
Myrtaceae				
Poaceae	29 (14.4)	24 (12.0)	16 (7.9)	3 (1.4)
Polygonaceae				
Sedge	4 (1.9)	7 (3.5)	11 (5.4)	2 (0.9)
Sapotaceae				
Solanaceae				
Verberaceae				
Borreria	1 (0.4)	14 (7.0)	35 (17.2)	
Bravasia				
Bursera				
Cassia				

Coccoloba	7 (3.4)	7 (3.5)	4 (1.9)	
Gymnopodium				
Hirea				
Ilex				
Machaerium				
Metopium				
Myrica	26 (12.9)	36 (18.0)	12 (5.9)	
Pinus	60 (29.8)	24 (12.0)	42.5 (20.9)	6 (2.9)
Quercus	24 (11.9)	12 (6.0)	21 (10.3)	5 (2.4)
Rhizophora				
Sebastiana				
Typha			139 (68.6)	
Zanthoxylum				
Indeterminate	1 (0.4)	8 (4.0)	3 (1.4)	25 (12.3)
Unknown		44 (22.0)	15 (7.4)	1 (0.4)
Total	**201 (100)**	**200 (100)**	**202.5 (100)**	**203 (100)**
Tracer Spores	606	256	643	589
Concentration Value (Grains/ml)	8,319	19,596	7,899	4,322

Table 7

Pollen Counts and Percentages from BZE-2007 Core 3, Continued

	Sample Number			
Pollen Taxa	**9**	**10**	**11**	**23**
Arecaceae	2 (0.9)	1 (0.4)		
Asteraceae High Spine	2 (0.9)			4 (1.9)
Asteraceae Low Spine				
Chaetoptelea				
Cheno-Am				
Combretaceae	17 (6.8)			130 (63.4)
Convolvulaceae				
Fabaceae				
Moraceae				
Myrtaceae				
Poaceae	2 (0.9)		2 (14.8)	3 (1.4)
Polygonaceae				
Sedge		11 (5.4)		
Sapotaceae		41 (20.3)		
Solanaceae				
Verberaceae				
Borreria			2 (14.8)	
Bravasia				
Bursera				4 (1.9)
Cassia				

Coccoloba	5 (2.4)	16 (7.9)		
Gymnopodium				
Hirea	4 (1.9)	24 (11.9)	2 (14.8)	
Ilex				
Machaerium				
Metopium				
Myrica				
Pinus	42.5 (20.7)	21 (10.4)	2.5 (18.5)	9 (4.2)
Quercus	21 (10.2)		1 (7.4)	13 (6.1)
Rhizophora				20 (9.5)
Sebastiana				
Typha	69 (33.7)			
Zanthoxylum				
Indeterminate	27 (13.2)	21 (10.4)	4 (29.6)	5 (2.3)
Unknown	13 (6.3)	25 (12.4)		
Total	**204.5 (100)**	**201 (100)**	**13.5 (100)**	**210 (100)**
Tracer Spores	554	420	404	129
Concentration Value (Grains/ml)	9,259	11,945	838	40,834

Table 7

Pollen Counts and Percentages from BZE-2007 Core 3, Continued

	Sample Number			
Pollen Taxa	**25**	**26**	**27**	**28**
Arecaceae				
Asteraceae High Spine	15 (7.4)	6 (2.8)	7 (3.1)	34 (16.6)
Asteraceae Low Spine				
Chaetoptelea				
Cheno-Am				
Combretaceae	108 (53.7)	149 (70.9)	29 (26.3)	44 (21.5)
Convolvulaceae				
Fabaceae				
Moraceae				
Myrtaceae				
Poaceae				1 (0.4)
Polygonaceae		4 (1.9)	4 (1.7)	
Sedge	6 (2.8)		18 (8.0)	1 (0.4)
Sapotaceae				
Solanaceae				
Verberaceae				
Borreria	1 (0.4)		25 (11.1)	7 (3.4)
Bravasia				
Bursera		4 (1.9)		2 (0.9)
Cassia				

Coccoloba	7 (3.4)			
Gymnopodium				
Hirea	2 (0.9)			8 (3.9)
Ilex				
Machaerium				
Metopium				
Myrica	1 (0.4)		12 (5.3)	34 (16.6)
Pinus	9 (4.4)	9 (4.2)	56 (25.0)	59 (28.9)
Quercus	26 (12.9)	13 (6.1)	32 (14.2)	12 (5.8)
Rhizophora	18 (8.9)	20 (9.5)	8 (3.5)	3 (1.4)
Sebastiana				
Typha	4 (1.9)			
Zanthoxylum				
Indeterminate	4 (1.9)	5 (2.3)	3 (1.3)	1 (0.4)
Unknown				
Total	**201 (100)**	**210 (100)**	**224 (100)**	**204 (100)**
Tracer Spores	103	129	113	367
Concentration Value (Grains/ml)	48,950	40,834	49,724	13,943

Table 7

Pollen Counts and Percentages from BZE-2007 Core 3, Continued

	Sample Number			
Pollen Taxa	**29**	**30**	**31**	**32**
Arecaceae	1 (0.3)			
Asteraceae High Spine	40 (15.6)	28 (14.0)	16 (7.5)	
Asteraceae Low Spine				
Chaetoptelea				
Cheno-Am				
Combretaceae	55 (21.5)	30 (15.0)	12 (5.6)	13 (34.2)
Convolvulaceae				
Fabaceae				
Moraceae				
Myrtaceae				
Poaceae				
Polygonaceae				
Sedge	31 (12.1)	22 (11.0)	56 (23.2)	15 (39.4)
Sapotaceae				
Solanaceae				
Verberaceae				
Borreria	1 (0.3)	32 (16.0)	76 (35.6)	
Bravasia				
Bursera			6 (2.8)	4 (1.8)
Cassia				

Coccoloba				
Gymnopodium				
Hirea		7 (3.5)	4 (1.8)	
Ilex				
Machaerium				
Metopium				
Myrica	31 (12.1)	20 (10.0)	3 (1.4)	2 (5.2)
Pinus	38 (14.9)	42 (21.0)	20 (9.3)	1 (2.6)
Quercus	44 (17.2)	14 (7.0)	16 (7.5)	1 (2.6)
Rhizophora	9 (3.5)			
Sebastiana				
Typha				
Zanthoxylum				
Indeterminate	3 (1.1)	5 (2.5)	4 (1.8)	4 (10.5)
Unknown				
Total	**255 (100)**	**200 (100)**	**213 (100)**	**38 (100)**
Tracer Spores	156	533	209	218
Concentration Value (Grains/ml)	20,501	4,706	12,782	2,186

Table 7

Pollen Counts and Percentages from BZE-2007 Core 3, Continued

Sample Number

Pollen Taxa	**33**	**34**	**35**
Arecaceae	2 (0.9)		
Asteraceae High Spine	11 (5.4)		2 (0.9)
Asteraceae Low Spine		1 (0.4)	
Chaetoptelea		1 (0.4)	
Cheno-Am		2 (0.9)	
Combretaceae	21 (10.3)	2 (0.9)	10 (4.8)
Convolvulaceae		1 (0.4)	
Fabaceae		1 (0.4)	
Moraceae		1 (0.4)	
Myrtaceae		2 (0.9)	
Poaceae		1 (0.4)	7 (3.4)
Polygonaceae			
Sedge	124 (61.0)	32 (14.8)	15 (7.3)
Sapotaceae			
Solanaceae		1 (0.4)	
Verberaceae		1 (0.4)	
Borreria		1 (0.4)	
Bravasia			
Bursera			4 (1.9)
Cassia			

Coccoloba	2 (0.9)	4 (1.8)	1 (0.4)
Gymnopodium			
Hirea	3 (1.4)	64 (29.7)	125 (60.9)
Ilex		3 (1.3)	
Machaerium		3 (1.3)	
Metopium		3 (1.3)	
Myrica		33 (15.3)	11 (5.3)
Pinus	10 (4.9)	23 (10.6)	8 (3.9)
Quercus	27 (13.3)	15 (6.9)	18 (8.7)
Rhizophora			
Sebastiana			
Typha		4 (1.8)	
Zanthoxylum			
Indeterminate	3 (1.4)	14 (6.5)	4 (1.9)
Unknown		2 (0.9)	
Total	**203 (100)**	**215 (100)**	**205 (100)**
Tracer Spores	459	430	118
Concentration Value (Grains/ml)	5,547	6,271	21,789

Core 1: Results

Core 1, the shortest of the three cores, was divided manually into two zones based on perceived trends in the pollen data revealed by CONISS. Zone one extends from 90 cm to 80 cm; while Zone 2 extends from 80 cm to 60 cm, the uppermost layer in the core. The lower zone was created to better isolate the swamp forest environment which was predominant further down in the core (Figure 4). The upper zone differs from the lower zone in that the pollen types prominent near the top of the core indicate a trend of forested swamp environment transitioning into wetlands, perhaps due to a rising water table level (Jones and Hallock 2007).

The lower zone has a large number of Combretaceae, or white mangrove, grains which declines gradually. In addition, *Rhizophora*, or red mangrove, pollen is also found in large quantities, though not exceeding the Combretaceae numbers. Both mangrove types noticeably decline around 85 cm and dramatically taper off at 80 cm. Pollen representing aquatic types is also present in the lower zone of Core 1. Cyperaceae (sedge) is the most prominent pollen type, but *Utricularia* (bladderwort) is present as well. Herbaceous pollen, such as Asteraceae and Poaceae are also noticeably present in the lower zone. Arboreal pollen types, including *Coccoloba*, *Hirea*, *Ilex*, *Machaerium*, Moraceae, *Myrica* (Wax Myrtle), *Pinus* (Pine), *Quercus* (Oak), Sapotaceae, *Ulmus*, and various ferns, are all present to some degree in the lower zone.

The upper zone of Core 1 is characterized by an elevated red mangrove presence. Combretaceae is present in decreasing amounts, while Rhizophoraceae slowly increases. Combretaceae spikes again around 65 cm, but then decreases again at the top of the core (60 cm). Rhizophoraceae percentages increase at approximately 70 cm. Followed by this increase, Rhizophoraceae percentages decreases dramatically at 64 cm. This decrease is followed by another slight increase at the top of the core and the end of the zone at 60 cm. Aquatic pollen types Cyperaceae, *Nymphea* (water lily), and *Utricularia* are also found in greater amounts in the upper zone. Cyperaceae percentages decrease significantly at 70 cm, but then gradually increase again at 65 cm. *Nymphea* is rare below 75 cm, but increases significantly at 70 cm.

By 65 cm, however, *Nymphea* reverts back to a concentration level more akin to that found at 70 cm. *Utricularia* noticeably increases close to the top of the core, between 65 cm and 60 cm in the upper zone. The percentage of Cyperaceae decreases significantly at 70 cm, but then gradually increases again at 65 cm. *Nymphea* is noticeably inconspicuous prior to 75 cm, but increases significantly at 70 cm.

Only a few herbaceous pollen types are noticeable in the upper zone of Core 1. These types include Asteraceae and Poaceae, both of which are present but do not dramatically alter in percentage values. The arboreal types prominent in the upper zone of Core 1 include *Hirea*, Moraceae, *Myrica* (wax myrtle), *Pinus* (pine), and *Quercus* (oak). The percentage of *Coccoloba* remains constant in a prominent way across the upper zone, and is noticeable toward the bottom of the upper zone, between 60 cm and 70 cm. *Gymnopodium* is a noticeable component of the upper zone, present between 70 cm and 60 cm. The percentage value of *Hirea* spikes twice in the upper zone, although never in a dramatic way. *Hirea* increases both at 80 cm and at 70 cm. Moraceae increases at 70 cm in the upper zone, after decreasing at 75 cm, toward the origin of the upper zone.

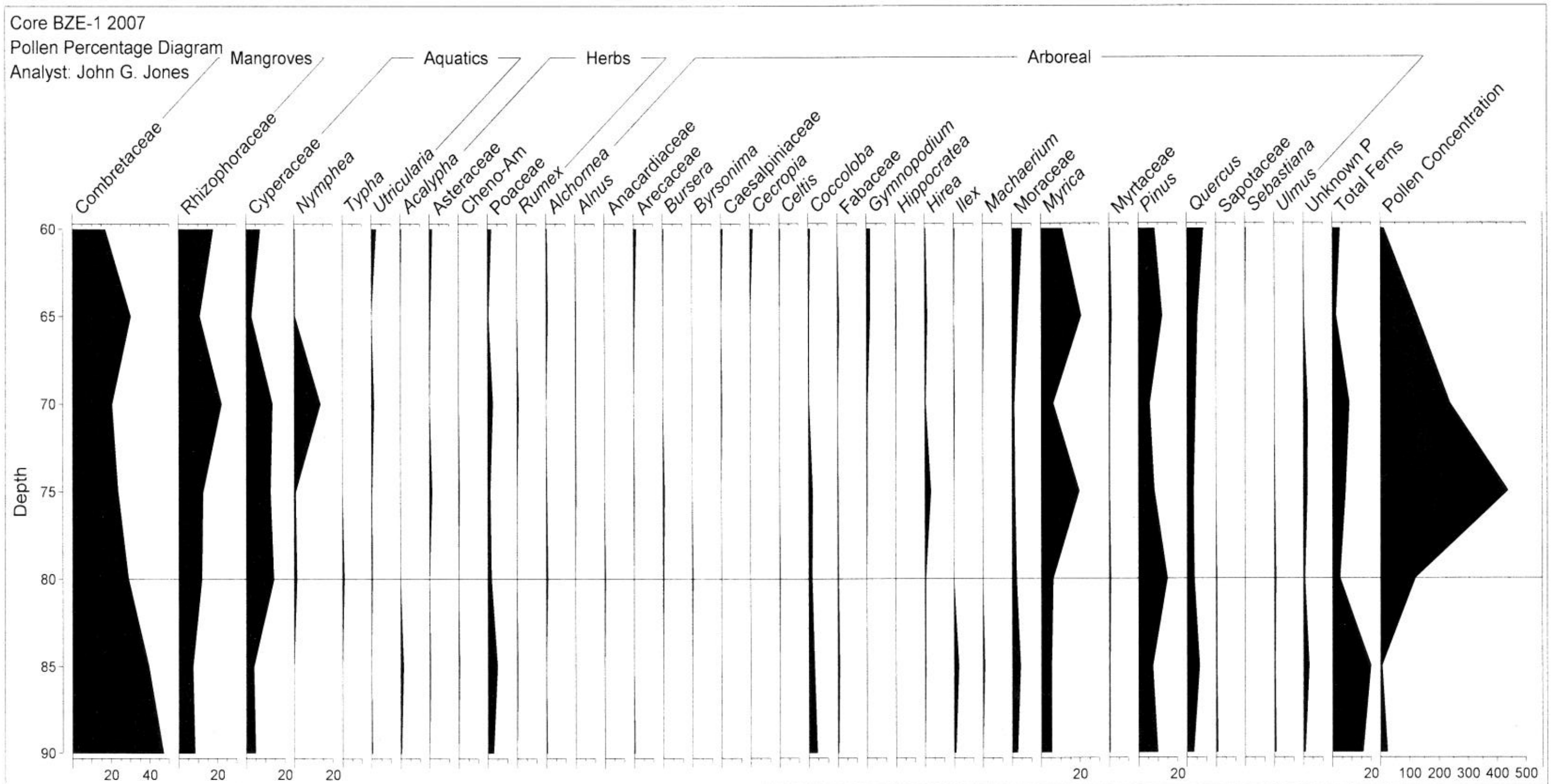

Figure 4. Pollen Percentage Diagram from Core BZE-1 2007.

Both *Myrica* and *Pinus* are large components of the upper zone of Core 1. *Myrica* spikes twice, once at 75 cm, and again at 65 cm. *Pinus* increases dramatically, once at the beginning of the upper zone, or at 80 cm, and at 65 cm, toward the end of the upper zone.

Quercus consistently increases from 80 to 60 cm, but never surpasses the percentage values of *Pinus* or *Myrica*. Ferns are also present in the upper zone, but not to the degree found in the lower zone. Ferns decrease from around 70 cm to the end of the upper zone. Overall pollen percentages for both zones exhibit a notable spike around 75 cm, or the upper zone. Conclusively for Core 1, there is a greater pollen percentage in the upper zone, between 80 and 60 cm.

Core 2: Results

Core 2 was also divided into three zones (Figure 5), reflecting obvious trends in the pollen data through the use of CONISS. The lower zone extends from 175 cm to 165 cm. This zone reflects a wetlands environment apparent at the basal end of the core. The middle zone, extending from 165 cm to 135 cm, indicates a changing environment. The pollen in this portion of the core reflects an encroaching wetlands environment, as well as pollen types typical of a cleared area, which is a possible indicator of a human presence (Jones and Hallock 2007). Finally, the upper zone extends from 135 cm. to the shallowest depth of 90 cm. This zone reflects an increasingly saline environment, as mangrove is prominent.

One radiocarbon date was obtained for Core 2. The date, 4435 +/- 37 B.P., was obtained from a sample taken from a depth of 140 cm (Table 3). The lowest zone is typified by an

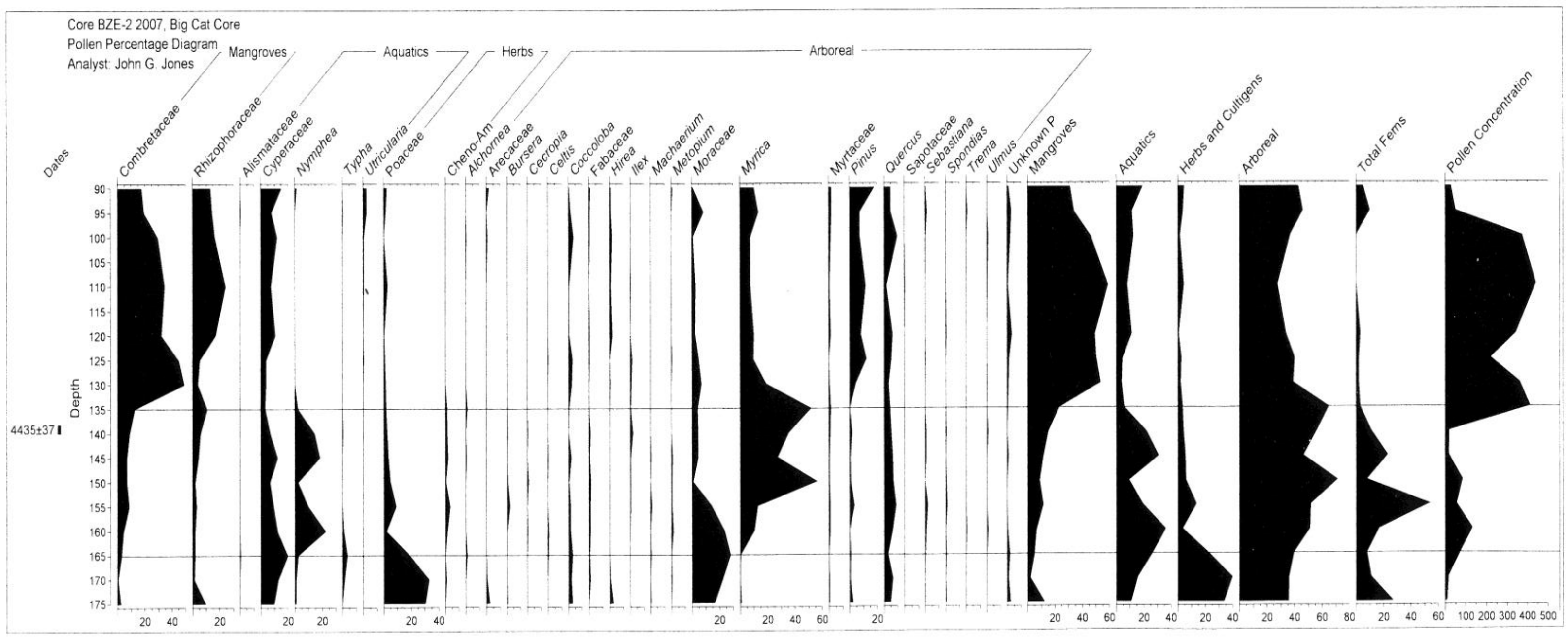

Figure 5. Pollen Percentage Diagram from Core BZE-2 2007.

arboreal environment, with some red mangrove (Rhizophoraceae) and herbaceous pollen types. Combretaceae is present, albeit in a lower amount than *Rhizophora*. Aquatic pollen types are prominent. Cyperaceae is present in large percentages, increasing at 165 cm. *Typha*, or cattail, is also present in the lowest zone, but the percentages do not increase until 170 cm, near the division for the middle zone. Poaceae, or grass type pollen, is present in large numbers in the lowest zone. Moraceae (Mulberry Family) and *Quercus*, arboreal pollen, are also present in the lowest zone.

The middle zone of Core 2 includes increasing mangrove pollen, with a continuation of aquatic, herbaceous, and arboreal-type pollen. Combretaceae increases toward the top of the middle zone, spiking at 155 cm. Rhizophoraceae, after an initial spike in the lowest zone, at 175 cm, gradually increases again toward the top of the middle zone. Cyperaceae and *Nymphea* are both prominent aquatic types. *Nymphea* spikes twice in the middle zone, at 160 cm and at 145 cm. Herbaceous-type pollen, such as Poaceae, is also present. Poaceae percentages spike at 155 cm, but are still found in lower quantities than in the lowest zone.

Arboreal-type pollen, including Moraceae, *Myrica*, *Quercus*, *Sebastiana* (white poisonwood), and *Spondias* (hogplum), is also present in the middle zone. Most prominent of these arboreal types are Moraceae, *Myrica,* and *Quercus*. Moraceae increases most noticeably at 165 cm and then decreases until around 150 cm. Following this decrease, Moraceae is found in low percentages throughout the middle zone. *Myrica* spikes twice, once at 155 cm and once at the base of the middle zone, at 135 cm. *Quercus* is also present in the middle zone and remains constant throughout this zone.

The upper zone of Core 2 is characterized by a substantial increase in mangrove-type pollen, including Combretaceae and Rhizophoraceae. Combretaceae, especially, is prominent in the upper zone. Aquatic types, such as Cyperaceae and *Utricularia*, are also present. Cyperaceae is present in the upper zone in greater amounts than *Utricularia*, however. Herbaceous pollen types, such as Poaceae, are also found in the upper zone.

Arboreal pollen types are also present, including *Coccoloba*, *Hirea*, *Ilex* (holly), *Arecaceae* (Palm Family), Moraceae, *Myrica*, *Pinus*, *Quercus*, and *Sebastiana*. Arecaceae, always rare, is only found at the top of the core. *Coccoloba* is present throughout the zone, but is most prominent at 125 cm and at 100 cm. *Hirea* is present from 120 cm through the conclusion of the upper zone and the core, at 90 cm. *Ilex* is present near the bottom of the upper zone, between 135 and 125 cm. Moraceae is present throughout the upper zone of Core 2, but is found in increasing amounts between 135 cm and 125 cm and between 100 and 90 cm.

Myrica, after spiking at 135 cm, decreases until 100 cm, however, at 100 cm *Myrica* increases dramatically. *Pinus* is present throughout the upper zone, but increases noticeably at 125 cm and toward the end of the core and the upper zone, at 90 cm. *Quercus* is also present throughout the upper zone, with small increases at 125 cm and at 100 cm. Finally, *Sebastiana* is found only near the top of the core, between 100 cm and 90 cm.

Core 3: Results

Three zones have been designated in Core 3, each of which illustrates pollen data trends (Figure 6). The lower, or basal, zone extends from 190 cm to 150 cm. This zone was created

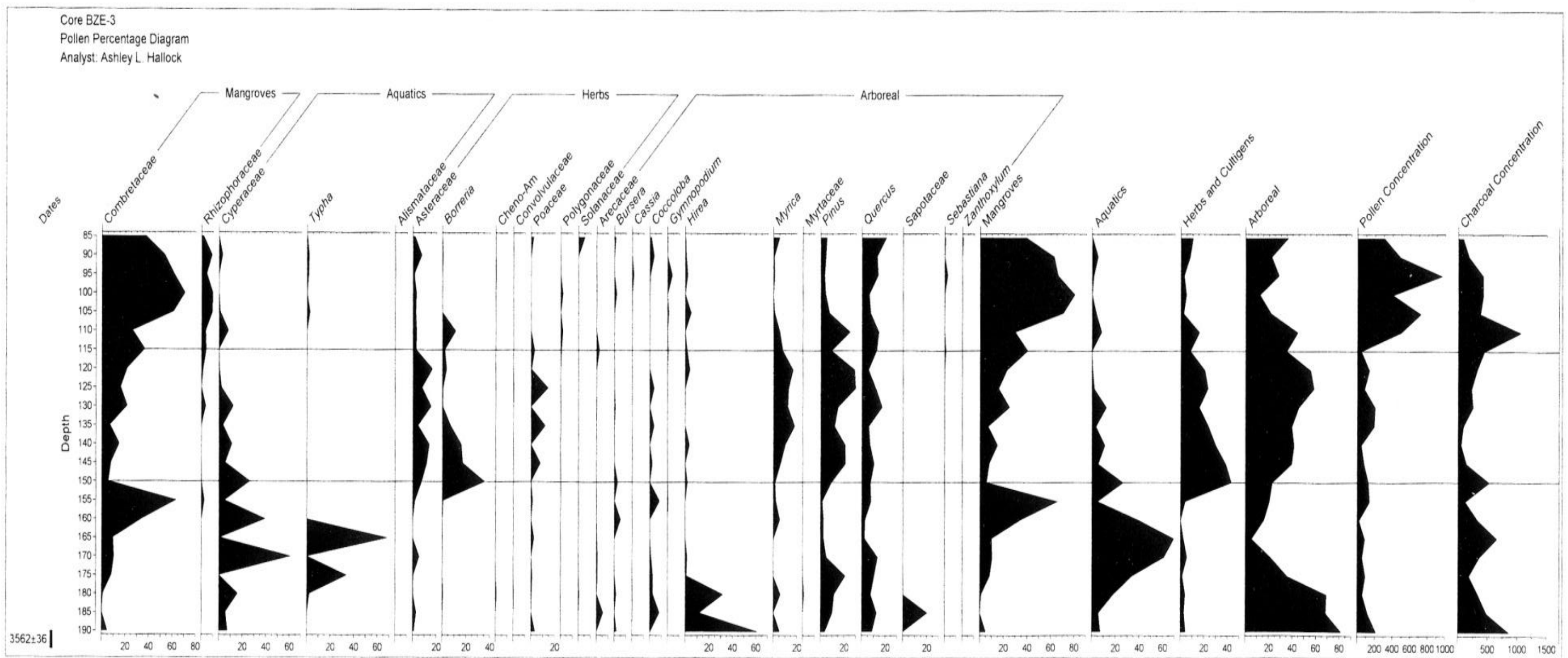

Figure 6. Pollen Percentage Diagram from Core BZE-3 Core 2007.

primarily to delineate the line between a mainly forested wetlands environment and a different environment in the middle zone. The middle zone extends from 150 cm to 115 cm. The middle zone of Core 3 was created to draw attention to the emergence of a new environment, changing from a forested wetlands to a primarily open field environment. The upper zone of the core, occurring from 115 cm to 85 cm differs from the two basal zones as indicated by greater percentages of mangrove pollen. The upper zone also represents a wetlands environment probably surrounded by forest.

A single radiocarbon sample from 195 cm in Core 3 was submitted for analysis (Table 3). A calibrated and corrected date of 3562 +- 36 was obtained, but the technician running the date expressed concerns over possible lab errors, thus the sample was analyzed again, coming out with a statistically identical date of 3518 +/- 35 years, verifying that this date is correct.

Pollen preservation at the base of this core, mostly below 185 cm, was problematic. Here pollen grains were imperfectly preserved and pollen concentration values were fairly low, reflecting this differential preservation. Causes for this are not known, but the sediment was fairly sandy, and it is likely that conditions present at the time were more oxidizing, and reflected a faster sedimentation rate.

The lowest zone of Core 3 is typified by mangrove, aquatic and arboreal pollen types. Herbaceous pollen types are poorly represented in the lowest zone. Combretaceae is found in low percentages from 190 cm to 180 cm. Above 180 cm, these percentages increase greatly, culminating in a spike between 165 cm and 150 cm. Red mangrove pollen is poorly represented in the lowest zone. It is present, however, between 180 cm and 185 cm.

Aquatic-type pollen, such as Cyperaceae and *Typha*, are present in greater amounts in the lowest zone of Core 3, compared to the upper zone of Core 3. Cyperaceae spikes at 180 cm, 170 cm, and 160 cm. The next notable increase occurs at the conclusion of the lowest zone, at 150 cm. *Typha* is found in significant amounts in the lowest zone of Core 3. The percentages of *Typha* increase sharply from 175 cm and 165 cm. Herbaceous pollen types are less prominent than other types in the lowest zone; however, types such as Asteraceae and Poaceae are present. Asteraceae is found at 190 and 170 cm. Poaceae is found in the lowest zone, around 190 cm, and in small amounts throughout the lower zone.

Arboreal pollen types, such as Arecaceae, *Bursera* (gumbolimbo), *Coccoloba*, *Gymnopodium*, *Hirea*, *Myrica*, *Pinus*, *Quercus*, and Sapotaceae (Sapodilla Family) are all found in the lowest zone of Core 3. Arecaceae spikes at 185 cm. *Bursera* increases between 190 cm and 180 cm and again at 160 cm. *Coccoloba* spikes at 185 cm and remains fairly constant throughout the remainder of the lowest zone, until it spikes again at 155 cm. *Gymnopodium* is faintly present at 155 cm. *Hirea* increases dramatically at 190 cm and 180 cm. *Myrica* is present at 190 cm, 180 cm, and 160 cm. *Pinus* is found in large amounts from 185 cm to 175 cm, in the lowest zone of Core 3. *Quercus* is also prominent in the lowest zone of Core 3, found from 190 cm to 165 cm. Following this zone, *Quercus* decreases but then increases again at 155 cm. Sapotaceae, always a rare grain, is well represented at 185 cm, probably reflecting the accidental inclusion of an anther.

The middle zone is typified by an increase in mangroves, aquatic types, herbaceous types, and arboreal type pollen. Combretaceae increases at 135 cm, contributing to the decision to create a third zone. Rhizophoraceae is also present in the middle zone with levels increasing at

130 cm and 140 cm. Cyperaceae is present in varying amounts throughout the middle zone, with small spikes at 140 cm and 130 cm. Following the increase at 130 cm, *Cyperaceae* decreases until 110 cm.

Herbaceous pollen, including Asteraceae, *Borreria* and Poaceae is present in the middle zone. The presence of Asteraceae is inconsistent and pollen grain percentages fluctuate widely. *Borreria* is present to a dramatic degree at the initiation off the middle zone, 150 cm. Followed by this rise, however, *Borreria* decreases. Poaceae is elevated between 145 and 115 cm. The Poaceae percentages decrease after 115 cm, the level chosen to mark the beginning of the final upper zone.

Forest elements are elevated during the middle zone (155-115 cm), including such types as *Bursera*, *Coccoloba*, *Hirea*, *Myrica*, *Pinus*, and *Quercus*. *Bursera* is present at the conclusion of the lower zone of Core 3, which is arbitrarily located at 155 cm. *Bursera* increases at 125 cm, then tapers off. *Coccoloba* increases at 145 cm, 135 cm, and 125 cm. *Hirea* increases at the conclusion of the lower zone, at 150 cm. Following this increase, *Hirea* does not increase again until 135 cm and then again at 120 cm.

The upper zone of Core 3 is dominated by mangrove-type pollen, particularly Combretaceae with lesser amounts of Rhizophoraceae grains.

Aquatic and herbaceous pollen are largely reduced within the upper zone. Increasing amounts of small forest taxa are noted however. The pollen core volume in this zone is exceptionally high, reflecting the near perfect state of the fossil grains.

Charcoal concentration counts were obtained for Core 3 (Appendix A). Charcoal percentages from the sediment core can be used as an indicator of land clearance by humans

(Faegri et al. 1989). Ancient peoples around the world have utilized a “slash and burn” approach to land clearance, a practice that leaves traces in the sediment record. When the trees and vegetation have been burned, the ashes enrich the soil and create a fertile bed for crops. After 7-10 years, typically the soil becomes exhausted and the people who utilized the field must move to new fields. Slash and burn agriculture is widely practiced in tropical climates and so it is not a culturally specific occurrence (Faegri et al. 1989:184).

When utilizing charcoal concentration percentages with a pollen percentage diagram, various patterns become apparent. A continuous pattern of charcoal indicates that humans may have been farming near the area and have cleared land by burning. However, if the charcoal pattern fluctuates significantly then the charcoal may reflect accidental burnings by humans or natural forest fires (Faegri et al. 1989).

In the case of Core 3, charcoal concentration values seem to fluctuate, suggesting human movement in the coring area. The fact that charcoal concentration is not homogenous indicates that humans were burning wood cyclically in order to clear out foliage, likely for nearby agriculture. In the lower zone, charcoal concentration values decline until 170 cm. In the middle zone, charcoal core values decrease when the pollen indicates human distribution is perhaps at its highest level in the area. The upper zone of Core 3 has the highest charcoal concentration values, in this core. This likely reflects increased burning in the area, despite minimal evidence of humans in the coring area.

Much data has been generated from the pollen counts discussed in the results section. Patterns have been discerned and the addition of charcoal data for Core 3 guides the interpretation process. Interpretation of the data and a discussion of how this data pertains to ancient paleoenvironments and the Maya are covered in Chapter six.

Chapter Six: Discussion

This chapter presents an interpretation of the raw data culled from the palynological analysis discussed in Chapter 5. Utilization of the plants found in this region (as indicated by pollen data) are also described. Additionally, a chronology for this area, and its shifting environment, will begin to take shape.

Core 1: Discussion

Core 1 represents a shorter time span than do the other cores, as the compressed sediments extend only from 60 cm to 160 cm below surface (BS) (Figure 4). Core 1 samples indicate that this area was a forested swamp. Pollen percentages are low in this zone, but nonetheless the dominance of types such as Combretaceae, *Coccoloba*, Moraceae and fern spores support the conclusion that the area where Core 1 was taken was, at one point, forested.

The results from the upper zone of Core 1, from 80 cm to 60 cm, seem to indicate that this forested area transitioned into a freshwater aquatic area. It has been suggested that the water table may have risen at one point (Jones and Hallock 2007). The presence of pollen types, such as *Nymphea*, supports the conclusion that this environment, received an influx of freshwater. In addition, both sedge and *Myrica* are also found in greater percentages in the upper zone of Core 1. Both pollen types prefer aquatic moist environments. All three types were likely present locally, and are currently dominant taxons in the core location area.

Core 2: Discussion

Core 2 is a longer sediment core than Core 1, and therefore likely represents a longer span of time (Figure 5). Alternately, Core 1 could represent a different depositional rate of sediments. The total sediment length collected was between 90 cm to 235 cm, and of the total sediment collected, twenty-two sediment samples were taken. Only pollen samples collected above 180 cm were analyzed for use in this study due to the scarcity of pollen near the basal section of the core (Jones and Hallock 2007). A single radiocarbon date from Core 2 was obtained, from 140 cm and dated to 4435 +/- 37 calibrated years B.P., indicating that this core spans the entire Maya era.

The bottom zone of Core 2 extends from 175 cm to 165 cm. Pollen types found in this zone are indicative of an open aquatic or wetlands environment, surrounded by a swampy forested area. Poaceae and sedge pollen support the proposition that this area was partially cleared, while the concentration of *Nymphea*, *Typha*, and to a larger extent, Cyperaceae, indicates that this site was an open wetlands environment. The presence of forest is supported by arboreal pollen types, such as Moraceae, *Coccoloba*, Arecaceae, and *Quercus*.

The next zone extends from 165 cm to 135 cm. This zone illustrates a different environment in this section. The area appears to have been cleared, likely by humans, and pollen percentages indicate the area now resembles an open freshwater wetland. There is an increase in *Nymphea* and *Myrica* pollen types, both of which prefer freshwater environments (Jones and Hallock 2007). While Poaceae, or grass-type pollen decreases, sedges increases, lending credence to the interpretation that this area was still an open environment. Further indication of land clearance, possibly for cultivation by humans, exists in the decrease in breadnut, or Moraceae, at 150 cm, and an increase in weedy-type pollen such as Cheno-Am (field weed) at 155 cm. (Jones and Hallock 2007). It is near the top of this zone, at 140 cm BS, that the radiocarbon date of 4435 B.P. was obtained.

The upper zone extends from 135 cm to 90 cm, the termination of Core 2. This environment would have post-dated 4435 B.P. The environment in the area at this time became more saline, and continued to stay open as opposed to densely forested. Evidence for increased salinity includes increased percentages of both white and red mangrove. Freshwater-loving plants as well as herbs declined as the salinity in the area apparently increased. Freshwater pollen types and herbs exhibiting dramatic reductions in the upper zone of Core 2 include *Myrica*, *Nymphea*, *Typha*, Poaceae, and Cheno-Am. The presence of a forested environment is implied by the increase in *Pinus* and the consistent presence of *Quercus*. However, both types are arboreal and the pollen could have come by wind from some distance.

Taken together, all three zones indicate that the area where Core 2 was collected could have, after 4435 B.P., been an area for salt production. It appears that the area was natural open wetlands, near a swampy forested area. Sometime before 4435 B.P., humans moved into the area. When they moved into the area they eliminated Ramon (Moraceae) plants and possibly cultivated the area. Although no cultigens were found in Core 2, the presence of weeds frequently associated with human crops, such as Cheno-Am, suggests that humans may have been practicing some form of horticulture and/or agriculture nearby.

After 4435 B.P., this wetlands region ceased to be freshwater, as the dominance of Combretaceae and Rhizophoraceae in the upper zone of Core 2 illustrates. Due to the influx of saltwater through coastal subsidence or a rising water table, humans likely would have ceased any local cultivation. A logical course of action might have been to take advantage of the saline-saturated land and produce salt. Settlement would have been relocated to a suitable area, with accessibility to the brine-saturated area.

Core 3: Discussion

The area where Core 3 was taken appears to have undergone changes similar to those in the area represented by Core 2 (Figure 6). Core 3 contains sediments measuring from 85 cm to 260 cm. However, only sediment from above 190 cm BS was utilized, as only this section appeared to have well preserved pollen. From sediment core 3, thirty samples were analyzed (Jones and Hallock 2007). The lowest zone extends from 190 cm to 150 cm. A radiocarbon date was taken at 195 cm BS, establishing an origin date for the core at 3562 +/-36 calibrated years B.P. and 3518 +/- 35 calibrated years B.P.

The environment represented in the lowest zone appears to have been a swampy freshwater forest. Though mangroves are present, only Combretaceae, or white mangrove, is represented in the lower zone. White mangrove is a species that prefers freshwater environments, but will tolerate a limited amount of salt. The presence of Cyperaceae and *Typha* attest to the area's possible inundation with water or a location near water at this time. They are both found in the lower zone in a large concentration. The presence of *Quercus* and *Pinus* probably reflects the openness of the area as pollen from these taxons often traveled some distance from the source. Other freshwater-loving plants, such as *Myrica*, are also represented in the lower zone. Charcoal spikes three times after 3562 +/- 36 years B.P. All three increases seem fairly consistent and not erratic, perhaps indicating the cyclic movement of people into the area or periodic forest clearance nearby due to slash and burn agriculture. The increases occur from 190 cm to 175 cm, from 175 cm to 165 cm, and once again at 150 cm (Figure 6).

The middle zone of Core 3, which extends from 150 cm to 115 cm, appears to have been an environment in transition. The presence of Combretaceae decreases, as do aquatic-type pollen. Arboreal pollen remains consistent and, most interestingly, herbaceous pollen increases. It appears that humans could have been moving into the area at this time. The Combretaceae may, in fact, be *Bucida*, or bullet tree, and not mangrove. In either case, if humans were moving into the area, for settlement or other reasons, they may have cleared local vegetation such as Combretaceae. This practice of clearing is supported by the fact that Asteraceae, *Borreria*, Poaceae, and *Coccoloba* also increased at this time.

Sedge, or Cyperaceae, decreases throughout the middle zone. The presence of sedge can be indicative of a human presence, as it is often present after humans clear land for cultivation. Though sedge does decline, it does not disappear entirely. *Coccoloba,* present in the middle of the zone, produces edible fruit that humans may have exploited. The presence of grass pollen indicates that forested areas might have been cleared for habitation or other activities. In addition, the Asteraceae Family's presence may indicate that humans may have been exploiting some of its more edible species, or more likely, represents weeds associated with a clearing and agriculture. The presence of *Borreria* also indicates humans were in the area at this time and that they were clearing foliage, perhaps for cultivation. The presence of *Pinus* and *Quercus* indicate that the area was likely to have been more open than in zone 3.

Toward the top of the middle zone, Rhizophoraceae pollen increases, possibly signaling an influx of salinity into the environment via coastal subsidence, or a rising water table. Interestingly, charcoal concentrations actually decline in the middle zone of Core 3, increasing only at 135 cm. Thus, humans may not have been aggressively burning foliage to clear the area until this date. An alternative explanation might be that charcoal influxes through slash and burn activities are minimal compared to the quantities produced through industrial salt production.

The upper zone extends from 115 cm to 85 cm, and once again, the data indicates that the environment changed. Rhizophoraceae and Combretaceae (both mangrove-type pollen) increase significantly. Aquatic freshwater pollen decreases, as do herbaceous pollen types. Arboreal-type pollen largely remains at consistent levels throughout Core 3, with the exception of *Myrica*. Taken together, the data indicates that as the environment transitioned from a freshwater one to a saline environment humans may have ceased use of it for habitation or cultivation. This environmental change is indicated by the dramatic increase in both Combretaceae and Rhizophoraceae pollen. Red mangrove prefers saline environments and, as the area transitioned into a brackish swamp-like environment, other mangrove types, such as Combretaceae, may have also thrived. The absence of freshwater types such as *Typha* (or cattail) and a decrease in the *Myrica* percentage also supports the assertion that this area was evolving from a freshwater environ to a saline one.

In addition, the decline of sedge, grass, palm (Arecaceae), and *Coccoloba*, indicates that humans may not have been using this area for food or habitation at this point. These plants are weedy opportunists that arise when humans clear areas of trees and other foliage. *Sebastiana*, or white poisonwood, also appears in the upper zone of Core 3. If humans were growing crops in this area, this flora could have grown nearby, but not in the precise location from where the cores were taken. The forest still remained near the coring location, however, likely occurring on higher areas, or reflected by pollen such as *Pinus*, *Quercus*, *Gymnopodium* (Bastard Logwood), and *Cassia*. Charcoal concentrations increase noticeably in the upper zone, especially at 110 cm.

It appears that this area was once, like the area represented by Core 2, a forested freshwater environment. However, at some point after 3562 +/- 36 years B.P., humans moved into the area and began to exploit local vegetation. There is no evidence for cultigens in this core. However, the presence of weedy type pollen seems to indicate that forest clearance was occurring. Additionally, charcoal fluctuates repeatedly throughout zone 3, indicating nearby slash and burn agriculture. Pollen data in zone 2, or the middle zone, indicates that humans continued to clear the land, as disturbance vegetation is present in the sample. It is likely that agriculture was still being practiced near the coring location. At some point following this influx of humans into the area, coastal subsidence occurred and the water table rose. This change in the water table increased salinity in the area, making the area unsuitable for human habitation or cultivation, but favorable for salt production.

The Utility of Plants

The idea that humans were present throughout the period represented in Cores 2 and 3 is supported by the appearance of such pollen types as *Bursera*, palm, Breadnut, and *Cecropia* *(*among others). Although pollen is rarely identifiable at the species level, palynologists can still make informed assumptions as to the likelihood of the presence of certain species. These assumptions employ the indicator species method which is most useful when investigating habitation sites or those with an anthropogenic presence (Faegri et al. 1989). By taking into account local modern vegetation, as well as other environmental indications, much can be reasonably postulated about a site (Faegri et al. 1989).

However, caveats exist and must be factored into the interpretation process. Such factors include the previously mentioned problem of identifying pollen to the species level, overcompensating for pollen which is dominant in the assemblage (i.e., those with wind or water as a vector as opposed to species that utilize insects as a vector), and the absence of an equivalent ancient comparison of vegetation types (Faegri et al. 1989). However, if these problems are kept in mind and the analyst reasonably tries to be aware of them, an interpretation is possible.

A study of mangrove peat shoot/root ratio reveals that, "localized subsidence or ...uplifting…may later alter swamp drainage patterns," thus causing peat accumulation by changing the "geological setting of the swamp" and possibly, in this case, lead to an influx of saline-rich water (Covington 1988: 58). The changing environment may have hindered the growth of cultigens or habitation in the region. The dramatic increase in charcoal at this point may indicate that humans were now producing salt in the area using the *sal cocida* method.

Taking all of the above data, cultural artifacts, and environmental requirements into account, it is reasonable to assert that there was a human presence in the area represented by Cores 2 and 3, after 3562 B.P. Core 1 is not considered here as it is a short core, and although pollen from this core may assist in the interpretation of local vegetation, it does not add to the data used in the interpretation of human activities in the area.

Local vegetation, such as *Cecropia*, or Trumpet Tree, grows near banks of water or in tropical wet/dry forests (Schlesinger 2001). Most importantly, however, this species often grows in areas where vegetation has been disturbed, such as in habitation sites or areas cleared for various activities by humans (Schlesinger 2001). *Cecropia* is found between 165 cm and 135 cm in Core 2. No *Cecropia* was found in Core 3. However, the depth at which the most disturbance vegetation is found (between 150 cm and 115 cm in Core 3), and thus when humans were likely within the area, coincides with the depth at which *Cecropia* is found in Core 2. The leaves of *Cecropia* have been used in the culture of the Maya to lower fevers by bathing the head of ill persons and to treat stomach swelling. In addition, the *itz*, or sap of *Cecropia*, has been used to alleviate skin ulcers, smother botfly larvae, and the hollow trunk is used for waterpipes (Atram and Ek 1999).

Bursera (here likely *Bursera simaruba* or Gumbo Limbo), is found in tropical environments, but it is also commonly found in ethnohistorically documented Maya gardens (Schlesinger 2001). This species has been used for medicine, fodder, building materials, incense, fuel, and food (Nations and Nigh 1980; Schlesinger 2001). For example, the bark has been used to produce a soothing balm for sores, insect bites, burns, and poisonwood (Schlesinger 2001). The leaves of *Bursera simaruba* have been used to make a tea employed as a cure for dysentery and inflamed bladder (Atran and Ek 1999). Once again, *Bursera* is found within the zones of Core 2 and 3-representing times of likely human presence. In Core 2, this pollen is found between 165 cm and 135 cm. In Core 3, this pollen is found periodically throughout the core, especially between 190 cm and 175 cm, 165 and 145 cm, and 105 and 90 cm.

Arecaceae, or palm, can be burned for salt as mentioned in chapter three, but the Cohune palm (*Attalea*) has also been used for oil, fuel, thatch, and food (hearts of palm) (Schlesinger 2001). Pollen from Arecaceae, identifiable usually only to the family level, might have provided such products for humans in the area. Arecaceae is found throughout both Cores 2 and 3, but not in significant percentages. In Core 2, Arecaceae is found between 175 cm and 165 cm (prior to 4435 B.P.), and between 105 cm and 90 cm. In Core 3 Arecaceae is found between 190 and 165 cm and between 120 and 110 cm. Arecaceae is a common component of most tropical forests, and therefore it is not surprising to find its pollen in both cores.

Humans in the area likely discovered this species and utilized it while in the area represented by the cores. The percentages of Arecaceae vary throughout Cores 2 and 3, a foreseeable result because it is an arboreal pollen type, and thus its influx rate likely varied throughout the years. Thus, even though this pollen is not found in as great a presence in Core 2 as compared to Core 3 (especially in the zone representing a time when humans likely occupied the area), there is no reason to think that humans did not have access to this species or utilize it.

Moraceae is also found in Core 2. The pollen from this family is largely from the plant *Brosimum alicastrum*, or breadnut. Breadnut is a nutritious food, with a high protein and nutrient content, frequently found growing in tropical forests (Schlesinger 2001). A single tree can yield up to 12,000 fruits several times a year, and wild *Ramon* trees can produce 1,763 kg of food per hectare. In comparison, maize (*Zea mays*) can produce only 324 kg of food per hectare (Coelho et al. 1976; Puleston 1982:353). There has been much scholarly debate about the relative importance of breadnut as a food source in comparison to maize for the Maya. Breadnut can be made into a flour and a mush as well as used to treat infected teeth (Schlesinger 2001).

Breadnut-type pollen is usually rare in these cores and elsewhere in Belize is dramatically reduced at the time of forest clearing and incipient agriculture (Jones 1994). This argues strongly that breadnut was not a food favored by the Maya.

Moraceae is present in Core 2, but not in Core 3. In Core 2, this species is found throughout the core, but especially between 175 cm and 150 cm. Likely when humans came into the area, they eliminated much of this plant, though some of it may have been maintained for the useful products it provided. Another factor to consider is that *Ramon* often grows in disturbance areas. Indeed, this plant is well known for growing profusely around Maya ruins in the present day. It is likely that the Maya eliminated the majority of breadnut, and that after the expansive construction of city centers and temples ceased, this plant resumed its growth aggressively, in the disturbed soil.

Despite this debate, the absence of Moraceae from Core 3 but presence in a large percentage in Core 2 remains puzzling. The vicinity near Core 3 likely reflects an environment favorable for human activities, while the Core 2 area represents an area somewhat removed from human habitation. This might account for the presence of the non-economic breadnut at core locality 2 during Maya times.

Myrtaceae, found sparingly in Core 3, but found throughout Core 2 in reasonable percentages, could also have been useful to the Maya. Myrtaceae pollen could represent *canxanche*, *guayabillo*, guava, or allspice depending on the species. Myrtaceae pollen is difficult to identify below the family level. Uses for this family of plants were varied. The leaves of the *guayabillo* could be employed as a press to cure headaches and bad winds (luck) (Atran and Ek 1999). Guava was consumed as a food, made into a balm for insect bites, and as a treatment for fungal infections. And the leaves and the sap were used to alleviate colic and menstrual cramps; a tea infusion derived from the leaves was employed to cure colic, while a salve from the boiled sap boiled was useful for menstrual cramps (allspice). Myrtaceae is found throughout Core 2, gradually increasing after 160 cm. It increases the most toward the top or surface level of the core--at 95 cm. In Core 3, it is found sparingly near the bottom-around 175 cm. Local peoples in the area likely utilized members of the Myrtaceae family, which they found among other indigenous flora in the area, as inferred from the pollen samples.

Asteraceae, which is found in Core 3, also had some uses for humans. Further, the presence of this species can also indicate land clearance for habitation sites or other activities by humans. The Asteraceae found during this study could be wormwood, *quebrahacha*, bitterwood, camphor weed, *hoja de garrapata*, or garden marigold, or many others (Atran and Ek 1999). Uses for Asteraceae include a wide range of medicinal applications. Wormwood could be steeped to create a tea for colic and diabetes, *Quebrahacha* was employed as a medicine for gallstones. Bitterwood found applications as an insect repellent, antibacterial ointment, and in a tea for malaria and for snakebite. Camphor weed became a balm used for aches, fevers, rashes, arthritis, and body ache. *Hoja de garrapata* was used to alleviate the unsavory results of skin lesions and gonorrhea. Garden marigold had a variety of uses: To prevent evil eye, to relieve stomach ailments, and to treat children's ailments such as shock, fever, fright, and loss of appetite (Atran and Ek 1999).

Asteraceae found in Core 3 is primarily within the zone which has likely human habitation, between 155 cm and 115 cm. It is found throughout the core, thus likely represents weedy rather than economic taxons. After they ceased using this area for habitation or other activities, Asteraceae levels returned to those levels found prior to any human habitation. It is interesting that Asteraceae is not found in Core 2, but its absence could simply be the result of an unfavorable location; perhaps Asteraceae just did not grow in that particular area.

The presence of Cheno-Am, while indicating the clearance of foliage and other forest structures by humans, also provides some clues as to what else humans were exploiting or utilizing in the area. Both Cores 2 and 3 have Cheno-Am concentrations at some point within the core. Core 2 has a noticeable amount of this pollen between 165 cm and 130 cm, within the zone of likely human activity or occupation. The Cheno-Am found within the cores could be goose foot or wormseed or any number of other weeds. The Itza Maya have used both of these varieties of Cheno-Am as a condiment, as a poultice for wounds, as medicinal material that they added to boiling water and used to bathe infections, and, when combined with garlic, as a cure for intestinal parasites (Atran and Ek 1999).

Combretaceae, here interpreted as white mangrove or bullet tree, is found in both Cores 2 and 3. It has been used by the Itza Maya to enhance the natural beauty of riverbanks, and more practically, by soaking the *pach* or bark to treat skin eruptions and to cure hides (Atran and Ek 1999). Combretaceae, along with Rhizophoraceae, is understood here as an indication of increasing salinity in the area. However, there is no reason to believe that the Maya did not utilize the *pach* or bark of bullet tree or white mangrove, once its usefulness had become apparent. Combretaceae is found throughout Core 2, but it dramatically increases at 130 cm. Following this initial spike, the quantity of this pollen decreases slightly, but never returns to the meager percentage concentration values exhibited prior to 135 cm.

Combretaceae is also found throughout Core 3. However, unlike the findings in Core 2, the species shows two increases. The first increase occurs prior to a definite human presence, at 155 cm. The second increase occurs at 100 cm after the human presence is less obvious. It could be that Combretaceae levels decreased as humans came into the area and utilized its bark and/or wood for structures, fires, or medicinal purposes. However, once the area became more saline and Rhizophoraceae (red mangrove) became prominent, it seems likely that the Combretaceae population increased as well.

Cyperaceae, which in this case could be *zacata arana*, tubux, or *navajuela*, is found throughout Cores 2 and 3. The zacate arana root could be used for ornamentation and as a ward against bad winds. *Navajuela* was employed as a knife, utilizing the leaf edge to cut flesh, presumably of game (Atram and Ek 1999). Cyperaceae, an aquatic-type pollen, is also an indication of a wetlands environment and is found in both cores. It is found consistently throughout Core 2, decreasing around 135 cm and increasing again toward the end of the core. In Core 3, it increases dramatically at 170 cm, 160 cm, and 150 cm. Fluctuations in Cyperaceae levels may indicate natural alterations during the lifespan of the population.

A decrease occurs toward the top of the core, between 120 cm and 85 cm. This decrease could indicate that Cyperaceae levels were decreasing, either in actual plant population, or pollen distributed, due to the influx of saline water. The quantity of pollen in Core 2 also decreases, in this case- between 135 cm and 100 cm, although never decreasing to the low levels found in Core 3. Perhaps the observed reduction in Cyperaceae was caused by overexploitation or human disturbance near the Core 3 collection area or perhaps the area around Core 2 was less saline, and therefore more favorable for sedge growth.

Fabaceae, or the legume family, is found in Core 2 but not Core 3. The Fabaceae pollen found in Core 2 could represent any number of taxons. For example, the presence of Fabaceae could be indicative of bastard logwood, hesmo, ant-acacia, stinking toe, *canlol*, yama bush, chinchin, locust tree, wild tamarind, or dogwood (Atram and Ek 1999). This list is incomplete, and, thus, the list of uses for this diverse family is also incomplete. Still, this abbreviated catalog is impressive. Ant-acacia could be used for necklaces; (*frijol abono*) was employed as a natural nitrogen-fixing fertilizer for milpas; senna or yama bush was boiled whole and used for bathing to cure sleepless children and evil winds (bad luck); *chipilin* leaves could be found in soups and tamales, or eaten to treat hangovers; devil's ear found use in the construction of furniture and canoes, and logwood bush bark was employed as cordage for thatch (Atram and Ek 1999).

Poaceae (Grass Family) is noted in both Cores 2 and 3. Grass pollen is rarely identifiable below the family level, thus specific identification is not possible. Although grasses are not often credited with utility as a food or medicine, they might have offered some use to the Maya. The northern Itza Maya have used grasses for both medicine and as animal fodder. Greater percentages of Poaceae are found near the bottom of the Core 2, from 175 cm to 165 cm. After this spike, Poaceae levels decline, but are nonetheless consistent throughout the rest of Core 2.

The presence of Poaceae in Core 3 is much more sporadic than in Core 2. It is consistently present at a low percentage in the lower zone, from 190 cm to 150 cm. In the middle zone Poaceae spikes several times--at 145 cm, 135 cm, and 125 cm. Near the top of the core, Poaceae decreases significantly. Based on its frequency throughout both cores Poaceae appears to have grown in the area as a result of land clearance for human activity. The presence of Poaceae especially lends credence to human land clearance within the area represented by

Core 3 due to its higher percentage.   However, the percentage of Poaceae may be higher in the lower zone of Core 2 because its location in a natural open area. Once people moved into the area and began burning and clearing the area in other ways, the levels of Poaceae decreased.

Polygonaceae, found in Core 3 from 120 cm to 100 cm, might have included *carretillo, palo de tomatillo*, grape tree, and purslane. Uses for Polygonaceae then could have included nourishment from the sap of *palo de tomatillo*, or as a building material (Atram and Ek 1999). That Polygonaceae is not also found in Core 2 is surprising, but perhaps the area where the sample was taken was less conducive for its growth.

Sapotaceae is also found in both Cores 2 and 3, and would have been a very useful plant. Sapotaceae can indicate *zapotes* (star apple), *chicle*, *zapote* or *sapote mam.* All of these species have edible fruits, and might have also been utilized as a chewing gum or to produce a tea for diarrhea. This family also has economically important wood, or can be mixed in honey or tea to aid digestion, and the bark could have been used to make a solution to cure skin rashes (Atram and Ek 1999). Sapotaceae is found mainly in the lower zone of Core 3, between 190 cm and 180 cm and in found in low concentrations throughout Core 2. This dispersion pattern of pollen suggests that it was locally found, but not necessarily cultivated.

Environmental Interpretation of Cores 1, 2, and 3

If the Maya were exploiting local plants, the means and nature of that exploitation would follow certain patterns and an understanding of those patterns grounds this interpretation. Although the Maya did practice sedentary agriculture after the domestication of maize and other relevant crops, they also practiced subsistence traditions such as hunting and gathering, fishing, and semi-sedentary horticulture. The Maya also cultivated substantial home gardens as well as locally controlled orchards (Lange 1971). Although much of the evidence for these practices is historic, researchers have made ethnographic comparisons, such as the work mentioned previously involving the uses of plants by the northern Itza Maya (Atran and Ek 1999). One study by Netting compared the Maya to the Ibo of Nigeria (Netting 1977), the rationale being that both the Maya and the Ibo inhabit similar environments. In this study, because the Ibo utilize orchard resources when their fields lay fallow, Netting (1977) concluded that orchard cultivation would have been possible for the Maya as well.

Practices among contemporary Maya, such as the Lacandon, may also offer some means of comparison to the ancient Maya. Many of the same plants that grew in ancient Mesoamerica in the Maya region also grow today and are utilized by native peoples. The Lacandon Maya are located in the Selva Lacandona, which is near the Jatate-Usumacinta River basin in eastern Chiapas, Mexico (Nations and Nigh 1980). They are descendents of the Yucatec-speaking Maya, who originally came from Guatemala (Nations and Nigh 1980). The Lacandons employ many subsistence methods, primarily based on milpa agriculture (Nations and Nigh 1980). When milpas are used, maize is planted with other crops which do not prohibit the growth of the primary crop, maize (Nations and Nigh 1980). The Lacandon have advanced knowledge of the ecosystem in which they live, and know how to exploit it in a productive way. Plants grown with maize include squash, sweet potatoes, yams, *jicama*, garlic, chilies, tomatoes, and sugar cane (Nations and Nigh 1980). However, when the milpas lay barren during the fallow period, the Lacandon grow orchards, which they refer to as *acahual* (Nations and Nigh 1980). Not only does the *acahual* provide food when maize is scarce, but it also provides grazing ground for wild game (Nations and Nigh 1980).

Core 3 shows ample evidence of nearby activity indicating that settlement and likely agriculture was taking place in the vicinity. Core 2, on the other hand, represents a more remote location, removed from areas of human activity. The area where Core 3 was taken may have been chosen by the Maya because it was a favorable location for an orchard or garden. If the clearing indicated in the pollen percentage diagrams was natural, this location might also have been an advantageous place to hunt game or collect plants. Plants such as *Bursera,* Arecaceae, and *Coccoloba* may indicate that some type of horticulture was practiced at this site.

The presence of humans in the area where this core was collected has been established as well as the proposition that they were manipulating the environment. However, a brief discussion concerning why and how the environment changed to make salt production feasible and attractive is necessary. The primary factor in this change is a well-established difference in the rise of sea levels between the northern and southern coasts of Belize (McKillop 2002). In Northern Belize, sea level rose between 6000 and 4000 B.C. After this period of increasing sea level rise, the water dropped between 3000 and 1000 B.C. However, after 1000 B.C., the water table rose again, this time discouraging farmers who now had flooded fields in comparison to the lush organic rich fields during the last period that the water table rose (Pohl et al. 1996).

Gradually, sea level rose through eustastic processes, or coastal subsidence. This process also led to a rise in peat accumulation and the continual accumulation of organic sediments along many areas of the Belizean coast. The areas discussed in this study lie along the modern central Belizean coast and, thus, are subject to this same coastal subsidence process. Between 6000 and

5000 B.C., in Northern Belize, the sea level rose. Elsewhere in Belize, the northern barrier lagoons were 4.9 meters below the present level, at approximately 4150 B.C. (Mazzullo et al. 1992:598), and this likely has dramatic ramifications for human settlement in the area.

At Ambergis Cay, in northern Belize, sea level reportedly increased several times before present. Sea level rose up to 1 meter below present at 1550 B.C. and up to 30 cm below present at 50 B.C., and 50 B.C., respectively (Mazzullo and Reid 1988; McKillop 2002). These dates correspond with sea level data obtained from studies done at Cob, Douglas, Pulltrouser, and Cobweb Swamps in Northern Belize (Pohl et al. 1996). Sea level apparently stabilized and then declined from 3000 to 1000 B.C. Following this period, sea level increased again at 1000 B.C. (Pohl et al. 1996). However, by A.D. 950, sea level had risen to its present state (Mazzullo et al. 1988).

As mentioned previously, the rate and timing of water table rise does differ between the southern and northern coasts of Belize. And because the southern and northern coasts are distinctly different regions and support different ecosystems, in conjunction with separate timing in the rise of sea level, these environments should be treated separately. Along the southern Belizean barrier lagoons and coasts, sea level has risen as well. However, the rate of sedimentation was gradual, occurring from 5050 B.C. to 2050 B.C. (McKillop 2002). The earliest flooding of the southern barrier lagoon has been dated to between 7050 B.C. and 5050 B.C. (Mazzullo et al. 1992; McKillop 2002).

The picture now emerging indicates that the area where the samples were taken was once wild forest and wetlands, which had undergone forest fires of natural human origin. As people moved into the area, perhaps moving toward the coast to exploit marine resources, they stopped to exploit local resources. Perhaps while building a nearby settlement, or when using this area as a seasonal hunting or gathering location, the area was modified. Areas that were already natural clearings were perhaps expanded to accommodate more activity. The nature of this activity likely involved collecting and/or cultivating local plants and hunting local game. The area was also freshwater wetlands at this time, as inferred by Core 1, Zone 2, Core 2, Zone 2, and Core 3, Zone 1, and humans may have fished or collected other aquatic resources. Archaeological findings from elsewhere in Belize, suggests that hunting and gathering was still a significant practice at this time.

It appears that after episodic burnings of local vegetation, either to encourage local game management in disturbed forests or to clear space for agriculture, the fires become less common. This pattern is apparent in Core 3, Zone 1 and Zone 2. At the time when humans first came into this area it is possible that wild non-desirable plants were no longer encroaching upon the space needed for human activity as frequently as in the past. Based on the lack of evidence plant cultivation, such as maize (*Zea mays*), humans likely did not build significant habitation structures in the area. However, the invisibility of these crops does not rule out the possibility that humans settled in this area and farmed intensively in this area. It is perhaps possible that the soil was not conducive to agriculture, and so local groups traded with nearby settlements for food provisions when needed. Or, perhaps, habitation was prompted by the variety of useful medicinal plants that inhabitants could exploit for local use and/or trade.

As the land subsided during probable Classic to Late Classic times, peats continued to build up in the area and the environment became more saline. Though humans may have ceased horticultural practices and moved away from the area, charcoal evidence suggests that they stayed near or within the area in order to practice salt production. Therefore, it seems logical that their habitation site was within walking distance of the salt production area.

The charcoal found in Core 3 would have been produced when using the *sal cocida* method of salt production, as evidenced by the charcoal concentration values that occur during the zones with increased numbers of saline tolerant plants. However, the presence of charcoal does not mean that no other method of salt production was practiced. There is no reason to believe that humans would not have used the method best suited for the area and resources at this time. Therefore, the *sal solar* method might have also been employed. As discussed in chapter three, the type of salt production used by the Maya throughout the lowlands has often been a point of conflict between scholars (Andrews 1983; McKillop 2002).

Having summarized the human-use pattern, natural vegetation, and chronology of the cores taken near Hattieville, Belize, the next chapter, chapter seven, can present the implications of these findings as they concern the original question posed in this thesis. This final chapter conclusively addresses the main question of this thesis: Was the Maya Lowlands, specifically central Belize, a region of salt production during the Maya Preclassic-Terminal Classic? The final chapter also offers some conclusions about the paleoenvironment, its appearance and evolution, during these time periods.

Sediment Cores and the Maya

Sediment cores analyzed for this study shed a great deal of light on past activities attributable to the Maya. Both Cores 2 and 3 span the period when the Maya lived in this area, and presumably all activities reflected in these cores represent Maya efforts. It is important to put these events into a chronological framework, although much speculation is required in the absence of radiocarbon dates.

The basal two zones from Core 2 reflect an open savannah shifting to a freshwater marshy environment. These events take place prior to 4400 B.P., effectively before the establishment of the Maya in this region. The upper zone of Core 2 shows the area becoming more saline, probably due to rising sea levels and the subsequent rise in the local water table. It is during this upper zone that the entire span of Maya cultural development would have taken place. The fact that no local human activity is reflected in the core attests to the unfavorable environment near the coring locality.

Core 3, however, is more enlightening in terms of human activity, although this core lacks good chronological control. The basal zone shows an open freshwater marshy area, surrounded by forests. Sustained cycles of particulate carbon input show that people were practicing significant burning in the area, but were somewhat removed from the actual coring locality. These events were taking place after 3562 B.P., during middle Pre-Classic and later times. At around 150 cm BS in the core, we see strong circumstantial evidence that people were practicing agriculture in the area, as reflected by elevated percentages of field weeds. This occupation of the area would have occurred during the Late Pre-Classic through Classic times, and probably represents household slash and burn farming. Low percentages of red mangrove pollen suggest this area was still essentially a freshwater environment. Rising percentages of red mangrove pollen toward the top of this middle zone, however, show that salt water was beginning to intrude into the area, making this area less useful for farming. These events unfortunately are not yet dated. As the area became more saline, above 120 cm, we see further increases in both red and white mangroves, and a dramatic decrease in field weeds, including grasses, Asteraceae and *Borreria*. Increased salinity had made the fields unusable for agriculture. Significant increases in particulate charcoal, though, hint that the area was now being used for salt production. Again undated at this point, this period may well represent Late or Terminal Classic times as is likely reflected in the archaeology of the nearby salt production of Wits Cah Ak'al (or whatever).

Chapter Seven: Conclusion

This study was initiated in order to answer two large questions: (1) were the Maya Lowlands, specifically central Belize, utilized as a region for salt production during the Maya Preclassic-Terminal Classic, and (2) what was the paleoenvironment like during these time periods? These questions have relevancy because little is known about how the Preclassic and Classic era Lowland Maya obtained their salt. Did they trade with people from other areas, such as the Yucatan, or other regions? Or perhaps they produced the salt themselves. It is also a worthwhile question because if this region was conducive to salt production and if salt was actually produced in the area, at least a portion of the paleoenvironment of central Belize will be known.

Through a detailed analysis of fossil pollen from these cores, we now have a fairly clear picture of the region's past environment and the appearance of humans in these landscapes. In addition, charcoal concentration values for Core 3, as well as radiocarbon dates for Cores 2 and 3, have also resulted in data that fills gaps in our knowledge of this time and place. What is already known from past archaeological work near Hattieville, Belize, is that the area where the samples were taken is dotted with many *tlateles*, or salt refuse mounds. This earlier archaeological work in the area has been conducted mainly under the auspices of the Xibun Archaeological Research Project (XARP).

Salt refuse mounds interspersed with other mounds that make up part of the Wits Cah Ak'al site are located near the Western Highway, in Belize (Murata 2008). These mounds, numbering 28 in total, contain many refuse sherds produced through the *sal cocida* method of salt production (chapter three). However, only mounds dating to the Late Classic and Terminal Classic periods actually contained briquetage, or *sal cocida*, refuse sherds (Murata 2008). Based on this distribution of briquetage, the consensus of the research team is that salt production likely occurred prior to the Late Classic in this area, but that the pre-Maya or Maya probably utilized another method, such as *sal solar*; there is no archaeological evidence to the contrary. Thus, the decision was made to sample sediments for pollen near the location of the 28 mounds with the hope that more information would be found to confirm that earlier salt production occurred or at least evidence of the likelihood that it occurred.

Of paramount importance is the question of ground water salinity. When did the water in the site area become saline, indicating the earliest possible time of salt production? That is, would salt production have been feasible prior to the Late Classic? Chemical tests on sediment have determined that the soil in the area is currently brackish, and a survey of the area has revealed several local salt springs (Murata 2008). The modern water table at the site is only 15-20 cm below ground level in some areas, and tests of the water revealed that it is of nearly the same salinity as those local salt springs (Murata 2008).

Core 1 is probably fairly young and its results do not offer any hints as to when this area became brackish. Cores 2 and 3, however, do offer insights into past salt levels in the ground water. Near the top of both cores, the percentage values for Rhizophoraceae (red mangrove) and Combretaceae (bullet tree or white mangrove) increase dramatically. Both types of pollen are indicative of increased salinity in the area as mangroves thrive in coastal and inland brackish marshes. An increase in mangrove percentages would indicate that the area had become brackish enough to support an increase in these taxons. In Core 2, this increase in mangrove pollen occurs between 135 cm and 90 cm, sometime around 4400 B.P. Results for Core 3 show similar mangrove-type pollen increases near the top of the core, around 115 cm. A radiocarbon date for this event is sorely needed, though it likely dates to a Classic or later time period. One irregularity in pollen spikes was found in this core. Within a zone showing a sudden increase in mangrove pollen in Core 3, pollen from Combretaceae spikes dramatically at 155 cm. After this spike subsides, the total percentage of Combretaceae increases again. Combretaceae pollen from this spike may in fact, represent the swamp forest tree *Bucida* rather than a halophytic white mangrove.

There exists, between the two cores, a small discrepancy at which the encroaching salinity appears. This discrepancy may be due to sediment compression and other factors, such as layout of the land, which could account for the misaligned dates. The location of Core 2 is a large low-lying area, likely to have been somewhat removed from areas of human occupation and cultivation. With the absence of definite upland areas, the local vegetation reflected by pollen in Core 2 is more limited. It is possible that the pollen in Core 2 appears to have been a more saline area than it actually was.

Just as likely, however, is that brackish conditions developed first in the area where Core 2 was taken and then appeared in the region represented by Core 3. Regardless of the original conditions, however, indications in the two cores as to when conditions become brackish differ significantly. Whether this difference is a result of sediment condition or of two distinct occurrences of an influx of brackish water can be answered to a degree by looking at conditions which made the brackish conditions possible at all.

Coastal subsidence has longed plagued the Belizean coast. In addition to coastal subsidence, other factors can come into play. Typically, when mangroves become dominant in an area, peaty sediment also accumulates. Peat tends to increase around mangroves due to the near constant deluge of roots, shoots, and other organic refuse from the mangroves anaerobic conditions inhibit organic decomposition. As the water tables rise, peats build up. Eustastic processes also bring about the continuing leverage of brackish water. This process likely accounts for the conditions of the samples taken from Cores 2 and 3.

That such a series of events occurred at varying times is puzzling, but perhaps the soil where Core 3 was taken was, at the time, at a slightly higher elevation than the soil comprising Core 2. Just as likely, however, is a scenario in which more mangroves grew around the location of Core 2 than the location of Core 3. Both scenarios are likely, based on the pollen data.

The analysis of particulate charcoal in Core 3 was illuminating. Samples for the basal zone display cycles of burning probably representations of human activity in the area, rather than natural burning episodes. These events probably reflect slash and burn activities in the general area, but somewhat removed from the coring location. In the middle zone there is a noticeable reduction in charcoal influx. This is in contrast to the pollen data which is showing a strong disturbance signal, suggesting agricultural activities. It is important to understand, however, that even though charcoal concentrations are relatively low in this zone, that these values are still high and not inconsistent with local agricultural activities.

Charcoal in the uppermost zone, above 120 cm is extremely high, peaking at around 110 cm BS (below surface). This dramatic influx of carbon is probably due to industrial rather than agricultural or household activities, and probably represents salt production at nearby Wits Cah

Ak'al. The process of manufacturing salt via the *sal cocida* method requires the continuous cooking of brine in open pots; a method requiring the combustion of massive quantities of firewood. Charcoal concentrations become reduced after this point indicating that less burning was taking place through time. This perhaps indicates decrease in the production of salt as a result of exhaustion of the wood supply.

However, a series of related questions remain: when exactly did this area become brackish, when did it come to be used for salt production, and was *sal cocida* the only method of salt production utilized? This study indicates that this region became brackish sometime after 4435 +/-37 years B.P. (2485 B.C. approx.) in Core 2 and after 3562 +/-36 years B.P. (1612 B.C.), for Core 3, probably around Late Classic times, although radiocarbon dates are needed to confirm the age of this event. This chronology places the onset of brackish conditions in the area sometime after the Early Preclassic periods. Although the Maya did produce salt in this region during the Late Classic and Terminal Classic, there is no record of salt production occurring before then. It is impossible to assess at this time, whether the Maya manufactured salt as soon as the area grew brackish or if this practice developed later. Unfortunately, it will not be easy to determine the nature of salt production in this area without further archaeological investigation.

We do know that mangrove pollen increases greatly in Core 2 at about 135 cm. The radiocarbon date of 4435 +/-37 years B.P. comes from a sample at 140 cm. Archaeological evidence of surface finds indicates people were present in this area in Archaic times, and the influx of salt into the environment may have been responsible for the abandonment of this immediate area, as Maya aged sites near coring location 2 are not known. The onset of brackish conditions at the location of Core 3 is more vague as the date comes from a sample taken at 190 cm, and indications of the onset of brackish conditions does not occur in this core until 130 cm (with one additional increase at 160 cm). All that can be said is that humans settled in the area prior to the onset of brackish conditions, but after 3562 +/-36 years B.P. By 150 cm, humans were in the area, altering the environment, and creating artificial clearings. If the salt was produced by the *sal cocida* method, it would have been used after the development of ceramics in the area, or during the Middle Preclassic (1000-400 B.C.), around the time when the Swasey ceramic complex occurred (Sharer 1994).

Elevated concentration values for charcoal strongly indicate that the *sal cocida* method of salt production was used. Perhaps production was seasonal, as is salt production at Salinas de los Nueve Cerros. At Salinas de los Nueve Cerros, the *sal cocida* method was employed during the wet season. During the dry season, the *sal solar* method of salt production was utilized (Dillon et al. 1988). The *sal solar* method of salt production would have left little archaeological evidence behind.

Aside from salt production, this study has also contributed to the corpus of information concerning the local paleoenvironment of central Belize during the time of the Archaic Maya and later. The three cores examined place local vegetation populations and their fluctuations in a rough chronology. This region, near modern Hattieville, Belize, was at one point a tropical wetlands, full of freshwater plants such as wax myrtle (*Myrica*), cattail (*Typha*), and water lily (*Nymphea*), as well as trees, such as oak (*Quercus*), pine (*Pinus*), and willow (*Salix*). Gradually, the area became less arboreal forest and more open wetlands. Humans came into the area after 3562 +/- 36 years B.P. (1612 +/- 36 years B.C.), altering vegetation, and increasing forest clearance.

The region around Wits Cah Ak'al in East Central Belize turned brackish sometime after the Archaic period at Core 2, and around the end of the Classic period in Core 3. Prior to the onset of brackish conditions, humans moved into this tropical wetlands area and cleared out some of the forest and foliage. The reason for this clearing of the land was likely for agriculture. However, useful wild medicinal plants, such as *Coccoloba* (Bob), *Bursera* (Gumbolimbo), and Arecaceae (Palm family), might also have been collected from the area. In addition, less obviously useful plants, such as Poaceae (Grass family) and Chenopodium (Cheno-Am), also could have been collected and would have provided economically valuable materials. Humans could also have exploited local freshwater sources. And as they used these resources, certainly local populations might have settled in the area. However, it is just as likely, barring yet-to-be-found archaeological evidence, that people used this region as a local or seasonal gathering space for horticultural or agricultural purposes. Open and cleared areas may have attracted local game, thus making this area even more attractive.

Once brackish conditions became prevalent, an effect of coastal subsidence, people could no longer use the area for agricultural purposes. Adapting to the new conditions, inhabitants devised another use for the area. Besides arboreal pollen, such as *Pinus*, many useful herbs declined during the onset of salinization in the area. The combination of already cleared areas or abundance of local wood to burn, and brackish water would have encouraged local populations to now utilize this area for salt production. Later populations apparently found that this area worked well for salt production as well (as evidenced by the nearby 28 salt refuse mounds).

However, further research must be done in order to better understand the chronology and specific mechanics of the events discussed above. Additional radiocarbon dates are needed, particularly for Core 3. A date obtained from 115 cm from Core 3 would significantly augment our understanding of when this area became brackish, and hence, suitable for salt production. Just as importantly, an analysis of charcoal concentration values in Core 2 would be invaluable. This data would contribute to the lattice of information already structuring our understanding of the application of the *sal cocida* method. Additional test pits or other excavation done in the area may reveal earlier pieces of briquetage or other evidence of salt production. There is much work left to be done on this project. Although this thesis has contributed much to our knowledge of the ancient Maya lowlands, further research can only lead to a more detailed understanding of the area and its people, as more information is discovered regarding the ancient environments of central Belize, salt production, and, of course, the Maya.

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APPENDIX A: CHARCOAL CONCENTRATION COUNTS FOR CORE 3

Sample Number	Fragments/CC of Sediment
85	84,031
90	181,859
95	426,428
100	423,920
105	375,006
110	1,062,307
115	447,749
120	321,075
125	230,773
130	255,857
135	91,557
140	55,812
145	141,725
150	528,018
155	125,420
160	335,499
165	658,455
170	364,345
175	188,130
180	343,651
185	481,613
190	863,517
195	1,114,984
200	428,309

APPENDIX B: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 1

Sample Number

Pollen Taxa	**1**	**2**	**3**	**4**
Anacardiaceae			1 (0.4)	
Apocynaceae	1 (0.5)			
Arecaceae	3 (1.5)			1 (0.4)
Asteraceae Low Spine	3 (1.5)			
Bromeliaceae	1 (0.5)			
Cheno-Am				
Combretaceae	34 (17.0)	45 (20.5)	60 (29.1)	95 (47.2)
Fabaceae				1 (0.4)
Moraceae	11 (5.5)	3 (1.3)	5 (2.4)	6 (2.9)
Myrtaceae	1 (0.5)	1 (0.4)	2 (0.9)	1 (0.4)
Poaceae	4 (2.0)	6 (2.7)	4 (1.9)	6 (2.9)
Polygonaceae	1 (0.5)			
Rhamnaceae				
Sedge	15 (7.5)	30 (13.6)	30 (14.5)	10 (4.9)
Sapotaceae			1 (0.4)	2 (0.9)
Acalypha	1 (0.5)			1 (0.4)
Alchornea	1 (0.5)		2 (0.9)	1 (0.4)
Alnus		1 (0.4)		
Bursera	1 (0.5)		1 (0.4)	

APPENDIX B: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 1, Cont.

Byrsonima			1 (0.4)	
Caesalpinia	2 (1.0)	1 (0.4)		
Cecropia	3 (1.5)			
Celtis	1 (0.5)		1 (0.4)	
Coccoloba	2 (1.0)	1 (0.4)	4 (1.9)	9 (4.2)
Dalechampia				
Gymnopodium	4 (2.0)	1 (0.4)		
Hippocratea				
Hirea	1 (0.5)	1 (0.4)	1 (0.4)	
Ilex	1 (0.5)	1 (0.4)		2 (0.9)
Machaerium				
Mimosa	1 (0.5)			
Myrica	22 (11.0)	14 (6.3)	13 (6.3)	11 (5.4)
Nymphea	1 (0.5)	30 (13.6)	3 (1.4)	
Pinus	17 (8.5)	13 (5.9)	31 (15.0)	20 (9.9)
Quercus	17 (8.5)	10 (4.5)	8 (3.8)	7 (3.4)
Rhizophora	36 (18.0)	49 (22.3)	25 (12.1)	17 (8.4)
Rumex		2 (0.9)		
Salix	1 (0.5)			
Sebastiana	1 (0.5)			
Typha			2 (0.9)	
Ulmus			2 (0.9)	2 (0.9)

APPENDIX B: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 1, Cont.

Utricularia	5 (2.5)	3 (1.3)		1 (0.4)
Indeterminate	7 (3.5)	2 (0.9)	5 (2.4)	6 (2.9)
Unknown A				
Unknown Z	1 (0.5)			
Unknown P		5 (2.2)	2 (0.9)	2 (0.9)
Total	**200 (100)**	**219 (100)**	**206 (100)**	**201 (100)**
Tracer Spores	443	23	43	211
Concentration Value (Grains/ml)	11,325	238,843	120,170	23,895

APPENDIX B: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 1, Cont.

Sample Number

Pollen Taxa	**25**	**26**	**27**
Anacardiaceae			
Apocynaceae			
Arecaceae	1 (0.4)		
Asteraceae Low Spine	1 (0.4)	3 (1.3)	1 (0.5)
Bromeliaceae			
Cheno-Am		1 (0.4)	1 (0.5)
Combretaceae	66 (30.2)	54 (23.6)	79 (39.5)
Fabaceae	1 (0.4)	1 (0.4)	2 (1.0)
Moraceae	7 (3.1)	4 (1.7)	9 (4.5)
Myrtaceae	3 (1.3)	1 (0.4)	1 (0.5)
Poaceae	1 (0.4)	3 (1.3)	10 (5.0)
Polygonaceae			
Rhamnaceae	1 (0.4)		
Sedge	6 (2.7)	29 (12.7)	8 (4.0)
Sapotaceae			1 (0.5)
Acalypha			3 (1.5)
Alchornea	2 (0.9)	1 (0.4)	
Alnus	1 (0.4)	1 (0.4)	
Bursera		2 (0.8)	
Byrsonima			

APPENDIX B: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 1, Cont.

Cecropia			
Celtis			
Coccoloba	1 (0.4)	5 (2.1)	6 (3.0)
Dalechampia	1 (0.4)		
Gymnopodium	4 (1.8)	1 (0.4)	
Hippocratea	1 (0.4)		
Hirea	3 (1.3)	7 (3.0)	1 (0.5)
Ilex			5 (2.5)
Machaerium	1 (0.4)		2 (1.0)
Metopium		1 (0.4)	
Mimosa			
Myrica	45 (20.5)	45 (19.7)	11 (5.5)
Nymphea	1 (0.4)	2 (0.8)	
Pinus	27 (12.3)	19 (8.3)	15 (7.5)
Quercus	12 (5.4)	8 (3.5)	13 (6.5)
Rhizophora	24 (10.9)	29 (12.7)	15 (7.5)
Rumex			1 (0.5)
Salix			
Sebastiana			
Typha			
Ulmus		1 (0.4)	1 (0.5)

APPENDIX B: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 1, Cont.

Utricularia		1 (0.4)	
Indeterminate	7 (3.1)	3 (1.3)	9 (4.5)
Unknown A			
Unknown Z			
Unknown P	1 (0.4)	5 (2.1)	6 (3.0)
Total	**218 (100)**	**228 (100)**	**200 (100)**
Tracer Spores	43	13	864
Concentration Value (Grains/ml)	127,170	439,935	5,806

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2

	Sample Number			
Pollen Taxa	**9**	**10**	**11**	**12**
Alismataceae				
Anacardiaceae				
Arecaceae	4 (1.9)	1 (0.4)		
Asteraceae Low Spine	1 (0.4)	1 (0.4)	1 (0.4)	1 (0.4)
Bromeliaceae		2 (0.8)		
Bursonima				
Cheno-Am				
Combretaceae	36 (17.7)	66 (29.5)	66 (32.1)	99 (49.0)
Fabaceae	2 (0.9)	1 (0.4)	2 (0.9)	
Liliaceae				
Moraceae	2 (0.9)	2 (0.8)	5 (2.4)	14 (6.9)
Myrtaceae	4 (1.9)	3 (1.3)	3 (1.4)	1 (0.4)
Poaceae	5(2.4)		1 (0.4)	3 (1.4)
Polygonaceae				
Psittacaceae				
Rhamnaceae				
Rubiaceae				
Sapindaceae				
Sapotaceae				
Sedge	31 (15.2)	27 (12.1)	22 (10.7)	8 (3.9)
Tiliaceae			1 (0.4)	

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Verbenaceae				
Acalypha				
Alchornea		1 (0.4)		
Alnus				
Anona				
Avicennia				1 (0.4)
Borreria	1 (0.4)			
Bravaisia		1 (0.4)		
Bursera				
Caesalpinia				
Cannabis	1 (0.4)			
Cecropia				
Celtis				
Coccoloba	1 (0.4)	8 (3.5)	1 (0.4)	5 (2.4)
Croton	1 (0.4)			
Dalechampia				
Desmodium				
Guazuma				
Gymnopodium				
Haematoxylum			1 (0.4)	
Hippocratea				
Hirea	2 (0.9)	4 (1.7)	4 (1.9)	1 (0.4)

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Ilex				2 (0.9)
Machaerium				
Maytenus				
Metopium	2 (0.9)			
Myrica	21 (10.3)	17 (7.6)	21 (10.2)	39 (19.3)
Nymphea	3 (1.4)			
Pachira		1 (0.4)		
Pinus	37 (18.2)	17 (7.6)	17 (8.2)	9 (4.4)
Podocarpus				
Quercus	10 (4.9)	22 (9.8)	13 (6.3)	7 (3.4)
Rhizophora	27 (13.3)	37 (16.5)	35 (17.0)	8 (3.9)
Rumex				
Salix	1 (0.4)			
Sebastiana	1 (0.4)	1 (0.4)		
Spondias			1 (0.4)	
Trema				
Typha				
Ulmus		2 (0.8)		1 (0.4)
Utricularia	5 (2.4)	1 (0.4)		
Zanthoxylum				
Indeterminate	3 (1.4)	2 (0.8)	3 (1.4)	
Unknown A				

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Unknown Z			1 (0.4)	1 (0.4)
Unknown P	2 (0.9)	5 (2.2)	7 (3.4)	2 (0.9)
Total	**203 (100)**	**223(100)**	**205 (100)**	**202 (100)**
Tracer Spores	182	15	15	14
Concentration Value (Grains/ml)	27,978	372,915342,815361,926		

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

	Sample Number			
Pollen Taxa	**13**	**14**	**15**	**16**
Alismataceae				
Anacardiaceae				
Arecaceae				1 (0.5)
Asteraceae Low Spine		1 (0.4)		11 (5.5)
Bromeliaceae				
Bursonima				
Cheno-Am	3 (1.5)	1 (0.4)	3 (1.4)	2 (1.0)
Combretaceae	18 (9.0)	14 (6.8)	9 (4.4)	1 (0.5)
Fabaceae	2 (1.0)	3 (1.4)	2 (0.9)	3 (1.5)
Liliaceae				1 (0.5)
Moraceae	9 (4.5)	2 (0.9)	48 (23.7)	45 (22.5)
Myrtaceae	2 (1.0)	1 (0.4)	2 (0.9)	1 (0.5)
Poaceae	5 (2.5)	10 (4.9)	4 (1.9)	66 (33.0)
Polygonaceae				
Psittacaceae				
Rhamnaceae			1 (0.4)	
Rubiaceae				
Sapindaceae				
Sapotaceae				
Sedge	14 (7.0)	14 (6.8)	25 (12.3)	26 (13.0)
Tiliaceae				

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Verbenaceae			1 (0.4)	
Acalypha				
Alchornea				
Alnus				
Anona	2 (1.0)			
Avicennia				
Borreria				
Bravaisia			1 (0.4)	
Bursera	1 (0.5)	1 (0.4)		
Caesalpinia				1 (0.5)
Cannabis				
Cecropia	1 (0.5)	2 (0.9)	1 (0.4)	
Celtis			2 (0.9)	
Coccoloba		1 (0.4)	7 (3.4)	4 (2.0)
Croton				
Desmodium				
Guazuma		1 (0.4)		
Gymnopodium				
Haematoxylum				
Hippocratea				
Hirea				1 (0.5)
Ilex	4 (2.0)	1 (0.4)		

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Machaerium				
Maytenus			1 (0.4)	
Metopium		1 (0.4)	3 (1.4)	1 (0.5)
Myrica	71 (35.5)	114 (56.1)	21 (10.3)	
Nymphea	39 (19.5)	5 (2.4)	46 (24.2)	2 (1.0)
Pachira				
Pinus	4 (2.0)	2 (0.9)		1 (0.5)
Podocarpus				
Quercus	11 (5.5)	14 (6.8)	13 (6.4)	13 (6.5)
Rhizophora	12 (6.0)	4 (1.9)	4 (1.9)	3 (1.5)
Rumex				
Salix				
Sebastiana	2 (1.0)		2 (0.9)	
Spondias	1 (0.5)	1 (0.4)		
Trema			1 (0.4)	
Typha	1 (0.5)		2 (0.9)	3 (1.5)
Ulmus	1 (0.5)		2 (0.9)	
Utricularia				
Zanthoxylum		1 (0.4)		1 (0.5)
Indeterminate	5 (2.5)	9 (4.4)	3 (1.4)	11 (5.5)
Unknown A	1 (0.5)			
Unknown Z			1 (0.4)	

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Unknown P			1 (0.4)	2 (1.0)
Total	**200 (100)**	**203(100)**	**202 (100)**	**200 (100)**
Tracer Spores	265	61	38	295
Concentration Value (Grains/ml)	18,931	83,476	133,341	17,066

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

	Sample Number			
Pollen Taxa	**17**	**29**	**30**	**31**
Alismataceae		1 (0.5)		
Anacardiaceae				
Arecaceae	1 (2.0)			
Asteraceae Low Spine	2 (4.0)	1 (0.5)	1 (0.4)	3 (1.4)
Bromeliaceae				
Bursonima				
Cheno-Am				
Combretaceae	2 (4.0)	39 (19.5)	73 (34.5)	91 (45.0)
Fabaceae		1 (0.5)		1 (0.4)
Liliaceae		1 (0.5)	1 (0.4)	
Moraceae	4 (8.3)	17 (8.5)	6 (2.8)	10 (4.9)
Myrtaceae	1 (2.0)	4 (2.0)	1 (0.4)	
Poaceae	6 (12.5)	3 (1.5)	6 (2.8)	2 (0.9)
Polygonaceae	1 (2.0)		1 (0.4)	
Psittacaceae				
Rhamnaceae		1 (0.5)		
Rubiaceae				
Sapindaceae		1 (0.5)		
Sapotaceae	1 (2.0)		1 (0.4)	
Sedge	4 (8.3)	16 (8.0)	16 (7.5)	8 (3.9)
Tiliaceae				

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Verbenaceae				
Acalypha	1 (2.0)	1 (0.5)		
Alchornea				
Alnus		1 (0.5)		
Anona				
Avicennia				
Borreria				
Bravaisia				
Bursera				
Caesalpinia				
Cannabis				
Cecropia				
Celtis				1 (0.4)
Coccoloba	4 (8.3)	3 (1.5)	1 (0.4)	6 (2.9)
Croton				
Desmodium		1 (0.5)		
Guazuma				
Gymnopodium		2 (1.0)		1 (0.4)
Haematoxylum				
Hippocratea				1 (0.4)
Hirea		2 (1.0)	2 (0.9)	
Ilex			1 (0.4)	3 (1.4)

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Machaerium				
Maytenus		1 (0.5)		
Metopium				1 (0.4)
Myrica	3 (6.2)	27 (14.5)	16 (7.5)	20 (9.9)
Nymphea	1 (2.0)			
Pachira				
Pinus	2 (4.1)	15 (7.5)	25 (11.8)	25 (12.3)
Podocarpus		1 (0.5)		
Quercus	4 (8.3)	10 (5.0)	4 (1.8)	11 (5.4)
Rhizophora	4 (8.3)	29 (14.5)	51 (24.1)	11 (5.4)
Rumex				
Salix				
Sebastiana		3 (1.5)		1 (0.4)
Spondias				
Trema		2 (1.0)		
Typha		1 (0.5)		
Ulmus			1 (0.4)	
Utricularia		5 (2.5)	1 (0.4)	1 (0.4)
Zanthoxylum		1 (0.5)		
Indeterminate	5 (10.4)	3 (1.5)	2 (0.9)	3 (1.4)
Unknown Z		1 (0.5)		
Unknown P	1 (2.0)	6 (3.0)	1 (0.4)	2 (0.9)

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Total	**48 (100)**	**200(100)**	**211 (100)**	**202 (100)**
Tracer Spores	405	99	12	23
Concentration Value (Grains/ml)	1,734	50,675	441,060	220,303

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Sample Number

Pollen Taxa	**32**	**33**	**34**	**35**
Alismataceae				
Anacardiaceae			1 (0.5)	
Arecaceae				
Asteraceae Low Spine			2 (1.0)	6 (3.0)
Bromeliaceae				
Bursonima	1 (0.4)			
Cheno-Am	3 (1.4)	4 (2.0)	7 (3.5)	
Combretaceae	27 (12.6)	14 (7.0)	17 (8.5)	6 (3.0)
Fabaceae		1 (0.5)	2 (1.0)	1 (0.5)
Giuzuma				
Liliaceae				1 (0.5)
Moraceae	9 (4.2)	9 (4.2)	29 (14.5)	56 (28.0)
Myrtaceae	2 (0.9)	1 (0.5)	2 (1.0)	
Poaceae	4 (1.8)	7 (3.5)	18 (9.0)	38 (19.0)
Polygonaceae				
Psittacaceae	1 (0.4)			
Rhamnaceae				
Rubiaceae		1 (0.5)		
Sapindaceae			1 (0.5)	
Sapotaceae				
Sedge	7 (3.2)	25 (12.5)	19 (9.5)	40 (20.0)

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Tiliaceae				
Verbenaceae				
Acalypha				
Alchornea	2 (0.9)	1 (0.5)		2 (1.0)
Alnus	1 (0.4)			
Anona				
Avicennia				
Borreria				
Bravaisia				
Bursera			4 (2.0)	
Caesalpinia				
Cannabis				
Cecropia				
Celtis		1 (0.5)		1 (0.5)
Coccoloba	1 (0.4)	4 (2.0)	3 (1.5)	6 (3.0)
Croton				
Desmodium				
Guazuma				
Gymnopodium		1 (0.5)		1 (0.5)
Haematoxylum				
Hippocratea				
Hirea				

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Ilex	1 (0.4)	1 (0.5)	1 (0.5)	
Machaerium		1 (0.5)	2 (1.0)	1 (0.5)
Maytenus				
Metopium		2 (1.0)	1 (0.5)	
Myrica	111 (51.8)	55 (27.5)	26 (13.0)	1 (0.5)
Nymphea	5 (2.3)	37 (18.5)	20 (10.0)	5 (2.5)
Pachira				
Pinus		1 (0.5)	7 (3.5)	2 (1.0)
Podocarpus			1 (0.5)	
Quercus	10 (4.6)	13 (6.5)	18 (9.0)	6 (3.0)
Rhizophora	23 (10.7)	9 (4.5)	6 (3.0)	4 (2.0)
Rumex				
Salix				
Sebastiana		2 (1.0)	4 (2.0)	1 (0.5)
Spondias			2 (1.0)	1 (0.5)
Trema				
Typha				7 (3.5)
Ulmus				
Utricularia				
Zanthoxylum				
Indeterminate	3 (1.4)	8 (4.0)	6 (3.0)	9 (4.5)
Unknown Z	2 (0.9)		1 (0.5)	

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Unknown P	1 (0.4)	2 (1.0)		4 (2.0)
Total	**214 (100)**	**200 (100)**	**200 (100)**	**200 (100)**
Tracer Spores	13	270	90	69
Concentration Value (Grains/ml)	412,921	18,581	55,742	72,707

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

	Sample Number
Pollen Taxa	**36**
Alismataceae	
Anacardiaceae	
Arecaceae	5 (2.5)
Asteraceae Low Spine	6 (3.0)
Bromeliaceae	
Bursonima	
Cheno-Am	
Combretaceae	5 (2.5)
Fabaceae	
Giuzuma	
Liliaceae	
Moraceae	33 (16.5)
Myrtaceae	1 (0.5)
Poaceae	61 (30.5)
Polygonaceae	1 (0.5)
Psittacaceae	
Rhamnaceae	
Rubiaceae	
Sapindaceae	
Sapotaceae	
Sedge	20 (10.0)

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Tiliaceae	
Verbenaceae	
Acalypha	
Alchornea	
Alnus	
Anona	1 (0.5)
Avicennia	
Borreria	
Bravaisia	
Bursera	1 (0.5)
Caesalpinia	
Cannabis	
Cecropia	
Celtis	
Coccoloba	6 (3.0)
Croton	
Desmodium	
Guazuma	
Gymnopodium	
Haematoxylum	
Hippocratea	
Hirea	5 (2.5)

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Ilex	
Machaerium	1 (0.5)
Maytenus	
Metopium	
Myrica	2 (1.0)
Nymphea	2 (1.0)
Pachira	
Pinus	5 (2.5)
Podocarpus	
Quercus	10 (5.0)
Rhizophora	20 (10.0)
Rumex	
Salix	
Sebastiana	1 (0.5)
Spondias	1 (0.5)
Trema	
Typha	
Ulmus	
Utricularia	
Zanthoxylum	
Indeterminate	9 (4.5)
Unknown Z	

APPENDIX C: POLLEN COUNTS AND PERCENTAGES FROM BZE-2007 CORE 2, Cont.

Unknown P	5 (2.5)
Total	**200 (100)**
Tracer Spores	540
Concentration Value (Grains/ml)	9,290