ILLUMINATING CLASSIC PERIOD MAYA FOODWAYS AT BUDSILHA

ILLUMINATING MAYA FOODWAYS AND ETHNOECOLOGY: PALEOETHNOBOTANICAL STUDY OF CLASSIC PERIOD MAYA AGRICULTURE AND ENVIRONMENT AT BUDSILHA

By MELANIE PUGLIESE, B.Sc.

A Thesis Submitted to the Department of Anthropology and the School of Graduate Studies in Partial Fulfilment of the Requirements for the Degree of Master of Arts

McMaster University

McMaster University MASTER of ARTS (2023) Hamilton, Ontario (Anthropology)

TITLE:	Illuminating Maya Foodways and Ethnoecology: Paleoethnobotanical Study of Classic Period Maya Agriculture and Environment at Budsilha
AUTHOR:	Melanie Pugliese
SUPERVISOR:	Dr. Shanti Morell-Hart
PAGES:	xi, 126

Plant residues recovered from the archaeological record, have the potential to provide valuable information about a wide range of human-plant activities. Microscopic botanical residues were extracted from sediments and artifacts recovered from Maya archaeological contexts at the Classic period site of Budsilha, Chiapas, Mexico to track plant use and agricultural production. I targeted phytoliths (fossilized plant cells), and starch grains (a plant's sugar storage unit) which allow for various plant taxa and species to be identified based on their distinctive morphology. This research contributed to the archaeology of the Maya area by providing new information about plant use and agricultural production. Moreover, mapping plant use during the highly populated and possibly environmentally-stressed Maya lowlands during the Classic Period (250-900 CE) reveals how ancient people were able to sustain large populations. This research can provide new insights into best practices in agriculture and environmental sustainability today.

Abstract

A much debated and sensationalized aspect of Classic period Maya history pertains to the understanding of the intersections between foodways, agriculture and collapse. Traditional collapse models focusing on large city centers follow the framework of environmental degradation as a result of swidden agriculture and maize monocropping leading to the Classic period Maya collapse. New research utilizing paleoethnobotanical methodologies has begun to create the foundation for a new understanding of collapse. During the Classic period an amalgamation of agricultural methods including agroforestry, homegardens and milpas coupled with a broad range of food crop species such as manioc, arrowroot, sweet potato, lerén, and canna enabled resiliency of Classic period Maya communities. In the Usumacinta River region within the southern Maya lowlands, Budsilha, a smaller secondary political center of Piedras Negras, provides the ideal location to study Classic period subsistence strategies and plant use.

The purpose of this study was to determine which plants were consumed and present in the environment during the Classic period and the role of maize in subsistence relative to wild taxa and root crops. Microbotanical analysis of phytoliths and starch grains recovered from artifact residues, human teeth, and sediments provided evidence of diverse subsistence and agricultural practices. Maya people inhabiting Budsilha during the Classic period grew various drought-resistant crops such as manioc, alongside expected crops like maize. These findings have implications for understanding Classic period Maya foodways, plant use, and the framing of Maya societal “collapse”. Understanding how Maya communities were able to sustain large populations during climatic shifts can provide possible solutions for countries undergoing similar stresses today.

Table of Contents

Abstract………………………………………………………………………………………...iv
Table of Contents…………………………………………………………………………..... v
Acknowledgements………………………………………………………………………... vii
List of Tables…………………………………………………………………………………...ix
List of Figures………………………………………………………………………….......... x
Chapter 1: Introduction……………………………………………………………………....- 1 -
  Understanding the Concept of Collapse………………………………………………. - 2 -
  Narratives Surrounding Maya Classic Period Collapse………………………………. - 5 -
  Aims of Current Study and Organization of the Thesis……………………………..... - 11 -
Chapter 2: Foodways and Plant Use in the Southern Maya Lowlands…………………..... - 13 -
  Approaches to Ancient Foodways in Mesoamerica…………………………………... - 13 -
  Agriculture and Plant Use in Southeastern Mesoamerica and Maya Lowlands……... - 16 -
  Classic Period Foodways of the Southern Maya Lowlands…………………………. - 19 -
  Foodways in the Usumacinta River region………………………………………….... - 24 -
    Faunal remains……………………………………………………………………. - 25 -
    Isotopic signatures………………………………………………………………… - 26 -
    Paleoethnobotanical residues……………………………………………………… - 28 -
  Key Thesis Questions: Expectations from the Literature……………………………. - 31 -
Chapter 3: The Usumacinta River Region and the Classic Period Maya Site of Budsilha….. - 33 -
  The Usumacinta River Region…………………………………………………………. - 34 -
  Budsilha: Political History and Environment………………………………………….. - 36 -
  Budsilha Excavations…………………………………………………………………... - 38 -
    Operation BU-1B-05………………………………………………………………… - 39 -
    Operation BU-1B-07-08……………………………………………………………... - 40 -
    Operation BU-1J-01-04……………………………………………………………… - 40 -
    Operation BU-8A-01………………………………………………………………… - 40 -
    Operation BU-6B-16-08…………………………………………………………….... - 41 -
    Operation BU-6B-18-05……………………………………………………………....- 42 -
    Operation BU-5B……………………………………………………………………...- 43 -
  Summary……………………………………………………………………………….... - 44 -
Chapter 4: Paleoethnobotanical Methodology: Recovery of Microbotanical Evidence………- 45 -
  Paleoethnobotanical Analysis…………………………………………………………….- 45 -
    Phytoliths……………………………………………………………………………...- 46 -
    Starch grains…………………………………………………………………………. - 46 -
    Isotopic Signatures…………………………………………………………………... - 47 -
    Macrobotanical residues……………………………………………………………... - 48 -
  Budsilha Excavations and Sampling Strategies……………………………………….. - 48 -

Artifact Extractions………………………………………………………………….. - 49 -
Extractions of residues from Budsilha artifacts and human teeth…………… - 50 -
Slide creation and specimen identification…………………………………... - 51 -
Sediment Sample Extractions…………………………………………………... - 52 -
Sediment digestion and flotation…………………………………………….. - 52 -
Slide creation and specimen identification…………………………………... - 53 -
Summary: Paleoethnobotanical Field and Laboratory Methods…………………….. - 53 -
Chapter 5: Plant Use in Budsilha: Results of Microbotanical Residue Analysis……………. - 55 -
Microresidue Analysis………………………………………………………….. - 55 -
Operation BU-1B……………………………………………………………. - 56 -
Operation BU-1B-07-08……………………………………………………... - 60 -
Operation BU-1J-01-04……………………………………………………… - 61 -
Operation BU-8A-01………………………………………………………… - 62 -
Operation BU-6B-16………………………………………………………..... - 65 -
Operation BU-6B-18-05……………………………………………………... - 67 -
Operation BU-5B……………………………………………………………. - 68 -
Comparison of all Recovered Botanical Remains…………………………………… - 70 -
Chapter 6: Classic Period Ethnoecology and Maya Plant Foodways at Budsilha……..…. - 79 -
Classic Period Plant Use at Budsilha: Food and Agricultural Practices……………... - 80 -
Ubiquity of Maize…………………………………………………………………. - 85 -
Managed Forests, Home Gardens, and Ornamental Flowers………………………... - 86 -
Situating Budsilha Plant Use within the Usumacinta River Region………………… - 89 -
Conclusions and Future Directions………………………………………………….. - 93 -
References……………………………………………………………………………… - 96 -
Appendix A…………………………………………………………………………..... - 110 -
Appendix B…………………………………………………………………………..... - 122 -

Acknowledgements

This research was made possible by the directors of the Proyecto Arqueológico Busiljá-Chocoljá (PABC), Drs. Charles Golden and Andrew Scherer.

Foremost, I would like to express my sincere gratitude to my advisor Dr. Shanti Morell-Hart for her guidance, unparalleled knowledge, motivation and enthusiasm. I would like to thank her for her invaluable knowledge, help in PEB techniques and fostering my love for paleoethnobotany. Dr. Shanti Morell-Hart introduced me to paleoethnobotany during my undergraduate career and I will be forever grateful.

My sincere thanks also go to my committee members Dr. Andrew Scherer and Dr. Karen McGarry for their knowledge, help and guidance during my Masters degree and thesis work. I am grateful for the insight and support of Dr. Andrew Scherer and his immense knowledge of Maya archaeology and the Usumacinta River region.

This project would not have been possible without the incredible work at Budsilha by Shanti Morell-Hart, Sarah Watson, Harper Dine, Meghan MacLeod and the members of the PABC in 2018. I am fortunate to have worked along side members of the PABC project during the 2022 field season who made conducting field work extremely enjoyable.

Thank you to everyone on the “Starch & Phyto IDs” email chain; Sarah Watson, Shalen Prado, Éloi Bérubé, Harper Dine and Moisés Herrera-Parra. Many thanks to my fellow MPERF lab member Moisés Herrera-Parra-- thank you for being there to share ideas, research, or just talk about plants.

Lastly, I would like to thank my friends, family and partner for their endless support. I would also like to thank Kenai for his endless emotional support and encouragement.

List of Tables

Table 4.1 Recovered Sample Type by Provenience ……………………………………………52
Table 5.1 Identified Species within each Wash ………………………………………….......71
Table 5.2 Counts of Identified Plant Species …………………………………………...........75

List of Figures

Figure. 2.1 Map of Maya Region …………………………………………….................. 16

Figure. 3.1 Map of the Usumacinta River Region……………………….……….........… 34

Figure. 3.2 Topographical Map of the Usumacinta Region and Surrounding Sites …......... 37

Figure. 3.4 Photo Depicting Budsilha Fields ……………………………………........ 38

Figure. 3.5 Operation BU-1 Excavation Map……………………………………........... 39

Figure. 3.6 Operation BU-8A Excavation Map…………………………………............. 41

Figure. 3.7 Operation BU-6 Excavation Map……..……………..…………….............. 42

Figure. 3.8 Operation BU-5 Excavation Map ………………………………................ 43

Figure. 5.1 BU-1B-05-07 Artifact 6 Microremains ……………...…………………........ 56

Figure. 5.2 BU-1B-05-07 Artifact 7 Microremains ……………..………………….......... 57

Figure. 5.3 BU-1B-05-07 Artifact 8 Microremains …..…………………………….......... 65

Figure. 5.4 BU-1B-05 Sediment Microremains …...……………………………........ 58

Figure. 5.5 BU-1B-07-08 Extraction 18 Microremains ………………………….......... 58

Figure. 5.6 BU-1J-01-04 Extraction 19 Microremains ……………………………........ 61

Figure. 5.7 BU-8A-01-02 Artifact 14 Microremains …...…………………………......... 63

Figure. 5.8 BU-8A-01-03 Artifact 20 Microremains ……………………………….......... 64

Figure. 5.9 BU-8A-01-02 Sediment Microremains ……………………….…........ 64

Figure. 5.10 BU-6B-16-08 Artifact 15 Microremains ………………………............... 65

Figure. 5.11 BU-6B-16-08 Extraction 16 Microremains ……………….……………...... 66

Figure. 5.12 BU-6B-18-05 Extraction 17 Microremains …………………….……...... 67

Figure. 5.13 BU-5B-2-2 Sediment Microremains ………………………………......... 68

Figure. 5.14 BU-5B-2-4 Sediment Microremains ……………………..………...... 68

Figure. 5.15 Presence of Species from Different Contexts ……………………...…........ 72

Figure. 5.16 Raw Number of Plant Specimens Recovered from Sediments ……...…......... 73

Figure. 5.17 Presence of Species from Different Contexts ……………………….……...... 74

Figure. B.1 All Unknown Phytoliths from Artifacts ……………………………….........122

Figure. B.2 Unknown Siliceous Tissues and Diatoms …………………………...........122

Figure. B.3 All Unknown Phytoliths from Sediments …………………………….......... 123

Figure. B.4 All Unknown Fibers ……………………………………………………....... 125

Chapter 1: Introduction

Ancient Maya societies occupied a wide variety of environments in Mesoamerica, extending from southern Mexico to western Honduras, from the Formative period up through Spanish contact (Coe 2015; Colunga-GarcíaMarín and Zizumbo-Villarreal 2004). Today, approximately five million contemporary Maya people continue to occupy the region, demonstrating ongoing cultural resilience and maintaining important traditions. The Formative period (1800 BCE – AD 250) was a time in which Maya communities across Mesoamerica formed core subsistence patterns involving the use of both wild and domesticated plant species (Colunga-GarcíaMarín and Zizumbo-Villarreal 2004; Morell-Hart et al. 2014). During the Classic period (AD 250 - 950) Maya communities were able to sustain significant population growth and occupy extensive regions all while maintaining cultural traditions for hundreds of years (Cagnato and Ponce 2017; Golden et al. 2016; Lentz 1991; McNeil 2012; Morell-Hart et al. 2021). During this period Maya people established many polities throughout southern Mexico and the Yucatán Peninsula, Belize and the Petén region of Guatemala and western Honduras (Solís-Castillo et al. 2015). By the Terminal Classic period, significant demographic shifts occurred in the Maya area including the abandonment of large city centers in the southern Maya lowlands (McNeil et al. 2010), making the "collapse" of various Maya kingdoms a long term process that began during the Classic Period (Golden et al. 2016). The cause of this "collapse" has been the center of many archaeological debates, many of which are framed around subsistence strategies, and specifically, an overreliance on maize agriculture and swidden milpa practices (Morell-Hart et al. 2022).

In this thesis, I investigate Classic period subsistence strategies and plant use within the southern Maya lowlands. Focusing on the Classic Period site of Budsilha located within the Usumacinta River region, I explore how plant use at this community compares to other sites including the larger nearby contemporaneous city of Piedras Negras. The results of this study elucidate foodways, agricultural techniques, ethnoecology, and diets during the Classic period. A key part of this effort involves understanding and interrogating the concept of collapse. To further understand the ethnoecology and foodways of the region, macrobotanical, microbotanical and isotopic analysis will be used to examine Maya interactions with their surrounding environment.

Understanding the Concept of Collapse

Globally, a significant amount of research has concentrated on the collapse of societies (Aimers 2007; Tainter 1988; Weiss and Bradley 2001) to understand causal factors and prevent such catastrophic outcomes from occurring today. Scholars are fascinated by questions of whether or not environmental degradation, civil conflict, foreign invaders, or other mysterious factors lead societies towards societal "collapse" (Tainter 1988). Unfortunately, the study of collapse has been approached with a lens of subjective and conceptual frameworks (Tainter 1988) coupled with a lack of understanding of population resilience and cultural change (McAnany and Yoffee 2009). In particular, the study of collapse was conceptualized in a time of "Eurocentric" views where the "west" was pitted against the "other," creating and perpetuating a problematic system of representation of "superior civilizations" (Hall 2018; Reardon and TallBear 2012; Tainter 1988). These systems of representation are hierarchical and positioned "Western" industrialized societies at the top of this hierarchy. The consequences of this way of thinking directly correlate to the understanding of traditional perspectives on collapse. With growing fears today of environmental degradation, population growth, and climate change, the focus on historical examples of "collapse" that evoke alarming potential future scenarios has increased (Butzer and Endfield 2012). Unfortunately, sensationalist writing has amplified these anxieties, playing off of worrying images of past societal collapse found all over the world (Butzer and Endfield 2012), from the "collapse" in Mesopotamia to the ancient Maya "collapse" at the end of the Classic period in Mesoamerica (McAnany and Yoffee 2009).

In order to comprehend how collapse is conceptualized in the deep past, it is important to first understand how the term is generally used. Collapse is said to be manifested through several different changes which include but are not limited to: a lower degree of stratification, smaller territory, reduced trade and redistribution of resources and less centralized control (Tainter 1988). Understanding the explanations for collapse are also important. Flannery (1972) constructed eleven variables that can be used when identifying causal factors, including: depletion of resources, intruders, economic factors, class conflict, social dysfunction, catastrophic events, chance accumulation of events, other complex societies, mystical factors (relying on concepts of decadence, vigor or senility), insufficient response to changing circumstances, and the discovery of new resources elsewhere (Tainter 1988).

The term also means different things to different scholars (Tainter 1988). While some may view collapse as only occurring once a society has reached a certain level of "complexity," others look to evidence of economic disintegration (Tainter 1988). Weiss and Bradley (2001) states that collapse that occurs suddenly and is characterized by regional abandonment or conversion to lower levels of sociopolitical control is brought about by disruptive climatic events that create new, stressful, and unfamiliar conditions. Similarly, some scholars point to poor decision making and destructive environmental practices as leading to the inevitable collapse of a society (Diamond 2011).

On the other hand, many scholars question the entire concept of collapse and its overall utility, given that its very notion disregards the importance of understanding resilience and ongoing social change (McAnany and Yoffee 2009). Notably, traditional collapse narratives have contributed to the erasure of contemporary Maya from the public awareness especially within tourist narratives of a romanticized 'pre-collapse' society. These scholars argue that true social collapse is in fact rare, by emphasising that a gradual decline and transformation rather than an abrupt "collapse" are the norm. This assertion undermines the previous assumptions that environmental disasters are the main underlying factor of societal collapse (Lawler 2010). In fact, complex societies show resilience to various changes and challenges that they may face, protecting them from single-point failures. Where previous studies relied on historical texts and ceramics, newer research looks to climate analysis, linguistics, bone, and macrobotanical and microbotanical analyses to provide a more nuanced understanding of resilience and change throughout Mesoamerica (Aimers 2007; Lawler 2010; McNeil et al. 2010; McNeil 2012).

Moreover, although "collapse" may have occurred based on changes in the aforementioned characteristics, the overall usefulness of this term may be insufficient (Tainter 1988). Collapse which implies an abrupt rather than a gradual change over time seldom occurs, as most "collapses" identified in the literature occur over hundreds of years (Lawler 2010; McAnany and Yoffee 2009). The concept of an abrupt collapse views societies in a state of stasis that a society should aspire to rather than as inherently fluid. Additionally, as art styles and literary traditions tend to survive beyond societal "collapse," the longevity of the society as a whole often transcends other social and environmental fluctuations (Tainter 1988). This gradual change is evident, for example, in the “collapse” of the Roman Empire. Archaeologists uncovered post-Roman villages that kept the empire’s practices of language and architecture construction long after its alleged demise (Lawler 2010). Therefore, it becomes clear that given ongoing social change and intrinsic resilience of populations, collapse is an infrequent occurrence and is subjective and problematic when used to describe certain populations.

Similarly, the “collapse” of the ancient Maya in Mesoamerica occurred gradually over hundreds of years during the Classic period, with various settled areas persisting long after the Terminal Classic period, which will be explored in the following section. This thesis addresses lifeways during the Classic Period, a time when maize agriculture and swidden agricultural practices were allegedly at their peak, creating conditions that scholars have framed as critical weaknesses for ancient Maya societies in the southern Maya lowlands. My findings, however, complicate this picture. The presence of various crop plants including roots and tubers and wild species highlights the broad range of species utilized and grown alongside maize.

Narratives Surrounding Maya Classic Period Collapse

The causes of societal collapse for ancient Maya populations have garnered a lot of scholarly and mainstream media attention (Aimers 2007; McNeil 2012). In particular, the supposed Maya “collapse,” which is said to have occurred during the end of the Classic period (A.D 200-900), has been the center of many archaeological debates (Aimers 2007). The Classic period was a time of immense cultural change (Morell-Hart 2011) where Maya communities were able to sustain large populations and occupy large territories (Golden et al. 2016; McNeil et al. 2010; Scherer et al. 2007). Maya people created monuments and hieroglyphic inscriptions while developing their own agricultural, literary, cultural, and architectural systems (Coe 2015; Morley and Sharer 1994). During this period the region became one of the most densely populated in the world, with some areas estimated to have 300 people per square kilometer (Abramiuk et al. 2011). By the end of the Classic period, however, large-scale abandonment of major city centers had occurred in the southern Maya lowlands (McNeil et al. 2010).

Located within the southern Maya lowlands, Piedras Negras is an example of this large-scale abandonment. As a major Maya polity during the Classic period, Piedras Negras underwent a rapid settlement increase coupled with the creation of monumental architecture during the Early Classic period as populations exploded (Golden et al. 2010). The location of the city was not ideal for agricultural purposes although to the north and south fertile farmland and valleys were present (Golden et al. 2010). At the height of its occupation 2000-3000 individuals likely lived at the site. Notably, Piedras Negras was abandoned during the Terminal Classic period before other sites in the area, as other sites were able to survive longer including the rival site of Yaxchilán (Golden et al. 2010). The paradox of Piedras Negras's rapid demise at the height of its territorial extent, population levels and power is outlined by Golden and Scherer (2013) and highlights the “fragility" of this site.

Many hypotheses have been put forward to explain the ancient Maya “collapse” that occurred between A.D 790 – 950, including warfare, natural disasters, climate change, shifts in political systems, and environmental degradation (McNeil et al. 2010). Documents written during the Spanish contact and colonial periods emphasized extensive reliance on maize as the principal mode of subsistence (Turner II 1974). This model of a maize-centric diet has persisted in popularity, with many scholars pointing to overreliance on maize as one of the major contributors to the ancient Maya “collapse” (Diamond 2011; Ebert et al. 2019; Turner II 1974). In models perpetuated by various scholars, Maya people have been accused of destroying their environment as they devasted the vast forests that surrounded them (see critiques by Ford 2008; McNeil et al. 2010).

Limitations of studies included assumptions that deforestation and monocropping practiced by ancient Maya farmers led to environmental degradation and a subsequent “collapse” (Ebert et al. 2019; McNeil et al. 2010; Turner II 1974). Earlier scholars believed that “complex” societies require large surpluses of food, particularly maize (Aimers 2007). Furthermore, these scholars assumed the tropical forest ecosystems the ancient Maya inhabited could not produce such surpluses (McNeil 2012). Alluding to poor environmental conditions such as soil infertility and erosion from high annual rainfall, coupled with large-scale deforestation and land degradation, the eventual “collapse” of ancient Maya polities was seen as inevitable (McNeil 2012).

These views of ancient Maya people, however problematic, were spread and popularized by the mainstream media (McAnany and Yoffee 2009). Stating that in the Western Hemisphere, the ancient Maya were the most advanced society of the time, Jared Diamond claimed that these individuals made poor agricultural and environmental choices which led to their collapse (Diamond 2003). The following are cited in his work as causes leading to the eventual collapse of the ancient Maya: pine forests that covered the area were cleared and burned for fuel, deforestation leading to droughts, chronic and unresolvable warfare, and overpopulation leading to depletion of natural resources (Diamond 2003). On top of this, he claims the attention to short-term rather than long-term problems by political leaders cemented this collapse (Diamond 2003). Focusing on wars, building monuments, and feeding large populations, Diamond claims these ancient Maya leaders, in their failure to perceive long-term problems, could not sustain themselves (Diamond 2003). Diamond, in his studies, pulled from the work of scholars such as

Coe (2015), Gill (2001), Hodell et al. (1995), and Webster (2002) though misrepresented the data in some cases or simply drew on outdated studies.

However, other compelling studies conducted over the past few years have shown a different story (McNeil 2012). Archaeologists today have reached a consensus that the "collapse" of the Maya lowlands occurred regionally with some areas evading the collapse altogether (Aimers 2007). New insights using macrobotanical and microbotanical evidence challenge the popularized narrative of poor choices and environmental destruction. Contradicting this narrative of environmental destruction, evidence now points to increases in forest cover during the Classic period in some areas (McNeil et al. 2010) along with the careful management of forest species (Fedick et al. 2023; Fedick 2010; Morell-Hart et al. 2022). In one example, pollen core analysis in Copán, Honduras, a large city center located within a region of economic trade and political evolution (Webster 1999), revealed that there was, in fact, an increase in forest cover from A.D. 400 to A.D. 900 (McNeil et al. 2010). This increased presence of forest species may indicate that Maya people were practicing environmental management practices to ensure the continued productivity of the environment and land (McNeil et al. 2010; Nigh and Diemont 2013).

Contrary to early assumptions about ancient Maya foodways and their relationship with the surrounding environment, research now provides evidence of a broad use of plants and animal species in the area. Recent research documenting the high settlement densities present during the Classic period has created a narrative shift in which scholars argue that simple swidden agriculture with long fallow periods could not have sustained such enormous populations (Fedick and Ford 1990). Instead, the ability to ensure adequate food supply with limited environmental degradation was probable as a number of scholars have documented how ancient Maya people created a mosaic of sustainable agricultural systems (Fedick 1996; Lentz 1991; McNeil 2012; Morell-Hart et al. 2021, 2022). Using a variety of agriculture techniques and systems during the Classic period, Maya communities were able to transform the surrounding environment into a cultivated and largely sustainable landscape (Dunning et al. 1998; Fedick et al. 2023).

Enhancing the productivity of the land, ancient Maya people also practiced agricultural techniques such as irrigation (Turner II 1974), fertilization (Fedick 2010), selective slash and burn agriculture, agroforestry and managed succession, and milpa farming (cyclic rotation of crops) (Fedick et al. 2023; White 2022). Additionally, current literature on Maya ethnobotany depicts the diverse presence of food plants, with more than 500 species indigenous to the Maya lowlands (Fedick 2010). With substantial evidence pointing to the use of a broad range of species by the ancient Maya (Chandler-Ezell et al. 2006; Fedick and Santiago 2022; Morell-Hart et al. 2014, 2022; Piperno and Holst 1998; Piperno 1998) and the presence of economically important forest species (Lentz 1991; McNeil et al. 2010; McNeil 2012), the aforementioned view of Maya people as careless stewards lacks archaeological evidence.

Archaeological investigations of the ancient Maya during the Late Classic period (AD 550 – 850) have also focused on the socioeconomic relationships between Maya communities and cities (Sharpe and Emery 2015). Knowledge of political organization has increased over the past 50 years with recent studies providing evidence of various locations of habitation ranging from large city centers to smaller settlements at the periphery. These various Maya communities were linked by political alliances between sites of various sizes, with the largest sites considered to be dominant over smaller communities. Debates over how much control these polities had over peripheral communities tend to follow one of two primary models: (a) larger sites with large monumental architecture, controlled resources, and trade, or (b) elites had little control over local economy and trade between sites and boundaries, and instead drew tribute or tithe (Golden et al. 2015; Sharpe and Emery 2015).

Since more archaeological research focuses on large primary centers, less is known about the smaller subordinate communities. Research on foodways in the Maya area has focused on ritual food use, ancient Maya elites, and large city centers, as well as climate change and the Classic period Maya "collapse" (Hoggarth et al. 2017). Shifting the focus to Maya communities who resided outside of these densely settled centers, more research is now addressing smaller-scale occupations. Through this research scholars have been able to provide direct evidence of the use of different plant species including root and tuber crops such as manioc (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), arrowroot (*Maranta arundinacea*), and yam (*Dioscorea bartlettii*); and forest species such as avocado (*Persea schiedeana*), coyol palm (*Acrocomia aculeata*), and ramón (*Brosimum alicastrum*) (Fedick 1996; Lentz 1991; Morell-Hart et al. 2021, 2022). Furthermore, Fedick and Santiago (2012), have documented the many food species available to ancient Maya people, even under extreme environmental conditions.

Despite evidence of this diverse set of cultivated and available resources, terrestrial animals, maize, and the occasional freshwater and marine resources are widely considered to be the main food staples of Maya diets from the Pre-Classic to the Terminal Classic period (López et al. 2011). This model fails to take into account the use and overall importance of various forest species such as pine, palms, figs, and mahogany (Ford 2008; McNeil 2012), and other agricultural crops such as chia, arrowroot, manioc, corn, sweet potato, beans, and various grass species (Morell-Hart et al. 2014, 2021; Piperno and Holst 1998).

Aims of Current Study and Organization of the Thesis

Addressing and intervening in these aforementioned debates, my study interprets botanical datasets from Classic period Maya archaeological contexts at the site of Budsilha Chiapas, Mexico. I identify the various species present at this ancient community and draw conclusions about plant propagation and uses by ancient Maya people. I evaluate (a) which plants were consumed and present in the paleoenvironment during the Classic period, and how this affects collapse narratives, and (b) the role of maize in subsistence and agriculture strategies, relative to wild taxa and staple root crops such as manioc.

Combining the results of my analyses with macrobotanical and bone isotope analyses, I compare plant taxonomic richness between other Usumacinta sites to situate plant use at Budsilha (a). I draw comparisons between plant taxa recovered from Budsilha and the larger polity of Piedras Negras to illuminate variable differences in Maya subsistence (a). I also compare the use of wild and forest species to understand exploitation of non-agricultural resources and agricultural resources (b). Finally, I compare the ubiquity of maize vs. root crops to assess differential use of these resources, to illuminate potential food related species that could affect resiliency during climatic shifts (b).

This thesis is arranged into five chapters. In the next two chapters, I provide background for this study, focusing on southern Maya lowland foodways and plant use followed by highlighting the characteristics and ecology of the Usumacinta River Region. I summarize what is known about the Classic period site of Budsilha. In the fourth chapter, I summarize the paleoethnobotanical methodology, and discuss microbotanical residue extraction and analysis. I also describe the Budsilha excavations that occurred in 2018. In the fifth chapter I present the results of my microbotanical artifact residue, tooth residue, and sediment analyses by context. I also present the results of isotopic analyses of teeth and macrobotanical analyses. In combining these analyses, a more complete picture of plant use and diets at Budsilha is possible. In the final chapter, I interpret the results, given expectations set up by the background information from the previous chapters. I discuss ethnoecology, agricultural methods, food related species, plant use, and diet. I also compare Budsilha results with other Usumacinta sites, Piedras Negras and Macabilero.

By re-evaluating the role of various food plants in ancient Maya lifeways, my work helps to complicate the simple narrative surrounding maize dependence and milpa crop failure, and explores the potential for resilient agricultural practices. Such work contributes to studies of collapse, and the purported Maya "collapse" specifically, by broadening the available data on smaller Classic period sites within the southern lowland region.

Chapter 2: Foodways and Plant Use in the Southern Maya Lowlands

Gaining an understanding of food, cuisine and plant use in Mesoamerica involves taking a holistic approach to foodways (agriculture, feasting, food and markets) and plant use (Staller and Carrasco 2009). Recent archaeological investigations have started to recharacterize ancient Maya foodways through interpretations of a plethora of archaeological evidence (Fedick et al. 2023; Lentz 1991; Morell-Hart et al. 2014, 2019, 2022; Piperno 1998; Somerville et al. 2013). Analyses such as zooarchaeology, chemical analysis, ceramics, bioarchaeology, and paleoethnobotany have been utilized to formulate an increasingly clear picture of ancient human plant use and complex foodways. As scholars move to reconstructing past diets from plant and animal remains, ceramics and other artifacts, information about ancient Maya communities has become more nuanced. Through the reconstruction of diets an understanding of trade, exchange systems and food production can be made (Landon 2002). Furthermore, understanding what plants were consumed and present within the environment during the Classic period along with evaluating the role of maize in subsistence and agricultural strategies relative to wild and staple root crops can be utilized to re-evaluate collapse narratives.

Approaches to Ancient Foodways in Mesoamerica

In Mesoamerican archaeology, both human and animal bone analyses, along with paleoethnobotanical analyses, have provided immense insight into complex fauna and flora consumption in the area. Zooarchaeology, the study of faunal remains such as animal bones recovered from archaeological sites, can be used to determine animals eaten and a species' relative importance, as well as butchering and preparation methods (Landon 2002). In trying to further understand the relationship ancient Maya people had with their surrounding environments, faunal remains are also vital to reconstructing local ecologies (Götz and Emery 2013). Through the analysis of faunal remains, the role of animals in diet, rituals, political economy and the environment can be elucidated (Götz and Emery 2013).

Scientific analyses, including isotopic analysis of bones and microbotanical analysis of sediments and artifacts, have been helpful in reconstructing diets through time (Lentz 1991; Morell-Hart et al. 2014; Reitz and Shackley 2012; Scherer and Wright 2015; Somerville et al. 2013). Food consumed in life leaves characteristic signatures (the basis of stable carbon and nitrogen isotope analyses) that become preserved in tissues and in the pores and fissures of artifacts such as ceramic vessels and obsidian blades. Both faunal and flora data obtained through isotopic analysis have emerged within the Maya region, providing information on maize domestication, the scope and scale of maize consumption, dietary differences among social classes, and insight into the "collapse" (López et al. 2011). Utilizing this chemical analysis of bone, archaeologists are able to reconstruct the diets of both humans and animals (Pearsall 2016). Where the analysis of human bones can give direct information about human diets, animal bones have the ability to provide information about the plants within the surrounding environment (Pearsall 2016; Somerville et al. 2013).

Paleoethnobotanical research utilizing ancient botanical remains seeks to understand the dynamic interrelationship between humans and plants (Pearsall 2016). Macrobotanical remains (seeds, nuts, and wood) and diagnostic microscopic plant residues (pollen, starch grains, and phytoliths) are left behind in/on soils, pottery, human teeth, and other locations allowing archaeologists to ascertain foodways, plant use, and the surrounding environment. Using macrobotanical and microbotanical remains recovered from the archaeological record it is possible to reveal changes in the paleoenvironment through time, how environmental changes influenced agricultural practices, foodways, and how plant resources were being used (Pearsall 2016). Notably, carbonized remains provide an ideal source of evidence of direct plant use as these species were charred through the exposure to heat likely in the process of burning and cooking (Gallagher 2014).

In Mesoamerica the increase in microbotanical analysis of starch grains, pollen and phytoliths recovered from sediments and artifact residues has broadened the current knowledge of human-plant interactions (Cagnato and Ponce 2017; McNeil 2012; Morell-Hart et al. 2014, 2019, 2022, 2022; Piperno 1998). Many economically relevant species in Mesoamerica produce diagnostic phytoliths, starch grains and pollen that can be used to accurately identify the family, genus and species of utilized plants (Pearsall 2016; Piperno 1985). Starch grains are found in plant tissues associated with the storage unit part of the plant. This starchy storage unit can be found across plants including fruits, seeds, roots, and shoots, and can be directly linked to food consumption as starchy parts would have been exploited for their high energy component (Pearsall 2016). Additionally remaining in the archaeological record, and found in sometimes harsher conditions compared to starch grains, are phytoliths, fossilized plant cells. These bodies of silica form in roots, stems, leaves and inflorescences, and retain the shape in which they are formed. Phytoliths can be found from extractions of artifacts as well as isolated in sediments. Depending on the location of deposition, phytoliths can provide information about plant use beyond foodstuffs including construction materials and the paleoenvironment in deep time. Similarly, beyond artifact residues, pollen grains have been used to determine the composition of the paleoenvironment (presence/absence of forest cover) from sediment cores (McNeil et al. 2010).

Agriculture and Plant Use in Southeastern Mesoamerica and Maya Lowlands

Southern Maya lowland communities (**Fig. 2.1)** are usually categorized distinctly from northern lowland communities and highland communities, based on significant environmental and topographical differences that exist between these zones (Solís-Castillo et al. 2015). The southern lowlands are characterized as having hilly landscapes with various surface rivers and annual rainfalls of approximately 2000-4000mm. Thus, this area was likely a highly productive zone for agriculture. During the Classic period, the population density of the southern lowlands is estimated to have ranged between 38-196 people per km^2 (Johnson et al. 2007).

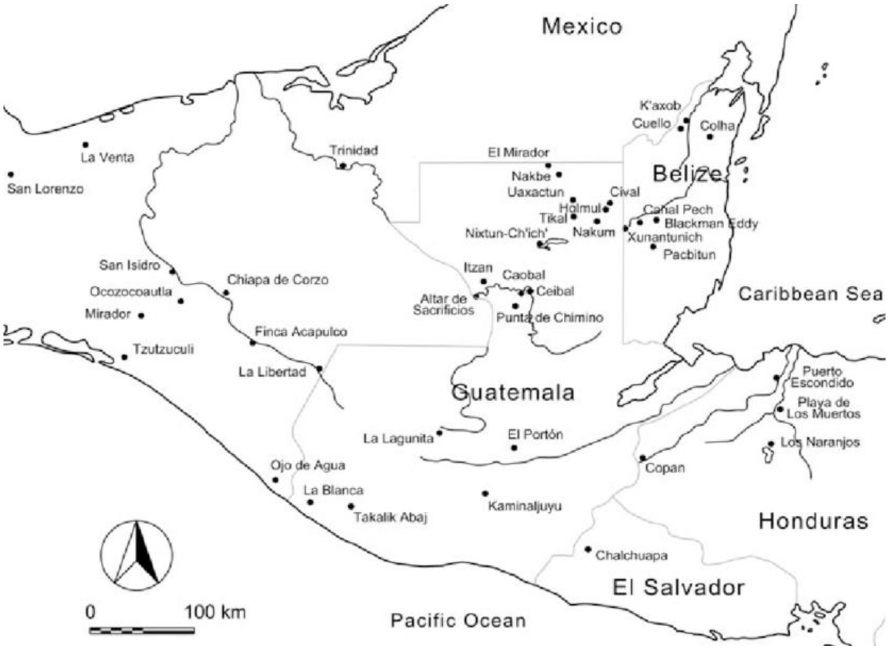


Figure. 2.1 Map of the Maya Region. The southern Maya lowlands are depicted. (Inomata et al. 2017).

During the Classic period, Maya communities had diverse diets although maize has long been considered the most important crop (Fedick 2010; Hoggarth et al. 2017; Lentz 1991). The subsequent Terminal Classic period in the southern lowlands is distinguished by the slowing and cessation of elite political activities, and population dispersion away from large urban centers, while many northern sites persisted or even grew in population (Emery 2007b; Golden et al. 2015; Lentz et al. 2015). Maya people during this period were thought to have limited options for subsistence, due to presumed depletion of forest resources and game animals although this picture is more complicated, as I describe below (Ebert et al. 2019; Fedick and Santiago 2022; Lentz 1991; Morell-Hart et al. 2021; Somerville et al. 2013).

Maya subsistence strategies were highly adaptive to various environments and variable throughout Maya occupied areas (Dunning et al. 1998; Fedick 2010; Scherer et al. 2007). Taking a smaller regional approach provides the opportunity to draw conclusions about Maya communities specifically within in the southern lowlands. Further challenging previous assumptions that Maya farmers degraded their surrounding environments through deforestation and intensive maize agriculture, recent studies have provided evidence of agricultural management and land use (Fedick et al. 2023; Morell-Hart et al. 2022, 2022). Moving away from the theory that the only agricultural system was swidden agriculture centered on maize, beans and squash (Harrison and Turner II 1978), various land and natural resource management strategies across Maya landscapes included terracing (Fedick 1996), multi-cropping (Ford and Nigh 2015), forest gardening (Fedick 2010), arboriculture (Lentz 1991), and homegardens (Wyatt 2020).

Such strategies would have allowed for increased maize production without the expansion of agricultural fields, while managing forests and diversifying crops. The resilience and adaptability of these complex strategies allowed ancient Maya populations to persist within the southern lowland area despite climatic fluctuations during the Preclassic to Terminal Classic periods (Dunning et al. 1998; Ebert et al. 2019;Fedick 2010). The Terminal Classic period also coincides with an extended drought evident within regional paleoclimate records which has been often cited as one of the contributors to the "collapse" (Hoggarth et al. 2017). It is interesting to note that climate change and severe droughts also affected Maya communities on previous occasions with two severe droughts occurring at the end of the Late Preclassic period followed by a wet period during the Early Classic period (Ebert et al. 2017; Nooren et al. 2018).

Although people inhabited the region prior to defined Maya periods, scholars identify the Early Classic period (1000 BCE.) as the period that Maya people migrated into the southern lowlands (Coe 2015; Lucero et al. 2014). Propelled by changes to the environment caused by several prolonged periods of drought, Maya communities explored new modes of subsistence practices. In particular, Lucero et al. (2014) highlights how Maya communities offset the presence of an annual dry season from Jan – May by creating water retention systems including wetland reclamation adaptations, watershed systems, aqueducts and reservoirs along rivers. Unfortunately, by the Terminal Classic period it was no longer possible to rely on these systems due to the presence of multi-year droughts leading to the abandonment of major centers (Lucero et al. 2014). At the site of Tikal and the surrounding area, for example, a transition from the interior southern lowland to riverine areas occurred (Lucero et al. 2014).

Human societies in different regions throughout Mesoamerica were already cultivating domesticated plants and raising domesticated animals as early as 5000 years previously. Utilizing paleoethnobotanical data including isotopic signatures, faunal remains, pollen cores, and macrobotanical remains, we see a complex relationship of Maya plant use from the

Formative up until and past the Terminal Classic period. Colunga-GarcíaMarín and Zizumbo-Villarreal (2004), tracked the use of domesticated plants in the southern Maya lowlands, highlighting an extensive use of various domesticated plant species in the area by at least 3400 BCE. Food species with wild populations or ancestors within the lowland Maya area associated with agriculture include *Carica papaya* (papaya), *Byrsonima crassifolia* (nance), *Manilkara zapota* (sapote), *Brosimum alicastrum* (ramon), and *Theobroma cacao* (cacao). Additionally, introduced domesticated food species associated with agriculture included *Ananas comosus* (pineapple), *Ipomoea batatas* (sweet potato), *Zea mays* (corn), *Phaseolus vulgaris* (common bean), *Cucurbita pepo* (squash), and *Maranta esculenta* (arrowroot) among others (Colunga-GarcíaMarín and Zizumbo-Villarreal 2004). Moreover, analysis of plant use from the Middle Formative period at the site of Los Naranjos, just two valleys away from the Maya site of Copán, detected the presence of *Zea mays* (maize), Lamiaceae spp. (mint family), Arecaceae spp. (palm family), *Manihot* sp. (manioc), *Ipomoea* sp. (sweet potato) Asteraceae sp. (sunflower family) and *Salvia* sp. (chia) (Morell-Hart et al. 2014). Although less prevalent in the archaeological record, Morell-Hart et al. (2014) also found *Calathea* sp. (lerén), *Cucurbita* spp. (squash), *Amaranthus* sp. (amaranth), *Phaseolus* sp. (common bean), *Annona* sp. (custard apple) and Arecaceae spp. (palms). Thus prior to the Classic period an established subsistence pattern existed using a multitude of domesticated and wild species.

Classic Period Foodways of the Southern Maya Lowlands

Maya communities living in the southern lowlands during the Classic Period were highly socially stratified, resulting in differential dietary and land use practices varying at both the local and site level across time and space (Scherer et al. 2007; Somerville et al. 2013). Using isotopic data, Somerville et al. (2013), found that while elite diets underwent a significant change through time over the course of the Classic Period, Maya commoners experienced little variation over time. They argue that previously observed regional variation in Maya subsistence patterns likely resulted from elite diets rather than variability across Maya societies. As they describe, elite subsistence would have been heavily impacted by economic and political circumstances, changing significantly through time (Golden et al. 2016), while commoner diets were more directly affected by local environments through household-based food production (Somerville et al. 2013; Wyatt 2020).

Elite diets display trends of less maize consumption through time in the southern Maya lowlands with Early Classic period elites consuming more maize than any other status group in any time period (Ebert et al. 2019; Scherer et al. 2007; Somerville et al. 2013). Isotopic analysis by Somerville et al. (2013), found early and Late Classic period elite carbon isotope averages indicating that most protein in diets came from maize, maize-fed animals, or marine fish. Two different photosynthesis pathways are utilized by plant species. Wild taxa use the C3 pathway while maize uses the C4 pathway (Kohn 2010; Richards and Britton 2020). Significantly, Terminal Classic elites underwent a major decline in maize consumption evident by less C4 than in previous periods. On the other hand, commoner diets did not rely heavily on C4/marine sources and were composed of an even mixture of C3 (forest species) and C4 marine products, with commoners displaying a trend of less maize consumption over time (Somerville et al. 2013). Overall, subsistence patterns for commoners appeared stable through periods of radical political, social, climate, and economic change. Household-based agriculture including managed forests, terracing, homegardens, and swidden agriculture allowed these individuals greater long-term stability (Dunning et al. 1998; Fedick 1996; Lentz 1991). Since time and space was allocated for other C3 economic food species, they likely supported a diverse array of C3 forest species and agricultural products.

At the southern lowland site of Cahal Pech, located in the upper Belize Valley, Ebert et al. (2019), looked at foodways from the Early Preclassic through the Classic period. During the Early Preclassic, consumption of maize was inferred from specialized ceramic colanders used to nixtamalize maize, impressions of corn cobs on pottery, and maize cupule fragments. Further skeletal stable isotope evidence showed exploitation of a variety of other plant species from the surrounding forests and homegardens, including squash and other fruit species. Additionally, faunal remains of terrestrial, freshwater, and marine species were also found. These findings have implications for the understanding of Maya subsistence patterns where diets were supplemented by homegardens containing a variety of food related plant species. Furthermore, utilizing LIDAR (light detection and ranging) analysis, Ebert et al. (2019), found that intensified agriculture was made possible through the use of terraces and water management systems during the Early Classic period. Similar to findings from Somerville et al. (2013), later agricultural intensification during the Late Classic period saw an increased reliance on maize, although individuals living in more rural settlements display evidence that maize was a smaller component of their diet with wild plant species commonly consumed (Ebert et al. 2019).

Adding to the diverse foodways of southern lowland Maya, zooarchaeological analysis provides information on an extensive use of animals for subsistence. Results of carbon isotope analyses indicate that deer within the Petén lakes district and Copán valley consumed more C4 plants than deer in northern Belize (Emery and Kennedy Thornton 2008). Emery and Kennedy Thornton (2008), used isotope analysis from deer remains to estimate deer diets during the Classic period. Deer dietary signatures, used as a proxy for the expanse of agricultural fields, support palaeoecological data suggesting agricultural fields replaced forest canopy. Deer consumed more maize during the Late Classic period than in the Pre- and Early Classic and the Terminal Classic, indicating the impact of Maya agriculture and settlement expansion during the Classic period. Interestingly, interior Petén sites had lower levels of maize consumption during the Late Classic period suggesting that despite the presence of dense settlements forest coverage was maintained (Emery and Kennedy Thornton 2008).

Similarly, pointing to human population growth, deforestation, and soil erosion beginning in the Preclassic, Emery (2007b), noted that adverse habitat changes may have occurred as high forest tree species were replaced by shrub forests, savannahs, and grasslands in the Classic period. This process of replacement would have had implications for large game species which prefer ecotonal habitats causing species that do not (white tailed deer) to show up more frequently in Late Classic assemblages than in Terminal and Post Classic assemblages. Following the Late Classic, human populations in the southern Maya lowlands were both smaller and more dispersed making large game less available or valuable as a food source. Coupled with fewer demands from elites, a wider diversity of smaller game was encouraged for hunting (Emery 2007b). This suggests that hunters were able to respond to changes in resources by exploiting more diverse and smaller game species.

Paleoethnobotanical work at the sites of Joya de Cerén, El Salvador and Tikal, Guatemala have also provided evidence of a broad use of plant species during the Classic and Terminal Classic periods. At the Late Classic Maya site Joya de Cerén, Kaplan et al. (2015) recovered carbonized bean remains from both wild and domesticated species. The presence of *Phaseolus vulgaris* and *P. lunatus* suggests that during the Late Classic period Maya continued to utilize wild food sources despite the presence and availability of domesticated food crops. Further analysis conducted by Lentz and Ramírez-Sosa (2021) at the site of Cerén found evidence of maize, beans, squashes, peppers and various root crops including manioc. Manioc's importance is also evident in a study by Sheets et al. (2012), where outside of the main city center raised-bed monocropping of manioc was present, with equal area to that of maize cultivation, likely indicating manioc was a staple crop. Thus, these fields of maize and manioc likely provided most of the food supply to Maya living in Cerén during the Late Classic while homegardens provided nutritional diversity (Lentz et al. 2015). Comparatively, at the Classic period site of Tikal, similar to Joya de Cerén, maize predominates while beans (*Phaseolus lunatus, Phaseolus vulgaris),* squashes (*Cucurbita moschata, Cucurbita pepo*), root crops (*Ipomoea batatas, Xanthosoma, Canna* cf. *indica*) and numerous fruit trees (*Theobroma cacao, Acrocomia aculeata, Pouteria sapota)* were also being utilized (Lentz et al. 2015). Notably, Tikal, which underwent an exponential period of population growth from the Late Preclassic into the Late Classic period as it became a center of both economic and political power, evidenced use of more forest species than Cerén (Lentz et al. 2015).

Furthermore, evidence of a broad use of plant species is also present during the Late Classic period at the site of Copán (Fedick 2010; Morell-Hart et al. 2021). With an extensive amount of archaeological research occurring at this site, there is a plethora of information regarding ancient Maya foodways. Management of forest species is evidenced by the increase in pollen from evergreen trees *Podocarpus* sp. during the Late Classic (Fedick 2010). Other taxonomic groups of tree and shrub species present in botanical samples from Copán include *Acrocomia* sp. and *Hedyosmum* sp. along with food-producing palms such as *Pacaya* palm (Fedick 2010; Morell-Hart et al. 2021). *Brosimum alicastrum* (ramon) has also been suggested as a staple crop along with 22 other edible species such as *Brosimum* spp., *Castilla elastica, Celtis* spp., and *Ficus* spp. Additional extensive paleoethnobotanical analysis conducted by Lentz (1991) analysing 208 macrobotanical remains recovered from Copán, identified maize throughout all time periods and status levels. Lentz (1991) also found evidence of a wide variety of species including carbonized seeds of *Phaseolus vulgaris* (common bean), two squash seeds of *Cucurbita moschata*, remains of two palm species *Acrocomia mexicana* and *Bactris* sp., and fruit tree species including *Persea americana* (avocado), *Byrsonima crassifolia* (nance) and *Pouteria* sp. (zapote).

Foodways in the Usumacinta River Region

Although the natural environment determines the frequency that animals can be hunted and the availability of plant species, political, economic, and labour relations between community members determined how species were distributed and which were utilized. Differential status of Maya (elites and commoners) and sites are a major source of variability within the archaeological record as evidence of varied plant use based on site and type is evident. A recent shift to study Maya communities outside of major polities is broadening what is known about Maya subsistence in the region. Stable isotope analysis, pollen core, microbotanical, and macrobotanical datasets have been used to primarily understand foodways and relationships with the environment (Cagnato and Ponce 2017; López et al. 2011; McNeil et al. 2010; Morell-Hart et al. 2021; Scherer et al. 2007; Sharpe and Emery 2015; Watson 2022). Looking at 10 studies of faunal remains, isotopic analysis and paleoethnobotanical analysis conducted within the Usumacinta River region, I will summarize the current knowledge of plant use, foodways and diets in the area.

Faunal remains.

In an extensive study of faunal remains recovered from Piedras Negras, Emery (2007a), identified a wide range of food species that were used by Maya people inhabiting this polity. Unsurprisingly, white tailed deer dominated deposits although these individuals used a wide variety of species including large and small mammals, birds, reptiles, and freshwater and marine molluscs. Other artiodactyls included *Mazama americana*, peccaries, paca, large *Orthogeomys hisidus* (hispid pocket gopher), smaller agouti, and bird species such as grouses. Marine and freshwater species included freshwater molluscs, river jute, river clam, and white river turtle. The presence of rabbits, turkeys, and other large birds was also noted. During the Classic period there is a notable increase in the consumption of deer and turtles along with a reduction in fish, birds and freshwater gastropods. This increase in species use may be attributed to a possible decline in resources leading to a need to turn to new species for food sources (Emery 2007a). The increased number of species may also be a reflection of elite hunting activities.

In another study conducted by Sharpe and Emery (2015), faunal remains from various subordinate communities and capital sites were analysed. White tailed deer was again ubiquitous at nearly every site, as well as often being the mammal found in the highest proportion. Large rodents, mainly paca and agouti, were found in equal portions at most sites, and of non-mammals, turtles were the most common. In Aguateca freshwater molluscs and turtles comprised more than half of the faunal remains recovered. Marine shells were frequent and cartilaginous fish spines were found at both Piedras Negras and Aguateaca. Additionally, freshwater species over terrestrial taxa were more frequent among communities at Petexbatún sites over Usumacinta sites. This difference is likely due to the dangerous and faster moving Usumacinta River being less enticing to hunt and collect shellfish from. Additionally, cleared forests and agricultural fields dominated the areas during the Classic period with an increased presence of white tailed deer, rabbits, armadillos, and turkeys (Sharpe and Emery 2015)

Sharpe and Emery (2015), also looked at differences between capital and subordinate sites. Faunal remains excavated from three capital sites Piedras Negras, Yaxchilán, and Aguateca found that these individuals utilized a wider variety of species than Maya at subordinate centers. Subordinate centers had more species from mature forests and exotic marine environments with secondary and tertiary sites more taxonomically diverse. Animal species were also found to vary between households of different statuses. Middle-ranking elites displayed the greatest diversity of taxa while high-ranking elites focused on a smaller number of more prestigious species. Markedly, non-elites mainly utilized river resources. These findings suggest the presence of a complex system of animal use within and between sites based on status (Sharpe and Emery 2015).

Isotopic signatures.

Farther north, in the southern part of Chiapas, the Late Classic period site of Chinikiha lies on the eastern side of the Usumacinta River (López et al. 2011). Previous studies theorized that an increase in maize consumption during the Late Classic period was linked to a decrease in meat consumption. Conflicting with this, recent studies at this site indicate that access to maize and meat may in fact be tied to distribution changes within social hierarchies. López et al. (2011), analysed faunal remains from middens and used isotope analysis to understand the diets of individuals found in various burials. The most common faunal remains recovered from a midden were white tailed deer although they also found a preference for freshwater turtles. Other species that were present include domestic dog, two species of rabbit, and collared peccary. Notably, 80% of the remains found had evidence of cut marks, changes in colour indicative of fire exposure, and fracture patterns similar to those commonly created during soft tissue extraction. Isotopic analysis was also completed by López et al. (2011), producing findings that individuals relied on C4 plants with some C3 plants, and terrestrial game was favoured despite access to freshwater fish and marine food sources, with members eating more meat from wild herbivores.

Differences in diets between classes are also evident at this site. López et al. (2011), found that the individual from the elite burial had the highest consumption of meat while two burials outside of the structure indicated a lower consumption of meat. Interestingly, a burial inside the patio structure containing a male with a monochrome vessel displayed isotope values indicating a diet based primarily on maize with some access to a variety of wild plant species. This individual had fewer stress indicators of a poor diet than the other individuals. On the other hand, isotope analysis from a burial located within a midden had the highest maize consumption along with evidence of dental disease. These findings strongly suggest differences in diets based on class along with elites favouring a maize-based diet with access to a range of other wild species.

Johnson et al. (2007) also indicates diets were increasingly maize rich during the Classic period. Notably, the border area between Piedras Negras and Yaxchilán had evidence of repeated clearing for agricultural purposes evident by the presence of ^{13}C enrichment of subsurface SOM. Thus, Piedras Negras and Yaxchilán had favourable soil conditions and sloped areas making these sites agriculturally important areas within the Usumacinta River region (Johnson et al. 2007). Similarly, carbon isotope analysis from bone collagen excavated from burials at Piedras Negras by Scherer et al. (2017), found evidence of high levels of maize consumption based on high mean δ^{13}C levels. Differences in δ^{13}C levels between elites and commoners was also evident as higher status individuals had δ^{13}C levels between -9.0 to -8.10‰ (consistent with high maize consumption) while lower status individuals displayed a broader range of values (Scherer et al. 2017). Moreover, isotope analysis from various sites across the Maya region indicates geographic variability in the dominance of maize consumption (Scherer et al. 2019). These findings suggest that during the Classic period there were variations in diets and consumption of maize.

Paleoethnobotanical residues.

The Late Classic period ancient Maya city of Palenque has provided insight into plant and animal use for food through the recovery of starches, phytoliths, faunal remains, and carbonized seeds (Durán et al. 2021). Microbotanical analysis conducted by Durán et al. (2021) of metates and pots identified the presence of *Capsicum* spp. (chile), *Zea mays*, starches related to Fabaceae and *Phaseolus* spp. (beans), and various starches such as *Ipomea batatas* (sweet potato). Some starches showed evidence of heat damage similar to roasting or boiling indicating their possible use in cooking practices. Notably, the low ubiquity of maize starches recovered from metates compared to chile and beans indicates the use of metates for grinding foods other than maize. Recent ethnographic research regarding metates showed that beans, lentils, legumes, and cereals were ground (Durán et al. 2021). Additionally, Maya tamales are made with a mix of pumpkin, agave, and bean pinole to form a paste. Durán et al. (2021), also found a high presence of starch grains located near the brim of ceramics compared to the bottom, highlighting their possible usage as a storage container for drinks or broths. Corresponding ethnographic evidence from the area expresses the use of beans cooked dry to make a powder which is added to drinks and other mixtures, and sweet potatoes used for both food and drinks such as *atole* (Durán et al. 2021).

Adding to the knowledge of a wide range of plant species for food use in the Usumacinta region, inhabitants of the Late-Terminal Classic period site of La Corona located within the southern Usumacinta in northwestern Petén displays evidence of plant use other than maize for subsistence (Cagnato and Ponce 2017). Cagnato and Ponce (2017), found evidence of manioc on various artifacts including grinding stones, (supporting evidence from Palenque), and ceramics sherds indicating the possible creation of fermented beverages. Sediment samples from five artifacts (four grinding stones and one ceramic sherd) yielded 53 manioc starch grains, with the largest quantity of starch grains recovered from a metate fragment. These grinding stones had evidence of manioc, chile peppers, and other tubers, suggesting a reliance on a broad diet during the Late Classic period. Moreover, Cagnato (2018) found numerous plant species from Late Classic period feasting contexts. These plant remains included field crops (*Zea mays*), Tree crops [*Cordia* cf. *dodecandra* (siricote) *Brysonima* (nance)], herbaceous plants [*Amaranthus* cf. *spinosus* (amaranth/pigweed), cf. *Chenopodium* sp. (goosefoot), Fabaceae (bean family), *Physalis* sp. (groundcherry), cf. *Solanum* sp. (nightshade)] along with an unidentified tuber fragment and spines of cf. Arecaceae (Cagnato 2018). Thus, this site within the Usumacinta River region provides evidence of a broad use of plant species during the Late Classic period and a reliance on species other than maize into the Terminal Classic. For Maya people inhabiting La Corona, manioc was likely an important food resource especially during the Terminal Classic period, when manioc was consumed at this site (Cagnato and Ponce 2017).

Similarly, the site of Macabilero has provided insight into foodways and plant use from the Formative period into the Classic period. Within the Petén area and located east of the Usumacinta River, Macabilero is a fortified settlement containing both defensive walls and terraced platforms (Watson 2022). Macrobotanical analysis conducted by Watson (2022), identified sweet potato, bean, maize, Jamaican pepper and knotweed. Moreover, microbotanical analysis of artifact residues and sediments provided evidence of a broad use of taxa including *Manihot esculenta*, *Canna* sp., *Marantaceae* sp., *Piper hispidum, Zea mays*, and *Ipomoea batatas* (Watson 2022). Interestingly, Watson (2022), found that during the Formative period individuals at this site consumed more manioc than any other crop. This study's results are comparable to those conducted by Cagnato (2018), Cagnato and Ponce (2017) and Durán et al. (2021) which found manioc to be a important and likely staple crop of the area.

Research conducted by the Proyecto Paisaje Piedras Negras - Yaxchilán (PPPNY) project and Shanti Morell-Hart has begun to elucidate foodways and plant use within the sites surrounding the Usumacinta River. The use and disposal as well as presence/absence of various plant species were analysed (Morell-Hart and González Córdova 2017). Paleoethnobotanical analysis of macrobotanical remains from Piedras Negras conducted by Morell-Hart and González Córdova (2017), revealed the presence of chile seeds, hojasanta genus, beans, Melastomataceae, Oenothera sp. as well as various unknown tubers and wood fragments from a structure located on top of a hill. Further preliminary sediment analysis recovered remains of the endocarp of the nance fruit and a few undefinable eroded charred remains. Similarly, preliminary results from excavations conducted by the Proyecto Arqueológico Busiljá-Chocoljá (PABC) project, Shanti Morell-Hart and Sarah Watson from Budsilljá, and Sak Tz'i' – Lacanjá, revealed various plant species utilized by Maya residents (Morell-Hart, et al. 2018). Identification of 45 taxon from seeds included maize, chile seeds, Asteraceae, Fabaceae, Rosaceae, *Rivina humilis*, Euphorbiaceae, Lamiaceae, and Moraceae (Morell-Hart, et al. 2018). Notably, these seeds were also recovered with various unknown tubers and wood fragments.

Following the same patterns as in the broader southern Maya lowlands, foodways and plant use of the Usumacinta River region were variable between elites and commoners. Where elite diets show changes through time, commoner diets remained more constant. Made possible by a variable diet including various forest species along with root and tuber crops, commoner diets and individuals at peripheral sites were seemingly able to maintain their foodways and plant use in times of environmental stress at the end of the Classic period. This is seen in the archaeological record which displays a constant presence of a wide array of plant species. Meanwhile, major changes occurred for elite diets, as evidenced by isotopic analyses and paleoethnobotanical analyses which demonstrate a decrease in maize and big game from the Classic to Late Classic period. While non-elites were able to continue thriving in the Usumacinta River region, larger sites were abandoned during the Terminal Classic.

Key Thesis Questions: Expectations from the Literature

To summarize, Maya foodways and subsistence practices underwent major shifts during the Early Classic to the Terminal Classic period, with different communities involved in different degrees of agricultural production (Scherer et al. 2007). Maya people inhabiting smaller centers likely relied on hunting and diverse agriculture to provide food, evident in the lack of isotopic changes from the Classic to Terminal Classic period and the presence of a broad range of plant species other than maize including both wild and forest species. In contrast, elites underwent major changes in the subsistence practices and resource management during a time of climatic shifts at the end of the Classic period. It is expected that larger centers would have been more susceptible to environmental pressures as maize helped to feed large populations.

Notably, archaeological research on ancient Maya populations in large city centers often overlooks the food resilience of smaller Maya communities and the Maya culture as a whole. This resilience is evident as smaller communities utilized diverse animal and plant food resources that remained almost constant from the Early Classic and Terminal Classic periods. More research specifically at more peripheral sites is vital to better understand the subsistence strategies of ancient Maya people, instead of solely relying on data regarding elite diets at major polities. Although many large southern lowlands sites underwent abandonment during the Terminal Classic period, the overall resilience of the Maya people and culture is evident in smaller communities and settlements.

The following questions will be analysed from the results of Budsilha excavations: Which plants were consumed and present in the paleoenvironment during the Classic period?; How does evidence of plant use affect understandings of collapse narratives?; and, What is the role of maize in subsistence and agricultural strategies as compared to wild taxa and staple root crops? Based on the aforementioned data, it was expected that a wide variety of plant taxa would be recovered from the botanical data. These species would include maize as well as other important forest species, wild species and root and tuber crops. The smaller site of Budsilha would provide more data on subsistence patterns and plant use of species that would have been grown at this site during the Classic period.

In the next chapter I describe the ecology and landscape of the Usumacinta River region. Situating my study within this region I summarize what is currently known about the Classic period site of Budsilha. Details of excavations at Budsilha in 2018 by locus and general findings from these excavations are summarized.

Chapter 3: The Usumacinta River Region and the Classic Period Maya Site of Budsilha

As demonstrated by the research summarized in the previous chapter, isotopic and paleoethnobotanical analyses yield invaluable information on plant use and the environment, bringing to light the breadth and complexity of Maya subsistence patterns. Targeting peripheral and subordinate sites for analysis of foodway changes over time will provide insight into the radical demographic shifts at the end of the Classic period. Understanding how the ancient Maya utilized their surrounding environment for subsistence to sustain large populations has implications for agricultural and environmental sustainability today.

The Usumacinta River region located with the southern lowlands provides an ideal location to study Maya subsistence patterns during the Classic period. Containing an amalgamation of both large city centers and smaller subordinate communities, this region offers insight into changing foodways and plant use during a time when larger city centers were abandoned. A holistic understanding of Maya subsistence and plant use is possible by combining research from a plethora of sites from large city centers to smaller hamlets. Notably, the Usumacinta River may have provided a water source during what is said to have been a period climatically lacking the necessary water capacity to sustain larger crop surpluses (Lucero et al. 2014). This chapter will explore what is known about the Usumacinta River region during the Classic period and highlight information from the Classic period site of Budsilha, the focus of my microbotanical analysis and interpretations.

The Usumacinta River Region

The Usumacinta (meaning “place of many sacred monkeys” or “river of the sacred monkey”), branches throughout the western region of the southern Maya lowlands (**Fig. 3.1**) (Canter 2007). Encompassed by two extensive systems of navigable rivers and a strong current, the Usumacinta was and is a swift commercial highway. This river network would have been an excellent travel route transporting people and goods in the region, with goods likely transported upstream to Yaxchilán or Piedras Negras, two rival centers during the Classic period (Golden et al. 2012). Hilltops and highpoints provided visibility of the surrounding landscape, giving these bordering settlements control over land routes and trade (Schroder et al. 2017). Despite this notion that the Usumacinta River was a highway, the river can be deadly and difficult to navigate requiring skilled navigation (Golden et al. 2012). Cargo that was fragile may have also been transported more efficiently by foot throughout the area (Golden et al. 2012).

Figure. 3.1 Map of the Usumacinta River Region. Various sites in the region are depicted. (Emery 2007a).

Today the river serves as a boundary between Mexico and Guatemala. Since the 2000s the Usumacinta River region, encompassing a total area of 73,000 km^2, has been identified as a biodiversity hotspot (Laako and Kauffer 2022). Consisting of humid tropical rainforests, this area provides habitat for various species and vital ecosystem services such as improving air and water quality, erosion prevention and sustaining biodiversity (Brockerhoff et al. 2017; Guerra et al. 2016). Issues with research in this area, encompassing the 365km long river, involve the difficulty in aligning research projects in two different countries: Mexico and Guatemala (Golden et al. 2012, 2015). Today, sites on opposite sides of the river are often studied as very distinct entities (Golden et al. 2012, 2015; Schroder et al. 2017). However, for the ancient Maya, it was the location of interconnected polities and communities (Golden et al. 2015; Schroder et al. 2017).

Settlements within the Maya lowlands during the Late Classic period were semi-dispersed, providing opportunities where diverse Maya communities had differential access and control over trade routes and areas of agricultural production (Schroder et al. 2017). The valleys in Guatemala and Mexico running southeast to northwest, roughly parallel to the Usumacinta River, are considered to be important land routes that encouraged political integration and competition among the communities and kingdoms of the Late Classic period (Golden et al. 2012, 2015; Schroder et al. 2017). The sites within this region include the capitals of two major Maya polities, Piedras Negras and Yaxchilán, both occupied from the Preclassic through the Terminal Classic periods (Golden et al. 2012). Yaxchilán and Piedras Negras reached the peak of their power during the Late Classic period (Golden et al. 2012).

Some small communities that emerged during the Preclassic and Early Classic periods were folded into the expansion of multiple city cores (Golden et al. 2012). The landscape in the

Usumacinta region underwent political change with the creation of defined and controlled borderlands made up of hamlets, tertiary centers (larger central architectural groups) and secondary centers (used for gatherings of mass amounts of people) (Golden and Scherer 2013). Unfortunately, by the Terminal Classic these dominant powers plunged into political and economic difficulties. During the Early Classic period, Piedras Negras was one of many small communities along the Usumacinta River (Scherer et al. 2007). Fuelled by immigration from other regions, around AD 400 – 450 this site underwent a population explosion that continued through to the Late Classic period. By the Late Classic period Piedras Negras was one of the dominant powers within the region, with 2000 – 3000 people estimated to have lived in the core. During the Terminal Classic period, economic and political difficulties ensued culminating in the defeat and slaughter of Piedras Negras' ruler around AD 808 by Yaxchilán (Golden et al. 2012; Scherer et al. 2007; Schroder et al. 2017).

The Classic period site of Budsilha, as I further discuss below, is a smaller site located south of Piedras Negras. This site was first identified by Maler in 1897 during a time where dense forest coverage still covered the Usumacinta River region (Scherer and Golden 2012). Situated within the middle Usumacinta River region, Budsilha is located just outside the contemporary town of Nueva Esperanza (Scherer and Golden 2012).

Budsilha: Political History and Environment

Situated within the middle Usumacinta River region on the eastern side of the Usumacinta River, Budsilha (**Fig. 3.2**) is a secondary political center of Piedras Negras (Golden et al. 2012; Scherer and Golden 2012; Schroder et al. 2017; Tiesler and Lozada 2018). Named after the nearby river (Budsiljá) and nestled among foothills and jagged cliff faces within the

Chiapas highlands there is no shortage of perennial surface water (Scherer and Golden 2012). Tributaries, large lakes and smaller lagunas make up this middle Usumacinta river region with the Usumacinta River flowing northwest towards the Gulf of Mexico (Scherer and Golden 2012).

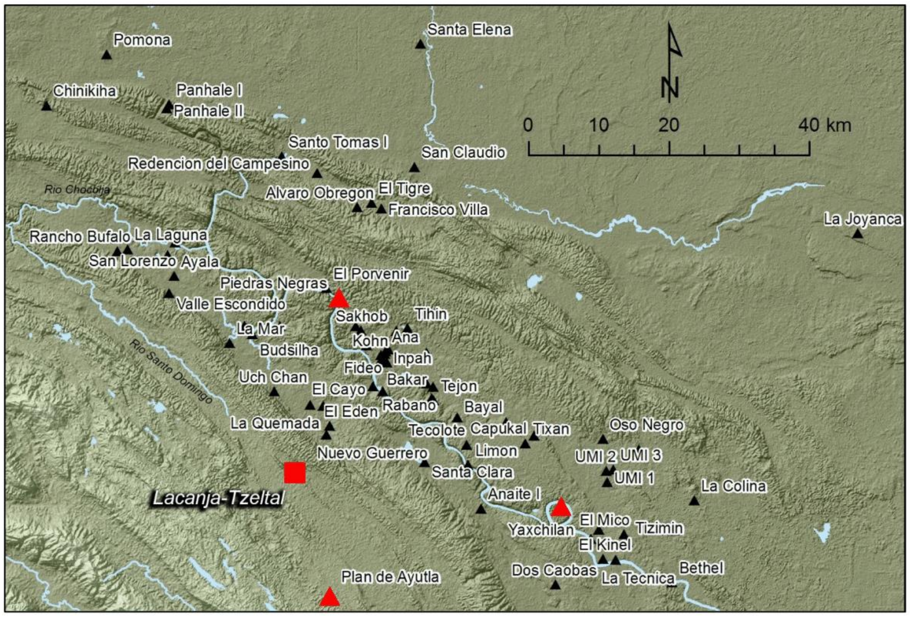


Figure. 3.2 Topographical Map of the Usumacinta River Region and Surrounding Sites. Budsilha is depicted amongst other neighbouring Classic period sites (Golden and Scherer 2018).

Budsilha is situated in a low-lying area adjacent to the river and its principal architectural complex is 450m south on a raised platform. The settlement was built above the flood zone, with the site core on a low rise and the surrounding settlement on the hilltops. During the Classic period Budsilha was suspected to have been seasonally inundated and the forest coverage surrounding the site was likely more substantial (Scherer and Golden 2012). Prone to flooding near the northern edge there seems to have been a landing site for canoes travelling the river. Following reconnaissance conducted by Scherer and Golden (2012) it was concluded Budsilha was likely a sparsely settled site lacking a substantial residential component and due to all identified structures being located atop hills except for the primary group the site was likely not a major residential community. Moreover, since the area surrounding Budsilha was an expansive and flat valley it would have been a coveted area by surrounding polities (**Fig. 3.4**).

Figure. 3.4. Photo Depicting Budsilha Fields. Photo taken by Shanti Morell-Hart (2018).

This site may have been a politically independent site although two hypothesis of political control have been put forward (Scherer and Golden 2012), (1) located to the west, La Mar may have governed the site making Budsilha a special-function site or (2) Budsilha was directly governed by Piedras Negras who had interest in expanding its regional political alliances. Moreover, evidence of Lacandon Maya at this site indicate Budsilha may have been a site of pilgrimage similar to Piedras Negras and Yaxchilán during the Classic period (Scherer and Golden 2012).

Budsilha Excavations

All of the samples analyzed in the current study came from excavations conducted during the 2018 field season by members of PABC. These excavations followed the standard excavation methodology for the PABC. Below, I briefly describe the results of each of the excavated lots.

Operation BU-1B-05.

At the west end of the main plaza, unit 1B-05 (**Fig. 3.5**) is located in front of a wall identified during the previous 2012/2013 field seasons (Morell-Hart et al. 2018). The aim of this operation was to sample the waste deposit for paleoethnobotanical remains within the identified special deposit in the plaza (Morell-Hart et al. 2018). From each level of the excavated unit, sediment samples were taken, and a metate, obsidian blade and ceramic sherd was sampled.

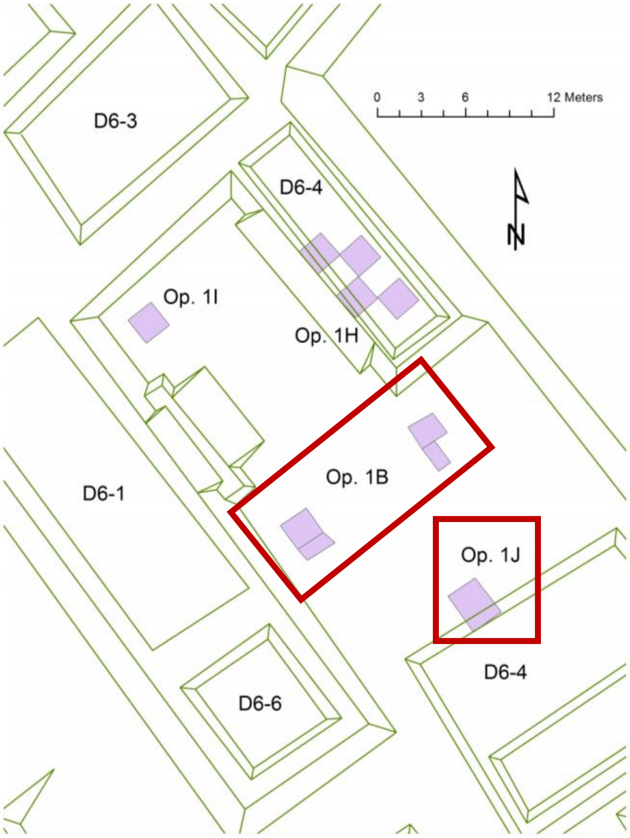


Figure. 3.5 Operation BU-1 Excavation Map.
Map depicting excavations from Operation BU-1. (Map created by C. Golden & J. Schnell)

Operation BU-1B-07-08.

This operation, located by the buried wall that crosses the main square, contained a crypt (**Fig. 3.5**) (Morell-Hart et al. 2018). Burial 10 contained a young man buried within fill containing detritus and elite household trash (Morell-Hart et al. 2018). The skeleton was in a state of poor preservation with some bones disorganized including the teeth and pelvis. Moreover, the quality of the artifacts recovered were higher than that of common household garbage (Morell-Hart et al. 2018). The left maxillary molar from the 10 yr. old was sampled for microbotanical analysis. Isotopic analysis was also conducted.

Operation BU-1J-01-04.

Covered by plaza fill, Burial 11 is located in front of the stairway of structure D6-5 (**Fig. 3.5**) (Morell-Hart et al. 2018). Evidence suggests the body was buried in the empty cist, which was subsequently filled (Morell-Hart et al. 2018). The skeletal remains were in a state of poor preservation, but were identified as an adult (Morell-Hart et al. 2018). The right third maxillary molar from the adult was sampled for microbotanical analysis. Isotopic analysis was also conducted.

Operation BU-8A-01.

Next to the structures D5-1, D5-2, and D5-3, identified as a residential core, Operation BU-8A-01 (**Fig. 3.6**) provided an opportunity to find household garbage that was disposed of/swept (Morell-Hart et al. 2018). Located northeast of the monumental core, and west and below structures D5-2 and D5-3, this area is a potential dump or sweeping area situated on a natural terrace (Morell-Hart et al. 2018). A ceramic pot from lot 2 with a large base was sampled for botanical analysis (Morell-Hart et al. 2018). A sediment sample was also taken from this lot.

Lot 3 contained a partially buried metate with two other fragments uphill east of the unit (Morell-Hart et al. 2018). This metate was sampled for analysis. Recovered materials from this operation were all consistent with common domestic trash (Morell-Hart et al. 2018).

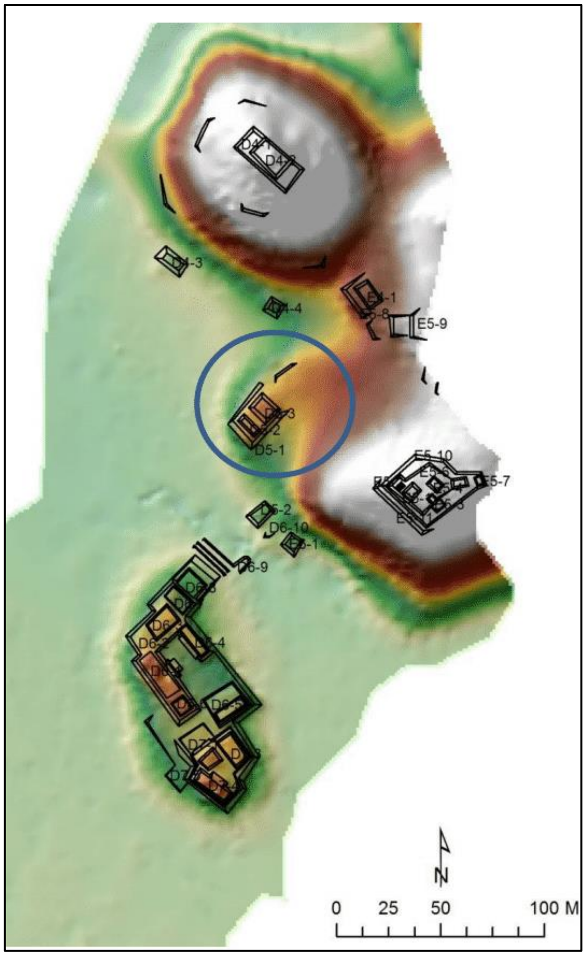


Figure. 3.6 Operation BU-8A Excavation Map.
Map depicting excavations from operation BU-8A. (Map created by B. Davenport, C. Golden, A. Scherer, & J. Dobereiner).

Operation BU-6B-16-08.

Burial 12 is located in the plaza between structures D7-3 and D7-4 (**Fig. 3.7**) (Roche Recinos 2018). This informal burial contained a complete hemispherical vessel and the skull of a child approximately 3-5 years old (Roche Recinos 2018). The absence of the postcranial skeleton suggests this is a special deposit of a vessel and a head of a child. The right deciduous 1st molar and basal sherd of a small bowl was sampled for microbotanical analysis.

Figure. 3.7. Operation BU-6 Excavation Map.
Map depicting excavations of operation BU-6A and BU-6B. (Map created by C. Golden, B. Davenport, A. Scherer, & J. Dobereiner).

Operation BU-6B-18-05.

Located in the plaza between D7-2, D7-3 and D7-4, Burial 9 is a crypt covered by fill from the plaza (**Fig. 3.7**) (Roche Recinos 2018). Notably, the crypt contained irregular stone walls and some worked stones. The Burial contained three teeth and four bone fragments of an adult in situ. The absence of long bones and skull fragments along with the presence of a second slab in the crypt suggests the individual was removed from the crypt in ancient times (Roche Recinos 2018). The left maxillary canine from the adult was sampled for microbotanical analysis. Isotopic analysis was also conducted.

Operation BU-5B.

This operation was conducted to investigate the central swampy area of Budsilha to determine if this area was used as an agricultural field (**Fig. 3.8**) (Dine, 2018). A 200g sediment sample was taken from lot 2 of unit 1 located south/southwest of the main structures. This lot contained compact soil with loam and clays (Dine, 2018). Unit 2 was located in the northeast in a location where the bedrock was not close to the surface. Lot 2 of unit 2 contained compact grey soil and a single sediment sample was taken (Dine, 2018). Two sediment samples were taken from lot 4 which contained silty mud. One sample was from the bottom while the other was from the top of the lot. This lot also contained charred remains (Dine, 2018).

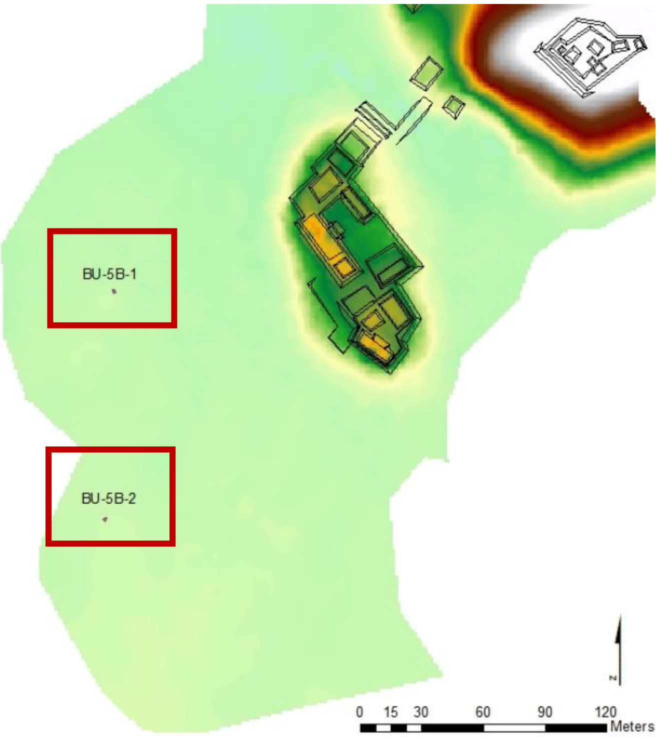


Figure. 3.8. Operation BU-5B Excavation Map.
Map depicting excavations of Operation BU-5B. (Map created by C. Golden, B. Davenport, A. Scherer, & J. Dobereiner).

In total, 11 sediment samples were taken from nine different lots, six artifact residue samples were taken from three different locations, and four human teeth residue samples were taken from four different burials. These samples were analyzed using several different methods, further detailed in Chapter 4 according to type of analysis.

Summary

Budsilha is an ideal location to study Classic period plant use and foodways of ancient Maya people. As a secondary political center, information from this smaller site will add to the knowledge of the complex and highly variable plant use within the broader Usumacinta River region. Examining collapse narratives and theories of maize crop failure, paleoethnobotanical data recovered from Budsilha will be evaluated to determine how the presence of particular plant species affect these narratives. Furthermore, assessing the role of maize in subsistence and agricultural strategies relative to wild taxa and staple root crops at Budsilha will illuminate potential food-related species that could affect resiliency during climatic shifts.

In the next chapter I summarize field sampling strategies and paleoethnobotanical laboratory methodologies used to target artifact and teeth residues, and phytoliths from soil samples. Microbotanical analysis methodology is also summarized and information on obtaining datasets of starch grains and phytoliths is highlighted. I also provide information on different types of datasets that can and will be targeted to answer my aims and questions about subsistence, foodways, plant use and ethnoecology.

Chapter 4: Paleoethnobotanical Methodology: Recovery of Microbotanical Evidence

In the previous chapters, I have described Maya foodways and plant use during the Classic period in order to understand which plants Classic period Maya people were consuming and growing. In this chapter, I describe field sampling strategies and laboratory methodologies used to target soil samples, and artifact residues to retrieve microbotanical datasets of starch grains and phytoliths. I also describe the various types of datasets that can be targeted to answer questions about foodways, agriculture, and the paleoenvironment in the past.

Paleoethnobotanical Analysis

In Mesoamerica, paleoethnobotanical approaches have been successfully used to determine artifact use (Cagnato and Ponce 2017; Chen et al. 2022), foodways, cuisine and diets (Cagnato 2018; Lentz 1991; Morell-Hart et al. 2021, 2022), changes in diet over time, ethnoecology and changes within the paleoenvironment, agriculture (Fedick 2010; McNeil et al. 2010; McNeil 2012; Morell-Hart et al. 2022) and feasting practices. A wide variety of studies have been conducted at various sites throughout Mesoamerica in order to broaden the understanding of Maya subsistence and the paleoenvironment. Utilizing microbotanical remains, macrobotanical remains or isotopic analysis various scholars have added to the current knowledge of plant use and diets in the past.

In this study, samples were obtained from artifacts and human teeth recovered from Budsilha, as well as sediments, to extract and identify botanical residues. Analyzed materials included two metates, four human teeth, an obsidian blade, and three ceramic sherds. Residue analysis of artifacts and human teeth has been successfully used to answer questions surrounding the link between tool types and their functions (Barton and White 1993; Perry 2004; Yang et al. 2009), which foods these individuals were consuming in the past (Duncan et al. 2009; Melton et al. 2023), and the ethnoecology of various areas to understand the dynamic plant human relationship (Jovanović et al. 2021; Kealhofer and Penny 1998; Morell-Hart et al. 2019). Further on, I incorporate prior studies of isotopic signatures in human bone, and macrobotanical residues. By combining these approaches, it is possible to obtain a more holistic picture of past foodways, diets, and the paleoenvironment (Morell-Hart 2019).

Phytoliths.

Made up of bodies of silica, phytoliths are fossilized plant cells or interstitial areas (Marston, Jade, et al. 2015; Pearsall 2016). During a plant's life, silica is deposited into its roots, stem, leaves and inflorescence. Once deposited the silica takes on the shape of the space in which it forms creating diagnostic phytoliths. Dicotyledonous are plants that deposit silica within their intracellular structures while monocotyledonous plants deposit silica directly into their cells (Pearsall 2016; Piperno 1985).

Starch Grains.

Ubiquitous across all plants, starch grains are found within leaves, fruit, seeds, roots and shoots (Shannon et al. 2009; Torrence and Barton 2016). The distinctive morphology of starch grains resulting from genetic composition can provide evidence of the presence of starch storage organs (Torrence and Barton 2016). Identification of different species can be done by looking at the shape of the hilum (nucleus), fissures (cracks), and lamellae (growth rings). Moreover, using polarized light, the shape of the extinction cross becomes visible allowing additional identification of diagnostic characteristics of starch grains (Elizabeth Reitz and Shackley 2012).

Isotopic signatures.

Isotopic analysis is another way in which information about diets and the paleoenvironment can be elucidated. Isotopic analysis of sediments can be used to determine plant use, paleoenvironment changes and the surrounding ecology (Fernández et al. 2005), and isotopic analysis of bone collagen can provide evidence of which foods individuals were consuming (Golden et al. 2015; Richards and Britton 2020; Scherer et al. 2007).

Different types of plants utilize either the C3 or C4 photosynthesis pathway. Wild species including forest taxa use the C3 pathway, maize uses the C4 pathway and CAM plants (orchids and bromeliads) have values that fall between the two (Kohn 2010; Richards and Britton 2020). C3 and C4 plants differ in the way that they assimilate atmospheric CO_2 into their tissues which can be identified in either sediments or bone collagen (Fernández et al. 2005; Marston, Jade, et al. 2015). Forest species, and terrestrial vegetation are all C3 taxa that are located within temperate environments, while C4 plants (maize and millet) become dominant within arid grassland ecosystems (Kohn 2010; Richards and Britton 2020). Similar to forest species, marine species also utilize the C3 pathway (Richards and Britton 2020).

Carbon and nitrogen isotopic analysis of bone collagen can provide direct information pertaining to human diets of the past (Richards and Britton 2020). This data allows for the distinction between diets comprised of marine and terrestrial sources, and C3 and C4 plants with those having consumed marine foods or C4 maize diets displaying unique signatures (Richards and Britton 2020). Maya mean $\delta^{13}C$ ranges from -14.7 to - 6.85‰, with values at the lower range indicating less maize consumption (Scherer et al. 2019). In order to obtain these residues, collagen, which comprises approximately 20% of bone, must be extracted from the bone (Richards and Britton 2020).

Macrobotanical residues.

Macrobotanical analysis has been a part of archaeological investigations in the Maya area well before microbotanical analysis. Charred, dried and waterlogged botanical remains are recovered from sediments through sieving or floatation (Pearsall 2016). These remains include seeds, nuts, and wood that are able to be identified with the naked eye or a low powered microscope (Pearsall 2016). The varying distinct morphology of seeds, fruits, nuts, and charred wood enables these plant remains to be identified to the family or species level (Pearsall 2016). All macrobotanical remains recovered from Budsilha excavation in 2018 were identified by S. Morell-Hart, M. MacLeod, H. Dine, and S. Watson.

Budsilha Excavations and Sampling Strategies

The samples collected during the 2018 field season were collected to maximize recovery of macrobotanical, starch grains and phytolith data sets. As described in the previous chapter, botanical remains were targeted from five different operations at Budsilha. Three types of deposits were excavated including agricultural areas (5B-01, 5B-02), residential architecture (8A-01, 8A-02) and ritual deposits (1B-05, 1B-06) (Morell-Hart, Dine, et al. 2018). Macrobotanical remains and starch grains provide information pertaining to diet while phytoliths provide information about agriculture and the surrounding environment. Research was orientated towards edible plants including cultivated and wild species, with an interest in presence/absence and patterns of use and disposal (Morell-Hart, Dine, et al. 2018). From Budsilha 13 floatation samples, 15 small sediment samples and 10 samples of artifact residues and human teeth were recovered during the 2018 field season (Morell-Hart, Dine, et al. 2018).

Sediment sample selection, collection, floatation, and processing was performed by S. Morell-Hart, H. Dine, S. Watson and M. MacLeod. Macrobotanical remains are retrieved from the archaeological record through sediment screening through a sieve, sediment floatation (10L of sediment), or in-situ (Pearsall 2016). Microbotanical remains can be retrieved from artifacts and sediments through laboratory isolation and extraction processes. Starches and phytoliths can be deposited on teeth during eating, and left on artifacts following storage, cooking and grinding (Pearsall 2016). Macrobotanical analysis was conducted by S. Morell-Hart and S. Watson.

Artifacts targeted from Budsilha excavations included obsidian blades, ceramic sherds, and metates. Human teeth from burials were also targeted. To avoid contamination artifacts were bagged as soon as possible (Morell-Hart, Dine, et al. 2018). Sediment samples were taken from various lots for phytolith isolation. Phytoliths become bound to the compounds within the soils as plants are burned, digested or decay which allows for the study of sediments in-situ (Pearsall 2016). In each selected lot small sediment samples of 200g scattered throughout the excavated area were taken (Morell-Hart, Dine, et al. 2018).

Artifact Extractions

Microbotanical residues extracted from artifacts and teeth provide evidence of direct plant use and consumption. Plant taxa identified to specific artifacts pinpoint an artifact’s use while species identified on teeth provide evidence of consumption. Phytoliths and starch grains preserved on artifacts and teeth can be recovered through extraction of botanical residues.

Extraction of microbotanical residues was conducted on two metates, three ceramic sherds, one obsidian blade and four human teeth.

Extractions of residues from Budsilha artifacts and human teeth.

Microbotanical residue extractions were performed in 2018 by Shanti Morell-Hart, Harper Dine, Sarah Watson, and Meghan MacLeod. Extractions proceeded according to established protocols of the McMaster Paleoethnobotanical Research Facility (Morell-Hart 2015) and other resources (Pearsall 2016). Artifacts and human teeth were assigned numbers, photos were taken, and any distinctive morphology was noted. Three centrifuge tubes were labelled with artifact number and designated wash (dry wash, wet wash, sonicated wash) for each artifact. Each tube was then labelled with its corresponding tag: Project-Site-Area/Feature-Group/Burial/Patio-Structure/Mound/Platform-Unit-Level-Wash

In order to minimize contamination, sterile preparation of the work station was performed and *Kimwipes* were placed on the surface of the workstation. Petri dishes, and sonicator were washed with distilled water before and between washes. Powder free gloves were changed between washes. Before each wash, a sterile pipette was obtained and placed in a labelled centrifuge tube.

First, a dry wash was completed of each artifact or human tooth. The surface of the artifact was gently rubbed with fingers allowing for material to fall into the petri dish. Residue that remained was lightly scratched off. This process continued until no material was falling off the artifact. Material in the petri dish was removed and pipetted into the corresponding centrifuge tube using distilled water.

Second, the wet wash was completed. Using a small amount of distilled water, the finger tips of gloves were wetted. The artifact or tooth surface was gently rubbed with fingers. A small amount of distilled water was washed over the surface until clear distilled water was present. Material in the petri dish was pipetted into the corresponding centrifuge tube.

Finally, a sonicated wash was completed. Sonication of artifacts and human teeth was performed at 30-40kHz for approximately 2-5 minutes. Sonication was repeated 1-7x allowing the sound waves to travel through the water into pores and crevices to release fixed residues. The material obtained went into the solution and was pipetted into its corresponding centrifuge tube. Smaller artifacts and human teeth were placed directly into distilled water within the petri dish. The sonicator spatula was then submerged in close proximity to the surface of the specimen. For larger artifacts such as metates and ceramic sherds the cupped portion of the artifact was filled with distilled water. The sonicator spatula was then placed at the surface.

Slide creation and specimen identification.

At the MPERF, slide preparation and analysis was completed. Slides were prepared according to the methodology outlined by Pearsall (2016). The workstation was washed using soap and water. *Kimwipes* were placed on the surface of the workstation. To minimize contamination each centrifuge corresponding to the specific wash of each specimen was opened and a sterile pipette was placed into it. Approximately 2-3 drops of residue solution were added from each centrifuge tube onto a corresponding microscope slide. The centrifuge tube was closed and the pipette was discarded. A cover slide was placed on top and excess liquid was removed with a new *Kimwipe*. Edges of the cover slide were sealed with *Sally Hansen Hard as Nails* coloured nail polish to delineate slide edges and keep the slide material aqueous for a longer period of time.

Identification of starch grains and phytoliths was conducted for each of the three slides (washes). Sample counts of identifiable specimens was targeted to N=100 although most slides had smaller counts. A Zeiss transmitted light microscope (100x-1000x magnification) and polarized light were utilized for the identification of each microremain.

Sediment Sample Extractions

Microbotanical and macrobotanical analysis of sediments provides evidence of plants that were present within the paleoenvironment, deposited through human activities, and/or grown agriculturally. Processing of sediments is conducted to isolate phytoliths for identification. Extractions of phytoliths were conducted on sediment samples from nine different contexts.

Sediment digestion and flotation.

10L sediment samples were taken from various lots of excavation units (**see Table 4.1**). Samples from lots were taken evenly from the center and four corners of the lots. The bulk of these sediment pinch samples were later processed for flotation of macrobotanical remains, but 200g of each 10L sample was taken as a pinch sample for microbotanical extractions. These 200g samples were processed for phytolith isolation at the MPERF according to the process outlined by Shanti Morell-Hart in 2018 (**Appendix A**).

Table 4.1. Recovered Sample Type by Provenience.
Provenience is displayed with corresponding number of microbotanical samples studied.
Number of recovered samples is depicted.14 different contexts were sampled.

	Sample Type			
Provenience	Sediment	Artifact	Tooth	Isotope Residue
BU-5B-01-02	2			
BU-5B-02-02	1			
BU-5B-02-04	2			
BU-8A-01-02	1	1		
BU-8A-01-03		1		
BU-1J-01-04			1	1
BU-1B-05-02	1			
BU-1B-05-04	1			
BU-1B-05-06	1			
BU-1B-05-07	1	3		
BU-1B-05-08	1			
BU-1B-07-08			1	1
BU-6B-16-08		1	1	
BU-6B-18-05		1	1	1

Slide creation and specimen identification.

At the MPERF, slide preparation and analysis were completed. Slides were prepared according to the methodology outlined by Pearsall (2015). The workstation was washed using soap and water. *Kimwipes* were placed on the surface of the workstation. The centrifuge tubes of the phytolith concentrate from the 200g sediment samples were opened, and a small amount of phytolith concentrate was transferred to a PCR tube. The centrifuge tube was then closed. Using a new pipette approximately 5 drops of immersion oil was added to the PCR tube. Using the same pipette, the oil was mixed with the phytolith concentrate. 2-3 drops of the residue solution were added to the microscope slide. The PCR tube was closed and the pipette was discarded. A cover slide was placed on top and excess liquid was removed with a new *Kimwipe*. Edges of the cover slide were sealed with *Sally Hansen Hard as Nails* coloured nail polish to delineate slide edges and keep the slide material aqueous for a longer period of time.

Identification of phytoliths was conducted for each sediment sample. Sample counts of identifiable specimens was targeted to N=100. A Zeiss transmitted light microscope (100x-1000x magnification) and polarized light were utilized for the identification of each microremain.

Summary: Paleoethnobotanical Field and Laboratory Methods

In this chapter, I have described field sampling strategies and laboratory methodologies used to target microbotanical residues, isotopes and macrobotanical remains to retrieve datasets to help answer questions pertaining to agricultural methods, foodways, plant use and ethnoecology. Although every methodology is necessarily a product of local field and laboratory situations, nonetheless, as described in Chapter 5, these methods were successful in obtaining a rich data set for this study. In Mesoamerica, utilizing paleoethnobotanical methods, a plethora of research questions have been answered by various scholars and researchers. Highlighting the success of other research with similar questions, this type of analysis is ideal for answering my specific research questions.

Chapter 5: Plant Use in Budsilha: Results of Microbotanical Residue Analysis

In previous chapters I outlined the paleoethnobotanical research methods used in this thesis to answer questions about ethnoecology, agriculture and foodways. I also highlighted the range of narratives pertaining to these questions, and expectations about Classic Period Maya people derived from these narratives. In this chapter I present the results of the paleoethnobotanical research conducted at Budsilha. During the 2018 field season, microbotanical and macrobotanical samples were collected from nine contexts. To pursue my research questions, from 2022-2023 I completed microbotanical analysis of residues from six artifacts, four human teeth, and 11 sediment samples, at the McMaster Paleoethnobotanical Research Facility (MPERF). Utilizing modern comparative collections, I identified residues from at least 18 plant taxa. Here, I present the results of these analyses. In the subsequent chapter I compare the ubiquity of maize with other taxa, including wild species and root crops, and compare these results with those from surrounding sites including Piedras Negras and Macabilero.

Microresidue Analysis

Identification of taxa from artifact residues indicates which species can be directly linked to the artifact's use, which plants were being utilized generally, and identifies the presence of plants within the environment. As described in Chapter 4, microbotanical remains were identified from each wash (sonicated, wet and dry) to help elucidate which plants were being processed, stored, or consumed. Microbotanical remains including phytoliths and starch grains were recovered from a total of six artifacts, four human teeth and 11 sediment samples during the 2022-2023 study (**Fig. 5.1-5.14**).

Operation BU-1B.

This operation was conducted as an extension of a special deposit within the plaza and to sample the midden context (Morell-Hart et al. 2018). This Classic period deposit contained large sherds, obsidian blade fragments, faunal bones, and broken ceramic vessels that could represent the remains of feasting (Morell-Hart et al. 2018). Notably, from Lot 7 multiple ceramic sherds, faunal bones including deer, and shells, an obsidian blade along with obsidian fragments, stucco, a figurine head and an almost complete metate were recovered (Morell-Hart et al. 2018). At the base of this lot half of a metate was recovered (**Fig. 5.1**).

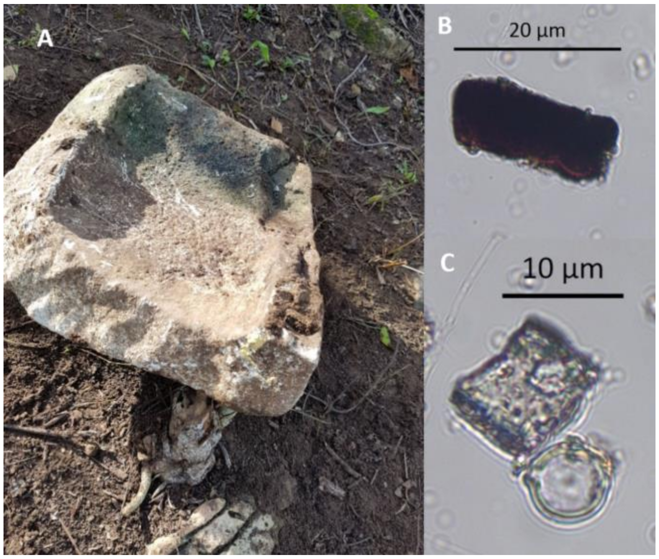


Figure. 5.1. BU-1B-05-07 Artifact 6 Microremains
Artifact is depicted in the field and recovery information is present. Artifact was very large and was sampled in the field. (a) half of a metate recovered from platform fill. Photo taken by Shanti Morell-Hart. (b) UNKN Wood, micro charcoal. Elongate. (c) UNIDENT damaged starch grain. No extinction cross present.

The microresidues recovered from the metate (**Fig. 5.1**) were limited. Overall, more microresidues were identified from the dry wash which included microcharcoal (**Fig. 5.1b**), an unknown fiber (**Fig. B.4a in Appendix B**), a damaged starch grain (**Fig. 5.1c**) and Chrysophyceae sp. (golden algae). No microremains were identified from the wet wash and the sonicated wash only contained Chrysophyceae sp.. Since golden algae was recovered from both the sonicated wash and the dry wash it can not be definitively connected to the artifact's use.

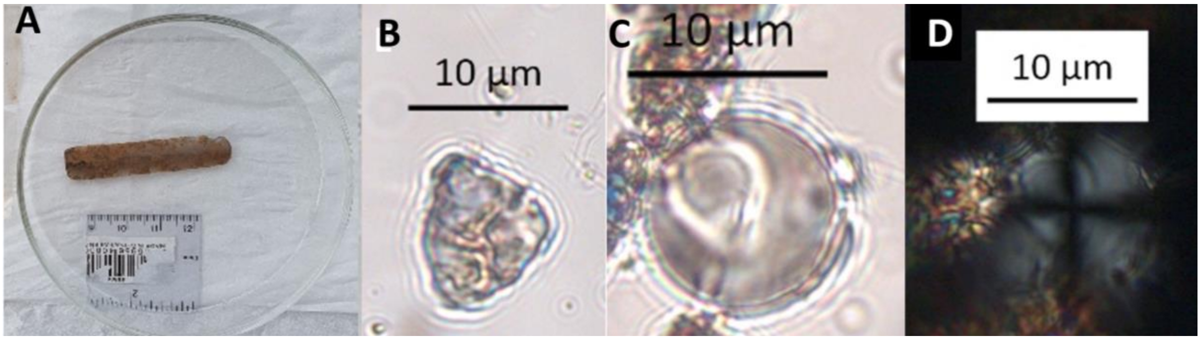


Figure. 5.2. BU-1B-05-07 Artifact 7 Microremains
Artifact is depicted with measurement visible and recovery information present (a) Proximal fragment of an obsidian blade. Wear is present along both margins. Photo taken by Shanti Morell-Hart. (b) UNIDENT heavily damaged starch grain. Extinction cross is very faint. Cracking on surface present. (c-d) UNIDENT damaged starch under regular transmitted light. UNIDENT damaged starch with extinction cross present under polarized light.

The microresidues recovered from Artifact 7, an obsidian blade (**Fig. 5.2**) contained more identifiable microremains, although no microremains were identified from the wet wash. From the sonicated wash two unknown tissues (**Fig. B.2a and Fig B.4e in Appendix B**), an unknown fiber (**Fig. B.4g in Appendix B**), golden algae, and an unknown phytolith 56 (**Fig. B.1a in Appendix B**) were recovered. The dry wash contained two different damaged starches (**Fig. 5.2 b-d**), and unknown phytolith 57 (**Fig. B.1b in Appendix 2**). The lack of identifiable microbotanical remains along with the presence of tissues and fibers from the sonicated wash may indicate that this obsidian blade was used for plant resource extraction or other non plant uses, such as butchering.

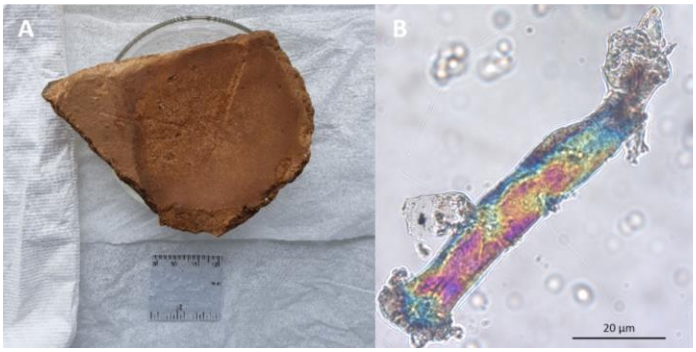


Figure. 5.3. BU-1B-05-07 Artifact 8 Microremains
Artifact is depicted with measurement visible and recovery information present (a) Basal sherd. Scraping on the interior side is present. Photo taken by Shanti Morell-Hart. (b) UNKN fiber. Large fluorescent fiber with severed edges.

The microresidues recovered from Artifact 8, a basal sherd (**Fig. 5.3**), were very limited as no identifiable remains were recovered from both the dry wash and the sonicated wash. The wet wash contained the sole microremain which was an unknown fiber (**Fig. 5.3**). It may be that the microremains from this ceramic vessel were not preserved or this vessel was used for other purposes than food storage or preparation. It is also important to note that this artifact was recovered from a secondary context.

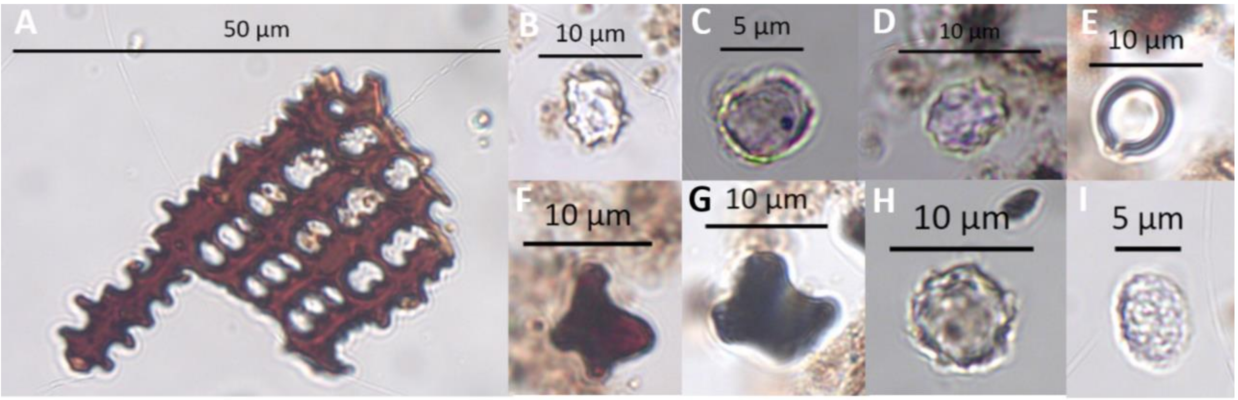


Figure 5.4. BU-1B-05. Sediment Microremains.
(a) Asteraceae sp. Large fragment. Recovered from lot 7. (b) *Maranta* sp. recovered from lot 7. (c) *cf. Canna* sp. recovered from lot 6. (d) Arecaceae sp. recovered from lot 6. (e) Chrysophyceae sp. recovered from lot 6. (f) Burned Poaceae sp. recovered from lot 6. (g) Burned grass possible Bambusoideae sp. recovered from lot 6. (h) Arecaceae sp. recovered from lot 2. (i) Arecaceae sp. recovered from lot 2.

A total of five sediment samples from various lots was taken from BU-1B-5 (**Fig. 5.4**). From Lot 2, Arecaceae sp. (palm family species), Asteraceae sp. (sunflower family species), cf. Poaceae sp. (grass family species) and golden algae was identified. Unknown phytoliths 39 and 55 (**Fig. B.3t, ak in Appendix B**) were also recovered, along with arboreal spheres. Lot 4 contained more unknown fibers (**Fig. B.4l-n in Appendix B**) than phytoliths. Identified plant taxa included Asteraceae sp. and Arecaceae sp., and there was only a single unknown phytolith, unknown phytolith 54 (**Fig. B.3aj in Appendix B**). This lot also contained arboreal spheres and two different unknown biological specimens (**Fig. B.2d-e in appendix B**). From Lot 6, cf. *Canna* sp. (achira), Asteraceae sp., golden algae, Arecaceae sp., Poaceae sp., and Marantaceae sp. (arrowroot family species) were identified. Unknown phytoliths 46, 51-53, and 55 (**Fig. B.3aa, ag-ai, ak in Appendix B** respectively) along with arboreal spheres were also recovered. Lot 7 contained the following identified taxa: Asteraceae sp., *Maranta* sp. (arrowroot), golden algae, and unknown taxa including arboreal spheres, phytolith 1, phytolith 47-50 (**Fig. B.3ac-af in appendix B**), and an unknown fiber (**Fig. B.4o in Appendix B**). Lot 8 contained no identifiable microremains. Some of these microremains including grass species had evidence of charring.

Macrobotanical identification conducted by S. Morell-Hart, S. Watson and M. Macleod in 2018 revealed the presence of 21 different taxa (**Table 5.2**), which represents the most taxa recovered in a single context. From Lot 2, Asteraceae sp., cf. Rosaceae sp. (rose family species), *Jussiaea* sp. (evening primrose), Lamiaceae sp. (mint family species) *Physalis* sp. (nightshade family, *Vitis tiliifolia* (grapevines), and *Piper hispidum* (Jamaican pepper) were recovered. Lot 4 contained *Philodendron* sp., Lamiaceae sp., *Jussiaea* sp., Poaceae sp., and Portulaca sp. (purslanes). From Lot 6 a total of 11 different plant families were identified which included

Arecaceae sp., Boraginaceae sp. (forget-me-not family species), *Melocactus* sp. (melon cactus species), *cf. Oreopanax* sp. (ginseng family species), cf. Bignoniaceae sp. (trumpet vine species), *cf. Guazuma ulmifolia* (bay cedar), *cf. Zea mays* (maize), and *cf. Capsicum annuum* (chile pepper). Lot 7 contained Arecaceae sp., Euphorbiaceae sp. (spurge family species), *Byrsonima crassifolia* (nance), and *Piper sp.* (pepper species). Species from the sunflower family was recovered from all lots: 2, 4, 6 and 7.

Operation BU-1B-07-08.

This operation was oriented north following the buried wall that crossed the main square (Morell-Hart et al. 2018). Lot 1 contained garbage fill although the quality of these artifacts including polychromes and figurines was higher than that of average household garbage (Morell-Hart et al. 2018). Burial 10 included a young man buried inside the garbage reused as fill. Excavators recovered obsidian fragments near the skull, and a concentration of ceramics and faunal bones in the rest of the burial location (Morell-Hart et al. 2018). The bones were poorly preserved and disorganized with the teeth located above the pelvis (Morell-Hart et al. 2018).

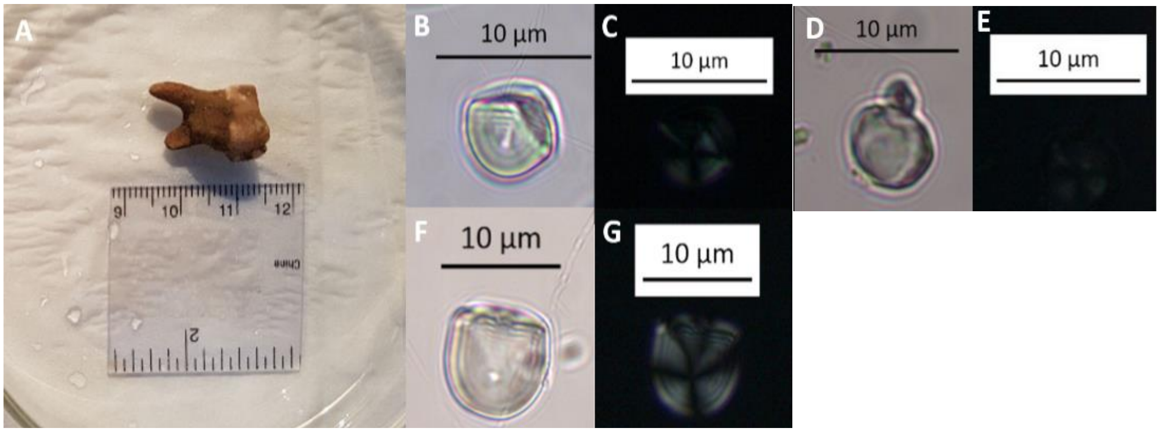


Figure. 5.5. BU-1B-07-08 Extraction 18 Microremains
Specimen is depicted with measurement visible and recovery information present (a) Left maxillary molar from a 10 yr. old recovered from burial 10. Photo taken by Shanti Morell-Hart. (b-c) *cf. Manihot esculenta* under regular transmitted light. *Cf. Manihot esculenta* with faint extinction cross present under polarized light. (d) *cf. Zea mays.* Damaged starch. *Cf. Zea mays.* Damaged starch with very faint extinction cross present. (f-g) *Manihot esculenta* under regular transmitted light. *Manihot esculenta* with extinction cross under polarized light.

The microresidues recovered from Extraction 18, a left maxillary molar (**Fig. 5.5**), contained various starch grains as well as unknown tissues and fibers. From the dry wash *Manihot esculenta* (manioc) *(***Fig. 5.5f-g**), *cf. Zea mays* (**Fig. 5.5d-e**) and a damaged undiagnostic starch was recovered. The wet wash contained an unknown tissue that was present throughout the sample and the sonicated wash contained *cf. Manihot esculenta* (**Fig. 5.5b-c**), an unknown tissue and an unknown fiber (**Fig. B.4d in Appendix B**). During the extraction of the dry wash residue some of the material was impacted into the tooth's crevasses. This may affect which plant species can be associated with the individual consuming during life as the distinction between dry wash, wet wash, and sonicated wash was complicated during processing.

Operation BU-1J-01-04.

Burial 11, filled with fill from the plaza, was uncovered in front of the stairway by D6-5, suggesting the body was buried and then the burial was refilled later (Morell-Hart, et al. 2018). Within the burial, the remains of an adult were recovered in poor preservation. Multiple skeletal fragments were recovered of both the cranium and post cranium. Notably, special artifacts were also recovered including a bead/tube of bone, shells, and pottery next to the head.

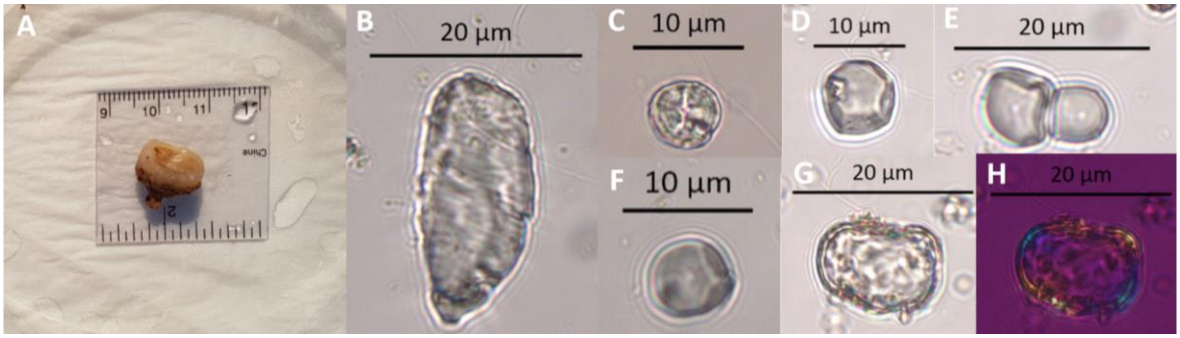


Figure. 5.6. BU-1J-01-04 Extraction 19 Microremains
Specimen is depicted with measurement visible and recovery information present (a) Right third maxillary molar from an adult recovered from burial 11. Photo taken by Shanti Morell-Hart. (b) cf. *Dioscorea* sp. phytolith. (c) Heavily damaged starch. *cf. Zea mays.* (d) *cf. Ipomoea batatas*. Damaged starch with flower like shape (e) UNIDENT starches attached to each other. (f) *Manihot esculenta* (g-h) UNKN damaged starch. Pitting on surface similar to fermentation damage. Extinction cross absent.

The microresidues recovered from Extraction 19, a right third maxillary molar (**Fig. 5.6**) contained various microbotanical remains. The dry wash contained cf. *Dioscorea* sp. (yams), *Manihot esculenta*, and a starch grain containing damage similar to fermentation damage (**Fig. 5.6b, f-h**). The wet wash contained two unidentifiable starches attached to each other (**Fig. 5.6e**). Unlike the dry wash, the sonicated wash contained *cf. Zea mays* (**Fig. 5.6c**), *cf. Ipomoea batatas* (sweet potato) (**Fig. 5.6d**), an unknown fiber (**Fig. B.4i in Appendix B**), and an unknown tissue similar to a specimen from the dry wash of Artifact 16. The presence of maize and sweet potato in solely the sonicated wash indicates this adult likely consumed both of these plants close to the time of their death.

Operation BU-8A-01.

This operation was new in 2018 and was located northeast of the monumental core in a residential core area (Morell-Hart, Macleod, et al. 2018). Located on a natural terrace this operation was conducted in an area believed to contain household rubbish that was either disposed of or swept (Morell-Hart, Macleod, et al. 2018). Lot 2 contained a high number of ceramic sherds, small figurine sherds, shell fragments and obsidian flakes (Morell-Hart, Macleod, et al. 2018). Lot 3 contained a partially buried metate.

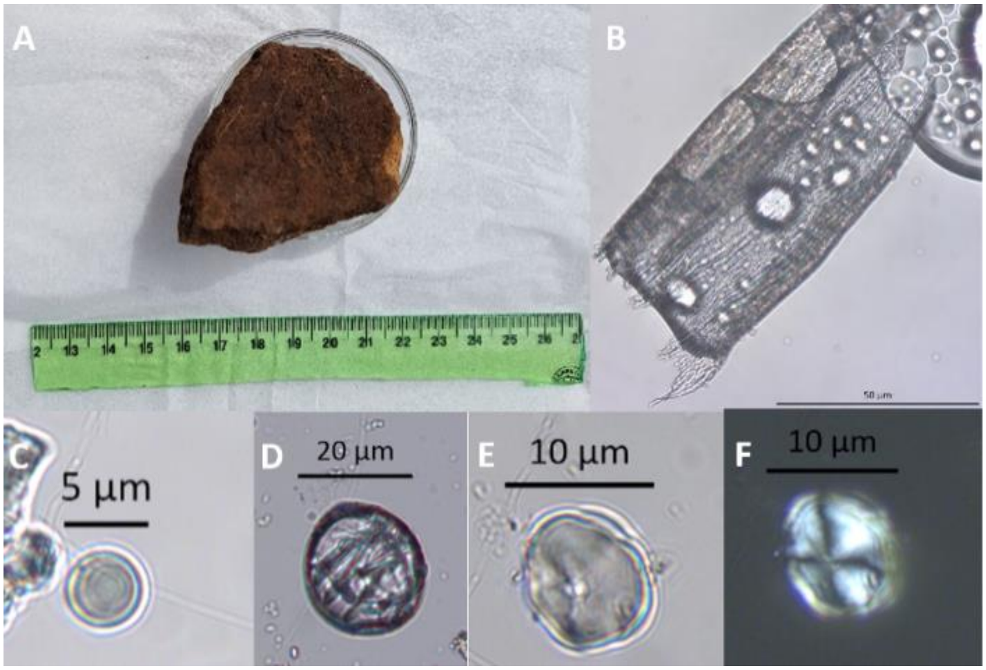


Figure. 5.7 BU-8A-01-02 Artifact 14 Microremains
Artifact is depicted with measurement visible and recovery information present. (a) Basal sherd. Both side and base portions are present. Photo taken by Shanti Morell-Hart. (b) UNKN siliceous tissue. Large tissue with striated surface. (c) UNKN phyto 59. Spherical, similar to *Canna* sp.(d) UNKN structure, possibly pollen. (e-f) UNIDENT damaged starch under regular transmitted light and polarized light. Extinction cross present.

The microresidues recovered from Artifact 14, a basal sherd (**Fig. 5.7**) contained various microremains. The dry wash contained the most recovered remains including two damaged starches, an unknown pollen grain, *cf. Canna* sp., unknown phytolith 58 (**Fig. B.1c in Appendix B**) and an unknown fiber. The wet wash contained unknown phytolith 59 (**Fig. 5.7c**) and the sonicated wash contained a large tissue/fiber (**Fig. 5.7b**). This ceramic sherd recovered from a midden context may have stored the non starchy part of the plant or the microremains from this ceramic vessel were not preserved.

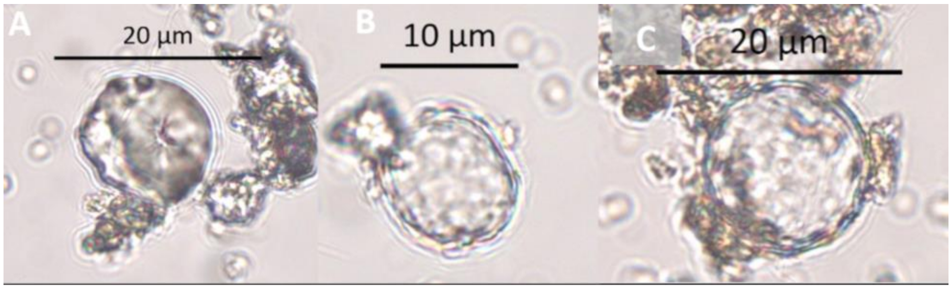


Figure. 5.8 BU-8A-01-03 Artifact 20 Microremains
Partially buried metate. No photo taken. (a) Heavily damaged starch. *Manihot esculenta*. (b) *cf. Cucurbita sp.*. Granular with distinct scalloping similar to *Cucurbita maxima* but size is closer to *Cucurbita andreana.* (c) UNKN phytolith. Scalloped edges. *Cucurbita sp.*.

The microresidues recovered from Artifact 20, a metate (**Fig. 5.8**) contained a variety of starches, phytoliths and fibers. From the dry wash, microcharcoal, two large unknown fibers and a phytolith of *Cucurbita* sp. (squashes) were recovered. The wet wash contained manioc, squash, an unknown tissue, and an unknown fiber. The sonicated wash of the metate had an unidentifiable, damaged starch grain, and an unknown fiber. The heavily damaged starch grain from the sonicated wash is likely associated with the artifact use as plant species would have been ground on the surface of the metate resulting in damage.

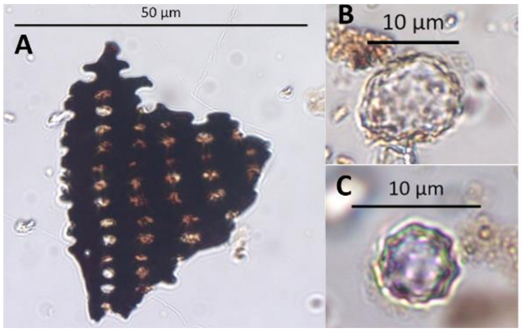


Figure. 5.9. BU-8A-01-02. Sediment Microremains
(a) Asteraceae sp. (b) Marantaceae sp. (c) Arecaceae sp.

Microremains recovered from a single sediment sample taken from BU-8A-1-2 (**Fig. 5.9**) contained a variety of identifiable taxa and unknown phytoliths. The unidentified phytoliths included unknown phytolith 20-29 (**Fig. B.3a-j in Appendix B**), and microcharcoal. This midden context contained a variety of identified taxa including Asteraceae sp., Poaceae sp., Marantaceae sp., Cucurbitaceae sp. (squash family species), and Arecaceae sp. Macrobotanical identification conducted by S. Watson in 2018 confirmed the presence of four different taxa (**Table 5.2**) from seeds in Lot 2: *cf. Zea mays*, Lamiaceae sp., Fabaceae sp. (bean family species), and Asteraceae sp.

Operation BU-6B-16.

This operation involved the excavation of a patio between the structures in the plaza. Within the courtyard of the architectural complex, Burial 12, an informal burial, was located between structures D7-3 and D7-4 (Roche Recinos 2018). Burial 12 contained the skull of a child 3-5 yrs. old and a ceramic vessel (Roche Recinos 2018). Notably, the teeth were located between the frontal bone and the vessel, and the absence of any postcranial skeleton suggested that this was a special deposit (Roche Recinos 2018). Underneath the ceramic vessel, multiple ceramic fragments, obsidian flakes, and quartz flakes were recovered, and the teeth were located between the frontal bone and the pot (Roche Recinos 2018).

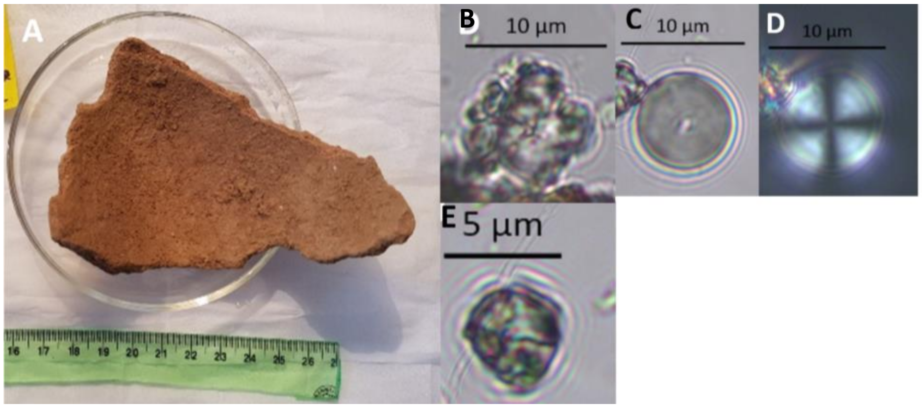


Figure. 5.10 BU-6B-16-08 Artifact 15 Microremains
Artifact is depicted with measurement visible and recovery information present (a) Basal sherd of a small bowl recovered from burial 12 containing a 3-5yr old. (b) Heavily damaged starch. (c-d) *Ipomoea batatas* under regular transmitted light. *Ipomoea batatas* with extinction cross present under polarized light. (h) Heavily damaged starch grain. Opaque and cracking on surface.

The microresidues recovered from Artifact 15, a basal sherd (**Fig. 5.10**) contained mostly starches. The dry wash only contained a heavily damaged unidentifiable starch grain. The wet wash contained *Ipomoea batatas* and a heavily damaged unidentifiable starch grain. Recovered from the sonicated wash was a heavily damaged unidentifiable starch grain and unknown phytolith 60 (**Fig. B.1e in Appendix B**). The *Ipomoea batatas* recovered from the sonicated wash may be related to direct artifact use, given the lack of *Ipomoea batatas* in the dry wash. The recovery of this basal sherd from a ceramic offering bowl from burial 10 can provide evidence of ritual plant use.

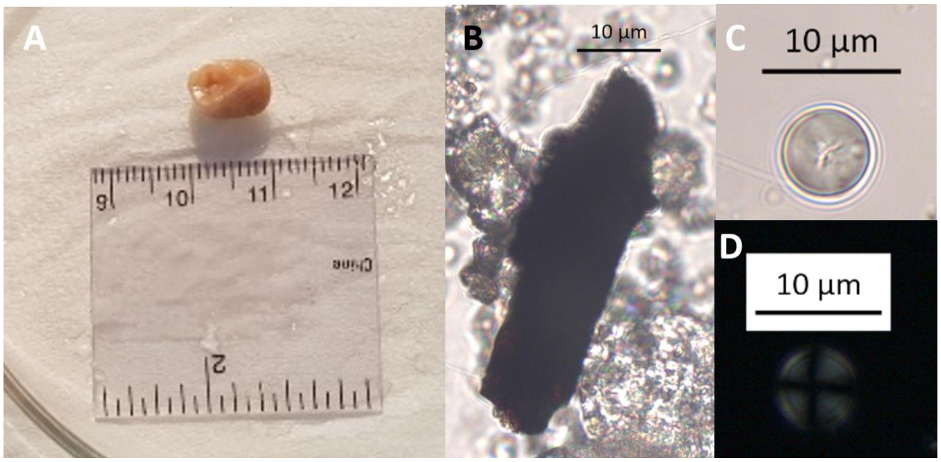


Figure. 5.11 BU-6B-16-08 Extraction 16 Microremains
Specimen is depicted with measurement visible and recovery information present. (a) Right deciduous 1st molar from a 5yr old recovered from burial 12. (b) UNKN Wood micro charcoal. Large fragment. (c-d) UNIDENT starch under regular transmitted light. Undiagnostic. Rounded with prominent hilum. Undiagnostic starch grain under polarized light with extinction cross.

The microresidues recovered from Extraction 16, a right deciduous 1st molar (**Fig. 5.11**) contained more tissue and fibers than starches. The dry wash contained an undiagnostic starch (**Fig. 5.11c-d**) and multiple pieces of an unknown tissue (**Fig. B.4c in Appendix B**). The wet wash contained microcharcoal (**Fig. 5.11b**) and an arboreal sphere. From the sonicated wash two fibers (**Fig. B.4h, j in Appendix B**) and multiple pieces of an unknown tissue similar to the recovered tissue from the dry wash was recovered. The presence of fibers and tissues along with the lack of starches recovered from the sonicated wash is similar, to the left maxillary canine from burial 9, may indicate the consumption of other plant parts or fauna by the 5 yr.-old individual.

Operation BU-6B-18-05.

Located within the same plaza as Burial 12, Burial 9 is a simple crypt covered with plaza fill (Roche Recinos 2018). This fill contained numerous obsidian artifacts. Ceramic fragments, obsidian fragments, snails and jutes were also recovered (Roche Recinos 2018). Only three teeth and four bone fragments were recovered *in situ* and many small bone fragments were present throughout (Roche Recinos 2018). It thus appears the individual was partially removed from the crypt in ancient times (Roche Recinos 2018).

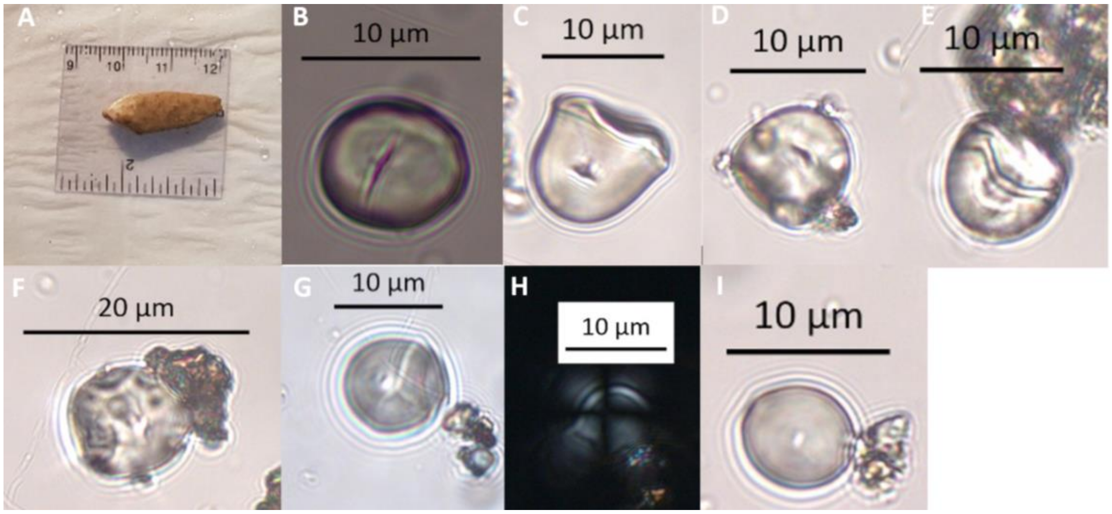


Figure. 5.12. BU-6B-18-05 Extraction 17 Microremains
Specimen is depicted with measurement visible and recovery information present. (a) Left maxillary canine from an adult recovered from burial 9. Photo taken by Shanti Morell-Hart. (b) UNKN starch. Very deep fissure.
(c) *Manihot esculenta* (d) *Manihot esculenta* (e) *cf. Manihot esculenta* (f) UNIDENT damaged starch. No extinction cross present. Scalloped edges. (g-h) UNKN damaged starch under regular transmitted light. Possibly sweet potato *(Ipomoea batatas)* but damaged. UNKN damaged starch with extinction cross present under polarized light. (i) UNIDENT starch grain. Nondiagnostic.

The microresidues recovered from Extraction 17, a left maxillary canine (**Fig. 5.12**) were mostly present in the dry wash. The dry wash contained multiple starch grains including damaged unidentifiable starch grains, sweet potato, and multiple manioc starch grains (**Fig.**

5.12c-d). The wet wash did not contain any microremains and the sonicated wash contained an unknown fiber (**Fig. B.4f in Appendix B**) and multiple pieces of unknown tissue (**Fig. B.4b in Appendix B**). The lack of starches recovered from the sonicated wash may indicate that these plants were not consumed by the adult individual but rather were present in the surrounding soils, or the starches did not preserve on the teeth for unknown reasons. Additionally, the presence of large fibers and tissue on the sonicated wash may indicate the consumption of other plant parts or fauna.

Operation BU-5B.

This operation was conducted to excavate an area believed to have been used as an agricultural field (Dine, 2018). From this swampy area a total of five sediment samples were taken from three different lots.

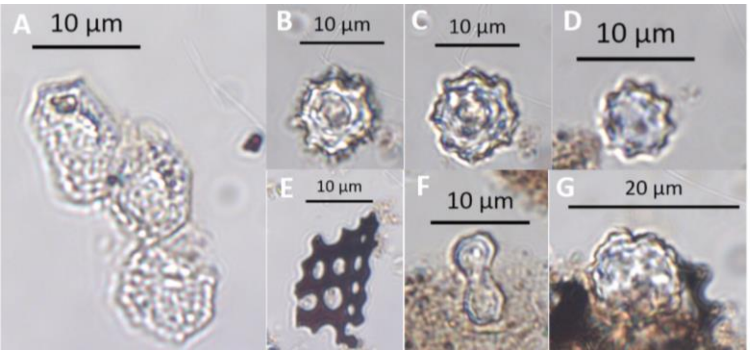


Figure. 5.13. BU-5B-02-02. Sediment Microremains
(a) Burseraceae sp. phytoliths. (b-c) Marantaceae/Arecaceae phytolith. (d) Arecaceae sp. palm phytolith with lobed surface. (e) Asteraceae sp. phytolith. (f) Poaceae sp. bilobate. (g) *Maranta* sp. phytolith.

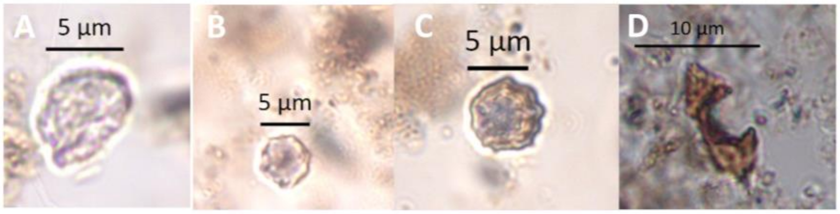


Figure. 5.14. BU-5B-02-04. Sediment Microremains
(a) Arecaceae sp. phytolith. (b) Arboreal sphere. (c) UNKN phytolith 1. (d) *Heliconia* sp. phytolith.

The two sediment samples recovered from BU-5B-1-2 (**Fig. 5.13**) contained a wide variety of phytoliths. A large number of Asteraceae sp. phytoliths were recovered including both small and large pieces. These phytoliths ranged from large plates 50um in length to smaller pieces approximately 20um in length. Other identified taxa included Arecaceae sp., Marantaceae sp., arrowroot, achira, calathea, and grass species. The sediment residues also contained unknown phytolith 45 and 46 (**Fig. B.3z, aa in Appendix B**), multiple unknown biological specimens (**Fig. B.3v in Appendix B**), arboreal spheres, and microcharcoal. The sediment sample recovered from BU-5B-2-2 (**Fig. 5.13**) contained various plant taxa, fibers and unknown phytoliths. Identified plant taxa included Burseraceae sp. (torchwoods), Arecaceae sp., Poaceae sp., Marantaceae sp., *Heliconia* sp., and Asteraceae sp. This sediment residue also contained unknown phytolith 1, unknown phytolith 41-44 (**Fig. B.3v-y in Appendix B**), and three unknown fibers (**Fig. B.3q-s in Appendix B**). The two sediment samples recovered from BU-5B-2-4 (**Fig. 5.14**) contained a range of different plant taxa including *cf. Cyathea* sp. (tree fern), *Heliconia* sp., and Asteraceae sp. The microremains also included arboreal spheres, microcharcoal, unknown phytolith 1, unknown phytolith 28 (**Fig. B.3i in Appendix B**), unknown phytolith 30-36 (**Fig. B.3k-q in Appendix B**), and an unknown fiber (**Fig. B.4k in Appendix B**). These microbotanical remains from BU-5B provide evidence of plants utilized for agricultural purposes as this operation was conducted away from the main structures within the central swampy area of Budsilha.

From the macrobotanical identification conducted by H. Dine, S. Watson and S. Morell-Hart, nine different plant families were identified (**Table 5.2**). From Unit 1 Lot 2, Asteraceae sp., *Oenothera* sp., Solanaceae sp., and cf. Verbenaceae sp. was recovered. Within the same unit, lot 3 contained Asteraceae sp., *Chenopodium* sp. (goosefoots), *Oenothera* sp., Poaceae sp., cf.

Eriogonum sp. (buckwheat), *Solanum* sp. (nightshades) and *Cissus verticillate* (possum grape vine). No identified macrobotanical remains were recovered from unit 2.

Comparison of all Recovered Botanical Remains

From the two metates analyzed, only one contained identifiable microremains in the sonicated wash. The metate recovered from platform fill of structure D-6-4 contained golden algae diatoms on both the sonicated wash and the dry wash. The other metate recovered from midden/fill next to structure D5-1 contained squash species from the both the wet and dry washes, and manioc from the wet wash (**Fig. 5.8**). Similarly, the ceramic artifacts did not have any identified microbotanical remains in the sonicated washes. The basal sherd recovered from a midden context (**Fig. 5.7**) only had *cf. Canna* sp. in the dry wash. The achira is thus likely associated with the surrounding midden rather than the vessel use. The other basal sherd (**Fig. 5.10**) of a small bowl recovered from Burial 12 contained sweet potato in the wet wash. Notably, the third basal sherd recovered from fill context contained no identifiable botanical remains from the three washes, and only a large fiber in the wet wash (**Fig. 5.7**). Moreover, the sonicated wash of the obsidian blade had golden algae diatoms, and large fibers.

Comparison of identified microremains from artifacts provides evidence of a varied use of plants, while teeth residues provide direct evidence of plant consumption. Direct association with obsidian blades indicates use for agricultural or plant resource extraction while ceramic residues indicate serving, cooking, or storage of the taxa. Each species from the sonicated washes was identified to a single artifact except for the golden algae diatoms which were identified on both a metate and obsidian blade. Overall, the teeth had the most identifiable remains from the sonicated washes. Sonicated residues from Budsilha artifacts and human teeth displayed a small number of taxa including golden algae, maize, sweet potato, and manioc.

The presence of identified taxa solely within the sonicated wash provides evidence of plants that can be directly associated with a particular artifact or tooth and its usage in the past. Taxa within the sonicated wash that are also present within the dry wash, wet wash, or both may be from the surrounding matrix and cannot be definitively tied to the tooth or artifact's use. The dry wash associated with the surrounding matrix, and the wet wash used as the buffer between the dry and sonicated wash, are used to eliminate possible species that are from the surrounding matrix. Comparing the identified species between the sonicated, wet and dry washes, **Table 5.1** shows which species have only been found in sonicated washes. Across all artifacts and human teeth, only a few identified botanical remains were recovered from sonicated washes. Only the obsidian blade and right third maxillary molar from an adult recovered from Burial 11 had species identified solely in the sonicated wash.

Table 5.1. Identified Species Within each Wash.
Comparison of identified species between sonicated wash, wet wash and dry wash. Species present in solely sonicated washes can be associated with direct use. Artifact 8 BU-1B-05-07, a basal sherd, is excluded from the table as no microbotanical remains were identified from the washes.

	Metate						Obsidian blade			Basal sherd						Tooth											
	BU-8A-01-03			BU-1B-05-07			BU-1B-05-07			BU-8A-01-02			BU-6B-16-08			BU-6B-18-05			BU-6B-16-08			BU-1B-07-08			BU-1J-01-04		
Species	s	w	d	s	w	d	s	w	d	s	w	d	s	w	d	s	w	d	s	w	d	s	w	d	s	w	d
cf. Canna sp.												1															
cf. Ipomoea batatas																									1		
cf. Manihot																						1					
cf. Manihot esculenta																		1									
cf. Zea mays																								1	1		
Chrysophyceae				1		2	11																				
Cucurbita sp.		1	1																								
cf. *Dioscorea* sp.																											1
Ipomoea batatas														1				1									
Manihot esculenta		1																3						1			1
UNKN dicot																				1							

Identification of phytoliths from sediment samples revealed a greater species diversity than artifact residues. Microbotanical remains were identified from 11 different contexts and three different operations (**Fig. 5.1-5.14**). Both sediment fractions (AB and S) were analysed individually. No identified remains were recovered from BU-1-B-5-8.

A wide variety of taxa was identified from the sediments, with a total of 16 species over 10 different plant families (**Fig. 5.15**). Identified taxa varied based on context, and the context the species was recovered from was compared to determine plant use. Analysis of identified species recovered from the sediment samples reveals the presence of various species and their association with different contexts. Some species including squashes and achira were limited to a single context (lot), while others such as heliconias were located within the same unit. Throughout the samples Asteraceae was ubiquitous throughout all sediment contexts. Recovered Asteraceae varied from large plates to small fragments and ranged in colour from black to brown. This analysis reveals which species could have been grown locally, and which were being utilized by individuals during the Classic period.

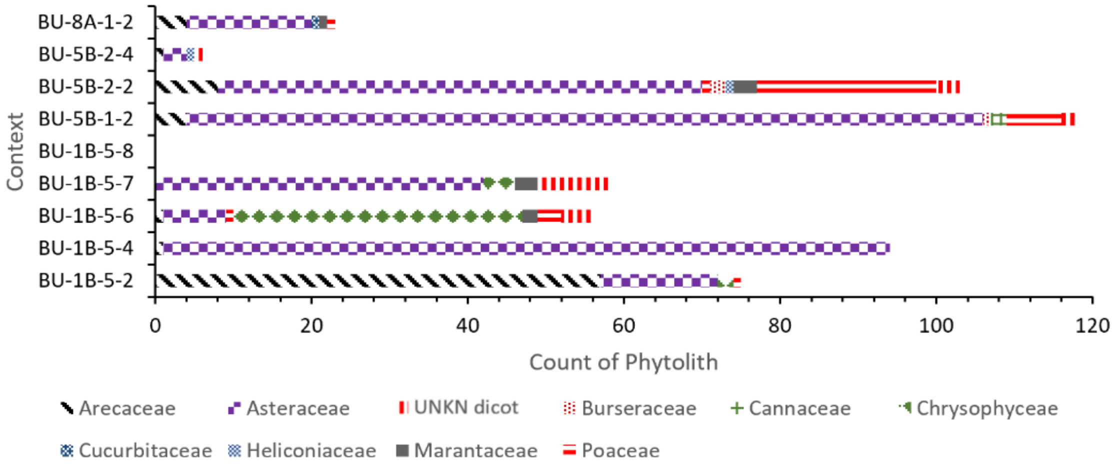


Figure 5.15. Presence of Species from Different Contexts.
Identified plant families are displayed. Nine different contexts were sampled.
Plant families are listed with common names. Arecaceae (palm family), Asteraceae (sunflower family), Burseraceae (torchwood family), Cannaceae (canna family), Chrysophyceae (golden algae), Cucurbitaceae (gourd family), Heliconiaceae (heliconia family), Marantaceae (arrowroot family), Poaceae (grass family).

The taxonomic richness of species recovered is significant with a total of 31 taxa identified. The types of identified taxa provide a picture of plants associated with humans and plants living within the Classic period environment. Based on the identified taxa from the sediments, Asteraceae was most prevalent in the assemblages making up more than half of identified taxa (63.6% of total identified taxa remains) (**Fig. 5.16**). Palm species (Arecaceae) comprised the second largest number of identified microremains (14% of total remains). Grass species including Bambusoideae sp., Panicoid sp., Poaceae sp., and Pooideae sp. totalled 6.9% of the identified microremains. Additionally, the presence of various agricultural species such as calathea, achira, arrowroot, squash and heliconia comprises 6.2% of the assemblage.

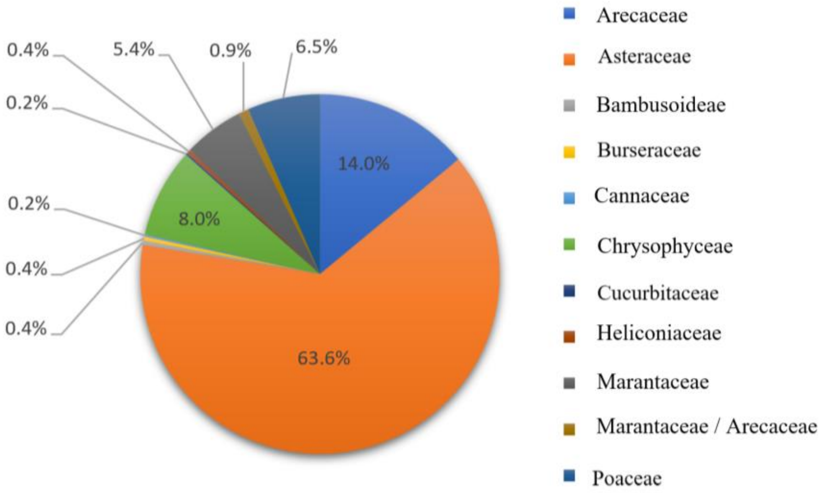


Figure. 5.16. Raw Number of Plant Specimens Associated Recovered from Sediments.
Data is presented in percentages of different identified phytoliths. N of identified microremains = 541
Plant families are listed with common names. Arecaceae (palm family), Asteraceae (sunflower family), Bambusoideae (bamboo subfamily), Burseraceae (torchwood family), Cannaceae (canna family), Chrysophyceae (golden algae), Cucurbitaceae (gourd family), Heliconiaceae (heliconia family), Marantaceae (arrowroot family), Poaceae (grass family).

A total of 23 different plant families were identified from macrobotanical remains (**Fig. 5.17**). Identified taxa varied based on context, and the context the species was recovered from was compared to determine plant use. Botanical remains recovered from the swampy area of Budsilha containing possible agricultural fields (operation 5B) contained wild species of

Asteraceae, Verbenaceae, grass species, Solanaceae (nightshades), and Vitaceae (grapes). From the residential core area (operation 8A) Asteraceae, Fabaceae, Poaceae and Lamiaceae (mints) was recovered. Recovered botanical remains from the midden context (operation 1B) contained a wide variety of species. The plant families identified within this context that was not identified within the other 2 operations included Arecaceae, Araceae, Boraginaceae (forget-me-not family), Oragraceae (evening primrose family), Rosaceae, Malvaceae (hibiscus/mallow family) and Portulaceae (purslane).

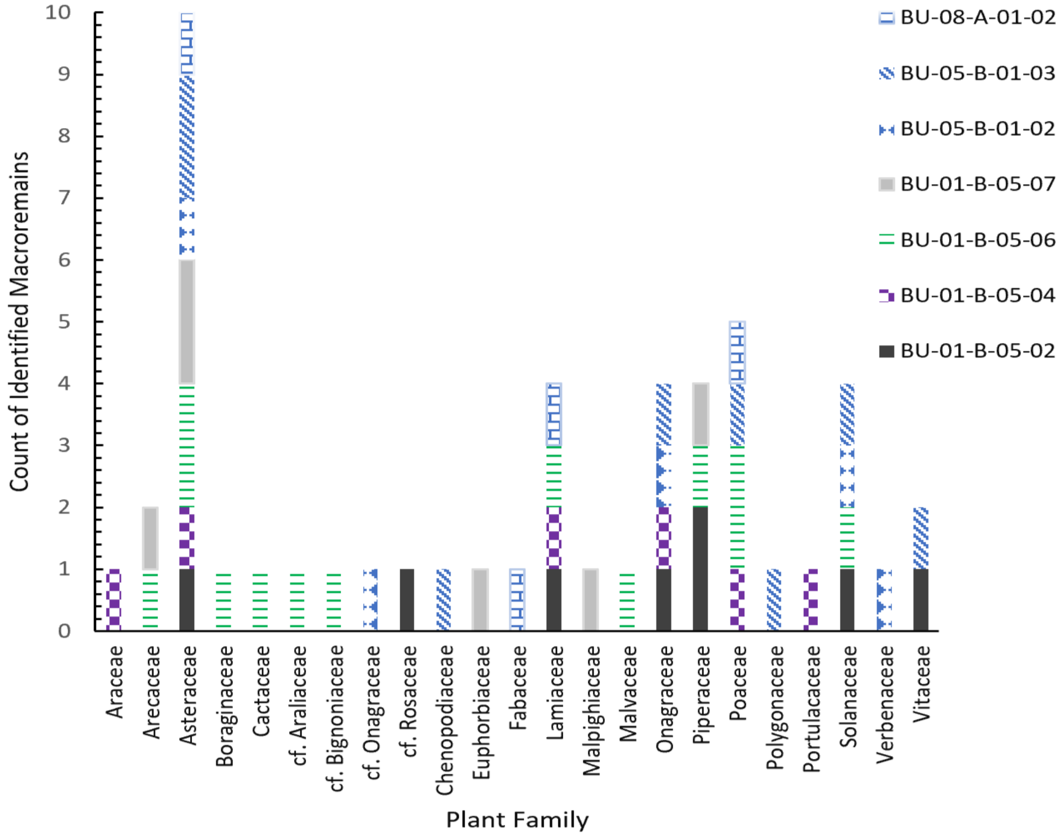


Figure. 5.17. Presence of Species from Different Contexts.
Identified macrobotanical remains of plant families are displayed. Macrobotanical remains were recovered from seven different contexts.
Species are listed with common name. Araceae (arums), Arecaceae (palms), Asteraceae (sunflower family), Boraginaceae (forget-me-not family), Cactaceae (cactus family), Araliaceae (ginseng family), Bignoniaceae (trumpet vine species), Onagraceae (evening primrose family), Rosaceae (rose family species), Chenopodiaceae (amaranth subfamily), Euphorbiaceae (spurge family), Fabaceae (bean family), Lamiaceae (mint family), Malpighiaceae (nance), Malvaceae (mallow family), Piperaceae (pepper family), Polygonaceae (knotweed family), Portulaceae (purslane family), Solanaceae (nightshades family) Verbenaceae (vervain family), Vitaceae (grape family).

Overall, the raw counts of identified microremains across sediments and artifacts is displayed in **Table 5.2.** There is little overlap between taxa identified on artifacts and taxa identified from sediments. Of all the identified taxa, only achira, golden algae, squash, and arboreal spheres were found within both sediment samples and artifact washes. All unknown phytoliths are depicted in **Figure B.3 in Appendix B**.

Table 5.2. Counts of Identified Plant Species
All identified plant species are depicted. Counts of identified remains are depicted based on recovery location. N= 742

	Sediment (Phytolith)		**Sediment (Phytolith)**	**Artifact Residue**	**Artifact Residue**	**Artifact Residue**	**Sediment Floatation**	**Sediment Floatation**	
	A/B Fraction		S Fraction	Sonicated Wash	Wet Wash	Dry Wash	Heavy Fraction	Light Fraction	Total
Araceae								**1**	**1**
Philodendron sp.								1	1
Arecaceae	**47**		**28**				**2**		**77**
Arecaceae sp.	45		28				2		73
cf. Arecaceae sp.	2								2
Asteraceae	**96**		**246**					**10**	**352**
Asteraceae sp.	96		246					1	343
Asteraceae sp. 1								6	6
Asteraceae sp. 30								2	2
Asteraceae sp. X								1	1
Boraginaceae								**1**	**1**
Boraginaceae sp.								1	1
Burseraceae			**4**						**4**
Burseraceae sp.			3						3
cf. Burseraceae sp.			1						1
Cactaceae								**1**	**1**
Melocactus sp.								1	1
Cannaceae	**1**		**1**			**1**			**3**
cf. Canna sp.	1		1			1			3
cf. Araliaceae								**1**	**1**
cf. Oreopanax sp.								1	1
cf. Bignoniaceae								**1**	**1**
cf. Bignoniaceae sp.								1	1
cf. Onagraceae								**1**	**1**
cf. Oenothera sp.								1	1
cf. Rosaceae								**1**	**1**
cf. Rosaceae sp.								1	1
Chenopodiaceae								**1**	**1**
Chenopodium sp.								1	1
Chrysophyceae	**43**			**2**		**2**			**47**
cf. Chrysophyceae sp.				1					1
Chrysophyceae sp.	43			1		2			46
cf. Cyatheaceae			**1**						**1**
cf. Cyathea sp.			1						1
Convolvulaceae				**1**	**1**	**1**			**3**
cf. Ipomoea batatas				1		1			2
Ipomoea batatas					1				1
Cucurbitaceae	**1**				**1**	**1**			**3**
Cucurbita sp.					1	1			2
Cucurbitaceae sp.	1								1
Dioscoreaceae						**1**			**1**
Dioscorea sp.						1			1
Euphorbiaceae				**1**	**1**	**6**		**1**	**9**

Euphorbiaceae sp.								1	1
cf. Manihot esculenta				1		3			4
Manihot esculenta					1	3			4
Fabaceae								**1**	**1**
Fabaceae sp.								1	1
Heliconiaceae	**1**		**1**						**2**
Heliconia sp.	1		1						2
Lamiaceae								**4**	**4**
Lamiaceae sp.								4	4
Malpighiaceae							**1**		**1**
Byrsonima crassifolia							1		1
Malvaceae							**1**		**1**
cf. Guazuma ulmifolia							1		1
Marantaceae	**16**		**11**						**27**
Calathea sp.	3								3
Maranta sp.	3		2						5
Marantaceae sp.	10		7						17
cf. Marantaceae sp.			2						2
Marantaceae/Arecaceae	**1**		**4**						**5**
Marantaceae sp./Arecaceae sp.	1		4						5
Onagraceae								**4**	**4**
Jussiaea sp.								2	2
Oenothera sp.								2	2
Piperaceae								**4**	**4**
Piper hispidum								1	1
Piper sp.								3	3
Poaceae	**36**		**4**	**1**		**1**		**5**	**47**
Bambusoideae sp.	1								1
cf. Bambusoideae sp.	1								1
cf. Chloridoideae sp.			1						1
cf. Zea mays				1		1		2	4
Panicoideae sp.	2		1						3
Poaceae sp.	25		2					3	30
cf. Poaceae sp.	1								1
Pooideae sp.	3								3
cf. Pooideae sp.	3								3
Polygonaceae								**1**	**1**
cf. Eriogonum sp.								1	1
Portulacaceae								**1**	**1**
Portulaca sp.								1	1
Solanaceae								**4**	**4**
cf. Capsicum annuum								1	1
Physalis sp.								1	1
Solanaceae sp.								1	1
Solanum sp.								1	1
UNKN	**79**		**39**	**2**	**4**	**5**			**129**
UNKN dicot	12		10		1				23
UNKN wood	12		2		2	3			19
UNKN phyto 1	30		2						32
UNKN phyto 20			1						1
UNKN phyto 21	1		1						2
UNKN phyto 22			4						4
UNKN phyto 23			1						1
UNKN phyto 24			1						1
UNKN phyto 25	1								1
UNKN phyto 26	1								1
UNKN phyto 27	2								2
UNKN phyto 28	2								2
UNKN phyto 29	1								1
UNKN phyto 30			1						1
UNKN phyto 31			1						1
UNKN phyto 32			1						1
UNKN phyto 33			1						1
UNKN phyto 34	1								1
UNKN phyto 35	1								1

UNKN phyto 36	1								1
UNKN phyto 37			1						1
UNKN phyto 38			1						1
UNKN phyto 39			2						2
UNKN phyto 40			1						1
UNKN phyto 41	1								1
UNKN phyto 42	1								1
UNKN phyto 43	1								1
UNKN phyto 44	1								1
UNKN phyto 45			1						1
UNKN phyto 46	4		3						7
UNKN phyto 47	1								1
UNKN phyto 48	1								1
UNKN phyto 49	1								1
UNKN phyto 50	1								1
UNKN phyto 51			1						1
UNKN phyto 52	1								1
UNKN phyto 53			1						1
UNKN phyto 54			1						1
UNKN phyto 55	1		1						2
UNKN phyto 56				1					1
UNKN phyto 57						1			1
UNKN phyto 58						1			1
UNKN phyto 59					1				1
UNKN phyto 60				1					1
Verbenaceae								**1**	**1**
cf. Verbenaceae sp.								1	1
Vitaceae								**2**	**2**
Cissus verticillata								1	1
Vitis tiliifolia								1	1
Total	**321**		**339**	**7**	**7**	**18**	**4**	**46**	**742**

Further analysis is required to identify unknown specimens, as well as potentially diagnostic Marantaceae vs Arecaceae microremains. Further research into possible diagnostic characteristics of individual species within the Asteraceae and Arecaceae family would also be helpful.

Overall, however, we see that a wide variety of plant taxa were present within the paleoenvironment during the Classic period and Maya people were utilizing a wide range of these species. Asteraceae sp. was recovered in the highest amount from sediment samples, while maize was very limited in its overall recovery. Overall, a total of 30 different plant families were identified from the sediment samples, artifacts and macrobotanical remains. These plant species include both wild and domesticated plants indicating the use of both agricultural techniques and forest management practices that would have helped these diverse plant species to thrive. In the final chapter, I draw comparisons using isotopic signatures and teeth residue washes to obtain a more holistic view of Classic period diets. I also compare the overall ubiquity of maize throughout the sample compared to other agricultural crops and wild species, to elucidate Maya foodways and plant use during the Classic period. Finally, I compare the plant species identified with ethnographic studies of Indigenous Maya communities to help understand how diets and food would have looked during the Classic period.

Chapter 6: Classic Period Ethnoecology and Maya Plant Foodways at Budsilha

Utilizing agricultural methods including homegardens, arboriculture, and terraces, Maya people inhabiting the southern lowlands of Mexico would have been able to harness the potential of many different species for food (Morell-Hart et al. 2022). In the previous chapters I have shown that the microbotanical analyses of artifact residues and sediments from Budsilha indicate a broad range of species present in the environment during the Classic period. In total, a minimum of 18 different plant species were identified from the sediment samples and artifact residues, while a minimum of 26 plant species were identified from macrobotanical remains, with three overlapping taxa (Arecaceae sp., Asteraceae sp., *cf. Zea mays*). These represent only 41 plants among the 497 different indigenous plant species Maya people used for foodstuffs, in a biodiverse and nutrient-rich subsistence pattern (Fedick 2020; Morell-Hart et al. 2022). Though this study revealed a small percent of the overall number of plants available as food, nonetheless, several broader interpretations can be made.

This final chapter addresses the two primary aims of the study: (a) identifying which plants were consumed and present during the Classic period, and (b) evaluating the role of maize in subsistence and agriculture strategies relative to wild taxa and staple root crops. The aims and results of this study will be discussed to address the role of maize in subsistence during the Classic period and how these results situate Maya plant use at Budsilha.

Classic Period Plant Use at Budsilha: Food and Agricultural Practices

The high species diversity of plant food crops consumed by Classic period Maya people includes various parts such as fruits/berries, leaves, herbs, seeds, nuts, flowers, roots, tubers, pods, shoots, oils, stems, and grains (Fedick 2020). The swampy field areas of Budsilha would have been an ideal location to grow various food crops, alongside better-drained areas in more upland slopes. Maya people inhabiting Budsilha during the Classic period would have been able to take advantage of the surrounding swamp area to intensify agricultural production of crops by capitalizing on the water source and expanding swamp boundaries (Scarborough 2007). To combat the water-saturated soils of the wetland area, community members created raised fields that would have increased yields and helped prevent crop loss from flooding (Comptour et al. 2018; Scarborough 2007).

Contemporary Indigenous Maya populations continue to cultivate geophyte crops including roots , tubers, and rhizomes, totaling 30 autochthonous plant species (Fedick 2020:232). Plants with consumable geophytes, including manioc, chaya, camote, arrowroot, achira, yams, and lerén, provide an invaluable source of food that can be stored in the ground for long periods of time (Fedick 2020; Morell-Hart et al. 2022; Rico-Gray et al. 1991). Biodiverse starchy root and tuber crops added to the heterogeneous diet of Classic period Maya people, offering them nutritional benefits including hypoglycemic, antioxidative, and immunomodulatory effects from plant compounds (Chandrasekara and Joshepkumar 2016). Previous assumptions viewed these root and tuber crops as a secondary or even famine foods due to the drought tolerance quality that allows them to survive when other crops fail (Cagnato and Ponce 2017). Many scholars have also stated that root crops were only used when maize was unavailable. This assumption was further solidified by the poor preservation of root and tuber botanical remains in the archaeological record (Chandler-Ezell et al. 2006). In contrast, for Maya people inhabiting Budsilha, root and tuber crops were likely an important food resource, especially during the Classic period, as most of these species can be ground and dried for long term storage (Fedick 2020) or simply harvested as needed. Since residues of these drought-resistant root and tuber crops were recovered from settlements in the swampy area of Budsilha, located close to a major water source, it is likely that these species were grown due to preference and historical precedence, rather than necessity in periods of drought.

A variety of roots, tubers, and rhizome food species were recovered at Budsilha from residues extracted from artifacts, human teeth, and sediment samples. Camote, or sweet potato (*Ipomoea batatas*) would have been cultivated in fields alongside other crops and is sometimes considered a staple food source for Indigenous Maya populations today (Bovell-Benjamin 2007). Camote, which is often boiled or grilled, is nutrient-rich, containing vitamins, minerals, amino acids, lipids and fats, making it a potentially important component of Classic period Maya diets (Vidal and Zaucedo-Zuñiga 2018). Moreover, achira (*Canna edulis*) leaves are utilized to wrap tamales, and this species produces an edible tuber that was likely consumed by Maya people (Bronson 1966; Morell-Hart et al. 2021). The arrowroot family (Marantaceae) includes arrowroot (*Maranta arundinacea*) and lerén (*Calathea allouia*), both edible tuber crops consumed by Maya people (Chandler-Ezell et al. 2006; Rushton et al. 2012).

Manioc *(Manihot esculenta)* was also recovered from artifact residues. Today manioc (cassava) is the sixth most important crop in the Americas, and is also commonly planted and eaten in times of drought (Cagnato and Ponce 2017). Ethnographic analysis by Cagnato and Ponce (2017), has provided insight into the use of manioc by contemporary Maya communities. Manioc can be consumed for its greens, but is most commonly cultivated for its starchy tubers which can be cooked as a pot vegetable, roasted, or processed into a flour used to make breads or fermented drinks. The environmental conditions of the Classic period, wet conditions which later shifted to dryer conditions between AD 750-900 (Hoggarth et al. 2017), would have made manioc an ideal food source. Manioc varieties can be left in fields for up to two and half years, grow well in droughts and soils with low pH, provide a calorie-rich source of food, can be stored in flour form to make unleavened breads (Cagnato and Ponce 2017), and grow in relatively infertile soils (Sheets et al. 2011). It is now evident that Maya used homegardens to grow manioc species, as shown in well-preserved field contexts at Joya de Cerén (Kaplan et al. 2015; Lentz and Ramírez-Sosa 2021; Sheets et al. 2012), and manioc may have served both as staple and famine food. For Ch’orti’ Maya people, cassava is grown separately from other crops within special milpas (Bronson 1966).

Shrubs with edible leaves include spurge family (Euphorbiaceae) species such as chaya (*Cnidoscolus* spp.) (Ford 2008), and pepperleaf (*Piper*) species, two types of plants known to be used by contemporary Maya people (Atran et al. 1993; Morell-Hart et al. 2022; Ross-Ibarra and Molina-Cruz 2002). Chaya roots and shoots are also edible and continue to be eaten today throughout Mesoamerica (Ross-Ibarra and Molina-Cruz 2002). In this study, seeds of Euphorbiaceae sp. and *Piper* sp. were recovered.

` Edible seeds critical to Maya diets of the Classic period, apart from maize and beans, were also recovered in this study. Contemporary ethnography has shown that various squashes (Cucurbitaceae spp.) including *C. moschata* and *C. pepo,* are primarily grown for seeds (Fedick 2020). These seeds are a source of food that is storable and nutrient-rich. There is contemporary cuisine containing squash seeds including *horchata*, a beverage containing fresh ground squash seeds and *pipian* sauces comprised of ground toasted seeds that are boiled (Zizumbo-Villarreal et al. 2016). Furthermore, a variety of sunflower family species (Asteraceae) also produce edible seeds (Fedick 2020). Cucurbitaceae spp. phytoliths, and Asteraceae spp. phytoliths and macrobotanical remains (seeds and achenes) were recovered in this study.

Although maize was not highly ubiquitous across the Budsilha samples, maize (*Zea mays*) was an important component of Maya diets during the Classic period. Maize is used in a wide variety of dishes including *atole*, *tortillas, tamales, sopes, pinole,* and *ponteduro* (Zizumbo-Villarreal et al. 2016). Domesticated and managed bean family species (Fabaceae) were also commonly grown within the milpa alongside maize, squashes (*Cucurbita* spp.), and chiles (*Capsicum* spp.) (Fedick et al. 2023). Lentz (1991), provides evidence that wild beans may also have been utilized as a food source during the Late Classic period. In this study, evidence of maize included both cupules and starch grains. Other grass species including Panicoid sp. Bambusoideae sp. and Chloridoideae sp. were also evident by the presence of phytoliths.

Fruit species including taxa within the plant families of nightshades (Solanaceae), peppers (Piperaceae), and grapes (Vitaceae) are also documented sources of food for ancient and contemporary Maya people. Chile pepper (*Capsicum annum*) and tomatillo (*Physalis* spp.) are both edible species within the Solanaceae family (Atran et al. 1993). Both of the recovered species of wild grape (*Vitis tiliifolia*) and Jamaican pepper (*Piper hispidum*) are also edible (Morell-Hart et al. 2022; Salleh et al. 2021). Nance (*Byrsonima crassifolia*), a succulent fruit, is also commonly found within the Maya lowland sites (Morell-Hart et al. 2022), and some Bignoniaceae sp. fruit such as jícara/calabash (*Crescentia alata*) can be cooked and added to salads and soups (Atran et al. 1993). Seeds of these various species were all recovered from Budsilha samples.

Fruit species from trees would also have provided a source of food. A total of 262 different autochthonous tree species, 26 of them palm (Arecaceae sp.), have been specified as being consumed by Maya people (Fedick 2020). These palm species foods included the fruit of coyol palms (*Acrocomia aculeata* and *Acrocomia mexicana),* used by Maya people for a variety of purposes and was a considerable contributor to their diets (Lentz 1990). The high fat content of the kernels and mesocarp of the fruit would have provided a nutrient-rich source of food (Lentz 1990). For ancient Maya people, the fruit of palms was likely eaten fresh or stored in pots for later use, roasted in stew-holes and the pulp consumed (Alcorn 1984). The kernel was also eaten, with a taste similar to hazel nut (Roys 1931). Contemporary *Acrocomia aculeata* sap from the trunk is also used to make the traditional fermented beverage *taberna* and the fruit is consumed as a preserve known as *dulce de coyol* (Ambrocio-Ríos et al. 2021). *Acrocomia mexicana* bears fruit abundantly after 4-5 yrs(Food and Agriculture Organization of the United Nations 1949). Fruits from Rosaceae family trees including black cherry (*Prunus serotina*), cherry (*Prunus capuli*) and monkey apple (*Licania platypus*) would also have provided a source of food (Atran et al. 1993). Arecaceae spp. endocarps and phytoliths, and Rosaceae sp. seeds were all recovered in this study.

In this selection of recovered plant residues, we see a variety of root, shoot and tuber crops including manioc, chaya, camote, arrowroot, canna, yams and lerén, that accompany maize. Additional food taxa include fruit species, including chile pepper, squash, coyol palm, nance, and wild grape, and edible leafy species, such as Jamaican pepper.

Ubiquity of Maize

Maize consumption is evident through the recovery of *Zea mays* microbotanical residues and macrobotanical remains. Starch grains were recovered from the sonicated wash of an adult tooth recovered from Burial 11. This finding provides direct evidence of maize consumption at Budsilha, although maize was not recovered from artifact residues or sediment samples in quantities or a frequency that would define maize as comprising the main component of diets. It is notable that maize was not identified to the species level from phytoliths in sediment samples, with only family level (Poaceae) identification possible, even though maize cob rondel forms and maize leaf cross-body forms are produced in high quantities by maize plants and are highly diagnostic. Macrobotanical analysis only recovered a single cupule of *cf. Zea mays* from the midden context. Overall, only four instances of maize were identified, making it only 20% ubiquitous across all samples in spite of its incredibly high visibility as compared to almost all other plants (Morell-Hart 2019).

The relatively low numbers and infrequent recovery of maize across the samples, however, does not equate to absence of use. Even so, it is possible that the low ubiquity of maize in the sediment samples is due to maize being grown not as the primary staple crop in Budsilha, but rather as one of several key foods consumed by Budsilha residents. Budsilha residents may have preferred other foodstuffs, or maize may have been grown and removed from the cob elsewhere. Tools used to process maize and ceramics used to store maize may also be different than the ones sampled during this study. Moreover, the swampy area of Budsilha may have been a poor environment to grow maize even with water management through field channeling, since grain crops require extensive dampness management (Morell-Hart et al. 2022). It may also be that water management was created to support the cultivation of other types of crops, such as cacao or cotton. It is also likely that maize starches did not preserve well, due to a number of taphonomic factors such as grinding, cooking, and decay in soils.

Here it is important to note that the overall ubiquity of maize within the archaeological record and in past research may in fact be due to its ability to be identified to the species level (Fedick 2020) through multiple proxies (Morell-Hart 2019). This recovery bias has helped to shape the narrative of Maya agriculture and food use. In a survey of plants across the Maya area, Fedick and Santiago (2012) found evidence that 71% of Maya food plants were drought resistant. Furthermore, they identified 15 other Maya food plants that follow the same C4 pathway as maize (Fedick 2020). These findings have implications for studies of plant use within the Maya region as questions of intensive maize use or recovery bias have helped to perpetuate traditional collapse narratives. Utilizing paleoethnobotanical data together with isotopic analysis helps to create a clearer picture of plant use and consumption.

Finally, the isotopic evidence conforms with maize findings in this study of materials from Budsilha. It is clear from Budsilha microresidues that maize was being consumed, although not at the frequency that is expected of a maize-centered diet. Burial 9 contained carbon isotope ratios of -12.35/8.20, while Burial 11 contained carbon isotope ratios of -11.37/10.13 (Scherer et al. 2019). A wide variety of food taxa was recovered indicating a broad use of various species for food. The isotopic evidence is consistent with a maize-based diet although carbon ratios were not as high as in major polities such as Piedras Negras (Scherer et al. 2019).

Managed Forests, Homegardens, and Ornamental Flowers

The Maya forest garden outlined by Ford and Nigh (2009), was a strategic land use technique that cycled through forest canopy, open fields of annual crops and orchard gardens, and back to forest canopy. The forest garden cycle contained three main stages including open milpa (*Cucurbita* spp., *Phaselous* spp., *Zea mays*), long lived perennials (*Burseaceae* sp., *Cucurbita pepo*, *Manihot esculenta*, *Brosimum* sp.) and closed canopy (*Brosimum* sp*.*, *Bursera* sp.,). During the open milpa stage, maize was accompanied by various herbs, legumes, roots, and tubers that worked together to enhance the nutrients in the soil, maintain moisture, and deter pests (Ford and Nigh 2009). Homegardens, alongside agroforestry, were ways in which Maya took advantage of their surrounding environment to grow and manage a diverse portfolio of plant species. Located close to residential areas, these gardens represent managed plant succession, enabling households to capitalize on a variety of food crops and plant resources (Morell-Hart et al. 2022). Decisions pertaining to how, when, and which plants to grow coupled with the advantage of growing both seed and root crops simultaneously was decided by individuals in the community (Sheets et al. 2011). The ability of individuals to choose which plant species to grow within their homegardens yields advantages such as maintaining sustainability over time and lessening the impact of climatic shifts or pests affecting specific crops (Sheets et al. 2011).

In various ethnographic studies of food-related species, both wild and forest species were used for foodstuffs (Morell-Hart et al. 2022). Non-domesticated and domesticated tree species can be managed within homegardens, milpas, or managed in forests. These gardens were not limited to food crops, as Maya cultivators also grew plants for medicinal purposes, and pollinator species. The home garden contained areas with early succession crops, fast-growing woody perennials, and in later years, shade-tolerant species and fruit trees (Morell-Hart et al. 2022).

Many of the recovered species from the sediment samples and artifact residues contained various plant taxa known for their ornamental features and uses, as well as ritual or symbolic uses. These included Asteraceae sp., *Canna* sp*.*, *Heliconia* spp., *Calathea* sp*.*, and Cyatheaceae sp., some of which have fragrant or colorful flowers. Among the contemporary beliefs of Indigenous Maya communities inhabiting Chiapas there is a concept of floral paradise, the ancestral place of origin (Taube 2004). This Flower World, which can be traced to Late Preclassic and Classic periods, encapsulated a floral mountain that served as a means of entry into the paradise realm of the sun, where the gods and ancestors could be located (Taube 2004). To ancient Maya people, Taube argues, paradise was a place full of beautiful fragrant flowers and vegetative plants. Maya people regarded and admired their surrounding natural world, including flowers, as beings of beauty (Taube 2004). Moreover, adding to this concept of beauty, colours can encompass complex meanings pertaining to social order and communication (Tokovinine and McNeil 2012). Despite the ephemeral nature of flower petals and sepals, which makes colours and types of flowers difficult to recognize within archaeological contexts (Tokovinine and McNeil 2012), it is important to recognize the significance of flowers spiritually and situate the Maya experience of the beauty of nature. Similar to home gardening today, where individuals plant various flowering species solely for their intrinsic aesthetic beauty, it is likely that Maya people of the Classic period inhabiting Budsilha also grew an array of flower species. These species were identified as both seeds and phytoliths recovered from sediments.

Sunflower family (Asteraceae spp.) early succession plants include a wide variety of flower species that are not only edible but have medicinal purposes (Ford and Nigh 2009). The beauty of this plant family is encapsulated in the national flower of Mexico, the dahlia, highlighting the importance of flowering ornamental plants (Nsabimana and Jiang 2011). Other plants utilized as both ornamentals and medicinals include eight different Cyatheaceae species found in Mexico, known as tree ferns (Chaparro-Hernández et al. 2022), and other verbena family (Verbenaceae spp.) flowering plants (Simpson 2010). Furthermore, doubling as both edible and ornamental plant species, some sunflower family species and achira are also used for apiculture (Rico-Gray et al. 1991). Other tree, shrub and herb flower species include borage family (Boraginaceae) species whose flowers range in colour from yellow, to orange to white (Cohen 2018); heliconias (*Heliconia* spp.), flowering plants grown as ornamentals due to their beautiful inflorescence and unique bracts (Ortiz et al. 2020); and two plants containing edible tubers, achira *(Canna sp.)*, and lerén (*Calathea sp.)*, prized as decorative plants for their bright flowers and smooth leaves (Rico-Gray et al. 1991; Sutherland 1986). Phytoliths of these ornamental species and seed remains of Asteraceae sp., Verbenaceae spp., and Boraginaceae sp. were recovered from various contexts.

These findings highlight the use of homegardens and a variety of plants grown for purposes other than food or resource extraction. Furthermore, it is clear that Maya relationships with plants and their surrounding environment were extensive, with an understanding of cyclical crop rotation, and agroforestry. The presence of a wide variety of ornamental species, non-domesticated taxa, and forest species further provides evidence for rethinking collapse in the Maya area.

Situating Budsilha Plant Use within the Usumacinta River Region

The results of this study highlight the diverse use of plant species grown at Budsilha during the Classic period, for subsistence and other purposes. During the Classic period at Budsilha, wild and forest species comprised a major component of the ethnoecology and plant resources. These results in many ways support what was expected and outlined in the previous chapters. New models of the Classic period collapse highlighting variable abandonment, biodiverse plant use, and resiliency are supported by the paleoethnobotanical data recovered from Budsilha. The findings of this study do not support the expectations set up by earlier collapse, swidden agriculture, and maize monocropping models. A wide range of plant resources, including non-domesticated, fallow, and forest species, indicates that forest coverage and biodiversity were maintained during the Classic period at Budsilha. Furthermore, cuisine at Budsilha involved a diverse set of taxa beyond the traditionally-modeled triad of beans, maize and squash. Within the broader Maya area, Budsilha provides further evidence of subsistence patterns, and land management practices, that would have been able to sustain Maya communities and maintain stability in the surrounding environment. Other paleoethnobotanical studies within the area of Budsilha help to situate this site within the region.

Macabilero, inhabited during the Formative period and the Classic period, is a hilltop site similar to Budsilha (Golden et al. 2021). Paleoethnobotanical analysis from the Late Formative, Pre-Classic and Late Classic period site of Macabilero revealed root, tuber, and rhizome crops such as *Canna* sp*., Ipomoea batatas,* and *Manihot esculenta,* as well as grain and seed crops *Zea mays* and *Phaseolus* sp. (Watson 2022). Watson (2022) found maize and manioc were consumed from the Late Formative to the Late Classic period. These findings overlap with this study in that food species sweet potato, maize, lerén and manioc were being utilized. Notably, at Macabilero, manioc was recovered at the highest frequency, with maize not recovered at the expected frequency that would fit the traditional collapse model. Thus, it is evident that species used in earlier periods continued to be utilized through the Classic periods. From this study Watson (2022) concluded that the palaeobotanical evidence recovered at Macabilero does not support a collapse narrative grounded in maize crop failure.

Paleoethnobotanical analysis at Piedras Negras conducted by Watson and colleagues (2022), revealed medicinal plant species through several proxies, indicating Piedras Negras was a site of medicinal practices within a marketplace setting. These practices included sweatbathing and pathological tooth extractions. From microbotanical analyses of human teeth, maize was identified on five of the seven extracted teeth. Other food species recovered from teeth residues included *Phaseolus* sp., and *Manihot esculenta* (Watson et al. 2022). Stable isotope analysis of skeletal remains was also conducted at Piedras Negras by Scherer and colleagues (2007). Findings of this study, which included high mean δ^{13}C levels coupled with an abundant amount of dental caries, indicated a high level of maize consumption during the Classic period (Scherer et al. 2007).

Carbon isotope values from Budsilha were comparatively lower than isotope levels recovered from Piedras Negras (Scherer et al. 2019). Higher carbon isotope values around -9‰ at Piedras Negras indicates a higher consumption of maize. Similarly, other Usumacinta sites in the region, including Tecolote, El Kinel, and Chinikiha, fall within a similar range as Piedras Negras (Scherer et al. 2019). Based on these findings, Budsilha has lower carbon isotope levels than Piedras Negras and other Usumacinta sites. Although still within the range of a diet including maize, the lower carbon isotope values at Budsilha indicate that other plant species were being consumed. At Budsilha, people were eating less maize than at the large polity of Piedras Negras (Scherer et al. 2019). This would have made Budsilha more resilient to possible maize crop failure. This data corroborates results from the microbotanical analyses, as within the sediment samples grass species comprised only 6.9% of total counts. Other agriculturally important species identified in the microbotanical study included manioc, sweet potato, and lerén, impossible to detect through bone isotope ratios. This indicates that sites within the southern lowlands underwent variable change during the Classic period which can be attributed to diets. With a larger reliance on maize, Piedras Negras residents would have been more susceptible to changing climatic conditions than people at Budsilha.

In contrast with the studies at Piedras Negras, tooth residues at Budsilha contained few microbotanical remains. The tooth recovered from Burial 9 (BU-6B-18-05), with a carbon isotope value of -12.35‰, included evidence of manioc and sweet potato within the surrounding matrix, and no maize. The tooth recovered from Burial 11 (BU-1J-01-04) had a carbon isotope value of -11.37‰, and contained residues of sweet potato and maize. Thus, the teeth microresidues corroborate the isotope data, in that maize was not recovered in as high frequency that would be if expected of a diet very highly reliant on maize. Both datasets highlight the importance of maize within Budsilha diets, but indicate that maize was eaten alongside other important plant crops including roots and tubers. The carbon isotope values closer to -14ppm (the average for non-maize dominant diet), coupled with the lower maize ubiquity within the residues, indicate maize was likely not the sole primary food source for individuals inhabiting Budsilha during the Classic period. Other economically important food crops were also clearly being utilized.

Comparatively, foods that individuals were eating during the Classic period would likely have been locally grown at Budsilha, since this is a small-scale township with less capacity to import or receive tribute, while foodstuffs at Piedras Negras would have been imported into the much larger city center and/or received in tribute. Given the results from Budsilha, it is evident that the picture of a solely or even highly maize-based diet does not apply, and the wide variety of food plant taxa identified indicate that the Classic period Maya people inhabiting Budsilha had a diverse diet made up of wild species, roots, and tubers, alongside maize. The diversity of food crop residues recovered through microbotanical analyses indexes a multitude of drought resistant crops and food strategies, as well as agricultural techniques including homegardens and management of non-domesticated species. These practices would have helped Budsilha individuals to be resistant to climatic shifts in the area, and potentially even resilient in the face of political strife. At larger sites such as Piedras Negras, the high ubiquity of species highly susceptible to drought, including maize, beans, and squashes, coupled with a low presence of drought-resistant species (Fedick et al. 2023), would have made these Piedras Negras inhabitants more susceptible to repercussions from food supply issues.

Conclusions and Future Directions

The wide variety of identified plant taxa recovered from Budsilha indicates that the ancient Maya inhabitants were able to take advantage of their surrounding environment, including both managed and cultivated contexts. This heterogenous environment allowed Maya communities to adjust to changing conditions including climactic and political shifts (Fedick 2020). Furthermore, diets of individuals at Budsilha during the Classic period included a broad range of plant species including non-domesticated and forest species, alongside crop plants including maize and various edible roots and tubers. Maize was recovered in small amounts with non-domesticated species recovered most frequently. Microbotanical residues, especially those recovered from teeth, provided direct evidence of consumption and human use of plants, while sediment samples provided evidence of agricultural activities and the paleoenvironment.

The findings of this research have implications for understanding plant use and the paleoenvironment in Budsilha during the Classic period. Alongside previous knowledge about foodstuffs in the area and subsistence patterns during the Classic period, mostly derived from macrobotanical and ethnographic studies, microbotanical analysis provides an additional line of information about Maya foodways. As populations increased during the Classic period, Maya communities turned to agricultural practices that included arboriculture, milpa cultivation of a number of seed and geophyte crops, forest management of non-domesticated species, and home gardening, all vital to providing nutritious foodstuffs. The shift to intensified agriculture, evidenced by channeled fields and terraces, did not cause non-domesticated species to become obsolete in the diet, and this study demonstrates that such resources remained an important part of this unique subsistence pattern.

Further research into more subordinate sites will help to create a broad and holistic picture of Maya foodways and the paleoenvironment during the Classic period. Broadening the scope of analysis to include more semi- and non-elite sites, as well as further paired analyses of isotopic signatures and botanical residue analyses, are vital to continuing to reveal the unique and variable foodways and plant practices of Classic period Maya people. Furthermore, continuing research into diagnostic characteristics of starch grains and phytoliths of various plant families will help to shape the picture of Maya plant use.

In order to meet the demands of food in the future, as climate change becomes an increasing problem and parts of the world become uninhabitable, scientists and society should look to many of the agricultural strategies of Classic period Maya people (Pushpalatha and Gangadharan 2020). Drawing parallels between the highly populated and changing climate of the Classic period Maya area, and countries undergoing similar stresses, has the ability to provide possible solutions (Marston, Guedes, et al. 2015). Maya case studies provide a roadmap to sustaining large populations during climatic shifts, including strategies such as avoiding monocropping, maintaining biodiversity, and retaining diversity in food crops, allowing for the continuance of functioning ecosystems and a healthy environment (Morell-Hart et al. 2022). For the Maya people inhabiting Budsilha during the Classic period, an understanding of the surrounding environment, coupled with diverse subsistence and agricultural practices, allowed them to sustain large population numbers during a time of environmental and political stress. Surrounded by magnificent forests, mountains, and beautiful flowers, Maya people balanced the needs of the community and the environment.

References

Abramiuk, Marc A., Peter S. Dunham, Linda Scott Cummings, Chad Yost, and Todd J. Pesek
2011 Linking Past and Present: A preliminary paleoethnobotanical study of Maya nutritional and medicinal plant use and sustainable cultivation in the Southern Maya Mountains, Belize. *Ethnobotany Research and Applications* 9:257–273.

Aimers, James J.
2007 What Maya Collapse? Terminal Classic Variation in the Maya Lowlands. *Journal of Archaeological Research* 15(4):329–377. DOI:10.1007/s10814-007-9015-x.

Alcorn, Janis B.
1984 *Huastec Mayan Ethnobotany*. University of Texas Press.

Ambrocio-Ríos, José, Carolina Orantes-García, María Sánchez-Cortés, and Alma Verdugo
2021 Use of the Coyol Palm (Acrocomia aculeata) for the Production of “Taberna,” a Traditional Fermented Beverage in México. *Frontiers in Sustainable Food Systems* 5:695494. DOI:10.3389/fsufs.2021.695494.

Atran, Scott, Arlen F. Chase, Scott L. Fedick, Gregory Knapp, Heather McKillop, Joyce Marcus, Norman B. Schwartz, and Malcolm C. Webb
1993 Itza Maya Tropical Agro-Forestry [and Comments and Replies]. *Current Anthropology* 34(5):633–700. DOI:10.1086/204212.

Barton, Huw, and J. Peter White
1993 Use of Stone and Shell Artifacts at Balof 2, New Ireland, Papua New Guinea. *Asian Perspectives* 32(2):169–181.

Bovell-Benjamin, Adelia C.
2007 Sweet Potato: A Review of its Past, Present, and Future Role in Human Nutrition. In *Advances in Food and Nutrition Research,* 52:pp. 1–59. Academic Press.

Brockerhoff, Eckehard G., Luc Barbaro, Bastien Castagneyrol, David I. Forrester, Barry Gardiner, José Ramón González-Olabarria, Phil O’B. Lyver, Nicolas Meurisse, Anne Oxbrough, Hisatomo Taki, Ian D. Thompson, Fons van der Plas, and Hervé Jactel
2017 Forest biodiversity, ecosystem functioning and the provision of ecosystem services. *Biodiversity and Conservation* 26(13):3005–3035. DOI:10.1007/s10531-017-1453-2.

Bronson, Bennet
1966 Roots and the Subsistence of the Ancient Maya. *Southwestern Journal of Anthropology* 22(3):251–279. DOI:10.1086/soutjanth.22.3.3629373.

Butzer, Karl W., and Georgina H. Endfield
2012 Critical perspectives on historical collapse. *Proceedings of the National Academy of Sciences* 109(10):3628–3631. DOI:10.1073/pnas.1114772109.

Cagnato, Clarissa
2018 Sweet, weedy and wild: macrobotanical remains from a Late Classic (8th century ad) feasting deposit discovered at La Corona, an ancient Maya settlement. *Vegetation History and Archaeobotany* 27(1):241–252. DOI:10.1007/s00334-017-0614-2.

Cagnato, Clarissa, and Ponce, Jocelyne
2017 Ancient Maya manioc (Manihot esculenta Crantz) consumption: Starch grain evidence from late to terminal classic (8th–9th century CE) occupation at La Corona, northwestern Petén, Guatemala. *Journal of Archaeological Science: Reports* 16:276. DOI:10.1016/j.jasrep.2017.09.035.

Canter, Ronald L.
2007 Rivers Among the Ruins: The Usumacinta. *The Pari Journal* 7(3).

Chandler-Ezell, Karol, Deborah M. Pearsall, and James A. Zeidler
2006 Root and Tuber Phytoliths and Starch Grains Document Manioc (Manihot esculenta), Arrowroot (Maranta arundinacea), and Llerén (Calathea sp.) at the Real Alto Site, Ecuador. *Economic Botany* 60(2):103–120.

Chandrasekara, Anoma, and Thamilni Joshepkumar
2016 Roots and Tuber Crops as Functional Foods: A Review on Phytochemical Constituents and Their Potential Health Benefits. *International Journal of Food Science* 2016. DOI:10.1155/2016/3631647.

Chaparro-Hernández, Irene, Juan Rodríguez-Ramírez, Luis Gerardo Barriada-Bernal, and Lilia Méndez-Lagunas
2022 Tree ferns (Cyatheaceae) as a source of phenolic compounds – A review. *Journal of Herbal Medicine* 35:100587. DOI:10.1016/j.hermed.2022.100587.

Chen, Ran, Yahui He, Xinwei Li, Jorge Ramos, Moran Li, and Li Liu
2022 Fermented maize beverages as ritual offerings: Investigating elite drinking during Classic Maya period at Copan, Honduras. *Journal of Anthropological Archaeology* 65:101373. DOI:10.1016/j.jaa.2021.101373.

Coe, Michael D.
2015 *The Maya*. 9th ed. edition. Thames and Hudson, New York.

Cohen, James I.
2018 A Revision of the Mexican Species of Lithospermum (boraginaceae). *Annals of the Missouri Botanical Garden* 103(2):200–257.

Colunga-GarcíaMarín, Patricia, and Daniel Zizumbo-Villarreal
2004 Domestication of Plants in Maya Lowlands. *Economic Botany* 58:S101–S110.

Comptour, Marion, Sophie Caillon, Leonor Rodrigues, and Doyle McKey
2018 Wetland Raised-Field Agriculture and Its Contribution to Sustainability: Ethnoecology of a Present-Day African System and Questions about Pre-Columbian Systems in the American Tropics. *Sustainability* 10(9):3120. DOI:10.3390/su10093120.

Diamond, Jared
2011 *Collapse: How Societies Choose to Fail or Succeed: Revised Edition*. Revised edition. Penguin Books, New York.

Diamond, Jared M.
2003 The last Americans: The sense of an ending. *Harper's Magazine*, June 1, 2003. https://harpers.org/archive/2003/06/the-last-americans/, accessed November 16, 2022.

Duncan, Neil A., Deborah M. Pearsall, and Robert A. Benfer
2009 Gourd and squash artifacts yield starch grains of feasting foods from preceramic Peru. *Proceedings of the National Academy of Sciences* 106(32):13202–13206. DOI:10.1073/pnas.0903322106.

Dunning, Nicholas, Timothy Beach, Pat Farrell, and Sheryl Luzzadder-Beach
1998 Prehispanic Agrosystems and Adaptive Regions in the Maya Lowlands. *Culture & Agriculture* 20(2–3):87–101. DOI:10.1525/cag.1998.20.2-3.87.

Durán, Benito Jesus Venegas, Esteban Moisés Herrera-Parra, and María Novelo Pérez
2021 Análisis e identificación de almidones arqueológicos en instrumentos líticos y cerámica del conjunto residencial Limón de Palenque, Chiapas, México. *Comechingonia. Revista de Arqueología* 25(1):25–44. DOI:10.37603/2250.7728.v25.n1.30412.

Ebert, Claire E., Julie A. Hoggarth, Jaime J. Awe, Brendan J. Culleton, and Douglas J. Kennett
2019 The Role of Diet in Resilience and Vulnerability to Climate Change among Early Agricultural Communities in the Maya Lowlands. *Current Anthropology* 60(4):589–601. DOI:10.1086/704530.

Ebert, Claire E., Nancy Peniche May, Brendan J. Culleton, Jaime J. Awe, and Douglas J. Kennett
2017 Regional response to drought during the formation and decline of Preclassic Maya societies. *Quaternary Science Reviews* 173:211–235. DOI:10.1016/j.quascirev.2017.08.020.

Emery, Kitty F.
2007a Aprovechamiento de la fauna en Piedras Negras: dieta, ritual y artesanía del periodo Clásico maya. *Mayab*(19):51–69.
2007b Assessing the impact of ancient Maya animal use. *Journal for Nature Conservation* 15(3):184–195. DOI:10.1016/j.jnc.2007.05.002.

Emery, Kitty F., and Erin Kennedy Thornton
2008 A regional perspective on biotic change during the Classic Maya occupation using zooarchaeological isotopic chemistry. *Quaternary International* 191(1). ICAZ 2006: Zooarchaeology of the Late Pleistocene/Early Holocene in the Americas and Zooarchaeological Evidence of the Ancient Maya and Their Environment:131–143. DOI:10.1016/j.quaint.2007.11.015.

Fedick, Scott L.
2010 The Maya Forest: Destroyed or Cultivated by the Ancient Maya? *Proceedings of the National Academy of Sciences of the United States of America* 107:953–4. DOI:10.1073/pnas.0913578107.
2020 Maya Cornucopia: Indigenous Food Plants of the Maya Lowlands. In *The Real Business of Ancient Maya Economies: From Farmers' Fields to Rulers' Realms*, edited by Marilyn A. Masson, David A. Freidel, and Arthur A. Demarest, pp. 224-237. University Press of Florida.

Fedick, Scott L. (editor)
1996 *The Managed Mosaic: Ancient Maya Agriculture and Resource Use*. University of Utah Press, Salt Lake City.
2010 The Maya Forest: Destroyed or cultivated by the ancient Maya? *Proceedings of the National Academy of Sciences* 107(3):953–954. DOI:10.1073/pnas.0913578107.

Fedick, Scott L., and Anabel Ford
1990 The Prehistoric Agricultural Landscape of the Central Maya Lowlands: An Examination of Local Variability in a Regional Context. *World Archaeology* 22(1):18–33.

Fedick, Scott L., and Louis S. Santiago
2022 Large variation in availability of Maya food plant sources during ancient droughts. *Proceedings of the National Academy of Sciences of the United States of America* 119(1):e2115657118. DOI:10.1073/pnas.2115657118.

Fedick, Scott L., Shanti Morell-Hart, and Lydie Dussol
2023 Agriculture in the Ancient Maya Lowlands (Part 2): Landesque Capital and Long-term Resource Management Strategies. *Journal of Archaeological Research*. DOI:10.1007/s10814-023-09185-z.

Fernández, Fabián G., Kristofer D. Johnson, Richard E. Terry, Sheldon Nelson, and David Webster
2005 Soil Resources of the Ancient Maya at Piedras Negras, Guatemala. *Soil Science Society of America Journal* 69(6):2020–2032. DOI:10.2136/sssaj2004.0306.

Flannery, Kent V.
1972 The Cultural Evolution of Civilizations. *Annual Review of Ecology and Systematics* 3:399–426.

Food and Agriculture Organization and of the United Nations
1949 *Report of the FAO Oilseed Mission for Venezuela*. Washington, D.C.

Ford, Anabel
2008 Dominant Plants Of The Maya Forest And Gardens Of El Pilar: Implications For Paleoenvironmental Reconstructions. *Journal of Ethnobiology* 28(2):179–199. DOI:10.2993/0278-0771-28.2.179.

Ford, Anabel, and Ronald Nigh
2009 Origins of the Maya Forest Garden: Maya Resource Management. *Journal of Ethnobiology* 29:213–236. DOI:10.2993/0278-0771-29.2.213.
2015 *The Maya Forest Garden: Eight Millennia of Sustainable Cultivation of the Tropical Woodlands*. 1st edition. Routledge, Walnut Creek, California.

Gallagher, Daphne
2014 Formation Processes of the Macrobotanical Record. In *Method and Theory in Paleoethnobotany*, edited by John M. Marston, Jade D'Alpolm Guedes, and Christina Warinner, pp. 18-73. University Press of Colorado.

Gill, Richardson B.
2001 *The Great Maya Droughts: Water, Life, and Death*. Revised ed. edition. University of New Mexico Press.

Golden, Charles, and Andrew K. Scherer
2018 Capítulo 1: Introducción. In *Informe de la Novena Temporada de Investigación Presentado Ante el Consejo de Arqueología Del Instituto Nacional de Antropología e Historia*.

Golden, Charles W., and Andrew K. Scherer
2013 Territory, Trust, Growth, and Collapse in Classic Period Maya Kingdoms. *Current Anthropology* 54(4):397–435. DOI:10.1086/671054.

Golden, Charles, Andrew Scherer, A. René Muñoz, and Zachary Hruby
2012 Polities, Boundaries, and Trade in the Classic Period Usumacinta River Basin. *Mexicon* 34(1):11–19.

Golden, Charles W., Andrew K. Scherer, Socorro del Pilar Jiménez Álvarez, Jeffrey Dobereiner, Whittaker Schroder, and Alan Méndez Cab
2015 Investigaciones recientes al nexo de Piedras Negras, Toniná, Palenque, Yaxchilán y Sak Tz'i'. In *XXIX Simposio de Investigaciones Arqueológicas en Guatemala*. Museo Nacional de Arqueología y Etnología.

Golden, Charles W., Andrew K. Scherer, Melanie Kingsley, Stephen D. Houston, and Héctor Escobedo
2016 The Life and Afterlife of the Classic Period Piedras Negras Kingdom. In *Ritual, Violence, and the Fall of the Classic Maya Kings,* edited by Gyles Iannone, Brett A. Houk, and Sonja A. Schwake, pp. 108–133. University Press of Florida.

Golden, Charles W., Stephen D. Houston, Mark Child, René Muñoz, and Héctor Escobedo
2010 The Moral Community: Maya Settlement Transformation at Piedras Negras, Guatemala. In *The Social Construction of Ancient Cities*, edited by Monica L. Smith. Illustrated edition. Smithsonian Books, Washington, DC.

Götz, Christopher Markus, and Kitty F. Emery
2013 *The archaeology of Mesoamerican animals*. Archaeobiology; number 1. Lockwood Press, Atlanta, Georgia.

Guerra, Carlos A., Joachim Maes, Ilse Geijzendorffer, and Marc J. Metzger
2016 An assessment of soil erosion prevention by vegetation in Mediterranean Europe: Current trends of ecosystem service provision. *Ecological Indicators* 60:213–222. DOI:10.1016/j.ecolind.2015.06.043.

Hall, Stuart
2018 The West and the Rest:Discourse and Power [1992]. *Duke University Press* 2. DOI:10.1215/9781478002710-009, accessed November 15, 2022.

Harper, Dine
2018 Capítulo 3: Budsilha: Operación 5b: Investigaciones en la Zona Pantanosa. In *Informe de la Novena Temporada de Investigación Presentado Ante el Consejo de Arqueología Del Instituto Nacional de Antropología e Historia*.

Harrison, Peter D., and Billy L. Turner II
1978 Farming Among the Maya: A Revised View: Pre-Hispanic Maya Agriculture. *University of New Mexico Press* 204(4394):739–740. DOI:10.1126/science.204.4394.739.

Hodell, David A., Jason H. Curtis, and Mark Brenner
1995 Possible role of climate in the collapse of Classic Maya civilization. *Nature* 375(6530):391–394. DOI:10.1038/375391a0.

Hoggarth, Julie A., Matthew Restall, James W. Wood, and Douglas J. Kennett
2017 Drought and Its Demographic Effects in the Maya Lowlands. *Current Anthropology* 58(1):82–113. DOI:10.1086/690046.

Johnson, Kristofer, Richard Terry, Mark Jackson, and Charles Golden
2007 Ancient soil resources of the Usumacinta River Region, Guatemala. *Journal of Archaeological Science* 34:1117–1129. DOI:10.1016/j.jas.2006.10.004.

Jovanović, Jelena, Robert C. Power, Camille de Becdelièvre, Gwenaëlle Goude, and Sofija Stefanović
2021 Microbotanical evidence for the spread of cereal use during the Mesolithic-Neolithic transition in the Southeastern Europe (Danube Gorges): Data from dental calculus analysis. *Journal of Archaeological Science* 125:105288. DOI:10.1016/j.jas.2020.105288.

Kaplan, Lawrence, David L. Lentz, Venicia Slotten, Payson Sheets, and Angela N. Hood
2015 Phaseolus from Cerén—A Late Classic Maya Site. *Economic Botany* 69(2):150–160.

Kealhofer, L., and D. Penny
1998 A combined pollen and phytolith record for fourteen thousand years of vegetation change in northeastern Thailand. *Review of Palaeobotany and Palynology* 103(1):83–93. DOI:10.1016/S0034-6667(98)00029-3.

Kohn, Matthew J.
2010 Carbon isotope compositions of terrestrial C3 plants as indicators of (paleo)ecology and (paleo)climate. *Proceedings of the National Academy of Sciences* 107(46):19691–19695. DOI:10.1073/pnas.1004933107.

Laako, Hanna, and Edith Kauffer
2022 Between colonising waters and extracting forest fronts: Entangled eco-frontiers in the Usumacinta River Basin. *Political Geography* 96:102566. DOI:10.1016/j.polgeo.2021.102566.

Landon, David B.
2002 Food and Foodways. In *Encyclopedia of Historical Archaeology*. Routledge.

Lawler, Andrew
2010 Collapse? What Collapse? Societal Change Revisited. *Science* 330(6006):907–909. DOI:10.1126/science.330.6006.907.

Lentz, David L.
1990 ACROCOMIA MEXICANA: Palm of The Ancient Mesoamericans. *Journal of Ethnobiology*(10(2)):183–194.
1991 Maya Diets of the Rich and Poor: Paleoethnobotanical Evidence from Copan. *Latin American Antiquity* 2(3):269–287. DOI:10.2307/972172.

Lentz, David L., Kevin Magee, Eric Weaver, John G. Jones, Kenneth B. Tankersley, Angela Hood, Gerald Islebe, Carmen E. Ramos Hernandez, and Nicholas P. Dunning
2015 Agroforestry and Agricultural Practices of the Ancient Maya at Tikal. In *Tikal: Paleoecology of an Ancient Maya City*, edited by David L. Lentz, Nicholas P. Dunning, and Vernon L. Scarborough, pp. 152–185. Cambridge University Press, Cambridge.

Lentz, David L., and Carlos R. Ramírez-Sosa
2021 Chapter 4 Cerén Plant Resources: Abundance and Diversity. In *Chapter 4 Cerén Plant Resources: Abundance and Diversity*, pp. 33–42. University of Texas Press.

López, Coral Montero, Luis Fernando Núñez, Pedro Morales, Edith Cienfuegos, and Francisco Otero
2011 Diet and health at Chinikihá, Chiapas, Mexico: some preliminary results. *Environmental Archaeology* 16(2):82–96. DOI:10.1179/174963111X13110803260804.

Lucero, L. J., S. L. Fedick, N. P. Dunning, D. L. Lentz, and V. L. Scarborough
2014 Water and landscape: Ancient Maya settlement decisions. *Archeological Papers of the American Anthropological Association* 24(1):30–42. DOI:10.1111/apaa.12027.

Marston, John M., d'Alpoim Guedes Jade, and Christina Warinner (editors)
2015 *Method and Theory in Paleoethnobotany*. 1 edition. University Press of Colorado, Boulder.

McAnany, Patricia A., and Norman Yoffee
2009 *Questioning Collapse: Human Resilience, Ecological Vulnerability, and the Aftermath of Empire.* Cambridge University Press, University of North Carolina, Chapel Hill.

McNeil, Cameron L.
2012 Deforestation, agroforestry, and sustainable land management practices among the Classic period Maya. *Quaternary International* 249. Long-term perspectives on human occupation of tropical rainforests:19–30. DOI:10.1016/j.quaint.2011.06.055.

McNeil, Cameron L., David A. Burney, and Lida Pigott Burney
2010 Evidence disputing deforestation as the cause for the collapse of the ancient Maya polity of Copan, Honduras. *Proceedings of the National Academy of Sciences of the United States of America* 107(3):1017–1022. DOI:10.1073/pnas.0904760107.

Melton, Mallory A., Aleksa K. Alaica, Matthew E. Biwer, Luis Manuel González La Rosa, Gwyneth Gordon, Kelly J. Knudson, Amber M. VanDerwarker, and Justin Jennings
2023 Reconstructing Middle Horizon Camelid Diets and Foddering Practices: Microbotanical and Isotope Analyses of Dental Remains from Quilcapampa, Peru. *Latin American Antiquity*:1–21. DOI:10.1017/laq.2022.80.

Morell-Hart, Shanti
2011 Paradigms and Syntagms of Ethnobotanical Practice in Pre-Hispanic Northwestern Honduras. UC Berkeley.
2015 *Proyecto Arqueológico Río Amarillo Copán (PARAC): 2015 Microbotanical Extractions from Artifacts*.
2019 Techniques for Integrating Macrobotanical and Microbotanical Datasets: Examples from Pre-Hispanic Northwestern Honduras. *Journal of Field Archaeology* 44(4):234–249. DOI:10.1080/00934690.2019.1591917.

Morell-Hart, Shanti, Harper Dine, Sarah Watson, and Meghan Macleod
2018 Capítulo 14: Análisis Paleoetnobotanico De Budsilha, El Porvenir, El Infiernito Y Lacanja Tzeltal. In *Informe de la Novena Temporada de Investigación Presentado Ante el Consejo de Arqueología Del Instituto Nacional de Antropología e Historia*.

Morell-Hart, Shanti, Harper Dine, and Sarah Watson
2018 Capítulo 9: Análisis Paleoethnobotánicos de Macabilero y Piedras Negras (2016-2018). In *Informe de la Tercera Temporada de Investigación Presentado Ante el Instituto de Antropología e Historia*, edited by Omar A. Alcover Firpi and Mónica Urquizú.

Morell-Hart, Shanti, Lydie Dussol, and Scott Fedick
2022 Agriculture in the Ancient Maya Lowlands (Part 1): Paleoethnobotanical Residues and New Perspectives on Plant Management. *Journal of Archaeological Research*. DOI:10.1007/s10814-022-09180-w.

Morell-Hart, Shanti, and Jesús Alejandro González Córdova
2017 Capítulo 18: Análisis Paleoethnobotanico de Piedras Negras. In *Informe de la Novena Temporada de Investigación Presentado Ante el Consejo de Arqueología Del Instituto Nacional de Antropología e Historia*, edited by Mónica Urquizú, Andrew K. Scherer, and Charles Golden.

Morell-Hart, Shanti, Rosemary A. Joyce, and John S. Henderson
2014 Multi-proxy analysis of plant use at Formative period Los Naranjos, Honduras. *Latin American Antiquity* 25(1):65–81. DOI:10.7183/1045-6635.25.1.65.

Morell-Hart, Shanti, Rosemary A. Joyce, John S. Henderson, and Rachel Cane
2019 Ethnoecology in Pre-Hispanic Central America: Foodways and Human-Plant Interfaces. *Ancient Mesoamerica* 30(3):535–553. DOI:10.1017/S0956536119000014.

Morell-Hart, Shanti, Meghan Macleod, and Sarah Watson
2018 Capítulo 5: Budsilha: Operación 8a: Investigaciones de un Grupo Residencial. In *Informe de la Novena Temporada de Investigación Presentado Ante el Consejo de Arqueología Del Instituto Nacional de Antropología e Historia*.

Morell-Hart, Shanti, Sarah Newman, Joshua Schnell, Meghan Macleod, Sarah Watson, Harper Dine, and Mallory Matsumoto
2018 Capítulo 2: Budsilha: Operación 1: Investigaciones en el Grupo Principal. In *Informe de la Novena Temporada de Investigación Presentado Ante el Consejo de Arqueología Del Instituto Nacional de Antropología e Historia*.

Morell-Hart, Shanti, Melanie Pugliese, Cameron L. McNeil, and Edy Barrios
2021 Cuisine at the Crossroads. *Latin American Antiquity* 32(4):689–704. DOI:10.1017/laq.2021.34.

Morley, Sylvanus Griswold, and Robert J. Sharer
1994 *The Ancient Maya: Fifth Edition*. Stanford University Press.

Nigh, Ronald, and Stewart AW Diemont
2013 The Maya milpa: fire and the legacy of living soil. *Frontiers in Ecology and the Environment* 11(s1):e45–e54. DOI:10.1890/120344.

Nooren, Kees, Wim Z. Hoek, Brian J. Dermody, Didier Galop, Sarah Metcalfe, Gerald Islebe, and Hans Middelkoop
2018 Climate impact on the development of Pre-Classic Maya civilisation. *Climate of the Past* 14(8):1253–1273. DOI:10.5194/cp-14-1253-2018.

Nsabimana, Consolate, and Bo Jiang
2011 The chemical composition of some garden Dahlia tubers. *British Food Journal* 113(9):1081–1093. DOI:10.1108/00070701111174541.

Ortiz, Simitrio, Guillermo López-Guillén, C.H. Avendaño-Arrazate, and Misael Martinez
2020 Morfología del polen de Heliconia spp. (Heliconiaceae) de México y su relación interespecífica e intraespecífica. *Revista de Biología Tropical* 68:933–946. DOI:10.15517/rbt.v68i3.40893.

Pearsall, Deborah M.
2016 *Paleoethnobotany: A Handbook of Procedures*. 3rd ed. Routledge, New York.

Perry, Linda
2004 Starch analyses reveal the relationship between tool type and function: an example from the Orinoco valley of Venezuela. *Journal of Archaeological Science* 31(8):1069–1081. DOI:10.1016/j.jas.2004.01.002.

Piperno, D. R., and I. Holst
1998 The Presence of Starch Grains on Prehistoric Stone Tools from the Humid Neotropics: Indications of Early Tuber Use and Agriculture in Panama. *Journal of Archaeological Science* 25(8):765–776. DOI:10.1006/jasc.1997.0258.

Piperno, Dolores R.
1985 Phytolith analysis and tropical paleo-ecology: Production and taxonomic significance of siliceous forms in new world plant domesticates and wild species. *Review of Palaeobotany and Palynology* 45(3):185–228. DOI:10.1016/0034-6667(85)90002-8.
1998 Paleoethnobotany in the Neotropics from Microfossils: New Insights into Ancient Plant Use and Agricultural Origins in the Tropical Forest. *Journal of World Prehistory* 12(4):393–449.

Pushpalatha, Raji, and Byju Gangadharan
2020 Is Cassava (Manihot esculenta Crantz) a Climate "Smart" Crop? A Review in the Context of Bridging Future Food Demand Gap. *Tropical Plant Biology* 13(3):201–211. DOI:10.1007/s12042-020-09255-2.

Reardon, Jenny, and Kim TallBear
2012 "Your DNA Is Our History": Genomics, Anthropology, and the Construction of Whiteness as Property. *Current Anthropology* 53(S5):S233–S245. DOI:10.1086/662629.

Reitz, Elizabeth J., and Myra Shackley
2012 Spores, Pollen, Phytoliths, Starch Grains, and Other Microbotanical Remains. In *Environmental Archaeology*, edited by Elizabeth J. Reitz and Myra Shackley, pp. 263–300. Manuals in Archaeological Method, Theory and Technique. Springer US, Boston, MA.

Richards, Michael P., and Kate Britton
2020 *Archaeological Science: An Introduction*. Cambridge University Press.

Rico-Gray, V., A. Chemás, and S. Mandujano
1991 Uses of tropical deciduous forest species by the Yucatecan Maya. *Agroforestry Systems* 14(2):149–161. DOI:10.1007/BF00045730.

Roche Recinos, Alejandra
2018 Capítulo 4: Budsilha: Operación 6b: Investigaciones de un Taller de Obsidiana. In *Informe de la Novena Temporada de Investigación Presentado Ante el Consejo de Arqueología Del Instituto Nacional de Antropología e Historia*.

Ross-Ibarra, Jeffrey, and Alvaro Molina-Cruz
2002 The ethnobotany of Chaya (Cnidoscolus aconitifolius SSP.Aconitifolius breckon): A nutritious Maya Vegetable. *Economic Botany* 56(4):350–365. DOI:10.1663/0013-0001(2002)056[0350:TEOCCA]2.0.CO;2.

Roys, Ralph L.
1931 *The Ethno-Botany of the Maya*. Tulane university of Louisiana middle American research series. Publication,no. 2. Dept. of Middle American Research, Tulane University of Louisiana, New Orleans, La.

Rushton, Elizabeth, Sarah Metcalfe, and Bronwen Whitney
2012 A late-Holocene vegetation history from the Maya lowlands, Lamanai, Northern Belize. *The Holocene* 23:485–493.

Salleh, Wan Mohd Nuzul Hakimi Wan, Hakimi Kassim, and Alene Tawang
2021 Traditional uses, chemical profile and biological activities of Piper hispidum Sw.: a review. *Biointerface Research in Applied Chemistry* 11:13115–13129. DOI:10.33263/BRIAC115.1311513129.

Scarborough, Vernon L.
2007 *The Political Economy of Ancient Mesoamerica: Transformations During the Formative and Classic Periods*. UNM Press.

Scherer, Andrew K.
2015 *Mortuary Landscapes of the Classic Maya: Rituals of Body and Soul*. University of Texas Press.

Scherer, Andrew K., Harper Dine, and Joshua Schnell
2019 Bioarqueología: análisis De Los Huesos Humanos De Paso Del Tigre, Huesos De Contextos No Funerario De Lacanjá Tzeltal Y Resultados De Investigaciones De Isotopos Estables De Rancho Búfalo, Budsilha, Y El Infiernito (Temporadas 1-9). In *Informe De La Décima Temporada De Investigación Presentado Ante El Consejo De Arqueología Del Instituto Nacional De Antropología E Historia*.

Scherer, Andrew K., and Charles Golden
2012 *Revisiting Maler's Usumacinta: Recent Archaeological Investigations in Chiapas,Mexico*. Precolumbia Mesoweb Press, San Francisco.

Scherer, Andrew K., and Lori E. Wright
2015 Dental Morphometric and Strontium Isotope Evidence for Population History at Tikal, Guatemala. In *Archaeology and Bioarchaeology of Population Movement among the Prehispanic Maya*, edited by Andrea Cucina, pp. 109–118. SpringerBriefs in Archaeology. Springer International Publishing, Cham.

Scherer, Andrew K., Lori E. Wright, and Cassady J. Yoder
2007 Bioarchaeological Evidence for Social and Temporal Differences in Diet at Piedras Negras, Guatemala. *Latin American Antiquity* 18(1):85–104. DOI:10.2307/25063087.

Schroder, Whittaker, Charles W. Golden, Andrew K. Scherer, Socorro Jiménez-Álvarez, Jeffrey Dobereiner, and Alan Mendez Cab
2017 At the Crossroads of Kingdoms: Recent Investigations on the Periphery of Piedras Negras and its Neighbors. *The Pari Journal* 17(4).

Shannon, Jack C., Douglas L. Garwood, and Charles D. Boyer
2009 Chapter 3 - Genetics and Physiology of Starch Development. In *Starch (Third Edition)*, edited by James BeMiller and Roy Whistler, pp. 23–82. Food Science and Technology. Academic Press, San Diego.

Sharpe, Ashley, and Kitty Emery
2015 Differential animal use within three Late Classic Maya states: Implications for politics and trade. *Journal of Anthropological Archaeology* 40:280–301. DOI:10.1016/j.jaa.2015.09.003.

Sheets, Payson, Christine Dixon, Monica Guerra, and Adam Blanford
2011 Manioc Cultivation at Ceren, El Salvador: Occasional Kitchen Garden Plant or Staple Crop? *Ancient Mesoamerica* 22(1):1–11.

Sheets, Payson, David Lentz, Dolores Piperno, John Jones, Christine Dixon, George Maloof, and Angela Hood
2012 Ancient Manioc Agriculture South of the Ceren Village, El Salvador. *Latin American Antiquity* 23(3):259–281.

Simpson, Michael G.
2010 8 - Diversity and Classification of Flowering Plants: Eudicots. In *Plant Systematics (Second Edition)*, edited by Michael G. Simpson, pp. 275–448. Academic Press, San Diego.

Solís-Castillo, Berenice, Alexandra Golyeva, Sergey Sedov, Elizabeth Solleiro-Rebolledo, and Sara López-Rivera
2015 Phytoliths, stable carbon isotopes and micromorphology of a buried alluvial soil in Southern Mexico: A polychronous record of environmental change during Middle Holocene. *Quaternary International* 365. Paleosols, pedosediments and landscape morphology as environmental archives:150–158. DOI:10.1016/j.quaint.2014.06.043.

Somerville, Andrew D., Mikael Fauvelle, and Andrew W. Froehle
2013 Applying new approaches to modeling diet and status: isotopic evidence for commoner resiliency and elite variability in the Classic Maya lowlands. *Journal of Archaeological Science* 40(3):1539–1553. DOI:10.1016/j.jas.2012.10.029.

Staller, John, and Michael Carrasco
2009 *Pre-Columbian Foodways: Interdisciplinary Approaches to Food, Culture, and Markets in Ancient Mesoamerica*. Springer Science & Business Media.

Sutherland, Cyril Hardy Nelson
1986 *Plantas comunes de Honduras*. Editorial Universitaria.

Tainter, J
1988 *The Collapse of Complex Societies*. Cambridge University Press.

Taube, Karl A.
2004 Flower Mountain: Concepts of Life, Beauty, and Paradise among the Classic Maya. *RES: Anthropology and Aesthetics*(45):69–98.

Tiesler, Vera, and María Cecilia Lozada
2018 *Social Skins of the Head: Body Beliefs and Ritual in Ancient Mesoamerica and the Andes*. University of New Mexico Press.

Tokovinine, Alexandre, and Cameron L. McNeil
2012 Colored things, chromatic stories: Searching for the pigments of the past. *RES: Anthropology and Aesthetics*(61/62):279–282.

Torrence, Robin, and Huw Barton (editors)
2016 *Ancient Starch Research*. Routledge, New York.

Turner II, Billy L.
1974 Prehistoric Intensive Agriculture in the Mayan Lowlands. *Science* 185(4146):118–124.

Vidal, Adria Renee, Alejandra Linaloe Zaucedo-Zuñiga, and Margarita de Lorena Ramos-García
2018 Propiedades nutrimentales del camote (Ipomoea batatas l.) y sus beneficios en la salud humana. *Revista Iberoamericana de Tecnología Postcosecha* 19(2). S.C., México.

Watson, Sarah
2022 Maya Food Strategies at Macabilero: A Paleoethnobotanical Study of Ancient Maya Agriculture and Ethnoecology During the Formative and Classic Periods. Unpublished MA thesis, McMaster University, Hamilton, Ontario.

Watson, Sarah, Joshua T. Schnell, Shanti Morell-Hart, Andrew K. Scherer, and Lydie Dussol
2022 Health Care in the Marketplace: Exploring Medicinal Plants and Practices at Piedras Negras, Guatemala. *Ancient Mesoamerica* (first view):1-24.

Webster, David
1999 The Archaeology of Copán, Honduras. *Journal of Archaeological Research* 7(1):1–53.
2002 *Fall of the Ancient Maya: Solving The Mystery Of The Maya Collapse*. Thames and Hudson, London ; New York.

Weiss, Harvey, and Raymond S. Bradley
2001 What Drives Societal Collapse? *Science* 291(5504):609–610. DOI:10.1126/science.1058775.

White, Christine (editor)
2022 *Reconstructing Ancient Maya Diet*. The University of Utah Press. https://uofupress.lib.utah.edu/reconstructing-ancient-maya-diet/, accessed November 16, 2022.

Wyatt, Andrew R.
2020 Gardens of the Maya. In *The Real Business of Ancient Maya Economies: From Farmers' Fields to Rulers' Realms*, edited by Marilyn A. Masson, David A. Freidel, and Arthur A. Demarest, pp. 0. University Press of Florida.

Yang, XiaoYan, JinCheng Yu, HouYuan Lü, TianXing Cui, JingNing Guo, and QuanSheng Ge
2009 Starch grain analysis reveals function of grinding stone tools at Shangzhai site, Beijing. *Science in China Series D: Earth Sciences* 52(8):1164–1171. DOI:10.1007/s11430-009-0089-9.

Zizumbo-Villarreal, Daniel, Patricia Colunga-GarcíaMarín, and Alondra Flores-Silva
2016 Pre-Columbian Food System in West Mesoamerica. In *Ethnobotany of Mexico: Interactions of People and Plants in Mesoamerica*, edited by Rafael Lira, Alejandro Casas, and José Blancas, pp. 67–82. Ethnobiology. Springer, New York, NY.

Appendix A

Processing and Analyzing Sediment Samples for Phytoliths (2018)
McMaster Paleoethnobotanical Research Facility (MPERF)

Developed by Shanti Morell-Hart

(in consultation with Dolores Piperno in 2006; Rob Cuthrell in 2008; MARS representative Jessica Giles in 2017; independent experimentation at UCB and the MPERF)

Phytolith Extraction from Sediments: Basic procedure sequence

(in parentheses, time estimates for a 20 sample batch = 40 processed samples total)

- 1) sediment ashing for sterilization of pathogens (1 day)
- 2) deflocculating sediment samples in water (1-10 days—depends on sediment composition)
- 3a) dividing sediment into a, b, and s fraction sizes (1 day)
- 3b) removing clay (1-10 days—depends on sediment composition)
- 4) microwave chemical digestion: removing carbonates with hydrochloric acid (HCl) solution, removing organic materials with nitric acid (HNO_3) solution, removing humics with hydrogen peroxide (H_2O_2) solution (1 day)
- 5) floating phytoliths with sodium polytungstate (SPT) solution and drying phytolith sample (1 day)
- 6) mounting phytolith sample (1 day)
- 7) scanning for phytoliths under the microscope (avg. 2-3 hours per slide = 80-120 hours total)

There are multiple washes and centrifuging steps between stages 3, 4, and 5.

Total time for 20 sample batch equaling 40 processed samples = 35- 55 days

NOTE: ***If extracting phytoliths for dating purposes, boil and sterilize all glassware and glass tubes.***

1) Sediment sterilization for foreign soils, following CFIA requirements

This is to eliminate any potential pathogens. The ashing process will also remove some degree of organics and any starch grains, so is inappropriate for a piggyback-style extraction process.

- Prepare and label foil envelopes for sediment samples.

- Heat muffle furnace to 200C.

- Put ~150mL of sediment from each sample into the appropriately labeled foil packet.

- Note the location of the foil packets in the muffle furnace.

- Soak any used tools, implements, etc. in bleach water solution in marked bucket.

- Heat sediment samples in furnace at 200C for at least 6 hours.

- Allow samples to cool in oven overnight. Samples are likely to clump a bit from the low-firing.

- Dispose of any contaminated materials (sample bags, packaging materials, gloves, disposables) in the Stericycle or Daniels bin for incineration.

2) Deflocculating Sediment Samples in Water

- Rinse set of 1000mL beakers.

- Label each beaker with masking tape and sharpie.

- Start with ~150 mL of dry sediment in a 1000 mL labeled beaker (beaker needs a height of at least 12 cm).

- Add 1-2 tbs. deflocculant (***sodium hexametaphosphate if dating phytoliths, baking soda [sodium bicarbonate] if not dating phytoliths***), and 1000 mL of *very hot* water.

- Stir every 15 min., about 20 times total (takes ~3 days). Mixture should be uniformly cloudy, with NO remaining clumps, and clays should be relatively suspended at the last stir.

- Consider sonicating samples for 10 mins (in several batches) in the large sonicating bath, to speed deflocculation (following Lombardo et al. 2016).

- On day of sieving, give one last stir, then wait at least1 hour before sieving to make sure silts have settled adequately.

3a) Removing Sand (S) Fraction and Larger Sediments (D) Fraction

- Set up a set of sieves in this order: No. 60 (250 um, for D fraction) on top of No.270 (53 um, for S fraction) on top of base pan (for A and B fractions).

-Label a set of 1000 mL beakers with same sample info as current 1000 mL beakers, with the addition of “A/B” to represent fraction.

- (***To reiterate***) After waiting at least 1 hour for silts to settle, pour off top 500 mL from samples (this is to reduce the liquid volume, so that the remaining water fits in sieve pan).

- Give mixture another vigorous stir, until all sediments are relatively suspended.

- Pour 1/3 of mixture through set of sieves, wait for liquid to go through, pour another 1/3, wait for liquid to go through, pour last portion.

- Keep an eye out for particulate charcoal (can be dated—only 100 micrograms needed for AMS dating, but NOT if sodium bicarbonate was used).

- Add 400 mL of clean water to corresponding labeled “A/B” beaker.

- Using A/B beaker clean “rinse water”, rinse off the upper fraction through screens and into the base pan. Pour approximately 100 mL at a time (any silt lumps can be gently “mashed” into the top screen while rinsing with a clean pipet).

- Keep an eye on run-off from screens into base pan-- when this water is fairly clean, remove upper (D) fraction. If D fraction is still not fairly clean, do an early pour-off of base pan liquid into corresponding labeled beaker and continue rinsing process until water is fairly clear.

- Pour contents of bottom pan (A&B fractions) back into corresponding labeled beaker.

- Total contents of beaker are usually +/- 1000 mL, unless more rinsing is needed for in-screen fractions, and more than one beaker has been used.

- If particulate charcoal is needed for dating (or to preserve potential macrobots or fauna or lithics), save the D fraction by overturning screen contents onto a labeled paper towel (wait a few days until fully dry, and bag this sample).

- If not preserving D fraction, dispose of screen No. 60 contents using proper soils protocols

- Clean off No. 60 screen.

- **Replace** upper No. 60 screen, clean No.270 screen under No.60 screen, under running water, until water is completely clear. This is because the No. 270 screen is VERY delicate and can be damaged by too much water pressure.

- Concentrate sand (S) fraction in the No. 270 screen (still UNDER the No. 60 screen) by running tap water onto screen while tilting screen so that water pushes the sand up against one side of the pan.

- Pour sand fraction (S) into labeled 50mL tube. This is messy, and some sand will be lost. Multiple tubes may be necessary.

- Keep adding a bit of water (under No. 60 screen), concentrating sand and pouring into labeled tubes, until most of the sand has been removed from the screen (some particles will remain in the screen).

- Clean off both screens. **Always leave larger No. 60 screen over smaller No. 270 screen to prevent damage.**

3b) Removing Clay from Fine (A) and Course Silt (B) Fractions

- Add water up to 900 mL mark (10 cm in height) to each beaker containing the A and B fractions.

- Stir vigorously-- quickly and sequentially so that everything is approximately at the same stage of stirring.

- Cover in plastic wrap.

- Let sit for 1.5 hours.

- Pour off +/- 400 mL of excess water.

- Add water up to the 900 mL mark and stir vigorously.

- Let sit for 1 hour.

- Rinse, repeat 1hour sequence (3 to 10 times) until water is fairly clear of suspended clay (whole procedure takes 1-10 days).

-After the last pour-off, pour the solution into a prepared 500mL beaker (simply move the masking tape label) and let the samples sit in the beakers overnight.

-The next day, pour off excess water and pour samples into labeled centrifuge tubes.

3c) Preparing samples for Chemical Digestion

- Redistribute fractions in labeled 50 mL centrifuge tubes to maximize processing. Coarse silt (B) and fine silt (A), and sand (S) should each have 1.5-2.0 cm of sediment at the bottom of the tubes

- Process one or several tubes of each sample at a time (depending on recovery strategy).

- Centrifuge tubes for 5 min. @ 1,000 rpm to consolidate sediments at the bottom of the tube

Don't use more than 1,000 rpm when sediment is in the tube at any time, but at phytolith isolation, washing, and drying stages, you can go up to 1,500 rpm for 10 min.

- Pour off excess water, leaving only the damp plug at base.

- In some cases you will want to make sure sediments are dried thoroughly (can dry overnight at roughly 65 degrees F in the oven) before weighing sediments and placing in tubes. In other cases, you can leave the sediments as damp samples and record the wet weights.

- Transfer material to the microwave vessels, weighing the material in the microwave vessel (taring for empty vessel weight) to stay below 20g.

- Record the weight of each unprocessed sediment sample in your laboratory notebook.

4a) Preparing the microwave equipment

-Ready the microwave vessel carousel—ensure all vessels and fittings are clean. There are 40 microwave vessels on the carousel, each holding a roughly 50 mL volume of material. Pressure sensors are at the base of the microwave.

- Place the vessels in the carousel. **Carousel with tubes will get fairly heavy once full, so be careful!**

- Ensure that you have at least 8 tubes in the carousel for processing. The vessels placed in the microwave carousel should all be filled-- dummy tubes with water work. Otherwise, microwave power will be too concentrated for the few tubes inside. For more than 8 tubes but fewer than 40, you can leave the carousel slots empty. Make sure to place tubes in the carousel according to p.13 of the manual. This will optimally match tubes to sensors.

4b) Preparation of sediment and solution in tubes

- Put, at most, 20 grams of material in each microwave tube. (RQC uses only roughly 10g). **Note which number on the carousel corresponds with which sample in your laboratory notebook.**

- Place carousel of tubes under fume hood.

- Put on lab coat, goggles, safety mask, and two pairs of gloves (double up).

- Prepare a beaker of distilled water (to clean syringe).

- Prepare a bucket in the sink with ~2 gallons of water an 1 box of baking soda. Stir into solution.

- Prepare nitric acid, hydrochloric acid, and hydrogen peroxide (or potassium chlorate) in beakers with syringes and place under fume hood. Have caps for microwave vessels prepared and ready under the fume hood.

- Recommended for 20 g of sediment (halve quantities for 10 g of sediment) in each tube:

1) 6 mL hydrochloric acid (10% aqueous solution)
2) 10 mL nitric acid (68-70% aqueous solution)
3) 2 mL hydrogen peroxide (30% aqueous solution)

- Using a 50 mL syringe, express chemicals, in turn, into each tube, while stirring gently with a glass rod. For some samples high in carbonates, the hydrochloric will react vigorously. In other cases, the nitric and hydrogen peroxide will react vigorously with organics. **Add each chemical slowly, as they may rapidly start to overflow.** Make sure to mark vigorous reactions of various chemicals or any spillage in your lab notebook.

In case of overflow or spillage: stay calm! It's okay if a little material spills onto your double-gloved hands. If you get any material on exposed skin or clothing, neutralize immediately with

the baking soda solution, then rinse clean in cool water. You can use paper towels, sponges, and kim wipes dipped in the baking soda solution to clean up the mess on the vessels and carousel, then put all these contaminated materials in the baking soda solution to neutralize the acids. As you clean, be careful not to drip any of this baking soda solution into the microwave vessels as it will neutralize the acids and/or potentially contaminate the sample. While cleaning, also make sure no sample has spilled into another. If you suspect cross-contamination, you'll need to start again with fresh material from the affected samples.

- Use beaker of distilled water, as needed, to cleanse the syringe if besmirched by accidentally touching tubes.

- Place plugs on all tubes, then screw on caps very tightly, using one click of the white plastic torque wrench (in drawer).

-Make sure all vessels are flush with the Kevlar sleeves and patted down to base of carousel.

4c) Preparation of microwave

- Ensure the damper above the microwave is open. If it isn't, unscrew the screw, slide out the metal sheet, and tighten the screw. Fumes from the microwave and oven go into the fume hood through the hosing attached to each.

- Make sure to place tubes in the carousel according to p.13 of the manual. This will optimally match tubes to sensors. Again, you will need to run a minimum of 8 tubes (some may be dummy tubes with only water).

-Place carousel in the microwave, matching up the divot at the base, to lock carousel securely onto microwave tray.

- With the microwave door open, flip the ON switch on the right side of the microwave. This will turn the carousel a full rotation, once, both clockwise and counterclockwise, to test the internal sensors.

- Close the microwave door.

4d) Setting and running the microwave

- After closing the microwave door, go to the main menu.

- Press the button for "One Touch Methods."

- Find the "ARCH SEDS" stored method for processing archaeological sediments and hit "enter".

- Check to make sure the protocols are correct:

ARCH SEDS

Control type: > ramp to temp

Vessel type: >Xpress

Sample type: > Organic

Temp Guard: On; >220C

Sample prep notes [chemical quantities listed above]

Ramp time: 20:00

Hold time: 55:00

Temp: 180C

Power: (variable—One Touch method auto corrects with more power for more samples)

Stirring: Off

- Press “play” icon (>) to start the program. The entire microwaving time should be ~130 minutes. **Do not attempt to uncap the tubes for AT LEAST 5 hours, but ideally the next day.**

4e) When microwaving is complete

Ideally, leave tubes overnight to cool in microwave. Before removing the tubes from the microwave, make sure the pressure is down to roughly 20 PSI or less.

- Remove the carousel of tubes and place under the fume hood. With gloves and goggles on, release/unscrew the cap of each microwave tube slowly. Allow the fumes to ventilate into the fume hood duct (10-80 mins).

- After the fumes have been ventilated, unscrew the caps fully. Remove the pressure plugs, and stir the sediment and solution in each microwave tube with clean glass stirring rods. This will aid removal from tube.

-Pour the mixture from each tube into an empty and **labeled** 50 mL tube.

- After pouring the mixture, carefully squirt water (using H2O squirt bottle) into the microwave tube to rinse remainder into the prepared 50 mL tube.

- Prepare a tub of 2 L water plus 1 box baking soda.

- Put empty microwave tubes, stirring rods, and any acid-residue materials into this tub to neutralize any remaining acids. Let materials sit for at least 30 minutes before cleaning.

- Centrifuge the tubes @3000 rpm for 5 minutes.

- Under the fume hood, dispose of this supernatant into a (single) beaker, then **transfer beaker contents into the container marked for special removal of hazardous waste**.

- Send each sample through a series of two rinses using distilled water. In each rinse, add water to the 50 mL mark, agitate until sediments go into solution, then centrifuge @3000 rpm for 5 minutes.

- After each water rinse, pour off supernatant into the tub of baking soda solution to neutralize any remaining acids.

(4f) Running samples again

If samples need more processing, add more hydrogen peroxide and redo microwave process.

4g) Clean-up

- After soaking for 30 minutes in the baking soda solution: tubes, caps, and pressure plugs (but NOT Kevlar sleeves) may be cleaned with contrex or alconox solution. If residues remain in microwave test tubes, they may be cleaned with acetone and rewashed.

5a) Making Heavy Liquid Solution:

-Start with 155 mL of water per pound of sodium polytungstate, THEN add 5 mL water at a time, measuring on scale until 2.3 g/mL is reached. Don't go over!

- Use dry sodium polytungstate. One pound sodium polytungstate will make roughly 175 mL of heavy liquid.

- Final specific gravity: aim for 2.3 (i.e. weight of 1 mL is 2.3 g)

- Start with water, add sodium polytungstate.

- Make solution, shaking slowly, and adding a bit at a time.

- Set scale to zero with an empty 2 mL capsule.

- Add 1 mL liquid, reweigh capsule.

- Add water to solution (5mL at a time) until 2.3g specific gravity is reached. It's okay to be within 0.05g of the 2.3g requirement.

If you run out of chemicals, and still aren't at the right specific gravity, you can boil the liquid or let evaporate slowly to increase specific gravity.

5b) Flotation of Phytoliths: Heavy Liquid Solution step

- Add heavy liquid solution to each centrifuge tube, to about 3-4 cm below top of tube, so that surface of supernatant is easily accessible with pipet.

- If organic material is still present in sample, the heavy liquid will turn red or black.

- Cap the centrifuge tube, stir, shake, and invert each tube to put all sediment into solution.

- Invert slowly (+/- 5 times) **just before** centrifuging. put into centrifuge immediately.

- Centrifuge for 5 min. @ 1,000 rpm.

- Lift test tubes out one at a time, **slowly**, to reserve surface tension (milky film atop test tube is phytolith "crust").

- Use a pipet to remove upper "crust" of phytoliths in a circular motion around the sides of the tube, just skimming the surface (first suction step)—add this solution to a labeled 15mL tube.

- Use pipet to suction from center of centrifuge tube solution, and "clean" the sides of the tube with the pipet, then quickly remove upper portion of phytolith material in a circular motion around the sides of the tube, just skimming the surface (second suction step)-- add this solution to labeled 15mL tube.

REPEAT (2 centrifuge extractions total):

- Cap the centrifuge tube, stir, shake, and invert each tube to put all sediment into solution. invert slowly (+/- 5 times) **just before** centrifuging.

- Put into centrifuge immediately.

- Centrifuge for 5 min. @ 1,000 rpm.

- Lift test tubes out one at a time, **slowly**, to reserve surface tension (milky film atop test tube is phytolith "crust").

- Use a pipet to remove upper "crust" of phytoliths in a circular motion around the sides of the tube, just skimming the surface (first suction step)—add this solution to labeled 15mL tube.

- Use pipet to suction from center of test tube solution, and "clean" the sides of the tube with the pipet, then quickly remove upper portion of phytolith material in a circular motion around the sides of the tube, just skimming the surface (second suction step)-- add this solution to test tube.

Do not fill labeled 15 mL tube to more than 1/3 of total volume with phytolith/liquid solution.

5c) Isolating Phytoliths: Removal of Heavy Liquid and Drying Phytolith Sample

- Add distilled water to 15mL centrifuge tube containing phytolith/solution extraction (up to the top of markings)-- this will lower the specific gravity and cause phytoliths to sink.

- Cap the tube, invert, mix, and shake until heavy liquid and water are in solution.

- Centrifuge for 10 min. @ 1,000 rpm.

- Slowly invert test tube to pour off supernatant, leaving behind phytolith ‘plug’ at base. if plug begins to become undone and go into solution, stop pouring off supernatant immediately and continue to next step.

- Re-add distilled water, repeat entire process.

- Perform 2-3 water washes total, until water emerges clear.

- Pour off last of water from tube (after centrifuging).

- Invert tube, quickly blot tube on a paper towel.

If drying immediately, add sample to a GLASS test tube and complete next 4 steps. Otherwise, skip to next section.

- Add acetone up to bottom of labeled tape.

- Stir, invert with parafilm, until sediment is dislocated from bottom of tube.

- Centrifuge 10 min. @ 1,500 rpm.

- Slowly pour off acetone supernatant.

With or without acetone step:

- Cover open centrifuge tubes loosely with parafilm or plastic wrap (just to prevent blow-ins) and allow to completely desiccate (several days to several weeks) inside the fume hood.

- Samples should eventually appear like a white clay or powder.

6) Mounting the phytolith concentrate material

For larger samples (the roughly 20 gram samples), the processing should leave several grams’ worth of material. At this point, the phytolith concentrate will be in the labeled 15 mL tubes.

-When the samples are fully dry, label a set of small 2 mL centrifuge tubes with the same set of labels. This will be the dry archived collection (separate from the wet archived collection and separate from the slides).

-Loosen the material in the 15 mL tubes, with a shaker or by hand or pipet or all of the above.

-Remove part of the material from the 15 mL tubes, and archive it in the 2 mL tubes. (A pipet works well for this—but **use individual pipets for individual samples**!

-Break off the end of a clean pipet, and use this as the reserved pipet for the immersion oil.

-Lay out a large KimWipe—the immersion oil is messy. Keep a set of small Kimwipes on hand.

(Immersion oil used: Type B from Cargille. Code 1248. Standardized at 23 degrees Celsius. Non-drying for microscopy. Viscosity, cSt = 1250 +/- 10%. Fluorescence = Low, relative to Cedarwood Oil.)

-On a clean small Kimwipe, label a slide with the same information listed on the tube, in both Sharpie and pencil.

-In each 15 mL tube, add enough immersion oil (with a clean pipet) to thin the phytolith material sufficiently for a slide. You'll want to be able to transmit light through the slide, and be able to distinguish different materials (vs. overly dark & overcrowded conditions on the slide due to too much material).

-Using the reserved individual pipet, mix the oil with the material.

-Drop one drop of mixture onto the center of the slide. If material seems too filled with phytolith material, add a drop of pure immersion oil. Add, in total, 1-3 drops of liquid.

-Place a coverslip (large) over the mixture, and press very lightly until mixture is evenly dispersed under the coverslip. Try to remove all of the air bubbles.

-Wipe any excess mixture from the sides of the slide.

-Apply a thick coat of color nail polish to seal the edges. (Sally Hansen hard-as-nails is the best)

-Make sure to curate the slides on their "backs", not edges.

7) Scanning for phytoliths under the microscope

Samples are already divided into AB and S fractions, processed, floated, and mounted on slides.

- Counts: 100 in AB fraction and 100 in S fraction = 200 total per sample

- Note: many additional phytoliths of an AB size are sometimes released into S fraction after chemical processing. By analyzing both fractions, this presents a better way to get phytoliths more trapped in sediments.

- Magnification power for scanning slides: for S fraction, at 200x, for AB, at 400x.

- Beginning in one corner of the slide, move systematically from top to bottom, left to right (as though reading a book). Moving from left to right, begin by moving to a field of view which overlapped only slightly with the previous, then slowly shift focus in and out. This enables a view "through" the transparent phytoliths, in order to gauge broad morphology. (i.e. starting on top surface, moving through the phytolith, then ending with the bottom surface).

- Morphology is also inspected by gently depressing the slide with a rubber-coated paperclip tip, in order to rotate the phytoliths in the immersion oil. This is especially helpful with phytoliths such as rondels, which appear spherical in planar view but like spools in profile.

-Do not count the elongate and bulliform phytoliths that are common in grasses, since these are incredibly abundant and ubiquitous, and will dominate all slide densities and slow the identifications considerably (i.e., you would needed to bump the counts to 1000 or more per slide).

- Make sure to photograph each (significant/diagnostic/novel) phytolith at three focal points, at least, then rotate and take additional photos.

Appendix B

All unknowns are depicted below. These figures provide the possibility for future identification of unknown microremains and can be cross referenced by other researchers studying other sites in the area. With further research into diagnostic characteristics of phytoliths, starch grains and fibers these unknowns have the potential to identified.

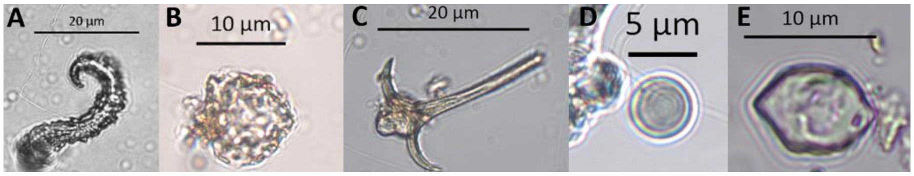


Figure. B.1. All Unknown Phytoliths from Artifacts
(a) Unkn phyto 56 tentacle shape; curled. Located on artifact 7. (b) Unkn phyto 57 possible cucurbit; smaller; scalloped surface. Located on artifact 7. (c) Unkn phyto 58 pick axe shape; curled one side (d) Unkn phyto 59 round; opaque; smooth edge; similar to canna sp. (e) Unkn phyto 60 diamond shaped but rounded; concave in center

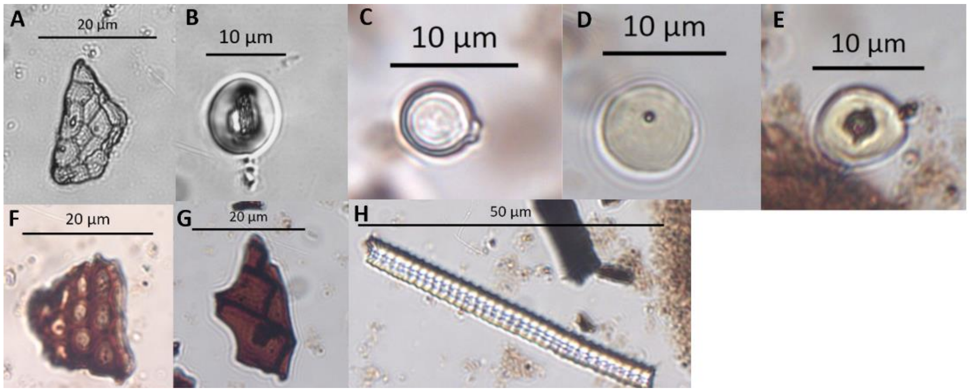


Figure. B.2. Unknown Siliceous Tissues and Diatoms
(a) UNKN siliceous tissue. Possible nuclei present. Located on Artifact 7 (b) UNKN spherical structure. Possible diatom. Found before. Located on Artifact 7 (c) Chrysophyceae (d) Unkn biological specimen. Located from sediment sample 15. (e) Unkn biological specimen. Located from sediment sample 15 (f) Unkn tissue honey combed; brown; rounded (g) Unkn tissue honey combed; brown (h) Unkn diatom elongate; linear rows of long craters on surface

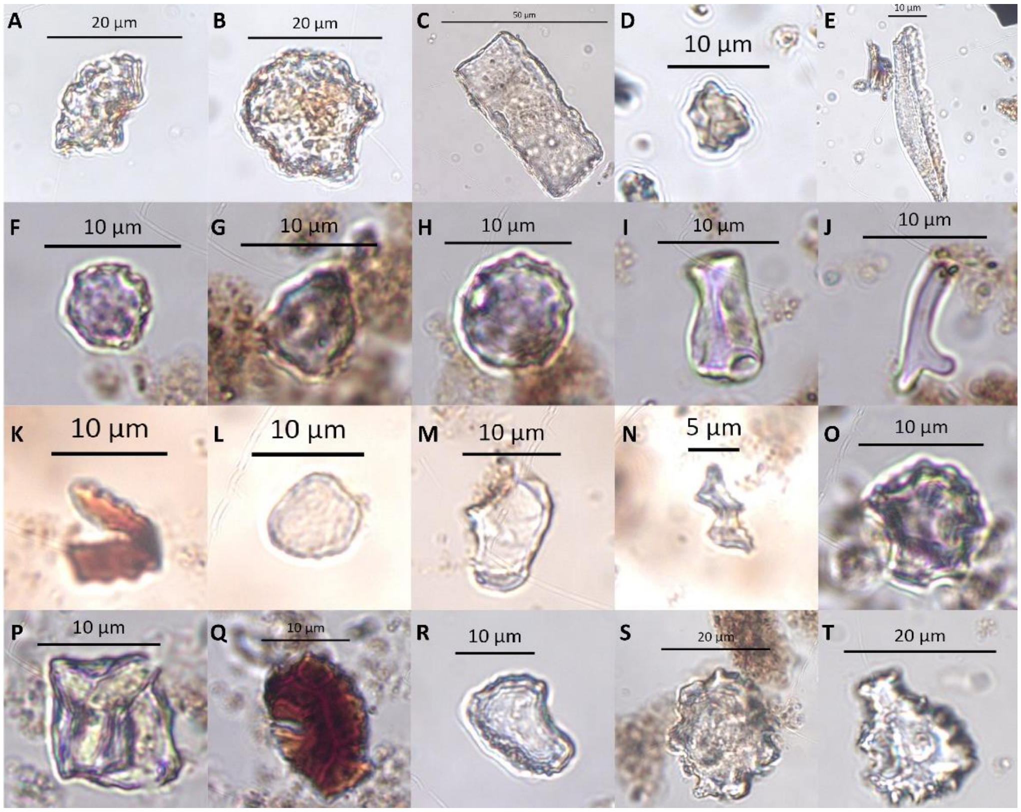
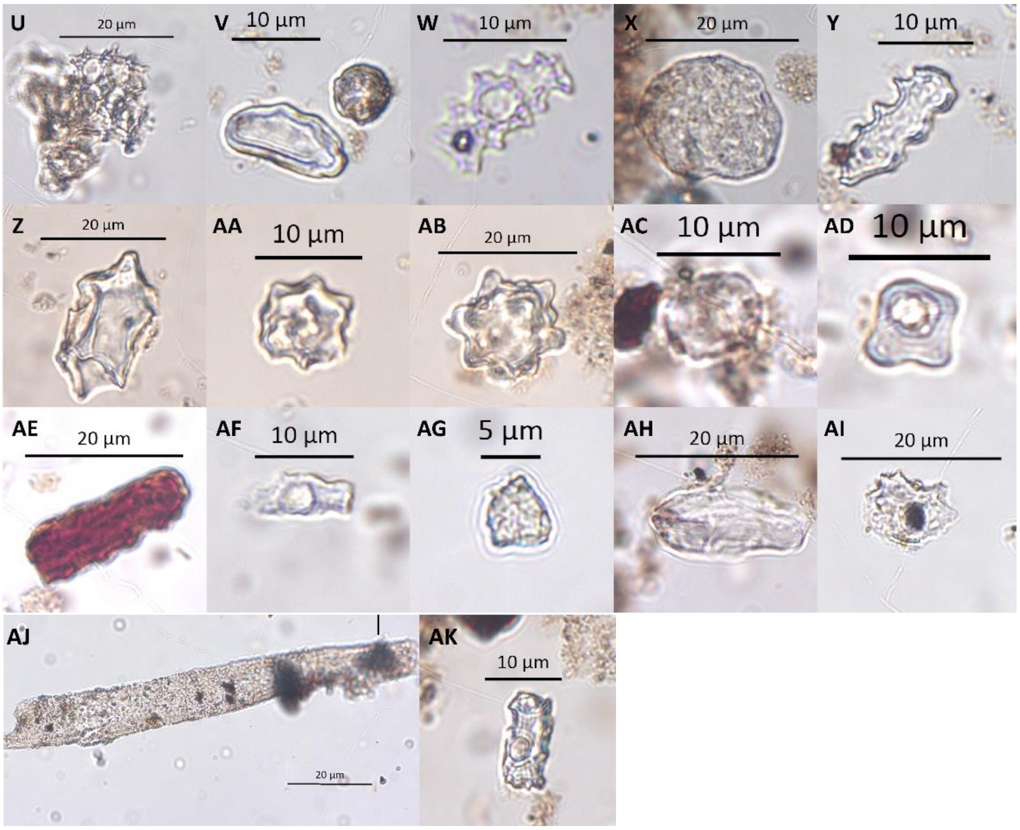


Figure. B.3. All Unknown Phytoliths from Sediments

(a) Unkn phyto 20. Irregular shape; cratered surface (b) Unkn phyto 21. Decorated sphere. (c) Unkn phyto 22. Large; rectangular; cratered surface (d) Unkn phyto 23. Cratered scalloped surface; irregular surface; lobed edges (e) Unkn phyto 24. cratered surface; irregular shape; eroded (f) Unkn phyto 25. Opaque; small; protrusions. (g) Unkn phyto 26 Some cratering; opaque; irregular triangular shape (h) Unkn phyto 27. Similar in shape to cucurbit sp. Although smaller in size. (i) Unkn phyto 28. Burrito shape; some craters on surface. (j)Unkn phyto 29. Branched end; rounded edges; y shaped. (k) Unkn phyto 30 charred; lobed edges; bent elongate (l) Unkn phyto 31 irregular circular shape; rough surface (m) Unkn phyto 32 Irregular shape; cratered surface (n) Unkn phyto 33 triangular pointed; attached in row (o) Unkn phyto 34 nodular sphere; neck; opaque (p) Unkn phyto 35 very irregular shape; square with propeller on one side (q) Unkn phyto 36. Brown charred; damaged (r) Unkn phyto 37 irregular shape; slightly scalloped edges (s) Unkn phyto 38 large nodular sphere (t) Unkn phyto 39 nodular sphere; neck; opaque



(u) Unkn phyto 40 smooth surface perforated epidermis with scalloped and curved edges (v) Unkn phyto 41 irregular elongate shape; trapezoidal; curved edges(left) UNKN phyto 1 (right) (w) Unkn phyto 42 nodular sphere; quadrilateral schlerid (x) Unkn phyto 43 elongate with large craters arranged linearly (y) Unkn phyto 44 elongate; scalloped edges (z) Unkn phyto 45 irregular hexagonal shape; surface concave to point at meridian (aa) Unkn phyto 46 sphere with nodular projection; concave in middle (ab) Unkn Marantaceae/Arecaceae (ac) Unkn phyto 47. opaque sphere; covered in debris (ad) Unkn phyto 48 square; curved edges; concave circle on one side (ae) Unkn phyto 49 burned elongate; possible Pooideae (af) Unkn ohyto 50 elongate; concave in center (ag) Unkn phyto 51 triangular; faceted (ah) Unkn phyto 52 elongate sphere (ai) Unkn phyto 53 irregular shape; black dot in center (aj) Unkn phyto 54 large elongate; faceted (ak) Unkn phyto 55 polar view lobed edges; round crater on one side

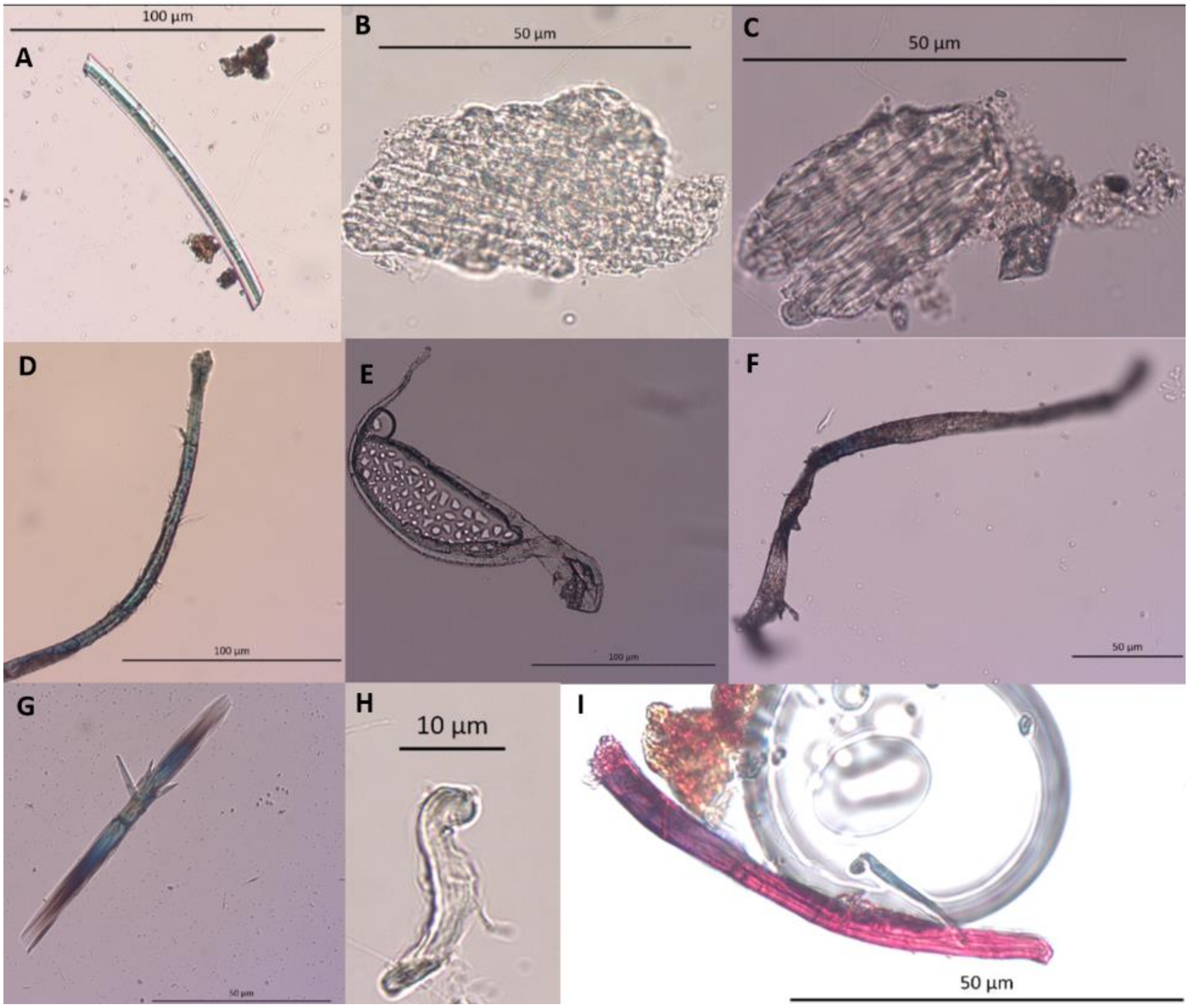
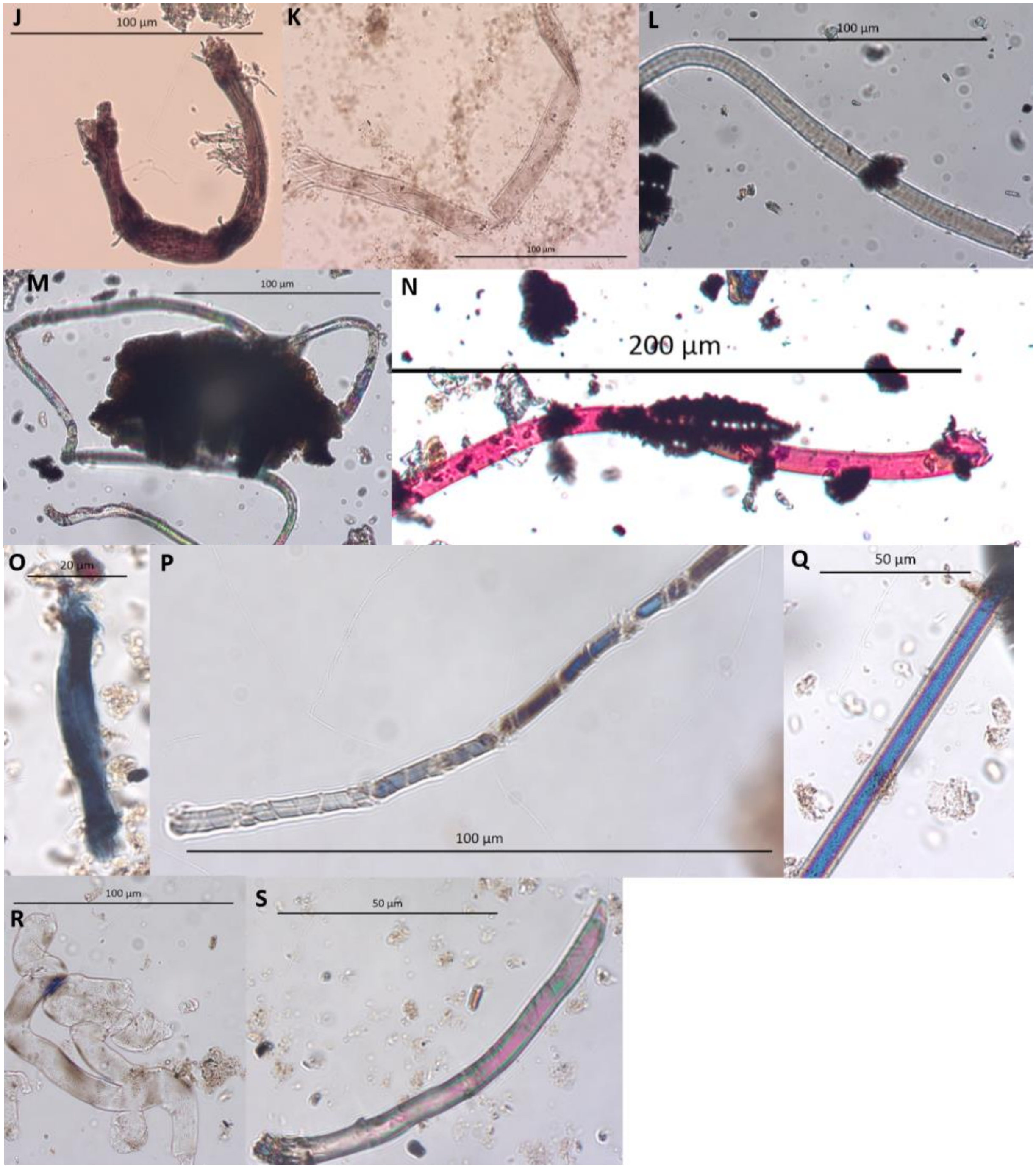


Figure. B.4. All Unknown Fibers

(a) Unkn fiber recovered from dry wash of metate. long; indented along median (b) Unkn tissue recovered from sonicated wash of human tooth. striated surface; lots of smaller pieces throughout the sample (c) Unkn tissue recovered from sonicated wash of human tooth. striated surface; lots of smaller pieces throughout the sample. (d) Unkn fiber recovered from sonicated wash of human tooth. very long thin blue fiber; opaque; large and branched (e) Unkn tissue/fiber recovered from sonicated wash of obsidian blade. large tissue/fiber; curled; luminesces under polarized light (f) Unkn fiber recovered from sonicated wash of human tooth. very large strand; opaque; blue in center (g) Unkn fiber recovered from sonicated wash of obsidian blade. large; blue in center; spindles (h) Unkn fiber recovered from sonicated wash of human tooth. small fiber; curled rounded head (i) Unkn fiber recovered from sonicated wash of human tooth. large; bright pink; broken edge on one side



(j) Unkn fiber recovered from sonicated wash of human tooth. large curved fiber; pink; severed edges (k) Unkn fiber recovered from sediment sample 1. very large fiber; torn on one side; large brown fuzzy debris throughout (l) Unkn fiber recovered from sediment sample 15. Curved; opaque; luminesces; long (m) Unkn fiber recovered from sediment sample 15. Very long curved fiber; luminesces (n) Unkn fiber recovered from sediment sample 15. Pink; long; curved. (o) Unkn fiber recovered from sediment sample 20. Large; blue. (p) Unkn fiber recovered from sediment sample 3. Large; luminescing. (q) Unkn fiber recovered from sediment sample 8. Very long; blue; luminesces (r) Unkn fiber recovered from sediment sample 8. Intestine like shape (s) Unkn fiber recovered from sediment sample 8. Large fiber; pink and green surface.