# MAYA FOOD STRATEGIES AT MACABILERO: A PALEOETHNOBOTANICAL STUDY OF ANCIENT MAYA AGRICULTURE AND ETHNOECOLOGY DURING THE FORMATIVE AND CLASSIC PERIODS

# MAYA FOOD STRATEGIES AT MACABILERO: A PALEOETHNOBOTANICAL STUDY OF ANCIENT MAYA AGRICULTURE AND ETHNOECOLOGY DURING THE FORMATIVE AND CLASSIC PERIODS

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# Abstract

Current hypotheses argue that shifts in ethnoecological practice resulted in the abandonment of many Formative Period (1000 BCE – CE 250) sites in the Maya area (Inomata et al. 2017; Douglas et al. 2015; Webster et al. 2007; Dunning et al. 2012). By utilizing paleoethnobotanical methods to recover actual botanical remains, I address understandings of agriculture and consumption practices of Formative Period Maya people, the impact of these practices on the landscape, and abandonment of Formative sites in the Usumacinta River region.

This study is focused on the site of Macabilero, an ancient Maya community with residential, defensive, and ritual features, abandoned during the Early Classic Period (ca 400 CE). Using paleoethnobotanical methodology, I consider arguments targeting the abandonment of Formative Maya sites. Studying transitionary periods, such as that between the Formative and Classic Periods, greatly contributes to our understanding of social and political change and how it is reflected archaeologically as well as related to the broader landscape. My research questions focus on plant staples at Formative Period sites as compared to staples at Classic Period sites, how these differences may reflect changes in ethnoecology and the abandonment of Formative sites, and what the implications may be for hypotheses about the Formative Maya “collapse” that relate abandonment to ecological stress and potential crop failures.

This study establishes that the people at Macabilero consistently chose to grow more reliable root crops, perhaps especially in times of unrest, alongside crops such as maize, beans, and squash. People at Macabilero made use of a wide array of resources in the landscape, and grew a diverse portfolio of crops, without relying overly on any one food resource.

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# Chapter 1: Introduction

The rise and fall of societies have fascinated people around the world for millennia, and have been key scholarly subjects of study. As Butzer (2012:3632) states, the concept of societal collapse is rather ambiguous, and gives the sense that societies rise and flourish, but will eventually fail. The Maya civilization is one of the more popularized examples of societal collapse, alongside others such as Easter Island and Egypt's Old Kingdom. This notion of "collapse" of ancient Maya societies is associated with the end of the Classic period (c. 250-1000 CE), but collapse has also been associated with the end of the Formative period (1000 BCE – CE 250) (Inomata et a. 2017; Dunning et al. 2012). Regardless as to how radical social shifts ultimately unfold, many major hypotheses for societal collapse are directly tied to climate and the environment (Cullen et al. 2000; Douglas et al. 2016; Weiss 2016). Climate change significantly impacts agriculture and ethnoecology and can result in new and different ways in which humans interact with their environments (Aydinalp and Cresser 2008; d'Alpoim Guedes and Bocinsky 2018; Castillo et al. 2018). But there are few radical societal shifts that can be tied simply to environmental causal factors. As Alcover Firpi (2020) has argued, "collapse" has rather simplistic narratives that do not thoroughly explain the social processes of community dissolution.

Current hypotheses argue that shifts in ethnoecological practice resulted in the abandonment of many Formative Period sites in the Maya area (Inomata et al. 2017; Douglas et al. 2015; Webster et al. 2007; Dunning et al. 2012). While ethnoecological research of Formative period Maya societies is not as abundant as Classic and even Post-Classic (1000 CE – 16th Century) Maya studies, interest has grown in this area over time. Many factors affect archaeological investigations of Formative period sites, but fortunately with advancing techniques, we are now able to address questions surrounding abandonment in better detail. My research draws upon analyses of botanical residues to assess the relationship between ethnoecological practice and abandonment. By utilizing paleoethnobotanical methods to recover actual botanical remains, I address understandings of 1) agriculture and consumption practices of Formative Period Maya people, 2) the impact of these practices on the landscape, and 3) abandonment of Formative sites in the Usumacinta River region.

I focus my study on the site of Macabilero, an ancient Maya community with residential, defensive, and ritual features, abandoned during the Early Classic Period (ca 400 CE) (Alcover Firpi 2020; Alcover Firpi and Rodas 2017; Alcover Firpi and Rodas 2018a; Alcover Firpi and Rodas 2018b; Alcover Firpi and Urquizú 2018a; Alcover Firpi and Urquizú 2018b; Alcover Firpi et al. 2018). At other sites in the Maya region during this period, much earlier investigations documented an extensive swidden agricultural system was being practiced, in addition to intensive, large-scale construction of reservoirs and other land management features near the end of the Formative period (Fedick and Ford 1990, Dunning et al. 2002). Localized control of water resources by elites, in addition to the intensification of local agricultural production and the stratification of land wealth, have all been cited as key factors in the transition, and sometimes abandonment of sites, from the Formative to the Classic Period (Dunning et al. 2002). More recent arguments have addressed drought (Douglas et al. 2015; Luzzadder-Beach et al. 2012) or the combination of many different factors such as environmental stressors (drought) and socio-political dynamics (Ebert 2017:230). My paleoethnobotanical analyses consider these arguments and add crop selection and management through direct evidence of botanical remains from Macabilero. I compare this data set with those of other Maya sites, Piedras Negras, Budsilja, and Sak T’zi’, to consider how anomalous/consistent these ancient practices at Macabilero might have been. Further, a focus on ethnoecology allows me to examine how people interacted with their environments and track the dynamic relationship between them. Studying transitionary periods, like the abandonment of Formative Maya sites, greatly contributes to our understanding of social and political change and how it is reflected archaeologically as well as related to the broader landscape.

I address several key questions in my research:

1. How do plant staples at Formative Period sites compare to staples at Classic Period sites?
2. How do these differences reflect changes in ethnoecology, as related to land management, and food choices?
3. What was the relationship between diet, ethnoecology and the abandonment of Formative sites?
4. What are the implications for hypotheses about the Formative Maya “collapse” that relate abandonment to ecological stress and potential crop failures?

To address these questions, I analysed botanical residues recovered from the Formative Period Maya site of Macabilero. I performed starch grain, phytolith, and macrobotanical analyses of botanical residues from artifacts and landscape features, at the McMaster Paleoethnobotanical Research Facility (MPERF). These residues were recovered from 24 samples (8 artifact samples, 2 sediment samples, 14 flotation samples) taken during the 2017 and 2018 field seasons. I then interpret these results in the context of environmental and political changes to assess how Maya people were interacting with surrounding landscapes, and how this changed over time.

## Significance

Although no previous paleoethnobotanical studies have been conducted at Macabilero, there have been paleoethnobotanical studies undertaken at other sites in the Usumacinta region, including Piedras Negras, Budsilja, El Porvenir, and Sak T'zi' (Dine 2018; Morell-Hart and González Córdova 2017; Morell-Hart and Watson 2018; Morell-Hart et al. 2018; Watson 2018a; Watson 2018b; Watson 2018c). Two of these sites, Piedras Negras and Sak T'zi', were Maya kingdoms during the Classic Period, while Budsilja and El Porvenir were smaller sites in the region (Golden and Scherer 2013; Golden et al. 2021). The paleoethnobotanical results from these sites set up expectations for remains and can also be used to situate Macabilero. By studying ancient settlements that were occupied during times of strife, archaeologists can home in on several key questions. If the settlements remained populated during times of severe climate change or warfare, how did communities effect resilience? Did certain communities do anything differently from settlements that were abandoned during this period?

Studying changes in ethnoecological relationships over time is critical for our understanding of ancient Maya social dynamics and cultural history (Morell-Hart et al. 2019; Stepp 2018). My research contributes to our understanding of Formative occupations as well as abandonment of sites at the end of this period. This research contributes information to an important, yet under-researched part of Maya history in the region. Moreover, by studying demographic shifts we can continue expanding our knowledge of past environments and how they affect societies on a multi-scalar level.

How can we apply our findings to contemporary problems? There is much that can be learned from the past that can be used in solving contemporary problems (Lane 2015; Morell-Hart 2012). Studies aimed toward Formative period site abandonments and community resilience can help to address contemporary problems of climate change and political unrest, factors hypothesized to be the causes of abandonment during the Formative time period. By examining how past Maya settlements survived during times of strife, we could potentially use this information to address contemporary problems and even those of the future.

## Regular Food and Trying Times

As many researchers have studied, ancient Maya peoples were no strangers to famine (Bricker and Bricker 2020; Dine et al. 2019; Hansen 2017; Hoggarth et al. 2017; Me-Bar and Valdez Jr. 2005). Dine and colleagues (2019:2) explain that famine foods are more revealing of ingenuity and innovation than prestige foods, since these foodstuffs are consumed during times of duress.

Plant staples by definition key components of diet, as they are commonly utilized and frequently consumed. But availability of plant staples can be greatly affected by how humans interact with their environment, including the agricultural strategies they choose to produce these staples. Dietary choices can be made for a wide variety of reasons, including basic edibility as well as aesthetic food preference and ritual necessity. The choice to turn away from a once staple crop due to drought and the reduced yields is but one example of a suggested causal relationship between foods and ecological processes. Drought, however, has been foregrounded as a major hypothesis for why Formative Maya settlements were abandoned. I explore each of these topics more fully below.

### *Plant Staples*

One of my main research goals was to establish which crops were staples at Macabilero and how these might compare to surrounding sites. Plant staples are commonly utilized plants that are found frequently (ubiquitous) and in higher quantities. Plant staples are routinely consumed and typically supply a large fraction of required energy for the consumers (Zimmerman 2019:1). The choice of staple plants is dictated by subsistence needs and ecology, alongside ideological associations (Seinfeld 2011:27). One of the most well-known plant staples that the ancient Maya relied upon is maize, now heavily consumed around the world. Maize can easily be identified as the most popular crop the ancient Maya utilized due to its popularity through time. Not only was the crop commonly ingested as a primary source of food, but it was also integrated into the ancient Mayas religious beliefs in the form of a Maize God (Morehart and Butler 2010:599). Alongside maize, beans and squash have also gained much recognition through the years as being significant food crops to ancient Maya peoples (Lentz 1991; Salazar et al. 2012; Sheets et al. 2011; Turner and Miksicek 1984; Rodríguez-Robayo et al. 2020). These crops were grown across Mesoamerica and consumed regularly in ancient Maya communities. When performing paleoethnobotanical analyses, we would thus typically expect to find residues of these species.

Many different factors can affect plant staples and how they are selected over time. Climates change, popularity shifts, and accessibility varies. Over time we have seen the rise and fall of many plants and animals due to these factors. Droughts can decimate crops (Lamaoui et al. 2018), pests can affect the stability of crop yields (Lamichhane et al. 2015), and influential people can shift favoured foods and the desire to consume them (Twiss 2012). Warfare can regulate crop selection (Allen 2016:55), flooding can result in crop loss and damage to soil (Brémond et al. 2013), domestication can make specific crops more favourable to their farmers (Chomicki et al. 2020).

In the Maya area, the Formative period is still being researched by archaeologists and hypothesized plant staples vary from site to site. By relying on the results of past archaeological studies, I will identify plants that have come to be categorized as staples for ancient Maya people during the Formative and Classic periods. After compiling this data and comparing my own results, I identify the differences or similarities between Formative period sites and Classic periods sites. I then expand on these results to interpret why these similarities or differences could potentially exist.

### *Ethnoecology and Choices*

Crop choice plays a large role in how people interact with their environments. Every plant is different, in terms of ecological requirements and biological preferences, must be tended in respect to those differences. While many different plants may share similarities and can be grown and managed simultaneously, certain types of crops, such as root and seed crops, have drastic differences in how they are planted, managed, harvested, and then utilized. This means that the ways in which humans interact and manipulate their environment can vary greatly and have a number of different effects on the land. As further explored, large-scale agricultural features are built, swidden agriculture removes forests, waterways are altered.

There is also the factor of available land in which crops could be planted. Mesoamerica features a variable terrain, filled with mountains, rivers, jungle, and fields. Depending on the landscape where settlements are established, geography can play a significant factor in which food choices are being made. If there is a change in food staples over time, given different species' requirements for growth, a shift in climate or environment could be a large factor. Land management also directly affects a population's plant staples. As previously mentioned, although the environment plays an important role in which plants can grow and thrive, the immediate environment can be altered by land management. Land management includes practices such as placement of human settlements (Collins-Elliot et al. 2020), water resource management (Wyatt 2014), preservation of biodiversity (Kettunen and Cuxil 2021), and agriculture (Lentz et al. 2014). Land management can be used to grow crops by altering the landscape to suit their needs and preferences, in processes such as deforestation or rerouting water channels (Beach et al. 2002). These changes of the landscape can increase overall production and thus allow for different plant crops to become staples.

Changes in staples can index many different things, such as changes in ethnoecology. If food staples shift and different crops are relied upon, different land management techniques are introduced and can result in people managing their land differently. By analysing my results regarding plant staples, tracking presence and ubiquity of various foods, I address which types of crops were being selected by ancient Maya people in each time period, what these choices indicate about the local environment, and interpret why these choices either changed or remained the same.

### *Diet, Ethnoecology, and Abandonment*

Dramatic shifts in food choices and/or crop environments may lead to eventual abandonment of a settlement. Conversely, careful management of crops and/or landscapes may help individuals to avoid abandonment of their communities. Ethnoecology encapsulates a wide variety of practices in which humans interact with their environment, allowing them more control over food production that conforms with dietary preferences (Cassino et al. 2019; Morell-Hart et al. 2019). By altering their landscape, people can create or improve favourable conditions for different sorts of crops that have specific requirements to grow and thrive. For example, when initially occupied, a settlement may be surrounded by forest, but by removing trees from field areas, crops that require more direct sunlight could thrive.

But humans cannot control every aspect of their environments, and when climatic changes such as drought occurs, there is little that can be done. When staple crops such as maize, very reliant on water, cannot survive a drought, their consumers have no choice but to rely on different crops that can produce food even in drought-like conditions (Fedick and Santiago 2022). Should they be unable to maintain sufficient food production, and have no ability to acquire food through trade, humans abandon their homes and move on in search of an environment that can support them.

Current hypotheses highlight explore a variety of different potential causes for the abrupt abandonment of Formative period settlements. Not all settlements were abandoned, many grew instead. El Cayo and Piedras Negras were dynastic centres near Macabilero that experienced this growth in size (Alcover Firpi 2020:120; Houston et al. 2003; Zender 2002). During the Late and Terminal Formative period defensive features were constructed at multiple sites in the Usumacinta River Valley, Macabilero being one of them. The construction of defensive features suggests that there was a threat of violence in this area during this time and coincides with the arrival of the dynasty at Piedras Negras (Alcover Firpi 2020:106-122; Martin and Grube 2008:140). There is no evidence of destruction at Macabilero. Alcover Firpi (2020:399) suggests that Macabilero's inhabitants left of their own accord and moved to the surrounding valleys of El Cayo where evidence of occupation continues into the Late Classic period (Alcover Firpi 2020:399). Alongside these political and social hypotheses, drought is also a potential cause behind the abandonment of settlements at the end of the Formative period (Douglas et al. 2015; Ebert et al. 2017; Webster et al. 2007). Ebert and colleagues (2017:230) highlight the relationship between climate change (drought) and socio-political dynamics, suggesting that these conditions favoured the "emergence of multiple adaptive pathways for complex societies".

By analysing ancient plant remains from the Formative site of Macabilero, I identify which foodstuffs were being consumed and relate these findings to plant growth habits. By identifying the conditions and environments where these crops grow, I am able to index potential environmental conditions that may have been occurring during the end of the Formative period. Environmental scientists suggest that severe prolonged drought occurred during the Formative period (Ebert et al.

2017:227). Ebert and colleagues (2017) developed a Bayesian radiocarbon chronology for the site of Cahal Pech and surrounding residential settlement groups to explore the several periods of severe drought during the Formative period. Douglas and colleagues (2015:1) use hydrogen and carbon isotope compositions of wax lipids in lake sediment cores to assess changes in water availability and land usage. Webster and colleagues (2007) analysed paleoenvironmental data from a stalagmite from western Belize and found that major droughts occurred during the Formative period. By analysing samples from both the Late Formative and the Early Classic periods, I am also able to view shifts in plant foodstuffs, or the lack of such shifts, through time. I correlate these results with abandonment at Formative sites.

### *Formative Period Maya "Collapse"*

Based on the paleoethnobotanical evidence from the Formative period site of Macabilero, we are able to see which crops were being consumed at the end of the period, and how these may have been impacted by ecological stress. For example, identifying high quantities of plant staples like maize and beans at all time periods would highlight that environmental stressors did not have a large impact on the community at Macabilero. However, where there is a lack of the expected plant staples, we could hypothesise that there were conditions impacting the people of Macabilero in a severe way that forced them to alter their diets. Such findings would also support hypotheses regarding potential climate change and drought-related conflict[1]. Through the results of the paleoethnobotanical analyses, we are able to

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[1] While drought may have exacerbated violence/conflict, it was likely not the sole variable. The diverse landscape suggests that multiple, interconnected issues could have caused site abandonment.

hypothesize which factors played a direct role in the lives of Macabilero occupants, and to which degree they reacted. I address this question by identifying plant remains and their nature (how they grow, where they grow, how they are farmed, harvested, stored, and ingested). By comparing my data to other paleoethnobotanical data from other ancient Maya sites, I identify expectations for crops at ancient Maya sites, then identify which are and are not present at Macabilero. Through this analysis, I highlight what role various plants could have played during times of ecological stress and potential crop failures.

## Thesis Organization

To address the four research questions described previously, my thesis is divided into six chapters. In Chapter 2, I provide an overview of ancient Maya people living at Macabilero. I begin by summarizing the general ecology of the region, highlighting key features and which plant types can grow in such environments. Following this review, I summarize what we know of the Formative period at Macabilero, the architecture, features, and general history. I then broaden this topic to include previous archaeological findings at Macabilero by summarizing the findings of each archaeological operation that has been undertaken by the Proyecto Paisaje Piedras Negras-Yaxchilan. Moving forward, I discuss the Formative Maya community, providing context as to who lived at Macabilero, and which activities occurred there. This chapter is concluded with a section dedicated to conflict in the Usumacinta and Macabilero’s role.

In Chapter 3, Foodways at Macabilero, I begin by providing a background in how different archaeological methodologies can be employed to study ancient foodways. Once these methodologies have been summarized, I expand into ancient Maya foodways and how these methodologies have been utilized to address questions about the Formative and Classic periods. I then discuss what is known or has been hypothesized about foodways in the broader Usumacinta River region, and specifically at Macabilero. Following the summary of foodways in this region, I set up specific expectations regarding foodways at Macabilero.

Chapter 4 is dedicated to the methodology of paleoethnobotany. I first introduce paleoethnobotany generally before expanding on the specifics of the methodology. I then discuss paleoethnobotanical sample collection and processing before delving into macrobotanical and microbotanical preparation and analysis. At the conclusion of the chapter, I include a summary of my methodology regarding macrobotanical and microbotanical preparation and analysis.

Chapter 5 describes the results obtained through the methodology I discussed in the previous chapter. I present the complete results of my paleoethnobotanical analyses and provide a summary of each identified species. After providing this background information, I focus on food species and through which method each was recovered. I then present results from different ancient tools: which food species each yielded according to artifact type. Following this, I separate results by time period to examine any potential changes through time. I present the identified food species and in which form of residue they were recovered.

In Chapter 6, I present my interpretations of the results of the paleoethnobotanical results, incorporating the background information from the previous chapters. I discuss plant staples, ethnoecology, land management, food choices, diet, and abandonment. I provide a general overview of the research and my analyses, highlighting my research objectives and providing recommendations for future research.

# Chapter 2: Maya Peoples at Macabilero

## Introduction

Macabilero is in the Petén department of Guatemala, situated on top of a hill to the east of the Usumacinta River, approximately 15 kilometres southeast from the site of Piedras Negras (Figure 2.1) (Alcover Firpi and Rodas 2017). What makes Macabilero stand out from other Maya sites in the area is its series of defensive walls and multi-terraced platforms that surround not only the site but also the surrounding valleys (Alcover Firpi and Rodas 2017; Golden et al. 2005). Based on these defensive structures, Macabilero may be one of the few Formative Period Maya fortifications documented in the Guatemalan lowlands (Alcover Firpi and Rodas 2017).

The Macabilero community was made up of individuals living at the site itself, and those in nearby villages. Current interpretations of life at Macabilero suggest this collective group may have built the structures at the site, utilized them as a community, and retreated here during times of conflict (Alcover Firpi 2020). However, it is important to note that research at Macabilero is still preliminary and this interpretation is based on the current available data. With Macabilero's proximity to the Usumacinta River, the occupants would have access to running water and food resources which could have adequately sustained the population (Golden et al. 2008). The Terminal Formative was a time of political unrest that resulted in violent conflicts across the Usumacinta River region which could have resulted in the intensification of fortifications at Macabilero (Alcover Firpi 2020:296; Golden and Scherer 2013; Golden et al. 2008; Scherer et al. 2022).

Macabilero was first documented by Edwin Shook in 1935 whilst surveying ancient Maya sites on the Usumacinta River (Alcover Firpi and Rodas 2017). Since its documentation, Macabilero was only visited once in the late 1930s and following this visit, Macabilero was not visited again until Charles Golden, Alejandro Gillot Vassaux and John Jacob Parnell revisited the site in 2000 with the help of local guides (Alcover Firpi and Rodas 2017; Golden et al. 2001; Golden et al. 2005). Prior to this research had occurred at the kingdoms of Piedras Negras and Yaxchilán, but less so on the other sites in the region (Golden et al. 2005; Golden et al. 2008; Houston et al. 2000; Houston et al. 2003). The return to this site offered researchers the possibility of answering questions about the political border between the kingdoms of Piedras Negras and Yaxchilán (Golden et al. 2001). During this time, Luis Romero, as part of the Proyecto Arqueológico Sierra del Lacandón (PRASL), conducted preliminary excavations and mapping (Alcover Firpi 2020:474; Alcover Firpi and Rodas 2017; Romero 2004). Since 2016, more intensive mapping and excavations have been conducted by the Proyecto Paisaje Piedras Negras Yaxchilan with the most recent field season concluding in 2019.

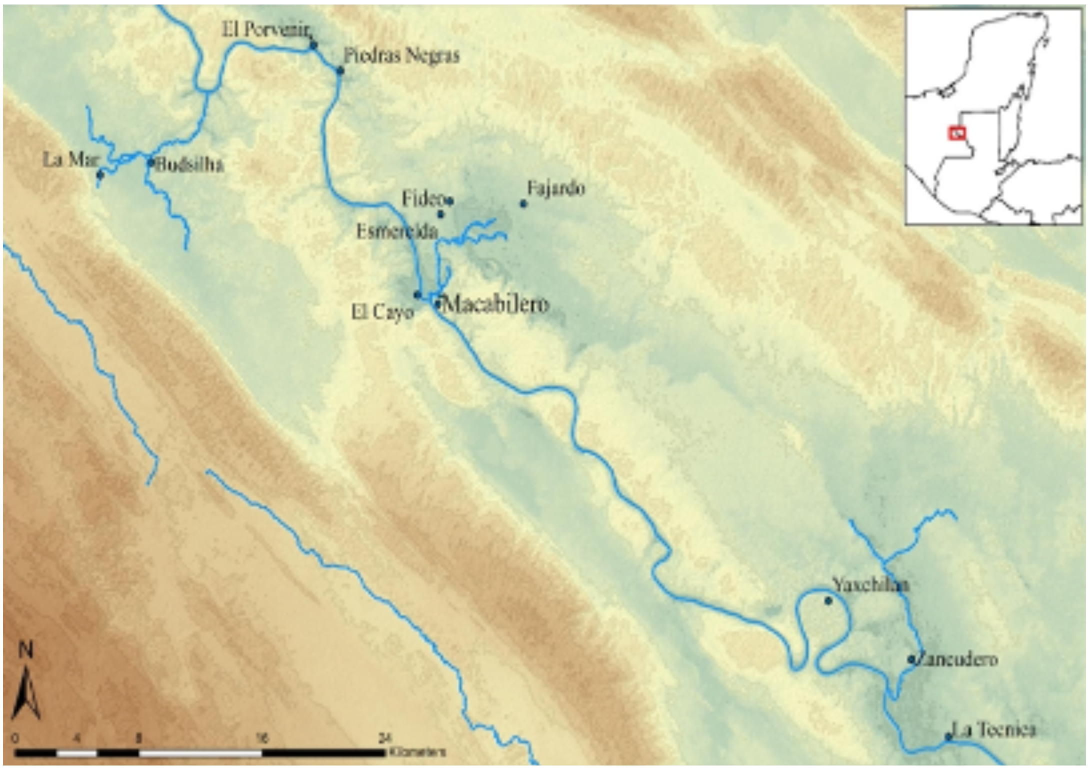

**Figure 2.1: Map with Macabilero and other important sites (Map prepared by Omar Alcover 2016; Alcover Firpi and Rodas 2017:282)**

In this chapter I provide background information on the ancient Maya site of Macabilero. I address the general ecology of the Usumacinta River region, an overview of Macabilero during the Formative period, what life was like for the community of Macabilero during this time, what conflict was occurring in the Usumacinta River region during this period and how Macabilero was involved, and why scholars hypothesize the site was abandoned during the Early Classic period.

## General Ecology of the Region

The Lowland Maya area, what is today southern Mexico, Guatemala, and Belize is currently covered by tropical forests that hinder an archaeologist's ability to assess the area on foot (Canuto et al. 2018). This area consists of approximately

95,000km$^2$ of rolling karst topography and wetlands, and was formed by the weathering of Cretaceous and Tertiary limestone (Aliphat 1994; Canuto et al. 2018). The Usumacinta River region, where Macabilero is located, has a karstic landscape with the following landforms: karstic plateau, karstic upland with hummocks, escarpment, slopes, karstic intermontane valleys, structural plains, *bajos* (seasonal swamps), *sibal* (marshes near lakes), and lakes (Aliphat 1994, as cited in Schroder 2019). The area is also full of good farmland and flint deposits (Alcover Firpi 2020; Canter 2007). The Usumacinta River itself is home to igneous and metamorphic stones (Roche Recinos et al. 2021). *Arroyos* (seasonal creek or stream), *cenotes* (surface connections to subterranean water), and caves are also apparent across this landscape (Alcover Firpi, 2020). The Upper Usumacinta region, the area between Piedras Negras and Yaxchilan, is made up of a series of longitudinal valleys that are separated by steep mountain ranges (Anaya-Hernandez 2006; Schroder 2019). The river itself is situated in the centre of an anticline and is bound within narrow gorges (Canter 2007). This region is covered in grasslands and dense tropical forests (Anaya-Hernandez 1999) that receive 1750-2500 mm of rain every year (Scherer and Golden 2014). Rainfall patterns vary, which affects agricultural schedules (Lucero 2006:284-285) and in areas such as these that receive more than 1200 mm of annual rainfall, there is a decrease in seasonality (Schroder et al. 2020:13).

The Usumacinta River, the largest river in Mesoamerica, serves as the political border between south-eastern Mexico and western Guatemala (Schroeder 2019) (Figure 2.2). The river is approximately 1000 kilometres in length and is known for its rather tumultuous conditions (Canter 2007). This river was likely one of the major trade routes that connected the Chiapan and Guatemalan Highlands to other regions such as the Maya Lowlands and areas along the Gulf of Mexico (Golden et al. 2012). Although this aquatic highway was likely an important route for Maya peoples to traverse, there were also other options that did not require the use of a canoe and risk the loss of bulk goods such as salt or corn (Canter 2007; Golden et al. 2012). One of the main reasons why the Usumacinta River was an important route was due to its connection to two major Maya polities, Piedras Negras and Yaxchilán, and the many small Maya sites, like Macabilero, situated along it (Canter 2007; Golden et al. 2012).

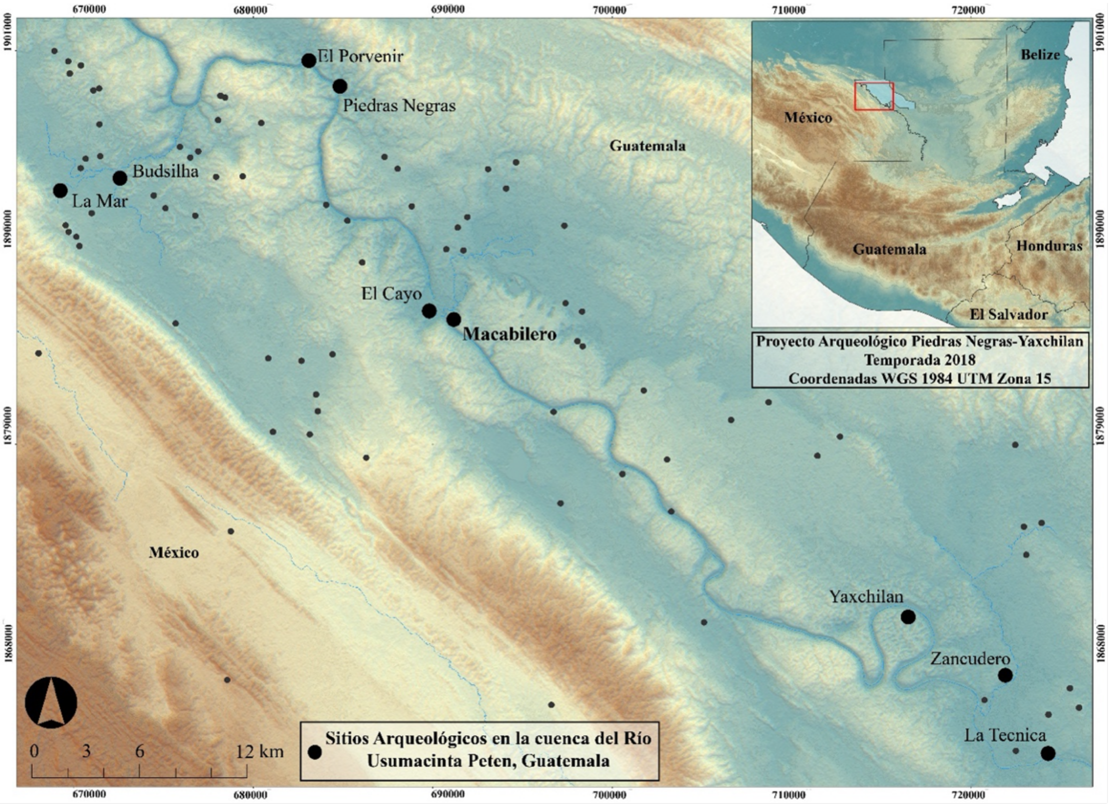

**Figure 2.2: Map of the Sierra del Lacandón (Map by O. Alcover; Alcover Firpi and Urquizú 2018a:3)**

Macabilero is situated on top of a hill, overlooking an arroyo (Canter 2007). The rim of this hill was steepened and strengthened by walls (Canter 2007). Macabilero is next to the largest beach on the Usumacinta, at the confluence of the Usumacinta and the arroyo Macabilero, and provides the residents with an easy transportation to larger sites like Piedras Negras or Yaxchilán (Canter 2007).

Alcover Firpi (2020) acquired WorldView 2 data (WV2), through which he was able to analyse vegetation indices of the area (Figure 2.3). He found that the environmental conditions of the study area allowed for healthy forests and lower vegetation to grow (2020:159). This is due to the gentle slopes and prevalence of water resources (Alcover Firpi 2020:159). The LiDAR study also identified $C_4$ plant signatures within wetland fields alongside an abundance of ecologically diverse and healthy areas around the wetland fields, suggesting that not all areas were cultivated, but some spaces may have once been managed forests (Alcover Firpi 2020:161). Multi-use agricultural spaces have been identified throughout the ancient Maya world (Chase and Chase 1998; Dunning et al. 1998; Pohl et al. 1996; Šprajc et al. 2021). These managed forests and wetland fields may have allowed for large amounts of varying flora and fauna to grow successfully, which further benefits the communities living in or near these spaces (Alcover Firpi 2020; Beach et al. 2019; Dussol et al. 2020). Managed forests provide a wide variety of useful plants and animals for communities to take advantage of, from pharmaceutical plants to construction supplies. While the presence of managed forests near Macabilero is still unknown, Alcover Firpi (2020) identified areas that could be further explored to establish the potential of managed forests in the area. All this ecological data suggests that the land around Macabilero was cultivable due to the potential for healthy forests and lower vegetation to grow, combined with the prevalence of water resources. Due to these conditions, combined with high levels of rainfall, many species would be able to thrive in conditions such as these, including many kinds of agricultural crops as well as managed non-domesticated species.

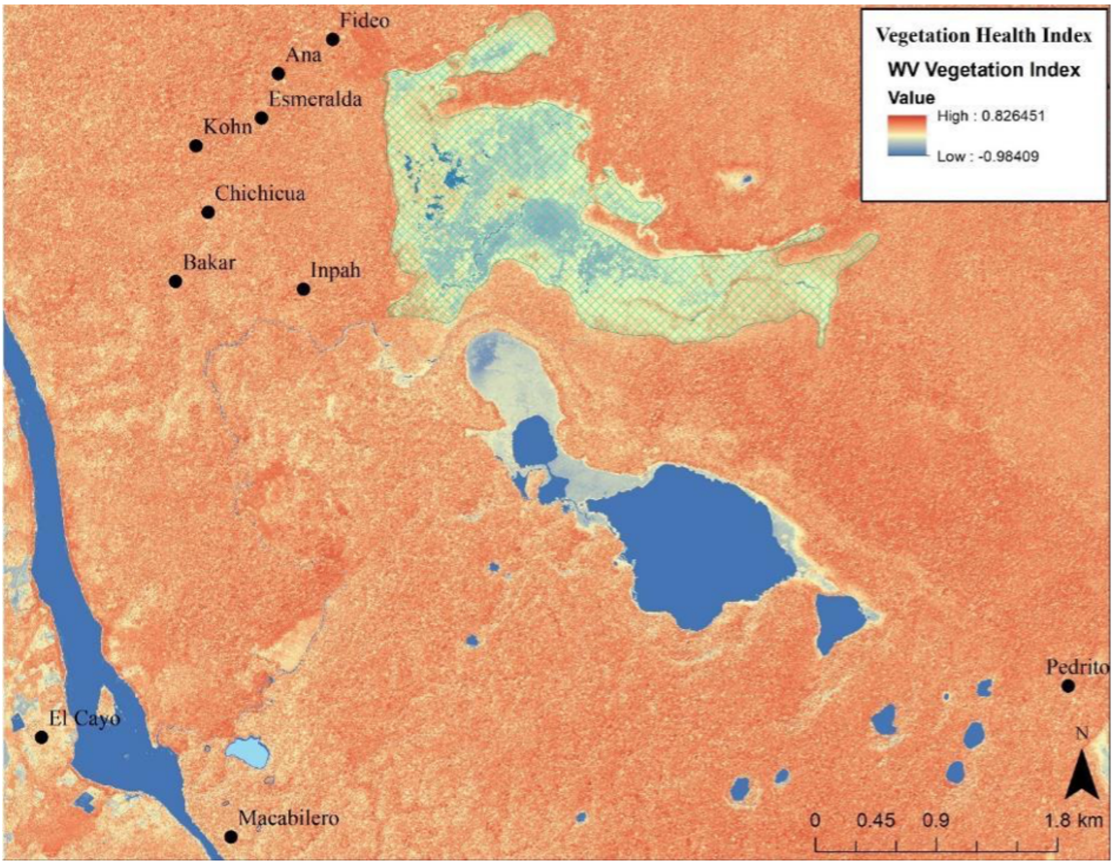

**Figure 2.3: World View 2 Vegetation Index signatures (Alcover Firpi 2020:173)**

## The Formative Period at Macabilero

During the Formative period there is abundant archaeological evidence for settlements across the landscape between Piedras Negras and Yaxchilan (Golden and Scherer 2013). The Usumacinta River Region's earliest documented settlements begin at some point between 800 and 500 BCE (Roche Recinos et al. 2021). Beginning in the Late Formative Period (c. 250 BCE – CE 350), occupation was scattered across the Usumacinta River Region with only a few sites having large-scale public architecture: Piedras Negras, Yaxchilan, El Porvenir, El Cayo, Zancudero, Fideo, El Kinel, El Infiernito, and Macabilero (Golden et al. 2008; Schroder 2019). During the Late Formative, these sites were approximately the same size and were dispersed throughout the Usumacinta River Region (Roche Recinos et al. 2021; Schroder 2019). At this time archaeologists hypothesize that Piedras Negras and Yaxchilan were the only two sites that were home to small chiefdoms, and these chiefdoms only had control over populations within their immediate vicinity (Golden et al. 2008). During this period, wealth differences first occurred, rulers became appointed, and there was an expansion of traditional rites (Lucero 2003; Stanton 2012; Powis and Cheetham 2007; Rice 2020). Over time social, political, and economic stratification increased and high-ranking families were eventually transformed into royalty (Lucero, 2003; Stanton 2012), with established royal dynasties common in the Classic Period.

At the centre of Macabilero there is an assemblage of small pyramids and extensive public plazas (Alcover Firpi 2020; Roche Recinos et al. 2021). Spread out across the interconnected hills are a series of extensive, rectangular platforms and pyramids (Alcover Firpi 2020; Roche Recinos et al. 2021). Macabilero was home to significant ritual activity, as shown the offerings left in a network of caves. Such offerings include ceramic vessels and the remains of sacrificed humans and animals (Alcover Firpi 2020; Roche Recinos et al. 2021). Toward the end of the Late Formative Period, some sites in the area underwent modifications to fortify defences against attacks resulting from a real or perceived threat of violence (Golden et al. 2008; Roche Recinos et al. 2021; Schroder 2019). Macabilero was one of the sites that underwent such a transformation. The small civic ceremonial centre located on the top of a steep hill was fortified by walls and monumental terraces at some point between 300 BCE and CE 200 (Alcover Firpi 2020; Golden et al. 2008; Roche Recinos et al. 2021). Golden and colleagues (2008:268) state that these defenses would be, "'site oriented,' consisting of features that were intended to defend a single settlement", as is the case at Macabilero.

A set of large, multi-terraced platforms were built above a network of caves (Figure 2.4) (Roche Recinos et al. 2021). The seven new levels of megalithic terraces surround the main group at Macabilero with the exception of the natural limestone escarpment on the western-side of the site-core (Roche Recinos et al. 2021). These terraces, paired with the limestone escarpment, greatly limited access to the site from the surrounding valleys (Golden et al. 2005; Roche Recinos et al. 2021). By CE 350 Macabilero was abandoned, with its population relocating to the surrounding kingdoms with royal dynasties such as Piedras Negras, Yaxchilan, or the *sajal*-governed centre, El Cayo (Golden et al. 2008; Inomata 2006; Roche Recinos et al. 2021). This movement of people may have been part of the creation of a political frontier between Piedras Negras and Yaxchilan (Golden et al. 2008). It has been hypothesized that the move from small sites, such as Macabilero, to the new capitals could have been the result of desire for a new lifestyle with vibrant political, economic, and social communities, or a result of the warfare that took place during the Formative period (Golden et al. 2008; Houston et al. 2003).

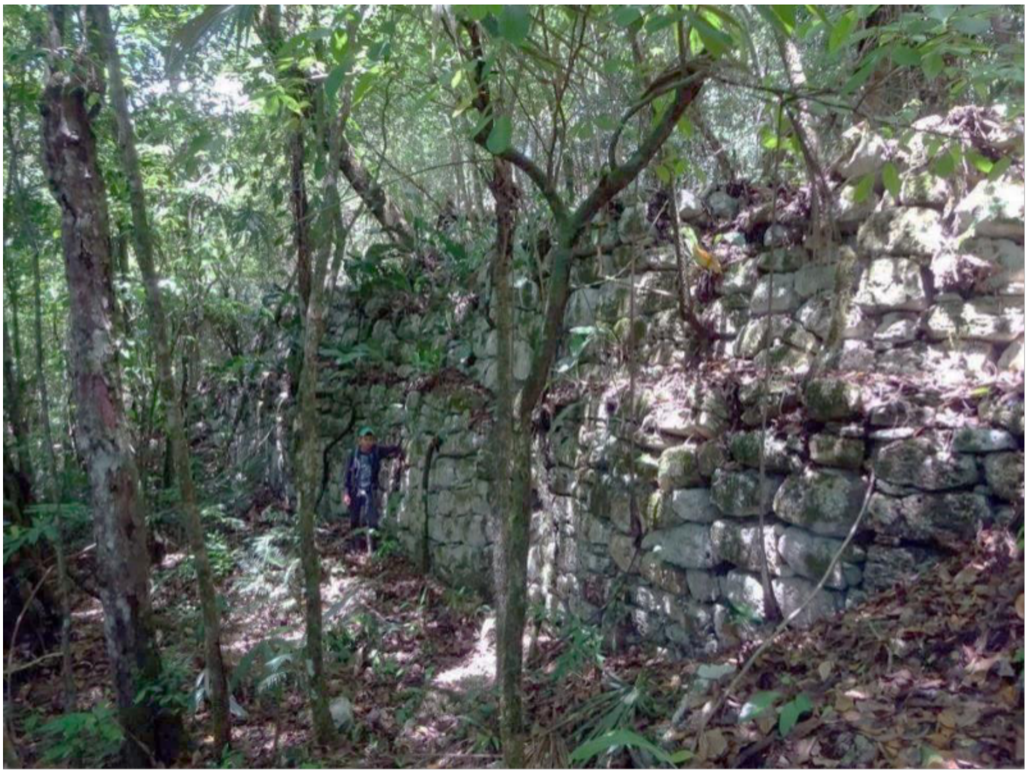

**Figure 2.4: Megalithic terrace at Macabilero (Alcover Firpi 2020:25)**

All the aforementioned activities at Macabilero came to a halt during the Early Classic period (ca. 400 CE) (Alcover Firpi 2020). During the Early Classic period, Macabilero was not the only site in the region to experience shifts in settlement; at Piedras Negras, construction also ceased until 400 CE (Alcover Firpi 2020). By the Early Classic period Piedras Negras was home to a potentially new foreign dynastic power which resulted in new ritual and administrative structures (Alcover Firpi 2020). Construction and renovation came to an end, and lacking evidence for intentional destruction, Alcover Firpi and Rodas hypothesize (2020) that the community at Macabilero may have chosen to abandon their home since they were no longer in need of a monumental defensive space and may have ultimately moved to El Cayo, a well-established and populated site that was geographically closer to the river and nearby valleys (Figure 2.5).

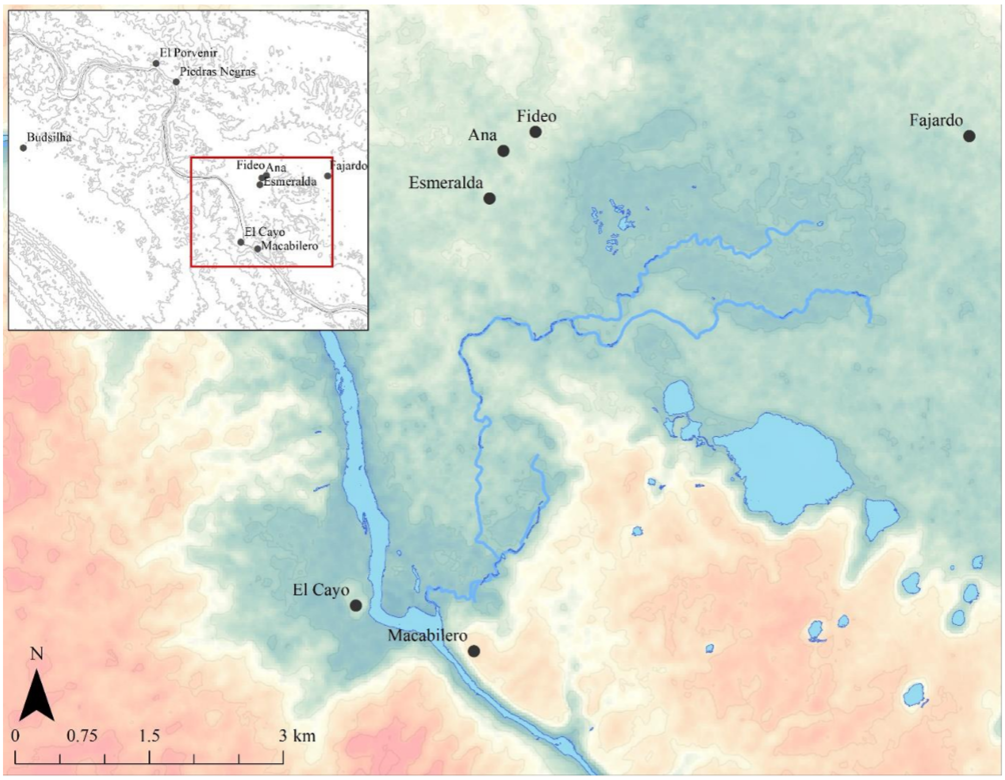

**Figure 2.5: Map with El Cayo and Macabilero (Alcover Firpi 2020:27)**

These transitions at Macabilero might have impacted crop production, and by extension, food security and settlement stability. The construction of megalithic terraces greatly impacted the settlement's accessibility, which was already limited due to the limestone escarpment. It is currently unknown what the terraces primary uses were, but they would have had a great impact on the settlement whether defensive or agricultural. As the uses of the terraces are currently unknown, it is possible to hypothesise that they were used to grow crops, as has been done at other settlements in the Maya region (Chase and Cesaretti 2019; Chase and Weishampel 2016). Utilizing the terraces to grow crops would have allowed for Macabilero's inhabitants to remain close to their defences and reduce risks associated with leaving their fortress during times of political strife. However, if the use of the terraces was primarily defensive, occupants of the site would have needed alternate means to secure their foodstuffs, especially in times of strife.

## Previous Archaeological Findings at Macabilero

During Proyecto Paisajes Piedras Negras-Yaxchilan (PPPNY) excavation seasons in 2017 and 2018, several different areas were targeted for research. The overarching goal of the 2017 field season was to investigate the chronology of the structures at the site and to complete an assessment on whether war during the Formative Period (800 BC-AD 250) played a role in the development of Macabilero and any surrounding areas (Alcover Firpi 2020; Alcover Firpi and Rodas 2017). The investigators worked on three operations located in the north plaza, the penultimate terrace at the site, and in the southern portion of the largest plaza of the site (Alcover and Rodas 2017). Based on results from the 2017 field season, the 2018 season targeted investigating the chronology of some of the main structures at Macabilero and further clarifying what role violence played in the development of this site (Alcover Firpi and Rodas 2018b). During this field season, eight operations were excavated. All three of the previous year's operations were revisited, while the remaining five operations were new to the 2018 field season. The newer operations included an area in the caves near the site, expanding the previous work on one of the structures from the north plaza, and a unit alongside another structure in the southern portion of the group (Alcover Firpi and Rodas 2018b). The final operation was in the Sereque Group which is northeast to the main areas of Macabilero (Urquizú and

Rodas 2018). The samples collected for paleoethnobotanical analysis were taken from Operations 3, 4, 5, 6, 8, and 9 (Figure 2.6).

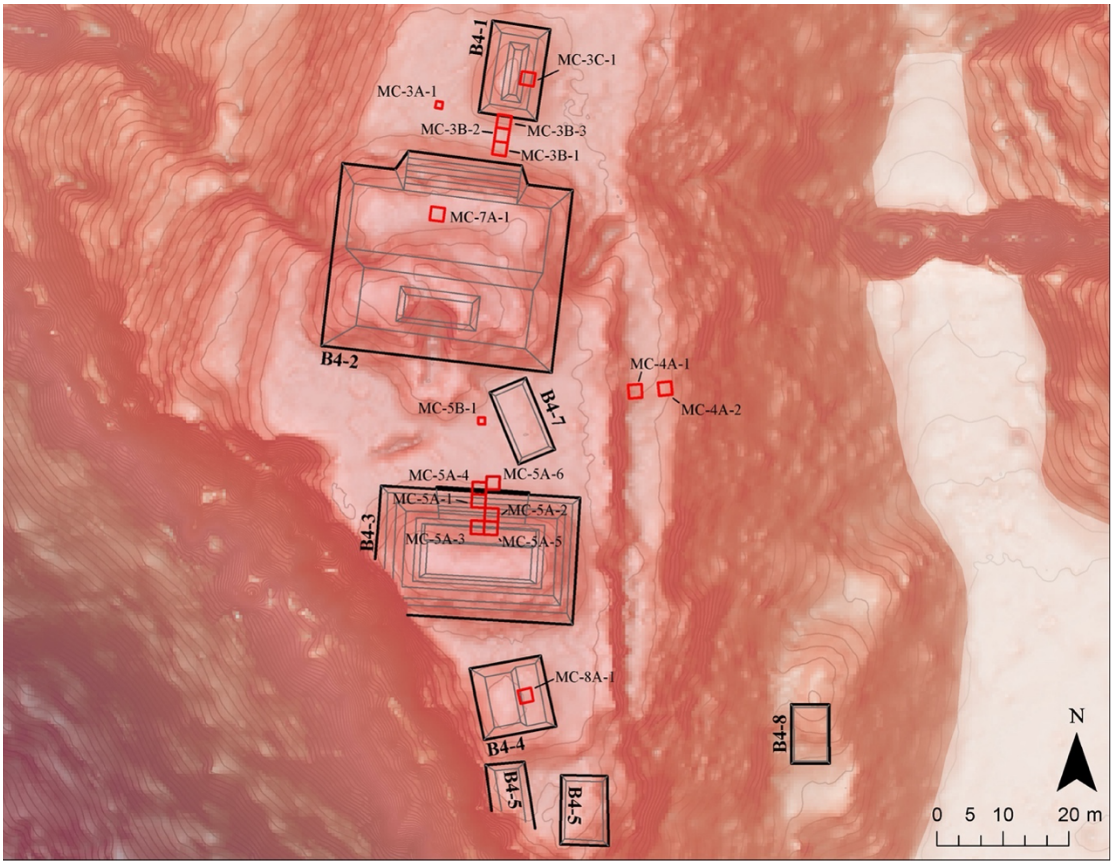

**Figure 2.6: Map of Macabilero (Map by O. Alcover; Alcover Firpi 2020:303)**

*Operation 3: B4-1* and *B4-2 (Camaleon Group)*

B4-1 is a small pyramid where excavators recovered a small smooth altar alongside the fragments of an Águila Naranja plate from the rubble level of B4-1 (Figure 2.7). This find highlighted the ritual significance of this structure in the north plaza since both of these elements are probably related to each other and were used in the same ceremonial activity (Alcover Firpi and Rodas 2018b). Also recovered from the west façade of structure B4-1 was a smooth stalactite fragment which held strong symbolism in the rituality of the Usumacinta River region, as recorded on a stela from

Yaxchilan (Alcover Firpi and Rodas 2018b). The site's largest pyramid, Structure B4-2 has a broad platform with an elongated structure on top of that. The plaza level that these two structures share had a thin layer of stucco (Urquizú and Rodas 2018). Using material from the fills excavated from this operation, Urquizú and Rodas (2018) indicated that this entire area was constructed between the Late Formative and Early Classic periods (Figure 2.8). Soil was collected for flotation to recover macroremains, a small amount of sediment was processed to recover potential phytoliths, and a ceramic basal sherd and distal obsidian blade fragment were samples for starch grains.

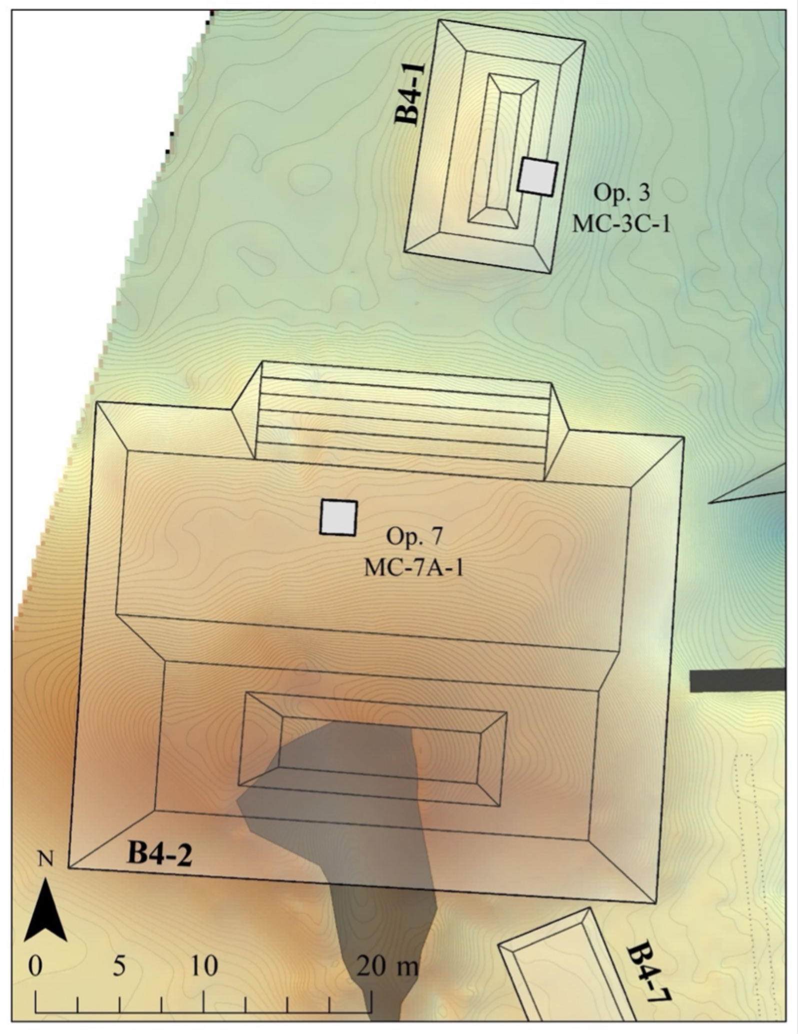

Figure 2.7: Map of Operation 3 and 7 (Map by O. Alcover; Alcover Firpi and Rodas 2018b:35)

**Figure 2.8: Altar recovered from B4-1 (Alcover Firpi and Rodas 2018b:37)**

### *Operation 4: Penultimate Terrace (East of South Plaza)*

This terrace system was built during the same time as the transition period between the Late Formative and Early Classic (Pom phase). Large limestone stones took up most of the filling of the terrace and there was evidence that these had a plaster finish, disallowing the possibility that they were used agriculturally. From these units a large amount of stone carving remains were excavated at the floor level and in between the stones of the fill, hinting at the idea that potentially stone blocks may have been brought up to these terraces and given their finishing touches here. (Alcover Firpi and Rodas 2018b). Soil was collected for flotation to recover macroremains and a small amount of sediment was processed to recover potential phytoliths.

### *Operation 5: Axis of Structure B4-3 (South Plaza)*

The results from this operation strongly supported the hypothesis that Macabilero was not necessarily built as a defensive fortress, but rather transformed into one between the Abal and Pom phases. The collected data and materials from these units suggest that the structures in this area formed a plaza. The structures were stuccoed and painted, demonstrating that a large amount of effort was put into maintaining them during their construction. During the Pom phase Structure B4-3 was modified, a small staircase was added with raised and reduced the square footage of the top platform (Alcover Firpi and Rodas 2018b). Alcover Firpi and Rodas (2018b) think that this space was inaccessible to the general public, with the creation of this additional staircase and the smaller platform on top creating an even more exclusive space for those who were welcome. The creation of tall pyramids, with limited square footage for standing room, rather than those with horizontal monumentality, grew in popularity throughout the Maya area with the rise of hierarchical organization (Inomata et al. 2020). Soil was collected for flotation to recover macroremains, a small amount of sediment was processed to recover potential phytoliths and a human tooth and long proximal blade fragment of an obsidian blade were sampled for starch grains.

### *Operation 6: Looted Burial*

Operation 6 had unfortunately been looted and thus the integrity of the deposit was completely compromised. Despite this disruption, a ceramic basal sherd was sampled for starch grains, with the assumption that this sherd corresponded in some way to the looted burial.

### *Operation 8: B4-4 (South Plaza)*

This two-level structure was built during the Late Formative period. There was a scarcity of cultural material connected with this structure so the function of structure B4-4 is unknown but could be examined in future excavations (Alcover Firpi and Rodas 2018b). Soil was collected for flotation to recover macroremains and a small amount of sediment was processed to recover potential phytoliths.

### *Operation 9: B3-1 (Sereque Group)*

Operation 9 was situated in and alongside structure B3-1, located in the Sereque Group, to best analyse the construction sequences of the structure (Figure 2.10) as described by Urquizú and Rodas (2018). Under the floor of the adjacent courtyard, a midden was identified that contained refuse from the Late Formative to the beginning of the Early Postclassic. Two burials were identified in this operation, with one being completely excavated and the other covered with the intention of recovering it in a future field season. These burials are hypothesized to date to the Late Formative to the Early Postclassic, respectively. One of the greatest boons of the Sereque Group is its location (Figure 2.11). The inhabitants of this group had quick access to drinking water from the Usumacinta and the nearby arroyo, and their various resources like hunting, fishing, and transportation. Luxury items like shell and Altar Naranja Group style ceramics, that are not available to all social classes, were also recovered from this operation. The recovered ceramic materials show that the population here had connections with the Central Petén area during the Formative period and for part of the Early Classic period (Urquizú and Rodas 2018). Soil was collected for flotation to recover macroremains, a small amount of sediment was processed to recover potential phytoliths, and two human teeth and a small obsidian blade fragment were sampled for starch grains.

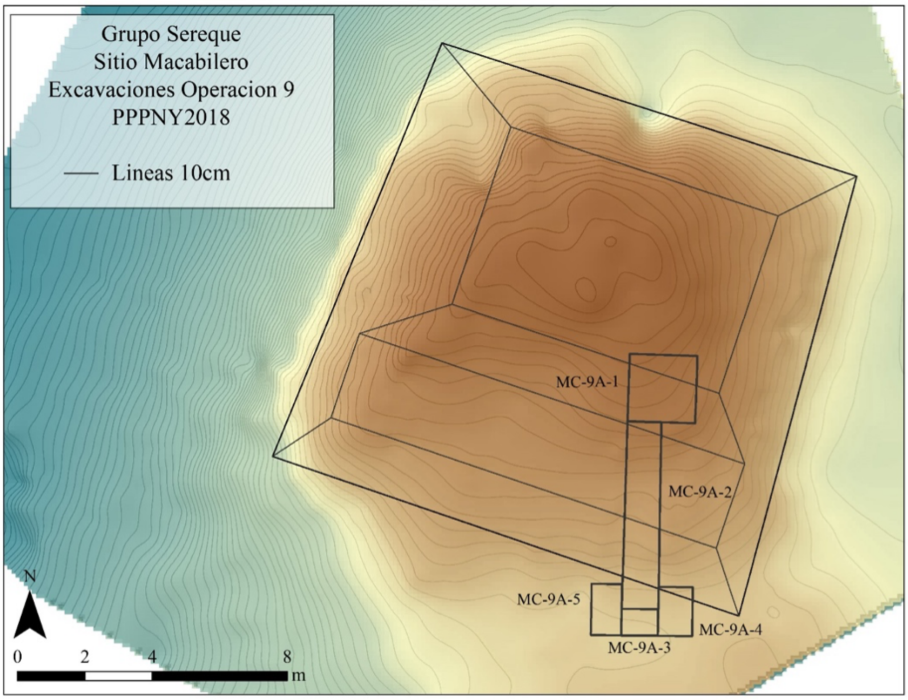

**Figure 2.9: Map of Operation 9 (Map by O. Alcover; Urquizú and Rodas 2018:74)**

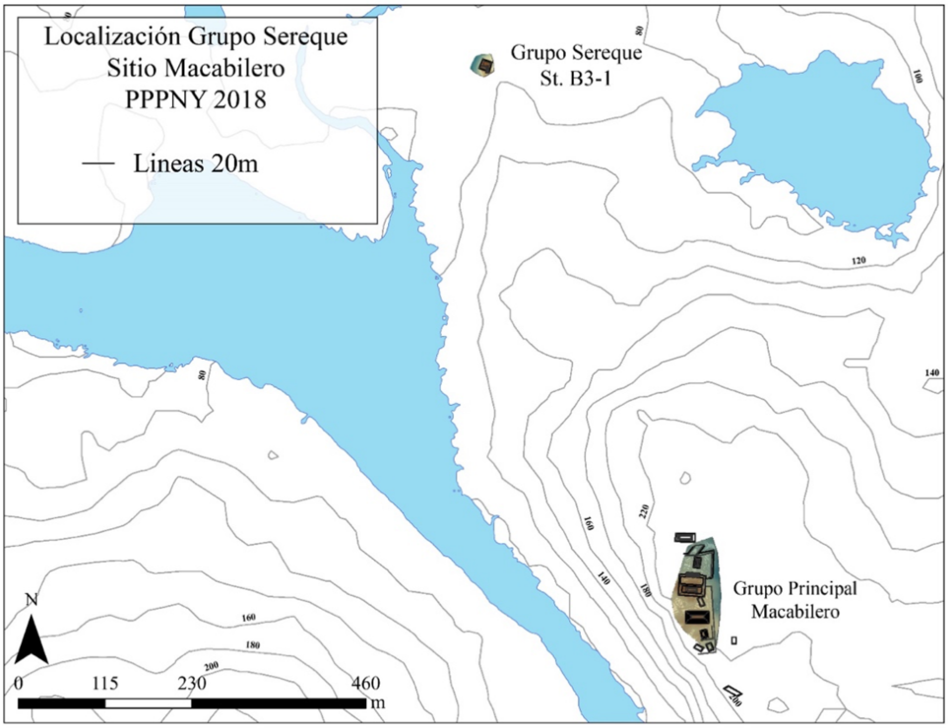

**Figure 2.10: Map of the Sereque Group in relation to the Principal Group of Macabilero (Map by O. Alcover; Urquizú and Rodas 2018:73)**

Towards the Late Classic and Early Postclassic periods, the connection shifts to show a stronger relationship with the ceramic traditions of the sites along the Usumacinta River, and even as far away as the Yucatan Peninsula, although the affiliation of this population with nearby ruling sites is unknown. Not only were the people residing at the Sereque Group identifying themselves through pottery, but also through their burials (Urquizú and Rodas 2018). These burials establish that this group was occupied for a long period of time, with its inhabitants sharing a collective memory and respect for their ancestors (McAnany and López Varela 1999: Golden and Scherer 2013; Urquizú and Rodas 2018). Alongside the presence of burials, this group is also situated close to the nearby caves and rock shelters which reinforces this location as a pilgrimage area (Lucero 2003; Urquizú and Rodas 2018). Recent research on Maya caves has shown that some of these sites have dynamic histories and could perhaps reflect actions by local groups that connect to different social, political, and economic systems (King et al. 2012; Morton 2015; Wrobel et al. 2017).

## The Formative Maya Community

One of the research questions regarding the construction of Macabilero regards *who* built and modified Macabilero. As previously discussed, Macabilero was not originally built to be a defensive fortress, rather those features were built after the first construction phase. Due to the scale of the site and its monumentality, there must have been a social cohesiveness that allowed for multiple groups to come together and build (Alcover Firpi 2020). It is very much possible for large construction projects to be achieved through communal consensus, there need not be an elite group to push for this sort of project to be completed (see Inomata et al. 2015; McAnany 2010). We do not know if there was a single leader at Macabilero, or if there was, what type of role they held.

If there was a leader or a group of leaders, there could have been several different motivations behind the construction of Macabilero. One of the excavations performed at Macabilero revealed a crypt with a single burial (Alcover Firpi et al. 2018). Alongside the skeletal remains, jade, pyrite, snail beads, and spondylus was recovered, suggesting that the individual occupied an important social position at the site (Alcover Firpi et al. 2018). This finding indicates there was some form of social distinction at Macabilero prior to the construction of defensive terraces and therefore, violence did not create a political Leadership system (Alcover Firpi 2020).

While we now know that there was some sort of social stratification at Macabilero, it is important to note that while these elite members may have played a role in the construction of the site, community members are also capable of having political opinions and potential matching agendas (Inomata et al. 2015). As hypothesized by Alcover Firpi (2020), Macabilero was created by more than one group, who constructed plazas and pyramids and had ritual practices. As Inomata and colleagues (2015) suggest, public rituals could have served as a way to mediate negotiations among diverse domestic groups and could even attract mobile populations, which is also supported by Lucero (2003). These areas could have been a place for small local groups to find equal footing and create a broader public sphere made up of the entire community (Inomata et al. 2015). This convergence of people would have given them a platform to share ideas which could have included agricultural practices and food production methods.

Moving forward in time to the addition of defensive structures and the production of weapons like sling stones, there would have been a different motivation behind this construction sequence compared to the original phase. One can assume that defensive measures like the construction of walls and weapons would be the result of a threat or the possibility of a threat. As implied earlier, it could have been a result of the entire community choosing to come together to work with or against potential leaders (Inomata et al. 2015). During a time of strife, the groups surrounding and residing at Macabilero may have built this fortress to protect themselves from outside threats, like the violence and warfare documented between Piedras Negras and Yaxchilán. At this point in time when defensive structures were being constructed, rituals were also of importance and supported by the discovery of items of ritual significance at Macabilero. This could show a sense of unity and trust among the people in the immediate vicinity as suggested by Golden and Scherer (2013), Inomata and colleagues (2015), and Lucero (2003). The transportation of people would have been a conduit for the transportation of ritual practices and their associated plants from their respective homes (Morell-Hart 2020:148).

By performing ritual and conducting daily life practices, social structure is formed and according to Lucero (2003:525) it "provides choices and constraints or limits within which individuals practice or act but does not determine behaviour. This leaves the door open for vulnerability and change." The practice of rituals within the Maya area was quite ubiquitous over the millennia, for both royals and commoners (Lucero 2003, 2006, 2010). Because of this, political powers were able to support strategic rituals because they incorporated traditional beliefs and practices, encouraging the interest in certain groups (Lucero 2003). Rituals allowed for food to become symbolic, something that can be used to alter political modes that affect identities and privilege (Weismantel 1988).

As Inomata and colleagues (2015:520) explain, "Archaeological data from Mesoamerican sites outside of the Maya area… indicate that public ritual was central to social life in early communities even before the emergence of the first Maya settlements." Cross-culturally, around the world different groups build visual symbols of dominance such as temples because they can provide an area for political competition and can stir up emotions and promote solidarity within a group (Kirch 1990; Lucero 2007; Trigger 1990). This kind of monumental architecture is permanent and materializes what cannot be materialized, even serving as a means of mass communication, and perpetuating a group's social memory (Chase 2016; Knapp 2006;

Lucero 2007). Large-scale agricultural features required a collective labour to be constructed, which ultimately symbolises social cohesion and memory, serving as a method of visibly communicating these values and helping to structure society (Morell-Hart 2020:142-143).

Furthermore, while Macabilero did not have a temple, there was an altar that was interpreted as being used for ritual activities alongside monumental terraces. While there is no physical proof, this area could also have functioned as an area where political competition or political concerns were addressed. In Mesoamerica, religion is vital for political legitimization, and because of this connection, rulers would conduct royal ceremonies at temples to enforce their connection with the gods (Estrada-Belli 2006; Freidel 2008; Knub et al. 2009; Lucero 2007; Wright 2011). Lucero (2003) specifically argues that rituals draw people together and that it was through the replication and expansion of domestic rituals that Classic Maya rulers acquired and maintained their political power. Estrada-Belli (2006) suggests that the Maya spatio-temporal worldviews combined with the creation of myth, where they are ritually enacted, are rooted in agrarian lifeways that some of the earliest Maya rulers appropriated at this time to fit a new ideology, one of central authority. Emerging Maya rulers would conduct structurally and functionally similar domestic rites in progressively larger-scale settings, thus incorporating larger groups of people (Lucero 2003). Ritual can integrate religious, social, economic, and political avenues which could potentially result in alliances, trade, and warfare (Estrada-Belli 2010; Lentz et al. 2005; Lucero 2003; Rice 2009; Rossi et al. 2015; Sharpe and Emery 2015). Morehart and Butler (2010:600) note that the offering of food connects with production, consumption, and exchange. While the offerings may not have been directly consumed, the burning and destroying of the offering represents consumption, which is ultimately connected to production and exchange (Morehart and Butler 2010:600). Food offerings often included “maize, squash, beans, chile peppers and the remains of edible fruit trees” (Morehart and Butler 2010:549). Maize has been recovered from caves throughout the Maya lowlands from Formative to Late Classic period contexts (Morehart and Butler 2010). Maize stalks and cobs have been recovered from Barton Creek Cave in the upper Belize valley (Morehart and Butler 2010:599).

Lucero (2003) explains that leaders often promote political change through ritual because they can then claim that their decisions and actions benefit all members of society. The state rarely goes uncontested, which has a wide variety of consequences (Golden and Scherer 2013). Golden and Scherer (2013) question the use or threat of violence as the primary means to structure society around a central authority. They argue that trust is needed to maintain a coherent political unit above the household level, and this was only accessible though communal activities (Golden and Scherer 2013). The sense of morality and trustworthiness could be fostered through daily personal interaction and observation or through highly charged events like feasting, warfare, and collaborative constructive efforts (Golden and Scherer 2013). Currently there is no evidence that supports the idea that the construction of public architecture or participation in warfare was voluntary during the Classic period but, there is also no evidence that Maya kingdoms had the infrastructure to impose labour through physical force or punishment so, Golden and Scherer (2013:405) conduct their work under the belief that this type of labour was voluntary. Feasting is a way to maintain and transform relations (Morell-Hart 2020:138). Due to their large scale, feasts required social cooperation or coercion (Morell-Hart 2020:142). Large-scale agricultural features would have been extremely beneficial for feasting and would have also symbolised social cohesion (Morell-Hart 2020:142-143).

## Conflict in the Usumacinta, Food Production, and Life at Macabilero

People at Macabilero and the nearby villages formed a community as they collectively built and utilized this defensive location, which also contributed to stronger social networks and turned Macabilero into a significant place for the regional community (Alcover-Firpi 2020:245-246). Over time Macabilero continued to expand in size and popularity, specifically regarding ritual practices (Alcover-Firpi 2020:245). Ritual can signify many different things, but relevant to this section, is that it can bring different peoples together, and potentially strengthen social bonds and commitments (Alcover-Firpi 2020:246). It is important to note, that not always does cooperation bring long-term cohesion between groups but signifies that individuals or groups can build trust with each other and come together to work towards a shared goal (Alcover-Firpi 2020:248).

Only three burials have been identified at Macabilero. The crypt that Burial 1 was in is hypothesized to have been built during the Formative Abal (300 BCE – 200 CE) (Alcover-Firpi 2020:261). The adult individual was interred with amazonite, spondylus, and pyrite, all prestige goods. These are also materials that would have arrived at Macabilero via long-distance exchange networks, symbolizing that people at the site had access to these trade networks and were not isolated from the lowlands (Alcover-Firpi 2020:261). The sex of the individual was unable to be identified due to the few remains that were excavated from the crypt, which was caused by the removal of the burial contents during the Late Abal Phase (100 – 200 CE) (Alcover-Firpi 2020:261-262). Due to the location of the crypt at a large and central structure at Macabilero and the prestige goods interred with the individual, Alcover-Firpi (2020:262), suggests that the occupant held an important social position, potentially even an elite.

Burial 3, also referred to as "The Man of Macabilero" by Scherer and colleagues (2021), lived during the Chacalhaz phase (750 – 850 CE) and is suspected to have lived much of his life at Macabilero or somewhere nearby (Scherer et al. 2021:2). Burial 3 was located in Grupo Sereque, hypothesized to be the home of commoners at Macabilero (Scherer et al. 2021:7). This individual had his head wrapped to form it into the shape of a maize cob (Scherer et al. 2021:4). There was also evidence of healed porotic hyperostosis on his cranium, suggesting that the individual suffered chronic anaemia as a child or survived scurvy as an adult (Scherer et al. 2021:4). In the years prior to his death, the Man of Macabilero suffered numerous skeletal fractures, which could have been the result of many different events but could have also potentially been the result of battle injuries (Scherer et al. 2021:6-7). Although only three teeth were recovered from this burial, Scherer and colleagues (2021:4) were able to identify evidence of dental aesthetics typical of the Usumacinta region on the recovered incisor and canine. The individual from Burial 3 was born during a period of instability at El Cayo and Piedras Negras, sometime between 700 – 780 CE, and died between 830 – 850 CE (Scherer et al. 2021:2-3).

At this point in time there is a huge discrepancy between the amount of known information between Burial 1 and Burial 3 due to Burial 1's limited amount of remains, but there are identifiable differences, nevertheless. Burial 1 is a suspected elite and Burial 3 has been identified as a commoner. While we know more about Burial 3's diet due to stable isotope studies, there is more to be explored through paleoethnobotanical methodologies in relation to their respective potential diets. At the end of the Formative period the Usumacinta River region saw real or perceived conflict that resulted in Macabilero's fortification, alongside that of other sites (Scherer et al. 2022). At the beginning of the Early Classic period, Piedras Negras and Yaxchilán had both established royal dynasties who waged warfare in the region (Scherer et al. 2022). This conflict between the two major polities in this zone rarely resulted in direct conflict due to intervening frontier zone where Macabilero is situated (Golden et al. 2006). According to Alcover Firpi and colleagues (2018), Macabilero remains one of the most enigmatic sites in the Sierra del Lacandón because of its unusual combination of defensive walls and megalithic terraces. Defensive features are obvious indicators of military conflict and "relate to evolving processes of polity formation, organization, and maintenance" (Golden et al. 2008:268). Macabilero has become one of a growing number of documented Formative fortifications in the Maya Lowlands.

Another large find at the site was the discovery of a large number of sling stones, potential weapons that have been documented in many parts of the Americas (Figure 2.12) (Alcover Firpi et al. 2018; Roche Recinos et al. 2021). Since Macabilero is so close in proximity to the Usumacinta River, where stones could be obtained, and the method of grinding these stones is somewhat simple, spherical stones, or slingstones, are an excellent option to the inhabitants at Macabilero (Roche Recinos et al. 2021). Because of their spherical shape, their location within the defensive space, and their overall consistency in weight and size, Alcover Firpi and Urquizú (2018b) are interpreting them as ancient weapons. This potential weapons presence at the fortified site of Macabilero during a period of interpolity conflict, demonstrates how communities were able to come together to create a defensive site (Roche Recinos et al. 2021:16).

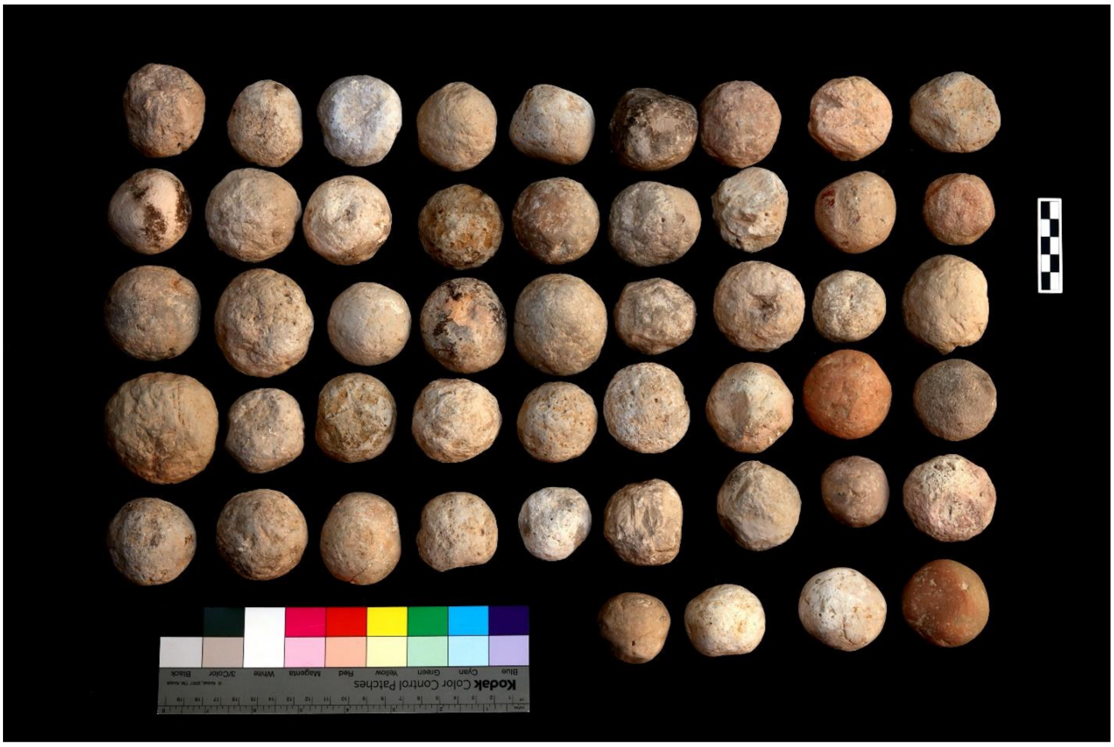

**Figure 2.11: Slingstones recovered from B4-1 (Operation 3) (Alcover Firpi 2020:377)**

Alcover Firpi and colleagues (2018) argue that Macabilero served as a defensive haven for nearby inhabitants and people located in nearby areas. Golden and his colleagues came to a similar conclusion in 2008, stating that the site "functioned as a fall-back position where a limited space and population could be protected" (Golden et al. 2008:268). Because of its position along the Usumacinta, evidence of defensive structures, and evidence of active conflict, Macabilero is an ideal place to study the relationship between conflict and socio-political development in the region. (Alcover Firpi and Urquizú, 2018a). Given the arguments about food production and its relationship to warfare, findings from Macabilero that relate to food production can be viewed at an individual and household level. What was being directly consumed by individuals can be found by sampling human teeth for plant materials. Warfare in relation to food production can also be viewed at the household level in relation to food storage facilities and the quantities of wild and non-wild foods being recovered (Wilson and VanDerwarker 2016:2). This could be a result of sacrificing a more diverse diet for safety (Wilson and VanDerwarker 2016:7).

## Research at Macabilero in Context

Macabilero is home to a variety of unique finds that range from defensive terraces to ritual altars. Different groups in the area came together to build Macabilero during the Formative period. With its location on the top of a hill next to the Usumacinta, the site was able to provide its community with a safe space for defending their people, but also a variety of resources like fresh water from the river during times of strife. The environmental conditions around the site were excellent for agriculture because of the area's gentle slopes and prevalence of water resources. These features encouraged the healthy growth of forests and fields that allowed a multitude of different flora and fauna to thrive. The site itself was home to significant ritual activity, proven especially by the network of caves where people left offerings such as ceramic vessels and the remains of sacrificed humans and animals. The site would later become defended by walls and monumental terraces, in times of conflict. Archaeologists have performed excavations across Macabilero in recent years to better understand site and its constructions, and what role warfare played in its construction and habitation. Archaeological findings support the concept that warfare greatly shaped the site, along with ritual practices due to the nearby caves. By 350 A.D.

Macabilero was abandoned, its citizens relocating to other sites in the area. The question remains as to how the Maya peoples at Macabilero interacted with their environment and how this affected the settlement's food security, food production, and agriculture.

# Chapter 3: Foodways at Macabilero

## Viewing Foodways Archaeologically

The study of foodways offers a means of examining how food influences humans, and vice versa. I use the term "foodways" following the initial description by Jay Anderson (Anderson 1971) and later expanded upon by scholars in the Maya region and beyond (Harvey 2018; Huambachano 2019; Landon 2018; Morell-Hart 2020). Food has always played an extremely significant role in the history of the world despite the differences that may separate groups. The study of food can grant insight into politics, economies, religions, and societies as food is essential to every human on the planet.  For this reason, food can also inform us about ethnicity, familial ties, self-identity, and heritage. Looking at foodways through time can expose transformation and persistence of different foods in past societies.

Studies of foodways of past societies have been carried out around the globe, in Africa (Kent 1993; Lyons and D’Andrea 2003), Central America (Brumfiel 1991; LeCount 2001), Europe (Dietler 1996; Janik 2003), North America (Frink 2007; Johannessen 1993; Larsen 2005), and Asia (Lev-Tov 2003; Lewis 2007). Some studies specifically look at food related topics such as identity (Parker Pearson 2003; Wilk 2013), ideology (Weismantel 1988), ritual (LeCount 2001) taboo (Visser 1986), memory (Sutton 2013), and emotions (Rozin et al. 1997), while others may focus on health (Nabhan 2013), status (Frink 2007; Moss 1993), the origins of agriculture (Lyons and D’Andrea 2013), and politics (Dietler 1996; Lewis 2007), among many other topics.

We can use many different archaeological methodologies to examine these topics s in the past, through studies of foodways. McDonough (2019) has reconstructed diets from Oregon during the Middle Holocene using coprolite analysis, Pavao-Zuckerman and DiPaolo Loren (2012) used faunal and ceramic assemblages to investigate social expectations on the Spanish colonial frontier, Smyth and Evershed (2015) conducted stable isotope analysis on lipids from Irish Neolithic vessels to gain insight into diet, food procurement, and processing activities, Rohnbogner and Lewis (2016) examined dental caries to investigate diet in Roman Britain, and Henderson (2013) used macrobotanical methods to understand slave subsistence at Thomas Jefferson's Poplar Forest during the 18th and 19th centuries. All these studies are examples of just how meaningful the study of ancient foodways can be while attempting to reconstruct our understandings of past societies.

## Major Approaches to the Archaeology of Foodways

There are many different methodologies that are employed to study foodways. Here, I focus on six key methods: zooarchaeology, ceramics, chemical analyses, bioarchaeology, coprolite analyses, and paleoethnobotany.

### *Zooarchaeology*

Zooarchaeology is the study of faunal remains and is extremely informative for several different reasons. Alongside paleoethnobotany, this form of research considers all cultural and temporal periods to analyse the human condition (Peres 2010). Zooarchaeology contributes, moreover, to our understandings of environmental change, seasonality, settlement patterns, resource-use, hunting practices, how humans interact with their landscapes, social stratification, and even sociocultural transitions (Kennedy and VanValkenburgh 2016; Lõugas and Bläuer 2021; Peres 2010; Sharpe et al. 2020). Faunal remain analysis allows for researchers to reconstruct ideas of economic autonomy, social cohesion, and identity as well (Wallman 2021). Faunal remains can be used in isotopic and genetic studies (Guiry et al. 2018; Manin et al. 2017; Sharpe et al. 2018).

Zooarchaeologists can specifically look at the production, preparation, consumption, and disposal of faunal remains to study foodways (Sunseri 2017). Examining each of these steps allows for zooarchaeologists to study which events take place at an individual and group level (Lõugas and Bläuer 2020; Sunseri 2017). The environment heavily dictates which species of animals thrive, and those that will not, in a given setting. Vegetation, suitable land for pastures, climate, and access to resources are a few different ways in which species rely on a certain environment (Wallman 2021).

The most common fauna recovered from Formative period contexts in the Maya area include deer, turtle, and dog (van der Merwe et al. 2000:25). Van der Merwe and colleagues (2000:25) analysed zooarchaeological remains via isotope analysis to discover if the Formative Maya at Cuello purposefully fed dogs maize to gain higher yielding meat. Their results showed that the dogs were scavengers, and not fed directly with food specially produced for them by humans. This study is an excellent example of the integration of zooarchaeology and isotope analyses to study foodways and the various roles that maize played in Maya communities. Zooarchaeological data can also be used to study resilience and dietary strain in the past, as done by Gaastra and colleagues (2020), Edvarsson and colleagues (2004), and Emery (2008). However, zooarchaeologists can be limited in their studies by time, the lack of comparative collections that include taxa of relevance, and erosion (Emery 2004; Peres 2010; Wallman 2021).

### *Ceramics*

Ceramics play an important role in the reconstruction of ancient foodways. Ceramics can be used to study how food was prepared in the past (Graff 2018). Cooking pots and vessels are targeted to estimate the number of diners and further explore whether eating was an event or a quotidian gathering (Cheetham 2010). Cooking vessel size could suggest if food preparation was a cooperative event between two or more households (Cheetham 2010). Ceramics can provide insight into stability or change of cuisine in relation to social, economic, or political changes (Graff 2018). Zulauf (2013) studied the functions of ceramic vessels from Rancho Santa Cruz, an early colonial (c. 1600-1750 CE) hamlet located in Mexico, to identify continuities in consumption practices and potential changes. Ceramics have been used to study famine (Lorence 2013; Orser 1997) and warfare (Abbott and Lack 2013; Stanton and Brown 2003; Stanton and Negrón 2001) in the past. Powis (2004) studied pottery from the Late Formative (300 BCE – CE 250) commoner households at the Maya centre of Lamanai in Belize. Examining the frequency and variety of ceramic types and forms recovered a variety of different contexts, Powis (2004) concluded there was no significant difference between the contexts of elite and commoner, domestic and ritual, during the Late Formative. Powis (2004) hypotheses that undecorated plainwares and fine wares were used both ritually and domestically.

*Chemical analyses*

Chemical analyses have a great deal of crossover with zooarchaeology, bioarchaeology, and paleoethnobotany, because lipid analyses and staple isotope analyses are indices of animals, plants, and human mediation of these food resources. The results from soil chemical tests can provide information of chemicals that were trapped within the soil matrix itself (Parnell et al. 2002). These tests can reveal information about uses of archaeological artifacts, agricultural fields, architectural features, paleoenvironmental changes, and human behaviour (Fernandez et al. 2005; Parnell et al. 2002). Phosphates are fixed by naturally occurring compounds in soil which can result in their adhesion to the soils for very long periods of time (Wells et al. 2000). Where other methodologies may fail, soil chemical analysis can provide clues from the soil itself and this method can even predict archaeologically significant features (Parnell et al. 2002). Regarding the study of foodways, soil chemical analyses can provide invaluable data on trends in plant food diversity, agricultural practices, long-term trends, and changes in food production and consumption (Fernandez et al. 2005; Parnell and Terry 2002; Sinensky and Farahani 2018). Soil chemistry studies have greatly improved our understanding of how drought (Luzzader-Beach et al. 2012), water contamination (Lentz et al. 2020) and site abandonment (Cook et al. 2017) affected the lives of the ancient Maya.

Artifacts also serve as great indices of foods consumed, as foodstuffs are held within them and can leave traces of organic residues behind for future archaeologists to find. The remains that survive the test of time can provide information on foodstuffs, the function of a vessel or implement and its association with certain foodstuffs, and local and regional economies and technologies (Eusebio 2015). Ceramics can also show a glimpse into transitionary periods and the introduction of different fauna and flora in diets (Craig et al. 2011; Roffet-Salque 2016). These transitions are extremely important to foodways research since they show changes in human and fauna relationships, social structures, social cohesion, economics, the local ecology and potentially even food taboos (Demirci et al. 2021; Dunne et al. 2020; Kidder 2019; Roffet-Salque 2016). Remains recovered from ceramics and artifacts also provide direct evidence of the preparation and eventual consumption of food (Dunne et al. 2016; Ganzarolli et al. 2018; Taché et al. 2021). For example, finding charred seeds from a site does not confirm without doubt that this plant remain was prepared and eventually consumed, whereas direct evidence of foods that were cooked within ceramics provides more support for these conclusions. The recovery of charred foodstuffs from ceramics is also an excellent source for reconstructing specific dishes. This is a rather rare find, but one that provides immense information in reconstructing past diets.

### *Bioarcheology*

There are several different types of research regarding human skeletal remains. Some researchers specialize in dental pathology, stable isotope analysis, and calculus studies to name a few. All these methods can be applied to studies regarding foodways. By looking at pathologies, dental caries and calculus, or nitrogen and carbon isotopic signatures, bioarchaeologists can investigate topics such as food consumption patterns and diet (Arcini et al. 2012; Cheung et al. 2019; Scherer et al.

2007). By utilizing bioarchaelogical materials, researchers can begin to understand how diet was connected to social identity (Knudson and Stojanowski 2008), gender roles (Agarwal 2012), socioeconomic status (Newman and Gowland 2016), disease (Snoddy et al. 2016; Zuckerman and Crandall 2019), and resilience (Hoover and Hudson 2016; Reitsema et al. 2017). Stable isotope analysis targets carbon and nitrogen from selected samples to assess past foodways. For human subjects, these samples can be collected from bone and dentine collagen, dental calculus, enamel, and even hair and fingernails (Harvey 2018:93). From these samples, researchers can identify carbohydrates, lipids, and proteins, all significant in the reconstruction of diet (Harvey 2018:93). Our understanding of Ancient Maya warfare has been greatly improved due to bioarchaeological studies (Barrett and Scherer 2005; Serfin et al. 2014). Bioarchaeology has also been used to study famines (Brzobohatáa et al. 2019; DeWitte and Yaussy 2020; Geber 2016). However, similarly to all other mentioned methods, bioarcheology is not without its limitations, and is highly subject to environmental conditions, soil acidity and faunal activity.

### *Coprolite analyses*

Coprolites, also known as paleofeces or ancient fecal matter, have been recovered from sites all over the world and contain a unique set of information about the organism itself, and the environment they lived in (Shillito et al. 2020; Witt et al. 2021; Zhang 2020). Coprolites can hold the remains of pollen, botanical materials, faunal bones, and even parasites (Shillito et al. 2020; Sonderman et al. 2019; Witt et al. 2021). Coprolites also provide an excellent opportunity for radiocarbon dating and isotopic analysis. Alongside identifying and analysing foodways, coprolites can be used to study climate change, health, sanitation practices, social organization, shifting population sizes, the local ecology, and even cultural practices (Jacobson et al. 2020; McDonough 2019; Shillito et al. 2020; Sonderman et al. 2019; Witt et al. 2021; Zhang et al. 2020). One of the setbacks of coprolite analysis in terms of examining foodways is that they only hold information from a very short time period due to the speed that digestive systems operate, so archaeologists are unable to make interpretations for longer time periods (Witt et al. 2021). For this reason, other research methods can be used, with samples drawn from other types of deposits, to get a broader view of foodways at the site (Shillito et al. 2020; Witt et al. 2021). What is unique about coprolite analysis is that coprolites are created by more than just humans, and researchers can look to coprolites from fauna to gain insight into past diets (Shillito et al. 2020; Witt et al. 2021; Zhang et al. 2020). Coprolite studies have shown results of the effects warfare has on the health of human populations (Reinhard and Camacho 2019).

### *Paleoethnobotany*

Paleoethnobotany is the study of ancient plantstuffs in relation to humans, at macroscopic and microscopic scales. This methodology can contribute information on diet, agriculture, climate and environmental changes, resource availability, socioeconomic changes, and more (McClatchie et al. 2022; McClung de Tapia and Martinez-Yrizar 2017; Morehart and Morell-Hart 2015; Peres 2017; Sheng et al. 2020; Wright 2010). Paleoethnobotany is a rather new methodology compared to the others previously mentioned. Since the start of the 21st century, paleoethnobotany has grown significantly, which further encourages future and current researchers around the world (Wright 2010). Combining paleoethnobotanical methods with others, such as bioarchaeology or ceramics, provides unique direct ways to view food archaeologically. Recovered ancient botanical remains like carbonized seeds, starch grains from a ceramic pot, or phytoliths from the soil itself, provide evidence for what was happening at a given site, at a specific point in time regarding food practices. Paleoethnobotanical studies of Formative period contexts have allowed for archaeologists to gain an understanding of what could be considered staple crops: maize, manioc, malanga, and sweet potato (van der Merwe et al. 2000:24). In their 2000 study, van der Merwe and colleagues (2000:25) set out to establish whether maize was a staple crop and what it played through time at the Formative site of Cuello. Paleoethnobotanical studies have revealed how foodways are affected during times of hardship (Geber et al. 2019; Langlie 2020). Methods in paleoethnobotany will be discussed in greater detail in the following chapter.

## Ancient Maya Foodways

Ancient Maya people lived in modern-day Mexico, Guatemala, Belize, Honduras, and El Salvador. They spoke many different dialects, built extraordinary monumental architecture, practiced agriculture, warfare, and religion, and much more. Early researchers instituted time periods (Archaic, Formative, Classic, and Postclassic) for the Maya region, which have been used by Maya archaeologists since their creation. As mentioned in earlier chapters, in this thesis, the Formative and Classic periods are the areas of focus. The Formative period (1600 B.C. – A.D. 200) began when mobile hunter-gatherers began settling into villages of farmers, while permanent social hierarchy in cities define the Classic period (A.D. 250 – A.D. 1000)

(Joyce 2004:14). The types of datasets described below are from across Mesoamerica, with an emphasis on visible faunal remains (bones) and botanical remains (seeds; wood), and stable isotope analyses.

### *Foodways During the Formative Period*

The Formative period is defined by the evidence of “agriculture, sedentary settlements, ceremonial and mortuary practices, and technological elaboration” (Doyle 2017:15), as well as ceramic production, monumental architecture, language, social complexity, and organization of labour and landscape (Doyle 2017:15-16). During the Formative period, Maya peoples practiced a variety of different agricultural methods, including the construction of canals, raised or ridged fields (Bloom et al. 1983; Hammond 1984; Paris et al. 2020:388; Pohl et al. 1996; Scarborough 1983; Turner and Harrison 1981), terraces (Hansen et al. 2002; Paris et al. 2020:388; Wyatt 2008), swidden (Bloom et al. 1983; Fedick and Ford 1990; Lentz et al. 2018; Rice 1976), and milpas (Beach et al. 2002; McClung de Tapia et al. 2019; Paris et al. 2020:388).

One of the ongoing struggles related to studies in Mesoamerica of the Formative Period, also known as the Preclassic Period, is the lack of preservation of archaeological materials. There are several factors that impact archaeologists’ ability to successfully excavate sites from the Formative Period, including environmental limitations, the destruction of sites, and the fact that buildings were removed and built over again by later populations (Brown and Friewald 2020:28; Doyle 2017:5-6). The history of archaeological work in Mesoamerica is very similar to that of the rest of the world: easily identifiable monumental cores have been primarily excavated while harder to find, older settlements have not been a primary focus (Doyle 2017:6). The limitations of Formative period studies can also be attributed to the large number of forests and jungles throughout Mesoamerica that hindered ground surveys but, with the recent advancement of LiDAR, the identification of Formative features has vastly improved (Beach et al. 2019; Brown et al. 2016; Chase and Chase 2017; Inomata et al. 2018).

Despite recent advancements in technology that have allowed the identification of structures from the Formative period, there is still the issue of preservation. Because of the tropical climate, archaeologists in the Maya area are faced with the challenges of working with fewer remains and attempting to identify those that have survived the test of time. Working with unideal preservation conditions is a situation very familiar to Mayanists, and even more so to those excavating sites further back in time. Excavating Formative period sites can be a very daunting task because of this combination, especially when it comes to studies focused on foodways. Erosion hugely impacts the preservation of foodstuffs like animal bones and charred plant remains and can make the identification process near impossible if these remains are recovered. Because of these hurdles, there is a noticeable gap in our knowledge of the Formative period, especially when compared to our knowledge of the Classic and Post-Classic periods.

As a result of these conditions, the study of foodways from the Formative period is certainly hindered, but nonetheless various studies have yielded critical results. Maize, squash, and beans have been the most popular food remains recovered from Formative period sites and have been interpreted as the most important crops for Maya peoples across different time periods (Feddema 1989; Powis et al. 1999; Sheets et al. 2011; Tykot 2002). Out of the three sisters, maize has been the primary focus for many archaeological studies (e.g., Johannessen et al. 1970; Kennett et al. 2020; Rushton et al. 2020; Smalley and Blake 2003; Taube 1996; Webb et al. 2007). Ebert and colleagues (2021:21-22) found that Maya peoples in the Eastern lowlands had a very maize-intensive diet from the Formative to the Colonial period (Ebert 2017).

Studies involving foodways have found that diets during the earlier Formative period were generally broader than those of the later Classic period and included both wild and domesticated species (Ebert et al 2021:10). Alongside maize, squash, and beans, terrestrial (agouti, deer, rabbit, dog, peccary, armadillo, gibnut, opossum), freshwater (catfish, *jute*, snail, turtle), and marine (grouper, parrotfish, various molluscs) fauna were also consumed (Crane 1996:273; Ebert et al. 2021:10; Hammond and Miksicek 1981:269; Powis et al. 1999; Van Der Merwe et al. 2002:25).

Botanical species recovered from Formative period contexts in Mesoamerica vary but share some overlapping taxa. Recovered from Cahal Pech, a medium-sized site in the upper Belize Valley, was coyol palm, ramón, and figs (Powis et al. 1999). High-status individuals at this site consumed more maize and marine fish compared to those of a lower social standing (Ebert et al. 2019). From the Mazatán area, avocado, laurel carpetweed, knotweed, and mustard (Feddema 1993:57). Maize and avocado were recovered from Tierras Largas in the Valley of Oaxaca (Winter 1976:Fig.2.8) and from the Tehuacán Valley, agave, amaranth, avocado, beans, chili pepper, cotton, coyol, gourd, maize, mesquite, plum, and prickly pear (Smith 1967:Table 26). Cuello, in modern day northern Belize, maize, squash, cacao, cotton, jauacte palm, crabboe, hogplum, mamey, allspice, chile, and avocado were recovered from early Formative contexts (Hammond and Miksicek 1981). At Cerros, maize, beans, squash, nance, coyol palm, mamey, guava, cotton, and chili pepper were recovered from the Late Formative, with maize having the highest counts (Crane 1996). Crane (1996:272) also found that over time the consumption of maize and squash was static, while the consumption of nance and coyol palm increased. Maize, armadillo, fish, turtle, iguana, opossum, crab, toad, rabbit, deer, *jute* snails, and freshwater clams were recovered from a feasting deposit at Blackman Eddy (Brown and Freiwald 2020:35-37). McClung de Tapia and colleagues (2019) recovered maize, bean, chili, sweet potato, manioc, amaranth, goosefoot, sage, tomatillo, jaltomata, and agave from the Altica, a site occupied during the Formative period in the Teotihuacan Valley.

### *Foodways During the Classic Period*

As previously discussed, compared to studies on Formative period occupations, a higher quantity of research from the Classic period has allowed for more intensive studies. The Classic period's improved preservation conditions combined with the interpretation of glyphs have allowed for more detailed foodways research to be conducted on topics such as social identity and stratification (Ardren and Miller 2020; Lentz 1991; Morehart and Helmke 2008; Somerville et al. 2013), ritual (Dussol et al. 2016; Johnson 2018; Lentz et al. 2016; Morehart 2002), and trade (Lentz et al. 2005; Morell-Hart et al. 2021). During the Classic period there was an intensification of agricultural production in the form of terraces and water management systems (Ebert et al. 2019) while managed forests, milpas, home gardens, raised fields and swidden agriculture continued from the Formative period (Somerville et al. 2013:1549).

While maize appears to have been a regular crop during the Formative period, its role drastically changed in significance by the beginning of the Classic period (Schwarcz 2010:186). Maize became the centre of Maya peoples diet (Ebert et al. 2019:593) and became the most important plant in the Maya area (Staller and Carrasco 2010; Tuxill et al. 2010:467). Classic Maya farmers were able to produce enough maize in large fields or on terraced slopes to support large urban centres (Schwarcz 2010:187). During the Classic period, the diets of Maya people at Piedras Negras were heavily comprised of maize (Scherer et al. 2007). Maize played an important symbolic role, as well as in ceremonies and the economy (Tuxill et al. 2010:467). Somerville and colleagues (2013:1544) found that in their study of eight archaeological sites in the southern lowlands, maize was the staple crop for Maya peoples in this region, regardless of their social standing, while there was large variability regarding the consumption of meat and marine products. The Maya commoner's consumption patterns remained static over time, even during times of social, political, climatic, and economic change (Somerville et al. 2013:1548). The Maya elite's consumption patterns changed through time, the consumption of maize and marine products lessening while the consumption of meat rose (Somerville et al. 2013).

At the Classic period village of Joya de Cerén, archaeologists found evidence that villagers consumed maize, beans, squash, manioc, malanga, chili peppers, and cacao (Farahani et al. 2017). A Late Classic feasting deposit from La Corona revealed high counts of maize, alongside a variety of other species, including nance, amaranth, beans, groundcherry, and goosefoot, among many others (Cagnato 2018:Table 1). From Copan, Lentz (1991:Table 1), recovered maize, beans, and species from the squash family. At Tikal, maize, beans, squash, sweet potato, achira, and malanga have all been recovered (Lentz et al. 2014:18515). A study involving both polities and subordinate sites in the Usumacinta and Petexbatun regions by Sharpe and Emery (2015) revealed that during the Late Classic, the residents of Piedras Negras, Yaxchilan, Aguateca, the polities, had a greater diversity of animal species, while subordinate sites had higher proportions of local taxa.

## Foodways in the Usumacinta River Region

The Usumacinta River is situated along the current borders of Guatemala and Mexico. This river was one of the major trade routes that connected the Highlands, Lowlands, and the Gulf of Mexico (Golden et al. 2012:11). Along the Usumacinta, two Maya kingdoms, Piedras Negras and Yaxchilan, had a strong influence over movement along the river (Golden et al. 2012:11). While drought was prevalent in parts of the Central and Northern Maya Lowlands, the Usumacinta region received the highest annual precipitation of the lowlands and its residents had access to an abundance of surface water (Schroder et al. 2021:4). While water was plentiful in this region, the area was nonetheless also subject to prolonged droughts and deforestation, which negatively affected soils. These shifting environmental conditions impacted this region’s inhabitants’ choices on where to settle and their need to create and tend to water management features (Schroder et al. 2021:5). LiDAR data collected from Benemérito de las Américas, Primera Sección, a Maya urban centre situated on the Upper Usumacinta River, revealed evidence for agrarian landscapes and water management (Schroder et al. 2021:15). There were areas with deep soil profiles that could have been conductive for swidden agriculture, homegardens, and groves;

agricultural techniques that were not practiced at dynastic centres like Piedras Negras or Yaxchilan due to their lack of access to deep soils (Schroder et al. 2021:15). Instead, the residents of these cities would have needed to rely upon surrounding areas to provide them with food (Schroder et al. 2021:15). Alongside the discovery of deep soil profiles, terracing around the acropolis, and reservoirs, the LiDAR survey also identified evidence for channelized or drained fields near Benemérito Primera Sección (Schroder et al. 2021:16). Drained fields can be used to control the water table in an area, and as a result, increase agricultural yields (Schroder et al. 2021:17).

By AD 450, Piedras Negras was an established dynastic centre and refuge for those abandoning the countryside after a period of instability caused by violence (Golden et al. 2021:19). Over time as the population at Piedras Negras grew, so did the kingdoms settlements and its reach (Golden et al. 2021:19). Agricultural infrastructure was intensified in regions with less settlement, while Piedras Negras itself elected to not expand in this area (Golden et al. 2021:20). While the city itself did not have intensive agriculture, there were lower toe slopes that could have supplied Piedras Negras' residents with maize (Golden et al. 2021:20). At the height of dynastic power, Maya peoples at Piedras Negras uniformly consumed maize and meat, despite their social standing (Golden and Scherer 2013:416). As Piedras Negras' dynastic power faltered, the consumption of maize declined for some residents while other residents increased their intake of fish instead of meat (Golden and Scherer 2013:416). Golden and Scherer (2013:416) hypothesise that this shift in diet could have been the result of stressors to agricultural practices and hunting and the resulting redistribution of foodstuffs among households. The abundance of agricultural infrastructure outside of Piedras Negras could have been a means of producing surpluses of food which would have been moved through trade, taxation, and tribute (Golden et al. 2021:20).

Unlike Piedras Negras, the kingdom of La Mar did have intensive agricultural infrastructure in the forms of terraces and wetland fields nearby (Golden et al. 2021:20). Golden and colleagues (2021:20) suggest that this proximity is a result of La Mar's court managing the production of crops but recognize that this discovery may only be the result of their LiDAR sampling strategy and suggest further LiDAR surveys to gain more insight on this matter. Lacanja Tzeltal, another kingdom in the Usumacinta region, had canalized wetland fields near its architectural core, but did not experience expansive settlement and the resulting intensification, as did Piedras Negras and La Mar (Golden et al. 2021:21).

The role that Macabilero held during its occupation was unique and provides an opportune chance to study what foodways looked like during the Late Formative and Early Classic periods under difficult circumstances for its inhabitants. A collective group of people joining together and living near one another during a time when the land surrounding Macabilero was unsafe, would undoubtedly affect the populations' ability to plant, harvest, produce, consume, and deposit foodstuffs. These circumstances could potentially have negative or positive effects on the population's diets and their reflective health statuses. The joining of different groups into one, could also result in the unification of different food practices and dishes, forming a potentially unique diet, and even identity, for the populace.

Around 810 CE when the Man of Macabilero was in his thirties or forties, the court at Piedras Negras collapsed, changing the lives of the people living at Macabilero drastically (Scherer et al. 2021:5). One of the effects of this collapse on the people at Macabilero was the cessation of tribute obligations and market exchange that may have been conducted at Piedras Negras and El Cayo (Scherer et al. 2021:5). With the collapse of a once mighty kingdom, it is not unlikely that communities in the region had to deal with a general sense of insecurity in a variety of different aspects of life, including food and violence (Scherer et al. 2021:5).

Dietary stable isotope analyses from Piedras Negras show that this collapse had severe repercussions on the food economy across the region (Scherer et al. 2007). During the most prosperous years at Piedras Negras (Yaxche Phase, 625-750 CE), all people at the site shared a similar diet, despite social stratification, rich with maize and terrestrial game (Scherer et al. 2007:97; Scherer et al. 2021:5). The people of Piedras Negras ate less maize and/or less terrestrial game in favour of riverine fish following the cessation of tribute after the kingdoms collapse (Scherer et al. 2021:5). Stable isotope analysis on the individual from Burial 3 shows that he continued to have access to maize decades after the collapse (Scherer et al. 2021:5). The massive quantities of jute shells recovered from Grupo Sereque combined with a very low nitrogen isotope ratio from the isotope analysis proves that the Man of Macabilero also preferred freshwater snails as his source of meat protein (Scherer et al. 2021:5). Later in life, the Man of Macabilero developed osteoarthritis, perhaps the result of living a very active lift, farming, canoeing, labouring, or participating in battle (Scherer et al. 2021:7). The individual in Burial 3 underwent many tooth extractions, either voluntary for infections, or from involuntary injury, and suffered from periodontal disease and numerous caries (Scherer et al. 2021:8). Alongside the extensive dental maladies, the Man of Macabilero had extensive periostitis, meaning that he had an active disease at the time of his death (Scherer et al. 2021:9). Upon his death, the Man of Macabilero was interred in the fill of the Grupo Sereque platform with bone fragments that are suspected to have been disturbed from an earlier internment in this chamber (Scherer et al. 2021:10). Although there is no exact date, at some point in time following the Man of Macabilero's death, a large quantity of faunal bones was deposited over his grave, perhaps signalling a feasting deposit to commemorate his death (Scherer et al. 2021:10).

## Expectations of Foodways at Macabilero

Due to the high decomposition rates in the humid tropic regions of Mesoamerica there has been a loss of perishable artifacts, and more specifically, food products (Bair 2010; Coronel et al. 2015). Results from previous paleoethnobotanical studies from sites in the Usumacinta River region showed that the presence of erosion on macrobotanical remains is very common and greatly impacts our abilities to retrieve these remains from the environment, let alone identify them (Morell-Hart and González Córdova 2017; Morell-Hart and Watson 2018; Morell-Hart et al. 2018a; Morell-Hart et al. 2018b; Watson 2018a, Watson 2018b, Watson 2018c). Despite poor preservation rates, Fedick (2017:142) identified nine plants that archaeologists can expect to find while performing research: "amaranth, beans, chenopodium, chili, jaltomate, maize, portulaca, squash, and tomatillo." These have been most commonly recovered archaeologically (Fedick 2017:142). While this is not an exact list of what will be found at every site, it allows archaeologists to have a general understanding of what could be expected while excavating. While exploring potential diets at Teotihuacan, once the largest city in Pre-Columbian Americas, Fedick (2017:142-143) found that 72% of the diet at this site was comprised of plants using the C4 or CAM pathway like agave, amaranth, cactus, and maize with the remainder of the plant diet was composed of C3 plants like tomatoes or squash. Based on the results from previous macrobotanical studies at Piedras Negras, Budsilha, and Sak Tzi (Morell-Hart and González Córdova 2017; Morell-Hart and Watson 2018; Morell-Hart et al. 2018a; Morell-Hart et al. 2018b; Watson 2018a, Watson 2018b, Watson 2018c), ancient Maya sites located in the Usumacinta River region, I expected to find plant remains from the following families: Agavaceae, Arecaceae, Asteraceae, Cactaceae, Ceropiaceae, Chenopodiaceae, Fabaceae, Malphiagaceae, Lamiaceae, Onagraceae, Piperaceae, Portulacaceae, Poaceae, Amaranthaceae, and Solanaceae.

Maize, cotton, cacao, copal, vanilla, squash, beans, chiles and annatto are all major crop plants in the Lowlands (Baron 2018; Barrera and Fernández 2006; Fedick 2017; Turner and Miksicek 1984). Many of these domesticates were used in a variety of different ways by Maya peoples, in construction, medicine, fuel, and food for example (Morell-Hart 2018). These plantstuffs would have been bartered, traded, gifted, and exchanged amongst communities, as the ability for a single household to produce and maintain this suite of basics would have been extraordinarily difficult (Morell-Hart 2018).

Isotopic evidence from Piedras Negras reveals that maize was extremely present at the site (Golden et al. 2021:19). Analyses of human skeletons indicate that at the height of the kingdom, from about AD 620 to 750, the residents of that capital enjoyed among the highest maize consumption levels in the Maya world, with similar levels of maize and animal protein consumed regardless of socioeconomic status (Golden et al. 2021:20). Analyses of isotopes from soils also reveal the presence of C4 plants like maize (Golden et al. 2021:19). Given our current understanding of ancient Maya foodways in general, and specifically in the Usumacinta region, there is a great expectation that maize will be found in sizable quantities, alongside the other two staples, beans, and squash.

By combining the available literature with previous paleoethnobotanical studies in the Usumacinta River region, expectations on plant staples at Macabilero can be established. Maize is expected to be the most ubiquitous in the Formative and Classic period contexts (Beach et al. 2006:173; Beach et al. 2011; Bérubé et al. 2020; Cheetham 2010; Ebert 2017; Ebert et al. 2017; Ebert et al. 2021; Kennett et al. 2020; Lentz 1999; Lohse et al. 2022). Other species that are expected to be recovered, although in smaller numbers compared to maize are: beans, squash, manioc, Jamaican pepper, fisherman's tobacco, trumpet tree, sweet potato, peppers, (Beach et al. 2009; Fedick 1996; Lentz 1999; Watson 2018a; Watson 2018b; Watson 2018c). Plant staples may not remain static over time. Based on the rising popularity of maize over time, as documented by other researchers (Freidel 2008; Somerville et al. 2013; Taube 1996), there is an expectation to recover more maize in the Classic period contexts. Following the results of this paleoethnobotanical research, the similarities or differences between plant staples during the Formative and Classic periods at Macabilero are used to enquire into ethnoecology, diet, food choices, and abandonment.

# Chapter 4: Methodology for Recovering Botanical Residues

## Introduction

Paleoethnobotany is a relatively new archaeological methodology with its inception in 1941 by Volney H. Jones (Pearsall 2015:27). The term *paleoethnobotany* was coined in 1959 by Hans Helbaek and has since been utilized around the world to explore relationships between humans and plants. Paleoethnobotany primarily aims to interpret how humans and plants interacted with each other and what that could mean on a larger scale. To study these sorts of relationships in the past, paleoethnobotanists examine plant remains recovered as a variety of forms, including wood, seeds, starch grains, phytoliths, pollen, and chemical residues. Each plant form requires different preparation, processing, and analysis, and can provide unique insights into the past. Macroremains, starches, and phytoliths will be explored in further detail in this chapter as these are the paleoethnobotanical elements that are studied in this research project.

Macroremains are plant tissues that are visible to the naked eye, like seeds and nuts, while microbotanical remains are invisible without technological aid. Microbotanical remains include starch grains, composed of glucose polymers that form shapes that are unique to specific plant species (Pearsall 2015:342), and phytoliths, inorganic plant opal silica bodies that can be used to identify plant families and species (Pearsall 2015:253). Paleoethnobotanical analysis is divided into three sections; recovery, identification, and interpretation (Pearsall 2015:35). One of the biggest concerns paleoethnobotanists face while completing analysis, especially in the Maya region, is the preservation of remains. Many plant remains do not survive the annual wet-dry cycle in the region and the exposure to microorganisms, but there are still macroremains that do survive and can be positively identified (Hageman and Goldstein 2009:2841). Plant morphology, processing, charring, environmental conditions, deposition, and recovery all play a role in successful identification of ancient plant tissues (Pearsall 2015:43). Ethnographic sources and a survey of the modern growth at the archaeological site can aid a paleoethnobotanists interpretation of the recovered material and determine how the plant remains entered the deposits (Pearsall 2015:37).

Regardless of the type of remain analysed, paleoethnobotanical methods provide a unique way to reconstruct past environments and the roles humans and plants held in those environments. The most common technique in paleoethnobotany is macroremain analysis, the study of botanical materials that are visible to the naked eye (Pearsall 2015:35). Macroremains are excellent proxies for exploring how past people interacted with plants. These remains include charred, desiccated, or waterlogged plant materials such as seeds or fruits (Pearsall 2015:35). The majority of macroremains that have been preserved in the archaeological record are the result of human actions that led to their carbonization (Pearsall 2015:182). The most common form of preservation is charring, which is often done through human actions that involve fire, like cooking (Pearsall 2015:41). These carbonized remains can be recovered during three stages, *in situ*, screening, or flotation and can be modern or ancient in origin (Pearsall 2015:35). The ancient seeds can enter archaeological deposits through three different means; direct resource use, indirect resource use, and seed rain (Pearsall 2015:37). Direct plant use can include food preparation, storage and consumption waste, or dung, fodder, decaying building materials (Pearsall

2015:37). Indirect plant use occurs when the plant itself is used, but not the seed, examples of this include dung fuel or grass seed falling from roof thatch (Pearsall 2015:37). Modern seeds can also enter the matrix via accidents such as being kicked into an open unit or even by the movement of earthworms and erosion (Pearsall 2015:36-40; VanDerwarker et al. 2016).

Pearsall (2015:182) suggests that macroremains are more supportive of exploring human behaviour as compared to phytoliths, which some scholars suggest are more central in terms of reconstructing how humans interacted with their landscapes (Ball et al. 2016; Harvey and Fuller 2005; Pearsall 2015:183; Strömberg 2004). Phytoliths are also inorganic, making them the most resilient type of botanical remain and can survive in conditions where macroremains and starches cannot (Cabanes et al. 2011:2480; Pearsall 2015:340). Phytoliths can provide unique insight into practices that do not involve fires or burning, processes often required for the preservation of macroremains. Phytoliths, along with starch grains, aid in determining ceramic and stone tool functions, exploring past vegetation and agriculture, identifying activity areas, and studying the domestication of plant species (Pearsall 2015:253).

Starch grains are for the most part recovered directly from artifacts allowing for analyses that are linked to specific items. These items usually consist of ceramic vessels, stone tools, and teeth. Because of these direct links, starch grains provide an excellent opportunity for studying diet and foodways. There are many root crops that do not produce phytoliths and are very rarely preserved as macroremains, so for some species, starches are the only viable way of finding residues in the archaeological record (Pearsall 2015:384).

Paleoethnobotany has been used to study a wide variety of archaeological topics including, but not limited to, plant exploitation (Asouti and Austin 2005; Bigga et al. 2015; Deiana et al. 2017), plant economies (Aura et al. 2005), diet (Bérubé et al. 2020; Lentz 1991; McDonough et al. 2022), agriculture and plant domestication (Dickau 2005; Farahani 2020; Langlie and Capriles 2021), climate (Behre et al. 2005; Stachowicz-Rybka 2015), and healing practices (Watson et al. 2022). Within the Maya region, paleoethnobotanical studies have been conducted to examine topics like diet (Bérubé et al. 2020; Lentz 1991), practices specific to particular plants (Cavallaro 2013; Lentz et al. 1996; Thompson et al. 2015), ritual (Lentz et al. 2016; Morehart et al. 2005), social structure (Morehart and Helmke 2008), and medicinal practices (Abramiuk et al. 2011; Carlson 2001; Flaster 2004; Watson et al. 2022). I frame my work in the context of prior successes of these paleoethnobotanical studies and build on these studies in my own research.

My research questions are as follows: How do plant staples at Formative period settlements compares to staples at Classic period settlements? How do these differences reflect changes in ethnoecology in relation to land management and food choices? What was the relationship between ethnoecology, diet, and the abandonment of Formative sites? What are the implications for hypotheses about the Formative Maya “collapse” that relate abandonment to ecological stress and potential crop failures? Paleoethnobotany provides an excellent opportunity to explore these questions, as it is the most opportune method to examine ancient plants and the relationships humans had with them.

## Paleoethnobotanical Sample Collection

The samples analysed for this thesis were collected to maximize recovery of macroremains, starch grains, and phytoliths. Macroremains provide great insight into diet, phytoliths can provide insight into agriculture and vegetation where macroremains and starches cannot, and starch grains provide direct insight into how plants were being used and consumed.

Macroremain analysis is the most common paleoethnobotanical approach (Pearsall 2015:35). Macroremains are visible to the naked eye and include seeds, fruits, shells, and wood, which have been recovered from archaeological contexts (Pearsall 2015:35). Macroremains can be preserved through the means of charring, desiccation, and waterlogging (Pearsall 2015:35). Seeds can be recovered from three sources: direct resource use, indirect resource use, and seed rain (Minnis 1981:145; Pearsall 2015:37). Direct use can include food processing and consumption, indirect use includes fuel and construction materials, and seed rain occurs when naturally dispersed seeds were blown into hearths or burned in middens (Minnis 1981:145). As the Maya region is situated in the semitropical environment of Mesoamerica, many plant remains do not survive because of the wet climate and exposure to microorganisms (Hageman and Goldstein 2009:2841). While some macroremains are carbonized and therefore preserved, they do not represent the entire record as many materials do not survive the test of time and the adverse conditions of their immediate environments.

Macroremains can be collected in situ, during the screening process, when excavated soil is passed through a screen, and/or through the flotation process (VanDerwarker et al. 2015), but recovered specimens are typically quite large, leaving smaller seeds underrepresented overall (Pearsall 2015:44). In situ collection occurs when archaeologists collect macroremains directly from a unit. This may be opportunistic, e.g., collecting a visible chunk of wood as an artifact, or sampled as a volume of sediment that is later processed. Macroremains can also be pulled during the screening process while in the field, depending on the size of the screen mesh being used. The smaller the screen, the higher the chance of identifying plant remains, but there is a still a chance of losing or damaging the botanical materials (Pearsall 2015:44).

There are three common sampling techniques at the unit level: composite, column, and point sampling. Composite samples are made up of soil gathered from across a context and is combined in one bag, column samples are made up of soil from a column in a unit, while point samples are made up of soils from a precise area (Pearsall 2015:76). While different sampling strategies can be conducted for recovering macroremains, there is never a guarantee of recovery. At the site level, blanket sampling is recommended by Pearsall (2015:74), a method that collects soil from all excavation contexts, but unfortunately it is extremely time consuming and often not possible. Field seasons run on extremely tight schedules with a limited amount of funding, which often disallows paleoethnobotanists from being able to conduct blanket sampling and instead must opt for judgemental sampling. Judgemental sampling is when a paleoethnobotanist or excavator selects certain contexts from which to pull samples. This option may be more restrictive compared to blanket sampling, but still provides a reasonable sampling strategy. This method also allows researchers to target specific areas most relevant to their research questions and goals.

Microbotanical analyses follow different protocols of recovery and processing. Artifacts and sediments can both be processed to recover microbotanical residues. There are two primary ways in which microremains can be deposited on or in artifacts, human interactions like cooking and grinding, or incidental exposure like dropping a blade in sediment (Pearsall 2015:271). Generally, artifacts targeted for microbotanical analysis should be selected based on the researchers' questions, but the most common artifacts are stone tools, ceramics, and teeth. These artifacts can provide direct insight into which plants were being utilized and how. Artifacts should be minimally handled to avoid contamination and bagged promptly upon discovery (Morell-Hart 2020). Occasionally, sampling is done in the field when specific artifacts may not be able to be exported or there is a higher risk of contamination with movement. If the artifacts are exported to a sterile laboratory, researchers can handle the items after sanitizing their hands and wearing gloves (Pearsall 2015:359).

Phytoliths are also recoverable directly from sediments. As the archaeological record is formed, phytoliths are released from plant tissues via decay, burning, or digestion (Pearsall 2015:267). They are released into the surrounding soils and bound in its organic and inorganic compounds which allows paleoethnobotanists to study sediments with *in situ* deposition (Pearsall 2015:267-269). Despite being relatively durable due to their composition of opal, phytoliths are can still be lost due to issues such as dissolution by the roots of plants, being in alkaline conditions, and mechanical abrasion (Cabanes et al. 2011:2480). The only way in which phytoliths can move from their initial space is if the soils they are bound to are moved, for example by bioturbation, which is something researchers consider when selecting where to sample (Cabanes et al. 2011:2480; Pearsall 2015:269). Sampling strategies for phytoliths in sediments follow the same general protocols described above for flotation samples, but at a smaller scale (~200g, in place of ~10L). While forming an excavation plan for the recovery of phytoliths, it is vital to tailor the sampling to the research questions. Based on the research questions, different soils and contexts will be sampled to target the best possible area from which to recover plant remains.

### Paleoethnobotanical Processing

In cases where botanical residues are not recovered in situ or in excavation screens, further processing is necessary to remove plant remains from artifacts and sediments.

In macroremain analysis, flotation is best for recovering high amounts of seeds since all seed sizes can be collected, providing a more meaningful way to conduct quantitative analysis (Hageman and Goldstein 2009:2841; Pearsall 2015:46). There are three ways of performing flotation: by hand, by machine, and by compression (Pearsall 2015:48). Flotation separates botanical materials from soil, which makes processing and sorting easier. Alongside this separation of soils and organic materials, flotation also divides samples into two smaller fractions, heavy and light, which expedites the sorting process. Pearsall (2015:46) argues that flotation machines, like the SMAP machine, are more effective than manual flotation systems for several reasons including higher agitation and efficiency. The SMAP (Shell Mound Archaeological project) machine was created in 1976 and is now commonly used at sites in the Americas (Pearsall 2015:52). The SMAP machine is used to separate heavy and light materials.

Microbotanical sample processing usually targets objects (such as artifacts) or human remains (such as teeth), or sediments (from features). Required supplies for microbotanical processing of tools and artifacts include distilled water, squeeze bottle, unpowdered gloves, labelling items, toothbrushes, plastic containers, centrifuge tubes, centrifuge bottles, sonication device, centrifuge, and pipettes (Morell-Hart 2020:1; Pearsall 2015:359-360). Ideally, three washes are carried out in extractions. For the dry wash, the researcher loosens any sediments from the artifact and transfers them to a container with distilled water. The dry wash is collected to identify material in the surrounding matrix and to track potential contamination (Morell-Hart 2020:1). For the wet wash, distilled water is applied to the artifact and collected in a container. The wet wash is taken to track the movement of material between the artifact and the surrounding sediments (Morell-Hart 2020:1). For the sonicated wash, the artifact is covered in distilled water and a sonication device is emerged in the water and turned on (Pearsall 2015:360). The container is sonicated for five minutes and then the water is transferred and stored before being mounted onto a microscope slide (Pearsall 2015:360). The sonicated wash is taken to recover materials most closely associated with the artifact (Morell-Hart 2020:1). Using a disposable pipette, the liquid from each wash can be mounted on a slide. The slide with the liquid is then covered with a cover slip and nail polish is applied to the edges to seal in the slide's contents (Pearsall 2015:369). Starches and phytoliths can be identified using a comparative collections and databases. By referring to historic and ethnographic texts, further analysis can be conducted on the identified species.

For phytolith extractions from sediments, many different phytolith processing procedures have been established around the world (Aleman et al. 2013; Coil 2003;

Cuthrell 2011; Horrocks 2005; Boyd et al. 1998; Pearsall 2015; Morell-Hart 2020). With varying types of soils around the world, phytolith extraction procedures need to be customized to the targeted soils for the best opportunity of successful collections (Pearsall 2015:282). Despite the wide variety of processing steps different researchers have established to best suit their soils, they are all centred around removing clay, carbonates, organic matters, and heavy matter from the samples to isolate the phytoliths (Cuthrell 2011; Morell-Hart 2018; Pearsall 2015). Because of the variation of phytolith procedures there is no exact standard of protocols to follow, but it is typical to see steps dedicated to dispersion, deflocculation, carbonate, oxide, and clay removal, organic digestion, dispersion, and heavy-liquid flotation (Cuthrell 2011; Morell-Hart 2018; Pearsall 2015; see Appendix B).

### Paleoethnobotanical Methodologies Used in the Current Study

The paleoethnobotanical goals for the 2017 field season were "to evaluate the condition of the samples in terms of preservation and amount of residues, and to form a guide for the selection of samples in future excavations" (Morell-Hart and González Córdova 2017:236). The information yielded from this field season came from analyzing the connections between the environment, artifacts, and identified plant species (Morell-Hart and González Córdova 2017). By the conclusion of the 2017 field season five flotation samples and five sediment samples were collected (Morell-Hart and González Córdova 2017). Dr. Shanti Morell-Hart, the principal investigator, and Jesús Alejandro González Córdova, a research assistant, organized the selection and collection of materials and the flotation and curing of sediment samples. Heavy fractions from Macabilero were sorted and classified by Omar Alcover Firpi, the principal investigator at the site, and research assistant, Ricardo Rodas. Microbotanical extractions were performed by Morell-Hart, González Córdova, and Matsumoto (Morell-Hart and González Córdova 2017). The 2018 field season aimed to find connections between the environment, artifact groups, and economic plants, with a focus on the presence/absence of various plant species and the patterns of their use and disposal. As for the 2017 field season, five soil samples were taken for analysis of phytoliths and macroremains. The findings of these research targets will help to understand the use of ancient plants in various contexts to further develop our knowledge of feeding practices and human relationships with the environment (Morell-Hart et al. 2018).

### *Sampling Strategy*

At Macabilero, samples were judgmentally collected on-site by excavators targeting a standard 10L per sample. Each sample was composite, that is, excavators sampled from across each excavated locus to get a broader picture of plant use in each context. The samples collected from Macabilero were from three different operations (Morell-Hart and González Córdova 2017). Samples were taken from inside the stucco floor of the central plaza (Operation 3-B), defensive terraces (Operation 4-A), and from the structure located in the south of the central plaza (Operation 5-A) (see Map 2.6 in Chapter 2). Morell-Hart targeted these operations for extractions because this selection strategy allows for a wide variety of contexts to be examined across the site, and within the spatial contexts from which the samples were pulled from as well. All collected samples were taken from Lot 2 or below, avoiding the exposed humus layer (Lot 1). Each sample was taken from the entire excavation area of the selected lot and bagged with both interior, and exterior labels (Morell-Hart and González Córdova 2017). At Macabilero, the samples taken for flotation varied between 4 and 6 litres instead of the standard 10 during the 2017 field season, and the standardized 10 litres during the 2018 field season. The 2017 field season was the first time the PPPNY conducted excavations at the site which meant that some practices were not yet standardized during excavations at Macabilero. Macabilero is also not easily accessible and moving the large samples from the site would have resulted in a lot of physical labour. These discrepancies have been considered during processing and analysis. For microbotanical sampling, researchers targeted a variety of different human teeth and artifacts like ceramics and lithic tools, from a wide variety of different contexts, to examine the broadest spectrum of visible plants (Morell-Hart and González Córdova 2017).

### *Flotation Sample Processing and Analysis*

Fourteen flotation samples from the 2017 and 2018 field season were floated in a flotation machine built by Morell-Hart (Figure 4.1), based on a modified model of Deborah Pearsall's (2015) SMAP machine (Morell-Hart and González Córdova 2017; Morell-Hart et al. 2018). Some samples were floated in the field at El Porvenir, and others were floated at the project headquarters in Guatemala City, but the same SMAP machine was used in all cases. The modified SMAP machine made and used by the PPPNY was made from a garbage bin, piping, a shower head, and a hand sieve. Prior to flotation, the five samples were soaked in deflocculant and water for several minutes (Morell-Hart and González Córdova 2017; Morell-Hart et al. 2018; Pearsall 2015). During the flotation process, the sample was divided into two fractions, light and heavy (Figure 4.2) (Morell-Hart and González Córdova 2017; Morell-Hart et al. 2018). A hose was used to push water up and out of the shower head that was secured to the bottom of the bin to encourage light materials to float, while heavy materials sank to the bottom and were collected in a fine mesh. Operators also used their hands to agitate the water and encourage any trapped light materials to float to the top to be collected in the hand sieve. Once all the floating materials were collected from the sample, they were hung on a line in their mesh fabric to dry prior to the sorting and identification process. The heavy fractions were placed in pans to dry. After samples were completely dried, each individual light and heavy sample ultimately stored in a plastic bag with labels indicating origin and content information.

The heavy fractions were preliminarily sorted without the use of a microscope to collect any potentially carbonized items. The potential carbon from the heavy fractions and the light fractions were catalogued and exported to the McMaster Paleoethnobotanical Research Facility (MPERF) (Morell-Hart and González Córdova 2017; Morell-Hart et al. 2018). There, the materials were sorted and identified using 10x-40x reflected light microscopy. Identified remains were tabulated in an Excel database.

**Figure 4.1: Modified SMAP flotation machine in use by S. Watson and H. Dine (Photo by S. Morell-Hart) (Morell-Hart et al. 2018:149)**

**Figure 4.2: Heavy and light fractions from Macabilero (Photo by S. Morell-Hart) (Morell-Hart et a. 2018:150)**

*Sediment Sample Processing and Residue Analysis*

Fourteen 200-gram sediment samples were collected from the same contexts as the flotation samples. The samples were exported to the MPERF laboratory where they were heavily processed using chemical treatments and flotation methods to clean and concentrate the botanical residues (Morell-Hart and González Córdova 2017; Morell-Hart et al. 2018; see Appendix B). The sediments were first sterilized of pathogens in a furnace at 200C for a minimum of six hours (Morell-Hart 2018:1). Over the span of three days, the sterilized sediments were deflocculated in water with sodium bicarbonate (Morell-Hart 2020b:1-2). Once the samples were deflocculated, each sample was divided into two separate fraction sizes by sieving (Morell-Hart 2018:2-3). The concentrate sand (S) fractions and fine and course silt (A/B) fractions then had their clays removed by pouring, replacing, and stirring water over the course of 10 days. Once the clays are removed, the samples were prepared for chemical digestion. The process involved centrifuging each sample and weighing to the target of 10 grams (Morell-Hart 2018:3). The 10-gram samples were transferred to beakers where they were combined with hydrochloric acid, nitric acid, and hydrogen peroxide prior being microwaved in a pressurized MARS 6 system at 180 degrees Celsius for ~130 minutes (Morell-Hart 2018:3-5).

Once removed from the microwave, the samples were ventilated under a fume hood for 80 minutes before being poured into 50 millilitre centrifuge tubes (Figure 4.3). The samples were then rinsed twice using distilled water and centrifuged at 3000 rpm for 5 minutes twice (Morell-Hart 2018:6). A heavy liquid solution made of sodium polytungstate was used to float phytoliths that were collected using a pipet and deposited into a 15-millilitre centrifuge tube. Distilled water was then added to the 15 millilitre tubes and centrifuged before pouring off the supernatant, leaving only the phytolith plug at the base (Morell-Hart 2018:7). Following the final pour off, acetone was added to each sample and then centrifuged to accelerate the drying process

(Morell-Hart 2018:8). Once the samples were fully dry, part of the sample was archived, and the remaining material was mounted onto a microscope slide with immersion oil (Morell-Hart 2018:8-9). Nail polish was used to seal the edges and the slides were examined using a magnification of 200x for the concentrated (S) fractions, and 400x for the fine and coarse (AB) fractions. Phytoliths and other microbotanical residues were identified from these slides using a transmitted light Zeiss microscope with polarizer. Identified remains were tabulated in an Excel database.

**Figure 4.3:Pouring ventilated sediment samples into 50 millilitre centrifuge tubes**

*Artifact Residue Processing and Residue Analysis*

Artifact residue extractions were taken in the field from eight artifacts and human remains: two ceramic fragments, three obsidian blades, and three human teeth (Morell-Hart and González Córdova 2017; Morell-Hart et al. 2018). The sampled ceramic sherds were mostly large vessel bases to target the clustering effect of residues in the background. We focused on obsidian blade fragments, half of which were proximal and the other half medial (Morell-Hart et al. 2018). The three individual teeth were collected from two separate human burials (Morell-Hart et al. 2018).

The extraction process was conducted by labelling sterile centrifuge tubes, preparing the workstation, materials, and artifacts, then completing three separate washes (Morell-Hart and González Córdova 2017; Morell-Hart et al. 2018). Three centrifuge tubes were labelled with the artifact information, sample number, and wash information. After the tubes were ready, the materials and workstation are prepared by washing all surfaces, laying out required materials such as kim wipes, pipettes, and petri dishes (Morell-Hart 2020:3). Once the workspace was set, the artifact was then removed from its labelled bag with fresh gloves and photographed. Notes were taken about the artifact with information about its context, morphology, and condition (Morell-Hart 2020:4).

After changing gloves, the dry wash was conducted by gently rubbing the targeted surface and margins with one's fingers over a clean and sterilized petri dish until no more material could be removed (Morell-Hart 2020:5). With a fresh set of materials (gloves, pipette, petri dish), the targeted area then underwent the wet wash. The artifact was rubbed with wet gloved fingers with occasional irrigation of the surface with distilled water. The goal of this step was to continue the process until the water flowed clear (Morell-Hart 2020:6). The sonication wash required a fresh set of materials and a sonication device (Figure 4.4). Depending on the morphology of the artifact, it was either immersed in a petri dish that had been partially filled with distilled water or the cupped interior of the artifact was filled with distilled water

(Figure 4.5). The sonication device was then either inserted underwater next to the surface of the artifact or inserted into the water immediately above the surface of the artifact (Figure 4.6). The sonication device was then turned on and used at 30-40 kHz for 2-5 minutes (Morell-Hart 2020:7). After the sonication sample was moved to its labelled centrifuge tube and secured, the artifact was patted dry with a kim wipe, photographed, and repackaged (Morell-Hart 2020:8).

After extractions were completed, the tubes were centrifuged for 5 minutes at 3000 RPM. Concentrated residues were then mounted onto a slide that was covered and secured with nail polish (Morell-Hart 2020:11). Phytoliths, starch grains, and other microbotanical residues were identified from these slides using a transmitted light Zeiss microscope with polarizer. The slide was examined at 400x with further investigation and photography at 650x. Identified remains were tabulated in an Excel database.

**Figure 4.4: Large vessel base being sonicated (Photo by S. Morell-Hart) (Morell-Hart et a. 2018:154)**

**Figure 4.5: Obsidian fragment being sonicated (Photo by S. Morell-Hart) (Morell-Hart et a. 2018:153)**

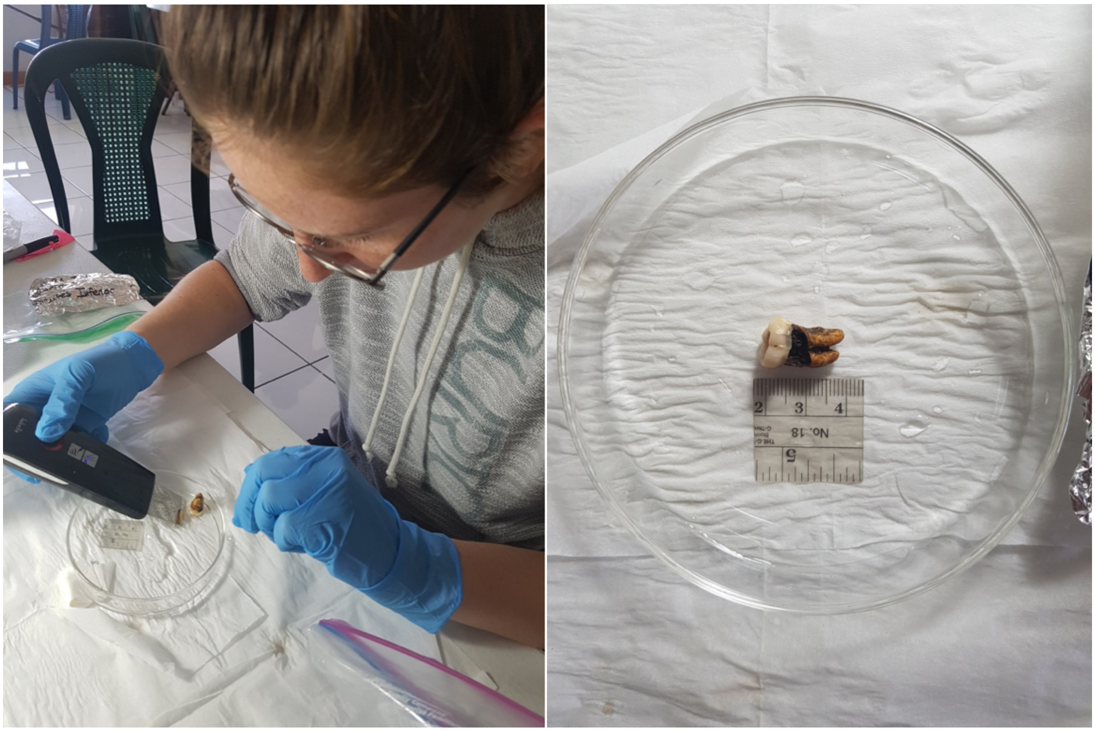

**Figure 4.6: Human tooth being sonicated (Photo by S. Morell-Hart) (Morell-Hart et al. 2018:154)**

## Methods for Understanding Ethnoecology at Macabilero

Many research questions have been best answered through paleoethnobotanical methods. My research similarly draws on these strategies to answer my specific research questions. There is a long history of paleoethnobotanical success with similar questions (Cagnato and Ponce 2017; Dine 2018; Ford and Nigh 2009; Morell-Hart et al. 2014; Morell-Hart et al. 2019; Slotten et al. 2020). Samples were judgementally collected by excavators on-site at Macabilero to best get a broader understanding of plant use in each context. A variety of different human teeth and artifacts from a wide variety of contexts were targeted to examine the broadest spectrum of visible plants. Flotation, sediment, and artifact processing were all analytical methods I selected to maximize paleoethnobotanical results and to answer my research questions. In the next section, I show the results of these analyses.

# Chapter 5: Non-domesticated Plants, Root Crops, and Maize: Results of Paleoethnobotanical Analyses

## Introduction

This chapter presents the results of the first paleoethnobotanical research conducted at Macabilero. As described in the previous chapter, during two field seasons macrobotanical and microbotanical samples were collected and processed to further our understanding of how humans and plants interacted with each other at this Formative period Maya site. During the two field seasons in 2017 and 2018, eight artifacts (three washes, 24 samples), 14 sediments (28 samples), and 14 flotation samples (28 samples) were collected. The results of analyses of all eight artifacts, 1 sediment, and 14 flotation samples are presented in this chapter. In short, many familiar taxa were identified at Macabilero, including sweet potato, bottle gourd, manioc, bean, and maize. All these species are commonly found throughout Mesoamerica (Allen et al. 2003; Dine et al. 2019; Fedick and Santiago 2022; Lentz 1999; Sheets et al. 2011) and have also been recovered from sites in the immediate vicinity of Macabilero such as Piedras Negras, Lacanja Tzeltal-Sak Tz'I', and Budsilja (Morell-Hart and Watson 2018; Morell-Hart et al. 2018b; Watson 2018a). Asteraceae species, wood sorel, Jamaican pepper, trumpet tree, and knotweed were also identified.

While all these species are quite typical and expected of ancient Maya locations, their relative ubiquities were sometimes surprising. In the below table (5.1), I summarize all results by presence/absence. I cluster macrobotanical and microbotanical remains by lot, following previous work by Morell-Hart (2019). Each count of taxon below represents a single lot where the taxon was recovered, not the total number of remains recovered. (E.g., *Canna* sp. was recovered from only one lot, whereas *Zea mays* or cf. *Zea mays* was recovered from three separate lots).

**Table 5.1: Ubiquity of taxa from Macabilero**

| | **(Phytolith Sediment)** | **(Phytolith Sediment)** | **(Flotation Sediment)** | **(Flotation Sediment)** | **(Artifact Residue)** | **(Artifact Residue)** | **(Artifact Residue)** | |
|---|---|---|---|---|---|---|---|---|
| | **A/B Fraction** | **S Fraction** | **Heavy Fraction** | **Light Fraction** | **Sonicated Wash** | **Wet Wash** | **Dry Wash** | **Grand Total** |
| **Asteraceae** | | | | **7** | | | | **7** |
| Asteraceae sp. 1 | | | | 5 | | | | 5 |
| Asteraceae sp. 2 | | | | 2 | | | | 2 |
| **Cannaceae** | | | | | | **1** | | **1** |
| *Canna* sp. | | | | | | 1 | | 1 |
| **Cannaceae/Marantaceae** | | **1** | | | | | | **1** |
| Cannaceae/Marantaceae sp. | | 1 | | | | | | 1 |
| **Convolvulaceae** | | | | | **1** | | **1** | **2** |
| cf. *Ipomoea batatas* | | | | | 1 | | | 1 |
| *Ipomoea batatas* | | | | | | | 1 | 1 |
| **Cucurbitaceae** | | | | **1** | | | | **1** |
| cf. *Lagenaria siceraria* | | | | 1 | | | | 1 |
| **Euphorbiaceae** | | **1** | | | **2** | **4** | **6** | **13** |
| cf. *Manihot esculenta* | | | | | 1 | 1 | 3 | 5 |
| *Manihot esculenta* | | 1 | | | 1 | 3 | 3 | 8 |
| **Fabaceae** | | | | | | **1** | | **1** |
| *Phaseolus* sp. | | | | | | 1 | | 1 |
| **Heliconiaceae** | | | | | | | **1** | **1** |
| Heliconiaceae sp. | | | | | | | 1 | 1 |
| **Marantaceae** | **2** | **1** | | | | | | **3** |
| cf. Marantaceae sp. | 1 | | | | | | | 1 |
| Marantaceae sp. | 1 | 1 | | | | | | 2 |
| **Oxalidaceae** | | | | **1** | | | | **1** |
| cf. *Oxalis* | | | | 1 | | | | 1 |
| **Piperaceae** | | | **1** | **1** | | | | **2** |
| cf. *Piper hispidum* | | | 1 | | | | | 1 |
| *Piper hispidum* | | | | 1 | | | | 1 |
| **Poaceae** | | | | | **2** | **2** | | **4** |
| cf. *Zea mays* | | | | | 2 | | | 2 |
| Panicoid | | | | | | 1 | | 1 |
| *Zea mays* | | | | | | 1 | | 1 |
| **Polygonaceae** | | | | **2** | | | | **2** |
| Polygonaceae sp. | | | | 2 | | | | 2 |
| **UNIDENT** | | | | | **2** | **5** | **4** | **11** |
| UNIDENT starch | | | | | | | 1 | 1 |
| UNIDENT starch grain | | | | | 2 | 5 | 3 | 10 |
| **UNKN** | **8** | **13** | **14** | **18** | **3** | | **7** | **63** |
| UNKN exocarp | | | | 1 | | | | 1 |
| UNKN fibre | | | | | 1 | | 1 | 2 |
| UNKN fruit | | | 1 | | | | | 1 |
| UNKN phyto 1 | 1 | | | | | | | 1 |
| UNKN phyto 10 | | 1 | | | | | | 1 |
| UNKN phyto 11 | | 1 | | | | | | 1 |
| UNKN phyto 13 | | 1 | | | | | | 1 |
| UNKN phyto 14 | | 1 | | | | | | 1 |
| UNKN phyto 15 | | 1 | | | | | | 1 |
| UNKN phyto 16 | | 1 | | | | | | 1 |
| UNKN phyto 17 | | 1 | | | | | | 1 |
| UNKN phyto 18 | | 1 | | | | | | 1 |
| UNKN phyto 19 | | 1 | | | | | | 1 |
| UNKN phyto 2 | 1 | 1 | | | | | | 2 |
| UNKN phyto 3 | 1 | | | | | | | 1 |
| UNKN phyto 4 | 1 | | | | | | | 1 |
| UNKN phyto 5 | 1 | | | | | | | 1 |
| UNKN phyto 6 | 1 | | | | | | | 1 |
| UNKN phyto 7 | 1 | | | | | | | 1 |
| UNKN phyto 8 | 1 | | | | | | | 1 |
| UNKN phyto 9 | | 1 | | | | | | 1 |
| UNKN seed 305 | | | | 2 | | | | 2 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| UNKN seed 353 | | | | 1 | | | | 1 |
| UNKN starch 1 | | | | | | | 2 | 2 |
| UNKN starch 2 | | | | | | | 1 | 1 |
| UNKN starch 3 | | | | | | | 1 | 1 |
| UNKN stem | | | | 1 | | | | 1 |
| UNKN tissue | | 2 | | | 2 | | 1 | 5 |
| UNKN wood | | | 13 | 13 | | | | 26 |
| UNKN wood phyto | | | | | | | 1 | 1 |
| **Urticaceae** | | | | **2** | | | | **2** |
| *Cecropia peltata* | | | | 2 | | | | 2 |
| **Vitaceae** | | | | **1** | | | | **1** |
| Vitaceae sp. | | | | 1 | | | | 1 |
| **Grand Total** | **10** | **16** | **15** | **33** | **10** | **13** | **19** | **116** |

## Identified Plant Species

Numerous edible root and seed species were recovered from Macabilero. Of the identified specimens, represented families include Asteraceae, Cannaceae, Marantaceae, Convulvaceae, Cucurbitaceae, Euphorbiaceae, Fabaceae, Heliconiaceae, Piperaceae, Poaceae, and Polygonaceae. The majority of recovered families were only identified in the form of a single taxon, or at most two taxa. A minimum of 17 taxa were identified from this study, with several unidentifiable or unknown species listed above. The most frequently recovered taxa were maize (*Zea mays*) and manioc (*Manihot esculenta*). As mentioned previously, preservation in the Peten forest, where Macabilero is situated, is poor. This greatly affects paleoethnobotanists' capabilities to successfully identify plant species. Despite this disadvantage, many species were identified, and several will be explored in detail below.

Asteraceae taxa (various) grow worldwide and are used as a source of food, medicine, construction materials, and ornamentals (Cilia-López et al. 2021:456; Lentz and Dickau 2005:244-249). Asteraceae is the richest family of flora in Mexico and grows from sea level to the mountains with excellent dispersal capacity (Cilia-López et al. 2021:456). Asteraceae species were found seven times in this study, in the form of macroremains (seeds) (Figure 5.1).

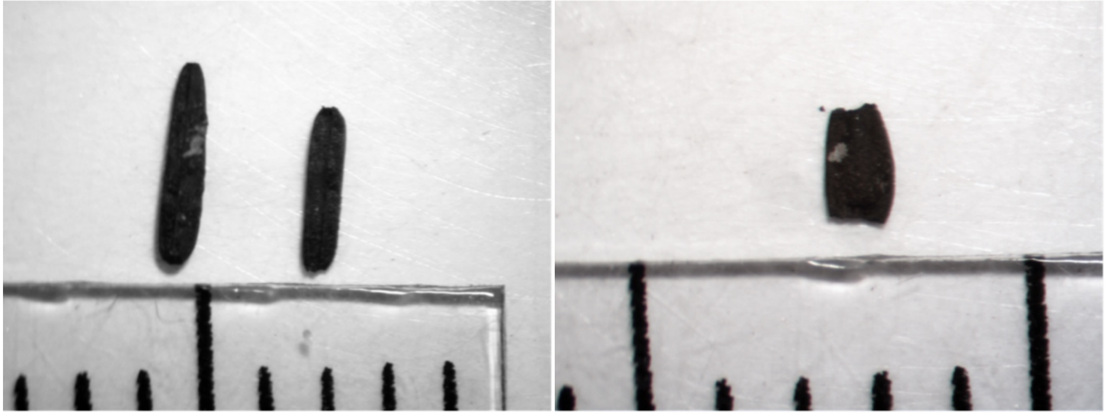

**Figure 5.1: Asteraceae species 1 and Asteraceae species 2 from MC-4A-1-4-LF**

The Cannaceae family grows in the Neotropics and can be found in low, open, and wet vegetation, as well as in forested areas, secondary vegetation, and as a weed in cultivated areas (Maas-van de Kamer and Maas 2008:265).The *Canna edulis* (achira) species has been cultivated as an ornamental (Balick and Arvigo 2015:137; Baran et al. 2010:1507) and as a food source, although it is not as nutritious, palatable, or high yielding as other crops found in this assemblage like manioc and maize (Gade 1966:408; Maas-van de Kamer and Maas 2008:266). Plants of the *Canna* genus grow in dense colonies in tropical and subtropical forests, wetlands, marshes, and riversides (Baran et al. 2010:1508). *Canna* was found once in this study, in the form of a starch grain (Figure 5.2).

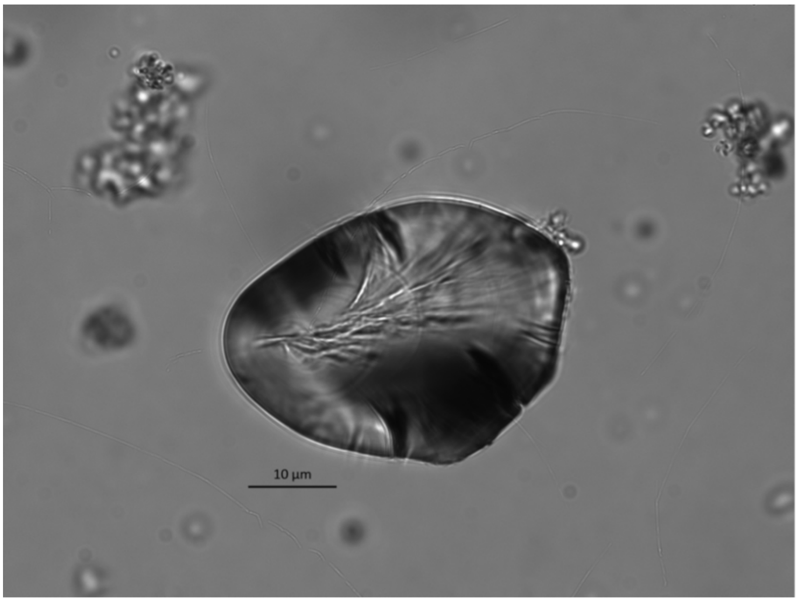

**Figure 5.2:** ***Canna*** **species from MC-9A-3-4 Wet Wash**

*Ipomoea batatas* (sweet potato) grows in tropical, subtropical, and warm temperate regions and is primarily consumed as a source of food (Srisuwan et al. 2006). Alongside human food, sweet potato is used to feed animals and is currently consumed as a source of medicine around the world (Mohanraj and Sivasankar 2014:733). Sweet potatoes are high in nutritional value and are full of carbohydrates, fibre, iron, and vitamins (Mohanraj and Sivasankar 2014:734). Yucatan Maya people use *Ipomoea batatas* to treat snakebite (Balick and Arvigo 2015:263). Sweet potato was identified twice in this study, in the form of starch grains (Figure 5.3).

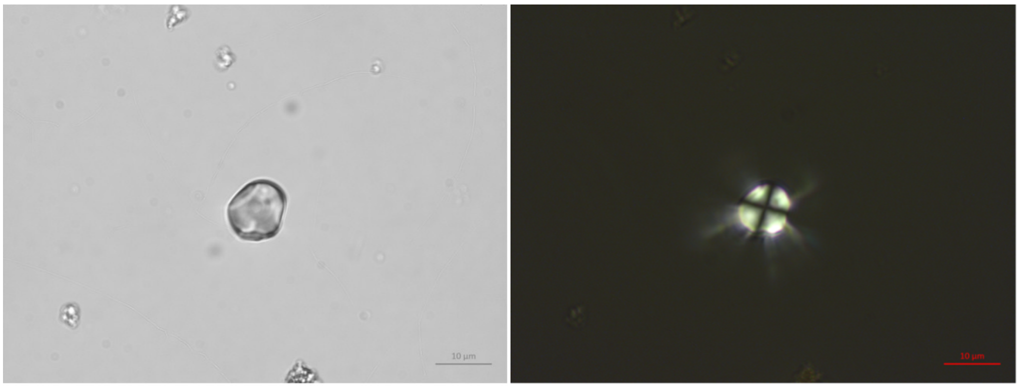

**Figure 5.3:** ***Ipomoea batatas*** **from MC-5A-3-6 Dry Wash**

*Lagenaria siceraria* (bottle gourd) is a member of the Cucurbitaceae family. Bottle gourds have been utilized as utensils such as containers and bowls, medicine, musical instruments, and as a source of food (Grimaldo-Juárez et al. 2018; Lentz 1991:273; Suárez-Hernández et al. 2022:1). Gourd plants inhabit tropical and temperate regions around the world, with Mexico being the origin of this taxon (Suárez-Hernández et al. 2022:1). Bottle gourd remains were found once in this study, in the form of a seed (Figure 5.4).

**Figure 5.4: cf. *Lagenaria siceraria* from MC-4A-1-3-LF**

*Manihot esculenta* (manioc) is considered a drought-crop as it is a resilient food source that is high in calories but low in fat and protein (Cagnato and Ponce 2017). While fresh manioc does not store well, when the root crop has been processed into flour it lasts indefinitely, and even unleavened bread made from this flour lasts for a long period of time before spoiling (Cagnato and Ponce 2017:277). Manioc is sensitive to excessive soil humidity but grows well in conditions other crops do not, such as drought and soils with high levels of aluminum or low levels of phosphorous (Cagnato and Ponce 2017:277). Manioc remains were found thirteen times in this study, in the form of starch grains (Figure 5.5 and Figure 5.6).

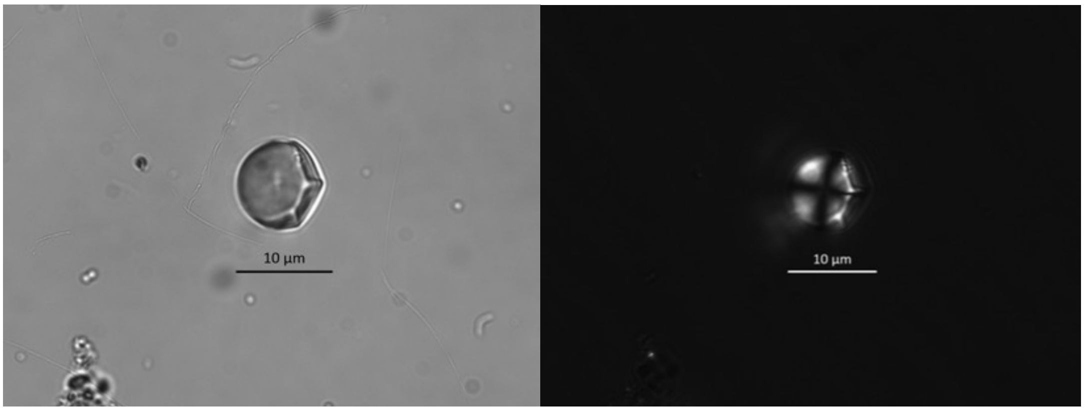

**Figure 5.5:** ***Manihot esculenta*** **from MC-3C-1-4 Wet Wash**

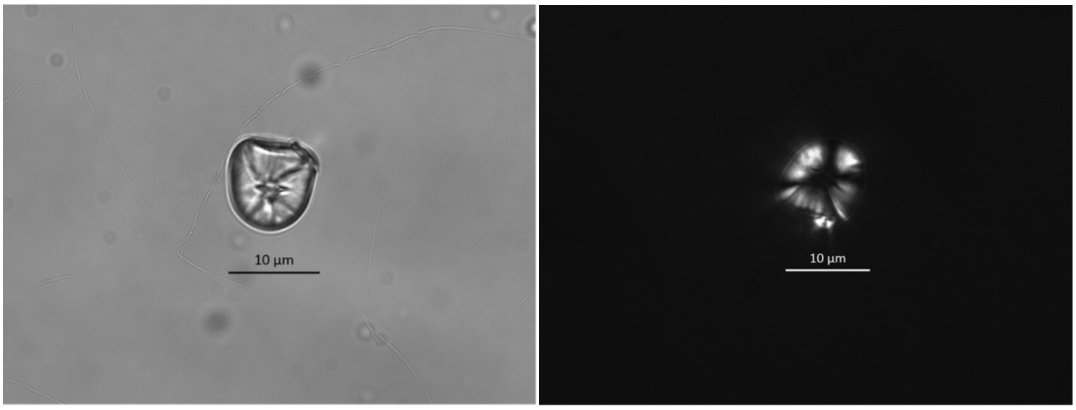

**Figure 5.6:** ***Manihot esculenta*** **from MC-3C-1-4 Wet Wash**

The Fabaceae (bean) family includes agriculturally significant crops such as pinto beans and lima beans. *Phaseolus*, the common bean genus, includes annual plants that grow in temperate and semitropical regions like Mexico and Guatemala (Corzo-Ríos et al. 2020:1). Beans are high in dietary fibre, resistant starch, and protein and are an extremely popular food item around the world (Corzo-Ríos et al. 2020:1). Species from the Fabaceae family are also used as a source of medicine in Belize (Balick and Arvigo 2015). A bean remain was found in this study, in the form of a starch grain (Figure 5.7).

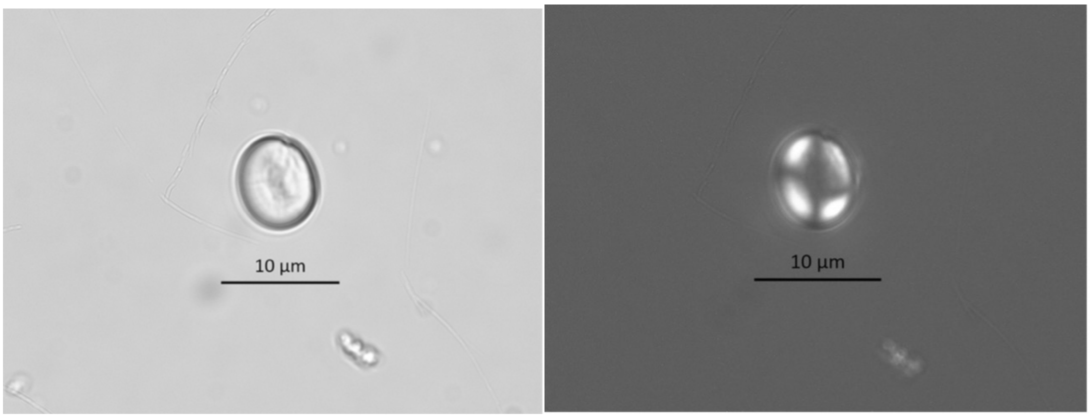

**Figure 5.7:** ***Phaseolus*** **species from MC-5A-3-6 Wet Wash**

The plants in the Heliconia genus are used as a medicine and source of food in Belize (Balick and Arvigo 2015). Heliconia species can be found in tropical and subtropical forests in the Americas (Avendaño-Arrazate et al. 2017:1211). Heliconias produce beautiful flowers that are cultivated as ornamentals (Avendaño-Arrazate et al. 2017:1211). Heliconias were found once in this study, in the form of a phytolith.

The Marantaceae (arrowroot) family is commonly used as a medicine, storage, food, and fibre (Balick and Arvigo 2015). Approximately 450 species of this family grow in the neotropics (Borchsenius et al. 2012:620). The most well-known species belonging to this family is arrowroot or *Maranta arundinacea* (arrowroot). The genus *Calathea* also belongs to Marantaceae and is currently a very popular ornamental. *Calathea allouia,* or lerén, is consumed in Central and South America. Marantaceae remains were found three times in this study, in the form of phytoliths (Figure 5.8).

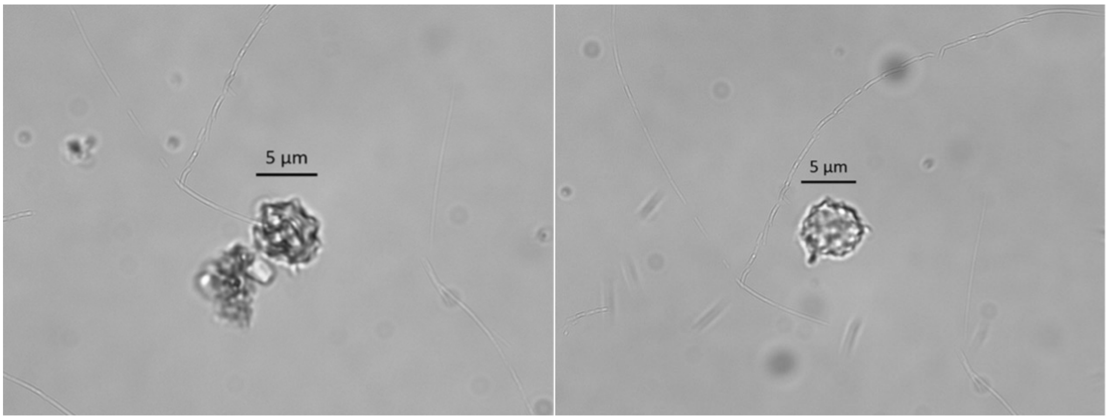

**Figure 5.8: Marantaceae species from MC-4A-2-3 A/B Fraction**

*Oxalis* (wood sorrel) is a cosmopolitan genus that is comprised of approximately 500 species (de Azkue 2000). *Oxalis* grows in the form of herbs and shrubs which have adapted to almost every environment (de Azkue 2000). Some species of *Oxalis* are utilized as a source of food and medicine (Bradbury and Emshwiller 2011; Sarkar et al. 2020). Wood sorrel species were found once in this study, in the form of a macroremains (seed).

*Piper hispidum* (Jamaican pepper) is a common shrub that grows in the American tropics in secondary growth and along streambanks of seasonal evergreen forests (Breedlove and Laughlin 1993:159). The flowers, leaves, roots, and stems are utilized in medical and healing practices (Lentz et al. 1998:256). Jamaican pepper was recovered twice in this study, in the form of macroremains (seeds).

Species in the Poaceae family are used as sources of food, medicine, building, fibre, and forage (Balick and Arvigo 2015). *Zea mays* is used to make food, beverages, and medicine (Balick and Arvigo 2015:156-157; Steinberg 1999:133). I discuss this taxon in greater detail throughout this chapter. Poaceae species apart from maize were found once in this study, in the form of a phytolith. Maize was recovered three times in this study, in the form of starch grains (Figure 5.9).

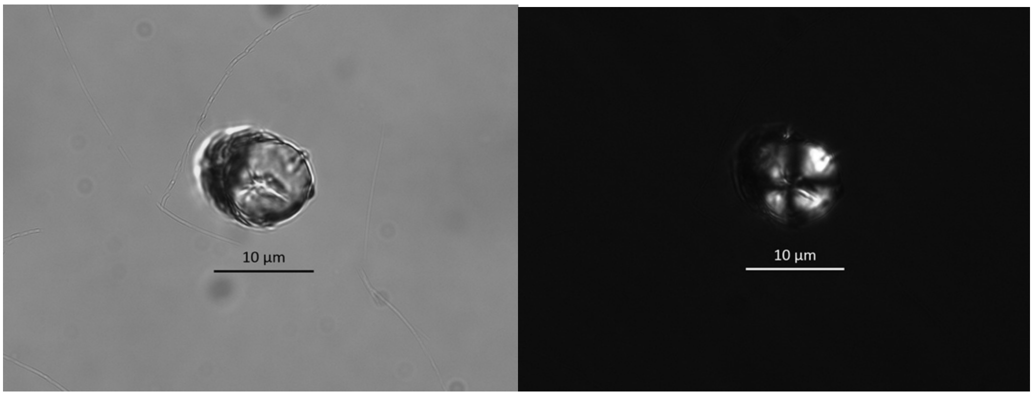

**Figure 5.9:** ***Zea mays*** **from MC-3C-1-4 Sonicated Wash**

The Polygonaceae (buckwheat) family grows in the form of herbs, shrubs, trees, lianas, or vines (Balick and Arvigo 2015:430; Martin and Barkley 1961:147). Taxa within this family grow in the tropical and temperate regions of the Americas in marshes, streams, lakes, and thickets (Standley and Steyermark 1946:125-129). The buckwheat family is used as food, medicine, construction, and charcoal (Balick and Arvigo 2015:430-432). Buckwheat family species were found twice in this study, in the form of macroremains (Figire 5.10).

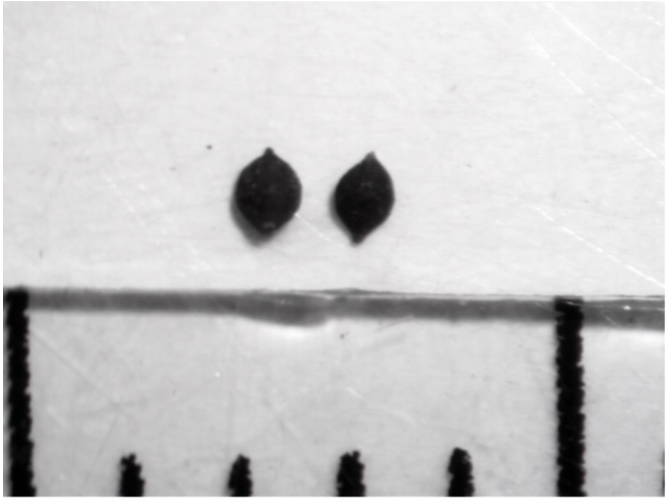

**Figure 5.10:** ***Polygonum*** **species from MC-3B-2-4-LF**

*Cecropia peltata*, otherwise known as trumpet tree, grows in Mexico, the West Indes, and South America (Lentz and Dickau 2005:61). This plant is a medium-sized tree of the lowland and often grows in pastures or second growth, thickets, or modified forests (Lentz and Dickau 2005:61). Trumpet tree is utilized in domestic medicine, split trunks can be used for water conduits and in construction of threshing platforms, and fried leaves make a high-quality smoking tobacco (Lentz and Dickau 2005:61). Trumpet tree was identified twice in this study, in the form of macroremains (seeds) (Figure 5.11).

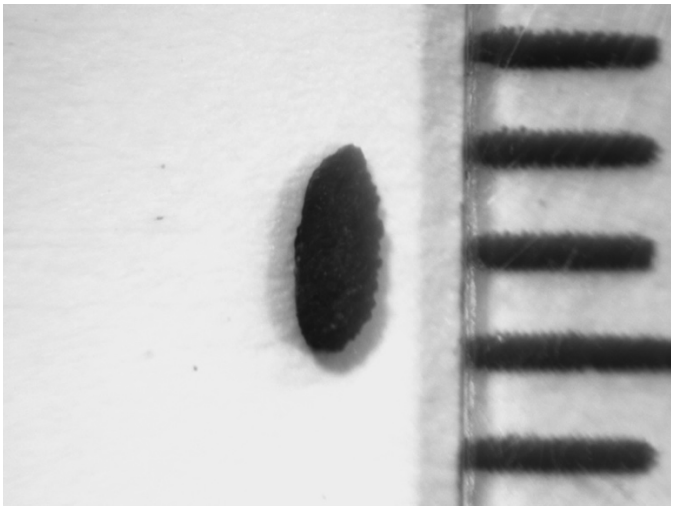

**Figure 5.11: *Cecropia peltata* from MC-4A-2-3-LF**

Species in the Vitaceae (grape) family are used as a medicine and food (Balick and Arvigo 2015:511-513; Kufer et al. 2005: Table 8; Lentz 1993:369; Lentz 1999: Table 1.1). They grow in the form of lianas or shrubs in lush low forests (Balick and Arvigo 2015:511; Lentz 1993:369). Grape family species were found once in this study, in the form of a macroremains.

As this overview of selected taxa demonstrates while there was a good variety of species recovered from samples taken from Macabilero, manioc (*Manihot escuelenta*) greatly outnumbered all other species. Alongside manioc, there was sweet potato, another root crop, that was recovered twice. Below, I use a subset of these results to address uniquity of identified food taxa by type of remain, identified taxa and artifact origin, identified taxa ubiquity according to time period, and identified root and seed crops and their recovered forms.

## Food Taxa: Recovered Remains and Ethnographic Studies of Preparation

To address my questions regarding plant staples and ethnoecology, I first turned to simply identifying food remains, and understanding this data based on the type of remain recovered. In the table below, I summarize the identified food taxa and the form in which they were recovered in. to get at potential plant staples and potential ethnoecological practices.

**Table 5.2: Ubiquity of identified food taxa by type of remain**

| | **Number of contexts where taxon remain was recovered** | | | |
|---|---|---|---|---|
| **Taxon** | **phytolith** | **seed** | **starch grain** | **Grand Total** |
| *Canna* sp. | | | 1 | 1 |
| Cannaceae/Marantaceae sp. | 1 | | | 1 |
| *Ipomoea batatas* | | | 1 | 1 |
| cf. *Ipomoea batatas* | | | 1 | 1 |
| cf. *Lagenaria siceraria* | | 1 | | 1 |
| *Manihot esculenta* | | | 8 | 8 |
| cf. *Manihot esculenta* | | | 5 | 5 |
| Marantaceae sp. | 2 | | | 2 |
| cf. Marantaceae sp. | 1 | | | 1 |
| Phaseolus sp. | | | 1 | 1 |
| *Zea mays* | | | 1 | 1 |
| cf. *Zea mays* | | | 2 | 2 |
| **Grand Total** | **4** | **1** | **20** | **25** |

Of the identified specimens recorded as sources of food, manioc (*Manihot esculenta*) had the highest ubiquity, with maize (*Zea mays*), having the second highest. This surprising finding is addressed in greater detail further on. The food taxa remain with the highest ubiquity was starch grains, followed by phytoliths and seeds. Marantaceae family taxa were the only potential foodstuffs recovered as phytoliths, while cf. *Lagenaria siceraria* was the only species recovered in the form of a seed. The lack of seed crop macroremains is unexpected. During my previous studies in the Usumacinta region, it was discovered that there was a lack of expected seeds from food crops (Lentz 1999), especially maize (Watson 2018a, Watson 2018b, Watson 2018c). For example, studies conducted at the ancient Maya kingdom of Piedras Negras did result in the positive identification of *Zea mays*, but mostly in the form of starch grains and phytoliths, with the very rare recovery of seeds or cupules (Morell-Hart and Watson 2018; Morell-Hart et al. 2018; Watson 2018a; Watson 2018b; Watson 2018c).

Edible underground storage tissues of plants, such as roots and tubers, were highly ubiquitous in this study. *Canna* rhizomes are rich in starch and are grown by Maya people in Yucatan and in other agricultural societies around the world (Abramiuk et al. 2011:268). Its tubers and roots are consumed, although they are not as nutritious or palatable as other crops like maize and manioc (Gade 1966:408; Korstanje 2017:93; Maas-van de Kamer and Maas 2008:266). Achira leaves are also used to wrap tamales and other foods (Balick and Arvigo 2015:137; Salazar et al. 2012:288). Sweet potato was and still is an important edible root around the world (Balick and Arvigo 2015:262; Batun Alpuche 2009:68; Piperno and Holst 1998:766). This root crop can self-propagate from cuttings (Bronson 1966:264) and is often consumed after boiling or baking (Salazar et al. 2016:141). As a root crop, sweet potatoes are not as susceptible to climate changes and perturbations and can withstand drought where other seed crops fail (Fedick and Santiago 2022:2; Staller 2010:34). Gourds are also commonly grown across Mesoamerica and often act as famine foods (Staller 2010:34). Bottle gourds (*Lagenaria siceraria*) are most commonly used as containers but are edible when unripe (Korstanje 2017:83; Grimaldo-Juarez et al. 2018). Their seeds are also eaten (Sheets et al. 2012:274).

Manioc is typically consumed after being cooked or it is processed into a flour that can last indefinitely (Cagnato and Ponce 2017:277). This root crop can grow efficiently in poor environments, such as drought or low soil pH, but does require well-drained soils (Cagnato and Ponce 2017:277). Many species of manioc must be processed, peeled, washed, and grated prior to consumption to eliminate a toxic compound that the crop creates (Cagnato and Ponce 2017:277). Manioc can be consumed after boiling, frying, made into a flour, or depending on the variety, eaten raw (Cagnato and Ponce 2017:278). It can also be roasted, steamed, grilled, or boiled (Schwerin 1972:40). As manioc was used as a root crop, it is difficult to find archaeologically, as it does not preserve well, is thoroughly processed prior to consumption (Cagnato and Ponce 2017:277) and has unconsumed seeds that are rarely carbonized. Manioc is cultivated year-round whereas other crops, such as maize, are restricted to seasonal cycles (Schwerin 1972:46). Once harvested, manioc deteriorates rapidly and needs to be consumed within two days before spoiling if not being processed into another state (Sheets et al. 2012:272-273). The Marantaceae family, otherwise known as the arrowroot family, typically grows underground rhizomes and tubers. Knowledge about what roles Marantaceae held in the ancient Maya world is still lacking, but researchers have learned that species like *Maranta arundinacea* (arrowroot) were harvested for their edible rhizomes and tubers (VanDerwarker et al. 2015).

Seed crops were less well represented in this study, by ubiquity. *Zea mays* was recovered solely in the form of starch grains. Many archaeologists have found maize to be one of, if not the most, significant crop among the ancient Maya (Farahani et al. 2017; Hull 2010; Price et al. 2018; Rand et al. 2020; Somerville et al. 2013). Maize can be prepared into a gruel to make *atole*, tamales, tortillas, dough or used in soups and stews (Cagnato 2018:247; Cheetham 2010:354; Cucina et al. 2011:560; Hull 2010). It can also be fermented and ingested as the alcoholic beverage *chicha* (Cucina et al. 2011:560). Maize was boiled, steamed, baked (Cheetham 2010:261). Taube (1989) hypothesizes that tamales were likely one of the main elite and ritual foods of Maya peoples.

Beans were also a very popular crop amongst the ancient Maya and are a member of the Mesoamerican food triad alongside maize and squash (Fedick and Santiago 2022:4; Lentz 1999). The ancient Maya consumed both wild and domesticated beans (Cagnato and Ponce 2017). The *Phaseolus* genus contains approximately 80 species that are native to the Americas (Feddema 1993:63). Common bean, tepary bean, small lima bean, and runner bean are all cultivated *Phaseolus* species that are important food crops (Feddema 1993:63). Alongside maize and manioc, common beans such as *Phaseolus vulgaris* were a prominent economic species among Maya peoples (Seinfeld 2011:49) The traditional lowland Maya diet consisted of maize, beans, squash, chilies, and, depending on the region, cacao (Hageman and Goldstein 2009:2842). Beans were picked and stored dry and were prepared for consumption by boiling (Staller 2010:42; Wyatt 2002:5). The beans would then sometimes be mashed and added to maize dough or stew, or the boiled beans would be flavoured with chile and eaten with tortillas (Wyatt 2002:5). Occasionally beans are used as a filling in tamales (Salazar 2012:290).

As seen in this subset of recovered botanical residues, starch grains were the most recovered form of food taxa. No taxa were recovered in multiple forms. Manioc was the most recovered species, with thirteen identified starch grains, while maize was the second-most, with three identified starch grains. Starch grains are usually representative of the edible part of the plant, while phytoliths are usually representative of the discarded/processed part of the plant. These food species can grow in varying conditions. *Canna* grows in low, open, and wet vegetation, as well as in forested areas, secondary vegetation, and as a weed in cultivated areas (Maas-van de Kamer and Maas 2008:265). Sweet potato grows in tropical, subtropical, and warm temperate regions (Srisuwan et al. 2006) and have good adaptability to marginal growing conditions (Truong et al. 2018). Bottle gourds grow in tropical and temperate regions and can be cultivated in all types of soil but thrives best in heavily manured loams. This species requires lots of water when grown during dry weather (Minocha et al. 2015). Manioc grows well in marginalised environments and can survive periods of long drought. Dependant on temperatures and mean rainfall, sweet manioc will have a shorter growing season compared to bitter manioc (Cagnato and Ponce 2017:277). Marantaceae species is a large family that grows broadly in the neotropics. Beans grow best under sun and in well-drained soil. Maize grows best with warm and sunny weather and moderate rainfall or irrigation. Of the above food plants, root crops such as manioc and sweet potato are drought resistant, while others such as maize, beans, canna and bottle gourd do not fare well in drought conditions.

## Food Taxa: Processing and Consumption

Using the same subset of food plants targeted in the previous section, I now turn to addressing which artifacts yielded which plant remains. In the table below, I summarize identified plant remains that were associated with artifacts and break down the exact artifact each species was associated with to get at my questions pertaining to plant staples and food choices.

**Table 5.3: Identified taxa and artifact origin**

| | **Origin** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Ceramic sherd** | | | TOTAL | **Human tooth** | | TOTAL | **Obsidian blade fragment** | | | TOTAL | **GRAND TOTAL** |
| **Taxon** | **Dry Wash** | **Sonicated Wash** | **Wet Wash** | | **Dry Wash** | **Wet Wash** | | **Dry Wash** | **Sonicated Wash** | **Wet Wash** | | |
| **Cannaceae** | | | | | | **1** | **1** | | | | | **1** |
| *Canna* sp. | | | | | | 1 | 1 | | | | | 1 |
| **Convolvulaceae** | | **1** | | **1** | **1** | | **1** | | | | | **2** |
| cf. *Ipomoea batatas* | | 1 | | 1 | | | | | | | | 1 |
| *Ipomoea batatas* | | | | | 1 | | 1 | | | | | 1 |
| **Euphorbiaceae** | **2** | **2** | **1** | **5** | **3** | **1** | **4** | **1** | | **2** | **3** | **12** |
| cf. *Manihot esculenta* | 1 | 1 | | 2 | 1 | | 1 | 1 | | 1 | 2 | 5 |
| *Manihot esculenta* | 1 | 1 | 1 | 3 | 2 | 1 | 3 | | | 1 | 1 | 7 |
| **Fabaceae** | | | | | | **1** | **1** | | | | | **1** |
| *Phaseolus* sp. | | | | | | 1 | 1 | | | | | 1 |
| **Heliconiaceae** | | | | | **1** | | **1** | | | | | **1** |
| Heliconiaceae sp. | | | | | 1 | | 1 | | | | | 1 |
| **Poaceae** | | **1** | | **1** | | **1** | **1** | | **1** | **1** | **2** | **4** |
| cf. *Zea mays* | | 1 | | 1 | | | | | 1 | | 1 | 2 |
| Panicoid sp. | | | | | | 1 | 1 | | | | | 1 |
| *Zea mays* | | | | | | | | | | 1 | 1 | 1 |
| **Grand Total** | **2** | **4** | **1** | **7** | **5** | **4** | **9** | **1** | **1** | **3** | **5** | **21** |

This table displays food taxa identified from residues deposited on tools, vessels, and human teeth. Ceramics, human teeth, and obsidian blades were sampled and the results from the dry, wet, and sonicated washes are displayed above. As described in the previous chapter, a dry wash is performed to collect materials that were in the surrounding matrix of the artifact, a wet wash to remove any additional adhering materials and track movement of residues, and a sonicated wash to view materials that were embedded in the artifact most likely through use. Residues from human teeth, are excellent proxies for understanding diet, as they provide evidence of which foods individuals were consuming. Ceramics can provide insight into plants that were being processed, prepared, and served, while obsidian tools provide a wider range of plantstuffs that were being processed and manipulated by humans for various purposes.

Recovered from the wet washes of the human teeth were a *Canna* species, *Manihot esculenta*, *Phaseolus* species, and a Panicoid grass. Apart from the Panicoid phytolith, all the identified materials are consumed as food sources. No botanical materials were discovered in the sonicated washes, which could mean that any deposited materials on the teeth were recovered entirely during the wet wash.

The wet and sonicated washes from ceramic vessels revealed several *Ipomoea batatas* and *Manihot esculenta* starches. Both species are common food items--sweet potato and manioc--and their association with ceramics can signify that these items were being cooked and served at Macabilero.

*Manihot esculenta* and *Zea mays* were also identified from the wet and sonicated washes of the obsidian blades, signifying that manioc and maize were being processed at Macabilero using these tools. In terms of the dry washes, manioc was identified in the surrounding matrices of the ceramics; sweet potato, manioc, and heliconia were present in the soil matrices around the human teeth; and manioc was present in the surrounding matrix of one of the obsidian blades.

One of the human teeth (MC-5A-3-6), manioc was recovered in both the dry and wet washes, while Heliconiaceae and sweet potato were solely recovered from the dry wash, and bean was identified only in the wet wash. Another of the human teeth (MC-9A-3-4), only had a *Canna* species and panicoid identified in the wet wash. The final human tooth (MC-9A-3-4) had manioc starch grains recovered in the dry wash. A ceramic sherd from a looted context (MC-6C-1-SURF) had manioc in the wet wash, and sweet potato and maize in the sonicated wash. Another ceramic sherd (MC-3C-1-2) had manioc in the dry and sonicated washes. An obsidian blade (MC-3C-1-4) had manioc in both dry and wet washes, and maize in the wet and sonicated washes.

As seen in this subset of recovered botanical residues, sweet potato, manioc, *Canna*, beans, and maize were all processed at Macabilero. We can also see that *Canna*, manioc, and beans were directly consumed as they were identified on human teeth, but it is important to note, these were all identified in the dry and/or wet wash. The dry wash is associated with the surrounding matrix of the artifact, while the wet wash is used to track movement of residues. These starch grains are associated with the surrounding matrix of the teeth, but they could also have been embedded in the artifact or were in the surrounding matrix of the teeth, meaning that they were indeed consumed by the individual.

## Food Taxa: Changes and Continuities Through Time

Using the same subset of food plants targeted in the previous sections, I now address changes and continuities of taxa through time, specifically regarding the Late Formative to the Postclassic. In the table below, I summarize the recovered plant species and the context in which they were found to get at my questions regarding plant staples, changes in ethnoecology and diet, abandonment, and what implications these results may have.

**Table 5.4: Identified taxa ubiquity according to time period**

| | **Time Period** | | | | | |
|---|---|---|---|---|---|---|
| **Taxon** | **Late Formative (3 lots)** | **Late Formative to Terminal Formative (2 lots)** | **Late Formative to Early Classic (5 lots)** | **Late Classic (1 lot)** | **No Context (1 lot)** | **Grand Total** |
| Asteraceae sp. 1 | 1 | 1 | 2 | | | 4 |
| Asteraceae sp. 2 | | 1 | 1 | | | 2 |
| *Canna* sp. | | | | 1 | | 1 |
| Cannaceae/Marantaceae sp. | | | 1 | | | 1 |
| cf. *Ipomoea batatas* | | | | | 1 | |
| cf. *Lagenaria siceraria* | | | 1 | | | 1 |
| *Lonchocarpus*/*Piscidia* | | 1 | | | | 1 |
| cf. *Piper hispidum* | | 1 | | | | 1 |
| Heliconiaceae sp. | 1 | | | | | 1 |
| *Ipomoea batatas* | 1 | | | | | 1 |
| *Manihot esculenta* | 2 | | 4 | 1 | 1 | 7 |
| cf. *Manihot esculenta* | 1 | | 4 | | | 5 |
| Marantaceae sp. | | | 2 | | | 2 |
| Panicoid | | | | 1 | | 1 |
| *Phaseolus* sp. | 1 | | | | | 1 |
| Poaceae sp. | | 1 | | | | 1 |
| cf. Marantaceae sp. | | | 1 | | | 1 |
| Polygonaceae sp. | | 1 | 1 | | | 2 |
| UNKN seed 305 | 1 | | 1 | | | 2 |
| UNKN seed 353 | | | 1 | | | 1 |
| *Zea mays* | | 1 | 2 | | | 3 |
| cf. *Zea mays* | | | 1 | | 1 | 1 |
| **Grand Total** | **8** | **7** | **22** | **3** | **3** | **43** |

The above dates are based on the chronological designation of ceramics that were identified from the same lots as the paleoethnobotanical samples, and any of the above time periods overlap with other time periods. But there are nonetheless some conclusions that can be made regarding the timing of various foodstuffs. Formative period contexts are the majority of the samples for paleoethnobotanical materials. Seventeen samples were dated to the Formative period, 12 to the Classic period, and four to the Postclassic period. Despite some overlap between the Formative and Classic periods, we can still see slight changes over time. Sweet potato and common bean taxa were only recovered from Formative period contexts, with no evidence from later contexts. Manioc and maize were all consumed at Macabilero from the Late Formative through the Late Classic periods. The Panicoid grass taxon was found solely in a Late Classic context. The only species recovered from the Postclassic contexts was *Piper hispidum,* which was also potentially present during the Late Formative period.

As seen in this subset of foodstuff residues, manioc was present at Macabilero from the Late Formative into the Late Classic. A *Canna* species and panicoid grass were the only taxa that were solely recovered from the Late Classic context. The remaining taxon were all belonging to Late Formative or Early Classic contexts. The Late Formative to Early Classic context had the highest richness of species, but this context also had the highest number of lots at five.

### Grains and Root: Recovered Forms of Foods

Using the same subset of food plants targeted in the previous sections, here I address identified root and seed crops specifically, and in which form they were recovered. In the table below, I summarize root, tuber, and rhizome crops, and seed and caryopsis crops, in relation to their recovered form of recovery (phytolith, seed, starch grain) to get at my research questions regarding staple crops and changes in ethnoecology and diet.

**Table 5.5: Identified root and seed crops and their recovered form**

| | **Phytolith** | **Seed** | **Starch Grain** | **Grand Total** |
|---|---|---|---|---|
| **Root, Tuber, and Rhizome Crops** | | | | |
| *Canna* sp. | | | 1 | 1 |
| Cannaceae/Marantaceae sp. | 1 | | | 1 |
| *Ipomoaea batatas* | | | 1 | 1 |
| cf. *Ipomoaea batatas* | | | 1 | 1 |
| *Manihot esculenta* | | | 8 | 8 |
| cf. *Manihot esculenta* | | | 5 | 5 |
| Marantaceae sp. | 2 | | | 2 |
| cf. Marantaceae sp. | 1 | | | 1 |
| **Seed and Caryopsis Crops** | | | | |
| cf. *Lagenaria siceraria* | | 1 | | 1 |
| *Phaseolus* sp. | | | 1 | 1 |
| *Zea mays* | | | 1 | 1 |
| cf. *Zea mays* | | | 2 | 2 |
| **Grand Total** | **4** | **1** | **20** | **25** |

Compared to seed crops, root crops had the highest ubiquity and highest number of taxa represented. Manioc alone was recovered in four times as many contexts as maize. This result is highly significant, as root crops are less likely to be detected archaeologically. They do not preserve well, produce few diagnostic phytoliths, are often propagated without seeds, and are prepared in ways that eliminate diagnostic starches (Cagnato and Ponce 2017; Hather and Hammond 1994; Isendahl 2011; Morell-Hart 2019; Piperno and Pearsall 1998). Tubers also do not carbonize well and their recovered phytoliths are typically very few or unidentifiable (Piperno and Holst 1998:765). The Marantaceae (arrowroot) and Cannaceae family specimens were only recovered in the form of phytoliths. Manioc (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), and the achira (*Canna* sp.) specimen were recovered solely in the form of starch grains.

Specifically looking at maize, this species can be identified in its many macroremain forms, whether that be cupule, kernel, stalk, leaf, or cob, and as starch grains and phytoliths (Morell-Hart 2019:237). It thus has many more "opportunities" to be visible in paleoethnobotanical research. Maize has been categorized as a staple food amongst Maya peoples (Ardren and Miller 2020:4; Batun Alpache 2009:68; Wyatt 2002) and has been recovered in all forms across Mesoamerica region (Balzotti et al. 2013; Morell-Hart 2011). Due to the results of studies such as these, maize is always expected to be recovered from ancient Maya sites and found in great numbers. But as we have found at Piedras Negras, Budsilja, and now Macabilero, maize is not something to be expected in great quantities in the Usumacinta River region, nor is it highly ubiquitous relative to root crop species (Morell-Hart and González Córdova 2017; Morell-Hart and Watson 2018; Morell-Hart et al. 2018; Watson 2018a; Watson 2018b; Watson 2018c). I interpret and address the significance of these results in the following chapter.

## Summary of Results

A wide variety of plant species were recovered from Macabilero in the forms of macroremains and microremains. These plants are domesticated and non-domesticated (whether gathered wild or managed), representing an ongoing knowledge of surrounding environments and landscapes. The Maya peoples at Macabilero were not over-reliant on domesticated crops, but also incorporated non-domesticated crops as well. Plants used as food, medicine, and ornamentals were all successfully identified. Many of the recovered plant species have also been identified at nearby Maya sites in the Usumacinta region. Several of the identified species are commonly used as food sources, such as sweet potato, manioc, and maize, all of which were commonly consumed in ancient Maya communities. Ceramics, human teeth, and obsidian blades were all sampled in this analysis, and yielded relatively high counts of root crop starch grains.

Many of the excavated contexts at Macabilero contained ceramics from two different time periods, making it difficult to study exact changes through time. Regardless, we do see gradual trends in time, including an ongoing reliance on Poaceae species (e.g., maize), manioc, and achira over time. One of the most interesting findings from these results is the relative lack of maize and beans represented and the relative frequency of root crops like manioc. As previously discussed, the odds of recovering seed crops such as maize are much higher compared to root crops, and yet root crops were recovered on a 4-1 basis compared to seed crops. The Maya peoples at Macabilero were not just relying on maize, beans, and squash, they were also frequently incorporating root and tuber species into their diet. In the following chapter, I consider: why were root crops favoured and what could this have meant for the people of Macabilero?

# Chapter 6: Ethnoecology and Plant Food Choices at Macabilero

## Introduction

Defining the "fall" or "collapse" of a society can be quite difficult, as these occurrences are never the result of single or simple causes, and societies undergo regular changes and demographic shifts. In spite of these cautions, ancient Maya societies have been heavily popularized as experiencing "collapse." This popular notion of Maya "collapse" is associated with the end of the Classic period, but the end of the Formative Maya period has also been marked as a "collapse" as well (Inomata et al. 2017; Dunning et al. 2012). Localized control of water resources by elites, the intensification of local agricultural production, the stratification of land wealth, drought, and socio-political dynamics have all been hypothesised as contributing factors in the abandonment of Formative settlements. In this final chapter I explore the relationships that humans may have had with the plants recovered as botanical residues, described in the previous chapter. I use these analyses of botanical residues to address agriculture, consumption practice, landscape use, and abandonment.

The goal of this final chapter is to address my specific research questions: How are plant staples at Formative period sites similar or different to those at Classic period sites? How does this reflect changes in ethnoecology, as related to land management, and food choices? What was the relationship between diet, ethnoecology, and the abandonment of Formative settlements? What are the implications for hypotheses about the Formative Maya "collapse" that relate abandonment to ecological stress and potential crop failures? These questions are posed to address our current understandings of ethnoecological relationships in the ancient Maya area, which in turn aids understanding of ancient Maya social dynamics and cultural history. Following my previous description in Chapter 5 of recovered plants, their associated contexts and time periods, and artifacts from which they were extracted, here I interpret these analyses to address the roles plants may have played at Macabilero and how people interacted with the landscape. Of particular significance will be a discussion about the prevalence of root crops compared to seed crops and the relative lack of maize at Macabilero. This discussion will closely tie into the research questions regarding plant staples, Formative Maya "collapse", and ethnoecology.

## Plant Staples

Maize, beans, squash, and manioc have been recovered from other Formative period Maya sites such as Cuello and Cerros (Morell-Hart et al. (in press); Seinfeld 2011:49). Another important crop recovered at Macabilero, bottle gourd (*Lagenaria siceraria*), is also a documented food choice during times of famine (Staller 2010:34). But the most well-known food staple of the Maya area is maize. Emerging as a domesticate in the Archaic period and growing in popularity as early as the Formative period, maize became not only a staple crop to Maya peoples, but an important symbol as well (Ardern and Miller 2020; Morehart and Butler 2010; Staller 2010). Maize was closely associated with Maya religious beliefs, to the point that there was a Maize God and humans were considered to be made from maize dough (Morehart and Butler 2010:599). Maize was transformed into tamales and tortillas, the primary maize foods that were represented in iconographic works, epigraphically, and linguistically (Taube 1989).

Based on the various ways in which maize was represented across media, there is no doubt it was being consumed, but recent results led to the question as to whether maize has been overrepresented (Morell-Hart 2019; Morell-Hart et al. (in press)). When compared to the recovery rates of presumed less popular crops such as manioc, maize recovery has been startlingly limited. Other popular plant crops, such as sweet potato, bean, achira, and gourd, were recovered from Macabilero, as is expected of a Maya site (Fedick and Santiago 2022; Lentz 1999). But none of these taxa are as prevalent when compared to the high counts and ubiquity of manioc (see also Sheets et al. 2011).

Tubers in general are more productive than maize and yield a larger harvest (Bellacero 2010:68). As Staller (2010:34) explains, tubers in general were extremely important crops because they were able to survive unstable climate conditions while crops such as maize could not, making them the more reliable crop choice. Manioc has high-drought resistance and would be highly likely to survive multiple years of extreme drought (Fedick and Santiago 2022:3).

In this study, starch grains representing manioc tubers were the most common and ubiquitous plant remain recovered. This finding is significant for several reasons. First, the caloric value of manioc is almost equivalent to maize, but manioc has a lower protein content (Bellacero 2010:68). Second, manioc can grow in a variety of different conditions (Bellacero 2010:67). While our understanding of ancient Maya relationships with manioc is still developing, we are aware that manioc and malanga (*Xanthosoma* spp.) are currently grown and relied upon in times of drought or when supplies of seed crops are low in stock (Sheets et al. 2011:2). Manioc is also capable of growing in more unbalanced soils than other seed crops, making it an ideal choice dependant on location (Sheets et al. 2011). The one condition manioc does not thrive in is waterlogged soils but can easily be planted in poor or acidic soils while other plants cannot. Beneficial for the grower, manioc takes less effort in tending and planting as well. Manioc very rarely produces seeds but is easily planted vegetatively, in the form of a stake, which is a portion of the stem of a manioc plant that is buried in soil (Sheets 2011:4). In combination, these features of manioc make it an attractive candidate as a staple food.

While there are many benefits to the growing and harvesting of manioc, it is a root crop that does have a very short shelf life and must be consumed within a few days of harvest before it deteriorates. The length of time this crop remains consumable does not compare to other popular crops of the time such as maize or beans. As the shelf life is so short, manioc must be processed into a dry flour soon after it is harvested, which lasts a considerable length of time in storage (Sheets et al. 2011:4). Another solution is to leave the manioc in the ground and only harvest as needed, saving the loss of a very valuable resource (Sheets 2011:4). Most varieties of manioc also require specialized processing to remove cyanins and render the tuberous root edible. As a staple food, then, manioc would require different harvesting and processing techniques than maize.

## Food Choices and Agricultural Practice

The Usumacinta River region, where Macabilero is located, has a karstic landscape with *arroyos, cenotes,* and caves (Alcover Firpi, 2020; Aliphat 1994, as cited in Schroder 2019). This hilly terrain is covered in dense tropical forests that receive high amounts of rain every year (Anaya-Hernandez 1999:42-43). The area is also full of good farmland and flint deposits. Situated next to the largest beach on the Usumacinta, Macabilero is very close to fresh water and a transportation route to large sites such as Piedras Negras and Yaxchilán (Canter 2007). The environmental conditions of this study area allow for healthy forests and lower vegetation to grow (Alcover Firpi 2020). Remote sensing analysis identified ecologically diverse and healthy areas around the wetland fields, suggesting that not all areas were cultivated, but some spaces may have once been managed forests (Alcover Firpi 2020). Managed forests provide a wide variety of useful plants and animals for communities to take advantage of, from pharmaceutical plants to construction supplies. Managed forests and wetland fields are excellent spaces for flora and fauna to thrive, further benefitting any surrounding communities (Alcover Firpi 2020). While the presence of managed forests near Macabilero is still unknown, Alcover Firpi (2020) identified areas that could further explore their potential in the area. This thesis has documented a number of non-domesticated species (see Table. 5.1) that were used in some way by Macabilero residents, whether they were gathering these plants wild or managing the plants in some way. The fauna identified at Macabilero follow the expectations of animals at Maya sites: white-tailed deer, dogs, rodents, small and large birds, and reptiles such as turtles, iguanas, and crocodiles. These fauna identifications reflect Macabilero's location near the Usumacinta River (Newman 2018) but also, as with recovered flora species, the use of a broad number of microenvironments.

Apart from wild, fallowed, or otherwise managed areas, using the studies of the modern terrain of Macabilero and the areas around it, we know that there was available land that could have been utilized for the production and harvest of various crops. Based on the recovery of crops such as maize, beans, manioc, sweet potato, and arrowroot, we know that these agricultural products were being consumed at Macabilero and probably being grown in the cultivable land surrounding Macabilero. These findings are consistent with those of other Maya sites (see Morell-Hart et al. in press) and thus expected at Macabilero. Unexpectedly, however, manioc was the most commonly identified plant crop from this settlement. As previously explored, manioc is extremely resilient in unfavourable conditions where other crops would perish and can last indefinitely once processed into a flour (Cagnato and Ponce 2017:277). Despite being a root crop, which is very hard to recover from the archaeological record, there was a clear abundance of manioc remains at Macabilero, compared to all other species.

During the Formative period, residents of Macabilero consistently made the choice to consume more manioc as compared with other crops. Given the history of Maya peoples favouring maize and the conditions in which manioc grows, combined with the hypothesized drought and political strife nearing the end of the Formative period, this ubiquity of manioc has broader implications. I present two possible explanations for this relative ubiquity, and the implications of each.

First, in times of strife, the people at Macabilero may have turned to a more reliable crop, manioc. Manioc has indefinite shelf life as a flour, grows underground until ready for harvest (added protection from crop pilfering and burning), and can be cultivated year-round make it an excellent crop (Cagnato and Ponce 2017:277). Further comparative studies from Early Formative and Late Classic occupations would help to address this hypothesis.

Alternately, or perhaps in tandem, by choosing to plant manioc, the people at Macabilero would be interacting differently with their environment as compared to farming more labour-intensive and water-needing crops like beans, squash, or maize. As motioned in the Lidar study of Macabilero and the surrounding area the conditions of this area allow for healthy forests and lower vegetation to grow (Alcover Firpi 2020:159), creating habitats in which a wide variety of plant crops could thrive, yet manioc, a purportedly less popular crop among Maya people, was recovered in abundance. Manioc grows in unfavourable conditions (added resilience in drought conditions or with poor soils), and as it is stored underground and grown year-round, the tubers can be planted and collected at any time. Seeing a shift from seed crops like maize that are more exposed to the elements, to root crops such as manioc and sweet potato that rely on less water and are less exposed to the elements, may indicate a potential drought during this time in this area. Future paleoethnobotanical studies targeting the terrain around Macabilero could strengthen this hypothesis.

Whether in conditions of political conflict or environmental duress, as described above, or potentially for preferred flavours and preparations (not explored here), we see a clear preference for manioc consumption. Regardless, at Macabilero we can see that if there were ecological stressors such as drought at the end of the Formative period, the people were able to continue living and residing at the site, supported by the reliability of manioc.

## Ethnoecology, Formative Period Abandonment, and "Collapse"

By the beginning of the Early Classic period Macabilero was for the most part abandoned (Alcover-Firpi 2020:15). While many other sites were also abandoned by the Early Classic period, other large centres like Piedras Negras and Yaxchilan experienced growth in size instead (Alcover-Firpi 2020:120). During the Late and Terminal Formative periods, centres either constructed defensive features or were abandoned. Macabilero was one of three sites in the Usumacinta River region that erected defensive features, signifying a time of increased violence (Alcover-Firpi 2020:122). Stressors were political and potentially environmental.

As explored previously, manioc and other root crops are extremely reliable, which is ideal during times of strife, when there are larger concerns than those involving food. Having a reliable crop like manioc during unstable times can provide reassurance, and the guarantee of meeting the population's food needs. During times of political strife, when there was warfare the people at Macabilero potentially did not wish to leave their fortified settlement. Having manioc flour ready to be prepared in storage, and the tubers stored underground in the surrounding area, would be much more accommodating compared to other crops such as beans and squash that exposed to pillaging and burning, more reliant on water and ideal soil conditions, and more easily given in tax and tribute. Populations that have undergone severe political stress, such as those in the Southeast Asian area of Zomia, have opted to grow root crops as well. James Scott (2009:181) writes that people who remained in their villages while others fled, would choose to grow root crops such as manioc or sweet potato, as they needed little care, could be harvested at their leisure, and could not be destroyed easily. At Macabilero, it may be that the underground tubers would not be destroyed should groups be moving nearby, and the habitants would not need to risk leaving the fortress and being exposed to the dangers of political strife. Similarly, Allen (2016:55) discusses the *kumara* crops significance to Maori people during war season. When *kumara*, otherwise known as sweet potato, is planted in October, the start of the war season is signalled. Once the *kumara* has been planted, the responsibilities of gardening were not as high, and the men could go to war while the women and children tended the crop. Because of the kumara planting in October, there was an abundance of food from November through March whilst the men were at war. It was then easier for the war parties to find food whilst on the move. The onset of harvest in April would often symbolize the end of the war season and the men would return (Allen 2016:55). *Kumara* storage pits are located within and outside communities' palisades and are common amongst the Maori (Allen 2016:56). Manioc season may similarly have nudged the scheduling of conflict in the May area. Furthermore, the relatively heavy consumption of manioc at Macabilero might have provided a buffer against site abandonment for reasons of conflict.

Alongside being reliable during periods of political instability, manioc is also reliable during times of poor climate. Where other crops fail, manioc is highly resilient and would have been an excellent crop to reliably cultivate during droughts, as hypothesized by several scholars (Ebert et al. 2019; Webster et al. 2007). The relatively heavy consumption of manioc might have provided a buffer against site abandonment for reasons of environmental stress.

Drought and warfare could have both occurred, making manioc the ideal crop for the people of Macabilero before they abandoned the fortress. Alcover Firpi (2020) hypothesizes, moreover, that the community at Macabilero decided to abandon their settlement since they were no longer in need of a monumental defensive space.

Regardless, at this point in time, given the heavy reliance on manioc crops and the use of non-domesticated species, maize does not appear to have held primary importance, and thus maize crop failure does not appear to be a reason for abandonment. People at Macabilero made use of a wide array of resources in the landscape, and grew a diverse portfolio of crops, without relying overly on any one food resource. For these reasons, Macabilero does not fit into the popularized notion of "collapse" due to maize agriculture failure.

## Directions for Future Research

Paleoethnobotanical analyses at Macabilero reveal lifeways at the end of the Formative period when conflict was evident. High counts and ubiquity of root crops combined with an overall lack of expected crops like maize, beans, and squash, highlight how the people at Macabilero consistently chose to grow a more reliable root crop, perhaps especially in times of unrest. Surrounded by warring territories, Macabilero was a fortress that defended its settlement from outside forces. Choosing to farm manioc in abundance could have eased their concerns about accessing food during such times, when it may have been unsafe to leave the interior of Macabilero. Should there have also been droughts and climatic turmoil, manioc also would have been a resilient resource that guaranteed the community with nutrients, when crops such as maize would have failed. By choosing to grow manioc, the people of Macabilero were able to remain at their settlement for a relatively long period of time and provide for their community during times of uncertainty.

This research contributes to our understanding of the Formative period and what conditions in the lower Usumacinta could have been like. Foodways are vital to this knowledge and provide insight into social, political, and environmental factors as explored in this project. We can see how political and potentially environmental concerns affected the foodways at Macabilero. Maize is universally expected to be found at Maya sites due to its popularity through time and yet, it was recovered minimally here, while manioc was recovered in abundance. Knowing that the people of Macabilero were able to survive and remain at the fortress, relying more heavily on root crops and non-domesticated species, may impact future studies of ancient Maya people.

Furthermore, our world is constantly shifting, and climatic stressors only grow each day. Knowing that root crops like manioc can sustain populations during times of political and climatic strife can be extremely beneficial to planning for our futures. Storing manioc flour and planting this root crop in greater abundance could be the solution to current and future problems around the world.

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# Appendix A – Macrobotanical Flotation Sample Sorting and Identification

Archaeobotanical laboratory work takes some basic procedural training in addition to learning plant morphological identification. Macrobotanical flotation is a method that is used to see plants in archaeological settings and examine the following: densities, condition, range of possible taxa, preservation, and composition.

**1) Preparing the flotation sample for analysis**
Macro-remain analysis of flotation samples usually entails the study of two components: the light fraction and the heavy fraction. The heavy fraction is the plant matter that sinks in water, having a heavier specific gravity than water, and the light fraction is the plant matter that floats, having a lighter specific gravity than water.

Using a data entry sheet, record critical information including the site name, provenance, the name of the sorter, the date sorting began, the volume of sediment that was processed to gain this material, and the weight of the complete sample. All provenance information should be filled in on both the front and the back of the form before any processing is begun in case the back is eventually scanned or copied separately.

The next step is to weigh the complete light fraction. Subtract the weight of the container of which the sample is in to establish the proper sample weight.

Separate the sample into different sizes by pouring it through a stack of size-graded geological mesh sieves. These make each sub-sample smaller in volume and more manageable while looking for the archaeological material, but also grades the size of items that are being viewed under the microscope for the same power of magnification. Always keep separated sub-samples fully labelled. Usually, samples are separated into four sizes: less than .5 mm (< .5mm); less than 1 mm (< 1mm, greater than .5mm); less than 2 mm (<2mm, greater that 1 mm), and greater than 2 mm (> 2mm).

Begin by sorting the largest fraction, which is the easiest to see, and then work through to the smallest fraction. Beginning with the largest sample allows for the sorter to evaluate the range of charring conditions and taxa before looking at smaller fragments.

2) **Flotation sample sorting procedures**
After the samples have been prepared, remove and identify all **charred** plant remains. It is critical to be systematic while sorting.

Make the material one layer thick on the sorting tray. This allows nothing to be hidden from view. Begin on one side of the sorting tray and move across the tray in rows of material. Once one row is completed, move down and continue. Brushes and featherweight forceps can be used to move objects to see everything present. Keep unsorted, in-sort, and already-sorted materials clearly separated in a sorting tray or petri dish.

Once the sample has been scanned, there will be two piles, one of charred remains and one of modern material, root hairs, snail shells, insects etc. Place the separated materials in different labelled containers and complete the sorting form with detailed notes.

Volume in litres records how much sediment matrix was floated and is required to calculate density figures. Excavation information is about the location in the site from where the sample was taken. The bottom comments, including diversity, amount of fragmentation, condition (especially range and diversity of charring), and overall plant density allow the sorter to discuss the types and ranges of the qualitative condition of the sample. For example, the extent and types of charring or fragmentation can inform us about the number of different deposits that might have created the specific sample (i.e., burning, then sweeping, then walking on the sweepings, etc.).

3) **Identification**

Identify the charred remains. Cluster the charred materials into broad categories such as wood, lumps, seeds, etc. Once materials are clustered into broad categories, try to cluster the materials into subcategories based on similarities and differences. The wood, lumps, and other non-seed materials will stay in broad categories, as they would require high magnification for identification.

Now make use of the reference collections to help identify genus and species such as *Zea mays, Theobroma cacao*, etc. Each of the identified piles should then be labelled with all provenience information as well as the plant's identity (use the Latin binomial). For unknown specimens or material, write "UNKN" and assign each type a number (i.e., UNKN 1, UNKN 2, etc.).

Once the taxa are separated and identified, weigh each set of specimens (by taxa) and record their combined count and weight on the identification form.

4) **Analyse the archaeobotanical data**

a. Briefly describe the density and condition of the sample. Was there more large material than small or the other way around? Did certain taxa appear only whole, or only in fragments? Were there many conditions of charring represented in the sample, or only one? Did your materials appear very eroded on the exterior (with rounded edges and missing seed testa) or only lightly eroded (with sharply fragmented edges and intact seed testa)?

b. Calculate the densities of the identified archaeobotanical remains, dividing the count of each taxon by the volume in litres that was floated. Record this figure as count/litre. (Normally, you would do the same for weight/litre as well).

c. To use exploratory statistics on the sample, make two bar charts of the recovered taxa. For each graph, make one axis the names of the taxa in your sample and the other axis the count of each taxon in your sample. One graph will have all the recorded archaeobotanical taxa categories, **except** wood. The other graph will be divided into four broad archaeobotanical categories: seeds, wood, lumps, and "other".

d. Based on the taxa you've recovered, and the condition of the sample, what is your broad interpretation of the context of this sample and its contents? What formation processes do you think helped to shape the condition of the sample and density of the remains?

# Appendix B – 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)
**Total time for 20 sample batch (equalling 40 processed samples) = 36 - 58 business days**

1) sediment sterilization of pathogens for foreign samples (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) clean-up and waste removal (continuous during processing; in total, can take 1-3 days)
7) mounting phytolith sample (1 day)
8) 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.

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

1) Sediment sterilization for foreign samples, following CFIA requirements
***This is to eliminate any potential pathogens. The heating process will also remove some degree of organics and 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 labelled 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.
- Gently break up each sediment sample in the foil placket, then put each sample into the corresponding labelled beaker. Start with ~150 mL of dry sediment per 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.
- Consider sonicating samples for 10 mins each (several batches of 5) in the large sonicating bath, to speed deflocculation (following Lombardo et al. 2016).
- 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 in solution at the last stir.
- On day of sieving, give one last stir, then wait at least 1 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 labelled "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 with a clean pipet while rinsing).
- 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 labelled beaker and continue rinsing process until water is fairly clear.
- Pour contents of bottom pan (A&B fractions) back into corresponding labelled 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 labelled 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 labelled 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 labelled 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 1 hour sequence (3 to 30 times) until water is fairly clear of suspended clay (whole procedure takes 1-10 days, depending on clay content).
- 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 labelled centrifuge tubes.

3c) Preparing samples for Chemical Digestion
- Redistribute fractions in labelled 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 beakers. In other cases, you can leave the sediments as damp samples and record the wet weights.
- Label a set of 600 mL beakers, using the number (1-40) that will eventually correspond to the microwave vessel number on the carousel. **Note which number on the carousel corresponds with which sample in your laboratory notebook.**
- Transfer sediments to labelled 600mL beakers, weighing the material in the beaker (taring for empty beaker weight) to target 10g per sample.
- Record the weight of each unprocessed sediment sample in your laboratory notebook or spreadsheet.

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 microwave tubes
- Take the set of samples in labelled (1-20, etc.) 600mL beakers, and place under fume hood in order. Put a glass stirring rod in each.
- **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 and 1 box of baking soda. Stir baking soda into solution using one of the large glass stirring rods.
- Under the fume hood, prepare three beakers: nitric acid, hydrochloric acid, and hydrogen peroxide (or potassium chlorate). Have a syringe ready for each.
- Recommended for 10 g of sediment (halve quantities for 5 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 or 15mL syringe, express chemicals, in turn, into each 600 mL beaker, while stirring gently with a glass rod. **Add each chemical slowly, as they may rapidly start to bubble up.** For samples high in carbonates, the hydrochloric will react vigorously. In other cases, the nitric and hydrogen peroxide will react vigorously with organics. 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 under the fume hood, 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 beakers 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 the beaker of distilled water, as needed, to cleanse the syringe if besmirched by accidentally touching material in the beakers.
- Wait for chemical reactions in the beaker to slow down or visibly cease (this may take 15-40 minutes).
- Stir each sample again with the corresponding glass stirring rod.
- Wait for chemical reactions in the beaker to slow down or visibly cease (this may take 15-40 minutes).
- Pour each labelled (1-40) chemical mixture into the corresponding microwave vessel tube (1-40). There may still be slight bubbling, but there should be no danger of bubbling over of the sample.
- Using 1-2 mL of nitric acid, rinse remaining sediment mixture adhering to each beaker into each microwave tube. Gently swirl in the beaker, then pour into microwave tube. (There will still be small amounts of sediment residue visible in each beaker.)
- Place pressure plug on each microwave tube, then screw on each cap very tightly, using one click of the white plastic torque wrench (in drawer).
- Place tube in Kevlar sleeve and fit each vessel tube into corresponding number on microwave carousel.
- Make sure all vessels are flush with the Kevlar sleeves and patted down to base of carousel.
- Place all glass stirring rods gently into the bucket of baking soda solution. Rinse each soiled beaker in this sodium bicarbonate solution before washing each beaker with alconox solution at the sink.

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 MARS microwave 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 counter-clockwise, 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 you can simply wait until the next day after cooling overnight.**

4e) When microwaving is complete
***(to reiterate)*** **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.**
- Check the log of the ARCH SED method to ensure all samples heated appropriately. If not, step 4d may need to be repeated.
- 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 **labelled** 50 mL centrifuge 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 50 mL tubes @3000 rpm for 5 minutes.
- Under the fume hood, dispose of this supernatant into a (single) beaker, then **transfer the combined beaker contents into the sealable container marked for special removal of hazardous waste with a yellow chemical waste sticker**.
- 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 of chemical waste
- 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.
- Make sure all chemical waste is in a sealed container, labelled with the chemical waste sticker, and under the fume hood.

5a) Making Heavy Liquid Solution
- Start with 150 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. *(Final specific gravity: aim for 2.3 (i.e. weight of 1 mL of solution is 2.3 g) Don't go under this specific gravity with too much water!)*
- Use dry sodium polytungstate. One pound of sodium polytungstate will make roughly 175 mL of heavy liquid.
- 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
- Label a set of 15 mL centrifuge tubes, one for each 50 mL processed sample.
- Add heavy liquid solution to each centrifuge tube, to about 2 cm above the top of the sediment. This may mean that the surface of the supernatant is a bit more difficult to access with the pipet, if the 50 mL tube has only a little processed material remaining.
- ***If organic material is still present in sample, the heavy liquid will turn red or black. This does not damage the sample but may mean more organic "background noise" ultimately on the slide.***
- 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 labelled 15mL tube.
- Use pipet to suction from centre 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 labelled 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 labelled 15mL tube.
- Use pipet to suction from centre 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 labelled 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 line 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 loosen 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 supernatant from tube (after centrifuging).
- Invert tube, quickly blot tube on a paper towel.

***If drying immediately, add sample to a GLASS or POLYPROPELENE (not polycarbonate!) test tube and complete next 4 steps. Otherwise, skip to next section.***

- Add acetone up to bottom of labelled tape.
- Stir, invert with parafilm, until all 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 (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 or beige clay or powder.

6) Clean-up and Waste Removal

- All glassware, stirring rods, etc. should be clean, dry, and placed back on the shelves.
- Microwave tubes, pressure plugs, and caps should be thoroughly cleaned and stored back in the microwave carousel. Store the clean Kevlar sleeves in the drawer next to the microwave.
- Wash all goggles used.
- Launder all lab coats used. The location of the drop off is the 1T area CSS – Customer Support Services; Stores and Linen in Hamilton Health Sciences (behind the yellow elevators). There is a fee of $2.50 for each lab coat laundered, which will be charged directly to an MPERF account.
- Make sure all chemical waste jars are labelled using the yellow chemical waste stickers and waiting on the shelf under the fume hood. These stickers are available at the ABB Stores (B166) and from: www.workingatmcmaster.ca/eohss
- **Schedule waste pick-up using the chemical waste removal forms.**

7) Mounting the Phytolith Concentrate Material

*For larger samples (the roughly 10-gram samples), the processing should leave 1-2 grams' worth of material. At this point, the phytolith concentrate will be in the labelled 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, by hand, by pipet, or all 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 separate pipets for individual samples**!
- Break off the end of a clean glass pipet and use this as the reserved pipet for the immersion oil.
- Lay out a large kim wipe—the immersion oil is messy. Keep a set of small kim wipe 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 kim wipe, label a slide with the same information listed on the tube, in both Sharpie and pencil.
- In each 15 mL tube, drop by drop, 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 centre 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 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. (Opaque Sally Hansen Hard As Nails is the best)

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

8) Scanning for Phytoliths under the Microscope: General Notes
*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 sediment sample
- Note: many additional phytoliths of an AB size are sometimes released into S fraction after chemical processing. By analysing both fractions, this presents a better way to get phytoliths more fully 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, 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 or blunted needle probe, 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 need 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.