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Getting to the Bottom of It: Geoarchaeological and Paleobotanical Investigations for Early Transitions in the Maya Lowlands

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Getting to the Bottom of It: Geoarchaeological and Paleobotanical Investigations for Early Transitions in the Maya Lowlands

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Abstract

Getting to the Bottom of It: Geoarchaeological and Paleobotanical Investigations for Early Transitions in the Maya Lowlands

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The cultural transition from the Archaic (8000 to 2000 BC) to the Preclassic Period (2000 BC – AD 250) in the Neotropics is critical for understanding the early development of Maya civilization in the Lowlands. This dissertation presents a model for some of the earliest inhabitants in northern Belize and explores the magnitude and timing of impacts concerning initial human-environmental interactions during the early stages of the Holocene. Specifically, geoarchaeological and paleobotanical evidence concerning the transition of subsistence strategies from semi-nomadic hunting and gathering into more intensive agricultural subsistence strategies in the Maya Lowlands. A multi-proxy approach addresses questions related to early anthropogenic change tied to the success of early sedentary villages in northern Belize. Insight concerning the long occupation of Colha and manipulation of the Blue Creek *rejollada* provide an opportunity to understand cultural transitions and trajectories of early Archaic people. This dissertation provides new radiocarbon dates, archaeological excavations, and environmental histories for Colha and the Blue Creek *rejollada*. The paleobotanical component of this research includes a dental calculus study expanding on food consumption, food processing, and evidence for the use of economic fibrous materials. An ethnobotanical component of this research contributes to understanding early Maya economic systems by providing overlap in horticultural and agricultural practices in the region despite cultural and temporal distances between ancient and modern people. Together, multiple lines of evidence expand and refine understanding of early human-environmental dynamics, which become integral to the success of subsequent Maya populations.

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Chapter 1: Theoretical Perspectives and Objectives

THE RESEARCH GAP

Scholars have long debated the emergence of Maya civilization (Adams 1977; Coe and Houston 2015; Gallenkamp 1976; Lohse 2010; Rice 2007; etc.). The cultural transition from the Archaic to the Preclassic in the Neotropics is a critical point in understanding the rise and increased complexity in the Lowlands. This task presents challenges due to the ephemeral nature of sites, rising sea levels along the coast, no Archaic monumental architecture, deeply buried horizons due to encroaching shorelines, and to some extent, research biases favoring Classic Period efforts (Alcala-Herrera et al. 1994; Awe and Lohse 2007; Garber and Awe 2007; Lohse 2009; Pohl et al. 1996). Scholars have even identified early occupations where residents scraped off surface soil from bedrock to create early plaza floors from marl and continued construction phases thereafter, clearing any previous ephemeral features (Inomata et al. 2013; Inomata et al. 2015).

I present a model for the earliest inhabitants of Colha contributing to understanding of the development of Maya civilization. Since the Lowlands boast the most diversity ecologically and geographically in Mesoamerica (Sharer and Traxler 2006), I support a multi-foci development proposed by King (2016) and Estrada-Belli (2016). This perspective acknowledges development was not uniform throughout major areas across the Lowlands; instead, interaction and influence between regions was a major component of development. I contribute to those models through a perspective emphasizing where Colha residents excelled: exploiting their environment for stone tool production and early wetland cultivation.

Maya Origins Models

In general, models for Maya origins aim to answer questions of changing social organization, subsistence, and settlement. Early models for Maya origins supported a Highland-to-Lowland migration based on work by Spinden (1928) and Tozzer (1957). Other Lowland-centric approaches argued that traditions at Tikal and Uaxactun were not influenced by Highland tradition (Estrada-Belli 2016; Kidder 1950; Morley 1946). Excavations at La Venta led scholars to propose a model in which Early Middle Preclassic farmers moved in from the Gulf Coast as part of the Olmec "Mother Culture," which continues to be debated today (Caso 1947; Coe and Houston 2015; Flannery and Marcus 2000). Similarly, Rosenswig (2010) proposes the Maya competed with and were influenced by the Olmec culture. To add to the abundance of proposed origins theories, Inomata (2013) argues that origins stemmed from interregional interactions from varying groups in the Maya Lowlands, Chiapas, and the Pacific and southern Gulf coasts.

What makes Colha a contender in contributing to Maya origins theories is resource availability for mining and wetland manipulation. First, Colha is located in the northern Belize chert-bearing zone. This area is known for high-quality chert outcrops, which occur on the surface resulting from weathering chert-bearing marls and limestone. Nodules can reach boulder size and are typically found on the surface, streambeds, and in *aguadas* (Shafer and Hester 1983; Iceland 2005). Colha chert is known for its banding or gray mottling with yellowish brown/honey colored materials. Over the span of Colha's occupation, 89 chert tool workshops or debitage mounds appear (Shafer and Hester 1983:522). By the Middle Preclassic, Colha was involved in a major toolmaking industry producing expedient and formal tools (Buttles 2002; Hester and Shafer 1994; King 2016).

Colha is one of many early sites which took advantage of this resource with Early Middle Preclassic components. Together Colha, Cuello, Kichpanha, Pulltrouser Swamp, San Estevan, Santa Rita Corozal, K'axob, and Nohmul are among sites in northern Belize which include Swasey and Bolay complex ceramics (Iceland 2005; Valdez 1994a). Large-scale tool production enabled Colha to be an important stakeholder in trade networks across the Lowlands. Primary and peripheral "consumer zones" support evidence for Colha's dominance in tool production. Tools were traded as far as Tikal (Moholy-Nagy 1991) and El Mirador (Sharer and Traxler 2006). Primary areas extended 75 km for utilitarian tools like oval bifaces and 200 km for elite goods including macroblades and eccentrics (Shafer and Hester 1983; Hester and Shafer 1994; Potter 1991). Barret's (2004) work at Blue Creek suggests that Colha's materials replaced local products even though the site had a pre-existing lithic industry.

In addition to a thriving tool-making industry, Colha was also engaged in intensive farming practices. During the Early Preclassic, between 1500 and 1000 BC, water levels dropped due to drier conditions, exposing organic-rich, fertile horizons on the margins of Cobweb Swamp (Pohl et al. 1996). This resource opportunity prompted horticultural practices among semi-nomadic hunter-gatherers. Around 1000 BC, water levels rose and submerged wetland fields. Nearby horticulturalists adapted to this change by modifying existing features with ditching or simple channel modification during the Early Middle Preclassic (Jacob 1995; Jacob and Hallmark 1996). These draining practices are also observed at Cerros (Jacob 1995; Scarborough 1980). At this time, it is theorized people managing the fields settled and established the first village at Colha around 900 BC (King 2016; King and Potter 1994). Cultural continuity in lithic technologies and forms supports the notion that settlers were local foraging cultivators rather than people from other regions (Iceland 1997). During the Late Archaic, the constricted uniface tool functions as a wood-working implement or as a digging tool (Valdez 2007). Use-wear studies suggest the constricted uniface was used primarily for land-clearing or hoeing. The stemmed biface point, also known as a Lowe point, also appears in Belize between 3000 and 850 BC (Gibson 1991; Lohse et al. 2006).

Large-scale deforestation and maize cultivation occur by 3400 BC. The first domesticates in northern Belize were manioc and maize dating to 3400 BC (Pohl et al. 1996). The maize cultigen likely spread from its origins in the Balsas region (Piperno et al. 2009; Ranere et al. 2009) to the Maya Highlands and Lowlands by 3500 to 3400 BC. Additional evidence for intensive agriculture indicates a decrease in Moraceae pollen taxa including *ramón* (Brosimum), wild rubber (Castilla) and cherry (Pseudolmedia) with increased disturbance taxa from Chenopodiaceae, Amaranthus, Poaceae, Asteraceae, cattail (Typha angustifolia), waxy myrtle (Myrica), and Myrtaceae. Early farmers were growing economic species including maize (Zea mays), chili (Capsicum sp.), cotton (Gossypium sp.), and manioc (Manihot esculenta) at Cobweb Swamp (Jones 1994:207-208).

This mirrors paleoecological records from wetlands at Cob and Pulltrouser Swamps after 2400 BC (Lohse et al. 2006). Middle Preclassic faunal evidence also support disturbed habitats, including a receded high-canopy rainforest (Shaw 1999). The transition to sedentism closely followed subsistence intensification at Colha and with it an established ceramic tradition known as the Bolay complex (900 – 600 BC) (Valdez 1987, 1994a). This complex predates Mamom ceramic types, the first extensively distributed Lowland traditions (Estrada-Belli 2016).

Together, archaeological and paleoecological evidence will support the importance of early Maya inhabitants in the region. Fine tuning early Maya occupations and understanding human-environment dynamics will shed light on the Archaic to Preclassic transition, as well as understanding of collective impacts early inhabitants had on the regional environment. This dissertation explores early contexts through geoarchaeological and paleobotanical proxies to expand on the sparse literature of the transition from small-scale lithic production and wetland management to the florescence of ancient Maya civilization.

Background on Belizean Sites with Archaic and Preclassic Components

Pre-Mamom ceramics provide the earliest concrete evidence for the first fully sedentary inhabitants in the Lowlands around 1000 BC. At Cahal Pech, the Cunil tradition is considered one of the oldest ceramics, dating conservatively between 1000 and 900 BC, in the Early to Middle Preclassic (Sullivan and Awe 2013). These dates come from sealed Cunil contexts as well as an area where soil had been scraped away (Hammond et al. 1995; Lohse 2009). At nearby Blackman Eddy, early Kanocha ceramics (part of the Cunil sphere) were also recovered and dated to around 1000 BC or slightly after (Garber et al. 2004; Lohse 2009). Cuello presents some radiocarbon dating from burials without burial goods and paleosols dating just past 1000 BC (Hammond et al. 1995; Hester et al.1996; Lohse 2009). Actun Halal also provides early occupation in Belize (Lohse 2009). This rock shelter in western Belize contains radiocarbon dates associated with lithic debitage and a constricted uniface around 2000 BC. Pollen analysis also indicates associated maize, cotton, and morning glory pollen present. Actun Halal is established as a temporary camp for mobile foragers by the Middle Preclassic based on Jenney Creek ceramics (Lohse 2009).

Colha still predates these findings and is considered one of the first sedentary villages with clearly defined ceramic complexes. Several dates from Colha are Archaic or Preclassic, and the site contains numerous aceramic deposits (Hester et al. 1996; Iceland 1997; Lohse 2006). Radiocarbon dates are predominantly from the main plaza and from Operation 4046. The main plaza includes Bolay, Chiwa, and Onecimo phases dating as early as 931-876 BC (Valdez 1987; Valdez 1994a). Operation 4046 contains two Archaic components dating approximately to 3400 – 1900 BC and 1500 – 900 BC (Iceland 1997). The former component in Operation 4046 contanins dense lithic production deposits, and the latter component contains numerous constricted uniface tools in various states of use and production (Iceland 1997:11).

Ceramic traditions combined with intensive exploitation and distribution of raw materials (chert) and wetland manipulation marks an important shift in the development of the early Maya village of Colha. Moreover, pottery use implies at least minimal food storage and possibly more complex cooking techniques, especially since these behaviors are more labor intensive and require sedentism (Cohen 2009). These multiple lines of early evidence for social complexity are not isolated incidents in the Lowlands.

Defining early village life requires multiple lines of evidence including lithics, paleobotanical and other data. For instance, Rosenswig et al.'s (2014) excavations at Freshwater Creek, Belize recovered lithic tools and starch grains from the Archaic Period. Patinated tools constructed from characteristic Colha chert were recovered from a distinctive aceramic soil horizon and indicate early settlement in northern Belize by people who harvested or processed economic cultigens along the Freshwater Creek drainage, as well as on small islands associated with the riverine system.

Freshwater wetlands in northern Belize at Pulltrouser, Cob, Pat, and Douglas Swamps also provide a significant early sequence supported by radiocarbon dates, pollen, and artifacts dating back to approximately 6000 BC (Pohl et al. 1996). Maize pollen grains at Cob Swamp appear at 2400 BC, Pulltrouser Swamp by 890 BC, and Douglas Swamp by 520 BC. The Cob Swamp grains are morphologically similar to the earliest grains from Cobweb Swamp near Colha and La Venta, Tabasco (Jones 1994). Manioc pollen is also present by 3400 BC at Cob Swamp and adds to the evidence for early cultivators in the area (Jones 1994; Piperno and Pearsall 1998a; Pohl et al. 1996). This is comparable to manioc pollen recovered from Colha at Cobweb Swamp and suggests that both maize and manioc were cultivated as early as 3,400 BP. Pollen data from Cob also reflect an abundance of Moraceae tree pollen and a relative absence of other vegetation types prior to 3000 BC. This indicates that introduction of cultigens occurred in a largely tropical forest environment with little disturbance taxa. It is only until approximately 2500 BC that maize, increased disturbance vegetation (Poaceae, Asteraceae, Borreria sp., Trema sp., Typha sp., and Cheno-Ams), increased particulate charcoal, and decreased Moraceae (upland forest) occur at Cob and Pulltrouser Swamps. This data contributes to a trend in intensified wetland management at the time.

Intensified agriculture occurs alongside hunting and fishing at Pulltrouser Swamp as well. A Late Archaic Lowe point was recovered from Pulltrouser Swamp associated with abundant chert debitage (Kelley 1993; Pohl et al. 1996). Faunal remains were also associated with the Lowe point including freshwater fish (Cichlasoma sp., Ictalurus sp., Synbranchus sp.), snakes (Colubridae), armadillo (Dasypus novemcinctus), and turtles (Staurotypus sp.) (Pohl et al. 1996:363-364). The Late Archaic in this area provides ample evidence for early village settlement. Swamp peripheries provided an abundance of faunal and wetland resources, fertile soils, and water. Additionally, maize and manioc would have been a relatively quick and low effort cultigen to maintain. This landscape also favored cultivation of ruderals and encouraged grazing land for a deer and other animals which flourish in anthropogenically disturbed areas.

The northern Belize chert-bearing zone attracts people from around the Lowlands and nomadic people likely begin to stay for longer periods at a time because of the diverse ecosystems in the region. These people then transition into horticultural practioners, while maintaining hunting and gathering practices. Knowledge from Archaic

Period inhabitants including stone tool production, horticultural practices, and hunting and gathering continue as people become more sedentary and endeavor to construct more permanent structures and intensify subsistence strategies. It is this resource advantage that allows for a large concentration of Maya sites, with Middle Preclassic and Archaic Period components often seen in Belize like Colha, Blackman Eddy, and Freshwater Creek, to continue a long-standing Archaic tradition that continues into Maya cultural periods (Iceland 1997; Lohse 2010; Rosenswig et al. 2014). In sum, the resource-rich chert-bearing zone becomes a central hub for early stone tool production during the Archaic Period in northern Belize and it is local people who exploit the area for both tool and environmental resources which later become the Maya (Valdez personal communication 2017).

BROAD THEORETICAL PERSPECTIVES

My approach to understanding the earliest Maya in the Lowlands of Belize focuses on geoarchaeological and paleobotanical techniques. Evidence from this multi-proxy approach presents long-term patterns and effects on the environment in tandem with cultural changes. I expand on environmental theory as an introduction to emphasize the importance of geoarchaeological and paleobotanical data for challenging archaeological contexts like the Archaic Period in Mesoamerica. Subsequent chapters include more targeted theoretical perspectives exploring prehistoric Maya economic systems and indigenous knowledge systems involving plants.

The Anthropocene

Increasingly complex niche construction behaviors shaped how people have transformed their environments. Archaeological and paleoecological data have explored long-term human impacts to understand ecosystem engineering and complex social relationships. Initially proposed by Crutzen and Stoermer (2000), the Anthropocene is characterized by long-term impacts of human-environment interactions resulting in increased atmospheric carbon dioxide and methane gas, climate change, and rising sea levels (Kaplan et al. 2011; Ruddiman 2007). This research focuses on its implications and consequences, however the question of when this epoch begins is constantly under debate.

For example, rather than assigning a rigid boundary at the start of the Industrial Revolution, Beach et al. (2015a), Boivin et al. (2016), Foley et al. (2013), and Ruddiman (2007) propose multiple phases of pronounced cumulative impacts visible in the environmental and archaeological records. Foley et al. (2013) suggest the term "paleoanthropocene" to describe the earliest period of human impacts on environmental systems. This perspective emphasizes the confluence of archaeological studies and environmental studies when thinking about the earliest agricultural civilizations and their impacts on the environment.

Ruddiman (2007) proposes a two-phase Anthropocene. The early phase is characterized by the beginning of agricultural practices of many civilizations globally along with intensive deforestation, livestock domestication, and large-scale biomass burning. Ruddiman argues that historical data and archaeological data support greater per-capita land use in preindustrial times. As much as three-fourths of the earth's cumulative deforestation occurs prior to the Industrial Revolution (Ruddiman 2013). This correlates with some of the earliest contributions of increasing greenhouse emissions, including intense forest and wetland destruction.

Kaplan et al.’s (2011) modeling of anthropogenically induced land cover change (ALCC) suggests evidence for early anthropogenic forest clearance and shows its causal effects on increased atmospheric emissions. Kaplan et al.’s ALCC modeling also supports the scenario that early inhabitants of the Neotropics were making immense modifications to their landscape before the last 3,000 years and before the Industrial Revolution (Kaplan et al. 2011; Nevle et al. 2011). The second phase begins with the Industrial Revolution, which reflects logarithmic increased methane gas and carbon dioxide emissions. A third Anthropocene boundary has been called the “Great Acceleration,” which refers to massive shifts in the state and functioning of earth systems driven by human activities which are beyond the range of variability during the Holocene after 1950 (Steffen et al. 2015).

Boivin et al. (2016) also offer a multi-phase Anthropocene in which four phases of anthropogenic forces alter biodiversity in a significant way. The first phase, global colonization, begins with Late Pleistocene megafaunal extinctions. Koch and Barnosky (2006) also support this concept in which large mammal extinctions are strongly correlated with people altering ecological niche systems through fire regimes, large-scale deforestation, and the introduction of non-human predators (dogs) during the Pleistocene and into the Holocene. The second phase revolves around the emergence and spread of agriculture and pastoralism during the early to middle Holocene. This is evident in numerous centers for the domestication of cultigens and animals on a global scale which led to demographic expansions. The next phases, island colonization and the urbanization and elaboration of trade networks, emphasize species translocation and exchange systems which increase species diversity and distribution.

Models for the commencement of the Anthropocene tend to point out how destructive and irreversible anthropogenic effects are on the environment; however, there is evidence for positive influences on the environment in which human practices have bolstered environmental systems. The Amazon is known to contain *terra preta*, anthropologically modified soil rich in organics and nutrients, which allows sustainable agricultural activities to thrive in areas otherwise deemed unsuitable for agriculture (Arroyo-Kalin 2010; Glaser and Birk 2012; WinklerPrins 2014). Across Mesoamerica, harsh environments or areas with hydrologic challenges are converted into what Fedick (1996) refers to as a "managed mosaic." Terracing, dams, channels, exploitation of *rejolladas*, arboricultural practices, soil conservation practices, wetland manipulation, and more have supported increased political complexity and the florescence of the ancient Maya civilization which is the focus of this research (Beach et al. 2009; Dunning et al. 2009; Fedick and Morrison 2004; Gómez-Pompa et al. 2003; Scarborough 2009; Turner and Harrison 1983).

These behaviors have since left markers in sedimentological records, which has been described as *legacy sediment* or sediment produced by major anthropogenic disturbance events such as deforestation, agriculture, mining, and other human-induced environmental changes (James 2013). Sedimentological markers from anthropogenic disturbance are visible in the Maya Lowlands, especially during the Early Preclassic or possibly earlier during the Archaic Period (Beach et al. 2006, 2015a, c; Dunning and

Beach 2004). Massive deforestation and intensified land-use creates erosional episodes in the form of *legacy sediment* along karst depressions in the Maya Lowlands. These layers are known as “Maya Clays” which are typically associated with artifacts in the archaeological record (Beach et al. 2006). Massive erosion episodes from deforestation and agricultural practices during the Maya Preclassic and Classic periods deposited sediment and buried the pre-Maya paleosols known as *eklu’um* or “dark earth.” This paleosol is common in many depositional environments of the central and southern Maya Lowlands (Beach et al. 2006; Dunning and Beach 2004; Solís-Castillo et al. 2013). Solís-Castillo et al. (2013) suggest the warmer and wetter environment during the Archaic Period supports the soil’s chemical and physical characteristics as markers for formation during an increased seasonality favoring agriculture. In fact, the most accelerated soil erosion episodes correlate to three time periods in the lowlands: the Preclassic, the Late Classic, and over the last few decades (Anderson and Wahl 2016; Anselmetti et al. 2007; Beach et al. 2006, 2015a; Torrescano – Valle and Islebe 2015).

Beach and colleagues (2015a) have also detailed “golden spikes,” or long-term markers of anthropogenic effects on the environment, particularly between 3,000 to 1,000 BP. Among them, Maya clays and buried paleosol sequences are perhaps the most pervasive in sedimentological records. Anthropogenic soil sequences can also contain increased carbon isotope ratios from tropical grasses like maize and enriched phosphorus signatures from human input. Architectural features and hydraulic systems such as temples and plazas, terraces, road systems, wetland fields, dams, and canals persist in areas which have reverted to overgrowth due to abandonment and in areas that are developed across Mesoamerica. The final marker includes ancient Maya influence on climate change and drought. This can be traced back to warmer temperatures and increased precipitation during the Archaic Period, a time which favored cultivation practices for early inhabitants reflected in disturbance taxa in pollen records (Solís-Castillo et al. 2013). The cultural shift towards more intensive strategies, deforestation, managed fire regimes, concurrent climatic drying, and urbanization accelerates erosional episodes and exacerbates atmospheric conditions during critical cultural periods (Anderson and Wahl 2016; Anselmetti et al. 2007; Beach et al. 2006, 2015; Torrescano – Valle and Islebe 2015).

These behaviors closely follow landscape transformations resulting from intensified cultivation and domestication of various plants and animals. Cultivation refers to a broad scope of activities in which humans actively care for plants, whereas domestication refers to genetic modification and physiological transformation of plants (Piperno and Pearsall 1998a). This process requires a complex trajectory and can last thousands of years (Smith 2015), making the Archaic Period (8000 – 20,000 BC) in Mesoamerica integral to cultivation practices in subsequent Maya periods. Major cultigens including Zea mays (maize), *Cucurbita pepo/Cucurbita argyrosperma* (squash), and *Phaseolus vulgaris* (common bean), *Manihot esculenta* Crantz (manioc), cotton (*Gossypium hirsutum* L), and chilis (*Capsicum* sp.) are products of domestication in Mesoamerica during the Archaic Period, which spread across the Maya Lowlands (Kennett and Beach 2013; Piperno 2009; Piperno et al. 2009; Pohl et al. 1996). Rice (2007) suggests that these cultigens were likely edible weeds growing in disturbed areas around human encampments. A symbiotic relationship ultimately develops a reliance where formerly "wild" plants require human interaction to successfully reproduce (Fuller 2010). This trend occurs simultaneously around the world approximately 10,000 to 12,000 years ago (Cohen 2009; Fuller 2010; Piperno and Pearsall 1998a).

Human Niche Construction

The cumulative impact humans have on the environment is clear with contemporary issues including air and water pollution, soil erosion, deforestation, and species extinction (Kaplan et al. 2011 and Ruddiman 2013). Archaeological research allows further understanding of how long people have modified and created landscapes either deliberately or unintentionally. Human niche construction theory (HNCT) provides a theoretical framework for early small-scale populations in the Maya lowlands which eventually lead to agricultural practices in Maya times resulting in major environmental changes. This framework is based on a subfield of evolutionary biology which emphasizes the ability of organisms to alter natural selection processes by responding to their environments and modifying it (Chase 2011; Lewontin 1983; O'Brien and Laland 2012; Schoener 2009).

Niche construction behaviors include animals building nests, burrows, and webs. Plants are also considered niche constructors because of their capacity to change atmospheric gases and nutrient cycles. Similarly, fungi decompose and store organic matter. Bacterial communities also have the capability to cycle nutrients (Day et al. 2003; Laland and Boogert 2010; O'Brien and Laland 2012; Odling-Smee et al. 2003). As

Laland and O’Brien (2010) and others argue, people are niche constructors because they are not passive reactors, instead they create and modify environments through their metabolism, activities, and choices. People form, improve, and sustain their environment through environmental manipulation and traditional resource management (Smith 2007a)

Intentional human behavior and agency heavily influences ecological niches. This understanding is fundamental in a related concept, sociocultural niche construction, where human social and cultural capacities are drivers for evolutionary processes (Ellis 2016). The immense capacity for human social learning within and across generations accumulates and evolves over time (Kendal et al. 2011). Human survival is largely dependent on complex social relationships, often with non-kin individuals from different groups or societies. Socioculturally constructed niches which include how people live, utilize, and change environments are the basis for sociocultural niche construction, not biology. For instance, social toolkits among hunter-gather societies include social hunting, stone tool production, resource sharing, niche development, and the expansion of favored species (Ellis 2016:67). This is also apparent with cultural processes as they operate faster than natural selection and can have evolutionary consequences (Laland et al. 1999).

Considered to be the ultimate niche constructors (Smith 2007 a, b), people have transformed various biotic communities and ecosystems to fit human needs and wants. Smith (2007a) outlines two levels of understanding human niche construction approaches as it applies to domestication: regional and species. For example, the domestication of plants and animals requires consideration of regional macroevolutionary components including “climate change, population growth, landscape packing and hardening of between-group boundaries, and intra and intergroup competition for resources and social status” (Smith 2007a:188). On the other hand, species level components include spatial and temporal scales of domestication. Morphological and genetic changes domesticates undergo are also considered at a species level analysis (Smith 2007a).

To understand the Archaic to Preclassic transition as it relates to the Anthropocene and its implications, Smith’s (2011) predictive model for human niche construction by small-scale societies organizes the management and transformation of wild plant species and animal resource exploitation. Smith identifies general categories of human niche construction behaviors based on human intervention of target species (2007b, 2011, 2014). General alteration of vegetation in ecosystems where humans reset successional sequences by creating mosaic and peripheral areas is a main component of human niche construction behaviors. These constructed areas have survived thousands of years and were first recorded by aerial photography in the 1970s and 1980s (Adams et al. 1981; Fedick 1996; Pohl 1990; Pohl et al. 1996; Pope and Dahlin 1989; Siemens 1983; Siemens and Puleston 1972; Turner and Harrison 1983). Fedick and Morrison’s (2004) work highlights diverse strategies in which ancient Maya created complex mosaics in the northern Maya lowlands. During the Late Preclassic and Early Classic periods, people intensively cultivated and manipulated wetlands in the Yalahau region. Wetlands also provided algae-rich soils which were transported and used as fertilizers for garden plots and cultivated trees within residential areas. The ancient Maya were so effective at responding and adapting to shifts in climate and hydrology that numerous volumes have documented mosaic systems across the Maya lowlands (see Fedick 1996; Gómez-Pompa et al. 2003; Lentz 2000a; Pohl 1985; Turner and Harrison 1983).

Smith (2007a) also considers hydraulic engineering and large-scale deforestation to be major biome modification behaviors. Examples of complex mosaic agrarian systems and soil practices have been long been studied to characterize ancient irrigation canals, raised field systems, and terracing (Beach et al. 2002; Dunning and Beach 1994; Dunning et al. 1999; Gómez-Pompa 1987; Lentz et al. 2013; Scarborough 1983; Turner and Harrison 1983).

Terracing in Guatemala and Belize occurs as early as the Late Preclassic period in Rio de la Pasion and Three Rivers Region (Dunning and Beach 2004). Terracing in *bajo* margins is also recorded at Nakbe in northern Petén dating to the Late Preclassic (Dunning et al. 2002). Calakmul, El Laberinto Bajo, and La Milpa also emphasize the importance of terracing and intensive cultivation of colluvial soils around bajo margins (Dunning et al. 2002) The three most common types of hydraulic systems in the lowlands include dry slope, footslope, and checkdam terraces (Dunning and Beach 2004). Dry slope terraces generally follow slope contours along moderate grades across landscapes, and are typically connected to residential complexes, field wall systems, or urban residential clusters. Footslope terraces occur along the base of steep slopes and function when controlled erosion from alluvial and colluvial sources fill them. These terraces are important for dry season farming due to their capability to store water for long periods of time. Checkdam terraces directly slow water flow and control soil erosion and occur in the Three Rivers region, and the Petexbatún region (Beach et al. 2003; Dunning and Beach 2004).

Intentional sowing of wild seed-bearing annuals near perennially inundated zones along river levees and lake edges is also considered a category of human niche construction behaviors (Smith 2011). This behavior is deduced from microbotanical evidence of wild and domestic taxa present in lake sediments and wetland peripheries throughout the lowlands during the Archaic and Preclassic periods including manioc (Manihot esculenta), maize (*Zea mays*), cotton (*Gossypium*) and chili (*Capsicum sp.*) (Jones 1994; Kennett et al. 2010; Kennett and Beach 2013; Pohl et al. 1996). Aquatic ecozones where wild species diversity is highly productive contributes to this niche construction behavior (Piperno and Pearsall 1998a).

Transplantation of perennial fruit-bearing trees or bushes near settlements to create orchards or bush gardens is another widely studied practice in Maya subsistence (Gómez-Pompa 1987; Lentz et al. 1996; McNeil et al. 2009; Simms 2014). Classic Maya people likely maintained gardens and orchards which included seed and vegetable crops, fruit trees, root crops, succulents, condiments, and utalitarian plants (Kennett and Beach 2013). At Chunchucmil and the Puuc region, evidence from ancient Maya house gardens (or *solars*) includes a variety of edible plants, condiments, and medicinal plants (Dunning and Beach 2004; Kennett and Beach 2013). According to Gómez-Pompa (1987), a critical component of these gardens includes wild plants maintained for medicinal purposes.

Human niche construction also considers manipulation of perennial fruit and nut-bearing taxa to create landscapes with desired resources without relocation (Smith 2011). This practice is associated with cultivation rather than domestication and is useful when considering naturally occurring plant taxa across various biomes in the Neotropics. A wide range of wild fruit bearing plants and trees occur in the Maya region and have been found in paleobotanical remains including *Brosimum alicastrum* (*Ramon* or *osh*), *Acrocomica mexicana* (palm), *Annona spp.* (pawpaw/sugar apple), *Byrosonima spp.* (Nance), *Chrysophyllum caimito* (star apple), *Manilkara zapota* (sapodilla),), *Oribignya spp.* (palm), *Spondias spp.* (cashew), *Persea americana* (avocado), *Pimenta dioica* (allspice), *Pouteria spp.* (mamey sapote), and *Theobroma cacao* (cacao), to name a few (Gómez-Pompa 1987; Hladik et al. 1993; Smith et al. 1992).

Perhaps the most visible creation of manufactured landscapes in archaeological, sedimentological, and microbotanical records is evidence for slash-and-burn agriculture dating back as the early Holocene (Smith 2007, 2011). Paleoecological records have established a long history of slash-and-burn agriculture, which also reflect some of the earliest settlements during the Archaic and Preclassic periods (Iceland 1997; Jones 1994; Kennett and Beach 2013; Kennett et al. 2010; Piperno and Pearsall 1998a; Piperno et al. 2009; Pohl et al. 1996; Renere et al. 2009; Rosenswig et al. 2014;). Pollen and microcharcoal data reflect this widespread behavior characterized by a decline in closed canopy forest pollen and increased micro-charcoal counts and disturbance taxa pollen. High productivity and speedy secondary forest regrowth are primary reasons this practice serves small-scale horticulturalists well (Culleton 2012). Primary staple crops including as maize, squash, and pumpkin are planted after the dry season. Secondary and tertiary crops to supplement subsistence are planted along wetland margins or river channels. This practice takes advantage of receding water in the dry season for growing additional cultigens (Kennett and Beach 2013). Secondary crops can also be planted in *matahambre*, which is a mulch comprised of felled vegetation that is not burned (Culleton 2012). This strategy accommodates a continual crop yield and economic buffering without a long-term storage option for crops (Kennett and Beach 2013).

In-place management and cultivation of perennial root crops is another human niche construction behavior which expands wild plant habitats (Smith 2011). Root crop cultivation in the Maya lowlands is supported by macrobotanical remains, starch grains, and pollen granules in archaeological contexts (Jones 1994; Miksicek 1983; Miksicek et al. 1981; Piperno and Holst 1998; Piperno and Pearsall 1998a; Pohl et al. 1996; Scott Cummings and Magennis 1997; Sheets et al. 2012; Wiseman 1983). Initial cultivation of root crops begins with replanting root segments selected for preferred size and starch characteristics. Cultigens including *Manihot esculenta* (manioc), *Maranta arundinacea* (arrowroot), and *Calathea allouia* (llerén) are domesticated in South America between 9,000 and 8,000 BP and later become valuable to small-scale societies in the lowlands (Smith 2007a).

Smith (2011) also includes the intentional alteration of a landscape to increase prey abundance such as deer, fish, mollusk, and shellfish through canals, ponds or gardens as an important human niche construction behavior. Managing landscapes to encourage certain species to thrive to take advantage of raw materials or food resources are archaeologically supported in the Maya lowlands as early as the Preclassic Period (Friewald 2010; Hamblin 1984; Lentz 1999; Shaw 1999; Thornton 2011; Wing and Scudder 1991). This trend occurs because certain animals like deer, rabbits, armadillos, peccaries, tapir, and foxes are well adapted to disturbed landscapes and habitat peripheries (Friewald 2010). *Odocoileus virginianus* (white-tailed deer) faunal remains have also aided in reconstructing ancient Maya hunting ranges and exchange networks across Mexico, Guatemala, Belize, and Honduras, ranging from Preclassic to Colonial times (Thornton 2011).

Other important animals present in archaeological contexts include *Mazama sp.* (brocket deer), *Canis lupus familiaris* (domestic dog), *Tayassuidae* (peccary), *Pecari tajacu* (collared peccary), *Tayassu Pecari* (white-lipped peccary), and *Tapirus bairdii* (tapir) which may serve important societal roles in ritual activities and as subsistence resources (Thornton 2011). These animals have been associated with trade networks between Motul and Trinidad, as well as Dos Pilas and Aguateca. The Pasion River made trade possible between polities for products including meat, hides, feathers, and bone artifacts or tools. At Piedras Negras and Caracol, peccary remains were recovered from numerous contexts. At Lamanai, evidence for non-local deer remains were likely imported from Mayapán (Thornton 2011). Other examples of animals associated with niche construction for trade and ritual include deer and peccaries from Tipu and Copan (Thornton 2011). Similar faunal evidence at Mayapán also suggests white-tailed deer were kept in captivity or managed in peripheral areas (Masson and Pereza Lope 2008).

Disturbed landscapes and peripheral landscape management are valuable when considering animals are not widely domesticated in ancient Mesoamerica as compared to other parts of the world during the Holocene. Evidence for the early domestication of *Canis canis* (dog), *Meleagris gallopavo gallopavo* (turkey), and *Cairina moschata* (muscovy duck) do however provide examples of additional terrestrial protein sources for ancient Maya diet (Kennett and Beach 2013). The end of the Pleistocene was a critical time for the domestication of plants and animals for a number of reasons (Lentz 2000b; Smith 2007).

At the end of the Pleistocene, climate was drier and lower CO_2 levels were not hospitable for many plants (Sage 1995). A shift to warmer, wetter, and more seasonal early Holocene climate encouraged human domestication behaviors world-wide (Smith 2007). The change in climate increased carrying capacity for human populations due to exploitation of various fruit trees, weeds, and tubers in campsites and other disturbed areas among semi-nomadic hunter gatherers in the New World (Lentz 2000b). Archaic period foragers and horticulturalists slowly, over six or seven thousand years, adapt more intensive subsistence strategies as they become more experienced at engineering landscapes to fit needs, or human niche constructors. This included developing storage and food processing technologies like early storage pits and grinding stones found in some of the earliest Tehuacán Valley sites (Byers 1967), Guilá Naquitz (Flannery 1986), and Tamaulipas (MacNeish 1958) (Lentz 2000b:95).

This critical change in human-environment dynamics sets a precedent for the future of plants selected for their phenotypes in domestication processes. This change, however, does not exclude the continual exploitation of wild plants and animals. *Milpa* fields become critical disturbed locations during fallow seasons for weedy herbaceous taxa and other useful plants and wild animals to be foraged and hunted. Weedy plant families including Amaranthaceae (amaranth), Asteraceae (sunflower), Chenopodiaceae (pigweed), Cyperaceae (sedge), Leguminosae (bean), Poaceae (grass), and Solanaceae (night shade) are among taxa continuously identified in archaeological and paleoenvironmental archives (Lentz 2000b:109). By combining theoretical concepts surrounding the transitional period between the Late Pleistocene and Holocene, I make a case for early Maya civilization human-environment dynamics which become integral to the success of subsequent Maya populations.

RESEARCH QUESTIONS

This dissertation explores the magnitude and timing of impacts concerning initial human-environmental interactions during the early stages of the Holocene. Specifically, archaeological and paleobotanical evidence concerning the transition of subsistence strategies from semi-nomadic hunter-gatherer into more intensive agricultural subsistence strategies in the Maya Lowlands during the Archaic (8000 to 2000 BC) to the Preclassic Period (2000 BC – AD 250) (Lohse 2010; Rosenswig et al. 2014). I combine theoretical concepts which consider human niche construction and its implications (Anthropocene) with early Maya village development.

I expand on human-environment dynamics, which become integral to the success of subsequent Maya populations. This dissertation employs paleoenvironmental proxies to expand and refine understanding of human-environmental relationships during Archaic to Preclassic transitions in the Maya Lowlands. Evidence gathered using a multi-proxy approach addresses questions related to early anthropogenic change resulting in deliberate and unintentional human niche construction tied to the early success of sedentary villages in northern Belize. Insight concerning the long occupation of Colha and the Blue Creek *rejollada* provide a special opportunity to understand these cultural transitions and the trajectories of early Archaic people.

1. What significant sedimentological markers do Archaic populations produce in wetland and upland environments?

Hypothesis and Methodology: *Archaic inhabitants produce the earliest erosional episodes in the Maya Lowlands coupled with pronounced charcoal peaks and the presence of disturbance and economic cultigen taxa in northern Belize. Other environmental markers include pronounced magnetic susceptibility and phosphorus values (Beach et al. 2015a).* This question is addressed through a comparison of two case studies involving geoarchaeological investigations at Colha and the Blue Creek *rejollada*. This entails a diachronic analysis of sediments using multiple proxies including microcharcoal particulate counts, magnetic susceptibility, Mehlich phosphorus, and the quantification of organic and calcium carbonate materials.

2. What technologies and traditions persist during Maya periods which originate during the Archaic?

Hypothesis and Methodology: *Wild plant use, horticulture, faunal exploitation, and raw material (especially chert) manufacturing practices persist through the* *transition between semi-nomadic hunting and gathering to sedentary village life at Colha.* This question explores evidence for production, processing, and consumption across the Lowlands to synthesize what we know about Maya civilization and what has been documented for Archaic assemblages. This is then compared with archaeological and botanical findings from Colha and the Blue Creek *rejollada*.

3. How do ethnographic studies contribute to archaeological interpretations of paleobotanical evidence, especially during the transitional period?

Hypothesis and Methodology: *Ethnographic data can be used as a tool for finding continuities between food systems and social relations of the past and present. Since paleobotanical remains provide evidence for economic systems, ethnobotanical data can provide insight to archaeological remains based on knowledge systems*. This question builds on concepts of production, processing, and consumption through an ethnobotanical case study in San Felipe, Belize. The study focuses on milpa and house gardening practices which have Archaic and Preclassic origins. The study also comments on the vast differences and some similarities to past and present human-environment dynamics.

DISSERTATION STRUCTURE

Chapter 2 is a survey of Mesoamerican geography and climate. This chapter presents the diverse landscapes considered in Maya research, emphasizing the need for a multi-foci origins approach. I detail each geographic area with geologic, climatic, and vegetative descriptions. Despite major geographic and climatic variability between the Lowlands and the Highlands, the Maya share many cultural systems between broadly classified zones. I also give the geophysical background for my research area in the Three Rivers Region and in northern Belize at Colha and Cobweb Swamp. Shared subsistence strategies and human-environmental dynamics across Mesoamerica contribute to various lines of evidence for early sedentism.

Chapter 3 focuses on the paleobotanical and geoarchaeological methods employed for this dissertation. The biology, deposition, morphology, and laboratory procedures for phytoliths and starches are discussed. Brief descriptions of important taxa are also organized in this section since I targeted economic species during the paleobotanical analysis. A background of geoarchaeological methods and laboratory procedures is also included in this chapter. Methods include microcharcoal analysis, magnetic susceptibility, Mehlich II Phosphorus, and loss on ignition.

Chapter 4 is a review of the cultural history at Colha. It spans the Archaic through the Postclassic Periods. This chapter sets the background for 2017 excavations (Chapter 5), the geoarchaeological upland and coastal comparison (Chapter 6), and an examination of dental calculus (Chapter 7). Chapters 3 and 4 are written separately to eliminate repetition in background sections for subsequent chapters. Each cultural period is discussed in terms of ceramic complex, lithic production, architectural style, and various social aspects pertaining to each era.

Chapter 5 includes a report on the inaugural year for the Colha Archaic Maya Project (2017). Excavations aimed to build upon previous efforts to refine the chronology for early occupation at Colha during the Archaic to Preclassic transition. The three-week field season focused on areas with early deposits in the 2000 and 4000 sectors of the site.

The report includes significant material culture finds, new radiocarbon dates, and the characterization of soils at the site. Osteological and faunal remains are also summarized in this chapter. Supplemental excavation details are included in the Appendices.

Chapter 6 is a case study featuring a comparison between two different human-modified landscapes. An upland *rejollada* with evidence for early anthropogenic manipulation of the feature and Colha. This chapter focuses on environmental markers left behind by human manipulation of specific landscapes. Both sites contribute to the environmental history of their respective areas and how people affect landscapes through soil analysis. The Middle to Late Preclassic shows distinctive environmental markers coinciding with important cultural developmental periods for Colha and Blue Creek.

Chapter 7 discusses the application of ethnographic data to archaeological and paleobotanical studies. I describe continuities and cultural distances in Mesoamerica through time. I survey prehistoric economic systems and review key botanical remains in the archaeological record. This chapter also provides useful additional information to aid the interpretation of dental calculus results (Chapter 8). The chapter also includes my own ethnobotanical case study from San Felipe, Belize with a discussion of overlap and differences between what we see archaeologically and what may be typical in modern Maya communities.

Chapter 8 is a case study on dental calculus from burials at Colha dating to the Middle Preclassic and Late Preclassic. I review various debris pathways and possible information from dental calculus. A discussion of considerations and complications with starch analysis provides information supplementing my results. I discuss results of starches and phytoliths as well as my interpretation of facets of economic systems and human-environment dynamics.

Chapter 9 concludes the dissertation with a summary of findings from my three case studies and how they address my research questions. I also summarize my contributions to Maya archaeology, geoarchaeological studies, and paleobotanical studies.

Table 1.1. Cultural Periods expressed in Years BP and Years BC/AD (modified from Beach et al. 2008).

Years BP	**Years BC/AD**	**Cultural Period**
450 - Present	AD 1511 - Present	Colonial to Modern
700 - 450	AD 1200 - AD 1511	Late Postclassic
1,050 - 700	AD 900 - 1200	Early Postclassic
1,180 – 1,050	AD 800 - AD 900	Terminal Classic
1,350 – 1,180	AD 550 - AD 800	Late Classic
1,700 – 1,350	AD 250 - AD 550	Early Classic
1,850 – 1,700	AD 159 - AD 250	Terminal Preclassic
2,400 – 1,850	400 BC - AD 159	Late Preclassic
3,000 – 2,400	1000 BC - 400 BC	Middle Preclassic
4,200 – 3,000	2000 BC - 1000 BC	Early Preclassic
9,000 – 4,200	8000 BC - 2000 BC	Archaic Period
21,000 – 9,000	20,000 - 8000 BC	Paleoindian

Chapter 2: Mesoamerican Geography and Climate

Regional landscapes encapsulate environmental histories vital for understanding and evaluating long-term anthropogenic change. The ancient Maya civilization occupied the area archaeologically known as Mesoamerica, extending southward from the Lerma and Pánuco rivers in Mexico into parts of Honduras and El Salvador. A spectrum of variation in geologic features, river systems, precipitation, temperature, vegetation, and soils create diverse habitats across the landscape. This area covers approximately 324,000 km^2 in an ecologically diverse zone often subdivided into broadly classified zones known as the Lowlands and the Highlands (Buttles 2002; Gallenkamp 1976; Sharer and Morley 1994). Further descriptions of areas within the Lowlands expand and set the background for study sites of this dissertation including the Three Rivers Region and the archaeological site of Colha.

THE HIGHLANDS

Beyond the Southern Lowlands, the Highlands are delineated by Southeastern Chiapas, southern Guatemala, and the western boundary of El Salvador (Gallenkamp 1976). The altitude of the Highlands reaches between 305 and 3960 masl where a series of active and extinct volcanoes cover the landscape. These highland ranges were formed by Tertiary and Pleistocene pyroclastic material (Coe 2015). The highlands can be further subdivided into the Northern Highlands, Southern Highlands, and the Pacific Coastal Plain and Piedmont (Buttles 2002; Sharer and Morley 1994).

Northern Highlands

The Northern, or Metamorphic Highlands, begin in the Río Grijalva and extend southward to the Río Motagua. The geology is characterized by Cenozoic limestone in the north and metamorphic and igneous Paleozoic areas in the south. The main ranges in the area contain alluvium rich valleys. The major river system for the northern highlands is the Río Usumacinta and its tributaries which flow into the Gulf of Mexico. Precipitation ranges from 2,000 to more than 3,000 mm along the Pacific coast of Chiapas and Guatemala. The average annual temperature ranges from 15°C in high altitude areas to 34°C in lower elevation tropical zones. Pine, oak, and tropical deciduous forest are the leading vegetation types (Buttles 2002; Sharer and Morley 1994:32).

Southern Highlands

The Southern, or Volcanic, Highlands are located between a belt of volcanoes parallel to the Pacific Coast and at the junction of two continental plates, making this region susceptible to tectonic movement and volcanic activity along the Mexican border in Chiapas to parts of Central America (Sharer and Morley 1994). The northern boundaries of the Southern, or Volcanic, Highlands begin with fertile alluvial soils of the major river system of Río Motagua and extends to the northwest with the Río Grijalva. Precipitation varies between 1,000 and 3,000 mm annually, with a dry season between January and May and a wet season between June and December. The average annual temperature ranges from 15°C to 28°C. Mixed evergreen and deciduous forest dominate the vegetation with patches of desert-like environments along the Río Motagua. (Buttles 2002; Sharer and Morley 1994:28).

PACIFIC COASTAL PLAIN AND PIEDMONT

The Quaternary coastal plains of the Pacific coast cradle the southernmost portion of the Southern Highlands along the Isthmus of Tehuantepec, southern Guatemala, and reaches the western portion of El Salvador. The major river system in this region is the Río Lempa in El Salvador. This area sees the highest rainfall in the Maya region between 2,000 mm to over 3,000 mm of precipitation annually between May and December. The temperatures average from 25°C to 35°C and decrease with altitudes between 150 and 800 masl. Vegetation in the higher altitudes includes mixed oak and pine woodland forest (Buttles 2002; Sharer and Morley 1994:24-26).

THE LOWLANDS

The Lowlands are mainly situated atop the Cretaceous and Tertiary Yucatan limestone platform which is approximately 3,000 m thick (Beach et al. 2006; Coe 2015; Johnson 1983). The shelf formed during the Eocene and rose during the Pleistocene. The landscape contains Quaternary river alluvium, Upper Cretaceous, Paleocene-Lower Eocene, Middle Eocene, and Miocene-Pleistocene stratigraphy. The Upper Cretaceous strata consists of various limestones, dolomitic limestone, and sandstone (Flores 1952:405; Johnson 1983).

In general, the region lies below 800 masl and the diverse environment supports saw-grass wetland, tropical deciduous forest, and low-scrub forest vegetative communities (Beach et al. 2006). The area hosts multi-story rainforests consisting of mahogany and ceiba at the uppermost canopy (40-70 m above ground), followed by a variety of vegetation including the American Fig, *sapodilla*, bari, Spanish Cedar, and other vegetation (25-50 m above the ground). The ground story includes species like the ramón tree, rubber and allspice trees, avocado, and a variety of tropical palms (15-25 m above ground) (Sharer and Morley 1994:33). The Lowlands can be further classified into different ecological zones including the Southern Lowlands and the Northern Lowlands.

The Southern Lowlands

The Mexican states of Campeche, Tabasco, eastern Chiapas, the Guatemalan Department of Petén, the entire country of Belize (formerly British Honduras), and the western portion of Honduras outline the Southern Lowlands. The Southern Lowlands can be further subdivided into the Southern (or Transitional) Lowlands and the Central (or Petén) Lowlands. The elevation in the Southern Lowlands ranges from 800-1000 masl throughout northern Chiapas to parts of Huehuetenango, El Quiché, Alta Verapaz, and Izabal, Guatemala. The geology is comprised of Mesozoic and Cenozoic karst formations. The major water systems in the Southern Lowlands include the Río Usumacinta and its tributaries, the Río Sarstoon, Lago Izabal, Río Dulce, and the lower Motagua river. The tropical climate in the region provides 2,000-3,000 mm of precipitation each year with average temperatures between 25°C and 35°C. There is a short dry period between March and May, allowing for mangrove and swamp vegetation to flourish in the coastal areas and tropical rainforests throughout the Southern Lowlands (Sharer and Morley 1994:35-36).

The Central Lowlands

The Central Lowlands are comprised of Cenozoic limestone located north of the Usumacinta drainage system. The region houses a major interior drainage basin lined by fourteen lakes. Lago Petén Itza is the largest of these lakes with a savanna to the south. The elevation in the Central Lowlands ranges from 150 masl in the savannas to 300 masl along the karst ridges of the basin. In the eastern Central Lowlands, the Maya Mountains in southern Belize reach the highest elevation at Cockscomb Peak at over 1,100 masl. Major river systems in the Central Lowlands include the Candelaria, Mamantel, Laguna de Términos, San Pedro Mártir, Río Hondo, New River, and the Belize River. The Central Lowlands average approximately 2,000 mm of precipitation annually and exhibits a rainy season from May to January, and a dry season from February to May. Temperatures average between 25°C and 30°C and can rise to 38°C during the dry season. The regional vegetation includes seasonal rainforest with multi-story canopies. In the rainforest, ceiba, American Fig, and mahogany typically rise to 50 m above ground. The main canopy consists of *ramón*, sapodilla, fig, and other taxa followed by a lower story composed of custard apple, allspice, palms, and other trees (10 m above ground). The forest floor houses a variety of trees, ferns, and broad-leaved plants (Sharer and Morley 1994:38).

The Northern Lowlands

The Mexican states of Yucatán, Quintana Roo, and the northern portion of Campeche outline the Yucatán Peninsula which are also known archaeologically as the

Northern Lowlands or the Yucatecan Lowlands. The area is comprised of Cenozoic limestone with a thin humic veneer. The landscape is relatively flat and the highest area, the Puuc hills, is approximately 100 masl. The major bodies of water include Laguna de Bacalar and the Asunciòn and Espíritu Santo bays. Precipitation varies from under 500 mm in the northwestern region to less than 2,000 mm in the rest of the Northern Yucatan with a pronounced wet season between June and December. Vegetation ranges from Palmetto along the coast, rainforest comprised of mahogany, Spanish Cedar, sapodilla, and hardwoods persisting inland (Sharer and Morley 1994:40).

Bajos and Other Wetlands

Bajos and other wetland features cover 40 to 60% of the Southern and Central Maya Lowlands. According to Dunning et al. (2002), some of the largest and earliest urban centers first emerged due to the stable ecosystems. Coastal Lowlands are low-lying, reaching between 1 - 20 masl. Wetlands along the coastal region are spring-fed and maintain mostly saturated soil conditions year-round. The interior Lowlands are more elevated between 120 - 300 masl and dominated by *bajos* as a series of depressions between the New and Hondo Rivers. These *bajos* primarily have low scrub and thorn growth vegetative communities that often mix in with mixed-forest growth in pockets known as *civales*. Modern *bajos* become infilled with clay during the rainy season but have been known to hold permanent shallow lakes in the Lowlands. (Dunning et al. 2002; Jacob 1995; Johnson 1983; Sharer and Morley 1994)**.** Their dry counterparts of infilled sinks are known as *hoyas* (Wilson 1980). During the Late Preclassic Period (400 BC to AD 250) *bajos* were manipulated into seasonal swamps by Maya communities.

The Yucatan Peninsula is also known for cenotes and associated *aguadas*, or shallow ponds. Cenotes are natural sink holes that collapse and expose the natural water table. In the northwest Yucatan, an event that deeply shaped the landscape of the Lowlands was the Chicxulub meteorite impact. This event occurred 65 million years ago, leaving behind a semicircular ring of cenotes which influence groundwater hydrology and soil pedogenesis (Dunning et al. 1998; Perry et al. 1995). Another major influence on wetlands is the Intertropical Convergence Zone (ITCZ) and the Bermuda High in the southern part of the Yucatan peninsula. This is where trade winds from the northeast and southeast converge and increase with high atmospheric pressure, causing a distinct wet season from May to November (Beach et al. 2008a, b; Wilson 1980). Weather conditions are favorable for an active hurricane season with the potential of landfall offshore to the north or east of the peninsula, or possibly in the northeastern or southeastern portion of the peninsula (Boose et al. 2003; Brown et al. 2014)

MAYA LOWLAND SOILS

Regional geophysical characteristics vary across the Lowlands. Soils are especially variable from area to area based on geologic features, elevation, vegetation, urban developments, and hydrologic systems. Soils in the Maya Lowlands are most commonly formed by carbonate parent materials with volcanic and aeolian inputs and are generally distinct between the northern and southern regions. Soils in the Three Rivers

Region and the Coastal Plain of Belize are part of the Maya Lowlands and are considered generally well-drained, clayey, shallow, calcareous, and are formed over carbonate rocks.

The Three Rivers Region uplands contain shallow and fertile clays classified as Mollisols, which are susceptible to erosion and are formed in humid, temperate regions. The lowland areas of the Three Rivers Region include shallow Mollisols as well, except in *bajos* where soils are very deep clay and include Vertisols and organic-rich histosols. Vertisols contain high percentages of clay and are highly susceptible to argilloturbation, or shrinking-and-swelling, during periods of drying and precipitation. Histosols consist of saturated soils with an abundance of organic material and are often referred to as peat or muck (Schaetzl and Anderson 2005; Soil Survey Staff 1999). Coastal Plain soils are mainly comprised of carbonate clays and sandy plain soils. Colha is situated within a karstic depression known as Cobweb Swamp and contains histosols and Vertisols.

Soil aggradation in the Three Rivers Region is primarily attributed to four major mechanisms. First, ancient anthropogenic input from ancient Maya agricultural practices including ditching and filling. Terrain along the escarpments of the Three Rivers Region also produces erosion and transports sediment downslope. During the wet season, flooding from Blue Creek, the Rio Bravo, and the Rio Hondo produce aggradation in the floodplains. Finally, aggradation also occurs when gypsum and calcium carbonate are precipitated during cyclical evaporation and transpiration (Luzzadder-Beach and Beach 2008). A distinct aggradation period occurred between the Early to Middle Preclassic period (2000 BC – 400 BC), adding 1.2 m and a distinct paleosol. Major river flooding, soil erosion episodes, anthropogenic changes in the landscape, and gypsum precipitation occur during the Late Preclassic (400 BC – 250 AD) through the Classic Period (250 AD – 900 AD) (Luzzadder – Beach and Beach 2008).

Increased phosphorus concentrations and depleted soil nutrients are also visible in the sedimentological record during ancient Maya times. Characteristic Maya clays begin to deposit around 3,000 BP, coinciding with Maya civilization, due to increased soil erosion and deforestation. Sea level rise is also visible in climatic records in the Maya Lowlands. The stratigraphy of Cobweb Swamp contains alternating marl and peat layers indicating two phases of sea level rise and the formation of freshwater lagoons. One phase dating to approximately 5,600 and 4,800 BP, and another phase at 3,400 BP. The marl layers include evidence for increased salinity such as ostracod, foraminifera, and mollusk microfauna. Maize and manioc pollen first appear at Cobweb Swamp during this time along with red mangrove pollen, which still grows in the area today. John Jacob (1995) and Mary Pohl et al. (1996) argue that wetland agriculture in northwest Belize may have begun as early as the Middle Preclassic based on their work at Cobweb Swamp near Colha where they identified ditching and channel modification on Cobweb Swamp's margins.

LOWLAND CLIMATE HISTORIES

Climate change plays an integral role in the environmental history of the Maya Lowlands during a time when aceramic populations were cultivating important economic species such as maize, beans, squash, cotton, chili peppers, avocados, cacao, and other well-known cultigens (Jones 1994; Kennett and Beach 2013; Piperno and Pearsall 1998;

Pohl et al. 1996; Zizumbo-Villarreal 2012). The Maya Lowlands experience overall cool, dry conditions between 22,000 and 10,000 BC with savanna vegetation (Brenner et al. 2002; Leyden 2002), and some shorter periods of montane pine-oak and temperate forest (Hodell et al. 2008). The region experiences increased warmer and wetter conditions around 8,500 BC allowing for a tropical forest to grow. Forest burning and clearing begins by 3,400 BC, which could also reflect climatic regional drying (Anderson and Wahl 2016; Brenner et al. 2002; Buttles 2002; Douglas et al. 2015; Jacob 1992). Similar climatic trends occur at Lago Paixban and Lago Puerto Arturo in the Petén, as well as along the Usumacinta region (Anderson and Wahl 2016; Solís-Castillo et al. 2013; Wahl and Anderson 2014; Wahl et al. 2006).

Widespread deforestation and swidden agriculture practices during the Archaic and Middle Preclassic periods also greatly affected natural vegetation. Evidence from maize pollen and phytoliths present in lake sediments and wetland peripheries throughout Mesoamerican lowlands during the Archaic Period document early horticulture practices (Jones 1994; Kennett et al. 2010; Kennett and Beach 2013; Pohl et al. 1996). These practices can also be a product of the vast diversity of periphery biomes within the Neotropics including aquatic ecozones where wild species diversity is highly productive (Piperno and Pearsall 1998). This environment served the Archaic population well for hunting, fishing, gathering, and small-scale horticulture.

The neotropical climate plays an integral role in the long environmental history of the Maya Lowlands. To better understand aceramic populations and the ancient Maya, a closer look at climatic trends will set the stage for a holistic understanding of long-term impacts people have on the environment. The Yucatan Peninsula has become a valuable source of paleoclimate studies for the Maya Lowlands. Paleoclimate studies in the Maya Lowlands began with pioneering work by Cowgill et al. (1966) at Laguna de Peténxil. Archaeologists and paleolimnologists from the Central Petén Ecology Project are credited with understanding early climate trends in the Lowlands from pollen and sedimentological analysis. Most famously, rapid erosion rates resulting from widespread deforestation during ancient Maya civilization occupation (Binford1983; Deevey 1983; Douglas et al. 2016).

Speleothems and lake sediment cores have been the principal method of obtaining paleoclimate records of the Maya Lowlands. These methods use isotope geochemistry as a major data proxy for paleolimnologists to study oxygen and carbon isotopes systems in minerals rich in carbonates, and hydrogen and carbon isotope systems in organic materials (Douglas et al. 2016). Challenges in interpreting speleothem data include variables in drip water processes, carbon dioxide saturation, accumulation in different cave systems, human input, and varying hydrologic systems, to name a few. Lake sediment cores also provide pollen granules to study changes in vegetation on a larger scale when linked with climate patterns over time. Interpreting pollen records also presents challenges in the neotropics.

Interpreting the degree to which human induced deforestation or regional drying is reflected in pollen records is debated (Leyden 2002; Mueller et al. 2009; Wahl et al. 2006). Other challenges in pollen record interpretation include variability in pollen production between plants, pollination mechanisms, and distance pollen travels to disperse in different areas and with different morphologies (Bhattacharya 2011; Douglas et al. 2016). Paleoclimate experts have accepted these challenges and continue to provide a history of climate in the Maya Lowlands.

Southwest Yucatan Peninsula

Torrescano - Valle and Islebe (2015) have reconstructed a 7900-year-old paleoclimate record for the southwestern Yucatan Peninsula from a core taken from Lake Silvituc. Pollen indicative of a tropical forest is prevalent for the Mid-Holocene period around 7,000 to 3,500 BP. Over 20% of pollen granules represent *Ficus*, Moraceae, and *B. alicastrum*. There is also evidence for a vegetation shift with a decline in *Ficus* and Moraceae at the end of the Mid-Holocene coinciding with similar findings at Lake Petén Itza (Islebe et al. 1996). Maize pollen was identified at Lake Silvituc at 2150 BC during the Late Archaic. This is earlier evidence for occupation than current archaeological findings dating to the Postclassic Period (Alexander 2000; Ojeda-Mas et al. 1996). The Late Holocene covering the last 3500 years indicates a series of dry climatic events as well as Maya occupation at Lake Silvituc. Tropical forest taxa including Moraceae, *Brosimum alicastrum*, *Ficus* and Fabaceae declined, while secondary growth and disturbance taxa increased, including Asteraceae, *Croton*, Mimosoideae-*Acacia*, *Bravaisia berlandieriana*, *Pinus*, Chenopdiaceae and Poaceae (Torrescano – Valle and Islebe 2015: 6).

Northern Yucatan Peninsula

Hodell et al. (2007) were able to reconstruct a history of paleoclimate spanning the last 3500 years based on stable isotopes combined with organic and carbonate content from sediment cores taken from Lake Punta Laguna near the archaeological site of Cobá. The Preclassic Period (2000 BC – AD 250) was characterized by variable lithologic levels, fluctuating water levels, and variable isotopic conditions suggesting steady seasonality. The Early Preclassic Period witnessed extensive slash and burn agriculture in tandem with accelerated soil erosion around 1700 BC. There is a drier shift in climate and lower lake levels during the Classic Period at Lake Punta Laguna (AD 250 – AD 750). Evidence includes low carbonate content and organic layers with increased oxygen isotope values.

Towards the end of the Classic Period, the area experiences wetter conditions, increased carbonate content, and lower oxygen isotope values. Pollen at Lake Cobá from the Middle Preclassic through the Late Classic Periods shows forest clearance beginning around 1650 BC with an abundance of grasses, including maize, as early as 850 BC. Maize and disturbance taxa decline as tree and shrub pollen percentages increase during the Late Classic Period. According to Leyden et al. (1998), this was not due to abandonment, but the relocation of milpas away from the site core as the site became more urbanized. Additionally, there is archaeological evidence for diking at Lake Cobá for water management purposes that coincide with isotopic and lithologic characteristics during this time.

Following this, the Terminal Classic Period (AD 750 – AD 1050) includes multiple drying events characterized by low carbonate content and increased oxygen isotope values. Finally, wetter conditions were restored during the Postclassic Period (AD 1050 – AD 1521) (Curtis and Hodell 1996; Hodell and Curtis 2007; Leyden et al. 1998). Cobá was likely abandoned during the Terminal Classic Period and repopulated during the Early Postclassic (Hodell et al. 2007; Leyden et al. 1998).

A sediment core from Lake Chichancanab reveal the Northern Yucatan experienced a series of short droughts with intermittent wet conditions during the Terminal Classic, much like the conditions at Cobá (Hodell, Brenner, and Curtis 2005). The chronology at Lake Chichancanab consists of two episodes of drought during AD 770 – 870 and AD 920 – 1100 with wetter conditions in between. The lithology of this core includes a series of alternating gypsum, then organic-rich strata. This paleoclimate history is also supported by a sediment core taken from Aguada X'caamal (Hodell et al. 2005). Salinity levels between AD 1480 and AD 1900 were much higher than today based on the presence of the saline-tolerant foraminifera *A. beccarii*. The Aguada X'caamal experienced increased oxygen isotope values and salinity resulting from drier conditions due to increased evaporation or a decline in precipitation towards the second half of the 1500s. Pollen cores from the Centote San José Chulchacá, approximately 52 km northwest, support a decline in *Brosimum*, or forest taxa (Leyden et al. 1996).

Lake Tzib revealed a similar paleoclimate history when compared to conditions at Cobá (Carillo-Bastos et al 2010; Hodell, Brenner, and Curtis 2005). Pollen and oxygen isotope data expand on the paleoclimate record over the past 7900 years. The early

Holocene (7,900 to 7,000 BP) was characterized by high precipitation with a diverse forest and some mangrove swamp vegetation. A decrease in forest taxa with an increase in Poaceae, Chenopodiaceae, and Cyperaceae occurred between 6,500 and 4,700 BP as conditions became drier. There is an increase in precipitation between 4600 and 4100 BP only to be met with drought around 3,500 BP, similar to the Cariaco Basin drought at 3,400 BP (Haug et al. 2001; Haug et al. 2003). Lake Tzib has evidence of maize by 3,500 BP, followed by increased precipitation into the Late Holocene. Drying periods also occur during the Preclassic and the Terminal Classic periods similar to Lake Chichancanab (Carrillo-Bastos et al. 2010; Hodell et al. 2007; Hodell, Brenner, and Curtis 2005)

Coastal mangrove vegetation has also been a useful tool for paleoclimate studies. The mangrove zone near Puerto Morelos, just south of Cancun, was cored to expand on the last 2500 years of vegetation history (Islebe and Sanchez 2002). The vegetation record suggests a strong mangrove environment between AD 2500 and AD 1500. A shift occurs when *Rhizophora mangle* (mangrove) is suddenly replaced by *Conocarpus erecta* around AD 1330. Secondary forest growth also accompanied the appearance of disturbance taxa including *Conocarpus erecta*, Apocynaceae, *Ficus-t*, *Trema*, *Hedyosmum*, and Poaceae. Again, these findings reflect a drying period also recorded at Lake Punta Laguna and Lake Chichancanab (Hodell et al. 2007; Hodell, Brenner, and Curtis 2005).

Central Petén Lowlands

Lake Petén-Itzá is the deepest lake in the Central Lowlands and the location of many paleoclimate studies. This massive lake has continuously held water, even during extended periods of drought (Correa-Metrio 2011; Hodell et al. 2008; Mueller et al. 2010). Lake Petén-Itzá yielded an 85,000-year paleoclimate record for Central America (Hodell et al. 2008). Between 85,000 and 48,000 years ago, conditions were cool and moist as evidenced by carbonate mud and clay, separated by a gypsum layer around 48,000 years. This gypsum layer was precipitated during a climate shift consisting of wet and dry periods. The period between 48,000 and 23,000 years ago consists of increased seasonality and a southward shift of the ITCZ system, resulting in increased precipitation and runoff.

The lithology includes bands of gypsum precipitated during drier periods layered between bands of clay deposited during wetter periods. This wet and dry pattern coincides with findings from the Cariaco Basin in Venezuela (Haug et al 2001; Haug et al. 2003). Following this period, clay-rich sediments indicate an extended time of cooler and wetter conditions between 23,000 and 18,000 years ago during the Last Glacial Maximum. Montane pine-oak vegetation including *Quercus*, *Pinus*, and *Myrica* are present during this time (Hodell et al. 2008). Corea-Metrio et al. (2012) describe the Last Glacial Maximum as also witnessing increased fire use along with *Pinus* and Poaceae vegetation.

Between 18,000 and 10,000 years ago, by the end of the Last Glacial Maximum, dry conditions spread across the Petén. At approximately 14,700 years ago, clay-rich sediment increased and gypsum precipitation decreased, signaling humid conditions. Mesic forests shifted into shrublands dominated by *Acacia*, *Celtis*, and Poaceae around 18,000 to 15,000 years ago (Corea-Metrio et al. 2012). Dry conditions returned across Lowland Central America around 13,800 years ago when clays covered gypsum layers, overlapping with the Older Dryas. Gypsum precipitation resumed once again during the Younger Dryas beginning at 12,800 years ago and ceasing around 11,500 years ago. This period includes the transition from grassland to forest vegetation with increased Moraceae taxa by Hodell et al. (2008); however, it conflicts with Leyden et al.'s (1993) pollen analysis of the commencement of a tropical forest during this time.

Similar paleoclimate records are visible with a 36,000-year climatological record from Lake Quexil. Overall cool, dry conditions persist between 24,000 and 12,000 years with savanna vegetation in the Maya Lowlands (Brenner et al. 2002; Leyden 2002). The region experiences increased warmer and wetter conditions around 10,500 BP allowing for a tropical forest to grow. Forest burning and clearing at Lake Quexil begins by 5,000 BP, which some argue could also reflect climatic regional drying (Anderson and Wahl 2016; Brenner et al. 2002; Douglas et al. 2016; Mueller et al. 2009).

Wahl, Byrne, and Anderson also report similar climatic trends at Lago Paixban and Lago Puerto Arturo using pollen, gastropods, and carbon isotope ratios (2014; Wahl et al. 2015; Wahl et al. 2006). *Zea mays* pollen first appears at Lago Puerto Arturo at 4,600 BP, and then again at 3,500 BP. Disturbance taxa including Poaceae and Asteraceae are also present during this time, supporting the presence of anthropogenic activity reflected in increased magnetic susceptibility readings as well. The highest disturbance pollen reflecting human imprint on the environment for this area occurs during the Late Preclassic. Lago Puerto Arturo had constant agricultural activity until about 11,00 BP, when the area was abandoned (Wahl et al. 2007; Wahl et al. 2014).

Lago Paixban was the source of a paleoclimate record spanning the last 10,300 years. This lake was an ephemeral lake between 10,300 and 9,200 BP and then became permanent based on a lack of microfossil evidence. Inorganic clays were deposited during this time which held both permanent water and microfossils. Pollen analysis from Lago Petén-Itzá indicates a mesic forest at 11,250 BP with Quercus, Asteraceae, and Poaceae vegetation, followed by a dominance in *Brosimum*, *Gymnanthes*, pine, oak, *Bursera* and other grasses (Hillesheim et al. 2005:369). At approximately 8,200 BP, a carbonate layer is deposited into Lago Paixban and forest taxa decreases. By 7,600 BP the region experiences increased humidity and an increase in riparian/*bajo* and sawgrass marsh vegetation as well as weedy taxa.

The lithology includes sediments rich in carbonates and organics. Climatic drying and increased human activity occur between 5,500 and 4,500 BP that causes the deposition of carbonates (Anderson and Wahl 2016; Wahl et al. 2015). Human disturbance continues an upward trend in the area with increased magnetic susceptibility values, disturbance taxa, and clay input. The last evidence for Zea pollen occurs around 340 BP right around the time Lago Paixban was abandoned. A sawgrass marsh developed as evidenced by fibric peat strata and Cyperaceae and *Nymphaea* vegetation (Wahl et al. 2015). The same patterns appear along the Usumacinta region with climatic drying around 5,500 BP and increased seasonality around 3,000 BP (Solís-Castillo et al. 2013).

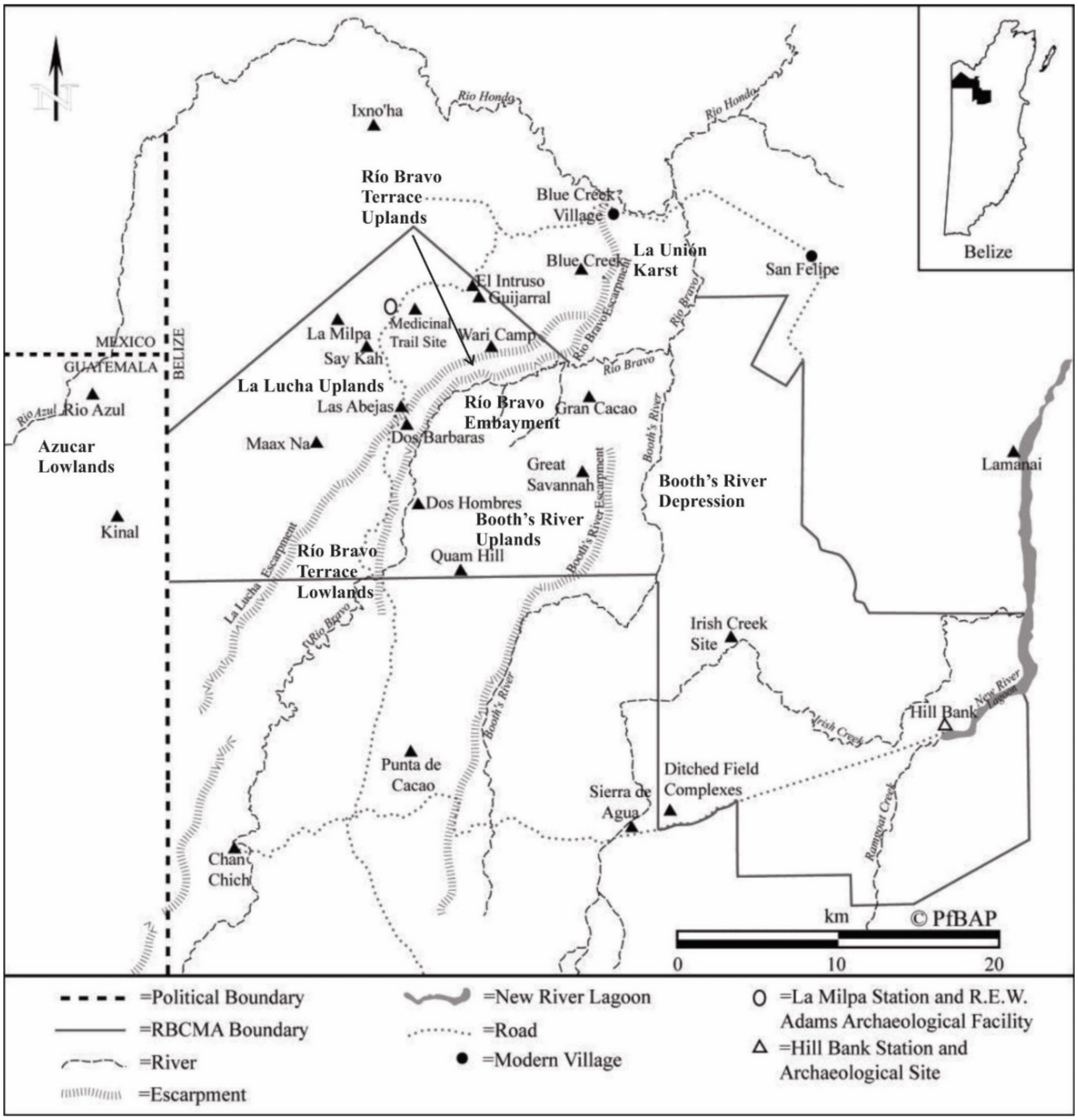
Mueller et al. (2009) suggest that forest decline at Lake Petén-Itzá began before intensive agricultural practices as a consequence of dry climate conditions and only coincide with anthropogenic input.

STUDY AREAS IN THE MAYA LOWLANDS

Three Rivers Region

Situated within the Southern Lowlands of the Maya region, the Three Rivers Region refers to the Rio Hondo and its three tributaries: Río Azul, Río Bravo, and the Booth's River. The area includes northeastern Petén, Guatemala and southeastern Quintana Roo, Mexico (Bridgewater et al. 2002; Brokaw and Mallory 1993; Dunning et al. 2003). Tertiary and Cretaceous carbonates lie beneath Northern Belize, which make up the eastern portion of the Petén Karst Plateau (Beach et al. 2006; Dunning et al. 1998). The plateau increases in altitude as it progresses inland from the northern and coastal plains where a series of normal faults include horst and graben features. The uplands contain several bajos, perennial wetlands, and limestone ridges (Dunning et al. 1999).

Figure 2.1: Map of PfBAP within the Three Rivers Region modified after Aylesworth and Valdez (2013).



Dunning et al. (1998) characterize the region into five ecological zones including La Lucha Uplands and Río Bravo Terraces, Río Bravo Embayment, Booth’s River Upland and Depression, Azucar Lowlands, and the La Unión Karst. On the eastern edge of the Petén Karst Plateau, The La Lucha Uplands and Río Bravo Terraces are separated by the La Lucha Escarpment. The hilly La Lucha uplands decrease in elevation and become the Rio Bravo Terrace Uplands and Rio Bravo Terrace Lowlands characterized by an increasing number of flat *bajos*. Vegetation in the uplands is sustained by well-drained soils and includes dry upland forest and mesic, or moderately wet, upland forest. *Bajos* within the uplands in the Three Rivers Region are lined with deep clays and contain scrub swamp forest. Transition forest occurs between upland forests and scrub forests with a lower canopy than an upland forest and is typical of areas on *bajo* peripheries (Browkaw and Mallory 1993; Dunning et al. 1999; Dunning et al. 2003).

Beyond the Río Bravo Terrace Uplands and Terrace Lowlands, the Río Bravo Embayment is located between the Río Bravo escarpment and the Booth's River Uplands area. This river floodplain area is spring-fed and contains several swamp and marsh systems. Soils in the area are rich in organics and have deep clay accumulation. The higher ridges in the embayment towards the east are shallow and have abundant calcium carbonates. The vegetation in the area includes two types of riparian forest dominated by either cohune palm or royal palms with spiny bamboo in some areas. Finally, the Booth's River Uplands and Depression lie east of all the Río Bravo areas described. The Booth's River roughly separates the fault-block ridge uplands and the Booth's River depression or valley (Bridgewater et al. 2002; Brokaw and Mallory 1993; Dunning et al. 2003; Scarborough and Valdez 2003). Much like the Río Bravo Embayment, the Booth's River soils are shallow, well-drained, and calcium carbonate rich in the uplands and deeply aggregated and poorly drained along the embayment area.

The Booth’s River Uplands are predominantly upland forest with riparian forest in lower elevations. The wetter Booth’s River Depression area contains mostly marsh vegetation with peaty clay soils. One of the most diverse areas in the Three Rivers Region is the Azucar Lowlands on the Northern Guatemalan and Northwestern Belize areas. The Azucar Lowlands is home to the largest *bajos* in the area and includes a scrub swamp forest and transitional forest types of vegetation. The area known as the La Unión Karst is outlined to the east of the northern portion of the Río Bravo Escarpment in Mexico and includes a series of cone karst formations, ridges, and *bajos*.

Table 2.1: Selection of dominant trees in various types of vegetation (Bridgewater et al. 2002; Brokaw and Mallory 1993; Dunning et al. 2003).

Mesic upland forest	Canopy	15-20 m	*Ampelocera hottlei, Brosimum alicastrum, Drypetes brownii, Hirtella americana, Manilkara zapota, Pouteria reticulata, Pseudolmedia sp., Sabal morrisiana*
	Subcanopy	below 15	*Cryosophila stauracantha*
Scrub swamp forest	Canopy	5-10 m	*Acoelorrhaphe wrightii, Bucida buceras, Caesalpinia gaumeri, Calophyllum brasiliense, Cameraria latifolia, Clusia sp., Haematoxylum campechianum, Manilkara zapota, Metopium brownei, Swietenia macrophylla*
	Ground Cover	Below 2-5 m	*Ardisia sp., Byrsonima bucidaefolia, Chysobalanus icacos, Coccoloba reflexiflora, Croton spp., Erythroxylum guatemalense, Eugenia rhombea, Gymnopodium cf. ovatifolium, Krugiodendron fereum, Myrica cerifera, Ouratea sp., Plumeria obtuse, Rapanea guianensis, Sebastiana tuerckheimiana*
Riparian cohune forest	Canopy	Up to 25 m	*Alseis yucatanensis, Aspidosperma cruentum, Attalea cohune, Brosimum alicastrum, Drypetes brownie, Licaria peckii, Pouteria amygdalina, Pouteria reticulata, Pouteria spp., Pseudolmedia sp., Rinorea sp., Stemmadenia donnell-smithii, Sabal morrisiana, Trichilia minutiflora, Trophis racemosa*
Marsh		Up to 12 m	*Acoelorrhaphe wrightii, Annona glabra, Conocarpus erecta, Rhizophora mangle*

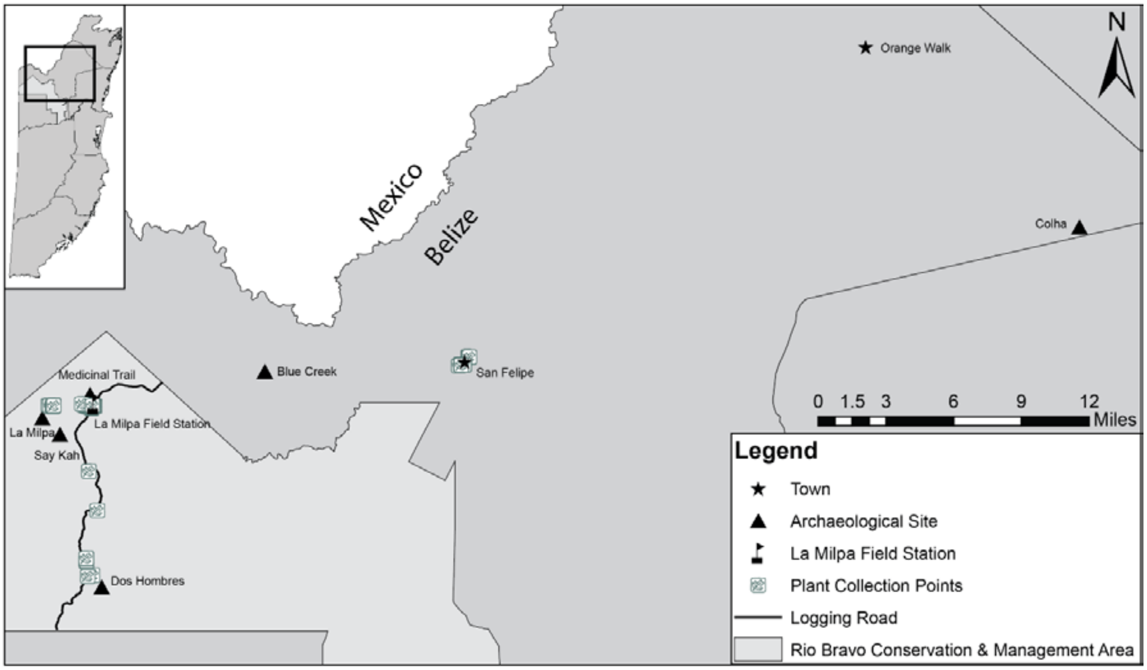
Research Area

This dissertation takes place in one of Central America’s smallest countries along the Yucatán Peninsula, Belize. A variety of ethnicities including *Mestizo*, Creole, Maya, Garifuna, Mennonite, and East Indian call Belize home (Central Intelligence Agency [CIA], 2018). Belize covers approximately 22,960 square kilometers and is the location of the second largest coral reef system in the world, numerous ancient Maya archaeological sites, thousands of acres of tropical rainforest and marshes, and complex limestone cave systems (Bridgewater 2012).

This dissertation took place in various areas of northern Belize within the Three Rivers Region. Plant specimens were collected for a phytolith reference collection within the Rio Bravo Conservation and Management Area (RBCMA), a private reserve spanning an area of over 260,000 acres of protected land owned and managed by a Belizean conservation organization known as Programme for Belize (PfB) (Government of Belize 2015; Nations 2006). My fieldwork was supported by Programme for Belize Archaeological Project (PfBAP), which works in conjunction with PfB to encourage research investigations which document pre-Maya, Maya, and other scientific and historic activities (Lewis and Valdez 2015).

The ethnographic component of this research took place approximately 45 minutes outside of the RBCMA in a small community of approximately 1500 residents called San Felipe, just east of the La Unión Karst (The Statistical Institute of Belize 2015). One of the research areas of this dissertation is located along the Río Bravo Escarpment approximately 200 m downslope from the ancient Maya site of Blue Creek in a *rejollada*, an infilled upland sinkhole. The final component of this dissertation took place at the archaeological site of Colha on the coastal plain of Belize.

Figure 2.2: Map of research sites and areas.



Archaeological Site of Colha and Cobweb Swamp

Colha is a large perennial marsh approximately 40 km^2 situated within the Central Lowlands near Belize’s coastal plain on the northern boundaries of the chert-bearing zone (Jacob and Hallmark 1996; Johnson 1983; Shafer and Hester 1983; Wright et al. 1959). The site is located approximately 20 kilometers from the coast and spans a maximum area of 36 km^2 (Buttles 2002; King 2000). The site is bisected northwest to southeast by the Old Northern Highway, and further bisected perpendicularly by Rancho Creek which drains into Cobweb Swamp. From there, Cobweb Swamp drains into the Caribbean Sea. Both Lopez Creek and Rancho Creek supply water inflow to the swamp. Colha encroaches Cobweb Swamp along the site’s southern and eastern peripheries.

The area has a tropical climate with annual rainfall between 1,300 and 2,000 millimeters with a dry season between November and April (Johnson 1983; Masson 1989). Belize's coastal plain includes subtle rolling relief, below 10 meters. Extensive wetland systems and pine ridge savannas cover the area. Cobweb Swamp is a perennial wetland remaining saturated throughout the year. Wetland fields remain inundated during the rainy season in the swamp forest. Water continues to saturate the wetland fields even in most dry seasons.

Colha is set along three types of vegetative communities including upland forest, swamp forest, and sawgrass marsh (Jacob 1995). Upland forest is dominated by cohune palms (*Orbignia cohune*) and trees including *Ficus*, *Ceiba*, and *Pouteria*. The swamp forest is mostly comprised of mangrove vegetation (*Conocarpus*, *Bucida*, and *Rhizophora*). Finally, the most diverse vegetative community is the sawgrass marsh with sawgrass (*Cladium jamaicense*), mangroves, sedges, grasses, and cattails in addition to marsh broadleaf trees and shrubs (Bhattacharya et al. 2011; Jacob 1995; Jacob and Hallmark 1996). Upland soils are predominantly shallow, calcareous, and contain abundant, organic-rich clays. Soils in the swamp forest are clay rich and are hydromorphic, or continually retain excess water. Sawgrass marsh soils are typically marls overlain by peats (Jacob 1995:178).

Stratigraphy at Colha within wetland field and non-field areas includes *sascab* (marl), a paleosol, Cobweb Clay, Maya Clay, and peat. *Sascab* is mostly calcium carbonate, up to 90%. Cobweb Clay is formed from weathered *sascab*, usually a black clay capping a greenish-gray clay occurring across the swamp margin and occasionally in non-field areas. The black clay may contain artifacts; however, the greenish-gray clay is sterile. The black clay covering the greenish-gray clay was formerly at the surface for thousands of years before becoming buried. Potsherds and lithics are common in Maya Clay, which is comprised of a calcareous gray clay. Maya clay at Cobweb Swamp occurs from alluvial or colluvial transport from the uplands, potentially associated from erosional episodes due to agricultural practices (Jacob 1995).

The general depositional history of Cobweb Swamp based on swamp margin studies (Jacob 1995) begins with the initial sascab deposition during the late Tertiary or Pleistocene (Jacob 1995; Jacob and Hallmark 1996). Slope wash and colluviation filled the swamp during the early Holocene due to cooler and drier climate conditions. Cobweb Clay formed during the late Pleistocene into the early Holocene. Sea levels rose after 5,600 BP and turned the swamp into a brackish lagoon with marine gastropods (*Certhidea costata*) and marine foraminifera (*Amonia beccarii*, *Elphidim* sp., and *Quiqueloculina* sp.) (Alcala-Herrera et al. 1994). Precipitated marl and peat filled the lagoon by 4,800 BP. A break in sea level rise allowed vegetation to grow in the marginal swamp area (Jacob and Hallmark 1996).

Wetland manipulation at Cobweb Swamp likely occurred in the Middle Preclassic during initial wetland agriculture and population growth at Colha. People likely modified existing features with ditching or simple channel modification. Cobweb Swamp was utilized for drainage purposes similar to those observed at Cerros (Jacob 1995; Scarborough 1991). Massive deforestation from intensive agricultural practices triggered increased runoff. Subsequently, increased water levels created a freshwater lagoon between 3,400 and 500 BP and deposited Maya clays.

Pollen evidence reflects a decrease in Moraceae pollen taxa including ramón (*Brosimum*), wild rubber (*Castilla*) and cherry (*Pseudolmedia*). Increased disturbance taxa is also observed with pollen from Chenopodiaceae, *Amaranthus*, Poaceae, Asteraceae, cattail (*Typha angustifolia*), waxy myrtle (*Myrica*), and Myrtaceae. Economic species at Cobweb Swamp include maize (*Zea mays*), chili (*Capsicum* sp.), cotton (*Gossypium* sp.), and manioc (*Manihot esculenta*) (Jones 1994:207-208). Finally, after Colha was abandoned, Cobweb Swamp was filled with peat before 500 BP after reforestation and shallow water levels from decreased runoff (Jacob and Hallmark 1995).

Chapter 3: Paleobotanical and Geoarchaeological Methods

PHYTOLITHS: BIOLOGY, DEPOSITION, AND MORPHOLOGY

Phytoliths have been known by a few different names including opal or silica phytoliths, plant or biogenic opal, or any combination including these terms. These particles are dehydrated silica formed within and around living plant cell walls. Phytoliths have a crystalline, non-organic structure which survives plant decay upon death. A German botanist named Struve was the first to observe phytoliths in living plants in 1835 (Piperno 1988, 2006). By 1854, Ehrenberg developed the first phytolith classification system (Ehrenberg 1854). Ecological phytolith research began to appear by the late 1950s (Smithson 1956, 1958; Beavers and Stephen 1958) and by the 1980s, phytolith research was well established as its own specialty within archaeological and paleoenvironmental research (Bozarth 1986; Pearsall 1982; Piperno 1985; 1988).

The second most abundant element in the earth's crust is silica. When minerals such as quartz and feldspar become weathered, soluble silica is released into the ground. Monosilicic acid (H_4SiO_4) in groundwater is absorbed by plants through their roots and is transported to aerial organs via a plant's xylem. Monosilicic acid is deposited as silicon dioxide (SiO_2) throughout plant cells through active or passive transport (Piperno 1988, 2006; Prychid 2003). When a plant dies and becomes devoid of water, the silica remains and can survive millennia. Active transport refers to a plant's genetic and physiological mechanisms which control phytolith production and passive transport includes external factors such as environmental variables. Transpiration and silica levels in sediments control the quantity of silica a plant absorbs. The higher the transpiration rate, the higher the intracellular or extracellular silicification. Environmental factors such as climate, growing conditions, and water supply regulate transpiration in plants (Piperno 2006a,b). Elements such as iron and aluminum oxides are known to increase phytolith resilience because they are absorbed into siliceous surfaces and hinder phytolith dissolution. Extremely high pH levels (above pH 9) negatively affect the dissolution of silica in sediments such as shell middens, but do not completely destroy phytoliths (Lewis 1981).

A phytolith, Greek for "plant stone," is not the only type of silica body found in common environments. Not all plants absorb and deposit silica uniformly throughout each plant part or between plant species. Silica bodies occur in a variety of plant and animal microorganisms including calcium oxalates, diatoms, and sponge spicules (Piperno 1988; Simpson and Volcani 1981). Phytoliths are more commonly formed in the epidermis of plant tissues than any other part of a plant. The inorganic nature of phytoliths makes them highly resistant to soil pedogenesis which may affect the preservation of other types of microfossils or microorganisms.

There are numerous ways phytoliths are released into the environment. The most common deposition is generally restricted to the final location of a plant's death before released into the uppermost horizons of sediments, therefore it is safe to say that phytoliths are preserved *in situ*. Piperno (1988) demonstrated that phytoliths are good indicators of local vegetation and that, at most, phytoliths are deposited 20m from their place of origin. Depositional research by Morris et al. (2010) also demonstrated the short distance phytoliths travel even from fire episodes and soil depth. Erosion from water runoff feeding into depressions or lakes can account for phytoliths transported from upland vegetative areas as well (Alexandre et al. 1997; Zhao and Piperno 2000). Pathways can also include animal droppings and aeolian transport from open landscapes (Parmenter and Folger et al. 1967; Piperno 2006). Fire can also be a pathway, especially in agricultural fields, archaeological middens, or refuse areas (Fredlund and Tieszen 1994; Piperno 1988, 2006a).

People can also play a more direct role in the deposition of phytoliths outside of agriculture through activities involving cooking, food processing, storage, or brewing (Pearsall 2015). Artifacts including tools and cooking vessels are likely to have microbotanical remains and be strong indicators of foodways. Despite the numerous ways phytoliths can be introduced into the environment, there are some limiting factors related to plant cellular structure which inhibit the application of phytolith research including multiplicity and redundancy. Plants have different parts which produce different phytoliths, also known as multiplicity. Many plants also produce the same types of phytolith shapes which is also known as redundancy (Nicolaides 2015). One of the greater strengths of phytolith analysis is that they do not require charring or waterlogging, making phytolith analysis more advantageous than other microbotanical analyses in the archaeological record (Shillito 2013).

Phytoliths can be identified by various taxonomic levels including family, subfamily, tribe, genus, species, and subspecies (Piperno 2006:23). Silicification in plants occurs most commonly in a plant’s epidermis or the outermost parts of fruits and seeds and the epidermis of glumes, lemmas, and paleas. Orchids and palm leaves produce phytoliths in subepidermal tissue. Diagnostic phytolith shapes occur most widely within families such as Poaceae and Cyperaceae. Some of the highest phytolith-producing plants include monocotyledons (grasses, sedges, and palms). As with pollen, there are also some shapes which occur throughout various plant taxa, regardless of their environment or global region. Many plants produce various types of phytoliths; however, there are some plants that do not produce phytoliths under any conditions. For example, aroids (flowering plants in the Araceae family), Amaranthaceae, Chenopodiaceae, yams (*Dioscorea spp.*), a variety of trees, and even most cacti are unable to produce phytoliths (Piperno 2006a:6). Hair cells and hair bases are commonly formed in the epidermis of eudicot leaves. Other times, incomplete silicification within cells forms saddle-shaped or bilobate phytoliths within grasses.

Phytolith Sampling

Phytolith sampling strategies take various forms including sampling from cultural contexts, natural contexts, modern surfaces, and from vegetation (Pearsall 2015). Sampling cultural contexts is ideal during excavation of areas with human activities such as archaeological sites or former agricultural fields. Sampling can be done on virtually any feature in vertical columns or from horizontal surfaces. Cultural contexts such as archaeological floors, vessels, or unique pits are ideal for phytolith sampling. Reconstructions of past environments on larger scales can be done by coring natural contexts like lakes or waterlogged areas away from human disturbance. Buried soil horizons and soil outcrops can also be sampled as natural contexts for environmental reconstruction.

Comparing natural and cultural contexts is useful in understanding human effects on the environment and long-term changes. Sampling modern surfaces for phytolith investigation is another useful strategy. This method functions as a “control” to measure any movement of phytoliths through soils and should reflect vegetation assemblages in the immediate vicinity. The final sampling strategy involves sampling vegetation to understand phytolith production for specific taxa and is required for building comparative reference collections. Specimens can be collected from vegetation from the area of research, agricultural fields, markets, or herbarium specimens. In any case, it is important to positively identify these samples and be able to isolate various plant parts when processing for phytoliths.

Vegetation sampling and multiple cultural contexts were sampled for paleobotanical analysis. Samples were taken from natural vegetation in northwest Belize within the Rio Bravo Conservation and Management Area and from multiple household gardens in the town of San Felipe in Orange Walk District (Aebersold, Hart, and Valdez 2016). These samples were used in creating a comparative reference collection vital for analysis in this dissertation. This was crucial to the interpretation of archaeological samples because they were compared to known modern plant phytoliths.

Plants were chosen based on relative abundance in vegetation. Three sets of plant specimens were collected for each type of plant collected: one for the reference collection, one for the Belize Herbarium in Belmopan, and one for the Herbarium at the University of Texas at Austin. An ethnobotanical study conducted with residents of San Felipe accompanied the collection process, which is expanded upon in chapter 7.

Selection focused on taxa from house gardens and small plots complimentary to cultivated taxa previously found in the archaeological record, especially those plants which serve a purpose outside of food.

Specimens were collected from plants with ample vegetation so that the parent plant would survive after we cut leaves, branches, or stems, and any fruits or flowers present. A record was created for each specimen that included photographs, GPS coordinates, field indicators, and any additional notes when possible. After collection, plant specimens underwent preparation for phytolith extraction, microbotanical charring, and pressing for herbarium vouchers. Possible environmental contaminates were removed by washing and rinsing specimens with a diluted soap solution and water before drying them in plant presses. Next, specimens were laid and pressed with newspaper and corrugated cardboard sheets. Dozens of specimens were packaged together at one time with herbarium straps before they were set to dry in a low powered electric oven.

Once specimens were dry, each specimen not designated for herbarium curation was cut into various plant parts including leaves, stems, fruits, flowers, etc. This ensured potential diagnostic phytoliths were separated and identified for processing before incineration. Plant remains were wrapped in multiple layers of aluminum foil and incinerated inside a metal oil drum with a lid. It is important to note that at least a few handfuls of vegetation per specimen were required for collection because the incineration process greatly decreases the volume of each sample, especially after each specimen is cut into different parts. The fire was fueled by kindling made of wood charcoal and newspaper that reached temperatures between 400° to 600°C. Samples were charred for macrobotanical reference samples or fully incinerated to ash for a phytolith reference collection. A furnace control sample for phytolith analysis was also collected to ensure that reference slides were free of contaminants.

Phytolith Processing for Vegetation

As with sediment samples, there are multiple methods for processing plant specimens for phytolith extraction (Parr et al. 2001; Pearsall 2015; Piperno 1988, 2006). The various methods include wet oxidation, dry ashing, and microwave digestion. For this dissertation, the wet oxidation method was employed at the Smithsonian Tropical Research Institute in Panama. Ashed samples from the field were placed in crucibles and were further incinerated in a muffle furnace for two hours at 500° C inside a fume hood. Approximately 0.1 g of ash was placed inside 16 x 100 mm glass test tubes. This amount of ash is enough to yield a representative sample of phytoliths for most taxa (Piperno 1988). A 10% HCl solution was added slowly and stirred with a rod to ensure any carbonate material was dissolved. The tubes were left covered loosely with aluminum foil overnight. The next day, the tubes were filled with deionized water and centrifuged for ten minutes at 2,500 rpm. The samples underwent two more washes where effluent was poured, tubes were refilled with deionized water, and samples were centrifuged.

After the ash was washed three times, the tubes were filled with a solution of 65% nitric acid (HNO_3) approximately 2 cm below the rim. The tubes were placed in a hot plate that accommodates 16 x 100 mm tubes. Samples were heated at a medium-high heat when a few bubbles appeared. To speed up the digestion process of all organic material, solid potassium chlorate ($KClO_3$) is slowly added in small amounts (less than .5 g). This is based on the oxidation procedure of a Schulze solution (three parts HNO_3 and one part $KClO_3$). Digestion is complete when no reaction occurs upon adding more $KClO_3$ and any remaining materials sink to the bottom of a tube (Piperno 1988). Most samples for this dissertation were digested in approximately one hour, but a few woody taxa required up to two days of oxidation.

Once samples were left to cool after oxidation, the effluent was carefully poured, and the tubes were filled with deionized water. The tubes were centrifuged for ten minutes at 2,500 rpm. This rinsing step was repeated two more times, for a total of three washes. The samples were filled with acetone and centrifuged a final time for ten minutes at 2,500 rpm. Upon pouring the last acetone effluent, the tubes were dabbed while upside down before turning upright. This step ensured that as much liquid as possible was removed from the tubes without disturbing the material inside. Samples were left to dry overnight in an oven at 45° C. When the samples were completely dry, they were mounted with Permount and sealed with nail polish.

STARCH GRANULES: BIOLOGY, DEPOSITION, AND MORPHOLOGY

Starch grains or starch granules are terms used to describe semi-crystalline aggregates comprised of amylose and amylopectin polymers (Pearsall 2015; Torrence and Barton 2016). Archaeological research utilizing starch analysis has been recognized since the early 1900s; however, studies were slow to appear in significant numbers until the 1980s with the study of tubers in waterlogged areas in Peru (Pearsall 2015; Ugent, Pozorski, and Pozorski 1992). It was Loy, Spriggs, and Wickler's (1992) study in the Solomon Islands which successfully recovered starch granules on stone tools dating back 28,000 years ago that began a modern era in starch analysis for archaeological research.

Glucose is a simple sugar, or monosaccharide, and is a basic carbohydrate. Starches are complex carbohydrates within plants that provide an energy storage formed from long chains of monosaccharides, or polysaccharides (Gott et al. 2016; Henry 2014). The formation of starches begins with the process of photosynthesis within chloroplasts. Light triggers a series of events in which water molecules are split and reconfigured with carbon dioxide to produce glucose, the basis for nutrients a plant requires for survival. Glucose travels between plant organs called chloroplasts to amyloplasts where it is converted into long-term storage as starch or used immediately (Gott et al. 2016; Henry 2014). This energy unit is converted back to glucose when a plant requires energy. Starch also provides an energy source when consumed by animals and humans.

Plants generate both transient starch and storage starch. During the day, photosynthesis is high and transient starch grains are formed within chloroplast organelles. These short-term energy starches are formed in the leaves and stems of plants. At night, transient starches may be used as energy or are converted back to sugar as long-term storage in amyloplasts (Devio 2016; Gott et al. 2016; Pearsall 2015; Raven et al. 2005). Plants store extra glucose until they need energy to germinate, create fruit, or create tubers. This type of long-term storage can be formed as a single grain or as a conglomerate of starch grains.

Genetic factors control if storage starch is manifested as a single grain or a conglomerate. Common conglomerate grain starches include manioc, rice, oats, and peas, but can be broken up into singular granules if milled (Perez and Bertoft 2010). Starches are ubiquitous throughout plant tissue, especially within storage organs such as roots, tubers, fruits, and seeds (Gott et al. 2016:36). Between 65% and 90 % of dry weight is attributed to starch in potatoes, yams, and manioc, and up to 75% of maize (Perez and Bertoft 2010; Sivak and Preiss 1998).

Although starch grain morphology is controlled by genetic makeup, size and shape can be influenced by internal and external environmental mechanisms (Gott et al. 2016). Growth begins at the hilum and layers are added in succession as the starch grows outward. This origin point connects starch grains to amyloplasts organelles. Starch granules can be further characterized by the presence of a lamellae, fissures, and a birefringent extinction cross (Perry 2001:142). Starch granule shapes vary from disc, oval, lenticular, elongated, kidney-shaped, or polygonal in shape.

Water composition and age are positively correlated with larger sizes in starch granules up to 100 μm, but granules typically range between 1 μm and 25 μm. Starch granules are made up of alternating rings of amylose and amylopectin called lamellae (Devio 2016; Gott et al. 2016; Henry 2014; Tester et al. 2004). Some plant species contain starches with fissures of various shapes which originate at the hilum and spread outward. Other unique distinctions include striations, ridges, and open hila/pores. Panicoideae cultigens such as corn, sorghum, and millet are known to have pores on starch grain surfaces (Fannon et al. 1992).

The semi-crystalline composition and highly ordered molecular structure of starch granules allows them to be observed under crossed polarized light due to their birefringent quality. This means that granules will appear as bright and glowing with an extinction cross against a black background. The center of an extinction cross defines a starch granule hilum. Other microscopic matter including faunal spherulites, cellulose rings, and some calcium carbonate particles within animal digestive tracts also exhibit birefringent qualities, but can be distinguished if they do not rotate upon turning a polarizing filter (Coil et al. 2003; Pearsall 2015). Additionally, a fungal spore called conidia also exhibits birefringence, but can be identified if it appears in rows and measures below 5 μm (Haslam 2006) Birefringent qualities of starches can be observed with any equipment with cross polarizing capabilities (Devio 2016; Pearsall 2015). Chemical extraction and drying can also reduce birefringence and the visibility of fissures and lamellae. These weaknesses encourage microfossil analysis to extend to phytolith analysis while identifying starch granules.

There are multiple ways starches are released into the archaeological record. Starch grains can be released into sediments as plant parts decay in agricultural fields, as people consume and discard starchy foods, and on the surface of artifacts used to store and process starches. The presence of starch granules in sediments can provide insight into the surrounding environment and designated activity areas. Starch granules are not integral to plant reproduction and are not dispersed over long distances from their origin. Instead, starch granule are primarily deposited *in situ* from underground storage organs, like tubers, and rarely move downwards through soils (Barton and Matthews 2006;

Haslam 2009). Flooding and soil erosion can lead to displacing starch granules; but this type of disturbance lends itself to the destruction of starch granules from soil bacteria and fungal organisms (Lentfer et al. 2002; Pearsall 2015). Moreover, starches present in sediments are not redeposited onto tool surfaces (Williamson 2016).

One of the most common deposition pathways is from plant tissues to artifacts like stone tools, manos and metates, and ceramic vessels via food processing activities. Coarse-grained artifacts like shell, bone, ceramics, and grinding stones are especially useful in providing protection against external degradation mechanisms. Starch granules become lodged within microscopic crevasses and pores, even within obsidian. There are many opportunities during food processing that can deposit starches into the archaeological record. Starches are released into the environment any time people discard inedible portions, peel, cook, slice, pound, or prepare foods (Beck and Torrence 2016; Hastorf 1999).

Desiccated plant remains, partially charred plants, and artifacts with plant-based glue or resins also function as a barrier against microorganisms that threaten starch granules (Barton and Matthews 2016; Parr 2002a; Ugent 1982). Analyzing these types of artifacts can provide useful data to understand tool function and plant processing (Chandler-Ezell et al. 2006; Pearsall 2015; Perry 2004; Fullagar 2006). Artifacts

Human activities can also modify starch granule morphology, chemical characteristics, and preservation. Food preparation presents several challenges during analysis. Activities such as grinding or pounding for extended periods of time will crack and sometimes break granules. Starch granules gelatinize and lose their birefringence between 60-80°C, prompting the positive identification of food items strictly from raw foods or poorly cooked foods (Copeland and Hardy 2018).

Taphonomic variables also pose challenges to starch granule survival and identification. The main threats to starch granule preservation in the environment are fungi, microbes, and any other organisms which produce starch-degrading enzymes. Some usual suspects include burrowing insects such as earthworms and ants. Fungi and bacteria are primarily responsible for breaking down organic matter in soil and jeopardize starch granule preservation. A decrease in water availability might hinder microbial activities, modify soil pH, and deactivate enzymatic processes (Barton and Matthews 2016). Water conditions do not always restrict starch survivability. Starch granules have been recovered in both arid and tropical environments (Barton 2005; Barton and White 1993; Loy et al. 1992; Piperno and Holst 1998; Rosenswig et al. 2014). Starch granules have also been known to survive in sediments with pH levels between three and nine (Balme and Beck 2002; Barton and Matthews 2016; Rossen et al. 1996; Tuross and Dillehay 1995).

Human digestion also threatens preservation at different stages including mastication, during enzymatic breakdown with saliva, and chemical digestion within intestines (Barton and Matthews 2016:78). Despite a rigorous digestion process, some starches survive human digestion after excretion within fecal matter (Horrocks 2016). Starch granules are also known to survive within dental calculus (Beck and Torrence 2016; Blatt et al. 2011; Cummings and Magennis 1997; Juan-Tresserras et al. 1997; Mickleburgh and Pagán-Jiménez 2012; Pearsall 2015). Although human input is a likely source of degradation, there are many variables threatening the preservation of starch granules. Crystalline structure, physical and chemical attributes, granule size, gelatinization susceptibility, and enzymatic variables all contribute to starch granule degradation.

Starch granule analysis provides an assortment of archaeological data. People have a variety of uses for starch-rich plants aside from food including use as material culture and chemical exploitation. Among hunter-gatherer societies studied by Cordain et al. (2000), a typical diet consists of 90% plants like fruit, seeds, nuts, and underground storage organs. Recent ethnobotanical studies confirm plant use for material culture requirements as low as 18% and as much as 70% (Atkins and Bowler 2001; Cotton 1996). Material culture derived from plants can include building materials, clothing, pigments, fibers, masks, canoes, and many other raw materials that can be deposited into the archaeological record.

In many cases plants have many parts that have more than one use. Gott's research in Australia (1999) identified multiple uses for *Typha domingensis* and *Typha orientalis*. *Typha* is used during tool production and is a source of fiber material in addition to providing tubers for consumption. What also makes starch-rich plants unique is that they are considered soluble macromolecules that have important qualities like high viscosities and adhesive qualities. Today, up to 70% of starch produced in Europe and the United States is not used for food, instead it serves industrial purposes (Lillford and Morrison 1997). Utilitarian uses for starch have been recorded throughout history. Starches have been documented to have medicinal uses, adhesive properties, pigments, fragrances, and even poisons throughout history (Beck and Torrence 2016:65; Cotton 1996).

Dental Calculus Laboratory Method

Dental calculus was sampled in the field laboratory at Programme for Belize Archaeological Project from 42 teeth using a sterilized dental pick. An osteology team headed by D. A. Riegert examined and cleaned human remains excavated at Colha during the 2017 field season. Teeth were identified and assigned by maxillary or mandibular position. Each tooth was visually inspected, handled with latex gloves, and calculus was labeled as retrieved from either subgingival or supragingival surfaces. Calculus was scraped onto a new, clean sheet of paper and debris was funneled into a 2 mm vial each time. Laboratory processing was executed at the Environmental Archaeology Laboratory at the University of Texas at Austin.

Approximately one milliliter of 10% dilute HCl was slowly added to each vial to disaggregate calcium carbonates from dentition fragments, calculus, or any sediment debris. Samples were then centrifuged for five minutes at 10,000 rpm. Next, effluent was poured off and samples were washed with RO water, vortexed, and centrifuged. This step was repeated three times before samples were set to dry for a few hours at 40°C. Samples were directly mounted onto slides with Entellan and analyzed at 400X power with a simple darkfield condenser to identify birefringent properties of starch granules, fibers, and any minerals.

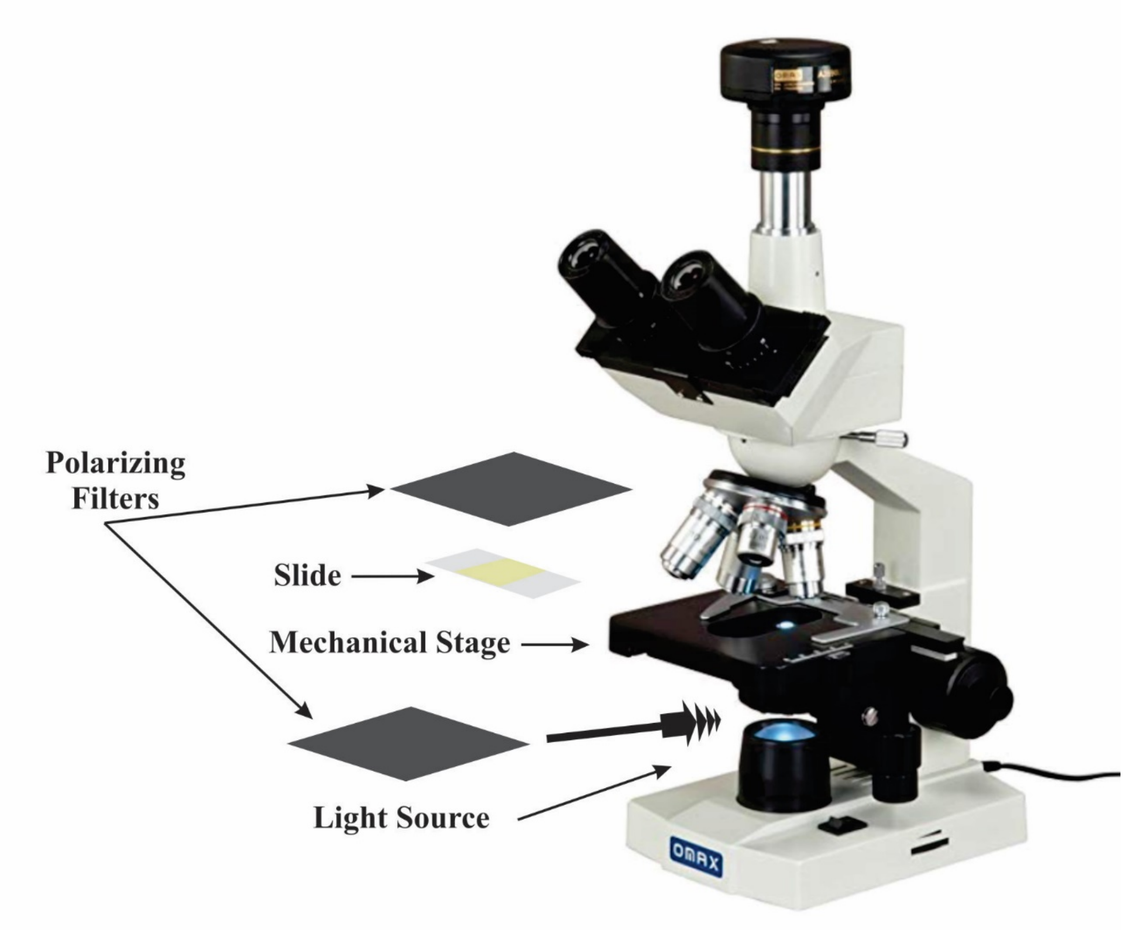
Dental Calculus Analysis

Dental calculous samples have a range of oral debris, making analysis of each sample unique in comparison to sediment analysis. Each slide containing dental calculus was analyzed in full for phytoliths, starch granules, fibers, and mineral debris. Results are expressed to include all findings for a broader analysis.

POLARIZING A MICROSCOPE

To observe birefringent qualities of microfossils, I applied a simple darkfield condenser. A generic sheet of polarizing filter was cut into two pieces. One sheet of polarizing filter was placed between the objective and each slide, and the other rested upon the LED light source. Simply rotating the bottom polarizing filter was enough to black out the background and observe birefringent qualities on various minerals, fibers, and starches. This easy set-up, demonstrated in Figure 3.1, is an inexpensive solution when a polarizing microscope is not available. Note, this setup uses a microscope with LED lights so the light source does not overheat and melt the polarizing film.

Figure 3.1: Microscope configuration using polarizing film modified from MicroscopeNet.com.



MICROFOSSIL IDENTIFICATION PARAMETERS

The scope of microbotanical analysis in this dissertation spans phytoliths, starch granules, and fibers. Phytoliths are identified according to the ICPN classification system if applicable (Madella et al. 2005). Forms not considered diagnostic are also included in counts to adequately represent the assortment of phytoliths observed in this dissertation. The phytolith reference collection gathered during 2016 and processed during 2017 was imperative to the analysis of this dissertation. Additionally, Dr. Dolores Piperno was extremely generous with access to her reference collection at the Smithsonian Tropical Research Institute Panama. Irene Holst supervised the process of digitizing a portion of the collection and provided additional sediment and reference collection training in phytoliths. Many published phytolith images were referenced to compare samples in this dissertation as well, especially Piperno's work highlighting neotropical flora (Piperno 1988, 2006c; Piperno and Pearsall 1998)

Each slide analyzed for dental calculus was scanned in its entirety. Starch granules were examined based on several qualities following guidelines from Pearsall (2015), Piperno (2006c), and Torrence and Barton (2006). Several characteristics for the identification of starch granules were required during analysis. First, each grain was inspected for an extinction cross and characteristics were described including strong, weak, straight arms, bent arms, right angle, etc. The size of each granule was measured in μm to note the length and width. The shape was also determined as best as possible in three dimensions (spherical, ovoid, reniform, hemispherical, polygonal, etc.). Any facets were also described to include number, angularity, rounded, sharpness, or other distinctive feature.

Key characteristics like lamellae were described as either not being visible, fine, coarse, or any other pattern. The hilum, when visible, was described as open, closed, centric, slightly eccentric, and so on. Any fissures were also described if they were linear, stellate, or other distinct forms to help with identification. The outer wall was also described if it was single, double, smooth, or irregular. The surface was also described in detail to include if it was considered smooth, granulary, bumpy, included radial lines, or other distinctive features. Lastly, granules were annotated if they were observed in compounds or as single granules

I referred to many images from publications to help with starch analysis (Berman and Pearsall 2008; Henry et al. 2009; Musaubach et al. 2013; Pagán-Jiménez 2015; Pagán-Jiménez et al. 2015; Pagán-Jiménez et al. 2016; Pearsall et al. 2004; Perry et al. 2007; Piperno 2006c, Piperno and Dillehay 2008, Piperno and Holst 1998, Torrence and Barton 2006, and Zarrillo et al. 2008). Best means of identification sometimes requires some starch granules and phytoliths to be rotated for absolute identification; however, the use of a permanent mounting medium did not allow for this additional step.

Microbotanical Diagnostic Morphologies

Arecaceae

Arecaceae, or palms, produce spherical spinulose phytoliths throughout the leaves, stems, fruits, and petioles. There are many uses for *Acrocomia* and *Attalea* species including construction, bedding materials, fruit and nut consumption, and oil extraction. Palm fruits produce amorphous starch granules; however, *Attalea maripa*, *A. butyracea*, and *A. racemosa* produce very similar starch granules. The granules can be aggregates in the shape of sheets and are distinguished by multiple, closely-spaced divots or "pockmarks." Interlinked extinction crosses are associated with the pockmarks under crossed polarized light. The grain sheets appear to be a series of transparent bacillus bacteria connected end-to-end with larger granules belonging to *Attalea maripa,* middle-range granules belonging to *A. butyracea*, and very fine grains with the smallest and shallowest pockmarking belonging to *A. racemosa* (Perry 2001).

Asteraceae

This family is more broadly known as the sunflower family and produces opaque perforated platelet phytoliths (Piperno2006a). Asteraceae may represent weedy taxa growing in agricultural fields and household gardens that could also be used for food or decorative purposes.

Cucurbita spp.

Cucurbita or squash phytoliths from rinds produce genus-specific phytoliths. They are spherical with a distinctive scalloped surface containing cavities. *Cucurbita* phytoliths range in size from 48 to 87 μm. Leaves of the *Cucurbita* also produce diagnostic hair cells that are variable in length and width. Phytolith production in hard rind within fruits is controlled by the genetic locus Hr (hard rind) (Piperno et al. 2002; Simms 2014: Fig 7.9d). Selection for a softer, non-lignified fruit produces phytoliths lacking in the distinctive scalloped characteristic. An intermediate level of lignification can produce scalloped phytoliths with shallow surfaces. *Cucurbita moschata* phytoliths have an elliptical shape with imprints from lignified cells in the mesocarp. Varieties of *cucurbita moschata* have been identified in the Northern Lowlands (Sanjur et al. 2002).

Capsicum spp. L.

The five most common types of economic chili peppers, *Capsicum spp. L.*, include *C. annuum*, *C. baccatum*, *C. chinense*, *C. frutescens*, and *C. pubescens* (Perry et al. 2007: 986). Each of these chili species produces large starch granules described as flattened lenticular with shallow depressions resembling red blood cells. A longitudinal fissure with sharp edges runs parallel to the longer axis of the granule if rotated into side view. Domesticated granules range in size from 13 to 45 μm, as opposed to smaller wild chili pepper species.

Gossypium spp.

Cotton fibers (*Gossypium spp.*) are long, flattened, and ribbon-like (Blatt et al. 2010). They have raised edges and are often rolled in a helix, much like a strand of DNA.

Ipomoea batatas

Ipomoea batatas, or sweet potato, starch granules are predominantly aggregates of polygonal grains with a small, transverse fissure and clear pressure faceting (Mickleburgh and Pagán-Jiménez 2012; Piperno and Holst 1998: Fig. 2). Starch granules can have different types of fissures including single and Y-shaped and the hilum can sometimes be open as well (Mickleburgh and Pagán-Jiménez 2012). Sweet potato starch granules range between 4 to 34 μm (Perry 2001). Sweet potato starch granules are similar to manioc starch granules; however, lamellae layers are more visible. Sweet potato starches exhibit extinction crosses where lines waver and can have rougher edges. Unlike, manioc, the extinction cross is not typically centric. As sweet potato compound granules form next to each other in aggregates, they produce more angular granules with more faceting.

Manihot esculenta

Manihot esculenta is more commonly known as manioc and comes in two varieties of starch granules, compound granules and undiagnostic spherical granules. Granules are typically round or hemispherical (bell-shape) with a larger proximal end and faceting at the base with a diagnostic stellate (winged), crossed, or y-shaped fissure radiating from the centric hilum (Mickleburgh and Pagán-Jiménez 2012; Piperno and Holst 1998: Fig. 1). Both the hilum and extinction cross are centric within granules which also exhibit two concave pressure facets at the basal end. Manioc granules have smooth surfaces, no lamellae, and are between 5 and 20 μm in length (Chandler-Ezell et al. 2006; Devio 2016: Fig. 9.1D; Perry 2001; Piperno 2006c).

Marantaceae

The *Marantaceae*, or arrow root, family includes *Calathea* (llerén) and *Maranta* (arrowroot). This economic family serves medicinal purposes, has many edible species, and is decorative. *Maranta* produces species-specific phytoliths in the seeds with a smooth head and pointed tip and a cylindrical body with ciliate ornamentation (Chandler-Ezell et al. 2006: Fig. 1; Iriarte et al. 2010: Fig. 3q). *Maranta* rhizome phytoliths have a conical shape with a nodular surface (Perry et al. 2006; Simms 2014).

Maranta starch granules are smooth, rounded, have an ovoid shape with slightly wavy margin, and an off-center (eccentric) hilum (Mickleburgh and Pagán-Jiménez 2012). There is occasionally visible lamellae and proximal fissuring at the hilum. Granules are between 10 to 50 μm and may have “Y” fissures (Perry 2001; Piperno 2006c; Piperno and Holst 1998). They are described as resembling a closed mussel shell with a slight ridge on the right. *Calathea allouia* starch granules are similar in shape as

Maranta starches; however, they are thicker with more squared off edges, the hilum present at one end of the granule, and fissures are rare. The hilum end is thicker, the granule tapers from this area, and size ranges from 22-42 μm (Perry 2001).

Phaseolus

Both *Phaseolus vulgaris* and *Phaseolus lunatus* are bean varieties containing hook-shaped phytoliths. Bozarth (1990: Fig. 1) explains that these hook varieties are formed within bean pods and are diagnostic of *Phaseolus*. It is important to also distinguish this morphology from similar curved hair phytoliths described by Piperno and Dillehay (1988: Fig. 2) belonging to Aristolachaceae, Moraceae, Urticaceae, Boraginaceae, and Leguminoseae. According to Bozarth (1990), Phaseolus phytoliths are wider by an average of 6 μm from the tip, making them distinguishable from other families. Bean starch granules are large, oval to kidney in shape and contain a longitudinal fissure extending the length of the grain and range from 14 – 60 microns long (Piperno and Holst 1998). Species identification is difficult due to the ambiguity of Phaseolus starch granules (Devio 2016; Simms 2014).

Poaceae

Twelve subfamilies make up the grass family Poaceae, but descriptions will be limited to likely forms within the scope of this dissertation. Grasses present in the archaeological record could represent thatching, bedding, and those used during food preparation. There are other grass pathways into botanical assemblages including foot traffic, bioturbation, aeolian and water transport, and from simply maintaining home gardens.

Phytoliths from the leaf epidermis of grasses can be distinguishable to subfamily (GPWG 2001; Piperno 2006; Piperno and Pearsall 1998). Panicoideae refers to tall tropical grasses like *Zea mays* and phytolith morphologies include bilobates, cross bodies, and rondels. Panicoideae phytoliths can be generalized as Poaceae since they produce diagnostic phytoliths within different maize parts like cobs, glumes, and leaves. Less diagnostic cross bodies, rondels, bulliforms, and scutiforms are more broadly classified as Poaceae. The majority of bilobate and cross body phytoliths are formed within Panicoideae leaves. Pearsall (1978) classifies large and extra-large Variant 1 cross bodies as *Zea mays* leaves. Classic *Zea mays* diagnostic cob phytoliths include wavy top, ruffle top, and spooled rondels described by Piperno and Pearsall (1998). Chloridoideae grasses are typically drought-adapted short grasses found in prairies, savannas, and agricultural weeds within seasonally dry tropics with squat saddle morphologies. Bambusoideae grasses, including bamboos, are present in woody and herbaceous taxa in forests and produce tall saddle phytoliths.

Maize starch granules can be spherical, hemispherical, or polygonal with four to six sides of varying lengths. Granules have deep compression facets and can have a spherical, V-shaped, or linear hilum with cracks or radial fissures (Holst et al. 2007; Musaubach et al. 2010). Flint maize starch is blocky polygonal with slightly smoothed edges and has a hollow, somewhat eccentric hilum with a “Y” or “T” shaped fissure that follows the planes of the granule. A discontinuous and indistinct double border are diagnostic qualities in flint type maize starch granules (Pagán-Jiménez 2015; Perry 2001; Piperno and Holst 1998). Flour maize starch granules, on the other hand, are smoothly rounded. Both extinction cross and inconsistent double border are also present in flour maize, but the hilum is not as clear and can be distinguished if it changes from white to gray during focusing. Maize granules vary in size from 6 to 26 μm (Holst et al. 2007; Pagán-Jiménez 2007).

MICROCHARCOAL BACKGROUND

Reconstructing Neotropical environmental histories is often facilitated by pollen analysis and illustrates Pre-Columbian forest clearance due to agricultural practices (Anchukaitis and Horn 2005; Dull 2007; Islebe et al. 1996; Piperno 2006 b; Wahl et al. 2006). However, pollen records primarily illustrate dramatic shifts in forest and disturbance taxa. Studies by Laurance (2004) and Fearnside (2005) have demonstrated that most anthropogenic impacts on tropical forests do not reflect a direct transition from dense forest to open herbaceous areas. This transition more closely resembles areas of cleared plots, successional plots, and areas of closed-canopy forests (Dull et al. 2010).

The humid Neotropics also have a distinct wet season, making fire episodes triggered by lightning rare when compared to human intentional and unintentional ignition. People play an important role in burning patterns through intentional manipulation and management of their environment during fire suppression or acceleration behaviors (Clark and Royall 1995; Turner et al. 2008b). Forest fires also become more susceptible to drought and anthropogenic cyclical forest burning (Dull et al. 2010; Stott 2000; Cochrane 2003; Marlon et al. 2009).

Microcharcoal analysis is useful for estimating fire frequency and magnitude on local and regional scales. Charcoal is transported via airborne and fluvial pathways during burning events and produces sampling peaks within the sedimentological record (Turner et al. 2008b; Turner et al. 2010). Erosion episodes linked to large-scale deforestation caused by fire during the Maya Preclassic period can be inferred from fire frequency and magnitude. Studies reflect an increase in charcoal peaks during the Preclassic period (or earlier) and a decline during the Classic period (Anderson and Wahl 2016; Beach et al. 2015a,c).

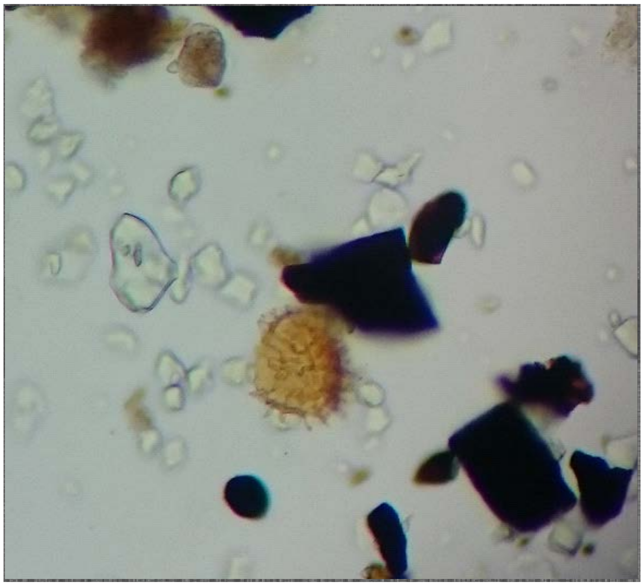
Microcharcoal Laboratory Method

After experimentation with clay-dense sediment samples, a micro-charcoal protocol was instated in the Soils and Geomorphology Lab modeled after Turner et al.'s (2010) density separation method. The method established by Turner et al. (2008a) includes a higher recovery rate than other published methods for finer charcoal fractions and is proven to be at least ten times more efficient for the recovery of standard pollen techniques.

Following a revised version of Innes et al. (2004), Turner (2007), and Ramsey et al. (2015), 2 g of sediment were subsampled and disaggregated in 80ml distilled water and 20ml of 10% hexametaphosphate in 300 mL beakers. Samples were left to soak for a few days, making sure to gently disaggregate stubborn clay after a few hours. After approximately three days of soaking and minimal agitation, suspended clays were pipetted every 90 minutes. Samples were then wet sieved through a 180 μm mesh, left to settle, and were pipetted once again. Next, 30ml of 10% HCI and two tablets of Lycopodium (Batch #3862: 9,666 spores each) were added. Once samples reacted for 90 minutes to ensure effervescence ceased, the HCl was washed out with RO water and samples were placed on a hot plate to evaporate excess water without letting the sample dry out. Samples were consistent with a moist sludge without cracks.

Samples were washed from the beakers into a 15 ml tube using 10 ml of sodium polytungstate (SPT) calibrated to a specific gravity of 2.5 g/ml. Samples were centrifuged at 1000 rpm for ten minutes. This separated the charcoal, leaving a pellet floating at the surface which was pipetted. Samples were then washed with RO water twice. Excess water was pipetted after the third wash and samples were pipetted into 5 ml plastic tubes in order to adequately remove any excess water from the remaining samples. A glycerol jelly mounting agent was used on slides and sealed with Entellan around the slip cover. Following Turner et al. (2008a), charcoal particulates were identified based on permutations of the following criteria: (1) particulates measure at least 30 μm in length or width, (2) color appears jet black, black, or contain a blue hue outline, (3) shape is angular to sub-angular, (4) may contain a cellular structure, (5) and may have straight or jagged edges. One hundred lycopodium spores were counted for each sample to account for a representative sample. Microcharcoal calculations are based on Innes et al. (2004) where microcharcoal particles of approximately 30 μm are the basic measurement unit. Fragments under 10 μm were not counted.

Figure 3.2: Microcharcoal particulates and lycopodium spore.



MAGNETIC SUSCEPTIBILITY

The degree to which a sediment sample can become magnetized is known as magnetic susceptibility (Dalan 2008). Measuring magnetic susceptibility allows for a quick and non-destructive characterization of sediments often used in paleoenvironmental studies (Rapp and Hill 2006). Ferromagnetic minerals in sediments are sensitive to environmental changes, such as burning events, or biological activities which break down organic matter (Ayala et al. 2007; Thompson and Oldfield 1986). Measuring the magnetic susceptibility in tandem with physical and chemical properties of sediments provides useful information regarding soil pedogenesis, past environments, and anthropogenic input over time in a variety of locations (Ayala et al. 2007; Gale and Hoare 1991).

For example, an Archaic component and two paleosol sequences associated with human occupation reflected increased magnetic susceptibility when compared to other horizons in a soil profile at the Canning site in North Dakota (Rapp and Hill 2006). Magnetic susceptibility has also been used in the neotropics to study paleosols and anthropogenic impacts in Maya Lowland geoarchaeological studies (Beach et al. 2006; Beach et al. 2018a). Increased readings are often indicators of burning events, changes in the environment related to wetter conditions, or human occupation.

Magnetic Susceptibility Method

There are numerous portable and stationary magnetic susceptibility tools available to measure magnetic susceptibility. This dissertation employed a GF Instruments SM-20 magnetic susceptibility meter to measure magnetic susceptibility to 10^{-6}SI units along soil profiles in 5 cm intervals. A total of three low frequency readings (χ_{LF}) were recorded up to 0.001 accuracy and the average was used to plot measurements.

MEHLICH II PHOSPHORUS

Measuring quantitative phosphorus has become a reliable tool in geoarchaeological studies. Phosphorus increases concurrently with areas of human input and leaves behind a permanent chemical signature that is only removed from erosion or major transport mechanisms. Phosphorus is naturally recycled between living organisms and sediments. Human activities which introduce higher phosphorus signatures in the environment involve natural fertilization techniques, household refuse and human waste, livestock handling, burials, and organic construction materials (Ayala et al. 2007;

Sweetwood et al. 2009; Terry et al. 2000). Measuring soil phosphates is useful in delineating archaeological sites throughout the excavation process and examining ancient agricultural practices (Beach et al. 2006; Beach et al. 2008b; Beach et al. 2018b, Dunning et al. 1998; Terry et al. 2000).

Mehlich II Laboratory Methods

Mehlich II Phosphorus testing for this dissertation followed Terry et al.'s (2000) Mehlich II extraction procedure. Soil samples were taken in increments along soil profiles during excavation. Sediment samples were subsampled (2 g) and sieved through a 2mm mesh. Samples were then mixed with 20 ml of Mehlich II extraction solution, shaken for five minutes, and filtered through a 15 cm filter paper. Next, 1 ml of the solution was aliquoted to a colorimeter vial and diluted to 10 ml using RO water. A packet of PhosVer 3 Reagent is added to each sample, shaken for 60 seconds, and let to settle for four minutes. Measurements were calibrated against a KH_2PO_4 (potassium dihydrogen phosphate) standard curve with known phosphorus concentrations to calculate each sample's phosphorus concentration. A Hach DR/850 Colorimeter measured the extractable phosphorus using the percent transmittance function at a wavelength of 690 nm.

LOSS ON IGNITION

Loss on ignition (LOI) methodology is based on the principle of differential thermal analysis. This principle is based on the process where a dried, powdered sample containing carbonate ($CaCO_3$) and organic matter will evolve upon ignition at various high temperatures (Dean 1974). This technique is useful for archaeological sediments because it can be correlated with human activity as well as soil formation processes like accretion, erosion, and vegetation growth (Ayala et al. 2007; Beach et al. 2006; Beach et al. 2008b; Dean 1974).

Loss on Ignition Laboratory Method

LOI for this dissertation was used following an adaptation of Heiri et al. (2001), as used by the National Lacustrine Core Facility, or LacCore. Sediments were subsampled (5 g) and passed through a 2 mm sieve into ceramic crucibles. Weights were recorded throughout the process before and after each burn in a Cole-Parmer Stable Temp 1100°C Box Furnace. Samples reached 100°C overnight to ensure humidity levels did not affect measurements. This sample weight functioned as the true pre-ignition weight for calculating organic matter and carbonate content. Samples were ignited to 550°C for four hours to remove organic materials and ignited to 1,000°C for two hours to remove carbonates. The amount of organic and carbonate content was determined using Dean’s (1974) equations.

550°C Ignition used to determine organic matter:

$$\text{\% Organic Matter} = \frac{(\text{Pre-Ignition Weight (g)} - \text{Post-Ignition Weight (g)})}{\text{Pre-Ignition Weight (g)}} \times 100$$

1000°C Ignition used to determine carbonate content:

$$\% \ CaCO_3 = \frac{(\text{Pre-Ignition Weight (g)} - \text{Post-Ignition Weight (g)})}{\text{Pre-Ignition Weight (g)}} \times 100$$

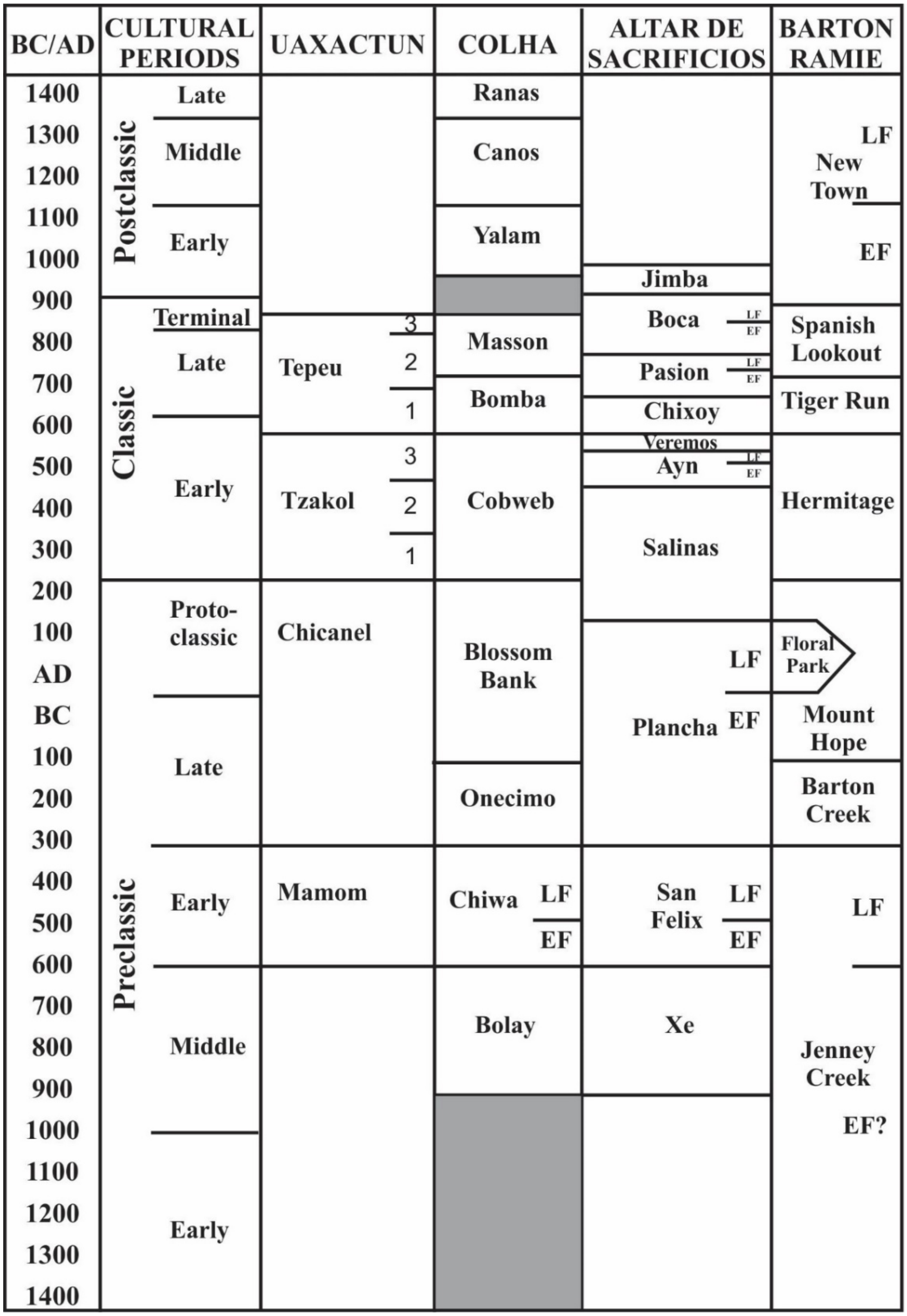
Chapter 4: Colha's Cultural History

Colha was first recorded by Normand Hammond with the Corozal Project Survey Team in 1973 (Hammond 1973; King 2000; Valdez 1987). Like so many sites in the Maya world, Colha was not originally noticed by traditional archaeological projects. Looting and non-professional "excavations" occurred during the 1970s and early 1980s (Valdez 1987). The site drew interest with intensive lithic scatters throughout several suspected stone tool production areas. This opportunity for studying Maya lithic technologies also prompted Colha to be an ideal location to better understand Maya chronology based on the evolution of stone tool forms in aceramic contexts. The long history of occupation at Colha from the Archaic Period through the Early Postclassic Period offers a unique look to understand the ancient Maya and their predecessors. With only a short hiatus lasting approximately 50 to 100 years leading into the Postclassic (AD 950), occupation continues into the Early Postclassic Period before abandonment in AD 1350. Colha flourished and experienced population peaks during the Late Preclassic and the Late Classic.

Multiple co-directors carried out intensive systematic investigations with the Colha Project beginning in 1979 including Hester, Schafer, and Eaton, as well as Adams and Ligabue (Hester 1979; Hester 1996; Hester et al. 1980; Hester et al. 1982; Hester et al. 1994). Archaeological investigations at Colha have focused on extensive chert deposits scattered throughout the site, lithic workshops, early Maya settlements, house mounds, and patio groups. Investigations at Cobweb Swamp have also contributed to understanding of Colha’s occupational history, subsistence economy, and overall function (see King 2000:95 for a detailed list of references).

Colha’s occupation spans the Archaic through the Late Postclassic. The earliest inhabitants likely began as small villages practicing wetland manipulation for economic cultigens, as well as early specialized stone tool manufacturing between 3400 and 1900 BC. The Maya chronological periods following this early occupation is demarcated by standardized ceramic complexes defined by Adams and Valdez (1979; 1980, Valdez 1987, 1994a) presented in Figure 4.1. The transition into the Preclassic is generally a period of establishment and increasing social complexity. Excavations in the 2000 and 4000 sectors have expanded what we know about this period (Buttles 2002). The following expands on the chronology of Colha based on ceramic complexes and previous excavations. Research has spanned the entire occupation; however, the cultural history review is centered on the Archaic and Preclassic periods to reflect the scope of this dissertation.

Figure 4.1: Colha Ceramic Complexes after Valdez (1987:28).



BC/AD	CULTURAL PERIODS		UAXACTUN		COLHA	ALTAR DE SACRIFICIOS	BARTON RAMIE
1400		Late			Ranas		
1300		Middle			Canos		LF
1200	Postclassic						New Town
1100					Yalam		
1000		Early				Jimba	EF
900		Terminal			▨	Boca LF EF	
800				3	Masson		Spanish Lookout
700		Late	Tepeu	2	Bomba	Pasion LF EF	Tiger Run
600	Classic			1		Chixoy	
500				3		Veremos Ayn LF EF	
400		Early	Tzakol	2	Cobweb		Hermitage
300				1		Salinas	
200							
100		Proto-classic	Chicanel				
AD					Blossom Bank	LF	Floral Park
BC						Plancha EF	Mount Hope
100		Late					
200					Onecimo		Barton Creek
300							
400			Mamom		Chiwa LF	San Felix LF	LF
500		Early			EF	EF	
600	Preclassic						
700					Bolay	Xe	
800		Middle					Jenney Creek
900							
1000					▨		EF?
1100							
1200		Early					
1300							
1400							

ARCHAIC PERIOD

Colha's earliest occupation comes from Cobweb Swamp. Jones' (1994) pollen analysis indicates forest clearance, disturbance taxa, and evidence for domesticated plant cultivation by 2500 BC. Inhabitants likely presided in ephemeral household structures and practiced hunting and gathering with some horticultural practices leading to larger scale wetland management. Large scale clearance facilitated the cultivation of manioc, cotton, chilies, and maize. Cobweb Swamp also contains evidence for field construction and ditching in areas of raised fields in marginal areas. These Archaic Period findings are confirmed with an aceramic stone tool assemblage on the periphery of an *aguada* near Cobweb Swamp (King 2000: Fig. 4, 5, and 9).

Several constricted unifaces and well-patinated chert tools were recovered from a stratigraphically isolated, aceramic horizon. This unique finding stands out because until then, constricted unifaces were typically recovered from construction fill and other mixed contexts at Colha and recovered as surface finds in other Archaic sites in northern Belize (King 2000; Hester 1996; Shafer et al. 1980). This area, away from habitation areas, indicates quarrying and specialized tool production (Hester et al. 1995; Iceland 1997). The aguada excavations also exposed a buried Middle Preclassic platform sealing the context of the aceramic horizon. The interface between the platform and aceramic horizon included a radiocarbon date between 900 and 800 BC (Hester et al. 1995; Iceland 1997). When compared to the site core, evidence for early settlement at Colha continues to grow.

PRECLASSIC PERIOD

Functional specialization, trade networks, and social differentiation was already in place by the Middle Preclassic at Colha (1000 – 400 BC). Occupation at the site core began during the Middle Preclassic between 900 and 800 BC (Anthony 1987; Iceland 1997; Potter 1980, Sullivan 1991, Valdez 1987). Inhabitants likely manipulated wetlands for agriculture and practiced "garden hunting" (Buttles 2002). Raw materials and goods are well established, and formal chert tools were distributed outside of Colha in reciprocal systems of exchange (Shafer 1994; Shafer and Hester 1991). Goods traded into the site include greenstone, igneous and metamorphic rocks, obsidian, and marine shells. Many of these goods can be observed in household features. Domestic middens and burials are comparable to other Middle Preclassic components in northern Belize (Valdez 1987; Valdez and Adams 1982). Cacao has also been identified through residue analysis from spouted vessels. These vessels associated with burials at Operation 2012 contained the chemical signature for *Theobroma cacao* (Hurst et al. 2002; Powis 2002).

The Middle Preclassic is comprised of Bolay (900 – 600 BC) and Chiwa (600 – 300 BC) ceramic complexes. The Bolay complex is the earliest ceramic complex corresponding to the early Middle Preclassic included in the northern Belize Swasey Sphere (Valdez 1987). Chicago Orange, Consejo Red, Honey Camp Orange-Brown, and Machaca Black are the principle ceramic groups. The most numerous Bolay groups include Chicago Orange, Ramgoat Red, and Quamina Cream, which develop into Chiwa Mamom groups. The Bolay complex also includes the "fat man" censor or potbellied form. The Chiwa complex dates to the Middle Preclassic and includes early and late facets. The principle ceramic group is the Juventud group. The Chiwa late facet includes spouted vessels or “chocolate pots” with modifications including incising, fluting, or other indentations (Valdez 1994a). There is evidence for increased exploitation and wetland modification of Cobweb Swamp including raised field cultivation associated with Juventud Red ceramics (Jacob 1995).

Evidence for small scale lithic production is present in residential contexts and construction fill. Lithic assemblages include expedient tools and hard-hammer percussion tools (King and Potter 1994; Potter 1991; Shafer and Hester 1983). The t-shaped adze and the biface with a wedge-shaped bit are distinctive forms which later develop into the tranchet bit tools during the Late Preclassic (Hester 1983, 1985; Meadows 2001). Potter’s (1991) use-wear studies of these specialized tools confirms that many of these forms were multi-functional. Lithic production later becomes more specialized, but it was already an important activity during the Middle Preclassic based on a variety of lithics showcasing chert-working activities including lithic debitage, multifunctional tools, expedient tools, tool blanks, and burin spalls.

Features during the Middle Preclassic include middens, caches, and fire pits lined with ceramics, and burials (Anthony 1987; Anthony and Black 1994; Buttles 2002; Sullivan 1991). A Middle Preclassic midden in Operation 2012 containing a ceramic cache and two jade artifacts. The lithics assemblages included a blade/burin complex comprised of various blade forms, burin spalls, blade cores, and trimmed blades (Potter 1982: Fig. 9, 10). Burin spalls are produced from macro blades after they exhaust their use and function as drills, perforators, or gravers. Associations of burin spalls with disk shell beads in Middle Preclassic contexts often suggests bead manufacturing (Potter 1980). These disk shell beads have also been found in other areas of northern Belize for the Middle Preclassic (Buttles 2002; Hammond 1991).

During the early Middle Preclassic semi-circular stone alignments containing outer terrace stone alignments were constructed on earthen and midden filled platforms. Structures include multiple construction phases and flooring episodes, indicating a continuous occupation during the early Middle Preclassic (Anthony 1987; Anthony and Black 1994; Buttles 2002; Sullivan 1991). It is during the Chiwa complex that specialized activity areas are first recognized. For example, Operation 2006 identified hearths, serialized plaster floors, and many *tecomates* (Buttles 2002; King and Potter 1994; Roemer 1979). Excavations at Operation 2012 focused on a small village with several large, open platforms containing burials with elite ceramic goods (King 2000). South of the site core at Operation 2006, an undefined specialized activity area was excavated with more plaster floors, large hearths, and *tecomates*, or neckless jars (King 2000, King and Potter 1994, Roemer 1979).

Burials from the early Middle Preclassic Bolay phase are typically extended supine, tightly flexed, or semi-flexed. They occur in domestic contexts with ceramic vessels placed over the head and may contain shell beads in the wrist and ankle areas. Middle Preclassic Chiwa phase burials are typically extended supine as well and contain larger numbers of burial goods (Buttles 2002). Excavations of three extended and contemporaneous burials located adjacent to platform structures at Operation 2031 provide insight to ties between the Bolay and the Chiwa complexes. A Consejo Red vessel was placed over the cranium in one of the burials. A Ramgoat Red vessel was placed over the cranium of the second burial. A Bolay ceramic censor was found with the third burial. This vessel is in the form of a “potbelly” figurine comparable to Late Preclassic sculptures from El Salvador and the Southern Pacific Coast of Guatemala (Anthony and Black 1994; Demarest 1986; Demarest et al. 1982; McInnis Thompson and Valdez 2008), only it occurs hundreds of years before. The Middle Preclassic village settlement in the 2000 sector would eventually grow into the site’s monumental center during the Protoclassic.

Following the Middle Preclassic, Colha’s population expanded and its inhabitants became more complex in terms of cultural, social, ideologic, and settlement patterns during the Late Preclassic (Hester and Shafer 1994). Colha flourished and the population peaked during the Late Preclassic. Chert was mined and worked into formal tools or traded. Approximately 36 lithic workshops appear as separate entities or perched on terraces around *aguadas* (King 2000), reflecting craft specialization occurring at the time. Over four million primary debitage and discarded tools have been recovered from the lithic workshops (Brown et al. 2004). Among them, edge abraders which are essentially broken tools that are reused to abrade bifaces. These reworked tools eventually lead to a shallow notch or depression on the reused tool (Hester 1983).

Political and religious aspects of the site became a substantial part of the settlement. Public monumental architecture emerged with temple structures with platforms, formal plazas, and a ball court (Buttles 2002; Eaton and Kunstler 1980). During the transition from the Middle Preclassic to the Late Preclassic, a plaza floor was constructed covering previous informal groups occurring in Operation 2031 (Anthony 1987; Buttles 2002; Sullivan 1991). Late Preclassic burial internment occurs in domestic and public spaces. Burials exhibit a diverse range of caches and traded goods (Buttles 2002). Colha was a settlement with a growing population, intensive craft specialization, and monumental structures suggest social stratification with an independent to semi-independent ruling elite class by the end of the Late Preclassic (Adams 1982; Buttles 2002).

Evidence for greater stratification involving a ruling elite class is observed through trade and non-utilitarian goods. Obsidian x-ray fluorescence sourcing by Brown et al. (2004) shows that as early as the Middle Preclassic and during the Late Preclassic Colha was engaged in a broad trade and distribution network. Highland Guatemalan obsidian from El Chayal, San Martin Jilotepeque, and Ixtepeque were all well represented in Preclassic contexts at Colha. Architectural and ritual deposits most commonly contained El Chayal obsidian. Lithic workshops most commonly had Ixtepeque obsidian. Both San Martin Jilotepeque and El Chayal were observed in obsidian midden deposits (Brown et al. 2004). Obsidian traded in from the Highlands continues to appear at Colha into the Terminal Preclassic.

Public ritual activity increases with practices like diverse cache deposits and lip-to-lip ceramic vessels (Buttles 2002). Oval bifaces, stemmed and unstemmed macroblades, narrow lenticular bifaces and symbolic forms contribute to a stabilizing elite community. According to Meadows (2001), biface forms serve as staff ends and that stemmed microblade and biface forms were symbolic of power. The tranchet bit tool (adze) and oval biface celt were developed during the Late Preclassic (Hester 1983). The tranchet technique involves removing a single flake from the distal end of the tool form to create the tool's bit (Meadows 2001; Shafer 1979, 1982; Shafer and Hester 1983).

The Onecimo and the Blossom Bank ceramic complexes come into use during the Late Preclassic, with the Blossom Bank complex continuing into the Terminal Preclassic (Valdez 1987, 1994). The Onecimo complex (300 – 100 BC) is a continuation of the Middle Preclassic Chiwa complex with abundant Sierra Red types. The Onecimo complex belongs in the Chicanel sphere and is related to the Barton Creek complex belonging to the Barton Ramie typology as well as the early facet Plancha complex belonging to Altar de Sacrificios. The Blossom Bank complex (100 BC – AD 250) is very similar to the Floral Park complex belonging to Barton Ramie. Many types in the Blossom Bank complex stem from the Onecimo complex. Attributes of these types include slips that are harder and glossier and the addition of more elaborate decorative elements including post-fired incised glyphs (Valdez 1994a). Together, craft specialization with stone tools and ceramics coupled with increased populations and public monumental architecture reflect various aspects of a more stratified community.

Changes in material culture, architecture, caches, and burial internment set up the Terminal Preclassic to transition into Classic Maya society. Colha exhibits a greater variation in raw materials and forms during the Terminal Preclassic (AD 100 – AD 250), especially obsidian, greenstone, and shell goods (Brown et al. 2004; Buttles 2002). Lithic manufacturing continues from the Late Preclassic with a greater occurrence of bifacial stone symbols (Meadows 2001). Reorganization of space is evident with a departure from domestic spaces into public spaces (Anthony and Black 1987; Sullivan 1991). A major change in architectural plan from apsidial or round to square or rectangular structures occurs at Operation 2031 with two non-domestic structures. Anthony (1987) suggests one rectangular structure functions as a storage room and the second structure functions as a ritualistic space such as a shrine or temple.

Cache and burial internment support a cultural shift from the Late Preclassic. The use of lip-to-lip caches containing raw materials remains in the Terminal Preclassic. Assemblages containing increased ceramic and symbolic stone caches supports the trend toward increased ritual activities. Symbolic stones are also called eccentrics and are often recovered in caches and burials, and may have indicated status (Hester 1983). Many caches were recovered from Operations 2031 and 2012, however a unique cache in 2012 reflects blood letting ritualistic behavior (Buttles 2002; Potter 1994). The cache in Strata 55, Operation 2012 contained shell beads and ornaments, shark teeth, jade beads, and a chert microblade. A brownish residue and brown spots were observed on the distal end of chert blade and many of the shell goods. The residues were positively examined for the human Immunoglobin G confirming human blood (Potter 1994). An enclosed burial crypt was excavated from a domestic feature in Operation 2031. The human remains presented no particular organization that may have served as an ossuary, meaning bones were deposited after being removed from other primary burials over time (Sullivan 1991).

CLASSIC

Colha experienced an overall decrease in populace and material culture during the Early Classic (AD 250 – 550). The Early Classic is defined by the Colha Cobweb complex which belongs to the Tzakol sphere. This complex is the smallest of all complexes and includes a variety of types including Aguila, Minaha, Balanza, Dos Arroyos Orange polychrome, and Actuncan Orange polychrome (Valdez 1987; 1994). There are no new construction phases and no lithic workshops for this period. Operation 2012 identified a stepped pyramid and platform formed continuously from earlier Middle Preclassic construction. This area represents a continued ceremonial precinct from the Late Preclassic through the Early and Late Classic periods with the presence of cache offerings and burial internments (Potter 1982). There is an overall scarcity of cultural material for the Early Classic. The southwestern quadrant of the site had once contained the greatest concentration of Early Classic cultural material; however, it was bulldozed in 1998 for a new citrus grove (King 2000).

The Late Classic (AD 550 – 800) was a time of regrowth in many aspects for Colha. The Bomba (AD 600 – 680) complex defines the Late Classic period at Colha. The Bomba complex is equivalent to Tepeu 1-2 and the Tiger Run complex at Barton Ramie. This complex comes from a continuation of the Tzakol sphere. The Mountain Pine group is the most common type. Bomba ceramic modes include medial ridges and barrel-shaped polychrome cylinders when compared to the Cobweb complex (Valdez 1984; 1994). Population growth stimulated the construction of domestic and public architecture (Eaton 1982a, b; 1994). Construction phases at the ballcourt and other ceremonial structures at Operation 2012 serve to provide space for ritual activities at this time (Eaton and Kunstler 1980; Potter 1982). There is a considerable decrease in caches when compared to the Late Preclassic and Protoclassic periods.

Lithic workshops intensify lithic production in larger numbers than the Preclassic, but in smaller clusters and appear as independent entities scattered throughout the site (Hester and Shafer 1994; King 2002). At this time, Late Classic workshops are typically associated with residences and each workshop specializes in a specific stage of production, type, or mode (Buttles 2002; King 2000). For example, there is a focus on stemmed blade, symbolic flake stones, and general utility bifaces and oval bifaces (Buttles 2002; Hester 1983). The location of lithic workshops between Colha and Altun Ha suggest the site may not have been controlling raw material acquisition or production, rather Colha was possibly under the tutelage of Altun Ha (Hester and Shafer 1994). Colha’s connection to Altun Ha is further supported by a decrease in flaked stone symbols at Colha with an increase at Altun Ha, which may represent a shift in elite structure and power (Meadows 2001; Pendergast; Shafer 1982). Other important resources continue to be diversified at Colha but occur in smaller numbers including obsidian, greenstone, and marine shell (Buttles 2002).

There were many additions and changes in terms of architecture within public and domestic spaces. For instance, structures and plazas were enlarged and expanded at the ballcourt at Operation 2009 (Eaton and Kunstler 1980). Other new construction activities include raised walkways between buildings, retaining walls, vaulted ceilings, and cut-stone veneers (Buttles 2002; Eaton 1982a, b). Domestic spaces include plans with rectangular or square-walled structures with pole and thatch superstructures (Day and Laurens 1980; Escobedo 1980; Roemer 1979; Valdez 1994b). Domestic areas also include associated burials, although some are also found in workshops (King 2001).

Following the Bomba complex during the Late Classic into the Terminal Classic, is the Masson complex, which equates to the Spanish Lookout complex at Barton Ramie. The Masson (AD 680 – 850) complex is considered a Tepeu 2-3 composite in the Late to Terminal Classic period. Ceramic types include Tinaja Red, Subin Red, and Palmar Orange-polychrome. Colha's population begins to centralize to the site's core by the Terminal Classic. Intentional destruction of structures is evident in many locations across Colha at this time and there is a shift in affiliation with the northern Yucatan (Buttles 2002; Eaton 1994). Changes in ceramics, lithics, and trade goods is visible during the Terminal Classic. Greenstone decreases in assemblages, and obsidian is sourced exclusively from El Chayal (Buttles 2002; Dreiss 1988).

There is a continuation of Late Classic forms in stone tool production with a few exceptions. For example, there is an obsidian workshop, specialized blade workshops, and the production of symbolic flaked stones is discontinued (Buttles 2002; Dreiss 1988; Hester and Shafer 1994; Masson 1989; Roemer 1984). Stemmed blade production also changes to accommodate shifting political environments. Stemmed blades are smaller and possibly functioned as spear tips (Masson 1989; Roemer 1984).

Ritual activity is observed through ceremonial structures at Operation 2012 and the ballcourt (Operation 2009). While not architecturally maintained, the ceremonial structure includes two construction phases at the base along the staircase centerline, suggesting a continued use for ritual activities (Potter 1982). Unusual burial internments also stand out during the Terminal Classic. At the base of structure in Operation 2012, plate fragments, obsidian, greenstone, and 25 disarticulated individuals were recovered and speculated to be casualties of war (Barret and Scherer 2005; Potter 1982).

Operation 2011 also uncovered an unusual burial area. A pit (80 cm x 100 cm) contained the decapitated and burned cranial remains of ten children, ten adult males, and ten adult females. Individuals exhibited elite physical characteristics including cranial modification and filed dentition. Associated materials include sherds, burned construction materials, faunal remains, and chert flakes (Barrett and Sherer 2005; Massey 1994; Mock 1994; Steele et al. 1980; Valdez 1987). Structure 2011 was destroyed after the cranial remains were buried and the ceremonial structure was burned. Similar events targeting elite areas and materials occurred with the destruction and burning at Operation 2025 (Potter 1982; Eaton 1994). These activities are linked with the end of occupation during the Terminal Classic at the site (King 2000; Massey 1994; Mock 1994). The Colha hiatus or termination begins at the end of the Masson complex and lasts approximately 50 to 100 years until about AD 950. This break in occupation allowed for the site to be reclaimed by natural growth and a new cultural group closely affiliated with northern Yucatan (Hester and Shafer 1991, 1994.)

POSTCLASSIC PERIOD

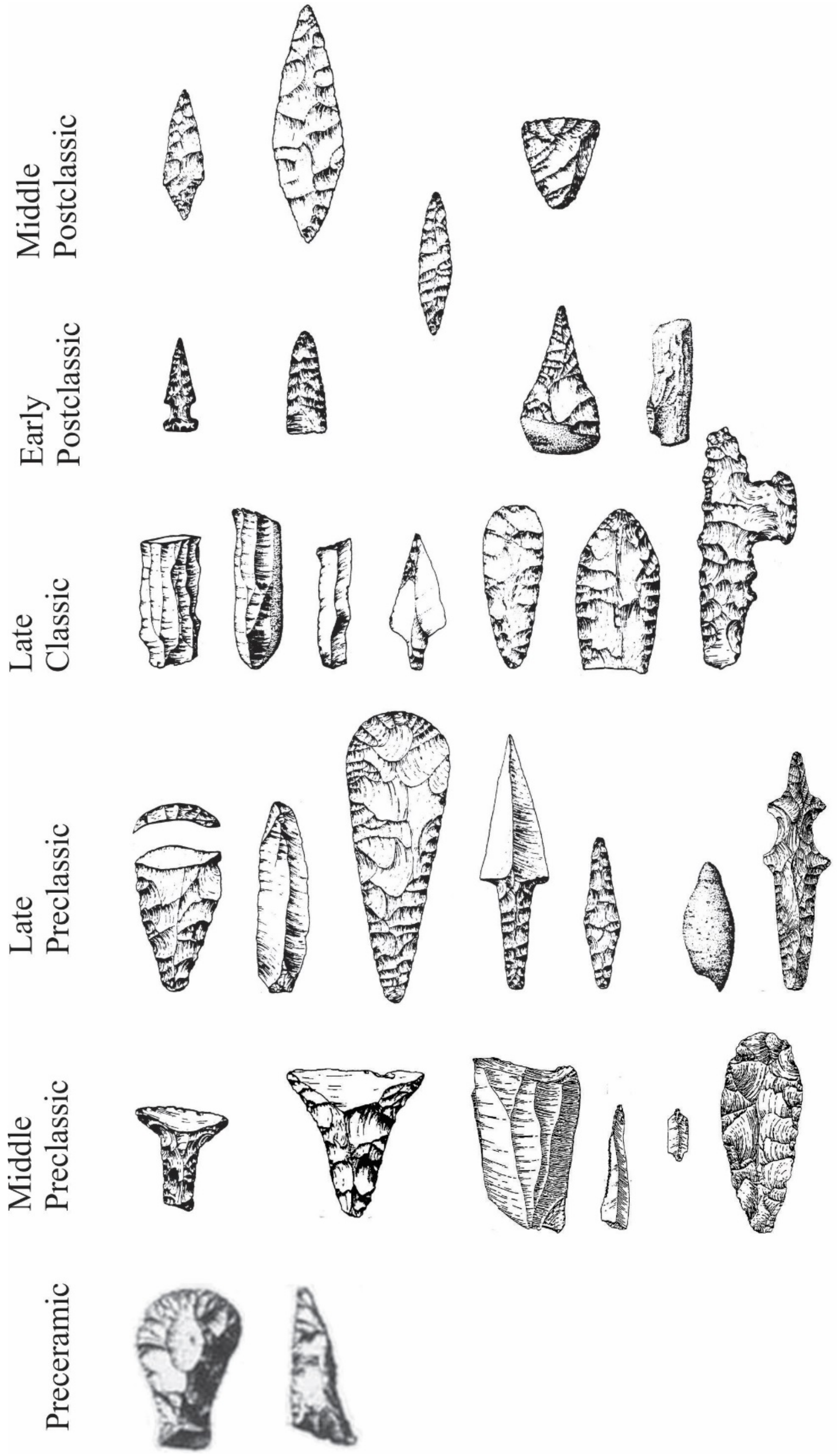
There is a complete change in typology and mode for the succeeding complex, the Yalam (AD 950 – 1150). The Early Postclassic Yalam complex is comprised of mostly

Zakpah Orange Red and a small percentage of Pek Polychrome types. Colha produced almost identical ceramics compared to Lamanai's complexes during the Early and Middle Postclassic (Valdez 1994a; Pendergast 1981). The Canos (AD 1150 – 1350) complex is a continuation of the Yalam during the Early Postclassic at Colha. The most common group is the Payil Red within the Payil group. The Yalam complex is the final functionally complete ceramic complex at Colha. The new inhabitants were likely attracted to Colha's position within the Chert Bearing Zone and constructed 12 lithic workshops during the Early and Middle Preclassic (Buttles 2002; Hester et al. 1980).

Lithic production during the Early Postclassic includes forms like side-notched dart point, tapered biface, and triangular preforms. Side-notched dart points are replaced by lenticular or lozenge-shaped bifaces as well as early stage preforms during the Middle Postclassic (Hester 1983; Hester and Shafer 1991). Technologies such as soft hammer percussion instruments like antler billets and punches are common in Postclassic assemblages. Chalcedony and obsidian are also brought in to be reworked at Colha (Dreiss 1988; Michaels 1994).

Colha resembled a small agrarian community during the Postclassic and settlement was primarily restricted to the site's monumental center (Buttles 2002; Hester and Shafer 1991). Domestic structures were constructed from available materials supporting pole and thatch superstructures (Eaton 1979; 1980). Several middens around the monumental center and a few associated with lithic production from the Early to Middle Postclassic yielded a variety of stone tools, obsidian, and groundstone materials (Shafer 1979; Shafer and Michaels 1994; Shaw and Mangan 1994). Charred botanicals and faunal remains provided useful subsistence strategy data (Taylor 1980). There is no evidence for new construction phases involving monumental architecture during the Postclassic. No other domestic ceramics occur at Colha through the Protohistoric. Finally, there are Mayapan-style censers brought to Colha recovered from Operation 2012 assigned to the Ranas (Post AD 1400) complex; however, this is the only non-functionally complete complex (Valdez 1994a).

Figure 4.2: Colha Lithic Sequence. Compiled from Hester (1982), Iceland (2005), and Potter (1991).



Lithic Sequence Key

Form descriptions from left to right by cultural period.

Middle Postclassic: lozenge biface; lenticular biface(large form); (lower image) lenticular biface (small form); triangular adze

Early Postclassic: stemmed point; triangular point; tapered biface (continues to Middle Postclassic); antler percussor (continues to Middle Postclassic)

Late Classic: polyhedral chert blade core; unifacial (tabular) chert blade core; blade; stemmed blade; small oval biface (celt); general utility biface; eccentric

Late Preclassic: tranchet bit tool and tranchet flake; macroblade; large oval biface; stemmed blade; stemmed biface; hammer stone; eccentric

Middle Preclassic: early form adze; t-form adze; blade with burin spall removals; burin spall drills; celt

Preceramic: constricted uniface; pointed uniface

Chapter 5: Colha Archaic Maya Project 2017 Excavations

The Colha Archaic Maya Project 2017 focused on fine tuning the chronology of earlier occupation periods for Colha during the Archaic (8000 - 2000 BC) and Middle Preclassic Period (1000 BC - 400 BC). A secondary objective included investigations surrounding this critical cultural and environmental transition through a paleoethnobotanical and geoarchaeological perspective. Excavations focused on an open area known as the 4000 sector with known Archaic components (Hester et al. 1995, 1996; Iceland 1997; Shafer et al. 1980) and the main plaza in the 2000 sector to investigate a Middle Preclassic village near former Operations 2011, 2031, and 2032 (Anthony and Black 1994; Barrett and Sherer 2005; Massey 1994; Mock 1994; Potter 1982; Steele et al. 1980; Valdez 1987).

The following is a condensed summary of excavations from the 2017 field season (Burns et al. 2018). Artifacts recovered from excavations include significant diagnostic lithics or ceramics, otherwise, only a few other cultural materials were observed. Sediment strata are described along with any significant archaeological findings to help frame the sampling and analysis of this dissertation. Characterizing horizons will also help to reveal what was happening in the environment which may indicate continuity of cultural practices during the transition. Additional lot descriptions and unit schematics are available in Appendices A and B.

Research aims at Colha have changed over the years and so have excavation procedures. Excavations at Colha initially employed the Tikal System. This system identifies "Operations" as excavation areas, "Suboperations" as individual units and

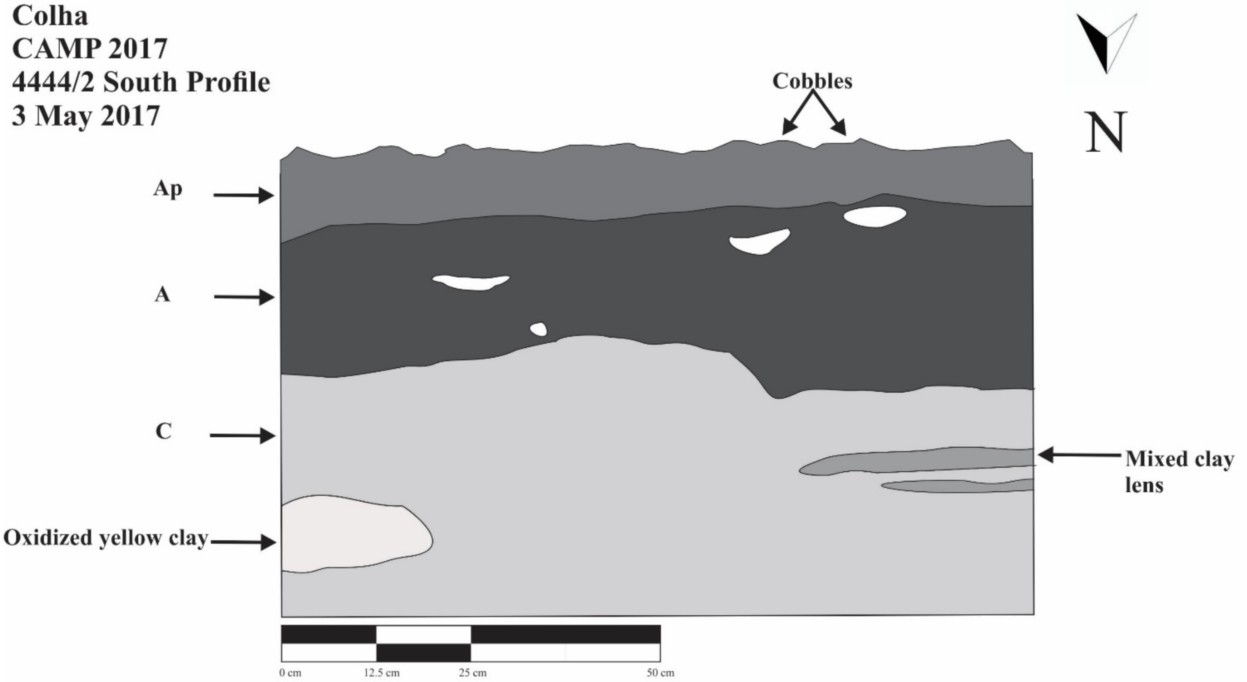
“Lots” as minimal units of recovery (Coe and Haviland 1982). For example, a burial, midden, or arbitrary excavation boundary are considered “Lots.” In 1983, excavations employed the STRAT System, or a modified Harris Matrix (Anthony and Black 1994). This approach focuses on individual stratigraphic units, or strats. This system recognizes each depositional layer, feature, or interface as a strat. This system presents challenges when excavating layers that are not clearly defined. For example, plow zones or secondary midden deposits. The 2017 excavations used the Tikal system with two Operations, 4444 and 2222.

OPERATION 4444

Suboperations 1 and 2

These units are located approximately 50m west of former Operation 4040/12, a residential area near Late Classic lithic workshops in 4040/6-10 (King 2000). These units had a plow zone of about 11-13 cm followed by 10-15 cm of black (10YR 2/1 to 10YR 3/1) clays with cobbles and a decrease in lithics and ceramics towards the end of this horizon. An Early Classic rim sherd from a jar was collected in 4444/2-2. The bottom of these Suboperations contained reddish-yellow (7.5 YR 7/6) silty clay with large cobbles and little to no cultural material.

Figure 5.1: Profile of 4444/2.



Suboperations 3 & 9 and 4 & 8

Suboperations 3 and 9 are situated west of 4444/1 and 4444/2, and one meter apart from each other. The first 20-35 cm consist of a plow zone with dark, heavy clays. The next horizon of sediment consists of mottled clay which is dark yellowish-brown (10YR 4/4) and brownish-yellow (10YR 6/6). There are occasional chert cobbles, lithics, and ceramics in this layer. A rock alignment covered a hearth feature in both Suboperations. The hearth feature is situated between 4444/3 (southeast wall) and 4444/9 (west wall). The feature is basin-shaped, lined with cobbles, and is approximately 20 cm in depth. Samples were collected from 4444/3 for radiocarbon dating. In 4444/3, a concentration of cobbles in the northeast quadrant was observed with coarser and drier sediment. Phytolith samples were collected from 4444/9 for analysis. Beyond this feature, we observed dark yellowish-brown clays with some lithics.

Suboperations 4 and 8 are situated 35 meters west of 4444/1 and 4444/2. These Suboperations also contained a plow zone followed by a layer of heavy black (10 YR 2/1) clay with cobbles, abundant flake debitage, and ceramic sherds. At approximately 35 cm, sediments were dark yellowish-brown clays. A carbon sample was recovered from 4444/4 for radiocarbon dating. Beyond this sediment is the yellow-brown matrix observed in previous lots with cobbles and a decrease in cultural material.

Figure 5.2: Profile of 4444/3

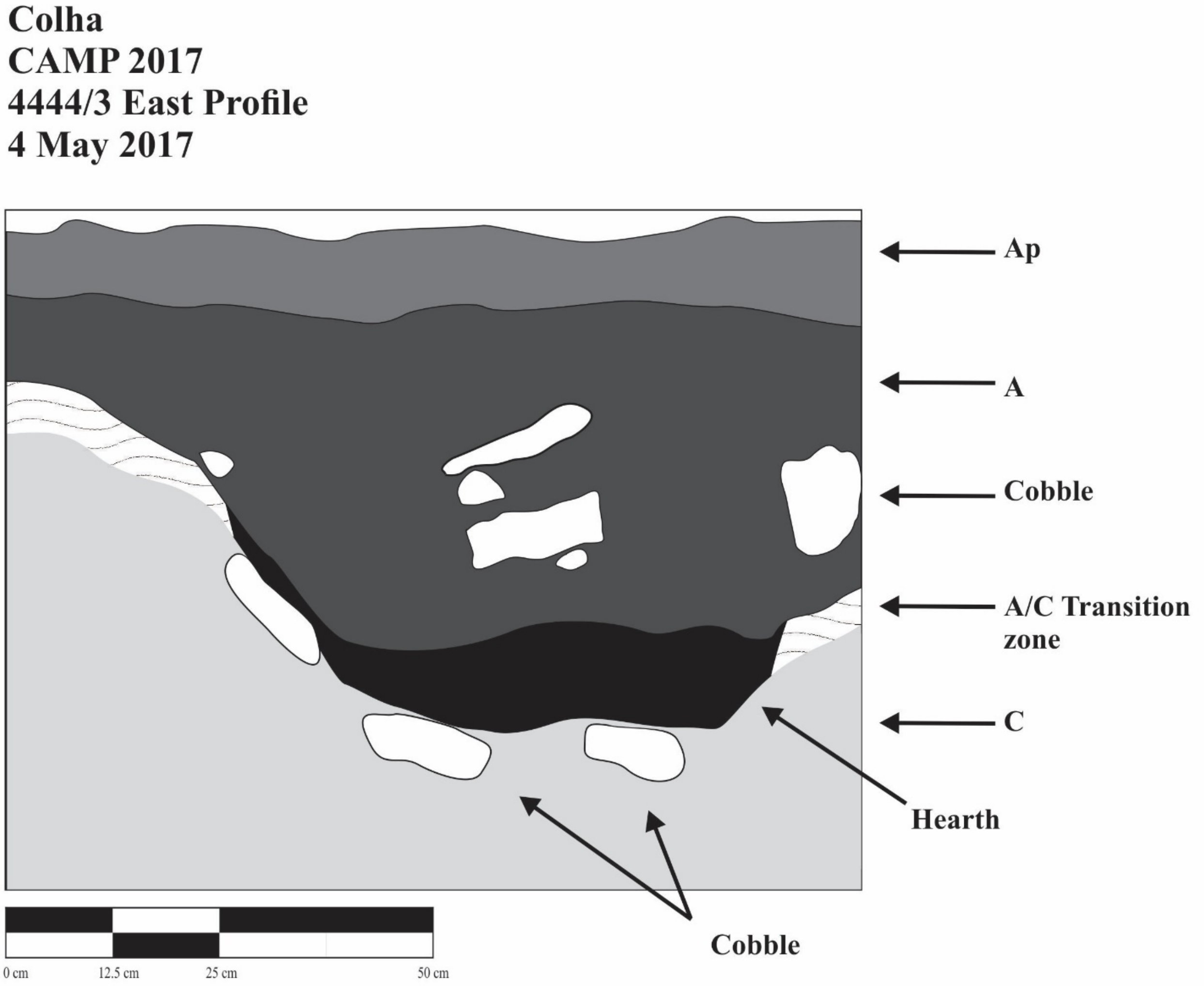
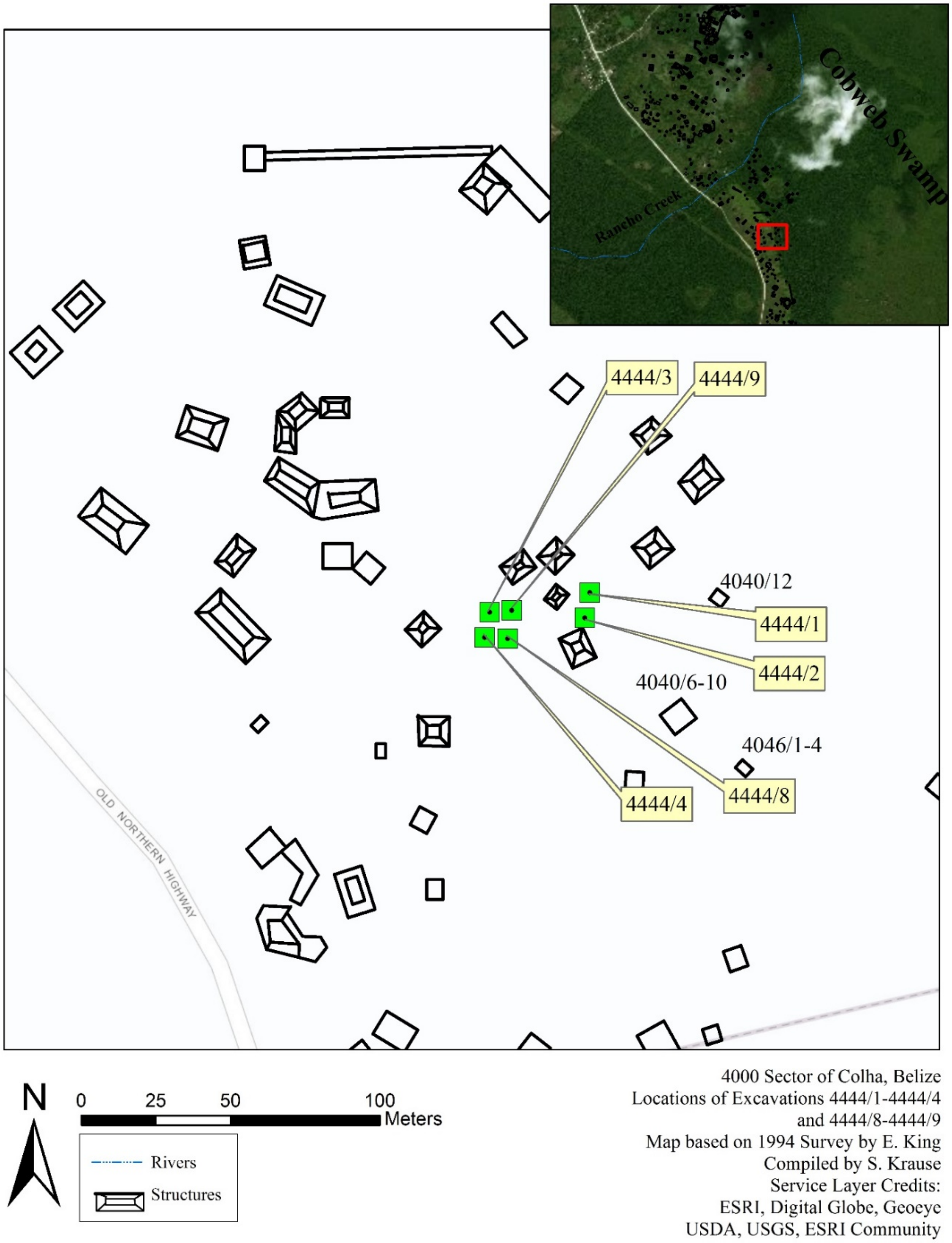


Figure 5.3: Map of Operation 4444 Suboperations 1-4 and 8-9



Suboperation 5

Suboperation 5 is located within the plaza of a large elite residence complex (4044) east of an aguada (4041) and a lithic workshop (4045) (King 2000). Investigations aimed to explore occupational sequences beyond Classic floor ballast, dating to earlier occupations of the site. Beyond the humic horizon, a plaster surface was observed at 18-35 cm. Excavations included the platform construction fill of a Classic structure with ceramics, blades, and bifaces. Beyond the fill layer, there was a buried paleosol between 70-90 cm with lithics and ceramics present. The remaining 90-100 cm consisted of brown and gray sediment which transitioned into bedrock.

Suboperation 6

Suboperation 6 is located south of Operation 4044. This Suboperation is representative of a small lithic workshop excavated for the potential of locating floors or platforms dating to the Preclassic. The first 25 cm included black (10YR 2/1) with an abundance of lithic and ceramic artifacts. The matrix was a light yellowish-brown (10YR 6/4) with some limestone pebbles between 25-55 cm. The final stratum in the Suboperation consisted of a very pale brown (10YR 7/3) matrix mottled with brownish-yellow (10YR 6/6) and grayish-brown (10YR 5/2). No cultural materials were observed in the matrix with manganese inclusions and gypsum grains. This Suboperation was closed after exposing large cobbles in the eastern quadrant approximately 20-30 cm in width.

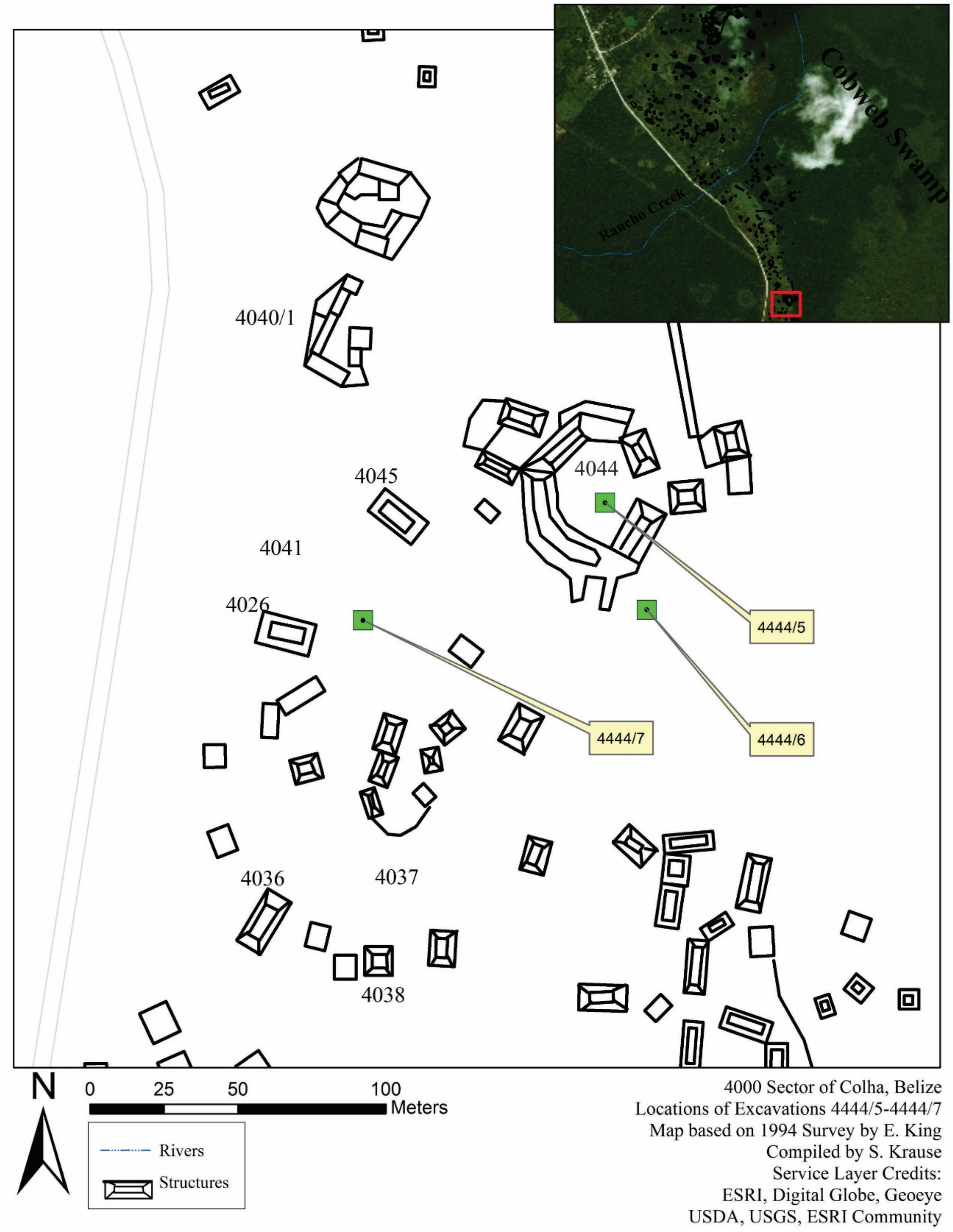
Suboperation 7

Suboperation 7 is located east of 4026, a Late Classic workshop, and south of an aguada (4041) (King 2000). The first 40 cm contain a plow zone and black, heavy clays (10YR 2/1). Sherds and lithics were scattered throughout the matrix. Between 40 and 58 cm the matrix consisted of brownish-yellow (10YR 6/6) mottled with dark grayish-brown (10YR 4/2) clays. There were also manganese nodules with specs of charcoal. Overall, this Suboperation did not contain much Preclassic cultural material and was terminated.

Table 5.1. Radiocarbon dates from Operation 4444. Dates calibrated on OxCal.

Provenience	**Age**	**Age Err**	**% Prob**	**Date Ranges BC**	**NOSAMS**
4444/3-2 (45 cm)	2190	20	60.7 %	360 - 273	148698
4444/3-2 (75 cm)	2160	20	49.8 %	232 - 158	148696
4444/4-3 (41 cm)	2110	20	86.2 %	196 - 87	148695

Figure 5.4: Map of Operation 4444 Suboperations 5-7.



4000 Sector of Colha, Belize
Locations of Excavations 4444/5-4444/7
Map based on 1994 Survey by E. King
Compiled by S. Krause
Service Layer Credits:
ESRI, Digital Globe, Geoeye
USDA, USGS, ESRI Community

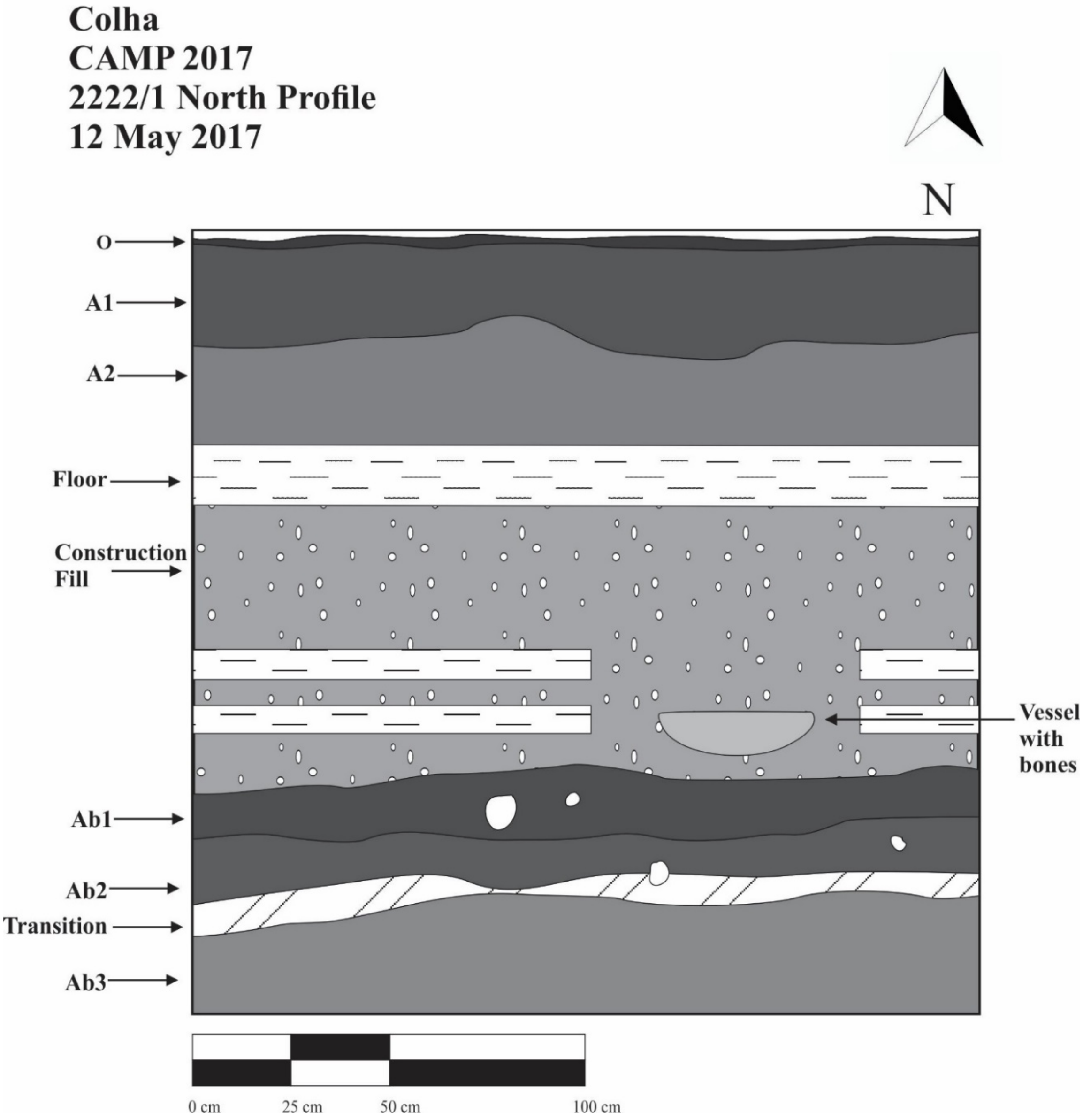
OPERATION 2222

Suboperations 1 and 3

Suboperation 1 was excavated east of Operation 2031 and north of Operation 2011. The matrix consisted of dark clays with chert and limestone cobbles until a depth of 32 cm. Artifact density was low throughout the matrix. The matrix became grayish-brown (10YR 5/2) to brown (10YR 5/3) coarse silty loam with abundant gravels. Plaster surfaces were uncovered at 55 cm, 97cm, and 120 cm. The matrix between 120-142 cm was a dark grayish brown (10YR 4/2) silty loam with fire cracked chert, shell, orange tecomate ceramics, burin spalls, bifaces, and bones. At the time, it was unknown that remains were human and therefore were not assigned a burial number until osteological and faunal analysis could be completed. Remains included severely burned cranial elements and upper cervical vertebrae estimated to be between one and a half and two and a half years old (Riegert and Gill 2017). The next layer of sediment was a dark grayish-brown (10YR 4/2) silty loam with charcoal, and human and faunal remains. As the Suboperation progressed, it turned a dark yellowish brown (10YR 3/4) and compact with limestone and manganese inclusions. More charcoal and remains were present in this layer. We encountered a weak red (5R 4/4) mottled with light brown (7.5YR 6/4) heavy clay. The clay matrix included charcoal, ceramics, limestone inclusions, shells, ash, and became coarser as it progressed to 174 cm. Several strata were sampled for radiocarbon dating in this Suboperation.

Suboperation 3 was excavated to investigate the surface uncovered in 2222/1-3. This Suboperation consisted of a dark humic layer where a uniface tool, chert flakes, and limestone cobbles were recovered throughout the first 42 cm. It is within this layer that a constricted uniface was recovered. A dark grayish-brown (10YR 4/2) silty matrix persisted until 80 cm. Shell fragments and bone fragments were found at 73 cm in the southeast quadrant.

Figure 5.5: Profile map of 2222/1.

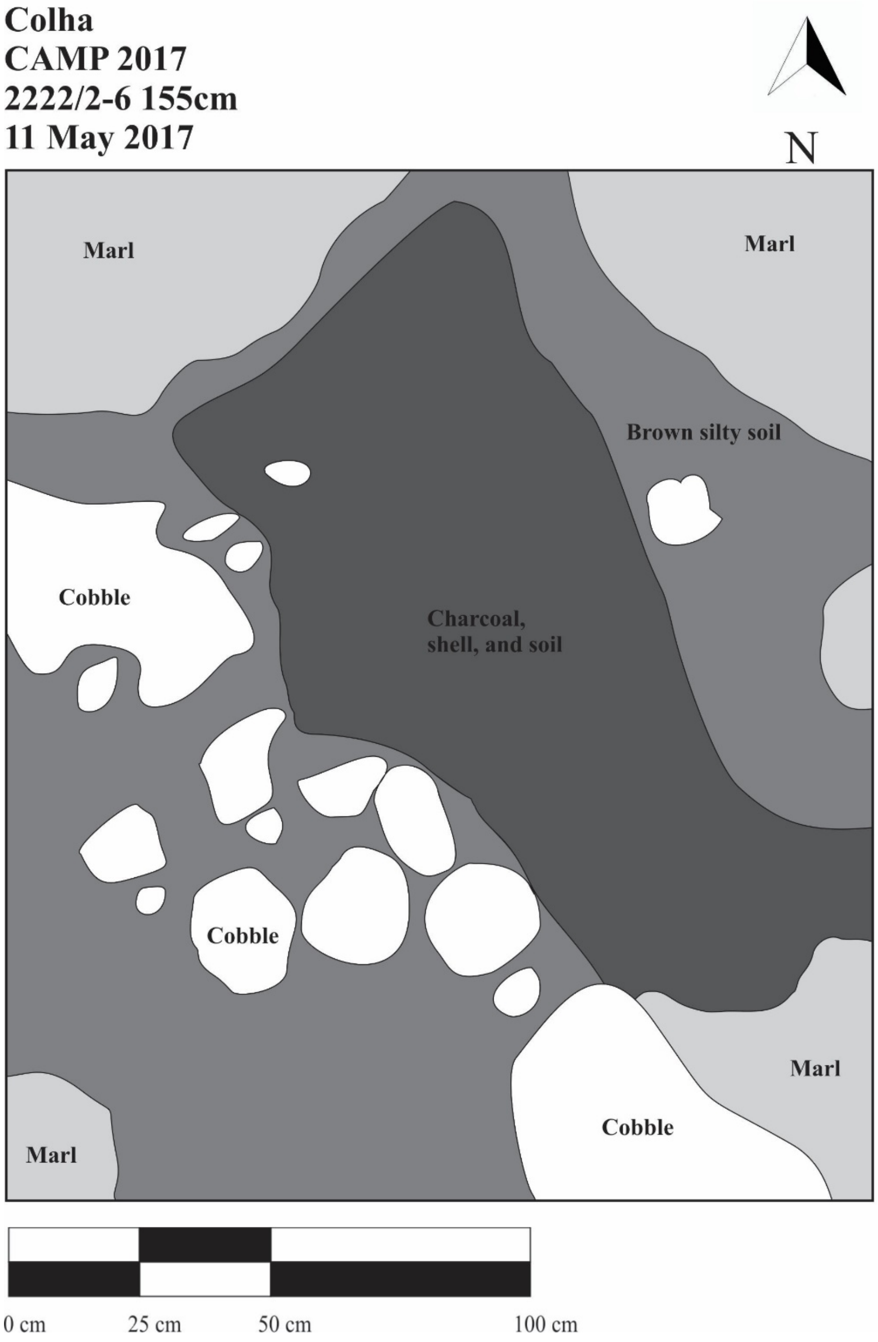


Suboperations 2,4, and 5

Suboperation 2 was excavated as an attempt to explore Middle Preclassic features as investigated by Anthony and Black (1994). The uppermost matrix consists of black (10YR 2/1) silty loam with a variety of lithics and redwares. A surface was excavated at 25 cm with limestone fill and burned rocks. Two more floor surfaces were excavated at 60, 100, and 120 cm. Suboperations 4 and 5 were opened to expand 2222/2 to further investigate a surface found at 120 cm. The surface at 120 cm was excavated to expose a brown (10YR 5/3) loam with an abundance of mussel shell fragments, charcoal, and a possible rock alignment dating to the Middle Preclassic. Further investigation of the area with shell and charcoal fragments led to the recovery of additional burin spalls and shells.

At this point, excavation was limited to the northern half of the Suboperation to better define the feature associated with the shell and burin spalls. Beneath the feature, the matrix consisted of a red (5R 5/6-5/8) clay mottled with light gray (2.5Y 7/2) and dated to the Early Preclassic. The red clay becomes more compact with depth and becomes sterile around 200 cm.

Figure 5.6: Plan map of 2222/2



Suboperation 6, 7, and Balk

Suboperations 6 and 7 were excavated to continue investigations in Middle Preclassic features from Suboperations 1 and 2. Beyond the silty loam humus, a series of plaster surfaces were excavated correlating with Suboperations 1 and 2. Human remains were excavated within the plaster surface of the third, fourth, and fifth floors of 2222/6. Below the burials, the matrix became a medium to dark brown clay with sand-sized limestone inclusions mottled with charcoal, shell, and some manganese inclusions. A double lug handle was recovered from a depth of 172 cm and the stratum was radiocarbon dated to the Early Preclassic in 2222/6. At 172 cm the matrix included mottling with yellow orange clay and at 176 cm the matrix included shell, charcoal, and limestone inclusions, much like in 2222/2.

Suboperation 7 included a silty clay loam humus with chert and limestone cobbles followed by a thick plaster surface at 37 cm. Several biface tools and a tranchet flake were observed. A pale brown silty loam was observed at 55 cm with a concentration of ash in the southern portion of the Suboperation. A cobble feature was identified at 94 cm associated with a burial and ashes. A plaster surface followed the cobble feature where multiple individuals were excavated and a constricted uniface was recovered. The red clay matrix previously seen in 2222/1 and 2222/2 was observed at 110 cm. At this stratum, a tightly bundled individual was associated with at least four ceramic vessels. The balk between 2222/6 and 2222/7 was also excavated to 120 cm due to burials in both Suboperations extending beyond those units. The balk contained at least nine stacked vessels, one individual, and a constricted uniface.

Figure 5.7: A partial schematic of a vessel cache in the balk between 2222/6 and 2222/7

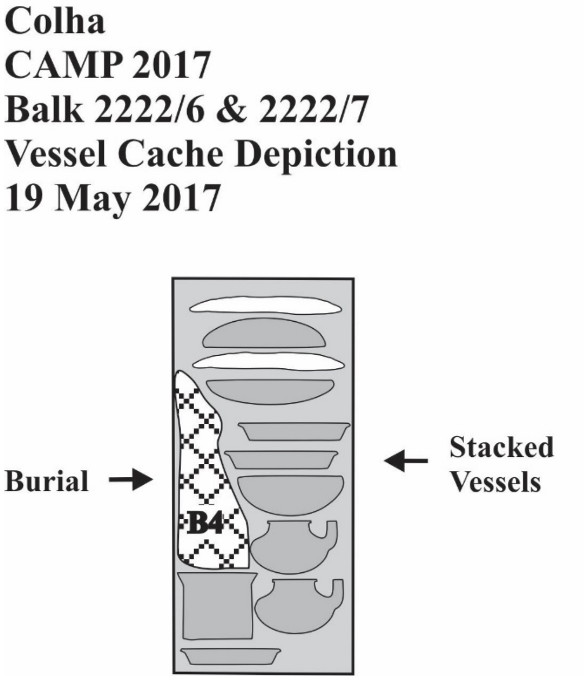
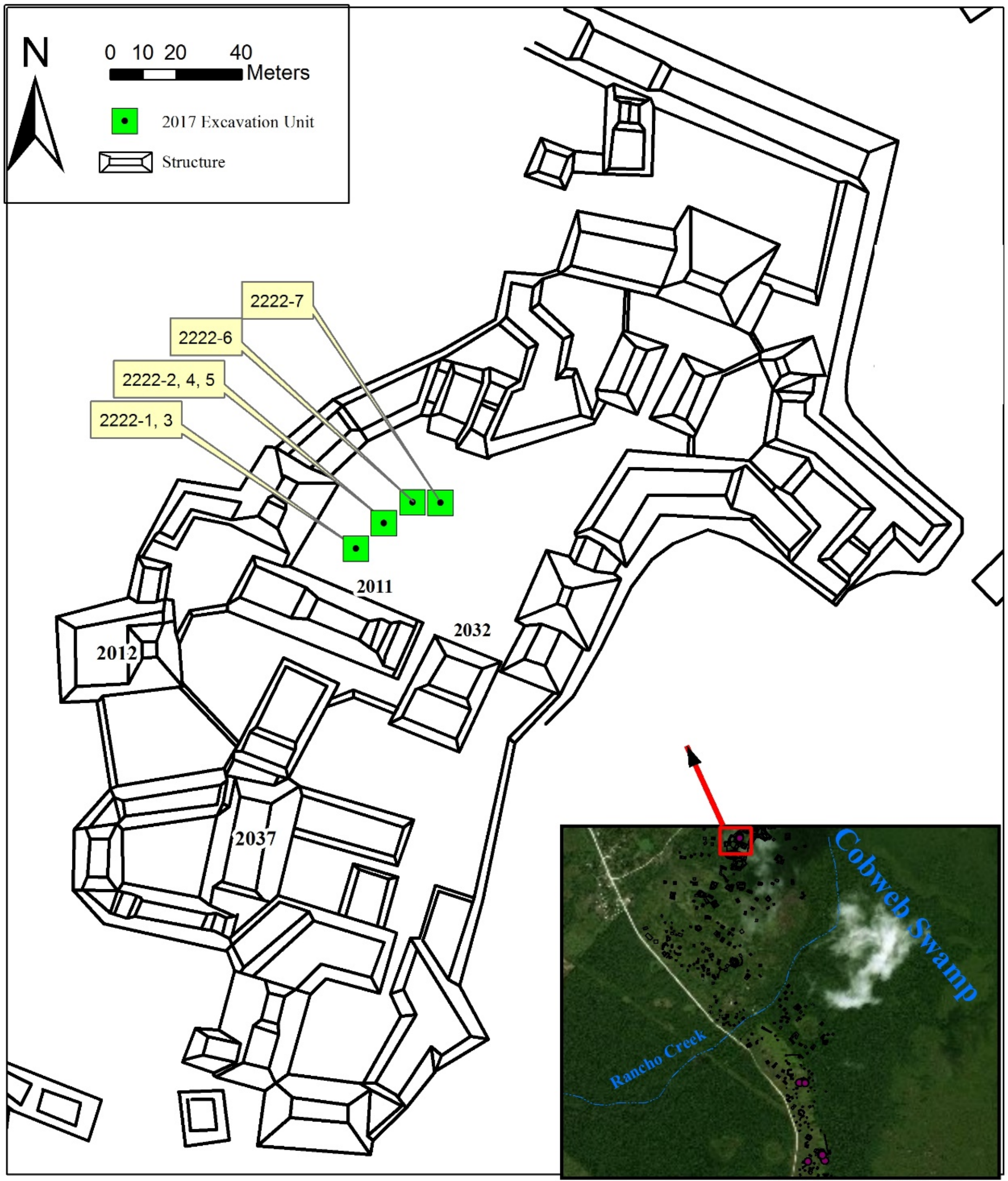


Figure 5.8: Map of Operation 2222



2000 Sector of Colha, Belize
Locations of Excavations in 2031
Map based on 1994 Survey by E. King
Compiled by S. Krause
Service Layer Credits:
ESRI, Digital Globe, Geoeye
USDA, USGS, ESRI Community

Table 5.2. Radiocarbon dates from Operation 2222. Dates calibrated on Oxcal.

Provenience	**Age**	**Age Err**	**% Prob**	**Date Ranges BC**	**NOSAMS**
2222/1-5 (130 cm)	2520	30	65.1 %	694 - 542	148699
2222/1-5 (130 cm)	2610	25	95.4 %	816 - 776	148697
2222/1-8 (156 cm)	2560	20	90.3 %	802 - 754	148703
2222/2-5 (130 cm)	2450	20	51.5 %	591 - 413	148700
2222/2-8 (182 cm)	2750	85	95.4 %	1127 - 790	148701
2222/6-12 (158 cm)	2960	25	92.8 %	1262 - 1108	148702

DISCUSSION

Efforts during the CAMP 2017 field season included the physical characterization of soils at Colha and the recovery of diagnostic lithics from the Middle Preclassic and Late Preclassic including burin spalls, tranchet flakes, and constricted unifaces. Human and faunal remains were also successfully recovered along with new radiocarbon dates for Colha. Many of these important contexts were also processed for further geoarchaeological and paleobotanical analysis, adding to the environmental history of the site (Burns et al. 2018; Kotsoglou et al. 2018; Riegert and Gill 2018).

A general interpretation of soil horizons at Colha (Operation 4444) includes a pattern of an "Ap" horizon followed by "A" and "C" horizons. All profiles include a "plow zone" of approximately 10-15 cm consisting of very dark clays with extensive root systems and artifacts including ceramic sherds and lithics. Colha's "A" horizons consist of very dark gray to a yellow-brown matrix with fine root systems, limestone concretions, charcoal, and include lithic flakes or tools and ceramic sherds. Colha has a distinct "C" horizon consisting of yellow silty clay with small limestone concretions.

Figure 5.9. General Descriptions based on Schoeneberger et al. 2012.

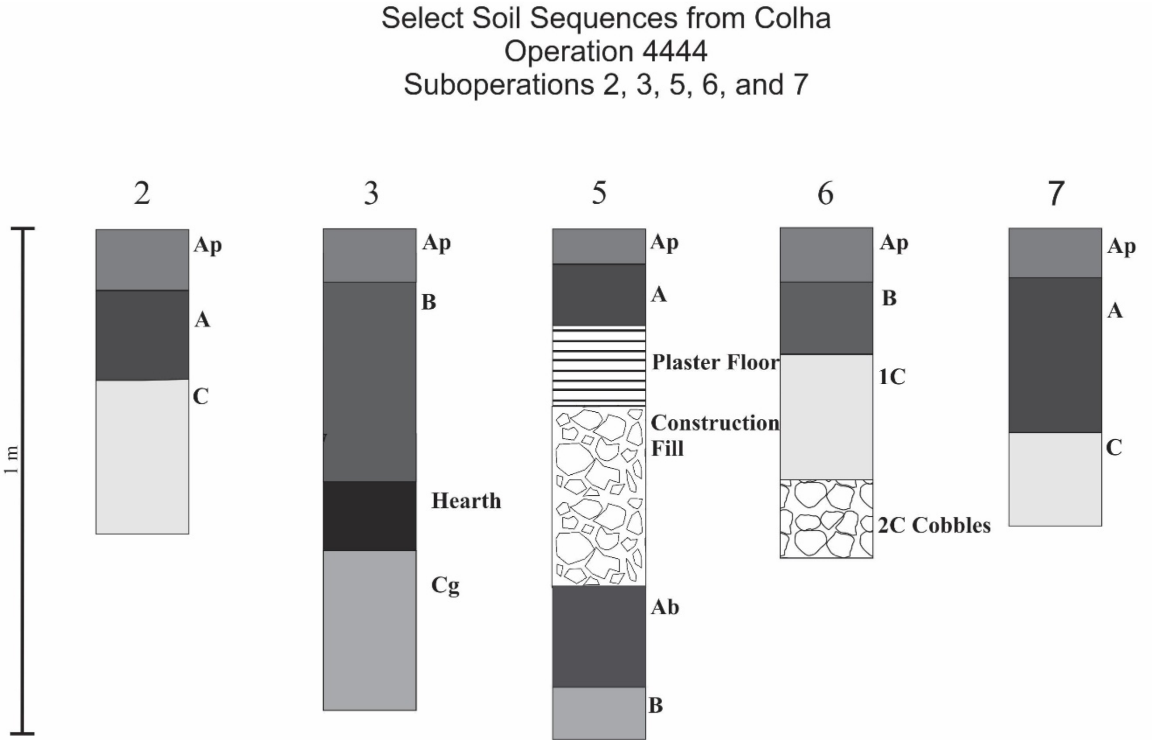


Table 5.3. Detailed descriptions of 4444/2, 3, 5, 6, and 7.

Sub Op	**Horizon**	**Depth cmbs**	**Color**	**Description**
2	Ap	0-11	10 YR 3/2	Plow zone with very dark grayish clay, coarse root system, with ceramic and lithic scatter
	A	11-26	10 YR 3/1	Very dark gray clay with fine root system, lithic scatter, and chert cobbles
	C	33-60	7.5 YR 7/6	Reddish-yellow silty clay with limestone concretions
3	Ap	0-10	10 YR 2/1	Plow zone with very dark grayish clay, coarse root system, with ceramic and lithic scatter
	B	10-50	10 YR 4/4 and 10 YR 6/6	Yellow/brown matrix with limestone concretions and a burn scar associated with feature in 4444/9-3
	Hearth	50-60	N/A	Dense charcoal and chert layer lined with large cobbles and reddish clay inclusions
	Cg	60-90	10 YR 7/8	Lighter clay with some light gray patches, concretions, manganese nodules, lithic scatter
5	Ap	0-10	10 YR 3/2	Plow zone with very dark grayish clay, coarse root system, with ceramic and lithic scatter
	A	10-20	10 YR 3/1	Very dark gray clay with fine root system, lithic scatter, and chert cobbles
	Plaster Floor	20-35	N/A	Hard, packed plaster floor at surface, then material is packed with pebbles
	Constructi on Fill	35-70	N/A	Large cobbles and boulder sized chert mixed with clay lenses
	Ab	70-90	10 YR 2/1	Black heavy clay with some disintegrating ceramic sherds and lithic flakes

Table 5.3 (continued)

	B	90-100	10 YR 6/4	Mottled brown and gray sticky clay with only a few lithics
6	Ap	0-12	10 YR 2/1	Plow zone with black clay, coarse root system, with ceramic and lithic scatter
	B	12-30	10 YR 6/4	Light yellowish brown, heavy clay with root systems with some lithics and ceramics
	1C	30-50	10 YR 4/2	Yellow clay with some limestone pebbles and some cobbles
	2C Cobbles	50-70	10 YR 7/3	Matrix consists of large cobbles, calcium carbonate, gypsum, and manganese inclusions
7	Ap	0-10	10 YR 3/2	Plow zone with very dark grayish clay, coarse root system, with ceramic and lithic scatter
	A	10-40	10 YR 2/1	Black heavy clay with a small lens of tan clay
	C	40-60	10 YR 6/6	Brownish-yellow dark brown with manganese nodules and some fine roots

Diagnostic lithics including burin spalls, tranchet flakes, and three constricted unifaces were recovered at Operation 2222. Burin spalls are small tools that often function as drills, perforators, or gravers. Middle Preclassic bead manufacturing is associated with burin spalls when they are in context with disk shell beads (Potter 1980). Several lots containing burin spalls were recovered from CAMP 2017. Some were recovered within a shell midden and included worked shells. Late Preclassic tranchet flakes were also recovered during excavations. These flakes are diagnostic because they are produced from a biface by removing a single flake from the distal end of a tool form to create the tool's bit or flake (Meadows 2001; Shafer 1979, 1982; Shafer and Hester

1983). Constricted uniface adzes are Archaic period tools which typically appear in construction fill and other mixed contexts at Colha. They have also been recovered as surface finds in Archaic sites around northern Belize (King 2000; Hester 1996; Shafer et al. 1980).

Figure 5.10: Burin spalls and worked shell. Photographs by Bruce Templeton.

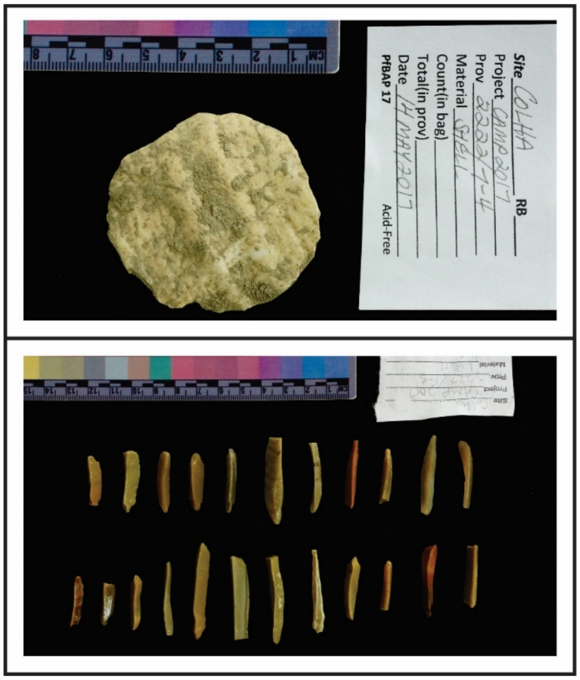
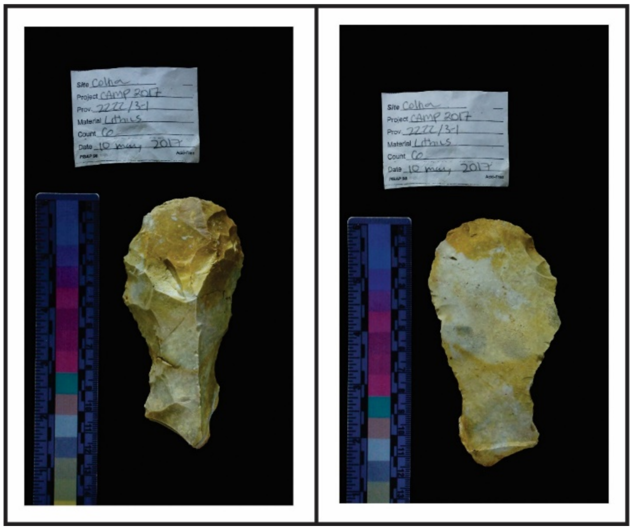


Figure 5.11: Constricted uniface. Photo by Bruce Templeton.



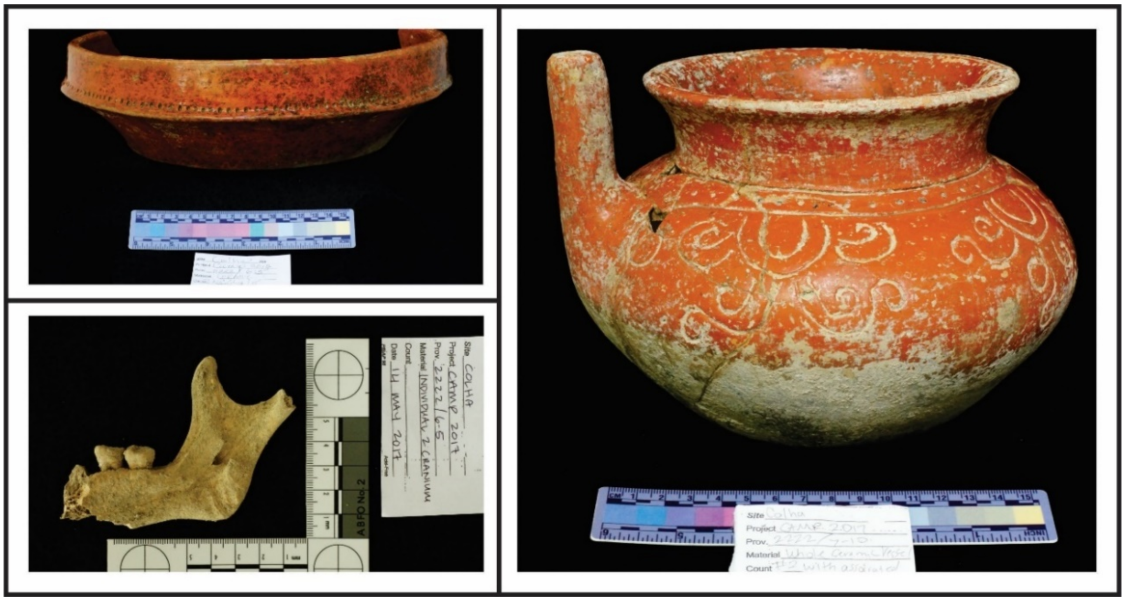
Osteological and Faunal Analysis

Human remains of 13 individuals were excavated in Operation 2222 throughout Suboperations 1, 6, and 7. Osteological analysis by D. A. Riegert and her team were able to determine age, trauma, and some health aspects of individuals from CAMP 2017 (Riegert and Gill 2018). The first burial (2222/7-4, 7-5) contained an adult who exhibited linear enamel hypoplasia and trauma to the cervical area. Burial 2 (2222/6-4, 6-5) included a male in late adolescence. Burial 3 (2222/7-5) included severely fragmented remains, prohibiting age or sex estimation. Burial 3 exhibited evidence of trauma in the left femur resulting from a perimortem fracture.

Burial 4 (2222/7-6, 7-10) was a complex assortment of disarticulated remains within stacked vessels and included primary and secondary burials for a minimum of four individuals. Three of the four individuals were determined to likely be male. Among the stacked vessels were several Middle Preclassic spouted vessels. These vessels have also been referred to as “chocolate pots” because the chemical signature for *Theobroma cacao* has also been identified through residue analysis (Hurst et al. 2002; Powis 2002). Disarticulated bones recovered from the balk (2222/7-8) were also recovered adjacent to burial 4 and are described as burial 8. Burial 6 (2222/7-5) contained a young adult of indeterminate sex. Burial 7 (2222/6-7) contained highly fragmented remains of an older adult exhibiting severe dental attrition and arthritic indicators.

Cranial remains of indeterminate sex from burial 9 (2222/7-9) were covered with an alignment of an inverted vessel, under a large plate that was underneath a stone, which was topped with a flat vessel. Finally, in Operation 2222/1-7, an isolated cache with remains from an individual between one and a half and two and a half years old was recovered. Remains were thought to be faunal at the time of excavation and were later renamed burial 10. The remains included burned cranial portions as well as upper cervical vertebrae. Many individuals were recovered with dentition. Their dental calculus was sampled for starch and phytolith analysis.

Figure 5.12: Examples of burial contents including a spouted vessel. Photos by Bruce Templeton.



The mortuary area also included mammalian, reptilian, avian and piscine remains analyzed by Lucy Gill (Riegert and Gill 2018). Speciated mammalian remains included white-tailed deer. A metapodial bone indicated it had been worked and manufactured into a bone tool. Other white-tailed remains included evidence of processing for consumption. Mammalian species in burial contexts also included rabbits, spider monkey, and *Canis familiaris*, or domestic dog. There were some mammalian remains that could not be speciated in the field. Avian remains included *Meleagris occellata* or ocellated turkey. Reptilian remains were recovered from Operation 2222/1-5. The burnt faunal remains of Testudine, or turtle, carapace were more than 50% carbonized prior to internment.

These assemblages are similar Late Archaic faunal remain findings from Pulltrouser Swamp. It is clear that both Colha and Pulltrouser Swamp provided an abundance of faunal and wetland resources for early in habitants. As people take advantage of the recources, these disturbed landscapes favor ruderal cultivation and grazing for deer and other small game. This form of niche construction behavior contributes to the success of subsequent inhabitants in the area.

The three-week field season at CAMP 2017 was a success and many components of Middle and Late Preclassic occupation were recovered. The project contributed to archaeological investigations of some of the earliest occupants at Colha, recovered human and faunal remains, diagnostic lithic tools and ceramics, and contributed to radiocarbon data for the site's chronology. Sediments also provided data for an environmental history approach to geoarchaeological techniques and phytolith analysis. Dental calculus also provided data for starch and phytolith analysis. While excavations did not reach earlier occupation periods, the transition into the Middle Preclassic can still be studied from the vast data set gathered during the 2017 field season (Burns et al. 2018; Kotsoglou et al. 2018; Riegert and Gill 2018).

Chapter 6: Anthropogenic Signatures: A Comparison of Environmental Change between an Upland and Coastal Site

INTRODUCTION

Many facets concerning long-term human impacts on the environment have been studied to understand human ecologies and mechanisms affecting social and political influences. The immense impact people have on the environment has even created a proposed geological epoch, the Anthropocene. This epoch is characterized by major environmental changes which are exacerbated or driven by human behaviors including exponential increase in atmospheric CO_2 and CH_4, warming temperatures, large-scale deforestation, and controlled fire regimes (Braje 2015; Foley et al. 2013; Ruddiman 2013; Kaplan et al. 2011). The earth's environmental systems are affected by simultaneous cultural transitions towards increased sedentism and large-scale landscape manipulation at a global level. To pinpoint the start of the new epoch is arbitrary; however, it is difficult to ignore the clear human-induced impacts on the environment over the last few millennia. I present a geoarchaeological comparison of long-term human impacts from two Maya Lowland sites, the Blue Creek *rejollada* and Colha. Specifically, I focus on pronounced anthropogenic signatures in sediments during the end of the Archaic (8000 – 2000 BC) to Preclassic (2000 BC – AD 250) cultural transition when people are major contributors of environmental change.

Increasing greenhouse emissions can be attributed to wetland manipulation and intense deforestation. Archaeological data supports Ruddiman (2013) and Kaplan et al.'s

(2011) models which expand on anthropogenic deforestation and its effects on atmospheric emissions. Moreover, archaeological data also supports the cultural phenomenon in which people in the Neotropics were modifying and manipulating their landscape long before the Industrial Revolution (Beach et al. 2015a, b; Fedick 1996; Gómez-Pompa et al. 2003).

The impact early inhabitants left behind remains in more forms than hydrologic systems, pollen records, cultural material, and structures. Studies have shown that one of the most ubiquitous markers left in the sedimentological record are Maya Clays (Beach et al. 2006; Beach et al. 2015a, b). Large-scale deforestation and increased land-use disrupted stable soil surfaces creating Maya Clays. These calcareous gray clays occur in soil sequences dating between 4,000 – 1,000 BP and contain cultural materials. Erosional episodes occurring during the Preclassic and Classic periods buried stable paleosols known as *Eklu'um* found across the Lowlands (Beach et al. 2006; Dunning and Beach 2004; Solís-Castillo et al. 2013).

Warmer temperatures and increased precipitation during the Archaic Period favored cultivation for early inhabitants which is also represented by disturbance taxa in pollen records (Solís-Castillo et al. 2013). The shift towards more intensive strategies, deforestation, managed fire regimes, concurrent climatic drying, and urbanization accelerates erosional episodes during the Preclassic, the Late Classic, and over the last few decades (Anderson and Wahl 2016; Anselmetti et al. 2007; Beach et al. 2006, 2015; Torrescano – Valle and Islebe 2015).

COMPARISON OBJECTIVES

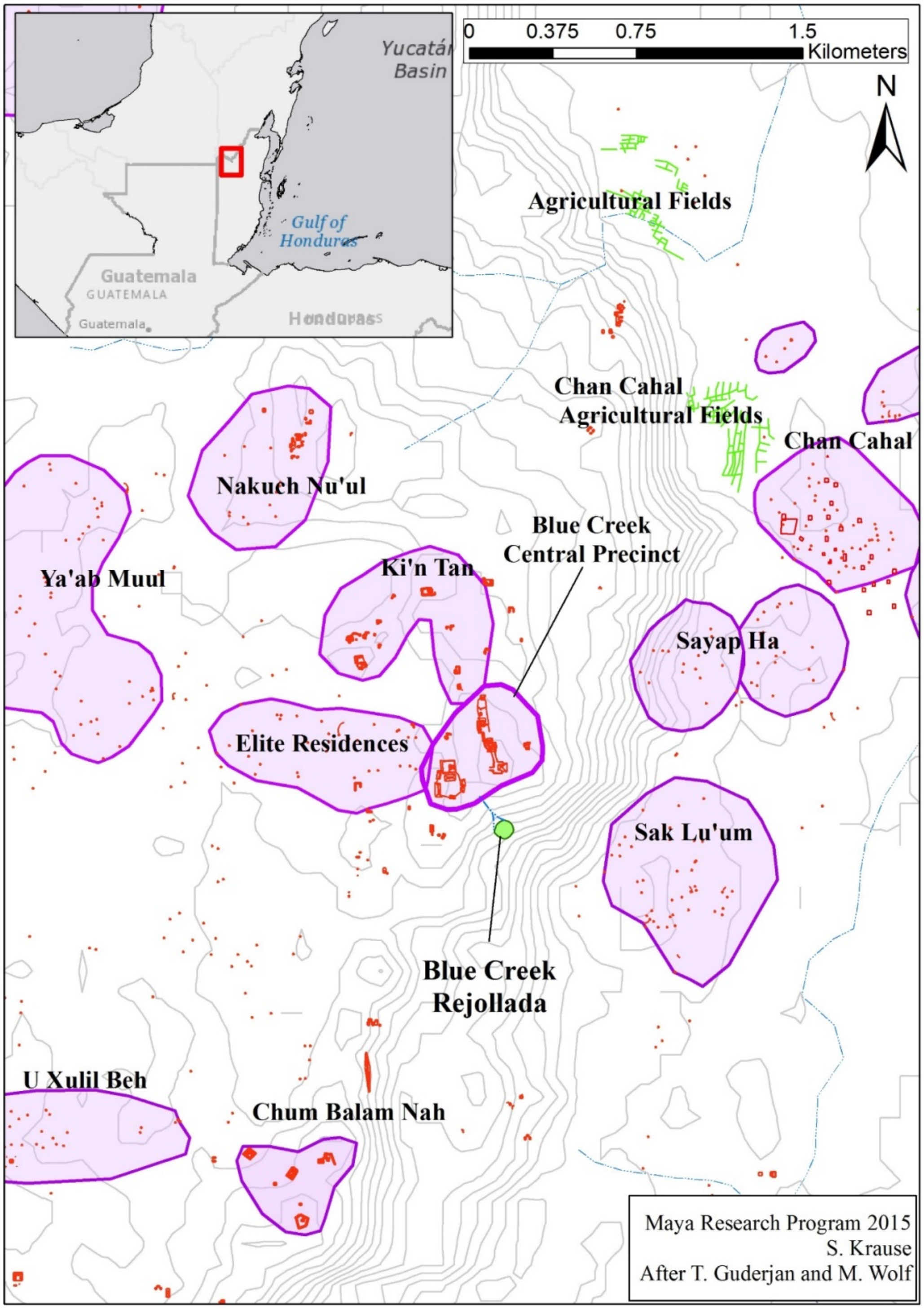
To better evaluate long-term anthropogenic impacts on Lowland environments, two different areas are compared which have evidence of early inhabitants dating back to the Archaic and Preclassic Periods. The first site is located within a filled in sink hole, called a *rejollada* (Aebersold et al. 2015, 2016; Munro-Stasiuk 2014). The *rejollada* is located between 119 to 124 masl on the Rio Bravo escarpment, 200 meters downslope from the archaeological site of Blue Creek (Guderjan 2004). This area serves as an ideal location to study wetland and upland manipulation by early inhabitants because Blue Creek's occupation goes back as early as the Middle Preclassic through the Late Classic (Aebersold et al. 2016; Guderjan 2004).

The second research area is the archaeological site of Colha. Situated approximately 20 kilometers from the Belizean coast, the site is a perennial wetland in the Belize Chert-Bearing Zone. Occupation at the site is known from the Archaic to Postclassic, with only a short interruption leading into the Early Postclassic (Buttles 2002; Hester 1979; Hester et al. 1994; Iceland 1997; King 2000; Shafer and Hester 1991; Valdez 1987). Examining sediment profiles and their chemical characteristics will serve to give a general characterization of various depths, environmental chronology, and connect human activities to landscape transformation over time. Human behaviors like resource manipulation and extraction from these two unique sites will demonstrate the long-term impact and environmental foot print left behind by early occupants.

RESEARCH AREA BACKGROUND

The Blue Creek *rejollada* includes well-drained soils with upland forest. The area contains bajos and other depressions filled with deep clays and scrub swamp forest (Brokaw and Mallory 1993; Dunning et al. 1999; Dunning et al. 2003). The *rejollada* overlooks the Río Bravo Embayment floodplain which is spring-fed and includes a series of swamp and marsh systems. The low-lying area beyond the escarpment contains numerous agricultural wetland fields, especially around the Chan Cahal complex (Baker 2007; Beach et al. 2015b) Its proximity to Blue Creek is important because the site core utilized rural areas, extending approximately 7 km outwards, to cultivate and procure food (Baker 2003, 2007; Guderjan 2002). There are three *rejolladas* adjacent to Blue Creek's civic-ceremonial core, possibly accounting for the main reason why the location was chosen to settle early on. Settlement patterns of structures built around *rejolladas* are also seen in other areas of the Yucatan Peninsula, especially in the northern Lowlands (Baker 2003, Hare et al. 2014; Lowry 2013; Munro-Stasiuk et al. 2014; Wright et al. 2009).

Figure 6.1. Map of the Blue Creek *rejollada* (Aebersold et al. 2016: Fig 1).



Rejolladas are unique landscape features containing valuable resources useful for ancient Maya lifeways. They contain micro-environments and retain more soil moisture when compared to surrounding terrain (Fedick 2014; Wright et al. 2009). Biodiversity is also significantly higher within rejolladas than surrounding areas due to their unique microclimates. Microclimates within rejolladas have moderate temperature ranges, cooler daytime temperatures, increased atmospheric moisture, and stable soil moisture throughout the year (Munro-Stasiuk et al. 2014). Microclimates observed within *rejolladas* are extremely favorable for growing cacao. Remnants of early produced cacao are still present in four *rejolladas* in the northern Lowlands (Lowry 2013; Munro-Stasiuk et al. 2014).

The deep, fertile soils within *rejolladas* are a valuable resource, especially in areas where soils are shallow like in the northern Lowlands or in sloped areas susceptible to erosion and nutrient loss. The deeper soils of *rejolladas* are moist and provide easy access for trees requiring deeper rooting (Fedick 2014; Munro-Stasiuk et al. 2014; Wright 2009). Soil depth in *rejolladas* from the northern Lowlands is reported to average between one and three meters and retains its moisture even during the dry season (Fedick 2014). *Rejolladas* are also relatively close to water tables and provide ideal locations for excavating wells. *Rejolladas* have been documented for both ancient and modern wells. These wells provide access to drinking water or for irrigation within the *rejollada* (Fedick 2014; Kepecs and Boucher 1996; Munro-Stasiuk et al. 2014). Ancient damming has also been recorded to store water in the Petexbatún region in Guatemala (Beach and Dunning 1997; Munro-Stasiuk et al. 2014).

Modern ethnographic studies show that *rejolladas* are used for cultivating economic species including cacao, mango, nance, sapodilla, mamey, yuca, avocado, and other fruit trees (Fedick 2014; Gómez-Pompa et al. 1990; Kepecs and Boucher 1996; Lowry 2013; Munro-Stasiuk et al. 2014). Carbon isotope profiles from *rejolladas* in the Petexbatún region in Guatemala support ancient maize agriculture (Dunning et al. 1997; Johnson et al. 2007; Munro-Stasiuk et al. 2014; Wright et al. 2009). Vegetation remains dense and lush throughout the year due to its fertile soils and steady moisture levels, making it ideal to grow various plants. *Rejolladas* were likely controlled by elites during the Classic Period due to their valuable resources and ability to grow cacao (Gómez-Pompa et al. 1990; Munro-Stasiuk et al. 2014).

Colha is also rich in wetland and raw material resources which inevitably supported a flourishing community. The site is outlined by Cobweb Swamp along the southern and eastern peripheries. Cobweb Swamp is a perennial wetland containing several wetland fields which remain saturated during the dry season. Vegetation includes upland forest, swamp forest, and sawgrass marsh. Each vegetative community grows valuable wetland species. For instance, the upland forest is predominantly cohune palms with other important species including *Ficus*, *Ceiba*, and *Pouteria*. The swamp forest has substantial mangrove vegetation and the sawgrass marsh boast the most diverse vegetation with sawgrass, mangroves, sedges, grasses, cattails, marsh broadleaf trees, and shrubs (Bhattacharya et al. 2011; Jacob 1995; Jacob and Hallmark 1996).

Previous studies at Cobweb Swamp have detailed the depositional history of the area beginning with sascab deposition during the late Tertiary or Pleistocene (Jacob 1995;

Jacob and Hallmark 1996). Cooler and drier conditions allowed for slope wash and colluviation to fill the swamp during the early Holocene along with the formation of Cobweb Clay. After 5,600 BP, sea level rise transformed the swamp into a brackish lagoon sustaining marine gastropods and marine foraminifera (Alcala-Herrera et al. 1994). Subsequent natural peat formation then occurred until a major flooding event dating sometime after 3600 years before present. This event triggered soil erosion across the landscape and deposited "Maya Clay" into the swamp (Jacob and Hallmark, 1996). This aggradation event has been linked to concurrent deforestation by Maya populations. By 4,800 BP, marl and peat filled the lagoon and the halt in sea level rise permitted vegetational growth along the swamp margins (Jacob and Hallmark 1996).

The wetlands provided soil nutrients and water for early inhabitants as management began during the Middle Preclassic. Population growth coincided with the modification of existing features like channels or by ditching. Cobweb Swamp also served drainage purposes comparable to practices observed at Cerros (Jacob 1995; Scarborough 1980). Between 3,400 and 500 BP, intensive agricultural practices produced increased runoff and deposited Maya Clays. This transformed the swamp into a freshwater lagoon. Pollen studies reflect a decrease in Moraceae species and an increase in disturbance taxa including Chenopodiaceae, *Amaranthus*, Poaceae, Asteraceae, cattail (*Typha angustifolia*), waxy myrtle (*Myrica*), and Myrtaceae. Cultivated taxa is also present including maize (*Zea mays*), chili (*Capsicum* sp.), cotton (*Gossypium* sp.), and manioc (*Manihot esculenta*) (Jones 1994:207-208). After abandonement in the Post

Classic, Cobweb Swamp was again filled with peat due to reforestation and decreased runoff (Jacob and Hallmark 1995).

The quality chert resource available to Colha is perhaps the strongest natural resource giving the site an advantageous position which supports early craft specialization and later large-scale exploitation and elite control over stone tool production and trade (Shafer and Hester 1983). Colha's chert occurs as surface outcrops as a product of chert-bearing marl and limestone weathering. The vast quantities of raw materials available facilitated 89 chert workshops and debitage scatters. The transition into more sedentary occupation and the beginning of raw material exploitation is visible in the Early Preclassic, and the transition into more sedentary occupation and craft specialization occurs in the Middle Preclassic. These practices intensify by the Late Preclassic in tandem with population growth and architectural expansion (Adams 1979; Shafer and Hester 1983). Reciprocal systems of exchange are evident with Colha-manufactured tools recovered from nearby Kichpanha and from sites outside of the Chert Bearing Zone including Cuello, Cerros, and Pulltrouser Swamp (Shafer 1994; Shafer and Hester 1991). It is evident that the Blue Creek *rejollada* and Colha had much to offer early inhabitants. The examination of sediments will expand on what we know about human exploitation and resource extraction from the upland and coastal area, and will help build on the environmental history in which humans have been active agents.

METHODOLOGY

Reconstructing environmental histories and anthropogenic effects requires multiple lines of evidence. Geoarchaeological techniques are coupled with archaeological data to better understand chronology and human-environment interactions. Microcharcoal, magnetic susceptibility, Mehlich II phosphorus content, organic content, and calcium carbonate content are the environmental proxies used in this study to examine sediments from the Blue Creek *rejollada* and a unit from Colha.

Sediments were processed for microcharcoal to evaluate fire magnitude and frequency linked to erosional episodes. Two grams of sediment were processed following a revised version of Innes et al. (2004), Turner (2007), and Ramsey et al. (2015) where clay particles and charcoal particulates were separated from each sample. Lycopodium spores were used to quantify counts based on Innes et al. (2004). Magnetic susceptibility is often a proxy used in paleoenvironmental studies because of its ability to determine environmental changes based on the degree to which sediment can become magnetized. Increased magnetic susceptibility readings are caused by burning events, fluctuating moisture content, and anthropogenic input in sediment profiles (Ayala et al. 2007; Dalan 2008; Gale and Hoare 1991; Rapp and Hill 2006). A GF Instruments SM-20 magnetic susceptibility meter was used directly on sediments to measure magnetic susceptibility to 10^{-6}SI units.

Mehlich II phosphorus was also measured to determine human input with Terry et al.'s (2000) extraction procedure. Two grams of sediment were processed and calibrated against a KH_2PO_4 (potassium dihydrogen phosphate) standard curve using a Hach

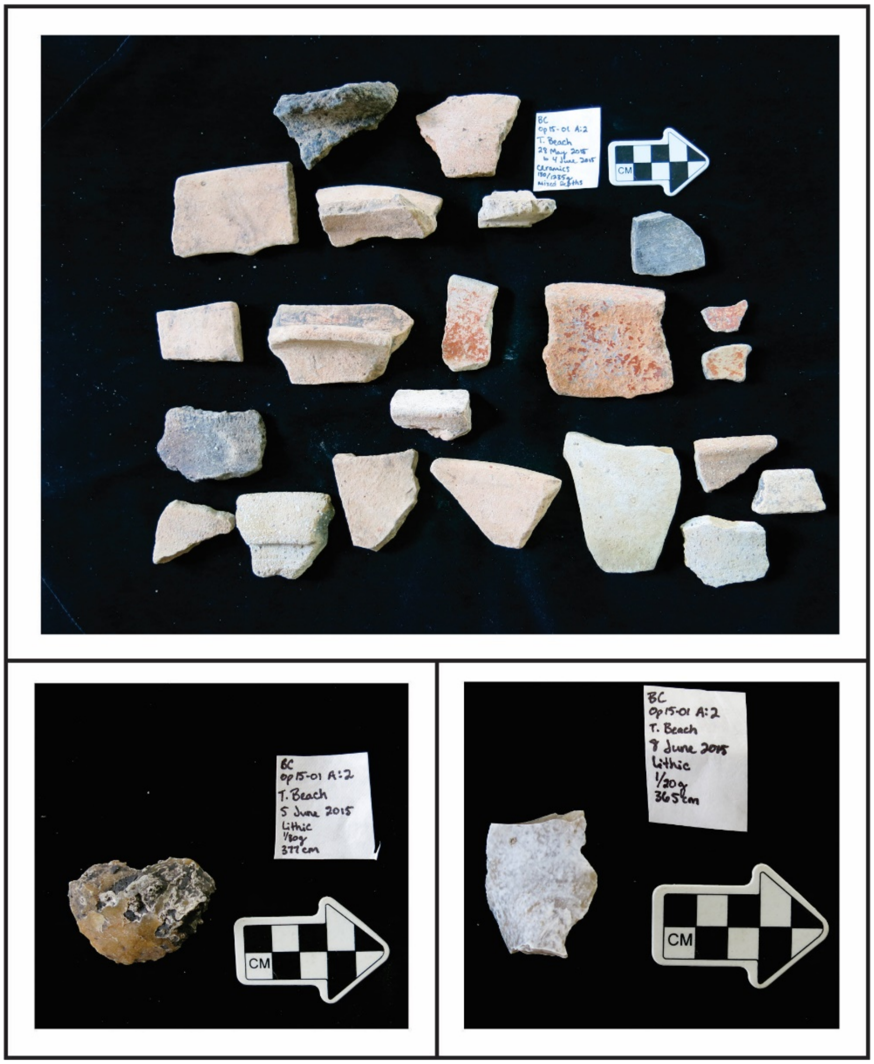
DR/850 Colorimeter. Organic and calcium carbonate content was determined by loss on ignition. This basic environmental proxy can also reflect changes in sediment deposition due to soil formation processes including accretion, erosion, and vegetation growth (Ayala et al. 2007; Beach et al. 2006; Beach et al. 2008b; Dean 1974). Five grams of sediment underwent ignition at temperatures of 100°C, 550°C, and 1000°C. Calculations determining organic and calcium carbonate content were determined by Dean's (1974) equations. Sediments were processed in the Soils and Geomorphology Laboratory within the Department of Geography and Environment at the University of Texas at Austin. Seven radiocarbon samples from the Blue Creek *rejollada* were processed at the Beta Analytic Radiocarbon Dating Facility in Miami, Florida. Two of these dates were inconsistent with the chronology of the *rejollada* and associated artifacts. The inconsistencies in dates younger than 500 years in horizons associated with ancient Maya artifacts could be due to contamination of the sample itself, a sampling error, or from other unknown reasons. The radiocarbon dates from Colha were processed at the National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) facility in Woods Hole, MA.

Blue Creek *Rejollada* Results

The Blue Creek *rejollada* was excavated in 2015 as a continuation of previous work in 2003 involving early occupation at Blue Creek (Aebersold et al. 2015, 2016). The 2003 trench reached a depth of four meters and uncovered paleosols between 3.5 and 2.9 m. These paleosols were also associated with Archaic stone tools recovered from the trench. Radiocarbon dates for the paleosols ranged well into the Late Archaic and Early Preclassic (3,940 BP to 4,140 BP) (Beach et al. 2006; Beach et al. 2008b). This early component predates all other evidence for early occupation at Blue Creek. Excavations in 2015 reached four meters in depth and yielded similar results to the 2003 excavations. The *rejollada* reached eight meters in width; however, the eastern side of the profile was not sampled due to the occurrence of a crotovena caused by bioturbation. This type of disturbance limited sampling and characterization to the western portion. Sediments were sampled at each unique horizon along the western portion of the profile for further analysis (0-10 cm, 20-30 cm, 50-60 cm, 180-190 cm, 250-260 cm, 295-300 cm, 335-340 cm, 370-375 cm, 375-380 cm, and 395-400 cm).

The uppermost A1 and A2 strata of the *rejollada* include a dark Mollisol with limestone gravel and an extensive root system in the organic-rich soil. As “A” horizons transition into “C” horizons, ceramic and lithic fragments are scattered and there are large limestone gravels, freshwater snail fragments, and sand-sized quartz crystals. The trench exhibits four distinct layers of very dark, clayey paleosols (AB1, 2, 3, 4). These paleosols contain oxidized, gravel-sized iron or manganese nodules and are associated with an abundance of cultural material. Ceramic sherds were recovered between 110 cm and 300 cm. Beyond this depth, ceramics were severely disintegrated and only occurred until 330 cm. Lithic tools and debitage were recovered from the surface and were present between 130 cm and 360 cm. Stone tool fragments were recovered up to a depth of 377 cm (Figure 6.2). The “Cgss” horizon consists of slicken slide gley, or decomposed limestone, had shell fragments, iron nodules, and corroded chert fragments.

Figure 6.2. Cultural materials recovered from the Blue Creek *Rejollada*



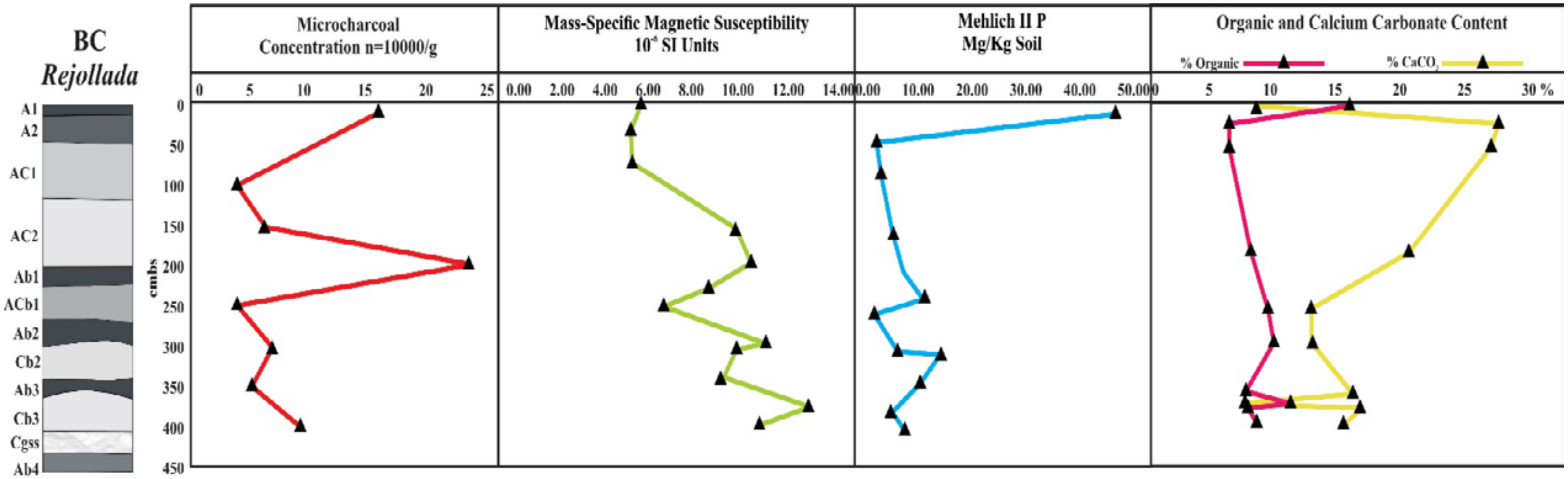
Analyses indicate a few areas of interest in the *rejollada* column. The uppermost horizon reflects a modern control on what is expected from agricultural periods, horizons between “A2” and “Cb2” are dated to Maya cultural periods, and there is a transition into the Archaic period around “Ab4.” Each of these areas has a variation of significant peak or frequency readings. For example, microcharcoal analysis reveals that frequency counts are greatest at 200 cm with over 227,000 particulates per gram. This stratum is above

“Ab2” which dates to the Middle Preclassic. The “A2” horizon is dated to the Early Classic period based on radiocarbon analysis. Although there are always complications with dates from soils, the peak amount at 200 cm likely indicates the Late Preclassic or, more broadly, sometime after the Middle Preclassic, but before the Early Classic Period.

The second highest frequency counts are at the surface with over 152,000 particulates per gram. These high counts are supported by modern industrial agricultural practices in the area from Mennonite farmers. Microcharcoal counts are not as robust below 250 cm; however, the third highest frequency count occurs at 400 cm. Approximately 90,000 particulates are present in the deepest paleosol, “Ab4,” at 400 cm. This is significant because two radiocarbon dates indicate that “Ab4” dates to the Archaic period. The paleosol frequencies are also significant when compared to the counts at 200 cm. During the Archaic period, the *rejollada* experienced frequencies up to 40% of what is reflected in Classic Maya times. This is important because it emphasizes the significant impact early inhabitants had on the *rejollada* when compared to the agriculturally-based Maya settlement.

Results also indicate clear fluctuations in magnetic susceptibility readings in the *rejollada’s* profile. Increased readings after 260 cm coincide with increased burning events and possibly wetter conditions within the *rejollada* due to human management or climate shifts. Phosphorus results are most pronounced at the surface and are appropriate for modern conditions on industrialized land. Other notable readings occur at 230 cm (11.38 mg/kg) and 300 cm (14.49 mg/kg). These are consistent with Maya occupation during the Middle Preclassic period indicating anthropogenic input at a critical cultural time for settlement at Blue Creek. The *rejollada* is comprised of approximately 5-10% organic content throughout most of the sequence, with slightly higher organic content within paleosols. Between 20-27% of "AC" horizons are comprised of calcium carbonate which reflects the gypsum and carbonate-rich sediments overlying paleosols.

Figure 6.3. Results for microcharcoal concentrations, magnetic susceptibility, phosphorus content, organic, and calcium carbonate content in the Blue Creek *Rejollada*.



Colha Results

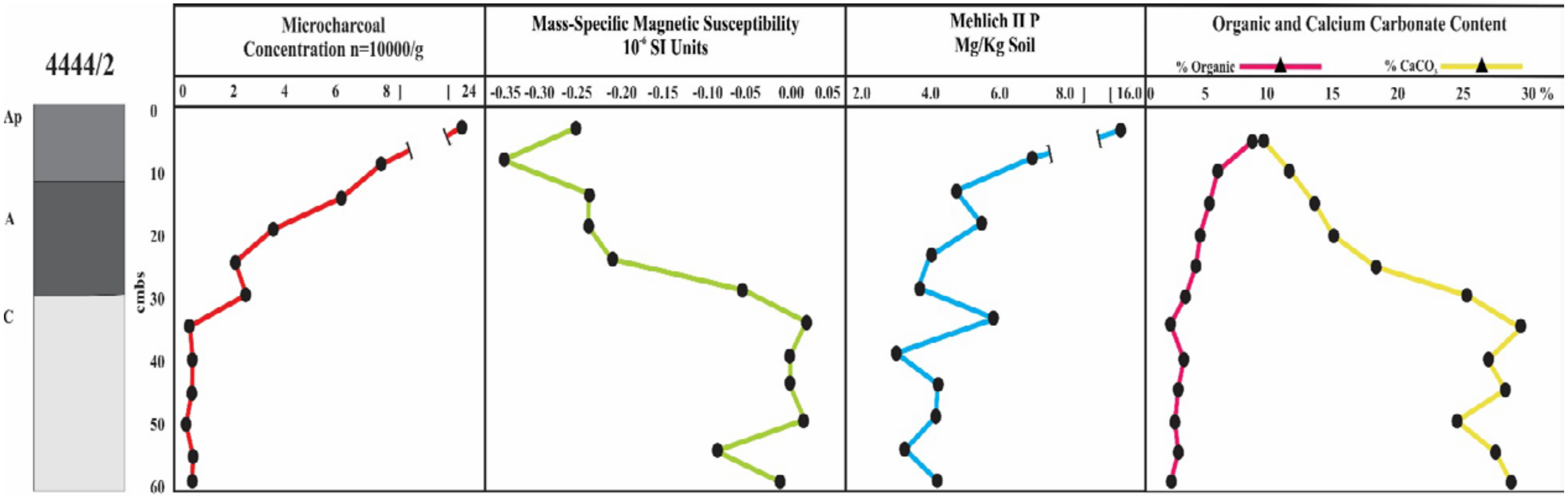
Excavations during the 2017 field season at Colha focused on the Archaic to Preclassic transition to evaluate human impacts on the environment through soil analysis and to analyze changing cultural adaptations. Sediments aid in revealing what is happening in the environment which may indicate continuity of cultural practices during the transition. While excavations included many areas in the 2000 and 4000 sector, the lack of prominent features makes Suboperation 4444/2 ideal for a general characterization of the sediments using geoarchaeological methods. For instance, we encountered several features such as a hearth, platforms, floors, or stone alignments which would skew interpretations of sediment analysis for a larger scale investigation involving geoarchaeological methods due the intentional removal of horizons by ancient people as they build structures or bury human remains. Sediments were sampled in five centimeter increments down the unit profile.

Two radiocarbon dates determined analysis for this study from an adjacent Suboperation, 4444/3. The horizons at 45cm (A horizon) and 75cm (B horizon) were dated to the Late Preclassic and coincided with cultural material recovered for that period. The characteristics of Suboperation 4444/2 were determined by microcharcoal, mass specific magnetic susceptibility, Mehlich II phosphorus content, organic and calcium carbonate content. Colha is located on a private farm and has been extensively plowed. The main plaza area has also been plowed, but is currently covered in forest regrowth. The Preclassic stratum is therefore relatively close to the surface. The soil horizons for Suboperation 4444/2 include a plow zone, or “Ap,” of approximately 10 cm consisting of very dark clays with extensive root systems and abundant cultural materials including ceramic sherds and lithics. The “A” horizon consist of very dark gray to a yellow brown matrix with fine root systems, limestone concretions, charcoal, and cultural material. Following this dark horizon is a stark change in the profile to a “C” horizon consisting of yellow silty clay with small limestone concretions.

Sediment analysis characterized the Late Preclassic component of the main plaza. The microcharcoal results show the highest frequencies at 5 cm with over 227,000 counts per gram. These microcharcoal counts are highest due to intensive agricultural farming practices on the property today. Microcharcoal counts for the Late Preclassic range from 24,000 to 61,000 counts per gram, which support a population peak during the Preclassic Period at Colha. Magnetic susceptibility readings are highest in the “C” horizon. A lack of cultural material and increased magnetic susceptibility readings show how the “C” horizon formed due to seasonal water table fluctuations, which form a “C” layer comprised of precipitated calcium carbonate and gypsum.

Constant human input from occupation and farming is apparent with Mehlich II phosphorous throughout the “A” and “C” horizons with concentrations ranging between 3.25 – 5.87 mg/kg. The most significant quantities of phosphorus (15.57 mg/kg) occur from modern contexts due to cattle input from grazing and farming on the property. Lastly, loss on ignition results reflect higher organic contents in the “A” and “Ap” horizons from vegetation growth and soil accretion. The highest amounts of calcium carbonate reiterate the composition of the “C” horizon as predominantly precipitated calcium carbonate and gypsum after 30 cm in depth.

Figure 6.4. Results for microcharcoal concentrations, magnetic susceptibility, phosphorus content, organic, and calcium carbonate in Suboperation 4444/2 at Colha.



DISCUSSION

Sediment analysis of the Blue Creek *rejollada* and the main plaza at Colha outline a long history of human-environment dynamics through the combination of geoarchaeological proxies and site histories. Although Blue Creek sits on the Rio Bravo escarpment and Colha is on the coastal plain, both sites chronicle human manipulation over time. The most dramatic comparison between the two sites is visible with microcharcoal frequency counts. The Blue Creek *rejollada* microcharcoal counts during the Late Preclassic period at 200 cm were calculated to be 227,151 per gram. Colha microcharcoal counts for modern times at 5 cm were 227, 441 per gram. This comparison illustrates the degree to which the *rejollada* was a valuable resource as a place to manipulate vegetation or soil resources.

Natural fires may occur in both areas; however, there are many reasons why it is more likely that fire management is the cause for microcharcoal peaks. First, a distinct wet season coupled with increased moisture within the *rejollada* do not favor the likelihood of regular naturally ignited fires from lightning or drought. The common occurrence of microcharcoal particulates greater than 90 μm also indicates that charcoal would have difficulty travelling through aeolian transport and was more likely deposited in a nearby location. Additionally, cultural materials present with charcoal peaks also support a strong case for fire signatures produced by people in the area. Colha's main plaza has overall less microcharcoal particulates due to the function of the plaza area. Where the *rejollada's* function seems to have served food procurement or resource manipulation purposes, the main plaza served as a space for elite residences. Hearths were recovered from a different sector of the site and wetland manipulation has been documented in the adjacent Cobweb Swamp. Fire regimes are clearly visible in both sites and we can infer to some degree the magnitude based on modern comparisons.

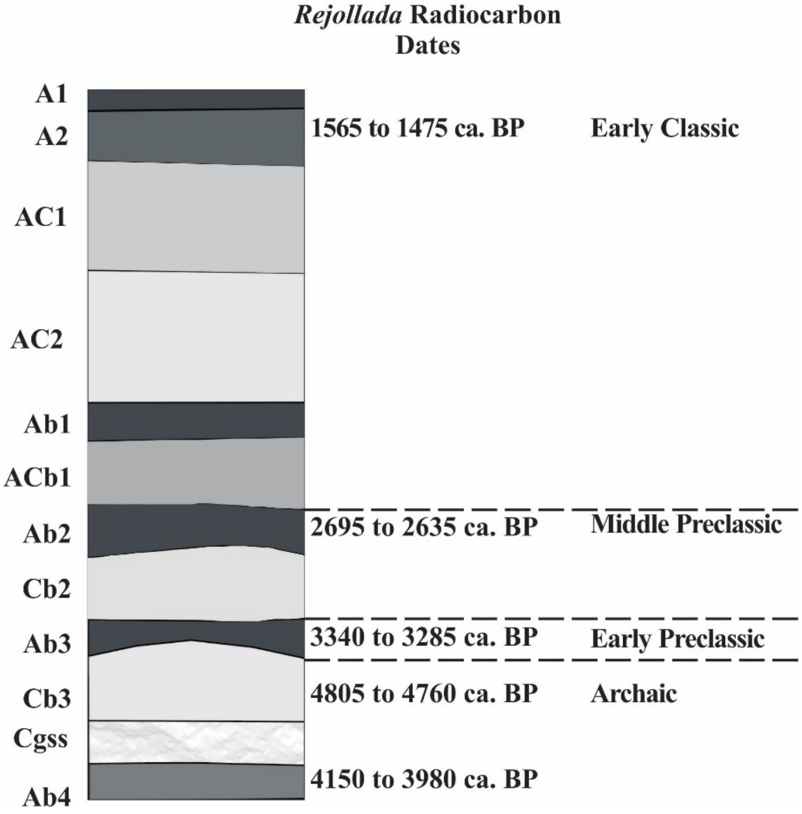
Both areas also present strong lines of evidence for human input when considering Mehlich phosphorus. The *rejollada* has increased phosphorus content during the Middle Preclassic and Late Preclassic. Colha has increased phosphorus content during the Late Preclassic as well. These periods are vital to each site as the size and social complexity was growing during those cultural periods. As Blue Creek grew, rural areas like the *rejollada* in this study would become invaluable to cultivate and procure food for the site core (Baker 2003, 2007; Guderjan 2002). By the end of the Late Preclassic, Colha had a growing population, developed intensive craft specialization, constructed monumental structures, and engaged in trade and distribution. These characteristics suggest social stratification with an independent to semi-independent ruling elite class by the end of the Late Preclassic (Adams 1982; Buttles 2002). Finally, disruptions in stable surfaces, such as the paleosols, observed in the *rejollada* indicate the deposition of calcareous Maya Clays. This pattern is a result of deforestation and is correlated with artifacts in erosional episodes, especially during the Archaic and Preclassic periods.

An interesting contribution to site chronology at Blue Creek is the long record the *rejollada* provides of early manipulation in the area (Figure 6.6). Some of the deepest ceramics and tools found in this study and in previous field seasons merit further study. Ceramics recovered from a depth of 330 cm in the rejollada are associated after “Ab3.”

The paleosol which dates to 3,340 to 3,285 BP and is comparable to *Cunil* pottery, some of the earliest pottery in Belize from the Maya Lowland site of Cahal Pech. This ceramic tradition dates between 2,860 and 2,760 BP or Early to Middle Preclassic periods (Garber and Awe 2009; Sullivan and Awe 2013). These dates have also been compared to Early Preclassic Kanocha phase ceramics at the site of Blackman Eddy (Garber et al. 2004). Lohse argues (2009) that paleosols are considered poor contexts for dating ceramics due to the deposition of old carbon; however, it is clear that early inhabitants of the Blue Creek area were taking advantage of the unique resource long before the site expanded to its full extent.

The Blue Creek *rejollada* and Colha present multiple lines of evidence for human behaviors which induce major environmental changes. Large-scale fire regimes, erosional episodes, and chemical input highlight the long-lasting impact early inhabitants contributed in a small scale. These local practices are not unique on a global scale and they do not occur only in ancient times. This large-scale pattern requires us to consider human behavior when evaluating the current state of environmental systems in terms of discussing the concept of the Anthropocene. Beach et al. (2015a) even argue for golden spikes to evaluate ancient Maya impacts to understand the beginnings of the Anthropocene. Most notably, the occurrence of Maya clays, paleosol sequences, and increased phosphorus footprints, all of which have been presented in this study in the upland *rejollada* and coastal site.

Figure 6.5: *Rejollada* radiocarbon dates.



CONCLUSIONS

The Blue Creek *rejollada* and Colha were examined for their physical and chemical characteristics to provide a general characterization of deposition, environmental chronology, and to connect human activities to environmental impacts throughout ancient Maya times and today. Evaluating fire frequency and magnitude revealed Blue Creek's earliest inhabitants created a complex environmental niche at the *rejollada* through fire regimes. The scale of environmental impact is comparable to modern agricultural practices at Colha. Erosional episodes, Maya clays, paleosol sequences, and increased Mehlich phosphorus were also prominent characteristics of human impacts in the two study sites.

These lines of evidence point to the importance of understanding the under-represented and long-standing contributors of the Anthropocene during pivotal cultural transitions. The transition to more sedentary lifestyles and more intensive strategies during the Archaic to Preclassic periods is still understudied; however, geoarchaeological proxies will help expand on our knowledge of early inhabitants.

Chapter 7: Connecting the Past and Present through Paleobotanical and Ethnographic Studies

The archaeological record is not only useful in understanding humanity through material culture, it doubles as a long-term environmental record for the study of human-environmental relationships (Beach et al. 2008a). Studying these environmental narratives through archaeobotanical records is vital to understanding human-environment dynamics. This chapter will cover food economic systems to discuss archaeological and ethnographic foodways in Mesoamerica. This will set a baseline for understanding the contribution of ethnographic interviews conducted to supplement this dissertation regarding investigations of human-environment relationships. Examples of food-based economic systems are widely studied; however, the following review mostly centers on Neotropical studies.

While Maya culture can be described in broad terms, it encompasses a variety of temporal and spatial scales. When considering economic systems surrounding foodways, it is important to recognize there are degrees of variation between ecological and cultural areas. Scholars caution against the application of ethnographic data without a critical lens, which often reveals historic discontinuities (Gillespie 2000; Perry 2001; Sheets et al. 2012; Simms 2014). Instead, Hastorf (1991:133) suggests using ethnographic relationships as a tool for finding “interpretable links” between food systems and social relations. Paleobotanical remains provide a direct link to economic systems including production, processing, and consumption (Hastorf 1988). Other “interpretable links” can be found in modern day practices from Maya descendants.

Archaeobotany and ethnography offer valuable contextual evidence when studying past environments because it is rare to find extensive explanations or exhaustive descriptions of plant taxa for many archaeological contexts (Moreno 2003). Indigenous knowledge provides a baseline for decision making at the individual and community levels which has the potential to improve sustainability and development efforts by building upon and strengthening local knowledge (Warren 2003). Warren (2003) describes Indigenous knowledge as “ethnically-based or community-based,” which is tied to a micro-environmental context that evolves over time. This concept requires us to understand Indigenous knowledge systems as dynamic and adaptive to external forces (Colajanni 2003).

Ingold (2003) also describes traditional knowledge as a continual process. When people change practices over time, it does not mean there has been a definitive break in tradition, rather, it is a part of the process of tradition. Moreover, traditional knowledge can be viewed as a skill due to its similarities to the concept. Skills have three main characteristics including properties of an entire system established by someone in a structured environment. They require decision making, mastery, and care. Finally, people acquire them by imitation and improvisation (Ingold 2003). By viewing Indigenous botanical knowledge as a process involving skills, it has the potential to contribute to a more nuanced look at how people transform and preserve the environment within anthropological and archaeological studies.

Researchers must carefully consider factors affecting the interpretation of paleobotanical remains. For example, excavations are biased in representing plant-related activities. This means that contexts limit the interpretation of plant uses, especially since many plant-related activities occur away from habitation spaces (Hastorf 1988; Simms 2014). Furthermore, context cannot always be defined for multiple activities in a single space. Postdepositional cultural and natural processes also affect the paleobotanical record. An exceptional outlier in preservation is the site of Cerén, El Salvador. The Middle Classic site was preserved by tephra during an eruption of the Loma Caldera volcano between AD 585 and 600. This event led to the best-known preservation of everyday life in a Maya village. The paleobotanical record consists of *in situ* macroremains, plaster casts of plant remains covered in tephra, and floated macrobotanicals (Lentz 1991; 1999; Lentz et al. 1996; Lentz and Ramírez-Sosa 2002; Sheets et al. 2012).

The most common cultigen at Cerén is maize, which is morphologically similar to Nal Tel maize race (Lentz and Ramírez-Sosa 2002). Maize was recovered from store rooms in baskets or corn cribs and from fields close to house compounds (Lentz et al. 1996). Common beans (*Phaseolus vulgaris* L.), Lima beans (*P. lunatus* L.), and other wild beans were recovered from ceramic vessels and other storage units mixed together. Seeds and squash rinds (*Cucurbita moschata* and *C. pepo* L.) were recovered from several contexts at Cerén. Although squash can be prepared by boiling, Wisdom (1940:92) describes grinding squash seeds as part of a common corn and bean paste among the Chorti Maya (Lentz et al. 1996). Large quantities of chili pepper remains (*Capsicum annuum* L.) were found in storage rooms, ceramic vessels, and hung from rafters in a kitchen.

Root crops including manioc (*Manihot esculenta* Crantz) and *malanga* (*Xanthosoma violaceum* Schott) were recovered from a house garden (Sheets et al. 2012). Another important economic cultigen, cotton (*Gossypium hirsutum* L.), was recovered from a metate trough and a storehouse. Cotton fiber was important for clothing and seeds are suggested to be pressed for their oil in cooking (Alcorn 1984:658), as a base for paint, or for medicinal purposes. Other notable finds include agave (*Agave* spp.), avocado (*Persea americana* Mill.), guava (*Psidium guajava* L.), calabash (*Crescentia alata*), nance (*Byrsonima crassifolia*), and cacao (*Theobroma cacao* L.) (Lentz et la. 1996; Lentz and Ramírez-Sosa 2002).

Other economic species that also serve utilitarian purposes were also present. For example, a loosely woven cloth made of maguey (*Agave* sp.) was found covering a vessel. This diverse plant is well documented for its use as food and for its fibers (Lentz et al. 1996; Parsons and Parsons 1990). Roofing structural materials such as thatching and beams from grasses (Poaceae), pine charcoal (*Pinus oocarpa*), malady (*Aspidosperma* sp.), Spanish cedar (*Cedrela* sp.), and fig charcoal (*Ficus* sp.) were recovered as macroremains. A *coyol* (*Acrocomia aculeata*) palm fruit was recovered as a carved spindle whorl. This is unusual since the coyol palm is widely recorded across Mesoamerica as an important species (McKillop 1994, 1996) and is abundant at Copán, just north of Cerén (Lentz 1991).

Wood used for beams and lintels are also recognized at Late Classic Tikal temples from sapodilla (*Manikara zapota*) and logwood or inkwood (*Haematoxylon campechianum* L.) (Lentz and Hockaday 2009). The sapodilla tree has edible fruits, is a principle component of natural chewing gum, and has many medicinal uses (Alcorn 1984; Balick and Arvigo 2015). Logwood has medicinal uses as well, but is traditionally used as a source of dye for clothing and was intensively exported during the 16th and 17th centuries by Spanish and English buccaneers in Belize (Balick and Arvigo 2015; Lentz and Hockaday 2009).

The small village of Cerén provides an excellent baseline for Maya economic systems and has been used as a comparative model for larger sites. For example, it has been compared with Tikal, a much larger site with similar vegetation and elevation (Lentz et al. 2014:18515). Tikal and Cerén share many similar crop systems and orchards which include maize *(Zea mays* L.), beans (*Phaseolus* spp.), squash (*Cucurbita* spp.), sweet potato (*Ipomoea batatas*), achira (*Canna* cf. *indica* L.), malanga (*Xanthosoma sagittifolium*), coyol palm (*Acrocomia aculeata*), sapote (*Pouteria sapota*), nance (*Byrsonima crassifolia*), avocado (*Persea americana*), and cacao (*Theobroma cacao*).

PREHISTORIC MAYA ECONOMIC SYSTEMS

Production

Hastorf (1988:122) defines crop production as activities resulting in the harvesting of mature plants including commodities such as food, construction materials, fuel, or fodder. Crop production is heavily intertwined with landscape management and wetland manipulation which are widely documented for Mesoamerica (Fedick 1996; Gómez-Pompa et al. 2003; Piperno 2006). The milpa cycle (also known as swidden or slash-and-burn agriculture) is perhaps one of the most widely known crop production practices in ancient and modern Maya practices. It involves a maize-based polyculture system in a series of cultivation and abandonment cycles. Before reclaiming fallow fields, small-scale farmers will burn fields to remove vegetation and redeposit nutrients into fields. This is only one form of landscape management which serves small-scale farmers or horticulturalists (Ford and Nigh 2010; Nigh and Diemont 2013). Massive political centers, such as Tikal and other large sites, require more intensive and varied agricultural systems to support increased populations.

Aerial photography in the 1970s and 1980s revealed wetland management systems as part of a larger "managed mosaic" which included numerous other forms of crop production (Adams et al. 1981; Fedick 1996; Pohl 1990; Pohl et al. 1996; Pope and Dahlin 1989; Siemens 1983; Siemens and Puleston 1972; Turner and Harrison 1983). Wetland management encompasses areas like *bajos* where people have adapted and formed ecological niches to produce food. Activities include ditching, terracing, horticulture, and agroforestry.

Wetland fields within northern Belize have a long history of management and adaptation. Wetland agriculture is evident in the Río Hondo flood plain as early as the Early to Middle Preclassic period by 3,000 BP (Bloom et al. 1985). This predates wetland fields at Cerros, Nicolás Bravo, and Pulltrouser Swamp dating to the Late Preclassic (Jacob 1995; Scarborough 1983,1991; Turner and Harrison 1983). Over time, draining riverbank fields by ditching was common practice to combat rising sea levels at San Antonio and surrounding areas. The same ditching or canal construction practices as a response to rising water levels is also observed at Albion Island and Douglas Swamp

(Pohl 1990; Pope et al.1996). Wetland fields at Cobweb Swamp also have evidence of early wetland manipulation by 3,400 BP. Ditching wetland fields results in gypsum precipitation and carbonate accumulation observed throughout northern Belize. Fedick (1995:31) suggests that any number of these cultivation patterns vary across landscapes based on settlement patterns and the agricultural capability of resources. These fields have persisted despite heavy regrowth. Some scholars argue that some tree species may even survive millennia of abandonment and still grow in the areas where they were once cultivated (Folan et al. 1979; Gómez-Pompa et al. 1990; Ross 2011; Ross and Rangel 2011).

Beach and colleagues have also studied wetland manipulation in the Maya Lowlands for years. Characterizing the geomorphology, soils, hydrology, and identifying anthropogenic markers has anchored their research which supports evidence for ancient crop production with raised fields, canals, and terracing (Beach 1998; Beach et al. 2008a,b, 2009; 2015b,c; 2018a,b; Dunning and Beach 1994; Dunning et al. 1998, 1999; 2002, Luzzadder-Beach and Beach 2009). Miksicek (1983) has also studied raised field systems at Pulltrouser Swamp. Miksicek identified manioc, maize, and avocado which strongly supported intensive management of the swamp when coupled with pollen data from the raised fields (Wiseman1983).

Palynological studies investigating climate have contributed to food production evidence as well. Pollen records indicate *Zea mays* pollen first appears at Lago Puerto Arturo at 4,600 BP, and then again at 3,500 BP. Agricultural activities are also supported by the presence of disturbance taxa including Poaceae and Asteraceae (Wahl et al. 2007;

Wahl et al. 2014). Manioc and maize pollen occur as early as 3400 BC at Pulltrouser Swamp in Belize (Pohl et al. 1996). At Colha, pollen evidence reflects a decrease in Moraceae pollen taxa, increased disturbance taxa, and economic species including maize (*Zea mays*), chili (*Capsicum* sp.), cotton (*Gossypium* sp.), and manioc (*Manihot esculenta*) (Jones 1994:207-208).

Processing

Evidence for processing foods includes preparation, storage, and cooking (Atalay and Hastorf 2006; Hastorf 1988). Processing most prominently takes place in habitation areas. Hastorf (1988:125) lists various activities to consider for processing which may leave behind botanical evidence including transportation, sorting, washing, drying, cooking, and storing. Evidence for processing includes chemical residues in “chocolate pots” or spouted vessels in the lowlands. Hall et al. (1990) first identified biomarkers for *Theobroma cacao.* in a vessel recovered from Tomb 19 at Rio Azul, Guatemala (Adams 1999). Studies from Colha have also identified cacao residues from Middle Preclassic burials (Hurst et al. 2002; Powis 2002). The earliest evidence for cacao vessels comes from Puerto Escondido, Honduras when residue analysis confirmed the presence of cacao dating to 1150 BC, possibly attributed to a fermented drink made from the pulp or seeds (Henderson et al. 2007). Other functional interpretations of ceramics can be linked with feasting and gift-giving which include forms for cooking, preparation, serving, storage, and transport (Beaudry-Corbett 2002; Brown and Gerstle 2002; Hendon 2003).

Grinding stones also provide strong evidence for processing foods in domestic spaces. Their durability and materials, lasting up to 150 years, make them ideal candidates for studying various forms of food processing (Devio 2016; Searcy 2011). While manos and metates are known mostly for processing maize into flour, they have been found to include distinctive forms and be multifunctional (Simms 2014; Watanabe 2000). Metates can function to grind maize, salt, chilis, achiote, or can even be used to capture or contain water (Devio 2016; Watanabe 2000). Using metates to extract cottonseed oil has also been suggested by Lentz et al. (1996) and observed among modern Huastec Maya (Alcorn 1984).

The earliest evidence for maize in the Central Balsas River Valley comes from starch granules recovered from grinding stones at the Xihuatoxtla shelter in Mexico dating back to 8,700 BP. Other stone tools including unifaces, bifaces, and hammer stones at Freshwater Creek, Belize have yielded Archaic period starches from maize, chili pepper, manioc, bean, and squash (Rosenswig et al. 2014). Other preceramic findings include a groundstone from the Aguadulce Rock Shelter in Panama which contained starches from maize, manioc, squashes, yam, and chilis (Perry et al. 2007). Panama also has other early preceramic and early village sites including La Mula and a Monagrillo shell midden where starch grains were recovered from stone tools including manioc, maize, arrowroot, and beans (Piperno and Holst 1998).

Consumption

Food consumption includes plant and animal products, which lends itself to broader categories of evidence (Hastorf 1988). In addition to food preparation and cooking strategies, isotopic signatures, faunal remains, and dentition can be considered as evidence for the consumption of various foods. Faunal remains from middens or mortuary areas can provide clues to ancient foodways and other cultural practices.

While there is ample evidence for a maize-based diet supplemented with other wild and domesticated cultigens, whitetail deer and other terrestrial game were an important aspect contributing to dietary variability in ancient Maya foodways (Friewald 2010; Lentz 1999; White et al. 2001). Differences in ecological niches, age, sex, and social status also contribute to dietary variability observed in isotopic studies. For example, Gerry and Krueger (1997) estimate that in the Petén and Copan Valley sites, maize accounts for up to 66% of total consumption. This is much more than what is estimated in the Belize River Valley. Less than half of dietary consumption in the Belize River Valley is estimated to come from maize in sites including Baking Pot, Barton Ramie, Blackman Eddy, Cahal Pech, Esperanza, Floral Park, and Saturday Creek (Friewald 2010:400). When compared to the Copan Valley, the Belize River Valley and Petén populations consumed more animal protein. Demographics within polities also exhibit variable diets. For example, in the Pasion River region and Pacbitun, males consumed more maize than women and children (Friewald 2010; Wright 1997). At Caracol and La Milpa, maize is considered a staple of elite diet (Friewald 2010).

Colha’s faunal records from early Middle Preclassic middens reflect a variety of terrestrial and aquatic species, with an emphasis on wetland species (Shaw 1999). Marine fish remains recovered from Colha, Cuello, and Cahal Pech suggest long-distance fishing trips to the coast or perhaps early regional exchange networks (Shaw 1999; Stanchly 1995; Wing and Scudder 1991). Whitetail deer has been continuously recognized as a dominant protein source at Colha, Cuello, Cerros, and Cahal Pech along with other animals including freshwater turtle, domesticated dog, reptiles, amphibians, and some small fish and bird taxa (Shaw 1999; Wing and Scudder 1991).

Domesticated dogs are the second most common faunal remains at Colha and are considered a valuable protein source before the introduction of domesticated turkey in the Postclassic (Hamblin 1984; Shaw and Mangan 1994). Similar trends from Petén sites are observed in Preclassic and Postclassic contexts. For example, in Middle Postclassic Lamanai and Tipu, large mammals like whitetail and brocket deer, reptiles, birds, and fish dominate assemblages. In Late Postclassic Lamanai, whitetail deer and domesticated dog continue to dominate assemblages despite the introduction of turkey and curassow. Fish, turtles, and riverine mollusks become more frequent in Late Postclassic Lamanai. At the same time, Tipu witnesses a greater dependence on small mammals such as armadillo, agouti, pacas, and peccary (Emery 1999).

Dental calculus also provides botanical evidence for consumption. Scott Cummings and Magennis’ (1997) analysis of dental calculus from burials at Kichpanha included starch and phytolith evidence for various comestibles and other activities involving plants. Maize (*Zea mays*) and manioc (*Manihot esculenta*) starch granules were identified in the dental calculus of several individuals. Numerous phytoliths from palms and grasses other than maize, were found to be embedded from weaving. Other fibers were suspected to be remnants of foodstuffs or from plants used for utilitarian purposes.

Human dentition pathology can also present evidence for diet, food preparation, and consumption. An increase in dental caries is often symptomatic of increased carbohydrate intake due to a shift in subsistence strategy from foraging to agriculture (Magennis 1999). Additionally, eating foods processed by grinding stones can wear down tooth enamel. Other food-related pathologies studied through Maya paleodiet include skeletal manifestations of anemia, scurvy, stature, enamel hypoplasia, and infectious disease (Danforth 1999; Glassman and Garber 1999; Magennis 1999; Whittington 1999; Wright and White 1996).

Macrobotanical Remains

Macrobotanical remains offer additional information relating to Maya food systems. Fragments large enough to be studied without high power magnification can be processed through flotation where carbonized materials are separated from soils, rocks, and other dense materials (Lentz 1999). Flotation work at the Preclassic site of Cuello in northern Belize also includes some of the oldest macrobotanical findings of maize in the Maya Lowlands (Hammond and Miksicek 1981; Miksicek et al. 1981). Identified carbonized remains from Preclassic contexts include three varieties of maize (*Zea mays*), squash (*Cucurbita moschata*), pine (*Pinus caribaea*), avocado (*Persea Americana*), wild chili (*Capsicum annuum*), cacao (*Theobroma cacao*), razor grass (*Scleria bracteate*), nance (*Byrsonima spp.*), cotton (*Gossypium sp.*), mamey (*Pouteria sapota*), jicama (*Pachyrrhizus erosus*), sweet potato (*Ipomoea batatas*), manioc (*Manihot esculenta*), hackberry (*Celtis sp.*), and a variety of *Xanthosoma* (elephant ears) (Hather and Hammond 1994; Miksicek 1981).

Miksicek (1983) examined fields and habitation areas at Pulltrouser Swamp for macrofloral remains as well. Economic species like maize, ziricote (*Cordia*), sapodilla (*Manilkara zapota*), and hog plum (*Sponidas*) were recovered in raised fields and habitation areas. The macrofloral evidence for the habitation area of Kokeal at Pulltrouser Swamp resembles modern Maya villages. Avocado, hog plum, siricote, copal, sapodilla, papaya, and allspice work well in household orchards to provide food, incense, shade, latex, construction material, medicine, and firewood (Miksicek 1983).

Cahal Pech, located in the upper Belize River Valley, has also yielded macrobotanical remains (Powis et al.1999). Charred remains and plant fragments at the site include maize (*Zea mays*), squash (*Cucurbita sp.*), wild fig (*Ficus sp.*), guava (*cf. Psidium guajava*), pine (*Pinus sp.*), glassy wood (*Astronium graveolens*), malady (*Aspidosperma sp.*), and aguacatillo (*Nectandra sp.*). Other economic cultigens recovered by Wiesen and Lentz' (1997) include common bean (*Phaseolus sp.*), ramón (*Brosimum alicastrum*), coyol palm (*Acrocomia aculeata*), and cotton (*Gossypium sp.*).

Macrobotanical remains from Early Postclassic contexts at Colha include maize (*Zea mays*) kernels and fragments, common bean (*Phaseolus vulgaris*), cotton (*Gossypium hirsutum*), achiote (*Bixa orellana*), jauacte palm (*Bactris major*), bitter gourd (*Momordia sp.*), epiphytic cactus (*Selenecereus sp.*), and pine wood (*Pinus sp.*) charcoal

(Miksicek 1979). Investigations by Caldwell (1980) also identified macrobotanical evidence for supa (*Acrocomia Mexicana*), chicle tree (*Achras zapota*), maize (*Zea mays*), Poaceae grass, papaya (*Carica papaya*), achiote (*Bixa orellana*), custard apple (*Annona reticulata*), and bullet tree (*Bucida buceras*) in Operation 2010 (Early Postclassic midden). Operation 2012 contained a partial mamey apple seed (*Calocarpum mammmosum*) dating to the Early Preclassic (Caldwell 1980).

Crane (1996) investigated macrobotanical remains and pollen at Cerros, a coastal Late Preclassic site. Identified cultigens include maize (*Zea mays*), squash (Cucurbita sp.), beans (*Phaseolus*), cotton (*Gossypium* cf. *hirsutum*), and chili pepper (*Capsicum* sp.). Important tree and root crops recovered from Cerros include nance (*Byrsonima crassifolia*), coyol palm (*Acromia Mexicana*), mamey (*Calocarpum mammosum*), guava (*Psidium* cf. *guajava*), and manioc (Manihot esculenta) to name a few (Crane 1996:269-271).

The southern coastal sites of Frenchman's Cay, Tiger Mound, Pelican One Pot, Orlando's Jewfish (underwater site), and Wild Cane Cay have been especially crucial in providing understanding palms as important Maya resources (McKillop 1994, 1996). McKillop suggests that native palms, especially *Orbignya cohune*, *Acrocomia mexicana*, and *Bactris major*, were an integral part of ancient Maya subsistence economy during the Classic and Postclassic periods. In addition to providing edible fruits high in calories, palm fruits are a good source of protein, carbohydrates, and vitamins. Other uses include thatching, building materials, fibers, and palm trunks can even be burned to produce salt (McKillop 1996).

SAN FELIPE CASE STUDY

Interviews conducted in 2016 and 2017 investigated milpa practices and cultigens grown today for supplementing diet, construction materials, household goods, and medicinal or hygienic purposes (Aebersold, Hart, and Valdez *Under Review*). This research also doubled as a sampling strategy for contemporary plant specimens to build a comparative phytolith reference collection. This collection of plant specimens contributed to collections at herbariums in Belize and UT Austin. A total of 40 plant taxa were collected from these ethnobotanical interviews (a complete list is available in Appendix C). Bridging archaeobotanical evidence with ethnobotanical accounts in the area will supplement research on Maya food systems and human-environment dynamics. The following includes a general overview of cultivation and milpa practices in San Felipe, Belize based on interviews, as well as the persistence of plants and animals in Mesoamerica over time. This will demonstrate how people have continued a legacy of knowledge and economic systems over time which is both dynamic and adaptive to external forces.

Ethnobotanical Interviews

Semi-structured ethnobotanical interviews were conducted with five individuals from San Felipe, a predominantly Maya community in northwest Belize, approximately 45 minutes outside of the Rio Bravo Conservation and Management Area (Alexiades 1996). Accounts of seven residents of San Felipe included common household gardening practices, *milpa* practices, common cuisine, *ofrenda* practices, hunting, and some gathering practices. For the purposes of this study, a *milpa* refers to an open-field horticultural system centered on maize (Nigh and Diemont 2013). I received help from Dr. Fred Valdez and Dr. Thomas Hart in the collection of plant specimens and photographing the process. Participants were extremely generous in providing plant specimens and talking about the role home gardens and *milpas* play in everyday lives.

Demographics

Long-standing archaeological projects like Programme for Belize Archaeological Project and Maya Research Program have maintained good relationships with their surrounding communities. During the 2015 field season, I worked closely with two colleagues from San Felipe who had been supporting archaeological excavations for close to 25 years. Their interest and support for my research became a valuable resource to include in my studies. After I was approved by the Internal Review Board to conduct interviews, they served as my guides around San Felipe and introduced me to some of the older residents in their community to participate in this study.

Since many traditional customs and practices surrounding plants is disappearing due to a modern market-based economy, it was a challenge to find people who were known for their traditional plant knowledge. A few people I interviewed mentioned that the oldest generation in the village had passed in the last three to five years. Traditional plant knowledge is continually lost from one generation to another, especially now when many younger community members have wage-based jobs and no longer tend fields. Both of my guides mentioned regretting not learning more from their parents and forgetting certain plants over the years.

Most of the people I interviewed were in their 60s and 70s. The oldest person I interviewed was 90 years old. They were mostly descendants of Mopan, Q'eqchi', or Yucatec Maya. Only one person did not identify with Maya ancestry. Instead, he identified as half Belizean and half British. Many people I spoke with, or their family, immigrated from Mexico, Guatemala, Honduras, or El Salvador to Belize. I conducted the semi-structured interviews in Spanish, therefore, I am responsible for any error in translation or understanding. The following is a summary of what I gathered from our conversations.

Household Garden and *Milpa* Plants

Household gardens were located in courtyard areas and surrounding residences. Some people had adjacent lots dedicated to growing plants or orcharding. Most interviewees had many common cultigens in their home gardens or plots including mango (*Mangifera indica*), coconut (*Cocos nucifera*), *achiote* (*Bixa orellana*), sweet potato (*Ipomoea batatas*), squash (Cucurbitaceae), papaya (*Carica papaya*), pumpkin (*Cucurbita pepo*), lime (*Citrus* spp.), hog plum (*Spondias radlkoferi*), chili (*Capsicum* spp.), oregano (*Plectranthus amboinicus*), chaya (*Cnidoscolus aconitifolius*), *makilito* or malanga (*Xanthosoma sagittifolium*), tomato (Solanaceae), and cashew (*Anacardium occidentale*). Some of these cultigens are not Mesoamerican domesticates; however, they are contemporary staple cultigens (Lentz 1999; Patch 2003; Piperno and Pearsall 1998).

Over half of cultigens in house gardens or adjacent plots were grown for the primary purpose of major edible components such as fruits, beans, tubers, or leaves.

Greenberg (2003) also identified some of the most common plant species found in numerous Maya house lots in Puerto Morelos, Quintana Roo that paralleled San Felipe including guava, limón (*Citrus* spp.), *epazote* (*Chenopodium ambrosioides*), guanábana (*Annona muricata*), habanero (*Capsicum chinense*), coconut (*Cocos nucifera*), chaya (*Cnidoscolus aconitifolius*), hog plum (*Spondias radlkoferi*), and tamarind (*Tamarindus indica*). In this study, one household highly valued heirloom habanero peppers because they were passed down for two generations. Habaneros and other peppers are difficult to identify in the archaeological record, but Cerén provides evidence for an abundant presence in households (Lentz et al. 1996). Having a variety of trees in each household is useful because many tree taxa regenerate quickly, provide shade, construction or thatching material, fuel resources, and provide root stability to prevent soil erosion despite human induced ecological pressures (Goldstein and Hageman 2010). Tending to household gardens often includes composting egg shells and food scraps. Making sure invasive weeds like *pica* and *corozo* are removed from gardens and *milpas* is also important for cultigen health.

Medicinal Plants, Condiments, and Other Multipurpose Plants

Many residents kept a variety of herbs as condiments and for medicinal purposes. A popular condiment was *oregano grueso* (*Plectranthus amboinicus*), which is also used to ease a cough, earache, or stomach issues. Basil (*Ocimum basilicum*), or *albajaca*, is often used to help treat fever, lower back pain, headaches, ear aches, vision problems, skin ailments, and stomach pains. *Culantro* (*Eryngium foetidum*) is grown in many homes as a condiment and to treat various digestive issues. *Flor de ajo* (*Mansoa hymenaea*) is a strong-smelling garlic vine mostly for cooking, but can also relieve intestinal issues (Balick and Arvigo 2015). There was one type of chili, mash ák (*Capsicum frutescens*), which was as an important ingredient in shaman rituals, aided in digestion problems, and served as a popular condiment. Epazote (*Chenopodium ambrosioides*) is another common herb used in cooking and is used to rid people of intestinal parasites (Arvigo and Balick 1993).

The *sorosi* (*Momordica charantia*) vine has numerous medicinal uses. It can be used to alleviate a number of skin problems as well as mouth and throat sores (Arvigo and Balick 1993). The *sorosi* fruit is edible and was used to cover a wire fence for privacy. Common in many home gardens and forest environments is a plant known as *siempre viva* (*Kalanchoe pinnata*). It has multiple medicinal uses including headaches, bruising, swelling, cough, cold, and flu. One household garden included tobacco (*Nicotiana tabacum*), but it is not grown for smoking purposes. Instead, it is used to treat fevers, joint pain, and inflammation (Balick and Arvigo 2015). *Ix canaan* (*Hamelia patens*) is common around household gardens and serves to treat skin ailments.

Flowers from *izote* (*Yucca guatemalensis*) are decorative and are often cooked in egg dishes in one household I visited. The pito (*Erythrina standleyana*) tree's leaves can be used to treat a fever. The pods and seeds can also be used to keep kerosene lamps clean (Balick and Arvigo 2015). *Madre de cacao* or *hotz* (*Gliricidia sepium*) is known for treating eye irritation and is a major component in soap from Mexico called *cacahuananche* (Arvigo and Balick 1993). The piñon (Jatropha curcas) serves to relieve headaches, mouth sores, skin conditions, relieve back pain, and digestive problems. The piñon is a host plant for an insect which produces resin valuable for finishing wood crafts in Mexico. Additionally, infused leaves may help settle dye for cotton and other fabrics (Balick and Arvigo 2015).

There are a number of useful plants which pertain to textiles or other fiber needs in addition to cotton (*Gossypium hirsutum*). Some people also remember their parents using *palo de tinta* (*Haematoxylum campechianum*) to dye clothing, but it is rarely used anymore (MacVean 2003). Another useful plant for textiles is henequin (*Agave fourcroydes*). The fibrous plant is used for weaving ropes or hammocks (Balick and Arvigo 2015; Colunga-García Marín 2003). Reeds, or *bejuco*, are also known to be used for their fibers in basketry weaving. Other economic species include hardwood trees like cedar (*Cedrela odorata*), pine (Pinus), and *ziricote* (*Cordia dodecandra*) which are often used for housing materials or crafting.

Additionally, many herbs, trees, shrubs, and vines also produce brightly colored flowers which many residents enjoy more than their edible or utilitarian properties. One interviewee grew a variety of flowering plants for the community church and was known for regularly providing flowers for special occasions. This is important to note because home gardens or plots are not exclusively comprised of common plants or herbs for consumption or medicinal uses, they may serve ornamental requirements. Many plants like hibiscus, orchids, cacti, and succulents often decorated courtyard and garden areas in San Felipe.

Figure 7.1 Examples of House Garden Plants. A. Flor de izote (Yucca guatemalensis) B. Pito (Erythrina standleyana) C. Ziricote (Cordia dodecandra) D. Oregano grueso (Plectranthus amboinicus).

Milpa Practices and Customs

For some San Felipe residents, a *milpa* can often be far from home (approximately six to seven miles). This distance limits tending and maintenance to once per week due to the availability of transportation into the *monte.* Others work full-time on their milpas and visit their plots six days a week. Field cultivation is a disappearing practice due to modernization and inadequate yields or income produced per household (Ewell and Merrill-Sands 1987; Greenberg 2003). *Milperos* grow a variety of cultigens mirroring garden plots including maize (*Zea mays*), beans (Phaseolus), squash (Cucurbitaceae) varieties, avocado (*Persea americana*), chili (*Capsicum* spp.), etc. The variety and quantity of cultigens is dependent upon on how much time someone can devote to their *milpa*. Additionally, tending fields also provides an opportunity to forage any wild plants or herbs that may be growing in disturbed areas for home gardens.

Irrigation is also variable between house plots and *milpas*. Many San Felipe residents rely on the town well for water to irrigate gardens, which they must be able to transport. Others rely solely on the rainy season, which can be problematic during drier years or if the rainy season is delayed. Interviewees identified two seasons for planting in *milpas*, beginning sometime in May to June and in November due to wetter conditions. This practice ensures crops like sorghum, rice, beans, banana, sugar cane, and maize survive without external irrigation technologies. In the past, the official planting day was March 19, or San Jose, but it is now considered too early based on weather conditions of the last few years.

These *milpa* fields also undergo fertilizing, and compost treatment throughout planting cycles to maintain soil nutrients. Fallen trees are often used for mulching. Either synthetic fertilizers or chicken droppings may be used to aid fields. There are also a variety of rituals and *primisias* or *ofrendas* (offerings) surrounding milpa fields including a drink called *cocolmeca*. *Atole*, a maize based drink sweetened with honey, can also be placed on the corners of the milpa before burning as an *ofrenda de gracias*. Whistling while burning milpas is said to bring and guide fire when it is time. Another practice to help *milpas* grow includes having children make frog calls to bring the rain at the beginning of the planting season. Other ceremonies of the Yucatan include ceremonial drinks, prayers, and calls mimicing a rainstorm (Redfield 1962:138).

There is also plenty of mythology surrounding *duende* sightings. It seems like everyone has a different perception of what a duende is or does, but a *duende* is generally a small gnome-like creature who plays tricks and occasionally does bad things to people who see it. People I interviewed believe they can be spotted at 6 am and 6pm near fig trees and often in *milpa* fields. Other bad omens include a yellow overcast on a milpa called *cancubul*. This is interpreted as a sign of diseased plants and must be corrected by putting a wood cross covered in ash nearby.

One custom shared among many of the people I talked to was cooking with a *pib*, earthen oven, on special occasions often relating to milpa cycles. Preparing a *pib* begins with digging a shallow pit and filling it with firewood and stones. A fire is lit and food packages containing chicken, turkey, tamales, etc. are placed inside once the fire is reduced to embers. The pit is sealed with papaya or banana leaves and earth to cook the food. This process can take a few hours up to two days. Other accounts of *pib* practices are well documented and vary from region to region (Hanks 1990; Redfield 1962; Simms 2014; Wandsnider 1997).

Wild and Domestic Animal Resources

Even with a market-based economy, supplementing diet with hunting or fishing has continued to some degree in San Felipe and surrounding areas. Fishing and hunting require licensing and is limited in many areas of Belize due to protected conservation areas and private land. In recent years, there have been disputes over land parcels between squatters and people who have been granted land by the government, complicating boundaries for hunting, *milpas*, and even some residential areas. In many respects, hunting has declined over time due to legal circumstances, not because of interest or tradition. Either way, it is an important component of diet surrounding gardening and *milpa* practices.

Many of the households I visited maintained animals like turkeys, chickens, and ducks in home gardens for protein and fertilization sources in addition to caring for a wide range of useful plants. This is a common practice in the Yucatan where house gardens often have an array of plant taxa and small livestock which may or may not be confined (Greenberg 2003; Wauchope 1938). Keeping domesticated birds to sell eggs provides a reliable source of income for some people in San Felipe. In some cases, chickens, ducks, and turkeys themselves were also a source of income since they are mature enough to sell within three to five months.

Virtually every household had outdoor pets like cats and dogs. Dogs were mostly kept for security purposes, but some dogs were hunting companions. White-tailed deer (*Odocoileus virginianus*), *coholito* (*Penelope purpurascens*), *chachalaca* (*Ortalis vetula*), *paca* (*Cuniculus paca*), armadillo (*Dasypus novemcinctus*), and *pavo de monte* (*Meleagris ocellata*) are all common animals that were hunted. Hunting deer, wild boar, and *paca* has also been documented in other Maya villages in the Yucatan (Redfield and Villa Rojas 1962:38) There were some animals that were not common among households. One household regularly consumed turtle and kept especially large carapaces for decoration. The same household also kept guinea pigs (*Cavia porcellus*), but it was unclear if they were pets or raised for consumption since they are known to be consumed in other parts of Latin America. Lastly, a few people mentioned they had once kept honey bees. The recent occurrence of Africanized bees has made it difficult to keep bees because of their aggressive nature. Bees provide honey and beeswax and they are considered to be protected by certain Maya deities (Redfield and Villa Rojas 1962:50).

Similar trends appear in archaeological faunal assemblages where animals associated with human disturbed landscapes include deer, peccary, armadillo, rabbit, and fox. For instance, Shaw (1999) identified a predominance of whitetail deer, dog, turtle, peccary, bird, and large rodent among Preclassic faunal assemblages at Colha, similar to many households in San Felipe. Wetland resources are also apparent in faunal assemblages such as snail, mollusk, and turtle (Freiwald 2010). These types of wetland resources were less apparent during our interviews, people mostly mentioned fishing as a rare occurrence.

DISCUSSION

Many common cultigens found in the archeological record are present in modern day gardens and *milpas* including maize, beans, squash, cotton, avocado, chili, cacao, etc. (Ford and Nigh 2015; Feinman et al. 2007; Lentz and Hockaday 2009; Ogata 2003; Zizumbo-Villarreal et al. 2012). Goldstein and Hageman (2010) argue that many times maize, beans, and squash are over emphasized in the archaeological record to the point they potentially distract from other important facets of Maya foodways. Furthermore, few archaeobotanical data sets from projects contain maize, beans, and squash in significant quantities. Archaeobotanical work by Goldstein and Hageman (2010) provides evidence for a heavy dependence on successional forest taxa associated with fallowing agricultural practices. Archaeobotanical data recovered from Chispas and Guijarral suggest food resources came from fallow fields, weeds, and from *bajo* resources (Goldstein and Hageman 2010). Ethnographic accounts support a variety of cultigens from home gardens and *milpas*, as well as hunting and gathering, in addition to market-based goods as part of complex food systems.

The temporal and cultural distance between contemporary Indigenous people and the archaeological record is undeniable; however, specific skills and traditional knowledge have the capacity to survive millennia. Ethnobotanical accounts have proven to be extremely accurate and useful in archaeological studies. Berlin's (2003) ethnobotanical efforts with local Tzeltal Maya recovered nearly 3,000 botanical species, reflecting a comprehensive botanical representation of the Chiapas central plateau. Links between archaeological assemblages and ethnographic accounts are present even in communities which have adapted to many modern ways like San Felipe. Atran and Ucan Ek's research on plant taxonomy among the Itzaj Maya also supports continuity of plant knowledge and use between Precolumbian ancestors and contemporary Maya communities based on folk taxonomy similarities, reoccurring species present across archaeological, ethnographic, and archival work, as well as linguistic evidence linking many taxa with the same names across various Maya dialects (1999).

Work done by Lentz et al. (1996) also presents numerous examples of economic fruit trees grown in house gardens or adjacent fields which correspond to trees observed in San Felipe household gardens including cashew, guava, hog plum, and papaya (Aebersold, Hart, and Valdez *Under Review*). Perhaps the largest difference between archaeological assemblages and modern-day homes, is faunal assemblages. This is in part due to a market-based economy and perhaps because any hunting is done outside the home, so it may not have been so apparent in our conversations. In addition to dogs, turkeys, peccary, and pacas, the most prominent meat protein is hypothesized to come from white-tailed deer based on archaeological studies of faunal assemblages (Freiwald 2010; Lentz et al. 1996; Shaw 1999). There is also epigraphic and linguistic evidence for the persistence of venison, cacao-based beverages, tamales, tortillas, and other foodstuffs in ancient and contemporary Maya diet (Hull 2010; Simms 2014; Stuart 2006; Taube 1989).

In Zizumbo-Villarreal et al.'s (2012) experimental ethnoarchaeology study surrounding a modern-day peasant community explores cultigen development through diet and cooking practices in Zaotitlan, Mexico. Wild plant taxa serve as important resources for various dishes and drinks, as well as various food preparation techniques and cooking vessels. Zizumbo-Villarreal and colleagues (2012) concluded that 68 wild plant species are consumed including wild progenitors of agaves, maize, beans, squashes, chan, chili peppers, tomatoes, ground cherries, hog plums, and avocadoes. Zaotitlan residents also prepare several dishes and drinks with what is considered ancient techniques and non-ceramic equipment including three-stone fireplaces, stone toasters, sets of fixed or mobile stone crushers and grinders, rock pits, fermenters, and earth ovens. This highlights the importance of gathering and traditional cooking styles despite modernity.

Ethnobotanical interviews conducted with residents of San Felipe provided modern examples of horticultural and agricultural practices in the region. Interestingly, many overlaps in practice and knowledge continue to occur despite long-distance immigration and time. By considering Indigenous knowledge as a dynamic process involving skills we can observe contemporary gardening practices as analogues to contribute to the archaeological understanding of the past (Altran and Ucan Ek’ 1999; Lohse and Valdez 2004). Residents of San Felipe practice regular maintenance and care of household gardens, adjacent land plots, and *milpas* outside of their homes. This study shows us that people continue to influence the environment and forest growth through management of valuable plants in the region. There is still much to learn about ancient Maya food systems. Attempting to salvage and record current food systems merits support in a time when industrialization is affecting traditional customs and knowledge systems.

Chapter 8: Dentition Debris: A Healthy Spread of Botanical Data and More

Most people have, or have had, dental calculus accumulation at one point or another. Salivary glands and the pancreas produce amylase which help break down food during digestion. Dental calculus forms when dental plaque accrues as a biofilm of bacteria and food remains becomes mineralized in the mouth. When dental plaque begins to accrue, it traps microremains and protects them from saliva chemical breakdown (Radini et al. 2017). It provides a sturdy mineral composite to reserve a range of microremains including starch granules, phytoliths, fibers, or other mineral debris (Cummings and Magennis 1997; Hardy et al. 2009; Mickleburgh and Pagán-Jiménez 2012). Calculus formation is variable between individuals and is determined by dental hygiene, genetics, diet, saliva, and local pH (Hardy et al. 2009).

Dental calculus accrues in gingival crevices above the gum-line (supragingival) or below the gum-line (subgingival) and continues to accumulate for an extended period if not removed (Hardy et al. 2009). Gingival crevices are well protected against salivary amylase and produce metabolic by-products high in pH. This enables the precipitation of calcium phosphate which becomes mineralized dental calculus. The spatial restrictions on calculus formation make *in situ* preservation of various oral debris an excellent avenue to study health and paleoethnobotanical histories of individuals (Blatt et al. 2011). Calculus is so sturdy that it has been observed in dentition dating back between 12 and 8 million years on a Miocene *Sivapithecus* and Pliocene hominid dentition (Blumenschine et al. 2003; Hershkovitz et al. 1997).

Assuming most microfossils embedded within calculus solely originate from food sources is a narrow perspective that does not account for a wide assortment of human behaviors. Radini et al.’s (2017) research on the multiple pathways oral debris enters dental calculus outlines multiple explanations for a variety of microfossils including phytoliths, starch granules, pollen grains, microcharcoal, fibers, and minerals. Pathways include gastrophagy, secondary pathways, inhalation, and the use of teeth as tools in addition to traditional means like food preparation and poor dental hygiene.

Gastrophagy refers to the practice of consuming the stomach contents of another animal. This practice has been ethnographically documented among hunter-gatherers who make use of every part of an animal (Sinclair 1953; Radini et al. 2017). Animals with herbivorous diets contain partially digested grasses and other plant materials that can account for microfossil debris in human calculus. Debris such as soil and dust are also consumed unintentionally. Underground storage organs are covered in soil and inevitably contain soil in hard to clean crevices that are eventually consumed. Inhalation of smoke and soot can also account for organic debris and microcharcoal within dental calculus. Inhalation of debris, not just fire byproducts, occurs throughout ceramic and stone production, long-term food storage, and during food processing. Se et al. (2010) argue that it is possible to inhale debris particulates up to 70 μm including microcharcoal, pollen, dust, fungal spores, insect parts, plant fibers, and other microscopic particulates (Blatt et al. 2011; Hardy et al. 2016; Radini et al. 2017). Accelerated tooth wear is a symptom of consuming food that has been processed using grinding techniques because people consume microscopic minerals and grit that may be preserved (Torrence and Barton 2016; Pearsall 2015; Piperno 2006a).

Crafting and the production of goods not only produces particulates which can be inhaled, but often the mouth is used to prepare raw materials or as a "third hand." Hardy (2008) has documented how people use teeth in activities such as softening and shredding material, leaf chewing, grooming, and to hold materials. Other common examples of deliberate activities include various personal hygienic practices. Whether it is chewing on sticks or plants to clean teeth or the application of plants for medicinal purposes, plant microfossils have several pathways into the mouth that may end up in dental calculus (Radini et al. 2017).

SAMPLING AND METHODS

Excavations in the main plaza at Colha included several individuals below a series of floors dating from the Middle to Late Preclassic Period (Burns et al. 2017). At least 13 individuals were exhumed including five adults and one late adolescent. Four individuals were male and other individuals were of indeterminate sex. Burials were elaborately interred with a series of stacked vessels including inverted plates, stones, and spouted jars indicative of the Middle Preclassic. Faunal remains interred with the burials included mammalian, reptilian, and piscine (Riegert and Gill 2017). There were also secondary interred remains, likely dating to the Late Preclassic, sealed by a series of floors. These burials presented an opportunity to study microfossil remains integral to a paleoenvironmental perspective for this dissertation.

Dental calculus samples were extracted in the field laboratory at Programme for Belize Archaeological Project by students and staff. Forty-two teeth were photographed and were cleaned using a sterilized dental pick after human remains were examined by D. A. Riegert and others. Before handling teeth, people were assisted in sterilizing hands with alcohol wipes before putting on new latex gloves to reduce contamination when handling remains. Teeth were designated sample identification numbers based on provenience and by maxillary or mandibular position. As each tooth was sampled, it was noted if calculus was scraped from either subgingival or supragingival surfaces (Figure 8.1). Calculus was scraped onto a new, clean sheet of paper and debris was funneled into a 2 mm vial each time. Samples were then transported to the Environmental Archaeology Laboratory at the University of Texas at Austin.

Figure 8.1. Dentition recovered from the Main Plaza at Colha. Notice examples of dental calculus buildup in green circles.

Samples were handled and processed underneath a fumehood to reduce contamination from airborne particulates. First, one milliliter of 10% dilute HCl was added to sample vials to disaggregate calcium carbonates. This helped digest dentition fragments, calculus, or any other carbonate debris in samples. Vials were then centrifuged for five minutes at 10,000 rpm and effluent was poured off. Samples were washed with RO water, vortexed, and centrifuged a total of three times before samples were set to dry at 40°C in a drying oven until all water was evaporated from the vials. Samples were mounted onto slides with Entellan and sealed with nail polish. Slides were analyzed at 400X power with a simple darkfield condenser to demonstrate birefringent properties and were photographed and measured with an OMAX 5.2 Megapixel camera and Toupview 3.7 software.

Due to the size of samples, each slide was scanned in its entirety. Samples included a range of microfossils including starches, phytoliths, fibers, and other types of debris. Results include all findings for a broader spectrum analysis. Starch granules are described based on several qualities following guidelines from Pearsall (2015), Piperno (2006c), and Torrence and Barton (2006). A counting sheet for each starch granule was required to annotate characteristics and sketch drawings. Characteristics for starch granule analysis included:

1. Extension Cross (strong, weak, straight arms, bent arms, right angle, etc.)
2. Size (measurement in μm including the widest and narrowest diameter)
3. Shape (spherical, ovoid, reniform, hemispherical, polygonal, etc.)
4. Facets (number, angularity, rounded, sharp, etc.)
5. Lamellae (not visible, fine, coarse, etc.)
6. Hilum (absent, open, closed, centric, slightly eccentric, etc.)
7. Fissures (absent, linear, stellate, Y, etc.)
8. Outer wall (single, double, smooth, irregular, etc.)
9. Surface features (smooth, granulary, bumpy, radial lines, etc.)
10. Single granule versus compound granule

My own comparative reference collection was used to aid in phytolith analysis as well as access to Dr. Dolores Piperno’s reference collection at the Smithsonian Tropical Research Institute in Panama. I did not build a reference collection for starches; however, there are many publications with images vital to analysis (Berman and Pearsall 2008; Henry et al. 2009; Musaubach et al. 2013; Pagán-Jiménez 2015, Pagán-Jiménez et al.

2015; Pagán-Jiménez et al. 2016; Pearsall et al. 2004; Perry et al. 2007; Piperno 2006c, Piperno and Dillehay 2008, Piperno and Holst 1998, Torrence and Barton 2006, and Zarrillo et al. 2008). Some starch granules and phytoliths also require rotation to identify with absolute certainty; however, the use of a permanent mounting medium did not allow for this additional step. The results are considered extremely conservative interpretations of botanical remains, even though many characteristic identifiers for phytolith and starch grains were successfully recognized.

CONSIDERATIONS AND COMPLICATIONS WITHIN STARCH ANALYSIS

Plant consumption does not guarantee the preservation of starches in dental calculus, moreover, specific patterns of consumption are difficult to predict. Dental calculus accretion varies from individual to individual and at different points in their lifetime. Additionally, different taxa produce starch at variable rates and many do not produce diagnostic starches (Blatt et al. 2011; Hardy et al. 2009; Mickleburgh and Pagán-Jiménez 2012). These challenges limit the scope of interpretation for this study when comparing evidence of botanical remains in dental calculus to previous botanical studies at Colha. My interpretation focuses on what is visible in dentition and how it compares to previous botanical studies in the area which demonstrate a modified wetland environment and ethnographic studies with subsistence and food processing data in Mesoamerica.

A common challenge in attempting to identify starch granules in this study was clearly defining diagnostic physical characteristics due to damaged starches. Studies have shown that production processes including boiling, baking, parching, popping, and fermenting can damage and modify starches and their diagnostic characteristics (Henry et al. 2009; Pagán-Jiménez 2007; Pagán-Jiménez et al. 2015; Piperno and Dillehay 2008). Boiling experiments have shown to cause swelling and distortion in starch morphology and varies from plant to plant (Henry et al. 2009:917). Grasses exhibited the loss of an extinction cross, lamellae, and a faint shadow or fold in grains once boiled. Some grasses are also vulnerable to gelatinization or exhibit more pronounced lamellae once boiled. Legumes (Fabaceae) were found to be more susceptible to boiling damage than grasses. Damage occurs within five minutes of boiling and less than one minute of grinding in legumes. Granules exhibit swelling, collapse in the center, and become extremely lumpy at the surface. This extensive damage makes it difficult to identify legumes and their distinctive longitudinal fissure and kidney, or reniform, shape. Baking produces similar effects on grass and legume starches (Henry 2014, Henry et al. 2009).

Parching, or roasting, is perhaps the most damaging and heterogeneous effect on starch granules. This production process causes starch surfaces to appear encrusted with small particles that may look like smaller granules or other damaged particulates (Henry et al. 2009:918). Popping also causes extreme swelling and gelatinization, sometimes growing to 50 μm. Grasses with larger starch grains can also exhibit folding and wrinkling once they undergo popping (Henry et al. 2009).

Mickleburgh and Pagán-Jiménez (2012) have also explored the effects grinding has on maize starches. Grinding kernels can reshape irregular or polygonal shaped starches into more homogeneous regular shapes. Maize starches will also become enlarged up to 20.8 to 23.2 μm above known maize ranges, especially when harder kernels undergo intensive grinding. Surface burrowing, fissuring, and striating has also been documented in maize resulting from grinding, roasting, and fermentation (Chandler-Ezell et al. 2006; Mickleburgh and Pagán-Jiménez 2012; Pearsall et al. 2004; Vinton et al. 2009). Hard kernels from Pollo and Nal-Tel maize also exhibit rougher surfaces, central darkened depressions, a brightened ring surrounding the hilum, and enlarged grains after grinding (Henry et al. 2009; Mickleburgh and Pagán-Jiménez 2012).

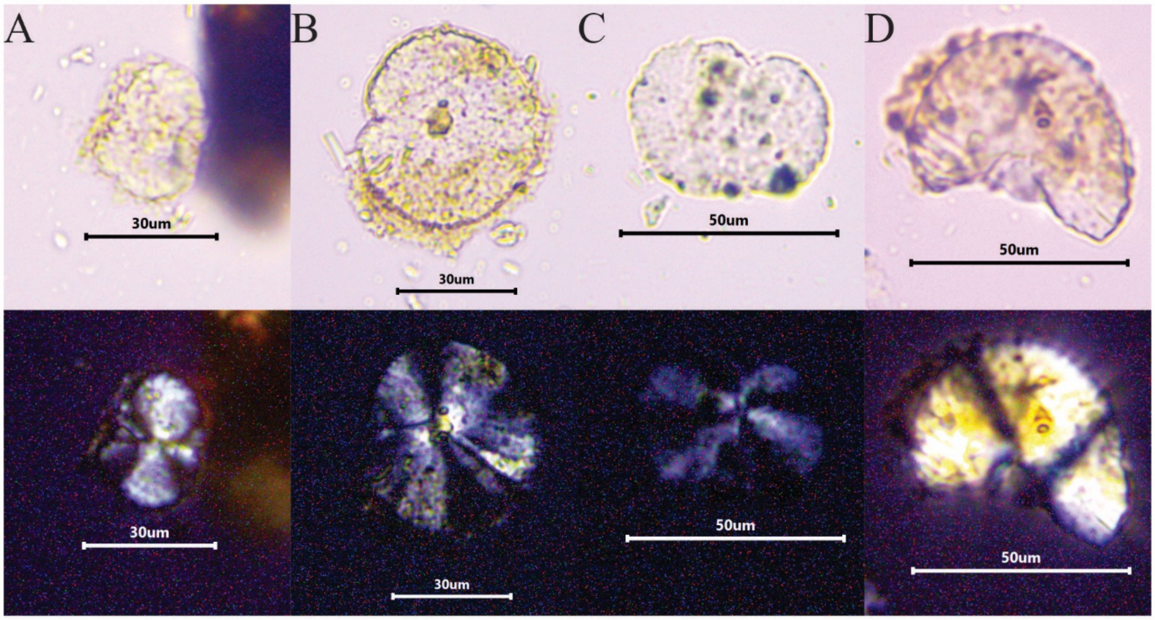
In the case of manioc, soaking will enlarge granules and increase fissuring and vacuole formation. Grinding manioc for at least five minutes will result in circular to star-shaped fissures which are enlarged and centrally located on the hilum. Pounding manioc will also disaggregate compound grains into individual ones. Unfortunately, boiling and parching manioc will gelatinize starches, therefore, finding manioc which has been processed with heat is unlikely (Chandler-Ezell et al. 2006).

STARCH RESULTS

Since many production processes like roasting, grinding, and boiling may cause starches to gelatinize, lose their birefringent properties, and alter important diagnostic surface features, I focused on starch granules that only had birefringent properties as a starting point. Ten out of 42 teeth had dental calculus containing starch granules with birefringent properties. At least 32 starch granules were identified, many with diagnostic features. Sixteen granules had clear indications of roasting, grinding, or boiling, which made it difficult to assign identifications. An additional eight granules identified are likely maize (*Zea mays*) with evidence for production processes. Other possible taxa include *Phaseolus* (bean), *Ipomoea batatas* (sweet potato), *Sagittaria* spp. (*makilito* or malanga), and yam (*Dioscorea* spp.).

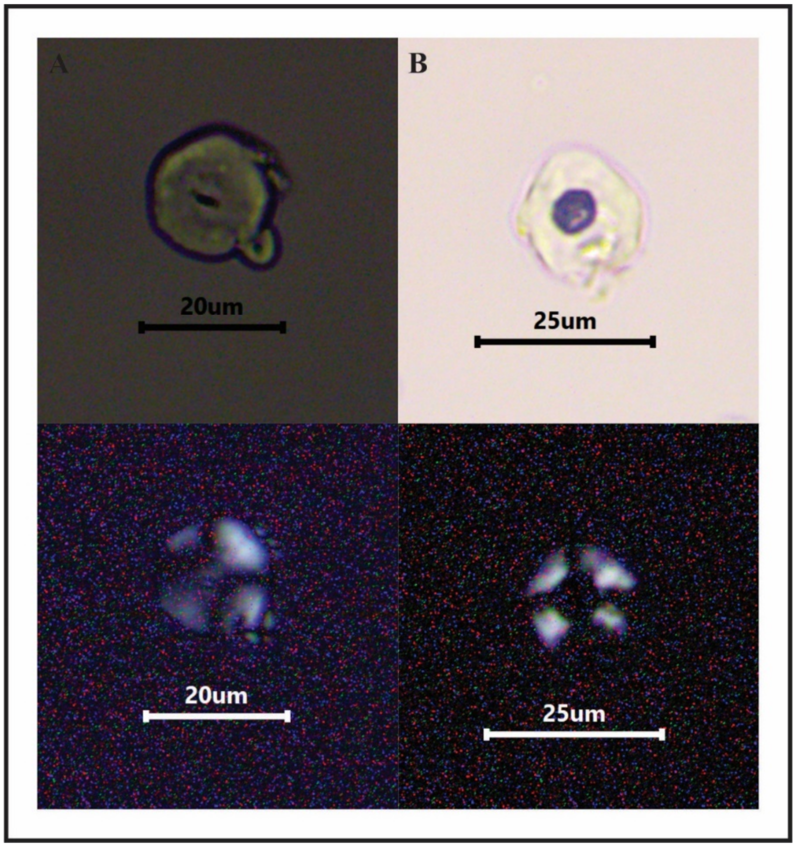
Many granules exhibited damage from roasting or parching visible on the surface. All granules in Figure 8.2 exhibit granulary surfaces with what appears to be encrustations of smaller particles from grinding described by Henry et al. (2009) and Mickleburgh and Pagán-Jiménez (2012). Vacuole formation was also visible in some grains, especially in Figure 8.2 B. This is common in tuberous starches that have been soaked, especially manioc (Chandler-Ezell et al. 2006). Severe fissuring to the point of fracturing is visible in Figure 8.2 D. This is has been documented from processing grains in various forms (Chandler-Ezell et al. 2006; Mickleburgh and Pagán-Jiménez 2012; Pearsall et al. 2004; Vinton et al. 2009). At times, granules displayed a brightened ring around the hilum which formed after grinding (Figure 8.2 A) (Henry et al. 2009; Mickleburgh and Pagán-Jiménez 2012). At this point, it is difficult to quantify how much granules may have enlarged without securely identifying additional diagnostic features. Granules ranged in size from 8.7 to 66.6 μm. This is within or close to the range of many cultigens including maize (6 – 26 μm), manioc (5-28 μm), and beans (12 – 60 μm) (Mickleburgh and Pagán-Jiménez 2012; Piperno and Holst 1998).

Figure 8.2. Damaged starches from grinding and parching.



Scholars have documented morphologies for many varieties of maize (Holst et al. 2007; Pagán-Jiménez 2015; Pearsall et al. 2004; Piperno et al. 2009). Many diagnostic features were visible including polygonal forms with pressure facets (Figure 8.3 A), hemispherical forms with pressure facets (Figure 8.3 B), centric hilums, spherical hilums, and linear fissures (Figure 8.3 A). Some granules also exhibited vacuoles (Figure 8.3 B) from roasting. Some maize races (Morochillo) have been reported to have dark circular areas around the hilum, resembling this feature (Pagán-Jiménez 2015:120).

Figure 8.3. Examples of typical maize granules found in this study.



Many granules exhibited damage from roasting or grinding; however, there are some granules which could possibly be identified as *Phaseolus* (bean), *Ipomoea batatas* (sweet potato), *Sagittaria* spp. (*makilito* or malanga), and yam (*Dioscorea* spp.). Many of these cultigens require processing which alters their diagnostic properties. One possible *Phaseolus* granule exhibited a reniform shape, coarse laminations, and a partial medial, ragged fissure. The extremely granulate surface and only partial medial fissure keep that granule from secure identification; however, its physical characteristics and size (39.3 μm) align with *Phaseolus* descriptions (Pagán-Jiménez 2015; Piperno and Holst 1998).

Ipomoea batatas granules are polygonal with a small, transverse fissure, well-defined pressure faceting, and range between 4 - 34 µm (Perry 2001; Piperno and Holst 1998). Pagán-Jiménez (2015) also suggests their extinction crosses are unique with two or three light, thin, curved arms, and a fourth broad and triangular arm. One starch granule exhibited the unique extinction cross, polygonal shape with two pressure facets, radial fissures, and an open, eccentric hilum. This granule does lack lamellae following the outline of the granule; however, the size (15.6 µm) is within acceptable range.

A granule exhibiting an oval shape with undulated margins, lineal fissures, and measuring 19.1 µm does meet most criteria for *Sagittaria* spp. described by Mickleburgh and Jimenez-Pagan (2012). The granule is slightly turned on one side, making it difficult to see if it has wavy lamellae following its margins, but the size is appropriate for *Sagittaria* spp. (11-79 µm). Another granule identified is likely *Dioscorea* spp. It has an elliptical to triangular shape, visible lamellae, distinct hilum, and a cuneiform-shaped depression extending from the hilum to the distal end of the grain. The grain is on the smaller side for *Dioscorea* at 25.5 µm (24-84 µm), but within range. There is also just enough debris covering the distal end to see if it is rounded or straight as described by Holst and Piperno (1998).

PHYTOLITH RESULTS

Phytolith production is controlled by genetic and environmental factors and can produce distinctive forms at various taxonomic levels including genus and species (Piperno 2006a). Monocots like grasses, sedges, and palms produce some of the highest phytolith counts and can often be classified by plant family. Herbaceous dicots and woody taxa also produce phytoliths, but with much lower frequency. Scholars have assembled classification systems based on phytolith morphotypes and have noted overlap among subfamilies. For instance, Bambusoidae, Pooideae, and Panicoideae contain rondel phytoliths that are indistinguishable from each other (Piperno 2006a).

Scholars often rely on the overall composition of assemblages to recognize patterns and distributions (Bozarth 2004; Piperno and Pearsall 1998b; Twiss et al. 1969, see Pearsall 2015 or Piperno 2006a for more). This process requires at least 200 – 250 phytoliths per sample to evaluate an assemblage (Piperno 2006a). Calculus samples provide very small phytolith assemblages compared to sediment samples, therefore, it is not possible to rely on the overall composition of phytolith assemblages. The phytolith analysis for this study will focus on diagnostic forms from economic species and will discuss other forms in more general categories.

Each of the 42 teeth sampled at Colha for dental calculus contained at least one phytolith and many contained multiple forms. Most notably, diagnostic phytoliths for *Cucurbita* spp. (squash, pumpkins, and gourds), *Zea mays* (maize), *Calathea* (llerén), and *Arecaceae* (palms) were observed. *Cucurbita* spp. phytoliths have shallow to deeply scalloped surfaces of contiguous cavities (Bozarth 1986, 1987; Piperno et al. 2002). Figure 8.4 A shows a scalloped form as viewed from the top. The small size is characteristic of wild species, but a more secure identification is not possible without a view of the length or its other characteristics. Samples also had a variety of rondel types. Figure 8.4 B shows a wavy or ruffle top rondel characteristic of maize (Bozarth 1993;

Piperno and Pearsall 1998b). Another economic diagnostic phytolith type in dentition included a form for *Calathea*. These phytoliths are considered irregular rhizome cylinders with small cylindrical bodies and a characteristic narrowed tip or head (Chandler-Ezell et al. 2006).

The most common diagnostic phytolith type in the calculus samples was a globular echinate form 8.4 D. These phytoliths are also called spherical spinulose and are produced by *Arecaceae* (palms) (Dickau et al. 2013; Perry 2001). Some samples also contained opaque platelet phytoliths diagnostic of *Asteraceae*, or the sunflower family. These phytoliths are generally representative of weedy taxa. There were also a wide range of grass types. Table 8.1 illustrates some varieties encountered in dental calculus samples. Several morphotypes include Bambusoideae, Chloridoideae, Panicoideae, and Pooideae grasses. Again, there is overlap in forms among grasses, and without higher counts of phytoliths it is difficult to reconstruct specific environments. Phytoliths from non-diagnostic grasses or weedy taxa comprise a sizeable portion of assemblages in teeth as well.

Figure 8.4. A) A scalloped *Cucurbita* phytolith, B) a wavy top rondel indicative of *Zea Mays*, C) an irregular rhizome cylinder indicative of *Calathea*, D) a globular echinate typical of *Arecaceae*.

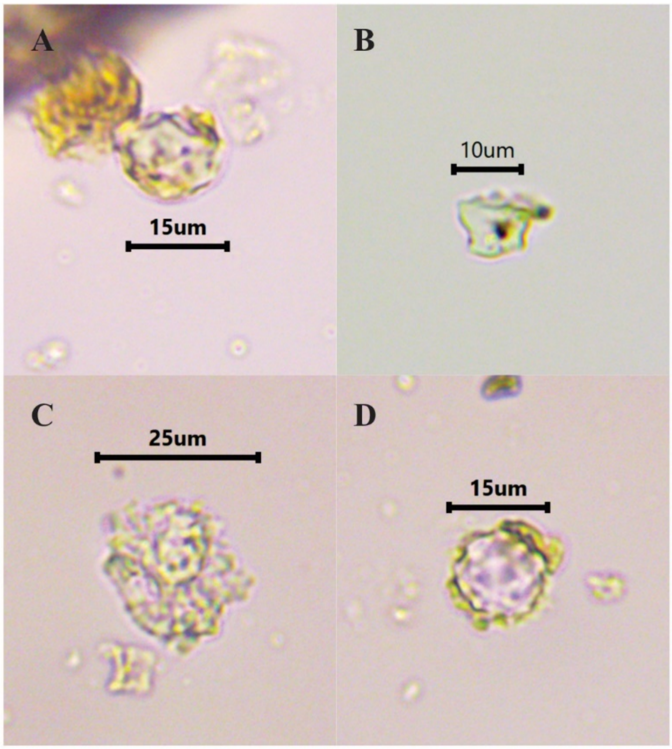


Table 8.1. Basic grass morphologies encountered in this study.

Morphologies	General Poaceae Class	Reference
Long Saddle	Bambusoidae	Lu et al. 2006; Piperno and Pearsall 1998b
Saddle	Chloridoideae	Lu et al. 2006; Piperno and Pearsall 1998b
Bilobate	Panicoideae	Finné et al. 2010; Piperno and Pearsall 1998b
Cross	Panicoideae	Bozarth 2004; Twiss et al. 1969
Rondel	Pooideae	Finné et al. 2010; Piperno and Pearsall 1998b; Twiss et al. 1969
Square to Rectangular	Pooideae	Piperno and Pearsall 1998b
Crenate	Pooideae	Guo et al. 2012
Trichome	None	Finné et al. 2010
Elongate (psilate, sinuate, etc.)	None	Dickau et al. 2013; Finné et al. 2010; Twiss et al. 1969
Cuneiform Bulliform	None, but prefer wet habitats	Lu and Liu 2003; Lu et al. 2006 (fan shapes); Sangster and Parry 1969

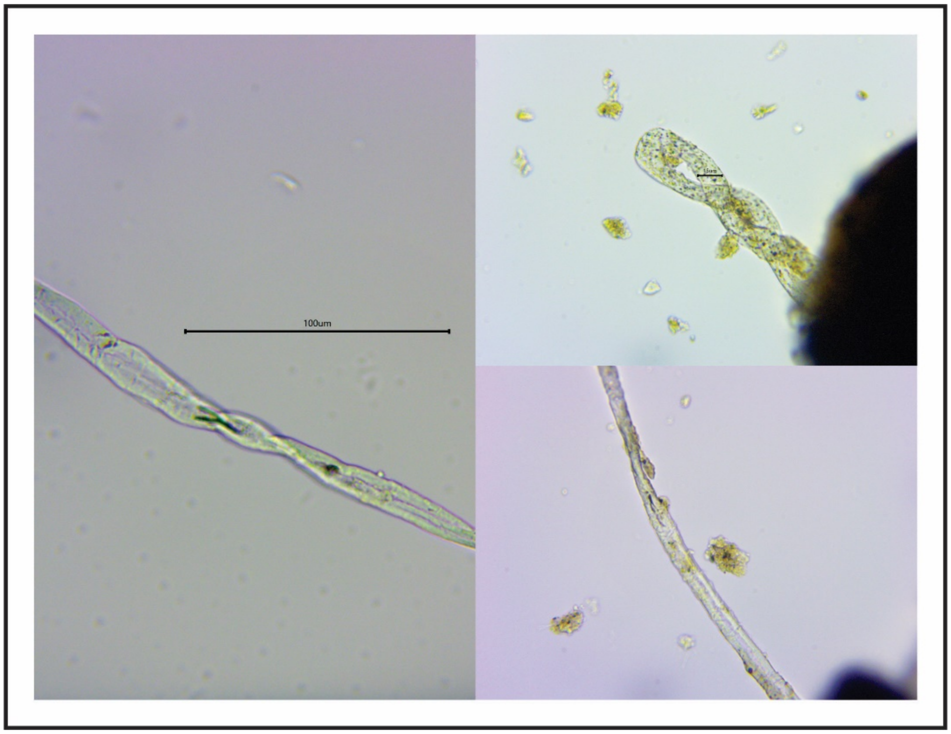
OTHER DEBRIS

Aside from botanical remains, debris including fibers, charcoal, and various minerals were also embedded in dentition. Cotton (*Gossypium hirsutum*) is a known Mesoamerican cultigen domesticated as early as 300 BC (Blatt et al. 2011; Bozarth 2004). Cotton fibers are elongated, flattened, and ribbon-like. They have raised edges and are often rolled in a helix, resembling a strand of DNA (Blatt et al. 2011). Three out of forty-two teeth contained cotton fibers (Figure 8.5). I did consider possible contamination of airborne fibers. I discounted this possibility because fibers were attached to clay and mineral particulates and had similar surficial impurities as phytoliths or starches.

Impurities could either be tiny undigested calculus particulates, clay particulates, or other partial particulates.

There were additional fibers which remain unidentified, but this is expected since they may be products of debris embedded while working with fibrous plants for basketry or other utilitarian purposes. Microcharcoal or burned particulates below 10 μm were also present in small numbers. This is also usual since starches presented evidence of parched or toasted foods. Most commonly, there are minerals within each sample that were not completely dissolved in the extraction process. This may be due to debris embedded in dental calculus over time from eating foods prepared with grinding stones or from fine sediment grains that were sampled while removing dental calculus.

Figure 8.5. Examples of *Gossypium hirsutum* fibers. Notice the elongated, flattened, ribbon-like structure with raised edges.



DISCUSSION

Dental calculus samples provided a wealth of information including food consumption, indicators for food processing, and even evidence for the use of economic fibrous materials. Strong evidence for major cultigens including maize (*Zea mays*), beans (*Phaseolus*), squash (*Cucurbita*), and cotton (*Gossypium hirsutum*) support staple Mesoamerican crop use at Colha. The importance of a diet consisting of root crops is also highlighted with evidence from sweet potato (*Ipomoea batatas*), *makilito* (*Sagittaria* spp), llerén (*Calathea*), and yam (*Dioscorea*). Palms, grasses, and other herbaceous taxa (*Asteraceae*) also provide insight to the importance of weedy taxa in anthropogenic landscapes.

Despite an increasing amount of paleobotanical studies across the Maya Lowlands, this study is one of two on dental calculus microfossils in the Lowlands. Scott Cummings and Magennis (1997) conducted phytolith and starch grain analysis on dental calculus from burials at the north central site of Kichpanha with similar results. Findings include numerous phytoliths from palms and non-maize grasses, possibly from common Festucoid grasses used for weaving. A variety of unidentified fibers were also encountered in the calculus, which may represent food or plants used for utilitarian purposes. Identified starch granules in the dental calculus at Kichpanha are predominantly from maize (*Zea mays*) and manioc (*Manihot esculenta*). Lastly, lithic debris was also prevalent in dental calculus samples likely due to food processing from tools or grinding stones which end up in the mouth (Scott Cummings and Magennis 1997).

Paleobotanical data recovered from sites across Belize support many findings of Middle Preclassic to Late Preclassic plant remains at Colha. In the upper Belize River Valley at Cahal Pech, studies done by Powis et al. (1999) have recovered plant remains using flotation. Charred remains and plant fragments were recovered and identified from maize (*Zea mays*), squash (*Cucurbita sp.*), wild fig (*Ficus sp.*), guava (*cf. Psidium guajava*), pine (*Pinus sp.*), glassy wood (*Astronium graveolens*), malady (*Aspidosperma sp.*), and aguacatillo (*Nectandra sp.*). Wiesen and Lentz (1997) also identified economic species at Cahal Pech including the common bean (*Phaseolus sp.*), ramón (*Brosimum alicastrum*), coyol palm (*Acrocomia aculeata*), and cotton (*Gossypium sp.*).

Hammond and Miksicek (1981) also recovered botanical remains at Cuello in northern Belize from floatation. Three varieties of maize (*Zea mays*), pine (*Pinus caribaea*), avocado (*Persea Americana*), razor grass (*Scleria bracteate*), and nance (*Byrsonima spp.*) were recovered from Early Preclassic contexts. Other notable finds from Preclassic contexts at Cuello include *jicama* (*Pachyrrhizus erosus*), sweet potato (*Ipomoea batatas*), manioc (*Manihot esculenta*), and a variety of *Xanthosoma* (elephant ears) (Hather and Hammond 1994).

There is still a gap in botanical analysis at Colha, especially for earlier occupations. Operations 2001 and 2010, both Early Postclassic, have been tested for macrobotanical remains via flotation. Initial work at Operation 2001 done by Miksicek (1979) identified maize (*Zea mays*) kernels and fragments, common bean (*Phaseolus vulgaris*), cotton (*Gossypium hirsutum*), achiote (*Bixa orellana*), jauacte palm (*Bactris major*), bitter gourd (*Momordia sp.*), epiphytic cactus (*Selenecereus sp.*), and pine wood (*Pinus sp.*) charcoal. Caldwell (1980) was able to identify macrobotanical evidence for supa (*Acrocomia Mexicana*), chicle tree (*Achras zapota*), maize (*Zea mays*), Poaceae grass, papaya (*Carica papaya*), achiote (*Bixa orellana*), custard apple (*Annona reticulata*), and bullet tree (*Bucida buceras*). A partial mamey apple seed (*Calocarpum mammmosum*) was recovered from a Middle Preclassic feature in Operation 2012.

Cotton is also multifunctional beyond textile manufacturing. Oil extracted from seeds is used to fry beans. The bark also has medicinal properties and is boiled to treat diarrhea, urinary problems, chest pain, waist pain, and rib pain. Cotton is also used in burials to wrap infants or wrap an adult’s head when they have died (Alcorn 1984:658-

659). This multi-purpose cultigen also confirms its presence in dental calculus. Although modern Maya use backstrap looms to weave, cotton preparation for weaving, grinding, and other medicinal purposes may require the use of teeth to separate seeds and fibers.

Dental calculus at Colha presents important data surrounding the reliance of root crops including sweet potato (*Ipomoea batatas*), *makilito* (*Sagittaria* spp), llerén (*Calathea*), and yam (*Dioscorea*). Cerén provides excellent preservation for extensive manioc agriculture and house gardening practices which also included other root crops (Lentz and Ramírez Sosa 2002; Sheets et al. 2012a,b). Root crops were also common staples in milpas and house gardens with the San Felipe community and in other Yucatecan communities (Culleton 2012; Redfield and Villa Rojas 1962). Hather and Hammond (1994) also recovered evidence for root crops at Cuello including manioc, sweet potato, *Xanthosoma* spp., and *Pachyrrhizus erosus* (*jicama*). Root crop agriculture at Colha also has a long history. Maize and manioc pollen first appear at Cobweb Swamp by 3,400 BP and wetland agriculture in northwest Belize is suspected to begin as early as the Middle Preclassic (John Jacob 1995; Mary Pohl et al. 1996).

The ubiquity of palm phytoliths also provides useful data archaeologically. Palms have diverse uses in addition to substantial nutritional value. Palm fruits are dense in calories from oil content and provide a good source of protein, carbohydrates, and vitamins. Three palms have been commonly observed in archaeological contexts: *Orbignya cohune* (also called *Attalea cohune*), *Acrocomia Mexicana, and Bactris major* (McKillop 1996). *Orbignya cohune* is known to provide fuel for cooking and is burned for smoke as insect repellent or to “smoke” bees. It also survives slash and burn clearing in addition to having edible palm hearts and fruits. The palm’s fruit stems can also made into a typical Belizean flybrush by repeatedly beating a trimmed stem at one end to disengage the fibers (McSweeney 1995). *Orbignya cohune* is also a source of charcoal, oil, house thatching material, animal fodder, and its fruits can even be used to attract wild game like peccaries (McKillop 1996; McSweeney 1995). Seed oil can also be extracted to make soap (MacVean 2003). This palm dominates the upland forest at Colha (Jacob 1995).

Huastec Maya also consume *Acrocomia mexicana* for its fruits as snacks; however, it is considered taboo for pregnant women to eat fruits because it causes babies to be born bald. It is also reported to have a medicinal use for curing a cough (Alcorn 1984:534). In Honduras, *Acrocomia mexicana* sap is collected and fermented to produce wine (Balick 1990). This palm’s oil can be extracted from seeds for cooking or from the pulp to be used as biodiesel. Crafting rings from the fruit endocarp or using spines as needles has also been documented. *Acrocomia mexicana* also serves many medicinal purposes. The fruit is used to treat colic and cough, seeds to treat intestinal parasites, and roots to treat diabetes. Lastly, its fruits can be used as animal fodder (Ramírez Hernández et al. 2013).

Bactris major also has edible fruits. The fruit can also be fermented to make wine. *Bactris major* roots can also be boiled to treat uterine problems. Its wood is used to fortify homes, craft bows and musical instruments (Balick and Arvigo 2015; McKillop 1996). In Belize, this palm can provide material for cooking tongs or *kis-kis*. A stem is split, rubbed with oil, and bent until the pith is removed. Once the stem releases the pith, it can be fired to make tongs for cooking, catch crabs, or handle coals (Balick and Arvigo 2015).

Many herbaceous taxa produce non-diagnostic phytolith forms, making it difficult to specify certain useful species recovered in archaeological records. Fortunately, it is well documented gathering wild taxa and taking advantage of agricultural weeds is an important part of ancient subsistence and modern medicinal purposes (Atran and Ek' 1999; Berlin 2003; Bourbonnais-Spear et al. 2006; De Los Angeles La Torre-Cuadros and Islebe 2003; Zarger and Stepp 2004). Many times these plants provide medicinal or hygienic purposes (Balick and Arvigo 2015; MacVean2003), which may account for their presence in the mouth. Zizumbo-Villareal et al. (2012) have documented at least 68 wild plant species consumed which include wild progenitors of agaves, maize, beans, squashes, chan, chili peppers, tomatoes, ground cherries, hog plums, and avocadoes. Moreover, even pollen records can only identify *Amaranthus* to genus. This includes a major portion of agricultural weeds in the archaeological record (Turner and Miksicek 1984).

Although many starch grains remain unidentified, their damage from cooking and preparation is useful and supported by ethnographic evidence. Boiling, toasting, and the use of a *pib* (earth oven) have been widely documented (Hanks 1990; Redfield and Villa Rojas 1962; Salazar et al. 2012; Wandsnider 1996; Zizumbo-Villareal et al. 2012). At Chan Kom, like so many Maya households, *nixtamal* is prepared as the basis for many dishes and drinks. Dried maize is boiled with lime to soften for a few minutes, then it soaks overnight before it is rinsed. The softened grains are then ground using a *metate*.

The resulting masa is used to prepare typical dishes like *tortillas*, *tamales*, and *pozole*, and drinks like *atole*.

Pinole is also a maize-based drink, but it does not require *nixtamal*. Instead, maize is toasted on a griddle, spiced, and then ground to form the basis of a beverage that is boiled (Redfield and Villa Rojas 1962:38-40). Beans are typically prepared by boiling them along with *epazote* (herb). Another cooking technique is the *pib* or earth oven. A pib is an important Mesoamerican cooking technique for daily, festive, and often ceremonial cooking (Salazar et al. 2012; Wandsnider 1997). Similar dishes requiring toasting, boiling, or baking in a *pib* are reported in Jalisco, Mexico (Zizumbo-Villareal et al. 2012). *Pinole* can also be made with toasted and ground bean seeds. Another dish, *panile*, is made by washing, toasting, and grinding squash seeds.

Tuberous foods supply a major source of carbohydrates, but sometimes require processing before they can be consumed. Manioc comes in a sweet and bitter variety. The sweet variety can be prepared by baking, frying or boiling. Bitter varieties require more processing since they contain high concentrations of cyanogenic glycosides and can be poisonous if consumed. Various techniques and tools such as grinding boards, sieves, presses, and griddles have been documented to process manioc (Devio 2016; Ugent and Pozorski 1986). Cooking tools and techniques in Mesoamerica have also included earthen ovens, three-stone fireplaces, stone toasters, fixed and mobile crushers and grinders, and rock pits (Zizumbo-Villareal et al. 2012).

The dentition from burials at Colha provided various lines of evidence for cultigen consumption, food preparation, and possible uses for non-comestibles like cotton

(*Gossypium hirsutum*). Expected crops including maize (*Zea mays*), beans (*Phaseolus*), and squash (*Cucurbita*) were only a partial representation of a diverse diet. Tubers including sweet potato (*Ipomoea batatas*), *makilito* (*Sagittaria* spp), llerén (*Calathea*), and yam (*Dioscorea*) were also likely represented in dental calculus. Conspicuous microbotanical remains for palms and other disturbance taxa also support a diverse diet and anthropogenic landscapes.

Chapter 9: Early Inhabitants: Environmental Signatures and Connections to the Earliest Maya

ADDRESSING THE RESEARCH GAP

This dissertation contributes to current dialogues surrounding cumulative impacts on the environment as well as the earliest Maya in Belize. Employing archaeological and paleoecological evidence supports the importance of early Maya inhabitants at Colha, as well as the environmental impact early settlers had on the Blue Creek *rejollada*. Despite the challenge of “finding” an Archaic site, Middle Preclassic lithic and paleobotanical evidence contribute to the concept in which the earliest Maya were local foraging cultivators thriving in an area with wetland resources and quality raw materials for tool production. This gives Colha an opportunity to become a locus for tool production and engage in trade networks as it grows in settlement and complexity.

A continuation of early wetland exploitation and lithic production is visible at Colha from excavations and paleobotanical evidence presented in this dissertation. Moreover, radiocarbon dates associated with Middle Preclassic ceramics and lithics push the earlier boundaries of the Middle Preclassic at Colha towards the Early Preclassic (1127 BC). This shortens the distance between Archaic and Middle Preclassic occupation at Colha. Similar patterns occur on the outskirts of Blue Creek, although to a much smaller extent. An early sequence of dates coupled with clear anthropogenic impacts on the environment show early inhabitants were widely engaged in upland manipulation. I presented evidence for this research gap in two case studies, Chapter 5 and Chapter 6.

I addressed my first research question in Chapter 6. The goal was to investigate significant sedimentological markers Archaic populations produce in wetland and upland environments. Although I was not able to gather an Archaic soil sequence from Colha, long-term impacts from previous populations can be inferred from archaeological and paleobotanical data (Chapter 5 and Chapter 8). Perhaps beyond the thick precipitated calcium carbonate and gypsic horizon lies the conclusion to sedimentological markers from Archaic people at Colha. Nevertheless, I was also able to construct an environmental snapshot of conditions at Colha during one of its population peaks in the Late Preclassic. This coincides with a boom in population and cultural complexities in social, ideologic, and settlement patterns at the time (Buttles 2002; Hester and Shafer 1994). Pronounced signals in phosphorus and microcharcoal concentrations support the thriving lithic production hub. This serves as an example for future geoarchaeological studies on what to expect when studying a large site. This research also contributes to geoarchaeological studies to assess the Anthropocene through critical markers left behind by early inhabitants (Beach et al. 2015a).

The Blue Creek *rejollada* provided a robust record of early land management dating back to the Archaic. This unique micro-environment boasted impressive microcharcoal counts equivalent to modern counts at Colha during the Late Preclassic. Multiple paleosols also provided a long chronological sequence for the *rejollada* and documented multiple erosional sequences resulting from deforestation. Radiocarbon dates established people in the area have a long history, dating to the Archaic period, taking advantage of its fertile soils and microclimate. Overall, both Colha and the *rejollada* chronicle erosional episodes, characteristic Maya clays, and increased microcharcoal particulates and phosphorus levels from human input.

Another goal of this dissertation aimed to find similar technologies and traditions which persisted throughout Maya periods that may have originated in Archaic times. This task was also addressed in Chapter 5, Chapter 6, and Chapter 8. The long chronology in the *rejollada* provides insight to early upland management which persists through modern Maya times. *Rejolladas* provide unique micro-environments which have many advantages. For example, modern and ancient studies have documented *rejolladas* as a source for water wells and damming (Beach and Dunning 1997; Fedick 2014; Kepecs and Boucher 1996; Munro-Stasiuk et al. 2014). They are also widely used for cultivating economic species. Since major Mesoamerican cultigens were domesticated during the Archaic, it is highly likely the Blue creek *rejollada* served as an early location for upland exploitation for semi-nomadic hunter gatherers, which later settled at Blue Creek. At the very least, the fire regime record and phosphorus input record reflect persistent management beginning in the Archaic.

Evidence for the persistence of Archaic traditions and technologies at Colha can be inferred based on other previous early contexts as well as evidence for wild plant and animal exploitation. Colha includes evidence for early tool production, early radiocarbon dates at the Main Plaza, faunal remains of wild taxa, and paleobotanical remains which support food processing in addition to economic cultigens. Colha's location along the Belize Chert Bearing Zone and Cobweb Swamp provides a diverse array of resources for early hunter-gatherers.

The quality chert in the area provides raw materials to make Colha a prominent stakeholder in lithic early lithic production and trade (Shafer and Hester 1983; Iceland 2005). This prompts the appearance of the constricted uniface in the area during the Late Archaic. This tool functions as a wood-working implement or as a digging tool for land-clearing or hoeing (Valdez 2007). Three constricted unifaces were recovered from the 2017 field season. They were recovered from construction fill, which has also been documented in the past. In previous excavations at an *aguada*, several constricted unifaces and well-patinated chert tools were recovered from an aceramic horizon (King 2000; Hester 1996; Shafer et al. 1980). Constricted unifaces, away from habitation areas, indicate quarrying and specialized tool production (Hester et al. 1995; Iceland 1997). Excavating beyond the mortuary area in the Main Plaza was limited and future excavations will possibly encounter earlier contexts.

As horticulturalists begin to settle in the area during the Archaic, Cobweb Swamp witnesses more intensive wetland manipulation and deforestation by early villagers who cultivated maize and manioc by 3400 BC (Buttles 2002; Jacob 1995; Pohl et al. 1996). At some point possibly during the Late Archaic or Early Preclassic, informal groups appear in the Main Plaza area. During the transition from the Middle Preclassic to the Late Preclassic, a formal plaza floor was constructed, covering the informal groups (Anthony 1987; Buttles 2002; Sullivan 1991). This chronology is supported more as boundaries of the Middle Preclassic move towards the Early Preclassic from the latest radiocarbon dates presented in Chapter 5.

Other evidence of early enduring practices at Colha includes the use of wild animals and plants. Middle Preclassic contexts included mammalian, reptilian, avian and piscine remains (Riegert and Gill 2018). White-tailed deer remains also indicated one of the bones was manufactured into a tool, while other remains included evidence of processing for consumption. Rabbits, spider monkey, and domestic dog were also among mortuary assemblages. Other remains like ocellated turkey and turtle were also recovered. These assemblages resemble Late Archaic faunal remain assemblages from Pulltrouser Swamp. Similar to Colha, Pulltrouser Swamp also provided an abundance of faunal, wetland resources, fertile soils, and water for early in habitants These disturbed landscapes favor ruderal cultivation and grazing for deer and other small game. Faunal assemblages in addition to botanical evidence support a variety of niche construction behaviors where people create ecological niches for their benefit either intentionally or inadvertently (Smith 2011).

Small scale societies domesticate important cultigens including *Zea mays* (maize), *Manihot esculenta* (manioc), *Maranta arundinacea* (arrowroot), and *Calathea allouia* (llerén) during the Archaic. Dental calculus highlights the continuation of important cultigens at Colha during the Middle Preclassic (Chapter 8). In addition to food, indicators for complex food processing and evidence for economic fibrous materials support the use of important cultigens first introduced during the Archaic period.

Paleobotanical evidence for maize (*Zea mays*), beans (*Phaseolus*), squash (*Cucurbita*), cotton (*Gossypium hirsutum*), sweet potato (*Ipomoea batatas*), *makilito* (*Sagittaria* spp), llerén (*Calathea*), yam (*Dioscorea*), palms, grasses, and other herbaceous taxa (*Asteraceae*) appear in dental calculus at Colha. Starch granules presented evidence for complex cooking techniques including grinding, parching, and boiling. The consumption and likely use of palms, which thrive in disturbed landscapes, was also prominent in dental calculus samples. Cotton fibers also presented examples of more complex niche construction behaviors since cotton serves multiple utilitarian purposes and has been documented in Archaic sites across the Lowlands (Jones 1994; Kennett et al. 2010; Lohse 2009).

These findings add to previous palynological studies in northern Belize, which demonstrate horticultural activities of early small-scale societies (Jones 1994; Pohl et al. 1996). Disturbed landscapes and clear cultivation indicators contribute to the magnitude of niche construction behaviors during the Archaic to Preclassic transition. Early Preclassic villagers at Colha intensify cultivation practices, increase tool production, and practice complex cooking techniques. These behaviors are certainly more labor intensive and occur in tandem with a surge in population and various cultural complexities which are not considered exclusive to Colha in the Lowlands. Paleobotanical and Middle Preclassic finding at Colha help refine the transitional period and contribute to larger discussions on early human impacts on the environment.

The final intention of this dissertation concerns the use of ethnographic studies in archaeological interpretations when analyzing early contexts. My research included an ethnographic component surrounding plant knowledge in San Felipe, Belize (Chapter7). This study demonstrates that despite cultural and chronological distances between the ancient Maya and their descendants, there are continuities in knowledge systems regarding wild plant and animal use. In addition to contributing to a modern analogue for plant use in the area, I was able to build a phytolith reference collection which aided the botanical portion of the dissertation.

I recognized overlap in house garden composition between modern and archaeological contexts including maize (*Zea mays*), beans (Phaseolus), squash (Cucurbitaceae) varieties, avocado (*Persea americana*), sweet potato (*Ipomoea batatas*), *makilito* (*Sagittaria* spp), and chili peppers (*Capsicum* spp.), to name a few. House gardens and *milpa* plots provided a variety of plants which are used to treat ailments, function as condiments, provide construction material, and serve other utilitarian purposes. This survey of plant knowledge at San Felipe emphasizes the wide variety of useful plants in disturbed landscapes and supports human niche construction behaviors similar to those in ancient Maya times.

Hunting and gathering practices also persist despite modernity among many San Felipe residents. Many residents benefited from successional forest taxa and fallowing agricultural fields for useful plants and small game. White-tailed deer, rabbit, *paca*, armadillo, and turkeys were commonly mentioned throughout our conversations. Often people mentioned gathering plants from the *monte* to contribute to their gardens or to treat specific ailments. Similar observations have been supported by botanical and faunal analysis (Goldstein and Hageman; Shaw 1999). The wide range of plants and animals which do not come from commercial sources included a nice overlap in archaeological studies. Furthermore, these findings contribute to understanding a diverse Maya diet, which does not solely revolve around maize.

CONTRIBUTIONS

This dissertation brings together sedimentological and archaeobotanical lines of evidence to push the boundaries of the beginning of Maya civilization, and perhaps even the Anthropocene. Contemporary environmental issues including air and water pollution, soil erosion, deforestation, and species extinction are not problems exclusive to modern times, but also have effects when various plants and animals were domesticated during the Archaic. Colha and the Blue Creek *rejollada* contribute to an understanding of how humans begin to engineer and transform their natural and social environments during the Archaic to Preclassic transition. This dissertation adds to previous research to refine this critical period in the Neotropics which is still understudied.

I contributed to understanding the Archaic to Preclassic transition with new radiocarbon dates, archaeological excavations, and environmental histories for Colha and the Blue Creek *rejollada* (Chapter 5 and 6). Colha excavations also contributed to better understanding of the earliest villagers in the area and how they took advantage of raw materials in the Chert Bearing Zone as well as wetland resources. The dental calculus study (Chapter 8) was the first at Colha and second in the Maya Lowlands after Scott Cummings and Magennis' (1997) study. This study offered evidence and insight into food consumption, food processing, and evidence for the use of economic fibrous materials. Together, multiple lines of evidence make a case situating Colha as one of many loci for Maya origins in the Lowlands.

This dissertation also included an ethnobotanical study (Chapter 7) which salvaged and documented disappearing plant knowledge in northwestern Belize from contemporary Maya descendants. I consider this a contribution to a type of community-based archaeology. This very concept has been brought to light with the emergence of indigenous archaeology in the United States. It is a space in which archaeology and indigenous epistemologies attempt to coexist. This approach includes the perspectives and voices of people who consider themselves related to the archaeological investigation by culture, biology, or descent (Lippert 2007). Community members of San Felipe and other small towns have worked closely with archaeological projects for several decades. This project included collaborators in a unique way. Collaborators shared their knowledge of plant use in addition to generously providing plant specimens for herbarium curation, and to create a phytolith reference collection used in this dissertation. Specimens were also curated for the UT Herbarium and the National Herbarium of Belize in Belmopan.

This research also contributed to international collaboration between universities and archaeological projects in of Linda Vista and San Felipe, Panama, and the United States as well as two research labs at UT, the Environmental Archaeology Lab and the Soils and Geomorphology Lab. This dissertation also contributed to teaching field and laboratory methods to undergraduate and graduate students.

FUTURE WORK

The research design for this project originally included various unique cultural contexts at Colha; however, attempts for processing sediments were unsuccessful. Fine tuning laboratory methods that work with facilities at UT for Neotropical sediments will require more experimentation. Results from those analyses will compliment data presented in this dissertation and contribute to Middle and Late Preclassic literature at Colha. Returning to Colha for more fieldwork targeting early village life would also contribute to the research presented here. Finally, publishing findings will broaden the audience for the research I have presented. Some of the work on the Blue Creek *rejollada* and ethnobotanical study have already been published in edited volumes of the Occasional Papers for the Center for Archaeological and Tropical Studies.

Appendices

APPENDIX A: LOT SUMMARIES FOR COLHA ARCHAIC MAYA PROJECT 2017

Table A.1: Lot Summaries for Operation 4444

Sub Op/Lot	Basic Description	Artifacts Collected	Special Notes
1-1	0-13 cm: plow zone and Classic cultural material	C=5; L=10	
1-2	15-25 cm: sascab and cobbles	C=6	
1-3	24-100 cm: black brown clay, calcite, sascab	sterile	
2-1	0-11 cm: dark brown clay, charcoal, freshwater snails, cobbles towards bottom	C=7; S=5; L=4	faunal tooth
2-2	11-26 cm: Very dark gray clay; snails, roots, fire-cracked chert	C=2; O=3	Early Classic jar rim collected
2-3	33-60 cm: some fire-cracked chert, snail shell; reddish yellow, silty sand with cobble	sterile	
3-1	0-40 cm: shells, roots, black brown clay Vertisols, chert cobbles	C=33; O=1; L=2	encountered broken vessel
3-2	40-75 cm: yellow brown, limestone concretions, cobbles on SE wall	L=22	possible hearth feature on E wall; collected charcoal for phyto and AMS; associated with 4444/9-3
3-3	75-81 cm: dark clay	sterile	possible rock alignment
3-4	81-90 cm: lighter gray pockets within dark soils, manganese nodules	L=7	possibly Preclassic or Archaic horizons
4-1	0-30 cm: black clay, plow zone, cobbles, abundant flake debitage, scattered non-diagnostic sherds, snails (35 m west of 4444/1 and 4444/2)	L=1	subop near lithic workshop near suspected Archaic/Preclassic interface; chert drill recovered at 26 cm

4-2	30-63 cm: yellow-brown heavy clay, orange and tan mottling	L=8; C=6	Archaic blade at 35 cm, chert cores, hammer stone at 46 cm, possible platform at 56 cm
4-3	63-75 cm: cobbles in NE quadrant; possible platform in yellowish brown clays; few debitage observed		
4-4	75-78 cm: yellowish brown with mottled clays, coarse sediments		feature removed
5-1	0-18 cm: black humic layer with roots	O=2; C=6; L=1; S=1	subop located in middle of large courtyard group 4044
5-2	18-35 cm: plaster floor followed by fill with few ceramics present		plaster floor
5-3	35-70 cm: platform construction fill of likely Classic structure, ceranics, blades, bifaces present		
5-4	70-90 cm: buried dark clay, observed lithics and ceramis		charcoal collected
5-5	90-100 cm: transition to bedrock mottled brown and gray	L=2	
6-1	0-25 cm: black, heavy clay	C=4	subop representative of small lithic workshop
6-2	25-55 cm: clay becomes lighter with some limestone cobbles present and yellow clays		
6-3	55-65 cm: pale brown matrix, calcium, gypsum, manganese nodules,		
7-1	0-40 cm: dark clays, plow zone, heavy lithic scatter, at 35 cm a small lens of tan clay appears in NE quadrant		South of 4041, East of 4026

7-2	40-58 cm:dark soils mottled with brownish yellow and greyish brown , some charcoal in matrix		
8-1	0-40 cm: black soil, root systems, shell, extensive lithic debitage, limestone inclusions		extension of 4444/4- returning to uncover possible platform and burn feature
8-2	40-80 cm: brown mottled with brownish yellow, calcium carbonates with limestone inclusions, chert cobbles	L=7	
8-3	80 cm: yellowish brown mottled with yellowish brown and greyish brown, sandy clay	sterile	
9-1	0-20 cm: dark clay plow zone, chert flakes and sherds	L=5	1 m E of subop 3 to investigate charcoal feature and rock alignment
9-2	20-70 cm: yellow mottled clay similar to 4444/3-2; occasional chert cobbles, lithic and ceramics observed at top of lot, bottom of lot has large chert bolders	L=2	extension of 4444/3-2 possible rock alignment
9-3	20-43 cm: burnt feature; basin shaped and rock-lined, cobbles above the burnt material, length (N-S) about 60 cm and depth about 20 cm		Hearth; collected samples for ams and phyto

Table A.2: Lot Summaries for Operation 2222

Sub Op-Lot	**Basic Description**	**Artifacts Collected**	**Special Notes**
1-1	0-32 cm: theoretically backfill from previous Potter excavations		north facing 2x1
1-2	32-57 cm: soil has abundant gravel, grayis brown in color, possible platform surface at 55 cm	C=36; L=15	
1-3	57-97 cm: dark grayish brown, coarse silty loam, debitage and shell collected, cobble and ceramics present under compacted marl		2 lithic tools found at 62 cm in SW corner
1-4	80-120 cm: lots 1-3 combined; high amount of cobbles, grayish brown soil, ceramic, bone, shell, and lithics observed	C=83; L=23; S=18; B=1	
1-5	120-142 cm; 2x2 bisected into 2x1 east to west; follows a darker soil exposed in 2222/1-4, silty loam, fire cracked chert throughout matrix, shell, bone, ceramic, and lithic in matrix	B=22, C=203, L=165, S=105	Burin spalls collected in this lot
1-6	142-150 cm; dark grayish brown, silty loam, charcoal is present in matrix, bone, lithics, ceramics, and shell collected, unit was sifted		
1-7	150-153 cm: dark yellowish brown, compact with limstone inclusions, roots, charcoal, burned bones, abandant bones throughout, teeth, shells, reduced and nodules in matrix		
1-8	153-156 cm: very dark, grayish brown, with yellowish brown inclusions, charcoal in matrix, shell and sandy limestone; shells, bone, ceramic, lithics present		carbon collected

1-9	156-160 cm: reddish brown, mottled with light brown, abandant charcoal, small limestone inclusions, gray mottling, shell, possible ash in matrix		
1-10	160-170 cm: similar to previous lot, but lot is coarser in texture and sandier, reddish brown, sandy, some limestone inclusions, less charcoal than previous lot, possible ash in matrix		
1-11	170-174 cm: lot was opened to probe potential stone alignment, silty limestone soil revealed at bottom of lot		
2-1	0-25 cm: silty loam with mixed artifacts, organic rich, humic level, charcoal present	L=185; C=13	opened in area designated as 2011, close to previous "Red Lady" excavations
2-2	25-60 cm: limestone fill and ballast, burnt rock likely associated with plaza in front of structure NW of the unit; Expansion to the south (4-1) and put in a 1x2 to the east (5-1)	L=22; C=38	
2-3	60-100 cm: second sequence of plaza floor and construction fill, floor is about 10 cm and ballast bellow is mostly cobbles of limestone and chert	C=5; L=4; S=3	
2-4	100-120 cm: third floor sequence, assiated with temple adjacent with subop 4 and 5	C=3; L=3	
2-5	120-135 cm: loamy silt, floor and ballast, mussel shell fragments and charcoal		mussel shell and charcoal; possible stone alignment in southern half

2-6	135-155 cm: burn and shell deposit at 150-155cm, brown silty soild with charcoal and stone alignment		burin spalls, shells, samples taken for ams and phytos
2-7	155-160 cm: mother of pearl fragments, less charcoal and mussell shell		northern 1x2 of 2222/2
2-8	160-175 cm: burnt red clay, below rock alignment and shell workshop		red clay
2-9	175-190 cm: compact red clay, hit sascab and sterile at 200 cm		charcoal for ams at 182cm
3-1	0-42 cm: 2x1 opened parallel to 2222/1-1; dark humuc with lithics, ceramics observed		
3-2	42-80 cm: underneath surface feature in 2222/3-1; silty loam with shell, bone present		possibly correlates with 2222/1-3
4-1	0-120 cm: comprised of humuc silty loam, limestone plaza floor, ballast fill and clay fill, only diagnostic artifacts collected		opened 2222/4 to the south of 2222/2 to expand search for Middle Preclassic features and earlier features, single lot; absorbed by subop 2 at 120cm (bottom of 2222/2-4)
5-1	0-120 cm: opened lot to the east of 2222/2 and 2222/5 in order to expand search for Middle Preclassic and earlier features. Subop treated as one lot. Humus, plaza limestone floor, ballast fill and clay interface		This subop was absorbed by subop 2 at 120 cm (bottom of 2222/2-3)
6-1	0-25 cm: silty loam with mixed artifacts, organic rich, humic level, charcoal present		
6-2	25-45 cm: lot opened to continue excavatons adjacent to temple. Classic Maya floor associated with use of temple structures nearby. Contination		should begin series of floors and construction features associated with adjacent

	of subops 2, 4, 5, 7.		temple structure
6-3	45-76 cm: continuation of floor and construction fill, plaster and large cobbles		
6-4	76-80 cm: burial found, individual 2 under ceramic vessel, disarticulated cranium with some bone fragments and post-cranial remains		Individual 2
6-5	80-103 cm: Burial under ceramic platter, several long bones in alignment towards northwest with pelvic area crushed		individual 5
6-6	103-109 cm: small bone fragments, lithics and ceramics throughout matrix, cobbles and fine roots, brownish gray soil,		
6-7	109-122 cm: remains found within break in plaster floor, remains in southwestern corner, metacarpals and long bones encountered, individual in crouched position		individual 7
6-8	122-132 cm: new plaster stratum below 6-7. Disarticulated bone in northwest quadrant, femur in northern corner, extending into balk, approx 20 cm in length		unexcavated until balk is removed
6-9	132-137 cm: began at a change instratigraphy in which 2222/6-8 was terminated. NW corner is not presently excavated due to long bones in SW section. Phalanges located in S of unit. Lot terminated at cobble strata.		

6-10	137-158 cm: fill material, small bone fragments collected from southern area, northwest corner remaining unexcavated, chert and limestone cobble, large ceramic vessel located inwestern subop wall, vessel uncovered will be 6-11 found at 149, biface fragment, dark brown strata with sandy sized limestone inclusions, mottled with charcoal and shell and some iron or manganese nodules		
6-11	vessel located in 6-10 (profile vessel #5)		
6-12	158-172 cm: begin 10 cm termination levels and screening with 1/4" fine mesh; clay-rich medium/dark brown with sand-sized limestone inclusions modeled with charcoal and shell and some iron/manganese nodules		double lug handle found at 172 cm, charcoal for ams at 158 cm
6-13	172-176 cm: matrix is unchanged from previous lot, some mottling with yellow/orange clay		yellow orange clay
6-14	176-206 cm: wetter yellow-orange matrix, fewer inclusions. Some shell, charcoal and limestone inclusions		red clay interface correlating with subop 2
7-1	0-37 cm: lithic debitage, ceramics, silty clay loam, chert and limestone cobbles, biface tools and tranche flake observed		
7-2	37-55 cm: silty, very pale brown, burned rock observed in ballast, chert and limestone cobbles, orange inclusions in NW quadrant, charcoal deposit in souther quadrant		

7-3	55-62 cm: silty loam, pale brown, shell, lithic, ceramic, ash in southern portion of unit, cores present		
7-4	62-94 cm: grayish brown soil, stone alignment in western quadrant, ashy particles in matrix, cores, tools, flakes, peeling back to expose stone alignment with bones at 88-92 cm, ceramic base covering bones		
7-5	94-110 cm: located within 7-4 as burial, lot directly above plaster floor. Three individuals on floor		multiple individuals- see sketch of all burials
7-6	94-110 cm: tightly bundled individual with at least 4 pots that have been heavily fragmented. Individual oriented E-W with head to east and facing south. Head was under a pot and long bones curved around another pot in the stomach area		bundled individual within red clay matrix
7-7	110-130 cm: directly below 2222/7-5; bones from individual 6 and some disarticulated bone fragments collected		
7-8	0-80 cm: remains of individual 8 at 60 cm. Balk divided at 80 cm. Area above individual 4 will become 2222/7-9 and area to the west will continue to be 2222/7-8		Balk wall separating 2222/6 and 2222/7
7-9	60-113 cm: lot containing vessel in 7-8 and contents under vessel; multiple vessels stacked in this lot; stone in between vessels; see sketches, long bones found under vessel collections		

7-10	80-120 cm: lot below 7-7; removed remaining balk material, at least 3 stacked vessels in this lot, see schematic for order		below 7-8

APPENDIX B: EXCAVATION MAPS

Figure B.1: Plan view of 4444/3-3

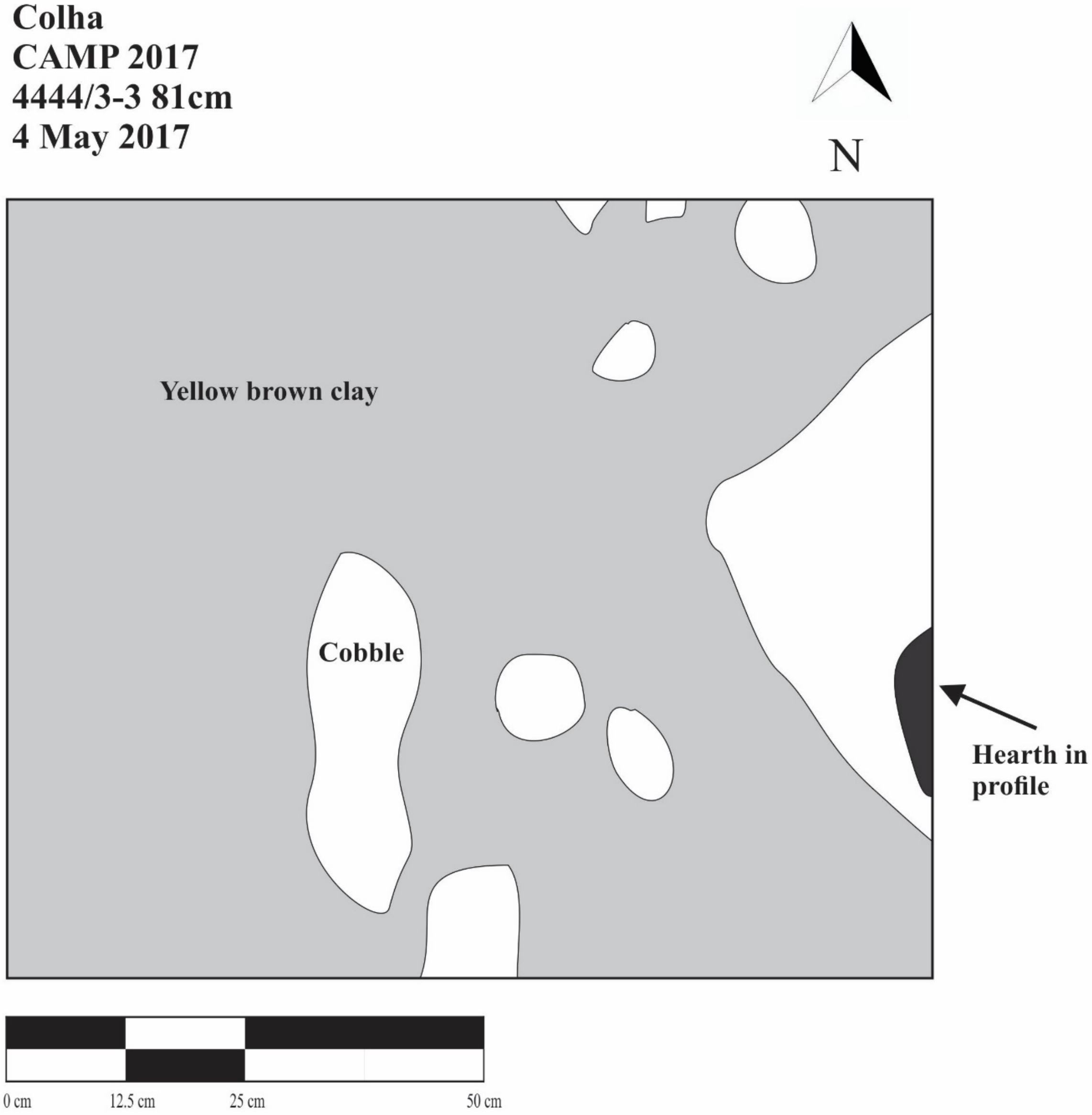


Figure B.2: Profile map of 4444/4

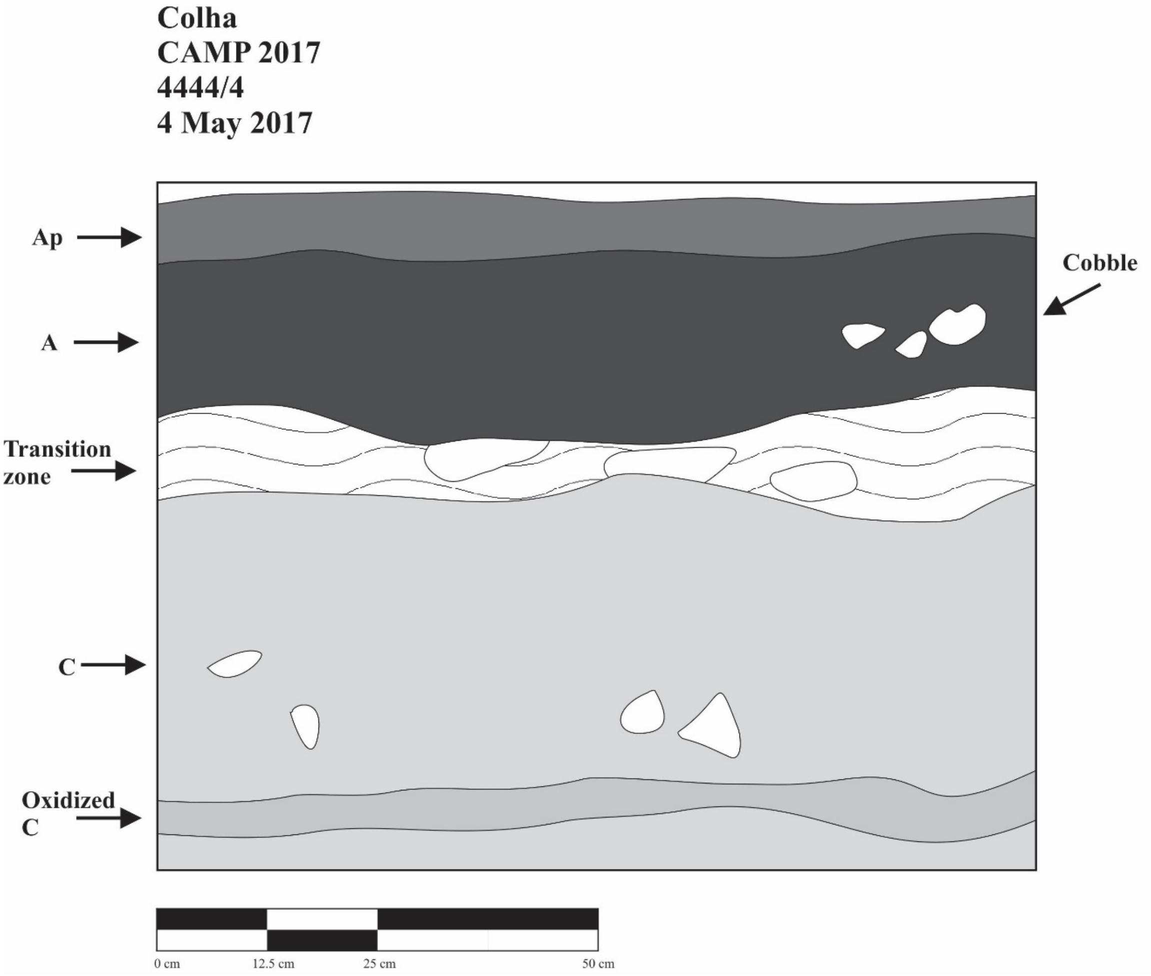


Figure B.3: Plan map of 4444/4-3.

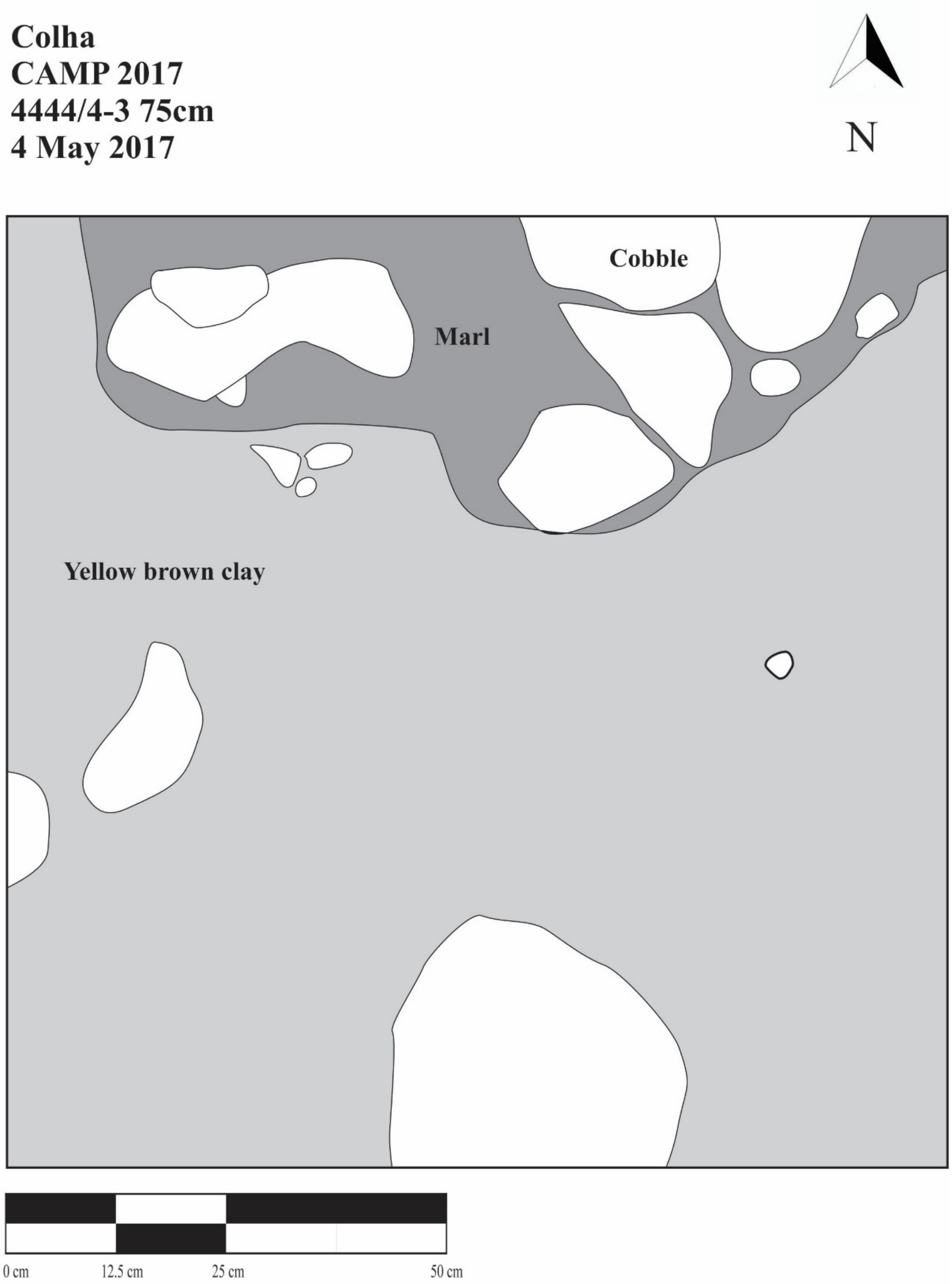


Figure B 4: Profile map of 4444/8

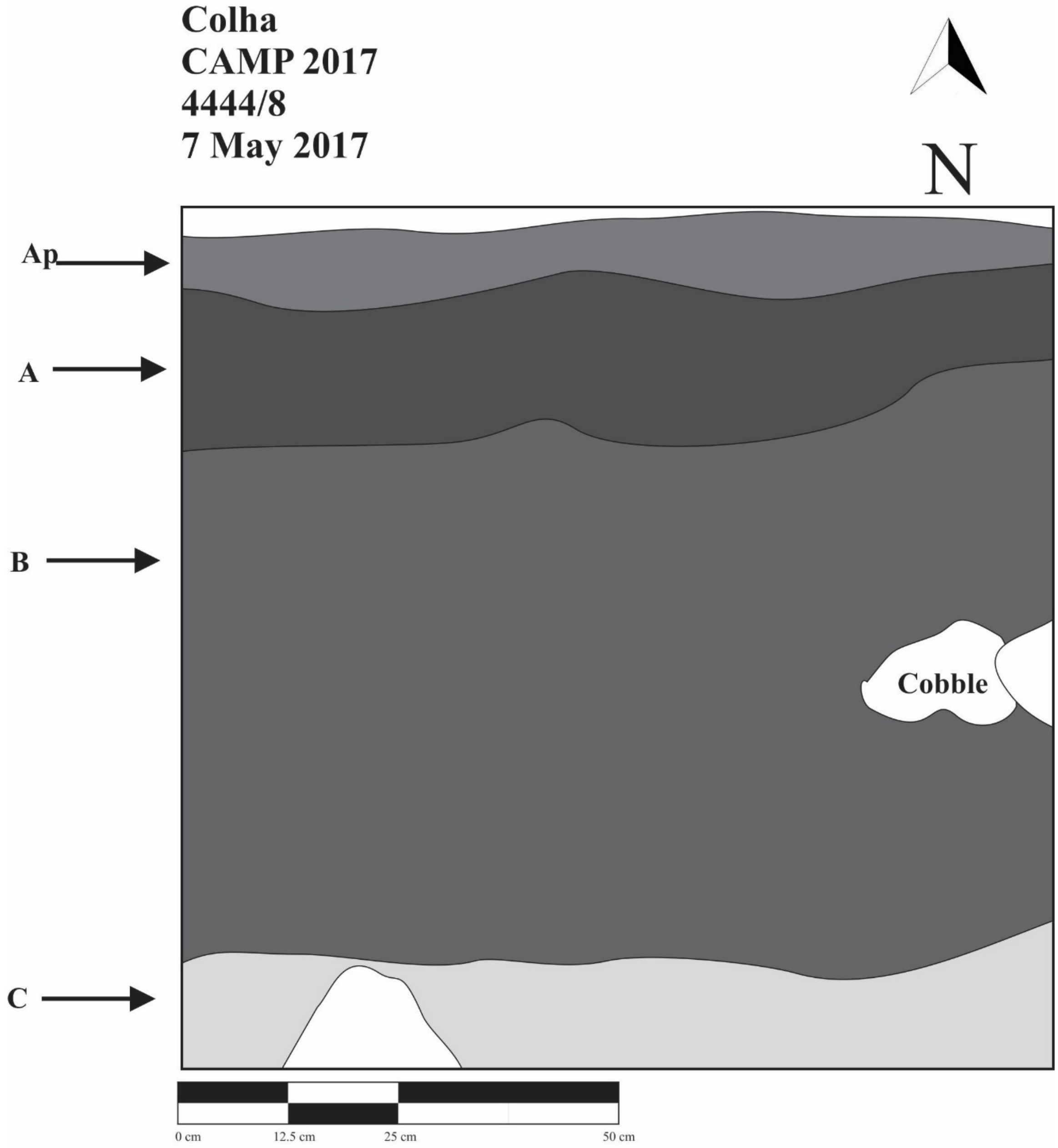


Figure B.5: Plan map of 4444/8-2

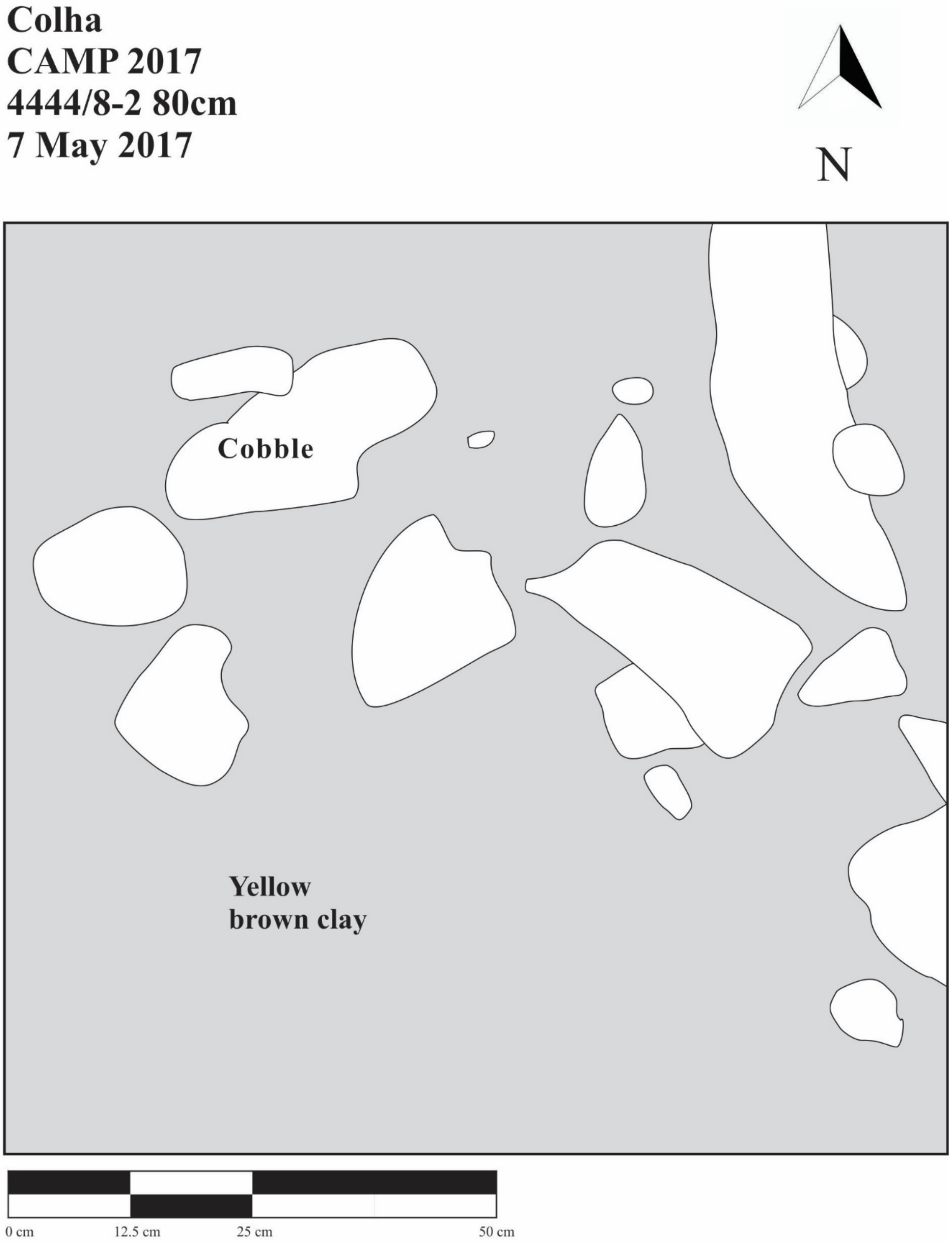


Figure B.6: Profile of hearth in 4444/9.

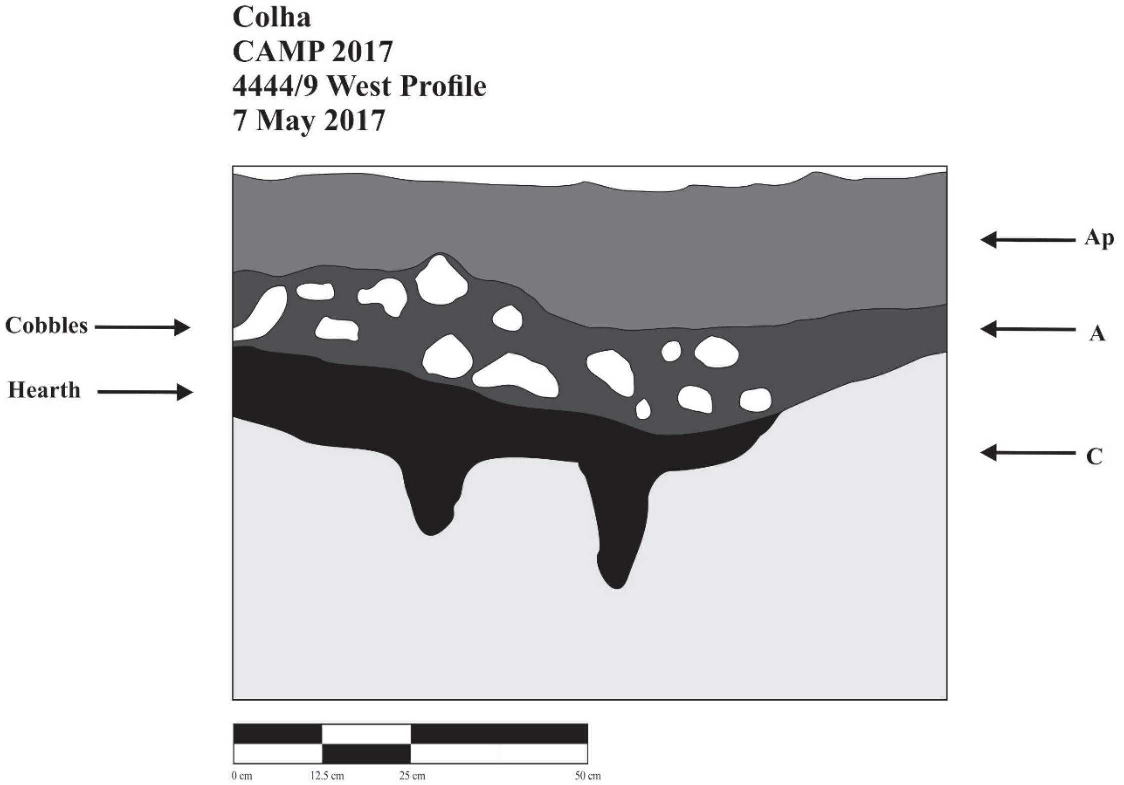


Figure B.7: Plan view of 4444/9-3.

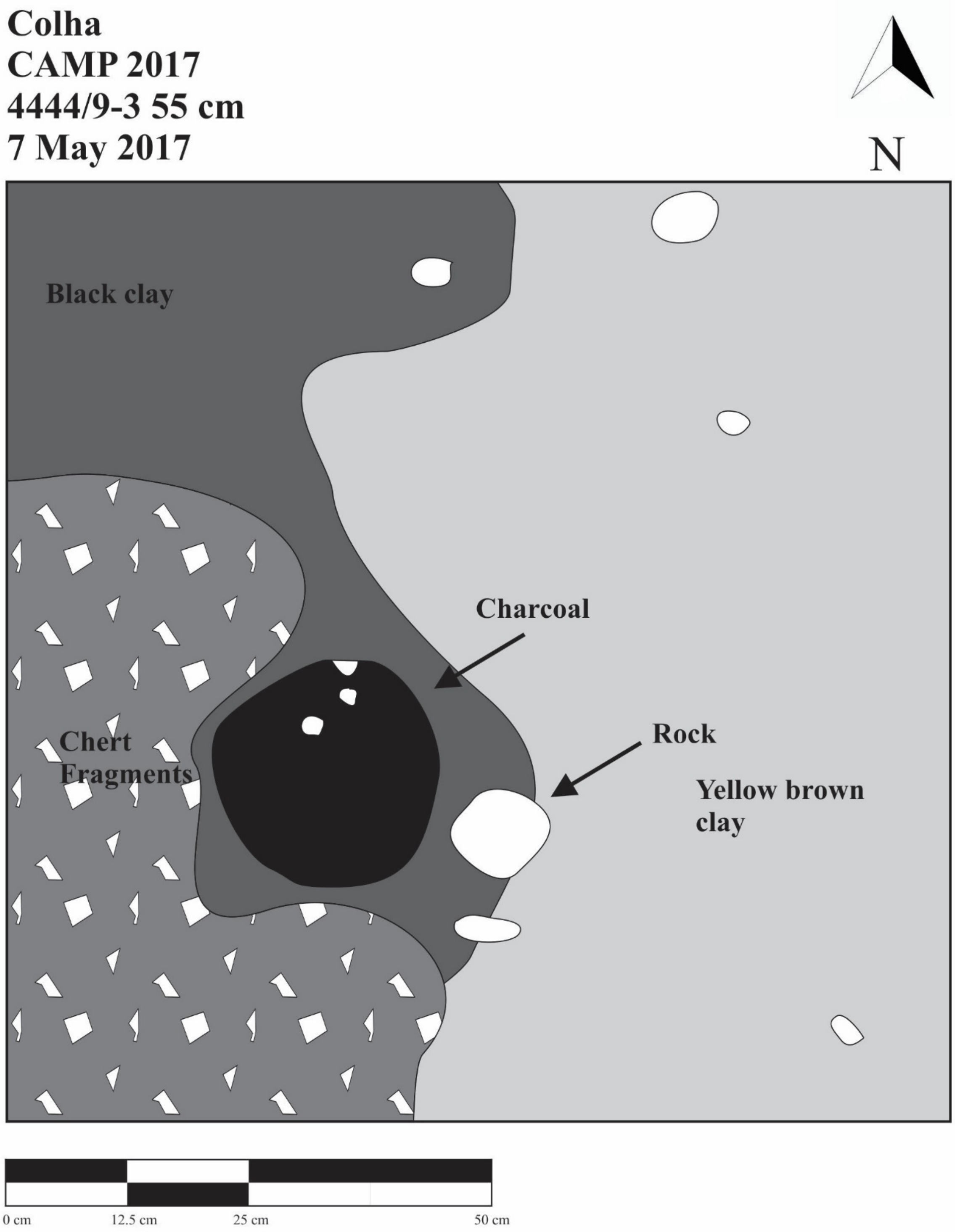
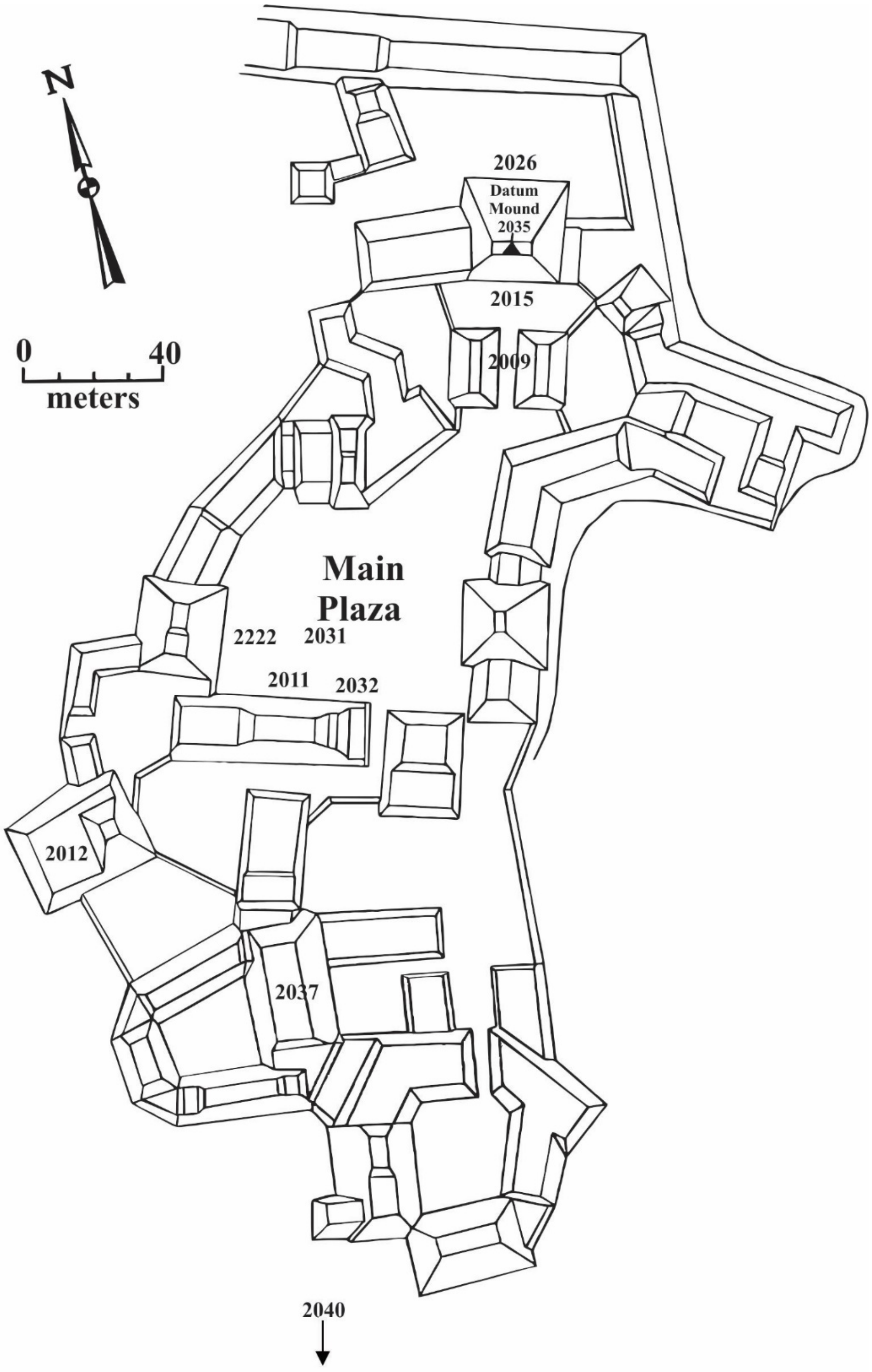


Figure B.8: Main Plaza at Colha



The monumental center at Colha after Hester, Shafer, and Eaton (1994) by Luisa Aebersold.

Figure B.9: Schematic of 2222/1 and 3

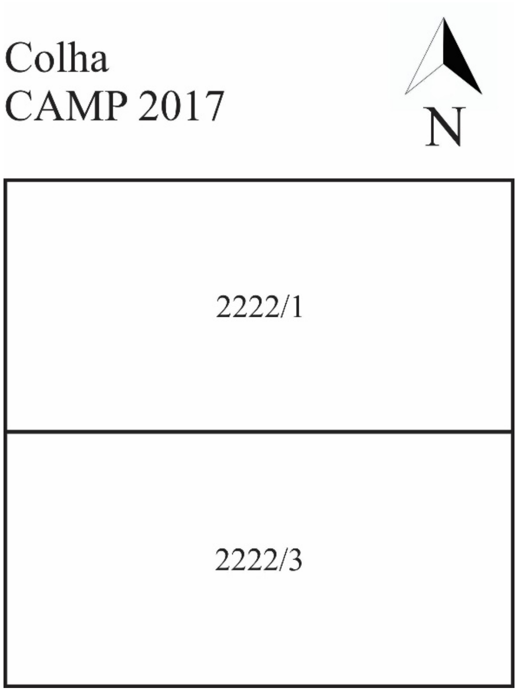


Figure B.10: Schematic of 2222/2, 4, and 5

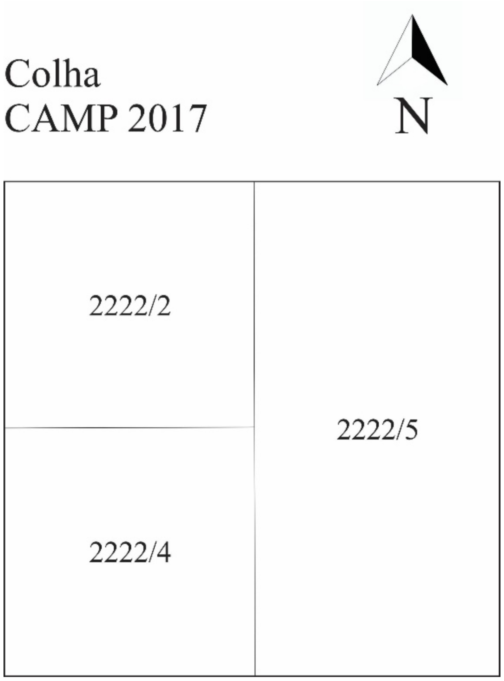


Figure B.11: Profile of 2222/2.

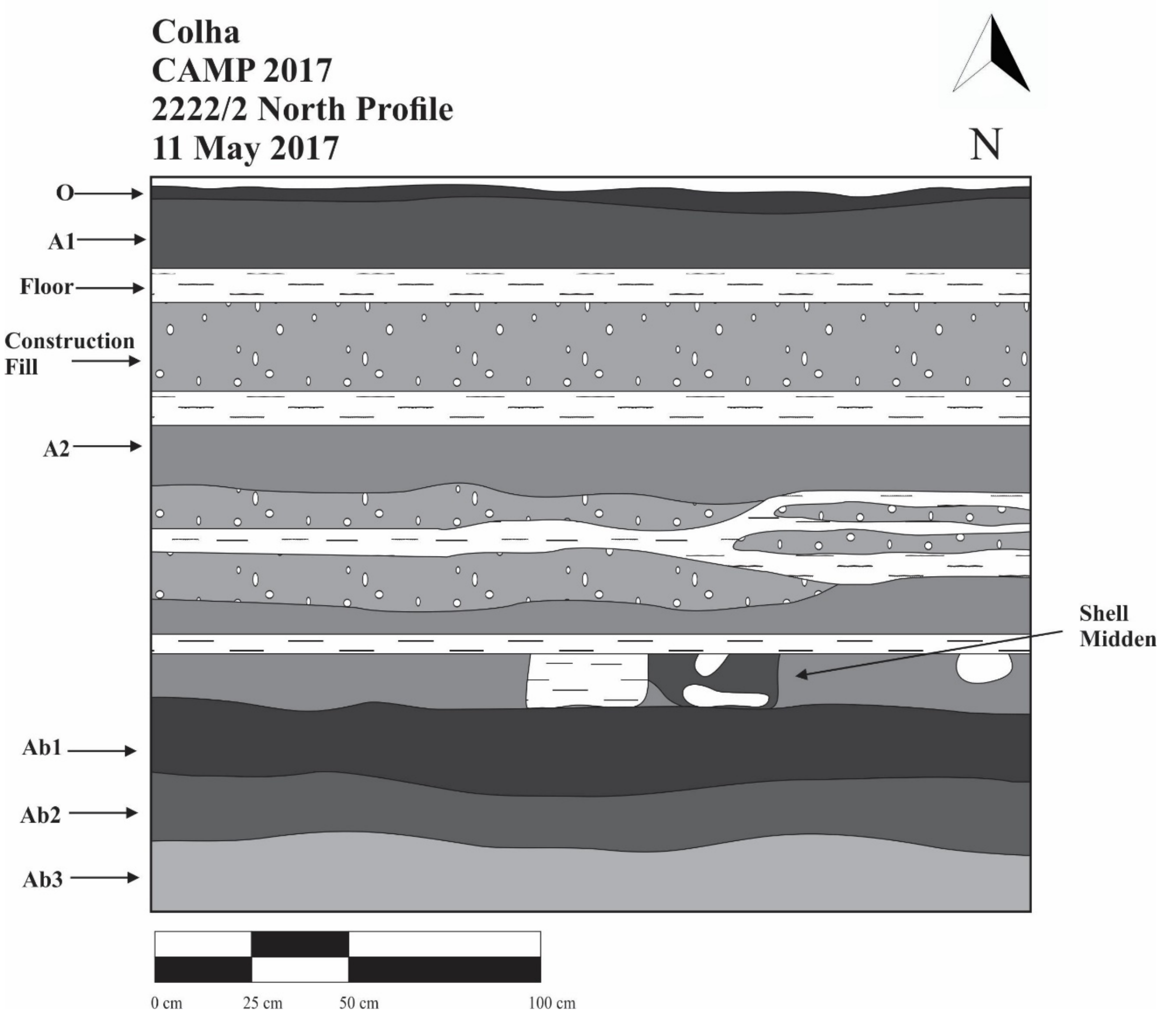

Colha
CAMP 2017
2222/2 North Profile
11 May 2017
N
O
A1
Floor
Construction Fill
A2
Shell Midden
Ab1
Ab2
Ab3
0 cm
25 cm
50 cm
100 cm

Figure B.12: Profile of 2222/6.

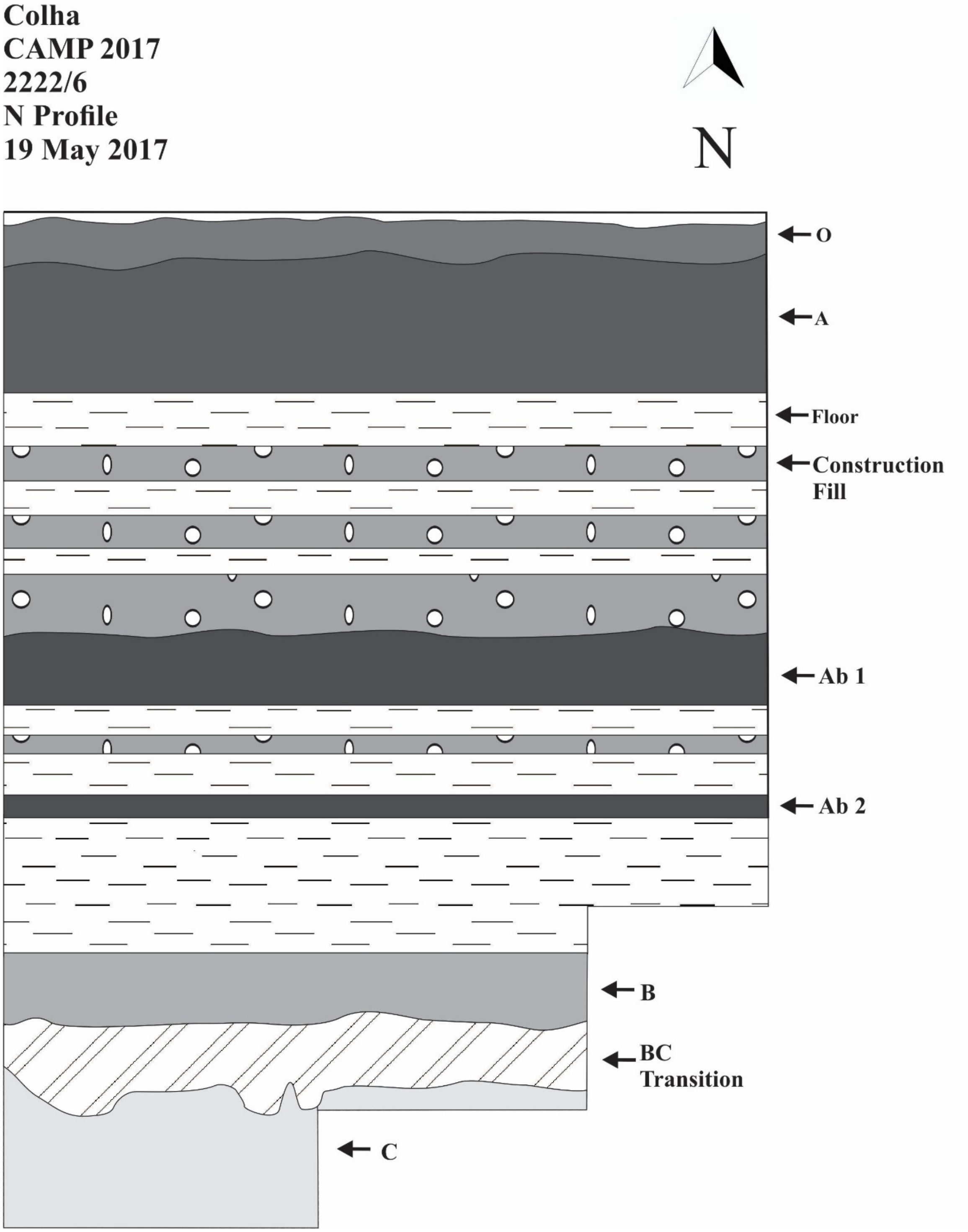


Figure B.13: Profile for 2222/7.

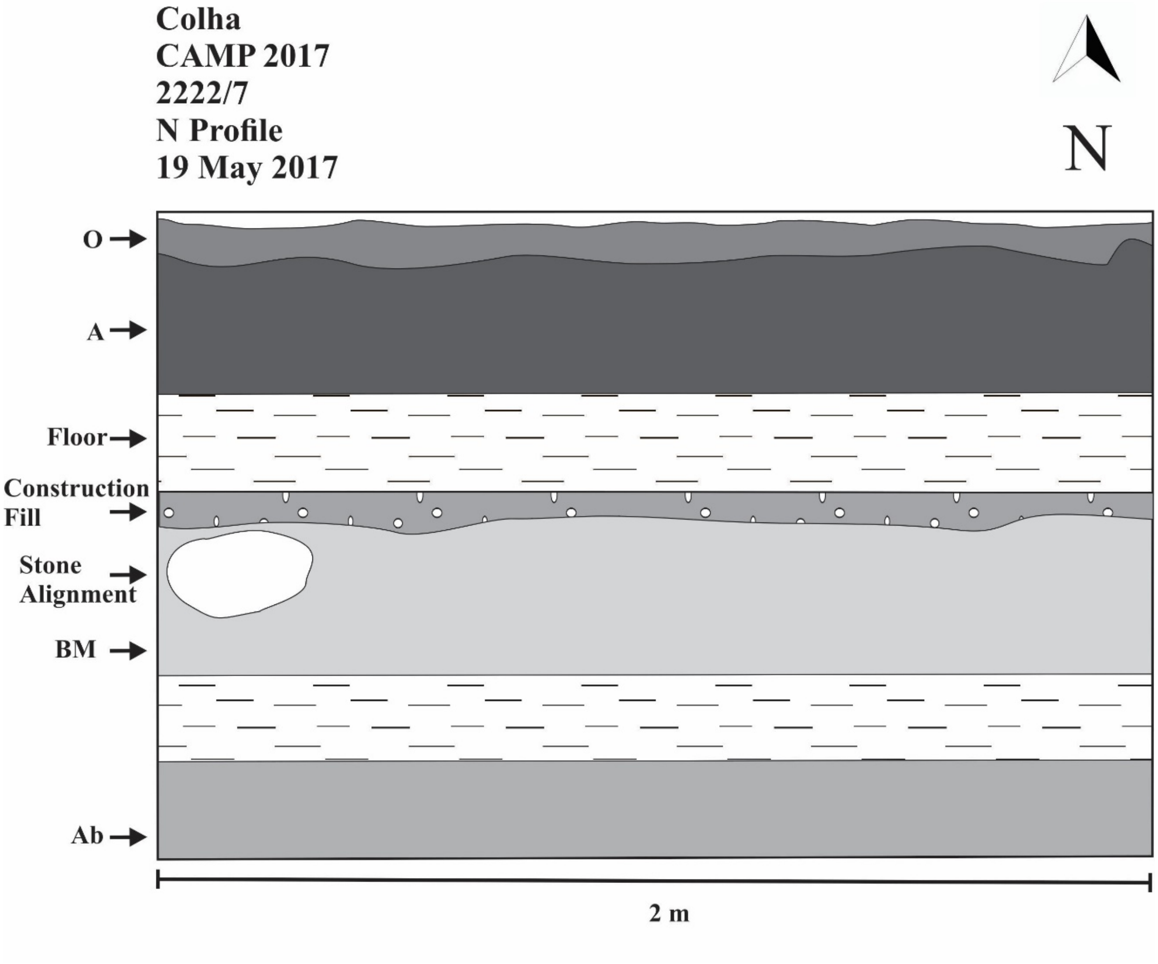
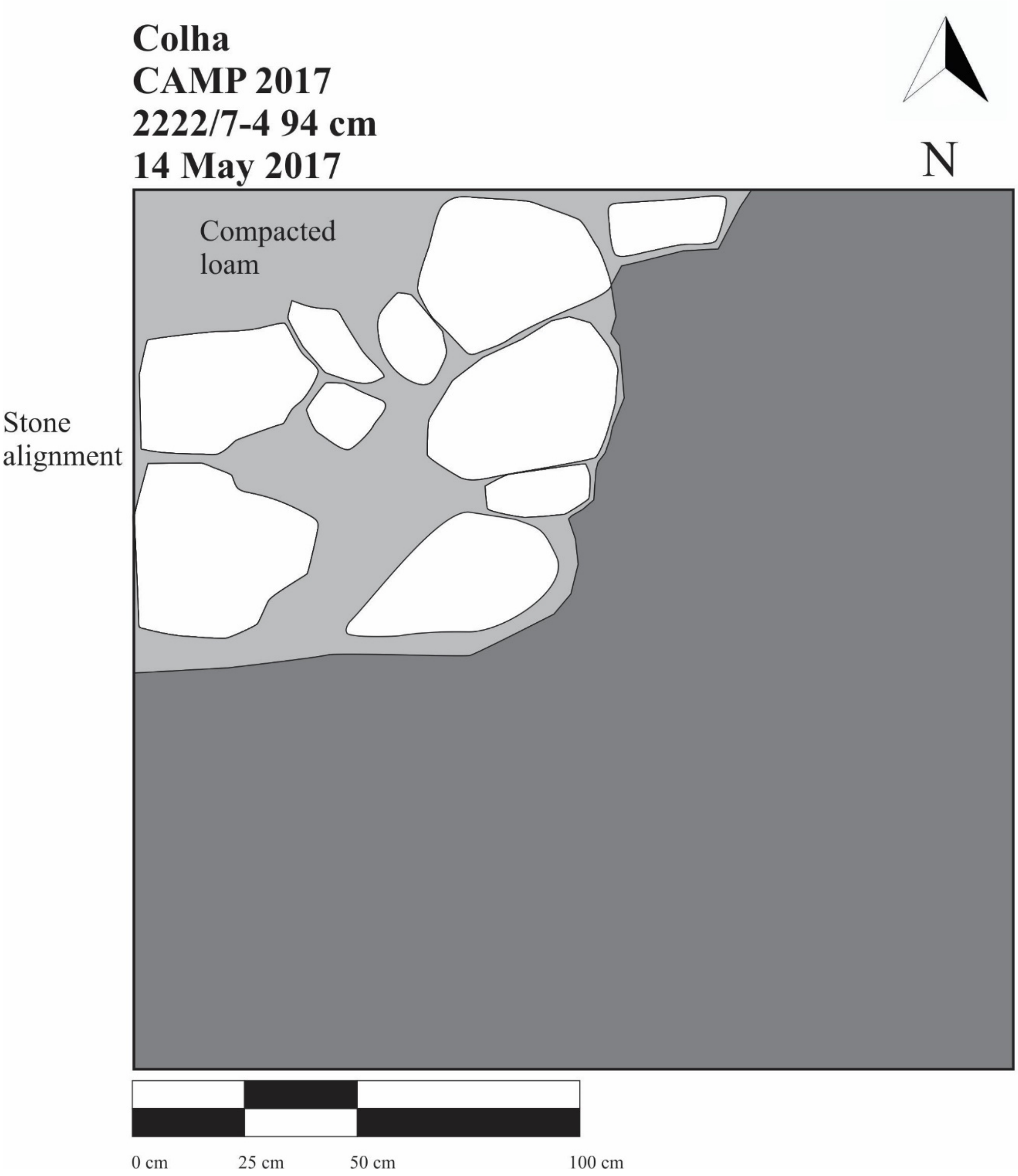


Figure B.14: Plan view of 2222/7-4.



APPENDIX C: TABLE OF PLANTS COLLECTED IN 2016

Table C.1: Plants collected from Programme for Belize Archaeological Project and San Felipe, Belize.

Plant ID	Scientific Name	Common Name
16-001	*Acacia dolichostachya*	
16-002	*Unknown*	
16-003	*Unknown*	
16-004	*Thevetia ahouai (L.) A. DC.*	cocheton
16-005	*Unknown*	
16-006	*Unknown*	
16-007	*Unknown*	
16-008	*Cupania belizensis Standl.*	
16-009	*Metopium brownei*	poisonwood
16-010	*Unknown*	
16-011	*Unknown*	
16-012	*Cordia dodecandra*	ziricote
16-013	*Cryosophila stauracantha*	escoba tree
16-014	*Piper psilorhachis*	buttonwood
16-015	*Ampelocera hottlei*	
16-016	*Ouratea sp.*	
16-017	*Sideroxylon fedexilin*	
16-018	*Unknown*	
16-019	*Chamaedorea*	
16-020	*Unknown*	
16-021	*Trichilia minutiflora*	
16-022	*Ampelocera hottlei*	
16-023	*Pouteria reticulata*	
16-024	*Trichilia pallida*	
16-025	*Pouteria reticulata*	
16-026	*Brosimum alicastrum*	Breadnut, Ramon
16-027	*Unknown*	
16-028	*Calophyllum brasiliense*	
16-029	*Pouteria campechiana*	
16-030	*Cassia grandis*	
16-031	*Cedrela odorata*	Spanish Cedar
16-032	*Attalea cohune*	

16-033	*Protium copal*	copal
16-034	*Sabal mauritiiformis*	
16-035	*Bactris*	
16-036	*Vitex gaumeri*	Fiddlewood
16-037	*Pimenta dioica*	allspice
16-038	*Swietenia macrophylla*	mahogany
16-039	*Nectandra salicifolia*	blackwater
16-040	*Terminalia amazonia*	
16-041	*Desmoncus schippii*	bayal
16-042	*Chrysophyllum cainito*	star apple
16-043	*Ipomoea batatas*	sweet potato
16-044	*Mangifera indica*	mango tree
16-045	*Cocos nucifera*	coconut palm
16-046	*Xanthosoma sagittifolium*	makilito
16-047	*Unknown*	siempre viva
16-048	*Terminalia catappa*	almond tree
16-049	*Plectranthus amboinicus*	oregano grueso
16-050	*Ruta sp.*	ruda
16-051	*Nicotiana tabacum*	tobacco
16-052	*Unknown*	stumpap
16-053	*Ocimum basilicum*	basil, *albajaca*
16-054	*Citrus spp.*	lime
16-055	*Capsicum chinense*	habanero
16-056	*Eryngium foetidum*	cimarron, cilantro
16-057	*Unknown*	ak
16-058	*Anacardium occidentale*	cashew tree
16-059	*Unknown*	nopal
16-060	*Momordica charantia*	sorosi
16-061	*Hamelia patens*	Flor de Vida
16-062	*Annona muricata*	Guanabana
16-063	*Jatropha curcas*	Piñon
16-064	*Spondias sp.*	Plum
16-065	*Capsicum frutescens*	mash-ik
16-066	*Cucurbita pepo*	pumpkin
16-067	*Dysphania ambrosioides*	epazote
16-068	*Carica papaya*	papaya
16-069	*Fernaldia pandurata*	loroco
16-070	*Mansoa alliacea*	Flor de ajo

16-071	*Yucca gigantea*	Flor de izote
16-072	*Erythrina berteroana*	Pito
16-073	*Spondias radlkoferi*	ciruela
16-074	*Unknown*	lemon grass
16-075	*Unknown*	os pip
16-076	*Unknown*	uva
16-077	*Bixa orellana*	achiote
16-078	*Unknown*	lime
16-079	*Cnidoscolus aconitifolius*	chaya
16-080	*Origanum vulgare*	oregano
16-081	*Unknown*	ciruela
16-082	*Tamarindus indica*	tamarindo

APPENDIX D: SUMMARY OF PHYTOLITH ANALYSIS

Table D.1: Dental calculus phytolith summary

No.	Provenience	Description	Phytoliths
1	2222/6-5	Burial 2: Right M2Supra	bulliform (4); cross (1); elliptical scalloped (Cucurbita moschata); psilate elongate (1); facetate terminal tracheate (1); globular echinate (1); Half dome cylinder (Calathea); parenchyma (non-grass)
2	2222/6-5	Burial 2: Right M1Supra/Sub	bulliform (1); sinuate elongate (1); globular echinate (1); multicell (unk) (1); squat saddle (2)
3	2222/6-5	Burial 2: Left M1Sub	bilibate (1); blocky with pits (1); half dome cylinder (2); squat saddle (1); wavy top rondel (maize) (1)
4	2222/6-5	Burial 2: Left C1Sub	psilate elongate (1); globular echinate (7); globular granulate (3)
5	2222/7-5	Burial 6: Right M2Sub	Asteraceae epidermis (1); globular echinate (1); keeled tall rondel (1); rectangular (1); rondel (3); tricomb (1)
6	2222/7-5	Burial 6: Left M1Sub	blocky (1); globular echinate (1); cross, thick shank (1); striated wide transport (Dioscorea) (1); unk (1)
7	2222/7-5	Burial 6: Right M2Sub/Supra	bulliform (1); psilate elongate (1); sinuate elongate (1); globular echinate (2); globular granulate (1); hair (1); squat saddle (1); papillae (1); keeled rondel (1); irregular complex short (1)
8	2222/7-5	Burial 1: Right M1Supra	rondel (3); globular echinate (1)
9	2222/7-5	Burial 1: Left M2Supra/Sub	rondel (1)

10	2222/7-5	Burial 1: Right M1Sub	blocky (5); trichome (9), crenate (1); sinuate elongate (1); rondel (1); unknown phyto (2)
11	2222/7-5	Burial 1: Right M2Supra	sinuate elongate (2); rondel (1)
12	2222/7-5	Burial 1: Left M3Supra	sinuate elongate (2); crenate (1); tricome (1); globular echinate (1); blocky (1)
13	2222/7-5	Burial 1: unidentified tooth root of a mesial tooth	psilate elongate (6); circular psilate (1); unknown phyto (1)
14	2222/6-7	Burial 7: Left C1Supra	psilate elongate (1); blocky (1); bulliform (1); sphere (cluster, possibly Canna, Bixa, Chrysobalanceae)
15	2222/6-7	Burial 7: Right C1Supra	blocky with pits and conifers (1); saddle ellipsoid; bulliform (1)
16	2222/6-7	Burial 7: Right M1Sub	sinuate elongate (1); verrucate elongate (1); hat-shaped (2); circular (12); lanceolate (1); saddle (3); tall saddle(1); scalloped (1) (Cucurbitaceae); hair cell (1); unknown phyto (1)
17	2222/6-7	Burial 7: Left P3Sub	bulliform (15); rondel (2); globular echinate (1); sinuate elongate (1); psilate elongate (1); round (1); hair cell (1); unknown phyto (3)
18	2222/6-7	Burial 7: Left P4Sub	psilate elongate (5); rondel (10); blocky (8); globular echinate (1); trichome (4); hair cell with base (1); segemented hair (1); Calathea allouia (2); jigsaw epidermal cell (1); polyhedral epidermis (2)
19	2222/7-5	Burial 1 and 3 Mixed: Left I2 supra/sub	psilate elongate (1); globular echinate (4); acicular (1); rondel (1); trichome (2); unknown phyto (1)
20	2222/7-5	Burial 1 and 3 Mixed: Left I1 Sub/Supra	bulliform (2); saddle (6); globular echinate (1); psilate elongate (1); bilobate; rectangular (3)
21	2222/7-9	Individual #1: Right M1Sub	conical (1); saddle (5); trichome (1); blocky (1); unknown phyto (1)

22	2222/7-9	Individual #1: Left M1 Supra/Sub	globular granulate (1); saddle (2); collapsed saddle (1); short saddle (1); unknown phyto (1)
23	2222/7-9	Individual #1: Right C1 Sub/Supra	bulliform (1); rectangular (1); trichome (8); saddle ellipsoid (1); flat tower (2)
24	2222/7-9	Individual #1: Right P4 Sub	bulliform (1); trichome (1); rectangle (3); tabular (1); straight edge plate (1)
25	2222/7-9	Individual #1: Left P4 Sub/Supra	saddle (8); rectangluar (1); sinuate elongate (4); rugulose conical (1)
26	2222/7-9	Individual #1: Right I2 Sub/Supra	saddle (6); trichome (2); rectangular (1)
27	2222/7-9	Individual #1: Right M2 Supra	sinuate elongate (7); rondel (1); hair cell (1); saddle (6); bulliform (1); trichome (1)
28	2222/7-10	Teeth from Vessel 3: Right M3 Supra/Sub	saddle (10); elongate psilate (1); trichome (1); rondel (1)
29	2222/7-10	Teeth from Vessel 3: Left C Supra/Sub	saddle (8); long saddle (1); flat tower (1); globular echinate (1); hair cell (1); hat-shape (1); conical (1); facetate terminal tracheid (1)
30	2222/7-10	Teeth from Vessel 3: Left I2 Supra/Sub	sinuate elongate (1); verrucate elongate (1); saddle (9); cone (1); trichome (6)
31	2222/7-10	Burial 4:Left P3 Supra/Sub	saddle (12); trichome (4); bulliform (3); blocky (1); rondel (1); hat shaped (1)
32	2222/7-10	Burial 4 Right P4 Supra/Sub	psilate elongate (6); sinuate elongate pitted (1); saddle (6); trichome (1); blocky (2); bulliform (1)
33	2222/7-10	Burial 4 Right M1/2 Supra	psilate elongate (4); saddle (12); blocky (3); trichome (2); tall rondel (1)
34	2222/7-10	Burial 4: Left I2 Supra	psilate elongate (13); bulliform (2); saddle (4) long saddle (1); rondel (1); blocky (2); trichome (6); oblong (1)
35	2222/7-10	Burial 4: Right P3 Supra/Sub	saddle (4); rondel (1); trichome (4); bulliform (1); psilate elongate (1); blocky (4); unknown phyto (2)

36	2222/7-6	Burial 4 second mandible: Right P3 Sub	saddle (6); rondel (3); globular echinate (2); trichome (4); bulliform (2); psilate elongate (19); blocky (5); conical (1); crenate (1); cross (1); dumbell (1); polyhedral epidermis (1)
37	2222/7-6	Burial 4: Right M1 Supra	trichome (1)
38	2222/7-6	Burial 4: Right C1 Supra/Sub	saddle (7); trichome (4); rondel (2); psilate elongate (4); blocky (3); bulliform (1); hair cell (1)
39	2222/7-6	Burial 4: Left I2 Sub/Supra	saddle (6); trichome (6); rondel (2); psilate elongate (14); verrucate elongate (1); blocky (2); bulliform (1); hair cell (1); perforated rod (1)
40	2222/7-6	Burial 4: Left C Supra	saddle (6); flat tower (1); rondel (1); trichome (2); psilate elongate (1); blocky (3)
41	2222/7-6	Burial 4: Right M2 Sub	saddle (6)
42	2222/7-6	Burial 4: Right P4 Supra/Sub	saddle (4); trichome (9); bulliform (2); rondeld (2); psilate elongate (1); blocky (1)

APPENDIX E: SUMMARY OF STARCH ANALYSIS

Table E1: Dental Calculus starch summary

No.	Provenience	Description	Starch	Description Summary
5	2222/7-5	Burial 6: Right M2Sub	**1**	Extinction cross 3 arms, triangular shape, extremely granulary and bumpy
9	2222/7-5	Burial 1: Left M2Supra/Sub	**9.1**	Six curved extinction arms, ovoid shape, slightly eccentric closed hilum. Fissures and lamellae not visible on a highly granulary surface.
			9.2	Damaged extinction cross, round shape, lamellae not visible, multiple ragged fissures, extensive debris blocking view.
			9.3	Extinction cross damageed, oval, coarse lamellae, closed eccentric hilum, radial fissures and granulary and bumpy surface.
			9.4	Extinction cross has narrow arms. Reniform shape with coarse lamellae and possible radial fissures. Extremely granulary and bumpy surface and slightly eccentric hilum.
			9.5	Damaged extinction cross, round shape, lamellae not visible, multiple ragged fissures, open and slightly eccentric hilum, extremely granulary and bumpy surface.
			9.6	Irregular extinction cross on an oval shape. Lamellae not visible, hilum slightly eccentric and open, lineal fissure.
			9.7	Extinction cross fading, reniform shape, bright circle around closed hilum, oblique

				fissure, granulary and bumpy surface.
			9.8	Extinction cross damaged, quadrilangular form with sharp facets, slightly eccentric hilum, oblique fissure. Surface is very granulary and bumpy with pitting.
			9.9	Compound, spherical grains covered by wrinkles, extinction cross diminishing, but wavy arms noted.
			9.10	Extinction cross slightly damaged, oval shape, lamellae not visible, hilum slightly eccentric and open, oblique fissures, granulary and bumpy surface.
			9.11	Extension cross has broad undulating arms, reniform shape, lamellae not visible, hilum closed and centric, surface is granulary, bumpy, and has dark depressions.
			9.12	Extinction cross with broad arms, lamellae not visible, oval shape, hilum centric, longitudinal fissures, surface is smooth and bumpy.
			9.13	Extinction cross damaged, reniform, lamellae not visible, hilum slightly eccentirc, longitudinal fissure, granulary and bumpy surface.
			9.14	Weak extinction cross, spherical shape, no visible lamellae, double outer wall, hilum centric with x fissures, granulary surface with dark pits

			9.15	Compound, spherical grain covered by starch fragments, extinction cross visible, dark pit and cuneiform shadow on distal end, suface is gralulary and very damaged.
			9.16	Extinction cross with wavy arms, renifrom, double outer wall with no visible lamellae, slightly eccentric hilum, circular fissure, and bumpy surface.
			9.17	Compound, spherical granules, extremely wrinkled, deep crack in granule
			9.18	Partial hemisphere grain with partial extinction cross and open eccentric hilum.
			9.19	Compound granule, extremely wrinkled, major crack in granule
			9.20	Extinction cross is eccentric, oval shape with distal end proturbence. Open hilum, linear fissure.
12	2222/7-5	Burial 1: Left M3Supra	**12.1**	Extinction cross has bent arms, ovoid shape with straight facets and a major concave depression in one facet, lamellae visible, eccentric hilum and smooth surface.
17	2222/6-7	Burial 7: Left P3Sub	**17.1**	Spherical granule with two straight facets, extinctive cross, granulary surface, centric hilum.
26	2222/7-9	Individual #1: Right I2 Sub/Supra	**26.1**	Extinction cross exhibits one triangular, broad arm (plus 3 others), polygonal shape with two pressure facets, open hilum, smooth surface with radial fissures.

			26.2	Compound polygonal with straight facets, extinction cross visible, open centric hilum, linear fissure, smooth surface.
29	2222/7-10	Teeth from Vessel 3: Left C Supra/Sub	**29.1**	Spherical compound (2) with extension cross, slightly eccentric hilum, granulary surface.
35	2222/7-10	Burial 4: Right P3 Supra/Sub	**35.1**	Extinction cross damage, oval shape with at least two straight facets, open, centric hilum, circular fissures, surface is granulary and bumpy.
			35.2	Spherical with straight arm extinction cross, at least two straight facets, eccentric hilum with Y fissure and smooth surface.
36	2222/7-6	Burial 4 second mandible: Right P3 Sub	**36.1**	Extinction cross damage, oval shape with at least two straight facets, open slighly eccentric hilum, radial fissures, very granulary and bumpy surface.
			36.2	Polygonal with pressure facets, extinction cross damage, slightly eccentric open hilum, circular fissure.
39	2222/7-6	Burial 4: Left I2 Sub/Supra	**39.1**	Extension cross damage, hemisphere with multiple straight facets, open slightly eccentric hilum, circular fissure, smooth surface.
41	2222/7-6	Burial 4: Right M2 Sub	**41.1**	Extension cross damage, hemisphere with closed, verry eccentric hilum, circular fissure, granuary surface, at least two pressure facets

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