From Foragers to Farmers in Tropical Forests: How Paleoindian and Archaic Peoples in Southern Belize Adapted their Lithics, Mobility, and Subsistence to a Changing Holocene Climate

by

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ABSTRACT

This study examines almost 5000 lithic artifacts from three rockshelters in the Belize, part of the Maya Lowlands. These sites bear evidence of human occupation throughout the last 14,000 years, a period over which I assess change in four lithic traits: 1) cortex, or the weathered outer surface of a toolstone cobble; 2) platform type, or the degree of preparation of striking platforms; 3) bifaciality, or whether tools were flaked on one or both faces; and 4) retouch, or the removal of small flakes from tool edges. These traits are differentially associated with two modes of technological organization: curation and expedience. Curation involves greater effort spent creating tools with longer use-lives and is associated with low levels of cortex, more complex platforms, more bifacial flaking, and higher amounts of retouch. It is also more typical of highly mobile hunter-gatherers who move their residential base often. Expedience, which entails less effort creating lithics with shorter use-lives, is associated with higher amounts of cortex, simpler platforms, less bifacial flaking, and lower levels of retouch; it is also associated with more sedentary hunter-gatherers.

My results indicate that, during the Late Pleistocene in Belize, groups favored curation and were likely highly mobile foragers inhabiting an open grassland landscape. However, not long after the Pleistocene-ending Younger Dryas climatic event (~12,600 to 11,700 cal BP), these groups began to favor expedience, indicating they'd begun to adopt a more sedentary lifestyle. This shift towards expedience and sedentism continued throughout the Early and Middle Holocene, when closed-canopy tropical forests came to dominate the landscape. I conclude that these foragers began to adopt lower levels of residential mobility much earlier than generally thought. Because the sparse, unpredictable nature of wild tropical forest flora and fauna favors high residential mobility, this means they were likely manipulating their landscapes and experimenting

with cultivars several millennia before the first appearance of sedentary farming villages. This further implies that the origins of sedentism and agriculture in tropical forests must be sought in the changing lifeways of pre-agricultural, semi-sedentary forager-horticulturalists of the deep past.

DEDICATION

I lovingly dedicate this dissertation to the best and brightest accomplishment in my life, my daughter Ayla Elizabeth Rizvi. Ayla, your Daddy is incredibly proud of how quickly you are growing into a bright, loving Kindergartner, and can't wait to see what revelations the coming years will bring. Your simple joy at everyday discoveries is a constant reminder of the curiosity that drove me to become a scholar and scientist. Your love and affection have motivated and sustained me through this long, arduous dissertation-writing process in ways you may never understand. For these, and so many other things, I thank you from the bottom of my heart. I love you!

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CHAPTER 1

PROJECT OVERVIEW

Thousands of years before the ancient Maya slashed their first maize fields out of the dense forests of Central America, their ancestors hunted, gathered, and fished their way across the same wild, uncultivated landscapes. Although the date of the initial colonization of Central America – and indeed, of the Western Hemisphere – is constantly being adjusted, a solid amount of evidence indicates that humans were regularly exploiting the region we now call the Maya Lowlands by at least 14,000 years ago (Stinnesbeck et al. 2017; K. M. Prufer et al. 2019; Douglas J. Kennett et al. 2020; Posth et al. 2018). Aside from the basic fact of their presence on the landscape, little is known about these earliest of Mesoamericans. More is known about the climate and ecology of the region during that time, however – enough to tell us these ancient humans were inhabiting a landscape quite different from the heavily forested mountains and plains their descendants farmed (Islebe et al. 2019). Paleobotanical evidence also tells us that they had not yet domesticated any of the plants that would become regional staple crops – maize, manioc, squash, and others (Piperno 2011). From these somewhat indirect lines of evidence, archaeologists have concluded that the first people to inhabit the Maya Lowlands were hunter-gatherers moving about a cooler, drier, and more open Central American landscape. We also know that this state of affairs didn't last all that long.

As Earth's orbit changed over the centuries, greater amounts of more direct sunlight brought about the end of the Last Ice Age – and the beginning of the warmer period we currently enjoy – around 11,700 years ago (Haug et al. 2001; Correa-Metrio et al. 2012). These higher levels of insolation led to melting of glaciers, increasing evaporation, and a multitude of climatic changes that affected Central America. Sea levels rose while precipitation increased over continent-wide areas. The Gulf Stream oceanic current carrying warm tropical waters began to shift northward during the middle of the Younger Dryas (Pearce et al. 2014), while the Atlantic meridional overturning circulation (AMOC) regained the strength it had lost during the last Ice Age and Younger Dryas cold event (J. et al. 2004). At the same time, CO_2 levels increased from Late Pleistocene lows of ~240 ppm to over 300 ppm (Wagner et al. 1999). And the floral biosphere responded with a fluorescence of growth brought about by these increasingly favorable conditions. Landscapes that had once been open savannahs quickly became covered in broadleaf forests that had, until then, been confined to mountaintop refugia where cooler air allowed for greater rainfall than the valleys below (Leyden 1984; Correa-Metrio et al. 2012).

At the same time – perhaps as a response to changing conditions, perhaps as a result of population growth and greater familiarity with the region – human groups were having measurable impacts on the ecosystems they had now occupied for several millennia (Ranere and Cooke 2020a; Ranere et al. 2009; Douglas J. Kennett et al. 2017). Predation on high-ranked megafaunal prey species likely hastened extinctions that had begun as a result of climate change (Doughty et al. 2016; Doughty, Faurby, and Svenning 2016). Environmental manipulation on small scales, such as the controlled use of fire to create open patches in otherwise closed canopy forests, led to mosaics of forest patches at different stages of development. Movement of human groups from one region to another introduced economic plant species that otherwise may not have traveled as far or crossed ecosystem boundaries on their own. In fact, human groups were likely influencing forest compositions during the same centuries that those same forests were first colonizing relatively new areas (Iriarte et al. 2020). Unlike tropical forests in Africa and Asia, which may have evolved for millennia alongside humans who made their homes there (Mercader 2002), these relatively new Central American forests had to adapt to the presence of human groups almost from the start.

At some point in that development, descendants of the first Americans domesticated the first cultivars and spread them throughout the region. The earliest regional evidence of cultivars contributing a significant contribution to the human diet to dates to 8800-7700 cal BP (Piperno and Dillehay 2008; Piperno 2011). In the Central Balsas region of Mexico and in central Panama, multiple proxies point to slash-and-burn cultivation being practiced as early as 7600-2700 BP (Pohl et al. 2007; Piperno 2011) Much later still, other descendants founded the first full-time, sedentary villages (Rosenswig 2015a). In the Maya Lowlands, this latter group initiated a pattern of widespread land clearance and forest management that persisted for at least a thousand years, culminating in the creation of enormous cities surrounded by heavily landscaped agricultural terraces (Torrescano-Valle and Islebe 2015; Carrillo-Bastos et al. 2010; Beach et al. 2009). The ruins of these cities continue to captivate and inspire generations of their descendants, not to mention tourists and archaeologists from elsewhere. Yet the story of how they started that journey is relatively unknown. When did ancient peoples first begin adopt less mobile, more sedentary settlement patterns? At what point did they come to rely more on cultivated resources than those they hunted and gathered? How did their lifeways change in response to these shifts in mobility? These questions, although equally as important as those about the first pyramids or the "collapse" of the ancient Maya, have received a great deal less attention (Lohse 2010; Rosenswig 2015a), and so, less is known about these seminal moments in Central American prehistory.

Background & Models

Hunter-gatherers in tropical forest have long posed something of a quandary to anthropologists and archaeologists (Mercader 2002). Although many such groups were known from the ethnographic literature, it was also clear that these groups had intimate ties with nearby horticultural or agricultural groups. Because these ties often involved trade of subsistence goods over long periods of time, some scholars began to wonder if hunter-gatherers could survive in tropical forests without recourse to some amount of "cultivated calories." These skeptics (R. C. Bailey 1981; Headland 1987) pointed out that, although such forests are seen as some of the most productive, diverse habitats on the planet, much of the biomass within them is inedible to humans, and that which is edible tends to be spread out and unpredictable (and more easily reached by arboreal competitors, such as other monkeys). Based on these ecological characteristics of "undisturbed" tropical forests, and the lack of "pure" hunter-gatherers in the literature, these scholars concluded that human groups couldn't survive in tropical forests without cultivation of some sort.

Almost immediately, other scholars pointed out the ingenuity that extant tropical forest foragers evince when exploiting their habitats (Colinvaux and Bush 1991; Iriarte et al. 2020; Roosevelt 2013; Yasuoka 2013). They pointed to archaeological evidence of human occupation of tropical forests before horticulture or agriculture had yet made an appearance in nearby areas. Overall, they concluded, tropical forests were rich enough in resources that hunter-gatherer groups could indeed make a living in tropical forests all by themselves. As the debate evolved, it began to turn more on the meaning of terms like "pure" foragers or "undisturbed" forests, as recognition grew that all foragers manipulate and disturb their environments, sometimes in ways similar to those of horticulturalists. Eventually, the initiators of the debate settled on stricter criteria for archaeological evidence that they believed could settle the debate: sites that had been surrounded by tropical forests in the past (not just the present) and that were older than 5000 years old (or even better, 9000 years old) (Headland and Bailey 1991). If such evidence could be found, it would show that human groups could indeed survive in tropical forests without cultivation.

Although I did not initially choose my project sites based on these criteria, I came to realize that they were ideally situated to capture the full suite of human behavioral adaptations in tropical forests – before the adoption of cultivation, during its initial development and dispersal, and at the dawn of fully sedentary, agricultural village life. I thus required models of human mobility, subsistence, and technology that would offer predictions about this wide array of behaviors. Thankfully, research into hunter-gatherer adaptations (and those of small-scale societies in general) had developed in tandem with the debate about cultivated calories in tropical forests. Early ideas about "pure" hunter-gatherers who were either "nomadic" or "sedentary" had given way to a conception of mobility that placed hunter-gatherer land use strategies along a spectrum from "Residential Mobility" to "Logistical Mobility" (Binford 1980, 2001; Barton and Riel-Salvatore 2014; Matt Grove 2009). Groups who favor Residential Mobility Strategies (RMS, also referred to as simply foraging) make frequent moves between residential camps; at each new site, resources surrounding the camp within a foraging radius are exploited until they reach low levels, at which time the entire group moves camp to a new site. On the other end of the spectrum are collectors, or those who favor Logistical Mobility Strategies (LMS); in these groups, residential camps are occupied for longer periods of time, and small task groups undertake logistical forays to fetch specific resources from sites farther away from camp. The development of this way of thinking allowed for groups to transition between the two strategies during the course of an annual cycle, and introduced a dynamic model to account for dynamic human behaviors.

At the same time, more nuanced studies of the ethnographic record showed us that the sharp division between foraging and horticulture was equally misguided.

Instead, some foraging groups engaged in practices similar enough to agriculture to be called "proto-agriculture" (Keeley 1995); likewise, some horticulturalists engaged in periods of Residential Mobility during which they relied mostly on foraged resources (e.g. Endicott and Bellwood 1991). And although few of these groups were still utilizing lithic technology by the time trained anthropologists arrived to observe them, those that were showed interesting associations between lithic practices and mobility strategies. Altogether, then, a number of different models and heuristic spectra existed which would allow me to avoid the black-and-white terms of past debates, and instead allow me to look for more dynamic changes in the data over time. By aligning spectra related to mobility and subsistence with a continuum of lithic technology, and assessing the available data to see where lithic artifact assemblages fell along the latter, I would be able to draw conclusions about unobservable behaviors like mobility using residues of observable ones – in my case, lithics.

Equally important to establish is a firm link between mobility and subsistence, especially behaviors related to proto-agriculture. To that end, I consulted two large datasets that aggregate and quantify information about hunter-gatherers from the ethnographic record: Keeley's (1995) and Binford's (2001) datasets. The former records one aspect of forager mobility by quantifying the longest period of time each foraging society typically spends at a single camp; it also captures proto-agricultural behaviors through an index called Plant Intensification, which is made up of observations of hunter-gatherer behaviors such as burning patches of land to promote secondary growth or the tending of wild plant species. In tropical and subtropical regions, these two variables are strongly positively correlated: that is, the greater the length of time at one camp, the higher the value of the Plant Intensification index. Furthermore, Binford's (2001) dataset records another variable related to mobility, the number of residential moves made by a given group in a typical year. This dataset is not without its problems, which I address in greater detail in Chapter 2, but I found it reliable enough to be useful. By cross-referencing Binford's (2001) dataset with Keeley's (1995), I created a small subsample of groups for whom all three variables were available. Though small, this analysis also showed the expected correlations amongst the variables – that is, less mobile groups relied more heavily on plant intensification. I present these data in greater detail in Chapter 2, along with a discussion of their implications for my research.

While the ethnographic data described above provides evidence of a link between human mobility and subsistence, it does little to explain the mechanism behind that link, and so cannot be used to make predictions about the timing of changes in mobility and subsistence. In order to do so, I draw on theorists (such as Piperno (2011)) who utilize the scientific approach known as Human Behavioral Ecology (HBE), which is "the study of human behavior from an adaptive perspective" (Nettle et al. 2013, 1032). HBE extends to humans a theoretical methodology developed by the field of behavioral ecology, which aims to "understand how an animal's behaviour is adapted to the environment in which it lives" (Davies, Krebs, and West 2012, 5). This paradigm utilizes fundamental concepts in evolutionary theory (such as adaptation and natural selection) to explain animal behaviors. HBE theorists do the same for human behaviors, and often utilize ethnographic research to show the myriad ways that foragers can manipulate tropical forests. In doing so, they dispense with terms like "pure" foraging or "undisturbed" tropical forests and allow that human groups might exhibit more than one type of mobility or subsistence in a given environment(Rosenswig et al. 2015; Douglas J. Kennett and Winterhalder 2005; Piperno 2011). Instead, Piperno (2011) utilizes the terms "nondomestication" or "predomestication cultivation" to describe the ways that foraging groups manipulate wild plants in their environment. Although Piperno (2011) does not explicitly make predictions about mobility in her work, ethnographic evidence described above (and detailed in Chapter 2) indicates that foragers alternate between periods of high-RMS and high-LMS throughout the year, in part based on their seasonal use of manipulated plants. However, my study does not have such sub-annual resolution; instead, I look for changes in mobility over a period of millennia, using several lithic traits that are thought to be directly related to mobility strategy used by the people who crafted the lithics in question.

The heuristic spectrum used for lithic technological organization ranges from curated to expedient tool production, use, and discard (Binford 1979; Bamforth 1986; Parry and Kelly 1987; Shott 1986). Essentially, curated tools are multi-purpose or flexible-use tools that are made in advance of their use; they are carried for longer periods of time and are sometimes resharpened or retouched to maintain a functional edge. They also tend to be recycled into another tool type by further retouch or flaking. On the other hand, expedient lithics are generally made at the time of use for a single purpose and are often discarded after they have performed their intended function for a rather short period of time, and are almost never recycled into another type of tool. Anthropologists and archaeologists have deduced hypotheses about why groups choose one type of technology over another according to factors such as subsistence, social convention, or raw material access.

It is this last factor – variability in access to lithic resources – that is thought to be the best predictor for where a group's lithic technology will fall on the continuum from curated to expedient (Bamforth 1986). According to these theorized relationships, groups that have reliable access to high-quality toolstone are predicted to favor expedient lithics, which generally have the sharpest edges and can be crafted with little effort. Groups with more variable access to toolstone are predicted to favor curation, which allows them to create tools that are flexible yet efficient, at the cost of greater time and effort in their crafting and maintenance. Importantly, mobility and settlement patterning are important drivers of lithic raw material access. High-RMS groups (i.e. those who move their residential camps frequently) tend to have more variable access to toolstone, and so focus on provisioning people with toolstone, whereas high-LMS groups (i.e. those with more stable residential camps) can provision those places with toolstone collected during logistical forays (Kuhn 1992). These associations have been validated by the ethnographic records of groups who maintain various types of lithic technology (Parry and Kelly 1987; M. Shott 1986). They have also been tested and validated using archaeological data, specifically in cases where some independent measure of mobility is available (such as raw material sourcing or strontium isotope analysis) to compare to lithic traits that indicate curation or expedience. These associations, and the evidence for them, will be explored in greater detail in Chapter 2.

Hypotheses & Test Predictions

Having established an empirically tested model that links forager subsistence, mobility, and lithic technological organization, I develop hypotheses about each topic for the specific case of the Archaic-period Maya Lowlands, specifically in Belize. These hypotheses flow from the theoretical debates described above, especially the “cultivated calories” debate and human behavioral ecology. Regarding the former, several Mayanists appear to share the opinion that tropical rainforests make poor habitats for hunter-gatherers. These scholars proposed that the first Maya farmers originated from outside the Maya Lowlands, followed large rivers into the interior, and colonized the otherwise empty tropical forests they found there (Ball and Taschek 2003:205; Puleston and Puleston 1971; Iceland 1997:176; Marcus 1995:6; Kelly 1993:224).

While it’s not entirely certain that these theorists explicitly shared the view that “undisturbed” tropical forests were uninhabitable to “pure” hunter-gatherers, they rest their assumptions on an overall lack of evidence for human populations dating to the Archaic period. In doing so, they essentially characterize the Maya Lowlands on the eve of Maya settlement as empty or so lightly occupied by highly mobile foragers as to be essentially unoccupied (a scenario I term the “Vacant Belize” hypothesis). In terms of the model I outlined above linking mobility and subsistence, the presumption that the Maya Lowlands were occupied by high-RMS foragers implies that they would not have practiced any sort of cultivation. Even low levels of cultivation (such as proto-agriculture) are highly associated with low residential mobility (a point I develop in greater detail in Chapter 2), whereas sparse, unpredictable wild resources in tropical forests demand high levels of residential mobility. In terms of lithic technology, were the Vacant Belize hypothesis true, I would expect to see heavily curated lithics throughout the entire Archaic-period sequence of my rockshelter sites because of the association between curated lithics and high-RMS foraging described above.

Yet what if the Vacant Belize hypothesis were not true? Assuming that the tropical forests of the Maya Lowlands were occupied by greater numbers of humans with low levels of residential mobility, how would their lithic technological organization change during the long Archaic period, and when might such changes have occurred? This question is not as easy to answer, as there are several different scenarios whereby the highly mobile groups of the late Pleistocene may have transitioned to less mobile forager-horticulturalists. Furthermore, there are several ultimate drivers that might have influenced the timing and nature of such changes. One is climate, which heavily influences the distribution and predictability of wild resources in any ecosystem, and so affects human mobility patterns and lithic technological organization. Central America’s climate underwent several dramatic changes throughout the end of the Pliestocene and Holocene, the time period during which my study's rockshelters were in use. In chapter 2, I review these changes in greater detail, and in Chapter 5 I present correlations between changes in lithic data and changes in a climate proxy, Bulk Sedimentary Titanium % from the Cariaco Ocean core, that spans almost the entire period for which I have data.

Another potential driver of changes in mobility and lithic technology is the greater familiarity with tropical forest plant resources that human groups would have gained over time. Theorists like Piperno (2011) argue that neotropical domesticates came about because of greater human experimentation with and even direct selection of various plant species over time. These human-plant dynamics can be directly observed with paleobotanical and, in the case of maize, bioarchaeological stable isotope data. At my study rockshelters, only the latter type of data have been analyzed and published (Douglas J Kennett et al. 2020), but the vast majority of it comes from the very end of the Archaic period, and so cannot be used to explain lithic changes observed in early parts of the sequence. Yet because increasing reliance on plants (both wild and cultivated) is likely correlated with time, in Chapter 4 I also present correlations between changes in lithics and the passage of time.

Of course, as mentioned above, climate also greatly influences the distribution and predictability of the wild plant resources that served as the raw materials with which humans experimented during the domestication process. It may not be possible to directly tease apart the separate influences of climatic changes and the passage of time. Yet if changes in lithic technology are more highly correlated with one or other, or if the nature and strength of those correlations change at one or more points in the sequence of rockshelter occupation, it may be possible to estimate at what point in time the influence of one factor (such as climate) declined while the influence of another increased.

Instead of predicting millennia of sparse occupation by highly mobile foragers bearing heavily curated lithics, the hypotheses described above predict dynamism in mobility, subsistence, and lithic technology linked to both climatic variables and human impacts on their environment. There are several possible scenarios for the timing of changes in these traits, which I will term "early," "middle," and "late". All share as a starting point the prediction that the earliest part of the Archaic would likely be marked by highly mobile groups descended from the first colonizers of the Maya Lowlands who occupied a much drier, more open landscape. In the "early" scenario, a change to low-RMS and low curation would be predicted to occur at the beginning of the Early, corresponding to the end of the Younger Dryas and the beginning of warming conditions and greater forestation. This scenario is based on the idea that climate, not greater expertise with and utilization of wild plants, is the biggest driver of changes in subsistence and mobility.

In the "middle" scenario, the same change in mobility and curation is predicted to occur at the end of the Early Holocene, coinciding with the peak in warmth and wetness evidenced by climate proxy data. This scenaio also emphasizes the growing importance of cultivars after 8000 cal B.P., which marks the domestication of maize in the Central Balsas region of Mexico. Finally, the "late" scenario predicts that it is not until the later part of the Middle Holocene that groups with much lower levels of RMS, and more expedient lithics would emerge. This prediction is based on the idea that it would take a relatively long time for human groups in Belize to develop a greater reliance on proto-agriculture or gain access to early cultivars domesticated in other regions (like the Central Balsas).

Beyond these somewhat straightforward hypotheses, a fourth scenario is that human groups shifted between high-RMS and high-LMS several times throughout the millennia in question, either in response to changing climate, changing importance of cultivars, or some other unknown factor. In this scenario, the overall trajectory of changes in mobility and subsistence would likely be non-linear, fluctuating in response to changes these drivers in a way that is difficult to predict. It would be evidenced by back-and-forth shifts in traits indicative of curation or expedience over the entire sequence. All of these hypotheses, and the test predictions they entail, are developed in greater detail in Chapter 2.

Study Area and Regional Chronology

I began fieldwork on this project in 2013, when I joined Dr. Keith Prufer and several of his students from the University of New Mexico at their field camp in Big Falls, Belize. Over the course of the next several field seasons, I continued to excavate with that team, either as part of the Uxbenka Archaeological Project (UAP) or Bladen Paleoindian and Archaic Project (BPAAP). All three of the shelters from which I draw my data are located in the Toledo district of southern Belize, and all three share similarities in overall setting and ecology. They are each located along jungle covered escarpments that parallel major watercourses (although today these rivers and creeks do run dry at certain times of the year). They each contain comfortably dry pockets even during the rainy season, and the lack of sunlight and water means very little plant growth occurs within the dripline. And all have evidence of extensive use by the Classic Period Maya who lived in nearby settlements and often buried at least some of their dead within the shelters. Below, I provide a brief introduction to each shelter; I discuss peculiarities of each shelter in Chapter 2, and present summaries of excavation results in Chapter 3.

The first site, Tzib'te Yux (hereafter Shelter 1), is located in the hills just outside of the large Maya polity of Uxbenka, near the present-day village of Santa Cruz. It sits roughly 10 meters above a wide, deep pool of the Rio Blanco that holds water even during the dry season, when other sections of the river run dry. It is the smallest of the three shelters, but still contains a roughly 80 m^2 sheltered space beyond the dripline of the overhanging cliff face. Prior to excavations, the shelter was known to local Maya communities and visiting archaeologists alike, in part because the crumbling remains of a large plaster frieze adorn its rear wall, a rare occurrence throughout the Maya Lowlands (Meredith 2014b). Excavations were first carried out to document the Classic-period Maya use of the shelter, but aceramic layers were encountered not far below the surface, in the densely packed midden of jute snail shells that characterizes much of the shelter's sediments. Charcoal samples were collected from within this midden as well as from the reddish clay layer beneath it, which lay in contact with the underlying bedrock and roof spall. After AMS dating returned surprisingly early Paleoindian and Archaic dates (K. M. Prufer, Meredith, et al. 2017), excavations within the shelter were expanded to document the extent of the jute midden and the red clay layer beneath it. By creating a sediment deposition model using a series of dates, Dr. Prufer and colleagues were able to ascertain that a large portion of the upper end of the deposition sequence was missing, possibly during Classic-period Maya use of the site.

The second site is called Maya Hak Cab Pek (Shelter 2), and is located much further into the interior of Belize within a large forested area known as the Bladen Nature Preserve. It sits about 15 meters above the Bladen Branch of the Monkey River, which also has dry sections during the dry season. First excavated in the 1990's by a team that included Dr. Prufer (who was then a graduate student) ((K. M. Prufer 2002; Saul, Prufer, and Saul 2005a, 2005b); it was the site of further excavations starting in 2014, when Dr. Prufer returned with a team as part of his BPAAP project (K. M. Prufer et al. 2015), and again in 2016, when I joined them in the field (K. M. Prufer, Thompson, et al. 2017). Although the earliest excavations focused only on ceramic-bearing levels from the Classic Maya period, its potential for deeper and older deposits made it an attractive subject for further study. Around 1000 lithics from this site were analyzed by project member Chris Merriman, who trained me in the methods he used so I could apply them to the unanalyzed lithics from this rockshelter, as well as the other two. Shelter 2 is larger than Shelter 1, but not as large as the third shelter. Importantly for this study, it was the only site to exhibit medium-to-large nodules of chert embedded in the limestone walls, where they had lain since being deposited when the entire formation was underwater.

The third shelter is known as Saki Tzul (hereafter Shelter 3), and is located not far from Shelter 2, along a tributary of the Bladen branch known as Ek Xux creek. It was first excavated in the 1990's along with Shelter 2 (Saul, Prufer, and Saul 2005a, 2005b), when only Classic-period levels were explored. Dr. Prufer and BPAAP did not return there until 2016 to excavate further below and assess the potential for preceramic deposits (K. M. Prufer, Thompson, et al. 2017). Shelter 3 is the largest of the three sites, over twice as long and half again as deep as Shelter 2; this disparity in size means that a much smaller proportion of Shelter 3 has been excavated, a fact that is discussed in the context of my lithic analysis results in Chapter 4.

Early attempts to understand the long pre-Maya time period generally focused on aceramic surface scatters of lithic material. In particular, MacNeish and colleagues (MacNeish 1981; MacNeish, Wilkerson, and Nelken-Terner 1980; MacNeish and Nelken-Terner 1983) created a relative chronology for the area based on several different styles of projectile points. These scholars assigned dates for each style using similarities to

North American projectile points that were more securely dated. Prior to the excavations on the part of UAP and BPAAP, only two such points were found in dateable contexts; recent work has highlighted problems with these dates, and with the entire method of tying Belizean chronology to North American projectile points (K. M. Prufer, Meredith, et al. 2017; K. M. Prufer et al. 2019).

Few other records of Archaic-period settlement were known from throughout Belize. For example, the area around the Maya-period site of Colha has yielded several sites with dateable strata that clearly demonstrate occupation by non-ceramic-using peoples (Harry B Iceland 1997). While lithic tools are plentiful, especially a type of adze known as a snowshoe scraper or constricted uniface, projectile points like those described above were not found there. In western Belize, another rockshelter site known as Actun Halal yielded pre-Maya ecofacts, including faunal remains of animals that went extinct in the region well before the Maya arose (Lohse et al. 2007). Altogether, then, there exist many tantalizing clues of human occupation of great time-depth in the region, but no sites containing well-stratified deposits dating throughout the long Archaic period had been excavated – until the three shelters described above yielded these materials. For this reason, they serve as ideal locations for testing hypotheses about forager mobility and subsistence through time and across space using lithic assemblage traits relating to curation and expedience.

Materials and Methods

Even among pottery-using cultures, lithic artifacts are among the most ubiquitous of archaeological finds; this is truer still for aceramic foraging groups like the pre-Maya peoples I study. Lithicists have developed numerous methods for characterizing lithics, often arranging traits along various spectra; they use these methods to reconstruct steps in lithic production, utilization, and maintenance; or to better understand the physics that determine lithic shape and size based on raw material, method of percussion, and platform size. For my purposes, I focus on several “core traits” that have been linked, either by theory or ethnographic observation, to either curation or expedience in lithic technological organization. In this study, those four traits are cortex, retouch, platform type, and flaking method.

Each of these traits varies in such a way that one or more variable states is linked to curation, and one or more to expedience. For instance, cortex refers to the weathered or calcined outer rind of a chert cobble; because it is often flawed and/or less durable than the interior, it is not as suitable for tool making (Andrefsky 2005; Dibble et al. 2005). Curated lithics tend to have very little cortex on them, since more mobile foragers tend to remove most of this unsuitable part of a chert cobble nearer to the source. Any remaining cortex will quickly be removed as tools fashioned from those cobbles are shaped, resharpened, recycled, and eventually whittled down to an unusable nub. On the other hand, foragers who utilize expedient lithics may not remove as much cortex, since they tend to cache cobbles near their central residential camps for future use rather than carrying them long distances. Furthermore, they are as apt to utilize and then discard a flake with cortex as one without; so long as one or more of its edges are sharp, it will get the job done and can then be discarded.

Each of the other three traits can be similarly linked to curation or expedience based on its state. Retouch refers to the intentional removal of small flakes from the working edge of a tool; it is often done to replenish or resharpen a worn edge or to produce a jagged, serrated edge (Bamforth 1986; Young and Bamforth 1990; Barton and Riel-Salvatore 2014). Foragers who curate their lithics will use retouch as a way to get more use-life out of each piece; in some cases, even the retouch flakes that are removed will be utilized despite their small size. Thus, retouching tools represents a way to both extend their use-life and get the most cutting edge out of a given mass of toolstone. On the other hand, foragers who practice expedience will be less concerned with keeping an old tool functional or getting the most cutting edge from a single cobble. Because they have ready access to fresh stone from their residential caches, they will simply chip off a fresh flake rather than continue to utilize an old one.

Platform type can be similarly aligned with the curated-expedient spectrum (Messineo and Barros 2018). The simplest platforms are those with cortex still on them; they represent no effort made to prepare a spot on the core to be struck by the hammer. Non-cortical plain platforms are only somewhat less simple; for these, cortex is removed, but no further modifications are made to the intended point of impact. Both of these types are associated with expedient rather than curated lithic technology. On the other hand, complex platforms represent increasing amounts of effort and planning put into platform creation. Crushed or ground platforms are those whose surface has been roughened to give a hammer better purchase. Faceted platforms are further modified through removal of small micro-flakes parallel to the platform surface; as with crushing, this allows for more controlled flaking by ensuring only one spot on the platform is impacted by the hammer. Because they represent greater effort, but also result in better conservation of lithic material, these types are associated with curated lithic technology.

Finally, the method that flakes are struck from cores and further shaped is also indicative of curation or expedience (Cornejo B. and Galarce C. 2010; Andrefsky 2005). Unifacial flakes are those with a single interior (or ventral) surface; once struck from the core, any further modification is done on only one side of the flake. Many types of scrapers tend to be unifacially flaked, because the working edge only needs to be removed on the dorsal side to allow the tool to continue functioning. On the other hand, bifacial flaking involves removing material from both the ventral and dorsal surface of a flake. Projectile points are among the best, most complex examples of bifacially flaked tools; for these tools, the original unifacial flake is almost unrecognizable because so much material has been removed to shape it into a specific form. Unifacial flaking requires far less effort and time than bifacial flaking; it is most closely linked to expedient lithic technology. Bifacial flaking, on the other hand, in some ways represents the epitome of curation in that it involves a great deal of investment and preparation, allows for the greatest control over the final product, and also produces the greatest quantity of smaller retouch flakes which can be used as informal tools in their own right. Each of these four traits, then, allows me to independently assess the level of curation each lithic represents.

In addition to these core traits, I measured a number of other basic traits (such as length, width, thickness, and mass), which I discuss in greater detail in Chapter 3. I had also intended to conduct a small chert-sourcing study on a 40% subsample of artifacts from each site. Over the course of several field seasons in Belize, I had collected geological chert specimens from locations near each rockshelter; Dr. Prufer collected additional specimens during his visits to the sites as well. I had planned to use a portable X-ray Fluorescence (pXRF) machine owned by Dr. Prufer's lab to conduct trace element analysis on these geological specimens and my 40% subsample of artifacts, following methods developed by one of Dr. Prufer's students (Nazaroff 2015). This would allow me to identify the proportion of chert artifacts that were made on local chert, which would in turn provide me a somewhat independent measure of mobility, in that non-local cherts would tend to be associated with greater residential mobility. However, due to a shutdown of lab-based research during the COVID-19 pandemic, most of my subsample was not analyzed in a timely fashion. Prior to the pandemic, I was able to assay all of the geological specimens and use them to create calibration curves for the pXRF machine.

For that reason, I will briefly discuss the results of my pXRF analysis of geological source specimens in Chapter 4.

Preview of Results

Because excavation results of all three sites have been previously published, I provide only a brief summary of work completed at each shelter. Most importantly for purposes of this dissertation, I also provide age-depth models for all three sites using both published and unpublished radiocarbon dates on samples gathered at each site over several field seasons. To calibrate these dates and provide age estimates for non-dated levels, I utilized a soil deposition model that is part of Bchron, a software package created for the R statistical platform to allow calibration of sediment cores and other depositional sequences (Haslett and Parnell 2008; A. C. Parnell et al. 2008). While taking into account unique depositional sequences, I used a similar process across all three sites. I first converted the depth measurements for each radiocarbon sample from "depth below datum" to "depth below surface," using ArcGIS 11.0 for cases where the rockshelter surface was noticeably uneven. I fed these measurements, and their associated uncalibrated dates, into the Bchron calibration package, which transformed the dates from "radiocarbon years before present" to "calendar years before present," or cal BP. Because Bchron also interpolates ages for depths that had no associated carbon sample, I was able to estimate depths for all levels of the rockshelter, and thus assign approximate ages to each lithic assemblage, a vital step for my ability to document changes in lithic technology over time.

In presenting my results, I focus on change over time for each lithic trait individually, and examine both Shelter-specific and aggregate trends. My unit of analysis for these trends is the level-based assemblages made up of those artifacts excavated in one level. In order to compare assemblages of different size from levels with different dimensions, I transform the data in two ways: proportionate and density-dependent. In the former, I calculate the percentage of each assemblage that evidenced a given trait state; for the latter, I calculate the volume-normalized artifact discard rate in terms of lithics per cubic meter per century. Finally, in looking for a relationship between time (represented by the level's Median Age) or climate (represented by the level's Mean Bulk Sedimentary Ti % from the Cariaco core) and frequency or density of each lithic trait, I chose to examine non-parametric correlations and covariance. For the most part, I begin by presenting linear trends as a way of broadly showing the way each trait varies as time passes. However, I also note that non-linear dynamics have been observed for this period in one important causal factor: climate. The late Pleistocene and Holocene periods have not witnessed entirely steady climates, nor have they been characterized by unidirectional change from cold and dry to warm and wet; rather, Central America experienced at least three swings from cold/dry to warm/wet (and back again) during the past 16,000 years. Because this climatic oscillation is non-linear, and because mobility (the driving force behind lithic organization) is in part driven by climatic and environmental variables, I expect to see oscillations in lithic trends over time as well.

Reassuringly, the four traits I examined show broadly similar trends in regards to organization of lithic technology in terms of curation vs. expedience regardless of the unit of analysis or method of transformation. For example, my analysis of cortex indicates that both the percentage of each assemblage made up of non-cortical artifacts (that is, those with 0% cortex) decreased somewhat steadily through time, from the earliest deposits in Shelter 1 through more recent deposits in Shelters 2 and 3. This decrease was marked by a peak in non-cortical artifacts occurring in the warm, wet interval between the Younger Dryas (an early period of cold/dry climatic conditions) and a shorter climatic event known as the 8.2ka Event. On its own, this would be an interesting pattern indicative in an overall shift from curated to expedient lithic technology with an interesting response to climatic change. Yet I observed similar patterns in the three other lithic core traits as well. In analyzing changes in the complexity of platforms in each assemblage, I noted that the Mean Platform Complexity Score (PCS) for each level decreased over time from a peak in the same interval mentioned above. Both retouched and bifacial artifacts (associated with curation) are most common in the earliest part of the sequence, but fall off quickly during the Middle Archaic period and remain at low levels throughout the rest of the Archaic. Taken together, these trends offer a glimpse of the socio-cultural development of human society during this dynamic time, when the open landscapes of the late Pleistocene were permanently colonized both by tropical forests and human groups during the Archaic.

Conclusion: Cultural Changes in a Changing Ecosystem

I end my study by synthesizing the lithic trait data for each site on its own, since each shelter had its own unique archaeological record that needs to be considered separately from the others. No less important is the aggregate data for examining long-term trends in lithic technological organization through time; although each site is unique, they also lie close enough to each other to have experienced similar changes in climate, ecosystem, and human utilization. I then put these non-linear trends in lithic data into context of regional climate change. Decades of work by paleoecologists has led to a nuanced understanding of the ways that temperature, humidity, and precipitation changed over the millennia of the late Pleistocene and Holocene periods. Some of this data comes from Belize itself, relatively close to the Shelters I examined (Beach et al. 2009; Jones 1994a); others comes from farther afield, from lake cores in the Yucatan and Guatemala, or ocean-floor cores from the Caribbean Sea (Correa-Metrio et al. 2012; Haug et al. 2001).

Together, these differing lines of evidence show consistent yet oscillating climatic patterns, beginning with the end of the Pleistocene. At that time, the region began to grow warmer and wetter as it emerged from the last Ice Age; for the first time, evidence of human occupation occurs in several parts of Central America. Yet this overall trajectory was interrupted by the centuries-long Younger Dryas event, which briefly brought a return to cool, dry conditions for most of the region. In addition to the paleoclimate data, I review archaeological evidence from several sites in Central America with deposits dating to this time (Ranere and Cooke 2020a; Scheffler, Hirth, and Hasemann 2012; Douglas J. Kennett et al. 2017). Moving forward in time, the Pleistocene epoch ends as the Younger Dryas gives way to warmer and wetter conditions once again, and the current Holocene epoch begins. The Early Holocene witnessed the first filling of several lakes from Yucatan to Guatemala, as sea levels rose and buoyed up the water table beneath the Yucatan peninsula and precipitation increased throughout the region (Correa-Metrio et al. 2012; Haug et al. 2001).

After a very brief interruption in this trend around 8200 years ago (the 8.2ka Event), the Middle Holocene period witness the warmest, wettest climate of the entire Epoch lasting up until 4000 cal BP (S. E. Metcalfe et al. 2000; Torrescano-Valle and Islebe 2015; Carrillo-Bastos et al. 2010). Tropical forests which had first begun to colonize the region around 10,000 cal BP now covered much of it. Yet it is also during this period that the first evidence of human disturbance of those same forests, as cultivars domesticated elsewhere in the region spread elsewhere. Maize pollen begins to show up in lake cores dating to the Middle Holocene, and increased charcoal and sedimentation shows the impacts that human disturbances have on the environment. Finally, as temperature and precipitation begin to decrease from their Middle Holocene highs towards the modern-day climate regime, the paleoecological signal becomes dominated by human-driven changes to the ecosystem (Torrescano-Valle and Islebe 2015; Carrillo-Bastos et al. 2010; Beach et al. 2009). Widespread forest clearance, evidenced by a sharp rise in grassy pollen and by increasing sedimentation rates, shows that growing populations of human groups have begun their turn to horticulture. Stable isotope data from individuals at two of the rockshelters also bears witness to this transition, as a diet with almost no maize in it gives way to a transitional one, and finally to a diet where maize is a staple (Kennett, Prufer, Culleton, et al. 2020). These changes occur at least 1500-700 years before the earliest known Maya settlements occur in the region, indicating that drastic changes in subsistence (in this case, the appearance of agriculture) may not be as immediately tied to the transition to sedentism as previously believed.

When the results from the abovementioned studies are synthesized with mine, the overall picture that emerges is a transition to sedentism in the Maya Lowlands that began well before human groups relied heavily on cultivation. Indeed, it appears that, just as the tropical rainforests of the region were reaching their apex in the Middle Holocene, humans had already begun to transition away from Residential Mobility Strategies and curation-based lithic strategies, and to favor Logistical Mobility and expedient lithic technology. My study not only provides evidence of thriving human occupation of rainforest well before the reliance on cultivation; it indicates those same humans had begun to move about the landscape less, and to transition from a foraging lifestyle to one based on collecting. Importantly, this transition likely entailed various “proto-agricultural” practices, such as creating clearings in the forest canopy through burning, or re-planting unused portions of wild plants. In manipulating wild resources and carving unique niches out of their tropical forest homes, these groups planted the seeds of sedentism and cultivation that would ultimately lead to the flourishing of Maya

Preclassic and Classic culture. These conclusions have far-reaching implications not just for Mayanists interested in the origins of the Classic Maya; not just for Mesoamericanists seeking the first truly sedentary, complex societies in the region; but for scholars everywhere who look to the past for the origins of the traits our civilization bears to this day: agriculture, urbanization, and social complexity.

CHAPTER 2

PRECERAMIC FORAGERS OF BELIZE: A TEST CASE FOR THEORIES ABOUT HUMAN MOBILITY AND SUBSISTENCE IN A TROPICAL FOREST

In this chapter, I outline the theories and models I use to derive testable hypotheses about subsistence and mobility of Late Pleistocene and Holocene human groups in Belize. For the first half of this chapter, I begin by summarizing a theoretical framework that informs my study known as Human Behavioral Ecology (HBE). It involves the application of principles from Behavioral Ecology to human beings (Winterhalder and Smith 2000) in order to derive specific, testable hypotheses about foraging behavior, mobility, and resource acquisition. I then summarize an important debate related to hunter-gatherer subsistence in tropical forests and discuss its potential impacts on the study of preceramic foragers in the Maya region. I review insights about resource management and landscape alterations in tropical forest gleaned from the ethnographic and archaeological study of foragers occupying these habitats. I also summarize the development of models that relate forager mobility to both subsistence and lithic technology. Finally, I derive hypotheses about forager subsistence and mobility that I can test using data on lithic technology from my study sites.

In the chapter's second half, I provide greater spatio-temporal context for my use of these models. I first review paleoclimatic and archaeological data from lower Central America that provide insight into changing Late Pleistocene and Holocene climate dynamics and their impacts on contemporaneous human populations in the region. I then focus my discussion more narrowly on my Study Area in the southern half of Belize by introducing the three sites from which I draw data and highlighting recent work at these sites that touches on questions of subsistence and mobility. I conclude by restating my hypotheses in terms of the specific implications they have for our understanding of human mobility and subsistence in the Maya Lowlands and discuss how they touch on questions related to the origins of sedentary, agricultural Maya lifeways.

Human Behavioral Ecology and its Application to Tropical Forest Foragers

Compared to the rest of the field, Human Behavioral Ecology, "the study of human behavior from an adaptive perspective" (Nettle et al. 2013, 1032), is a relatively young theoretical framework within anthropology (Winterhalder and Smith 2000). Beginning in the 1970's, scholars applied to human groups insights derived from the study of animal Behavioral Ecology (or BE for short), which aims to "understand how an animal's behaviour is adapted to the environment in which it lives" (Davies, Krebs, and West 2012, 5). This paradigm utilizes fundamental concepts in evolutionary theory (such as natural selection and adaptation) to explain animal behaviors. HBE theorists do the same for human behaviors, and often utilize ethnographic research to show the myriad ways that humans adapt their behavior to environmental constraints in order to maximize fitness. In very general terms, this means they must decrease the cost-to-benefits ratio of accessing basic resources like food, water, and raw materials.

Most HBE models share the following characteristics: a *goal* related to natural selection; a *currency* that can be used to measure and compare the relevant costs and benefits; a set of *constraints* provided by the social and environmental context; and a *decision* or *alternative set* describing the range of behaviors to be evaluated based on the above (Winterhalder and Smith 2000:54). Several of HBE's most fruitful models derive from Optimal Foraging Theory (OFT), which seeks to understand how humans make decisions about how and where to forage, whether in terms of resource patches (the "patch choice" model), prey species (the "prey-choice" model), or narrow-vs-broad subsistence strategies (the "diet breadth" model). For example, Piperno (2011:463-465) uses the diet breadth model to describe how Late Pleistocene/Early Holocene foragers in the neotropics attempted to maximize their fitness (the *goal)* – here measured as "energetic returns of their subsistence" (the *currency)* – by choosing between a continued emphasis on full-time hunting and gathering, or a turn to what she calls "predomestication" or "nondomestication cultivation" (the *alternative set*). Throughout her discussion, she reviews evidence about the changing environmental *constraints* brought about by Late Pleistocene/Early Holocene climatic changes and by the actions of human agents who willfully enriched their environments and, intentionally or not, influenced the evolutionary course of the ancestors of important cultivars. A wealth of paleobotanical data from throughout Central and South America detail the changing energy returns of these cultivars and the timing and pace of such changes. Altogether, this line of reasoning allows her to conclude that the diet breadth model better fits the data than the alternative model known as coevolution, or the "slowly unwinding reciprocal plant/human interactions involving experimentation with numerous different taxa" (Piperno 2011:467).

At my study sites, there is not yet the same wealth of paleobotanical information as Piperno (2011) uses to make her argument, so the models I summarize below are not truly HBE models; they do not have the same specificity as those she uses. However, both optimal foraging theory in general, and the diet breadth model in particular, inform the models I utilize to develop hypotheses about long-term changes in human mobility at my study sites. Specifically, the predictions of optimal foraging theory have implications for more than just subsistence-related behaviors – they also entail that the distribution of vital subsistence resources will be one of the biggest drivers of residence location and permanence (Binford 1980; Douglas J. Kennett and Winterhalder 2005; Piperno 2006; Kelly 2013b). Indeed, cultural anthropologists and archaeologists have long recognized the important roles that mobility strategies play in hunter-gatherer lifestyles, and so have spent much time and energy studying them. Archaeologists continue to do this despite the fact that past societies' mobility patterns can be observed in very few cases, and even then, only indirectly. Thus, archaeologists look to the ethnographic record to see how the mobility strategies practiced by extant groups are patterned on socio-ecological variables, which can often be more directly assessed with archaeological data. Quite often, these socio-ecological constraints entail strict limitations on the variation in mobility that foraging groups can exhibit – for example, in some tropical forests, wild, edible plant biomass tends to be sparsely distributed, difficult to procure, and unpredictably abundant (a point I develop in greater depth below). Archaeologists use the linkages between ecology and subsistence to estimate the likely amount of residential mobility practiced in the past, which in turn constrains other socio-ecological traits like territoriality, complexity, and reproductive histories (Kelly 2013b).

Yet human ingenuity being what it is, foraging groups often overcome these constraints – and so confound the heuristic shortcuts that archaeologists rely on. Such groups managed their resources to varying degrees by manipulating their environments in different ways – some more subtle than others. These hunter-gatherers crossed the fuzzy boundary between "pure" foraging and cultivation and entered the grey area of proto-agriculturalists (Keeley 1995), part-time horticulturalists (Endicott and Bellwood 1991), or garden hunters (Linares 1976) who practice nondomestication cultivation (Piperno 2011, 2006), terms I discuss in greater detail below. While their larger ecological realities gradually changed around them, they begin to carve out niches – sometimes quite literally – that allowed them to move beyond the constraints on mobility and subsistence imposed by the natural distribution of resources. Eventually, these behaviors allowed a new, distinct type of resource management most often known as horticulture, defined by Piperno and Pearsall (1998) as the practice of planting garden plots not far from residential structures. Importantly, this subsistence strategy also involves a less mobile type of land-use strategy. Eventually, in certain tropical forests regions, such as the Maya lowlands, human groups pushed the boundaries of environmental constraints even farther by becoming fully sedentary agriculturalists who cleared and tended large fields far from their homes.

In the following sections, I trace the intellectual history of the debate around the evolution of human subsistence patterns in tropical forests, illustrate its theoretical underpinnings in the wider anthropological and ecological literature, and develop hypotheses about how and when tropical foragers began to shift to cultivation. I will then present the geographic and chronological context of the data I use to test the predictions made by these hypotheses, and end with an overall discussion of how my work might impact our overall understanding of the timing of the shift from highly mobile forager to fully sedentary farmers in the Maya Lowlands.

Tropical Forest Ecology and Subsistence

The late 1980's and early 1990's witnessed a fierce anthropological debate about the ability of non-agriculturalist foragers to survive in pure, undisturbed tropical rainforests (R. C. Bailey 1981; R. C. Bailey and Headland 1991; Colinvaux and Bush 1991; Headland 1987). Such rainforests are generally defined as "evergreen or mixed evergreen and deciduous forest lying within the tropics (roughly between 23" 27' North and 23" 27' South), with minimum temperatures not falling below freezing, and with a mean annual rainfall greater than 1,000 mm" (Bailey 1981:60). Depending on the latitude in which they're located, the amount of precipitation received, and its distribution throughout the year, such forests can be described as tropical or subtropical, evergreen or semi-deciduous, wet or moist; they are also sometimes referred to as jungle. These ecosystems are characterized by a high proportion of primary to secondary biomass – the former comprised of inedible plant tissues (i.e. trunks, woody branches, stems, and leaves), and the latter, edible tissues (i.e. palm nuts, flowers, fruits, and underground storage organs). What secondary biomass exists is generally sparsely distributed and temporally unpredictable (Piperno and Pearsall 1998). Because important prey species exploit edible secondary biomass, faunal resources are similarly sparsely distributed and unpredictable.

This overall picture led several authors (R. C. Bailey 1981; R. C. Bailey and Headland 1991; Headland 1987) to argue that tropical rainforests could not provide human groups with sufficient calories throughout the year without some sort of input from cultivated food; this became known as the "cultivated calories" hypothesis. In response, other authors (Colinvaux and Bush 1991) with a more optimistic view argued that tropical forests possess such a wide variety and density of resources that human groups could easily have survived, though likely only in small, highly mobile groups. Both sides agreed that a larger sample of sites was needed, especially those that met two important criteria: evidence of occupation prior to the adoption of cultivars and forest-clearing practices (a threshold that some set at 5000 BP, while the most conservative set at 9000 BP); and evidence that the sites were covered in tropical forests at those times, not just in modern times.

In the years since this debate first took shape, a number of developments have changed its contours and terms. For example, a handful of archaeological cases have yielded evidence of human exploitation of tropical forests as many as several millennia before the initial domestication of known crops. In central Malaysia, several caves and rockshelters appear to have been occupied during the wet, tropical early Holocene period, but not during the preceding, drier Pleistocene (Endicott and Bellwood 1991). In neotropical Columbia, archaeologists have documented the presence of human groups in tropical forest contexts dating to 8600 BP (Gnecco 2003; Iriarte et al. 2020; Lombardo et al. 2020); these groups appear to be utilizing the wild progenitors of plant resources that would later become important domesticates. And as Roosevelt (2013:74) summarizes in his review of the archaeology of the Amazon, "late 20th century research has uncovered several stratified early forager archaeological sites from ca. 13,000 to 10,000 cal BP in the northwest, southeast, and mainstream lower Amazon." These sites exist despite the fact that "[r]ainforest persisted over most of Amazonia… [and] tropical plants have been continuously dominant during the entire period of human occupation" (Roosevelt 2013:72).

Along with these archaeological discoveries of human groups occupying tropical forests for millennia before cultivation in any form was practiced, further work on diversity and nutrient value of tropical forest plants has highlighted the ways that Neotropical forests are not necessarily as difficult to survive in as those of Baily & Headland's (1991) model, which was informed by the case of Baka pygmies who occupy the Central African rainforests. For example, Iriarte et al. (2020) have documented the staggering array of wild plants that provide nutrients: from a much wider variety of tubers to other not-as-familiar plants such as heliconia that are rich sources of protein and carbohydrates. Another factor influencing the richness of neotropical rainforests is the overall similarity over a vast geographic space: plants that were first utilized in one part of Amazonia, for example, were readily transplanted and incorporated into the diets of groups living in far distant parts (Iriarte et al. 2020). This large-scale similarity is contrasted by the smaller-scale diversity of ecotones that can occur where tropical forests, savannah, and riverine environments create a "mosaic" that "likely attracted… early foragers for the establishment of temporary or semi-permanent camps" Iriarte et al. 2020: 248.

More recently, researchers have moved away from the black-and-white formulation of the overall question, showing that terms such as “pure” foraging or “undisturbed” forests do not match either the ethnographic or archaeological evidence. Instead, recent research focuses on the mixed nature of human subsistence and forest management (see “Tropical Forest Disturbance by Human Groups”, below). Furthermore, several Neotropical ecosystems are now recognized as source regions for important domesticates, and also provide the best evidence for the first sedentary, agricultural settlements in the western hemisphere (Piperno and Pearsall 1998; Fuller et al. 2014; Piperno 2011; Rosenswig 2006; Iriarte et al. 2020; Lombardo et al. 2020). This realization has led some of these thinkers to take a more moderate view. They recognize that, while tropical forests are difficult environments for human exploitation, they also provide opportunities for innovation. Because early experimentation with important cultivars occurred in tropical forests, human groups must have been living in and heavily exploiting those ecosystems for centuries prior to domestication.

Given its geographic and chronological focus, one might think that my study of three Archaic-period rockshelters in Belize could add an additional case of “pure” foragers exploiting “undisturbed” tropical forests; however, it is likely that the authors of the original cultivated calorie hypothesis (R. C. Bailey 1981; R. C. Bailey and Headland 1991) would not agree. Strictly speaking, evidence from my project may not meet the two criteria they developed. For one, the age of some of the deposits makes the data too young to weigh in on this question, because the authors require evidence older than 5000 BP (and preferably older than 9000 BP), by which time they believe all tropical forests had been so heavily impacted by human activities as to no longer be “pure” or “undisturbed” (Bailey and Headland 1991:270). Additionally, because our project has not yet completed paleoecological profiles, we do not yet know if the areas around the three rockshelters meet the other strict criteria proposed by Bailey and Headland (1991): that is, that they were surrounded by tropical wet/evergreen forest throughout the Archaic period, as opposed to the moist/seasonal forests which occur in their vicinity today (Hartshorn et al. 1984). Later in this chapter, I review the paleoecological data from throughout Mesoamerica, and the Yucatan peninsula in particular, that indicates this was likely the case, but we do not yet have site-specific data to address that concern.

Through the ongoing efforts of the Uxbenka Archaeological Project (UAP) and Bladen Paleoindian and Archaic Project (BPAAP), led by Dr. Keith Prufer, my colleagues are currently seeking to document changes in subsistence through paleobotanical and faunal analysis, and changes in diet through bioarchaeological analysis. Additionally, speleothems from Yok Bulum cave (in the vicinity of Shelter 1) have already yielded precise, annual-scale climate records of rainfall for the Classic Maya time period (D. J. Kennett et al. 2012; Ridley 2014); older sections of these same speleothems are currently being analyzed for similar data on the Archaic age (K. Prufer, pers. comm.). These other lines of evidence will serve to further test the hypotheses generated from the ethnographic record and will also help discern whether these sites meet the two strict criteria of the "cultivated calorie" debate proposed above.

Tropical Forest Management by Human Groups

As alluded to above, an important exception to the sparse, unpredictable distribution of resources in tropical forests occurs when primary or climax forests are made more open by the creation of holes or patches in the canopy, a process known as fragmentation (Stahl and Pearsall 2012; see Stahl 2000 for an example from Late Holocene Ecuador, and Salzmann and Hoelzmann 2005 for a Middle Holocene example from West Africa). These open areas evince rapid growth of vegetation with greater amounts of edible secondary biomass in the form of flowers, fruits, or underground storage organs. Important vegetable resources such as yams (*Discorea sp.)*, palms (*Palmae sp.)* and many species of fruit trees flourish in these temporary, light-rich patches (Piperno and Pearsall 1998). These bursts of edible vegetation also serve to lure animals who take advantage of the glut of edible biomass, causing a corresponding concentration of faunal resources. Disturbances in climax forest cover can be caused by natural events, as when powerful storms knock down towering trees, rivers change course according to natural changes in hydrology (R. C. Bailey and Headland 1991), or sea level rise favors an abundance of halophytic mangroves (Salzmann & Hoelzmann 2005). However, such disturbances, and the concentration of resources they generate, can also be caused by human activity.

The ethnographic record bears witness to many instances of increased tropical forest productivity due to human activity, both unintentional and intentional. Regarding the former, floral resources can be concentrated when human groups consume large quantities of fruits or tubers at their daily residential site, leaving behind a relatively dense concentration of seeds or tuber pieces that can sprout new roots and leaves. Due to this concentration of economically useful plants, abandoned residential sites become important foraging patches in the future (Politis 1996; Yasuoka 2013). An ethnographic example of this phenomenon is provided by the Nukak Maku of Columbia's Amazon Rainforest, whose abandoned residential camps in time become productive foraging patches due to the concentration of seeds left behind by foragers consuming large quantities of fruit while staying there (Politis, 1996:505).

Hunter-gather groups like the Baka of Cameroon (Yasuoka, 2013) are also known to intentionally replant unused pieces of tubers in order to increase the density of economically important resources like yams. In his cross-cultural study of such practices, Keeley (1995:248) notes the ubiquity of the use of fire to create gaps in the canopy both to encourage certain types of vegetation and to attract prey or to kill individuals from non-resource-producing plant species to keep them from competing with members of economically valuable plant species in the same habitat. One such method used to remove less valuable trees is known as ring girdling, a practice that involves cutting a trunk-encircling band into the bark that disrupts phloem (tissues in the bark that transports sugars from their leaves to their roots) and so kills the tree (Gardner 1997:177). When practiced by groups who are otherwise dependent on wild resources, these types of behaviors, termed "para-cultivation" by Dounias (2001) or "protoagriculture" by Keeley (1995), are thought to have played an important role in the eventual domestication of tropical cultivars (Piperno and Pearsall 1998). Horticulturalists – defined in the neotropics as groups that create small garden plots within their camps or adjacent to their houses (Piperno and Pearsall 1998:6) – intentionally disturb small areas of the forest canopy in order to grow their cultivars. These garden plots also attract faunal species that favor open habitats and the fast-growing vegetation therein – species that horticulturalists like the Guayami or Cuna of Panama exploit through "garden hunting" (Linares 1976; Sherzer, Howe, and Sherzer 1975). Like the forager camps above, old garden plots can become important sites of hunting and gathering even after abandonment. Finally, neotropical agriculturalists are those who practice larger-scale swidden or slash-and-burn agriculture, creating fields of disturbed vegetation outside the immediate vicinity of their residential sites (Piperno and Pearsall 1998). An ethnographic example of such behavior is provided by the Kekchi Maya (Wilk 1981), modern-day residents of the villages near Tzib'te Yux rockshelter who clear large patches of the forest to plant staple crops, and who also undertake logistical forays into the surrounding forest to hunt wild animals and gather wild plants. Such forays provide important high-quality protein to diets that are otherwise marked by heavy reliance on maize, manioc, and other high-carbohydrate resources.

In these varying ways, human groups have managed to eke out a living in tropical forests, ecosystems which otherwise might be seen as hostile to long-term human occupation. Importantly for this proposal, each of the three lifeways described above – hunter-gatherer, horticulturalist, or agriculturalist – is associated with a different type of mobility strategy, since each has differing effects on – and responses to – resource distribution and predictability.

Mobility and Sedentism among Human Groups

Most human behavioral ecologists today would probably agree that residential mobility is directly related to the density and predictability of resources as well as the means of acquiring them (Winterhalder and Kennett 2006; M. Grove 2010; Hamilton et al. 2016). These authors examine differing mobility strategies as responses to differing resource distribution profiles and often focus on the origins of sedentism, which "receives special treatment because… the transition from a nomadic to a sedentary existence was the crucible of significant, pervasive, and permanent changes in the social and political lives of hunter-gatherers" (Kelly 2013, 78; see also Rosenberg 1998; Wilson 1991). In the following sections, I review the development of two ways of characterizing mobility that my study will take into account. I then review the link between mobility and subsistence strategies, with examples of each subsistence strategy taken from the ethnographic literature.

Modeling Mobility: the Forager-Collector Continuum and Degree of Sedentariness

Early views of mobility among hunter-gatherers emphasized four categories of foragers that varied according to how much and how often they moved, and ranged from "fully nomadic" to "fully sedentary" (Beardsley et al. 1956; Murdock 1967). Drawing on a huge body of ethnographic literature, Binford's (1980) forager-collector continuum replaced these earlier schemes as the leading heuristic device for characterizing mobility among hunter-gatherers as it relates to resource distribution. The foraging end of this spectrum is marked by the movement of people to resources and, because it involves frequent base camp movements, is also known as the "Residential Mobility Strategy" (RMS) (Riel-Salvatore and Barton 2004, 337). The collector end of the spectrum involves moving resources to people, and, because it favors task-specific or logistical trips over residential moves, is also referred to as a "Logistical Mobility Strategy" (LMS) (Riel-Salvatore & Barton 2004:337). Such groups practice a type of internal differentiation known as the task group (Binford 1980): a smaller, specialized group of individuals focusing on a single resource type. They also experience a greater degree of sedentism than high-RMS groups, sometimes staying in the same base camp for months at a time – a pattern known as semi-sedentism (Kelly 2013).

Recently, Marean (2016) proposed adding a second dimension of human mobility, the "degree of sedentariness" as measured solely by the number of residential moves. This two-dimensional scheme captures not only the degree of LMS relative to RMS, but also the fact that groups with the same RMS-to-LMS ratio can still experience different amounts of residential mobility. For example, among high-LMS/low-RMS groups, the Central Inuit make more residential moves than others, such as coastal Californian hunter gatherers. These latter types of foragers approach total sedentism (Marean 2016:2), a pattern which tends to be found in groups that focus on dense, predictable resources found in coastal, riverine, or lacustrine environments (Kelly 2013; Marean 2016).

Importantly, human groups can practice high-RMS during one part of the annual cycle, and high-LMS during another part, switching between them as dictated by seasonal and social changes, such as population density (Grove 2009; 2010; 2016). However, because of the intimate link between mobility type and social organization (Barton and Riel-Salvatore 2014:336) this type of switching back and forth is not thought to occur on time scales as short as days or weeks. Rather, such groups favor one mobility strategy for one stretch of time, and change to the other mobility strategy – with its concomitant effects on social organization – for another.

Mobility and Subsistence, Intertwined

Ethnographic data shows that such scheduling of mobility type is intimately linked to the manner of food acquisition. In a survey of tropical foragers, Binford (1980) found that 90% of such groups could be classified as nomadic or seminomadic, meaning that they experience a large number of residential moves, and spend little time in any one residential site, during the entire year. For example, the Aché of eastern Paraguay spend periods ranging from several weeks to months foraging for resources in the tropical forests that surround their mission settlement. During these excursions, they have been observed to move camp daily, only staying in one spot during periods of intense rainfall, or during infrequent macroband events known as club fights (Hill and Hurtado 1996). These daily movements of the entire population – men, women, children, and even pets – exemplify the extreme end of the forager-collector spectrum, and evince a high ratio of RMS to LMS. Even the short periods of sedentism described above are not resource related, but instead caused by inclement weather or social events (club fights).

The initial adoption of domesticates in tropical forests would likely have disrupted this strategy of high residential mobility, since many cultivated foods required periods of semi-sedentism for the creation, maintenance, and harvesting of garden plots or fields (Piperno and Pearsall 1998; Piperno 2011). These activities did not necessarily lead to sedentism for the entire growing season, however, since earlier forms of some domesticates (such as teosinte, the ancestor of maize) required less in the way of tending and maintenance (Douglas J. Kennett and Voorhies 1996). Instead, itinerant horticulturalists likely adopted semi-sedentism, staying in one location for at least part of the growing season, but reverting to high residential mobility during the rest of the year. Similar patterns are found among other practitioners of mixed economies in tropical forests, such as the Batek of Malaysia (Endicott and Bellwood 1991), who spend the 3-month "fruit season" in relative sedentism among abandoned Malaysian orchards, but resume a high-RMS way of life for the rest of the annual cycle.

Finally, agriculturalists are known to have the least amount of residential mobility, since later forms of domesticates they rely on (especially plants like maize) cannot as effectively propagate or defend against wild competitors or animal predation without human intervention, and so require almost constant care. Additionally, agriculture is distinguished from horticulture by the former's use of larger plots of land outside the residential area (Piperno and Pearsall 1998); the creation, maintenance, sowing, and harvesting of such plots requires a much greater time commitment than does horticulture. However, even sedentary agriculturalists often practice logistical forays for raw materials or wild food resources, especially in Neotropical forest areas with few domesticated animals, such as southern Belize (Wilk 1981). Thus, subsistence strategy – and its concomitant manipulation of the natural environment – generally dictates the degree of sedentism and the scheduling of residential mobility for groups in the Neotropics.

Models & Hypotheses

Decades of work by anthropologists of varying theoretical backgrounds have documented the subsistence and mobility strategies of many foraging, horticultural, and agricultural societies. As described above, these observations have yielded several models of human behavior that make with predictions that can be tested against the archaeological record. One such model linking human residential mobility to subsistence patterns was developed by macroecological theorists like Binford (1980) and Keeley (1995) who focused on the ways that human behavioral patterns were associated with aspects of their environment like latitude, primary productivity, or annual precipitation. Anoter model that I reference, HBE's Optimal Foraging Theory, has been used by Piperno (2016) and Piperno et al. (2017) to derive test predictions about changes to subsistence related to early cultivation that are then tested against the archaeological record. Yet another model, developed by lithicists like Parry & Kelly (1987) and Kuhn (1992), uses ethnographic data on lithic production and utilization to interpret archaeological assemblages. In the following section, I reference these models to create a frame of reference (*sensu* Binford 2001) and develop hypotheses that I then test against the archaeological record of Late Pleistocene and Holocene human occupation in Belize.

Models of Forager Mobility and Subsistence

In order to do so, I have consulted two large ethnographic datasets created by Binford (2001) and Keeley (1995), focusing on tropical and subtropical groups in general and tropical and subtropical rainforest dwellers in particular. Keeley's (1995) dataset of 96 foraging societies records one proxy for degree of sedentariness as his variable STAY, which captures the longest period of time spent at a single camp (usually during the dry season). Keeley also creates a measure he calls "plant intensification (PI)" (1995:257) for the groups in his dataset, using several variables that capture proto-agricultural characteristics and practices that influence resource distribution. These include the percentage of the diet provided by plants (G); level of burning of vegetation by groups for various subsistence-related purposes (BRN); the level of yield and processing effort for utilized plants (I); and whether or not these groups plant, sow, or otherwise tend wild plants (SOW). These latter characteristics shade into the definition of horticulture as described by Piperno & Pearsall (1998); thus, Keeley's dataset provides an initial test of the hypothesis linking greater sedentism to greater manipulation of the forest environments and plant resources. Fig. 2.1 presents an analysis of all tropical and subtropical groups (n= 32) in his dataset, revealing strong, significant predictive power of STAY on PI ($R^2 = 0.56$, $p<0.0001$), indicating that increasing sedentism and proto-agricultural practices are indeed linked.

However, as mentioned above, mobility can be characterized by at least two dimensions: degree of sedentariness (as approximated by Keeley's STAY variable), and reliance on RMS vs. LMS, meaning Keeley's dataset may provide an incomplete picture of forager mobility. To address this aspect of mobility, I utilize an even larger dataset of 390 foraging societies compiled by Binford (2001:117) as part of his magnum opus,

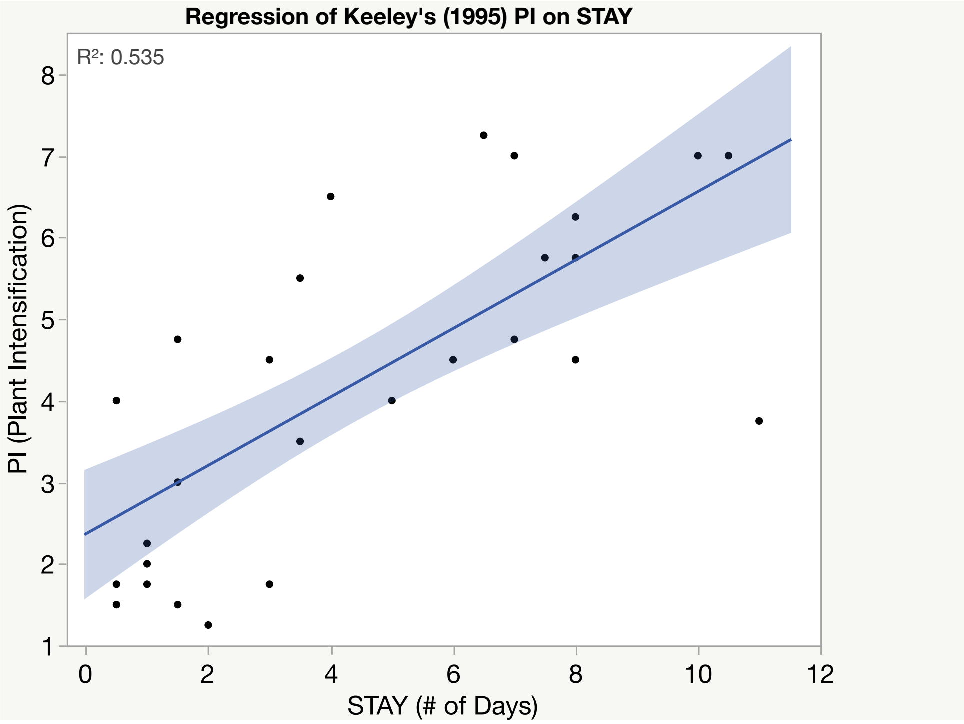


Figure 0.1: Linear regression trendline showing relationship between number of days at residential camp (STAY) and intensity of plant resource utilization (PI)

Constructing Frames of Reference, despite some potential problems with the data noticed by other authors. For example, Hill (2002:416) notes that, based on his own familiarity with some of the 390 cases, there are “numerous errors” in the coding scheme that Binford and his students deployed to convert qualitative ethnographic data to quantitative scores. Yet he also concedes the noise introduced by these errors won’t conceal “important trends” because of the very large sample size. Of more concern is his critique that highly productive environments – such as tropical rainforests – are relatively under-represented in the sample compared to low-productivity environments, a concern shared by others who have reviewed his book (Ames 2004; M. J. Shott 2002). I attempt to control for this by limiting my subsample to 32 groups who live at tropical and subtropical latitudes, thus removing some of the least productive environments in the Arctic and sub-Arctic. All three reviewers mentioned here identify numbers of other problems with the results and theoretical implications arrived at by Binford, but because I use only the raw data themselves, I do not address those problems here.

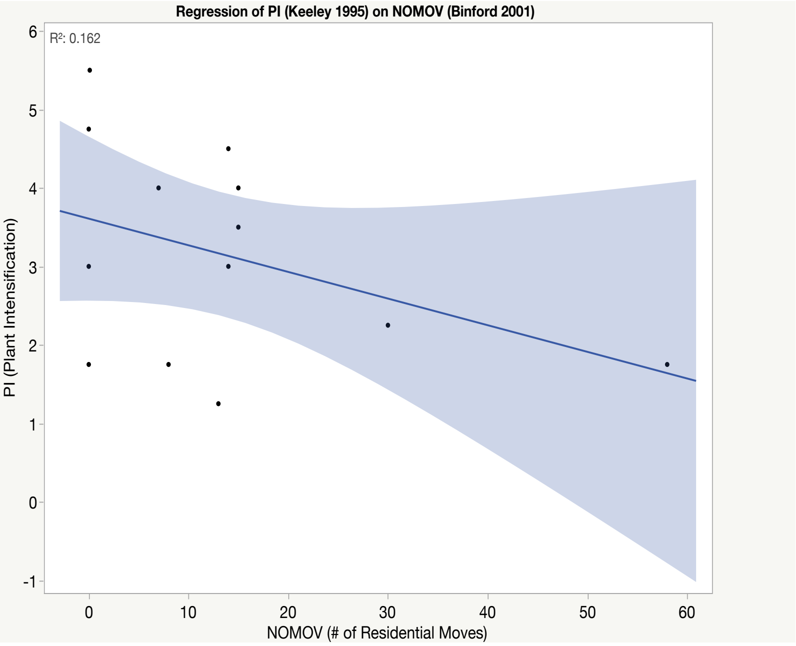


Figure 0.2: Regression of Keeley's (1995) Plant Intensification (PI) variable on Binford's (2001) NOMOV variable, which captures the number of residential moves a group makes.

Binford (2001) records information pertinent to the relative reliance on RMS vs. LMS foraging through his NOMOV variable, which captures the number of residential moves made by a group in a typical year. Groups that score high on this index move their entire camp frequently, and thus practice low LMS/high RMS. Although the societies sampled by the two datasets do not overlap completely, a small subsample of tropical and subtropical groups ($n = 13$) are found in both datasets, allowing for a more complete analysis of mobility and subsistence (Fig 2.2). First, Binford's measure of mobility appears to be moderately negatively correlated with Keeley's PI measure (Pearson's $R = -0.40$, $p=0.17$), and has a low predictive power ($R^2 = 0.16$), although neither statistic is significant. Secondly, I used a multiple regression of PI on the two mobility variables (Keeley's STAY and Binford's NOMOV) to see if they could together explain more of the variation in PI than either did alone (Fig. 2.3). The results reveal moderate predictive power ($R^2 = 0.36$, $p = 0.11$), although neither of the parameters were significant at the 0.9 level (Fig. 2.3). The lack of significance for these latter two comparisons, but not for

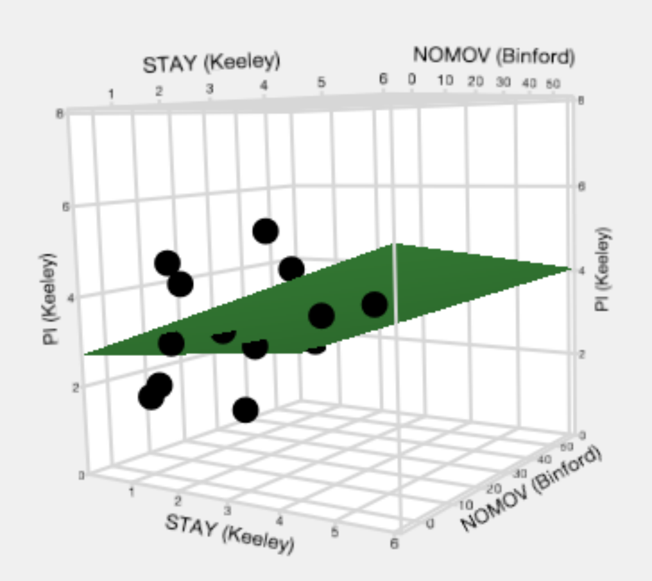


Figure 0.3: 3D Scatterplot showing relationships among Keeley's PI variable, his STAY variable (in # of days) and Binford's (2001) NOMOV variable, in number of residential moves.

the first (i.e. between PI and STAY) may in part be due to their smaller sample size. Taken together, the ethnographic record provides support for the association of greater plant intensification with lower residential mobility and greater periods of sedentism.

Models Linking Variations in Mobility to Variations in Lithic Assemblages

In order to assess the non-observable mobility of Late Archaic foragers using their lithic assemblages, I required another suite of models that ties mobility strategy (RMS vs. LMS) to lithic traits that can be observed. The link between mobility strategy and lithic technology arises from raw material provisioning practices: LMS involves "provisioning places" with raw material, while RMS involves "provisioning people" (Kuhn 1992, 188) in a way that parallels the food-getting behaviors of both mobility strategies. In short, LMS foragers can more easily cache quantities of toolstone at their more stable central places, while RMS-dominant foragers cannot. Consequently, a high amount of LMS provides more reliable access to lithic raw material, which impacts lithic traits such as amount of cortex and frequency of cortical pieces, intensity and frequency of retouch, platform type, and manner of tool-making (bifacial or unifacial flaking) (see Models and Hypotheses, below). In the following sections, I review the history of this distinction and its inspiration from the ethnographic literature on technological organization. I then summarize how it has been tested in computational modeling (Barton and Riel-Salvatore 2014) and applied to archaeological data (Kuhn 1992; Parry and Kelly 1987; Riel-Salvatore and Barton 2004).

Intellectual History. Beginning with Binford's work in the 1970's (Binford 1973, 1977, 1979), lithicists have described lithics technology as being organized along a spectrum ranging from curated or expedient (Bamforth 1986; Kuhn 1992; Nelson 1991; Parry and Kelly 1987; M. Shott 1986). The two ends of this spectrum are defined according to the amount of energy put into stone tool creation and maintenance, the length of a tool's use-life, and whether or not it is recycled (Bamforth 1986). Curated tools are those that are "effective for a variety of tasks, are manufactured in anticipation of use, maintained through a number of uses, transported from locality to locality for these uses, and recycled to other tasks when no longer useful for their primary purposes," while expedient tools are those that "are manufactured, used, and discarded according to the needs of the moment" (Bamforth 1986:38). Because of the differences in provisioning people vs. provisioning places noted between RMS foragers and LMS foragers, groups practicing either strategy experience differing levels of raw material availability, and these differences impact their decisions to continue using old, partially used artifacts, instead of replacing them with something newer (and generally sharper). RMS foragers tend to practice greater curation behaviors than LMS groups, because they experience greater variation in raw material availability (Bamforth 1986; Kuhn 1992; M. Shott 1986).

Lithic scholars provide both theoretical and empirical support for this distinction. Regarding the former, Binford (1979) first proposed that curation is the most efficient way to create and utilize tools for a variety of vital tasks related to subsistence and survival. Torrence (1983:11-13) argued that curation allows foragers to deal with "time stress" by using time not spent on other vital tasks to prepare and create tools for future use. Bamforth (1986:40), however, took issue with both of these arguments and instead argued that curation is a response to "lithic resource availability, settlement pattern, and other structural characteristics of the society in question." In his view, variation in lithic resource availability favors curation, which allows foragers to create multi-functional tools while they have access to sometimes-scarce lithic resources, and to maintain and recycle those tools for longer periods of time when lithic raw materials are unavailable. On the other hand, when there is greater reliability in access to toolstone, foragers will tend to favor expedient lithic strategies, which allow brand new, single function tools to be created at the time of need, and then abandoned after little use. Importantly, all of these authors predict specific relationships between this facet of lithic technology and settlement patterning (or, mobility); more frequent residential moves mean less reliable access to quality toolstone and so favors curation, while less frequent residential moves allow foragers to build up larger caches of toolstone that they use to create expedient tools when needed. Almost from the start, then, these scholars theoretically linked curation with high RMS foragers, and expedience with high LMS groups. Furthermore, these associations have been empirically validated through observations in the ethnographic record, computational modeling of forager mobility and lithic discard, and studies of archaeological lithic assemblages.

Ethnographic Support. Binford's (1979) based his work on observations of the Nunamiut of Alaska, who tend to favor high-LMS settlement patterns in which lithic raw material procurement is "embedded" within other tasks (i.e., toolstone cobbles are collected during logistical forays to obtain specific food resources and then transported back to the main residential camp). He notes that hunters always refresh their personal gear with newly-made items before setting out on such forays, and also rely on so-called "situational gear" created from materials on hand to meet the specific needs of the situation; both are examples of expedient rather than curated lithic technology. Bamforth (1986) examines ethnographic data on the !Kung San gathered by Lee (1979) and Yellen (1977), foragers who tend to favor high-RMS strategies. He notes that these foragers spend more time and energy maintaining and recycling tools, a sign of curation. Shott (1986) compiled ethnographic data from a number of foraging societies ranging from high-RMS groups like the Guayaki (Ache) to low-RMS groups like the Chenchu. Rather than focus explicitly on curation or expediency, he assessed these groups' lithic technology in terms of diversity and complexity, terms developed by Oswalt (1976) to characterize lithic assemblages of extant foraging groups. Importantly, these two aspects map onto the curated-expedient spectrum in that expediently-created toolkits are generally more diverse and less complex, while curated toolkits are generally less diverse but more complex. Shott (1986) found that residential mobility (measured as frequency of residential moves) portrayed a moderate negative relationship with diversity and a moderate positive relationship with complexity. In other words, more mobile foragers had more curated toolkits. Similarly, he found a strong positive relationship between logistical mobility (measured as length of time at a single residential camp) and toolkit diversity (but no relationship with complexity).

A final example of ethnographic data used to support the deduced link is provided by Parry and Kelly (1987), who rely on unstandardized lithic cores and unretouched flake tools as markers of expedient lithic technology. They cite a number of ethnographers working in areas as diverse as New Guinea, Brazil, western Australia, and southern Africa who provide detailed accounts of expedient lithic creation and utilization. Interestingly, many of these groups have a high-RMS settlement pattern, which at first glance would seem to go against the theorized and observed association between high-RMS and curation. However, as Parry and Kelly (1987:301) explain, these groups are in fact the exception that proves the rule, because they "have access to abundant and widely distributed lithic materials," thus supporting the idea that it is lithic resource availability, and not mobility *per se*, that has the biggest impact on lithic technology. For the most part, high RMS limits lithic resource ability in all human groups but those blessed by the lithic abundance described above. These ethnographic data bolster the overall argument that mobility and lithic technology are linked in the ways theorized by Binford (1979) and others.

Support from Computational Modeling. Additionally, computational modeling of these dynamics using an agent-based model (ABM) has provided further support for their validity (Barton and Riel-Salvatore 2014). ABMs are a type of simulation in which the movements and decisions of agents (in this case, human foragers) are governed by simple rules, and parameters affecting agents mimic environmental constraints, such as the frequency of raw material sources on the landscape or distance between resource patches. In Barton & Riel-Salvatore's (2014) model, agents practice either LMS or RMS, but can switch between the two strategies. Certain patches on the landscape are designated as camps; for LMS, they can be either base camps or resource extraction camps, while for RMS, they are all residential camps. They also carry with them lithic artifacts that possess a "fixed amount of potential useability that is tracked as *lithic utility units* (LUU)" (Barton & Riel-Salvatore 2014:337; emphasis in original). These units are meant to represent four possible states of a single lithic item – unused, utilized, resharpened, or exhausted. Lithics move through these states when agents perform activities; once they reach the exhausted state, they are dropped at whatever camp the agent is occupying. Finally, in some sets of model runs the authors allowed both LMS- and RMS practicing agents to take varying amounts (from 0% to 50%, set at time of model initiation) of additional fresh, unused lithics from raw material sources to their next destination camp and leave them there for future use, a feature meant to model provisioning or caching of lithic raw material.

The authors evaluated the degree of curation vs. expedience in the resulting simulated lithic assemblages by measuring retouch frequency, that is, the proportion of resharpened and exhausted artifacts (a metric they applied to real-world archaeological sites – see below). The amount of extra lithics provisioned had a very large effect on this measure – for example, when both types of agents could provision their next camp with no extra lithics, their camps had assemblages with the same high retouch frequency approaching 1.0. Yet on later model runs, when both types of agents were allowed to provision their next camp with 50% additional material, LMS base camps had a much lower retouch frequency than RMS residential camps – in large part because LMS foragers kept returning to (and provisioning) the same base camp with fresh stone, while RMS foragers spread their excess raw material a higher number of lightly occupied residential camps. This difference in retouch frequency became even more pronounced when LMS foragers returning to a base camp were allowed 50% provisioning, but both LMS foragers moving to their next resource extraction camp, and RMS foragers moving to their next residential camp, were allowed only 10%. This restriction was meant to model overall resource provisioning differences between LMS- and RMS- practicing foragers described above.

Curation, Expedience, and Mobility in Archaeology. Several archaeologists have developed methods to assess the degree to which foragers practiced RMS or LMS based on the amount of curation seen in the lithic assemblages (Barton and Riel-Salvatore 2014; Dibble et al. 2005; Kuhn 1992; Riel-Salvatore and Barton 2004). Specifically, curation behaviors can be seen in lithic technological traits such as lower amount of cortex (or rough outer stone surface) on each artifact, greater degree of platform preparation, greater intensity of retouch (or resharpening) on each tool, and a tendency towards bifacial instead of unifacial tool type. At the assemblage level, these traits appear in both frequency and higher volume-normalized discard rates for each class of artifact. I discuss each of these traits in greater detail in Chapter 3.

These methods have been used to fruitfully characterize lithic assemblages in a wide variety of archaeological contexts. For example, (Barton et al. 2011) summarize the recurrent association seen in many parts of western Eurasia between a site's retouch frequency and overall artifact density, which is taken as an independent proxy for the intensity of occupation. As theorized, the authors observed that retouch frequency declines as artifact density increases, a link that supports the idea that the more often foragers utilize a given site as a base camp, the better they can provision it with fresh toolstone, and the less they need to curate their lithic artifacts through retouch. Clarkson (2008) finds a similar relationship existed throughout the Holocene in Wardaman County, northern Australia; interestingly, he finds that use of ochre and other symbolism in the area peaked when retouch was highest and artifact density lowest, an independent line of evidence suggesting that symbolic use of the site was greatest when it was less frequently visited by more highly mobile foragers (Clarkson 2008:311).

Finally, Cornejo B. and Galarce C. (2010:397) describe their creation of a curation index (which they term "C Index") as a way of measuring how curative each assemblage is. The lithic traits they combine to create this index are the quality of raw material, platform morphology (similar to my study of platform preparation type), and reduction categories (which includes bifacial retouch as the most curated category). They find that these three markers of curation covary in expected ways, and thus provide mutually supportive independent lines of evidence. They also note that the assemblages with the highest C Index came from a camp which they have interpreted (on the basis of other evidence) as a hunter-gatherer residential camp, while that with the lowest C Index belonged to semi-sedentary horticulturalists (Cornejo & Galarce 2010:401).

The second dimension of mobility described by (Marean 2016b) – that is, degree of sedentariness as measured by the number of residential moves alone – poses some problems for the abovementioned model tying curation to high-RMS and expediency to high-LMS. At high levels of sedentism (i.e., few or no residential moves), it may not be possible to distinguish between groups that still practice many logistical forays from groups that practice only a few, because the lithic-provisioning behaviors of both may be quite similar. However, the ethnographic literature suggests that groups fitting the former pattern, such as those occupying coastal territories in northern California or northeast Australia, tend to have small, highly circumscribed, densely populated territories (Marean 2016; Dennehy, Harris, and Marean 2014). None of the archaeological evidence for Archaic-period Belize currently points to the high population densities characterizing these highly sedentary but low-LMS foragers. Also, the ethnographic record shows that highly sedentary foragers of this type occur only in coastal, lacustrine, or permanent riverine settings, none of which describe the area around the rockshelters (where rivers and creeks run dry during the dry season).

Summary: Deriving Hypotheses about Archaic-period Mobility from Theory

Two views regarding changes in subsistence practices leading up to the origin of agricultural Mayan society have been advanced. The first view, which I refer to as the "cultural-historical view," reflects the current preoccupation with complex Mayan society and is based loosely on culture history of the Classic-period Maya and on the general lack of data for pre-Mayan groups. It may also have been influenced by the "cultivated calories" hypothesis, in that the cultural-historical view sees the Maya lowlands as "virgin territory" and the cultivated calories view emphasizes the role "undisturbed" tropical forests. Whether intentionally or not, both camps seem to view tropical rainforests as generally inhospitable to foraging groups. The cultural-historical perspective hypothesizes that the Archaic-period Belizean landscape was either vacant or so sparsely occupied by highly mobile foragers as to contain almost no trace of their occupation. According to this view, these foragers proved to be no barrier to Maya-speaking agriculturalists bringing domesticated plants and animals, and a sedentary way of life, into Belize during the following Preclassic period (Ball and Taschek 2003:205;

Puleston and Puleston 1971; Iceland 1997:176; Marcus 1995:6; T. C. Kelly 1993:224). The test predictions of this hypothesis would entail lithic evidence showing greater curation and less expediency (signatures of a high level of RMS relative to LMS, and a low degree of sedentism) throughout the entire Archaic period.

On the other hand, the perspective informed by ethnography, lithic studies, and HBE provides a much more dynamic set of expectations about subsistence patterns throughout the Belizean Late Pleistocene and Holocene periods based on the relationship between ecology, subsistence, and mobility described above. In general, this view hypothesizes increasing human manipulation of natural resources allowing increasing sedentism in the Neotropics. The natural distribution of tropical forest resources requires almost constant movement for successful exploitation (Bailey and Headland 1991; Hill and Hurtado 1996); likewise, the lightest form of manipulation, protoagriculture, requires a high reliance on RMS as human groups "move to produce" (Politis 1996), with short periods of LMS as groups manage wild resources in their habitat, or collect the fruits of that management. With increasing environmental manipulation in the form of horticulture, groups become semi-sedentary (or high-LMS-reliant) for at least part of the annual cycle, but revert to a highly mobile, RMS-dominated type of mobility for the rest of the year (Endicott and Bellwood 1991). Finally, small-scale agriculturalists practice both the greatest amount of environmental manipulation, in the form of slash-and-burn swiddening of extra-residential fields, and the highest level of sedentism, living year-round in villages but still undertaking logistical forays for wild resources and other raw materials (Wilk 1981). This hypothesis generally predicts an emphasis on lithic curation early in the site history for all three shelters, changing to a reliance on lithic expediency in the period leading up to the end of the Archaic.

Table 0.1: Test Predictions of each Theoretical Perspective.

Theoretical Perspective	**Expectations about Lithic Technology**	**Expectations about Mobility Patterns**	**Expectations about Subsistence**
Cultural-Historical	Static, curated	Static High-RMS	"Pure" hunting and gathering
HBE-informed (Early, Middle, Late Variants)	Dynamic, shifting from initially curated to more expedient based on climate and plant dependence	Dynamic, shifting from initially high-RMS to high-LMS	Initially large-mammal based hunting & gathering, shifting to proto-agriculture horticulture

However, the exact timing and abruptness of this change is difficult to predict based on current data on the introduction or adoption of cultivars in Belize, which is not yet fine-grained enough to predict exactly when a shift to cultivation (and thus to lower mobility and greater expediency in lithic assemblages) might have ccured. At least three scenarios are possible: Early, Middle, or Late. In an Early scenario, a shift to greater reliance on wild plants would occur immediately after the Younger Dryas, coinciding with the local extinction of megafauna and the replacement of open savannah-like ecosystems with closed-canopy tropical forests. In a Middle scenario, this same shift would've occurred later, once the climate reached its peak of warmth and wetness in the middle Early Holocene, an environment marked by less climatic variability likely more amenable to early experimentation with cultivars (Richerson, Boyd, and Bettinger 2001). Finally, under a Late scenario, human groups may have remained highly mobile throughout the "Holocene Climatic Optimum", dominated as it was by the highest annual rainfall and wettest tropical forest landscapes, which would still require a rather high amount of residential mobility to successfully exploit. Under this scenario, a shift to lower residential mobility (and lower levels of curation) would only occur after the 8.2 ka Event, a drying event at the start of the Middle Holocene that presaged the eventual end of the Holocene Climatic Optimum and a return to a somewhat drier, cooler climate similar to that seen in Belize today (where the dry season is only a month or two shorter than the wet season). Table 2.2 provides a summary of these two sets of hypotheses.

Tropical Forests Foragers in Time & Space: A Summary of Regional Climate Dynamics and Archaeological Evidence

In the following section, I review evidence from multiple lines of evidence in the region that paint a picture of human occupation in Central America during the millennia covered by my study. I first define the chronological periods often used to divide up the long pre-agricultural period. I then review climate proxy data and archaeological evidence for each period in order to provide a backdrop for the data I later present from my lithic analyses. Following this section, I provide specific details about my Study Area and the three sites from which I collected data.

Chronological terms: Geological vs. Cultural

Many paleoecological studies adopt *geological* epochs when discussing their findings with respect to climate change over time. These periods have the advantage of being applied more or less globally, and of being based on specific “stratotypes” or known geological standards that show an environmental change taken to be the boundary between one period and another (Walker et al. 2012:650). In the case of my data, the earliest geological period I touch on is the Pleistocene, but the bulk of my data comes from the following (and present) Holocene era. On the other hand, archaeologists working in the Maya lowlands generally refer to different *cultural* periods, using a mix of North American terms (such as Paleoindian and Archaic), and Mesoamerican terms (such as Preclassic/Formative). These cultural periods tend to be based on changes in material culture (i.e. the invention of ceramics or the adoption of sedentary village life) that are more interesting to archaeologists and observable in the archaeological record. However, the exact boundaries between one period and another tend to vary from one region to the next, and even archaeologists working in the same region sometimes disagree on their exact placement (Rosenswig et al. 2015). Of course, geologists also debate the placement of chronological boundaries, but geology benefits from the existence of a larger organization, the International Union of Geological Sciences (IUGS), that promulgates specific standards in the formal subdivisions of time; Mesoamerican archaeologists pay heed to no such body. For these reason, as I turn to a broader, region-wide synthesis of paleoenvironmental data (based on non-cultural samples like lake cores or speleothems) and archaeological data (based on excavations into cultural deposits), I will adopt the names and dates of geological periods and their subdivisions as a way to organize and tie together disparate datasets. In so doing, I follow precedents set by archaeologists working in lower Central and South America who utilize these same general divisions to refer to cultural periods there.

Late Pleistocene-Early Holocene. It is only recently that the formal boundary between Pleistocene and Holocene epochs was placed at 11,700 cal BP (coinciding with the end of the Younger Dryas) (Walker et al. 2012:650). The geological subdivisions of the Holocene epoch were also recently proposed and accepted by the (IUGS) (Walker et al. 2012). As of this writing, the IUGS recognizes three formal sub-epochs for the Holocene: Early, Middle, and Late. The use of this same nomenclature by Mesoamerican archaeologists to divide the cultural Archaic Period into three subperiods creates more than a little confusion, especially since the two sets of boundaries do not always agree. For example, the Pleistocene-Holocene boundary occurs at 11,700 cal BP, but the transition between the Paleiondian and Archaic periods is generally placed at 10,000 cal BP (Lohse et al. 2006). I utilize the former boundary, and refer to the Late Pleistocene and Early Holocene periods where appropriate.

Early-Middle Holocene. Moving forward in time, the boundary between the Early and Middle Holocene has been recognized geologically by the "8.2 Event," which I have referred to often while presenting my results. This event, described as "a major short-lived cooling episode that is clearly reflected in the isotopic signal in Greenland ice cores" (Walker et al. 651), has been observed in multiple climate proxies from locations around the globe. Additionally, archaeologists in north Africa, southern and south-eastern Europe, and the Near East have noted cultural effects that may be due to this event (Walker et al. 2012:653). Thankfully, in Mesoamerican archaeology, the boundary between Early and Middle Archaic is generally set at 8000 cal BP, so the end of Early Archaic essentially coincides with the end of the Early Holocene.

Middle-Late Holocene. The next geological boundary, between Middle and Late Holocene, has been placed at 4200 cal BP and is defined "by a mid/low-latitude aridification event (hereafter, the 4.2 event)that is reflected in proxy records from North America, through the Middle East to China; and from Africa, parts of South America, and Antarctica" (Walker et al. 2012:653). Confusingly, in Mesoamerican archaeology the boundary between the Middle and Late Archaic culture periods is set at various points between 5500 and 5000 cal BP, with different dates sometimes used within the same work (see Kennett 2012). Furthermore, many studies of the Middle Archaic period make note of its fragmentary and sparse archaeological record, meaning the choice of a specific boundary may be somewhat arbitrary. And some archaeologists go even further and omit the Middle Archaic altogether, preferring to speak only of Early and Late Archaic periods separated by a boundary at around 6000 cal BP. Regardless of how the end of the Middle Archaic is defined, it does not align with the 4.2 event used in geology, but instead precedes it by at least a millennium. This unsystematic definition of chronological boundaries is yet another reason I use the geological term Middle Holocene throughout my study.

Late Holocene. Finally, the geological period of the Late Holocene is currently taken to mean everything after the 4.2 event. Yet even within geology, there is some debate as to the extent of human impact on climate, particularly since the Industrial Revolution; this has led some geologists to formally propose using the term "Anthropocene" to differentiate this most recent part of Earth's past from the preceding Late Holocene. No specific date has yet been adopted for this boundary, but by most accounts it would fall well after the end of the Archaic and even Classic periods in Mesoamerica. The corresponding archaeological boundary, between the Late Archaic and the subsequent Preclassic period, generally occurs at the first adoption of ceramics, sedentism, and/or agriculture in a given area; unsurprisingly, the timing of this event varies quite a bit throughout greater Mesoamerica. In the Maya region, this boundary is generally set at 1000 or 900 BC (that is, 3000 or 2900 cal BP), and is referred to as the Late Archaic/Middle Preclassic transition (Rosenswig 2015b). The use of "Middle" in this terminology alludes to the fact that other regions (such as the Olmec heartland of the Gulf Coast or the Soconusco region of the Pacific coast) witnessed this transition almost 1500 years earlier, at the start of the Early Preclassic/Formative around 2500 BC (that is, 4500 cal BP).

Adding another wrinkle of complexity to the Late Archaic period, some researchers divide it into early and late subphases, also referred to as Early and Late Preceramic, respectively (Lohse et al. 2007). The exact dates of these two subphases are not agreed upon by scholars working in this region (Harry B. Iceland 2005), but the boundary between these phases is marked by an apparent hiatus in occupation at several sites between 3900 and 3500 cal BP. However, Lohse et al. (2007) point out that this hiatus may not be due to abandonment of the region but rather to a lowering of the water table, an environmental event that would've negatively affected sedimentation and deposition of pollen, charcoal, and other cultural materials. Whether real or apparent, the scholarly distinction between these two phases of the Archaic is common enough in the literature that I use it as needed. Overall, though, I adopt the geological terminology throughout the following sections, rather than attempt to wade through the varying definitions of cultural periods that seem to plague archaeologists wherever they go.

The Big Picture: Trends in Climate throughout the Late Pleistocene & Holocene

Below, I utilize the chronological terms defined above to present a broad overview of socioecology in lower Central America based on paleoenvironmental data and archaeological research. For each of these periods, I include a map showing sites of paleoecological and archaeological interest discussed in the text (see Table 2.2 for a list of site abbreviations used on each map). As I discuss the evidence used in paleoenvironmental reconstructions, it will be helpful to keep in mind the general climatic trends observed throughout the entire sequence in multiple proxy datasets. These trends are exemplified by the paleoecological record of the Cariaco Basin off the coast of Venezuela (Fig. 2.4, top panel), data I utilize in my lithic analysis in Chapter 5. This record comes from the upper 5.5 m of a deep sea core that contains long-term fluctuations in bulk sediment titanium concentrations. These changes are a result of shifts in overland rainfall, which is itself dependent on sea-surface temperature and the north-south position of the Intertropical Convergence Zone (ITCZ). During warmer climatic intervals, sea surface temperatures rise and the ITCZ shifts north, leading to greater rainfall over the northern portion of South America. This in turn causes higher amounts of terrestrial run-off, which carries with it greater concentrations of terrigenous metals (like titanium) that eventually are deposited on the seafloor. During cooler climatic events (like the Younger Dryas), sea surface temperatures fall and the ITCZ migrates southward, leading to lower levels of overland precipitation and thus, lower concentrations of titanium in river-borne sediments (Haug et al. 2001).

Another more recent paleoclimatic record of rainfall in Central America is also

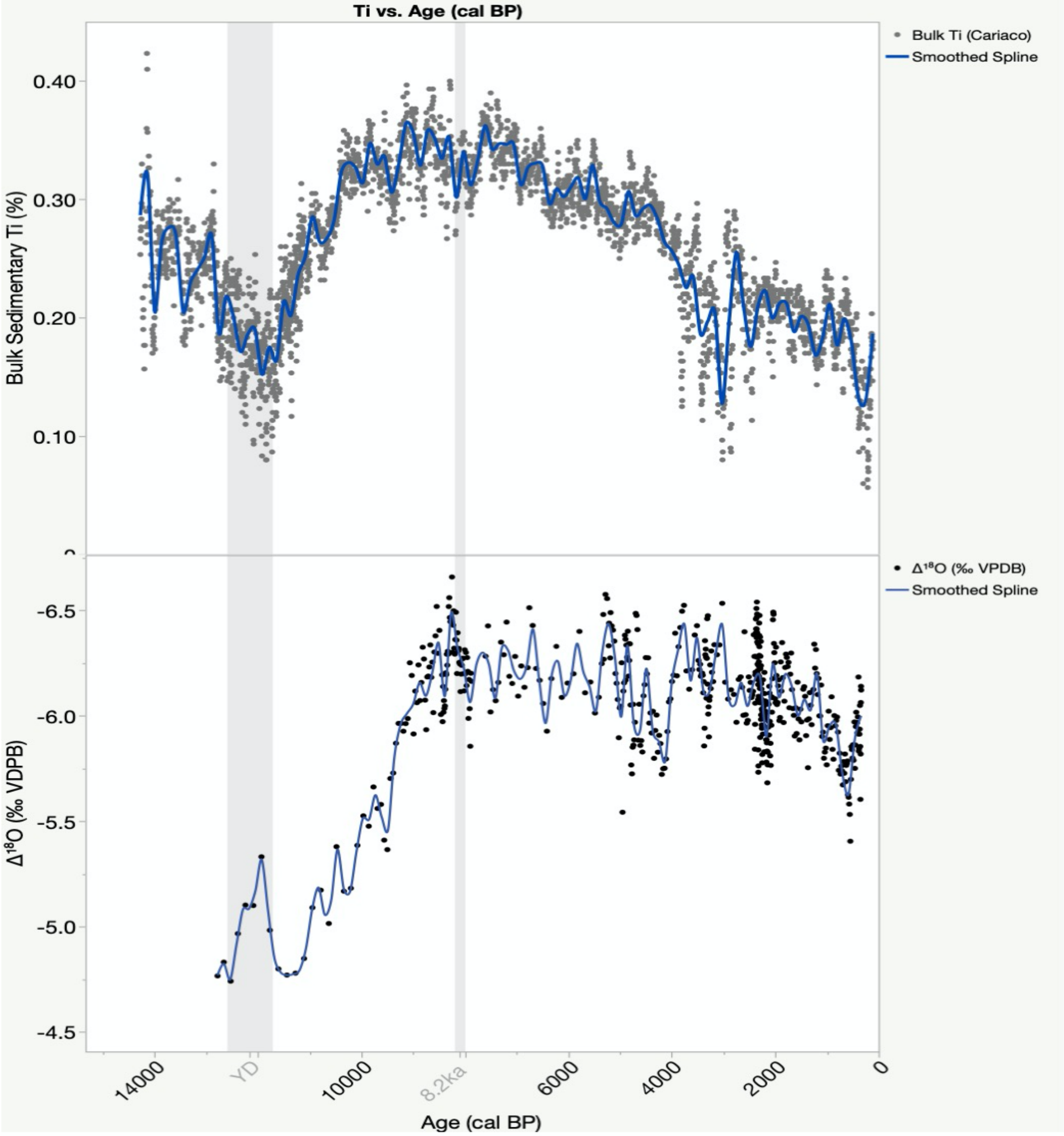


Figure 2.4: Two paleoclimate proxy records. Top: trends in the concentration of Titanium in a deep sea core from the Cariaco Basin seabed. Recreated from data published by Haug et al. 2001. Bottom: trends in the differential ratio of ^{18}O to ^{16}O as compared to a standard (VDPB). Recreated from data published by Winter et al. 2020.

shown in Fig. 2.4 (bottom panel). This record, taken from a speleothem growing in Rey Marcos cave in Guatemala, reflects changes in the oxygen isotope ratios of calcium carbonate (Winter et al. 2020). There are several reasons that this paleoclimate data may better represent climatic conditions in Belize. For one, it is based on variations in the ratio of ^{18}O to its lighter, more common counterpart ^{16}O, and thus the authors "interpret the Δ ^{18}O variations in the stalagmite as reflecting regional convective intensity" (Winter et al 2020:3) For another, it is much closer geographically to Belize, and since it sits on the Caribbean side of the Guatemalan highlands, it almost certainly experiences the same rainfall regime, whereas the Cariaco core recorded changes in rainfall over Venezuela. However, it possesses one conspicuous disadvantage which led me to choose the Cariaco record for use in my analysis: its oldest isotope sample is dated to 12,778 cal BP, while the Cariaco record extends back to 14,277 cal BP. Although my study does not contain a great number of assemblages dating back that far, they are numerous enough to warrant the use of a climate record that covers their time period.

Climate and Ecology of the Late Pleistocene and Early Holocene (pre-8200 cal BP)

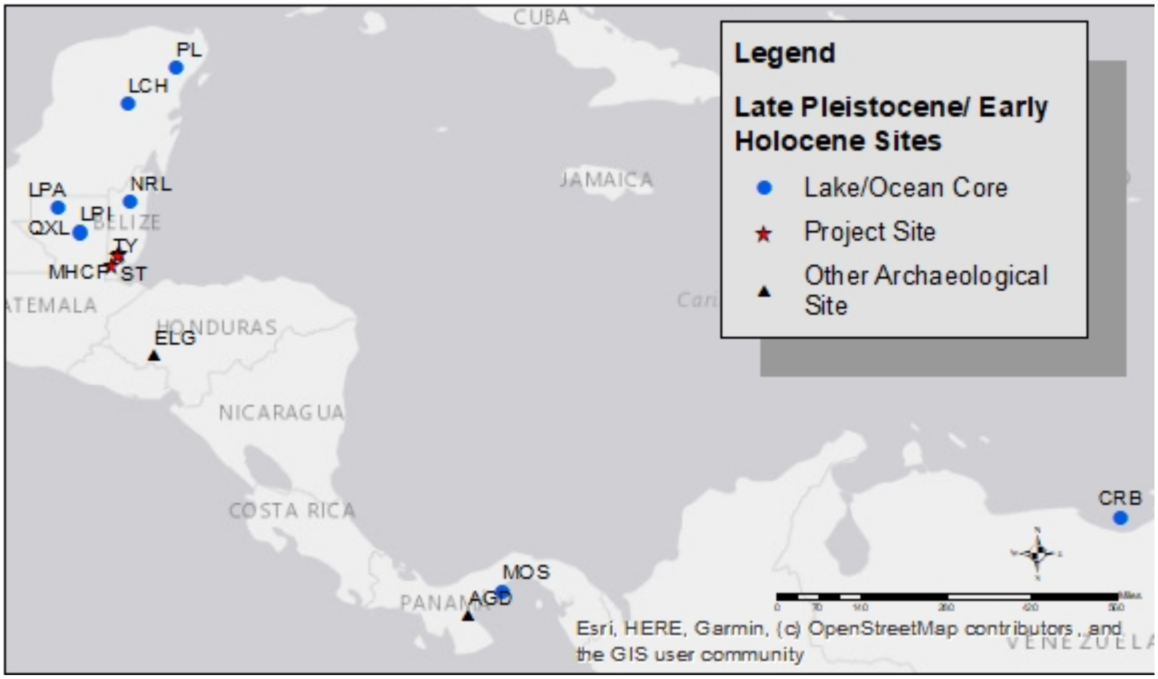
As multiple lines of evidence attest (Fig. 2.4), the first humans to colonize Central America during the Late Pleistocene inhabited a landscape quite different from that of the Archaic period. As described above, the Cariaco Basin core indicates that the Younger

Table 2.2. List of archaeological and paleoecological sites mentioned in the text; abbreviations are used as labels in Figures 2.5 through 2.8.

Site	Country	Map Abbrev.
Aguadulce Rockshelter	Panama	AGD
Aguada Fenix	Mexico	AGF
Actun Halal	Belize	AHL
Bajo Donato	Guatemala	BJD
Cob Swamp	Belize	CBS
Chan Cahal Wetlands	Belize	CCW
Chen Ha Cave	Belize	CHC
Colha	Belize	COL
Cariaco Basin	Coast of Venezuala	CRB
El Gigante Rockshelter	Honduras	ELG
Lake Coba	Mexico	LCB
Lake Chichancanab	Mexico	LCH
Lago Puerto Arturo	Guatemala	LPA
Lake Peten-Itza	Guatemala	LPI
Laguna Silvutuc	Mexico	LSV
Lake Tzib	Mexico	LTZ
La Yeguada	Panama	LYG
Maya Hak Cab Pek (Project Site 2)	Belize	MHCP
Saki Tzul (Project Site 3)	Belize	ST
Tzib’te Yux (Project Site 1)	Belize	TY
Monte Oscuro	Panama	MOS
New River Lagoon	Belize	NRL
Progresso Lagoon	Belize	PGL
Lake Punta Laguna	Mexico	PL
Pulltrouser Swamp	Belize	PTS
Quexil/Salpeten	Guatemala	QXL
Rey Marcos Cave	Guatemala	RMC
San Jose Chuchaca	Mexico	SJC

Dryas witnessed some of the lowest precipitation amounts of the last 14,000 years, leading scholars to posit an overall southward shift of the Intertropical Convergence Zone (ITCZ) during this time (Haug et al. 2001). This low-rainfall trend gave way to one of increasing precipitation from 12,5000 to 10,500 cal BP, finally stabilizing at a relatively high level of precipitation during the so-called Holocene 'Thermal Maximum' which lasted from ~10,500 to ~5500 cal BP.

Closer to my study area, lake cores from New River Lagoon in northern Belize (S. Metcalfe et al. 2009) and several lakes in eastern Guatemala (Leyden 1984; Correa-Metrio et al. 2012; Wahl et al. 2016) and the Yucatan peninsula (S. E. Metcalfe et al. 2000) provide further evidence that the regional climate during the late Pleistocene was much drier and more variable than the following Holocene. These same studies show a drastic increase in temperature and precipitation at the end of the Younger Dryas. This drastic change in climate had corresponding impacts on ecology. A lake core taken from Lake Peten-Itza in Guatemala (with a pollen record stretching back to 65,000 BP)



Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

Figure 2.5: Sites mentioned in the text bearing evidence of Late Pleistocene/Early Holocene paleoecology and/or archaeology. Created in ArcMap 10.6.1

indicates that the transition from the Pleistocene to the Holocene was the most significant floristic change in the entire core. At that time, tropical forests similar to those found today first developed as a result of a warmer and wetter climate (Correa-Metrio et al. 2012; Hodell et al. 2008). Similarly, in discussing lake cores from nearby Guatemalan lakes Salpeten and Quexil, Leyden (1984:4858) concludes that "the 'primeval' tropical forests are no more than 10,000 to 11,000 years old," indicating the landscape prior to that time was much more open than today.

Archaeology of the Late Pleistocene and Early Holocene (pre-8200 cal BP)

The climate changes noted above seem to have greatly influenced hunter-gatherers throughout the region. One Central American site which provides cultural evidence dating to that transition is El Gigante rockshelter located in southwestern Honduras (Scheffler and Hirth 2008; Scheffler, Hirth, and Hasemann 2012; Douglas J. Kennett et al. 2017). The two lowest culture-bearing strata (referred to as Early and Late Esperenza phases) at this rockshelter date between 11,110 and 10,080 cal B.P. and 10,160 and 9550 cal B.P., respectively; both contain abundant flaked stone tools (including bifacial projectile points), deer and other faunal bones, and a variety of wild plant remains. Analysis of seasonality of this floral produce indicates the shelter was used most intensively during the wet season, leading the authors to conclude that it may have functioned as an ephemeral residential camp for small groups of hunter-gatherers (Scheffler et al. 2012:604). Above these two strata, the next overlying stratum dates between 8990 and 7670 cal BP (and will be discussed in greater detail in the below section on the Middle Holocene). Overall, the two lowest strata from this rockshelter indicate a unique hunter-gatherer adaptation focusing on larger game and a narrow subsistence base during the Early Holocene, a period that also witnessed dramatic changes in ecology from a drier, more open biome to one that was wetter and more dominated by closed canopy ecosystems (Kennett et al. 2017). Importantly for my study sites, a recently published analysis of 37 bifacial projectile points and point fragments indicates that those which can be definitively dated all date to the Early Holocene Esperanza phase (Harry B. Iceland and Hirth 2021). The authors note that these dates overlap nicely with those of the Lowe points from my study's sites recently published by Prufer et al. (2019). No complete or fragmentary bifacial project points could be confidently dated to any later phase, further supporting the general conclusion that bifacial projectile points disappear from the archaeological record after 10,000 cal BP (see discussion of El Gigante during the Middle Holocene, below)

In lower Central America – specifically the isthmian land bridge occupied by present-day Costa Rica and Panama – a number of sites attest to the colonization of the area first by Clovis and then by Fishtail Projectile Point bearing cultures dating to the Late Pleistocene/Early Holocene transition (Ranere and Cooke 2020a). Specifically, the authors note a multitude of sites around the Aguadulce rockshelter with abundant evidence for biface production, either through the presence of diagnostic bifaces themselves, or bifacial thinning flakes that are characteristic of both Clovis and Fishtail Projectile Point lithic technologies. These markers of bifacial technology are very abundant in Late Pleistocene contexts, become less common throughout the Early Holocene (which is contemporaneous with the Early Archaic), and "are completely absent from the archaeological record in Panama after ca. 7900 cal BP" (Ranere and Cooke 2020:4). However, a variety of different unifacial scrapers (similar to those found in the lowest levels of Site 1 in my analysis) were also noted. These unifacial tools, along with a multitude of other tool types used in animal butchery and skin preparation – such as burins, gravers, and scraper-plans – point to an overall reliance on the processing of animal carcasses over plant exploitation (Ranere & Cook 2020).

In order to explain this pattern, and the overall dispersal of humans into this region, Ranere & Cook (2020) put together multiple lines of evidence to describe the rapid movement of hunter-gatherers from one high-quality ecosystem to another. The authors theorize that the very earliest occupants of the area "leapfrogged" down the Pacific coast, avoiding densely forested interior areas in favor of more open ecosystems found on continental shelves exposed by lower sea levels. In support of this argument, they point to the rapid expansion of human groups from northern Mexico to Panama in the space of just 240 years. This rapid pace implies that populations were moving too quickly to become familiar with novel plant resources in each ecosystem they encountered. On the other hand, they point out the important prey taxa that could be found in every ecosystem stretching from Alaska to Tierra del Fuego, making hunting an easier subsistence strategy than plant exploitation for these initial colonists.

Climate and Ecology of the Middle Holocene (8200–4000 cal BP)

Paleoclimatic reconstructions for the Middle Holocene generally agree that the period was characterized by a warm, wet climate – perhaps even more so than that seen today. The evidence from the Cariaco Basin (see Fig. 2.7) indicates an overall stable, high-precipitation regime lasting from roughly 10,500 to 5,500 cal BP (Haug et al. 2001), a development the authors link to changes in orbital parameters that resulted in increasing seasonality of insolation in the southern hemisphere, pulling the ITCZ further south. Interestingly, the authors do note a short interval of lower precipitation that lasted from roughly 8300 to 7800 cal BP, and which coincides with the "8.2ka event" mentioned above and attested to in other climatic records. In nearby Panama, cores from a former crater lakebed on Monte Oscuro indicate the lake was first permanently filled around 10,500 ^{14}C yr BP (uncalibrated), and that an "open, dry-land vegetation" regime gave way to "a tropical forest with considerable species diversity" around the same time

(Piperno and Jones 2003:83). Later, around 7500 ^{14}C yr BP, increases in charcoal concentrations and grass pollen, coupled with decreases in arboreal pollen, indicate forest modification by human groups who may have been practicing slash-and-burn horticulture. The first evidence of maize in the form of phytoliths also dates to this time. Similar trends are noted in the speleothem data from Rey Marcos cave in Guatemala (Winter et al. 2020), confirming that the trends observed further afield in Central America also occurred much nearer to my study area. Overall, then, paleolimnological data from the region indicate an increase in wet conditions and the further growth of tropical forests, followed by human disturbance of that forest later in the period.

Lake cores from the Yucatan indicate that, after 9000 BP, rising sea levels pushed up the water table, allowing several modern-day lakes to fill. The earliest sections of cores taken from Lake Chichancanab indicate that wet conditions approaching or even exceeding modern levels occurred after 8000 BP, and that the "most rapid rise in lake level

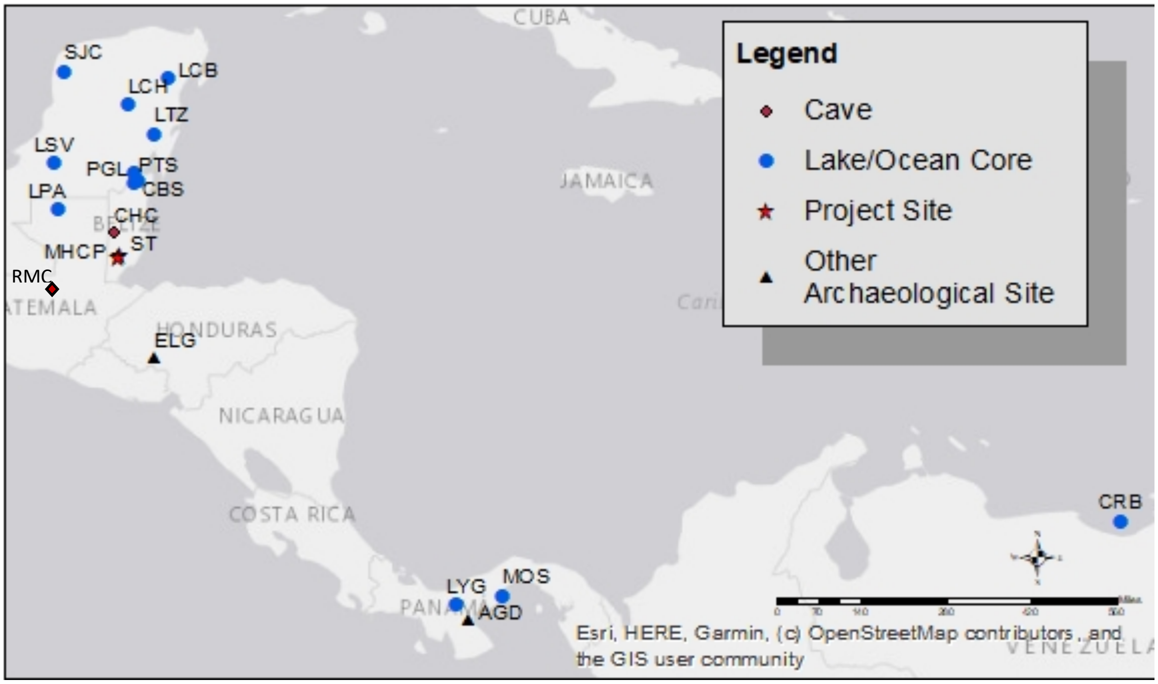


Figure 2.7: Map showing locations of coring and archaeological sites mentioned in the text. Created in ArcMap 10.6.1

occurring about 7200 BP" (Metcalfe et al. 2000:711). Pollen evidence from a core from cenote San Jose Chulchaca indicates the absence of tropical forest taxa such as Cyperaceae and *Brosmium* (more commonly known as ramon) until about 6800 cal BP. In the southwestern Yucatan region, a core drilled at Laguna Silvituc indicates an overall moist climate with tropical forest taxa dominating the pollen profiles (Torrescano-Valle and Islebe 2015).

Pollen and oxygen isotope data from Lake Tzib, a lagoon in southeastern Yucatan not far from northern Belize, indicate low- to medium-stature humid forest conditions, an increase in wetland plants, and relatively high precipitation for the period 7900-7000 cal BP (Carrillo-Bastos et al. 2010). After this period, drier conditions begin to prevail, and the period from 7000-5000 cal BP is marked by a decrease in humid forest taxa, while drier forest taxa increase. This trend appears to reverse around 5000 cal BP, when pollen from both humid forest and flooded wetland taxa begin to increase. Oxygen isotope data on gastropod shells indicate a similar dip in precipitation around 5000 cal BP, followed by an uptick, leading the authors to conclude that "[t]he vegetation around the lake was at that time a mosaic of medium-stature forest and [savannah] vegetation" (Carrillo-Bastos et al. 2010:194). A continental-scale paleoclimate reconstruction for all of Latin America (Marchant et al. 2009:751) indicates that the Yucatan peninsula was one of the only places to have a significantly wetter climate and biome during the Middle Holocene than today. That study indicates that, at 6000+/-500 cal BP, the Yucatan peninsula was characterized by warm evergreen forest biome, rather than the modern-day drier climate marked by warm mixed broadleaf forest and tropical dry forest.

Likewise, a core from Lago Puerto Arturo with an 8700 year record contains oxygen isotope data indicating that the climate became more and more moist from the earliest dates until ~6250 cal BP, after which a drying trend set in (Wahl, Byrne, and

Anderson 2014). Pollen data from the same core show low values for weedy plant species associated with dry conditions; similarly, deep-water plants such as water lilies were more abundant than shallow-water sedges, indicating overall wet conditions throughout the middle Holocene. The authors note that several regions around the perimeter of the North Atlantic seem to have witnessed the same climate regime (sometimes referred to as the Climatic Optimum), followed by a return to drier climate around 5500 BP. Roughly one millennium later, maize pollen makes its first appearance in the core at ~4600 cal BP, although its presence seems to be merely sporadic until ~3500 BP (Wahl et al. 2014:24). Similarly, a speleothem from Ray Marcos cave on the Caribbean side of the Guatemalan highlands also indicates "a relatively sharp wetting in the early Holocene (11,000-9000 years BP)" (Winter et al. 2020:2).

In Belize, Pohl et al. (1996) undertook a coring program at Cob and Pulltrouser swamps in northern Belize, and documented maize and manioc microbotanical remains dating to as early as 5400 cal BP, though they stress that maize cultivation was not common until 4400 cal BP. At that time, the predominance of high forest taxa in pollen diagrams indicates that any cultivation "took place at a time when high tropical forest dominated the regional vegetation, and disturbance was minor" Pohl et al. (1996:363). Furthermore, speleothem data from Chen Ha Cave in the western Vaca Plateau similarly indicate a wetter, less variable climatic regime than that of both the Early Holocene and present Late Holocene periods (Pollock et al. 2016). In that study, the authors attribute these changes to a more northerly annual migration of the ITCZ leading to a longer, wetter rainy season for the area. Because the sites in my study area are located southwest of the Vaca Plateau on the windward side of the Maya Mountains, they likely experienced even higher levels of precipitation during the mid-Holocene.

Archaeology of the Middle Holocene (8200–4000 cal BP)

Archaeologically speaking, El Gigante rockshelter boasts two strata dating to this time frame (Kennett et al. 2017). The lower of these two strata was briefly mentioned above, as it lies at the boundary between the Early and Middle Holocene; the upper lies entirely within the Middle Holocene and dates between 7610 and 7430 cal BP. Faunal analyses from these strata show declines in the frequency of deer bones relative to other small game such as turtles, birds, and crabs (Douglas J. Kennett et al. 2017). Importantly, the authors note that the size of deer bone fragments during this phase are similar to those from earlier phases, indicating the change in frequency is more likely related to changing subsistence than to changes in carcass processing (Scheffler et al. 2012:605). At the same time, there is a complete lack of bifacial projectile points in these layers, which the authors tie into the general transition away from large game hunting seen throughout Central America after 10,000 cal BP.

In terms of floristic resources at the site, the authors note the first utilization of some grassy plants, an increase in fruiting plants, and a continuation of the maguey exploitation noted from earlier periods. Importantly, however, maize is not present in these layers, despite its initial domestication at the end of the Early Holocene and its "widespread dispersal… through the lowland neotropics" not long after (Kennett et al. 2017:9026). A number of hearths and refuse pits, and an increase in wood relative to herbaceous charcoal, indicate the occupants undertook longer and/or more frequent stays at this rockshelter during the Middle Archaic. Overall, they posit that the shelter occupants experienced "a gradual transition from generalized foraging to logistically based resource exploitation made possible by more intensive exploitation of faunal resources and both annual and perennial plants" (Scheffler et al. 2012:605).

To the southeast, several Panamanian sites bear evidence dating to the Middle Holocene. At a site near La Yeguada, excavation data reveals "an early human presence and the development of horticultural systems using seed and root crops between ca. 8000 BP and 5000 ^{14}C yr BP" (Piperno and Jones 2003:84). Ranere & Cook (2020) also describe a "mixed subsistence economy" at Aguadulce shelter including a wide variety of fish, birds, small mammals, and reptiles, as well as palm, arrowroot, and numerous other economically important plants. The nearby site of Cerro Mangote shows a similar reliance on a wide variety of fauna, but also a heavier reliance on white-tailed deer, whose larger biomass made it the "most important meat package" (Ranere & Cook 2020:12). Overall, these sites portray groups of hunter-gatherers beginning to use cultivars and in general broadening their resource base.

Closer to my study sites, Rosenswig et al. (2014) describe their analyses of seven stone tools from several Archaic-period sites in northern Belize near Progresso Lagoon. In addition to being geographically close to one another, the sites share features such as aceramic layers of distinctive grainy orange soil containing heavily patinated lithic tools. This orange soil is found throughout northern Belize and often associated with patinated lithics. Most of the sites occur on islands or shorelines of lagoons in the area. Unfortunately, only three charcoal samples were recovered and radiometrically dated, yielding two Middle Holocene dates and one Late Holocene. While this paucity of dates makes it difficult to exactly place these sites within the long Archaic period, the lack of ceramics and the presence of several economically valuable plant species known to be domesticated during the Middle Holocene indicates a Middle-to-Late Holocene occupation.

Lithic analysis indicates that these occupants crafted unifacial and (rarely) bifacial tools. Starch grain and phytolith analyses of these tools attest to the fact that they were most often used in the exploitation of floral, not faunal, resources. All seven of the tools chosen for analysis contained "[s]tarch granules of maize (*Z. mays*) and other economic species" (Rosenswig et al. 2014:316). While maize granules were the most frequent type, manioc and chili pepper starch grains were also reported, as well as a single squash grain and several grains from various types of beans. The authors indicate this data provides "direct archaeological evidence that semi-sedentary forager-farmers in northeastern Belize used maize and other domesticates during the millennia preceding the onset of sedentary agrarian life in the Maya area" (Rosenswig et al. 2014:320).

Climate & Ecology of the Late Holocene (post-4000 cal BP)

The start of the Late Holocene period is marked by a continuation of the increasingly warm and wet climatic conditions noted above (Fig. 5.17). At Laguna Sitivuc in the southwestern Yucatan peninsula, the first maize pollen appears around 4100 cal BP, indicating human occupation and manipulation of the landscape well before the

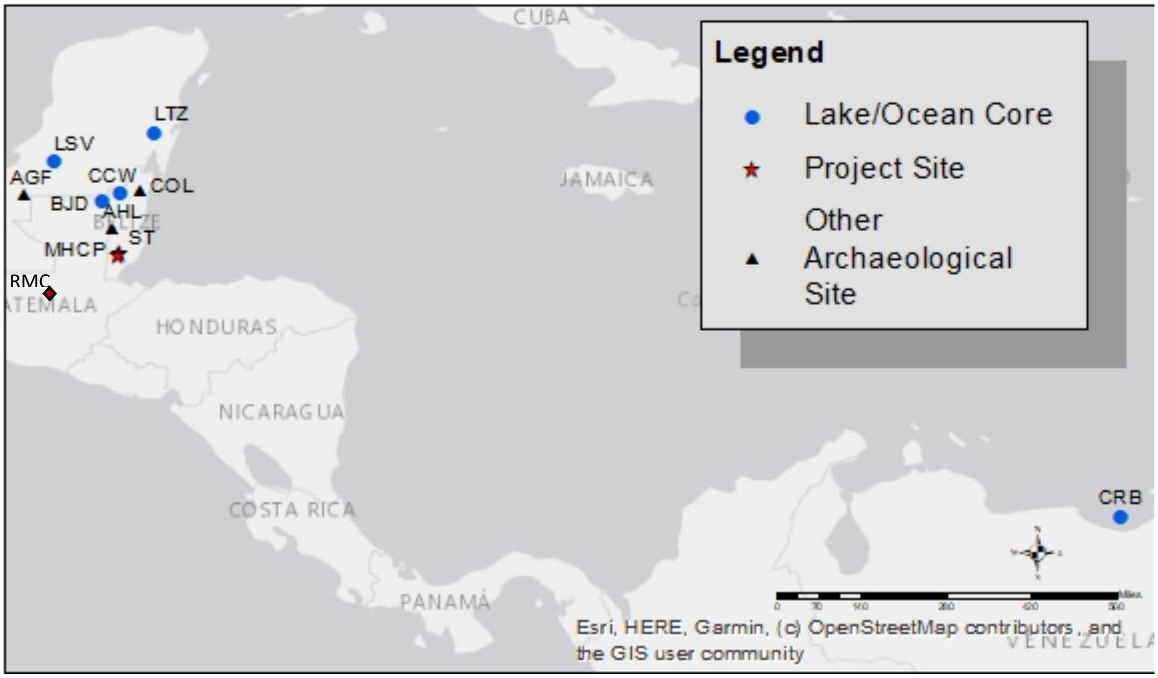


Figure 2.8: Map showing locations of coring and archaeological sites mentioned in the text. See Table 2.2 for abbreviation meanings.

generally accepted picture of occupation beginning in the Preclassic (Torrescano-Valle and Islebe 2015). Wetter conditions prevail in that area until 3000 cal BP, when pollen evidence indicates the presence of a medium-stature forest and relatively high levels of precipitation relative to the Middle Holocene (Carrillo-Bastos et al. 2010:194). The pollen data from Lake Tzib (LTZ) in the eastern Yucatan indicate medium-stature forest prevailed while oxygen isotope data confirm an overall wet climate (Carrillo-Bastos et al. 2010). At around 3500 cal BP, however, both pollen and isotope data from this lake indicate a drought that coincides with one noted in paleoecological datasets from as far away as northern Central America and the Cariaco Basin (CRB) off the coast of Venezuala (Haug et al. 2001). Interestingly, this drought appears to coincide with the first evidence of maize pollen at Lake Tzib along with increasing prevalence of disturbance taxa (at 3650 and 3700 cal BP, respectively). These data fall at the very beginning of the Middle Preclassic Maya period (generally seen as dating to 900 BC, or 2900 cal BP), and multiple pollen proxies from that area indicate land clearance and maize farming.

Closer to the study sites, evidence of Late Holocene paleoecology comes from cores drilled at Bajo Donato (BJD) in northeastern Guatemala and the nearby Chan Cahal wetlands (CCW) in northern Belize (Beach et al. 2009). At both sites, the authors note four distinct soil deposition phases, the earliest of which (Zone 1) dates to the Late Holocene (Late Archaic) time period. Data from this soil horizon at Chan Cahal "included relatively abundant charcoal and herb and cultigen, wetland, and *Z. mays* pollen; thus indicating evidence for burning and agriculture in the Archaic and Preclassic mixed forest" (Beach et al. 2009:1717). The overlying soil zones at both sites appear to straddle the Late Archaic/Preclassic transition and are also marked by the presence of *Z. mays* pollen, though not in great amounts.

At Pulltrouser Swamp (PTS), several lines of evidence point to extensive forest disturbance and an increase in maize and manioc pollen after 2500 cal BP (Jones 1994b), developments attributed to non-ceramic using Late Archaic populations who may (or may not) have become the ceramic-using Maya of the Middle Preclassic. Importantly, an abundance of high-quality chert nearby is thought to be an important factor in the use of this site, during both Archaic and later Maya periods. Thus, this part of Belize would've given early forager-horticulturalists predictable access to high quality toolstone and would likely have encouraged a more expedient than curated form of lithic technology. In reviewing this palynological and paleoclimate evidence in the context of increasing maize consumption throughout Central America, Lohse (2010:320) concludes that "although maize and (probably) manioc production was commonplace elsewhere in Mesoamerica as well, it is clear that no significant break in the paleoenvironmental record marks the initial appearance of sedentism" during the Late Archaic.

Archaeology of the Late Holocene (post-4000 cal BP)

As mentioned above, in certain parts of Mesoamerica the Early Preclassic (or Early Formative) period begins around 2500 B.C. – overlapping the Middle/Late Holocene boundary of 4000 cal BP. At that time, the first full-time villages were being constructed and the first ceramics invented along the Pacific coast (in the Soconusco region at the border of Mexico and Guatemala) and around the Gulf coast (in what is known as the Olmec heartland). In other words, some areas of the greater Mesoamerican region were fully "ceramic" at the same time that peoples in Belize were in the Early and Late Preceramic. Within the Maya Lowlands, there appears to be only one ceramic-bearing site, Aguada Fenix, with occupation dating to the Early Preclassic – although it does not seem to have been occupied by completely sedentary groups. Because it overlaps chronologically with the end of the Late Archaic in Belize, I will discuss this potentially precocious, culturally Maya site here before turning to the Late Archaic evidence at my study sites.

In part due to the use of LiDAR over large parts of the Maya Lowlands, archaeologists have recently become aware of the site of Aguada Fenix, which lies in the Usumacinta region where Mexico meets the northeastern corner of Guatemala. The site provides some of the first evidence of Early Preclassic ceramics in the Maya region. The earliest ceramic-bearing sediments at the site yielded radiocarbon dates of 1250-1150 and 1150-1050 BC, indicating that "the people of this region had begun to use ceramics by 1200 BC, one to two centuries earlier than those of Ceibal, Tikal, Cahal Pech, Cuello and other Maya communities" (Inomata et al. 2020:2). In addition to these early dates, what makes the site most distinctive is a massive rectangular platform measuring 1413 x 399 m (an area of 563,787 m^2 or roughly 56.4 hectares), with an estimated construction volume of 3,200,000–4,300,000 m^3. Although the lowest levels of the platform date to only 1000 BC, it's massive size and early ceramics make this site stand out from other large Middle Preclassic sites in the Maya Lowlands such as Ceibal and El Mirador.

Yet another interesting feature is a relative paucity of residential platforms, which are so common at other Middle Preclassic Maya sites. In fact, builders of the site may not have been Maya speakers at all, although the authors note that the ceramics found more closely resemble later Real ceramics from Ceibal than they do contemporaneous Olmec ceramics from the Gulf Coast. In addition, all obsidian pieces so far analyzed can be traced to Guatemalan sources, unlike those from the Olmec center of San Lorenzo, at which Mexican sources predominate. Overall, the authors conclude that the builders of Aguada Fenix "appear to have had closer cultural affinities with the Maya lowlands than with the Olmec area" (Inomata et al. 2020:3). Furthermore – and of particular relevance to my study – the lack of residential platforms at Aguada Fenix (and similar, smaller sites in the Usumacinta area) “suggests that a substantial portion of the inhabitants of the Middle Usumacinta region maintained a degree of residential mobility” (Inomata et al. 2020:3). Of course, the absence of residential platforms (which would’ve been entirely novel for the area at that time) in this case is not necessarily the same as proof that the sites were not occupied full time – for example, smaller, perishable structures built directly on the ground may have existed, and would leave little trace for LiDAR to find.

A similar lack of sculptures or depictions of elites provides yet another contrast with the Olmec region, where monumental stone heads are thought to depict powerful chieftains or kings at the top of a steep social hierarchy. Although the paleobotanical evidence thus far analyzed does point to the use of maize at the site, the authors note that “Aguada Fénix may be analogous to early ceremonial constructions that emerged during pre-agricultural or incipient agricultural periods in other parts of the world” (Inomata et al. 2020:4). The site presents an intriguing example – alongside Gobekli Tepe, a Pre Pottery Neolithic A temple in southern Anatolia; monumental constructions of the Jomon culture of Japan; and Poverty Point and the numerous Late Archaic shell rings of the Southeastern US – of monumental architecture built by social groups that were almost certainly not full-time farmers (Dennehy 2011).

I return now to my discussion of archaeological evidence of the Late Archaic period in Belize. Initially, the Belize Archaic Archaeological Reconnaissance (BAAR) recorded sites of aceramic lithic scatters throughout the country (MacNeish and Nelken-Terner 1983), but relied on problematic dating methods to seriate them throughout the Archaic period based on stylistic similarities to other North American point types (Lohse et al. 2006). A more recent study (Stemp et al. 2016) analyzing Belizean projectile points thought to date to the Archaic periods – including several found within the vicinities of all three rockshelters – finds significant difference in point size and possible function (i.e. dart vs. thrusting spear points) according to stylistic type. The authors conclude that this variation likely reflects two complementary functions: wounding animals with the sharpened projectile or spear points, and butchering and processing the carcasses with the serrated, alternately beveled edges.

Implicit within this analysis is the typical view of highly mobile Archaic foragers dependent on animal resources. Notably, however, the authors also find problematic the relatively young Late Archaic age assigned to these types, in that it is based on only two examples from insecure contexts. They also note that other projectile point types from much older, Paleoindian contexts (both in Belize and elsewhere in North and Central America) share similar characteristics. Even more recently, all three of the shelters in my study yielded complete and partial projectile points from securely dated, well stratified contexts (Keith M. Prufer et al. 2019) with minimum ages falling between 10,223 and 9300 cal BP, making it likely that these projectile points are diagnostic of a much older time period, well before the initial adoption of cultivars.

In the western part of the country, a rockshelter known as Actun Halal provides securely dated evidence of Late Archaic occupation in that region (Lohse et al. 2007). Researchers documented a geoarchaeological unit (Stratum II) that was devoid of ceramics but which contained many lithics. Radiocarbon dating provides evidence for two Late Archaic components, “the first conservatively dated from 2400-1800 B.C.E. and the second from about 1400-1210 B.C.E” (Lohse et al. 2007:27) – in other words, the Early and Late Preceramic. One constricted adze similar to those found in northern Belize (see below) was recovered from this second component. Additionally, palynological analyses of sediments dating to this sequence demonstrate the presence of both economically valuable crops like maize, and potentially ritually valuable plants such as morning glory. Altogether, this evidence points to the early use of cultigens “long before settled villages and the appearance of ceramic technologies," and the possibility that "preceramic peoples were consuming hallucinogenic plants [such as morning glory] in cave settings long before the Maya recognized these locales as ritually significant" (Lohse et al. 2007:27-28).

Until recently, nearby northern Belize boasted "one of the densest concentrations of known Archaic-period sites in Mesoamerica" (Rosenswig 2015:136), a richness my study area equals in copious materials from southern Belize. In the north, Colha provides a well-known, securely-dated context for Late Archaic lithic production at a site that would go on to become an important Maya settlement (S. M. . Wilson, Iceland, and Hester 1998; Barrett, Shafer, and Hester 2011; Shafer and Hester 1991; Harry B. Iceland 2005). In particular, constricted unifaces, a fairly well-known type of adze also found in the Caribbean, were produced and used extensively at the site (Rosenswig 2015b) and are "thought to be diagnostic of the late Preceramic in northern Belize" (Iceland 2005:17). Believed to have been used for land clearance and/or wood-working, the tools often have a distinctive shape, with a constricted waist near the base that likely facilitated hafting. However, they also can be quite variable in shape, due in part to their extensive resharpening (Harry B Iceland 1997). Importantly, Lohse et al. (2007:3) note that though these adzes were almost always unifacially flaked, "occasional bifacial specimens are found where stone materials are not as plentiful," providing yet another association between bifacial flaking and raw material scarcity.

Abundant lithic debitage associated with the production of constricted unifaces has been identified through refitting with unifacial tool blanks; this lithic material is so abundant at one particular site near Colha that Iceland (2005:22) terms it a "Preceramic quarry-production locale." Intriguingly, this locus was the site of a later Middle Preclassic platform that also bears plentiful evidence of lithic production and use. In fact, Iceland (2005) indicates that Colha may be unique in the Maya region for the apparently continuous use of the site from the late Preceramic into the "ceramic" Middle Preclassic and beyond – that is, until its abandonment in the Terminal Classic Maya period. He also notes important continuities in lithic production techniques throughout these phases, including "blade and bifacial components, beveled-bit adze forms (the constricted uniface), bifacial celt forms, and the use of macroblade and macroflake blanks produced by hard-hammer percussion on prepared macrocores" and goes so far as to name it the "Colha Lithic Tradition" (Iceland 2005:21). Being that this lithic tradition predates any ceramic typologies or traditions at the site, he indicates that the constricted uniface may be a "stylistic expression of a northern Belize regional identity at this time" that presages "the Bolay ceramic sphere," the first widely-used Middle Preclassic ceramic type in the region (Iceland 2005:24).

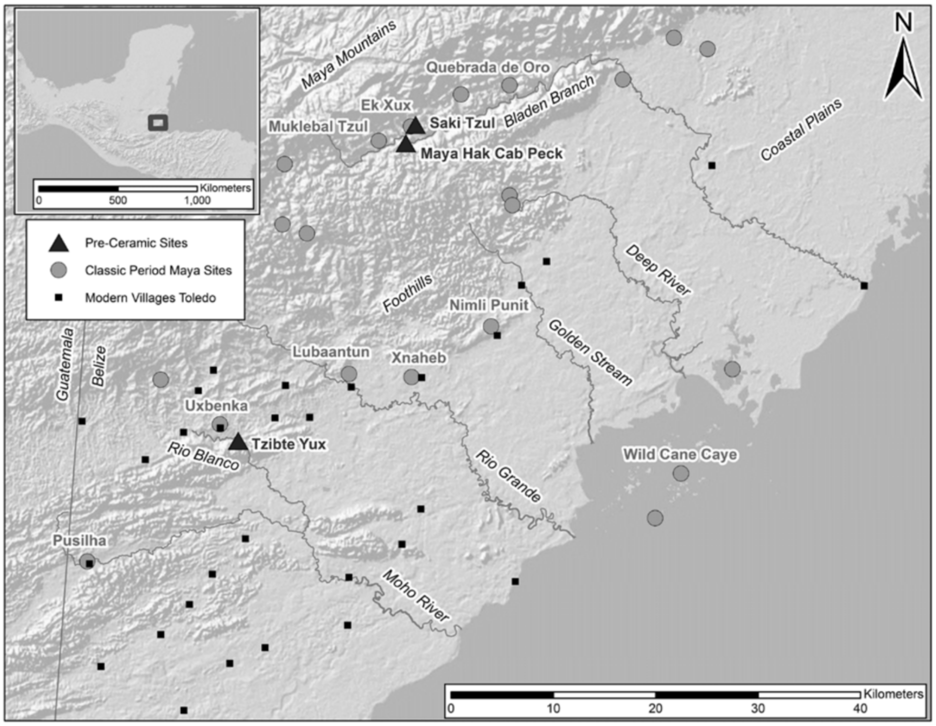


Fig 2.9: Map showing location of Shelter 1 (Tzibte Yux), Shelter 2 (Maya Hak Cab Pek), and Shelter 3 (Saki Tzul), along with later Classic Maya sites and modern-day villages. Map credit: Amy Thompson in Prufer et al. 2020:200.

Study Area

My study assesses changing trends in lithic technological organization across all of the chronological periods discussed above, using materials collected from three Belizean rockshelters: Tzib'te Yux (Shelter 1), Mayahak Cab Pek (Shelter 2), and Saki Tzul (Shelter 3). All are located in the Toledo district of southern Belize (see Fig. 2.9). Excavations in these rockshelters have resulted in numerous field reports, masters' theses (Orsini 2016a; Meredith 2014a) and published manuscripts that focus on the rockshelter's chronology (K. M. Prufer, Meredith, et al. 2017), evidence of population linkages with South America in the form of bifacial lithic styles and ancient DNA (K. M. Prufer et al. 2019) and dietary patterns (Douglas J. Kennett et al. 2020). Further paleobonatical, sedimentological, and zooarchaeological analysis of faunal remains is underway (K. Prufer, personal communication). Here, I present a summary of each shelter and their chronostratigraphic contexts; excavation results are discussed in greater detail in Chapter 4.

Shelter 1: Tzib'te Yux

Shelter 1 is located along the Rio Blanco roughly 40 km inland from the Caribbean coast and has been the focus of five seasons of investigation by the Uxbenká Archaeological Project (UAP) directed by Dr. Keith Prufer at the University of New Mexico. Initial ^{14}C samples from the bottom of the first test unit (excavated in 2012) returned a surprisingly early Terminal Pleistocene date of 10,571-10,526 BC (K. M. Prufer, Meredith, et al. 2017:323). Further excavations were conducted during the 2013 to 2015 field seasons using arbitrary 5cm levels (unless changes in stratigraphy dictated otherwise). These layers evinced mostly horizontal stratigraphy, with a slight dip in the rear of the rockshelter. Published site reports (Meredith 2014b; Meredith and Dennehy 2015; T. Dennehy et al. 2016) summarize findings dating to the Classic and Preclassic

Maya period, as well as the bottom-most red clay layer, which yielded the Terminal Pleistocene date mentioned above. A continuous, anthropogenic shell midden, composed of shells from an aquatic snail known as jute (pronounced “hoo-tay”; genus *Pachychilus*) characterized the intervening stratigraphic unit. Each lithic artifact larger than 2cm in diameter was point plotted in three dimensions using tape and line level.

Shelter 2: Maya Hak Cab Pek

Shelter 2 is located along the Monkey Branch of the Bladen River in the mountainous Bladen Nature Reserve. Two early seasons of fieldwork there have been described in Prufer (2002), and results of more recent excavations there, under the auspices of the Bladen Paleoindian and Archaic Project (BPAAP, also directed by Dr. Prufer), have been recently published (K. M. Prufer, Robinson, and Kennett 2020). Strata occur in more or less horizontal layers, with a dip occurring near the rear (eastern) wall of the shelter similar to that seen in Shelter 1. During the 2014 season, the topmost excavation units were dug in 20-cm arbitrary levels; once aceramic layers were reached (~130 cmbd), 10-cm levels were used, and diagnostic lithics, large fauna pieces, and carbon samples were all point plotted. During the 2016 season, 5cm levels were used for the aceramic layers so as to better constrain assemblages to a shorter time period. As in shelter 1, sediments in shelter 2 contained archaeological materials as well as concentrations of jute shell, in some cases making up almost 25-50% of sediment (K. M. Prufer 2002). However, the density of jute at Site 2 was much less than at Site 1, with highest jute density occurring in contexts dating between 5,000-4,000 BP, the only levels that can be referred to as a true shell midden. The noted difference in jute concentrations between the two rockshelters could be due to differing levels of jute consumption, or to differing depositional or taphonomic processes.

Shelter 3: Saki Tzul

Saki Tzul (Shelter 3) is located about an hour's walk from Shelter 2, along a tributary of the Bladen River known as Ek Xux Creek. It is much larger than Shelter 2, and also lies about twice as high above its creek as Shelter 2 is above the Bladen river. It was first excavated in the 1990's (Saul, Prufer, and Saul 2005), but only Maya-era levels were uncovered. In 2016, we excavated another portion of the site to seek preceramic deposits; radiocarbon samples from that excavation evidenced deeply stratified deposits dating from the Paleoindian through the Archaic periods. As at Shelter 2, jute are present but do not form a true shell midden aside from one stratigraphic zone (see Chapter 4). The difference in jute concentrations between Shelter 1 on the one hand, and Shelters 2 and 3 on the other, may reflect differences in local abundance of jute or levels of jute consumption. Project members are using more recent excavation data to better constrain the chronology and also address questions regarding taphonomy and sediment and jute deposition (K. M. Prufer et al. 2019; Douglas J. Kennett et al. 2020; Prufer, Keith M.25 and Kennett 2020). Because jute can supply a dense, predictable source of calories and protein, it may have made these shelters more attractive as either residential bases or processing sites for logistical task groups.

Similarities and Differences among Project Sites. In each rockshelter's immediate landscape, the amount of surface water available (which is known to impact forager mobility – see Kelly 1983, 2013) is affected by geology. Like much of the Maya area, Shelter 1 sits amongst porous limestone hills that generally prevent good access to surface water; however, surface sediments in the immediate vicinity of the rockshelter are underlain by impermeable sandstone formations known as the Toledo Beds, allowing perched aquifers to feed perennial springs. The areas around sites 2 and 3 lack these impermeable layers, but several springs are available which, along with the nearby river, serve as perennial sources of water in the area (K. Prufer, pers. comm). In both locations, the predictability and density of the riverine resources make these rock shelters comparable in terms of access to water and aquatic foods. However, their differing geological settings and resultant ecologies (Shelter 1 in jungle-covered foothills not far from the coastal plain, Shelters 2 and 3 in mixed broadleaf-evergreen forests in the igneous Maya Mountain uplands) make them ideal settings to explore differences in mobility due to landscape characteristics.

The intensity of forest clearance and density of settlement practiced in Maya times, coupled with the high seasonal rainfall (over 3000 mm per year), means that open-air sites dating to the Late Archaic may be deeply buried. Thus, these rockshelters offer rare opportunities to retrieve Archaic-period materials. Recently, the UAP has also undertaken geoarchaeological testing of riverine terrace trenches near Shelter 1. Analysis of carbon samples from several layers has allowed project members to calculate changes in the rate of sedimentation from the pre-Maya Archaic to the Preclassic (Maya) times; these rates suggest increasing forest clearance evidenced through increasing sedimentation and charcoal frequency (Meredith 2015; Thompson and Merriman 2014), and provide another line of evidence regarding changes in mobility and subsistence during this period that I will compare to my assessment of mobility based on lithic traits.

Subsistence at Project Sites: Recent and Ongoing Work

Several recent works focusing on Holocene-period subsistence have utilized data from ancient faunal and human remains from all three shelters. Because of the salience of this topic to my study, I review not only these works but their larger contexts here. I first summarize work examining the importance of the ubiquitous jute (both as a source of calories and calcium carbonate used in other ways) found at all three sites, followed by a synopsis of a study analyzing Preceramic faunal assemblages from Shelter 2. Finally, I delve into a recent study examining early maize consumption that uses isotopic evidence gleaned from human remains from Shelters 2 and 3.

Jute as Food and Lime Source. Because of their ubiquity in the Maya lowlands and potential value as a dense, predictable food resource, there has been a considerable amount of scholarly study of jute. The shells of these aquatic, riverine snails generally measure 2-5cm in length (Meredith 2014a); however, season or age of collection cannot yet be established due to the paucity of research into this species' life cycle. Jute shells have been found at a wide variety of Maya sites, including large and small Maya cities, rockshelters, and caves. Prior work has focused on both their practical value as a food source (Moholy-Nagy 1978; Healy, Emery, and Wright 1990; Sidrys 1983) or lime source for increasing the nutritional yield of maize (Bressani and Scrimshaw 1958; Nations 1979), and their ideological value related to sacred waters, the Maya underworld, and ritual deposits in caves and rockshelters (Halperin et al. 2003; K. M. Prufer 2002). Regarding the nutritional yield of the snails, Healy, Emery, and Wright (1990:177) conducted an analysis that found jute to have less protein, but more fat and carbohydrate, than other mollusks of similar size; in fact, nutrient yields were comparable to rabbit and turtle meat. Analysis of jute shells from the midden at Shelter 1 indicate more than 90% are "spire-lopped", meaning the tip had been chipped off, severing the snail's attachment to the shell and allowing its easy extraction (Meredith 2014b). This indicates that the jute were indeed consumed, though whether on-site or at another location is unclear.

However, neither analysis included an estimate of net caloric yield, which would require estimates of energetic costs of searching for, handling, and processing the snails. Because of this, it is not yet possible to state where jute might fall along a ranking of faunal resources in the area, an important step for models of foraging behavior such as patch choice (CITE). Some modern-day Maya regard them as “poor man’s food” (Healy, Emery, and Wright 1990:179), and most studies assume they would serve as a poor but necessary source of protein in a diet otherwise dominated by maize and other vegetal resources. As a source of lime used to enrich the protein content of maize, their overall nutrient contribution to a maize-based diet would be substantially greater than as a direct source of protein alone (Nations 1979:569); however, such use consumes the shell, and so cannot completely explain the high quantities of jute shells found at all three project sites. Given that a deep pool of the Rio Blanco (which remains filled even during the dry season) lies just below Shelter 1, it seems likely that the initial processing of jute occurred in the shelter, since transporting jute in their shells to other residential sites would require relatively greater energy than transporting the de-shelled snail (which at ~5 grams weighs over 90% less than a specimen in its shell) (Andrews 1969). Shelter 2 sits about 10 m higher above its likely source of jute (the Bladen river), and Shelter 3 over twice as high above its source (Ek Xux creek), requiring a scramble up nearly 25 m of steep karstic terrain. This difference in height above jute source may partly account for the differing concentrations of jute in sediments between Shelter 1 on the one hand, and Shelters 2 and 3 on the other.

Faunal Assemblages at Shelter 2. Orsini (2016) provides an initial overview of faunal use at Shelter 2, specifically comparing differences in faunal diversity in assemblages from preceramic (Pleistocene through Late Holocene) levels to those from ceramic (Preclassic Maya) levels. At the time, a detailed age-depth model had not been developed, so the author utilized the presence or absence of ceramics in each level as a rough indicator of time period. The preceramic assemblage in her study also covers roughly 5500 years, since the earliest levels date between 9120 and 8756 BC while the latest date between 3499 and 3348 BC. The ceramic assemblages, on the other hand, cover the roughly 2250 years of the Preclassic Maya period. For this reason, the preceramic assemblages constitute a larger sample of faunal remains (n=1051, or 64% of the total) compared to the ceramic (n=600, or 36%).

The author notes that overall preceramic species diversity (as measured by the Number of Identified Species, or NISP, as well as the Shannon Diversity Index) was higher than ceramic, but that this was likely a function of changing species composition over a greater span of time and greater variety of climate regimes. And when the author excluded unidentified faunal remains and blue land crab (which were anomalously more common in the ceramic levels), the ceramic assemblages appeared more diverse, with a higher NISP and Shannon Diversity Index. In terms of faunal classes, large mammals make up a significantly higher proportion of preceramic (36.9%) compared to ceramic (21.3%) assemblages (*p* values not reported). Additionally, proportions of reptiles were significantly higher in the ceramic (22.3%) than preceramic (7.5%). Overall, this study documents a shift from a subsistence pattern narrowly focused on large mammals to one more broadly focused on a wider variety of other animal taxa, one the author notes is consistent with the idea of a Broad Spectrum Revolution (Flannery 1969) thought to be occurring throughout Mesoamerica during the Holocene (Orsini 2016:61).

Isotopic Signatures of Maize Use from Shelters 2 and 3. Further direct evidence of changing Holocene subsistence patterns comes from a recently-published study by my colleagues at UNM and several other universities that focused on stable isotope analyses of human remains from Sites 2 and 3 (Douglas J Kennett et al. 2020). These investigators sought to understand how much maize may have contributed to the diet of individuals who were buried in these two rockshelters, and whether that contribution changed over time. Specifically, the authors assessed the presence of isotopes of carbon (^{13}C) in bone collagen, which is related to the dietary significance of plants using either the C_3 (Calvin-Benson) photosynthetic pathway or the C_4 (Hatch-Slack) pathway (maize being one of the only plants in the lowland neotropics that uses the latter, although plants in the Amaranthaceae taxon do as well). The authors also assessed the presence of ^{15}N in bone collagen to control for the possible contribution of marine resources to the diet (which can "mimic the consumption of C_4 plants"); furthermore, the authors included ^{13}C from bone apatite in their analysis because it "generally reflects the whole diet (carbohydrates, lipids, and proteins)" unlike bone collagen, which "is strongly biased to the protein component of the diet" (Kennett et al. 2020:2). Having thus controlled for other possible sources of carbon, the authors found three broad groupings of individuals' diets based on their putative reliance on maize: the pre-maize diet, the transitional maize diet, and the staple maize diet.

These three diets also corresponded to different chronological periods. The pre-maize diet was found in individuals whose remains were directly dated to between 9600 and 4700 cal B.P., and thus represents the dietary makeup during the end of the Early Holocene throughout most of the Middle Holocene. These individuals showed no enrichment of ^{13}C in bone collagen typical of diets heavy in C_4 plants, and ^{15}N values typical of foragers focusing on terrestrial, and not marine, resources. The authors conclude these individuals represent "a population consuming C3 plants and terrestrial animals from lowland tropical environments," yet note that "[o]ther domesticates such as squash (*Cucurbita spp.*) or manioc (*Manihot esculenta*) also cannot be ruled out" since they are also C_3 plants (Kennett et al. 2020:4). Additionally, ^{13}C values in bone apatite indicated 0 to 21% C_4 contribution to the diet. Given this range of values, the authors conclude that they "cannot rule out minimal consumption of C4 plants (e.g., Amaranthaceae or maize), particularly in the case of three individuals … with values between 16 and 21% C4 dietary contribution coming from C4 carbohydrate-rich source(s)" (Kennet et al. 2020:5). Altogether, the authors posit that, prior to 5600 cal B.P., humans use of the two rockshelters was "persistent but episodic, suggesting low-density populations exploiting a resource-poor neotropical forest" (Kennet et al. 2020:6).

The picture is somewhat different for individuals relying on the so-called transitional maize diet, whose remains were dated to between 4700 and 4000 cal B.P. (i.e. the tail end of the Middle Holocene). Both the ^{13}C and ^{15}N collagen values indicate substantially more C4 plants in the diet, given that collagen is more sensitive to sources of protein and maize is a relatively rich source of ^{13}C-enriched protein. Bone apatite is even more enriched in ^{13}C, and indicates that maize (by this point the most abundant C_4 plant in the ecosystem) contributed around 25% of the diet. The authors note that, although there is a higher amount of variability in the apatite values for this group than the pre-maize diet group, this may have more to do with the small sample size and its variation in terms of age (with 7 of 10 individuals being younger than 3 years old). The enriched collagen values in particular indicate that proteins from maize kernels, and not just carbohydrates from stalk juices, were contributing more than 25% of the total diet. The authors also note that this isotopic signature (of increasing reliance on maize) corresponds chronologically with evidence from other parts of the Maya lowlands (including those discussed above) that human groups were beginning to utilize land for swidden agriculture. They posit that, rather than a sudden introduction of a fully realized domesticate and its associated processing methods, this change in subsistence may have had to do with genetic changes in maize (either from local experimentation or the introduction of exotic strains) affecting its productivity, or the advent of the alkaline processing of maize known as nixtamalization. Although they do not speculate on the mobility or density of these early farmers, it seems likely that the increased reliance on maize, and the increasing labor demands for its farming and processing, would've required longer and more frequent periods of sedentism near growing fields, perhaps within the rockshelters themselves.

Conclusion

The results of my assessment of Archaic-period mobility (via lithic analysis) will impact thinking on changes in human group subsistence leading up to the Preclassic period. Lithic assemblages consistently presenting traits associated with curation rather than expediency would show that foragers throughout the long Archaic period favored high-RMS mobility. This would further indicate that these societies still practiced a mobile hunter-gatherer lifestyle, even as other parts of the same region witnessed a turn to less mobile proto-agriculture or even horticulture. Alternatively, lithic assemblages that change from curated to more expedient over time would support the view that these groups increasingly relied on LMS over RMS throughout the entire Archaic. This in turn would support the idea that Archaic-period foragers in southern Belize had begun to manipulate their environment and rely on cultivated foods, allowing them to decrease mobility and, potentially, increase population size.

Finally, if my results indicate fluctuations in mobility through time at each rock-shelter, a third scenario – asynchronous development or adoption of horticulture throughout the Archaic, and differing subsistence strategies at each rockshelter – would be supported. Because climate can fluctuate over the course of millennia, and because forager behaviors like mobility and subsistence are in many ways constrained by environmental factors, this scenario would support the HBE idea that human behavior and climate are linked, especially during periods when humans are relying on wild resources. However, once cultivars have been domesticated and more wildly spread out, this same theory would expect to see a decoupling of climatic factors from behavioral outcomes, since agriculturalists have somewhat greater control over resource yields in the face of climatic instability.

CHAPTER 3

MEASURING CURATION AND EXPEDIENCE IN LITHIC ARTIFACTS

In order to assess the relative level of expedient to curated lithic technology used through time at each rockshelter, I conducted analysis of four core traits (flaking type, platform type, amount of cortex, and presence of retouch). Additionally, as part of my collaboration with Dr. Prufer's lab at UNM, I collected data on other traits such as length, width, thickness, and mass; texture and color; and presence and type of edge damage. Although I do not present results of the latter set of traits, I list them so as to present a full accounting of my work (Table 3.1). Unless otherwise noted, the units of analysis for data collection were the assemblages found in each excavation level. The volume of material excavated in these levels varied, as some units were larger than others, and some levels thicker (though most were between 5 and 10 cm in depth). In order to account for this so that levels of different sizes could be compared, I also calculated volume of excavated sediment using ArcGIS 14.0's Cut Fill tool. I then used this volume to derive volumetric artifact densities for each level in terms of number of artifacts per m^3 of fill. Moreover, several of the traits measured by my study report data on a percentage or proportional level, allowing for comparison between levels of different volumes.

Individual Attribute Analysis

The first step in my study was to collect basic information about each artifact using a process known as Individual Attribute Analysis (IAA) (Nazaroff 2015) (see Fig. 3.1 for general lithic terminology used in this section). In general terms, this involved recording each lithic's macroscopic properties, then examining each under 14x magnification to record its microscopic properties. Finally, I used digital calipers to record length, width, and thickness measurements for both the platform (when intact)

Table 3.1: List of additional lithic metrics and traits measured as part of data collection, but not included in the lithic analysis for this dissertation.

Trait	**Description**
Raw Material Color	Munsell color of each chert artifact, based on the Munsell Rock Color Chart (Munsell Color (Firm) (2011))
Opacity	5-part scale to determine amount of translucence (Luedtke 1992)
Texture	5-part scale based on size and luster grains (Rick & Asch 1978)
Lithic Size	Length from platform to distal end; width measured at widest part perpendicular to platform; thickness measured where length & width measurements crossed.
Platform Size	Platform length measured from where platform met each margin; platform width measured from dorsal to ventral edge at widest portion
Edge Shape	Qualitative descrition of profile of edge; included straight, serrated, convex, concave, and combinations of these.
Edge Damage	Qualitative description of damage to each edge, including micro-flaking, polish, striations, and crushing
Thermal Alteration	Qualitative description of evidence of thermal alteration, whether intentional or unintentional; included discoloration, potlids, crazing, and burn marks.
Mean Retouch Height	Measured on unifacially retouched artifacts only. Average of retouch height as measured at three points along retouched edge - proximal, distal, and middle. Retouch height for unifacial artifacts measured with respect to ventral surface as baseline

and the lithic as a whole. lithicists now recognize that such debris are in fact the desired end-product of the flaking process and are often utilized as “informal” tools themselves (Andrefsky 1994; Sullivan and Rozen 1985) even though they do not bear the (visible) markings of further modification or retouch. Thus, the distinction between “tools” and “debitage” has less to do with the functional nature of the piece or the uses to which it was put, and more to do with the effort put into shaping it (Andrefsky 2005).

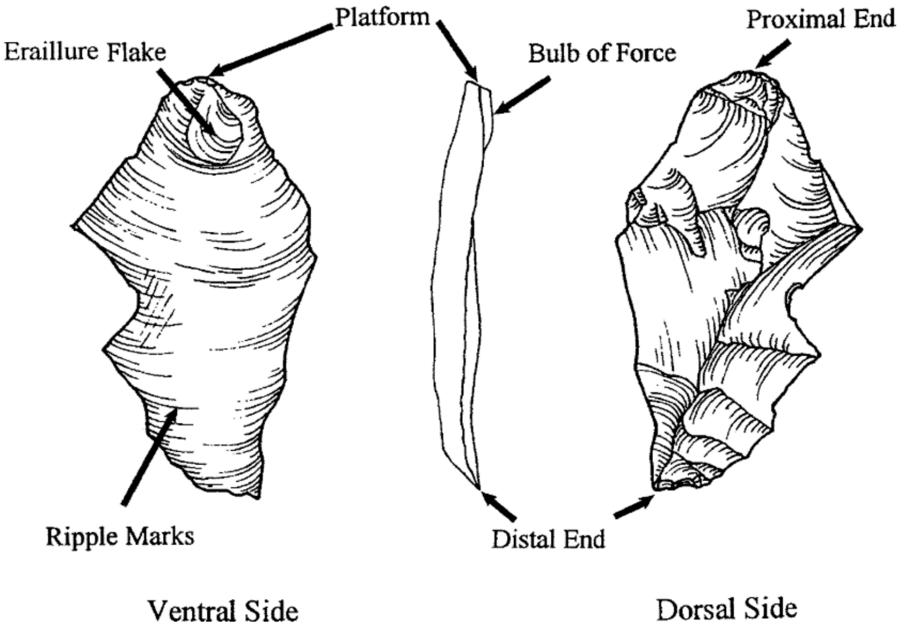


Figure 0.1: Basic lithic orientation and terminology. Figure 2.7 from Andrefsky (2005:19)

I first identified each lithic's raw material type. Over 99% of the artifacts were created on chert, which was relatively easy to identify due to its unique breakage patterns and textures. In cases where the raw material type was not immediately obvious, I resorted to inspection at 14X magnification to assist in its identification. Chert refers to cryptocrystalline sedimentary rocks wherein the size and uniformity of individual mineral grains allow for some degree of control in the fracturing of the parent material (Luedtke 1992). Its visible and tactile characteristics include a relatively smooth surface with either no visible grains, or visible grains that do not cause a roughened texture. Surfaces are often somewhat lustrous, and freshly fractured edges are often acute and quite sharp. These characteristics make chert conducive to controlled shaping and thus, a highly valuable material for lithic manufacture (Andrefsky 2005).

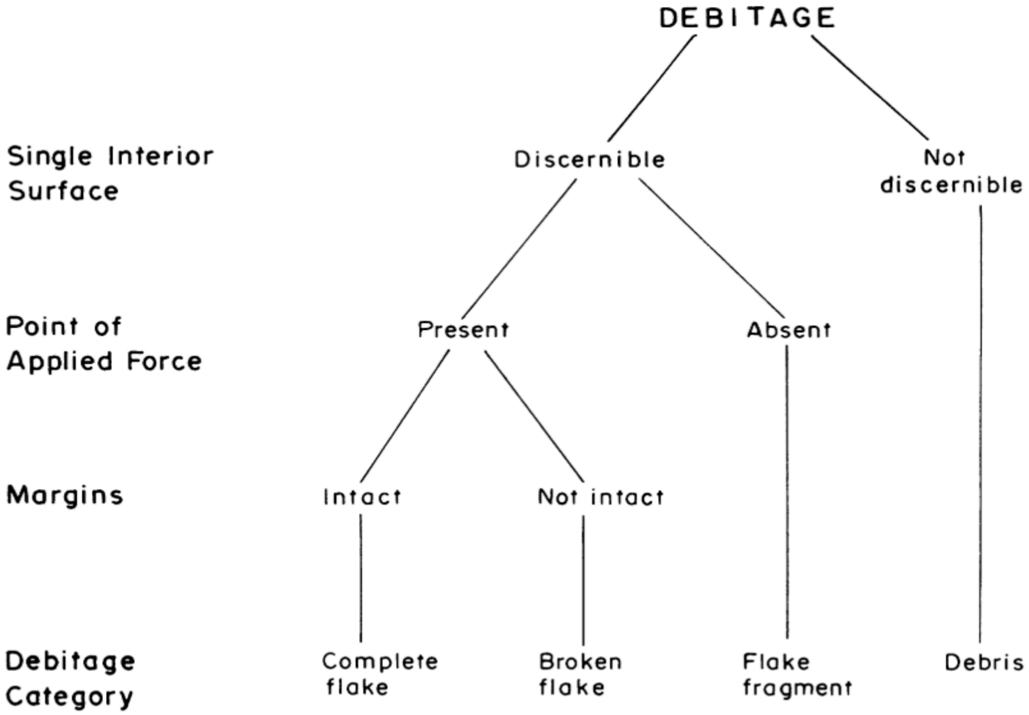


Figure 0.2: Sullivan & Rosen (1985)'s attribute key for debitage. Figure 2 from Sullivan & Rosen 1985:759

Debitage Classification

The second step in the IAA was to determine each piece's completeness using a modified Sullivan and Rozen (1985) classification scheme, which follows a decision-tree format to classify pieces into nested categories (Fig 3.3). The first branch in the decision-tree asks whether or not the pieces has a "single interior surface", that is, a single surface that doesn't have flake scars from prior flaking attempts. In terms of standard flake orientation, this face would be considered the "ventral" surface. I classified anything without such a surface as debris, and further determined many such pieces to be angular debris (Andrefsky 2005:84), meaning they were blocky or chunky rather than flat or flake-like.

Once I had classified a lithic as non-debris, I identified its platform, that is, the striking surface stretching from margin to margin and associated with a pronounced bulb of percussion (a.k.a. bulb of force) or concentric lines of force radiating outward like ripples in a pond. The second branch in the decision tree involved both identifying the platform and examining it for a "point of applied force" (Sullivan and Rozen 1985), otherwise known as the specific spot on the platform where the hammerstone had struck the core to detach the flake (or in Andrefsky's (2005) terminology, where the hammerstone had struck the "objective" piece resulting in a "detached" piece). In some cases, this proved to be fairly straightforward, as I could easily locate a spot on the platform from which lines of force or the bulb of percussion originated. Sometimes humps or rounded ridges also occurred in parallel to these lines of force, showing places where the force of impact rippled through the stone like a wave. Oftentimes, the point of applied force was also marked by a small scar known as an *errailleur* scar, which refers to a much smaller flake detached from the bulb of percussion by the force of the original blow (Andrefsky 2005).

Following Sullivan and Rozen (1985b), I classified lithics without an identifiable point of applied force as fragments and further the remaining section of flake (such as distal, medial, or lateral) where possible. The presence of a flake termination on one edge was quite useful in this regard, allowing me to orient the piece even in the absence of a platform and thus help me identify whether I was looking at the distal (terminal) end or a right or left margin (i.e. a lateral fragment). I classified fragments with neither a platform nor an intact terminal end as medial fragments, whereas those with part of a platform and terminal end were referred to as longitudinally split (i.e., a vertical fracture had sheared off one entire side's margin).

In cases where I could locate the point of applied force, I examined the flake's margins (that is, the original right and left sides of the piece) to see whether or not they were intact, allowing an accurate measurement of the flake's maximum width. I classified those with any section of any margin fractured off "broken" flakes, since they had all the characteristics of a flake but could not be measured for maximal width. Only those with basically intact margins (excepting small chips or fractures in the narrower part of the flake, which would not be measured for maximum width) were considered complete flakes, regardless of the damage done to the distal or proximal edges. Overall, this classification scheme resulted in four basic, mutually exclusive categories: debris, flake fragments, broken flakes, and complete flakes. Importantly, these categories are free of any assumptions regarding the piece's eventual function or use-life.

Core Trait 1: Cortex

I noted the amount each piece's surface covered in cortex, which refers to the outer surface of a chert cobble. Oftentimes, this surface appeared visually distinct from inner material, as it had been subjected to erosion during its journey from its place of origin to its place of collection. However, for cobbles found *in* situ within the limestone beds where they formed, cortex may not be roughened or weathered, but instead refers simply to the boundary between the chert and its parent limestone material. This boundary marks the place where the twin processes of calcium carbonate dissolution and silicate precipitation were arrested during the chert nodule's formation (Maliva and Siever 1989). In either case, it is generally visually distinctive and, most importantly for this study, is often composed of somewhat unworkable stone that is either less silicified or that contains numerous flaws. Therefore, it is often removed at the site where the cobble is encountered; its presence in a non-quarry site is indicative of chert caching such as might be practiced by logistically mobile foragers who stockpile their residential locations with chert encountered during their resource-collecting forays. For each piece, I noted the amount of cortex, if any, found on the dorsal (exterior) surface using the following quartile ranges: 0%, 1-25%, 26-50%, 51-75%, 76-99%, and 100%. To do so, I mentally divided the dorsal surface in half, and then in half again, to estimate the percentage of cortex on it.

Core Trait 2: Platform Type

In cases where I could identify a striking platform (that is, for proximal fragments, broken flakes, and complete flakes), I first characterized it according to its completeness. Complete platforms generally cover the entire proximal end of a flake and intersect both the right and left margins; they also and show no further loss of material on their dorsal or ventral edges in the form of fractures or flake scars. Partial platforms are those that do not intersect with one or both of the flake's margins, or which show significant material loss on their dorsal or ventral sides. Complete platforms were measured for length and width (see below), whereas partial platforms were not, since the original length and width could not be ascertained due to material loss. Furthermore, I noted the presence or absence of three additional platform traits: a lip or ridge on the ventral edge of the platform; grinding on the surface of the platform; or step fractures parallel to the edge of the platform. The latter two indicated some degree of platform preparation, while the first is thought to be a mark of soft hammer percussion (Andrefsky 2005).

Secondly, I determined each platform's type based on its shape, form, and other visible characteristics. In very general terms, platform types can be ranked from simple to complex: simple platforms are more typical of expedient lithic technology, while complex platforms are more often found with curated lithics (Mackay 2014; Messineo and Barros 2018). The simplest platforms (i.e. those requiring the least preparation) are those that are partially or completely covered by cortex, which are termed *cortical* platforms. *Plain* platforms are those without any cortex, and represent the least amount of preparation possible (i.e. removing the weathered or flawed cortex before striking off a flake). I used the *crushed* designation for those pieces whose platforms seemed crushed or otherwise damaged by force; such crushing can be done intentionally to give the hammer better purchase on the platform and so prevent slippage while it is being struck. Finally, I labeled as *faceted* those platforms with more than one facet, each of which is a scar left by a microflake being removed from the surface of the platform. As with crushing, faceting allows for greater precision of hammer strike, and also represents intentional platform preparation (Andrefsky 2005).

Other platform characteristics noted were the presence of *grinding* or abrasion on the surface of the platform (regardless of type), as well as *stepping*, which refers to flake scars with step terminations (Andrefsky 2005). Grinding can occur as a type of intentional platform preparation, since it results in a roughened platform surface that prevents the hammerstone from slipping on contact. However, it can also be the result of other processes, including use-wear of a lithic core or tool prior to flaking, or even unintentional damage from the core or tool being stepped on or rubbed against another hard surface. For stepping, the step fractures can occur either on the surface of the platform or directly exterior to it. In the former case, I would characterize the platform as faceted and include them in this analysis. But the latter case (exterior stepping) is more ambiguous. Some lithicists refer to the removal of exterior stepped flakes as *brushing*, which involves removing small flakes from the exterior side of the objective piece directly adjacent to the intended platform (C. Merriman, pers. comm.). On the other hand, such stepping may instead be a side-effect of natural use-wear of a lithic such as a scraper. Small, overlapping step fractures occur quite commonly along the dorsal surface of a scraper's working edge; often, that edge is resharpened or rejuvenated by removing the worn, stepped edge. This removal often involves flipping the lithic over and using the edge's smoothed ventral surface as the platform for a retouch or resharpening flake. When done by expert knappers, the new edge of the original piece is sharp and rejuvenated, while the old edge (and its step fractures) come away with the retouch flake. It’s not always possible to tell whether a stepped platform resulted from one or the other of these two different processes – brushing, which involves intentional preparation, or retouch, a byproduct of lithic use and rejuvenation. Because of this equifinality, I chose not to analyze the number or proportion of ground or stepped platforms in the assemblages.

Core Trait 3: Retouch

Retouch refers to the intentional flaking of the edge in order to shape, re-sharpen, or otherwise modify it (Andrefsky 2005; Clarkson 2002). Generally these scars are distinguishable from other edge damage due to their size and shape (see Fig. 3.2). They also often have a negative bulb of percussion (or bulb of force) at the point where the retouch flake was removed from the piece being modified; this negative bulb presents as a divot or dimple that is deeper than the rest of the retouch flake scar and is located adjacent to the edge where the retouch flake was removed. Macroscopic types of edge damage – such as fractures or breaks due to damage during use or after deposition – lack these negative bulbs of percussion because they occurred not as the result of intentional flake, but some other force. Retouch scars are visible to the naked eye, whereas other types of edge damage related to use (such as micro-flaking, striations, or edge polish) can only be discerned under magnification.

Retouch scars are often found adjacent to one another along a single edge, although in some cases only a single retouch scar might be found on a given edge. These scars can be worked into either the dorsal or ventral surface of the piece, in which case the piece is classified as “unifacially retouched”. However, in some cases, retouch occurs on both surfaces (either along a single edge or scattered around more than one edge), in which case I classified the piece as “bifacially retouched”. I based any further classification of tool type on the form or shape of pieces that resembled well-known tool types from other lithic assemblages, such as scrapers or projectile points, which are sometimes collectively referred to as formal tools (Andrefsky 1994; Binford 1979; R. L. Kelly 1988). It should be noted, however, that these were exceedingly rare in the assemblages examined in this study.

As with flaking in general, retouch can be unifacial or bifacial; that is, it can occur on only one face of a flake (the dorsal or ventral face), or it can occur on both. Bifacial retouch is sometimes used in the *initial* shaping of a tool, for example in thinning the edges of a bifacial preform to create a more streamlined final product. However, retouch also occurs on tools whose original edges have dulled with use, and it thus represents an attempt to get more use out of a tool by refreshing it’s edge. The intensity of retouch – that is, the number and size of retouch scars – is often interpreted as a signal of curation in a lithic assemblage, since it involves an act of using a single piece over a greater period of time rather than replacing it with a sharper freshly flaked piece.

Core Trait 4: Bifaciality

I identified lithic artifacts as bifacial if they showed evidence of retouch on both the dorsal and ventral surface of the flake. However, very few artifacts showed evidence of any retouch whatsoever; fewer still had retouch on both surfaces. For purposes of this analysis, I include one other distinctive type of flake associated with bifacial lithic technology: the Bifacial Thinning Flake, or BTF. These small flakes are thought to be the direct result of the thinning or shaping processes described above (Andrefsky 2005, 123). While it can be difficult to tell if they had been used as tools themselves, BTFs do provide a good indication that larger pieces were being subjected to bifacial flaking. They can be recognized by several distinctive traits, including “curved longitudinal cross-sections, extremely acute lateral and distal edge angles, feathered flake terminations, narrow faceted striking platforms, a lip, little or no cortex, and a small flattened or diffuse bulb of force" (Root 1992:83). These flakes are not explicitly part of the modified Sullivan-Rozen typology I used to characterize artifacts in my study; however, since they were fairly easy to recognize, a "BTF" tag was added to each one's entry when encountered.

It should be noted, however, that there exists another category of debitage resulting from attempts to thin or trim a biface: the biface edge flake (BEF). While BTFs are thought result only from the thinning of formal bifacial tools (such as projectile points), BEFs are not associated with any one specific type of tool. They are characterized as "failed attempts at bifacial thinning, resharpening flakes on large bifaces, or the result of use-related impact" (Stemp 2000, 38). While they share many characteristics with BTF's (such as a smooth interior surface and a feathered termination), they can be distinguished by their pronounced bulb of percussion that sometimes bears an erailleur scar (Stemp 2000, 38). During my analysis, I did not attempt to distinguish between these two forms of debitage, so it is possible that some flakes I tagged as BTFs are instead BEFs. However, given that both types are associated with the same trait of interest – bifaciality – this does not truly alter the interpretation of my lithic assemblages.

CHAPTER 4

RESULTS OF EXCAVATIONS AND AGE-DEPTH MODELLING

In this chapter, I review rockshelter names and locations and briefly describe the excavation units and levels examined in this study. I then present a brief discussion of Bayesian chronostratigraphic modeling, which allowed me to construct age-depth models for each unit using radiocarbon dates obtained via Accelerated Mass Spectroscopy (AMS) dating of charcoal samples collected during excavations. Next, I provide more in-depth discussion of excavations at each shelter and illustrate the spatial context for each lithic assemblage, which is made up of the lithic artifacts collected within a single level of each excavation unit. In looking for evidence of changes in lithic curation over time, I consider these assemblages to be palimpsests composed of multiple occupational events that likely occurred during a given period, but that serve as a general snapshot of the dominant mobility and lithic technological strategies of the time. Finally, I present age-depth models for each shelter constructed from its radiocarbon samples. Aside from simply allowing me to date each lithic assemblage, the age-depth model also allows me to calculate sediment deposition rates for each time period of interest. This calculation further allows me to normalize the density of lithic artifacts in each assemblage against its level's sedimentation rate.

Review of Sites

The three sites from which lithic assemblages were drawn are Tzib'te Yux, Mayahak Cab Pek, and Saki Tzul; I will refer to them as Shelter (or Site) 1, 2, and 3, respectively. Shelter 1 is different from the other shelters in two important ways. Firstly, it is located in the karstic foothills and valleys of the Rio Blanco drainage of southern Belize's Toledo district, whereas Sites 2 and 3 are located deep within the Bladen Nature Preserve of the Maya Mountains, also in the Toledo District. While Shelter 1 is closer to the coast than the other two, it is still ~35 km from the sea, which is more than a single days' journey on foot. Secondly, only the oldest levels of Shelter 1, which date to the late Paleoindian/Early Archaic time period, appear to be stratigraphically intact (K. M. Prufer, Meredith, et al. 2017; K. M. Prufer et al. 2019). The shelter was intensively used by the Classic Period Maya (250-900 CE), who likely removed some of the topmost layers (possibly for construction fill) and who also buried individuals that intruded into older, pre-Maya levels. Although Maya-period burials also occurred at the other shelters, the sediments (particularly the *jute*-shell middens) at Shelter 1 appear to be more heavily compacted than those of other two shelters. This compactions means that Shelter 1's Maya-period burials intrude upon much older sediments than do those in Shelters 2 and 3. Therefore, only Shelters 2 and 3 appear to contain well-stratified deposits dating to the Middle and Late Archaic periods as well as the late Paleoindian/Early Archaic transition, whereas Shelter 1's deposits date only to the latter.

Age-depth Modeling: Theory & Method

Before proceeding to describe specifics details of each rockshelter's excavation and their age-depth models, I discuss the overall theory behind and methods used in age-depth model construction. Such models are necessary when there are fewer securely dated radiocarbon samples than there are depths of interest (Haslett and Parnell 2008), as is the case in all three of my sites. At each site, a great many radiocarbon samples were collected; of those, a smaller number were determined to be dateable based on the amount of charcoal and type of floral material preserved. Unless otherwise stated, all charcoal samples were subjected to "Acid-Base-Acid, combustion, and graphitization methods" (see Prufer et al. 2019:11 for sample preparation). Most initial sample prep work occurred at the University of New Mexico's Environmental Archaeology Lab, while

AMS dating was conducted at Pennsylvania State University, University of California at Irvine, or Directams.com.

Once radiocarbon determinations were returned by the lab, further work needed to be done to calibrate each sample and use them to create an age-depth model that relates each level's depth below surface to a given calendar age BP. This allowed me to could assign approximate dates to the lithic assemblages analyzed in this study. To construct an age-depth model, I used the software program Bchron, which interpolates between samples of known age and depth (which are known as chronological control points) and predicts likely ages for each depth without a known age. In their review of age-depth model construction, Lacourse and Gajewski (2020) describe how a variety of interpolation methods can be used, ranging from simple linear interpolation between control points, to the use of smoothing functions (such as splines) for interpolation, to Bayesian approaches that take prior information into account.

Like all Bayesian statistics, the latter methods rely on Bayes' theorem that "the posterior is proportional to likelihood times prior," where posterior refers to age estimates for depths without known dates; prior refers to external information about the parameters unrelated to the known data (such as their stratigraphic relation to each other); and likelihood "represents the probability distribution of the data [i.e., known dates] given the parameters [i.e., unknown dates]" (Parnell et al. 2011:2949). Such methods are unique in that they "enforce monotonicity of ages (positive accumulation rates) and incorporate assumptions about accumulation rates… and/or how they vary" (Lacourse and Gajewski 2020:29). Compared to other approaches, the authors note that Bayesian models better handle the full range of uncertainty for all radiocarbon samples. Such uncertainties arise from radiometric dating itself (i.e., standard error intervals provided by labs, usually in the form of "+/- XX years") and from calibrating dates using a calibration curve, which has its own 95% confidence interval.

Calibration curves are used by archaeologists and paleoecologists (among others) to convert radiocarbon age estimates provided by labs (e.g. 8960 +/- 30 ^{14}C BP) into a range of calendar years before present (e.g. 9928 – 10214 cal BP) (Reimer et al. 2020). Unlike other radioactive isotopes, ^{14}C decays into a daughter product (nitrogen) that "is not captured in most materials and, even if it were… would be swamped by the pervasive nature of nitrogen in the Earth system" (Reimer et al. 2020:726). Additionally, the ratio of radioactive ^{14}C isotope relative to other stable isotopes of carbon varies over time and space based on a number of factors ranging from differential cosmogenesis of ^{14}C to the influence of upwelling ocean water with lowered levels of ^{14}C. All of these factors make it more difficult to know the starting value of ^{14}C in a plant at the time of its death and to thus correctly assess it's true age.

Calibration curves (such as IntCal20, the recently updated Northern Hemisphere atmospheric curve) rely on radiocarbon samples that can be independently dated through dendrochronology or other means with annual-scale resolution. In particular, IntCal 20 uses a securely-dated dendrochronology record extending back to 13,910 cal BP; beyond that, it incorporates "statistically integrated evidence from floating tree-ring chronologies, terrestrial macrofossils from lake sediments, foraminifera from marine sediments, speleothems, and corals" (Reimer et al. 2020:727). Yet despite these advances, the calibration curve still carries an inherent level of uncertainty that is captured by the 95% confidence interval around the curve itself. Calibrating a single radiocarbon age estimate thus involves the intersection of two inescapable levels of uncertainty: the standard error provided by the lab, and the confidence interval of the calibration curve. The end result of the process is an age range capturing the most likely values (i.e. 95% highest posterior density region, or HDR) of the true age of a single carbon sample.

Age-depth modeling takes this process one step further by using the HDR of the known samples to estimate HDRs at depths for which there are no radiocarbon samples. To create my age-depth model, I used the Bchron package of the R coding environment, which uses a Bayesian method similar to that described above. My choice of which Bayesian software to use was driven in part by by my greater familiarity with the R coding language, and also by Bchron's utility in querying age-depth models to assign dates to intervening layers that did not contain radiocarbon samples. As inputs, this package takes each sample's ^{14}C age determination and standard deviations (provided by the lab) and its stratigraphic position (i.e. depth). I also specified the desired number of predictions or age estimates, specifically one age per cm; this ensures that there will be enough estimated ages to create a model that covers the majority of depths between control points. Given these inputs, Bchron iteratively generates a large number of potential chronologies through an algorithm known as a "Markov chain Monte Carlo", which "proposes parameter values [i.e., dates at unsampled depths] and accepts or rejects them depending on how well they match the likelihood and the prior" (Parnell et al. 2011:2953). Given a sufficiently large number of iterations (the default is 10,000), the model will converge on a single chronology, that is, a series of HDRs constructed from the accepted parameter values at each depth of interest. Moreover, this model can later be queried to determine ages for depths that were not originally specified as inputs at model initiation. These HDR's are summarized as two bracketing dates which capture the 95% (2σ) confidence interval. This obviates the need to describe multiple "peaks" in the HDR that generally occur when only one date is calibrated at a time.

One issue that complicates this process is the presence of outlier dates, that is, chronological control points that do not fit the underlying assumptions of the modeling process. These may occur when a date appears to be too deep for its calibrated radiocarbon date (or put another way, is too young for its depth) compared to the rest of the known samples. Such outliers may be a result of stratigraphic mixing, where sediment from upper layers makes its way to those that are lower. Some such instances of stratigraphic mixing are the result of well-known, interesting cultural phenomena: for instance, burials or caches inherently involve placing younger material (often including burnt offerings or human remains) into strata below the current living floor. Other types of stratigraphic mixing can be caused by burrowing rodents, crustaceans, or insects; plant and tree roots; and even other types of human behavior that are of less interest (a child poking holes into a dirt floor with a stick, for example). Generally, carbon samples that are likely to be the result of such mixing are screened out at the outset; for instance, if the top-most level of a burial feature is poorly defined, it can be difficult to assign any carbon within it to a specific depth (i.e., the living surface when the burial was deposited), and so such samples will not be included in the age-depth model. Even samples that appear to be just outside a burial pit can potentially be the result of stratigraphic mixing during or after the burial process and so could justifiably be excluded. Despite such screening, however, some samples that appear to be valid may still yield ages that are too young or too old for their depth compared to the rest of the samples.

Most software packages have a method for identifying such outliers; in Bchron, the software scores each sample between or 1 depending on how well it conforms to the rest of the known samples. These scores are then averaged over the entirety of model runs; any date with an average score equal to or approaching 1 is likely an outlier.

Moreover, the software recognizes two types of outliers: the first are those "where the calendar age probability distribution of a determination only requires a small shift to satisfy the monotonicity (older = deeper) constraint", while the second are those which "require a large shift" to accomplish the same effect (Parnell et al. 2008:1875). The software ignores Type 2 outliers as it simulates it's 10,000 model runs, whereas it trims the HDR of a given Type 1 outliers so that the remaining section is consistent with the rest of the dates, and then uses this revised HDR in its model runs (Parnell et al. 2008:1875). The software provides a list of the average outlier scores for each date, allowing the user to see those dates that are ignored by the model. In each shelter, the excavation units of interest were contiguous and fell within a 9 m^2 area, so a single age-depth model was developed that combined dates from all units of interest.

Excavation Results and Age-Depth Models for Each Shelter

What follows is a brief description of the excavation procedure and results for each shelter, which are summarized in greater detail in a variety of site reports and peer-reviewed publications. Following that, I present the age-depth model constructed from each sites' radiocarbon dates, and an in-depth look at the ways that sedimentation rates at each shelter changed over time.

Shelter 1: Tzib'te Yux (TY)

This shelter was excavated over the course of four field seasons (Meredith 2014b; Meredith and Dennehy 2015; T. Dennehy et al. 2016; K. M. Prufer, Meredith, et al. 2017; K. M. Prufer et al. 2019; Douglas J Kennett et al. 2020). During the first field season in summer of 2012; a single excavation unit (2012 Excavation, which I refer to as Unit 1a below) was dug in 20cm arbitrary levels, in part because the great antiquity of the deposits had not yet been discovered (see Figs. 4.1 & 4.2). Those excavations revealed the existence of four depositional layers or contexts, an arrangement that was confirmed in several subsequent units (Meredith 2014b; K. M. Prufer, Meredith, et al. 2017). The first layer (from surface to ~15-20 cm below) consisted of an unconsolidated midden consisting of mixed *jute* snail shells, fauna, and lithic flakes in uncompacted sediments; below that lay a dense snail-shell midden composed of the same materials as the layer above but highly compacted (20-45 cm below surface). Beneath that lay a reddish-brown clay layer that contained far fewer cultural materials than the jute-rich midden above. Finally, the bottom-most layer consisted of a mostly culturally-sterile yellowish-red clay lying directly above the large limestone boulders which likely resulted from roof-fall and breakdown of the shelter's cliff face.

After the first charcoal sample from the red clay layer was AMS dated to the late Paleoindian/Early Archaic time period (see Fig. 4.2), the project returned every summer from 2013 to 2015. During the 2013 field season, excavation units were placed to determine the extent of the stratigraphic units noted in Unit 1a, especially for the red clay layer. Units placed in the central and western portions of the rockshelter (Units 1b through 4) found that, although the jute midden appeared to run along its entire length, the red clay layer was confined to the western side. Because these units do not appear to capture the entire Paleoindian-Archaic sequence, this study does not include artifacts excavated from them. However, the three Units of the eastern side (Units 1a, 5/6, and 7) did intersect all three stratigraphic contexts, and so their numerous lithic artifacts constitute Shelter 1's sample in my analysis. I joined the project for the 2014 field season

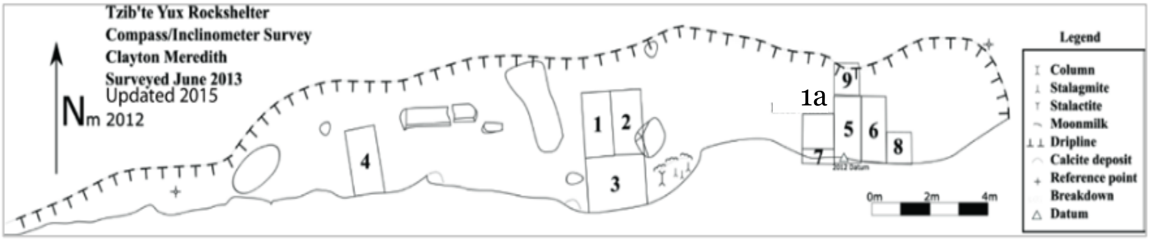


Figure 4.0.1. Plan view of Shelter 1 (Tzib'te Yux), showing location of the 2012 Excavation Unit as well as Units 5, 6, and 7 (Prufer, Meredith, et al. 2017:322).

in order to help finish excavation of Unit 5/6. I returned in 2015, during which we completed excavations of Unit 7 and opened two further Units (8 and 9, which are not included in this study because we only excavated ceramic-yielding levels).

Interestingly, a small cave opening at the eastern end of the shelter appears to be partially filled in with sediment, including jute-rich soils. To the north and slightly above it, a broken rock shelf has allowed sediment from the adjacent hillslope to slump into the eastern end of the shelter. Although most recent excavations were not able to determine the timing of this collapse or the filling up of the adjacent cave opening, it seems likely that the cave opening was much larger during the early Holocene due to the lower level

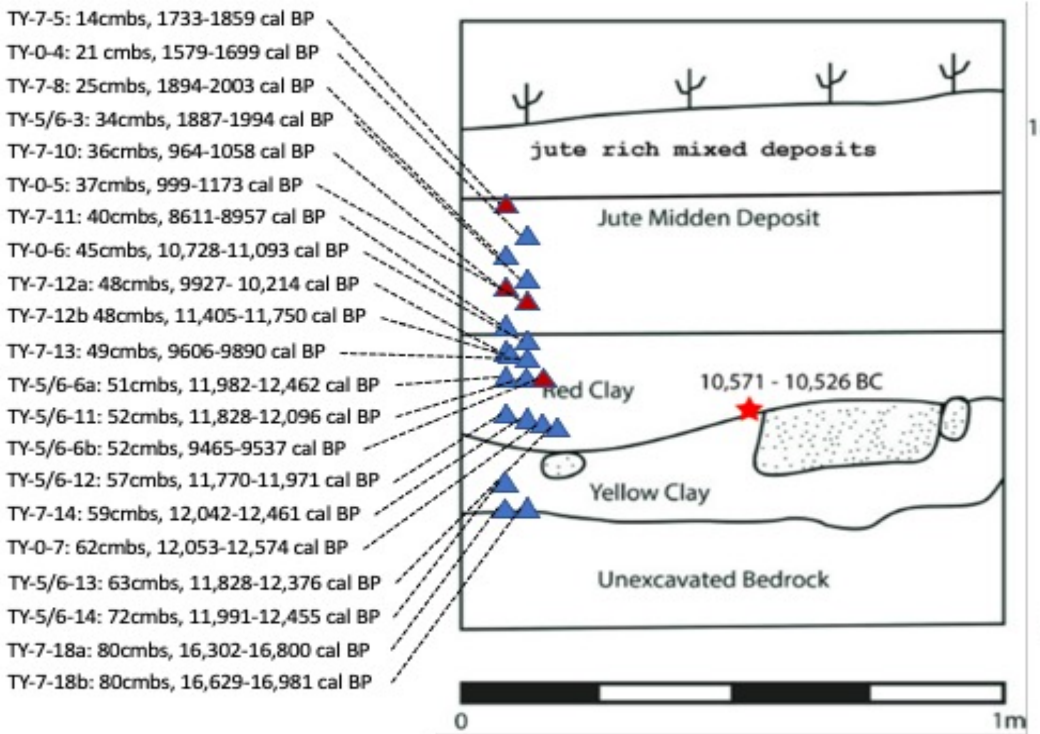


Figure 4.0.2. Shelter 1 schematic profile (based on Unit 0's south balk) showing relative depths of charcoal samples used in creation of age-depth model. Blue triangles indicate dates included in age-depth model; red triangles indicate dates identified as outliers by Bchron and so excluded from model; red star shows location of first radiocarbon sample that returned a late Paleoindian/Early Archaic date. Depths are provided in cm below surface, and calibrated dates are given as 95% credible intervals. Profile created by Clayton Meredith and published as Fig. 4 in Prufer et al. 2017:323

of the rockshelter floor (which would've been the yellowish-red clay layer directly above bedrock). Future excavations at Shelter 1 may focus on this feature in order to assess potential Paleoindian utilization of the cave.

Age-depth Model for Shelter 1. The modern-day floor of Shelter 1 is generally flat aside from a slight dip towards the rock face in the rear of the shelter; each of the stratigraphic layers described above shares this general topography. The three units of interest border each other within a 3x3 meter area, and shared the same datum and unit string height during excavation across multiple field seasons. For these reasons, I combined radiocarbon dates derived from charcoal samples from all three units into a single age-depth model. All original depths, which were recorded as "centimeters below datum" using the same datum string, were converted to centimeters below surface. As can be seen in the age-depth plot for Shelter 1 (Fig. 4.3), the model shows a fairly tight

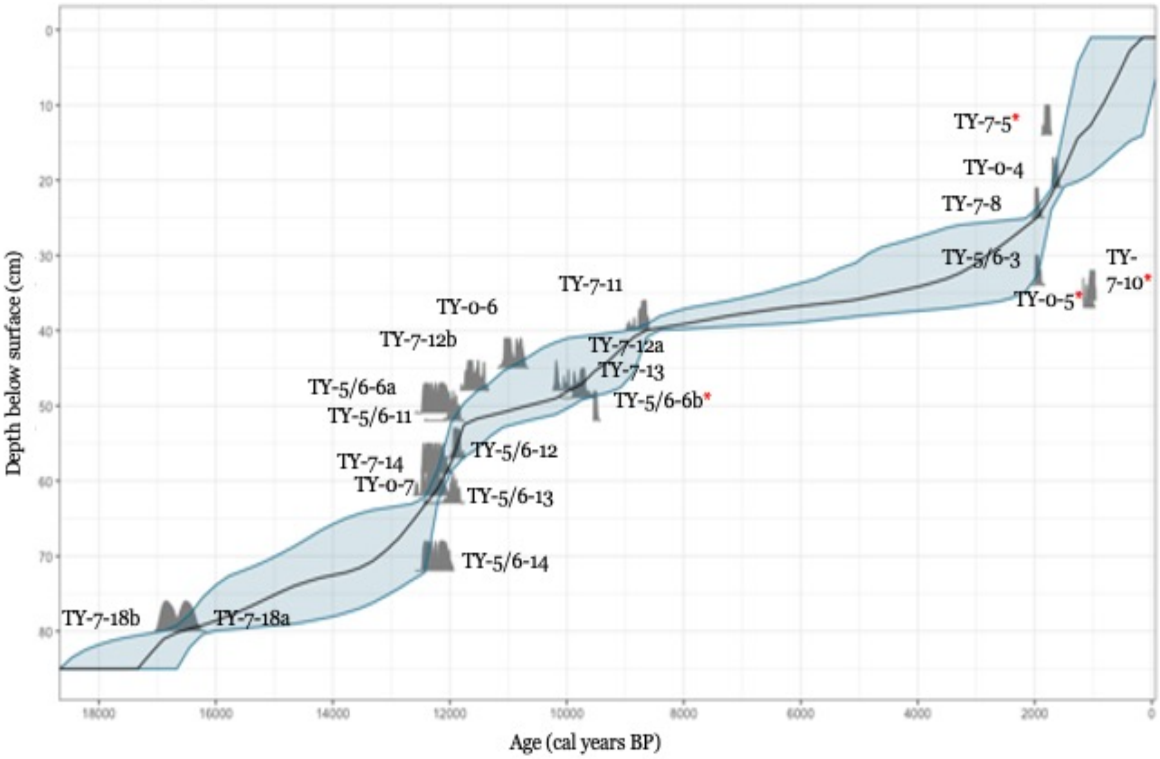


Figure 4.3: Age-depth Model for Site 1. Dates marked with red asterisks were identified as outliers by Bchron.

95% confidence interval from the earliest date (16985-16639 BP) to the latest (2000-1925 BP). Although there are four outliers (which are marked with red triangles in Fig. 4.2 and red stars in Fig. 4.3), they are clustered near the other dates which anchor the overall age-depth model. However, the abrupt "jump" from the youngest date (1810-1880 cal BP, found at ~18 cmbs) to the surface is notable, as is the conspicuous gap in dates (visible in both the profile (Fig. 4.2) and the age-depth model (Fig. 4.3)) between the cluster at the end of the Middle Archaic (8773-8632 BP) and the cluster that occurs during the Early Classic Maya period (2000-1617 cal BP). As Prufer et al. (2017:324) speculate, the latter anomaly may be due to mining of jute from the rockshelter during Classic Maya times for "plaster production, soil conditioning, or food processing." The authors also note that the eastern end of the rockshelter wall bears the remnants of a large plaster frieze, which contains many fragmentary jute shells; it seems likely that the Classic Maya utilized the rockshelter floor as a convenient source of jute shells to use as temper or fill for the plaster sculpture itself. Regardless of the motivation behind it, such mining may have removed much of the sediment of the top-most layers, taking with it the charcoal samples that would otherwise have been excavated and included in my age-depth model.

The earlier end of Shelter 1's age-depth model indicates that the site may represent one of the oldest occupations in the Maya Lowlands. Notably, the model includes three dates older than 13,250 cal BP, the earliest possible start of the Clovis period (Waters and Stafford 2007:1123), and so imply a pre-Clovis presence at Site 1. While these three separate samples (two wood charcoal and one carbonized seeds) are better than one, they alone do not provide sufficient evidence to definitively conclude that the shelter was utilized by pre-Clovis humans. As Prufer et al. (2017:7) note, "we consider any association of this [pre-Clovis] date and human activity to be provisional and pending additional excavation and documentation." For purposes of this study, it is sufficient to note that the shelter appears to have been intensively utilized during the Late Paleoindian/Early Archaic transition, and provides the oldest lithic material in the study – 53 potentially pre-Clovis lithics.

In addition to providing date estimates for the entire record of Shelter 1, the age-depth model also illustrates salient trends in sediment deposition rates and how they vary over time. In general, those parts of the model with more horizontal slope demonstrate slower sedimentation rates. For example, during the 6000 year stretch from roughly 8500 to 3000 cal BP, the model indicates that only 10 to 15 centimeters of sediment accumulated – figures which yield sedimentation rate of 0.17 or 0.25 cm/century, respectively. Yet this section is also thought to have been highly disturbed by jute mining in antiquity (see above), so these sedimentation rates are likely not entirely accurate. On the other hand, sections of the model that are more vertical can be interpreted as times of faster sediment accumulation. For example, during the 1500 years between 14,000 to ~12,500 cal BP, the model indicates that somewhere between 10 and 30 cm of sediment were deposited (along with many charcoal samples indicative of human occupation). These figures yield sedimentation rates ranging between 0.67 and 2.0 cm/century – almost an order of magnitude higher than the rate mentioned above. Finally, there are several sections of the model showing intermediate steepness, such as the 4000 year stretch between the inflection points at 12,500 and 8500 cal BP. During that period, somewhere between 10 and 17 cm of sediment accumulated, which provide sedimentation rates of 0.25 and 0.425, respectively. This section of stratigraphy also yielded a significant number of charcoal samples.

The association between faster sediment deposition and increased charcoal sampling is likely not a coincidence; human utilization of the rockshelter was a primary contributor of sediment to an area that was otherwise mostly sheltered from colluvial (i.e. hill-slump) or aeolian (i.e. wind-driven) sources of sedimentation. Further direct evidence of anthropogenic sediment accumulation comes from the modified nature of *jute* snail shells in both the upper unconsolidated *jute*-rich brown sediment, the dense shell midden below, and the red clay layer beneath both. In all contexts, more than 90% of snail shells have the tips of their spire removed, a feature consistent with processing of whole snails to allow the animal inside to be more easily detached and eaten (Halperin et al. 2003). Interestingly, the spire tips themselves were very rarely recovered, despite use of a 1/8" screen during excavation. This discrepancy has been interpreted as evidence of initial processing (i.e. spire lopping) away from the site, followed by transport to the Shelter for consumption of the resulting snail, and/or possibly ritual deposition of the discarded snail shell. The latter interpretation is supported by numerous jute deposits in Classic-period ritual contexts throughout the Maya region (especially in caves and rockshelters) (Halperin et al. 2003), which provides an intriguing piece of evidence for cultural continuity between pre-Maya and Maya-period utilization of Shelter 1.

Shelter 2: Maya Hak Cab Pek (MHCP)

As mentioned above, Shelter 2 was first excavated by Dr. Prufer and colleagues in the late 1990's as part of the Maya Mountains Archaeological Project, which sought to understand Classic Maya use of cave and rock-shelter sites in the Maya Mountains (K. M. Prufer 2002; Saul, Prufer, and Saul 2005b; K. M. Prufer and Dunham 2009). Those excavations were exploratory and only involved levels dating to Maya ceramic time periods. Charcoal samples from those somewhat shallow excavations dated to the Middle Preclassic period (~400 BC), which is a relatively early period for the Maya region as a whole; nearby cave contexts yielded older, Archaic-period dates (~3500 BC). Due to these factors, and because the 2012 excavations at Site 1 had revealed extensive pre-

Maya occupation there, Dr. Prufer returned to Site 2 in 2014 to test it for similar Archaic and/or Paleoindian cultural materials (Prufer, Keith M.25 and Kennett 2020; Ebert et al. 2015; K. M. Prufer, Thompson, et al. 2017). Excavations that season were confined to two large units, 1W and 1E; the former was placed atop trenches 28-30 from the 1998 excavations, while the latter was placed on previously unexcavated sediments directly east of 1W. A datum was placed in the rockshelter wall near the SW corner of Unit 1W to provide depth provenience (see Fig. 4.4).

Because the 2014 operations were constrained by time and limited resources, initial levels were dug in 20 cm increments, but once aceramic layers were encountered, levels were dug in 5-10 cm increments (unless a cultural or stratigraphic change deemed otherwise). At the time, only Unit 1W was excavated to bedrock, while Unit 1E was first subdivided after Level 6 (~100 cmbd) and then ended after the excavation of Burial 6 (~210-230 cmbd). Dr. Prufer returned to the shelter in 2016 with a larger team (including myself) for a longer period of time. Our goal in 2016 was to continue excavating Unit 1E down to bedrock; we also placed a new excavation unit (Unit 2)

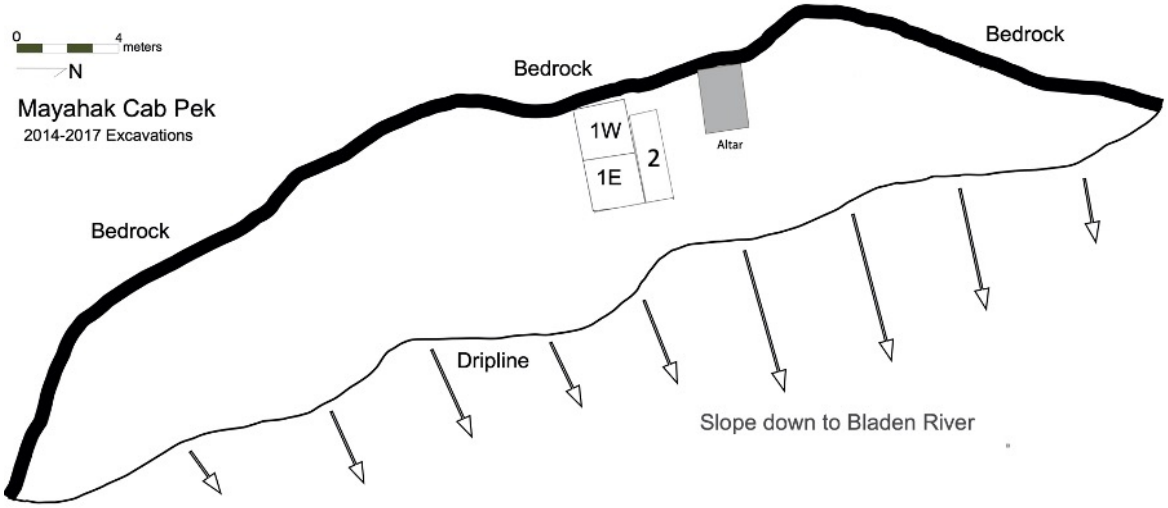


Figure 4.4: Plan view of Site 2, Mayahak Cab Pek (MHCP), showing locations of Units 1E, 1W, and 2, as well as Maya period altar feature. Plan view first published as Fig. S1 in Kennett et al. 2020, p. 10 of Supplementary Materials.

directly north of Unit 1E to extend the overall dimensions of the excavated area. During the course of excavations, we uncovered a number of additional features including: a large circular rock cairn made up of large unworked limestone cobbles; another, smaller arrangement of naturally smoothed river cobbles that seemed somewhat disturbed by the larger rock cairn; and, below that, a large, ovoid pit full of ashy soil, charcoal, and burnt human and faunal bones.

Altogether, these two seasons of excavation yielded over 3000 lithic artifacts, the vast majority of which are pieces of debitage. Of these, a smaller subsample were included in my study: from the 2014 seasons, 1635 lithics were analyzed by project lithicist Chris Merriman; from the 2016 field season, I analyzed a further 645. I chose to include only those assemblages recovered from level fill, not intrusive features like burials, because the purpose of my study was to document overall changes in lithic use and subsistence through time, whereas those deposited within the features were

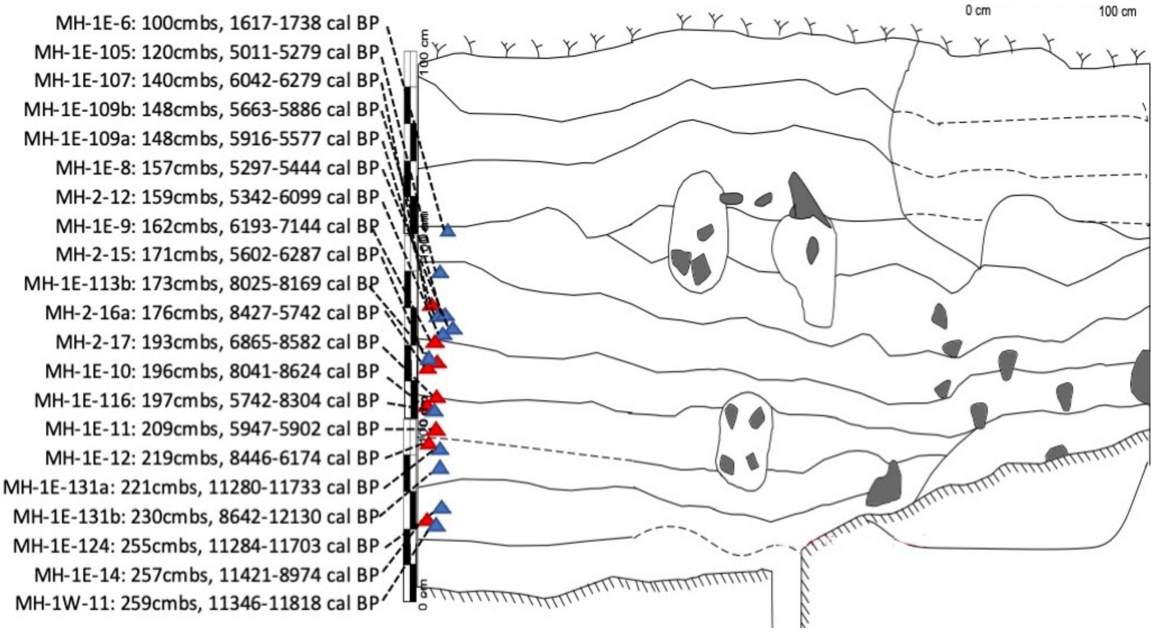


Figure 4.5: Shelter 2 Profile with relative depths of dated charcoal samples. Profile is based on composite of Unit 1's southern balk at the end of the 2017 excavation season. Dates are plotted at correct depth but staggered to avoid overlap. Red triangles indicate outliers rejected by the model. Initially published as Fig. S2 in Kennett et al. 2020, page 11 of Supplementary Materials.

probably deposited rapidly for reasons potentially unrelated to subsistence. I also chose only those assemblages thought to date to the period of interest, that is, the Early through Late Archaic. At the time I made these decisions, the full age-depth model had not yet been completed, so the final temporal range covered by the included assemblages does not quite match my initial goal. However, of the three shelters, Shelter 2 covers by far the longest stretch of time, from end of the Pleistocene (~12,500 cal BP) through the Late Holocene (1100 cal BP), due in part to the inclusion of later assemblages from upper levels analyzed by Merriman.

Dr. Prufer and colleagues returned to Shelter 2 during subsequent field seasons (2017-2019) in order to take Units 1E and 2 down to bedrock, and to place new units for recovery of additional materials. Due to the timing of my lithic analysis, assemblages from these later excavations were not included in this study. However, as described below, some charcoal samples from lower levels of Unit 1E that were excavated in later seasons were included in the age-depth model. These later excavations, together with those of 2014 and 2016, "revealed a ~2.8-m sequence of cultural midden and mortuary deposits" ((Douglas J Kennett et al. 2020, 3). The lowest levels are "organic-rich (silt to silty loam) and contain debris from the limestone cliff outcrop, igneous flaked stone tools of local origin (choppers and hammer stones), large chert bifaces (Lowe points), and animal, riverine shellfish (*Pachychilus* spp.), and human remains" (Douglas J Kennett et al. 2020). Notably, no ceramics were found in these layers, which date between 12,000 and 6000 cal BP. Above these layers are two levels dating between 6000 and 4000 cal BP, which are made up of jute midden deposits. Finally, the uppermost levels are "composed of alternating layers of organic-rich rocky sediment and dense *Pachychilus* spp. midden. These deposits date after ~3000 cal B.P. and contain pottery fragments, flaked stone chert," and abundant faunal remains (Douglas J Kennett et al. 2020). A number of burials were also encountered during these excavations, showing remarkably good preservation for a tropical climate; this was attributed to the generally dry condition of the shelter, which received little rainfall.

Age-depth Model for Shelter 2. Unlike Shelter 1, Shelter 2's floor slopes gently from NW to SE, although this change in height is not very dramatic. The age-depth model I developed for Shelter 2 combines radiocarbon dates from 2014, 2016, and 2017 excavations in Units 1E, 1W, and 2. During the this process, I discovered that two charcoal samples had depth measurements which were inconsistent with the depth of the levels in which they were found. These particular samples were retrieved from 2017 excavations, during which several datums were in use to facilitate excavation. Because of possible confusion about which datum was being used for each measurement, I did not include these two dates in my final age-depth model (Fig. 4.7). This confusion about

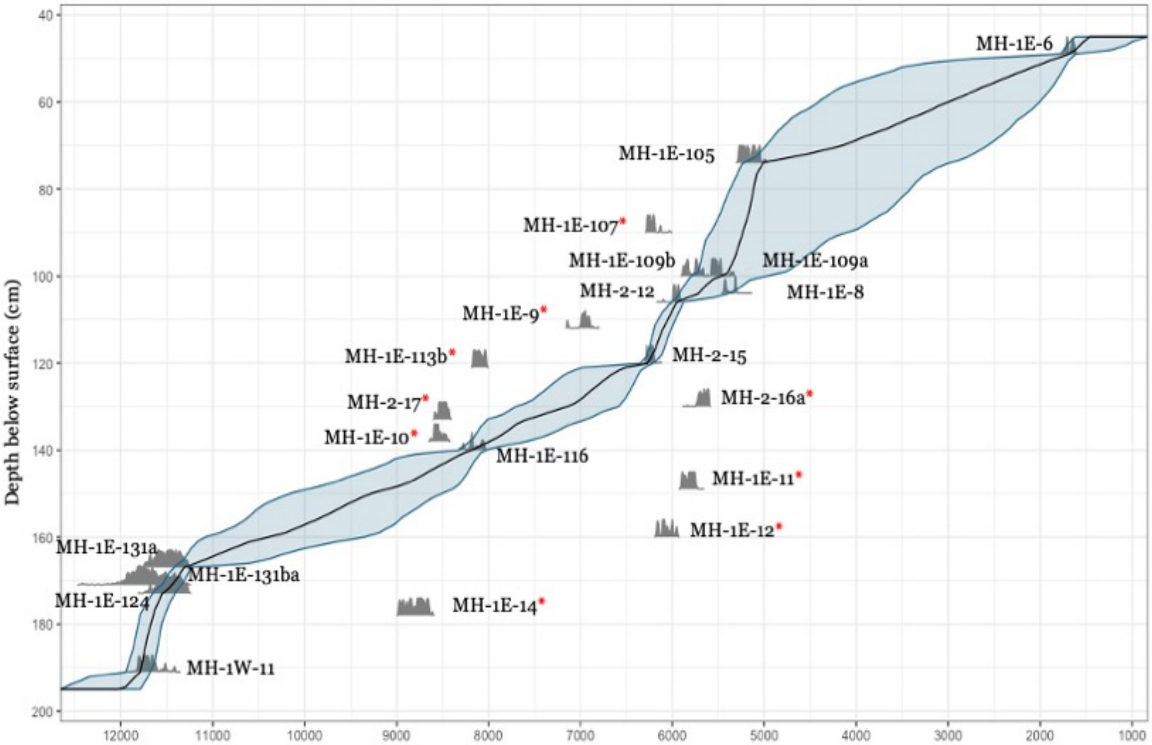


Figure 4.7. Age-depth model for Shelter 2. Dates identified as outliers by Bchron are marked with a red asterisk.

datums across seasons may also explain the higher number of outliers rejected by the model for Shelter 2. Additionally, the upper levels of Unit 1W were actually excavated in the late 90's, and two charcoal samples from its levels returned Late and Middle Preclassic dates; however, they were not included due to uncertainty about which datum was used to obtain depth measurements. The model shows that the shelter appears regularly occupied from the Late Pleistocene/Early Holocene transition (~12,000 cal BP) through to the beginning of the Late Archaic (around 5000 cal BP), although there are definite gaps between clusters. The lack of dates from younger levels reflects my project's focus on deeper, aceramic levels, rather than a lack of Maya-period occupation.

Additionally, numerous ceramic sherds from those excavations revealed a variety of types from the Early through Late Classic periods, although these have not been analyzed in enough detail to be precisely dated. A large number of sherds were also recovered during the 2014 and 2016 excavations, and a cursory review of the 2016 materials showed a similar span of Early to Late Classic styles (Prufer, Thompson, et al. 2017:20). My model also does not include dates from the beginning of the Late Archaic and into the Preclassic, despite the fact that several burials were directly dated to this interval, indicating rockshelter utilization throughout (Kennett et al. 2020:3). I chose to exclude these dates because burials are, by nature, intrusive, and so the relationship between age and depth of sample is not as straightforward as in non-burial samples. Additionally, due to the homogenous color and texture of sediment within and external to burial features, it was often difficult to delineate the topmost depth of the burial and so to identify which level it was contemporaneous with (K. Prufer, pers. comm).

As with Shelter 1, Shelter 2's age-depth model contains relevant information about sedimentation rates throughout the occupation of the shelter. However, unlike Shelter 1, Shelter 2 appears to have witnessed a relatively constant sedimentation rate, evidenced by the generally linear shape of the model. The earliest section (from roughly 12,000 to 11,250 cal BP) does show a slightly higher sedimentation rate of 11.2 cm/century. After the 11,250 cal BP inflection point, the model is generally linear until around 6250 cal BP, indicating a stable sedimentation rate of 0.94 cm/century for roughly 5000 years. This earliest part of this long stretch includes a significant segment with no carbon dates (although other cultural materials attest to human utilization of the rockshelter); after 9000 cal BP, charcoal samples are again fairly abundant. From 6250 to 6000 cal BP, the model shows a short period marked by a higher sedimentation rate of 3.2 cm/century; this segment is also one of the best constrained of the entire model, showing a relatively narrow confidence interval. After 6000 cal BP, the confidence interval widens dramatically, and the model appears to show several inflection points between times of lower and higher sedimentation. However, given that the wide confidence interval could easily contain a much more linear trajectory between these dates, I choose not to put too much interpretative weight on these inflection points.

Shelter 3: Saki Tzul (SK)

The third shelter in this study lies a little under an hour's walk from Shelter 2, and so shares many of the same environmental characteristics. Instead of lying above the Bladen river, it sits above Ek Xux creek, which is a tributary of the Bladen of roughly the same size and depth. The biggest difference is the distance at which the shelter lies above the river; whereas Shelter 2 can be reached in five minutes or less, Shelter 3 is only accessible after an arduous 10+ minute scramble up a steep slope. At roughly 1700 m^2 in area, Shelter 3 has a much larger dry area than the other two, and is sheltered by a massive cliff face which extends the dripline 8-15m out from the shelter's rear wall (Fig. 4.8). However, when heavy storms passed during excavations, the team noted that some rain did get blown in, thus explaining the presence of vegetation at the rear of the shelter, well within the dripline (K. M. Prufer, Thompson, et al. 2017; K. M. Prufer, Robinson, and Kennett 2020; Douglas J Kennett et al. 2020). Luckily, it seems this moisture wasn't sufficient to negatively impact preservation, as well-preserved burials and numerous charcoal samples were recovered within Shelter 3. A huge boulder seems to have broken off the cliff face in antiquity, providing even more shelter between it and the rear wall; because this was likely valued by occupants in antiquity, our excavation units were placed there (see Fig. 4.8).

Like Shelter 2, Shelter 3 was first excavated in the late 1990's by Dr. Prufer and colleagues. At the time, the archaeologists focused on ceramic-yielding, Maya-period levels, and recovered several burials, diagnostic pottery sherds, and other artifacts (Saul, Prufer, and Saul 2005b). In 2016, Dr. Prufer and colleagues (including myself) returned to the shelter as part of the same expedition that excavated at Shelter 2. Three excavation

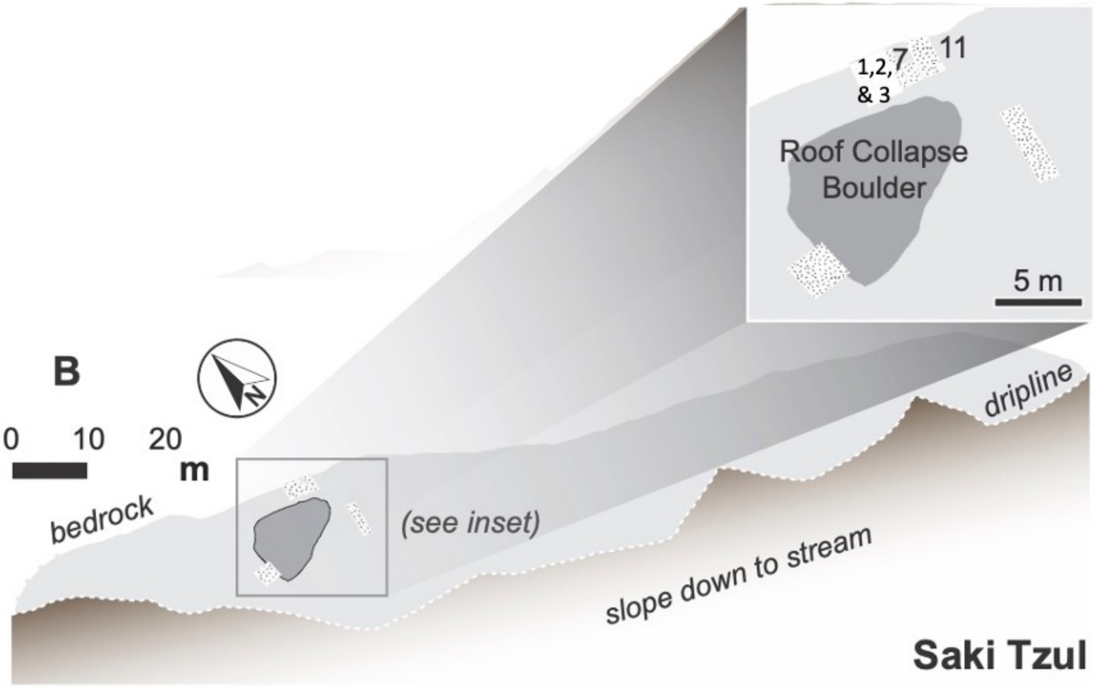


Figure 4.8. Plan view of Shelter 3, with inset showing area behind large boulder where excavation units were places. Originally published as Fig. S2 in Kennett et al. 2020, page 11 in Supplementary Materials.

units were placed in the gap between boulder and rear wall, starting with Unit 1, a 2 x 1 m unit (K. M. Prufer, Thompson, et al. 2017; Douglas J. Kennett et al. 2020). Although the floor of the shelter was generally flat, the ground in the gap was somewhat sloped from south to north. Initial excavations indicated this slope was not mirrored by the subsurface stratigraphy, so the first level was dug to an arbitrary depth across the unit.

During excavations, a cluster of rocks (which turned out to be covering a sub-adult burial) was noted in the SW corner at a depth of 97cmbd, and so a 1m x 50cm unit

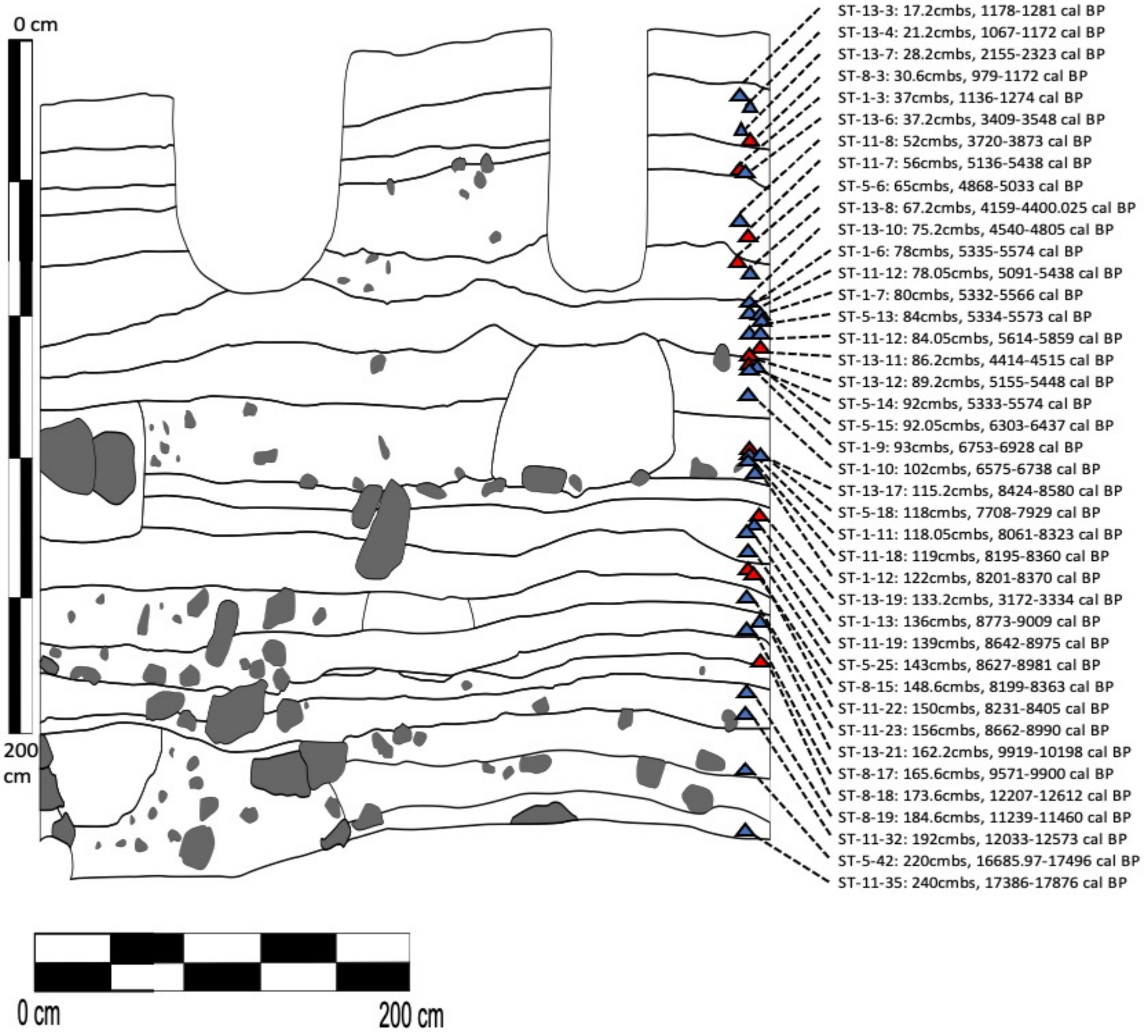


Figure 4.9. Shelter 3 Unit 7 East profile with charcoal samples (from all units) plotted according to depth below surface. Vertical dimensions of profile have been exaggerated by a factor of 2 to allow for all dates to be plotted legibly.

(Unit 2) was placed adjacent to that corner. At roughly 150cmbd, another burial was noted, and was eventually found to extend into the western wall just north of Unit 2. Unit 3 was placed to the north of Unit 2 in order to fully expose this burial (Feature 10); unlike prior units, removal of the overlying sediments was carried out quickly (due to time constraints), and sediments were not screened; only larger artifacts were collected *in situ*. Upon reaching the level of Feature 10, Unit 3 was combined with Unit 2, and subsequent levels were excavated and recorded as before. The combined Unit 2/3 was ended at a depth of 145 cmbd, whereas Unit 1 continued until it reached a depth of ~180cmbd; neither of the Units had reached bedrock by that point. As with Shelters 1 and 2, lithic artifacts associated with clearly intrusive contexts (such as burials) were not analyzed as part of this study. During the 2017-2019 field seasons, Dr. Prufer and colleagues returned to Shelter 3 and placed several more excavation units for recovery of additional material. Due to time constraints, lithic assemblages from these later excavations were not included in this study. However, the age-depth model for Shelter 3 does included a number of charcoal samples from these later excavations, in large part because they produced an abundance of dateable, non-intrusive charcoal samples.

Age-depth Model for Shelter 3. Although my lithic analysis only focused on the Middle and Late Archaic levels of Units 1 and 2/3 at Shelter 3, I present its entire age model here (Fig. 4.10). I do this in part because it again attests to the great antiquity of human activity in the Maya mountains, and also because at least half of the available dates are in the late Paleoindian/Early Archaic period. After removing charcoal samples with provenience problems, thirteen outliers remained in this age-depth model, although all but one are close to the model's confidence interval. It is worth noting that the dates in the bottom left corner are, like the oldest dates in Shelter 1, pre-Clovis in age, and so should be taken as provisional until samples from future excavations can replicate their

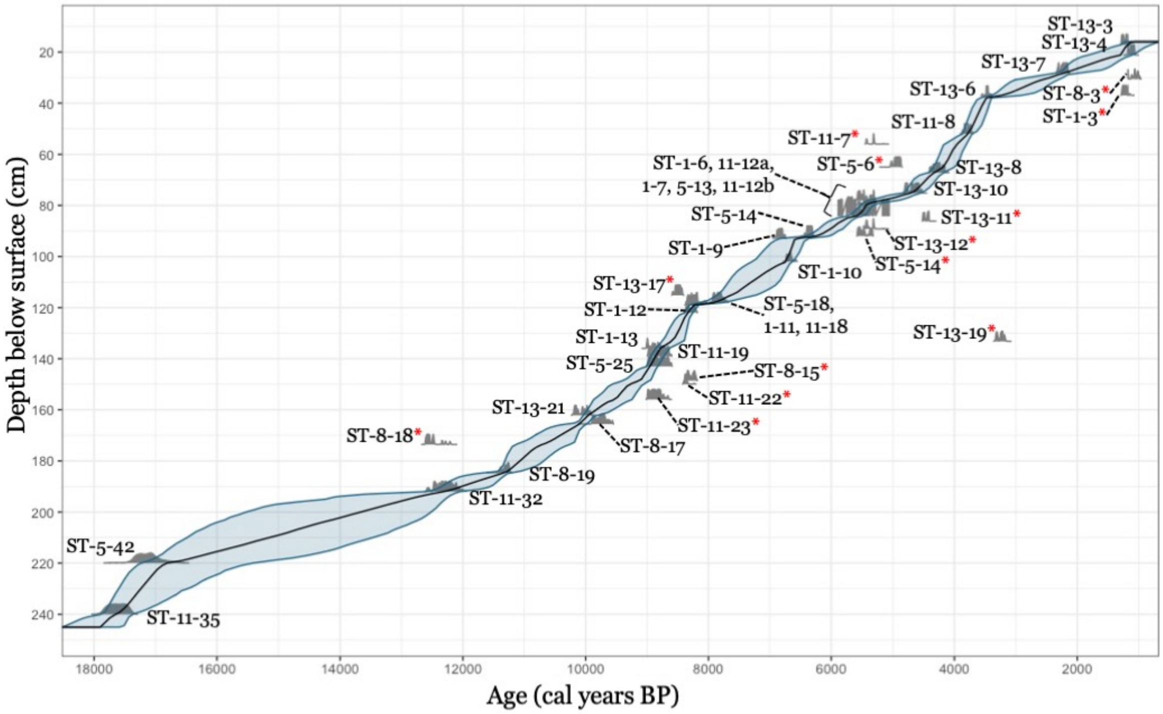


Figure 4.10. Age-depth model for Shelter 3. Dates identified as outliers by Bchron are shown with a red asterisk

age and depth. After these two early dates, a notable gap appears until the next two dates around 12,5000 BP. It seems likely that, like Shelters 1 & 2, this represents the initial heavy use and/or consistent occupation of the site. From this point on, radiocarbon evidence suggest "regular use of the sites starting in the late Pleistocene and continuing through the Classic Period… [t]he data suggest steady but episodic use from 13,000 through the adoption of agriculture at 4,700-4,000 CalBP, and a separate rise in use of the rockshelters during the Classic Period (ca. 2,800-1,000 CalBP)" (K. M. Prufer, Robinson, and Kennett 2020:204; see also Kennett, Prufer et al. 2020).

In the Shelther 3 age-depth model, several clusters of dates appear to be associated with (and likely related to) changes in sediment deposition rates – a dynamic also observed at Shelters 1 and 2. Between the earliest inflection point at 17,000 cal BP (at 220 cmbs) and the next at roughly 11,500 (at 185 cmbs), the model suggests a relatively slow deposition rate of 0.64 cm/century. From this point until 8250 cal BP (at

120 cmbs), the deposition rate increases to 2 cm/century as 65 cm of sediment is deposited in just 3250 years. The next 1500 years (from 8250 to 6500 cal BP) witness a somewhat slower deposition rate of 1.6 cm/century. This section of the model does include several inflection points indicating rapidly shifting sediment accumulation rates, but its confidence intervals are also relatively wide compared to other sections, indicating greater uncertainty around the exact dates and times of sediment accumulation.

Unlike Shelter 2's model, however, the latter half of Shelter 3's age-depth model has fairly tight confidence intervals, allowing me to say more about its rapidly changing deposition rates. From 6500 cal BP to the next inflection point (at the largest single cluster of dates around 5500 cal BP), 12 cm of sediment accumulate, yielding a relatively slow accumulation rate of 1.2 cm/century. During the next millennia (from 5500 to ~4500 cal BP), only 5 cm of sediment are deposited, yielding an even slower deposition rate of 0.5 cm/century. From 4500 to 3500 cal BP, the deposition rate is again fairly rapid, at 3.7 cm/century. Finally, the period from 3500 until the model ends around 1000 cal BP witnessed a return to a slower sediment deposition rate of 0.8 cm/century. In explaining the difference in stratigraphy and compactness between Shelter 2 (characterized by less compact stratigraphy and greater overall sediment accumulation) and Shelter 3 (which bears a longer chronology relative to depth), Dr. Prufer and colleagues note that "differences in stratigraphy may be related in part to aspect. [Shelter 3] has a south facing shelter open to the large (1 km wide) Ek Xux valley with some windblown rainfall and more air circulation today. [Shelter 2] opens to the NE and partially faces into a box canyon and receives very little sunlight or air circulation. These differences in sunlight, moisture, and air circulation may have facilitated more biogenic decay and movement of fine sediments at ST than MHCP, and less accumulation over time" (K. M. Prufer, Robinson, and Kennett 2020:204)

The authors also note that differences in shelter size may have led to less spatially dense occupation of Shelter 3, which at 1700 m^2 is also almost 10 times as large as Shelter 2. As mentioned earlier, another difference between the two sites is ease of access; Shelter 3 requires a more arduous, > 80 m climb up from the nearby Ek Xux creek, whereas Shelter 2 is a little less than 30 m above the Bladen branch of the Monkey river. Finally, the authors note that "[t] he upper levels at [Shelter 3] are more disturbed than at [Shelter 2], perhaps due to [its] proximity to the [Classic Period Maya] ruins of Ek Xux" (K. M. Prufer, Robinson, and Kennett 2020:203). The accompanying perturbation of the shelter's sediments may in part account for the lack of Late Archaic dates, as seen to a greater extent in Site 1.

Conclusion

In this chapter, I have attempted to provide the spatio-temporal context for the results of my lithic analysis, which I present in the next chapter. This context includes the physical characteristics of each rockshelter, with particular focus on the ways each shelter is different from the others, and how those differences may have impacted the frequency and density of human occupation at each. I also provided a detailed description of the methods used in constructing age-depth models for each site. These models are particularly important to my analysis for two reasons: 1) they allow me to provide age estimates for each assemblage of artifacts, and to thus compare contemporaneous assemblages among the three shelters and to look for changes in assemblages over time; and 2) they allow me to calculate the sediment deposition rates at each shelter for each assemblage. This latter point is particularly necessary when I compare each assemblage's artifact density (that is, lithics per m^3), as the deposition rate provides an estimate of how much sediment was being deposited along with the artifacts during each given time period. It thus allows me to normalize the spatial density of artifacts (in lithics per m^3) against the sedimentation rate, transforming it into the more meaningful spatio-temporal density of artifacts (in lithics per m^3 per century).

CHAPTER 5

RESULTS OF LITHIC ANALYSIS

As discussed in Chapter 4, I grouped lithics into assemblages based on the excavation level in which they were found. These levels were not always perfectly horizontal, in that one corner or another was often a centimeter or two higher or lower than the others. To make it easier to assign a single age to each level, I first simplified each level's start and end depth to a single number by averaging together the four corner and center depths and rounding up to the nearest cm, resulting in a depth range for each level. I then calculated the midpoint of this depth range, and queried the age-depth model in Bchron about the predicted age for that depth. For each query, the software returned a 97.5% high-density range (HDR) of calibrated dates as well as the first, median, and third quartile for that range. In order to simplify this age prediction and compare levels of similar ages (both within and between rockshelters), I used the median of that interval. Michczyński (2007:401) argues that the best "point estimate" for a given HDR is it's mode, because in his simulations it performed better than the median or mean in matching the true calendar age of a sample. However, since many of my predicted age ranges had multiple modes with no clear way to choose between them, I chose to use the median provided by BChron instead.

I also examine links between the traits and climate proxy data, specifically concentrations of titanium (Ti) from the Cariaco deep-sea drilling project. As discussed in Chapter 2, varying levels of Ti in the Cariaco core are thought to reflect changes in the northernmost position of the Intertropical Convergence Zone (ITCZ); in turn, the ITCZ's position is a direct result of sea surface temperatures of the North Atlantic that are affected by differing levels of insolation throughout the Holocene (Haug et al. 2001:1307). Any relationships observed between my lithic traits of interest and the

Cariaco Ti levels might indicate a link between changes in lithic technological organization, mobility, and climate; on the other hand, if the two datasets are not

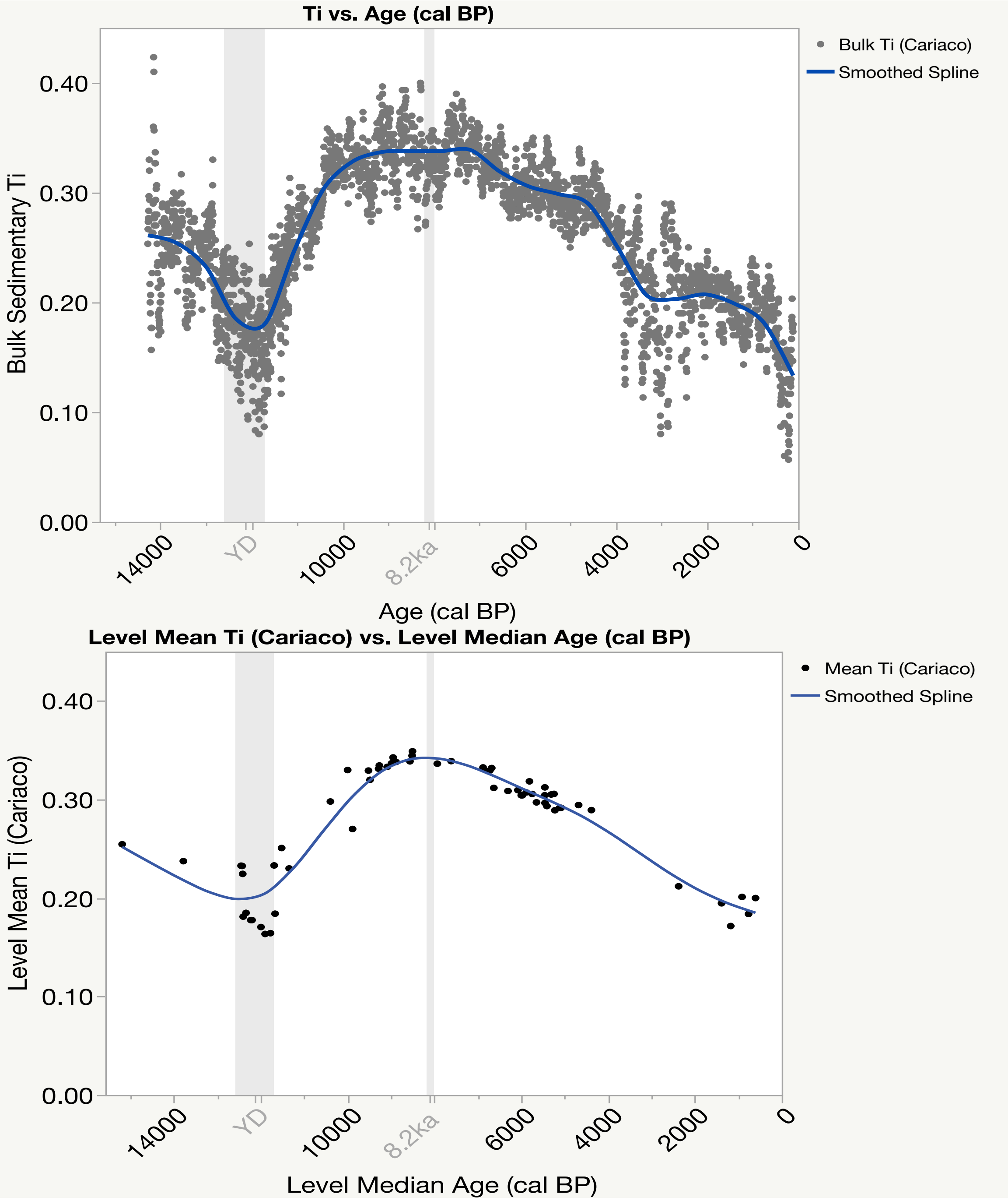


Figure 5.0.1. Graph of bulk sedimentary titanium vs. age for a) the original 2769 dated samples and b) the simplified 68 average Ti values for each level using bracketing ages at level top and bottom depth.

correlated, it might indicate lithic and mobility strategies that are independent of climate. A third possibility is a linkage between these factors at one part of the sequence, followed by a decoupling in another part; such a pattern might be expected in cases where human groups were growing less dependent on non-cultivated resources acquired from their environment, and more dependent on cultivars whose growth could be more directly managed.

In order to directly compare data from my assemblages to the Cariaco data, I first simplified the latter by averaging together the Ti values for all dates falling between a given level's Start and End Ages (cal BP). For example, Assemblage MH-1E-7 comes from Shelter 2, Unit 1E, Level 7, which has a Start Median Age of 4205 cal BP, and an End Median Age of 5202 cal BP. The average bulk sedimentary Ti value for all dated samples that fall between those dates is 0.291. Although this results in a vastly simplified dataset (Fig 5.1), it allows me to look for correlations between the Cariaco dataset and my own.

I also calculate the volume-normalized artifact Discard Rate (which I term Lithic DR) for each assemblage and examine changes in these rates over time. To arrive at this rate, I first calculate the volumetric artifact density by dividing each assemblage's artifact count by the volume of sediment excavated in its level. I then divide this figure by the number of centuries that passed between the bottom and top of the level. As with the Level Median Age, I obtained this interval by querying the age-depth model for the median age of the start and end depths for each level. By subtracting the younger age from the older, I arrive at the number of centuries it took for the level's volume of sediment accumulated. This process yields a volume-normalized artifact discard rate in terms of artifacts/m^3/century (or n/m^3/cent). These discard rates can be interpreted as a proxy for the occupational intensity of the site at a given time; in that way, they give insight into the relative amount of RMS or LMS practiced by the groups who stayed there. In general terms, high-LMS groups will produce assemblages with higher discard rates, since they stay at a site for longer, utilizing greater amounts of short use-life lithics and discarding them in greater quantities. On the other hand, high-RMS groups will produce assemblages with lower Lithic DR, since they spend less time at a given site, are more likely to create long use-life lithics, and take them with them when they leave.

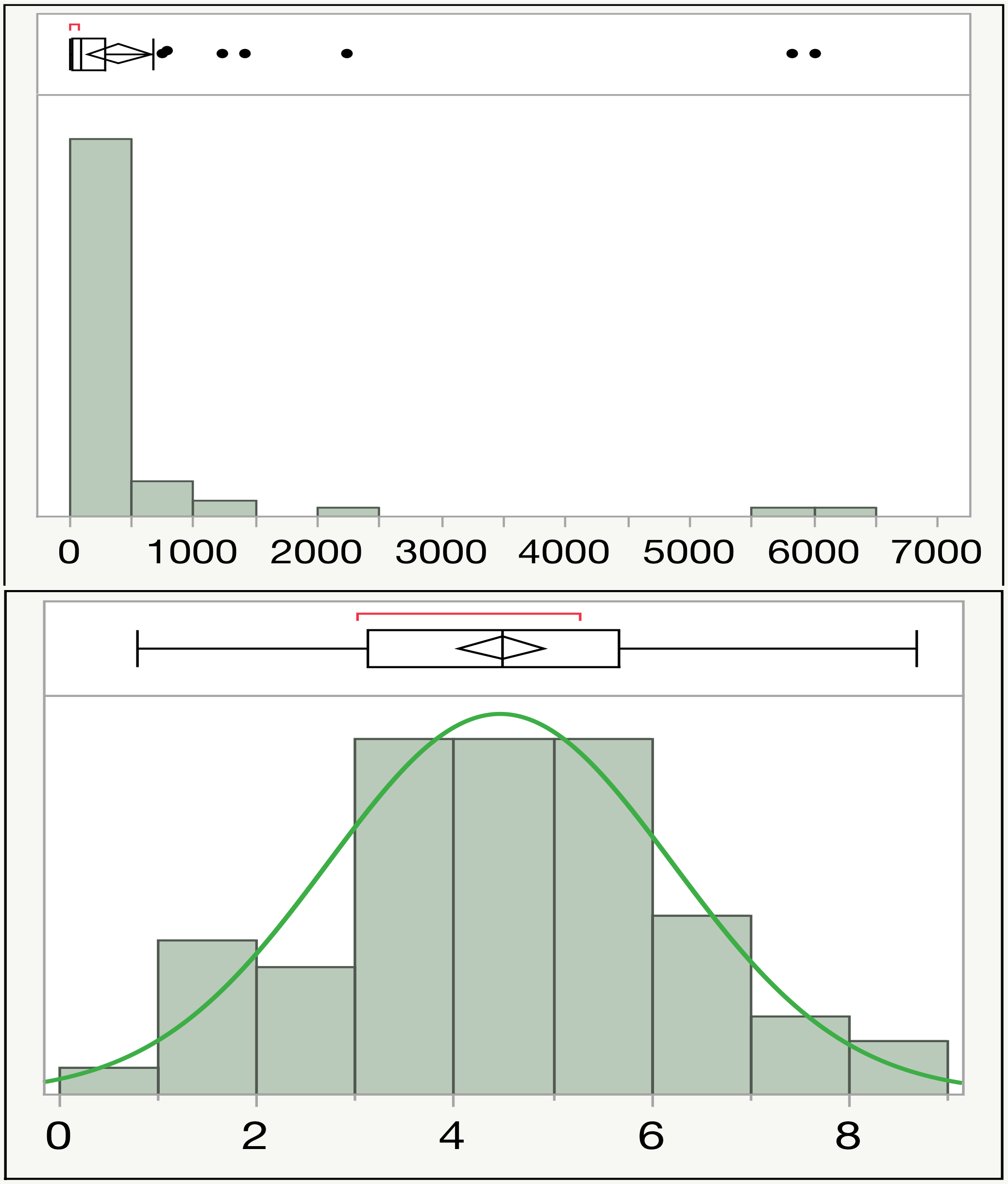


Figure 5.0.2. Histograms and boxplots for two version of Lithic DR: untransformed (top panel) and Log transformed (bottom panel)

However, these discard rates are not a measure of curation *per* se, in that they are not traits of the lithics themselves, but features of the assemblage. By looking at variations over time in this discard rate, I hope to illuminate additional patterns of lithic use that might yield insight into lithic technological organization and, by extension, mobility patterns throughout the entire sequence. Figure 5.2 (top panel) shows the distribution of this variable. Because it was so highly skewed, with a few outliers at the extreme left end of the distribution, I also Log transformed the variable to create Log(Lithic DR). This has the effect of creating a more normally distributed variable (Fig. 5.2, bottom panel) with no outliers identified in the boxplot.

Trait-by-Trait Analyses

In the following sections, I present results for each trait on its own. I first describe any transformations applied to the raw data as collected during lithic artifact analysis. I then present histograms showing the overall distribution of each trait of interest. Finally, I present data on traits that are highly correlated, which allows me to select a smaller subset of traits for further analysis in terms of time trends and covariation with climate proxy I'm using, Bulk Sedimentary Ti from the Cariaco core.

Curation Trait #1: Cortex

First, I present data on the amount of cortex present in each assemblage. During data collection, I had characterized each lithic according to the percentage of its dorsal surface that was covered in cortex using 5 cortex bins as follows: 0% (all cortex removed), 1-25%, 26-50%, 51-75%, and 75-100%. By summing the number of lithics in each bin, I can characterize assemblages according to how many of their lithics fell into each cortex bin: e.g., 25% in the 0% bin, 3% in the 1-25% bin, etc. However, analysis and visualization of change over time for five frequency statistics proved too cumbersome. Therefore, I simplify my characterization of each assemblage's cortex values in two ways:

by calculating a Mean Cortex figure for each assemblage, and by combining the three middle Cortex Bins into a single Cortex Group. I first describe my method for estimating each assemblage's Mean Cortex value, and examine its relationship to time and climate data. I then do the same for Cortex Groups, but analyze their relationships to time and climate using two metrics – frequency of artifacts in each Cortex Group, and volume-normalized Discard Rates of each.

Mean Cortex. My first method for simplifying cortex bins involves converting each of the original 5 cortex bins into a single number representing the midpoint of its range. In the case of 0%, this was simply 0, but I converted the other bins as follows: 1-25% - **13%**; 26-50% - **38%**; 51-75% - **63%**; 76-100% - **88%**. By assigning a single cortex value to each piece and averaging each assemblage's cortex values together, I arrived at Mean Cortex value for each assemblage (Fig. 5.3).

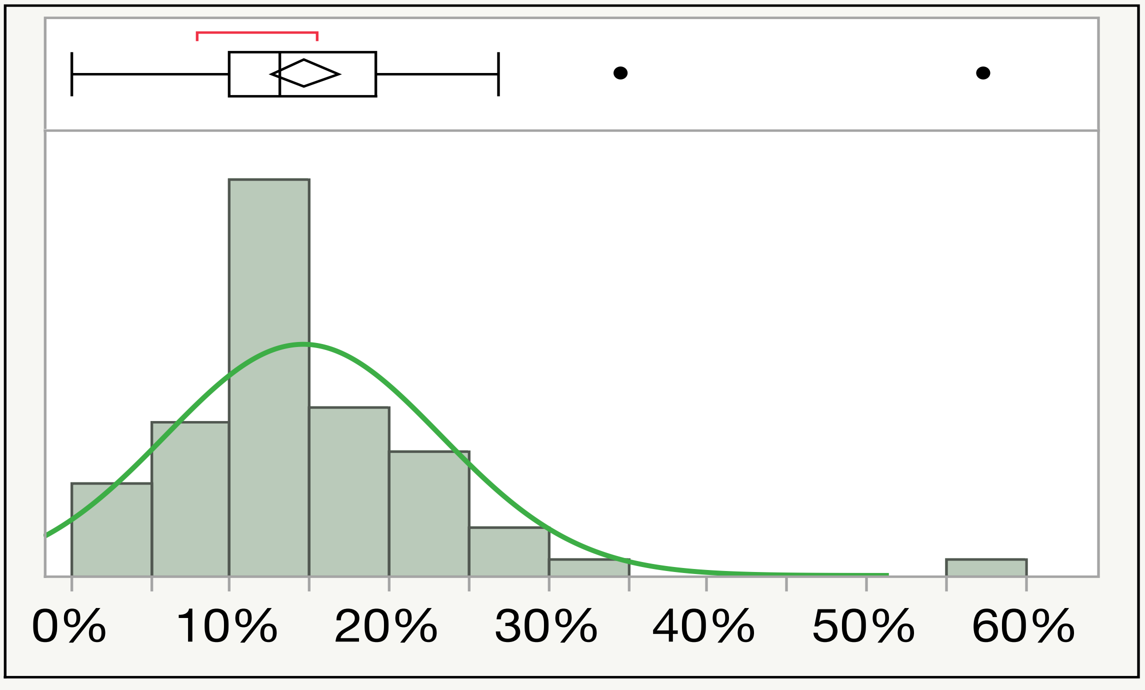


Figure 5.3: Histogram and boxplot showing distribution of Mean Cortex (%)

Cortex Groups: Frequency. My second method for simplifying my analysis of cortex involves examining the covariance among the 5 original bins and combining any strongly-covarying bins into a single Cortex Group. In examining pairwise correlations between artifact counts in all 5 bins, I find that the three middle bins – 1-25%, 26-50%, and 51-75% - are very highly correlated with each other (Pearson's R > 0.94, p<0.0001 for all three). The remaining two cortex bins – 0%, and 76-100% - are only moderately correlated with the other three bins (Pearson's R < 0.76, p<0.0001), but are highly correlated with each other (Pearson's R = 0.86, p<0.0001). I also examine correlations among the five bins in terms of relative frequency (that is, the percentage of each assemblage that falls within a given bin) rather than raw counts. When transformed this way, the three middle bins are moderately correlated with each other, with Pearson's R ranging from 0.44 and 0.55 (p<0.0001 for all pairs). However, they have moderately high but negative correlations with the 0% bin (Pearson's R ranging from -0.72 and -0.79, p<0.0001 for all pairs), and low correlations with the 76-100% bin (Pearson's R ranging from -0.10 to 0.18, p<0.025 for all three). Finally, the 0% and 76-100% bins are moderately negatively correlated with each other (Pearson's R = -0.39, p<0.0001).

These correlations suggest two groupings of cortex bins. The three middle bins are highly correlated with each other as counts, and moderately correlated with each other as percentages, so I add together their artifact counts to form one new cortex group. I keep separate the first bin (0%) because it captures completely non-cortical lithics, which are a sign of extreme curation in an assemblage. Because its relative frequency metrics is highly negatively correlated with the 76-100% bin, I added the latter into the group with the three middle cortex bins. This process results in two Cortex Groups: Non-cortical % (0% Cortex) and Cortical % (1-100% Cortex), which capture the two ends of the curation-expedience spectrum. Figure 5.4 shows their distributions.

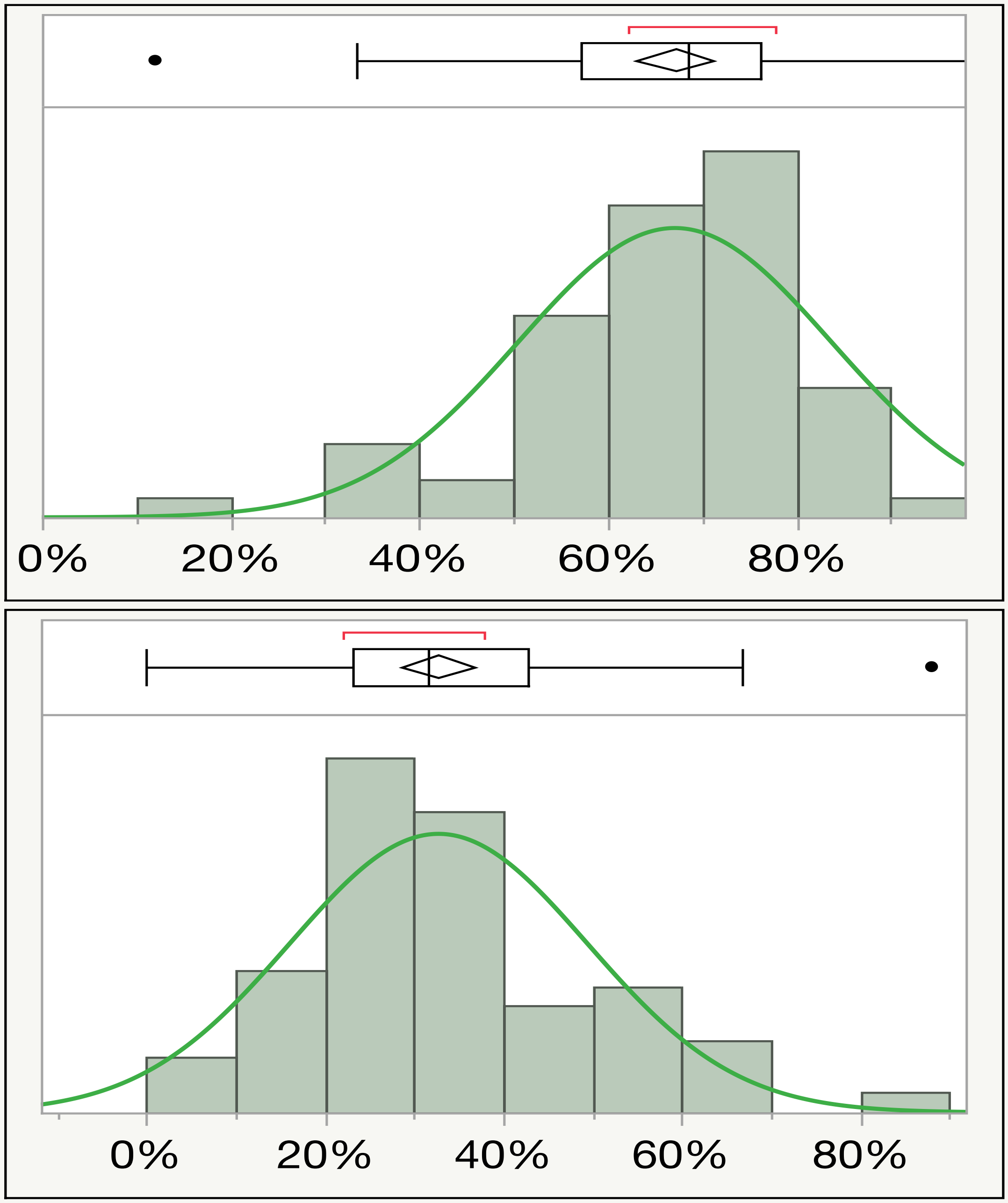


Figure 5.4. Histograms and boxplots for Non-cortical % (top panel) and Cortical % (bottom panel) from the aggregate data

Curation Trait #2: Platform Type

I now turn to a consideration of changes in platform type through time at each site, and in aggregate. Most of the lithics I analyzed did not have their original platforms attached, so the sample size for this part of the analysis is necessarily smaller (n = 1848, less than half that for the cortex analysis). This sample includes only broken or complete flakes, the two types of debitage that have either partial or complete platforms. Furthermore, I observed a large difference between the three sites in the number of platforms relative to sample size. For instance, 43% of Site 1's lithics had full or partial platforms; Site 2 had a similar proportion of 38%. However, for Site 3, that proportion dropped to 20%. Pairwise Student's t-tests indicate that Site 3 is significantly different from Site 1 ($p<0.005$) and Site 2 ($p<0.01$), but that Sites 1 and 2 are not significantly different from each other ($p=0.25$). Discovering the reasons behind of Site 3's difference is more difficult, however. On one hand, taphonomic differences, such as greater trampling of lithics underfoot at Site 3 compared to 1 or 2, could result in more fractured flakes and fewer flakes with platforms. However, given Shelter 3's vastly greater size, I would expect it to have more intact platforms than the other sites, since human occupation and lithic discard areas would more likely be separated in space. On the other hand, it is also possible that greater curation of pieces at Site 3 would result in more platforms being lost due to use, retouch, or re-shaping. The difference in overall platform frequencies between the three sites thus provides an intriguing bit of evidence for greater curation being practiced at Site 3.

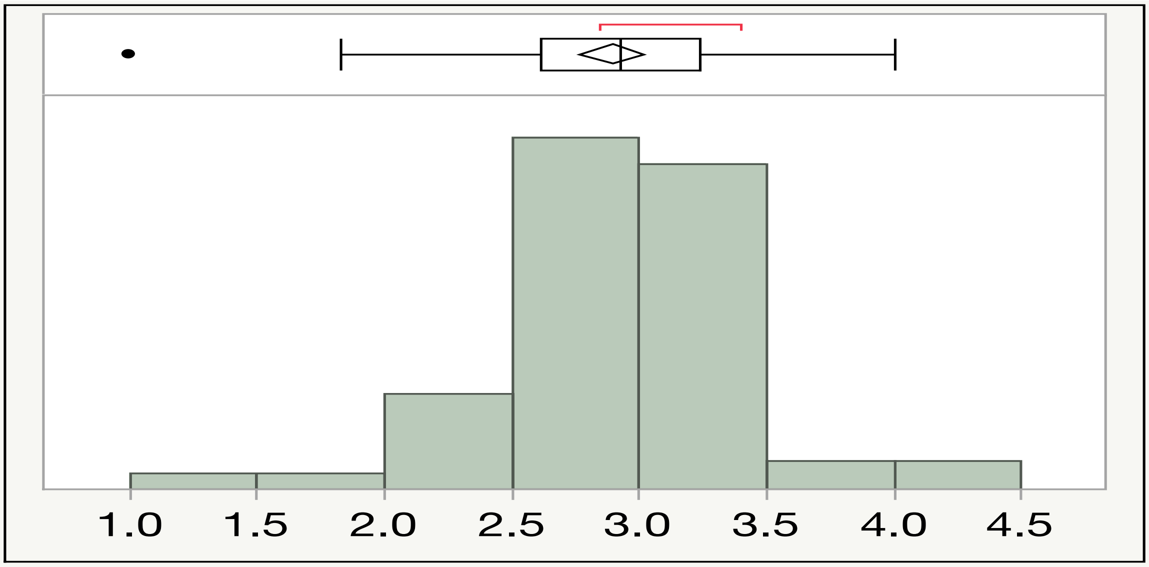


Figure 5.5. Histogram and boxplot of Mean PCS for aggregate data.

As with cortex, I characterized each individual lithic as to its platform type (cortical, plain, crushed, or faceted) during data collection. On the assemblage level, this allows me to calculate the percentage of each assemblage's lithics with a given platform type (e.g., 3% cortical, 35% plain, etc). However, this results in a four different frequency statistics to track through time for each assemblage. In order to simplify my analysis, I first rank each platform type in order from simplest to most complex: 1 for cortical, 2 for plain, 3 for crushed, and 4 for faceted. For simplicity, I refer to this ranking as a Platform Complexity Score (PCS). I then recode each piece using this numerical value, allowing me to calculate the mean PCS for each assemblage. Lower mean PCS values indicate a preponderance of simpler platforms, while higher values indicate a greater presence of complex platforms. Figure 5.5 shows the distribution of this trait in the aggregate data.

Curation Trait #3: Retouch Frequency

The third curation-related trait I examine is retouch, measured as the percentage of each assemblage's lithics that bore at least one retouch scar (or Retouch %). Unlike the prior to curation traits discussed, there were far more assemblages (n = 35) with no retouched lithics (that is, Retouch % = 0). Since retouch is a trait associated with curation, this complete lack of retouch could potentially be taken to indicate little to no curation in those assemblages. However, since an absence of evidence is not the same as evidence of absence, I do not want to place too much emphasis on those assemblage's with 0 Retouch % during my analysis of this trait's covariance with time and climate. To that end, I also conduct that analysis with 0 Retouch % assemblages removed, which resulted in a much smaller sample size (n = 31). I refer to this trait as Retouch % 2, and provide distributions of these two variables in Figure 5.6 below

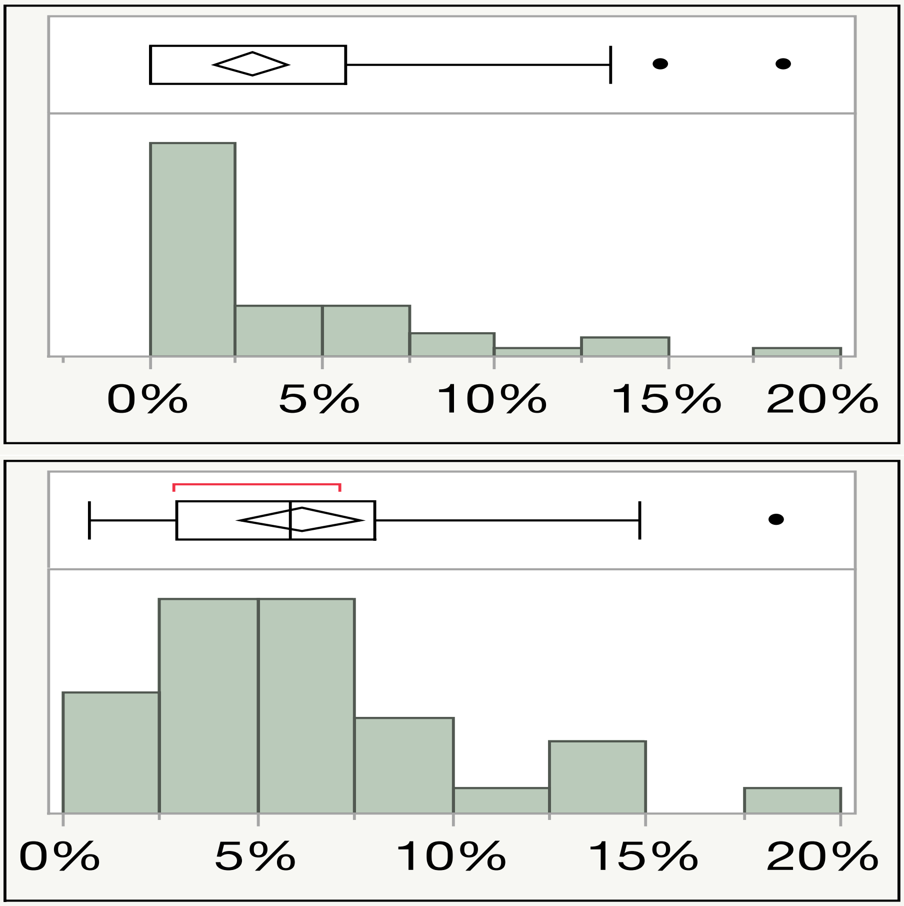


Figure 5.6. Distributions of retouch trait values with zero values included (Retouch %; top panel) and with zero values removed (Retouch % 2; bottom panel)

Curation Trait #4: Bifaciality

I now turn to my analysis of bifacial artifacts. In this study, very few bifaces (or biface fragments) were recovered, and they are believed to belong to the Lowe complex of projectile points (see Stemp et al. 2016; Prufer et al. 2019 for a fuller discussion of these artifacts). For this study, it is sufficient to count them as a type of biface for purposes of characterizing a given assemblage as to its bifaciality. In addition to these formal bifacial tools, I include one other distinctive type of flake associated with bifacial lithic technology: the Bifacial Thinning Flake, or BTF. These small flakes are thought to be the direct result of the thinning or shaping processes described above. While it can be difficult to tell if they had been used as tools themselves, BTFs do provide a good indication that larger pieces were being subjected to bifacial flaking. They can be recognized by several distinctive traits, including “curved longitudinal cross-sections, extremely acute lateral and distal edge angles, feathered flake terminations, narrow faceted striking platforms, a lip, little or no cortex, and a small flattened or diffuse bulb of force” (Root 1992:83). These flakes are not part of the modified Sullivan-Rozen typology used by the study; however, since they were fairly easy to recognize, a “BTF” tag was added to each one’s entry when encountered.

To quantify “bifaciality” using these categories, I calculated each assemblage’s “bifacial frequency” by adding together its bifacially retouched tools, bifaces, and BTF’s, and dividing by the total number of lithics in the assemblage. Although this approach does aggregate two different types of lithics – that is, actual bifacial tools and byproducts of bifacial flaking – it seemed the best way to capture the degree of bifaciality of the diverse lithic assemblages. One could argue that the creation of each bifacial tool might have yielded a dozen or more BTF’s, so giving each the same weight could underestimate the true degree of bifaciality. However, as noted above, the number of bifacially retouched tools (n = 33) and formal bifaces (n = 2) in the entire study was extremely small, so analyzing them as their own separate category seemed fruitless. Rather than ignore them entirely, or assign them an arbitrarily higher weight to account for the greater number of BTF’s each might have yielded, I simply added them to the number of BTF’s (n = 158) to yield a total number of lithics related to bifacial manufacture (n = 193). As with Retouched artifacts, I use two metrics to examine changes in bifaciality of assemblages through time: proportion of each assemblage made up by bifaces (Biface %). As with retouch, a large number of assemblages (n=42) had 0 Biface %, so I also ran my analyses looking at just those assemblages with non-zero Biface % values (which I termed Biface % 2; n=24). Figure 5.7 shows distributions of these two variables.

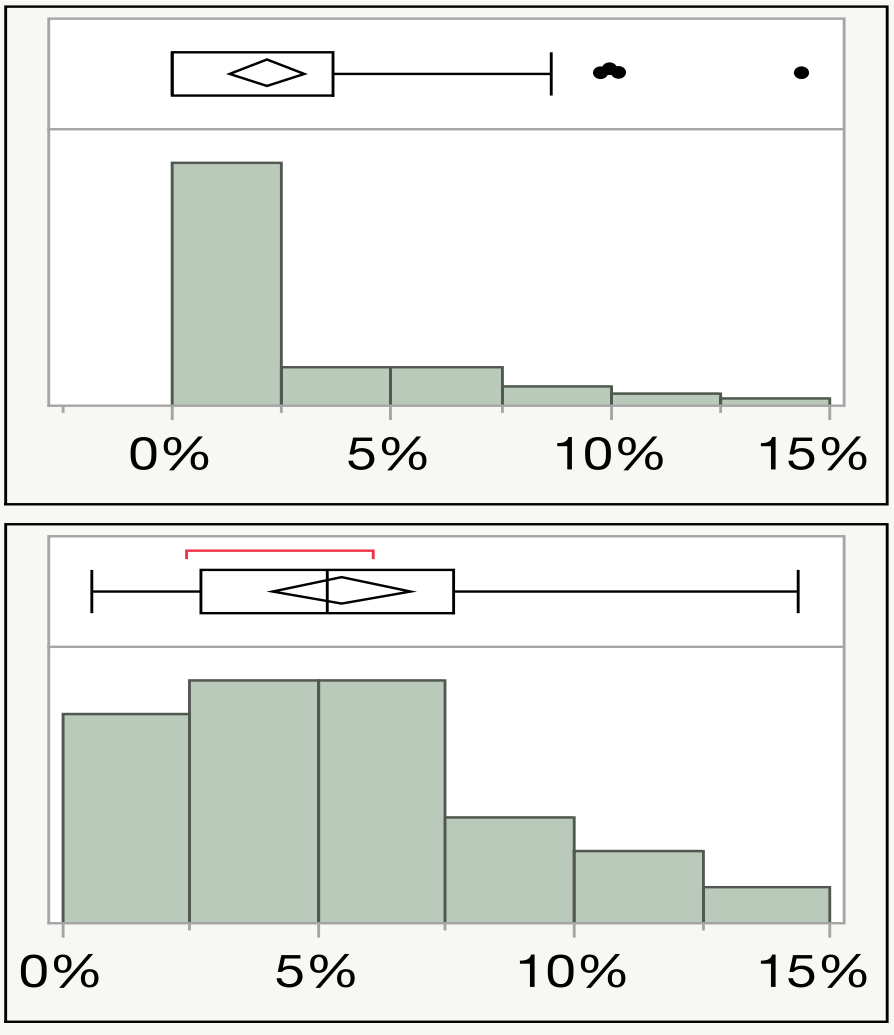


Figure 5.7. Histograms and boxplots for bifacial curation trait, with zero values included (Biface %, top panel) and removed (Biface % 2, bottom panel)

Covariance among Traits

Having provided some basic context for the lithic curation traits of interest, I now present a discussion about the ways they co-vary. Of note in this regard is the fact that most of the traits are not normally distributed; all except Log(Lithic DR) are skewed in one way or another, or have kurtosis (peakedness) that is significantly different from that of a normal distribution. What this means is that I must use a non-parametric statistic to quantify their degree of covariation. Instead of Pearson's R, below I report Spearman's ρ (or rho), which is a non-parametric measure of correlation that doesn't rely on assumptions of normality. Like Pearson's R, p-values can be reported that indicate whether or not any observed relationships are statistically significant. In theory, one might expect that the covariation amongst these traits would be high for the assemblages in my study, since they are all theorized to be related to the same basic dynamic: the organization of lithic technology in relation to a groups level of residential mobility. However, as I will show, only a few of the traits were significantly correlated in the way I expected. Although this does require some further explanation, it has the benefit of narrowing the scope of my analyses somewhat. When I examine the relationships of these traits to the independent variables of time and climate in the following section, I will focus on only one trait of each pair that co-vary significantly with each other.

Biface % & Retouch %. The first pair of traits I consider are Biface % and Retouch %, as they had one of the higher Spearman's ρ values of 0.58 ($p<0.0001$). Figure 5.8 (top panel) portrays this result graphically. Although there does appear to be a strong, positive linear trend, it is important to keep in mind that a large number of points overlap at point (0,0) on the graph, because there were so many assemblages that had 0 values for both Retouch % and Biface % (n=26). For this reason, I also show the correlation between Retouch % 2 and Biface % 2, which was moderately strong but not significant at the 0.05 level (Spearman's rho = 0.29, p=0.19). That these traits appear to co-vary when 0 values are included is an intriguing sign that those values are in fact evidence of absence of these traits. If one trait was missing from one group of assemblages, while the second was missing from an entirely different group, it would provide quite mixed results in terms of curation: there would be no way to tell (on the basis of these two traits alone) whether the assemblages without retouch were less curated than those without bifacial technology. The non-significant correlation between

Retouch % 2 and Biface % 2 is a somewhat reassuring that the co-variance is not based entirely on assemblages with zero retouch or bifaces; instead, it appears that

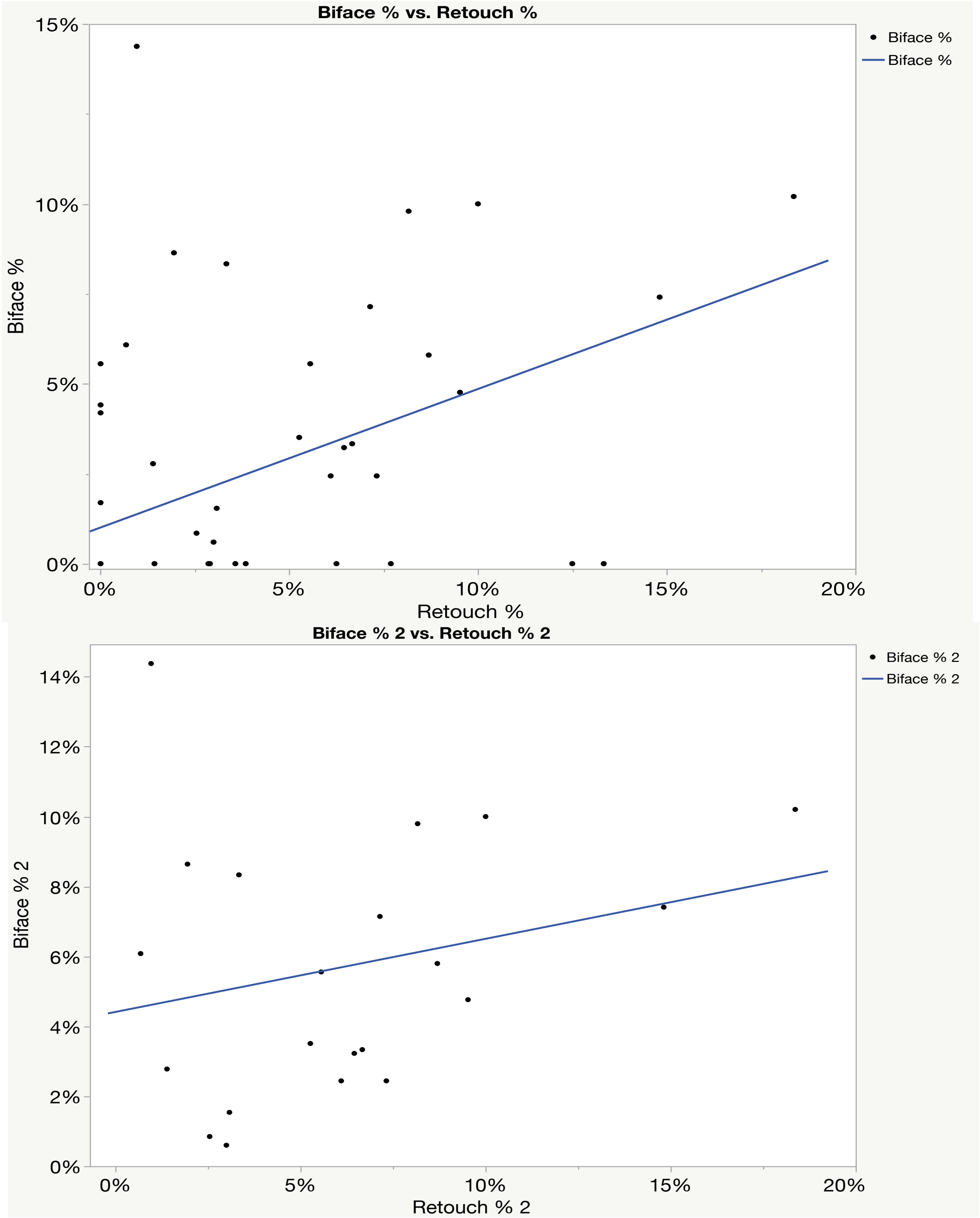


Figure 5.8. Scatterplots showing relationship between Biface % and Retouch % (top panel) and between Biface % 2 and Retouch % 2

assemblages with relatively high Biface % are also likely to have relatively high Retouch % values, which is consistent with the interpretation that both are results of curation.

Biface % & Non-cortical %. The next pair of traits I consider is Biface % and Non-cortical %, which showed a significant, moderate correlation (Spearman's rho = 0.44, p<0.0005) (Fig. 5.9). The positive relationship between these two traits, which was one of the only to reach significance, is as expected under model of the curation-expedience spectrum. Assemblages that had a high Biface % also had higher relative frequencies of non-cortical artifacts, both of which are associated with curation. However, because of the presence of zero values in the Biface % trait, I also note a lower, non-significant correlation for Non-cortical % and Biface % 2 (Spearman's rho = 0.24, p=0.23). Once I removed the 42 assemblages with 0 Biface %, I was left with a much smaller sample (n=24), which may in part explain the non-significance of the weak correlation.

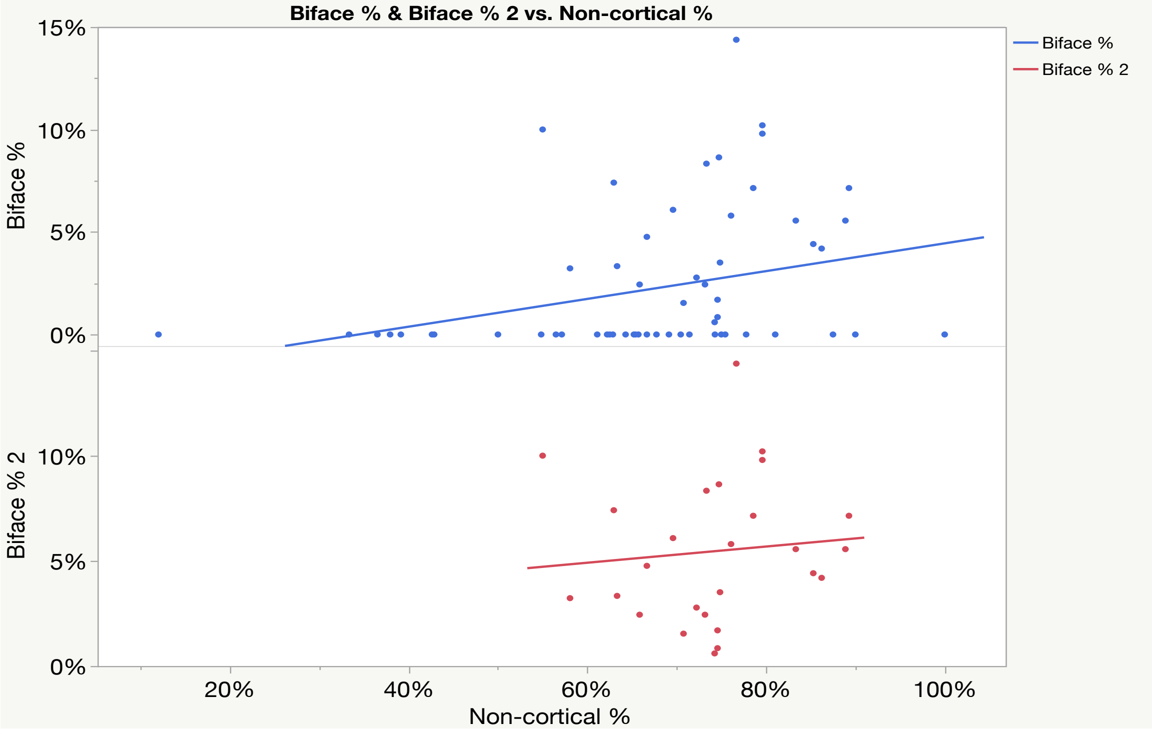


Figure 5.9. Scatterplots of Non-cortical % vs. Biface % (top panel) and Biface % 2 (bottom panel) for the aggregate data.

Biface % vs. Mean PCS. The next set of relationships I present are those between Biface % and Mean Platform Complexity Score (PCS) (Fig. 5.10). These two traits showed a low, significant correlation (Spearman's rho = 0.27, $p<0.05$), which is as expected under the curation-expedience model: assemblages with more evidence of bifaciality also had more complex platforms, both of which are signs of curation. Interestingly, when I remove zero values from Biface %, the correlation becomes even stronger and more significant (Spearman's rho = 0.58, $p<0.005$). This serves as further confirmation that these two traits are positively related in the manner expected, since it occurs despite a lower sample size (n=24).

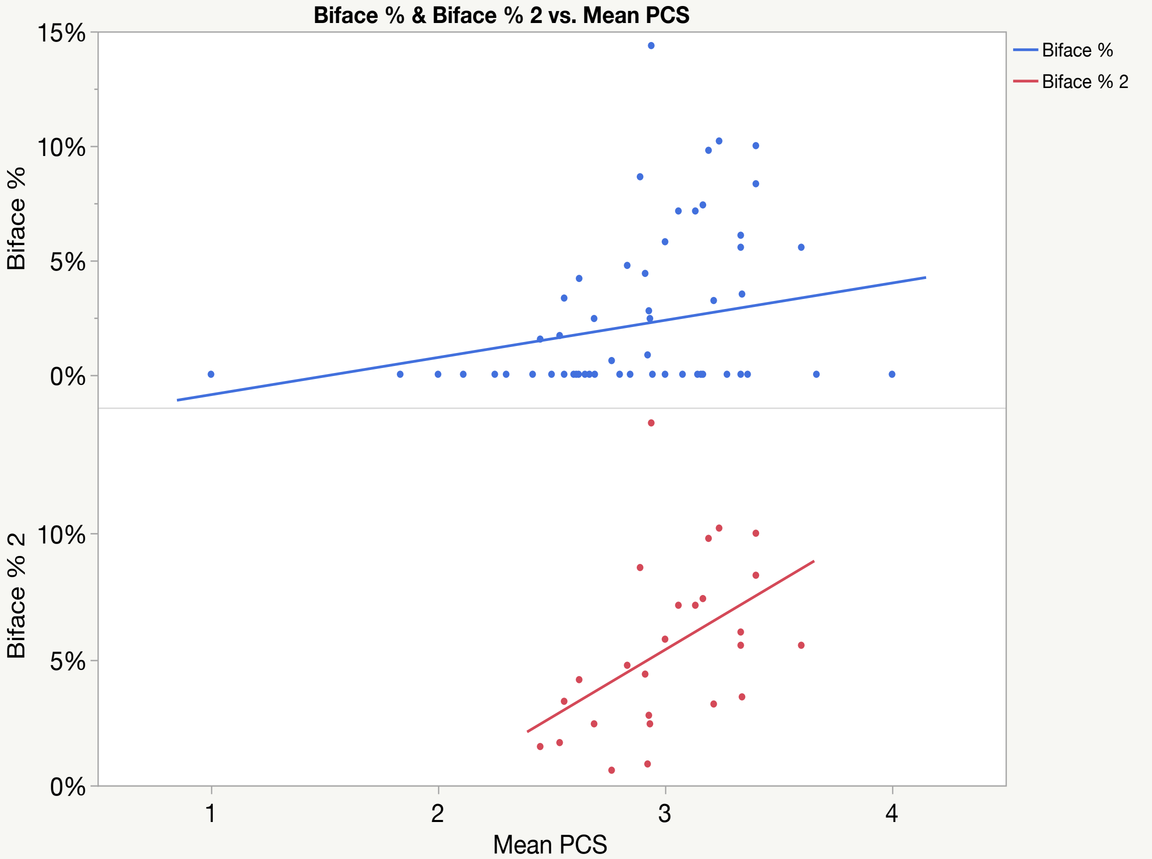


Figure 5.10. Scatterplots of Mean PCS vs. Biface % (top panel) and Biface % 2 (bottom panel) for the aggregate data.

Non-Covarying Traits. As briefly alluded to above, the fact that all of the traits do not co-vary in the manner expected does require some further explanation. One trait pair for which I had expected to see a significant negative correlation was Lithic DR and Retouch %. As Riel-Salvatore and Barton (2004) showed, there tends to be a strong, negative correlation between frequency of retouched pieces and total artifact volumetric density (that is, the number of artifacts per m^3 of sediment). This is because artifact density is a sign of occupational intensity and thus, logistical mobility: the more intensely occupied the site, the more likely that its occupants were more sedentary, and the less likely that would be to practice curation-related behaviors like retouching their stone tools. The lack of a relationship between Retouch % and Lithic DR in my aggregate data may in part be due to the fact that I calculated volume-normalized discard rates, which are essentially artifact volumetric densities that take varying sedimentation rates into account. Riel-Salvatore & Barton (2004, 259) argue that just that sort of normalization is preferable to simple artifact volumetric densities where high-resolution chronologies are available. Further work on these assemblages, and refinements of their artifact discard rates, may shed further light on the observed lack of relationship.

Variation in Lithic Traits over Time and Changing Climates

I turn now to a more in-depth look at the ways these traits change over time and with variations in climate. In presenting these results, I focus only on those traits that had a significant relationship (as evidenced by Spearman's rho) to either time or climate, and refrain from presenting two traits that co-varied strongly with each other. For example, I found that Retouch % (both with and without 0 values) had no correlation with either time or climate proxy; I also know that it was correlated with Biface %, so I refrain from providing more details about it. On the other hand, one trait, Lithic DR, was not correlated with any of the traits discussed above, and so might have garnered more attention here. However, I found that it also had no correlation with either time or climate proxy, and so will not discuss it at greater length here. Finally, Mean PCS was correlated with Biface %, but my analysis indicated no relationship with time or client, so I do not discuss it further here. The following graphs and statistics all derived from the aggregate data; after presenting these relationships, I will turn to a Site-by-Site analysis.

Cortex vs. Time and Climate. The first curation trait I will examine is Cortex, in particular Non-cortical %, higher values of which are thought to indicate greater

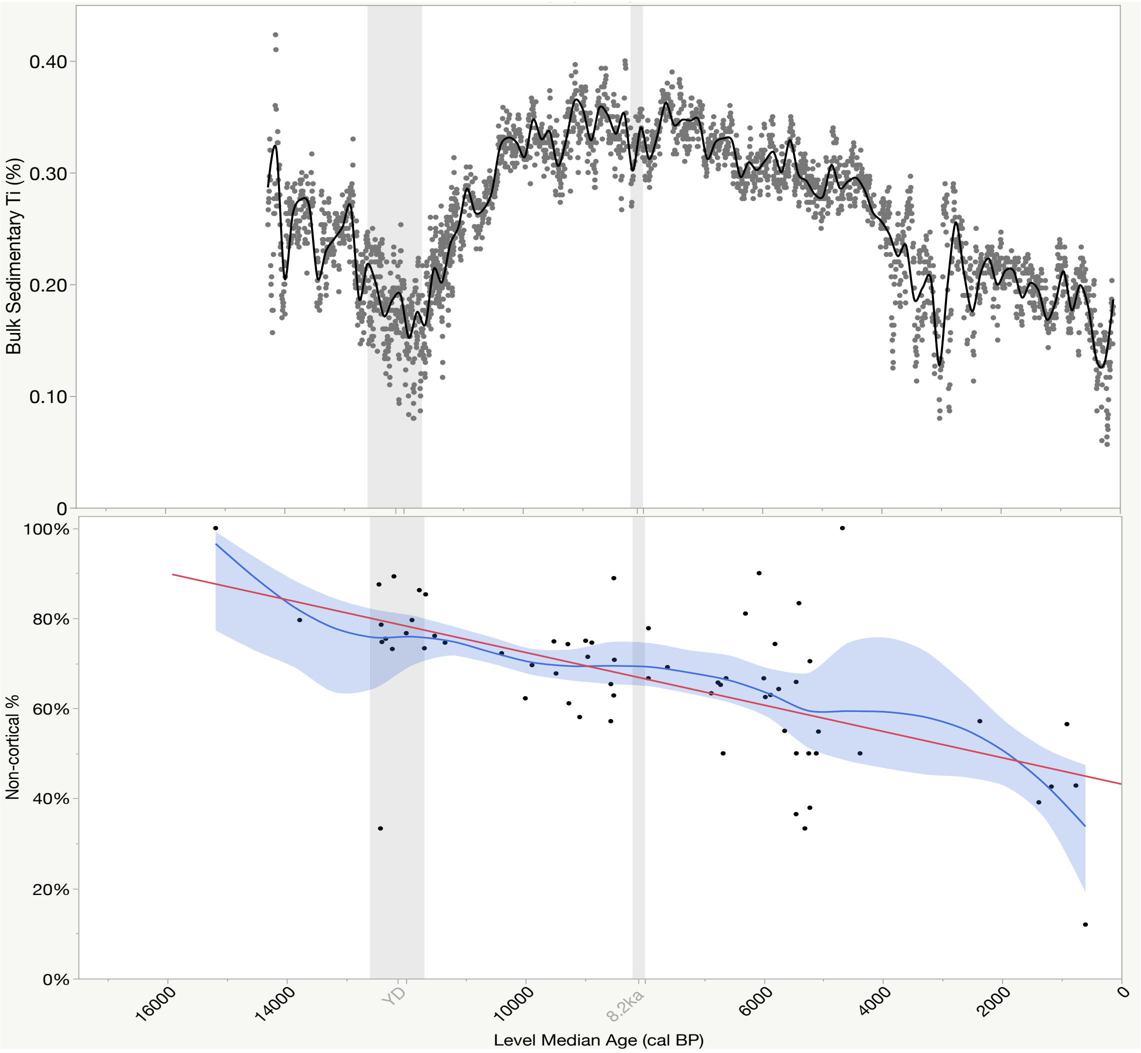


Figure 5.10.1. Scatterplots showing changes in Bulk Sedimentary Ti (top panel) and Non-cortical % (bottom panel) over time.

curation. As can be seen in Figure 5.11, this trait does have a significant, strong negative relationship with time (Spearman's rho = 0.6, $p<0.0001$), but has no relationship with climate. The blue-shaded confidence interval around the smoothed spline indicate a fairly tight conformance to the linear trend (illustrated by the red trendline); there appears to be greater variation just prior to and during the Younger Dryas, and again during a period between 6000 and 5000 cal BP. The confidence interval is also relatively wide after 5000 cal BP until roughly 2000, but this appears to be related to a lack of assemblages from that time, not greater variation in Non-cortical %. Overall, this trait indicates a shift from higher RMS to higher LMS over time, although the exact reason for that shift cannot be deduced. However, it is possible to eliminate climate as a driver, since it had no significant relationship with this variable. Therefore, another time-related variable must be sought to explain the shift towards sedentism. As I discuss in greater detail in Chapter 6, the best contender for that variable is increasing reliance on manipulated floral resources and, eventually, cultivars.

Biface % vs. Time and Climate. Because I found Biface % (both with and without zero values) had a significant relationship to several of the other traits, I spend a greater amount of time discussing it here. This variable also showed significant correlation with both time and climate. For example, Biface % (zero values included) had a moderate negative relationship with Bulk Sedimentary Ti % (Spearman's rho = -0.28, $p<0.05$), indicating decreasing curation during warmer climatic intervals. However, it also showed a stronger, positive correlation with time (Spearman's rho = 0.47, $p<0.0001$), indicating decreasing curation over time. Together, these two sets of relationships appear to support the interpretation mentioned above, that some time-related variable (such as increasing use of plants and/or cultivars), and not climate, is the driving factor behind a shift towards greater sedentism evidenced by this trait. Figure 5.12 portrays these relationships graphically.

Interestingly, the strength of these relationships reverses when assemblages with zero Biface % are removed. Compared to Biface %, Biface % 2 (non-zero values only) shows a much stronger, negative correlation with climate (Spearman's rho = -0.52, $p<0.01$), indicating that warming climate led to a decrease in biface production and, thus, curation. At the same time, compared to Biface %, Biface % 2 shows a weaker relationship with time, though it does not quite reach significance at the 0.05 level.

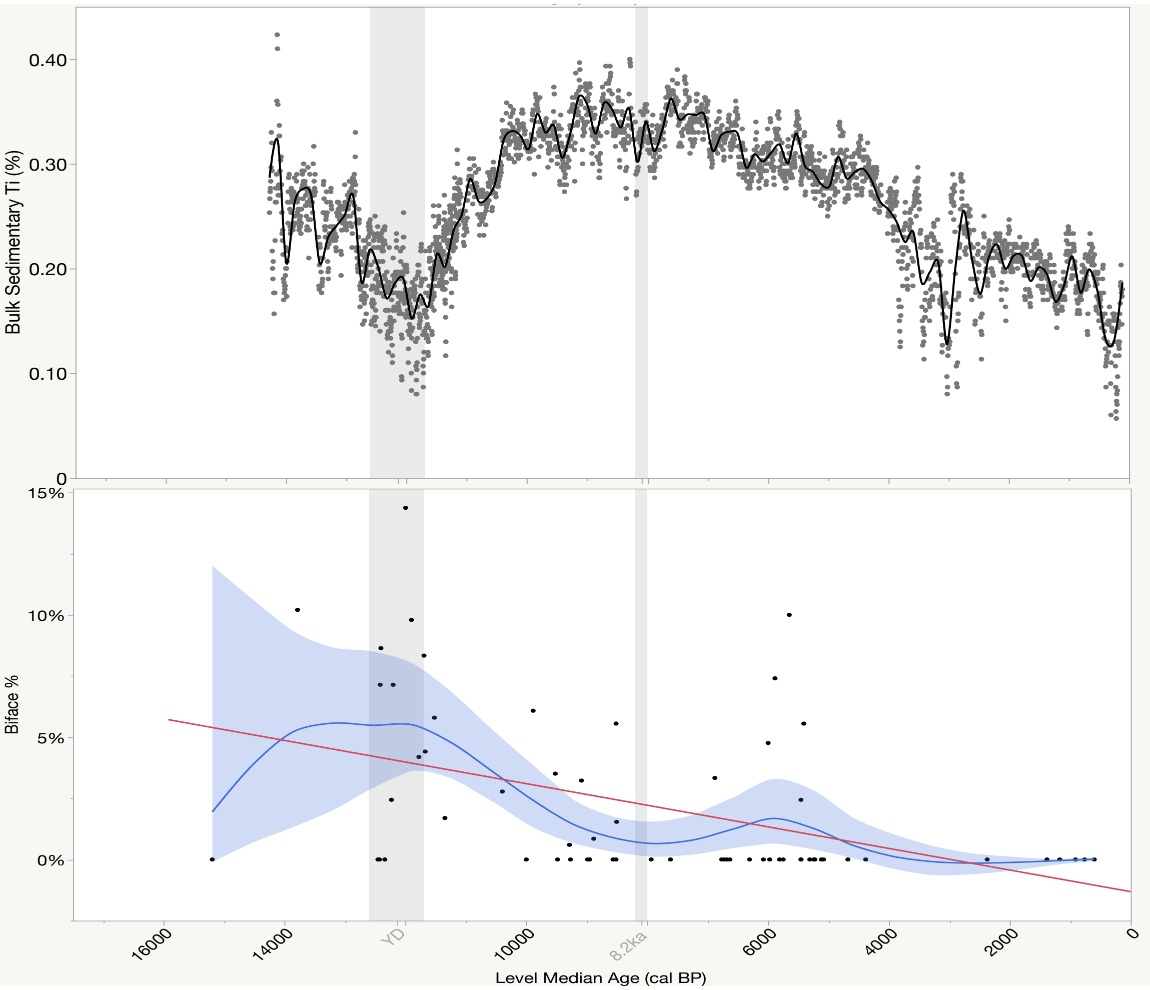


Figure 5.12. Scatterplots showing relationships between climate proxy (top panel) and Biface % (bottom panel) over time.

(Spearman's rho = 0.35, p=0.07). This would appear to indicate that a time-related variable like increasing plant manipulation does not better explain the shift to sedentism than does the overall climatic change. Figure 5.13 shows these relationships.

One feature of note in both of the Biface % graphs is the apparent peak in bifaciality later in the sequence, just after 6000 cal BP (blue triangles in Fig. 5.13 bottom panel). There is a similar but higher peak during the Younger Dryas that likely coincides with the presence of megafauna and a more open, savannah-like landscape, both of which favor big game hunting, bifacial production, and greater residential mobility.

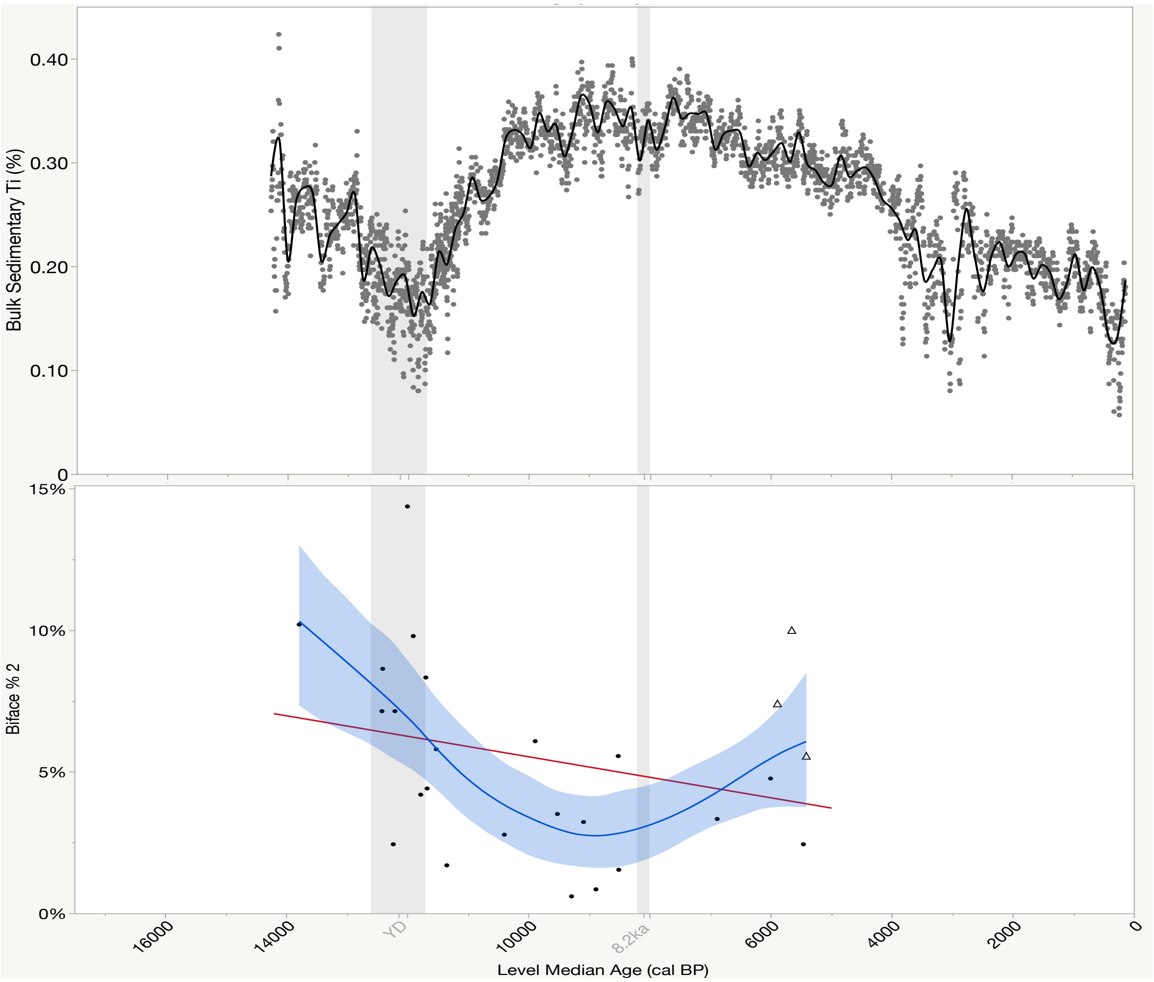


Figure 5.13. Scatterplots showing relationship between climate proxy (top panel) and Biface % 2 (bottom panel) with time. Blue triangles represent assemblages accounting for a late-occuring peak in bifaciality.

Similar dynamics would not be at play at 6000 cal BP; indeed, the climate proxy record indicates consistently warm, wet climate during that time, and the paleoenvironmental proxies discussed in Chapter 2 indicate a mostly closed-canopy tropical forest landscape. Highly-ranked megafauna had been extinct for millennia by that point, so bifacial projectile points would not have been as necessary. Because this peak seems somewhat anomalous, I took a closer look at the assemblages that cause it, and compared them to the assemblages that were responsible for the peak in bifaciality during the Younger Dryas (Fig. 5.14).

Upon further inspection of these assemblages, several differences between the

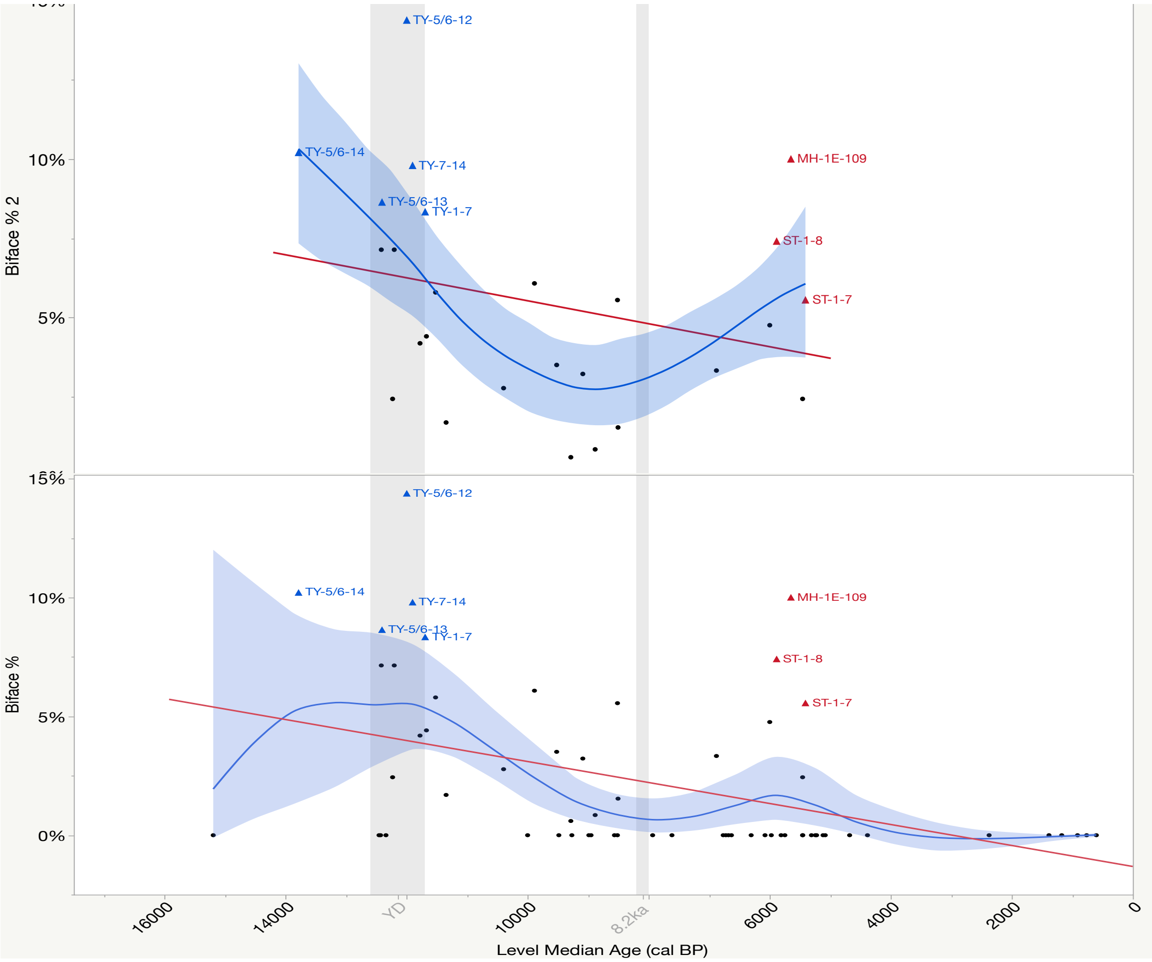


Figure 5.14. Scatterplots showing change over time in Biface % 2 (top panel) and Biface % (bottom panel). Blue triangles denote Early sites with high Biface % values; Red triangles denote Late sites with high Biface % values.

two groups (which I'll term Early and Late) were immediately apparent. The three assemblages making up the Late peak were all small, ranging in size from 18 to 27 artifacts. These had only one or two bifacially retouched artifacts, and even smaller numbers of Bifacial Thinning Flakes (BTF's); but in the context of their small number of lithics, these produced relatively high Biface % values. Their Lithic DR values were also moderate, indicating lower occupational intensity. By contrast, the assemblages in the Early peak were all larger, ranging in size from 49 to 463 lithics; these assemblages had a few bifacially retouched tools (including one Lowe projectile point) and dozens of BTF's. They also had high Lithic DR values, indicating higher occupational intensity. It seems possible, then, that the assemblages in the Late peak were unduly influenced by a few bifacially retouched tools in their overall small samples of artifacts. Additionally, the nature of these tools has to be studied in greater detail, as I intentionally used a very low threshold to call something bifacially retouched: it need have only one retouch scar on each face to fall into that category. That type of minimal bifacial retouching is quite different from the intensive bifacial retouching evident on projectile points like the Lowe point mentioned above. If some of those few bifacially retouched artifacts are reclassified and removed from the Biface % figure, it would likely greatly decrease that peak in values, which would also change the strength of that traits relationship with both climate and time. With that said, I now turn to a site-by-site analysis of these traits.

Synthesis of Site-specific Results

Below, I synthesize the results for a selection of curation traits for each site, focusing only on those traits that showed a significant relationship to either time or climate, As a reminder, in all plots age increases to the right, so negative correlations show a positive slope, and vice versa. It will also be helpful to keep in mind each traits relationship to curation and expedience. Increasing Non-cortical % is thought to be a sign of increasing curation, as more cortex is removed from lithics by lithicists who craft more complex tools with longer use-lives. Likewise, increasing Biface % is thought to be a sign of increasing curation, as it is related to efforts to get the most utility out of each unit of lithic toolstone. Finally, increasing Lithic DR is taken as a sign of increasing occupational intensity at a site, which is further related to decreasing residential mobility. Although it is not itself directly a sign of curation, it is expected to be negatively

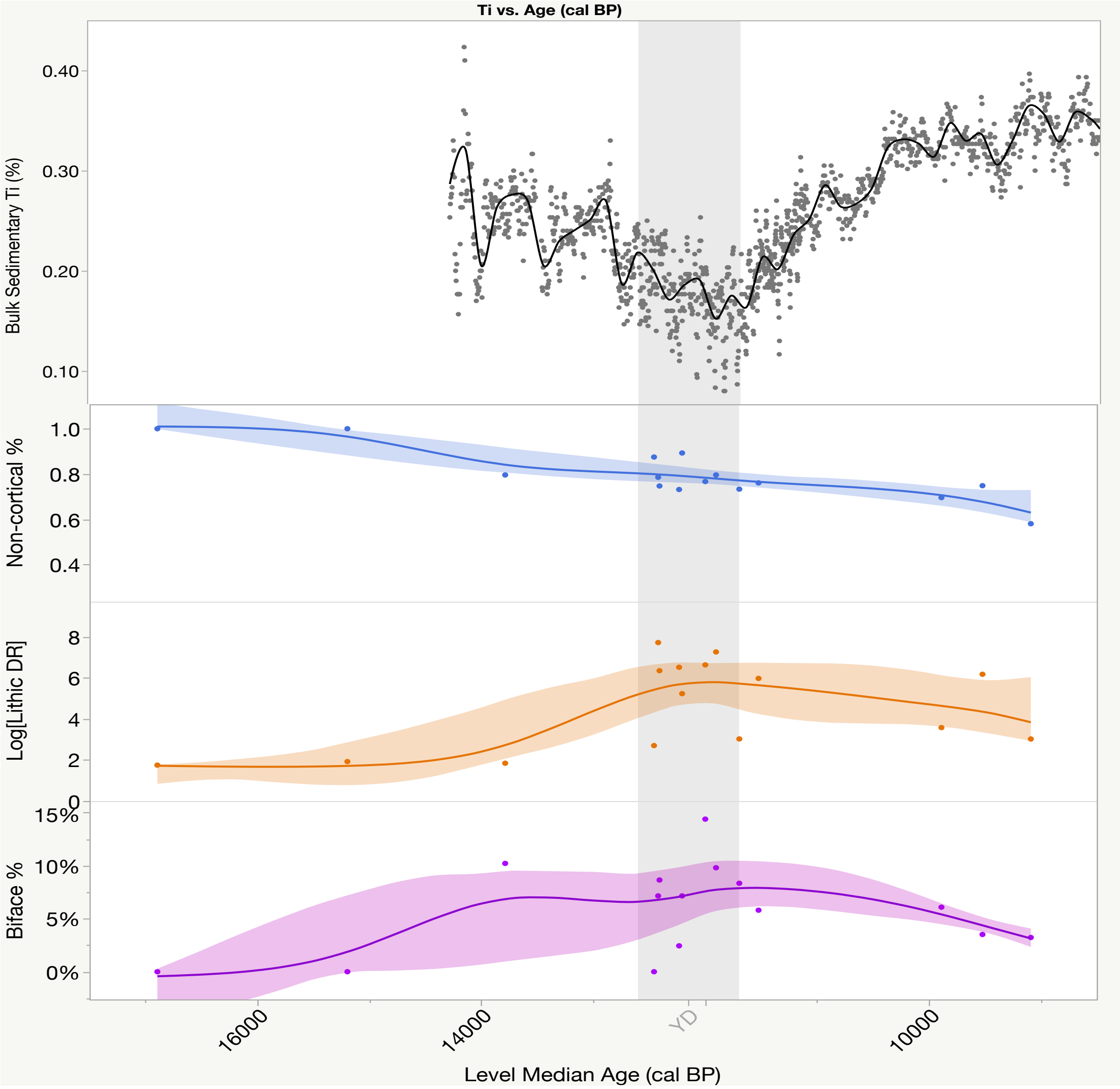


Figure 5.15. Trendlines for climate (top-most panel) and three lithic traits of interest (bottom three panels) over time for Site 1's assemblages.

to curation traits, as low Residential Mobility generally favors higher curation-related behaviors and traits.

Site 1: Tzib'te Yux

Because Site 1 was occupied during the earliest part of the overall sequence, and contained materials dating only from the Paleoindian and very Early Archaic period, I had expected it to have the most divergent results. The Paleoindian period included a major climatic shift, as the last Ice Age ended with the cool, dry conditions of the Younger Dryas, and the Holocene began with a shift to warmer, wetter conditions. Therefore, I confine my interpretation of lithic technological patterns to what is known about environmental factors during the Paleoindian in Mesoamerica in general and in the Maya lowlands specifically. This period is too early to have witnessed the rise and spread of cultivars – and indeed, its climate may have been hostile to human manipulation of ancestral domesticates (Richerson, Boyd, and Bettinger 2001). It thus serves as a sort of "baseline" for what lithic technology and residential mobility would've looked like during a dramatically different climatic regime prior to extensive use of cultivars. Data on other potentially influential factors – such as societal structure, cultural norms, or religio-ritual behaviors – are essentially unavailable for this period, so I cannot consider their impact on lithic technological patterns at this time. However, it is important to note that they were doubtless as important then as they are to forager-horticulturalists today.

Overall, the trendlines for these curation traits paint a somewhat mixed picture of lithic curation for Site 1 (Fig. 5.15; Table 6.1). Non-cortical % shows a strong positive relationship with Level Median Age (Spearman's rho = 0.74, $p<0.005$), indicating a shift to less curation over time, while Biface % and Log[LithicDR] show no relationship with time. Relationships between these same traits and the Cariaco Ti data are also mixed with regard to the curation-expediency spectrum. Cariaco Ti % has no correlation with Non-cortical % but moderate positive correlations with Log[LithicDR] (Spearman's rho = 0.6, $p<0.05$) and Biface % (Spearman's rho = 0.5, $p=0.07$). The latter two variables provide mixed interpretations regarding curation and mobility; Log[LithicDR] seems to indicate increasing occupational intensity (and lower Residential Mobility) with warmer climate, but increasing Biface % with warmer climate supports the opposite interpretation. It is worth noting, however, that the two oldest assemblages could not be included in the calculation of Spearman's rho for the climate proxy, as the Cariaco core does not extend that far back in time. These three assemblages are all quite small, however (combined n = 56 lithics), so their influence on Spearman's rho calculations for Level Median Age may not be too great.

The increase in Biface % during the Younger Drays may be related to the appearance during this time of the Lowe complex of projectile points, a style unique to Belize that shares some traits with both North American Folsom and South & Central American Fishtail projectile points (K. M. Prufer et al. 2019). Several of these points have been found *in situ* at Sites 1 and 2, although their bracketing dates (10,223 and 9,300 cal BP, 2σ) are a good deal later than the Younger Dryas. Only one of these points was

Table 5.1: Correlations (Spearman's $\boldsymbol{\rho}$) between lithic traits and time (Level Median Age (cal BP)) and climate (Level Mean Ti (%)), as well as implications for lithic curation trends.

Trait	**Correlation with Time**	**Change in Curation over Time**	**Correlelation with Climate**	**Change in Curation with Climatic Warming**
Non-cortical %	0.74, $p<0.005$	⬇	none	n/a
Biface %	none	n/a	0.5, $p=0.07$	⬆
Log[Lithic DR]	none	n/a	0.6, $p<0.05$	⬇

explicitly included in my study because the others were either not available for analysis at the time or because they were found in later excavations. However, if they or points like them were being manufactured, thinned, or resharpened Site 1, they may account for the increase in Bifacial Thinning Flakes (BTF's) that I included in my calculation of Biface %. These types of projectile points are typical of highly curated lithic assemblages, as they

take a great deal of time and preparation to successfully create. They are generally completely decorticated, and have extensive retouch or thinning flake scars in one face of each side, creating beveled, serrated edges. As Prufer et al. (2019:15) point out, there appear to be "no bifacial technocomplex for [Central America] for the Early to Late Archaic (9,000–3,900 BP). Middle/Late Archaic bifacial technocomplexes are notably absent from the well dated sites across lower CA and SA." These epitomes of curation, then, appear to be solely associated with the Late Pleistocene and the first millennia and a half after the Younger Dryas (i.e. the early part of the Early Holocene).

Site 2: Mayahak Cab Pek

Table 5.2: Correlations (Spearman's $\boldsymbol{\rho}$) between lithic traits from Site 2 and time (Level Median Age (cal BP)) and climate (Level Mean Ti (%)), as well as implications for lithic curation trends.

Trait	Correlation with Time	Change in Curation over Time	Correlelation with Climate	Change in Curation with Climatic Warming
Non-cortical %	0.74, $p<0.0001$	⬇	none	n/a
Biface %	0.37, $p<0.05$	⬇	none	n/a
Log[Lithic DR]	none	n/a	0.3, $p<0.1$	⬆

The assemblages for Site 2 include artifacts from levels encompassing the end of the last Ice Age, the Younger Dryas, the 8.2 ka Event, and the overall climatic amelioration of the Holocene. Because of this long record and the drastic climatic shifts it encompasses, Site 2 provides a crucial test of the relationships between my lithic traits of interest and the two independent variables I'm examining – time and climate. Figure 5.16 provides scatterplots and trendlines of these relationships, and table 6.2 summarizes them. Non-cortical % continues to show a decline across the entire sequence and boast a a strong correlation with Level Median Age (cal BP) (Spearman's rho = 0.74, p<0.0001), and Biface % also shows a moderate correlation with time (Spearman's rho = 0.37, p<0.05). Neither variable is correlated with climate proxy Bulk Sedimentary Ti. Together, these traits indicate decreasing curation (and RMS) through time, rather than with warming climate. Log[LithicDR] has no relationship with time but does show a low,

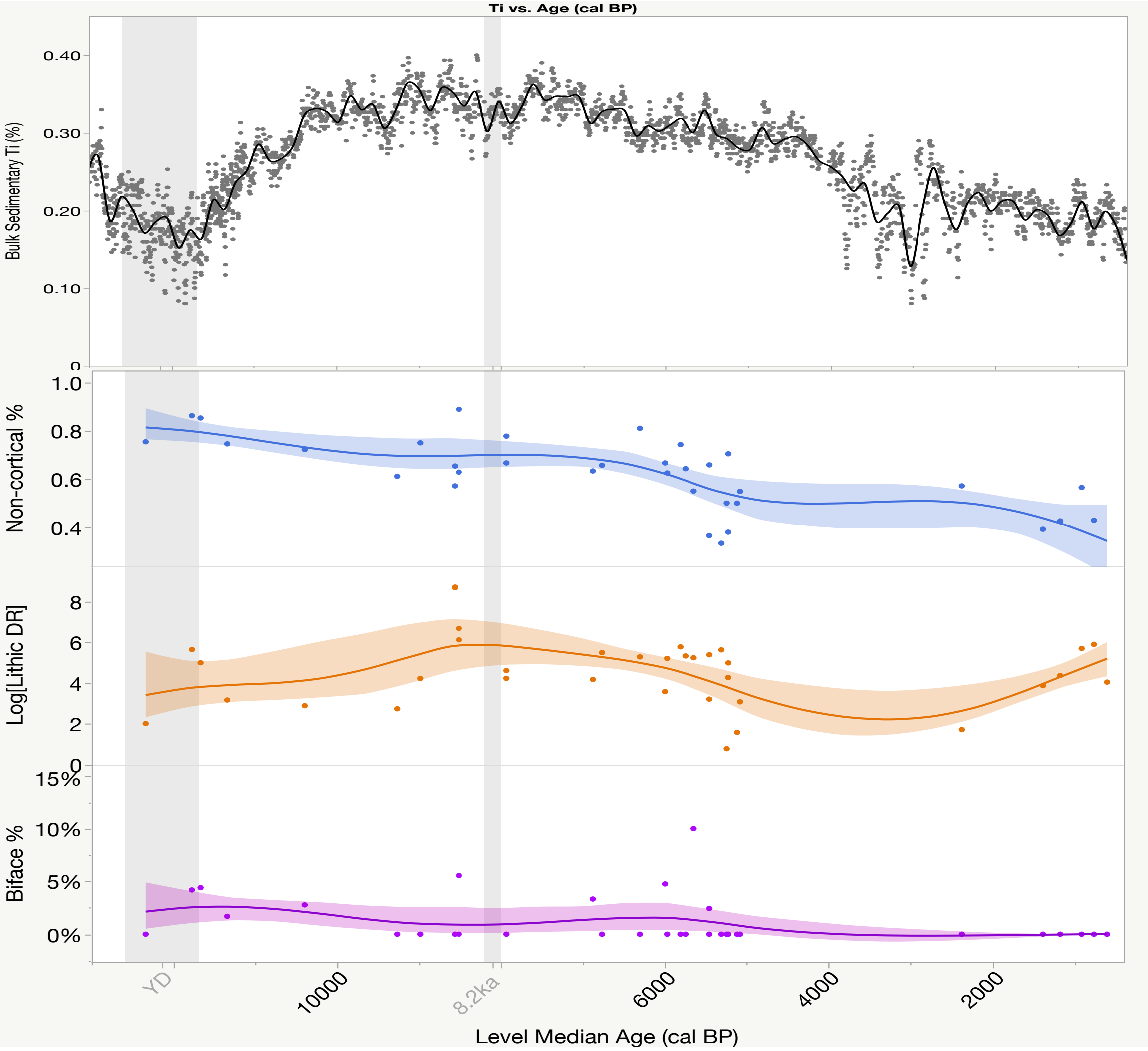


Figure 5.16. Scatterplots showing relationships between climate proxy data (top panel) and three curation traits of interest (bottom 3 panels) over time for Site 2.

weakly significant correlation with Ti (Spearman's rho = 0.3, p<0.1), indicating that occupational intensity (and so, LMS) may have risen during times of warming climate (between the YD and 8.2 ka events) but that this trend did not persist over time; altogether these traits also paint a somewhat mixed picture of curation at Site 2.

Site 3: Saki Tzul

As discussed above, Site 3 is unlike the other two sites in several important ways that might have impacted both the availability of raw material and the general use of the shelter as a residential base. Its much larger size may have impacted the density of

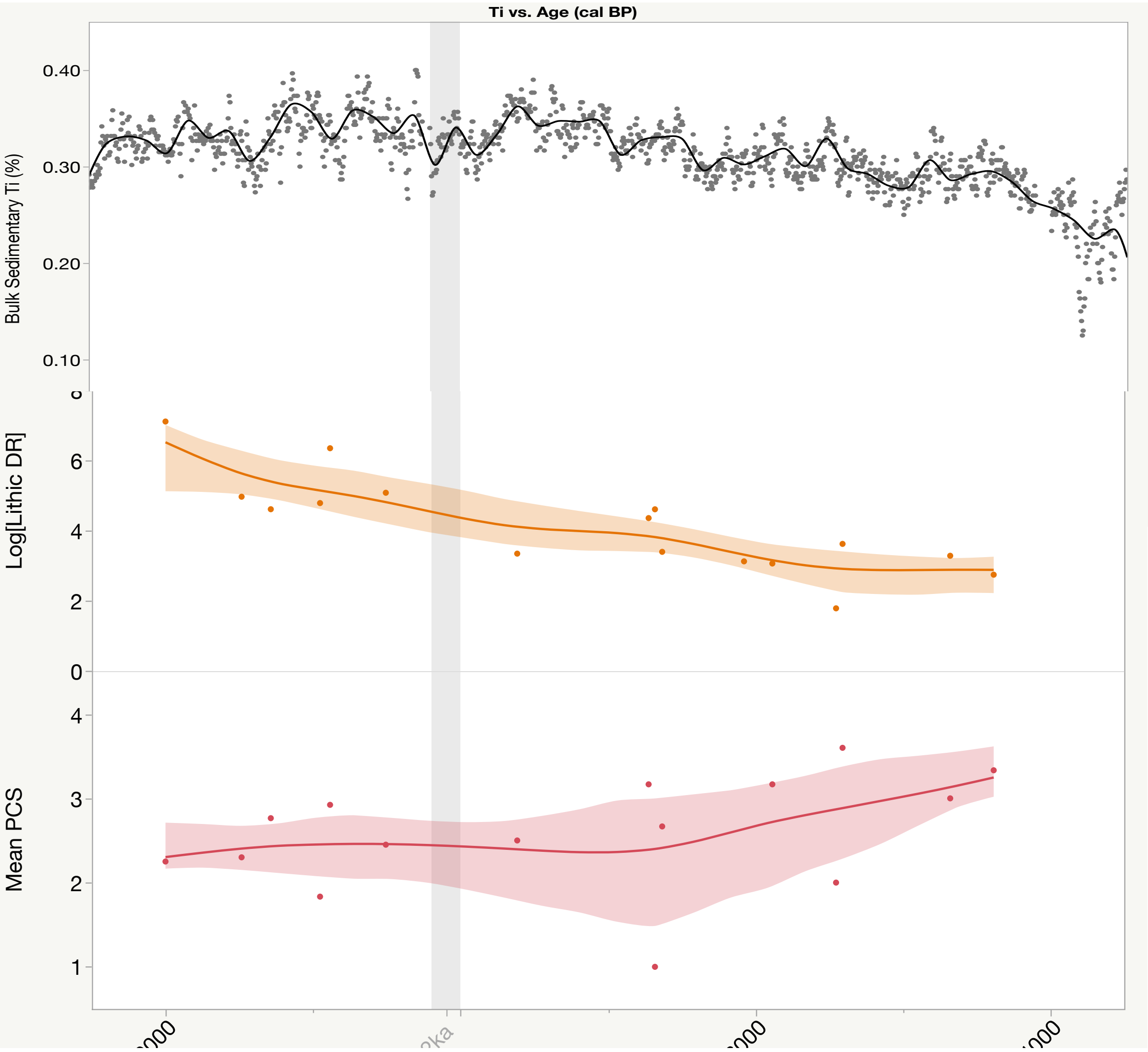


Figure 5.17. Scatterplots showing trendlines for climate proxy data (top panel) and three curation traits of interest (bottom 3 panels) for Site 3.

Table 5.3: Correlations (Pearson' R) between lithic traits from Site 3 and time (Level Median Age (cal BP)) and climate (Level Mean Ti (%)), as well as implications for lithic curation trends.

Trait	Correlation with Time	Change in Curation over Time	Correlelation with Climate	Change in Curation with Warmer Climate
Log[Lithic DR]	0.85, $p<0.0001$	⬇	0.7, $p<0.005$	⬇
Mean PCS	-0.52, $p<0.05$	⬆	none	n/a

artifacts deposited at any one location, even if groups of the same size were using each shelter. Additionally, due to limits on my analysis imposed by time constraints, I was only able to collect data from assemblages dating to the more recent levels of the shelter, leading to a smaller, truncated archaeological record. Yet even this data yields an interesting picture of human activity at this site during the Middle and Late Archaic time periods. This span of time includes the two millennia leading up to the 8.2 ka Event, the event itself, and the three millennia following it. As with Shelter 1, which served as a baseline for the Late Paleoindian/Early Archaic time period, Shelter 3 acts as a window into the dynamics at play during the Middle to Late Archaic time periods.

Of the lithic traits of interest examined so far, neither Non-cortical % or Biface % show any correlation with time or climate. Log[Lithic DR] does have a strong relationship with time (Spearman's rho = 0.85, $p>0.0001$), indicating a decrease in occupational intensity as age decreases. It also shows a strong correlation with climate proxy (Spearman's rho= 0.7, $p<0.005$), indicating decreasing occupational intensity as the climate begins to cool from its Middle Holocene optimum. Mean PCS does show a significant negative correlation with time (Spearman's rho = -0.52, $p<0.05$), the first time that variable has shown such a relationship in the site-specific analyses. This negative correlation indicates that platforms become more complex as age decreases towards the present, a sign of generally increasing curation. It does not show any relationship with climate proxy Bulk Sedimentary Ti. Altogether, these traits paint a general picture of increasing curation and greater RMS over time. Table 5.3 summarizes these relationships.

Overall, these relationships seem to indicate that groups at Shelter 3 were returning to curation-focused lithic technology as time passed and the climate gradually decreased from its mid-Holocene high. This would generally seem to be an anomaly, as the other two shelters provided mixed signals of curation in relation to time and climatic change. However, given the small numbers of test pits relative to Shelter 3's much larger size, it is equally possible that occupation was simply spread over a larger area than in the other two smaller shelters. Additionally, because Shelter 3 is a great deal more difficult to get to than its smaller counterparts, its occupants may have been less willing to provision it with fresh toolstone, and more willing to continue utilizing older lithic artifacts past their point of maximum utility. Either of these two explanations could yield the somewhat divergent results Site 3 evinces when compared to Sites 1 and 2.

CHAPTER 6

DISCUSSION & CONCLUSION: CHANGING CLIMATES, CHANGING CULTURES

In the following sections, I present a summary of the most relevant findings from the above lithic analyses for specific chronological periods, and discuss their implications for mobility and subsistence. I then attempt to synthesize these results with the paleoecological and archaeological data from throughout Central America (presented in Chapter 2) that indicate a myriad of changes in subsistence and mobility were occurring at relatively early dates. Finally, I discuss what implications my study has for the question of the origins of the Ancient Maya, and for the study of how areas dominated by non-agricultural groups become dominated by agricultural groups. I end with some suggstions for future research.

Late Pleistocene/Early Holocene (pre-8200 cal BP)

For this period, three traits showed strong, significant correlations with time and/or climate (see Table 6.1). Two of these traits (Non-cortical % and Biface % 2) show decreasing curation over time while both traits (along with Biface %) indicate decreasing curation with warming climate. Following the logic of Ranere & Cook (2020) in their article about Panamanian sites of Monte Oscuro and Aguadulce rockshelter, I assume that, by the Late Pleistocene, the first humans to occupy Belize would have encountered

Table 6.4: Correlations (Pearson' R) between lithic traits from all three shelters and time (Level Median Age (cal BP)) and climate (Level Mean Ti (%)) during the Late Pleistocene/Early Holocene, as well as implications for lithic curation trends. All correlation values are significant at the 0.0001 level (unless otherwise noted).

Trait	Correlation with Time	Change in Curation over Time	Correlation with Climate	Change in Curation with Warmer Climate
Non-cortical %	0.64	⬇	-0.57, p<0.001	⬇
Biface %	none	n/a	-0.57, p<0.001	⬇
Biface % 2	0.68, p<0.001	⬇	-0.56, p<0.05	⬇

an environment very different from the one seen today and throughout the following Holocene period. Assuming they entered the area at the same rapid pace that those authors estimate, they would have had little time or experience with native plants by the time they arrived. This means that, instead of experimenting with ancestral cultivars, they would have relied solely on hunting game (including megafauna) and gathering highly ranked wild plants. Trends in Late Pleistocene and Early Holocene lithics from my study bear out this interpretation, as I observe relatively high levels of curation consistent with this picture of highly mobile hunter-gatherers at the beginning of the sequence and throughout the Younger Dryas. Climatological and archaeological evidence from El Gigante rockshelter in Honduras (Douglas J. Kennett et al. 2017; Scheffler, Hirth, and Hasemann 2012; Scheffler and Hirth 2008) and from the Panamanian sites in lower Central America (Ranere and Cooke 2020b; Ranere et al. 2009) region support my interpretation that the sites in my study were first occupied by hunter-gatherers who relied more heavily on Residential than Logistical Mobility Strategies, and who likely exploited faunal resources to a greater extent than wild floral resources throughout the Younger Dryas.

After that climatic event, however, there seems to be a rather drastic turn to expedience. In particular, the pattern of decreasing bifacial and retouched artifacts in the aggregate data echoes the evidence from both El Gigante and the Panamanian sites, where bifacial lithics essentially disappear (Ranere & Cook 2020) and a wider diet breadth is noted in both floral and faunal remains (Douglas J. Kennett et al. 2017; Ranere et al. 2009). That this occurred so quickly after the Younger Dryas seems to support the idea that it was partly due to climate, which was rapidly rebounding from its Late Pleistocene low, rather than merely the passage of time (and the greater familiarity with nascent cultivars it might afford). The corollary of this turn to expedience is an increase in LMS and a decrease in RMS. Unfortunately, it is difficult to tell at this time if that shift in mobility was due to a precocious, sudden adoption of cultivars, or due to changes in floral and faunal species composition as a result of climate change that may have favored LMS over RMS. Overall, these sites show a preponderance of formal bifacial and unifacial tools that gives way to informal, expedient tools by the end of the Early Holocene period. My interpretation is that the sites in my study were occupied by hunter-gatherers who practiced Residential (and not Logistical) Mobility Strategies, and who likely relied more heavily on faunal resources than on wild floral resources.

Middle Holocene (8200-4000 cal BP)

The aggregate data from my three study sites do not shed much light on curation and mobility-related behaviors during the Middle Holocene. Only one trait, Mean PCS, showed a significant, negative relationship with climate proxy (Spearman's rho -0.44, $p<0.05$). This one trait indicates that platforms were less complex during the Holocene Climatic Optimum (at the start of the Middle Holocene) and became more complex as climate began to cool and dry towards its present day conditions. Overall, this fits with a picture of lower residential mobility during times of warm, wet climate, and greater residential mobility during cool, dry periods. However, because it is only a single trait, and because none of the other traits showed similar relationships, I cannot place too much interpretive weight on it.

The climatic and data reviewed in Chapter 2 indicate that the Middle Holocene period witnessed some of the greatest climatic and cultural changes throughout the region, as climate dropped from its pre-8.2ka Event peak. Compared to the Cariaco Ti data (Fig 6.1 top panel), the Guatemalan speleothem data (Fig. 6.1 bottom panel) better illustrates the climatic variability that occurred in Central America after 8000 cal BP. It was during this same period of climatic variability that groups began experimenting with cultivars. However, my lithic results from this period reflect only gradual continuations of trends that had begun in the preceding Early Holocene. That these gradual changes occurred during the initial appearance of important cultivars like maize may indicate that an overall shift from animal to plant exploitation (including C3 plants like manioc), and not a sudden invention of horticulture, was driving the changing mobility patterns and concomitant changes in lithic practices. In other words, occupants of these three

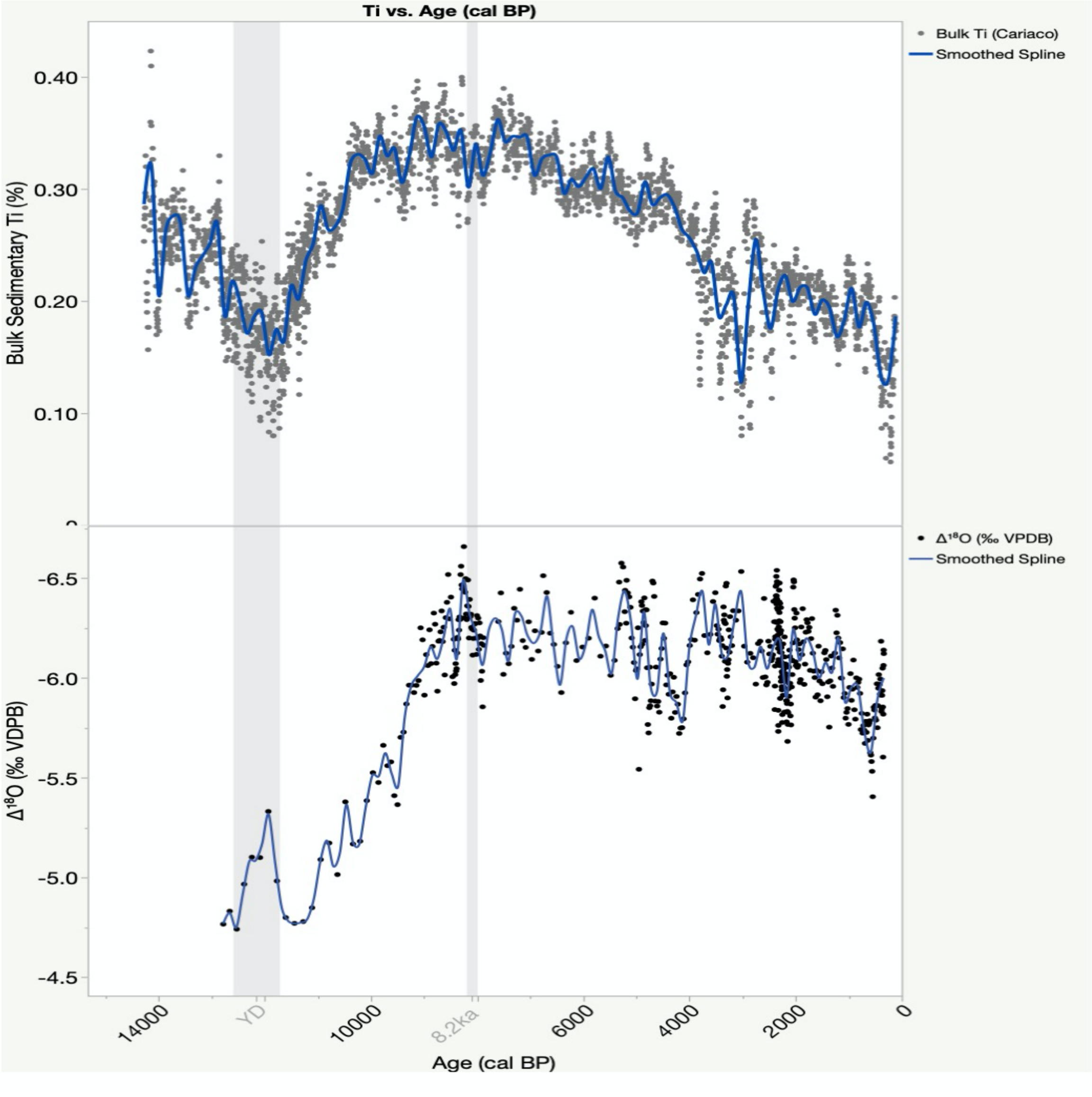


Figure 6.1: Two paleoclimate proxy records. Top: trends in the concentration of Titanium in a deep sea core from the Cariaco Basin seabed. Recreated from data published by Haug et al. 2001. Bottom: trends in the differential ratio of ^{18}O to ^{16}O as compared to a standard (VDPB). Recreated from data published by Winter et al. 2020.

sites seem to have undertaken the same “gradual transition” from high to low residential mobility described for El Gigante, Honduras, during the same period of time (Scheffler et al. 2012:605)

Lithic Results: the Late Holocene (post-4000 cal BP)

Six lithic assemblages from Site 2 date to the later part of the Late Holocene. However, as mentioned in Chapter 3, the post-2000 cal BP section of the the age-depth model is anchored by only one radiocarbon date, and so the assigned dates are provisional. Indeed, all of these dates fall during the Classic (~2300 to 1100 cal BP) or Postclassic (1100 to 500 cal BP) periods of Maya culture. Initial ceramic analysis indicates these levels contained Classic-period ceramics, providing even more evidence that the upper portion of the age depth model requires several more radiocarbon dates to allow for accurate interpolation of intervening depths. Given that they bear ceramic evidence of Classic Maya culture, I can confidently assume that the lithics contained in these levels were deposited during the Classic Maya period. They thus serve as interesting comparative examples of lithics created by fully sedentary, agricultural societies. There is a possibility that they were knapped by people living at nearby Maya sites and not at the rockshelter itself, which may in some way influence the composition of lithic debitage and tools found there. I discuss the possible relationship between the rockshelter and its neighboring Maya sites in greater detail later in this chapter.

For now, I simply note that only one trait, Mean Cortex %, shows any kind of significant relationship with either time or climate; it has a strongly negative correlation with Level Median Age (Spearman’s rho = -0.83), indicating that cortex-bearing artifacts become more common as age decreases towards the present. This in turn indicates a turn towards expedience and away from curation, and an associated turn towards LMS and away from RMS. Of course, during this period, there are simply no Bifacial or

Retouched artifacts to speak of, which in and of itself is an interesting observation that is consistent with a narrative of lower curation and RMS. However, the lack of data doesn't allow me to speak to those traits' relationships with time or climate. Without larger numbers of assemblages and better chronological control, it is not possible to draw firm conclusions from these data and their trendlines.

However, other data from my project sites support the overall picture of a population in flux, perhaps one transitioning from a mixed foraging-horticultural lifestyle to one more reliant on maize farming and its attendant social and behavioral adaptations. The stable isotope analyses from Sites 2 and 3 also included a number of individuals dating to the Late Holocene time period who had what Kennett et al. (2020:6) call a "staple maize diet." These burials include several individuals who predate the Middle Preclassic ceramic horizon in this time period, as well as many more from the Preclassic and Classic Maya time periods, during which the rockshelter was still in use, likely as a burial and ritual site. Although the two groups straddle the Middle Preclassic ceramic horizon, both sets of individuals share similar ^{13}C and ^{15}N isotopic signatures. The authors conclude that a C_4 plant (likely maize) contributed 21 to 68% of dietary carbon, and that marine sources likely contributed little to no calories overall. Interestingly, Kennett et al (2020) note the overlap between individuals from their study and those of a larger dataset of Classic Period Maya populations that differentiated between elites and non-elites (or "commoners"). Specifically, elites in the larger study had even more enriched isotopic signatures, while those of commoners indicated "equal amounts of C_3 and C_4 foods and relatively high C4 protein sources like maize or maize-fed animals". The individuals from Sites 2 and 3, even those dating to the Classic Maya period, had isotopic values overlapping those of the commoners. The authors do not pursue this intriguing line of evidence any further, but do note elsewhere in the paper that both rockshelters lie within 3 km of a small Classic Maya site, Ek Xux (K. M. Prufer 2002). Overall, their study leaves open the possibility that the groups occupying the rockshelters – or at least, those who buried their dead there – possessed a rather egalitarian social structure in which everyone had more or less equal access to maize (however much or little of it there was at the time).

The closest Maya polity, Ek Xux, bears no evidence of settlement until the Late Preclassic, which began around 2400 cal BP (Saul, Prufer, and Saul 2005b). Unlike most other Maya sites, the architectural features within Ek Xux contain no burials; instead, this community seems to have buried their dead at Sites 2 and 3, (as well as a third nearby rockshelter not included in this study) (Saul et al. 2005:297). Intriguingly, the upper levels of Site 2 (first excavated by Dr. Prufer and colleagues in the 1990's) contain a so-called ossuary pit containing Middle Preclassic ceramics, the lower levels of which have been dated to 360 to 50 B.C., corresponding to the transition between the Middle and Late Preclassic periods. As Saul et al. (2005:303) note, this burial feature "coincides with the earliest known settlement in the Ex Xux Valley, possibly indicating that mortuary use of the rockshelter was part of the burial strategies of the earliest settlers in the region."

At the time of Saul's (2005) publication, however, the great antiquity of pre-ceramic deposits (including burials) at Sites 2 and 3 had not yet been discovered; the recent discoveries by Dr. Prufer's team further complicate an already complex picture. Our work indicates that the rockshelters were in use from the Early Archaic onward by human groups with low rates of lithic curation (and by extension, lower rates of residential mobility); therefore, it may no longer be accurate to describe the Preclassic-age burials belonging to the "earliest settlers in the region" (Saul et al. 2005:303). Yet the lack of clear cultural continuity between the earlier Preceramic layers and the overlying

Preclassic levels makes it difficult to draw firm conclusions. It is certainly possible that the older occupants of the rockshelters were direct ancestors of those who first built Ek Xux – indeed, the fact that burials continued to be placed within the rockshelters, and not at Ek Xux, long after the site had been built provides some support for such a conclusion. Yet it is equally as likely that the older groups were instead replaced by incoming farmers looking for as yet “unclaimed” land on which to build a sedentary settlement.

A third possibility is that both groups coexisted for a time and eventually blended together as the benefits of a sedentary village lifestyle came to outweigh those of a more mobile foraging one. Based on his review of Late Archaic sites throughout Belize, Rosenswig (2015) argues for just this type of patchwork hybridization of groups in describing the “adaptive mosaic” of lifestyles present in Belize during the Late Archaic/Middle Preclassic transition. We do not yet know how long this transitionary state existed, but it seems plausible (and even highly likely) that it did so for too short a time period to leave a distinctive, substantial trace in the archaeological record. As discussed previously, isotopic evidence indicates that the “transitional maize” diet (Kennet et al. 2020) lasted only 700 years at Sites 2 and 3, and thus supports both the brevity of the transition and continuity of occupation, rather than replacement. Further paleogenetic work on burials from these two rockshelters is ongoing (K. M. Prufer, Robinson, and Kennett 2021), and may yet provide insight into the relatedness, if any, amongst individuals through time or between shelters and settlements.

Beyond Time and Climate: Other Potential Drivers of Change

Table 6.6: Correlations (Pearson' R) between lithic traits from all three shelters and time (Level Median Age (cal BP)) and climate (Level Mean Ti (%)), as well as implications for lithic curation trends, for the entire sequence. All correlation values are significant at the 0.0001 level (unless otherwise noted).

Trait	Correlation with Time	Change in Curation over Time	Correlation with Climate	Change in Curation with Warmer Climate
Non-cortical %	0.67	⬇	none	n/a
Biface %	0.47	⬇	-0.3, p<0.02	⬇

Because we know that the first human groups to enter the Americas were highly mobile hunter-gatherers, and the last indigenous people to occupy the Maya lowlands were sedentary agriculturalists, it is clear that mobility and subsistence drastically changed during the Holocene epoch. Yet as my review of the data from each site individually and in aggregate has shown, neither time nor climate (as represented by the Cariaco Ti % data) show conclusively strong relationships with the lithic traits I measured. Yet clearly, lithic technology also changed a great deal between the start of the sequence and its end. Here I provide a final review of the aggregate data from throughout the entire sequence, and expand on the potential that management of non-cultivars through proto-agricultural practices have for being a driver of change that may better fit the lithic data than either time or climate.

From Late Pleistocene to Late Holocene: Trends in the Aggregate Data. When I examine the entire lithic sample across the entire sequence of dates, much stronger relationships with time and climate occur, but the number of traits that evince them is smaller (Table 6.6). For example, the relationship between Biface % and Level Median Age is strongly positive (Spearman's rho = 0.47, p<0.0001). Time also shows a strong correlation with Non-cortical % (Spearman's rho = 0.67, p<0.0001). Both of these lithic traits indicate the same overall trend regarding lithic technology: over time, curation decreased and expediency increased. That Biface % shows a strong relationship with time is not necessarily a surprise, as other authors (including those involved with my project) have noted the overall lack of bifaces after the early Middle Holocene. But the strong relationship with Non-cortical % indicates it was not just lithic tool form or flaking technique, but lithic curation in general, that changed drastically over time. These relationships are stronger than the ones these same lithic traits have with the climate proxy data. Level Mean Ti % has essentially no relationship with any traits, except that its relationship to Biface % is low-to-moderately negative (Spearman's rho = -0.3, $p<0.0001$). Given the relationships with time described above, these weak or nonexistent relationships between lithic traits and climate are perhaps unsurprising.

Based on the trends in these two traits across the whole sequence and with the entirety of the aggregate dataset, it appears the passage of time is more closely related to directional changes in lithic behavior (i.e. from curation to expediency) than is climatic change. Yet the passage of time on its own cannot have caused the changes observed in lithic technology (and does not have an ironclad relationship with it, anyway); instead, its influence must pass through intermediary causes. Scholars such as Piperno 2011, Piperno (2006), Kennett et al. (2020), and Ranere et al. (2009) identify one such cause: changing relationships between human groups and their subsistence resources. Unlike time, these relationships are not strictly unilineal; for example, inherent in Piperno's (2011) concept of proto-agricultural experimentation with cultivars is the likelihood of both success and failure. Likewise, the earliest versions of cultivars were nowhere near as nutritious as their eventual descendant crops would be; this too leaves open the possibility that human groups might adopt, then give up, proto-cultivars as their ranking of these foods changed. Such rankings are also based on the abundance, distribution, and predictability of wild resources that were also likely undergoing changes in abundance and distribution with changes in climate. Eventually, however, the human-cultivar relationship reached a point of equilibrium, and human groups became more or less dependent on staple foods.

Kennett et al.’s (2020) study of stable isotopes from human remains excavated in Shelters 2 and 3 (summarized in Chapter 2) provides an amazingly detailed look at how that transition occurred for one such staple. That their analysis was able to identify pre-maize, transitional-maize, and staple-maize diets is due in large part to the unique photosynthetic pathway that maize uses. It seems unlikely that such a detailed method for analyzing the presence of specific cultivars in prehistoric human diets could be found for enough cultivars to truly document the changing relationships that human groups had with the majority of known cultivars. Without such quantifiable data about changing subsistence patterns, it’s is not yet possible to find a better explanatory fit for the changing lithic curation practices – and the mobility strategies they entail – that my study documents. However, it is possible to make draw some conclusions about Late Pleistocene and Holocene mobility from the data I present. For one, my study confirms that transitions away from a heavy reliance curation and on Residential Mobility Strategies came earlier in the Holocene rather than later. Were this change evident in only one trait (such as Biface %), it could potentially be argued it was related to something other than a change in mobility that might affect lithic tool production and utilization – the Late Pleistocene extinction of megafauna, for example. That Non-cortical % also shows a decline in curation beginning at the same time argues for a more comprehensive explanation, one that takes into account the ability of tropical forest foragers to actively manage floral resources in their environment.

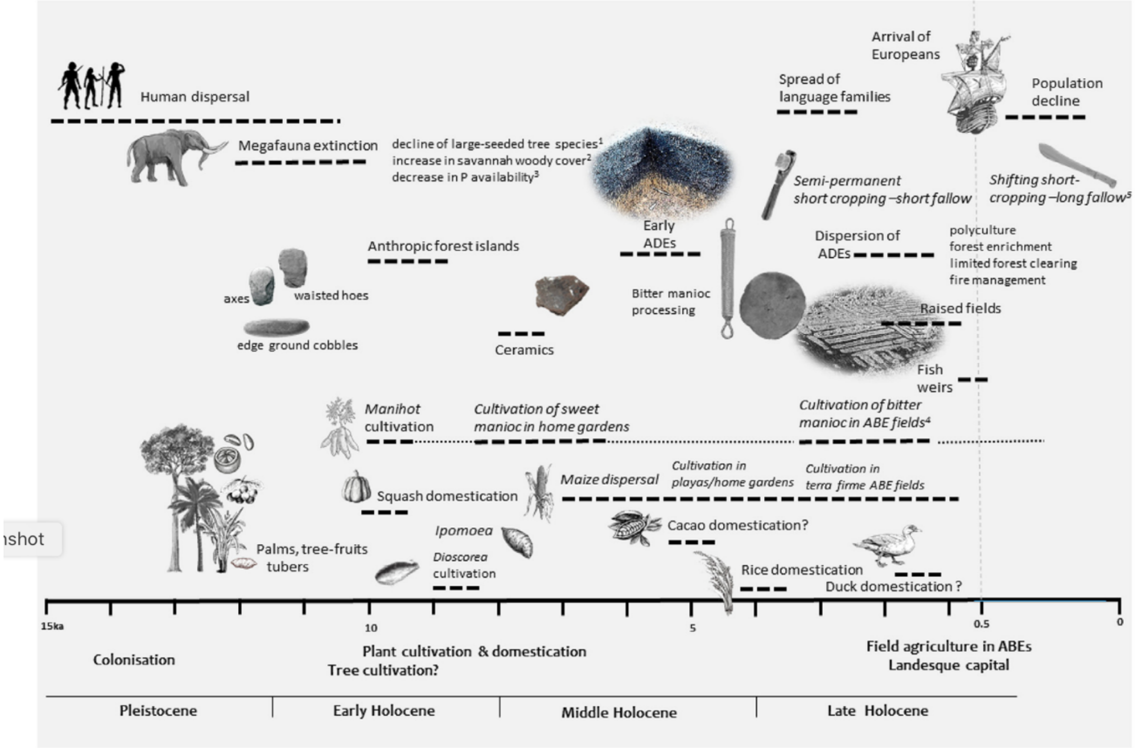


Figure 6.2. Model of interlinked processes of wild plant manipulation and forest landscape management giving way to more intensive field preparation and cultivation strategies during the Middle Holocene. Figure from Iriarte et al. 2020, 21, Fig. 10.

In particular, evidence from the Amazonian region points to the early utilization of the ancestral versions of important cultivars like maize, manioc, palms, and fruit trees prior to 8.5 ka (Piperno 2011; Ranere et al. 2009; Iriarte et al. 2020). Irirarte et al. (2020, 20) argue that the earliest colonists of the Amazon region, rather than being narrowly-focused on big game hunting, utilized "a broad-spectrum diet of tropical roots and tubers, tree and palm fruits and nuts, as well as many medicinal/narcotic plants" (Fig. 6.2). Similarly, (Lombardo et al. 2020) have documented the cultivation of important plant resources manioc (*Manihot esculenta)* and squash (*Curcubita maxima)* around 10,000 cal BP, several millennia earlier than most evidence of cultivars in the region. While the presence of these plants does not necessarily indicate full-scale agriculture, it does argue for a greater amount of plant manipulation (or paracultivation) than generally thought. As discussed in Chapter 2, modern-day foragers with greater levels of plant intensification also tend to practice greater amounts of logistical mobility, and have longer stays at their base camps, than do those with less plant intensification. Although the recent work from the Amazon does not yet include independent estimates of mobility, the evidence for extensive plant intensification at such early dates would support the notion that a turn away from high-RMS and towards high-LMS was already underway. Should paleobotanical data from my study sites show a similar adoption of a broad-spectrum, plant-heavy diet, it would serve to further support my study's documentation of a similar turn towards high-LMS earlier in the sequence.

The Middle Preclassic: Whence Came the ancient Maya?

Despite my project's temporal focus on the Holocene, in the end it included only one assemblage dating to the Late Holocene's Middle Preclassic period, which saw the first distinctly Maya settlements appear throughout the Maya Lowlands. At the time I was selecting assemblages for inclusion in my study, our limited chronological data indicated that the assemblages I chose lay just below and above the initial appearance of ceramics in both sites. However, I was only able to securely date these assemblages after completion of the more detailed soil deposition model described in Chapter 4, which included charcoal samples from several field seasons analyzed over a period of years. Once I realized this period lacked representative assemblages, I was unable to include additional assemblages dating to it, in part due to time constraints. At the time, I was also hoping that some of the assemblages analyzed by project lithicist Chris Merriman would end up dating to this period; this turned out not to be the case. Despite my studies lack of direct evidence of Middle Preclassic lithic technology, my project does bear on the larger question of Maya origins, in that it chronicles the lifeways of people living quite near two early Maya centers in the period just before they were founded. For that reason, I turn now discuss the implications my study has for Maya origins.

As mentioned above, ceramic-using peoples first created fully-sedentary villages in the Maya Lowlands during the Middle Preclassic period (also known as the Middle Formative), which generally is thought to begin around 3000 cal BP (or 1000 B.C.). Many early theories about the origins of the Maya implied that they had migrated from elsewhere to fill in an otherwise vacant terrain (see Lohse 2010). More recent research, including that presented in this study, has provided abundant evidence that the Maya Lowlands in general, and Belize in particular, were occupied continuously from the end of the Pleistocene onward. This has clear implications for the origins of the Maya, who are generally identified by the presence of the first ceramics at any given site.

As Lohse (2010:316) notes in his review of the Late Archaic in Belize, early theories about the origins of the Maya were "diffusionist in nature" and focused on influences from the older Olmec civilization of the Gulf Coast of Mexico, or the migration of "Mixe-Zoque speakers from the Isthmus of Tehuantepec or by way of Honduras or by proto-Mayan speakers from the Guatemala Highlands." Glottochronological studies place this linguistic expansion around 4200 cal BP, well within the transitional maize diet period mentioned above. These studies also note that several words related specifically to maize cultivation and utilization likely came from a Proto-Mayan ancestral language (Kennett et al. 2020, citing Campbell 2017). Teasing apart the migration of peoples from the spread of languages, and both of those from the expansion of important cultivars, is beyond the scope of this dissertation. However, I note here that the turn towards sedentism, a trait that is first associated with the appearance of Maya culture in Belize, began in the Middle Holocene, and perhaps even earlier. While it is true that other Maya cultural touchstones – such as reliance on maize and ceramic technology – had geographic origins outside of the Maya lowlands, a great deal of evidence suggests that internal, autochthonous developments were at least as important as external factors.

A similar focus on internal developments over external explanations characterizes the work of South American theorists like Iriarte et al (2020) and Lombardo et al. (2020). The former in particular has been instrumental in arguing against a view which sees agriculture as an external development brought into Amazonia by outside groups around 2000 cal BP (Vrydaghs and Denham 2018). Instead, Iriarte et al. (2020) have used data from 23 different soil profiles across 10 different sites in southwestern, central, and eastern Amazonia to document the presence of cultivars and the initiation of anthropogenic soil improvement well before the posited "arrival" of agriculture from outside the region. In doing so, they explicitly argue against the Eurasian perspective of the definition of agriculture, which is "characterized by clear morphogenetic changes in plants or animals, environmental transformations resulting in forest clearance for agriculture, and packages of associated cultural, political and social traits" (Iriarte et al. 2020, 3). They summarize the huge amount of paleobotanical evidence showing the great diversity of ancestral cultivars that have been traced to several different centers of domestication, and contrast this with the typical view of Eurasian agriculture focused as it is on a much smaller number of grains.

Importantly for my study sites, work on ancient DNA from several individuals highlights the long-distance populations movements occurring between South and Central America well before culturally Maya settlements arose in Belize (K. M. Prufer, Robinson, and Kennett 2021). These data indicate a shared genomic ancestry with both North and South American peoples dating back to at least 7000 cal BP. Combined with similarities in projectile point morphology between South American and Belizean styles, these data indicate that human populations were exchanging genes and ideas about stone tool manufacture thousands of years before the first agricultural sites were settled. Given these ancient ties, it is seems likely that similar ideas about cultivars, as well as the crops themselves, were also being exchanged well before culturally-Maya groups arose in the region. Rather than supporting the narrative that agriculture came to Belize along with colonizing Maya-speakers from elsewhere in Central America, these data indicate the equal, if not greater, contributions of forager-farmers with a long history of plant manipulation and cultivation in the region.

Lohse (2010) begins by reviewing the evidence for widespread maize and manioc cultivation during the Late Archaic, much of which I described above. Importantly, this evidence comes from different ecological settings – from low-lying wetland fields such as Pulltrouser Swamp (PTS) in northern Belize to the upland rockshelter of Actun Halal (AHL) in western Belize. In each case, cultivars are not the main source of calories – instead, they can be "seen as a way to offset the risks of food shortages or overcome variation in the seasonal availability of other primary resources" (Lohse 2010:322). He goes on to point out that the earliest village settings in the Maya region also bear evidence of only a modest use of cultivars like maize and a larger reliance on a wide range of fauna – in other words, a mixed subsistence economy not unlike that of the Late Archaic. Although my study does not directly assess paleobotanical or fauna remains, the results of my lithic analyses do complement this picture, as they imply that rockshelter occupants in southern Belize relied on some sort of proto-agricultural behaviors. As discussed in Chapter 2, the widely dispersed, unpredictable nature of tropical forest resources requires environmental modification in order to make them more concentrated and predictable. Without these modifications, subsistence resources would remain too sparsely distributed to allow for longer periods of logistical mobility. Almost all human groups impact their environment in this way, but in tropical forests especially, longer periods of sedentism require greater reliance on proto-agricultural practices and the resources they generate. Therefore, I can tentatively conclude based on lithics alone that occupants at these rockshelters relied at least in part on cultivars by the Middle Holocene. Indeed, isotopic evidence from human remains at Sites 2 and 3 indicate a low level of maize in the diet by the end of the Middle Holocene (i.e., the transitional maize diet), followed by reliance on maize as a staple during the Late Archaic/Late Holocene (Kennett et al. 2020).

Another type of economic and technological evidence that Lohse (2010) uses as support for cultural continuity across the Archaic-Preclassic divide is lithic production and use. Previously, I had mentioned the work of Iceland (2005) in defining a "Colha Lithic Tradition," which originally seemed confined to the part of northern Belize around Colha. Along with a diagnostic artifact type (a type of adze known as the constricted uniface), this tradition included techniques such as "hard hammer macroblades and macroflakes as blanks for tool manufacture" and only "limited biface production" (Lohse 2010:327). This latter aspect fits well with my finding that bifacial flaking remained relatively low throughout most of the Middle and Late Archaic.

Lohse (2010), however, points out that constricted adzes (some of which were bifacially flaked) have been found in northwestern and western Belize, outside of Colha's influence, and were not always made on high quality chert. He also cites as evidence for more specialized and controlled bifacial flaking the finely-crafted bifacial projectile points known as Lowe and Sawmill points, which at the time of his writing were thought to be diagnostic of the Late Archaic time period (Lohse et al. 2006, 2007; Lohse 2010). However, this chronological association was based on only two associated radiocarbon dates, both of which were problematic for various reasons (Prufer et al. 2019). In contrast, my colleagues in southern Belize have found five complete or partial Lowe points from "well dated stratigraphic contexts" (Prufer et al. 2019:6) at Sites 1 and 2. As Prufer et al. (2019) conclude, "[c]hronologies from both rockshelters bracket the minimum age of the [Site 1] and [Site 2] Lowe points as calBP 10,223 and 9,300 2σ," well within the Early Holocene geological period and the Late Paleoindian/Early Archaic cultural phase.

As mentioned earlier, my own study included only one of these points, in part because they were deemed too early to fit within my initial focus on the Archaic period, and in part because they were unavailable for study at the time of my lithic analysis. However, based on my analyses of the rest of the lithic assemblages of these sites, I can generally conclude, contra Lohse (2010), that bifacial tools and lithic production methods declined sharply during the Early Holocene along with other signatures of curation, and remained scarce until the Middle Preclassic. This somewhat weakens the overall argument for cultural continuity from the Archaic to the Preclassic, because Middle Preclassic lithics do feature some bifacial points and bifacial thinning flakes. For example, in examining Maya economy as represented by the Maya site of Ceibal in Guatemala, Aoyama (2017:281) analyzes Middle Preclassic lithic assemblages that constitute "the largest sample of this critical period in the Maya lowlands to date." Bifacial artifacts – points, tools, and thinning flakes – make up less than 1% of his sample of early Middle Preclassic chert assemblages, which are otherwise dominated by informal percussion flakes, flake cores, and numerous other informal tool types. This tiny percentage is greater than the complete lack of bifacial artifacts in all assemblages in my study that date after ~4000 cal BP. Still, it more compellingly argues for continuity from the Archaic to the Preclassic than do the carefully crafted bifacial Lowe complex points which are now recognized as thousands of years older than previously believed (Prufer et al. 2019).

Lohse (2010:330) also reviews radiocarbon dating and stratigraphy at five different sites throughout Belize, including three (Cuello, Blackman Eddy, and Cahal

Pech) that are “arguably the earliest permanent sites yet known in the Maya Lowlands” and two (Colha and Actun Halal) that he characterizes as “arguably the two best-dated Lowland Archaic sites.” Overall, he notes a variety of dates that could be used to argue for the first appearance of sedentary, ceramic-using Maya populations. At the time of his writing, he concluded that none of these show “clear, irrefutable indication of pottery before 1000 B.C.” (Lohse 2010: 343). However, more recent work (Ebert, Pierce, and Awe 2019) indicates that one site, Cahal Pech, was founded by 1200 B.C. by populations using Cunil pottery, one of the earliest form of ceramics in Belize.

The sites with evidence of the earliest pottery – Blackman Eddy and Cahal Pech in western Belize – do not show the clearest evidence of pre-ceramic Archaic populations. At Cahal Pech, these pre-ceramic populations are attested to only by a unique dark paleosol with no ceramics but abundant chert artifacts. It is dated by a single radiocarbon date whose 2-sigma range of dates (1213–537 B.C.) is extremely long, making it difficult to conclude that pre-ceramic peoples utilized the site prior to construction of the first floor by ceramic-wielding villagers. On the other hand, Colha and Actun Halal show the persistence of pre-ceramic peoples into the period after 1000 cal B.C., but do not show the earliest pottery. The view is further complicated by the apparent custom that the first villagers had of clearing existing soils from their sites down to bedrock, meaning any pre-ceramic components there would be removed or perhaps incorporated as fill in other contexts. Altogether, this points to the coexistence of groups pursuing different lifestyles and using different artifacts within two relatively nearby areas of Belize, leading Lohse (2010: 343) to conclude that the Late Archaic-Middle Preclassic transition period “would have been incredibly dynamic, bearing witness to many of the transformations that defined later Maya society.”

Due to time constraints and a constantly evolving chronostratigraphic understanding of my three sites, the lithic assemblages from my project did not explicitly overlap this transition. At the time of this writing, analysis of ceramics from ceramic-bearing levels is still ongoing, so the style and time periods of the earliest ceramics at my project's sites are not known. Furthermore, direct evidence of the Archaic-to-Preclassic transition may be lacking from my sites for various reasons. At Site 1, the nearby polity of Uxbenka contains evidence of human occupation from "paleosols dating a span from ca. 1200-900 cal BC in the later part of the Late Archaic period" (Culleton 2012:75). However, more concrete artifactual evidence indicates the site was not settled until the Late Preclassic period (~2300 cal BP) (Meredith 2015), substantially later than other Middle Preclassic sites in northern and western Belize. Additionally, the sediment layers from Site 1 do not contain the entire record from the Paleoindian through Late Archaic; as noted in Chapter 2, sediment from that site appears to have been stripped away by the Ancient Maya, perhaps for use as construction fill, but also to create the plaster frieze that adorns the rockshelter wall. Because of this discontinuity, and the relative lateness of Maya settlement in the immediate area, my study cannot directly evaluate lithic technology or mobility during the Archaic-to-Preclassic transition for Site 1.

It is important to note, however, that there is further evidence of human activity near Site 1 during this crucial time. Geological trenches dug into nearby floodplains provide evidence of a "stable surface with evidence of a pre-ceramic human occupation. A radiocarbon age … dates this surface to the Early Preclassic/Formative, with an age of 1134 – 1046 cal BC" (Thompson and Merriman 2014:99). In other words, investigations on the river-side floodplains that lie between Site 1 and Uxbenka do reveal some evidence for human occupation dating to this time, but it was too ephemeral to have left much of an archaeological trace. That may be because it was left by mobile human groups who didn’t stay in one spot long enough to leave a substantial trace; or it may be that more sedentary groups did occupy these terraces but did not do so for a long-enough period of time to leave a substantial trace. Further excavations in the area of Site 1 are needed to resolve these possibilities.

Future Research Directions in Southern Belize.

To better delineate the transition between the Late Archaic and Middle or Late Preclassic utilization of the areas around my study sites, future work might focus more exclusively on the levels dating to this crucial transitional time period. If overall patterns of lithic technology (not just those traits related to curation/mobility) show continuity during this time (at one site or all three), it would provide greater evidence for the participation of rockshelter occupants in the founding of Ek Xux and/or Uxbenka; on the other hand, should significant differences be found between levels with ceramics compared to those without, it would argue for a scenario whereby incoming Maya farmers replaced more mobile rockshelter occupants. Other types of evidence that could differentiate between these hypotheses include comparisons of mortuary traits (burial position, status, etc.); bioarchaeological analyses of health, nutrition, and/or cultural modifications; or isotopic analyses of strontium to differentiate individuals who grew up in local areas from those from non-local areas – and from those with a more mixed isotopic signature resulting from greater mobility during childhood.

Another direction for future work would be in the geochemical sourcing of chert used to create lithic artifacts. I briefly alluded to this type of analysis earlier because my project’s scope had originally included just such an analysis, but time and other factors prevented me from concluding this aspect of my work. Specifically, a representative subsample of lithic artifacts from each shelter were not able to be analyzed via portable X-ray Fluorescence (pXRF) in time. However, I was still able to gather trace element data on a sample of geological chert specimens from the area around each site – and in the case of Site 2, from chert nodules embedded within the wall the shelter itself. Determining the trace element profile of chert sources like these is the first step in being able to tell whether artifacts were knapped on local or non-local chert. The hope is that each source's geochemical "fingerprint" will be different enough that chert from two different sources can be differentiated based on trace element profiles, and not merely on visual characteristics such as color, texture, or opacity.

To that end, I was able to assay 38 different geological specimens via pXRF. The trace element profiles of some specimens indicated they were not fully silicified – that is, they had relatively high amounts of $CaCO_3$, and were chemically more similar to limestone than chert. These silicified limestone cobbles – which could also be referred to as calcareous chert – were similar enough in appearance and texture to be included in my sample of source specimens. It is likely that ancient foragers who were more familiar with the different types of chert available at each locale, would not have seen these types of chert as worthy of their use, since its high carbonate content makes it less knappable. Yet at the same time, a few of the oldest artifacts, especially those from Site 1, share certain qualities in texture that might indicate calcareous cherts like these specimens were in fact used to craft tools. The use of such poor quality toolstone is not as well studied as is the use of high-quality, fine-grained materials (see Will 2021 for a discussion of this dynamic as it relates to Africa's Middle Stone Age), yet it may explain the presence of these artifacts. Luedtke (1992) provides another possible explanation related to heating, stating that flint can become "calcined – for example, heated to such high temperatures that it changes to cristobalite. Although the silica changes back to alpha-quartz upon cooling, the flint is whitened and severely damaged; thus, it is easy to crush and grind." This handful of lithic artifacts (not including the bifacial points and unifacial scrapers described previously) share a common characteristic of having clean, flat planes and facets on the outside – yet, when broken (either in antiquity or during excavation), they reveal a very friable, brittle texture totally unsuitable for flaking. Such artifacts posed something of a conundrum for our project – had ancient toolmakers found a way to cleanly knap and utilize stone that would otherwise defy knapping in the present day? Might they be an example of chert that has been unintentionally heated after flaking, such as when a fire is built over discarded, shallowly-buried lithics? Or had some aspect of taphonomy caused the material to become more friable and brittle over time?

Such questions are outside the scope of the current study, in part because of the problems in gathering pXRF data described above. However, one working hypothesis is that these most ancient artifacts were in fact originally knapped on high- or medium-quality chert (i.e., chert with a high enough proportion of silicate to be glass-like). Over the centuries after their deposition, they were subjected to leaching of silicate material by moisture in the soil, which left behind only a friable and brittle scaffolding of carbonates that, for the most part, kept its original shape (C. Merriman, pers. comm). Yet even the fact that these artifacts had enough carbonate in them to maintain that shape indicates they were not knapped on "pure" chert – rather, they were likely knapped on the same partly-silicified limestone that we encountered in our survey of geological specimens. A somewhat similar phenomenon is thought to be responsible for the distinctive white patina seen on Archaic-period chert objects in northern Belize. As Rosenswig et al. (2015:311) put it,

> "Patination results from the chemical exchange of calcium carbonate from the underlying bedrock to form an outer rind on the surface of stone tools. The patina ranges from 1 to 5mm in thickness and gives these Archaic tools a distinctive clean, white appearance that obscures the natural color of the chert from which they were made... Where tools exhibit recent breakage, a high quality Colha chert is almost always visible beneath the patina. In contrast, Formative and Classic

> period stone tools from the area can have a light patina "wash" that does not obscure the character of the raw material."

The friable artifacts in my study are in fact completely white through and through, as if a patina that had started on the surface had eventually penetrated throughout the entire artifact. A few do show breakages where a much thicker white patina surrounds a smaller central section of material of a different color – usually greyish brown, the natural color of cherts in the area. Therefore, it may be that a combination of leaching and/or chemical exchange with the surrounding limestone bedrock resulted in the de-silicification of these artifacts and their resultant friable texture and easy breakability.

Beyond simply identifying which artifacts were knapped on calcareous chert, a sourcing study should also be able to identify what percentage of artifacts in each assemblage where knapped on local vs. non-local chert. Such data would have obvious implications for mobility, but they may not be as easy to interpret as the other types of curation and expedience data analyzed above. For one thing, there are numerous ways that stone from one area can end up in another; direct transport from source to place of deposition is only the simplest. The complex trade relations noted for the Middle Preclassic makes it obvious that fully sedentary farmers can attain materials from far afield, even if they never visited those locations themselves. In some ways, however, trade is dependent on a certain level or sedentism; or, at least, a coordinated attempt to be in the same place at the same time. The ethnographic record is full of instances of hunter-gatherer fission-fusion cycles that make gift exchange (quite different from formal trade relations) possible even among mobile groups (Kelly 1993). During certain times of the year, such groups split into small bands, sometimes no more than a nuclear family, and spread out in different directions to exploit far-flung resources. Then during another season, those same groups come together and live for a while as a macro-band, potentially exchanging resources (along with unrelated mates) from two different ends of the overall territory.

It should be noted, however, that such fission-fusion events are more common in environments with more extreme seasonality than that of the neotropics (Kelly 1993; 2013). In tropical forest environments, the main seasonal difference is in amount of rain, and neither the rainy nor dry season necessarily concentrates resources sufficiently to support a large group for a long period of time. The complex trade arrangements noted in places with dense, sedentary groups of hunter-gatherers (such as California) would not likely work in Belize without some sort of food production around the sites of aggregation. Therefore, if non-local cherts were identified in various rockshelter assemblages, they would more likely be signs of residential mobility rather than reliable trade relationships maintained over long ranges.

Concluding Thoughts

In this dissertation, I have attempted to draw conclusions about social and behavioral adaptations – namely, mobility and subsistence – from limited lithic data. As stated in Chapter 2, my goal was to use the data available to address predictions made by various hypotheses about the nature of forager mobility and subsistence during the long Archaic period. The main hypotheses discussed fall into two tiers, one which asks whether or not the Maya Lowlands were occupied prior to the arrival of the Maya, and the other which asks when a transition to sedentism may have occurred. The first tier is necessary because the “Vacant Belize” holds that, on the eve of the Middle Preclassic period, the Archaic-period Maya Lowlands were either unoccupied, or so sparsely occupied by highly-mobile hunter-gatherers as to be essentially vacant. This perspective is largely based on the rather rapid appearance of the Maya at the end of the Archaic and the paucity of evidence for pre-Maya settlement throughout most of the area. This view has much in common with one side of the “cultivated calories” debate of the 1980’s – specifically, the scholars who believed that “pure” tropical forests do not contain enough dense, predictable resources to sustain human groups without recourse to plant manipulation and/or cultivated resources. Although its proponents never directly cite that debate (or really, any scholars at all), it may have influenced their thinking.

Without a doubt, my study results document the great antiquity of human exploitation of the Maya Lowlands throughout the Late Pleistocene and Holocene periods. Furthermore, my study results indicate that these occupants had already begun to abandon a highly mobile lifestyle based around big game hunting as early as the end of the Younger Dryas. The first lithic trait to indicate this shift was Biface %, which steeply declined just as climate began to ameliorate at the start of the Early Holocene. At the same time, Non-cortical % began to show a more gradual transition towards lower values, a finding in keeping with the general trend of lowered mobility. This trend continued throughout the ensuing Middle Holocene period, indicating that groups were becoming more and more settled as time went on and likely more dependent on plant intensification. Not only were the Maya Lowlands occupied on the eve of Maya cultural arrival, they were likely occupied by somewhat sedentary forager-farmers. My research also has implications for the “cultivated calories” debate, in that it shows unequivocal evidence of human presence and exploitation 1) prior to 9000 cal BP and 2) in landscapes that were undoubtedly covered in tropical forest. These two criteria had been put forward by the more skeptical side of the debate as the only type of evidence that would convince them that tropical forests could sustain human occupation without cultivation. Because multiple paleoclimatic proxies from locations throughout the Maya Lowlands attest to tropical forest development a full millennia before that critical date, and because no cultivars are known to date to that period, the sites I studied meet the proposed criteria; therefore, I can reject the hypothesis that pure tropical forests cannot support full-time hunter-gatherers.

The second tier of hypotheses, informed by HBE theorists like Piperno (2011) and Kennett et al. (2020), takes these assumptions as its starting point, and asks at what time this transition to greater sedentism occurred. The predictions of this set of hypotheses are much more varied, in no small part because these theorists recognize the dynamic nature of human socio-ecological interactions as well as the ingenuity of human groups in manipulating their environments. Environmental conditions – including climatic swings like that of the Pleistocene-Holocene transition – provide constraints to human activities, but not in a deterministic fashion (Piperno 2011). Instead, those conditions set the stage for a number of possible adaptive strategies – including changes to subsistence through proto-agricultural practices, and changes in land use through logistical mobility strategies. Humans adapt their lithic technology for these different conditions, both by utilizing the advantages of a more stable central place through caching of toolstone, and by developing different toolkits for novel subsistence problems. One possible trajectory of these changes would be unidirectional increases in proto-agricultural practices, logistical mobility, and use of expedient lithics, starting very early in the sequence once the megafauna had died out; I refer to this as the Early variant of this hypothesis. Another potential time when that shift may have occurred would be during the Holocene Climatic Optimum that began in the mid-Early Holocene; I refer to this as the Middle variant. Finally, it is possible that a transition to greater sedentism was delayed until after the 8.2ka drying event, when climate has begun to decrease from its warmest, wettest state, and a wider variety of important plants and incipient cultivars are attested to by the paleobotanical record (as covered in Chapter 2). This last variant I'll refer to as the Late variant.

Unfortunately, my lithic data did not provide a satisfactory way to definitely choose amongst these three variants. For example, the Younger Dryas saw some of the highest values for curation-related traits in my whole study, indicating that its cooler, drier conditions favored higher mobility. However, directly after its end, bifacial artifacts became much more infrequent in my assemblages, and stayed that way throughout almost the entire sequence – a dynamic that provides support for the Early variant. Because no domesticates are known from that time, however, any subsistence and mobility changes may have had less to do with human manipulation of plant resources and more to do with ecological events – for instance, the extinction of high-ranked prey megafauna throughout the region. The only other lithic trait to show a substantial, significant relationship with time was relative frequency of non-cortical artifacts. Unlike Biface %, this marker of expedience showed a slow, steady decline from the earliest part of the sequence through the entire Holocene. Because there were no obvious inflection points or sharp decreases, it is much more difficult to pinpoint a specific time that a transition to high-LMS may have occurred. Both the Middle and Late variants of the HBE-informed hypothesis are supported these dynamics.

Further work on my study's assemblages, and on the hundreds of lithic artifacts from these sites that have yet to be analyzed, may provide a way to better pinpoint when such a shift occurred – or if it even did. Such data will also be important for shedding light on the ways that longer periods of sedentism effected social organization, both at the local scale and further afield. Because I couldn't use the lithics I examined to directly assess these sorts of changes, I have for the most part avoided speculating on them. Yet sedentism is believed by many theorists to be a necessary precursor to social traits such as labor specialization and wealth inequality, which together make up the larger trait of social complexity (Kelly 2013). By the time the Maya arose in the Lowlands, such complexity had reached rather large scales in several important areas of Mesoamerica such as Oaxaca, the Soconusco, and the Gulf Coast. Unfortunately, it is difficult to directly assess the complexity of the earliest Maya sites, since they were often built over by later, larger ceremonial centers or residential areas. However, the evidence from my study of the Archaic period shows that all of the necessary ingredients for social complexity were in place well before the Preclassic and Classic Periods. When viewed in this light, the relatively sudden Middle Preclassic emergence and fluorescence of socially complex Maya centers at several sites in the Lowlands is, perhaps, not so surprising after all.

REFERENCES

Ames, Kenneth M. 2004. “Review : Supposing Hunter-Gatherer Variability.” *American Antiquity* 69 (2): 364–74.

Andrefsky, William. 1994. “Raw-Material Availability and the Organization of Technology.” *American Antiquity* 59 (1): 21–34.

———. 2005. *Lithics: Macroscopic Approaches to Analysis*. 2nd ed. Cambridge: Cambridge University Press. https://doi.org/10.2307/507457.

Andrews, Edward Wyllys. 1969. *The Archaeological Use and Distribution of Mollusca in the Maya Lowlands*. New Orleans: Middle American Research Institute, Tulane University.

Aoyama, Kazuo. 2017. “Ancient Maya Economy: Lithic Production and Exchange around Ceibal, Guatemala.” *Ancient Mesoamerica* 28 (1): 279–303. https://doi.org/10.1017/S0956536116000183.

Bailey, Robert C. 1981. “Hunting and Gathering in Tropical Rain Forest: Is It Possible?” *American Anthropologist* 91 (1): 59–82.

Bailey, Robert C., and Thomas N. Headland. 1991. “The Tropical Rain Forest: Is It a Productive Environment for Human Foragers?” *Human Ecology* 19 (2): 261–85. https://doi.org/10.1007/BF00888748.

Ball, Joseph W., and Jennifer T. Taschek. 2003. “Reconsidering the Belize Valley Preclassic: : A Case for Multiethnic Interactions in the Development of a Regional Cultural Traiditon.” *Ancient Mesoamerica* 14: 179–217. https://doi.org/10.1017/S0956536103142034.

Bamforth, Douglas B. 1986. “Technological Efficiency and Tool Curation.” *American Antiquity* 51 (1): 1986.

Barrett, Jason W., Harry J. Shafer, and Thomas R. Hester. 2011. “Lessons from the Field: The Contribution of Colha to Lowland Maya Lithic Research.” In *The Technology of Maya Civilization: Political Economy and Beyond in Lithic Studies*, edited by Zachary X. Hruby, Geoffrey E. Braswell, and Oswaldo Chinchilla Mazariegos, 15–29. Sheffield Oakville: Equinox.

Barton, C. Michael, and Julien Riel-Salvatore. 2014. “The Formation of Lithic Assemblages.” *Journal of Archaeological Science* 46: 334–52. https://doi.org/10.1016/j.jas.2014.03.031.

Barton, C. Michael, Julien Riel-Salvatore, John M. Anderies, and Gabriel Popescu. 2011. “Modeling Human Ecodynamics and Biocultural Interactions in the Late Pleistocene of Western Eurasia.” *Human Ecology* 39 (6): 705–25. https://doi.org/10.1007/s10745-011-9433-8.

Beach, Tim, Sheryl Luzzadder-Beach, Nicholas Dunning, John Jones, Jon Lohse, Tom

Guderjan, Steve Bozarth, Sarah Millspaugh, and Tripti Bhattacharya. 2009. "A Review of Human and Natural Changes in Maya Lowland Wetlands over the Holocene." *Quaternary Science Reviews* 28 (17–18): 1710–24. https://doi.org/10.1016/j.quascirev.2009.02.004.

Binford, Lewis R. 1979. "Organization and Formation Processes: Looking at Curated Technologies." *Journal of Anthropological Research* 35 (3): 255–73.

———. 1980. "Willow Smoke and Dogs' Tails : Hunter-Gatherer Settlement Systems and Archaeological Site Formation." *American Antiquity* 45 (1): 4–20.

———. 2001. *Constructing Frames of Reference: An Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets*. Berkeley: University of California Press.

Bressani, Ricardo, and Nevin S. Scrimshaw. 1958. "Effect of Lime Treatment on in Vitro Availability of Essential Amino Acids and Solubility of Protein Fracturing in Corn." *Agricultural and Food Chemistry* 6 (10): 774–78.

Carrillo-Bastos, Alicia, Gerald A. Islebe, Nuria Torrescano-Valle, and Norma Emilia González. 2010. "Holocene Vegetation and Climate History of Central Quintana Roo, Yucatán Península, Mexico." *Review of Palaeobotany and Palynology* 160 (3–4): 189–96. https://doi.org/10.1016/j.revpalbo.2010.02.013.

Clarkson, Chris. 2002. "An Index of Invasiveness for the Measurement of Unifacial and Bifacial Retouch: A Theoretical, Experimental and Archaeological Verification." *Journal of Archaeological Science* 29 (1): 65–75. https://doi.org/10.1006/jasc.2001.0702.

———. 2008. "Changing Reduction Intensity, Settlement, and Subsistence in Wardaman Country, Northern Australia." In *Lithic Technology: Measures of Production, Use, and Curation*, edited by William Andrefsky, 286–316. Cambridge: Cambridge University Press.

Colinvaux, Paul A., and Mark B. Bush. 1991. "The Rain-Forest Ecosystem as a Resource for Hunting and Gathering." *American Anthropologist* 93 (1): 153–60. https://doi.org/10.1525/aa.1991.93.1.02a00100.

Cornejo B., Luis E., and Patricio Galarce C. 2010. "C Index: Dimensioning the Expedient/Curative Continuum in Lithic Technology." *Chungara* 42 (2): 393–404. https://doi.org/10.4067/S0717-73562010000200004.

Correa-Metrio, Alexander, Mark B. Bush, David A. Hodell, Mark Brenner, Jaime Escobar, and Tom Guilderson. 2012. "The Influence of Abrupt Climate Change on the Ice-Age Vegetation of the Central American Lowlands." *Journal of Biogeography* 39 (3): 497–509. https://doi.org/10.1111/j.1365-2699.2011.02618.x.

Culleton, Brendan J. 2012. "HUMAN ECOLOGY, AGRICULTURAL INTENSIFICATION AND LANDSCAPE TRANSFORMATION AT THE ANCIENT MAYA POLITY OF UXBENKÁ, SOUTHERN BELIZE." University of Oregon.

https://doi.org/10.1017/CBO9781107415324.004.

Davies, Nicholas B., John R. Krebs, and Stuart A West. 2012. “Natural Selection, Ecology and Behaviour.” *An Introduction to Behavioural Ecology*, 1–23.

Dennehy, Timothy J. 2011. “Monumentality Among Complex Hunter-Gatherers: Three Case Studies.” City University of New York Hunter College.

Dennehy, Timothy J., Jacob Harris, and Curtis Marean. 2014. *Australian and Californian Tribal Area as a Function of Coastal Proximity and Mean Annual Precipitation*. Austin, TX: Society for American Archaeology 2014 Annual Meeting.

Dennehy, Timothy, Clayton Meredith, Asia Alsgaard, and Micah Smith. 2016. “Excavations at Tzib’te Yux Rockshelter: Report of the 2015 Field Season.” In *Uxbenka Archaeological Project: Report of the 2015 Field Season*, edited by Keith M. Prufer and Amy E. Thompson, 35–46.

Dibble, Harold L., Utsav A. Schurmans, Radu P. Iovita, and Michael V. Mclaughlin. 2005. “The Measurement and Interpretation of Cortex in Lithic Assemblages.” *American Antiquity* 70 (3): 545–60.

Doughty, Christopher E., Søren Faurby, and Jens Christian Svenning. 2016. “The Impact of the Megafauna Extinctions on Savanna Woody Cover in South America.” *Ecography* 39 (2): 213–22. https://doi.org/10.1111/ecog.01593.

Doughty, Christopher E., Søren Faurby, Adam Wolf, Yadvinder Malhi, and Jens Christian Svenning. 2016. “Changing NPP Consumption Patterns in the Holocene: From Megafauna-‘Liberated’ NPP to ‘Ecological Bankruptcy.’” *Anthropocene Review* 3 (3): 174–87. https://doi.org/10.1177/2053019616650466.

Dounias, Edmond. 2001. “The Management of Wild Yam Tubers by the Baka Pygmies in Southern Cameroon.” *African Study Monographs* 26: 135–56.

Ebert, Claire E., Daniel E. Pierce, and Jaime J. Awe. 2019. “Preclassic Ceramic Economy in Belize: Neutron Activation Analysis at Cahal Pech.” *Antiquity* 93 (371): 1266–83. https://doi.org/10.15184/aqy.2019.93.

Ebert, Claire E., Keith M. Prufer, Martha J. Macri, Bruce Winterhalder, and Douglas J. Kennett. 2015. “Terminal Long Count Dates and the Disintegration of Classic Period Maya Polities.” *Ancient Mesoamerica* 25 (2): 337–56. https://doi.org/10.1017/S0956536114000248.

Endicott, Kirk, and Peter Bellwood. 1991. “The Possibility of Independent Foraging in the Rain Forest of Peninsular Malaysia.” *Human Ecology* 19 (2): 151–85. https://doi.org/10.1007/BF00888744.

Fuller, Dorian Q, Tim Denham, Manuel Arroyo-Kalin, Leilani Lucas, Chris J Stevens, Ling Qin, Robin G Allaby, and Michael D Purugganan. 2014. “Convergent Evolution and Parallelism in Plant Domestication Revealed by an Expanding Archaeological Record.” *Proceedings of the National Academy of Sciences of the United States of*

America 111 (17): 6147–52. https://doi.org/10.1073/pnas.1308937110.

Gardner, Paul S. 1997. "The Ecological Structure and Behavioral Implications of Mast Exploitation Strategies." *People, Plants and Landscapes*, no. Caldwell 1958: 161–78.

Gnecco, Cristobal. 2003. "Against Ecological Reductionism: Late Pleistocene Hunter-Gatherers in the Tropical Forests of Northern South America." *Quaternary International* 109–110: 13–21. https://doi.org/10.1016/S1040-6182(02)00199-4.

Grove, M. 2010. "Logistical Mobility Reduces Subsistence Risk in Hunting Economies." *Journal of Archaeological Science* 37: 1913–21. https://doi.org/10.1016/j.jas.2010.02.017.

Grove, Matt. 2009. "Hunter–Gatherer Movement Patterns: Causes and Constraints." *Journal of Anthropological Archaeology* 28 (2): 222–33. https://doi.org/10.1016/j.jaa.2009.01.003.

———. 2016. "Population Density, Mobility, and Cultural Transmission." *Journal of Archaeological Science* 74: 75–84. https://doi.org/10.1016/j.jas.2016.09.002.

Halperin, Christina T., Sergio Garza, Keith M. Prufer, and James E. Brady. 2003. "Caves and Ancient Maya Ritual Use of Jute." *Latin American Antiquity* 14 (2): 207–19.

Hamilton, Marcus J., José Lobo, Eric Rupley, Hyejin Youn, and Geoffrey B. West. 2016. "The Ecological and Evolutionary Energetics of Hunter-Gatherer Residential Mobility." *Evolutionary Anthropology* 25 (3): 124–32. https://doi.org/10.1002/evan.21485.

Hartshorn, Gary, Lou Nicolait, Lynne Hartshorn, George Bevier, Richard Brightman, Jeronimo Cal, Agripino Cawich, et al. 1984. "Belize Country Environmental Profile: A Field Study." San Jose. https://doi.org/10.1017/CBO9781107415324.004.

Haslett, John, and Andrew C. Parnell. 2008. "A Simple Monotone Process with Application to Radiocarbon-Dated Depth Chronologies." *Journal of the Royal Statistical Society: Series C (Applied Statistics)* 57 (4): 399–418.

Haug, G. H., K. A. Hughen, D. M. Sigman, L. C. Peterson, and U. Röhl. 2001. "Southward Migration of the Intertropical Convergence Zone through the Holocene." *Science* 293 (5533): 1304–8. https://doi.org/10.1126/science.1059725.

Headland, Thomas N. 1987. "The Wild Yam Question : How Well Could Independent Hunter-Gatherers Live in a Tropical Rain Forest Ecosystem?" *Human Ecology* 15 (4): 463–91.

Headland, Thomas N., and Robert C. Bailey. 1991. "Introduction : Have Hunter-Gatherers Ever Lived in Tropical Rain Forest Independently of Agriculture ?" *Human Ecology* 19 (2): 115–22.

Healy, Paul F., Kitty Emery, and Lori E. Wright. 1990. "Ancient and Modern Maya

Exploitation of the Jute Snail (Pachychilus).” *Latin American Antiquity* 1 (2): 170–83.

Hill, Kim. 2002. “Reviewed Work(s): Constructing Frames of Reference: An Analytical Method for Archeological Theory Building Using Ethnographic and Environmental Data Sets by Lewis R . Binford.” *Journal of Anthropological Research* 48 (3): 416–19.

Hill, Kim, and A. Magdalena Hurtado. 1996. “The Ache.” In *Ache Life History: The Ecology and Demography of a Foraging People*, 41–81. New York: Aldine de Gruyter.

Hodell, David A., Flavio S. Anselmetti, Daniel Ariztegui, Mark Brenner, Jason H. Curtis, Adrian Gilli, Dustin A. Grzesik, et al. 2008. “An 85-Ka Record of Climate Change in Lowland Central America.” *Quaternary Science Reviews* 27 (11–12): 1152–65. https://doi.org/10.1016/j.quascirev.2008.02.008.

Iceland, Harry B. 2005. “The Preceramic to Early Middle Formative Transition in Northern Belize: Evidence for the Ethnic Identity of the Preceramic Inhabitants.” In *New Perspectives on Formative Mesoamerican Cultures*, 15–26. Oxford: Archaeopress.

Iceland, Harry B., and Kenneth G. Hirth. 2021. “The Paleoindian to Archaic Transition in Central America: Esperanza Phase Projectile Points Recovered at the El Gigante Rockshelter Site, Honduras.” In *Preceramic Mesoamerica*, edited by Jon C. Lohse, Aleksander Borejsza, and Arthur A. Joyce, 259–77. London and New York: Routledge Taylor & Francis Group.

Iceland, Harry B. 1997. “The Preceramic Origins of Maya Civilization: The Results of the the Colha Preceramic Project in Northern Belize.” *Anthropology* Doctoral.

Iceland, Harry Bame. 1997. “The Preceramic Origins of the Maya : The Results of the Colha Preceramic Project in Northern Belize.” University of Texas at Austin.

Inomata, Takeshi, Daniela Triadan, Verónica A. Vázquez López, Juan Carlos Fernandez-Diaz, Takayuki Omori, María Belén Méndez Bauer, Melina García Hernández, et al. 2020. “Monumental Architecture at Aguada Fénix and the Rise of Maya Civilization.” *Nature* 582 (7813): 530–33. https://doi.org/10.1038/s41586-020-2343-4.

Iriarte, Jose, Sarah Elliott, S. Yoshi Maezumi, Daiana Alves, Regina Gonda, Mark Robinson, Jonas Gregorio de Souza, Jennifer Watling, and Josephine Handley. 2020. “The Origins of Amazonian Landscapes: Plant Cultivation, Domestication and the Spread of Food Production in Tropical South America.” *Quaternary Science Reviews* 248: 106582. https://doi.org/10.1016/j.quascirev.2020.106582.

Islebe, Gerald A., Alicia Carrillo-Bastos, Alejandro A. Aragón-Moreno, Mirna Valdez-Hernández, Nuria Torrescano-Valle, and Nancy Cabanillas-Terán. 2019. “Holocene Paleoecology and Paleoclimatology of South and Southeastern Mexico: A Palynological and Geospatial Approach.” *The Holocene and Anthropocene*

Environmental History of Mexico: A Paleoecological Approach on Mesoamerica, 195–207. https://doi.org/10.1007/978-3-030-31719-5_10.

J., McManus, Francois R., Gherardi J.-M., Keigwin L., and Brown-Leger S. 2004. "Collapse and Rapid Resumption of {A}tlantic Meridional Circualtion Linked to Deglacial Climate Changes." *Nature* 428 (April): 834–37.

Jones, John G. 1994a. "Pollen Evidence for Early Settlement and Agriculture in Northern Belize." *Palynology* 18: 205–11.

———. 1994b. "Pollen Evidence for Early Settlement and Agriculture in Northern Belize." *Palynology* 18 (1): 205–11. https://doi.org/10.1080/01916122.1994.9989445.

Keeley, Lawrence H. 1995. "Protoagricultural Practices among Hunter-Gatherers: A Cross-Cultural Survey." In *Last Hunters, First Farmers: New Perspectives on the Prehistoric Transition to Agriculture*, edited by T. Douglas Price and Anne Birgitte Gebauer, 243–73. Santa Fe: School of American Research Press.

Kelly, Robert L. 1983. "Hunter-Gatherer Mobility Strategies." *Journal of Anthropological Research* 39 (3): 277–306.

———. 1988. "The Three Sides of a Biface" 53 (4): 717–34.

———. 2013. *The Lifeways of Hunter-Gatherers: The Foraging Spectrum*. Cambridge: Cambridge University Press.

Kelly, Thomas C. 1993. "Preceramic Projectile-Point Typlology in Belize." *Ancient Mesoamerica* 4: 205–27.

Kennett, D. J., S. F. M. Breitenbach, V. V. Aquino, Y. Asmerom, J. Awe, J. U. L. Baldini, P Bartlein, et al. 2012. "Development and Disintegration of Maya Political Systems in Response to Climate Change." *Science* 338 (6108): 788–91. https://doi.org/10.1126/science.1226299.

Kennett, Douglas J., Keith M. Prufer, Keith M. Prufer, Brendan J. Culleton, Richard J. George, Mark Robinson, Willa R. Trask, et al. 2020. "Early Isotopic Evidence for Maize as a Staple Grain in the Americas." *Science Advances* 6 (23): 1–12. https://doi.org/10.1126/sciadv.aba3245.

Kennett, Douglas J., Heather B. Thakar, Amber M. Vanderwarker, David L. Webster, Brendan J. Culleton, Thomas K. Harper, Logan Kistler, Timothy E. Scheffler, and Kenneth Hirth. 2017. "High-Precision Chronology for Central American Maize Diversification from El Gigante Rockshelter, Honduras." *Proceedings of the National Academy of Sciences of the United States of America* 114 (34): 9026–31. https://doi.org/10.1073/pnas.1705052114.

Kennett, Douglas J., and Barbara Voorhies. 1996. "Oxygen Isotopic Analysis of Archaeological Shells to Detect Seasonal Use of Wetlands on the Southern Pacific Coast of Mexico." *Journal of Archaeological Science* 23 (5): 689–704. https://doi.org/10.1006/jasc.1996.0065.

Kennett, Douglas J., and Bruce Winterhalder. 2005. *Behavioral Ecology and the Transition to Agriculture*. Ewing, NJ, USA: University of California Press. http://site.ebrary.com/lib/huntercollege/docDetail.action?docID=10110312.

Kennett, Douglas J, Keith Malcolm Prufer, Brendan J Culleton, R George, Mark Robinson, Willa Trask, Gina Buckley, et al. 2020. "Early Isotopic Evidence for Maize as a Staple Grain in the Americas." *Science Advances* 3 (June): 1–12. https://doi.org/10.24200/tjer.vol1iss1pp0-0.

Kuhn, Steven L. 1992. "On Planning and Curated Technologies in the Middle Paleolithic." *Journal of Anthropological Research* 48 (3): 185–214.

Lee, Richard B. 1979. *The !Kung San: Men, Women, and Work in a Foraging Society*. Cambridge: Cambridge University Press.

Leyden, B. W. 1984. "Guatemalan Forest Synthesis after Pleistocene Aridity." *Proceedings of the National Academy of Sciences* 81 (15): 4856–59. https://doi.org/10.1073/pnas.81.15.4856.

Linares, Olga F. 1976. "'Garden Hunting' in the American Tropics." *Human Ecology* 4 (4): 331–49.

Lohse, Jon C. 2010. "Archaic Origins of the Lowland Maya." *American Archaeology* 21 (3): 312–52.

Lohse, Jon C., Jaime Awe, Cameron Griffith, Robert M. Rosenswig, and Fred Valdez. 2006. "Preceramic Occupations in Belize : Updating the Paleoindian and Archaic Record." *Latin American Antiquity* 17 (2): 209–26.

Lohse, Jon C, Lisa LeCount, John G Jones, Tim Beach, and Ashley Hallock. 2007. "In Search of the Preceramic: 2006 Season Investigations at Actun Halal, Belize." http://www.famsi.org/reports/06019/06019Lohse01.pdf.

Lombardo, Umberto, José Iriarte, Lautaro Hilbert, Javier Ruiz-Pérez, José M. Capriles, and Heinz Veit. 2020. "Early Holocene Crop Cultivation and Landscape Modification in Amazonia." *Nature* 581 (7807): 190–93. https://doi.org/10.1038/s41586-020-2162-7.

Luedtke, Barbara E. 1992. *An Archaeologist's Guide to Chert and Flint*. Los Angeles: University of California Press.

Mackay, Alex. 2014. "Informal Movements: Changing Mobility Patterns at Ngarrabulgan, Cape York, Australia," no. May.

MacNeish, Richard S. 1981. "Second Annual Report of the Belize Archaic Archaeological Reconnaissance." Andover, Mass.: Robert S. Peabody Foundation for Archaeology.

MacNeish, Richard S., and Antoinette Nelken-Terner. 1983. "Final Annual Report of the Belize Archaic Archaeological Reconnaissance." Boston: Center for Archaeolocial

Studies, Boston University.

MacNeish, Richard S., S. Jeffrey Wilkerson, and Antoinette Nelken-Terner. 1980. *First Annual Report of the Belize Archaic Archaeological Reconnaissance. Archaeology*.

Maliva, Robert G., and Raymond Siever. 1989. “Chert Formation in Carbonate Rocks.” *The Journal of Geology* 97 (4): 421–33. http://www.jstor.org/stable/pdf/30078348.pdf?acceptTC=true.

Marchant, R., A. Cleef, S. P. Harrison, H. Hooghiemstra, V. Markgraf, J. Van Boxel, T. Ager, et al. 2009. “Pollen-Based Biome Reconstructions for Latin America at 0, 6000 and 18 000 Radiocarbon Years Ago.” *Climate of the Past* 5 (4): 725–67. https://doi.org/10.5194/cp-5-725-2009.

Marcus, Joyce. 1995. “Where Is Lowland Maya Archaeology Headed?” *Journal of Archaeological Method and Theory* 3 (1): 3–53.

Marean, Curtis W. 2016a. “The Transition to Foraging for Dense and Predictable Resources and Its Impact on the Evolution of Modern Humans.” *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 371 (1698): 160–69. https://doi.org/10.1007/s13398-014-0173-7.2.

———. 2016b. “The Transition to Foraging for Dense and Predictable Resources and Its Impact on the Evolution of Modern Humans.” https://doi.org/10.1007/s13398-014-0173-7.2.

Mercader, Julio. 2002. “Forest People: The Role of African Rainforests in Human Evolution and Dispersal.” *Evolutionary Anthropology* 11 (3): 117–24. https://doi.org/10.1002/evan.10022.

Meredith, Clayton. 2014a. “ANALYSIS OF SMALL CAVE SITES RELATED TO THE UXBENKÁ POLITY: APPLICATION OF FT-IR TECHNIQUES IN THE STUDY OF RITUAL PRACTICE.” *Master’s Thesis*. University of New Mexico.

———. 2014b. “Survey and Excavations within the Rock Patch.” In *Uxbenka Archaeological Project: 2013 Field Season*, edited by Keith M. Prufer, Amy E. Thompsom, and Valerie V. Aquino, 83–93.

———. 2015. “Geoarchaeological Investigations of Alluvial Terraces South of the Rio Blanco.” In *Uxbenka Archaeological Project: Report of the 2014 Field Season*, 23–31. https://doi.org/10.1017/CBO9781107415324.004.

Meredith, Clayton, and Timothy J. Dennehy. 2015. “Excavations at Tzib’te Yux Rockshelter.” In *Uxbenka Archaeological Project: Report of the 2014 Field Season*, 33–35.

Messineo, Pablo G, and María Paula Barros. 2018. “Lithic Raw Materials and Modes of Exploitation in Quarries and Workshops from the Center of the Pampa Grasslands of Argentina,” no. February 2015. https://doi.org/10.1179/2051618514Y.0000000007.

Metcalfe, Sarah, Ann Breen, Malcom Murray, Peter Furley, Anthony Fallick, and Angus McKenzie. 2009. “Environmental Change in Northern Belize since the Latest Pleistocene.” *Journal of Quaternary Science* 24 (6): 627–41. https://doi.org/10.1002/jqs.

Metcalfe, Sarah E., Sarah L. O’Hara, Margarita Caballero, and Sarah J. Davies. 2000. “Records of Late Pleistocene-Holocene Climatic Change in Mexico - A Review.” *Quaternary Science Reviews* 19 (7): 699–721. https://doi.org/10.1016/S0277-3791(99)00022-0.

Michczyński, Adam. 2007. “Is It Possible to Find a Good Point Estimate of a Calibrated Radiocarbon Date?” *Radiocarbon* 49 (2): 393–401. https://doi.org/10.1017/S0033822200042326.

Moholy-Nagy, Hattula. 1978. “The Utilization of Pomacea Snails at Tikal, Guatemala.” *American Antiquity* 43 (1): 65–73.

Nations, James D. 1979. “Snail Shells and Maize Preparation: A Lacandon Maya Analogy A.” *American Antiquity* 44 (3): 568–71.

Nazaroff, Adam Joseph. 2015. “Entanglement: A Study in Neolithic Resource Exploitation in the Middle East.” Stanford University. https://searchworks.stanford.edu/view/11391822.

Nelson, Margaret C. 1991. “The Study of Technological Organization.” In *Archaeological Method and Theory*, 57–100.

Nettle, Daniel, Mhairi A. Gibson, David W. Lawson, and Rebecca Sear. 2013. “Human Behavioral Ecology: Current Research and Future Prospects.” *Behavioral Ecology* 24 (5): 1031–40. https://doi.org/10.1093/beheco/ars222.

Orsini, Stephanie Raye. 2016a. “From Turkeys To Tamales : Paleoindian To Preclassic Period Faunal Use At Maya Hak Cab Pek Rockshelter In Southern Belize,” 1–75.

———. 2016b. “FROM TURKEYS TO TAMALES : PALEOINDIAN TO PRECLASSIC PERIOD FAUNAL USE AT MAYA HAK CAB PEK ROCKSHELTER IN SOUTHERN BELIZE A Thesis Presented in Partial Fulfillment of Requirements for the Degree of Master of Arts in the Department of Sociology and Anthropo,” no. May.

Parnell, A. C., J. Haslett, J. R.M. Allen, C. E. Buck, and B. Huntley. 2008. “A Flexible Approach to Assessing Synchroneity of Past Events Using Bayesian Reconstructions of Sedimentation History.” *Quaternary Science Reviews* 27 (19–20): 1872–85. https://doi.org/10.1016/j.quascirev.2008.07.009.

Parnell, Andrew C., Caitlin E. Buck, and Thinh K. Doan. 2011. “A Review of Statistical Chronology Models for High-Resolution, Proxy-Based Holocene Palaeoenvironmental Reconstruction.” *Quaternary Science Reviews* 30 (21–22): 2948–60. https://doi.org/10.1016/j.quascirev.2011.07.024.

Parry, William J., and Robert L. Kelly. 1987. “Expedient Core Technology and Sedentism.” In *The Organization of Core Technology*, edited by J. K. Johnson and Carol Morrow, 285–304. Boulder: Westview Pr.

Pearce, Christof, Marit Solveig Seidenkrantz, Antoon Kuijpers, and Njáll Fannar Reynisson. 2014. “A Multi-Proxy Reconstruction of Oceanographic Conditions around the Younger Dryas-Holocene Transition in Placentia Bay, Newfoundland.” *Marine Micropaleontology* 112: 39–49. https://doi.org/10.1016/j.marmicro.2014.08.004.

Piperno, Dolores R. 2006. “The Origins of Plant Cultivation and Domestication in the Neotropics: A Behavioral Ecological Perspective.” In *Behavioral Ecology and the Transition to Agriculture*, edited by Douglas J. Kennett and Bruce Winterhalder, 137–66. Berkeley: University of California Press.

Piperno, Dolores R., and Tom D. Dillehay. 2008. “Starch Grains on Human Teeth Reveal Early Broad Crop Diet in Northern Peru.” *Proceedings of the National Academy of Sciences of the United States of America* 105 (50): 19622–27. https://doi.org/10.1073/pnas.0808752105.

Piperno, Dolores R., and John G. Jones. 2003. “Paleoecological and Archaeological Implications of a Late Pleistocene/Early Holocene Record of Vegetation and Climate from the Pacific Coastal Plain of Panama.” *Quaternary Research* 59 (1): 79–87. https://doi.org/10.1016/S0033-5894(02)00021-2.

Piperno, Dolores R., and Deborah M. Pearsall. 1998. *The Origins of Agriculture in the Lowland Neotropics*. San Diego: Acadamic Press.

Piperno, Dolores R., Anthony J. Ranere, Ruth Dickau, and Francisco Aceituno. 2017. “Niche Construction and Optimal Foraging Theory in Neotropical Agricultural Origins: A Re-Evaluation in Consideration of the Empirical Evidence.” *Journal of Archaeological Science* 78: 214–20. https://doi.org/10.1016/j.jas.2017.01.001.

Piperno, Dolores R. 2011. “The Origins of Plant Cultivation and Domestication in the New World Tropics: Patterns, Process, and New Developments.” *Current Anthropology* 52 (S4): S453–70. https://doi.org/10.1086/659998.

Pohl, Mary D., Kevin O. Pope, John G. Jones, John S. Jacob, Dolores R. Piperno, Susan D. DeFrance, D. L. Lentz, John A. Gifford, Marie E. Danforth, and J. Kathryn Josserand. 1996. “Early Agriculture in the Maya Lowlands.” *Latin American Antiquity* 7 (4): 355–72.

Pohl, Mary E D, Dolores R Piperno, Kevin O Pope, and John G Jones. 2007. “Microfossil Evidence for Pre-Columbian Maize Dispersals in the Neotropics from San Andres, Tabasco, Mexico.” *Proceedings of the National Academy of Sciences of the United States of America* 104 (16): 6870–75. https://doi.org/10.1073/pnas.0701425104.

Politis, Gustavo G. 1996. “Moving to Produce: Nukak Mobility and Settlement Patterns in Amazonia.” *World Archaeology* 27 (3): 492–511.

Pollock, A. L., P. E. van Beynen, K. L. DeLong, V. Polyak, Y. Asmerom, and P. P. Reeder. 2016. "A Mid-Holocene Paleoprecipitation Record from Belize." *Palaeogeography, Palaeoclimatology, Palaeoecology* 463: 103–11. https://doi.org/10.1016/j.palaeo.2016.09.021.

Posth, Cosimo, Nathan Nakatsuka, Iosif Lazaridis, Lars Fehren-schmitz, Johannes Krause, David Reich, Cosimo Posth, et al. 2018. "Reconstructing the Deep Population History of Central and South America Article Reconstructing the Deep Population History of Central and South America," 1185–97. https://doi.org/10.1016/j.cell.2018.10.027.

Prufer, Keith M.25, Plate 2.1, and Douglas J. Kennett. 2020. "The Holocene Occupations of Southern Belize." *Approaches to Monumental Landscapes of the Ancient Maya*, 16–38. https://doi.org/10.5744/florida/9780813066226.003.0002.

Prufer, Keith M. 2002. "Communities, Caves, and Ritual Specialists: A Study of Sacred Space in the Maya Mountains of Southern Belize." Southern Illinois University Carbondale. https://doi.org/10.16953/deusbed.74839.

Prufer, Keith M., and Peter S. Dunham. 2009. "A Shaman's Burial from an Early Classic Cave in the Maya Mountains of Belize, Central America." *World Archaeology* 41 (2): 295–320. https://doi.org/10.1080/00438240902844236.

Prufer, Keith M., Christopher Merriman, Clayton Meredith, Willa Trask, Mark Robinson, and Josue Ramos. 2015. "The Bladen Paleoindian and Archaic Project, 2014 Field Season Report Prepared for the Forest Department, Government of Belize." In *Uxbenka Archaeological Project: Report of the 2014 Field Season*, edited by Keith M. Prufer and Amy E. Thompson, 37–51. Belmopan, Belize: Institute of Archaeology, Belize.

Prufer, Keith M., Mark Robinson, and Douglas J. Kennett. 2021. "TERMINAL PLEISTOCENE THROUGH MIDDLE HOLOCENE OCCUPATIONS IN SOUTHEASTERN MESOAMERICA : LINKING ECOLOGY AND CULTURE IN THE CONTEXT OF NEOTROPICAL FORAGERS AND EARLY FARMERS." *Ancient Mesoamerica*. https://doi.org/10.1017/S0956536121000195.

Prufer, Keith M., Amy E. Thompson, Asia Alsgaard, Willa Trask, Clayton Meredith, Mark Robinson, Timothy Dennehy, and Marina Adame. 2017. "Rockshelter Excavations at Mayahak Cab Pek and Saki Tzul in the Bladen Nature Reserve, Maya Mountains, Belize." In *Bladen Paleoindian and Archaic Archaeological Project and Uxbenka Archaeological Project: Report of the 2016 Field Season*, edited by Amy E. Thompson and Keith M. Prufer, 5–44.

Prufer, Keith M, Asia V Alsgaard, Mark Robinson, Clayton R Meredith, J Culleton, Timothy Dennehy, Shelby Magee, et al. 2019. "Linking Late Paleoindian Stone Tool Technologies and Populations in North , Central and South America." *PloS One* 14 (7): 1–20.

Prufer, Keith M, Clayton R Meredith, Asia Alsgaard, Timothy Dennehy, and Douglas Kennett. 2017. "The Paleoindian Chronology of Tzib'Te Yux Rockshelter

Rockshelter in the Rio Blanco Valley of Southern Belize." *Research Reports in Belizean Archaeology* 14: 321–26.

Prufer, Keith M, Mark Robinson, and Douglas J Kennett. 2020. "PRECERAMIC OCCUPATIONS OF MAYAHAK CAB PEK AND SAKI" 17: 199–208.

Puleston, Dennis E., and Olga S. Puleston. 1971. "An Ecological Approach to the Origins of Maya Civilization." *Archaeology* 24 (4): 330–37.

Ranere, Anthony J., and Richard G. Cooke. 2020a. "Late Glacial and Early Holocene Migrations, and Middle Holocene Settlement on the Lower Isthmian Land-Bridge." *Quaternary International*, no. June: 1–15. https://doi.org/10.1016/j.quaint.2020.06.002.

———. 2020b. "Late Glacial and Early Holocene Migrations, and Middle Holocene Settlement on the Lower Isthmian Land-Bridge." *Quaternary International*. https://doi.org/10.1016/j.quaint.2020.06.002.

Ranere, Anthony J, Dolores R Piperno, Irene Holst, Ruth Dickau, and José Iriarte. 2009. "The Cultural and Chronological Context of Early Holocene Maize and Squash Domestication in the Central Balsas River Valley, Mexico." *Proceedings of the National Academy of Sciences of the United States of America* 106 (13): 5014–18. https://doi.org/10.1073/pnas.0812590106.

Reimer, Paula J., William E.N. Austin, Edouard Bard, Alex Bayliss, Paul G. Blackwell, Christopher Bronk Ramsey, Martin Butzin, et al. 2020. "The IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (0-55 Cal KBP)." *Radiocarbon* 62 (4): 725–57. https://doi.org/10.1017/RDC.2020.41.

Richerson, Peter J, Robert Boyd, and Robert L Bettinger. 2001. "Was Agriculture Impossible during the Pleistocene but Mandatory during the Holocene? A Climate Change Hypothesis. ." *American Antiquity*, no. 66: 387–411.

Ridley, Harriet E. 2014. "Recent Central American and Low Latitude Climate Variability Revealed Using Speleothem-Based Rainfall Proxy Records from Southern Belize." Durham University.

Riel-Salvatore, Julien, and C. Michael Barton. 2004. "Late Pleistocene Technology, Economic Behavior, and Land-Use Dynamics in Southern Italy." *American Antiquity* 69 (2): 257–74.

Roosevelt, A. C. 2013. "The Amazon and the Anthropocene: 13,000 Years of Human Influence in a Tropical Rainforest." *Anthropocene* 4 (2013): 69–87. https://doi.org/10.1016/j.ancene.2014.05.001.

Root, Matthew J. 1992. "The Knife River Flint Quarries: The Organization of Stone Tool Production." Washington State University.

Rosenberg, Michael. 1998. "Cheating at Musical Chairs: Territoriality and Sedentism in an Evolutionary Context." *Current Anthropology* 39 (5): 653–81.

Rosenswig, Robert M. 2006. “Sedentism and Food Production in Early Complex Societies of the Soconusco, Mexico.” *World Archaeology* 38 (2): 330–55. https://doi.org/10.1080/00438240600694115.

———. 2015a. “A Mosaic of Adaptation: The Archaeological Record for Mesoamerica’s Archaic Period.” *Journal of Archaeological Research* 23 (2): 115–62. https://doi.org/10.1007/s10814-014-9080-x.

———. 2015b. “A Mosaic of Adaptation: The Archaeological Record for Mesoamerica’s Archaic Period.” *Journal of Archaeological Research* 23 (2): 115–62. https://doi.org/10.1007/s10814-014-9080-x.

Rosenswig, Robert M., Deborah M. Pearsall, Marilyn a. Masson, Brendan J. Culleton, and Douglas J. Kennett. 2014. “Archaic Period Settlement and Subsistence in the Maya Lowlands: New Starch Grain and Lithic Data from Freshwater Creek, Belize.” *Journal of Archaeological Science* 41 (January): 308–21. https://doi.org/10.1016/j.jas.2013.07.034.

Rosenswig, Robert M., Amber M. VanDerwarker, Brendan J. Culleton, and Douglas J. Kennett. 2015. “Is It Agriculture yet? Intensified Maize-Use at 1000cal BC in the Soconusco and Mesoamerica.” *Journal of Anthropological Archaeology* 40: 89–108. https://doi.org/10.1016/j.jaa.2015.06.002.

Salzmann, Ulrich, and Philipp Hoelzmann. 2005. “The Dahomey Gap: An Abrupt Climatically Induced Rain Forest Fragmentation in West Africa during the Late Holocene.” *Holocene* 15 (2): 190–99. https://doi.org/10.1191/0959683605hl799rp.

Saul, Julie Mather, Keith M. Prufer, and Frank P. Saul. 2005a. “Rockshelter Burials From the Ek Xux Valley, Belize.” In *Stone Houses and Earth Lords: Maya Religion in the Cave Context*, 297–322.

Saul, Julie Mather, Kieth M. Prufer, and Frank P. Saul. 2005b. “Nearer to the Gods: Rockshelter Burials from the Ek Xux Valley, Belize.” In *Stone Houses and Earth Lords : Maya Religion in the Cave Context*, edited by K. Prufer and J Brady, 297–322. Boulder: University of Colorado Press.

Scheffler, Timothy E., Kenneth G. Hirth, and George Hasemann. 2012. “The El Gigante Rockshelter: Preliminary Observations on an Early to Late Holocene Occupation in Southern Honduras.” *Latin American Antiquity* 23 (4): 597–610. https://doi.org/10.7183/1045-6635.23.4.597.

Scheffler, Timothy E, and Kenneth G Hirth. 2008. “The El Gigante Rock Shelter, Honduras.” *Department of Anthropology* Ph.D. (May): 446. http://ezproxy.lib.ucalgary.ca:2048/login?url=http://search.proquest.com/docview/304508951?accountid=9838%0Ahttp://sfxhosted.exlibrisgroup.com/calgary?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:dissertation&genre=dissertations+%26+theses&sid=Pro.

Shafer, Harry J., and Thomas R. Hester. 1991. "Lithic Craft Specialization and Product Distribution at the Maya Site of Colha, Belize." *World Archaeology* 23 (1): 79–97. https://doi.org/10.1080/00438243.1991.9980160.

Sherzer, Joel, James Howe, and Joel Sherzer. 1975. "Take and Tell: A Practical Classification from the San Blas Cuna." *American Ethnologist* 2 (3): 435–60.

Shott, Michael. 1986. "Technological Organization and Settlement Mobility: An Ethnographic Examination." *Journal of Anthropological Research* 42 (1): 15–51.

Shott, Michael J. 2002. "Book Review: Lews R. Binford. Constructing Frames of Reference: An Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets." *Antiquity* 76 (291): 266–68. https://doi.org/10.1177/001316447503500129.

Sidrys, Raymond V. 1983. *Archaeological Investigations in Northern Belize, Central America*. Los Angeles: Institute of Archaeology, University of California at Los Angeles.

Stahl, Peter W., and Deborah M. Pearsall. 2012. "Late Pre-Columbian Agroforestry in the Tropical Lowlands of Western Ecuador." *Quaternary International* 249: 43–52. https://doi.org/10.1016/j.quaint.2011.04.034.

Stahl, Peter W. 2000. "Archaeofaunal Accumulation , Fragmented Forests , and Anthropogenic Landscape Mosaics in the Tropical Lowlands of Prehispanic Ecuador Author (s): Peter W . Stahl Published by : Cambridge University Press Stable URL : Https://Www.Jstor.Org/Stable/972176 " 11 (3): 241–57.

Stemp, W. James. 2000. "An Analysis of Stone Tool Use in the Maya Coastal Economies of Marco Gonzalez and San Pedro, Ambergris Caye, Belize." *Dissertation*. McGill University.

Stemp, W. James, Jaime J. Awe, Keith M. Prufer, and Christophe G.B. Helmke. 2016. "Design and Function of Lowe and Sawmill Points from the Preceramic Period of Belize." *Latin American Antiquity* 27 (3): 279–99. https://doi.org/10.7183/1045-6635.27.3.279.

Stinnesbeck, Wolfgang, Julia Becker, Fabio Hering, Eberhard Frey, Arturo González González, Jens Fohlmeister, Sarah Stinnesbeck, et al. 2017. "The Earliest Settlers of Mesoamerica Date Back to the Late Pleistocene." *PLoS ONE* 12 (8): 16–18. https://doi.org/10.1371/journal.pone.0183345.

Sullivan, Alan P., and Kenneth C. Rozen. 1985. "Debitage Analysis and Archaeological Interpretation." *American Antiquity* 50 (4): 755–79.

Thompson, Jessica, and Chris Merriman. 2014. "Geoarchaeological Investigations of Alluvial Terraces along the Rio Blanco." In *Uxbenka Archaeological Project: 2013 Field Season*, edited by Keith M. Prufer, Amy E. Thompsom, and Valerie V. Aquino.

Torrence, Robin. 1983. "Time Budgeting and Hunter-Gatherer Technology." In

Pleistocene Hunters and Gatherers in Europe, edited by G. Bailey, 11–22. New York: Cambridge University Press.

Torrescano-Valle, Nuria, and Gerald A. Islebe. 2015. "Holocene Paleoecology, Climate History and Human Influence in the Southwestern Yucatan Peninsula." *Review of Palaeobotany and Palynology* 217: 1–8. https://doi.org/10.1016/j.revpalbo.2015.03.003.

Vrydaghs, Luc, and Tim Denham. 2018. "Rethinking Agriculture : Introductory Thoughts DEFINING AGRICULTURE : PERSISTENT PROBLEMS," 1–15.

Wagner, Friederike, Sjoerd J.P. Bohncke, David L. Dilcher, Wolfram M. Kürschner, Bas Van Geel, and Henk Visscher. 1999. "Century-Scale Shifts in Early Holocene Atmospheric CO2 Concentration." *Science* 284 (5422): 1971–73. https://doi.org/10.1126/science.284.5422.1971.

Wahl, David, Roger Byrne, and Lysanna Anderson. 2014. "An 8700 Year Paleoclimate Reconstruction from the Southern Maya Lowlands." *Quaternary Science Reviews* 103: 19–25. https://doi.org/10.1016/j.quascirev.2014.08.004.

Wahl, David, Richard D. Hansen, Roger Byrne, Lysanna Anderson, and Thomas Schreiner. 2016. "Holocene Climate Variability and Anthropogenic Impacts from Lago Paixban, a Perennial Wetland in Peten, Guatemala." *Global and Planetary Change* 138 (September): 70–81. https://doi.org/10.1016/j.gloplacha.2015.09.011.

Walker, M. J.C., M. Berkelhammer, S. Björck, L. C. Cwynar, D. A. Fisher, A. J. Long, J. J. Lowe, R. M. Newnham, S. O. Rasmussen, and H. Weiss. 2012. "Formal Subdivision of the Holocene Series/Epoch: A Discussion Paper by a Working Group of INTIMATE (Integration of Ice-Core, Marine and Terrestrial Records) and the Subcommission on Quaternary Stratigraphy (International Commission on Stratigraphy)." *Journal of Quaternary Science* 27 (7): 649–59. https://doi.org/10.1002/jqs.2565.

Waters, Michael R., and Thomas W. Jr. Stafford. 2007. "Redefining the Age of Clovis: Implications for the Peopling of the Americas Michael." *Science* 315 (February): 1122–26.

Wilk, Richard R. 1981. "Agriculture, Ecology and Domestic Organization among the Kekchi Maya." University of Arizona.

Will, Manuel. 2021. "The Role of Different Raw Materials in Lithic Technology and Settlement Patterns During the Middle Stone Age of Southern Africa." *African Archaeological Review* 38 (3): 477–500. https://doi.org/10.1007/s10437-021-09446-6.

Wilson, Peter J. 1991. *The Domestication of the Human Species*. New Haven: Yale University Press.

Wilson, Samuel M ., Harry B . Iceland, and Thomas R . Hester. 1998. "Preceramic Connections between Yucatan and the Caribbean." *Latin American Antiquity* 9 (4):

342–52.

Winter, Amos, Davide Zanchettin, Matthew Lachniet, Rolf Vieten, Francesco S.R. Pausata, Fredrik Charpentier Ljungqvist, Hai Cheng, et al. 2020. “Initiation of a Stable Convective Hydroclimatic Regime in Central America circa 9000 Years BP.” *Nature Communications* 11 (1): 1–8. https://doi.org/10.1038/s41467-020-14490-y.

Winterhalder, Bruce, and Douglas J. Kennett. 2006. “Behavioral Ecology and the Transition from Hunting and Gathering to Agriculture.” In *Behavioral Ecology and the Transition to Agriculture*, 1–21. Berkeley and Los Angeles, California: University of California Press. http://site.ebrary.com/lib/huntercollege/docDetail.action?docID=10110312.

Winterhalder, Bruce, and Eric Alden Smith. 2000. “Analyzing Adaptive Strategies: Human Behavioral Ecology at Twenty-Five.” *Evolutionary Anthropology* 9 (2): 51. https://doi.org/10.1002/(SICI)1520-6505(2000)9:2<51::AID-EVAN1>3.3.CO;2-Z.

Yasuoka, Hirokazu. 2013. “Dense Wild Yam Patches Established by Hunter-Gatherer Camps: Beyond the Wild Yam Question, Toward the Historical Ecology of Rainforests.” *Human Ecology* 41: 465–75. https://doi.org/10.1007/s10745-013-9574-z.

Yellen, John E. 1977. *Archaeological Approaches to the Present: Models for Reconstructing the Past*. New York: Acadamic Press.

Young, Donald, and Douglas B. Bamforth. 1990. “On the Macroscopic Identification of Used Flakes.” *American Antiquity* 55 (2): 403–9.