IF IT LOOKS LIKE A SCRAPER: AN INVESTIGATION OF A NOVEL LITHIC TOOL FORM FROM WAKA’

By

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A thesis submitted in partial fulfillment of
the requirements for the degree of

MASTER OF ARTS IN ANTHROPOLOGY

WASHINGTON STATE UNIVERSITY
Department of Anthropology

DECEMBER 2023

To the Faculty of Washington State University:

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ACKNOWLEDGMENT

I first thank the sources which provided funding for this thesis; the Bergen Excellence in Archaeology Fund, Department of Anthropology, Washington State University, (to Rachel Horowitz), the Donald E. Crabtree Award, Department of Culture, Society, and Justice, University of Idaho (to Garrett Toombs), and the Nicholas Michael Scoales Fellowship in Archaeology Award, Department of Anthropology, Washington State University (to Garrett Toombs). The members of the Proyecto Arqueológico Waka' must be acknowledged as well given that their hard work has allowed me to study these artifacts in the first place. Additional thanks to Juan Carlos Pérez, Griselda Pérez Robles, and Damaris Menéndez for their assistance in exporting the archaeological scrapers from Guatemala for analysis. I also thank the following institutions for granting permission for archaeological investigations at Waka': the Instituto Nacional de Antropología e Historia, the Ministerio de Cultura y Deportes, and the Departamento de Monumentos Prehispánicos.

Several people aided in the experiments and analyses I conducted; Cameron Blumhardt, Emily Kinney, Jordan Rumford, Sam Neunzig, Jordan Thompson, Anthony Locatelli, and Anna Coon helped in everything from photography to washing deer flesh off of stone tools, and I am grateful for their assistance. Additionally, John Blong was extremely important for guidance in my microfossil analysis and for teaching me about paleoethnobotany in general. I would also like to thank Erin Thornton, for her knowledge on the Maya and for teaching me about isotope analysis, which while it was not utilized in my thesis, I am forever grateful to her for expanding my horizons to subjects I had no familiarity with.

I owe a great deal of thanks to the Lithics Lab at the University of Idaho, and especially the flintknappers and ancient technologists Dave Quinn and Daniel Crandall. They showed genuine interest in my research, and offered feedback and assistance where they were able. They also were extremely generous with their obsidian supplies, always encouraging me to grab a bigger piece to knap. They formed a community of knappers that provided much needed respite on cold and dreary winter days on the Palouse.

I cannot thank Rachel Horowitz enough for the past two and a half years that I have been lucky enough to call her my advisor. Especially for her patience, understanding, and support of me during what became the most difficult year of my life so far. She has taught me so much about the Maya, and continued to help me in my career goals even as I realized Mesoamerican archaeology wasn’t for me. Her guidance on lithic analysis is an invaluable asset which I will carry forth for the rest of my career. I am especially thankful for her trusting me with the knapping space at WSU, my talent has grown tremendously thanks to her encouragement. I will always remember the meetings of flintknapping club which were often only comprised of the two of us.

I am thankful to be in the place I find myself now; Republic, Washington, and to have the job I do working on the Colville National Forest. This place is home to some of the most interesting, generous, and kind people I have ever had the pleasure to meet; Dan and Ann Fagerlie, Tim Dingman, Mel Cole, and Stuart Chilvers; thank you. I am grateful not only to my newfound friends, neighbors, and coworkers, but to the Forest itself. It became the perfect setting for me to finish my writing.

I owe my mental health to the support of family and old friends; Ethan Haut, Remy Clodfelter, Alyssa Walton, Alex Cohen, and Sami Jameson, who even while thousands of miles away, still found time to stay in touch. Same to my sisters; Kellyn and Brooke, who provided me with memes and photos of cute animals, and who helped me move across the country to Pullman to pursue my degree. I'd also like to thank my mother and father, who were always there for a phone call whenever I needed. A special thanks to my mother, who in addition to helping me move to Pullman, was willing to overcome her fear of mountain passes to help me move to Republic. An equally special thanks to my father, who made a spontaneous visit to Republic shortly after I settled into my cabin for a fishing trip. Even though it ended without fish and with countless mosquito bites, that visit was immensely meaningful and memorable.

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Abstract

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December 2023

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Lithic artifact functions are often determined by analysis of form alone. Artifact function can be determined through experimental archaeology, use-wear, and paleoethnobotanical analyses. Determining artifact function provides information about the types of tasks people performed, including activities involving materials which are unlikely to preserve in the archaeological record. Such data are valuable for our understanding of day-to-day activities and larger scale past economic organization. This thesis addresses the function a novel form of unifacial scraper from the Classic period (250 – 900 AD) Maya city of Waka', Guatemala.

I employed experimental replication, use-wear analysis, and paleoethnobotanical analyses to ascertain potential functions for the specific tool type. This study shows that these tools were likely intended to process soft organic materials such as maguey cacti, but in practice they were employed for a variety of tasks. Beyond investigating the function of a novel tool form, produced on chert, which is underappreciated in Maya archaeology, this thesis uses this information to comment on the nature of Classic period Maya economies. This research adds to broader ongoing reassessments of Maya economies, which are now recognized as more similar to our own economies than previously thought. I find that these scrapers were quotidian tools manufactured by specialists and exchanged through a commercial system, illustrating that Classic Maya economies were complex, multi-scalar, and commercialized.

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DEDICATION

I dedicate this work to my grandfather, H. Dean Toombs, who encouraged me to “be the best”.

To which my mother would quickly add; “the best that you can be”.

CHAPTER ONE: INTRODUCTION

Stone tool analysis has the potential to inform researchers about activities that otherwise leave no trace in the archaeological record (Aoyama and Sharpe 2022). Stone preserves better than most other forms of material culture, and so it is no wonder that the oldest known artifacts are stone tools, and that the earliest archaeologists had an interest in determining stone tool function (Andrefsky 2009; Whittaker 1994). Early attempts at determining lithic function were largely based on artifact morphology. The use of generalized terminology such as "choppers" or "handaxes" are examples of terms that are left over from this morphological approach (Shea 2014; Wilkins 2020). Making anthropological interpretations based on stone tool morphology continues to be a hotly debated topic within the field of lithic analysis (Bordes 1972; Dibble 1995; Dibble et al. 2017; McPherron 2003), but such debates are superfluous if archaeologists cannot conclude that tools were used for specific tasks. Confident interpretations of function require analyses that go beyond morphology alone.

It is now common for archaeologists to employ methods such as use-wear analysis (e.g., Aldenderfer et al. 1989; Anderson 1980; Andrefsky 2014; Aoyama 1995, 1996, 2009; Aoyama and Sharpe 2022; Chapman et al. 2015; Stemp et al. 2010, 2019; Walton 2019, 2021; Whittaker 1994:283-288), paleoethnobotanical analysis (e.g., Anderson 1980; Dussol et al. 2016; Goodale 2010; Hardy and Garufi 1998; Morell-Hart et al. 2021; Pearsall 2016; Shafer and Holloway 1979), and experimental replication (e.g., Andrefsky 2014; Bordes and Crabtree 1969; Clark and Woods 2014; Crabtree 1966, 1968; Crabtree and Butler 1964; Flenniken 1980, 1981; Flenniken and Hirth 2003; Flenniken and Raymond 1986; Titmus and Clark 2003; Whittaker 1994) to determine artifact function. This thesis adds to this conversation by applying use-wear analysis, experimental replication, and paleoethnobotanical analysis to understand the function of a particular form of flaked stone artifact. These artifacts are morphologically scrapers (Figure 1) which were recovered from the Classic period (250-900 CE) Maya city of El Perú-Waka' (Figure 2). I refer to this city by using its original name of Waka'. While these tools morphologically resemble scrapers (Whittaker 1994:27), use-wear analysis, paleoethnobotanical analysis, and experimental replication are applied to make interpretations of their functions.

Figure 1. Ventral (A) and dorsal (B) views of an artifact scraper from Waka'.

Figure 2. Map showing the Maya region, Waka’ is shown as a red star (Base map from Inomata et al. 2017, Figure 1).

Furthermore, this thesis explores not only the tasks they were used in, but also what specific materials were processed. Such information sheds light on economic activities of the

Classic period lowlands, as the tropical climate means that organic materials rarely preserve archaeologically. I suggest that these artifacts were used to process soft organic materials, with likely candidates including maguey cacti (*Agave* sp.) and manioc root (*Manihot esculenta* Crantz). However, my research shows that they were used for a variety of tasks, including processing harder materials causing significant use-wear on the edges of some of the tools.

On a larger scale, the methods outlined in this thesis can be used to advise on how to best determine the function of flaked stone artifacts. Furthermore, the results aid in interpretations of Classic period Maya economies at Waka'. Economies are embedded within and inseparable from their cultural setting, which includes material culture such as these artifacts. By studying the scrapers, I am able to make commentary on how they were valued, exchanged, and used within said economies, which in turn can aid in making big picture assessments on the nature of Classic period Maya economies in general.

Thesis Objectives

This thesis has two primary research objectives. Objective one is applying empirically based methods of stone tool analysis to determine the function of a novel tool form. Studying morphology alone makes too many assumptions and limits what can be concluded about these tools. Instead, I demonstrate the utility of employing additional means of determining tool function, namely use-wear analysis, paleoethnobotanical analysis, and experimental replication.

Objective two is to use these interpretations to gain specific insight on how these tools were used and what role they played within the economic contexts at Waka'. As I discuss in Chapter Two, Maya lithic technology has long been underappreciated by archaeologists (Braswell 2011; Clark 2003; Horowitz 2020). Additionally, archaeologists mischaracterized Maya economies as being simple, non-commercialized, and primarily limited to the exchange of prestige goods by elites and subsistence by non-elites (Masson and Freidel 2012; Masson 2020, 2021). Few studies of economy at Waka’ have been conducted (Eppich and Freidel 2015; Eppich 2020) and this thesis aims to utilize a novel tool form of an underappreciated material culture to expand what is known about Waka’s economy. By placing this tool form within its economic context, I am adding to the growing body of evidence that Maya economies were complex, commercialized, and multi-scalar.

Thesis Format

This thesis is organized into seven chapters, Chapter One introduces the scrapers in question, states the two research objectives, and outlines the remainder of the thesis.

Chapter Two provides background on the Maya region, including the climate, culture-history, and economic organization. I then explore the role that Waka’ played in the political history of the region, and review what is known about the economy at Waka’. The Classic period Maya existed within a complex web of political alliances and rivalries, making the contextualization of Waka’s position key to understanding the history of the site.

Chapter Three discusses the lithic technology of Mesoamerica to demonstrate that lithics were essential to all members of precontact Mesoamerican societies. Common tool forms in the region are discussed, as well as less common tool forms such as the scrapers from Waka’. This chapter discusses the context in which the scrapers were found and introduces possible functions. This discussion is accompanied by a review of common methods for determining stone tool function and how each method is relevant to this study.

Chapter Four reviews the methods I used to investigate the tools. Paleoethnobotanical analysis included the creation of a reference collection, sampling the artifacts, and analysis of diagnostic microfossils. Then I review the experimental replication methods. The manufacture and use of the replica tools is detailed, such as the material types tested, the use of controls, and the manner of their use. Lastly, I describe the process used to examine the experimental and artifact use-wear under digital microscope.

Chapter Five details the results of the analyses. For paleoethnobotanical analysis, this means reviewing the observed microfossils. Many microscopic remains were observed, but only a single diagnostic starch grain, belonging to manioc, was identified. I tentatively identified other starch grains as maize (*Zea mays*) and grains which are characteristic of arrowroot (*Maranta* sp.) as well. As for the replication and use-wear analysis, qualitative data are presented on the efficacy of the replica tools for each task and edge modification are provided. I found that the replica tools were effective for processing most of the soft organic materials tested, save for wood, and that they sustained minimal edge damage. Meanwhile, the artifacts showed some key use-wear differences from the replica use-wear, including two artifacts with extensive use-wear which indicated their use in processing harder materials than those tested.

Chapter Six reviews these data and evaluates potential functions. I was unable to conclusively point to a single task for which these tools were used, but I ruled out several hypothetical tasks such as woodworking and hide scraping. My results indicate that the tools were used to process a variety of materials, but they probably were intended to process some sort of soft organic material. Soft organics such as maguey or manioc are both viable options, and I lean towards the maguey scraping hypothesis. This information is used to evaluate the role that these tools played in Classic period Maya economies at Waka', including discussion of how they were exchanged and valued.

Chapter Seven synthesizes this study, concluding that the tools were multifunctional, but were designed to process soft organics. I then contextualize the tools within Waka's economy. I argue that they served as quotidian implements for household tasks and that their use was not restricted to any particular social class. Furthermore, I contend that these tools were made by specialists and exchanged within Waka's commercial economy as commodities.

Summary

I close this chapter by returning to my two primary research aims. First, this study adds to the conversation on how to determine the function of stone tools by demonstrating the need for multiple lines of evidence aside from morphology alone to make conclusions. Analysis of these tools provides a means of investigating economic activities that do not preserve in the archaeological record of the Maya lowlands. Second, it calls attention to a long-understudied form of material culture within the Maya region, and uses information gained about this novel tool form to contribute to the ongoing reassessment of Maya economies.

CHAPTER TWO: THE MAYA REGION AND WAKA'

In this chapter, I introduce the scraper's culture-historical setting. This chapter includes an overview of the Maya region with a focus on the Classic period (250-900 CE) Maya lowlands climate, history, politics, and economies. I then describe the city of Waka' during the Classic period to provide context on the city's role in regional history. The chapter closes with an overview of economies at Waka', which are crucial for understanding the value, production, circulation, and use of the chert scrapers.

Geography and Climate of the Maya Region

The Classic period Maya inhabited what is today southern Mexico and northern Central America, consisting of the modern nation states of Mexico, Belize, Guatemala, El Salvador, and Honduras (Figure 2). The broader geographic region, which includes central Mexico and northern Central America, is referred to as Mesoamerica and is often studied within archaeology as such, as many of its inhabitants share cultural traditions. The Maya region contains two main environmental zones, the tierras altas (highlands) and the tierras bajas (lowlands). The highlands are located at 800 meters or greater above sea level. They are characterized by a rough topography of mountains and valleys and are rich in valuable mineral resources such as obsidian, basalt, jade, and pyrite, among others. Rainfall varies greatly from below 1000 mm to 3000 mm annually and is largely influenced by altitude. The area is home to numerous active volcanoes, providing volcanic minerals and fertile land for agriculture at the cost of catastrophic eruptions (Houston and Inomata 2009:10; Sharer and Traxler 2006:34-39).

Figure 3. Map showing the location of Waka' in the Maya lowlands (map by D. Marken).

The Maya lowlands comprise sections of Guatemala, Belize, and parts of the modern-day Mexican states of Tabasco, Campeche, Quintana Roo, Chiapas, and Yucatán, as well as parts of Honduras and El Salvador (Houston and Inomata 2009:4-10). The lowlands are defined as areas below 800 meters in elevation. Karstic limestone forms a nearly ubiquitous bedrock across the region that contains numerous caves. Rain and waterflow play a significant role in shaping the landscape. The water forms cenotes; holes in the limestone karst which are more common in Yucatán, and bajos; low-lying areas that are often filled with water, which are more common in the Peten. Average temperatures range to between 25-28°C, with climate varying from subtropical to near temperate depending on altitude and rainfall (Leyden et al. 2002:86).

Early researchers mistakenly characterized the lowlands as resource poor in every regard when contrasted with the highlands (Rathje 1972). The perception that the lowland jungles were resource poor was in large part due to biases held by Euro-American researchers who had little emic knowledge of the jungles, and who were accustomed to temperate climates (Masson 2021). This perceived disparity was crucial to early models of the development of hierarchical societies in the region (Rathje 1972). Early scholars suggested that trade brought on by resource scarcity was a key driver of the rise of political inequality and social hierarchy. It was believed that sustaining large, sedentary populations required the organization of trade to acquire non-local resources facilitating the urban centers, monumentality, and social inequality present in the Classic period lowlands (Mason 2021:109; Meggers 1954).

However, the lowlands are in fact not resource poor. They may lack the mineral resources found in the highlands, but the region displays remarkable biodiversity in terms of flora and fauna found throughout the tropical jungle. This includes terrestrial species that were valued as food sources such as deer, peccaries, and tapirs and aquatic food sources such as jute (*Pachychilus* snails), catfish, turtles, and crayfish. Jaguar skins and tropical bird feathers found in the lowlands were important to Maya ritual and were widely traded. Plants such as avocado trees, cacao, and vanilla vines were harvested for consumption, while multiple other plant species provided valuable materials such as rubber, dye, cacao, and construction materials (Sharer and Traxler 2006:41-46).

The Maya extensively altered their environment to make it suitable for sustaining large sedentary populations (Canuto et al. 2018; Garrison et al. 2019; Šprajc et al. 2021). Studies reveal vast networks of water management and agricultural systems that contributed to highly productive maize-centered agriculture. Maize was key to the Maya diet, but crops such as chili peppers, beans, squash, and manioc were also important cultivars (Wyatt 2002).

Lastly, the lowland bedrock is a nearly ubiquitous limestone which was important for making mortar and plaster and contains chert for stone tools (Houston and Inomata 2009:9; Sharer and Traxler 2006:41-45). The most significant resource difference between the lowlands and highlands was that of lithic toolstone, such as obsidian and granite. This difference meant that trade between the two regions was frequent and a key component of Maya economies.

Culture-History

Maya culture-history is typically divided into several distinct periods (Table 1). This thesis focuses on the Classic period (250-900 CE) in the lowlands. The earliest evidence for human occupation in the lowlands dates to the Terminal Pleistocene, but the exact timing is poorly understood (Lohse et al. 2006; Lohse 2010; Lohse et al. 2021; Prufer et al. 2021; Stemp and Rosenswig 2022). The continuous habitation of the same localities for thousands of years has made it very difficult to study the earliest human occupants of this region, because of frequent reconstruction in those same localities.

Table 1. A general culture-history chronology for the Maya region. *The exact date for human arrival in Mesoamerica is still debated, this date should be taken to mean human occupation by at least this time (Adapted from Sharer and Traxler 2006:98).

Period	Dates	Major Cultural Developments
Paleoindian	12,000* - 8,000 BCE	First people in Mesoamerica
Archaic	8,000 - 2,000 BCE	Sedentary communities and agriculture
Early Preclassic	2,000 - 1,000 BCE	Initial evidence of social inequality
Middle Preclassic	1,000 - 400 BCE	Growth in social inequality
Late Preclassic	400 BCE - 100 CE	Initial states
Terminal Preclassic	100 - 250 CE	Transformation of initial states
Early Classic	250 - 600 CE	Expansion of lowland states
Late Classic	600 - 800 CE	Apogee of lowland states
Terminal Classic	800 - 900/1100 CE	Decline and transformation of states
Postclassic	900/1100 CE - European Contact	Reformulation and revival of states
Colonial period	Post Contact	Intrusion of Europeans into Maya region

Regardless of when humans entered the region, they lived as highly mobile foragers until around 2000-1000 BCE. Over the course of the Preclassic period (2000 BCE-250 CE) there was a shift from foraging, egalitarian societies to agricultural, sedentary, and hierarchical societies. One way this can be seen is in the appearance of large-scale environmental modifications. The Preclassic Maya built E-groups, which are ceremonial complexes consisting of two pyramidal structures which track the rising and setting of the sun on equinoxes and solstices (Chase and Chase 2012). They also began building infrastructure to make the terrain more suitable for agriculture, as seen in changes in pollen frequencies from lake cores (Leyden et al. 2002). Researchers have found evidence of other environmental modifications in the form of anthropogenic soils from urban development and agriculture dating back to at least 1000 BCE (Beach et al. 2006; Beach et al. 2018). Studies such as these illustrate that the Maya lowlands were well populated long before the Classic period.

One of the key shifts during the Preclassic period is the rise of an elite class with political power, which can be seen through increasing monumental construction and long-distance trade. New research illustrates the early beginnings of monumental construction, as seen at the sites of Aguada Fénix (1000-800 BCE; Inomata et al. 2020) and Ceibal (950 BCE; Inomata et al. 2015). Ceibal was built by relatively mobile people, demonstrating the gradual shifts in subsistence activities in the region (Inomata et al. 2015). The influence of the elite class can also be seen through their participation in long-distance trade for goods such as obsidian, cacao, and jade (Sharer and Traxler 2006:220). The Preclassic period also marks the emergence of states and divine kingship (Saturno et al. 2005).

These trends of increasing elite centralization and monumental construction continued and increased in scale during the Classic period (250-900 CE; Chase and Chase 2012:261-262;

Sharer and Traxler 2006). Numerous population centers emerged and engaged in a complex network of trade, diplomacy, and conflict. These population centers were supported primarily by maize agriculture and varied in population density. According to recent lidar surveys, Tikal, one of the largest and densest cities in the lowlands, is estimated to have been home to more than 38,000 people within 147 km^2. Such a density was only possible due to significant land modification for intensive agriculture. However, density varied between cities, for example, La Corona was estimated to be home to over 40,000 people across 432 km^2 (Canuto et al. 2018).

As a result of population growth and increased elite power, conflict became a hallmark of the Classic Period, with Tikal and Calakmul representing the two most powerful rival city states of the Late Classic period. Tikal was the older and more established power from the Early Classic, but its authority was challenged by the rise of the *Kaanul,* or Snake, dynasty towards the end of the Early Classic and into the Late Classic. The city of Dzibanche was originally home to the *Kaanul* dynasty, but their seat of power shifted to Calakmul in the 400's CE. The balance of power between the two rivals and their alliance networks ebbed back and forth during the Classic Period in a series of armed conflicts (Martin and Grube 2008; Martin 2020; Sharer and Traxler 2006:357-359, 495-497). Conquest in the Maya lowlands rarely resulted in the complete destruction or subjugation of the defeated, instead, Tikal and Calakmul both employed indirect rule often via marriage (Navarro-Farr and Eppich et al. 2020; Navarro-Farr and Kelly et al. 2020; Navarro-Farr and Robles et al. 2021; Patterson and Freiwald 2015). The inability of any single polity to establish a larger empire in the lowlands likely reflected political realities that these states encountered in projecting military power across a large and densely populated region (Sharer and Traxler 2006:496).

One of the defining events of the Classic period is the arrival of the enigmatic individual Sihyaj K'hak' in 378 CE. This event, known as La Entrada, resulted in the installation of Yax Nuun Ahiin as the ruler of Tikal shortly after the death of the previous ruler, Chak Tok Ich'aak. The exact nature Chak Tok Ich'aak's death and the origin of the Yax Nuun Ahiin are unclear, but there is a connection to the powerful Central Mexican polity of Teotihuacan (Canuto et al. 2020; Houston and Inomata 2009:106; Martin and Grube 2008; Martin 2020). Some have theorized that Yax Nuun Ahiin's father, "Spearthrower Owl," sent Sihyaj K'hak' to install his son as the ruler of Tikal. The presence of non-local goods suggests that the Maya had contact with Central Mexico before this date (Houston and Inomata 2009:107), and it is still uncertain if this event represents diplomacy or subjugation (Estrada-Belli et al. 2009). However, it is clear that the Maya existed in a complex political world with inter-regional interaction with contemporaneous Mesoamerican states with whom they shared not only cultural similarities, but direct contact and political intrigue as well. Waka' was the first of many cities to be visited by Sihyaj K'hak' (Canuto et al. 2020; Guenter 2014), and it served as the starting point for this important shift in Classic period Maya history.

The Classic Period ends with what is frequently referred to as a "collapse" of Maya civilization. This is seen by the cessation of most large-scale monumental construction and the abandonment of many urban centers in the central and southern lowlands with a corresponding shift in population to the northern lowlands. The exact cause of this "collapse" is still uncertain but many of the leading explanations include some element of climate change, namely drought. However, it is probable that several factors contributed to this dramatic pivot in Maya culture-history, including political unrest, warfare, and economic destabilization (Douglas et al. 2016). Other researchers (e.g., Aimers 2007) challenge the use of the term "collapse", and while recognizing that there were fundamental changes to the nature of central and southern lowland Classic Maya societies, emphasize the continuity in occupation that existed in other parts of the Maya region, particularly the northern lowlands (Aimers 2007).

Classic Period Economic Dynamics

The nature of precontact Maya economies continues to be a long-debated topic amongst Maya archaeologists. Returning to Rathje's (1972) explanation of precontact Maya economies, the role of elite organizers participating in the long-distance trade economy for goods like salt, obsidian, and ground stone, was originally given primacy and defined as "extra market" while locally based market interactions between households were considered non-existent (Rathje 1972:368-369). The recognition of the complex market economies that are now known to have existed in the Maya lowlands was in part constricted by existing conceptualizations of ancient economies. These conceptualizations were largely informed by the work of Polanyi and his contemporaries in the classic formalist vs. substantivist debate within economic anthropology (see Halperin 1994; Polanyi 1957; Smith 2004; Wilk and Cliggett 2007:3-13).

A full summary of this debate is not necessary for this thesis, but I will briefly discuss the difference between the two camps on the issue of ancient economies. Formalists argued for a universalist approach to understanding economies ancient and modern, with the same concepts being applied in both cases (Smith 2004:75).

Substantivists argued for a relativist approach to understanding economies. They believed that the seemingly complex market economies of the West were fundamentally different from ancient and non-Western economies. They argued that economies should be studied within their cultural context, as they were embedded within other aspects of society. Substantivists considered non-Western economies to exclusively rely on mechanisms of exchange other than commerce such as barter, redistribution, or self-provisioning (Hirth 1996; Smith 2004). The arguments of the substantivists contributed to many early mischaracterizations of Maya economies, namely the assertion that past economies could not reflect present day commercialized economies. Formalist arguments also contributed to mischaracterizations of ancient economies in general, mainly by their failure to recognize the embedded nature of economies within their cultural context (Halperin 1994; Hirth 1996; Polanyi 1957; Smith 2004; Wilk and Cliggett 2007). Recent approaches to Maya economies reconsider the role of these perspectives, and I discuss these shifts in perspective on Maya economies below.

More recent analyses critiqued early assumptions that the precontact Maya lacked commercialized market economies for several reasons. The first major critique is that one of the foundational assumptions made by early Maya researchers; the characterization of the lowlands as being inhospitable, is faulty. Instead, contemporary research emphasizes Maya infrastructure and environmental modification made to suit their needs (Canuto et al. 2018); the Maya were not doomed from the start as Meggers (1954) argued (Masson 2021).

Second, the primacy of elite engagement and participation in economies was challenged, and the importance of examining household level economic activities gained traction (Masson 2020, 2021; Masson and Freidel 2012; Robin 2013). Earlier researchers assumed that elites participated in an exclusive, closed-circuit economy based on the exchange of non-local goods which excluded commoners (Masson 2021:111-112). Meanwhile, commoners were either self-provisioning (Masson 2021:112) or beholden to elite acquisition of non-local goods (Rathje 1972).

It is now recognized that both elites and commoners across the Maya region and Mesoamerica in general engaged in crafting activities for exchange. Commoners engaged in full-time and part-time craft specialization (Horowitz 2021; Masson et al. 2020), the products of which were often intended for use within households, but there is also evidence for exchange beyond their own household (Brumfiel and Nichols 2009; Horowitz 2018, 2022b; Horowitz et al. 2022; Masson and Freidel 2012). Meanwhile, elite crafting was often centered around reinforcing authority, and producing goods used in royal rituals (Aoyama 2009; Sharpe and Aoyama 2022). Elites and commoners made and exchanged goods and participated in some of the same economic settings instead of being confined to separate spheres as earlier researchers suggested.

Finally, the existence of market exchange and marketplaces has been documented (Cap 2021; Masson 2021; Masson and Freidel 2012). Archaeological studies of Terminal Classic and Postclassic period sites and ethnographic observations of Maya markets by early European explorers suggested the existence of commercial exchange and marketplaces, but earlier scholars argued markets developed after the Classic period (Masson 2021; Masson and Freidel 2012). The origins of the institutions observed by Europeans at contact are now known to be much older, dating to at least the Classic Period, and potentially earlier. Market economies tied together consumers and producers of varying status across the lowlands, with marketplaces located in regional centers providing a physical space for market exchange to occur (Cap 2020, 2021; Masson 2020; Masson and Freidel 2012).

Research in the Mopan River Valley at Xunantunich and Buenavista del Cayo illustrate the complex interdependencies of Classic period Maya producers and consumers and the central role that marketplaces played in that integration (Cap 2020, 2021; Yaeger 2010). Marketplaces served as a tethering point between the city and its hinterlands, allowing producers to bring their goods to consumers to be sold. At Xunantunich, household goods like ceramic vessels and chert tools were two of the most commonly exchanged goods, which can be easily identified in the archaeological record (Cap 2021; Yaeger 2010:174). Furthermore, these exchanges were organized without the explicit oversight from elites wherein consumers acquired goods, such as chert tools, directly from producers at marketplaces (VandenBosch et al 2010:292, Yaeger 2010:187).

It was once thought that elites exercised total control over long distance trade for goods like obsidian, ground stone, and salt (Rathje 1972). Researchers now recognize that while the elite participation in long-distance trade was significant to Maya economies, it existed alongside local market exchange (Masson 2020, 2021; Masson and Freidel 2012). Elites and commoners engaged in market exchange in the same spaces, and elite participation in the market economy was a means of state building and legitimizing their authority (Cap 2021:173). The Maya engaged in a complex system of multi-scalar economies throughout the lowlands during the Classic period. I now shift attention to Waka'; one of many population centers participating in this system.

Waka'

Waka' is located in the southern Maya lowlands in the present-day department of Petén in Guatemala (Figure 3). The site was identified by oil workers in the 1960's (Navarro-Farr and Rich 2014:4) and given the name El Perú. Later investigations and epigraphy would reveal its original name; Waka', meaning "centipede water" (Guenter 2014:149). Looting of the site began in the 1960s, followed by archaeological investigations in 1970 (Navarro-Farr and Rich 2014:6). Today, the site is referred to as El-Perú, Waka', and El Perú-Waka', but I use the original name of Waka'.

Waka’ is located on a limestone escarpment that rises over 100 meters out of the jungle, providing a defensible position and a commanding view of area (Navarro-Farr and Rich 2014:4-9). Its proximity to the San Juan and San Pedro Mártir rivers, which are navigable and were frequently used for trade, made Waka’ a vital trade and communication hub. East-west routes along the rivers connected the Maya region with central Mexico, meanwhile, the “Great Western Route,” overland trails which ran by the city, connected the southern lowlands with the northern highlands (Eppich 2020:157-158). Because of these trade routes, the site was crucial to political and economic management of the Maya region. Tikal and Calakmul jockeyed for control and influence over the city for centuries (Freidel and Escobedo 2014:21).

Waka’ would be victim, or accomplice, to the political machinations of both Tikal and Calakmul at different times throughout the Classic period. Indirect rule was common; elite individuals from foreign households were placed in control of Waka’ to enforce the will of the foreign family. Lady Kabel is the most well recorded example of this at Waka’, she was a member of the foreign *Kaanul* dynasty who was married to the Wakeño king to represent the interests of the *Kaanul* dynasty abroad during the Late Classic (Navarro-Farr and Eppich et al. 2020; Navarro-Farr and Kelly et al. 2020; Navarro-Farr and Robles et al. 2021; Patterson and Freiwald 2015).

Waka’ was a densely packed urban center (Figure 4), with a density of 45 structures per km^2 across the entire site. However, the urban core of Waka’ is far denser, at 1100 structures per km^2. To provide a sense of scale, the entire site of Tikal has a density of 147 per km^2; the density of the Waka’ core is nearly double that of Tikal’s, which makes the Waka’ urban core one of the most densely populated in the Maya region (Canuto et al. 2018; Marken 2015; Marken et al. 2019; Marken et al. 2022; Thompson et al. 2022; Tsesmeli 2014). Like other urban centers, Waka' contains a civic-ceremonial core, home to a palace, temples, four plazas, water management features, elite residences, and other public spaces, within an area of 0.62 km^2. Around the site core, Waka' has a near-periphery and a far-periphery, reflecting the density of the settlement around the site core, and the presumed integration of these individuals into the site (Canuto et al. 2018; Marken 2015).

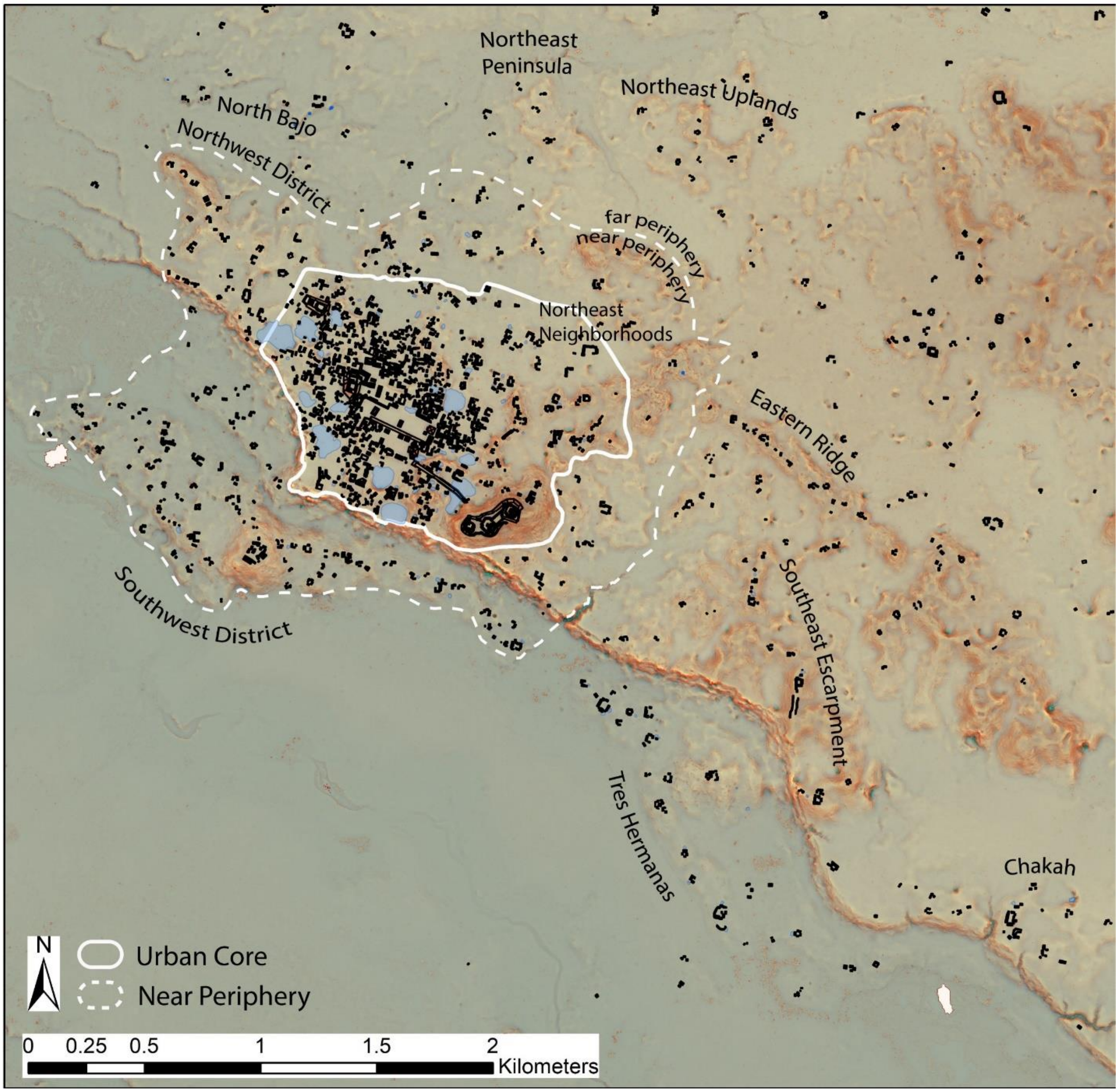

Figure 4. Site map of Waka' showing the density of settlement (Map by D. Marken).

The urban core is situated on the top of the limestone escarpment, containing monuments and public spaces which were intentionally placed on rises to be highly visible on the landscape, likely to reinforce power dynamics (Tsesmeli 2014). The near periphery is defined by a less constrained but still dense array of residences. Excavations of middens from this zone suggest that its inhabitants had less access to prestige goods than residents of the urban core (Marken 2015:134-138). Lastly, the far-periphery exhibits the most dispersed settlement, although it is still home to a few nucleated neighborhoods (Horowitz et al. 2022; Marken 2015:139-141).

Political History of Waka'

Waka' shifted political alliances between Tikal and Calakmul several times in its history, often due to military defeats at the hands of the rival alliance. Many stela and other carved stone monuments bearing artwork and glyphs have been found at Waka', which sometimes describe this complex political alliance network. While such inscriptions are almost exclusively focused on the elites (Navarro-Farr and Kelly et al. 2020:40), they have been crucial for providing historical context for Waka' and its place in regional history. The site has been inhabited since at least the Late Preclassic period (400 BCE-100 CE), while the oldest recovered stela, Stela 15, was erected in 416 CE, well into the Classic period (Guenter 2014:150).

Stela 15 provides a record of Waka's role in La Entrada in 378 CE; it was the first Maya city visited by Sihyaj K'hak'. This event dates to a few days before Sihyaj K'hak's arrival at Tikal. The stela suggests a connection between the foreign Teotihuacano and the Wakeño ruler K'inich Bahlam I. Researchers believe that K'inich Bahlam I was also installed by Sihyaj K'hak' based on later stela depicting Wakeño lords dressed in Teotihuacan style. Waka' was allied with Tikal at this time, and given the regime change at Tikal shortly after Sihyaj K'hak's arrival there, it is probable that Waka' experienced a similar shift in power (Canuto et al. 2020; Guenter

2014:150-152, Martin 2020). New evidence at the site provides further evidence for the role of La Entrada in the site's history and is still being analyzed at this time (Rachel Horowitz, personal communication 2023).

Later in the Classic period, Waka' would be an important ally of the *Kaanul* dynasty based at Calakmul, with the Calakmul-led alliance defeating Tikal militarily in the early part of the Late Classic period. These political connections to Calakmul can be seen archaeologically by the presence of material culture such as Late Classic Palmar Orange polychrome ceramics in elite tombs at Waka' (Navarro-Farr et al. 2021). Tikal reemerged as the dominant power under the rule of Jasaw Chan K'awiil I, who lead a major military victory over Calakmul in 695 CE (Sharer and Traxler 2006:390-400). His heir, Yik'in Chan K'awiil, would again defeat Calakmul in 736 CE, then defeating Calakmul's closest allies, Waka' and Naranjo in 743 and 744 CE respectively (Sharer and Traxler 2006:400). Waka's defeat in 743 CE was substantial enough for it to be dramatically recorded on the innermost wooden lintel in Tikal's largest temple, which reports on the capture of one of Waka's patron deities. Despite the seemingly catastrophic loss at the hands of Tikal, monumental construction resumes at Waka' within 20 years (Guenter 2014:159-160). This later construction continues to venerate Waka's connection to the *Kaanul* rulers, the tombs of *Kaanul* dynasty queens were revisited and modified with the intention of enshrining their legacy (Navarro-Farr et al. 2020).

The conflict between Calakmul and Tikal during the end of the Early and into the Late Classic periods was not just political-economic, but also ideological. Calakmul and its allies frequently depict female elites on monuments, while Tikal's monuments only contain males. Waka' had influential female rulers, namely Lady K'abel, a member of the *Kaanul* dynasty, the royal family which was centered at Calakmul at the time (Patterson and Freiwald 2015). Lady

K’abel is often depicted as a warrior queen, and given the title *Ix Kaloomte’*, indicating she held higher status than her husband, K’inich Bahlam II (Guenter 2014:156; Navarro-Farr and Eppich et al. 2020; Navarro-Farr and Robles et al. 2020; Navarro-Farr and Robles et al. 2021). Lady K’abel’s status suggests that she, and other *Kaanul* women, were entrusted with representing and enforcing the interests of the *Kaanul* dynasty abroad. Placing *Kaanul* women in elite positions at foreign cities was a form of indirect political control that the rulers of Calakmul, as well as other elite rulers, could exercise as complete subjugation was impractical (Navarro-Farr and Eppich et al. 2020; Navarro-Farr and Kelly et al. 2020; Navarro-Farr and Pérez Robles et al. 2020; Sharer and Traxler 2006:496-497).

The epigraphic record at Waka’ ends in the late 700 or early 800’s CE; there are no legible texts after this time, but there are pseudo-glyphs dating to the Terminal Classic period. There is also evidence of tombs being re-entered and monuments being moved from their original place during the Terminal Classic period, meaning that there were at least a few inhabitants left in the city (Navarro-Farr et al. 2008; Guenter 2014:163-164). Waka’ was one of the many urban centers to be depopulated and abandoned as part of the Classic period Maya “collapse” towards the end of the first millennia CE. However, the archaeological record continues, with the remaining residents consolidating in the urban core and continuing to repurpose and move old monuments. Evidence of continued use from structure M13-1, an important ritual center at Waka’, has been interpreted as a form of reverence and remembrance for ancestors and earlier divine kings. Terminal Classic residents of Waka’ were recalling times which were less stressful than the present, venerating the rulers they had in the Classic period (Navarro-Farr et al. 2008; Navarro-Farr et al. 2016)

Classic period Economies at Waka’

The economies operating within Waka' were complex, including multiple scales of production and forms of exchange. Research from the Tres Hermanas district at Waka' demonstrates that non-elite households practiced multicrafting of materials like shell and textiles, possibly of maguey fiber, using stone tools manufactured by specialists from outside the district (Horowitz et al. 2022). The presence of non-local tools being used to make multiple crafted items illustrates the complex integration of multiple scales of production at the site.

I begin by defining value; Graeber (2001) describes three ways of talking about value. The one of most concern for discussing the value of scrapers at Waka' is "value" in an economic sense, (Graeber 2001:1), which is "the degree to which objects are desired, particularly, as measured by how much others are willing to give up to get them" (Graeber 2001:1). Kopytoff (1986) and Appadurai (1986) utilize the concept of commodities to discuss economic value. For Kopytoff, a commodity is "a thing that has use value and that can be exchanged in a discrete transaction for a counterpart" (1986:68). To Appadurai, a commodity is simply "anything intended for exchange" (1986:9). Objects can then be split into commodities or inalienable possessions; those objects which have "subjective value that place(s) them above exchange value" (Weiner 1992:6). However, objects are not inherently one or the other, and they can shift from being commodities to inalienable possessions throughout their life histories depending on how they were exchanged (Appadurai 1986; Kopytoff 1986; Millhauser and Overholtzer 2020:3-4; Yaeger 2010:168). Thus, to make commentary on value, exchange mechanisms must be considered.

The precontact Maya had commercial exchange systems that were often, but not always, centered at formal, physical marketplaces, and such marketplaces likely existed at Waka' (Eppich 2020:150). Current research shows that commercial exchange existed within Classic Maya urban centers, but the work of Eppich and Freidel (2015; Eppich 2020) argues that it was not the only exchange mechanism that existed at Waka', as multiple forms of exchange exist in all societies.

Detecting specific exchange mechanisms from archaeological data has been challenging for researchers, especially as physical marketplaces often do not leave easily recognizable archaeological traces (Cap 2021). However, Hirth (1998) suggests the use of the "distributional approach" as a means of detecting commercial exchange vs. redistribution in the archaeological record. Hirth suggests that households in a market system should have similar material culture, reflecting equal access to material (Hirth 1998:456). Meanwhile, households participating in a redistributive economy should have increased heterogeneity as that the distribution of material culture will reflect existing social hierarchies (Hirth 1998:455).

Eppich and Freidel (2015) adapted Hirth's (1998) distributional approach to a study of ceramic distribution at Waka'. From their analyses, they suggest the presence of commercial exchange at Waka', but also of other distribution networks. Furthermore, different ceramic types were exchanged through different mechanisms, such as polychrome vessels exchanged through prestige gift giving (Eppich and Freidel 2015:215). Eppich (2020) discusses commercial exchange at Waka', but suggests its' use fluctuated due to political upheaval, especially during the Late Classic. Here, systems of autarky and barter take the place of commerce when faith in marketplace institutions to provision participants broke down (Eppich 2020:168-170).

Lastly, having shown there were several exchange mechanisms through which commodities changed hands at Waka', I discuss a final mechanism through which non-commodities, or inalienable goods (Weiner 1992) were exchanged; the ritual economy. Ritual economy, the "process of provisioning and consuming that materializes and substantiates worldview for managing meaning and shaping interpretation" (McAnany and Wells 2008:1), seeks to recognize that economy is embedded in all aspects of human culture, including spirituality.

Studies of the ritual economy at Waka’ found that a variety of items including animals, plant foods, and lithics were used in the ritual economy (Cagnato 2016; Fridberg 2015; Hruby and Rich 2014). Many plant species used in ritual at Waka’ include quotidian foods such as maize, beans, squash, manioc, and chili peppers, but also ritually specific plant products such as copal (Cagnato 2016). The same can be said for animals, deer and turtle were commonly eaten as quotidian foods but also found in ritual contexts (Fridberg 2015). Meanwhile, quotidian lithics like chert bifacial thinning flakes have ritual significance when placed en masse above burials at Waka’ (Hruby and Rich 2014, see also Horowitz et al. 2020). These studies provide examples in which objects that might be considered quotidian commodities become inalienable goods (Weiner 1992) depending on their social context.

Economies at Waka’ were complex, but they were like any other economies in any other society. They were embedded within broader social context, including supernatural contexts, and participation in any given economy ebbs and flows in response to changes in society at large. Considering context is key to making interpretations on the place that these scrapers held in Waka’s economy, including their value, which I address in Chapter Six.

Summary

This chapter provided a broad overview of the Classic Maya lowlands’ climate, politics, and economies with focus on the site of Waka’. Context is key to understanding any archaeological data, and in this case setting the stage for how the Classic period Maya world operated, especially regarding economic exchange, is crucial to interpretating the place held by chert scrapers in Waka’s economy. Such interpretations involve anthropological approaches to value as well, which I have introduced here and will utilize more fully in Chapter Six. Now that broader context has been provided, focus shifts to lithic technology.

CHAPTER THREE: MESOAMERICAN LITHIC TECHNOLOGY AND SCRAPERS FROM WAKA'

In this section, I explore the history of lithic analysis in Mesoamerica with a focus on the Maya region. I provide a brief overview of the types of lithic resources and technologies that were made and used in the Maya lowlands. Lithic studies in Mesoamerica have long been underappreciated by archaeologists (Braswell 2011; Clark 2003; Horowitz 2020) despite stone being a critical resource to Maya lifeways, the abundance of lithic remains found by Maya archaeologists, and the skill demonstrated by Maya knappers. Lithic analysis can contribute to our understanding of the Classic period Maya from quotidian activities (Aldenderfer et al. 1989; Stemp 2004; Stemp et al. 2010) to the most sacred of elite rituals (Agurcia et al. 2016; Hruby and Rich 2014). Next, I summarize and scrutinize some of the ways archaeologists have investigated stone tool function: morphology, ethnoarchaeology, experimental replication and use-wear analysis, and paleoethnobotany. I then introduce and describe the artifact scrapers and their contexts. This chapter closes with an assessment of how these approaches might be useful for determining the function of the artifact scrapers from Waka'.

Lithic Studies in The Maya Region

The lack of interest in the study of Maya lithics is in part due to a general aversion of archaeologists studying sedentary societies to focus on lithics, tools which are instead seen as belonging to the realm archaeologists studying mobile foragers (Horowitz and McCall 2019). Much of the theoretical framework for lithic studies was born out of ethnographic and forager studies (Binford 1977, 1978, 1979; McCall 2012), which focused on issues that were not at the forefront of studies of sedentary groups, such as the impacts that seasonal mobility has on tool form.

Maya and Mesoamerican archaeologists as a whole took considerable time to recognize lithic technology as being worthy of study (Braswell 2011; Clark 2003; Horowitz 2020; Horowitz and McCall 2019). Mesoamerican archaeologists' aversion to lithics resulted in a failure to apply effective theoretical frameworks for interpretation. Theory for understanding Mesoamerican lithic technology fell behind that of other artifact types, such as ceramics. Even in recent decades, Mesoamerican lithicists have remarked upon the lack of suitable theoretical frameworks. For example, Clark's (2003) review of Mesoamerican obsidian studies states, "For the most part the simple pattern noted here indicates that Mesoamerican flaked stone studies are parochial and, to a large extent, generally atheoretical" (Clark 2003:43).

The New Archaeology of the 1970's made significant inroads in theoretical approaches on lithic analysis of foraging societies (Binford 1977, 1978, 1979). The standard for Maya lithicists at the time was the index fossil approach (Whittaker 1994:261), using specific lithic forms as chronological markers (Barrett 2011:58; Braswell 2011; Wauchope 1975). Braswell (2011) termed this period, before the first Maya Lithic Conference in 1976, "The Appendix Stage", in which data on lithics were relegated to publication appendices. Major change came after this conference, in what Braswell terms "The Cartographic Stage". Maya archaeologists sought to expand what was known about Maya lithic technology through techniques such as geochemical sourcing, experimental replication, and the use of the chaîne opératoire framework.

Braswell (2011) terms the period after the Second Maya Lithic Conference in 1982 "The Behavioral Stage," where production and exchange continued to be major research themes, utilizing concepts from Behavioral Archaeology. Investigations of lithic procurement, consumption, discard, and ethnoarchaeology were central to this stage (Braswell 2011). Braswell terms the final, and present, stage of Maya lithic studies "The Technology Stage" which he suggests begins after the Third Maya Lithic Conference in 2007. In this stage, concepts from Postprocessual archaeology mixed with Processualist themes, and actor-network theory was incorporated into Maya lithic studies (Braswell 2011:4-7; Hruby et. al 2011). Many of the previous research themes and methods continue to be utilized, such as experimentation (Hirth 2003).

Despite a gradual broadening of interest in and research themes about lithic studies (e.g., Cadelan et al. 2023; Horowitz et al. 2020; Horowitz 2021, 2022b; Sharpe and Aoyama 2022; Stemp et al. 2021; Stemp and Peuramaki-Brown et al. 2019), lithicists in the Maya region have tended to prioritize obsidian, a non-local material in the Maya lowlands, over the locally available chert. The focus on obsidian was in some part due to the development of geochemical sourcing, mostly X-Ray Fluorescence (XRF) during "The Cartographic Stage" (Braswell 2011). This method led to extensive studies on obsidian trade across Mesoamerica (Clark 2003:32-39).

Obsidian was primarily traded and used in the form of prismatic blade cores (Figure 5) and blades (Figure 6). This efficient technology offers a high ratio of cutting edge per volume of stone (Sheets and Muto 1972) and has its origins dating back to at least 3500 BCE, with widespread use arising between 1000 BCE -700 BCE (Clark 2003; Flenniken and Hirth 2003; Hirth and Flenniken 2002; Titmus and Clark 2003). The presence of large amounts of blade cores points to the existence of full-time blade-core specialists, especially considering that blade-core manufacture requires years of practice to perfect the skill of mass producing such standardized tools (Knight 2017).

Figure 5. An obsidian blade core from a Postclassic Period context from the site of Q'umarkaj, Guatemala (photo by R. Horowitz).

Figure 6. Obsidian blade segments from Postclassic Period contexts from the site of Q'umarkaj, Guatemala (photo by R. Horowitz).

The lowland Maya may have lacked direct access to obsidian, but much of the lowlands has ample access to chert of variable quality (Barrett 2011; Hearth and Fedick 2011; Hester and Shafer 1984, 1994; Horowitz 2018b). Chert is generally considered harder to knap and does not produce as sharp an edge as obsidian, but it does offer advantages in durability (Whittaker 1994:66). Chert is available in patches across the lowlands, with the exception of the Chert Free Zone of northern Yucatán (Dahlin et al. 2011; Hearth and Fedick 2011). Not all chert is created equal, however, its quality varies dramatically within the same area, riverbed, or even in the same cobble. Therefore, chert was frequently field tested before being reduced (Horowitz 2018b).

Chert was used for tools such as drills, perforators, general utility bifaces (GUBs), and projectile points (Figure 7A-E). GUBs, a tool form frequently found in the lowlands, were used for a variety of cutting, chopping, digging, and other quotidian tasks (Aldenderfer et al. 1989; Clark and Woods 2014:201; Eaton 1991; Gibson 1991; Horowitz et al. 2019; Lewenstein 1987, 1991a,b; Shafer and Hester 1991; Titmus and Woods 2003; Valdez 1989; Woods and Titmus 1996). They offered versatility and longevity in their robust shape and were often retouched when dull.

It is common for biface retouch flakes from GUBs to be found in market contexts. Here, non-specialists could buy newly made GUBs, or they could take their GUBs to be resharpened through edge retouch (Cap 2015, 2019, 2021). It is likely that almost everyone in the Maya lowlands had at least some familiarity with knapping, but the knappers in the marketplaces were specialists (Cap 2019; VandenBosch et al. 2010: 291-293). Bifacial manufacturing workshops and quarry sites have been recorded across the lowlands and provide additional evidence of knapping specialists (Barrett 2011; Hester and Shafer 1984, 1994; Horowitz 2015, 2018b, 2018c, 2021; Shafer and Hester 1983, 1991; VandenBosch 1999; VandenBosch et al. 2010; Whittaker 2009).

While most workshops were small, part-time operations centered around single households (Horowitz 2021), the most well-known workshop site is Colha, located in present day northern Belize. Colha was home to a community of knapping specialists who provided the surrounding settlements with bifacial tools on an industrial scale (Hester and Shafer 1984, 1994; Shafer and Hester 1983, 1991). Debitage deposits at Colha are comprised of 95-99% bifacial thinning and platform preparation flakes. It was estimated that a single cubic meter sample from Colha contains 4,956,125 pieces of debitage that are above $3mm^2$ (Roemer 1991:58; Shafer and Hester 1991:82-83). This indicates an almost exclusive focus on biface reduction at a scale greater than other biface workshops in the region. For example, a biface workshop examined near Xunantunich by VandenBosch and colleagues (2010) estimated densities between only 900,000 and 2 million per m^3 compared to Colha's nearly 5 million per m^3. Colha's place in the Maya economy has been interpreted through the producer-consumer model where production sites like Colha served as central places for the distribution of bifacial tools to consumer sites located outside of the chert bearing zone, such as larger settlements like Nohmul (Barrett et al. 2011; Chase and Paige 2020; Dockall and Shafer 1993; McSwain 1991).

Figure 7. A sample of chert tools from the site of Waka'. (A) various bifaces (Horowitz 2022a, Figure 23), (B) retouched flake tools (Horowitz 2022a, Figure 15), (C) drills (Horowitz 2022a, Figure 25), (D) stemmed bifaces (Horowitz 2022a, Figure 3), (E) a finely made lanceolate biface of high-quality brown chert (Horowitz 2022a, Figure 34).

In addition to being valuable commodities for daily life, lithic resources also had sacred significance as animate beings to the ancient Maya. The ancient Maya believed that all objects taken from the ground, including stones, were imbued with a life-force that played an active role in ritual activities such as bloodletting (Levine and Carballo 2014; Stemp and Pernet et al. 2019; Stone and Zender 2011:82-83). This is also exemplified by the manufacture of eccentrics, or flaked stone artifacts with expressly supernatural associations (Figure 8). Knapping specialists (Agurcia et al. 2016; Hruby 2008) often used chert, but also obsidian, which had spiritual power associated with lightning, and enhanced this power by knapping it into ritually significant forms. Eccentrics are almost exclusively found in ritual contexts such as burials or dedicatory caches in the forms of deities or objects of supernatural significance (Agurcia et al. 2016; Hruby 2008; Stone and Zender 2011:82-83).

Figure 8. (A) A notched eccentric from Waka' (Horowitz 2022a, Figure 36). (B) An elaborate eccentric from Copan's Rosalila Structure (Agurcia et al. 2016, Figure A.28).

Many of these powerful objects are nearly impossible for modern knappers to replicate today (Titmus and Woods 2003). The knappers who made them might have been supported by elite patrons, but it is more likely that they were elites themselves (Agurcia et al. 2016; Hruby 2008). Elite crafting was common in the Maya region in part as a source of legitimacy for elite authority (Aoyama 2009; Sharpe and Aoyama 2022), which is also the case in other societies (Helms 1993). The amount of practice required to manufacture an eccentric would require full-time specialization, meaning those with other work demands could not make them. The access to the sacred knowledge necessary to produce eccentrics was highly guarded and used to legitimize elite authority, and so elite status was closely tied with the ability to create finely crafted objects such as eccentrics (Hruby 2008).

Despite the Maya producing a wide range of lithics, both as tools and sacred objects, one artifact form that is rarely identified in the Maya lowlands are scrapers. Scrapers are typically unifacially retouched flakes with steep and wide-angled edges which were suitable for a number of tasks, including cutting, planing wood or bone, and scraping hides and other materials (Whittaker 1994:27). Stone scrapers are present in other parts of Mesoamerica, such as Oaxaca and central Mexico (Haines et al. 2004; Hester and Heizer 1972; Mandujano 2002; Parsons and Darling 2000; Parsons and Parsons 1990; Smith 2011), and in the highland regions of the Maya region in modern-day Chiapas, Mexico (Paris et al. 2015). In the lowlands, however, they are rarely discussed and are generally absent from the lists of lithic forms found in site reports (e.g., Chase and Paige 2020; see also Horowitz 2022a).

Finding rare tool forms like scrapers in the lowlands allows study of previously unrecognized economic activities, which first requires further investigation of the artifact's function. Lithics, due to their preservation, often provide the only window into studying economic activities that involved materials that rarely preserve archaeologically. Archaeologists have traditionally explored lithic artifact function through four techniques: morphology, ethnoarchaeology, experimentation, and paleoethnobotany, which I discuss below.

Typologies and Morphological Analysis

One of the most basic concepts within archaeology is the creation of artifact typologies. Typologies simplify information and help make sense of the world around us. Within archaeology, types are useful for creating chronologies, but one of the fundamental and often debated issues of typologies is if they reflect an underlying reality, or only exist in the minds of the archaeologists using them (Ford and Steward 1954; Whittaker 1994: 260-261). For lithics, typologies are often created based on assumed function, paleolithic handaxes and choppers are examples of tools whose names reflect assumed functions (Shea 2014; Wilkins 2020) rather than any analysis of their actual uses.

Another issue with typologies is that they imply the existence of a static form which does not reflect the reality of lithic technology. Lithics are a reductive technology, in which components are removed to create a product. This contrasts with an additive technology like ceramics, in which parts are added to make a finished product. Because of their reductive nature, we can see the lithic manufacturing process in the archaeological record by examining flakes; the parts removed from stone tools. This also means that lithic tools change form over time, as they are used and resharpened to maintain their original function or are recycled into different tools. Either way, their morphology, and thus typology, changes over their use life (Andrefsky 2009; Flenniken and Raymond 1986; Frisson 1968; McPherron 2003).

Stone tools are dynamic and are often not designed with a finished product in mind (Dibble et al. 2017). The misconception that they are designed with an end product in mind, the “finished artifact fallacy,” is at the base of the Binford Bordes debate (see Bordes 1972) concerning the interpretation of Mousterian assemblages. Binford argued that European Paleolithic stone tool assemblages represented different subsistence activities, while Bordes argued they represented different cultures (Dibble 1995). It is more likely that they are the result of different reduction activities, as tools at different stages of their use life will have different morphologies, which are often falsely interpreted as different types (Dibble 1995; Dibble et al. 2017; McPherron 2003; Whittaker 1994:260-261). Thus, overreliance on typologies to inform us about past activities results in flawed interpretations, as the typologies we observe in the archaeological record are a snapshot of a reduction continuum, and not static types.

We may be able to say that the morphological scrapers from Waka’ fit the characteristics for what, in our minds, matches the description of the scraper type artifact, but this is but one point of the artifact’s use life. The tools must be examined within the context of the reduction continuum at the site, instead of isolating them as finished artifacts which are discrete from the broader assemblage. Furthermore, saying that they were used for scraping tasks is another issue entirely, and so additional evidence will need to be employed before we can confidently call them scrapers.

Ethnoarchaeology

Lithic technology was used by almost every human society up until the last few thousand years, and in some places continues to be used in the present. Ethnographic accounts of lithics have been used to interpret the archaeological record (see McCall 2012). For example, Gamo pastoralists of Ethiopia use obsidian scrapers to process animal hides (Weedman 2000; Weedman Arthur 2018) while the Chukchi reindeer herders of Siberia use stone scrapers to process reindeer hides (Beyries and Rots 2008).

Both cases represent instances in which anthropologists were able to observe the intended function of a stone tool that would otherwise be difficult to discern from the archaeological record alone. An archaeologist might find a morphologically similar scraper from the same region of Siberia or Ethiopia and conclude that it was used for the same tasks that we see them used for today. Therin lies the main strength of ethnoarchaeology, the recognition that many forms of material culture that exist in the archaeological record may still be used today or have similar forms (Lee and Hayden 1987:viii). This, in theory, can reveal far more about the archaeological record than is normally afforded by archaeological context alone.

However, ethnoarchaeology often cannot tell us as much about the past as it would be hoped, primarily because of the unquantifiable differences between contemporary and archaeological stone tool using societies. It is important to recognize said limitations (Feinman and Nicholas 2007:99-100; Kuhn and Stiner 2001; Wobst 1978) and especially important to not view contemporary stone tool using societies as living fossils (Tylor 1894) given that culture and material culture are never static.

Ideally, ethnographic comparisons to the archaeological record will come from descendent communities. In Mesoamerica, there are limited ethnographic examples of lithic producers and users (e.g., Clark 1991a,b, Hayden 1987), none of which discuss scrapers. For example, the Lacandon Maya are one of the few Mesoamerican societies that still make stone tools today, which they sell to tourists as souvenirs (Whittaker 1994:51). Ethnoarchaeological studies examined Lacandon tool making techniques to gain insight on the production of lithic technology of the ancient Maya (Clark 1991a,b). However, contemporary Lacandon arrows are used for functionally distinct purposes from past ones, limiting inferences regarding function.

Alternatively, tools used by contemporary populations conducting similar tasks to those of the Classic period Maya might hold clues to a stone artifact's function. There are examples of iron scrapers (Figure 9) used today in highland Mexico. These iron scrapers are round, dull, and with even edges, similar to traditionally defined typological stone scrapers known across the archaeological record of stone tool using societies (Whittaker 1994:27). The highland Mexican iron scrapers are hafted in a wooden handle and are designed to scrape and deflesh maguey (*Agave* sp.) cacti without cutting through their fibers, while others are designed to cut out the heart at the center of the plant. These plants were, and continue to be, economically significant crops across Mesoamerica, including the Maya lowlands, and are used to produce textiles, maguey sap or agua miel, and an alcoholic beverage called pulque (Parson and Parsons 1990; Parsons and Darling 2000).

The existence of stone antecedents to the contemporary iron scraping tool technology are known in the archaeological record of highland Mexico and consist of two forms. The first are 'turtleback scrapers" (Figure 10); Haines et al. 2004; Hester and Heizer 1972:108; Parsons and Darling 2000:87) described as "dome shaped wedges" (Hester and Heizer 1972:108) featuring steep retouch from a single platform or planar surface. The other form are flakes with distal retouch to create what is a more traditional typological scraper shape (Figure 9; Mandujano et al. 2002; Parsons and Darling 2000:88; Smith 2011). The function of the later form of archaeological scraper from highland Mexico was confirmed by a combination of use-wear analysis and experimental replication, in which experimental obsidian scrapers showed recognizable use-wear in the form of microflaking, striations, and polish when examined under a scanning electron microscope (Mandujano et al. 2002; Smith 2011; Walton 2019). It is possible that the scrapers from Waka' were used for the same purpose given their morphological similarities to the present-day iron scrapers and the archaeological obsidian scrapers (Figure 9).

Figure 9. A contemporary hafted iron scraper (left) used to process maguey cacti in highland Mexico. Two archaeological examples of obsidian maguey scrapers (right) (Parsons and Darling 2000, Figure 7).

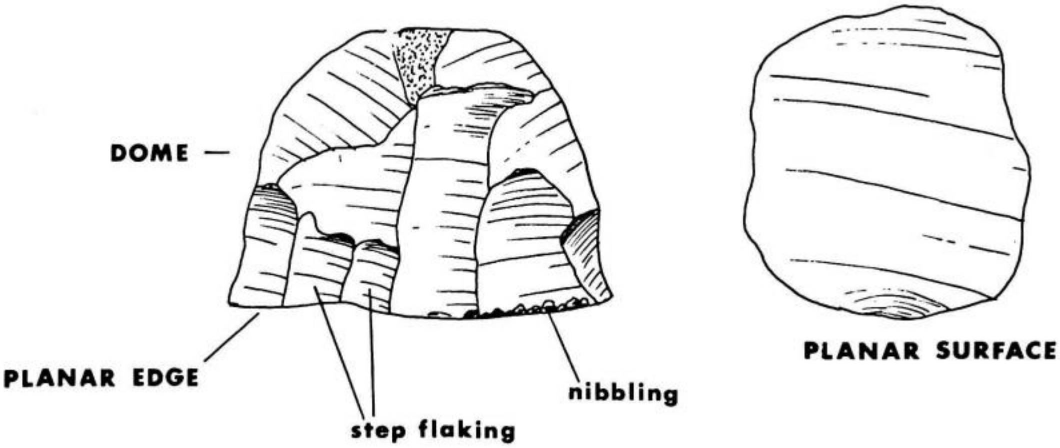

Figure 10. Drawing of a "turtleback" scraper from highland Mexico (Hester and Heizer 1972, Figure 1).

Experimentation and Replication

An additional approach to understanding tool function comes from experimental archaeology, and particularly replication experiments. Few ethnographic accounts of stone tool production exist (see Clark 1991; McCall 2012; Weedman 2000; Weedman Arthur 2018; Whittaker 1994:50-57). Many ethnohistoric accounts from Euro-American explorers, scientists, and missionaries are fraught with ambiguity or lack of detail about knapping as the observers were either disinterested or did not understand what they were seeing (e.g., Kroeber 1961; Flenniken and Hirth 2003). Furthermore, knowledge of stone tool manufacture was largely lost by the time archaeology as a science came into being. One of the few places where stone tool manufacture persisted in Euro-American culture was in the gunflint industry, where gunflint knappers used steel hammers to make the flint strikers used in flintlock weapons (Watt and Horowitz 2017; Whittaker 1994:52-53).

Numerous Europeans and Euro-Americans learned to replicate stone tool artifacts during the late 1800 and early 1900's. These flintknappers frequently produced replicas for profit and used mechanical devices, jigs, and levers which do not reflect the knapping tools and techniques used in the archaeological record or in contemporary Indigenous societies. Such unscrupulous motives and non-plausible replication techniques meant that the utility of replication was not recognized by archaeologists for considerable time (Whittaker 2005:34-59). Replication experiments became common in archaeology in the 1960's due in large part to the work of Don Crabtree and Francois Bordes. These researchers aimed to replicate ancient stone technologies to learn about how the artifacts observed in the archaeological record came to be. Early replicative studies included heat treatment (Crabtree and Butler 1964), fluting (Crabtree 1966), and blade technology (Bordes and Crabtree 1969; Crabtree 1968). Replication has been applied to study

Mesoamerican lithic technology such as prismatic blade cores (Flenniken and Hirth 2003; Titmus and Clark 2003), bifaces (Hirth et al. 2003; Whittaker et al. 2009), and eccentrics (Titmus and Woods 2003).

Even after experimental replication became accepted as a method to study the archaeological record, debate continued over how much this method can tell us about the past. While many archaeologists can replicate stone tools, knapping experiments can only tell us how a tool could have been made. Some archaeologists argued that modern knappers can know by doing, by replicating stone tools and the use of inductive reasoning, one could discover how a tool was made. The same was argued for how a tool was used (Clark and Woods 2014:197-200).

Flenniken, a pioneer of experimental archaeology, was one of the main advocates of this school of thought. He suggested that researchers could achieve objective results by using "the aboriginal tools as controls, by aboriginal stoneworking fabricators, employing the same raw materials, and following the same, not similar, reduction techniques" (Flenniken 1980:290). The goal of this process was to replicate the entire use life of a tool from its creation to deposition to "demonstrate, not prove, actual processes that occurred" (Flenniken 1980:290, see also Flenniken 1981).

Ideally, good experiments will follow such guidelines, but it has been demonstrated that knapping experiments always have a degree of subjectivity (Clark and Woods 2014). One can show the potential ways a tool could have been made in the past, but successful replication does not equate to proof that an artifact was made the same way. Again, the same can be said for how a tool was used. This is especially true considering that archaeologists making and using tools in a laboratory setting do so in a completely different physical and cultural landscape.

Contemporary knappers and archaeologists do not possess the same skills and cultural knowledge that ancient knappers did (Clark and Woods 2014).

That being said, replication provides examples of plausible methods of replication and plausible uses for artifacts when paired with other lines of evidence. Approaches such as the aforementioned typological and ethnographic methods can make observations from the replication and application of stone technology to experimental tasks more valuable. Experimental archaeology creates an additional line of evidence for determining tool function in the form of use-wear analysis (Whittaker 1994:283-288).

Use-wear analysis is usually aimed at determining the action a tool performed, such as slicing, chopping, or scraping as well as the density of the material it processed (e.g., hard or soft). Some studies, including this one, seek specific answers such as the exact material that was processed (Andrefsky 2005:195-199). Common forms of use-wear, which is also called edge damage or edge modification, include polish, edge rounding, edge crushing, striations, flake termination types, and the direction of flake removals, although others group these forms of use-wear into three overarching categories: striations, polishes, and microchipping (Andrefsky 2005:196).

Researchers first noticed that the edges of stone tools were modified from use by identifying "sickle sheen"' macroscopically visible polish that develops from cutting silica rich plants like grasses. This form of use-wear is easy to see with the naked eye (Anderson 1980; Semenov 1973) and so it was quickly recognized by archaeologists working in the Near East in the early 1900's (Odell 2003:136).

While striking, sickle sheen is an exceptional form of use-wear in that it is visible to the naked eye. Most use-wear requires magnification to be seen, and these forms of use-wear were not studied until the 1950's. The Russian scientist Sergei Semenov used the tiny scratches called striations appearing from experimental studies of metal tools to model the same form of use-wear on stone tools. This work was translated into English in 1964 (Semenov 1964) and spurred similar kinds of research in the English-speaking world.

Today, use-wear analyses using magnification are divided into low-power and high-power analysis. Low power analysis utilizes reflective-light microscopy, while high-power uses incident-light microscopy (Odell 2005:137). Many studies utilize high-powered scanning electron microscopy (SEM), which is capable of thousands of times magnification. Minute forms of use-wear, such as microremovals on obsidian blades used in bloodletting rituals (Stemp 2019), can only be recognized with this high-powered analysis.

Use-wear analysis has been extensively used to identify tools used for specific tasks including woodworking, plant and animal processing, shell and bone craft production, and ritual activity (Aldenderfer et al. 1989; Cadalen et al. 2023; Chapman et al. 2015; Goodale 2010; Hardy and Garufi 1998; Sharpe and Aoyama 2022; Stemp 2004, 2016; Stemp et al. 2018, 2021; Stemp and Helmke et al. 2010; Stemp and Peuramaki-Brown et al. 2019; Walton 2019, 2021). In the Maya region, researchers have conducted use-wear analysis to investigate domestic activities such as food ways and craft production (Aldenderfer et al. 1989; Chapman et al. 2015; McKillop and Aoyama 2018; Stemp et al. 2021; Stemp and Helmke et al. 2010; Stemp 2004). These have revealed the function of quotidian items like GUBs (Aldenderfer et al. 1989) or obsidian blades (Stemp and Braswell et al. 2019) and provided evidence of plant use even when macroremains do not preserve (Chapman et al. 2015). Other use-wear studies in the Maya region show the connection of elite identity to craft production of objects with high symbolic value, such as eccentrics, bone and shell beads and pins, and jade adornments (Agurcia et al. 2016; Aoyama

2009; Sharpe and Aoyama 2022). Ritual bloodletting, an activity that leaves little recognizable trace, has also been investigated through use-wear analysis of obsidian blades. Analysis of microscopic use-wear shows that even brief contact with soft skin can leave recognizable microchipping visible with SEM (Stemp 2016; Stemp et al. 2013; Stemp and Peuramaki-Brown et al. 2019; Walton 2021).

On the whole, use-wear studies have been crucial to Maya archaeologists for finding evidence of tasks that otherwise do not preserve in the archaeological record because of their ephemeral nature or poor preservation. This is especially relevant in the lowland Maya region where preservation conditions for organic materials are poor (Cadalen et al. 2023), or when researchers are interested in ritual activities which do not leave significant remains in the first place.

Despite these potential benefits, use-wear analysis is not without its issues; one of the main drawbacks is its qualitative nature. It requires experience to recognize and distinguish forms of use-wear from other forms. While polish from plants and hides or antler and shell may look similar, research has shown that they can be distinguished (Aldenderfer et al. 1989; Stemp and Childs et al. 2010). Certain forms of use are easier to see than others; contact with hard materials will cause more use-wear than contact with soft materials. Furthermore, subsequent forms of use-wear can obliterate earlier forms of use-wear, especially if a tool is used to process a harder material later in its use life (Whittaker 1994:283-288).

With recognition of these drawbacks, the method is a mainstay of building knowledge about the function of lithic technology. If an experiment is conducted with replicability in mind, it can allow archaeologists to recognize when an artifact was used for particular tasks based on the form of use-wear present on an artifact’s edge. In this case, replicating the artifact scrapers from Waka' using the same tools, materials, and techniques that could have been used by ancient Maya knappers allows their use in controlled scraping experiments that generate use-wear on their edges. The use-wear could serve as a baseline for what expected use-wear on the artifacts should look like if they were used for the same task. Scraping cacti leaves was a potential task of interest given the aforementioned morphological similarities and ethnographic accounts, but the Classic period Maya also utilized countless additional plant species (e.g., Cagnato 2016; Morell-Hart et al. 2021; Sharer and Traxler 2006:41-45; Wyatt 2002). Ethnographic examples of scraper use frequently include hide working (Beyries and Rots 2008, Weedman 2000, Weedman Arthur 2018), so in addition to cacti processing, this thesis will include alternate uses such as processing other plant species as well as animal hides that were used by the Classic period Maya.

Paleoethnobotanical Analysis

The final method discussed here is paleoethnobotanical analysis. Paleoethnobotanical analysis is a well-established technique used to study lithic function as early as the 1970's (Shafer and Holloway 1979). The development of this method is in part tied to the development of use-wear analysis and the recognition of sickle sheen. The discovery of sickle sheen sparked increased interest in the traces that plants leave on stone tools. Macroscopically visible plant residues can be studied microscopically to determine the plant to which the residue belongs (Hardy and Garufi 1998; Zurro and Gadekar 2023). However, such remains are unlikely to preserve on tools, especially in hot and humid environments (Pearsall 2016:40-46).

Tools used in plant processing sometimes retain microscopic elements of the plants that are not always visible to the naked eye. Such elements, termed microfossils, include phytoliths, calcium oxalate crystals, starch grains, and pollen, all of which provide insight into the types of plants processed and, in some cases, can be diagnostic of specific taxa. Not all plants leave microfossils, some produce only certain types, while others produce microfossils that can be hard to identify or are diagnostic for multiple species (Lancellotti and Madella 2018). Despite this, there are many microfossil forms that have been thoroughly researched and can be confidently assigned to specific plant families, genera, or species (Lancelotti and Madella 2018, Neumann et al. 2019, Pearsall 2016:253). Microfossils are also much more likely to preserve than are macroremains, and so they have the potential to reveal tool functions in depositional environments that have poor preservation (Pearsall 2016).

However, most applications of microfossil analysis focus on ground stone artifacts, such as manos and metates, instead of flaked stone, but there is increasing interest in applying microfossil analysis to flaked stone (Zurro and Gadekar 2023). Ground stone tools often retain large amounts of plant microfossils because of sustained and intensive plant processing. Ground stone artifacts are also often made of more porous materials with larger grain size, providing plenty of opportunities for plant remains to become trapped, which also increases the odds that they will be recovered (Adams 2002). Flaked stone is expected to retain fewer microfossils than ground stone because of its compact cryptocrystalline structure, and so effective sampling techniques are even more important, which I detail in Chapter Four.

Paleoethnobotanical analyses in Mesoamerica have expanded greatly in recent years (Cagnato 2016; Cagnato and Ponce 2017; Dussol et al. 2016; Farahani et al. 2017; Freidel 2021; Morrell-Hart et al. 2021). Mesoamerican archaeologists have utilized macro and microfossils to reconstruct ancient Mesoamerican diets (Morrell-Hart et al. 2021; Wyatt 2002). Paleoethnobotanical analyses are not just descriptive, but contribute to examinations of power, agency, and social structure (Freidel 2021; Morehart and Morrell-Hart 2013:483), such as through examinations of the impact of social class on diet (Lentz 1991) and the role of chocolate consumption in feasting (LeCount 2002).

Phytoliths

Of the microfossils examined in this thesis, I first discuss phytoliths, which are opal silica bodies formed in plants by the absorption of monosilicic acid present in the soil. Some scholars (e.g., Jones and Bryant 1992; Reinhard and Danielson 2005; Tyree 1994), use the term phytolith for both calcium oxalate and opal silica structures, but to avoid confusion, in this thesis 'phytolith' will only be used when referring to opal silica structures (see Pearsall 2016:254). The term 'microfossil' will be used to encompass calcium oxalate, opal silica, and starch grain bodies. Plant pollen is also included in this term, but pollen is not discussed in this thesis.

Phytoliths are formed by the transport and deposition of monosilicic acid through a plant's xylem, which then forms inorganic silica casts of a plant's organic structures. These silica casts form within the organic structures of particular plants (Lancelotti and Madella 2018; Pearsall 2016:253). Formal descriptions and typologies of the numerous forms of phytoliths exist in the International Code for Phytolith Nomenclature (ICPN), which allows for results to be comparable (Neumann et al. 2019).

Phytolith analysis is useful for archaeological studies as a phytolith's silica composition means good preservation, especially when compared to the organic plant tissues in which they form. Second, phytoliths can be distinctive to the family level and sometimes even to genus or species levels, making them useful for identifying specific plant types. Moreover, distinct phytoliths from specific parts of plants can also be identified, meaning they can reveal what specific plant parts were processed. Third, phytoliths can be found in a variety of contexts from stone tools to sediments. Lastly, phytoliths are deposited locally, and are thus representative of local activities, and more likely to be directly related to human activities. This is opposed to other microfossils such as pollen which can travel thousands of kilometers (Lancelotti and Madella 2018; Pearsall 2016:190, 253).

Cacti such as members of the *Agavaceae*, in which the maguey is included, are known microfossil producers (Callen 1967). Many studies of cacti microfossils are based in the US Southwest (Callen 1967; Jones and Bryant 1992; Reinhard and Danielson 2005) and have reported on cacti phytoliths from the epidermis (Callen 1967:271). These studies have also reported on another form of cacti microfossil; calcium oxalate crystals. I consider both forms of microfossils in this thesis.

Calcium Oxalate Crystals

Calcium oxalate crystals are mineral bodies which form in a variety of plants. Cacti produce calcium oxalate crystals that can be used to identify specific cacti species (Callen 1967, Jones and Bryant 1992, Raman et al. 2014), including *Agave* sp. Calcium oxalate crystals are found in similar contexts to phytoliths and are useful for addressing similar questions. However, unlike phytoliths, calcium oxalate crystals do not mold to the shape of organic plant tissues, but instead are formed in the vacuoles of specialized plant cells or in the cytoplasm of parenchymal plant cells (Jones and Bryant 1992:216; Webb 1999). This is an oversimplistic explanation, and there is still much that is unknown about calcium oxalate crystal formation (Raman et al. 2014:722). This gap in understanding calcium oxalate crystals can be problematic for identifying artifact function because it means that calcium oxalate crystals are harder to match to specific plants and plant parts than phytoliths.

Furthermore, calcium oxalate crystals are not diagnostic to individual species, making the identification of specific taxa challenging. However, studies differentiate between cacti families based on crystal morphology and size ratio comparisons (Jones and Bryant 1992) and through raphide morphology. Raphides are a specific type of crystal which corresponds better to specific plant families, including *Agavaceae* plants (Crowther 2009; Raman et al. 2014; Webb 1999). Raphides are needle shaped calcium oxalate crystals which appear as bundles or stacks of hundreds to thousands of crystals.

Archaeologists focus on raphide analysis as their cross sections and end forms have the potential to distinguish different families of plants (Crowther 2009; Raman et al. 2014). Agavaceae plants are identified by type III raphides which have octagonal or hexagonal cross-sections with two symmetrical and pointed terminations (Crowther 2009; Raman et al. 2014). The other form of calcium oxalate crystals considered in this thesis are styloids, which are columnar shaped elongated calcium oxalate crystals that are sometimes referred to as 'pseudo-raphides' (Crowther 2009; Raman et al. 2014:722-723). While these crystals are not known to be diagnostic to specific families, their presence was noted in reference collection samples in this thesis, which will be discussed in Chapter Four.

Phytoliths and calcium oxalate crystals are the most promising microfossil types assuming that the artifacts in question were used to process maguey as the ethnographic evidence suggests. However, the ancient Maya utilized countless plant and animal species (e.g., Cagnato 2016; Morell-Hart et al. 2021; Sharer and Traxler 2006:41-44; Wyatt 2002), and so it is important to consider other uses that these tools could have had, which means examining a final form of microfossil.

Starch

The last form of microfossil I examined are starch grains, which are semi-crystalline microfossils composed of six-carbon sugar D-glucose polymers produced from various organs within a plant (Copeland and Hardy 2018; Pearsall 2016:341-343). It serves as an energy storage mechanism within a variety of tissues of green plants. Starch grains are often circular to ovoid in shape and can be diagnostic to specific species based on characteristics such as their size, shape, hilum, lamellae, and polarization crosses. Because starch is semi-crystalline, it reacts to polarized light which aids in the identification of these features. Starch can withstand environmental conditions that organic macro-remains cannot and is local in deposition, much like calcium oxalate crystals and phytoliths (Copeland and Hardy 2018; Fullagar 2006; Pearsall 2016:341-346).

However, unlike calcium oxalate crystals or phytoliths, starch grains are less durable and can be destroyed or damaged by environmental conditions such as extreme heat or moisture (Pearsall 2016:351). Such preservation issues must be considered given that the artifacts in question were recovered from the tropics of the Maya lowlands.

I considered starch because of the importance of manioc (*Manihot esculenta* Crantz), also known as cassava, along with other starchy roots, in the Maya lowlands. Some varieties are toxic to humans and require processing to make them safe for consumption. The most common way to process manioc is to grate it to create manioc flour (Cagnato 2016; Cagnato and Ponce 2017; Chapman 2013; Chapman et al. 2015; Devio 2016). Evidence of manioc grating tools; chert "teeth" inserted into wooden boards, has been found in the lowlands (Cagnato and Ponce 2017; Chapman 2013; Chapman et al. 2015), but this does not mean that alternate tool forms could not have been used for processing. The artifact tools from Waka' might represent an alternate form of manioc processing tool, especially given that other manioc grating tools have yet to be found at the site.

Manioc is known to be an infrequent producer of opal silica phytoliths (Lancelotti and Madella 2018:56) and is not known to produce calcium oxalate crystals. However, Chandler-Ezell and colleagues (2006) have reported the presence of opal silica secretory bodies from manioc root, stem, leaves, rind, and fruit when the plant is processed. While promising, the appearance of manioc opal silica phytoliths on the edges of the scraper artifacts is still unlikely, so starch grain microfossils were examined as a possible form of evidence that these tools were used in processing manioc. Manioc produces a high volume of starch, and its grains have been recovered from archaeological contexts in tropical locations and from Maya sites (Chapman 2013, Chapman et al. 2015; Cagnato 2016; Cagnato and Ponce 2017; Devio 2016; Morell-Hart 2021; Sheets et al. 2012; Wyatt 2002).

Summary

This thesis first seeks to utilize what is known from the ethnographic record, the culture-history of Mesoamerican lithic technology, and what can be observed from the morphology of the tools. I then use experimental replication, paleoethnobotanical, and use-wear analysis to provide multiple lines of evidence to suggest functions for the tools. The goal is not just to provide plausible uses for the tools, but to explore what knowing their function can tell us about the people using them.

The Scrapers from Waka'

The artifacts on which this thesis focuses are unifacially worked chert tools (n=4; Figure 11A-H, Table 2) which, morphologically speaking, fit the description of a scraper (Whittaker 1994:27) and resemble the obsidian scrapers from highland Mexico (Mandujano et al. 2002; Parsons and Darling 2000:88; Parsons and Parsons 1990; Smith 2011). They possess steeply back edges that have been unifacially retouched on their distal end of the dorsal side. The artifacts were designated as “Artifact Scraper” 1 – 4, or “AS” for short. AS1 and AS2 are complete, while AS3 and AS4 are broken, with AS3 showing evidence of burning.

Figure 11. Ventral and dorsal views of scrapers AS1 (A,B), AS2 (C,D), AS3 (E,F), AS4 (G,H).

Table 2. Dimensions of the Scrapers Examined in Thesis

Tool ID	Provenience	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)	Platform Width (mm)	Broken=
AS1	WK24-D-4-2-92	79	85	9	99.8	4	no
AS2	WK21-F-2-4-15	70	65	8	49.5	3	no
AS3	WK21-F-3-2-8	46	48	10	27.6	x	yes
AS4	WK21-F-1-2-4	35	50	8	21	x	yes

The flaking patterns on the dorsal side of the tools suggest intentional cortex removal. The tools generally lack signs of knapping errors such as step or hinge fractures, on their dorsal sides, which is a probable indicator that they were made by a skilled flintknapper. Given what is known about lithic production in the Maya region, where finely made flaked stone tools were mostly made by specialists, this knapper was probably a specialist (Agurcia et al 2016; Hester and Shafer 1984, 1994; Shafer and Hester 1983, 1991; VandenBosch et al. 2010; Whittaker 2009). The retouched distal end also indicates the work of a skilled knapper, as there are very few errors present, the flake patterning is evenly spaced, and the tool edges are consistent (Figure 12). This sort of precision was likely achieved through pressure flaking, which is slower but more precise than direct percussion. With direct percussion, the knapper relies on hand eye coordination in a rapid motion, while pressure flaking allows for more even and accurate flake removals as the pressure tool is placed directly on the platform. The large size of the scrapers combined with their small platforms indicates that they were made from prepared cores designed to produce the desired blank for the scraper.

Figure 12. The fine retouch on the distal end of AS1, despite the presence of hinge and step fractures above the margin of the tool, the edge itself is consistent.

All of the artifacts were produced on high-quality brown chert. The chert is possibly local in provenance (Hruby and Rich 2014), but is rarely found as debitage at Waka', and is mostly found as completed formal tools, particularly projectile points and other thin bifaces. The fact that the material is only found in these forms suggests that the chert is either non-local or is harder to come by than other lower quality cherts (Horowitz 2018a; Horowitz 2022a). The selection of high-quality material and evidence that they were made by a skilled knapper, probably a specialist, suggests they were used for a specific task because of the added cost of manufacture needed to produce this tool. Unretouched flakes make extremely effective tools (Andrefsky 2014), so taking the time to extensively modify a stone tool suggests that it was used for a more specific task.

All scrapers examined in this thesis were recovered from reservoirs in Waka's urban core (Figure 13). These reservoirs are in high status areas home to wealthy residents who lived in larger residences near the site core. Their high status is evidenced by their location in the site core, the size of the residences, and the mix of high-status goods, such as greenstone, that were found in the same context from which the scrapers were recovered (Marken et al. 2019:238). Due to their large size, it is likely that AS1 and AS2 were not exhausted at discard, in contrast with the exhausted formal tools, like GUBs, which were found in the same context (Horowitz 2018a), Meanwhile AS3 and AS4 were probably exhausted or broken at discard. Here I discuss contextual information for each of the four examples studied in this thesis, and then the context for the remaining 13 scrapers which are known to exist from the site.

AS1 comes from the Xucub reservoir (Op WK24D-4-2-92) and was found just to the north of an access platform within the reservoir. The Xucub reservoir is the second smallest reservoir in the urban core, its small size and surrounding residential structures suggest that access to the water in the reservoir was restricted compared to the nearby larger reservoirs (Marken et al. 2022). It is surrounded by the Xucub group, a neighborhood home to elite residents located within the site's urban core. The scraper was recovered in a midden deposit in the reservoir in association with other chert artifacts, an almost complete ceramic vessel, bone tools and fragments, shell, figurine fragments, and thousands of ceramic fragments (Marken et al. 2019:238). The lithics from the Xucub Reservoir (Table 3) suggest generalized core reduction and generalized use activities (Horowitz 2018a).

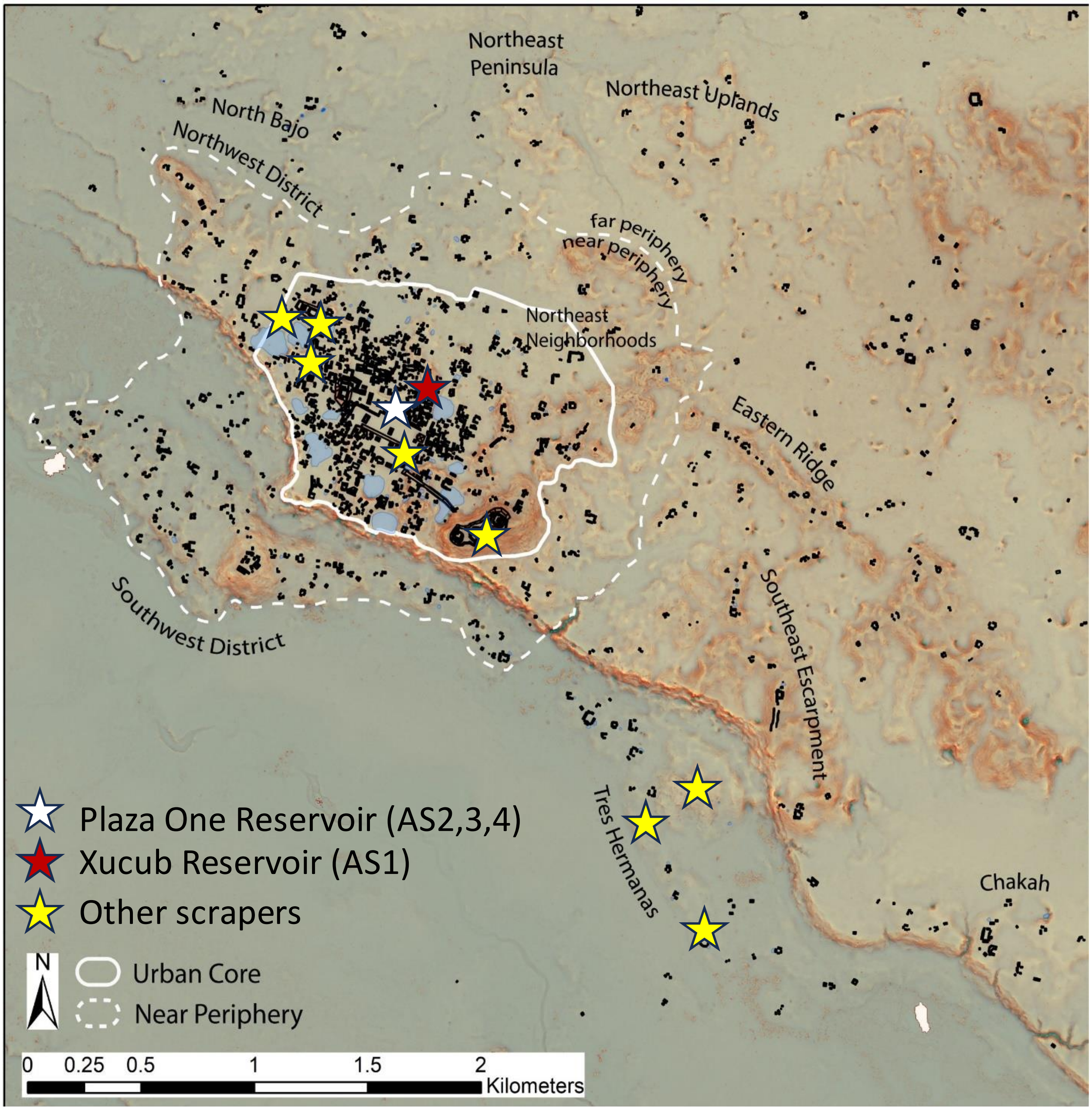

Figure 13. Map showing the localities from which scraper artifacts were found at Waka' (base map by D. Marken).

Table 3. Lithics Op WK24D (Horowitz 2018: Table 9)

Lithic Form	Count
Debitage	249 (86.2%)
Biface	32 (11.1%)
Core	4 (1.4%)
Drill	2 (.7%)
Uniface	1 (.3%)
Scraper	2 (.3%)
Total	289 (100%)

The remaining scrapers examined in this thesis were recovered from midden contexts in the Plaza One Reservoir, also in the site's urban core. The Plaza One Reservoir is the smallest of the reservoirs in the urban core, and its location and size again suggest restricted access, like the Xucub reservoir (Marken et al. 2022). These scrapers were identified in the northern edge of the Plaza One Reservoir in association with ceramic sherds, shell artifacts, bone, chert, and obsidian (Ricker et al. 2019:175-184). Chert artifacts from Op WK21F (Table 4) also reflect generalized core reduction and biface discard, but with a larger percentage of debitage than at WK24D, meaning that more lithic reduction occurred around the Plaza One Reservoir than the Xucub Reservoir.

Table 4. Lithics from Op WK21F (Horowitz 2018a: Table 7)

Lithic Form	Count
Debitage	237 (90.8%)
Biface	18 (6.9%)
Scraper	3 (1.1%)
Drill	3 (1.1%)
Total	261 (100%)

In addition to the four tools examined in this thesis, there are other examples (n=13; total from site n=17) recovered from contexts across the site (Figure 13, Table 5). These implements are made of the same high-quality chert and feature similar morphologies to the ones analyzed in this thesis with small platforms, unifacial retouch, and fine attention to flaking (Horowitz 2022a). Given the unusual form of these objects, the presence of 17 examples of this artifact at Waka' with similar features made of the same material suggests that they serve a specialized purpose.

I now consider the context of all 17 artifacts known to exist. While the four tools examined in this thesis come from high status areas, the presence of these tools at multiple locations that crosscut social class and status across the site is intriguing. Three scrapers were collected from the Tres Hermanas district, a cluster of residences outside the site's urban core. The district is located in the far periphery, defined by rural settlements with lower population density than in the site's urban core (Marken 2015). Tres Hermanas was home to lower-status residents who engaged in multi-crafting activities, including shell adornment manufacture (Horowitz et al. 2022). One key point from the analysis of lithic material from this locality is that the occupants were not making their own bifaces, and instead were acquiring formal tools from outside the household (Horowitz et al. 2022), likely through commercial exchange. The lack of lithic reduction on site means it is likely that the artifact scrapers were produced outside the household and were obtained through a commercial system like other formal tools found at Tres Hermanas.

Five of the remaining tools stem from the following locations: the Payes (n=3) and Xican (n=1) groups, and the Ical (n=1) neighborhood. All are located in the northwest section of the site core (Marken and Cooper 2018), which would have been home to more elite residents like those around the Plaza One and Xucub reservoirs. The scrapers from these localities are similar in context to those from the Xucub and Plaza One reservoirs as well; primarily associated with domestic refuse. Other tools stem from Str M13-1 (n=4), which was a major ceremonial center located in the site's core. The structure was home to important ritual activities commemorating local history at Waka', such as La Entrada and the reigns of past rulers. These included termination rituals in which domestic refuse, including the scrapers, was placed inside the structure (Navarro-Far et al. 2008; Navarro-Farr et al. 2021; Navarro-Farr and Eppich et al. 2020; Navarro-Farr and Pérez Robles et al. 2020). Other lithic artifacts were also used in these rituals, such as intentionally broken bifaces (Navarro-Farr et al. 2023). Finally, the last scraper was found within construction fill at the royal palace (Str L12-4), located on a prominent landform amongst Waka's acropolis which contained monumental structures and residences home to the city's most elite. The location of this scraper further indicates that these tools crosscut social status boundaries at the site from commoners up to the most elite families at the site.

Examining the dimensions of the artifacts (Table 6) reveals that one of the most striking features of the tools is their relatively small platforms (Figure 14) contrasted with their large widths. The average width is over six times the platform size. As will be discussed more thoroughly in Chapter Four, the small size of the platforms combined with the large, expanding flake body provides clues about how the tools were made. The small platform size also suggests that the tools were intentionally made, as large flakes with small platforms like these are unlikely to be accidental.

Table 5. Dimensions of Other Scraper Tools Known from Waka'

Provenience	Location	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)	Broken? (yes/no)	Platform Width (mm)
WK19-B-6-1-34	Tres Hermanas	90	64	14	96.7	no	6
WK19-E-4-4-148	Tres Hermanas	30	45	11	24.1	yes	N/A
WK19-F-23-5-223	Tres Hermanas	75	72	13	99.3	yes	N/A
ES169-B-282-4-34	Payes	55	62	12	58.6	no	15
ES169-B-282-4-49	Payes	70	66	14	72	no	10
WK22-A-10-3-36	Payes	31	48	10	22	yes	5
ES172-A-293-3-3	Xican	26	48	10	20.5	yes	N/A
ES166-G-278-2-33	Ical	26	40	12	12.3	yes	N/A
WK01-A-22-1-51	Str M13-1	48	25	5	9.7	yes	N/A
WK01-A-14-1-42	Str M13-1	55	44	10	28.2	no	10
WK01-H-72-2-359	Str M13-1	48	35	8	15.9	yes	N/A
WK01-C-29-02-102	Str M13-1	64	60	12	65.1	no	11
WK18-C-135-5-320	Royal Palace	22	34	8	8.9	yes	N/A

Table 6. Artifact Scraper Tool Dimension Averages

Tool Type	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)	Platform width (mm)
All Artifacts	51.1765	52.4117	10.2353	45.0117	8
Non-Broken Artifacts	69	63.7143	11.2857	67.1286	8.42857

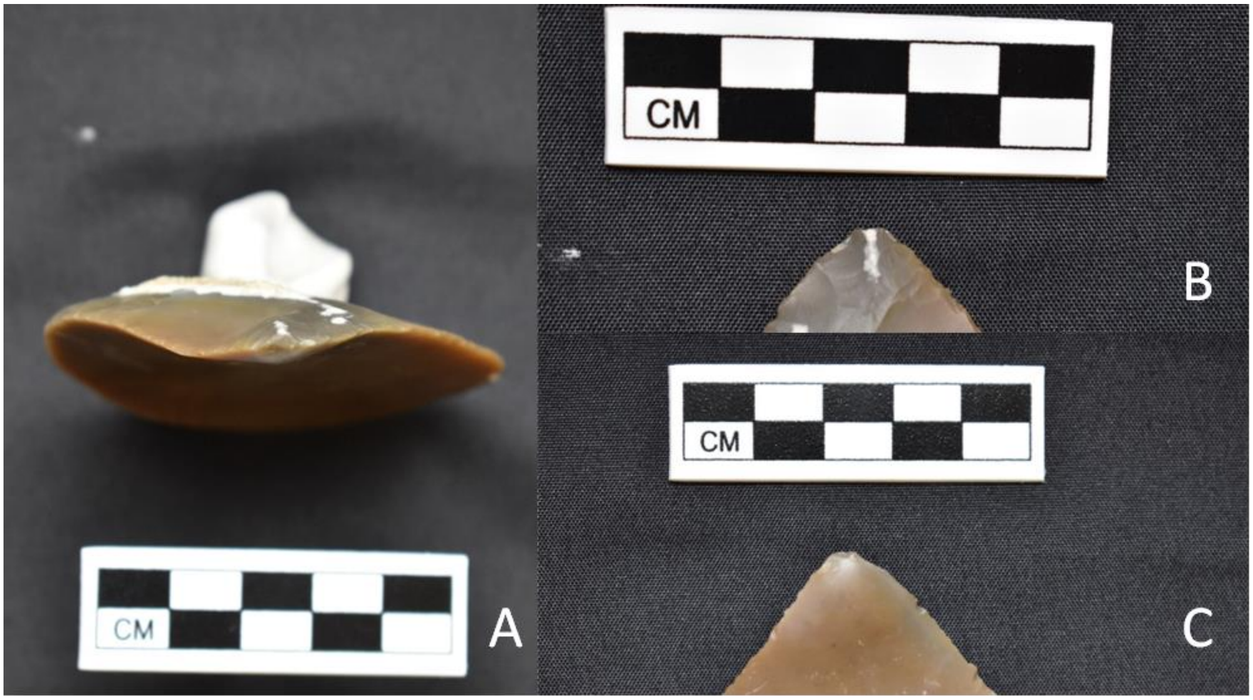

Figure 14. The extremely small platform present on AS2, only 3mm wide. (A) plan view of platform, (B) dorsal side, (C) ventral side.

While many examples of this artifact form have been identified at Waka', similar artifact forms have not been identified elsewhere in the region. The most similar artifacts are chert palettes recovered from Aguateca (Figure 15), located around 100 km south of Waka'. These palettes are also unifacially worked and made on large flakes (Aoyama 2009) but are distinct in that the platforms are obliterated by retouch in many examples, and Aoyama (2009) describes the ventral surfaces of the palettes as intentionally polished, which is not the case with the Waka' scrapers. Furthermore, the palettes were only recovered from elite contexts at Aguateca, while the scrapers from Waka' are found in a variety of contexts.

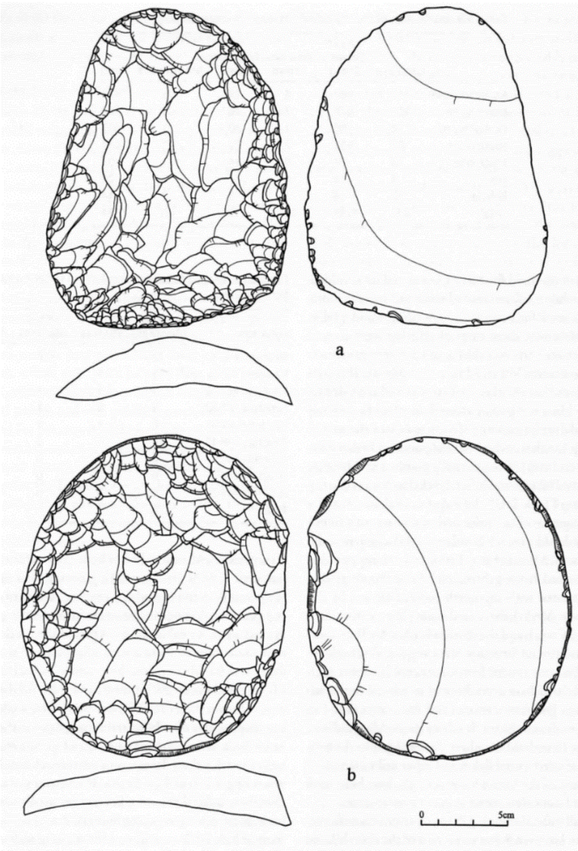

Figure 15. Illustrations of chert palettes from Aguateca (Aoyama 2009, Figure 5.19) Note the lack of platforms and extensive retouch distinguishing them from the scrapers from Waka'.

Determining the Function of the Scrapers from Waka'

I now assess the potential paths of investigation to determine an artifact's function; morphology, ethnoarchaeology, paleoethnobotany, replication and experimentation, and use-wear analysis. Morphologically, the artifacts from Waka' fit the description of scrapers, but as this may not reflect an artifact's true purpose, additional lines of evidence are needed. Considering the existing ethnographies, maguey scraping seems to be a plausible function. However, other organic materials that are commonly processed, or could be processed using scrapers will be examined as well. Manioc is one such crop that could be processed with a scraper, additionally, woodworking and hide scraping are viable options given the known use of both wood products and hides by the Classic period Maya (Cadalen et al. 2023; Robinson and McKillop 2013; Schlesinger 2001; Sharer and Traxler 2006:41-44). To evaluate the potential function of the Waka' scrapers, I employ paleoethnobotanical analysis and replicative use-wear analysis by processing these materials. The exact processes undertaken to investigate the function using experimentation will be addressed in the following section.

CHAPTER FOUR: METHODS

In this section, I outline the analyses conducted to explore the function of the artifact tools from Waka' using the methods outlined in the previous chapter including paleoethnobotanical analysis, experimental replication, and use-wear analysis. First, I discuss the creation of a microfossil reference collection of modern plant microfossils to compare to potential archaeological microfossils. Next, I describe the collection of microfossil samples from the four scraper tools from Waka'. I then discuss the experimental replication of the tools through flintknapping and provide a description of the scraping experiments. These experiments include processing maguey, manioc, deciduous and conifer woods, and deer hide. Lastly, I detail the examination of use-wear on the artifacts and the replica tools.

Reference Collection Creation

A reference collection was created for comparison between archaeological and modern samples. The appearance of known microfossils in the artifact samples would indicate their use for processing those plants. To make this reference collection, slides of microfossils from manioc and maguey were prepared. A large leaf from an *Agave americana* cactus grown on the Pullman campus of Washington State University (WSU) was selected and divided into three components; the flesh of the cactus, the skin, and the spines. Manioc (*Manihot esculenta* Crantz) root was purchased from a local grocery store in Pullman, WA and samples were taken of its flesh and skin. The plant samples were divided by anatomical components to see if different microfossils appeared in each plant part.

The phytolith and calcium oxalate crystal reference collection was prepared according to ashing procedures outlined in Pearsall (2016:294). Samples from both plants were washed individually in 10% HCl and distilled water to remove extraneous debris from their surfaces and placed in an oven at 100 °C to dry. The manioc and maguey flesh had to be left to dry for longer than the rest of the samples because of their size and moisture content.

Once dry, the samples were placed in ceramic crucibles and cooked in a muffle furnace at 550 degrees Celsius until ashed. Once cool, the ash samples were transferred into 50 mL test tubes, mixed with 40 mL of distilled water, and vortexed. The test tubes were then centrifuged at 3000 rpm for three minutes. After centrifuging, the excess water was poured off while the remaining ash sample was mixed with ethanol and left to dry. Lastly, a small amount of each dried ash sample was placed on a 3 x 1 inch glass microscope slide and mounted using Entellen^{TM} mounting medium. The slides were left to dry and examined under an Olympus SC100 microscope; magnification ranged from 100-600x. All microfossil samples were examined using polarized and non-polarized light to see distinctions between opal silica phytoliths and calcium oxalate crystals and starch, the latter two react under polarized light. While samples were expected to produce only certain forms of microfossils, (i.e., manioc producing starch, maguey producing phytoliths and calcium oxalate crystals) switching between polarized and non-polarized was a precautionary measure to ensure no microfossil was missed.

Manioc starch samples were collected by smearing manioc flesh directly on a 3 x 1 inch slide and mounted using a solution of 50/50 glycerol and water, and then nail polish. The starch reference collection was prepared separately because starch grains do not survive the ashing process. Polarized light was used when examining the manioc samples, as it facilitates starch identification by improving the sharpness and visibility of diagnostic features such as the hilum, fissures, extinction crosses, and polymer layers (Pearsall 2016:342).

The manioc reference collection illustrated features like those described in the existing literature (Cagnato 2016; Chandler-Ezell 2006; Lancelotti and Madella 2018). Manioc produces abundant starch grains between 5 - 20 microns in diameter. They possess one to three basal facets, have fissures that are y-shaped to stellar in form, and usually have open and eccentric hila (Cagnato 2016:216). Manioc starches in the reference collection feature distinct extinction crosses under polarization and frequently form in aggregates (Figure 16).

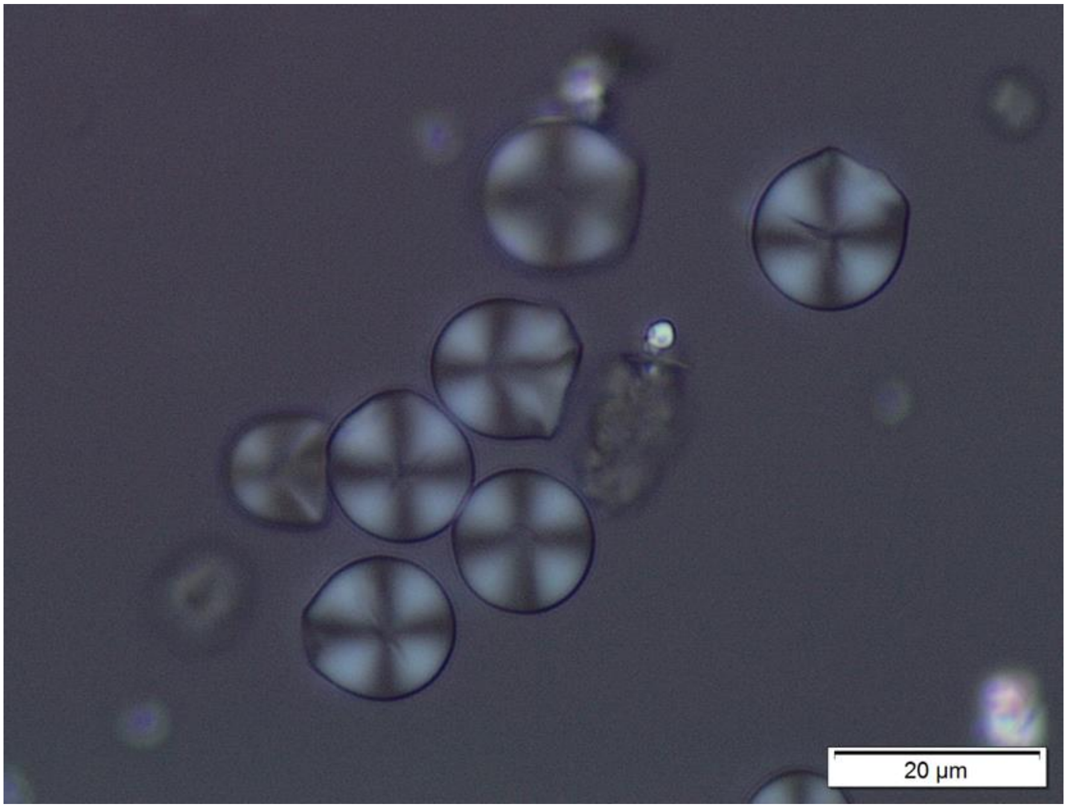

Figure 16. Examples of manioc starch grains collected from experimental scraper S5, photographed under polarized light.

Neither the manioc flesh nor skin produced any diagnostic opal silica phytoliths. The presence of opal silica sheets was noted but these were undiagnostic and do not reflect the shape of the silicified secretory bodies as described in Chandler-Ezell (2006). Overall, there was a notable lack of diagnostic plant microfossils from both the manioc skin and flesh samples, but this was not unexpected as manioc is known to be an infrequent producer of phytoliths (Lancelotti and Madella 2018:56, Chandler-Ezell 2006).

The maguey cactus samples contained far more microfossils. There were several locations on the slides that had multiple layers of microfossils built up, making it difficult to identify particular microfossil forms, especially from the cactus skin. While silica sheets were noted, there was a lack of diagnostic opal silica phytoliths in all three samples. Instead, an abundance of calcium oxalate crystals was observed; many of which formed in unidentifiable crystalline aggregates. These aggregates represent shattered and fragmentary elements of larger calcium oxalate crystals, sometimes called crystal sand (Raman et al. 2014).

Many of the crystals observed match the descriptions of raphides (Figure 17), which appeared primarily in bundle form, and styloids (Figure 18). The raphide forms appear to be type III raphides of the *Agavaceae* family as would be expected, but higher-powered microscopy would be required to confirm this.

The results from the creation of a reference collection provide expectations for what microfossils should be encountered if the artifacts were used to process maguey or manioc. The samples from the reference collection were compared to microfossil samples taken from the artifacts which are described in the following section.

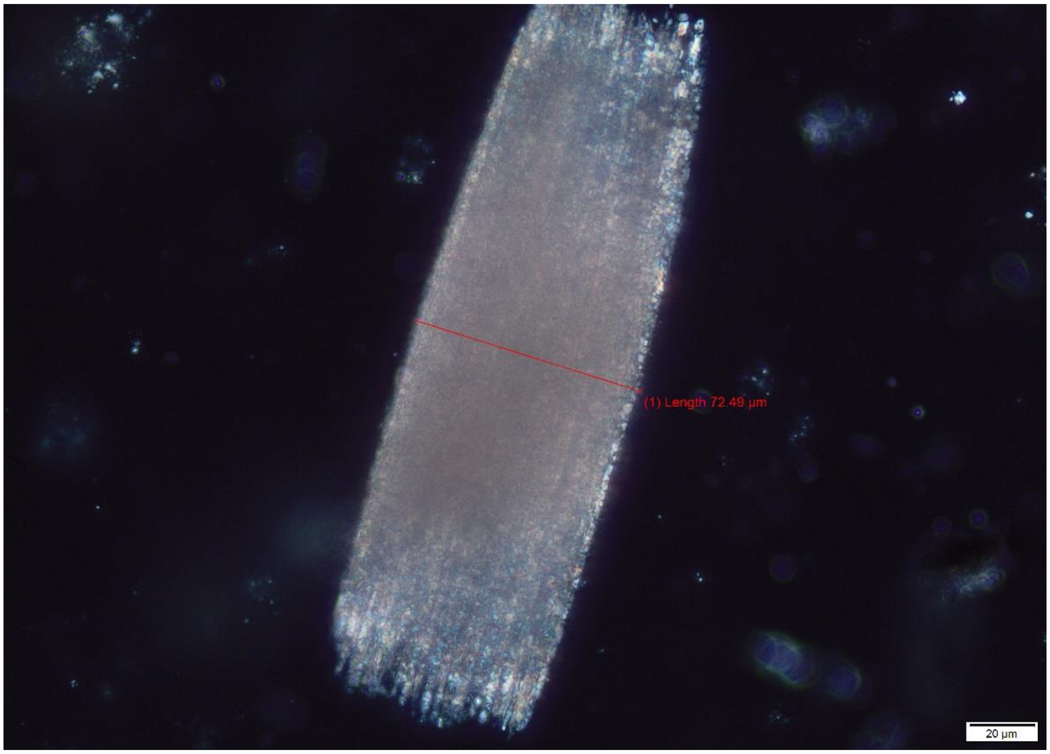

Figure 17. A raphide bundle from the maguey cacti microfossil reference collection, photographed under polarized light.

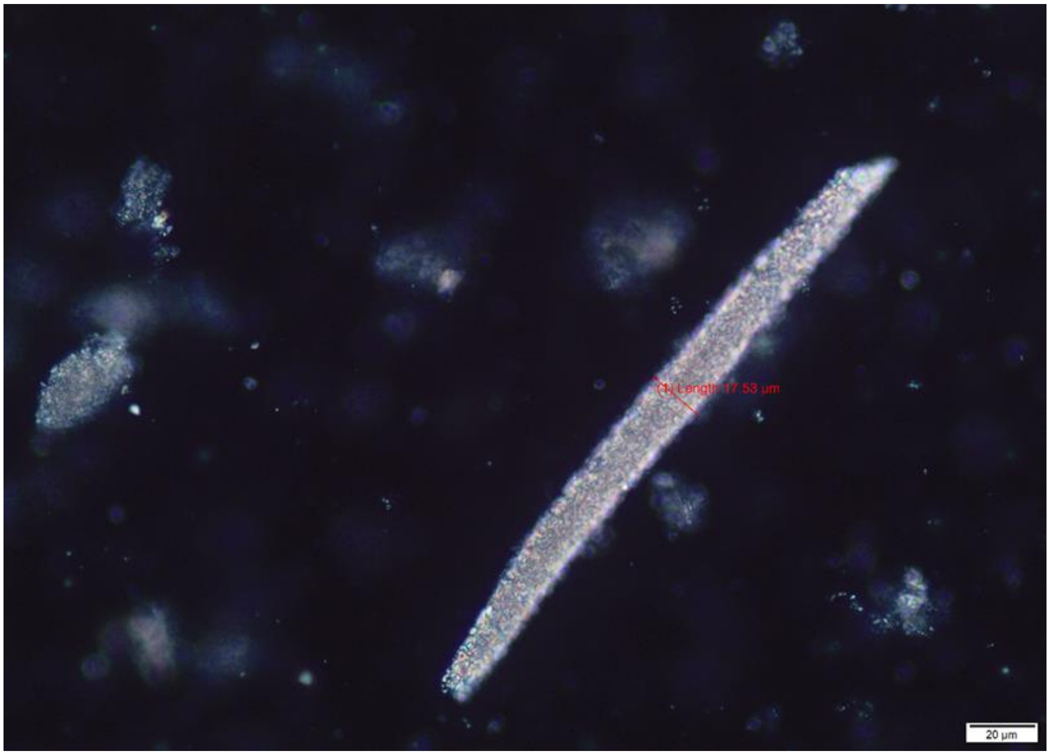

Figure 18. A styloid crystal from the maguey cacti microfossil reference collection, photographed under polarized light.

Artifact Sampling

Standard procedures for microfossil extraction from stone artifacts either involve the full submersion of an artifact in a sonicating bath or point sampling using water and pipetting or a sonicating brush (Fullager 2006; Pearsall 2016:359-362). The benefit of point sampling over a full submersion is control over the sampling location. Point sampling is also the more conservative strategy allowing for future investigations to resample the same tools.

This study used a hybrid strategy of sampling like that discussed by Joyce and colleagues (2021) which used point sampling followed by full submersion for two reasons. First, the retouched edges of the artifacts were the most likely to have been in contact with the materials being processed, microfossil recovery on the working edge is important for determining function. Microfossils can end up on artifacts from environmental deposition, and this ideally is controlled for by sampling and examining the microfossils from the surrounding matrix (Barton 2006;

Fullagar 2006:189-190), which was not available for this study. Secondly, it is possible that the artifacts were hafted, in which case, microfossils from hafting elements on the proximal end of the scrapers could be misinterpreted as microfossils from use if a full submersion was implemented. Point sampling the edge and the proximal end of the scrapers would allow such distinctions to be made.

To fully understand the use of the artifacts, I also employed a full submersion which was more likely to yield a significant number of microfossils than a limited point sample. I tested the hybrid strategy of point sampling and then full submersion first on an experimental scraper (arbitrarily labeled “S5” for “Scraper 5”) that had been used to process manioc root.

I held the experimental scraper’s retouched edge in a weigh boat filled with distilled water while the weigh boat was floating in a sonicating bath. This method of point sampling the utilized edge via sonicating bath first, and then use of a full artifact submersion was effective at recovering manioc starch microfossils from this scraper. However, very few starch grains were recovered from the point sampling of the utilized edge, none of which were diagnostic because they were damaged (Figure 19), which is to be expected of starch grains, as they are less durable than opal-silica phytoliths (Pearsall 2016:351-356). The full submersion produced countless diagnostic manioc starch grains (Figure 20).

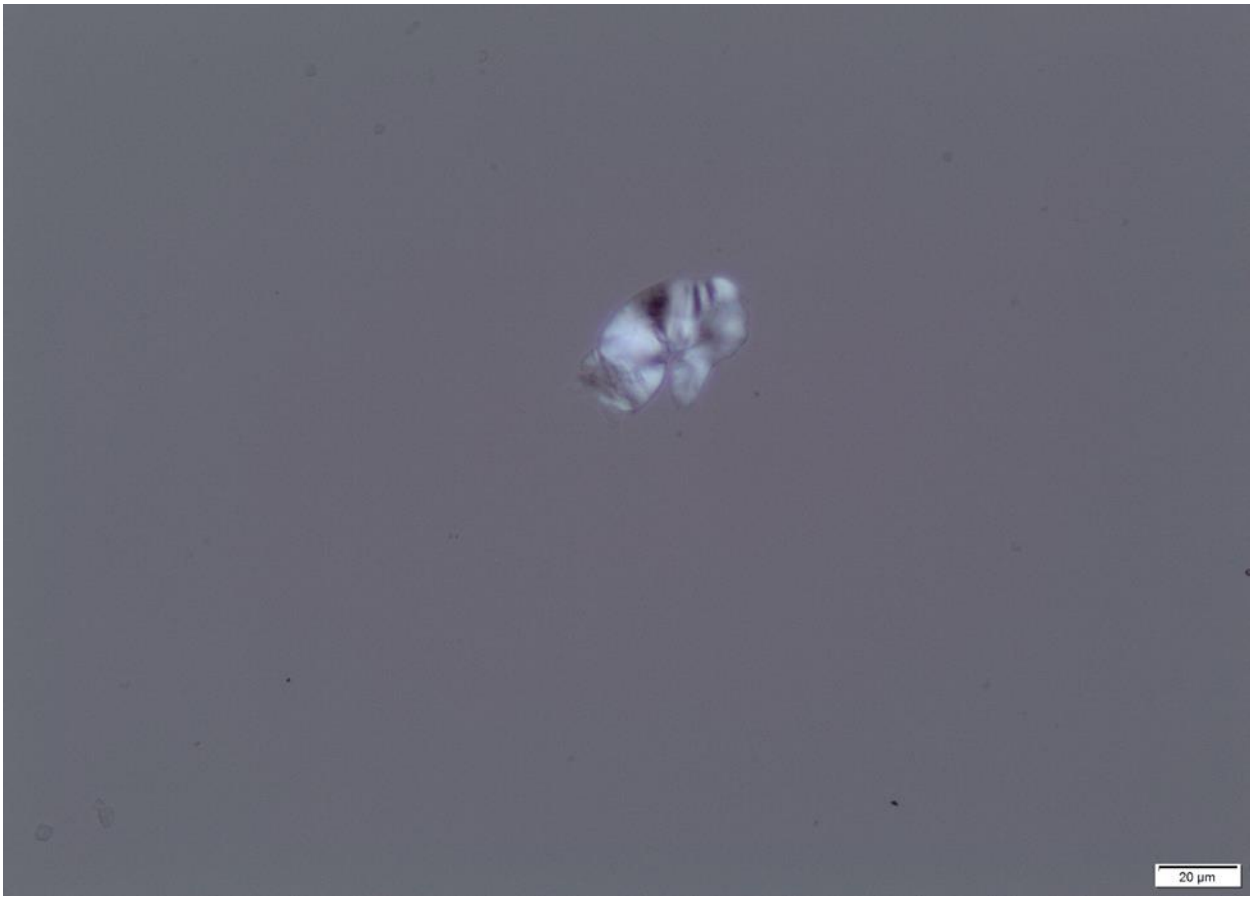

Figure 19. Damaged starch grain from the edge of S5, photo taken under polarized light.

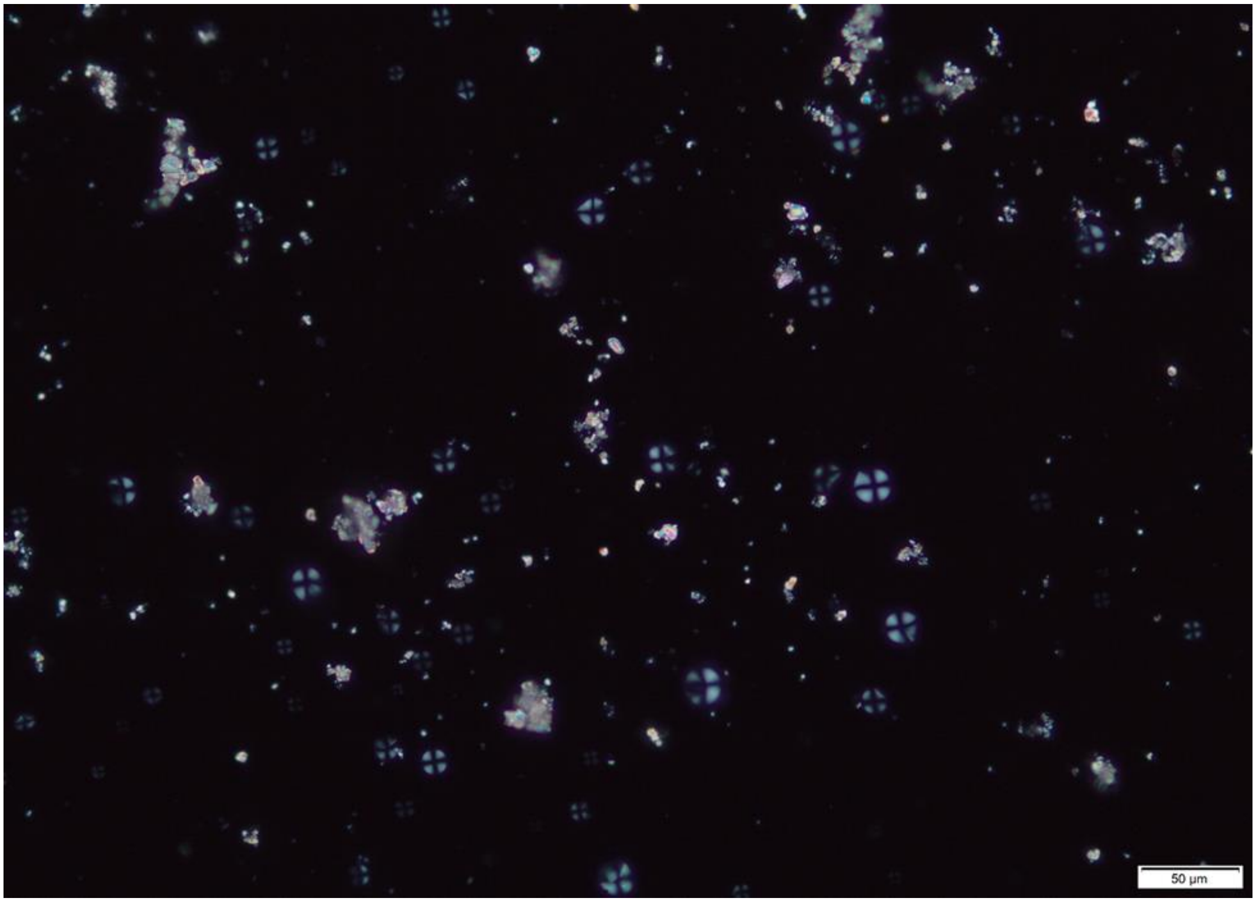

Figure 20. Numerous manioc starch grains from the full submersion bath of S5, photo taken under polarized light.

The artifacts were first dry brushed to remove and examine adhering sediments separately from samples collected via sonicating bath. These adhering sediments have a higher chance of containing microfossils from the deposition matrix, and the dry brushing was an attempt to remove them from the tools. Next, the retouched edges of the artifacts were submerged in deionized water contained in a sterile weighing boat that was floating within a sonicating bath for 5 minutes of sonication. This process was then repeated for a full submersion with a separate weighing boat. The largest two artifacts (AS1, AS2) had to be submerged twice as they were too big to fit in the weigh boat at once. In total, 12 samples were collected, three from each scraper corresponding to a dry brush, tool edge submersion, and then full artifact submersion (Table 7).

The samples were then placed in 15 ml plastic test tubes and filled with distilled water until each was at 15 ml. The samples were then concentrated into a "plug" at the bottom of the tube by centrifuging them at 2500 rpm for three minutes. After centrifuging, excess water from the test tubes was decanted to prepare for heavy density separation.

Table 7. Successful Extraction of Microfossils

Sample Taken	Successful Yield? (yes/no)
AS1 Dry Brush, light	yes
AS1 Tool Edge, light	yes
AS1 Bath, light	yes
AS2 Dry Brush, light	yes
AS2 Tool Edge, light	yes
AS2 Bath, light	yes
AS3 Dry Brush, light	yes
AS3 Tool Edge, light	yes
AS3 Bath, light	yes
AS4 Dry Brush, light	yes
AS4 Tool Edge, light	yes
AS4 Bath, light	yes
AS1 Dry Brush, heavy	no
AS1 Tool Edge, heavy	yes
AS1 Bath, heavy	yes
AS2 Dry Brush, heavy	no
AS2 Tool Edge, heavy	yes
AS2 Bath, heavy	yes
AS3 Dry Brush, heavy	yes
AS3 Tool Edge, heavy	yes
AS3 Bath, heavy	yes
AS4 Dry Brush, heavy	no
AS4 Tool Edge, heavy	yes
AS4 Bath, heavy	yes

The use of sodium poly-tungstate (SPT) allows for the separation of heavier particulates such as sediments from lighter microfossils such as starch grains, phytoliths, or calcium oxalate crystals. SPT makes mounting samples on sides as well as microscopic analysis easier as the slides are not cluttered with larger particles of sediment obstructing the view of preserved microfossils. SPT was first calibrated to a density of 2.0 g per cm^3 and 10 ml of this solution was added to the sample tubes after the distilled water had been decanted. The samples were vortexed to mix the concentrated sample with the SPT of this specific density to extract starch from the heavier contents. After vortexing, the samples were again concentrated causing the lighter particulates to rise and gather on top of the SPT solution as a film. Clean disposable pipettes were used to extract this film and transfer it to a new 15 ml test tube for each sample.

Phytoliths and calcium oxalate crystals are heavier than semi-crystalline starch grains. These microfossils would remain in the heavier density plugs at the bottom of the original 15 ml test tubes after the initial use of SPT. To separate these heavier microfossils from extraneous sediments, the original test tubes were again filled with distilled water, vortexed, concentrated by centrifuging, and then excess water was poured off. Another round of SPT treatment was used with 10 ml of SPT calibrated to 2.3 g per cm^3. The phytolith and calcium oxalate crystal samples were vortexed, concentrated via centrifuging, and the resulting films were extracted and placed in new 15 ml test tubes. The original samples of heavier sediments and particulates that were not separated were kept in a refrigerated storage locker for potential future analyses.

This procedure aimed to produce 24 samples, six from each scraper, three of which were “light” starch grain samples, three of which were “heavy” phytolith/calcium oxalate crystal samples. The “light” samples were each filled with 15 ml of distilled water and vortexed before 1 ml of the sample was extracted using clean pipettes and then placed onto labeled glass slides. The 1 ml of sample on the slide was mixed with a 50/50 solution of glycerol and distilled water before being spread evenly on the slide. Lastly, a cover slip was placed over this mixture which was then secured by brushing nail polish on the corners and edges of the cover slip. The control slide was also prepared in this manner.

The “heavy” samples were filled with 15 ml of distilled water, vortexed, concentrated with the centrifuge, and then the excess water was poured off. The sample plug was then covered with a small amount of ethanol, mixed up, and then transferred over to a glass vial and left to dry. The dried material was then scraped onto a glass slide and mixed with 3-4 drops of Entellan to serve as a mounting agent upon which the coverslips were placed. AS1, AS2, and AS4 did not yield enough material to be collected for the heavy phytolith samples from dry brushing, so the number of heavy slides was only 9, making the total number of artifact sample slides 21 (Table 7). The artifact samples slides were examined and photographed using the same microscope and techniques in the analysis of the reference collection material.

Throughout the entire procedure, steps were taken to avoid contamination from modern starches as informed by past research (Barton 2006; Fullagar 2006; Pearsall 2016). This included frequent handwashing, not using gloves containing starch, and cleaning equipment and surfaces with vinegar, all of which took place within a clean fume hood in a laboratory that was designed for residue and microfossil analysis. Additionally, a control slide with uncovered glycerol and water mixture was left in the corner of the fume hood for the entire process to provide a measure of potential contaminants. The slide was examined using the same microscopic techniques and equipment as the rest of the samples and was found only to contain a few modern fibers, which were observed in some of the artifact sample slides but do not impact the results.

Having sampled the artifacts for microfossils, they were washed again in water to remove any final adhering sediments that might interfere with use-wear analysis. The employment of experimental replication and use-wear analysis was crucial to this project because of the depositional environment in which the tools were found. While microfossils are more likely to survive in the tropics than macro remains are, the use-wear present on a stone tool can remain unaltered for millions of years (Lemorini et al. 2014) in environments where organic remains do not survive. The results of the microfossil analysis are presented in Chapter Five.

Experimental Replication and Use-Wear Analysis

Experimental Replication of Artifacts

To replicate the artifacts, decisions about raw material, reduction techniques, and other methods used to produce the replica tools were made. These were based on known information about Mesoamerican lithic reduction practices (Clark et al. 2020; Horowitz 2018b; Shafer 2023l; Whittaker et al. 2009) and an examination of the artifacts to determine the types of reduction which were utilized in their production.

One of the greatest strengths of experimental archaeology is the opportunity for researchers to exercise control over variables that is not usually afforded when studying the archaeological record. While we cannot recreate the past, sound results are achieved by using experimental techniques that replicate the creation and use of the artifacts being studied as closely as possible. Ideally, I would use the same materials, techniques, and tools that ancient Maya knappers used to make the artifacts. Unfortunately, the source of the toolstone used to make the artifacts is unknown, so I selected a substitute raw material.

Visual examination of the artifacts revealed that the toolstone was similar to other high-quality cherts; having a waxy and dull luster, and a highly cryptocrystalline structure in which grains were imperceivable to the naked eye (Whittaker 1994:65-72). I used Edwards Plateau chert from Central Texas as a substitute for four reasons. First because it is of similar high-quality to the brown chert from which the artifacts were made. By high quality, I mean it possesses a high silica content, a cryptocrystalline structure, a similar waxy luster, and flakes predictably overall (see Lewis et al. 2022 for further discussion of toolstone "quality"). However, exactly how similar this material is to the original cannot be known for certain without having comparative samples of the brown chert. Second, it is available in large quantities for purchase online, and third the cobbles were large enough to produce the flakes necessary for this study. Lastly, I was familiar with this material, having used it previously. Eleven experimental scrapers were needed, one served as a blank, unutilized edge for comparison during use-wear analysis. The other 10 were used in simulated maguey, manioc, wood, and hide processing experiments (Table 8). Three failed attempts at producing a suitable scraper were also recorded but not listed here.

Table 8. Experimental Scrapers Metrics

Scraper #	Task, Time Used (min)	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)	Platform width (mm)
S1	deciduous, 30	104.43	60.62	15.65	163.1	4.4
S2	blank	79.92	78.99	15.27	128.6	25.95
S5	manioc, 10	61.06	57.31	12.21	47.1	7.25
S6	manioc, 30	76.08	81.59	13.01	128.2	34.29
S7	maguey, 10	63.53	60.19	10.96	50.1	34.33
S8	deciduous, 10	61.62	66.41	16.28	76.3	26.02
S9	maguey, 30	70.73	62.26	9.95	50	33.07
S11	conifer, 10	88.26	52.38	13.45	71.9	6.23
S12	conifer, 30	71.52	49.16	9.67	38.9	16.61
S13	deer hide, 10	72.6	60.54	9.11	48	31.19
S14	deer hide, 30	87.74	57.41	10.21	61.9	20.78

To produce the scrapers, reduction techniques and tools were chosen to match the artifacts' morphologies, and also to be plausible for Classic period Maya knappers. Platform analysis is a key component of lithic studies, platforms often indicate what tools and techniques were used to detach a flake from a core (Andrefsky 2001:9-11). Two of the four scrapers (AS1, AS2) had intact platforms (Table 2, Figure 11). Examination of the platforms indicated that direct percussion with a soft hammer was used to detach the large flakes used as blanks, as suggested by the diffuse bulbs and smaller platforms associated with soft hammer percussion (Whittaker 1994:187). This is also consistent with archeological analyses of Maya percussion tools showing that soft hammerstones were commonly used (Shafer 2023; Whittaker 2009).

Maya knappers utilized a variety of tools for flintknapping. These included organic soft hammer tools, many of which do not preserve (Clark and Woods 2014; Clark et al. 2020; Shafer 2023, Whittaker 1995:185-187). Inorganic hammerstones are also known in the Maya world, which were often made of recycled granite manos, chert cobbles, or recycled chert cores. These recycled materials were often used because of the lack of appropriate raw material for hard hammerstones in the limestone rich Maya Lowlands (Horowitz 2018b). Soft hammerstones of materials such as limestone or sandstone were also used and made effective tools for producing flakes with soft hammer characteristics such as diffuse bulbs and small platforms (Clark et al. 2020; Shafer 2023; Whittaker et al. 2009:148).

While a soft limestone hammerstone is the most likely tool used to make the artifact blanks, such hammerstones were not available. Instead, a sandstone hammerstone of similar softness to limestone was used to create the scraper flake blanks. I also have extensive experience using sandstone hammerstones. Because the platform was not going to be examined or involved in the experiments, selecting the exact same hammer used to make the blanks was not critical to the experiment, but care was taken to assure that the overall size and shape of the experimental scraper blanks was comparable to that of the artifact scrapers (Table 9). This was achieved in most regards except for the platform size for the experimental scrapers which are significantly larger than the artifacts scrapers, mostly due to limited core size and the number of cores available. However, as the platforms were not crucial to the use of the scrapers, this discrepancy is acceptable.

Table 9. Artifact and Experimental Scraper Dimension Averages

Tool Type	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)	Platform width (mm)
All Artifact	53	53.5625	10.375	45.1438	8
Non-Broken Artifact	69	63.7143	11.2857	67.1286	8.42857
Experimental	72.9031	61.2977	12.2554	72.0538	21.82909

Production of the replica artifacts required platform preparation on large cores to detach an appropriately large flake blank. The experimental replication indicated that fairly large cobbles, ideally larger than 20 cm in width, were required to produce these tools. Smaller sized raw material does not leave enough space for the extensive platform preparation and core shaping, and in this case, led to several production errors.

Figure 21 Flintknapping experimental scraper replicas. (A) Creating flake blanks with sandstone direct percussion, (B) a flake blank after being struck from the core, (C). Retouching the edge of the flake blank using hard hammer direct percussion.

The scraper edges, the focus of the experiments, were knapped using a small granite hammerstone for the first nine experimental scrapers (Figure 21, 22). This technique removed small, steep, and adjacent flakes from the dorsal side with low angle strikes against the ventral side which was used as a continuous platform.

Figure 22. Experimental scraper S5, Dorsal (A) and Ventral (B) sides.

The last two experimental scrapers were made using pressure flaking with a white-tail deer antler tine, as this technique was found to more closely match the extreme precision required to produce the remarkably consistent retouched edges on AS1 and AS2 (Figure 23).

The edge angles on artifact and experimental tools were not measured, as this technique of analysis is often critiqued as imprecise because of its difficulty to measure consistently (Valletta 2020). However, the edges of the artifacts and the experimental tools were close to 90 degrees on most of the scraper edges.

All debitage was collected during the knapping replication and labeled separately according to which scraper blank it corresponded to, even if the blank ultimately was not suitable for making a replica scraper. The debitage from blank production was kept separate from the debitage from edge retouch. Debitage was not examined in this thesis, but it was saved for potential future analyses.

Figure 23. (A) Ventral and (B) dorsal views of S6, which was retouched using hard hammer direct percussion. This is contrasted with (C) ventral and (D) dorsal views of S13 which was retouched using pressure flaking with an antler tine, resulting in a far more consistent edge.

Experimental Use-Wear Generation

11 replica scrapers were knapped, weighed, measured, and photographed before use. One was saved as a control for use-wear analysis, while the other 10 were used to scrape five different material types; maguey leaf, manioc root, conifer wood, deciduous wood, and deer hide (Table 8). The leaf was allowed to soak in water for 24 hours and the spines were removed prior to scraping per contemporary maguey processing practices (Parsons and Darling 2000). An unretouched Edward's Plateau chert flake was first used to remove the spines of the leaf before scraping. The goal of the scraping was to remove the maguey flesh to simulate the extraction and harvest of the fibers (Figure 24).

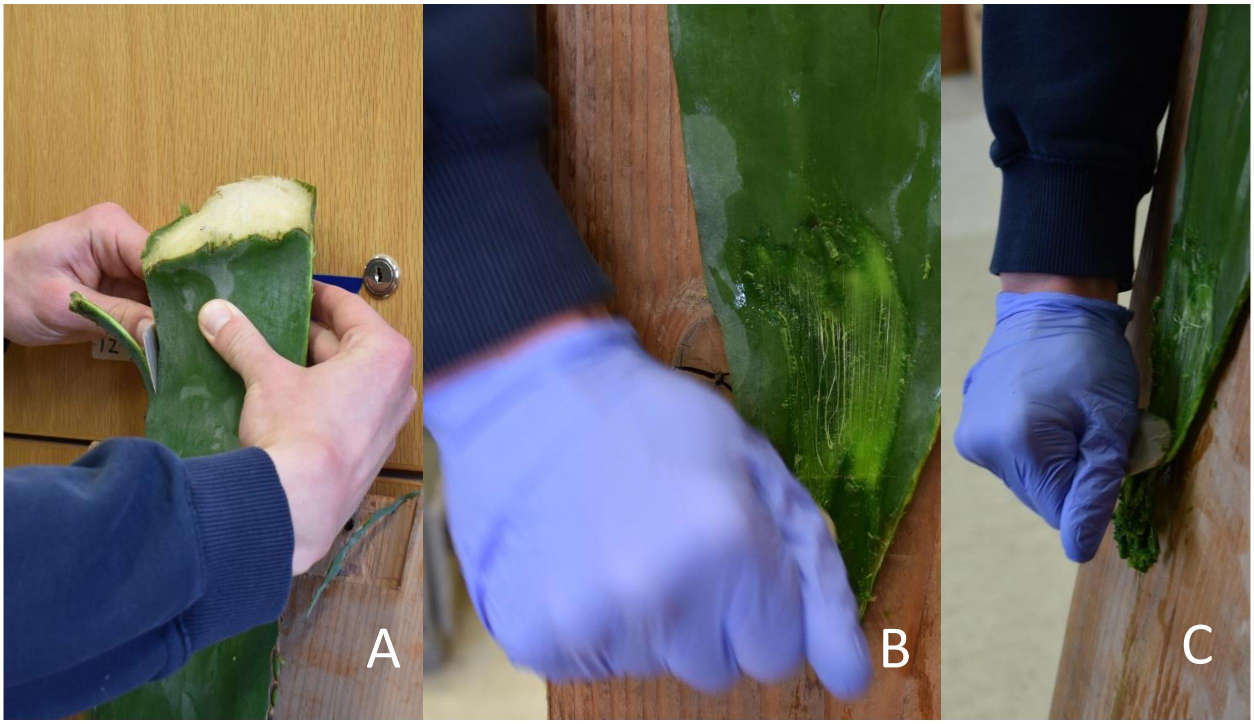

Figure 24. Removing the spines of a maguey leaf using an unretouched flake (A), defleshing the maguey leaf using an experimental scraper (B, C).

Manioc root was purchased from a local grocery store in Pullman, Washington, and the skin removed with an unretouched Edward's Plateau chert flake before scraping. The flesh was then scraped to create a pulp, a method of processing manioc for consumption (Figure 25).

Figure 25. Grating a manioc with experimental scrapers.

Ponderosa pine (*Pinus ponderosa*) and Black Hawthorn (*Crataegus douglasii*) wood were collected from a park in Pullman, WA to represent types of wood available in the Maya lowlands (Cadalen et al. 2023; Robinson and McKillop 2013, Schlesinger 2001, Sharer and Traxler 2006:41-44). The wood samples were not modified before scraping, and the scrapers were used to remove wood fibers as if the wood was being whittled (Figure 26).

Lastly, an ethically hunted white-tail deer hide was purchased from a taxidermy and animal products store in Moscow, Idaho. The hide had not been treated in any way aside from having been briefly frozen, but it was allowed to thaw before scraping. The goal in this experiment was to remove adhering fats and muscles to prepare the hide for tanning treatment (Figure 27). For this experiment, a piece of leather was used to better grip the scraper as fat and grease made the tool difficult to hold and use during the defleshing.

Two scrapers were used for each material type, the first for 10 minutes, and the second for 30 minutes of unidirectional scraping (Table 8). The timer was stopped if a material being processed was exhausted. For example, a full manioc root was processed before 30 minutes had elapsed, and so the timer was stopped until a new manioc root was skinned, and processing was resumed. One scraper (S14) was accidentally dropped and broken in half after use in deer hide defleshing, but it retained its edge and was still analyzed. After processing, the scrapers were washed in water, weighed, and measured again to see if measurable edge damage had occurred. The results of these experiments will be discussed in the following chapter.

Figure 26. Scraping deciduous Black Hawthorn (*Crataegus douglasii*) (A) and Ponderosa pine (*Pinus ponderosa*) (B).

Figure 27. Defleshing a white tail deer hide.

The edges of the artifact and experimental tools were analyzed and photographed using a Dino-Lite EdgePlus AM4917 Series digital microscope at up to 239x magnification. All experimental replicas were examined, including the control S2 which was not used for any processing activities (Table 8). I examined S2 in order to establish a baseline for what the edge of an unutilized scraper looks like so edge modification from use could be distinguished from the knapping process.

The entire edge of each tool was examined at 50x magnification minimum, while magnification was increased for areas of interest. Forms of edge damage such as polish, rounding, crushing, and striations were recorded using a simple categorical scale of: “none”, “minor”, “medium”, and “major.” These forms of edge damage were chosen based on the types of use-wear reported in previous studies of the maguey scrapers from highland Mexico (Hester and Heizer 1972; Smith 2011), studies of manioc grating tools (Chapman 2013; Chapman et al. 2015), and general use-wear studies in Mesoamerica (Aldenderfer et al. 1989; Aoyama 1995, 1996, 2009, Sharpe and Aoyama 2022, Stemp and Helmke et al. 2010, Stemp and Peuramaki-Brown et al. 2019; Walton 2019, 2021). Meanwhile, the types of flake removals observed were recorded as the presence or absence of feathered, step, or hinge terminations. The locations of the use-wear were recorded as either the distal end or side of the tool, as well as the presence on the ventral or dorsal side.

Conclusion

Using these multiple lines of evidence, I seek to answer how the tools were most likely used. The methods selected follow established conventions of artifact function identification and were within my skill set to conduct. In doing so, I seek to determine which tasks were inviable and suggest viable options to make further commentary on the role that these tools played and the value they had in the lives of the people that made and used them. The results of these analyses are discussed in Chapter Five.

CHAPTER FIVE: RESULTS

In this chapter, I summarize the results of the paleoethnobotanical, experimental replication, and use-wear analyses conducted in this thesis. I begin with a discussion of the microfossils observed from paleoethnobotanical sampling of the artifacts. These results were achieved through three forms of sampling: dry brushing, submerging the tool edge in a sonicating bath, and lastly through full artifact submersion in a sonicating bath. These samples produced microscopic remains, of which plant microfossils such as phytoliths, calcium oxalate crystals, and starch grains were the primary focus.

I next move to the experimental replication, diagraming what replica scrapers were used for which task, along with a brief qualitative assessment of their suitability for each task. The replica scrapers were used to grate a manioc, deflesh a maguey leaf, scrape conifer and deciduous wood, and to deflesh a deer hide. These experiments generated use-wear on the replica scrapers, which could then be compared to the use-wear present on the artifacts. I lastly discuss said use-wear on both the artifacts and the replica scrapers. The types of use-wear observed, their locations, and their intensity were recorded and are reported on.

Paleoethnobotanical Results

The paleoethnobotanical analysis was aimed at identifying diagnostic plant microfossils, primarily calcium oxalate crystals from maguey cacti and starch grains from manioc. Opal silica phytoliths were also considered. Full artifact submersion in a sonicating bath appeared to yield the densest amount of microfossils to be analyzed for all tools. Although no quantitative measure of sample yield was undertaken, the three sampling methods of dry brushing, sampling the edge, and a full submersion bath produced strikingly different amounts of microscopic objects on their respective slides. This difference in sample yield is expected considering the full submersion means a far greater surface area is agitated by the sonicating bath than when only the tool edge is submerged or from dry brushing alone. Submersion of the tool edge in a sonicating bath yielded the second highest quantity of microfossils, with dry brushing yielding the least dense samples, three of which (AS1, 2, and 3 heavy fraction) failed to yield enough sample to be analyzed (Table 7).

While many microscopic bodies were observed, very few recognizable plant microfossils were identified. Some microscopic objects included insect remains, fungal spores, and plant pollen, all of which likely originated from adhering sediments from the depositional environment rather than tool use. Future analysis of microfossils from the depositional matrix could aid in discerning what microscopic bodies are or are not found in the matrix, clarifying which were from artifact use. No matrix was analyzed in this study as it was not collected during excavations.

Heavy Fraction

The heavy fraction contains the heavier calcium oxalate and phytolith microfossils if any were adhering to the artifacts. No diagnostic phytoliths were observed, nor were any calcium oxalate crystals observed across the samples. Because a great deal of microscopic remains were seen in the heavy fraction, it is unlikely that recovery methods are to blame. Instead, it could be that the tools were not used to process any phytolith producing plants, or that the microfossils did not preserve. While phytoliths preserve far better than the organic components that they mold from, they are not indestructible, especially in basic (high pH) environments (Pearsall 2016:274). It is possible that phytoliths present on tool edges did not survive the basic limestone derived soils of the Petén.

Light Fraction

I observed 11 starch grains across the 12 light fraction slides (Table 10). Two grains from AS3's dry brush sample were not investigated, as one was damaged (Figure 28A) making identification impossible, while the other (Figure 28B) was located in the nail polish sealant outside the slide cover, meaning it could not be concluded to be archaeological. Lastly, two barely visible starch grains (Figure 28C) from AS3's bath sample were unable to be brought into focus under the microscope to be studied, and so could not be investigated. Of the remaining seven grains, one was identified as manioc, which will be discussed later. The last six starch grains (Figure 29) did not match the characteristics of manioc starch, which was the focus of the starch grain analysis, but some discussion of them is merited as they also hold the potential to reveal clues about the artifact's function.

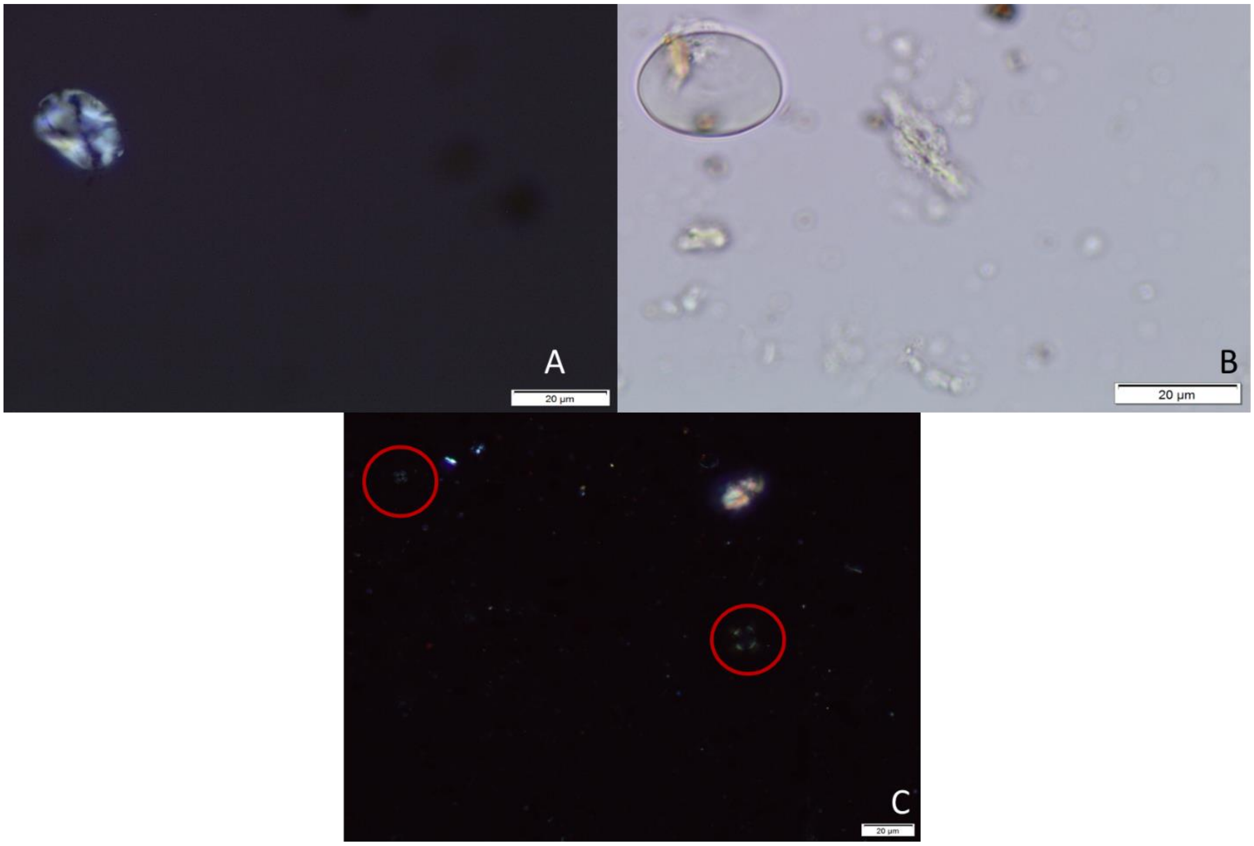

Figure 28. Starch grains which could not be investigated (A, B, C), the scale bar reads 20 microns for all photos. A and C were photographed with polarized light.

I did not include starch grains other than manioc in my modern reference collection, meaning that my interpretations would instead need to be based on previous research. I consulted previous studies of starch grains recovered from archaeological contexts in the Caribbean and Central America (Berman and Pearsall 2008; Piperno 2006; Piperno and Holst 1998; Piperno et al. 2000, 2009), including a study from Waka' (Cagnato 2016), to investigate the remaining six starch grains. Using these resources, I have tentatively identified four of the starch grains observed as maize starch (*Zea mays*) (Figure 29A, B, D). The primary features which these grains share with maize starch grains are their irregular shapes due to compression facets, their transverse to Y shaped fissures from the hilum, the presence of an extinction cross, and their size between 5 - 25 microns (Figure 30A-D).

It should be noted that maize starch is a common modern contaminant that can come from many sources. Maize is found in many modern products, including commonly used lab equipment such as disposable gloves, and is common in food (Crowther et al. 2014). Furthermore, I was unable to control for contamination that occurred before the microfossils were examined, which includes everything from when the artifacts were excavated to just before samples were taken. Steps such as not using starch containing products, frequent handwashing, the use of a fume hood, and the use of a control slide were all taken to reduce the chance of contamination. Given these steps, and that the control slide was free from maize starch, it is unlikely that contamination from the lab environment is responsible for the maize starch present on the artifacts, and that it is more likely archaeological in origin.

This leaves two grains, one from AS3's dry brush (Figure 29C) and one from AS3's full submersion bath (Figure 29E). Both grains bear morphological similarities, having no visible lamellae, are around 20 microns in length, ovoid, and eccentric hila. These features are characteristics of species such as arrowroot (*Maranta* sp.), starch grains of which have been recovered at other sites in the Petén such as La Corona (Figure 31A, B) (Cagnato 2016:271). Arrowroot is a tuberous root similar to manioc and would have been processed and consumed in similar ways to manioc, meaning that finding evidence of both arrowroot and manioc on these tools would not be surprising. However, this is a preliminary identification, and needs to be confirmed with comparison to arrowroot starch reference material. This is especially so given that arrowroot starch is not as well studied as are maize and manioc. A reference collection would help resolve the morphological discrepancies between the potential arrowroot starch observed on the scrapers (Figure 29C, 29E) and the arrowroot starch (Figure 31) from Cagnato's study (2016:271). These include differences of shape, the former being more uniformly ovoid, while the latter being more irregular. The latter also have wavy extinction crosses, while the former are just curved.

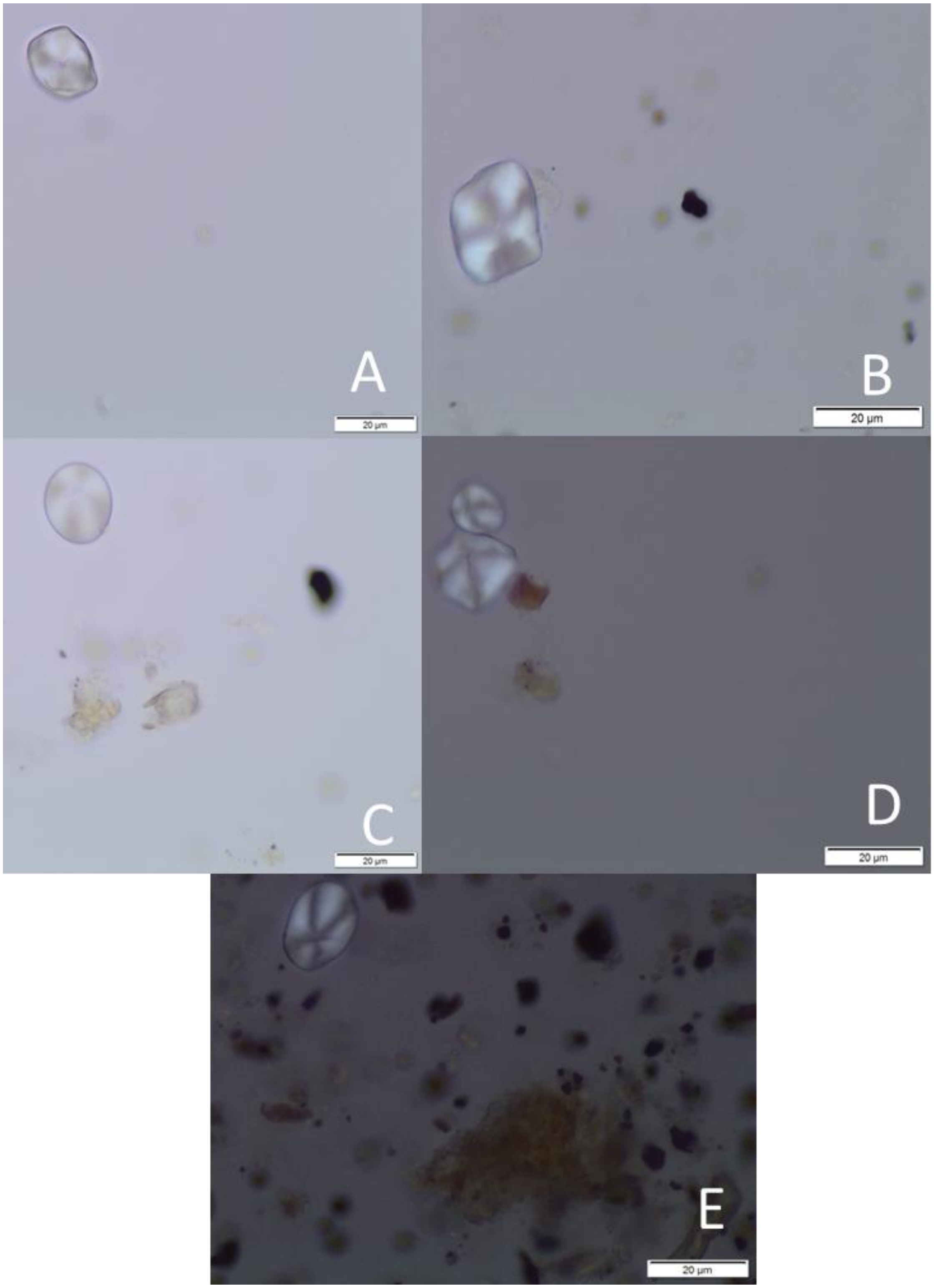

Figure 29. The six other starch grains observed which were not identified as manioc: AS2 dry brush, cf. *Zea mays* (A), AS3 dry brush cf. *Zea mays* (B) and cf. *Maranta* sp. (C), AS3 tool edge, cf. *Zea mays* (D), and AS3 Bath, *cf. Maranta* sp. (E). The scale bar reads 20 microns in all photos, and all photos were taken under polarized light.

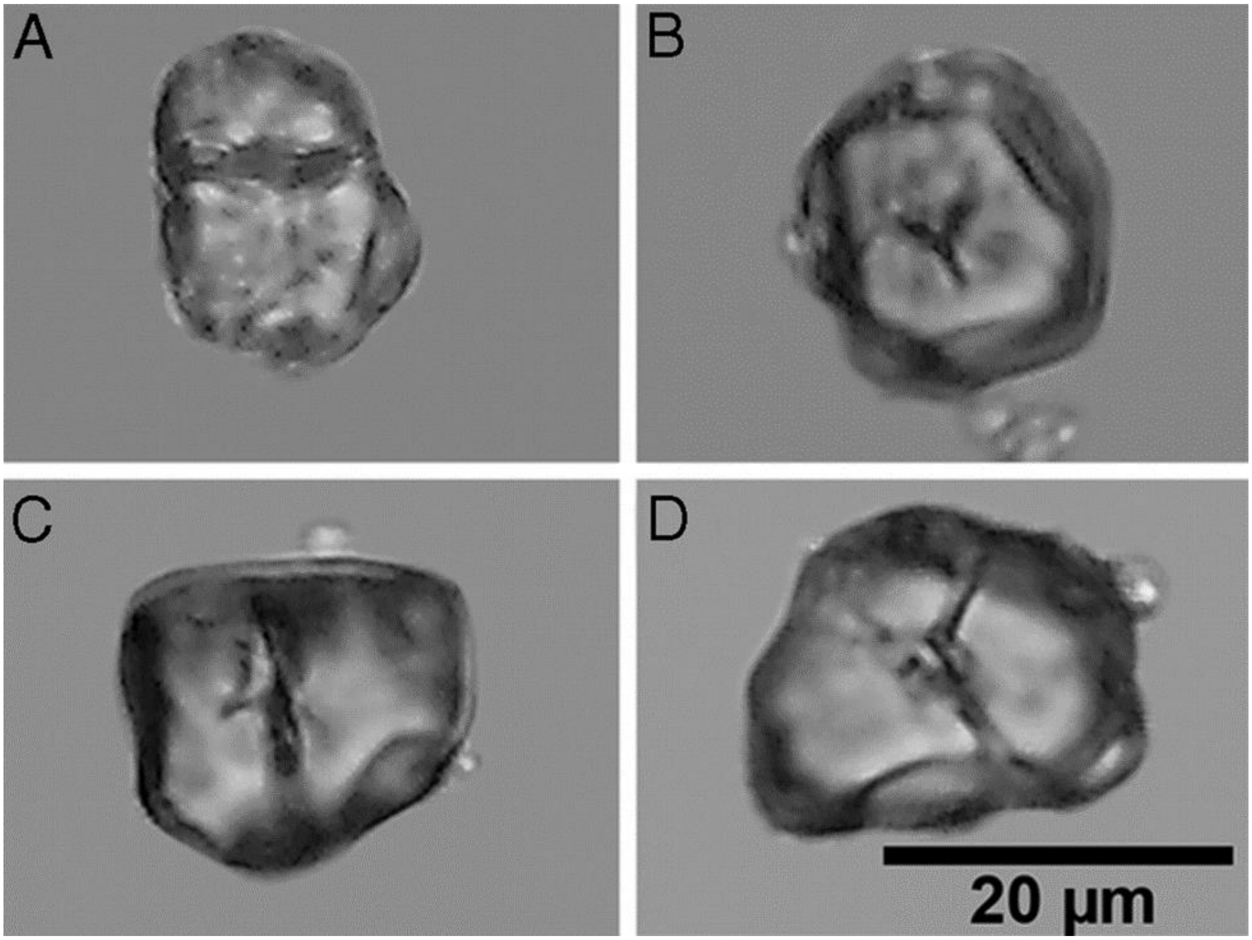

Figure 30. (A-D) examples of archaeological maize starch grains from Mexico (Piperno et al. 2009, Figure 1).

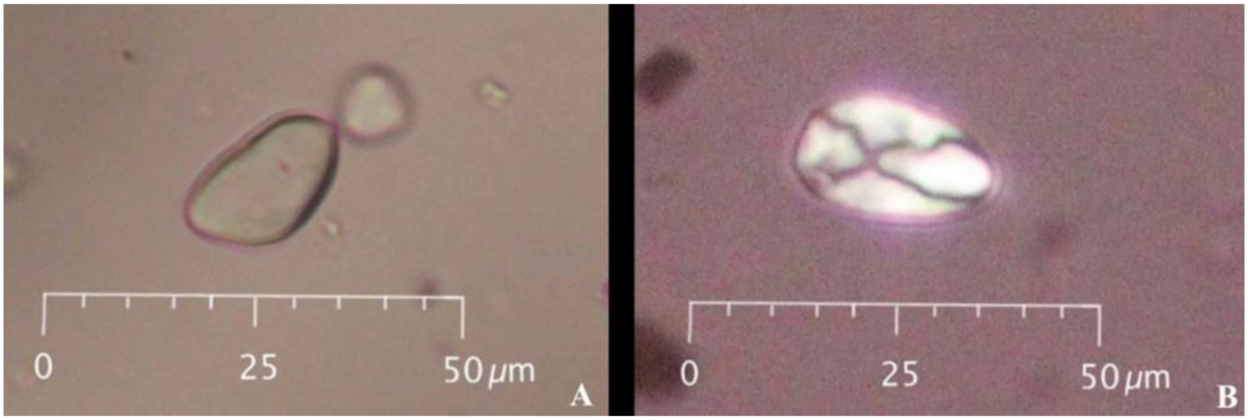

Figure 31. (A, B) archaeological arrowroot starch grains recovered from Waka (Cagnato 2016, Figure 5.10).

Table 10. Presence of Starch Grains in Light Fraction Samples

Light Fraction Sample	**Damaged Starch**	**Starch located outside slide cover**	**Starch not in focus**	**Manioc**	**Tentative Maize**	**Characteristic of Arrowroot**
AS1 brush						
AS1 edge						
AS1 bath						
AS2 brush					1 (Fig 29A)	
AS2 edge						
AS2 bath						
AS3 brush	1 (Fig28 A)	1 (Fig 28B)			1 (Fig 29B)	1 (Fig 29C)
AS3 edge					2 (Fig 29D)	
AS3 bath			2 (Fig 28C)			1 (Fig 29E)
AS4 brush						
AS4 edge						
AS4 bath				1 (Fig 32)		

Returning now to manioc, I confidently identified a single manioc starch grain (Figure 32) from AS4's full submersion bath. This grain was identified as manioc starch based on several morphological features: it has an extinction cross under polarized light, an eccentric hilum, basal facets, a unique bell shape; and is 15-20 microns across (Figure 16) (Berman and Persall 2008; Cagnato 2016; Chandler-Ezell 2006; Lancelotti and Madella 2018; Piperno 2006).

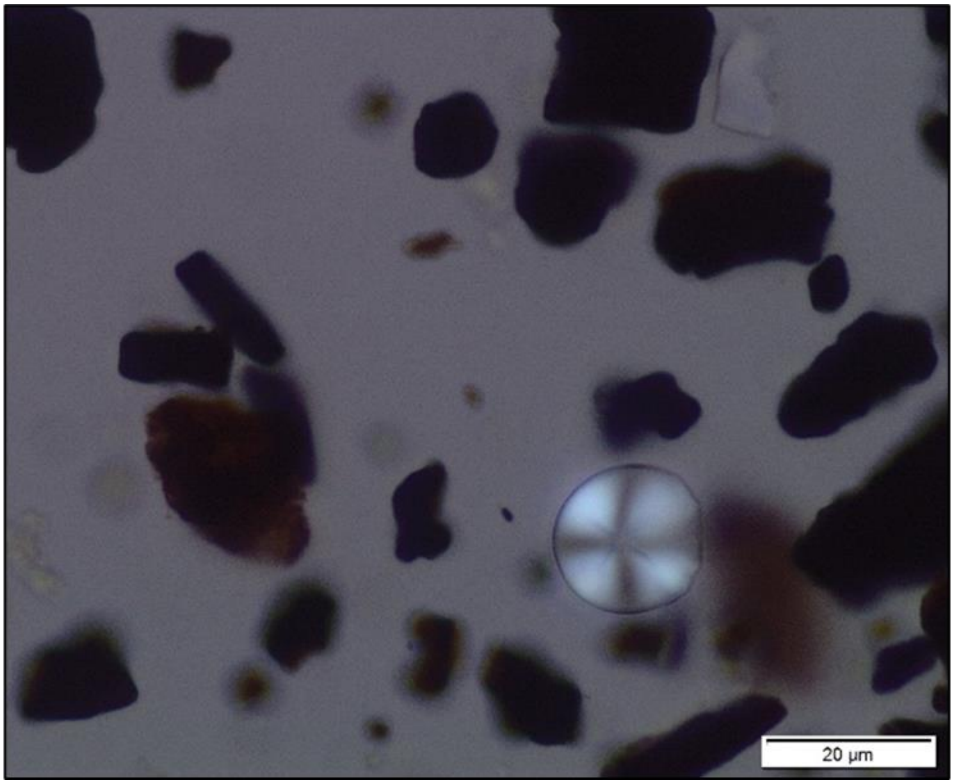

Figure 32. Starch grain with characteristics diagnostic of manioc from AS4's full bath submersion, photographed under polarized light.

Contrasted with the bountiful yield of manioc starch from experimental manioc grating and extraction from S5 (Figure 16), a single manioc starch grain does not match expected results for a manioc grating tool. One possible explanation for this discrepancy is the poor preservation conditions of the tropics (Pearsall 2016:351). It is possible that the excessive moisture of the Maya lowlands may not have allowed for the preservation of starch grains that were at one point present from use.

The microtopography of a tool is also worth consideration in explaining why so few starch grains in general were recovered. Tools with more varied surfaces, such as ground stone, allow for more microfossils to become trapped than tools with consistent surfaces like flaked stone (Adams 2002). Other studies in the Maya lowlands (Cagnato 2016; Cagnato and Ponce 2017) have successfully recovered up to 23 manioc starch grains from a single ground stone tool, suggesting that ground stone tools used to process manioc do retain larger counts of starch grains despite the tropical environment.

Studies of flaked stone used to process manioc in the Maya lowlands report lower levels of starch recovery than studies of ground stone. Devio (2016:109) reports 14 manioc starch grains across seven different flaked tools. These tools were chert teeth used to grate manioc, along with other plants. The fact that chert teeth used to process large quantities of manioc did not produce significantly higher starch grain counts lends credibility to the possibility that the single starch grain observed in this thesis is indicative of the use of AS4 in manioc processing.

Of the tools analyzed, AS3 and AS4 were the most likely to have preserved microfossils because they had extensive edge crushing, allowing more opportunities for microfossils to be retained. The observation of starch from the damaged scrapers, which have more varied microtopography than undamaged tools, conforms to these expectations. An additional point of interest is the fact that AS3 is burned. Since starch grains do not survive extreme heat (Pearsall 2016:351) this means that if AS3 was used to process starchy plants, it must have occurred after the tool was burned. That is the case if the burning was before deposition. If it was after deposition, then the starch might instead be from adhering sediments from the depositional matrix, which I will now discuss further.

It is possible the starch found on the any of the tools came from the depositional matrix and is not related to use. Starch is generally local in deposition, especially compared to pollen, and generally does not spread far from its point of origin. Even though starch grains were found on the tools, they could have arrived there by means other than directly processing the corresponding starch producing plants. Starch grains can become airborne (Dozier 2014; Laurence 2023) meaning that if people nearby the aguadas were processing manioc, maize or arrowroot for example, these starches might end up in the depositional matrix. Given that most of the grains recovered were from adhering sediments (Table 10), this possibility is worth seriously considering.

Summary of Paleoethnobotanical Analysis

The results of the microfossil analysis did not yield conclusive evidence suggesting that the tools were used exclusively for any single task. While the discovery of a manioc starch grain on AS4 could indicate that it was used to process manioc, it likely did so at the end of its use life after the tool had been severely damaged. This suggests that the tools were not primarily intended to serve as manioc graters. Furthermore, there are non-manioc starch grains, some of which could not be identified, but each of which could indicate alternative uses in processing plants such as maize or arrowroot. However, it is also possible that the starch grains are not related to processing, and instead come from modern contamination or the depositional matrix. It is also possible that people using the tools had starch from other plants present on their hands, which could be transferred to the tools, despite their lack of use in these tasks. With only a small number of grains recovered, and without access to the sediments present from the depositional matrix to examine, there remains the possibility that these microfossils are not related to processing.

Experimental Replication Results

Of the 11 scrapers I knapped (Table 8), scraper S2 was kept as a control while the other 10 were used in experiments designed to simulate hypothetical tasks in which people used the artifacts. The scrapers were weighed and measured before and after use, but there were no significant changes in metrics after use, the slight differences in the table are due to false precision rather than modification from use in the experiments (Table 11).

Table 11. Experimental Scraper Dimensions Before and After Use

Scraper #	Length before (mm)	Width before (mm)	Thickness before (mm)	Mass before (g)	Length after (mm)	Width after (mm)	Thickness after (mm)	Mass after (g)
S1	104.4	60.6	15.7	163.1	104.8	61	15.8	162.9
S2	79.9	79	15.3	128.6	x	x	x	x
S5	61.1	57.3	12.2	47.1	61.4	57.5	12.5	47.1
S6	76.1	81.6	13	128.2	76.2	81.7	13.1	128.4
S7	63.5	60.2	11	50.1	63.4	61.1	11.2	50.1
S8	61.6	66.4	16.3	76.3	61.6	66	16.3	76.2
S9	70.7	62.3	10	50	71	62.7	9.9	50.2
S11	88.3	52.4	13.4	71.9	88.1	52.1	13.4	71.9
S12	71.5	49.2	9.7	38.9	70.4	49.8	9.8	38.9
S13*	72.6	60.5	9.1	48	72.9	60.4	9.3	48.1
S14*	87.7	57.4	10.2	61.9	87.5	57.4	10.4	61.3

*S13 and S14 were retouched using pressure flaking instead of direct percussion.

Qualitatively, the scrapers performed well for the tasks of defleshing the deer hide, scraping maguey, and grating manioc, but were less effective for woodworking. This was easily observed in the woodworking experiments as the wood pieces removed rapidly decreased in size from chips to small flecks of wood as the already dull edge of the tool was further dulled. This meant I had to apply more pressure to remove wood as the experiment progressed. Previous research (Andrefsky 2014) has shown that fresh, sharp flakes make far more effective wood whittling tools than modified flakes. The heavily modified and intentionally dulled edge of the tools were illustrated to be ineffective through this experiment, as was expected.

On the other hand, the experimental scrapers were effective at other tasks involving soft organics, which are the types of materials that scrapers are typically employed to process. I did not notice any change in the amount of material being removed during the maguey, manioc, or deer hide experiments. A dull edge is desirable for these tasks, as a sharp edge could damage the maguey fibers or the deer hide by cutting them apart instead of separating them from undesired material. While the experimentation suggests that the tools could be used for maguey, manioc, or deer hide, use-wear analysis is employed to make less subjective conclusions of the artifact’s function.

Use-Wear Analysis

The edges of the blank scraper S2 were examined to establish a baseline for what the edges of an unused scraper look like. This was important to establish because the edges of the artifact tools were clearly retouched from intentional knapping to create a consistent and steep edge which should not be confused with use-wear. Many use-wear studies focus on the edges of unretouched flakes (Andrefsky 2014) which makes edge damage from use easy to spot and unambiguously related to use as long as post depositional modification can be ruled out. In this study, it was imperative to distinguish the difference between edge modification from the knapping process and edge damage from experimental use. I found that S2's edges showed signs of what could have been interpreted as use-wear, that were in fact a consequence of the knapping process. This included edge crushing and the presence of step and hinge flake terminations (Table 12, Figure 33).

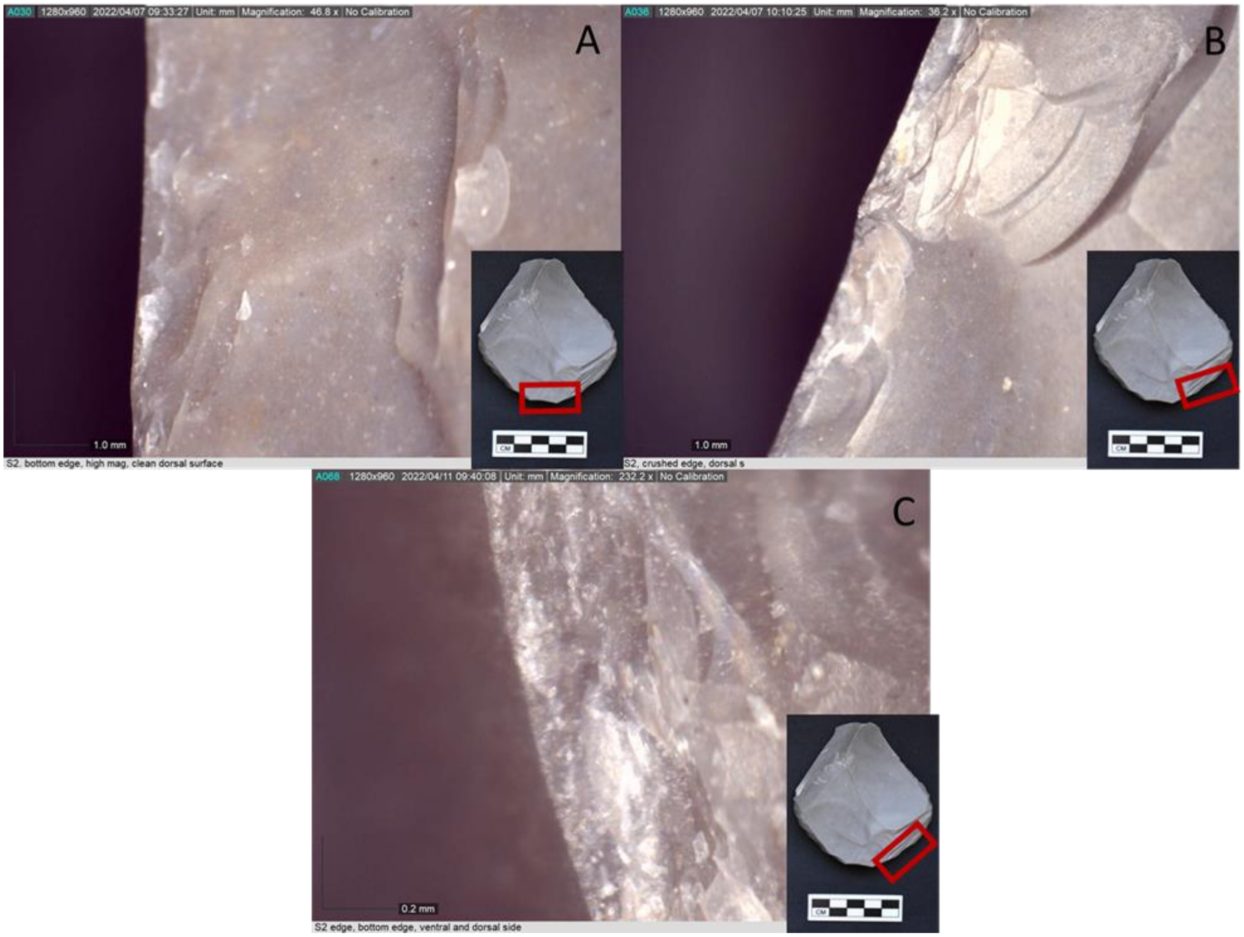

Figure 33. A larger hinge termination (A), multiple step terminations (B), and edge crushing (C) observed on the dorsal side of S2's distal end.

Crushing, step, and hinge fractures were not found across the entire tool edge, and instead were found on isolated sections of the tool edge on the dorsal side of the tool. This observation makes sense as flakes were removed from the dorsal side with a hammerstone using the ventral side as a continuous platform. Isolated crushed areas were caused when I struck too close to the edge of the tool causing the platform to crush, while hinge or step terminations occurred when I miss judged the angle of the blow necessary to detach a flake. Both of these are common knapping errors (Whittaker 1994:93-103), and in this case are unambiguously caused by knapping because S2 was never used. Thus, finding isolated pockets of crushing, step terminations, or hinge terminations on the experimental or artifact tools can be interpreted as knapping errors, rather than use-wear. Finding these features across the entire tool, or at least across large sections of the edge, would suggest edge modification from use.

With this in mind, I analyzed the remaining 10 experimental scrapers as well as two unretouched flakes that were used to skin the manioc and remove the spines from the maguey leaf. The use-wear on the utilized experimental scrapers was largely indistinguishable from the edge of the blank S2. They presented many isolated step or hinge fractures, as well as isolated areas of crushing, which are a result of knapping errors instead of use.

The one major difference between the edges of the unutilized blank and the utilized experimental scrapers was the presence of edge rounding. The edge rounding observed was minor but appears across the edge on dorsal side of the distal end of all utilized scrapers. It was less commonly observed further away from the distal end, as the medial edges of the tools were less likely to have come into contact with the material being processed. This contrasts the observations made on S2, which retained sharper and unrounded edges on its distal end (Figure 34)

Table 12. Use-Wear Analysis of Experimental Scrapers

Scraper Examined	Rounding	Crushing	Removals on	Termination types	Striations	Polish
S2 (Blank)	none	intermediate	dorsal only	feather, step, hinge	none	none
S5 (manioc, 10)	minor	minor	dorsal only	feather, step	none	none
S6 (manioc, 30)	minor	intermediate	dorsal only	feather, step	none	none
S7 (maguey 10)	minor	minor	dorsal only	feather, step	none	none
S9 (maguey 30)	minor	minor	dorsal only	feather, step, hinge	none	none
S8 (deciduous, 10)	minor	minor	dorsal only	feather, step, hinge	none	none
S1 (deciduous, 30)	minor	minor	dorsal only	feather, step	none	none
S11 (conifer, 10)	minor	minor	dorsal only	feather, step, hinge	none	none
S12 (conifer, 30)	minor	minor	dorsal only	feather, step	none	none
S13 (deer hide, 10)	minor	minor	dorsal only	feather, step	none	yes
S14 (deer hide, 30)	minor	minor	dorsal only*	feather, step, hinge	none	yes
Unretouched flake (manioc)	intermediate	none	ventral only	feather	none	none
Unretouched flake (maguey)	minor	none	both	feather, step	none	none

*S14 was dropped shortly after use, a single flake on the ventral side was removed from the impact with the ground, unrelated to experimentation.

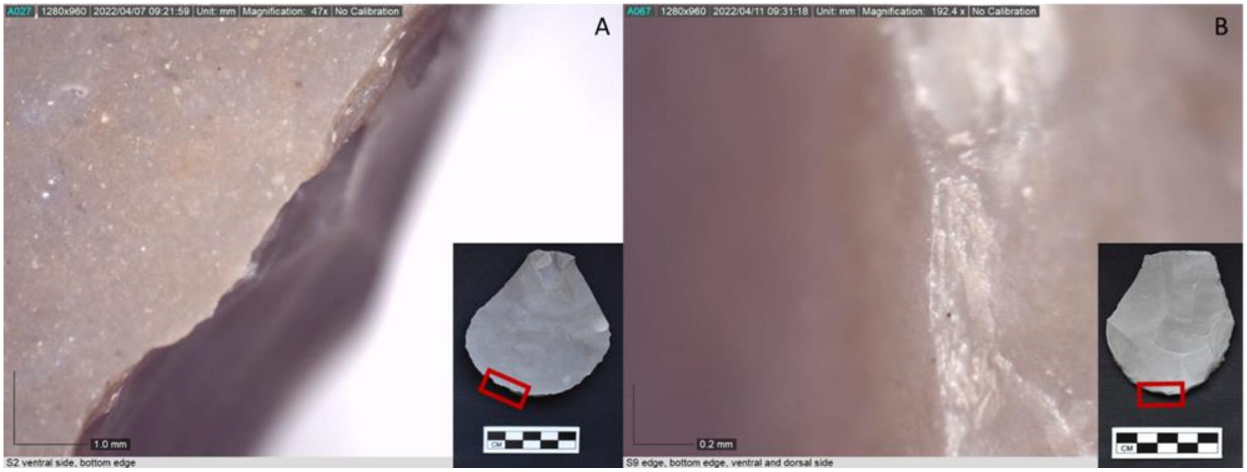

Figure 34. The unrounded, sharp edge of S2 visible on the ventral side at the distal end of the tool (A), contrasted with the rounded and dulled edge of the utilized S9 viewed on the ventral and dorsal edge of S9's distal end (B).

Meanwhile, the presence of isolated step and hinge terminations and minor to intermediate edge crushing was observed across all scrapers. In some cases, these features were seen on medial sections of the retouched tools which likely did not come into contact with the processed material. The locations of these features suggest that they are attributable to the knapping process instead of use as they appear on both the blank and utilized scrapers, are only found in isolated areas, and not across the entire used edge of the tool.

Polish (Figure 35) was observed on the dorsal side of the distal edge only on the scrapers used to deflesh the deer hide, which is consistent with existing studies of use-wear showing that tools develop this sort of polish from contact with animal hides (Aldenderfer 1989). One commonly reported form of use-wear that was not observed were striations (Andrefsky 2005:196). The absence of striations stands in contrast with reports on obsidian maguey scraping tools from highland Mexico (Hester and Heizer 1972; Smith 2011), likely because obsidian is less durable than chert (Whittaker 1994:66) and therefore more likely to sustain damage from use.

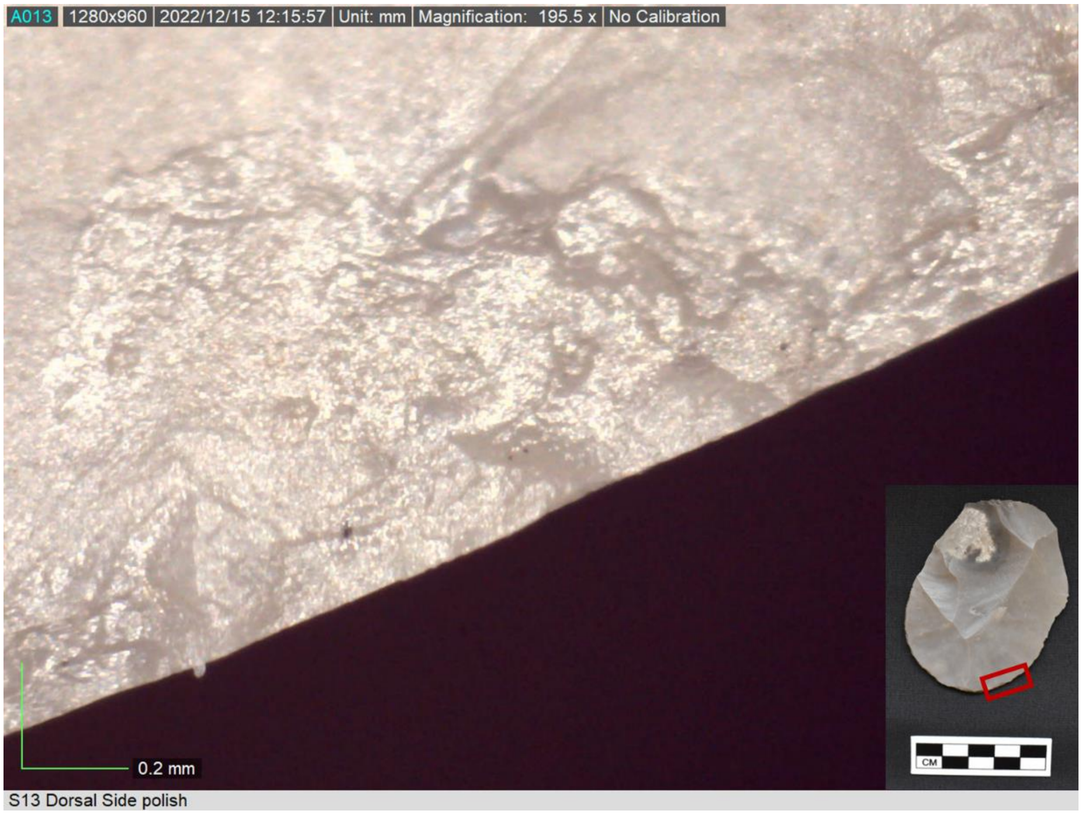

Figure 35. Polish observed on the distal end of the dorsal side of S13.

Examination of the edges of the unretouched flakes provides evidence that the edges of the experimental scrapers and the artifact tools are highly durable. Each flake was used for less than a minute to remove organic components in preparation for scraping, but their unretouched edges still retained recognizable traces of use such as edge rounding and microchipping (Figure 36) (Table 12). These features do not appear in isolation and are instead found across large sections of the utilized edges of the flakes. It is commonly known that flake edges are easily damaged by post depositional processes, and this damage can be confused with use-wear (Andrefsky 2005:197). However, these tools were never subjected to processes that could have modified their edges between the time they were made, used, and examined.

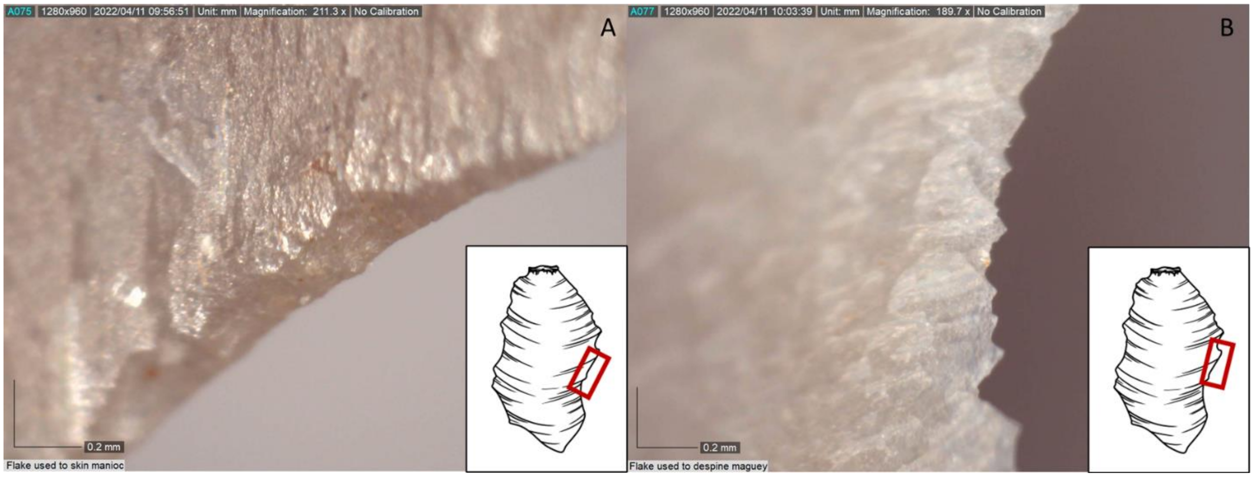

Figure 36. Edge rounding on an unretouched flake used to deskin manioc (A) and microchipping (B) observed on the edge of an unretouched flake used to despine a maguey leaf. Illustrations by Anna Coon, photos by author.

Artifact Use-wear

As for the artifacts, the presence of edge rounding on all four artifacts indicates that they were used at least for a short duration (Table 13, Figure 37). None of the artifacts had recognizable polish or striations. AS1 and AS2 generally show patterns of edge modification that are consistent with the patterns of use observed in the experiments. They have rounding across the entire distal ends while retaining sharp portions further up the medial sections of the tool. They also have isolated pockets of crushing, as well as hinge and step terminations that are more likely attributable to knapping errors than use-wear (Figure 38).

However, AS1 and AS2 do show microchipping (Figure 39) across the dorsal side of the distal end which was not observed on the experimental scrapers. This microchipping, as it is not isolated, and interrupts the regularly spaced and larger flake scars that are from intentional retouch, is suspected to be use-wear. This use-wear was not observed on the experimental scrapers and will be further discussed in the following chapter, but it could be a sign of longer duration of use for similar tasks or use in different tasks that were not tested here.

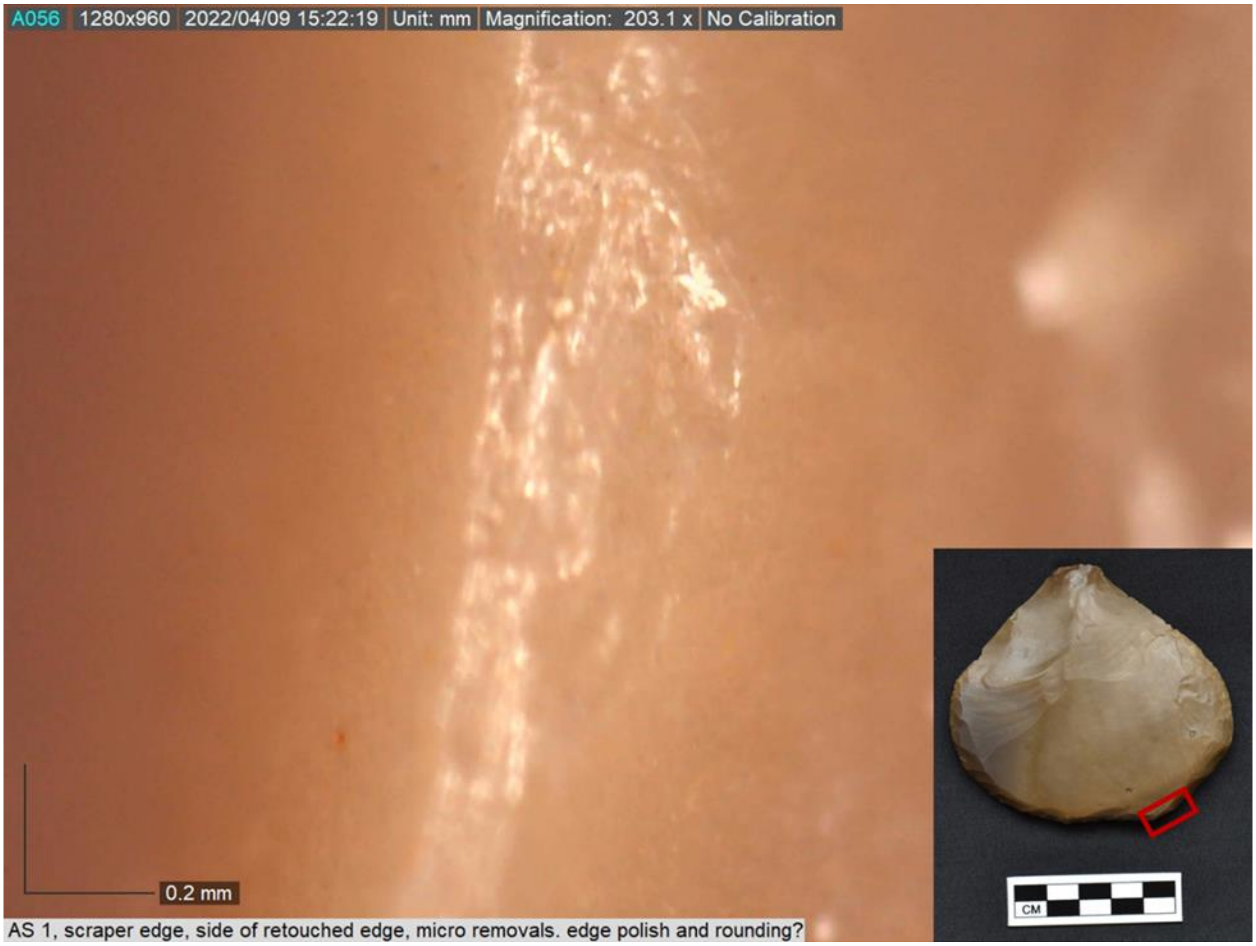

Figure 37. Edge rounding observed on the edges of the distal end and dorsal side of AS1.

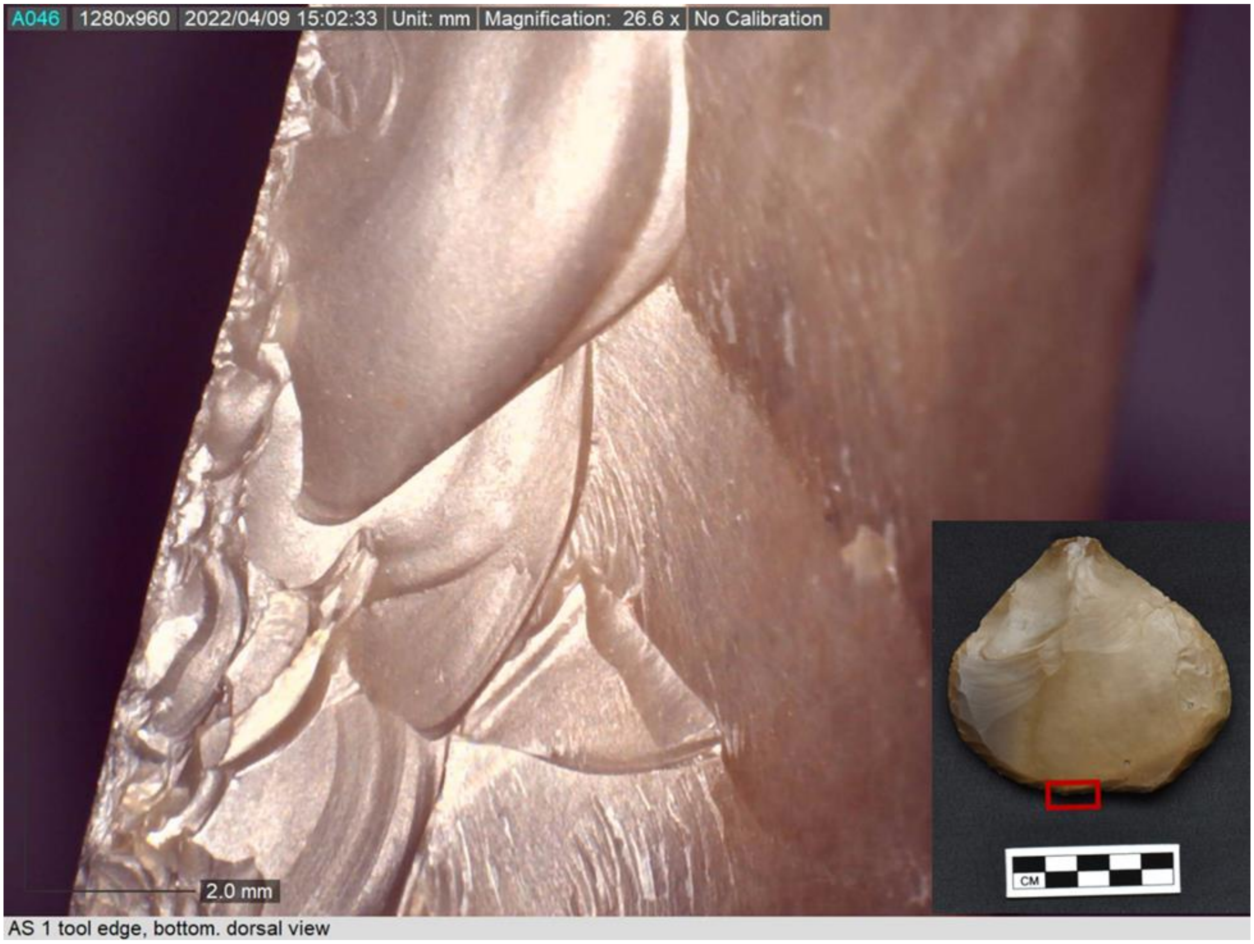

Figure 38. Several knapping errors present on the dorsal side of the bottom distal end of AS1, especially apparent is the large hinge termination in the top center of the photo. Microchipping is also visible from low power magnification in this photo along the margin of the dorsal side.

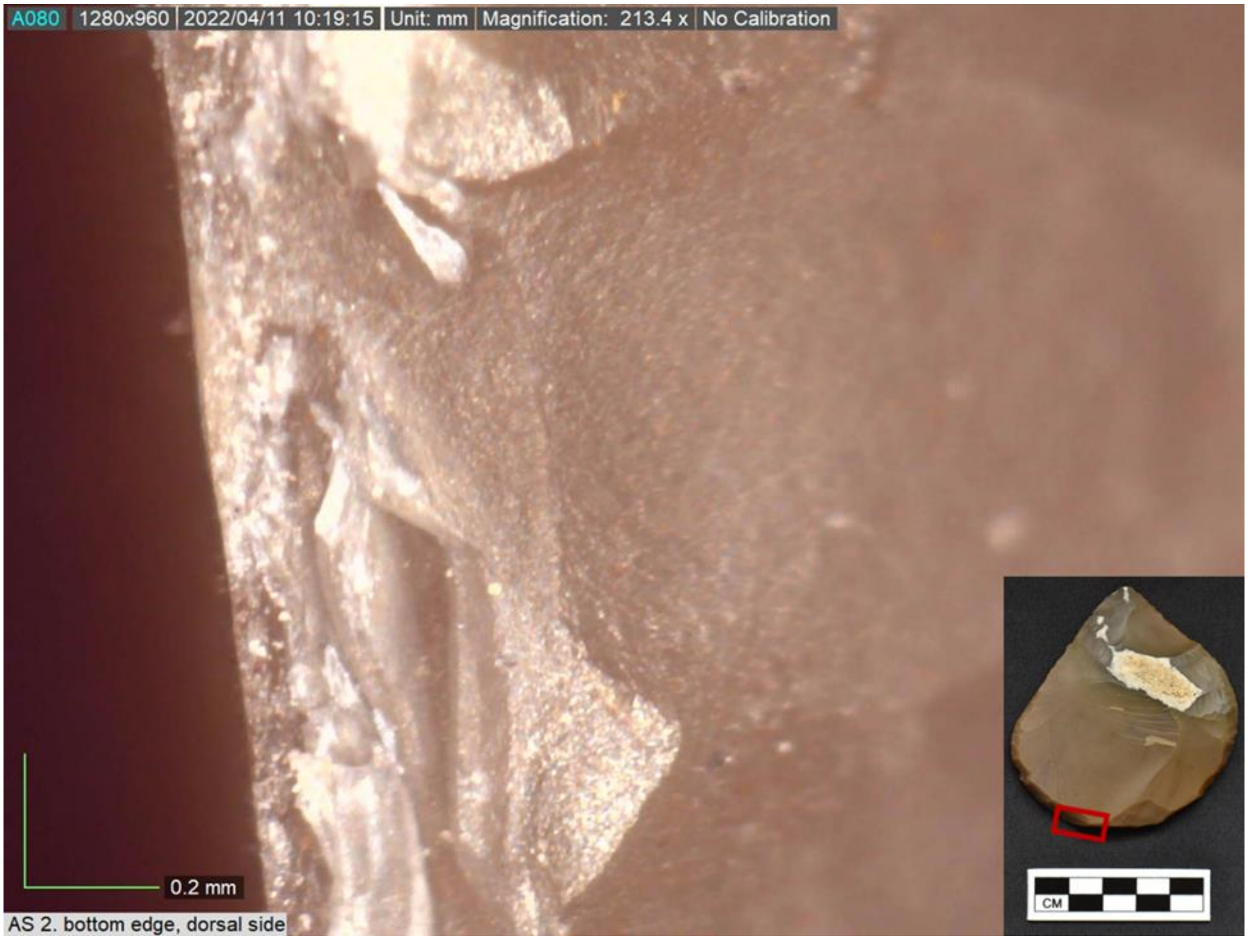

Figure 39. A closer view of microchipping observed at the distal end on the dorsal side of AS2. This microchipping is suspected to be use-wear because it is not isolated, appears across most the entire distal end of AS1 and AS2, and interrupts the larger intentional retouch flakes.

Table 13. Use-Wear Analysis of Artifact Tools

Artifact Examined	Rounding	Crushing	Removals on	Termination types	Striations	Polish
WK24-B-4-2-92 (AS1)	minor	minor	dorsal only	feather, step, hinge	none	none
WK21-F-2-4-15 (AS2)	minor	minor	dorsal*	feather, step	none	none
WK21-F-3-2-8 (AS3)	major	intermediate	both	feather, step	none	none
WK21-F-1-2-4 (AS4)	major	major	both	feather, step, hinge	none	none

*a few ventral removals near platform, otherwise entirely dorsal.

Meanwhile, AS3 and AS4 show far more extensive edge crushing and rounding (Figure 40), and they also have removals on both dorsal and ventral sides (Figure 41), while the experimental scrapers only have dorsal removals. It is worth noting that because it was burnt, AS3 appears as a much darker color than the other brown artifacts. It also has potlidding making analysis more difficult than on the unburned examples. What these results mean for interpreting the function of the artifacts will also be discussed in the following chapter.

Figure 40. Extensive edge rounding present on the distal end of the ventral and dorsal edges of AS3.

Figure 41. Removals and crushing on the ventral side on AS4's distal end.

Summary

In sum, the use-wear analysis provided a means of distinguishing edge modification from knapping from use-wear. This ensured that isolated areas of edge modification from knapping errors are not confused with use-wear. It also showed that minor edge rounding was consistent between artifact and experimental scrapers. However, the experimentation did not replicate the microchipping observed on AS1 and AS2 nor the extensive edge crushing and rounding on AS3 and AS4. Some possible explanations for the lack of microchipping and the extensive edge crushing and rounding are discussed in the following chapter. As with the paleoethnobotanical analysis, the experimental replication and use-wear analysis did not conclusively point to any single function for the scrapers, but instead suggests that some scrapers were used for different tasks than others.

CHAPTER SIX: DISCUSSION

In this section, I consider the results of my analysis and evaluate their significance for interpreting tool function. I was unable to definitively conclude that the tools were used for a particular task. Overall, all lines of evidence support the use of the scrapers to process some sort of soft organics, particularly AS1 and AS2, while AS3 and AS4 were also used on harder materials. Use-wear from subsequent activities can obliterate earlier forms of use, and AS3 and AS4's extensive edge damage might be obscuring earlier uses, especially for softer materials. The paleoethnobotanical results show that later in their use life they may have been used to process various plants, including, but not limited to, manioc. This study is not able to rule out the presence of these grains from the depositional matrix or other post-depositional contamination, and so their use in processing these plants remains a possibility.

Meanwhile, the use-wear analysis suggests AS1 and AS2 were used to process soft organic materials while AS3 and AS4 were used on harder materials which caused more use-wear. The exact causes of microchipping on the edges of AS1 and AS2 and the extensive edge modification on AS3 and AS4 remains unknown but will be considered here as well. Beyond determining function, I discuss the implications of likely functions for the role of these tools in Classic period Maya economies at Waka'.

Discussion of Results and Possible Functions

While I am unable to conclude that these tools were used for a specific task, I have demonstrated that AS1 and AS2 were used to process soft organic material. Their use in processing soft organic material can be established because their edges show minimal signs of use-wear, like the edges of the experimental scrapers used to process soft organic material.

Based on the experiments here, we can exclude hide processing and woodworking from the list of plausible soft organics. Hide scraping can be ruled out because of the lack of distinctive hide polish on the edges of the artifacts that was observed on the experimental scrapers used to process hide. Woodworking is unlikely because previous experimentation has shown that a sharp, unretouched flake makes the most effective woodworking tool possible (Andrefsky 2014). It is doubtful the makers of these tools would put in the effort to extensively retouch a large flake only to make a less effective woodworking tool than an expedient flake knife. Furthermore, the scrapers' ineffectiveness at woodworking was qualitatively observed in my experiments.

Eliminating the wood scraping hypothesis leaves viable functions of manioc processing, maguey defleshing, or some other soft organic processing that was not tested in this thesis. Maize should be considered for future testing as there is tentative starch grain evidence for both from the paleoethnobotanical analysis. Arrowroot might be considered as well, but its use-wear is likely similar to that produced from manioc processing. The presence of the single manioc starch grain, while not enough to conclude that all scrapers were intended to process manioc, suggests that someone may have used AS4 to process manioc towards the end of its use-life. I say end of use-life because the same activities that could crush the edges of the tool would have crushed the starch. The same is especially true of the starches on AS3, which would not have survived burning, again meaning these two tools processed soft starchy materials after processing more durable materials.

Again, it is important to remember that these interpretations are made presuming that the starch is not from post-depositional contamination, or from starch present in the depositional matrix. The other possibility discussed earlier for non-use related starch ending up on the tools is that the people using them had starch from other activities on their hands. If this is the case, this still means that the tools were used in proximity to processing soft organics like manioc, maize, or arrowroot, and this supports an interpretation of their use in quotidian tasks.

AS1 and AS2's use-wear patterns are consistent with the use-wear observed from the experimental manioc scrapers, however, I believe the use-wear is most consistent with what should be expected from maguey scrapers. Scraping maguey is more likely to produce the microchipping observed on the artifacts as maguey leaves are defleshed against a hard surface (Parsons and Darling 2000), such as wood, which is more likely to cause microchipping. I chose to grate manioc by holding it in my hand, which did not provide a hard surface for the tools to encounter, making microchipping from manioc processing unlikely. The microchipping is likely a result of increased duration of use in processing material which was not observed simply because of the limited duration of the experiments. This does not mean that microchipping did not occur, only that it was not enough to be recognizable on the experimental scrapers. The microchipping on the edges of AS1 and AS2 is likely from a significantly longer duration of use than cannot be easily replicated through contemporary experimentation.

It should also be noted that striations were not observed on the artifact or experimental scrapers, which were found to be diagnostic of obsidian maguey scrapers (Mandujano et al. 2002; Smith 2011). However, I contend that the maguey scraping hypothesis is still plausible, as it is commonly noted in use-wear studies that certain forms of stone, especially obsidian, develop signs of use-wear much faster than tougher stones like chert (Andrefsky 2005:196-197; Whittaker 1994:65-66, 270). Thus, the data gathered from this thesis does not preclude their use as maguey scrapers. Furthermore, I noted earlier that the scrapers from Waka' bear morphological similarities to obsidian maguey scrapers in Mexico. The scrapers are also found at

Waka' in association with artifacts such as spindle whorls in the Tres Hermanas district (Horowitz et al. 2022) which could mean maguey textile manufacture was occurring there. Of the soft organics tested, I find maguey scraping to be the most likely task for AS1 and AS2.

Meanwhile, AS3 and AS4 were used for another task. The extensive edge rounding and crushing on AS3 and AS4 could not have resulted from soft organic processing. Studies note that use-wear on stone tool edges can be obliterated by subsequent use-wear, especially when a tool is used to process a harder material later in its life (Whittaker 1994:283-288). This means that AS3 and AS4 could have begun their use life as soft organic processors, but they were repurposed for harder materials thus obliterating earlier use-wear. Regardless, they were then used to process soft organics towards the end of their use life due to the discovery of starch grains on the highly damaged or burnt tools.

The fact that AS3 and AS4 have removals on both dorsal and ventral sides also means that the manner in which they were used differs from AS1 and AS2, as removals occurring on the dorsal side alone means they were used in a unidirectional motion as the experimental scrapers were. Removals on both sides means they were used in a multidirectional motion, again evidence that they served different functions than AS1 and AS2.

Given this, I am inclined to believe that these tools may have been manufactured with a singular intended function, but in practice they were multifunctional. Such a finding is to be expected given what is commonly observed with lithics across the world, that they are often not designed with a singular function in mind. This is supported by the results of this thesis demonstrating that multiple tasks can be seen in the use-wear, experimental, and paleoethnobotanical analysis. If there was an intended function, I believe maguey scraping to be the most likely of those tested based on the results of the use-wear analysis.

Placing the Tools within Classic period Maya Economies at Waka'

I reached the conclusion that these tools were intended to process soft organics but were in practice multifunctional. I now discuss their place in the Classic period economy of Waka', specifically how they were exchanged, and what this can tell us about their value. Discussion of their place in Waka's economy and their value must include discussion of their context and of the other uses of the brown chert. I break my assessment into three key claims: One, they were commodities, two; they were most commonly circulated through commercial exchange, and three; their value is best understood by comparison with other items produced on the same raw material.

The first claim is that these scrapers were commodities according to Appadurai's definition of a commodity as "anything that is intended for exchange" (1986:9). I found this term appropriate given that they are found in household refuse, were likely used within households, but there is no evidence that they were manufactured within those households (Horowitz 2022a). Given that the chert is non-local (Horowitz 2022a; Hruby and Rich 2014) and that commercial exchange networks and lithic production specialists existed (Cap 2021; Eppich and Freidel 2015; Eppich 2020; Mason and Freidel 2012; VadenBosch et al. 2010; Yaeger 2010), it is likely that these tools were acquired through exchange.

While the majority of the tools fit the necessary criteria of commodities, those found at structure M13-1 are from ritual termination deposits, thus making them inalienable goods (Weiner 1992). However, they were found with other goods often found in domestic contexts (Navarro-Far et al. 2008; Navarro-Farr et al. 2021; Navarro-Farr and Eppich et al. 2020; Navarro-Farr and Pérez Robles et al. 2020). The presence of other domestic refuse at M13-1 suggests that the scrapers found there are examples of commodities repurposed as inalienable goods, rather than expressly made as inalienable goods. The presence of domestic refuse in termination deposits is common in Terminal Classic ritual deposits, like that at M13-1. All other contexts support their use in domestic activities due to their associations with other domestic refuse, including some from lower status households, and so it is more than likely that they were quotidian commodities. Based on the experimental and paleoethnobotanical results of this thesis, it seems likely that they were employed for scraping tasks within the household, such as processing common foodstuffs, or multiuse plants like maguey.

My second claim is that the tools circulated through a commercial economy. This claim is primarily based on Eppich and Freidel's (2015; Eppich 2020) work which found that a commercial economy, alongside other types of exchange mechanisms, existed at Waka'. They utilized Hirth's (1998) distributional approach to make these conclusions, but the same approach cannot be applied to the tools in this thesis because the sample is too small; with only 17 examples. A similar study could be conducted if all the brown chert tools from Waka' were considered as a single material type for the distributional approach. A qualitative assessment of the homogeneity of this material should conform to the expectations of a commercial exchange system. Many of the scrapers that have been found so far come from higher status households, and so investigating commoner households is necessary to ensure that Hirth's distributional approach has enough data from households of different status to be applied effectively.

Despite the small sample size, the scrapers follow expectations of a market distribution system as outlined by the distributional approach; they crosscut social status lines and are not concentrated in any single household or class (Horowitz 2022a). The claim that they were distributed in a market system is also supported by the fact that lithics were commonly distributed within commercial economies in the Maya lowlands (Cap 2021; VadenBosch et al.

2010; Yaeger 2010). The scrapers exchange in commercial economy is expected as most lithics, other than expedient tools made it households and inalienable goods, were exchanged through such systems.

My third claim is that the value of the scrapers can be best understood by studying the other artifacts of the same brown chert. The brown chert is usually found in the form of large, thin, and finely made bifaces, projectile points, or as scrapers with debitage being rare. The low quantities of brown chert debitage at the site, the existence of knapping specialists in the Maya region, and the fine retouch and flake removals on the tools allow me to conclude that these tools were made by specialists. Further support of this is that the material is high-quality and non-local, meaning that it had to be selected. Selecting appropriate raw material is crucial for successful tool production, and this is something that requires knapping expertise (Horowitz 2018c). These factors all mean that the chert passed through the hands of specialists first, adding value to the chert. Finding a source of the brown chert or a workshop where it was reduced would help to confirm this. The chert is not restricted to any portion of the site (Horowitz 2022a:39) or to any particular status group. This means that the material, while having value above that of locally available cherts, was not so valuable that only the elites could afford it.

To further explore their value, I apply Horowitz's (2022b) approach to understanding the value of chert resources in the Maya lowlands. The high quality of the brown chert, its scarcity, and restricted access, because it was non-local, all suggest it had higher value than locally available cherts. There is further evidence of this value in the fact that tools made of brown chert are often found in extensively used and recycled forms. Perhaps the best example of this is AS3. This scraper was burned to the point of potliding but had starch grains preserved on its edge.

This means that someone must have picked the tool up and used it after it had been burned or else the starch would not have survived.

I contend that a scraper would have been at least as valuable as a thin biface or projectile point given that this chert is typically used for these tools at Waka'. AS1 and AS2 are large enough that they could have been used to make a biface instead of a scraper, meaning that in terms of raw material cost alone their value is comparable. The fact that these scrapers were multifunctional, like GUBs, leads me to believe their value is closer to that of a GUB than a projectile, which is narrower in function. Seeing that these other tool forms are also common commodities at Waka', which sometimes are repurposed as inalienable goods in ritual contexts (Hruby and Rich 2014; Navarro-Far et al. 2008; Navarro-Farr et al. 2021; Navarro-Farr and Eppich et al. 2020; Navarro-Farr and Pérez Robles et al. 2020), adds to the strength of this interpretation.

It is plausible that the bifaces and scrapers were made and sold by the same knappers in the markets of Waka'. The scrapers are made using the same material and showcase similar knapping skills necessary for making a biface or projectile. However, this cannot be confirmed with the limited information available about the brown chert. Finding either an outcrop of the high-quality brown chert, or a workshop where it was being knapped would provide a significant source of information about who was making these tools and their value.

Summary

In this chapter, I considered the data generated from my experiments to conclude that the scrapers were used for different tasks primarily indicated by their various forms of use-wear but also through microfossil analysis. I suggest that their initial intended function was to process soft organics, of which maguey seems the most plausible based on the use-wear on AS1 and AS2.

They were then recycled to process harder materials resulting in the more extensive use-wear seen on AS3 and AS4. Yet, they remained suitable for processing soft organics even in their more worn state, as evidenced by the surviving starch grains. Alternatively, they could have been multifunctional from the start, AS1 and AS2 simply being examples of scrapers used in soft organic processing, while AS3 and AS4 being examples of those used to process harder materials.

With a better understanding of the scraper's uses, much can now be said about the place that these tools held within Maya economies. They were clearly highly valuable, perhaps worth as much as a fine biface, and I argue that they were specialist made commodities distributed within Waka's commercial economy, but also making their way into the ritual economy at structures like M13-1. While valuable, they were not exclusive to elite households alone, and were affordable to commoners who employed them for quotidian tasks just as elites did. In the final chapter, I synthesize the results of this thesis, which aims to provide commentary on how best to determine the function of flaked stone tools, but also to provide insight on economic activities in the Maya lowlands, and on Maya economies in general, using these tools as a case study.

CHAPTER SEVEN: CONCLUSION

In this chapter, I present the conclusions reached in this study. I close by returning to my two main research aims, the first being to study how stone tool function should be determined. The second being to study these tools within their context at Waka' to call attention to an understudied form of material culture, and to contribute to conversations on Maya economies. Too often are tool functions determined based on fitting tools into existing typologies informed by their morphology alone. This practice continues despite the existence of more empirically grounded techniques of analysis such as paleoethnobotanical analysis, use-wear analysis, and experimental replication. This study utilized these techniques to go a step beyond the use of morphology alone for making functional determinations of the morphological scrapers from Waka'.

With hypothetical functions for the scrapers in hand, I next turned to the more specific aim of investigating the scrapers themselves within their context at Waka'. Maya and Mesoamerican lithics have long received less attention than other forms of material culture (Braswell 2011; Clark 2003; Horowitz 2020). This study explores a unique tool form of a material that has been historically underappreciated despite the crucial place that stone tools held in Maya society. Investigating this tool provides insight into economic activities involving organic materials that do not preserve. It also contributes to ongoing reassessments of Maya economies when the tools are contextualized within said economies, namely, that Maya economies were more commercialized than older theories suggested (Masson and Freidel 2012; Masson 2020, 2021). I now address both research aims in greater depth.

Determining Artifact Function

Morphology alone can be a good starting point for making functional interpretations of tools, especially when paired with ethnographic studies of tools with similar morphologies. The artifact tools from Waka' are morphological scrapers, which are similar to contemporary and archaeological maguey scrapers in nearby highland Mexico. This morphological similarity provided one line of evidence suggesting the tools from Waka' were also scrapers used in maguey processing.

However, morphology alone can be misleading (Shea 2014; Wilkins 2020) and stone tools rarely serve a singular purpose. In the case of formal tools, even when they match established typologies, such is the case for these scrapers, empirically based results require us to test these assumed types. Furthermore, because tools can be multifunctional, additional interpretive methods are needed. Experimental replication of the tools provided a qualitative assessment of their utility which cannot be achieved through other analyses. This approach helped assess if the tools were effective or ineffective for a given task. Experimentation showed that scrapers made ineffective woodworking implements, supported by existing research on effective woodworking stone tools (Andrefsky 2014). Meanwhile, they seemed to be effective at processing the other soft organics tested in the experiments; maguey, manioc, and deer hide.

While useful, experimental replication can be subjective (Clark and Woods 2014) and, as with morphology, an additional line of evidence is needed. Here, I used paleoethnobotanical and use-wear analysis to make more empirically based interpretations of function. A starch grain with characteristics diagnostic of manioc is present on AS3, which could mean that it was used for processing manioc. Seeing there are other starches which are not manioc also means the tools may have been used to process other starch producing plants, possibly including maize and arrowroot. However, the use-wear analysis shows extensive edge damage which means the tools were also used for more than soft organic processing. It lastly shows that the tools were not hide scrapers because they lacked distinctive hide polish.

Using these multiple lines of evidence, I can conclude that the tools show signs of use in different tasks and may not have had a singular intended function. It is still plausible that they were originally intended for use as maguey scrapers like the morphologically similar scrapers in Mexico, and then were recycled for other tasks. Such tasks include manioc processing, as well as processing other soft starch producing organics, and harder materials which rounded and crushed the tool edges.

This thesis has added to the contemporary standards of research showing that use-wear, experimentation, and paleoethnobotanical analyses are crucial for determining artifact function. The use of morphology alone is not sufficient to determine function, especially for multifunctional tools. These approaches become more significant when a potentially multifunctional tool is newly discovered in the culture-history of the region, which is the case here as scrapers in the Maya region are otherwise unheard of.

Scrapers within the Context of Waka'

The second research aim was to make commentary on Classic period Maya economies and the place that these tools held within them, with considerations of their value. I have argued that the tools served to complete quotidian tasks with households. They are most commonly found in association with domestic refuse, even when found in ritual contexts like those at M13-1. The experimental results also show that they were useful for common household tasks like soft organic processing. Second, they were specialist made commodities, based on morphological analysis showing that the tools were skillfully knapped of high-quality chert which usually made into other fine, specialist made tools. There is no evidence that the tools were made within the households that they are found in, so they had to be exchanged for, indicating they were commodities. Third, they were exchanged within a commercial system. This is based on comparisons with the forms of exchange observed at Waka' (Eppich and Freidel 2015; Eppich 2020) and how lithics were generally exchanged in the Maya region (Cap 2015; 2019; 2021; VandenBosch et al. 2010; Yaeger 2010). It would be highly exceptional for quotidian tools such as these to have been commonly exchanged using mechanisms other than the commercial system given the currently available data. While this mechanism is the most common, there are of course multiple economies present at Waka' and it is possible that these tools were exchanged through systems such as barter or were used in the ritual economy which we have direct evidence of from structure M13-1.

As for their value, it is clear from their extensive recycling and reuse, even of burned artifacts, that they were valuable, likely akin to the bifaces made of the same high-quality brown chert (Horowitz 2018; 2022a). However, they were not so valuable that nonelite households were unable to afford them. This is supported by considerations of value from Chapter Six, which discussed the ways in which brown chert was used and distributed at Waka'.

This research is significant because it studies a unique and novel tool form of lithic technology which is traditionally an underappreciated material in the Maya region (Braswell 2011; Clark 2003; Horowitz 2020). By doing so, it also contributes to the ongoing reassessment of the nature of Maya economies, which are now being shown to have been far more commercialized than previously acknowledged (Masson and Freidel 2012; Masson 2021). Furthermore, this is one of but a few studies (Eppich and Freidel 2015; Eppich 2020; Horowitz et al. 2022) to consider an economic perspective at Waka' specifically.

One outstanding question that this thesis has been unable to address fully is why the scrapers exist in the first place? The scrapers from Waka' are currently the only known examples of this tool form in the Maya lowlands, and at present I have three possible explanations.

The first, and best hypothesis is that these tools existed and were designed as part of a particular industry; maguey processing. The morphological similarities to highland Mexican obsidian maguey scrapers (Haines et al 2004; Hester and Heizer 1972; Mandujano 2002; Parsons and Darling 2000; Parsons and Parsons 1990; Smith 2011) suggests that these tools had a similar purpose, and so their morphology might reflect intentional design for use in this industry. If intentional design for a single function is the case, then maguey processing is also more likely than manioc because alternate manioc processing tools are known to exist (Chapman 2013; Chapman et al. 2015). The discovery of these tools at the Tres Hermanas district, which has other evidence of fiber processing (Horowitz et al. 2022), could also suggest that the artifacts took part in the process. This would be a significant conclusion to reach given that maguey is not known to have been grown in the lowlands, making the discovery of maguey scraping tools at a lowland site highly noteworthy, and meriting more investigation. With the presently available evidence, I believe this explanation to be the best account of why the tools exist.

Alternatively, the artifacts could have been intended as multipurpose tools, which this thesis has shown that in practice, they were used as such. Perhaps similar in concept to GUBs (Aldenderfer et al 1989; Clark and Woods 2014:201; Eaton 1991; Gibson 1991; Horowitz et al. 2019; Lewenstein 1987, 1991a,b; Shafer and Hester 1991; Titmus and Woods 2003; Valdez 1989; Woods and Titmus 1996), these tools could have been manufactured to serve a variety of different tasks. The fact that these tools are found in a variety of contexts again suggests that in practice, the scrapers were multifunctional, and could have been designed that way. But if this was so, then why are they not found at other sites? This brings me to my other, less likely hypothesis. It could be that they are a marker of Wakeño identity. This is unlikely given that lithic industries are highly similar across the Maya region, and even across Mesoamerica. The small number known to exist, only 17, again casts doubt on this hypothesis, but it would explain why they only exist at Waka'.

Future Directions

This thesis illustrates that the scrapers were intended to process soft organic materials, with morphological and experimental evidence suggesting they served as maguey scrapers. Paleoethnobotanical analysis also provides potential evidence of processing several types of soft organics including manioc, with tentative evidence of maize, and potentially arrowroot. AS3 and AS4 show that in practice, they were also employed to scrape harder materials causing more extensive use-wear. Secondly, I contextualized this novel tool form within the Classic period economy of Waka'. This thesis shows that the scrapers were valuable, but not exclusively elite, quotidian commodities which were specialist made and exchanged through a commercial system.

Despite these insights, future studies could investigate additional functions through more experimentation, higher power magnification, and by increasing the sample size. More experimentation could serve to investigate other possible functions. Future experimental and use-wear studies could be used to study alternative scraping functions. One possible scraping function not tested in this thesis is ceramic manufacture; the tools could have been employed to scrape and smooth ceramic vessels (López Varela et al. 2002:1144). The fine distal retouch could have been suitable for scraping and smoothing pottery. Other soft organics could have been processed as well, while I selected what I believe to be good candidates, it is known that the lowland Maya utilized thousands of plant and animal species (Sharer and Traxler 2006:41-45).

The paleoethnobotanical results from this thesis show that there is tentative evidence for maize and arrowroot processing, meaning that these two plants merit additional scraping experiments.

Other non-scraping tasks might be investigated as well; the un-retouched lateral edges of the scrapers were not analyzed in the same way as the retouched distal ends. AS2 showed potential use-wear in the form of a few flake removals on the dorsal side along the lateral edge. Experimentation could also be used to see if these tools make effective cutting implements, but it would first require use-wear analysis on the lateral edges to see if there are additional signs of potential use-wear.

The use of higher power magnification could reveal forms of use-wear that were not able to be seen at only 239x magnification. As noted by Stemp and colleagues (2019) certain forms of use-wear, especially those resulting from a short duration of contact with soft materials such as skin in bloodletting activities, require up to 400x magnification to recognize. Previous use-wear studies of obsidian maguey scraping tools (Hester and Heizer 1972; Smith 2011) recognized the presence of striations and microremovals. It is likely that with a more durable material like chert, such use-wear may not develop at all or would need high powered magnification to detect.

Lastly, a larger data set is always a benefit. There are as of now, 13 other examples of this tool known from Waka'. Each one of these has the potential to reveal new information about their intended functions. Both use-wear analysis and additional paleoethnobotanical analysis would be a fruitful means of further investigating these additional examples.

Conclusion

My research has shown that the scrapers were intended to process soft organic materials, with the most likely candidate being maguey cacti (*Agave* sp.), but also manioc root (*Manihot esculenta* Crantz), with tentative evidence for other soft organics such as maize or arrowroot.

However, this thesis shows that in practice, the tools were employed in a variety of other tasks as evidenced by extensive use-wear which only could have resulted from processing harder materials. Such conclusions of tool function were only found through the use of multiple lines of evidence, all studies aiming to investigate artifact function should go beyond morphology alone to make sound conclusions.

With the conclusions reached from my first research aim, I am next able to contextualize these tools within the Classic period economy at Waka'. I demonstrated that these scrapers merit investigation, not only as a novel lithic tool form, but also for having the ability to inform ongoing reassessments of Classic Maya economics (e.g., Masson and Freidel 2012; Masson 2021; Rathje 1972). My examination of these tools provides an example of non-elite managed provisioning through commercial exchange.

Studying these tools within their economic context reveals multiple levels of integration between the citizens of Waka' and its hinterlands. Despite my findings that these are quotidian tools used for day-to-day scraping tasks within households, they passed through many hands before reaching their final deposition environments in households. The scrapers are made of non-local chert, which had to be shaped by specialists and then distributed within the city. My research suggests this was done primarily through a commercial system, one in which both elites and commoners participated in to acquire the same tool form. These scrapers contribute to the growing body of evidence showing that Classic period Maya economies were complex, that they were multi-scalar, and that they were commercialized.

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